NEON PREVENTIVE MAINTENANCE PROCEDURE: SOIL HEAT FLUX SENSOR

PREPARED BY	ORGANIZATION	DATE
Edward Ayres	FIU	01/20/2016
Natchaya Pingintha-Durden	FIU	01/20/2016
Madeline Cavileer	ENG	08/22/2022

APPROVALS	ORGANIZATION	APPROVAL DATE
Kate Thibault	SCI	12/01/2022

RELEASED BY	ORGANIZATION	RELEASE DATE
Tanisha Waters	CM	12/01/2022

See configuration management system for approval history.

The National Ecological Observatory Network is a project solely funded by the National Science Foundation and managed under cooperative agreement by Battelle. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	05/05/2016	ECO-03659	Initial release
B	04/04/2017	ECO-04604	Added procedure to check that cables and other infrastructure are at least 30 cm from the sensors
C	09/20/2017	ECO-04924	Authored Section 2.4, 4.2.1, 6 and 7. Updated Applicable Document numbers and sources applicable to this document in Section 2. Expanded upon maintenance procedures to include sensor subsystem in Section 5.
D	08/29/2022	ECO-06876	Incorporated minor revisions and clarifications from NCC WFH Project 16. Updated branding, formatting, and terminologies. Removed redundant information regarding Sensor Refresh in Section 6. Added RDs in Section 2. Fixed broken links (webpages, document headings, Figures and Tables). Added Figure 2 in Section 4.
E	12/01/2022	ECO-06923	Minor formatting fixes

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1 DESCRIPTION

1.1 Purpose

NEON sites host sensors that take measurements from air, wind, soil, and sun. Regular maintenance of sensors and infrastructure is necessary for the continued operation of the observatory, and to identify small problems before they escalate.

This document details procedures necessary for preventive maintenance of the **Soil Heat Flux** sensor.

1.2 Scope

The procedures detailed in this document are strictly preventive. This document assumes the Soil Heat Flux sensor is the Hukseflux Heat Flux Plate HFP01SC-10 (NEON P/N: CF03900001).

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain information that shall be applied in the current document. Examples are higher-level requirements documents, standards, rules, and regulations. Visit the NEON Document Warehouse for electronic copies of these documents.

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. 050005	Field Operations Job Instruction Training Plan
AD [04]	NEON.DOC.000845	Soil Heat Flux Installation Procedure
AD [05]	NEON.DOC.000779	TIS Soil Plot Layout
AD [06]	NEON.DOC.001436	TIS Communications Interconnect Map
AD [07]	NEON.DOC.004257	All Systems Standard Operating Procedure: Decontamination of Sensors, Field Equipment, and Field Vehicles
AD [08]	NEON.DOC.000395	NEON Sensor Command, Control and Configuration (C3): Soil Heat Flux
AD [09]	NEON.DOC.000769	Electrostatic Discharge Prevention Procedure

2.2 Reference Documents

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document. Visit the NEON Document Warehouse for electronic copies of these documents.

RD [01]	NEON.DOC.000008	NEON Acronym List
RD [02]	NEON.DOC.000243	NEON Glossary of Terms
RD [03]	NEON.DOC.000395	Soil Heat Flux Command Control and Configuration
RD [04]	NEON.DOC.003146	Soil Sensor Depth Selection
RD [05]	NEON.DOC.004998	NEON Corrective Maintenance Procedure: Soil Heat Flux Sensor Splitter Cable Field Repair
RD [06]	NEON.DOC.004262	Soil Heat Flux Formal Verification Procedure
RD [07]	NEON.DOC.004739	NEON Installation, Operation & Maintenance Procedure: Mobile Deployment Platform (MDP) Soil Module

2.3 External References

External references contain information pertinent to this document but are not NEON configuration-controlled. Examples include manuals, brochures, technical notes, and external websites.

ER [01]	Hukseflux. User Manual HFP01 & HFP03 Heat flux plate/heat flux sensor v1620.
ER [02]	Hukseflux. HFP01 Heat flux plate/heat flux sensor Brochure.

