NEON PREVENTIVE MAINTENANCE PROCEDURE: SOIL CO_2 CONCENTRATION

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	05/05/2016	ECO-03708	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	03/30/2018	ECO-05502	Added Section 6 and new content in each section since initial release.
D	08/15/2018	ECO-05749	Updated Section 5 preventive maintenance instructions, and added 5.3.4 O-Ring & Rubber Seal Maintenance. Made updates to Section 6 re-installation instructions from lessons learned in the field. Made minor corrections to grammar/wording and added an AD in Section 2.
E	09/18/2019	ECO-06254	Updated Figure 12 and expanded guidance to grease the larger rubber seal per INC0031936.
F	12/01/2022	ECO-06923	Updated NEON logo and minor formatting fixes

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1 DESCRIPTION

1.1 Purpose

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

This document establishes mandatory procedures and recommended practices for preventive maintenance of the **Soil CO_2 Concentration** to meet the objectives of the NEON project, and its respective stakeholder and end users.

1.2 Scope

Preventive Maintenance is the planned maintenance of sensors and infrastructure with the goal of ensuring that the instrument and/or infrastructure performs correctly to ensure the collection of the best available science, by preventing excess depreciation and impairment. This maintenance includes, but is not limited to, inspecting, calibrating, adjusting, cleaning, clearing, lubricating, repairing, and replacing, as appropriate. The procedures in this document are strictly preventive and do **not** address corrective actions.

This document addresses preventive maintenance procedures to maintain the Vaisala GMP343 diffusion-model sensors (***CF08000000*** *Subsystem, CO2, Soil - Depth 2cm - 51cm)* at applicable NEON Terrestrial Instrument System (TIS) sites. This includes preventive maintenance procedures and requirements for the Soil CO_2 Concentration instrument, subsystem and supporting infrastructures.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

The following applicable documents (AD) contain mandatory requirements and/or supplementary information that are directly applicable to the topic and/or procedures herein. Visit the NEON Document Warehouse for electronic copies of these documents.

AD [01]	NEON.DOC.004300	Environmental, Health, Safety And Security (EHSS) Policy, Program and Management Plan
AD [02]	NEON.DOC.004301	EHSS Environmental Protection Manual
AD [03]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD [04]	NEON.DOC.001436	TIS Comm Interconnect Map
AD [05]	NEON.DOC.000804	Site Flora and Fauna Maintenance Plan
AD [06]	NEON.DOC.00XXXX	Site-specific Flora and Fauna Maintenance Plan
AD [07]	NEON.DOC.000103	NEON Sensor Command, Control, and Configuration: Soil CO2 Sensor
AD [08]	NEON.DOC.000769	Electrostatic Discharge Prevention Procedure
AD [09]	NEON.DOC.002051	NEON Installation Procedure: Soil CO2
AD [10]	NEON.DOC.004275	Soil CO2 Formal Verification Procedure
AD [11]	NEON.DOC.000779	TIS Soil Plot Layout
AD [12]	NEON.DOC.003146	Soil Sensor Depth Selection
AD [13]	NEON.DOC.001214	L1G300 Soil CO2 IRGA Sensor Calibration Fixture Manual
AD [14]	NEON.DOC.004257	All Systems Standard Operating Procedure: Decontamination of Sensors, Field Equipment, and Field Vehicles
AD [15]	NEON.DOC.005038	NEON Standard Operating Procedure (SOP): Sensor Refresh
AD [16]	NEON.DOC.002043	Assy, Soil CO2 Inner Pipe 2cm-51cm Depth

2.2 Reference Documents

Reference documents contain information complementing, explaining, detailing, or otherwise supporting the information included in the current document.

RD [01]	NEON.DOC.000008	NEON Acronym List
RD [02]	NEON.DOC.000243	NEON Glossary of Terms
RD [03]	NEON.DOC.002768	TIS Subsystem Architecture, Site Configuration and Subsystem Demand by Site - SCMB Baseline
RD [04]	NEON.DOC.004637	TIS Verification Checklist
RD [05]	NEON.DOC.003656	NEON Preventive Maintenance Procedure: Soil Throughfall Collector
RD [06]	NEON.DOC.003622	NEON Preventive Maintenance Procedure: Soil Water Content and Salinity Profile
RD [07]	NEON.DOC.003593	NEON Preventive Maintenance Procedure: Soil Temperature Profile

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]	Vaisala (2013) User's Guide: Vaisala CARBOCAP Carbon Dioxide Probe GMP343, Version M210514EN-E. Vaisala Oyj., Helsinki, Finland.

2.4 Acronyms

Acronym	Description
CPER	Central Plains Experimental Range (Domain 10)
CO_2	Carbon dioxide
Comm	Communications
JORN	Jornada (Domain 14)
NEMA	National Electrical Manufacturers Association
SP	Soil Plot
TALL	Talladega National Forest (Domain 08)
TEP	Terminal Emulator Program

2.5 Terminology

The use of common names for NEON instrumentation and subsystems vary across departments and domains. This section aims to clarify and associate the common names with the technical names herein. The aim of this section is to marry up terms under one name so Technicians are aware of the component referenced in the procedures herein, but also aware they may be called another term in a group discussion with headquarters or training staff.

SYNONYMOUS COMMON NAME(S)	NEON TECHNICAL REFERENCE NAME
Power Box, Comm Box, National Electrical Manufacturers Association (NEMA) Enclosure, Power/Comm Infrastructure, Combo Box, Arbor	**Device Post**

3 SAFETY AND TRAINING

Personnel working at a NEON site must be compliant with safe fieldwork practices in AD [01] and AD [02]. 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 work in unsafe conditions.

All technicians must complete safety training and procedure-specific training to ensure the safe implementation of this protocol per AD [03]. Refer to the site-specific EHSS plan via the NEON Safety document portal for electronic copies.

Preventive maintenance of TIS Soil Arrays may require the use of a special equipment to access the sensor subsystem assemblies. Follow Domain site-specific EHS plans via the Network Drive and NEON safety training procedures when conducting maintenance activities. Conduct a Job safety Analysis (JSA) prior to accessing the sensor subsystems onsite. Reference the Safety Office SharePoint portal for JSA templates and additional hazard identification information.

In the event the current method to conduct the procedures herein are no longer safe for use due to unforeseen or unknown site dynamics, consult with the NEON Safety Office via the NEON Project's Issue Management and Reporting System (i.e., ServiceNow) for alternative methods to conduct TIS preventive/corrective maintenance and Sensor Refresh procedures.

4 SENSOR OVERVIEW (SENSORS ONLY)

4.1 Description

The soil CO_2 concentration measurements within each soil plot will be used to create a profile of CO_2 concentration with depth that, in combination with soil CO_2 diffusivity data, can be used to estimate soil respiration rates and CO_2 efflux into the atmosphere. Soil respiration is a proxy for total biological activity of plant roots, microbes, and fauna in the soil and represents one of the largest fluxes of CO_2 from ecosystems to the atmosphere. As a result, soil respiration rates are directly related to several important ecosystem processes, such as organic matter decomposition, biologically mediated nutrient cycling, and whether the ecosystem is a net source or sink of CO_2.

The soil CO_2 concentration assembly consists of an outer tube that is permanently installed in a borehole in each soil plot. Reference **Figure 1**. The outer tube has inlet holes around its lower end to allow soil air from the desired measurement level to diffuse into the tube. The sensor is mounted within the inner assembly, which can be inserted and removed from the outer tube without disturbing the surrounding soil. This allows regular calibration and corrective maintenance of the sensors to be performed while maintaining an undisturbed soil profile. A rubber seal prevents aboveground air from reaching the sensor headspace and the sensor is encased in CO_2 permeable materials to protect it from dust and soil animals, while providing connectivity to the soil air.

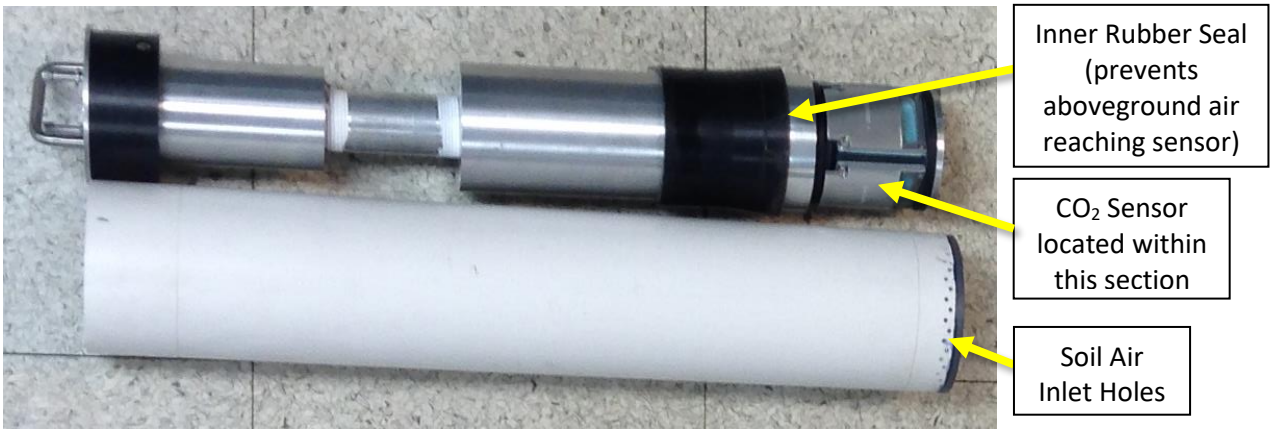

Figure 1. Soil CO_2 concentration assembly (top cap not shown). The outer tube (bottom) and inner assembly, which contains the sensor (top) on the left.

4.2 Sensor Specific Handling Precautions

4.2.1 Instrument

Do not step within 30 cm of the sensor assembly to avoid disturbing the soil that the sensor is measuring. This is particularly important for soil CO_2 concentration measurements since the air inlets are often located near the soil surface and diffusion of CO_2 into the assembly will be altered by any changes in soil structure (e.g., due to compaction).

Do not allow water or other debris to enter the assembly tube. Handle sensor filter with rubber gloves.

Employ ESD protocols per AD [08] when handling Soil CO_2 sensors for Sensor Refresh, or while conducting maintenance activities. Do not allow the sensor filter to get wet or dirty; ensure all gaskets are reinstalled when re-assembling the entire assembly to mitigate leaks into the assembly and pump any residual water from the sensor's reinstallation location before reinstalling in the ground.

4.2.2 Subsystem

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 Technicians must ground themselves. Reference AD [08]. Conduct Lockout/Tagout (LOTO) procedures to disable machinery or equipment to prevent the release of hazardous energy while performing service and maintenance activities.

