AOS PROTOCOL AND PROCEDURE: SECCHI DISK AND DEPTH PROFILE SAMPLING IN LAKES AND NON-WADEABLE STREAMS

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	05/28/2015	ECO-02892	Initial release
B	02/08/2017	ECO-04359	Update NEON template; Revisions to under ice sampling
C	01/19/2018	ECO-05293	Add snow depth measurement, clarify auto-stabilize for handheld YSI, move datasheets to appendix
D	12/19/2018	ECO-05968	Update ice-cover and stratification and high flow in rivers

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1 OVERVIEW

1.1 Background

Aquatic communities and water quality are highly dependent on water clarity and temperature. Secchi depth is often used as a quick measurement of productivity as it measures the depth to which light penetrates and can indicate a lake is either oligotrophic (low nutrient) or eutrophic (high nutrient). In lakes, light penetration is typically limited by phytoplankton growth (although turbidity also limits light penetration in some lakes).

Depth or vertical temperature profiles indicate whether the lake or river is thermally stratified, where the body of water is separated into two or more layers based on temperature. Typically, in a thermally stratified system, the top layer of water is warmer (epilimnion) while the lower layer is colder (hypolimnion). The area separating the two layers is known as the thermocline. The thermocline occurs when the rate of decreasing temperature with increasing depth is greatest, where there is a change of>1^{o}C per 1.0 m change in depth (USEPA 2012). Thermal stratification can dramatically change the water chemistry and biology of each layer. If the lake or river is thermally stratified, samples may be taken at multiple depths to capture the conditions of each layer in the associated protocols (RD[08-12]).

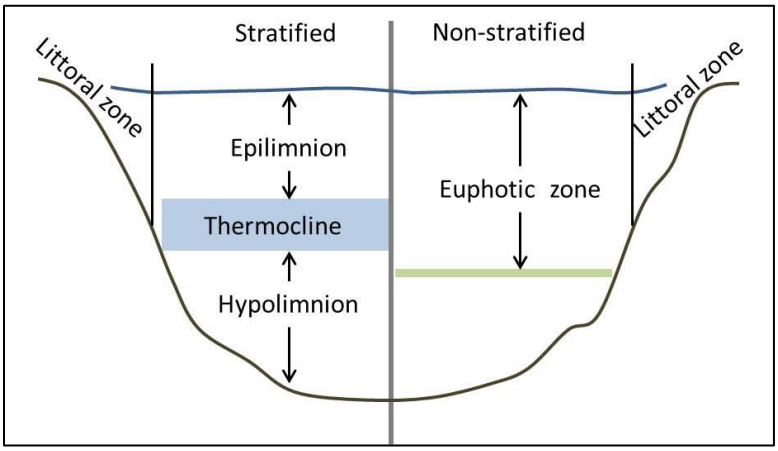

Figure 1. Diagram representing the zones in a thermally stratified and non-stratified lake.

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

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

1.3 Acknowledgments

This document is based on the protocols of the US Environmental Protection Agency (USEPA) National Lakes Assessment program (USEPA 2012) and the USEPA Sampling Procedures of the Great Lakes (USEPA 2010).

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 Level 1, Level 2, Level3 Data Products Catalog
RD[04]	NEON.DOC.001271	NEON Protocol and Procedure: Manual Data Transcription
RD[05]	NEON.DOC.001646	General AQU Field Metadata Sheet
RD[06]	NEON.DOC.002191	Datasheets for Secchi Depth and Depth Profile Sampling
RD[07]	NEON.DOC.004257	NEON Standard Operating Procedure (SOP): Decontamination of sensors, field equipment and field vehicles
RD[08]	NEON.DOC.003045	AOS Protocol and Procedure: Periphyton and Phytoplankton Sampling
RD[09]	NEON.DOC.001194	AOS Protocol and Procedure: Zooplankton Sampling in Lakes
RD[10]	NEON.DOC.003044	AOS Protocol and Procedure: Aquatic Microbial Sampling

RD[11]	NEON.DOC.0025905	AOS Protocol and Procedure: Water Chemistry Sampling in Surface and Groundwater
RD[12]	NEON.DOC.001191	AOS Protocol and Procedure: Sediment Chemistry in Lakes and Non-wadeable Streams

2.3 Acronyms

Acronym	Definition
DO	Dissolved oxygen
NLA	National Lakes Assessment
PFD	Personal flotation device
USEPA	U.S. Environmental Protection Agency

2.4 Definitions

Benthic: The region in or near the sediments or bed of a body of water (e.g., bottom of the lake).