2.4 Acronyms

Acronym	Description

A/R	As Required
P/N	Product Number
CVAL	Calibration, Validation and Audit Laboratory
ESD	Electro-static Discharge
IOCR	Initial Observatory Capability Review
JSA	Job Safety Analysis
LOTO	Lock-out/Tag-out
SP	Soil Plot
TIS	Terrestrial Instrument Site

3 SAFETY AND TRAINING

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 fieldwork practices as outlined in AD [02] and AD [01]. Additional safety issues associated with this field procedure are outlined below. The Field Science 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.

All ecologists must complete required safety training and protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD [03]).

4 SENSOR OVERVIEW (SENSORS ONLY)

4.1 Description

The soil heat flux plate measures the heat flux into and out of the soil at its installation depth (8 cm below the soil surface at NEON sites). These data will be used to determine the energy balance of the NEON TIS site, which informs a systematic uncertainty, and will be included in the calculation of the turbulent flux measurement system overall uncertainty. The heat flux plate has a diameter of 80 mm and a thickness of 5.0 mm (**Figure 1**, ER [01]).

The sensor is permanently installed in the soil and shall not be removed for regular inspection, recalibration, or replacement unless a problem is identified.

Figure 1. Top view of the Soil Heat Flux sensor.

4.2 Sensor Specific Handling Precautions

There are no sensor specific handling precautions for the Soil Heat Flux sensor. Installation of the sensor is permanent in the soil and does not require handling unless to address corrective actions/repairs.

4.2.1 Grapes

Grapes contain ESD sensitive parts; therefore, all Grapes require ESD (antistatic) packaging and handling during inter- and intra-site transport, reception, and storage. As a rule, when handling (installing, removing, and servicing) these electrical components, all Ecologists must ground themselves. Reference AD [09].

4.3 Operation

The Soil Heat Flux sensor collects measurements via a thermopile in the sensor plate, which measures the temperature gradient across the ceramic-plastic body of the sensor (reference ER [01] and **Figure 2** below). The sensor performs a self-calibration periodically using an embedded heater to generate a known heat pulse through the plate.