4.3 Operation

The soil CO_2 concentration sensor is a Vaisala GMP343 diffusion model sensor with 0-20,000 ppm range (**Figure 2**). A light source in the sensor shines light through the sensor headspace, which connects to the air outside the sensor, and onto a mirror where it reflects onto a Fabry-Perot Interferometer and infrared detector (ER [01]). The interferometer changes between a CO_2 absorption band and a reference band that is insensitive to CO_2. The ratio between the infrared detector measurements corresponding to these bands is proportional to the CO_2 concentration of the air in the sensor headspace.

Figure 2. Vaisala GMP343 CO_2 Sensor.

5 INSPECTION AND PREVENTIVE MAINTENANCE

5.1 Equipment

Table 1. Equipment needed for Preventative Maintenance.

Item No.	Description	Quantity
Tools		
NEON, IT	NEON Laptop	1
GENERIC	Ethernet Cable	1
GENERIC	#2 Philips Head Screwdriver	1
GENERIC	Camera	1
GENERIC	Compass	1
GENERIC	Wood plank, rubber mat, or similar (~60 x 40 cm) for standing on in soil plot	1
MX103120	3M Antistatic Wristband (ESD Requirement)	1
Consumable Items		
0338570000	Bag, Disposable Desiccant, Indicating Silica Gel, for 60 Cubic Inches	15
0373890000	GPL-201 Grease, PFPE/PTFE, High Vacuum, Silicone & Hydrocarbon Free, 2oz Tube	1
CF00550062	Kit, For Updating CF00550061, Including Modifying CO2 Probe Ring And O-Rings	A/R
GENERIC	DI water & Lint Free-Cloth (to clean rubber seal before applying grease)	1
Resources		
	Terminal Emulator Program (TEP) (i.e., PuTTy, MobaXterm, other SSH/Telnet client)	

5.2 Subsystem Location and Access

All the sensors within the soil plots are making measurements of the environment immediately surrounding them. **Figure 3** provides an example of a soil plot in Domain 10 at the Central Plains Experimental Range (CPER) TIS site. (This provides graphical overview of a soil plot sensors that resides at most TIS sites.)

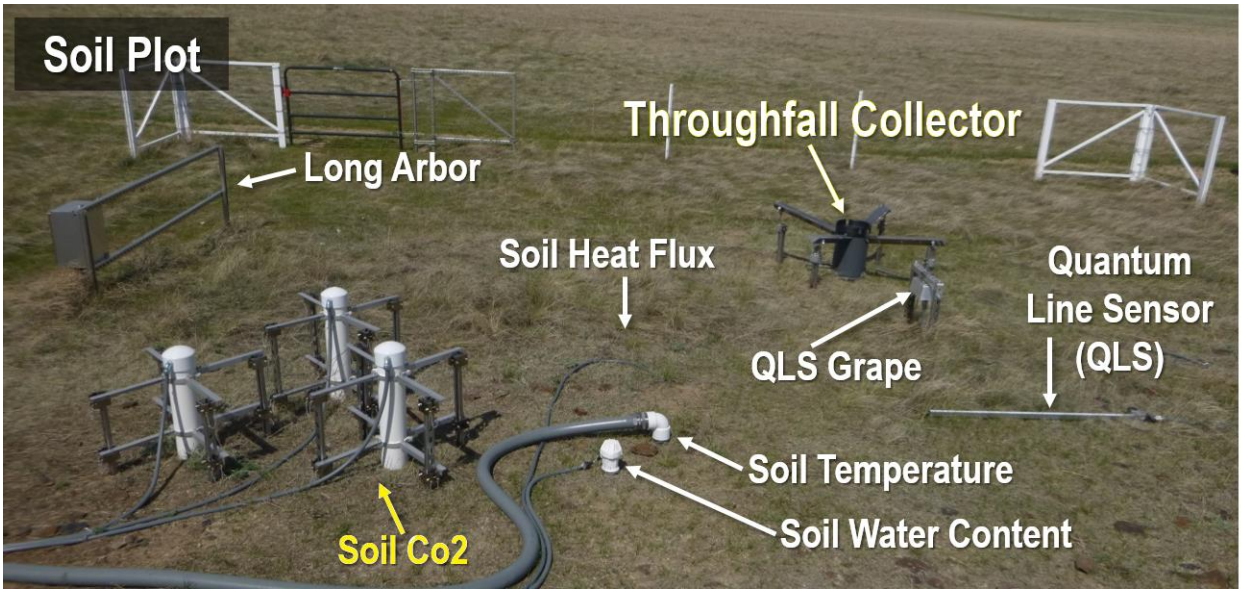

Figure 3. Soil Plot 1 (Domain 10, CPER) with Cattle Fencing (Not Shown: Device Post, Short Arbor, HMP and NR01).

It is important that FOPS does not disturb the soil plot and surrounding area while conducting maintenance activities. The NEON project headquarters (HQ) recommends grouping sensor maintenance activities together to minimize influencing the surrounding area and reduce FOPS ecological footprint in each plot. Minimize the amount and frequency of trips in and out of each plot and surrounding area as much as possible.

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. The NEON project only permits foot traffic between the soil array path and each soil plot (i.e., no wheeled carts or other machinery), with the exception of equipment to perform maintenance to meet the conditions specified in the Flora and Fauna plans in AD [05] and AD [06]. For example, a rototiller to mimic plowing at an arable site.

Important: Once Technicians reach the device post at the relevant soil plot, they must walk towards the soil plot following the route of the conduit from the device post to the soil plot arbor remaining at least 1m (~3.3') outside of the soil plot at all times (see **Figure 4**). Always travel the shortest route towards the assembly that remains at least 1m outside of the soil plot.

Remain at least 1m outside of the plot unless maintenance activities requires close contact with a sensor. When approaching a soil plot, do not step or place tools on the ground within 30cm (~1') of any sensors within the soil plot to minimize disturbance to the soil and vegetation surrounding the sensor.

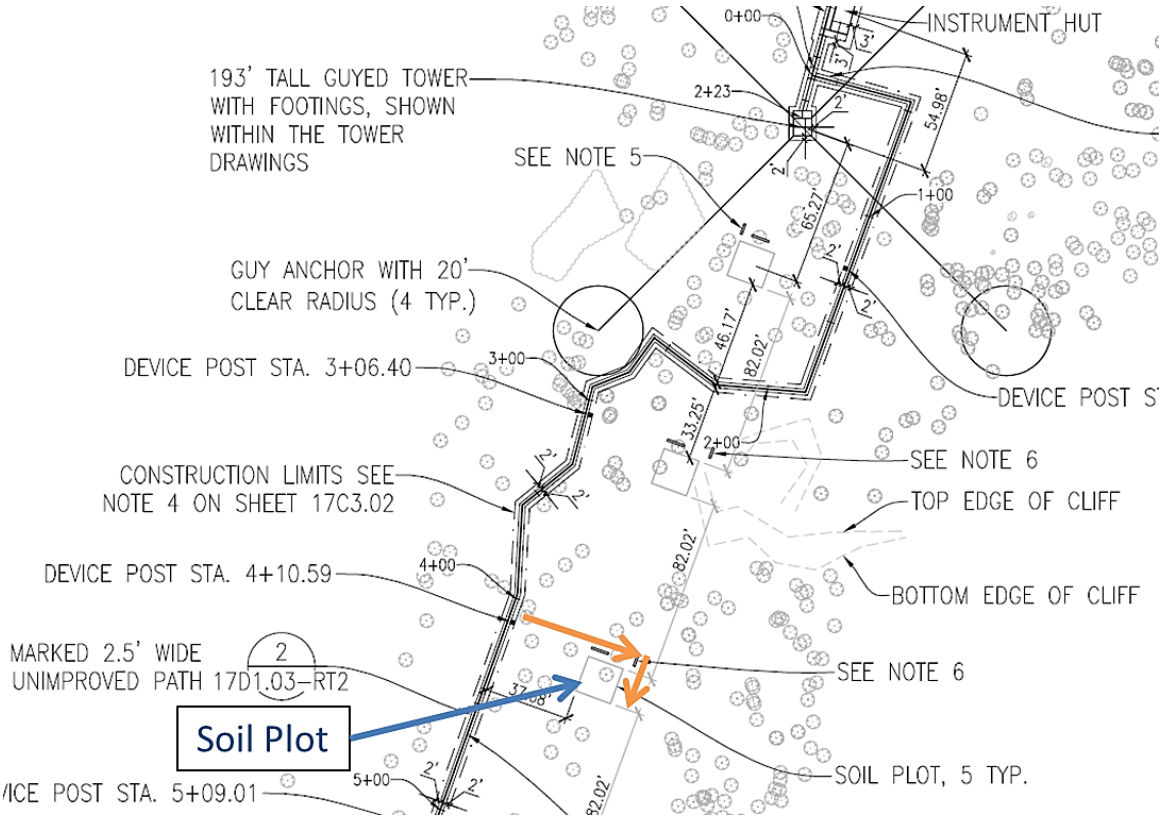

Figure 4. Walking Route Example (Orange Arrows) From the Soil Array Path to a Soil Plot (D17 SOAP Civil Construction).

The soil CO_2 concentration sensors are installed in the soil sensor section of a soil plot (AD [11]). Three soil CO_2 concentration sensors are installed in each of the five TIS soil plots at each NEON terrestrial site. The three sensors within each plot are installed with their soil air inlets at different depths to allow the gradient of CO_2 concentration with depth to be determined. The outer assembly tube is installed perpendicular to the **soil surface** at the location where it is installed. Metal braces keep the assembly securely in place. The aboveground portions of the soil CO_2 concentration assemblies are visible in the soil plot. Reference **Figure 5**.

Figure 5. Three soil CO_2 Concentration Assemblies within a Soil Plot (Foreground).

5.3 Maintenance Procedure

Table 2. Soil CO_2 Concentration Sensor Maintenance Intervals**.**

Maintenance		Bi-weekly	Eight Weeks	Quarterly	Bi-Annual	Annual	As Needed	Type
Soil CO_2 Concentration Sensor								
	Remote Monitoring	X					X	P
	Visual Inspection	X					X	P
	Check Desiccant	*X*	X				X	P
	Apply Grease to Gaskets & Rubber Seals					X	X	P
	P = Preventive, R = Repair, X = Indicates preventive maintenance task time interval may increase due to environmental (season/weather) or unforeseen/unanticipated site factors.							

5.3.1 Remote Monitoring

Verify TIS soil sensors are sending data to HQ via the SAS Report. For Soil CO_2 data streams that are missing/red via SAS, conduct a real time verification of each missing/failed data stream to double check if the data streams are online, but failing to transmit data streams to HQ. Otherwise, look up to view if the subsystem components have power. Conduct this check using a Terminal Emulator Program (TEP), such as PuTTy or MobaXterm, to connect to each Grape in the soil array. The data state of health presents indicators to focus preventive maintenance efforts; anomalies in the data or if the Soil CO_2 is

off the network, it may dictate preventive maintenance tasks for investigation to determine if onsite corrective action is necessary. Use the Grape MAC address/Sensor EPROM ID with the command prompts in **Table 3**.