Epilimnion: Top layer of water of a thermally stratified lake, denoted by highest temperatures and least dense water in the summer (Figure 1).

Euphotic zone (or "Photic zone"): The upper layer of lake water where sunlight penetrates and photosynthesis can occur.

Eutrophic: Having high primary production. In lakes, this is often a response to nutrient enrichment leading to increased production of algae or algal blooms.

Hypolimnion: The dense bottom layer of a thermally stratified lake that sits below the thermocline (Figure 1). This layer is denoted by cooler summer temperatures and slightly warmer winter temperatures relative to the epilimnion.

Metalimnion: The layer of water in a thermally stratified lake that sits between the hypolimnion and the epilimnion. The metalimnion is often equated with the thermocline (Figure 1).

Oligotrophic: The ecosystem response to low nutrient content. In lakes, this often equates to very clear water and little algal production.

Pelagic: The part of the lake that is not near shore or close to the bottom.

Secchi disk: 20 cm diameter disk with black and white markings used to determine water clarity.

Stratified: Layers within the system (e.g., warm and cold water layers indicate thermal stratification).

Thermocline: A distinct layer in a body of water where the change in temperature is more rapid than increasing depth - usually a change of more than 1^{o}C per meter (USEPA 2012). The denser and cooler layer below the thermocline is defined by the hypolimnion. The warmer upper layer is termed the epilimnion.

Thalweg: The line of least resistance to water flow in a stream or river, often the line of maximum water velocity.

3 METHOD

Secchi depth and depth (or vertical) profiles are data commonly collected during pelagic sampling (Poikane 2009, USEPA 2010, USEPA 2012). These data should be collected when collecting samples for any SOP that samples the water column:

- phytoplankton (RD[08])
- zooplankton (RD[09])
- pelagic microbes (RD[10])
- pelagic surface water chemistry (RD[11])

Secchi depth and vertical profile data are only collected at the deepest location of the lake (buoy) or near the non-wadeable stream sensor set (Figure 2). These data not only provide metadata to accompany the sampling modules, but also inform sampling depths based on euphotic depth (phytoplankton) and thermal stratification (water chemistry, microbes).

Secchi depth measurements are only collected during ice-free periods. Depth/vertical profile measurements, including temperature, DO, and specific conductivity, are collected throughout the year along with the associated protocols (RD[08-11]). Data collected for this protocol may apply to several protocols performed in a day. Collect data for this protocol once before starting sampling for other protocols, you do not need to repeat Secchi and depth profile data collection for each protocol in a single day.

