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

PREPARED BY	ORGANIZATION	DATE
Stephanie Parker	AQU	12/08/2016

APPROVALS	ORGANIZATION	APPROVAL DATE
Andrea Thorpe	SCI	02/06/2017
Mike Stewart	SE	02/07/2017

RELEASED BY	ORGANIZATION	RELEASE DATE
Jennifer DeNicholas	CM	02/08/2017

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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

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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 or not 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]).

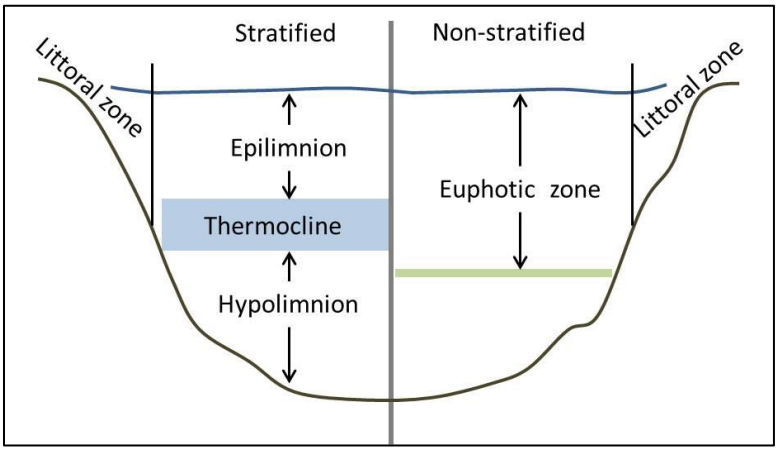

Figure 1. Diagram representing the zones in a thermally stratified and non-stratified lake.

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 Performance QA/QC Plan

2.2 Reference Documents

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

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Level 1, Level 2, 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.001154	AOS Protocol and Procedure: Aquatic Decontamination
RD[08]	NEON.DOC.003045	AOS Protocol and Procedure: Periphyton, Seston, 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]).

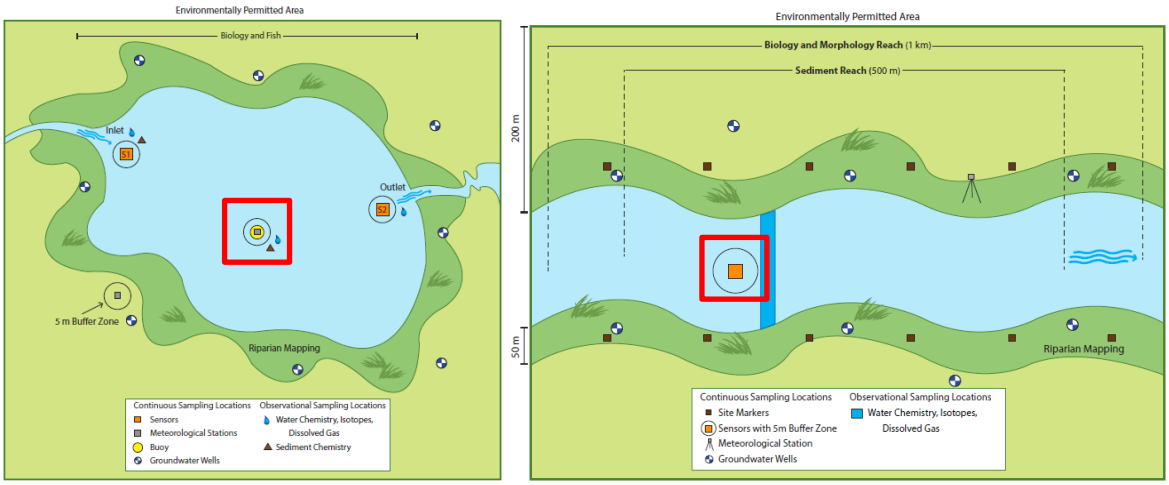

Figure 2. A generic site layout for lakes and non-wadeable streams with Secchi depth and vertical profile sampling locations (red box).

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 will be performed on data collected via these procedures according to the NEON Science Performance QA/QC Plan (AD[05]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Data collection occurs with associated protocols (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 shifted from one particular location to another. In general, sampling is considered to be compromised when sampling at a location becomes so

limited that data quality is significantly reduced. If sampling at a given plot becomes compromised, a problem ticket should be submitted by Field Operations 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 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.