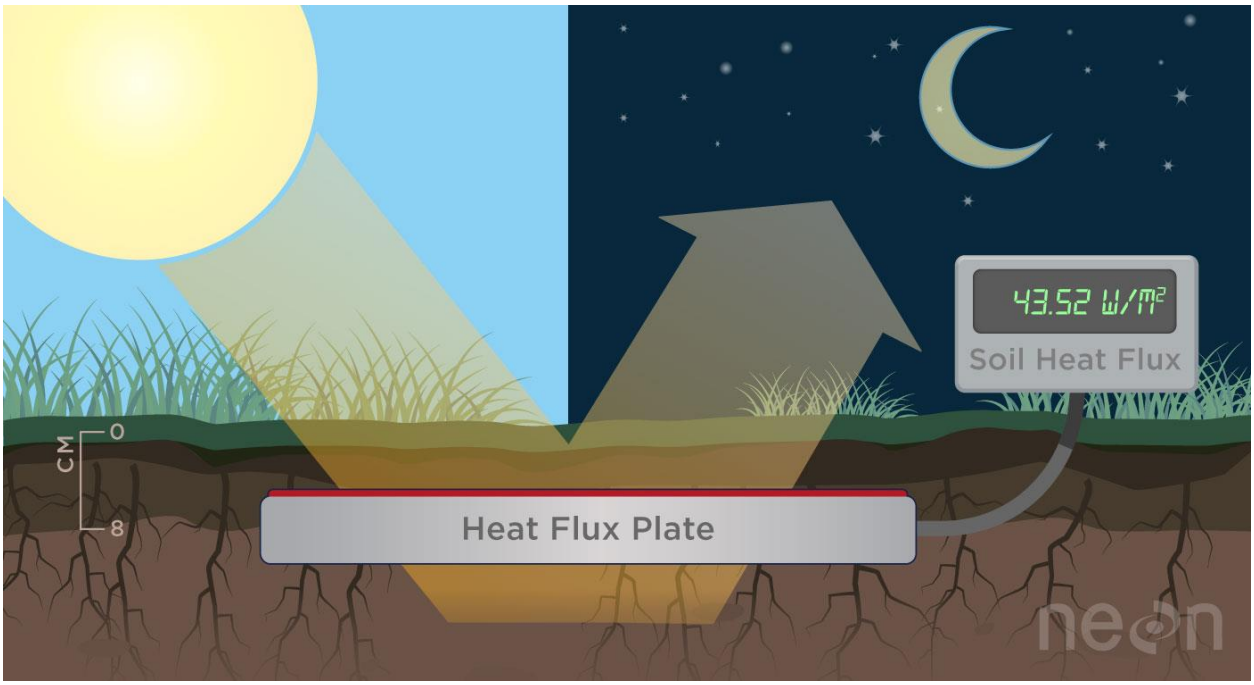

Figure 2. The Soil Heat Flux Sensor Collects Measurements via a Thermopile in the Sensor Plate, which Measures the Temperature Gradient across the Sensor's Ceramic-Plastic Body.

5 INSPECTION AND PREVENTIVE MAINTENANCE

5.1 Equipment

Table 1. List of equipment needed to perform preventative maintenance.

Item No.	Description	Quantity
Tools		
NA	Camera	1
S-16061FO	Stake Flags	A/R

5.2 Subsystem Location and Access

All the sensors within the soil plots are making measurements of the environment immediately surrounding them; therefore, it is essential that disturbance to the soil plot and surrounding area is kept to an absolute minimum. To ensure compliance, conduct all necessary maintenance activities within a soil plot at the same time, whenever possible to minimize trips in and out of the plot and surrounding area.

Access to the soil plots shall follow the designated route that was established during site construction. Typically, this route starts at the staging area and follows a clearly marked path that passes the instrument hut before reaching the soil array path. Only foot traffic is acceptable between the soil array path and each soil plot (i.e., no wheeled carts or other machinery), apart from special equipment necessary to perform maintenance to meet the conditions specified in the Flora and Fauna Protocols (for example, a rotor tiller to mimic plowing at an arable site).

Once you reach the device post for the relevant soil plot, walk towards the soil plot following the route of the conduit from the device post to the soil plot arbor, always remaining at least 1 m (~3.3’) outside of the soil plot (see **Figure 3**). Take the shortest route towards the assembly that keeps you at least 1 m outside of the soil plot.

Note: Always remain at least 1 m outside of the plot unless you must perform activities that require you to be closer to, or inside, the soil plot. If you do approach the soil plot, do not step or place tools on the ground within 30 cm (~1’) of any sensors within the soil plot to minimize disturbance to the soil and vegetation surrounding the sensor.