PRO TIP: *To perform these functions, Technicians must acquire the Grape MAC address and/or the EEPROM ID of the sensor. Use this to verify function of Grapes and Sensors post-Sensor Refresh, too. Reference these from site sensor mapping documents and update these documents accordingly to have relevant information on hand.*

PuTTy Login Username: user | Password: resuresu

Table 3. View Grape and Sensor Data Streams (MAC and EPROM ID are Examples for this Command).

Remote Monitoring Commands	Description
`vd | grep [MAC address]`	This displays the data from the grape with the MAC Address entered (e.g., using "7CE0440015FD"). Enter either in decimal or hexadecimal format. Use "**grep –i**" to ignore case.
`vd –s [sensor eeprom id]`	To view data from a sensor. For example "root@D23-HQTW-LC1:~# vd -s 3171982"
`vd –s [sensor eeprom id] –r [stream number]`	To view data from a sensor and specific data stream.

Important: Verify the physical location of the Soil CO_2 Concentration sensors with their Maximo CFG Location. The shallow, medium, and deep sensors must align with the shallow, medium, and deep CFG locations in Maximo or the data is no good!

PRO TIP: Soil CO_2 concentrations are typically higher than the CO_2 concentrations in the air (atmospheric CO_2 concentrations). A value that is close to the site's Eddy Covariance sensor values may indicate that the sensor is exposed to the atmosphere and no longer measuring for soil CO_2. In addition, if the data streams appear "noisy", it may mean the sensor requires cleaning and re-calibration.

5.3.2 Visual Inspection

Conduct a bi-weekly visual inspection on the Soil CO_2 concentration assembly and subsystem. Conduct the following maintenance inspections.

Note: 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. Stand outside of the soil plot and observe the location of the Soil CO_2 assembly unless you need to get closer to perform this task.

1. If there is no snow or standing water around the sensor check for noticeable soil erosion, deposition, and burrowing around the assembly location and within 30 cm radius of the sensor location. Also check for any gaps between the edge of the assembly tube and the wall of the borehole (the assembly tube should be flush with the surrounding soil).

*Note: If snow or standing water is present, **DO NOT** perform this check.*

a. If soil disturbance is noticeable or if a gap between the assembly and the borehole is present, submit a ticket in the NEON project Issue Reporting/Management System for science evaluation to determine corrective actions, if necessary. Photograph the erosion for the trouble ticket to enable a quicker evaluation response.

2. If no snow or standing water is present around the assembly, ensure there are no cables or other NEON project/BEI infrastructure within 30 cm of the assembly. Exclude the cable that connects to the assembly.

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

   b. If there is a cable within 30 cm of the assembly, if possible move the cable so that it is at least 30 cm from the assembly, and submit a ticket in the NEON project Issue Reporting/Management System including a description and photo showing distance of the cable from the assembly.

5.3.3 Instrument Desiccant Inspection

Note: 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.

If snow or standing water is less than 10 cm deep immediately around the sensor location, check the desiccant in the soil CO_2 concentration assembly every 8 weeks (±1 week). If snow or standing water depth is ≥10 cm, do not check the desiccant until the level decreases.

Employ judgement when navigating the soil plot to minimize disturbance to the area when standing and kneeling to perform this task. In many cases, particularly locations with sparse ground-level vegetation and/or when the soil is wet, this can be best achieved using the wood plank or rubber mat positioned ≥30 cm (~1 foot) from all sensors to distribute your weight over a wider area within the soil plot. However, if vegetation is particularly dense around the sensor the disturbance caused by using the plank or mat may be greater than simply standing or kneeling directly on the ground.

1. Brace the white PVC tube with one hand and lift up the top cap using your other hand. Be careful to avoid movement or rotation of the tube during this process by holding it firmly.

Note: If it is raining, use a shield (e.g., poncho) to prevent moisture or other debris entering the tube. If the rain is too heavy to prevent water entering the tube even when using a shield, postpone this check until conditions improve.

2. The desiccant pack is under the top pipe cap (**Figure 6**). There is no need to undo any screws or remove the sensor from the tube to check the desiccant. Check the color of the packet of

indicating silica desiccant to see if the desiccant color has changed. **Figure 6** is an example of indicating desiccant requiring replacement. Swap desiccant when the color change is over 50% of the packet(s). (Colors may vary depending on supplier/manufacturer.)

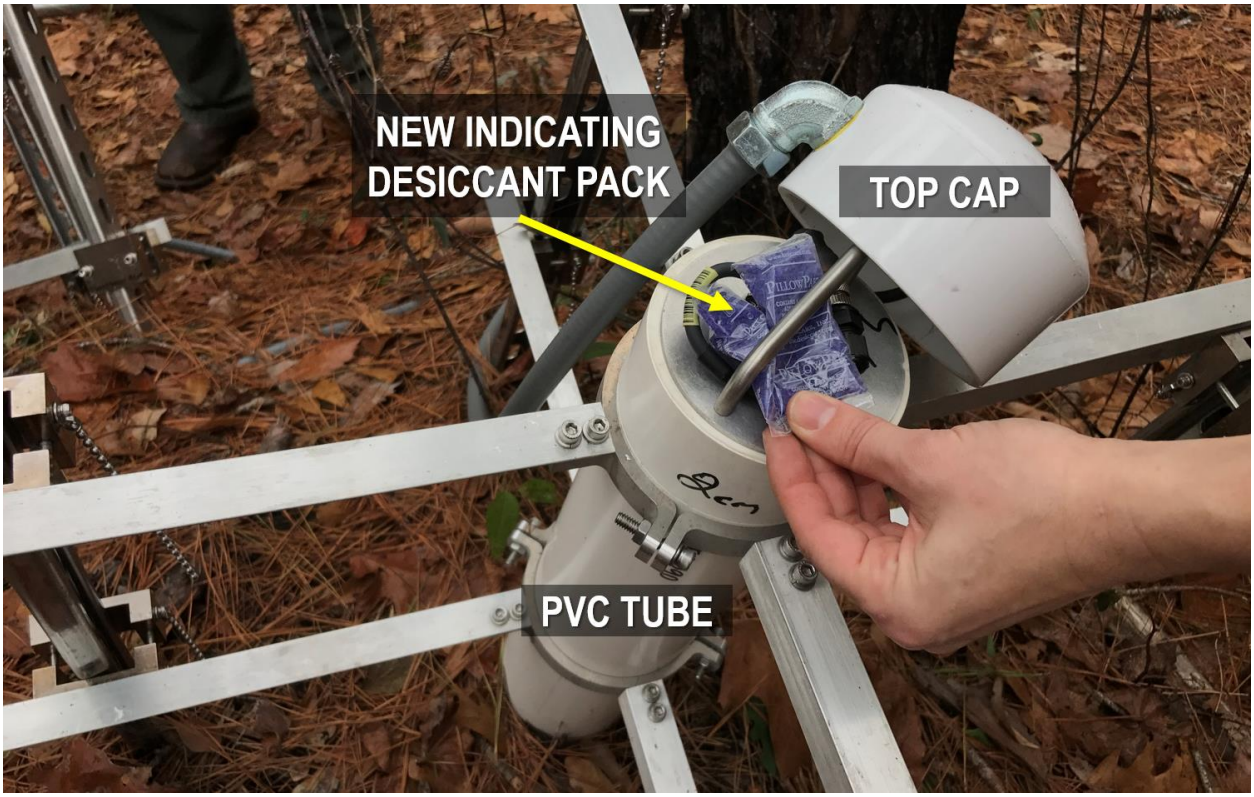

Figure 6. Soil CO_2 Concentration Sensor Desiccant Inspection – New Desiccant Pack – Turns Pink when Expired (D08 TALL).

If the desiccant requires changing for three or more sequential inspections, submit a ticket stating the sensor assembly, sensor installation depth, and soil plot number (see site-specific requirements for plot number), as this may indicate that the desiccant requires more frequent checks or it may indicate a leak in the assembly.

5.3.4 O-Ring & Rubber Seal Maintenance

The O-Rings (***0355280000*** *O-Ring, Viton Fluorelastomer, Dash Number 145, A60 Durometer* and ***0355270000*** *O-Ring, Viton Fluorelastomer, Dash Number 033)* on the Soil CO_2 Concentration assembly require greasing with ***0373890000*** *GPL-201 Grease, PFPE/PTFE, High Vacuum, Silicone & Hydrocarbon Free, 2oz Tube* pre-installation of new filter sensors (**Figure 7**).

Figure 7. GPL-201 Grease, PFPE/PTFE, High Vacuum, Silicone & Hydrocarbon Free, 2oz Tube.

Figure 8 points out the areas where the O-rings reside that require greasing. *Reference AD [16], NEON.DOC.002043 for installation instructions of the gaskets on the sensor assembly.*

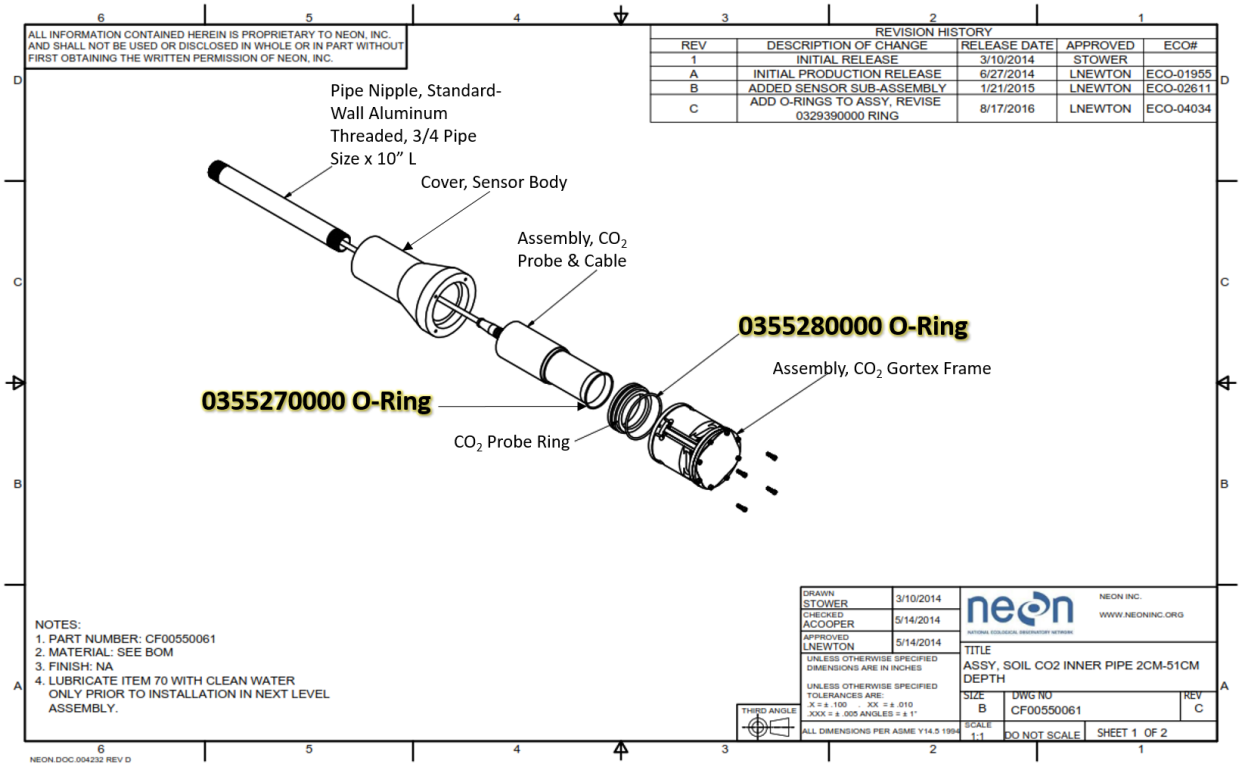

Figure 8. CF00550061 Assy, Soil CO_2 Inner Pipe 2CM-51CM Depth: O-ring & Probe Ring Locations.