See Section 10 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, technicians may conduct sampling from the boat, without dismounting from the vessel. In addition, technicians are required to use extra caution in waters where alligators are present and to make sure a safe distance from hazards is maintained.
2. All personnel must be wearing a personal flotation device prior to entering the boat.
3. All employees shall have access to a form of communication with other team members such as a two-way radio.
4. Technicians should 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.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items						
MX100393	R	Secchi disk and weight	Determining the depth of the euphotic zone	Secchi depth	1	N
	R	Braided polyester line, calibrated	Determining the depth of the euphotic zone	Secchi depth	1	N
	R	Handheld meter (temperature, DO, conductivity)	Measuring vertical profile	Vertical profile	1	N
	R	Handheld GPS unit (with batteries, ± 1 m accuracy) or Humminbird	Navigation to sampling location	All	1	N
	R	Depth finder, hand-held or Humminbird	Measuring total depth of sampling location	All	1	N
Consumable items						

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
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

Technicians 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, a problem ticket should be submitted. 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 technicians 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 the stabilizing feature on the handheld meter (YSI Pro2030).
    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.

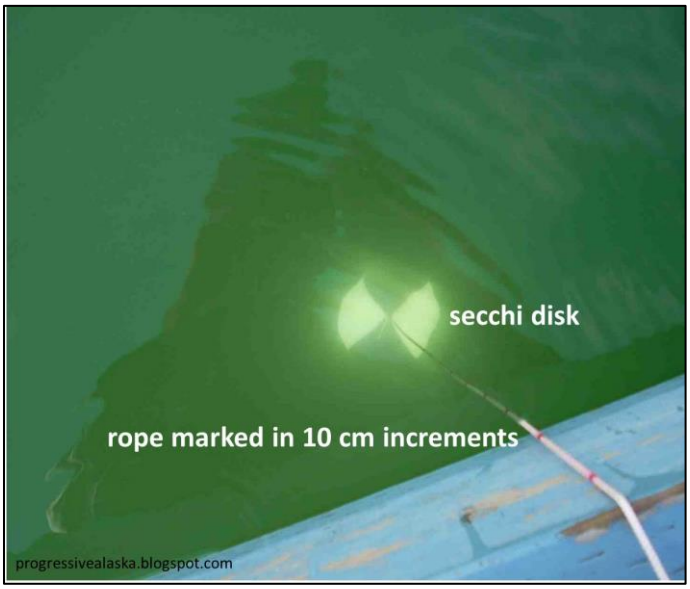

Figure 3. Example of a Secchi disc underwater.

3. Record depth read from the lines on the Secchi rope to the nearest 0.1 m on the Secchi depth field data sheet (Figure 4, 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.

NEON Secchi Depth and Vertical Profile Data

Lakes and Non-wadeable Streams

Site ID: *SUGG*
Date: *2016-09-30*
Local time: *10:30*

Sampling protocol: *NEON.DOC.002792* **Rev:** *B*
Recorded by: sparker@battelleecology.org
Collected by: *jstewart@Field-ops.org*

Station ID	Ice present?	Ice 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*	

Figure 4. Example of field datasheet for Secchi depth data collection (red box).

SOP C Vertical Profile and Thermal Stratification

1. Put probe of the handheld meter into the water.
   a. If lake is iced over, drill a hole through the ice with the auger and measure the ice thickness. Record ice thickness on the field datasheet.
   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 on the field data sheet (Figure 5, RD[06]).
   a. In deeper thermally stratified lakes, once the temperature measurements in the hypolimnion have stabilized, 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).
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). Record on field datasheet.
   a. NOTE: There may be two thermoclines present in deep lakes.

NEON Secchi Depth and Vertical Profile Data

Lakes and Non-wadeable Streams

Site ID: *SUGG*
Date: *2016-09-30*
Local time: *10:30*

Sampling protocol: *NEON.DOC.002792* **Rev:** *B*
Recorded by: sparker@battelleecology.org
Collected by: *jstewart@Field-ops.org*

Station ID	Ice present?	Ice 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*	

Figure 5. Example of field datasheet for vertical profile data collection (red box). Circle "stratified" or "unstratified" after determining the temperature profile.

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.

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. 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

The following datasheets are associated with this protocol:

Table 3. Datasheets associated with this protocol

NEON Doc. #	Title
NEON.DOC.001646	General AQU Field Metadata Sheet
NEON.DOC.002191	Secchi Depth and Depth Profile Sampling

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

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.

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.

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).