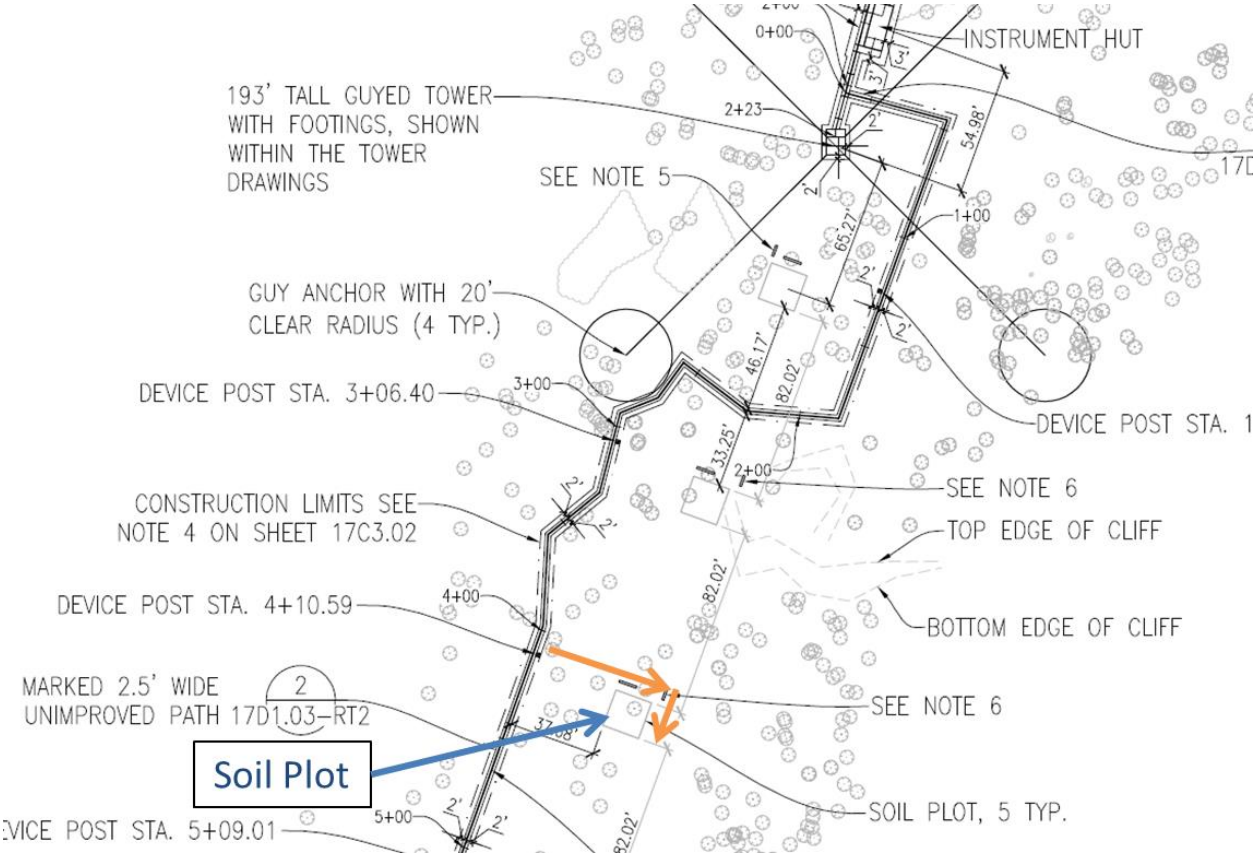

Figure 3. Example walking route (orange arrows) from the soil array path to a soil plot based on D17 SOAP civil construction plans.

Installation of the Soil Heat Flux sensor occurs in the soil sensor section of a soil plot (AD [04]). One Soil Heat Flux sensor is installed in three TIS soil plots at each NEON site (i.e., a soil plot may have zero or one Soil Heat Flux sensor, but no more than one). The soil plots that contain a Soil Heat Flux sensor are chosen to maximize the distance between measurement locations, as a result the Soil Heat Flux sensor will not necessarily be in the same soil plots at each NEON site. For example, a TIS site may have soil plots 1, 3, and 5 contain a Soil Heat Flux sensor, while at another site, soil plots 1, 4, and 5 may contain a Soil Heat Flux sensor. The site-specific requirements define which soil plots receive a Soil Heat Flux sensor for TIS sites and locations are in each site's As-Built document, which resides in the NEON Program Document Warehouse.

Since the installation of the Soil Heat Flux sensor is at 8 cm below the soil surface, it is not directly visible within the plot. The Soil Heat Flux sensor assembly cable is the only component that is visible, which is visible entering the soil to where the Soil Heat Flux sensor is buried. According to AD [04], the Soil Heat Flux sensor location is approximately 44-52 cm (~17-20 inches) in front of the location where the cable enters the soil (**Figure 4**). The exact location of each Soil Heat Flux sensor is in the sites' Initial Observatory Capability Review (IOCR) documents.

Figure 4. The Soil Heat Flux sensor is located approximately 44-52 cm (~17-20 inches) in front of the location where the cable enters the soil (dashed orange circle).

5.3 Maintenance Procedure

Prior to conducting visual inspections on each soil plot, conduct a remote inspection on their subsystems via the Location Controller (LC) and through data monitoring software, from either the Domain office or the Instrumentation Hut. The data state of health presents indicators to focus preventive maintenance efforts; anomalies in the data may dictate preventive maintenance tasks for investigation to determine if corrective action is necessary. These tasks take precedence over subsystems presenting normal values (e.g., removing electrical and communication equipment due to an HVAC failure in the summer). The Merlot Grape (12V) and Soil Heat Flux sensor are two items to check remotely to verify state of health. See **Table 4** for the command prompts to check if the sensor and its subsystem (the Merlot Grape) are functioning properly on our network.

Conduct the following inspection on each Soil Plot containing this sensor system and subsystem:

1. Do not stand or place tools on the ground closer than 30 cm (~1 foot) from the edge of the sensor location or any other sensor within the soil plot.