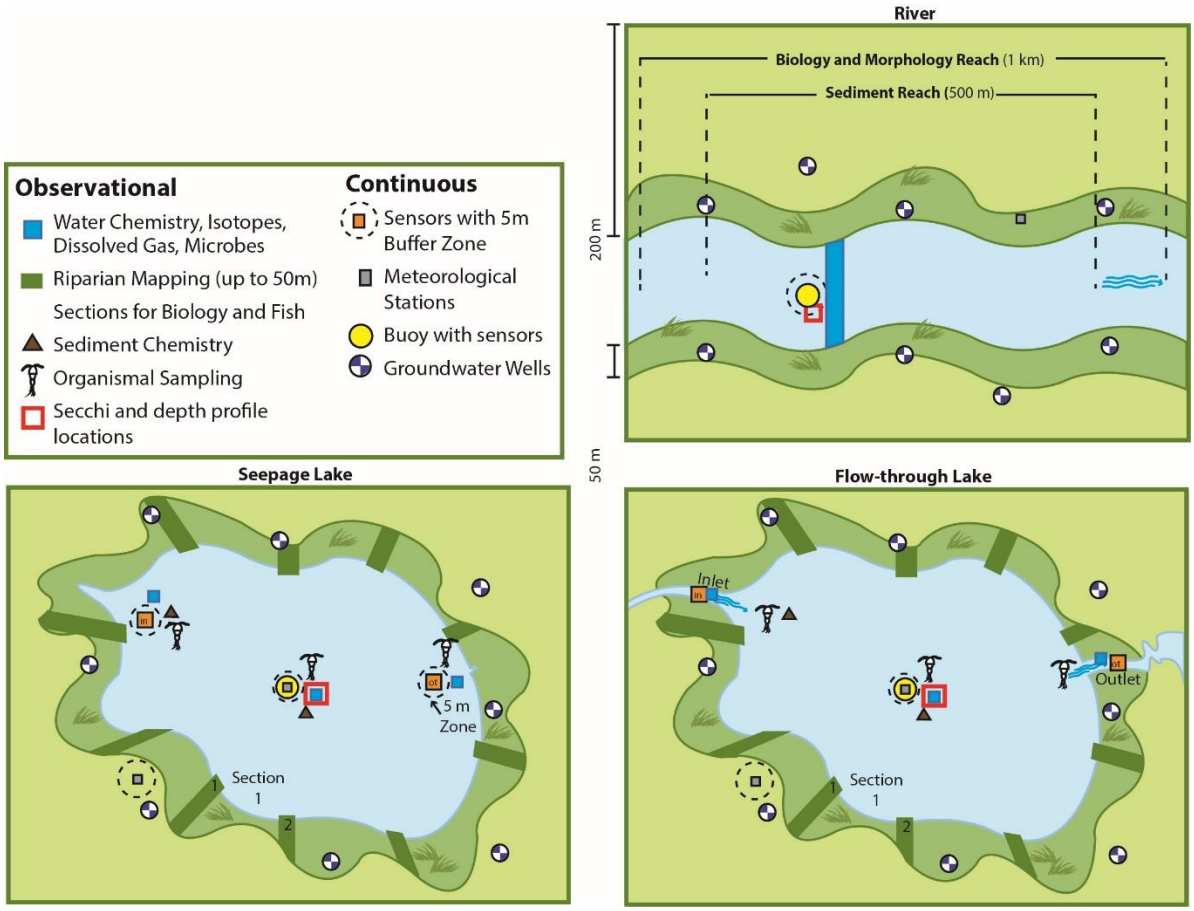

Figure 2. A generic site layout for lakes and non-wadeable streams with Secchi depth and vertical profile sampling locations (red box). Seepage lakes have no true inlet or outlet stream. In flow-through streams, inlet and outlet infrastructure are located in the inlet or outlet stream channel.

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 ecologists **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 field ecologists document the problem and enter it in NEON's problem tracking system.

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

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Data collection occurs with associated protocols (phytoplankton, zooplankton, pelagic microbes, and pelagic surface water chemistry, RD[08-11]).

4.2 Criteria for Determining Onset and Cessation of Sampling

Secchi depth will only be measured during ice-free periods. Vertical profile data will be collected year-round.

4.3 Timing for Laboratory Processing and Analysis

There is no laboratory processing associated with this protocol.

4.4 Sampling Timing Contingencies

All data collection for this protocol occurs with the associated protocols listed in RD[08-11]. Data from the protocol are necessary for determination of sample depth in RD[08], RD[10], and RD[11]. For RD[09] and RD[12], it is good practice to collect Secchi depth and profile data at the same time as samples, but not required to complete the protocol. Follow contingent decisions for each associated protocol.

Table 1. Contingent decisions

Delay/Situation	Action	Outcome for Data Products
Hours	If circumstances occur that impede sampling (e.g., wildlife, weather), start over the next day that conditions permit.	None as long as data are collected with the appropriate protocols (RD[08-12]).

4.5 Criteria for Permanent Reallocation of Sampling Within a Site

Secchi and depth profile data collection will occur on the schedule described above at 1 location per lake/river site. Ideally, sampling will occur at these sampling locations for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (relocatable sites). However, circumstances may arise requiring that sampling within a site be moved from one particular location to another. In general, sampling is considered to be compromised when sampling at a location becomes so limited that data quality is significantly reduced. If sampling at a given plot becomes compromised, use NEON's problem reporting system to report to Science.

There are two main pathways by which sampling can be compromised. Sampling locations can become inappropriately suited to answer meaningful biological questions (e.g., a terrestrial sampling plot becomes permanently flooded or a stream moves after a flood and the location is no longer within the

stream channel). Alternatively, sampling locations may be located in areas that are logistically impossible to sample on a schedule that is biologically meaningful.

Secchi and depth profile data collection in lakes and non-wadeable streams would only be relocated if the buoy relocates, as sampling always occurs near the sensor infrastructure.

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 Ecologist 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.