In addition, grease the inside, outside, outer edge of the lip, and the small lip that adheres to the aluminum housing of the large black rubber seal in the **Figure 9** to prevent the assembly from seizing in warm temperatures. Before you grease this component, ensure it is clean. Use DI water and a lint free cloth wipe clean the part and apply fresh grease on an annual basis (HQ recommends conducting this during Sensor Refresh).

Figure 9. Clean and Grease Rubber Seal Annually.

6 REMOVAL AND REPLACEMENT (SUBSYSTEM ONLY)

6.1 Equipment

Table 4. Removal and Replacement Equipment List.

Item No.	Description	Quantity
	Tools	
GENERIC	#2 Philips head screwdriver	1
GENERIC	¼" drive Torque Screwdriver with $^1/_4$" sq. Adapter + $^3/_{16}$ Hex Bit $^1/_4$ " drive (0-25 in-lbs. or 0-50 in-lbs. Torque Measuring Screwdriver McMaster-Carr 5699A26 or Equivalent)	1
GENERIC	Hex Wrench Set (3/16" Allen Driver is necessary)	1
MX103120	3M Antistatic Wristband (ESD Requirement)	1
GENERIC	Wood plank, rubber mat, or similar (~60 x 40 cm) for standing on in soil plot	1
GENERIC	Landscaping/mechanics gloves for traction removing cap/handling objects	1 Pair
GENERIC	Peristaltic pump (pump water from tubes to reinstall sensor)	1
GENERIC	Soft-faced hammer/rubber mallet or large flat bladed screwdriver	A/R
	Consumable Items	
0338570000	Bag, Disposable Desiccant, Indicating Silica Gel, for 60 Cubic Inches	15
GENERIC	Packaging to Transport Non-Decontaminated Sensors to the Domain for Refresh	A/R
GENERIC	DI Water & Lint-Free Cloths (to clean rubber seal before applying grease)	A/R
0373890000	GPL-201 Grease, PFPE/PTFE, High Vacuum, Silicone & Hydrocarbon Free	1 Tube
GENERIC	Powder-free Nitrile Gloves	A/R
See below	ESD Packaging for Grape(s)	5
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
MX104219	Grainger Red Inspection Tag, Paper, Rejected, PK1000	A/R
CB08180000	Plastic Grape Dust Caps Kit	2-6

Note: When working on power systems, use tools with insulated handles. Always shutdown the power prior to removing or replacing any components. Do not hot-swap (Power is ON) any component or sensor connections at TIS sites.

6.2 Removal and Replacement Procedure

The Field Operations Domain Manager 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 project 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 5** for sensor refresh requirements for the subsystem infrastructure on the Soil CO_2 concentration sensor(s).

Table 5. TIS Soil CO_2 Concentration Sensor Refresh Requirements.

	LOCATION		TIMEFRAME			
	CVAL	*FIELD*	*BIWEEKLY*	*ANNUAL*	*NA*	COMMENTS
Soil CO_2 Concentration Sensor	X			X		Send only the sensor with a clean dry filter to CVAL in an ESD bag/packaging. *Reference Section 6.3 for more details and Figure 27.* Follow ESD protocols.
Concord (24V) Grape	X			X		Follow ESD protocols.

6.2.1 Soil CO_2 Concentration Sensor Removal/Replacement Procedure

6.2.1.1 Soil CO_2 Concentration Sensor Removal Instructions

Remove the Soil CO_2 Sensor from the Soil Plot using the following procedure. If snow or standing water depth is ≥10 cm, do not remove the sensor until the level decreases. If it is unlikely that the water or snow level will decrease in a reasonable timeframe, submit a ticket in the NEON project Issue Management System for HQ guidance. **Do not allow water into the access tube.**

1. De-energize the entire soil plot per *Section 8 Appendix A – How To Power Down A Soil Plot* (SP) Power Box.

2. Remove the cover from the Soil Temperature Enclosure on the nearest Arbor with a Phillips head screwdriver (**Figure 10**). Use **Figure 24** to reference Grape connections or AD [04].

Figure 10. The Soil CO_2 Sensors Connect to the Grapes in the Soil Temperature Enclosure on the nearest SP Arbor.

3. Disconnect the RJF cable (**Figure 11**) going into the Soil CO_2 concentration Concord (24V) Grape from the bottom of the enclosure (**Figure 11**).

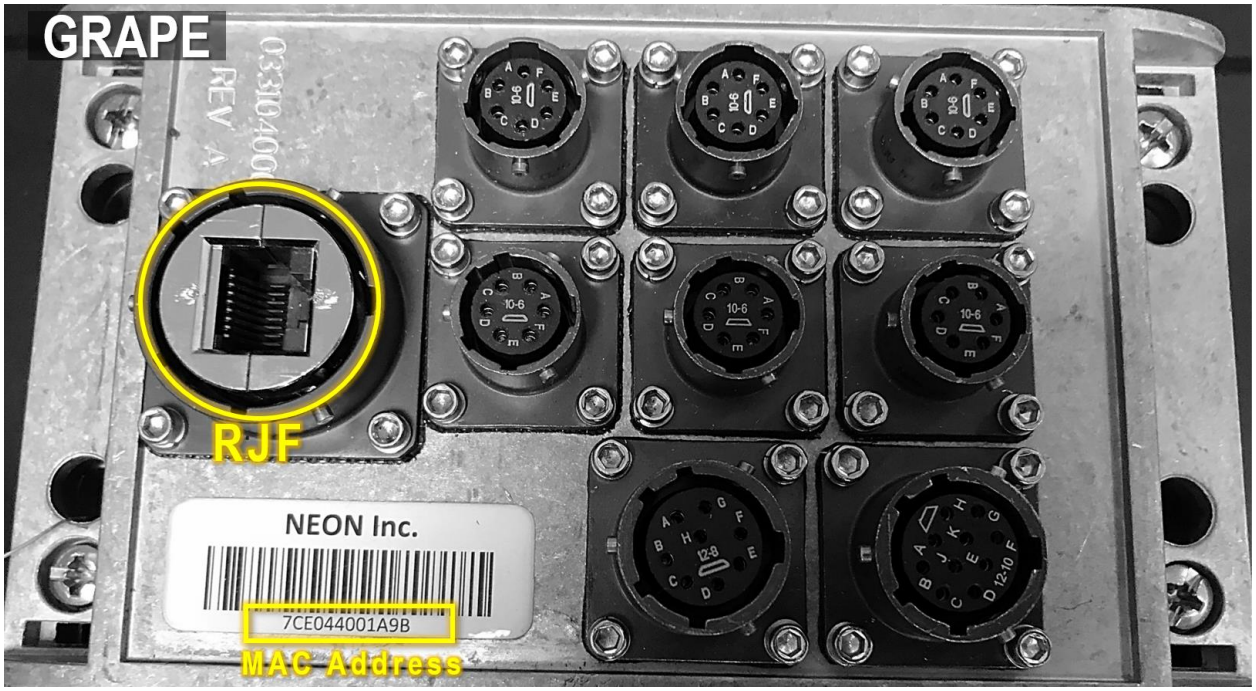

Figure 11. RJF Connection on a Grape.

a. However, if Technicians are also removing the Concord Grapes for Sensor Refresh, disconnect the white Ethernet cable inside the box that connect to both RJFs on each Grape. After removing the RJF connection, disconnect the Soil CO_2 concentration sensor

connections (these are the black cables in the enclosure. The white cables connect to the Soil Temperature sensors).

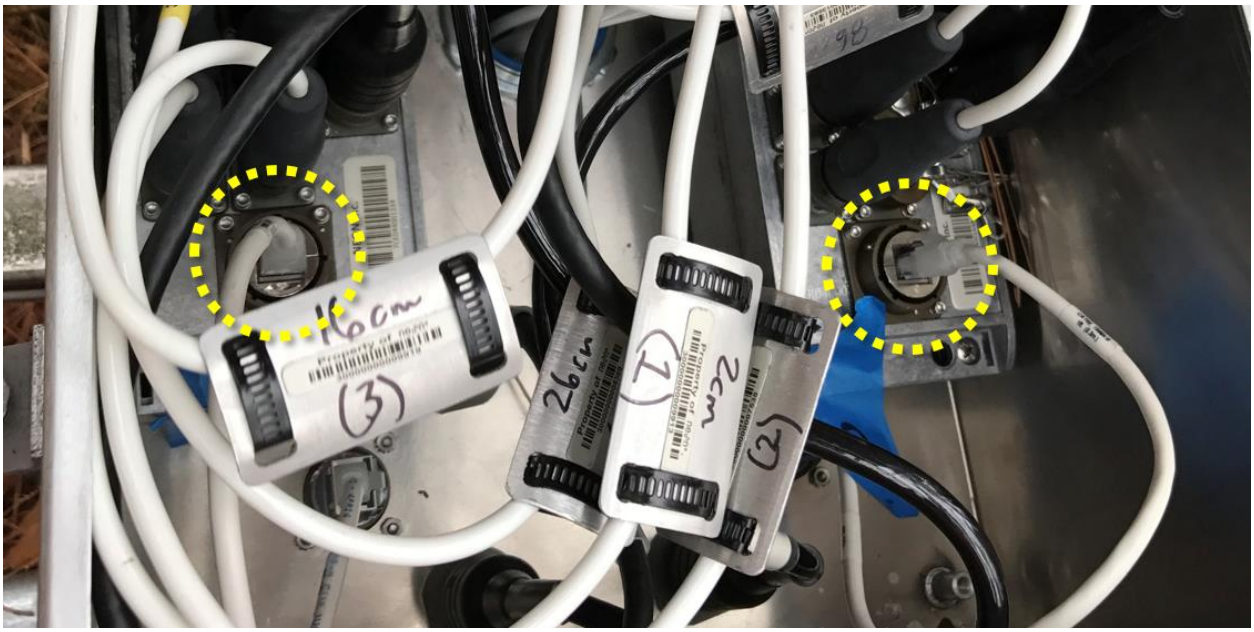

Figure 12. Remove RJF/Ethernet Connectors from Soil CO_2 Concentration Sensors Concord (24V) Grapes.