2. Conduct an inspection around the sensor for any disturbance. To conduct this inspection, stand outside of the soil plot and observe the approximate location of the heat flux sensor.

    a. If there is no snow or standing water around the sensor check for noticeable soil erosion, deposition, and burrowing above the sensor location and within 30 cm radius of the sensor location every 2 weeks.

Note: If snow or standing water is present, do not perform this check.

b. If there are no signs of disturbance, do nothing.

c. If soil disturbance is noticeable, submit a ticket through the NEON Program's Issue Management and Reporting System including the soil plot (SP) number, a description, and photo showing the affected area. NEON Science and Engineering will determine the next steps and provide guidance to conduct corrective actions.

3. If there are no signs of snow or standing water around the sensor, check that there are no cables or other NEON infrastructure within 30 cm of the sensor, excluding the cable that directly connects to the sensor.

    a. If there are no cables within 30 cm of the sensor, do nothing

    b. If there is a cable within 30 cm of the sensor, if possible, move the cable so that it is at least 30 cm from the sensor, and submit a problem ticket including a description and photo showing distance of the cable from the sensor.

4. Do not walk on the armored cable to the sensor. Mark the sensor area and armored cable using stake flags or fiberglass snow stakes to provide awareness for Domain staff and visitors of locations to avoid. **Figure 5** is an example of using snow stakes to identify the sensor for reference.

5. Inspect the Soil Heat Flux Merlot Grape (12V). Verify connections are secure and there are no signs of corrosion, overheating or deterioration.

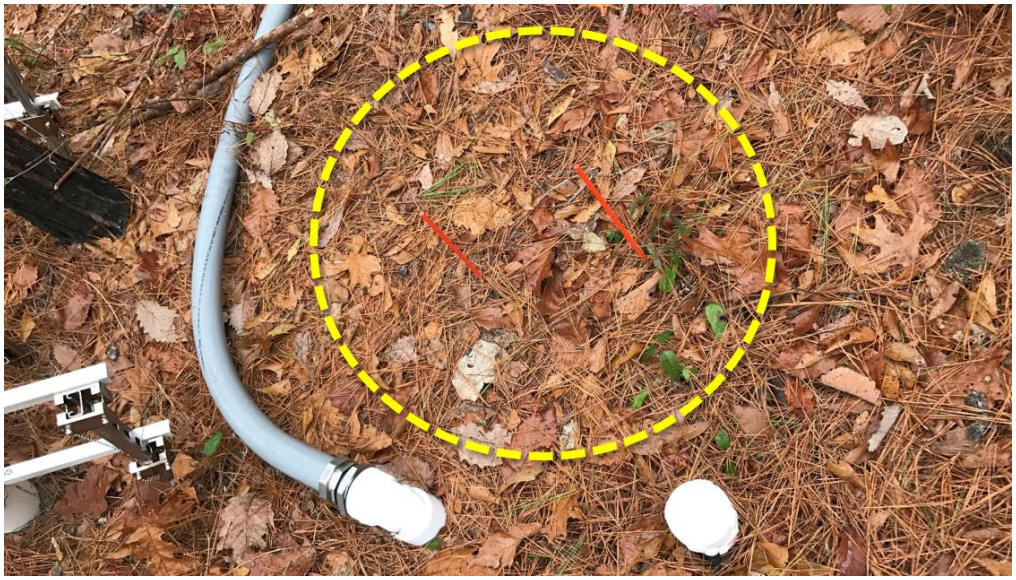

Figure 5. Fiberglass Snow Stakes Identifying the Soil Heat Flux location in a Soil Plot (SP) (Domain 08, Talladega National Forest TIS Site).

6 REMOVAL AND REPLACEMENT (SUBSYSTEM ONLY)

The Soil Heat Flux Merlot Grape (12V) is the only part of the sensor/subsystem that requires annual calibration and validation.

6.1 Equipment

Table 2 contains a list of equipment to conduct sensor refresh at TIS sites for specific instrumentation and/or subsystem components that require calibrations and validations. This also includes unique equipment necessary for removal and replacement procedures. Equipment recommendations and applicability may adjust over time as the implementation of NEON sensors and subsystems mature.