See Section 9 in the NEON Operations Field Safety and Security Plan (AD[02]) for aquatic-specific field safety requirements. In addition, the following safety requirements are sought:

1. Due to site-specific hazards that may be encountered, sampling may be conducted from the boat, without dismounting from the vessel. In addition, use extra caution in waters where alligators are present and maintain a safe distance from hazards.
2. All personnel must be wearing a personal flotation device prior to entering the boat.
3. All personnel shall have access to a form of communication with other team members such as a two-way radio.
4. Be aware of any site-specific hazards and to the waters of that particular location (i.e. current status, tidal charts, etc.).

6 PERSONNEL AND EQUIPMENT

6.1 Equipment

The following equipment is needed to implement the procedures in this document. Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

Table 2. Equipment list – Secchi Depth and Vertical Profile Sampling

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items								
MX111388	CDW-G	4452963	R	Mobile data entry tablet	Field data entry	All	1	Do not immerse in water
MX100447	Grainger, W.W.	9CJR8	R	Secchi disk	Determining the depth of the euphotic zone	Secchi depth	1	N
MX100450	Grainger, W.W.	8X278	R	Weighted braided polyester line, calibrated	Determining the depth of the euphotic zone	Secchi depth	1	N
MX100514	Thomas Scientific, Inc. Fisher Scientific Company, LLC	1185K52 15177622	R	Handheld meter (temperature, conductivity)	Measuring vertical profile	Vertical profile	1	N

Item No.	Supplier	Supplier ID	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
MX110375	Fondriest Environmental, Inc. Fisher Scientific Company, LLC	605202 15177458		DO Galvanic Probe and replacement tips	Measuring vertical profile	Vertical profile	1	N
MX110075 MX102739	Forestry Suppliers, Inc. Cabela's Inc. Recreational Equipment Inc.	39481 IK-270217 895022	R	Handheld GPS unit (with batteries, ± 1 m accuracy) or Humminbird	Navigation to sampling location	All	1	N
MX109276	Amazon Capital Services Inc.	B00X0WT8MQ	R	Depth finder, hand-held or Humminbird	Measuring total depth of sampling location	All	1	N
Consumable items								
RD[05]			R	Aquatic Field Metadata Sheet	Recording metadata	All	1	N
RD[06]			R	Secchi Disk and Depth Profile Datasheet	Recording data	All	1	N

R/S=Required/Suggested

6.2 Training Requirements

Field staff must complete protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[04]).

All personnel required to operate a boat shall be trained through an approved program. All others shall be aware of boating safety procedures.

Personnel will be trained in the field protocols associated with this document, and trained in safe working practices for lake- and river-based field work.

6.3 Specialized Skills

Where applicable, personnel will be licensed to operate a boat and able to safely handle a motor and drive a boat safely.

6.4 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below is an estimate based on completion of a task by a skilled two-person team (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, use NEON's problem reporting system to notify Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Data collection requires two field ecologists for 30 minutes per site, plus additional time for the associated protocols. There is no lab processing for this protocol.

7 STANDARD OPERATING PROCEDURES

SOP A Preparing for Sampling

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 should be carried along with the mobile devices to sampling locations at all times.

A.2 Preparing for Secchi and depth profile data collection

1. This SOP shall be implemented prior to any other sampling with associated protocols.
2. Calibrate the handheld meter to the manufacturer's specifications. Dissolved oxygen (DO) must be calibrated on site each day that the meter is used to account for local barometric pressure.
    a. Enable Auto Stable for conductivity or DO on the handheld meter if it helps with data collection (see YSI Pro2030 user manual and NEON Training Center presentation 'Using and Maintaining the Handheld YSI' for maintenance information).
    b. During winter, calibration may be done in the truck to prevent ice crystals from forming in the sensor chamber.
3. Collect Secchi depth and vertical profile data at the buoy location.
4. Navigate the boat to the sampling location and turn motor off.
5. Gently lower anchors at the bow and stern so as not to suspend sediments.
    a. Anchor ropes must be 2x the water column depth to allow the boat to drift into position and not affect sampling procedures.
    b. Allow ~5 minutes for sediments to settle after lowering the anchor; you can use this time to prepare the sampling equipment.
    c. The boat must be anchored at the bow and stern to prevent the boat from rotating in order to collect representative water column samples.
    d. Always sample near the bow of the boat to minimize any prior effects of the motor on the water column.