4. Technicians must employ their judgement onsite to minimize soil disturbance to the area where standing and kneeling are necessary to perform this task. In many cases, particularly locations with sparse ground-level vegetation and/or when the soil is wet, this can be best achieved using the wood plank or rubber mat positioned ≥30 cm (~1 foot) from all sensors to distribute your weight over a wider area within the soil plot. However, if vegetation is particularly dense around the sensor, the disturbance caused by using the plank or mat may be greater than simply standing or kneeling directly on the ground.

5. Brace the white PVC tube body with one hand and lift up the top pipe cap using the other hand. Be careful to avoid movement or rotation of the tube during this process by holding it firmly.

Note: If it is raining, use a shield (e.g., poncho) to prevent moisture or other debris entering the tube. If the rain is too heavy to prevent water entering the tube even when using a shield, postpone maintenance until conditions improve.

6. Remove the desiccant pack(s) that resides under the pipe cap. Check the color of the packet of indicating silica desiccant (**Figure 13**). If the desiccant color is changing and/or has changed for over 50% of the packet, swap the packet(s) for fresh (new/recharged) desiccant.

    a. *Reference Section 5.3.3 Instrument Desiccant Inspection for more information on desiccant for this sensor.*

7. Disconnect the cable from the sensor (**Figure 14**).

Figure 13. Top Pipe Cap Removed with Fresh Desiccant (D14 JORN).

Figure 14. Sensor Connector (D08 TALL in left picture).

8. Use an allen wrench/hex key to loosen two hex head screws on top of the sensor (**Figure 15**), ***no further than the height of the handle.***

Figure 15. Loosen Two Hex Head Screws on Top of the Soil CO_2 Concentration Sensor (D14 JORN).

9. Remove the sensor from the PVC tube by pulling up vertically on the handle to carefully extend the length of the entire assembly so the airtight seal separates from the lower section of the sensor housing. This de-compresses the airtight wedge seal and allows air to escape as you slide the sensor housing down to the bottom of the access tube. Be careful to avoid movement or rotation of the tube during this process. Hold the assembly firmly in place while removing the sensor portion from the PVC tube (**Figure 16**). Use two Technicians for this step, if necessary.

Figure 16. Remove the Sensor from the Sensor Housing/PVC Tube (D08 TALL).

PRO TIP: If the lower section of the assembly will not extend after you loosen the top two screws by the maximum allowable amount, ***then push the two hex screws down into the assembly with your thumb to separate the airtight seal at the base of the sensor housing. This action should release the wedge seal to enable Technicians to pull up and remove it from the PVC pipe.*** *If the screws do not push down to release the seal, tap gently on the screw tops, alternating from screw to screw with a soft face hammer, or pry gently against the handle with a large flat-bladed screwdriver. If using a flat-bladed screwdriver, rotate the screws a few turns to get the correct prying angle to conduct this action. If this*

method is not successful, try slightly loosening the screws on the sides of the white plastic ring at the top of the assembly. If you loosen these screws, you must retighten them just before sliding the assembly back into the access tube.

10. Inspect the inside of the PVC tube for water ingress (**Figure 17**). An assembly with a mesh screen that resides at the bottom of the PVC tube to prevent water ingress.

Figure 17. Inspect PVC Tube/Sensor Housing for Water (D08 TALL).

    a. If water level is higher than the inlet holes in the tube, submit a ticket including an estimate of the water level. Note any signs of leak locations. Provide photos to support description and any evidence of damage/tampering or wear and tear.

    b. If there is no evidence of damage/tampering or wear and tear, pump the water out of the tube before reinstallation of the sensor.

    c. After pumping, if the tube refills with water at a quick pace, this is likely due to a seasonal or weather-related event. Wait for the water to recede before reinstalling the sensor. If the water does not recede, submit an incident task in ServiceNow.

11. If the sensor is not immediately reinstalled, reinstall a size 4 PVC cap. Brace the white tube with one hand and then reattach the top cap using your other hand. Be careful to minimize movement or rotation of the access tube during this process by holding it firmly.

12. Continue to the next section when the sensor is ready for reinstallation into the sensor housing (PVC tube).

6.2.1.2 Soil CO_2 Concentration Sensor Reinstallation Instructions

Reinstall the Soil CO_2 Sensor from the Soil Plot using the following procedure. If snow or standing water depth is ≥10 cm, do not replace the sensor until the level decreases. If it is unlikely that the water or snow level will decrease in a reasonable timeframe, submit a ticket in the NEON project Issue Management System for HQ guidance. **Do not allow water into the access tube. Before handling the**

sensor filter, please put on powder-free nitrile gloves. The filter accumulates dirt easily when outside the sensor housing.

13. Ensure power is OFF for the sensor/soil plot, if returning from the Step 11 in *Section 6.2.1.1 Soil CO2 Concentration Sensor Removal Instructions* above.

    a. If not, de-energize the entire soil plot per *Section 8 Appendix A – How To Power Down A Soil Plot* (SP) Power Box and follow Step 2 – Step 10 in the previous section.

14. Use a hex wrench/key and remove the four hex screws holding the sensor in the waterproof of the sensor housing (**Figure 18**). This is a good time to put on a pair of powder-free nitrile gloves. The filter accumulates dirt easily when outside the sensor housing.

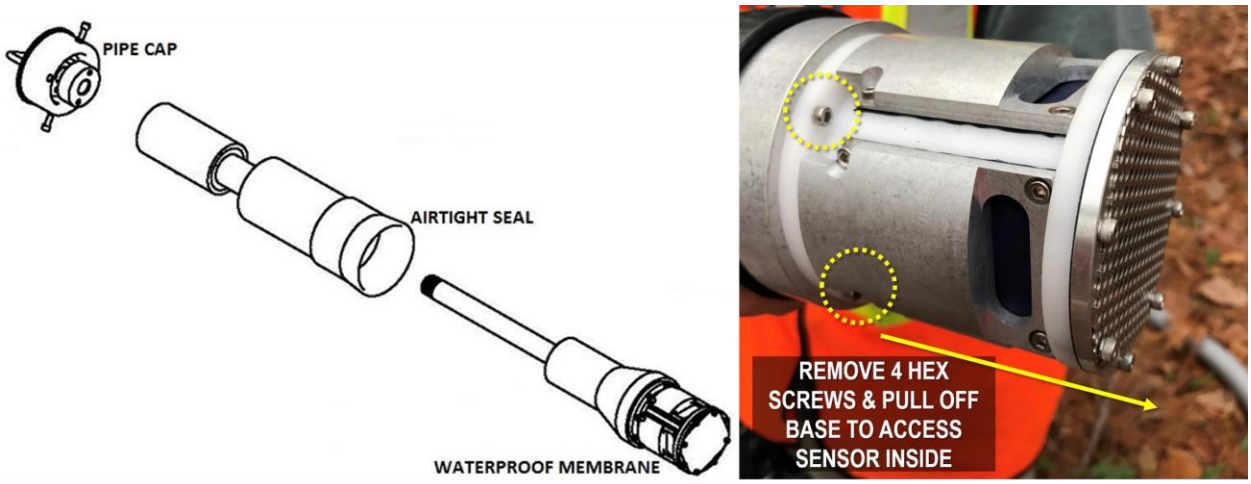

Figure 18. Soil CO_2 Concentration Sensor Components and Removal to Access Filter.

15. Wearing clean rubber gloves, carefully remove the sensor filter from the sensor housing. A threaded ring holds the sensor filter in place (**Figure 19**). Unthread the sensor from the ring and then unscrew the ring from the sensor housing.

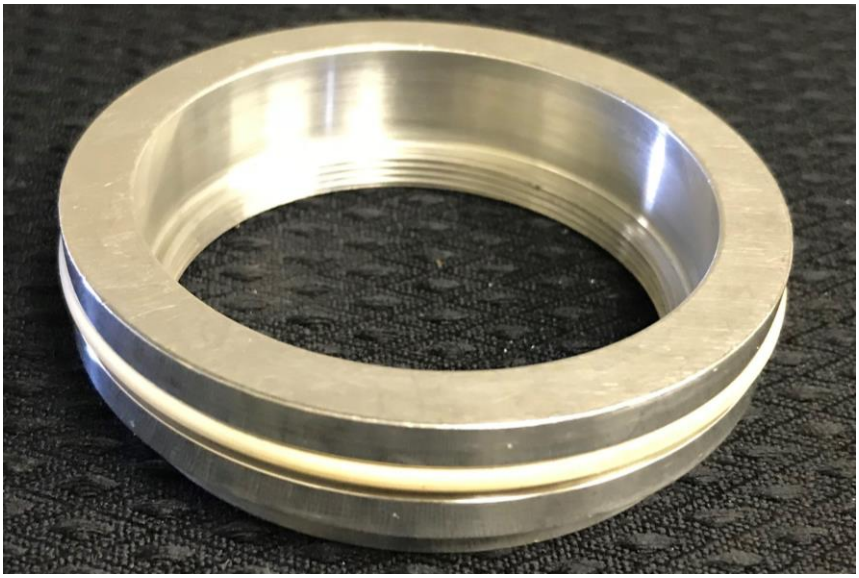

Figure 19. Soil CO_2 Concentration Ring with O-Ring that holds the Sensor Filter in Place.

16. Place the probe ring (**Figure 19**) on the new Soil CO_2 concentration sensor filter. (This Probe Ring remains with the Domain for Sensor Refresh. Do not send the Probe Ring to CVAL.) Ensure the probe ring has an O-ring of a thick cross-section on its threads.

17. The Soil CO_2 Concentration sensor contains two types of O-Rings. Apply a thin coat of Krytox grease to both O-ring surfaces and reinstall the O-rings on the probe ring and sensor assembly. The larger, thicker cross-section O-Ring sits in the groove of the Probe Ring and is visible in **Figure 19**. The smaller, thinner black O-Ring sits on the Sensor probe body groove below the sharp threads and filter (see **Figure 21**).