Table 2. Removal/Replacement and Sensor Refresh Equipment List.

P/N	MX/NEON	Description	Quantity
Tools			
4620	MX103120	3M Antistatic Wristband (ESD Requirement)	1
GENERIC		3/16” Allen Wrench	1
Consumable Items			
3M	*See below*	ESD Bags for Sensor Refresh	1
	MX105865	3M Bag, ESD Shielded, 8 inch x 11 inch, Cushioned	A/R
	MX105931	3M Bag, ESD, Static Shield, 6 x 8 Inches, Zip Closure, Non-Cushioned	A/R
	MX105864	3M Bag, ESD Shield, 6 Inch X 7 Inch, Cushioned	A/R
	MX105866	3M Bag, ESD Shielded, 14 Inch X 15 Inch Cushioned	A/R
	MX105935	3M Bag, ESD, Static, 15 x 18 Inches, Zip-Closure Top	A/R
	MX110345	3M Bag, ESD Static Shield, 12 inch x 12 inch, Zip Closure	A/R
S-2670		ESD wrap: ULINE Color-tined Cast Goodwrappers - Plastic Wrap (Palletizing for Sensor Refresh) in Red (S-2670R), Blue (S-2670BLU), Green (S-2670G), Orange (S-2670O), and Black (S-2670BL)	A/R
GENRIC		Towel (To Leverage Grip or Wipe-off Items)	1
1HAB2	MX104219	Grainger Red Inspection Tag, Paper, Rejected, PK1000	A/R
		Plastic Grape Dust Caps	A/R
S-16061FO		ULINE Stake Flags - 2 1⁄2 x 3 1⁄2", Fluorescent Orange or Fiberglass Snow Stakes	A/R
Resources			
GENERIC	MX106639	Sturdy Container and/or Backpack (Transport Sensors from each Soil Pit Location)	1

6.2 Removal and Replacement Procedure

Field Science is responsible for managing the removal and replacement of the sensors onsite for preventive maintenance and/or sensor swaps and manages field calibration and validation of sensors, as appropriate. The NEON Program Calibration, Validation and Audit Laboratory (CVAL) is responsible for the calibration and validation of select sensors and manages Domain sensor refresh (swap) schedules.

To minimize data downtime and optimize the availability of sound data, coordinate instrumentation and subsystem **annual** calibration, validation, and preventive maintenance requirements to occur within the same timeframe. See **Table 3** for sensor refresh requirements for the Soil Heat Flux sensor.

Table 3. Soil Heat Flux Sensor Refresh Requirements.

	LOCATION		TIMEFRAME			
	CVAL	*FIELD*	*BIWEEKLY*	*ANNUAL*	*NA*	COMMENTS
Soil Heat Flux Merlot Grape (12V)	X			X		TIS: Only Concords, Merlots, and Catawbas require annual refresh.

Note: Always shutdown the power prior to removing or replacing any components. Remove the Ethernet Cable from the Grape to power down the Soil Heat Flux sensor and Grape.

As a reminder, please maintain ESD (antistatic) packaging and handling during inter- and intra-site transport, reception, and storage of Grapes.

6.2.1 Remove/Replace Soil Heat Flux Merlot Grape(s) (12V)

1. Record EPROM ID, "Property of" Asset Tag number, Removal/Replacement date and time. The following template is a great example for capturing Sensor Refresh information to update logistic records and monitor the Grape state of health via the LC pre- and post-swap.

Soil Heat Flux Merlot Grape (12V) |Soil Plot #_____

	Old Grape	New Grape
EPROM ID		
14-digit Asset Tag (Property of)		
Uninstall / Install Date and Time		
Moved in Maximo?		

Source: Soil Plot Verification Checklist, V 1.0 via Gregory Cain in D09, May 22, 2017

2. Wear an anti-static wristband. Employ ESD protocols when handling Grapes. Reference AD [09].

3. Detach the armored Ethernet cable from Grape (RJF connection). This action will power down the Grape. (This must occur to prevent damage to the Grape.)

4. Remove/Replace Grapes from each Soil Plot arbor by removing the four screws that affix the Grape to the Grape Shield. If it is difficult to reach these four screws, remove the Grape Shield from the arbor via the two captive screws on the clamp with a 3/16" allen wrench.