SOP B Secchi and Euphotic Zone Depth

1. Determine and record the total water depth from the depth finder or sonar readings.
2. Lower the Secchi disk slowly into the water on the shady side of the boat until the white quadrants disappear from view (Figure 3).
   a. NOTE: Do not wear sunglasses as this will interfere with the readings.

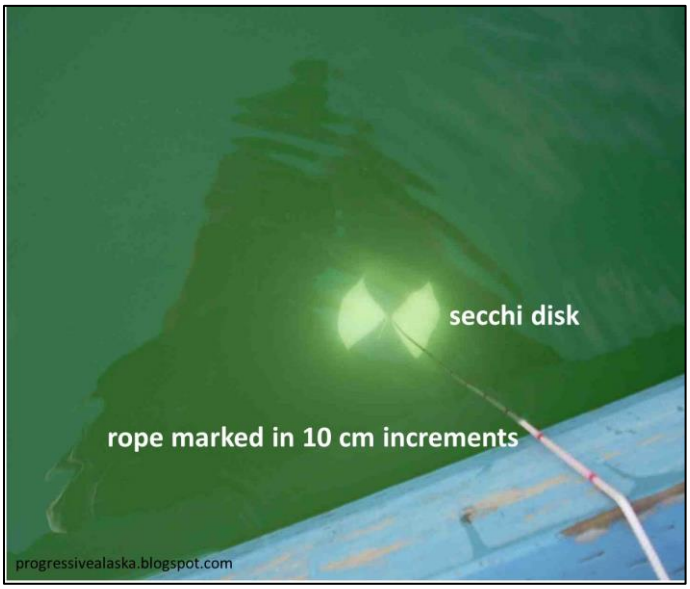

Figure 3. Example of a Secchi disc underwater.

   b. At river sites, high flow may interfere with Secchi readings. You may attach a weight to the probe if necessary. If you are unable to keep the line perpendicular to the water surface, you may select "high water velocity' in the mobile app.
3. Record depth read from the lines on the Secchi rope to the nearest 0.1 m on the Secchi depth field data sheet (Appendix C, RD[06]).
   a. You may also attach a meter tape to the Secchi disk to determine depth
4. Lower the Secchi disk approximately 0.5 m deeper than the first reading.
5. Slowly pull the disk up until the white quadrants reappear, record depth to nearest 0.1 m on field data sheet as "Secchi 2".
6. Take the mean the two depths and record on the data sheet (RD[06]).
7. Multiply mean Secchi depth by 2.5 to determine depth of the euphotic zone (Poikane 2009) and record on field datasheet. The mobile app calculates this for you.

SOP C Vertical Profile and Thermal Stratification

1. Put probe of the handheld meter into the water.
   a. If lake is iced over:
      1) Drill a hole through the ice with the auger and measure the ice thickness. Record ice thickness in the mobile app.
      2) If there is snow on top of the ice, measure the snow thickness and record.
      3) Measure the maximum depth from the bottom of the ice layer.
      4) When lakes are iced over, stratification is not expected. Sites with deep lakes can complete the depth profile by collecting data at 5 depths spanning the height of the water column, from top to bottom under the ice.
   b. When air temperatures are below freezing, extra care must be taken to prevent YSI membranes from freezing, such as storing the probe in a warm water bottle.
2. Starting at the top of the water column, and slowly lower through the water column until the probe reaches the bottom, stopping at 0.5 m intervals to record depth, water temperature, DO, and specific conductivity in the mobile app(Appendix C, RD[06]).
   a. In deeper thermally stratified lakes, once the temperature measurements in the hypolimnion have stabilized (isothermal conditions, or 3 temperature readings in a row that are within 0.1 ^{o}C of each other), measurements may be taken every 1 m between the hypolimnion and the lake bottom.
   b. When collecting data under the ice, you may collect data at >0.5 m intervals as long as a minimum of 5 data points are collected.
   c. When collecting data under the ice, start measurements from the bottom of the ice layer (top of the water).
   d. At river sites, high flow may interfere with depth profile readings. You may attach a weight to the probe if necessary. If you are unable to keep the cable perpendicular to the water surface, you may select “high water velocity’ in the mobile app.
3. Determine whether or not the lake or river is thermally stratified by determining the presence or absence of a thermocline. The thermocline occurs where the rate of decrease in temperature with increasing depth is greatest (>1^{o}C per 1.0 m depth change). This will be calculated by the mobile app.

   a. NOTE: There may be two thermoclines present in deep lakes.