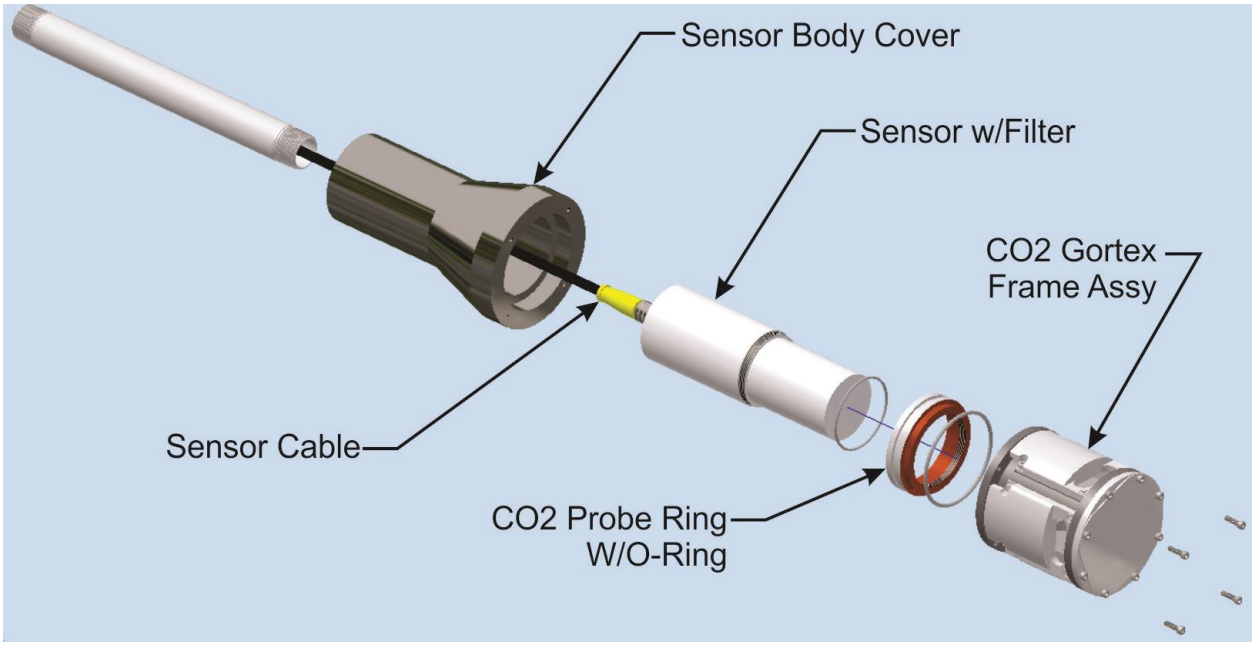

Figure 20. Soil CO2 Assembly Components for Reassembly Reference.

a. Reference **Table 1** for part numbers for each O-ring to replace annually and as necessary, and for the Krytox grease to apply during Sensor Refresh.

b. *Use AD [16] for additional reference information on the sensor O-ring, such as* ***Figure 21****.*

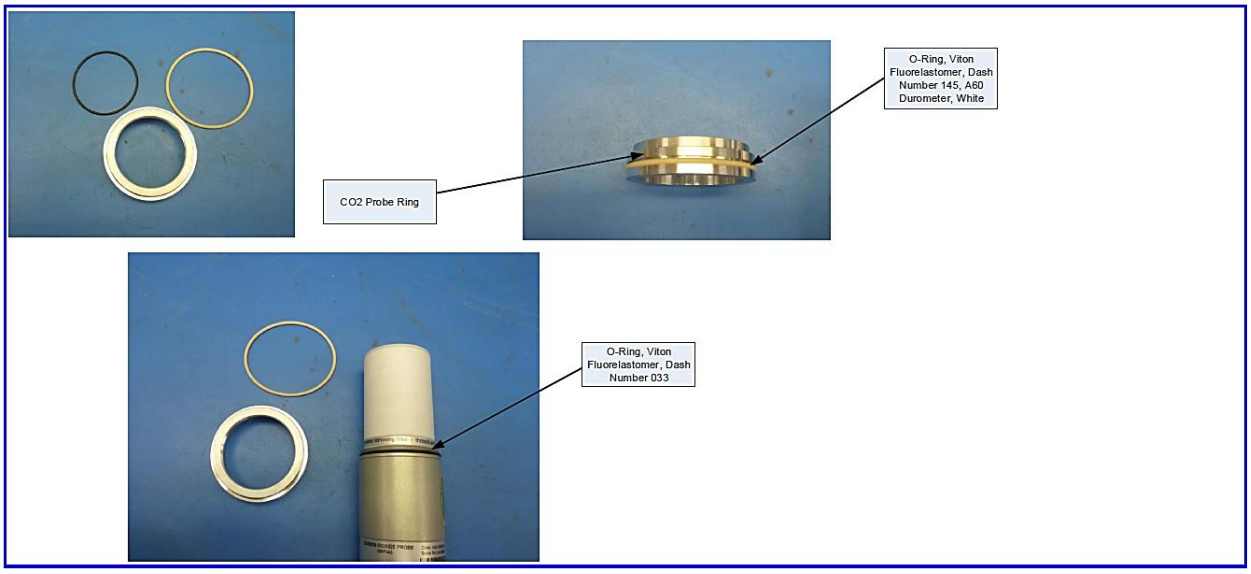

Figure 21. NEON.DOC.003993 CF00550010 Assembly, Soil CO2 Inner 2-51CM Rework.

Note: Ensure all O-rings are on the sensor assembly when reassembling a "refreshed" sensor. Reference AD [16], NEON.DOC.002043 for installation instructions of the O-rings on the sensors.

18. Thread the filter cable of the new sensor through the sensor body cover and then to the top of the sensor assembly (reference **Figure 20** on the previous page).

Figure 22. Reinstall Sensor into PVC Tube.

PRO TIP: Try to get the cable as straight as possible and smooth out any kinks before threading through the sensor housing. Do not pop the sensor into the sensor housing UNTIL the cable threads through the sensor housing and out the top or it may become increasingly difficult to thread the cable when the sensor is in place.

19. After the cable exits the top of the sensor housing, insert the new sensor with the Probe Ring installed into the sensor body cover.

    a. Verify that the new filter that accompanies the new sensor installation to ensure it is secure and seats correctly (as it was when the old filter was removed) and reinstall the Gortex frame assembly and its freshly greased O-ring by reinstalling the four hex screws using a hex wrench/key.

        *i. Reference **Figure 20** and two are visible in **Figure 18** on the previous page.*

20. Apply a thin coat of Krytox grease (P/N 0373890000) only to the lower ¼" and bottom of the rubber black seal. This will help maintain airtightness, and make future removal/reinstallation simpler.

    a. *Reference Section 5.3.4 O-Ring & Rubber Seal Maintenance for additional guidance.*

21. With a damp clean rag, thoroughly wipe the inside of the PVC tube to remove any contaminants that might compromise the seal.

22. Reinstall the sensor housing back into the PVC tube (**Figure 22**). Ensure there is no standing water in the PVC pipe. Pump the water out before installing the sensor assembly. If the tube refills with water quickly, wait for it to recede before reinstalling. Insert the sensor so the handle is oriented 90° from where you intend to route the cable out the side of the cap. This prevents interference with the cable seal-tight connector on the pipe cap, and it allows all components to

seat properly on the access tube.

Note: At sites with high humidity and groundwater accumulation, carefully minimize the moisture inside the access tube by pumping out any water in the tube immediately before installing the sensor assembly, then tighten the screws at the top to 12-15in. lbs. with a small torque wrench to create a seal as quickly as possible. This traps air within the assembly headspace and forms a bubble that minimizes the amount of moisture that can re-enter the tube. If the water level is visibly rising in the tube, postpone sensor reinstallation until this is no longer occurring.

23. Press downward on the sensor assembly while tightening each top screw by a maximum of two turns at a time (**Figure 23**). Tighten one screw, then alternate to the other screw, then continue alternating until both screws are tightened to 12-15 inch-lb. This secures the sensor assembly in the access tube, and forces the black seal against the inside of the PVC tube. **DO NOT USE STANDARD TORQUE SPECIFICATIONS.** If you are able to pull the assembly free from the access tube, it is not secure enough and requires additional tightening/inspection for damage.

Figure 23. Press Down & Tighten the Two Hex Screws on Top to 12-15 in. lbs. with a Small Torque Wrench.

PRO TIP: Downward pressure on the sensor assembly is required because tightening the screws tends to lift the assembly upward. Also, the gortex assembly will deteriorate over time. If the assembly continues to leak after every effort to prevent it onsite, it may require a replacement. Submit a ticket in ServiceNow for corrective actions.

24. Align the keyways inside the sensor cable connectors and connect the instrument's sensor cable at the top of the assembly to the long cable that routes away from the soil plot (**Figure 14** from earlier in the procedure).

25. Install fresh desiccant pack(s) (**Figure 13**). Maintaining fresh desiccant is important!

26. Route the connector and the excess cable under and around the handle at the top of the tube and verify that there will be no interference among any of these parts or the desiccant pack when attaching the PVC pipe cap.

27. Reinstall the PVC pipe cap on top. Be careful to minimize movement or rotation of the access tube during this process by holding the collar firmly.

28. Plug the 10-pin and 8-pin cables into the grape (inside the Grape box on the Arbor) in accordance with AD [04] (**Figure 24**).