5. Connect the sensor to the Grape per AD [07].

6. Reattach the armored Ethernet cable to the Grape after the sensor connections are secure.

7. Verify the Grape is on the network and streaming data via Data Monitor or a terminal emulator program (e.g., PuTTY). To verify function of the Grape post-swap, there are two ways to complete this action – through the Grape MAC address or the Soil Heat Flux sensor EPROM ID. See **Table 4** for the command prompts below.

PuTTY Login Username: **user** | Password: **resuresu**

Table 4. Verify Grape Function Post-Sensor Swap (MAC and EPROM ID are Examples for this Command).

PuTTY Command	Description
`vd | grep 15FD`	This displays the data from the grape (grep) with the MAC Address 7CE0440015FD
`vd -s 15068`	This displays data from the sensor (-s) with EPROM ID 15068

Source: Genny's Fav LC Commands by Genevieve Faria, February 07, 2017, N:\Common\FieldOperations\Useful TIS Info\LC Stuff

6.3 Cleaning and Packaging of Returned Parts

Field Operations staff clean, package, and ship the sensors back to the CVAL at the NEON Program HQ (Battelle) for annual sensor swap/calibration requirements. (Please note: if a sensor is defective, submit a trouble ticket and affix a red tag (**Figure 6**) with the trouble ticket number on it). Clean the Grape (also known as decontamination; *Reference AD [07])* by removing all biologics from the device prior to capping the connections and placing in ESD packaging. Reference **Table 2** for the equipment, tools, and consumables necessary for conducting the NEON HQ, CVAL Sensor Refresh procedures for the Environmental Enclosure Grapes.

Please remove all arachnids and/or insects from tower instruments prior to packing and shipping. Reference AD [07].

For the cleaning and packaging of Grapes post-removal, conduct the following steps:

1. Check mounting holes for spiders and spider webs. Remove biologics and clean connectors.
2. Cap all connectors.
3. Conduct decontamination and remove any additional biologics from the devices.
4. Place the device in an ESD bag and shipping container.
5. Update asset records via the NEON's project Asset Management and Logistic Tracking System (e.g., All devices in transit to HQ shall be moved to TRANSIT in Maximo). NEON HQ, Logistics Warehouse (LOGWAR) receives the Grapes for refresh and distributes to CVAL.

Note: In general, to minimize errors for CI, all devices leaving a CFGLOC must move to SITE first, then TRANSIT/DxxSUPPORT.

6. Provide an electronic packing list to CVAL with the Box number and Asset Tag number (14-digit Property Tag ID ("Property of") number) of each item. CVAL uses this information to verify items via LOGWAR/general HQ distribution of shipments.

7. Prepare a Bill of Lading.

For any Non-CVAL initiated sensor returns, please notify CVAL of the return.

6.4 Sensor Refresh Record Management of Assets

In addition to the physical movement of devices, the sensor refresh process requires dedicated and accurate record management of asset movement and location. However, the Soil Heat Flux is self-calibrated and should only be disturbed for repair reasons. This section is provided for awareness in the event the sensor is relocated/moved.

6.4.1 NEON Asset Management and Logistic Tracking System Requirements

Ecologists must update the instrumentation records via the NEON's project Asset Management and Logistic Tracking System (MAXIMO). NEON HQ must maintain accurate record keeping on the location, date, and time offline of an instrument to ensure NEON HQ, Computer Infrastructure, Data Products, and CVAL are aware to apply the correct algorithms, calibrations, and processing factors. Ensure the CFG location reflects the current site of the sensor. All devices leaving a CFGLOC must move to SITE first, then TRANSIT/DxxSUPPORT.

6.4.2 Command and Control Program Information Requirements

Provide notification of the new sensor/subsystem NEON Asset Tag Number via the Asset Management and Logistic Tracking System (MAXIMO), which is the 14-digit Property Tag ID ("Property of") number on the sensor/subsystem and EPROM ID via the NEON Program issue management and reporting system. This ensures integration of the new sensors/subsystems into the NEON Command and Control program. Route and/or add NEON Engineering to the ticket to notify the appropriate points of contact.