C.1 Ending the Sampling Day

1. Equipment maintenance, cleaning and storage
   a. Decontaminate all equipment that has come in contact with lake/river water according to the NEON Aquatic Decontamination Protocol (RD 09)].
   b. Dry all equipment thoroughly before storage.
2. Data QA/QC
   a. Required checks

1) Check that stratification or no stratification has been recorded properly.

b. Nice to check
   1) Site ID, collect date, sampling protocol version
   2) Maximum and minimum depths
   3) Ranges of YSI readings – are they what you expect at this site and time of year?

SOP D 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. For detailed instructions on protocol specific data entry into mobile devices, see the NEON Internal Sampling Support Library (SSL).

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

8 REFERENCES

Poikane, S. 2009. Water Framework Directive intercalibration technical report. Part 2: Lakes. EUR 28838 EN/2, Office for Official Publications of the European Communities, Luxembourg.

U.S. Environmental Protection Agency (USEPA). 2012. National Lakes Assessment Field Operations Manual. EPA 841-B-11-003. U.S. Environmental Protection Agency, Washington, DC.

U.S. Environmental Protection Agency (USEPA). 2010. Sampling and analytical procedures for GLNPO's Open Lake Water Quality Survey of the Great Lakes. http://www.epa.gov/greatlakes/monitoring/sop/ (17 Mar 2015)

APPENDIX A DATASHEETS AND MOBILE APPLICATIONS

The following datasheets and mobile applications are associated with this protocol:

Table 3. Datasheets and mobile applications associated with this protocol

NEON Doc. #	Title	Mobile Applications
NEON.DOC.001646	General AQU Field Metadata Sheet	(AOS) Field Metadata and Gauge Height [PROD]
NEON.DOC.002191	Secchi Depth and Depth Profile Sampling	(AOS) Secchi [PROD]

Datasheets can be found in Agile or the NEON Document Warehouse, user guides for mobile applications may be found in NEON's internal sampling support library.

APPENDIX B QUICK REFERENCES

B.1 Steps for Secchi Depth Data Collection

Step 1 – Anchor boat at bow and stern at sampling location.

Step 2 – Lower Secchi disk on the shady side of the boat to the point where it disappears, record. Ensure that Secchi line is perpendicular to the water surface.

Step 3 – Raise Secchi disk to the point where it reappears, record.

Step 4 – Calculate mean Secchi depth and multiply by 2.5 to get euphotic depth.

B.2 Steps for Vertical Profile Data Collection

Step 1 – Lower handheld probe into water. Ensure that Secchi line is perpendicular to the water surface.

Step 2 – Record depth, temperature, DO, and specific conductivity every 0.5 m to the bottom of the lake or river.

Step 3 – Determine whether the lake is thermally stratified or not (if temperature change is >1 ^{o}C per 1.0 m).

APPENDIX C PAPER DATASHEET EXAMPLE

See also RD[06] for blank paper datasheets.

NEON Secchi Depth and Vertical Profile Data

Lakes and Non-wadeable Streams

Site ID: *SUGG* **Sampling protocol:** *NEON.DOC.002792* **Rev:** *G*

Date: *2017-09-30* **Recorded by:** *sparker@battelleecology.org*

Local time: *10:30* **Collected by:** *jstewart@Field-ops.org*

Station ID	Ice present?	Ice thickness (m)	Snow thickness (m)
buoy.c0	*no*		

SECCHI

Maximum depth (m)	Clear to bottom?	Secchi depth #1 (m)	Secchi depth #2 (m)	Secchi mean depth (m)	Euphotic depth (m)	Remarks
4.0	*no*	*1.5*	*1.4*	*1.5*	*3.6*	

VERTICAL PROFILE

Circle one: Stratified (Unstratified)

Sample depth (m)	Water temp (°C)	Specific conductance (µs/cm)	DO (mg/L)	DO (% saturation)	Remarks
0.5	*14.4*	*81.8*	*6.5*	*63.5*	
1.0	*14.1*	*82.9*	*6.0*	*58.5*	
1.5	*14.0*	*83.2*	*6.0*	*57.9*	
2.0	*14.0*	*83.3*	*5.9*	*57.1*	
2.5	*14.0*	*83.4*	*5.9*	*57.0*	
3.5	*13.9*	*83.4*	*5.9*	*57.0*	
4.0	*13.9*	*83.4*	*5.8*	*57.0*	