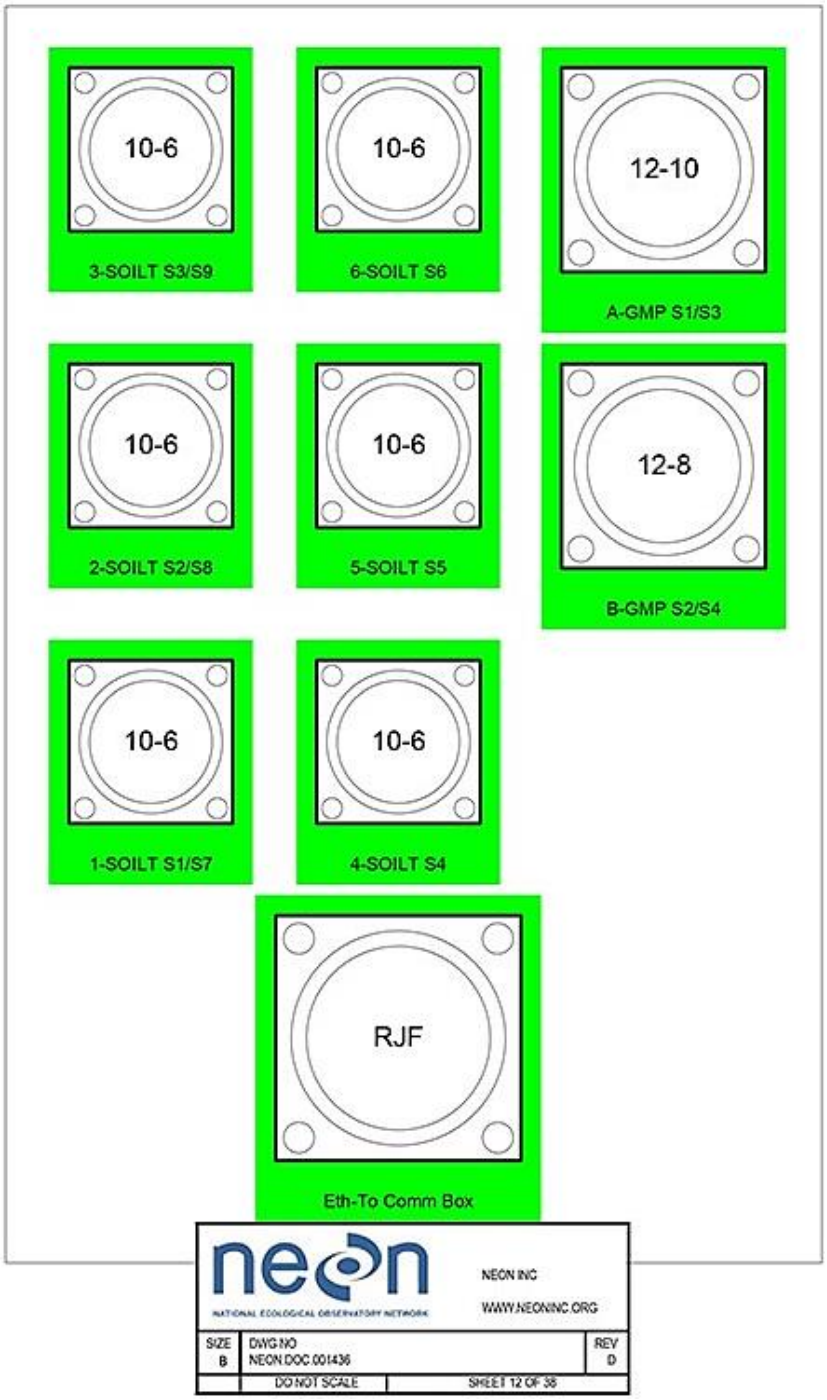

Figure 24. Soil CO_2 Concentration Sensor Mapping (Source: AD [04]).

*Note: AD [04] supersedes **Figure 24** in the event the TIS Grape Mapping Interconnect is updated for these assemblies.*

6.2.2 Grape Removal/Replacement Procedure

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

AIS / TIS (Circle One) | Site Name: _____
Merlot / Concord / Catawba (Circle One) Grape | Location: S - ___ / ML - ___ / Other _____

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

2. Employ ESD protocols when handling Grapes. Reference AD [08].

3. Power down the site at the Soil Plot Device Post. *Reference Appendix A – How To Power Down A Soil Plot* (SP) Power Box.

4. Open the enclosure (**Figure 25**) housing the two Concord 24V Grapes for the Soil CO_2 concentration sensor (black cables) and Soil Temperature Sensors (white cables) using a Philips head screwdriver.

Figure 25. Soil CO2 Concentration Sensor(s) Concord (24V) Grape(s) Location on Arbor in/next to Soil Plot.

5. Disconnect the armored Ethernet cable connecting to the RJF/Eth to Comm connection. Reference AD [04] and/or **Figure 24**.

6. Disconnect sensor connection(s) (**Figure 26**).

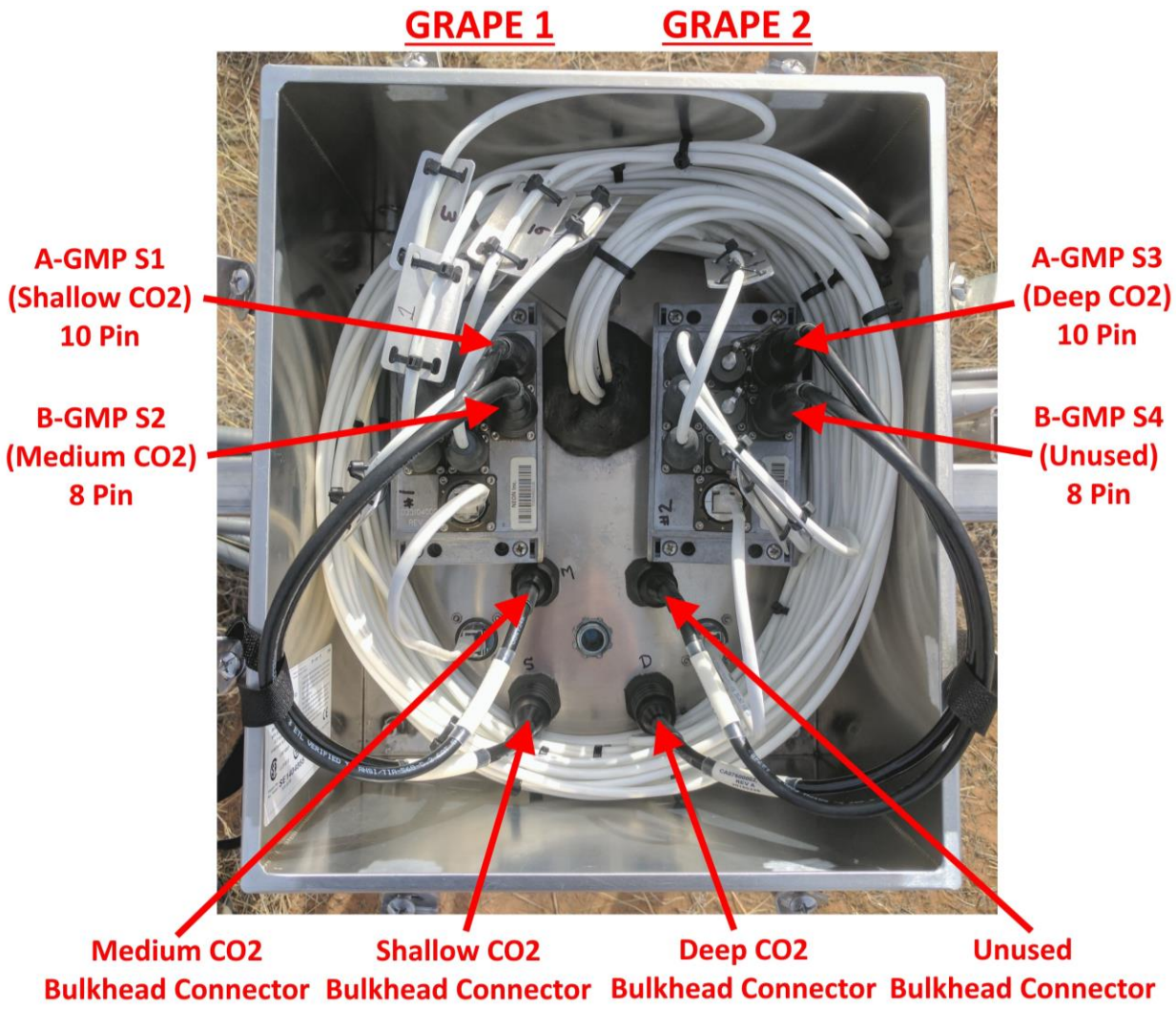

Figure 26. Soil CO_2 Concentration Sensor Connections (Source: AD [09]).

7. Disconnect grounding and remove Concord Grape(s) from enclosure on Arbor.

8. Place dust caps on the Amphenol connectors of the old Grape and remove caps from the new Grape (s).

9. Reinstall new Grape(s) into the enclosure on the SP Arbor and reground Grape(s) to box.

10. Re-connect sensor and armored Ethernet cable connections in accordance with AD [04].

11. Re-energize the site and verify Grape and Soil CO_2 concentration sensor function. Connect locally to the Soil Plot Arbor Comm Box DIN Rail PoE Switch or Instrument Hut LC or from the Domain using a TEP (e.g., PuTTy) and **Table 3**.

6.3 Cleaning & Packaging of Returned Sensor

Field Operations staff clean, package, and ship the sensors back to the CVAL at the NEON project HQ (Battelle Ecology) for annual sensor swap/calibration requirements. (Please note: if a sensor is defective, submit a trouble ticket and affix a red tag with the trouble ticket number on it.) Clean the Grape (also known as decontamination; *Reference* AD [14]*)* by removing all biologics from the device prior to capping the connections and placing in ESD packaging.

Please remove all arachnids and/or insects from tower instruments prior to packing and shipping. Reference AD [14]*.*

Note: Reference AD [15] for additional guidance on Sensor Refresh Requirements.

For the packaging of the Soil CO_2 concentration sensors and their Concord Grape(s) post-removal, conduct the following steps:

1. Check mounting holes for spiders and spider webs. Remove biologics and clean connectors.
2. Cap all connectors on Grapes and Cables. (It is OK if the sensor power cable does not have a cap if it is in an ESD bag and ESD protocols are followed through transit/handling.)
3. Conduct decontamination on the Grape(s) and Soil CO_2 concentration sensors per AD [14].
4. Place the cover over a clean dry filter and pack sensor assembly in ESD packaging (**Figure 27**).

Figure 27. Soil CO_2 Concentration Sensor Refresh Packaging.

*PRO TIP: **Please be aware the filter threads are sharp**.* **Figure 27** displays what FOPS is required to send to CVAL and the condition the filter should be in (clean and dry).

5. Pack 24V Concord Grape(s) in an ESD bag/packaging.

6. 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 Sensors and 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.

Important: Verify the physical location of the Soil CO_2 Concentration sensors with their Maximo CFG Location. The shallow, medium, and deep sensors must align with the shallow, medium, and deep CFG locations in Maximo or the data is no good!

7. 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.

8. Prepare a Bill of Lading.

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

For Sensor Refresh, package sensor items via packaging from CVAL HQ with packing list or per guidance via the Issue Management System and return to the NEON project HQ using the following address:

BATTELLE ECOLOGY, **ATTN: CVAL**
1685 38TH STREET, SUITE 100
BOULDER, CO 80301

Only include sensors/subsystems for refresh. Additional equipment must ship separately as they may require attention from other NEON HQ departments. Sensor refresh shipments go direct to CVAL. If sensors are shipping to HQ to address a trouble ticket, per guidance via the Issue Management System, return to the NEON project HQ using the following address:

BATTELLE ECOLOGY, **ATTN: REPAIR LAB**
1685 38TH STREET, SUITE 100
BOULDER, CO 80301

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.

6.4.1 NEON Asset Management and Logistic Tracking System Requirements

Technicians 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.

7 ISSUE REPORTING OUTPUTS

FOPS must report issues encountered while conducting preventive maintenance in the NEON project 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
- Technician 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/MAC Address, etc.
- Provide Diagnostic Information (from firmware, if applicable), such as error codes, values, etc. Provide screenshots.

Table 6. Soil CO_2 Concentration Sensor Metadata Output Checklist.