7 ISSUE REPORTING OUTPUTS

Field Science must report issues encountered while conducting preventive maintenance in the NEON Program Issue Management/Reporting System. To ensure a quick response and remedy to an issue, please include as much information and detail, as possible. This includes, but is not limited, to the following:

- Domain and Site name
- Date and Time
- Ecologist Full Name
- Issue Narrative (detailed narrative of the issue, specific location of issue on tower infrastructure, relevant 2nd/3rd order effects to infrastructure, possible cause [e.g., weather event, obstruction, human activity])
- Multiple Photographs (to capture vantage points/perspectives for remote diagnostic)
- Provide Part Number/Manufacturer Information, EPROM ID, Asset Tags, IP Address, MAC Address, etc.
- Provide Diagnostic Information (from firmware, if applicable), such as error codes, values, etc. Provide screenshots.

Table 5. Metadata Output Checklist.

Issue Reporting Datasheet: Soil Heat Flux		
Datasheet field	**Entry**	
NEON Site Code		
Maintenance Date		
Maintenance Ecologist		
Preventive Maintenance	**Issue Noted**	**Issue Summary**
Sensor - Condition Check (Inspect for a disturbance in soil area)	☐	
Environmental Information (Any standing water or heavy snowpack?)	☐	
Merlot Grape (12V)	☐	
Cables, Connectors, Bolts, etc.	☐	
Notes		

For Soil Heat Flux sensor corrective actions, ensure proper tracking of the asset via the NEON issue management and tracking system (e.g., Service Now) to establish a chain of custody of the asset between Engineering Repair Laboratory and CVAL.

Conduct the following tasks to ensure the proper management of the asset between sites:

For each issue where NEON, HQ is replacing a defective instrument/subsystem at a TIS site, please create a sub-task in the NEON Issue Management and Reporting System for the defective asset from the reported issue. Resolution of an issue does not occur with the installation of a replacement, but with the root cause analysis of the issue deriving from the defective asset. Field Science may resolve the ticket upon installation of the replacement if a sub-task exists for the defective asset for NEON HQ to conduct root cause analysis.

1. Ship all defective equipment/assets with a red "Rejected" tag. **Figure 6** displays the ideal information requirements for each tag.

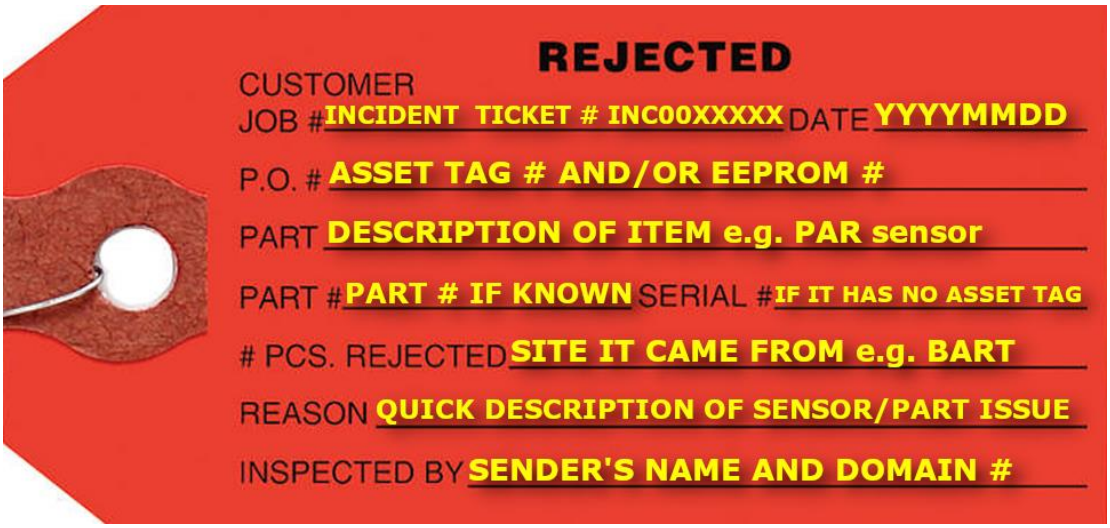

Figure 6. Red Rejected Tag for Defective Assets (MX104219).