Issue Reporting Datasheet		
Datasheet field	**Entry**	
NEON Site Code		
Maintenance Date		
Maintenance Technician		
Preventive Maintenance	**Issue Noted**	**Issue Summary**
Cables & Connectors - Condition Check	☐	
Sensor - Condition Check	☐	
Sensor - Configuration Check	☐	
Sensor – Clean	☐	
Sensor – Other Specific Checks	☐	
Sensor – Desiccant Status	☐	Saturated: ☐ Yes ☐ No Replaced: ☐ Yes ☐ No
Sensor – O-Ring/Rubber Seal	☐	
Environmental Information	☐	
Notes		

Issue Reporting Datasheet

Ship all defective equipment/assets with a red "Rejected" tag. **Figure 28** displays the minimum information requirements for each tag.

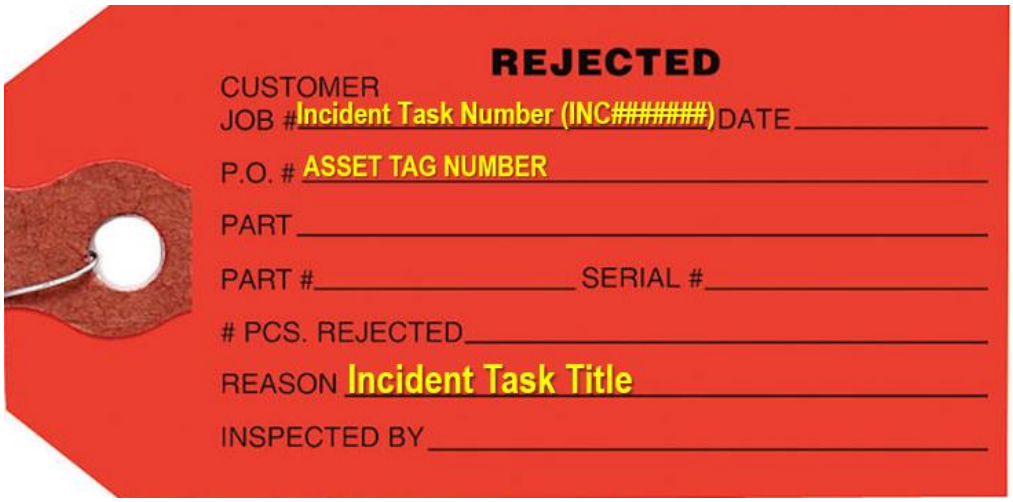

Figure 28. Red Rejected Tag for Defective Assets (MX104219).

8 APPENDIX A – HOW TO POWER DOWN A SOIL PLOT (SP) POWER BOX

Powering down the soil plot enables Technicians to perform work with less hazard to themselves and to the equipment. It also mitigates requiring NEON Headquarters to conduct data quality analysis when Technicians are onsite close enough to the sensors to influence data collection.

1. Power down the plot from the Soil Plot Device Post Power Box.

    a. Open the Power Box using a Philips head screwdriver (**Figure 29**).

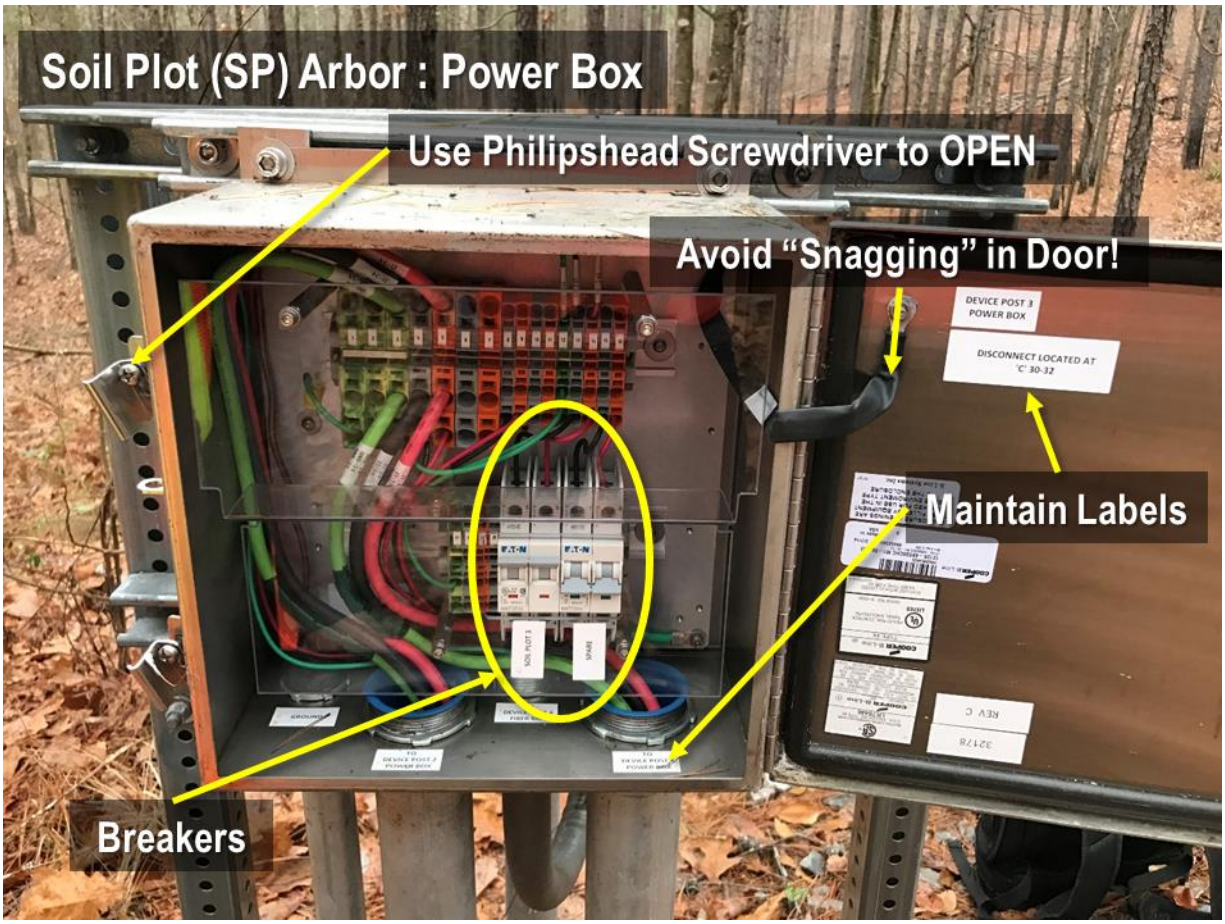

Figure 29. Open Soil Plot Device Post Power Box (D08 TALL).

    b. Flip both breakers from RED to GREEN to de-energize the sensors (**Figure 30**).

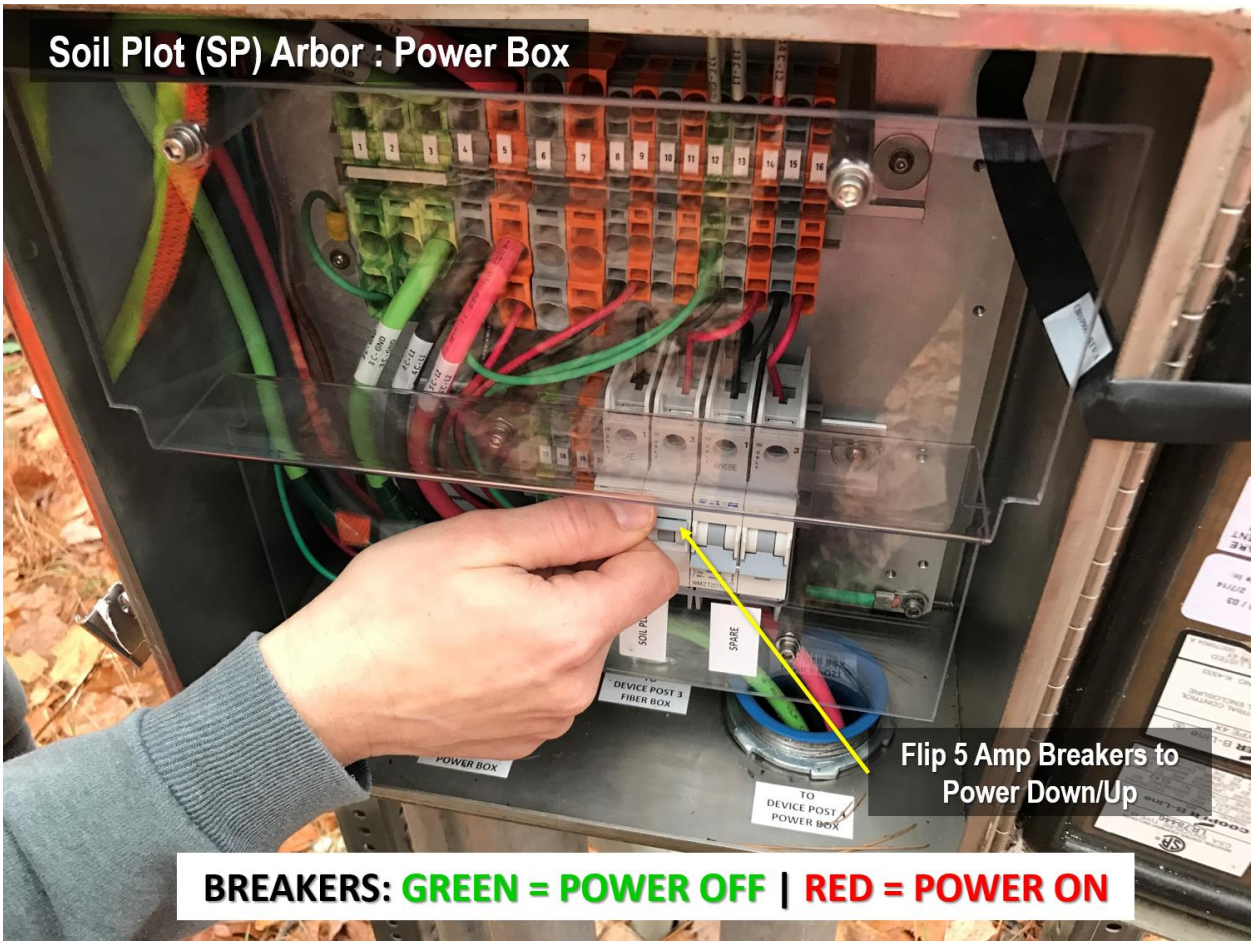

Figure 30. Flip 5Amp Breakers (D08 TALL).

c. Conduct LOTO procedures and proceed with the Preventive Maintenance, Sensor Refresh and/or Corrective Maintenance.

If there is a need to remove a single sensor assembly onsite, then power down the sensor assembly from its Grape. Remove the Ethernet cable from the Concord Grape RJF/Eth-To-Comm connector before disconnecting or connecting sensor connections.

9 SOURCES

Hand Model(s): Genevieve Faria, Alex Clayton