TIS SOIL PIT SAMPLING PROTOCOL

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	01/31/2014	ECO-01384	Initial Release
B	6/09/2015	ECO-03053	Added sampling strategy when soil pit is not approved, as well as other clarifications/updates.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1 DESCRIPTION

1.1 Purpose

This document describes the protocols associated with the TIS soil pit, including location of the soil pit, soil profile description, and sampling at terrestrial NEON core and relocatable sites. This document serves as a reference document for the FIU team as well as communicating the sampling methodology to users of the TIS Soil Pit data and samples (e.g., users of the TIS Soil Archive).

1.2 Scope

The scope is limited to FIU activities related to the location of the TIS Soil Pit and sampling protocols. The scope does not extend to the activities of other NEON teams in relation to the soil pit (e.g., FCC and EHS) unless directly relevant to FIU's sampling activities.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

AD[01]	NEON.DOC.004316 NEON EHS Safety Policy and Program Manual

2.2 Reference Documents

RD[01]	NEON.NPR.000008 NEON Acronym List
RD[02]	NEON.NPR.000243 NEON Glossary of Terms
RD[03]	NEON Soil Pit Excavation and Sample Collection Job Safety Analysis

2.3 Acronyms

USDA	Unites States Department of Agriculture
NRCS	Natural Resource Conservation Service
NASIS	National Soil Information System
TIS	Terrestrial Instrument System
APHIS	Animal and Plant Health Inspection Service

3 INTRODUCTION

FIU require that a soil pit is dug at each NEON terrestrial site for four reasons: 1) to determine the depth of the top and bottom of each soil horizon, which will be used to determine soil sensor depths in the soil array; 2) to collect soil to calibrate sensors to the local soil type; 3) to collect samples for physical and chemical analyses; and 4) to collect soil for archiving. Every NEON core and relocatable site includes at least 1 TIS Soil Pit. Here we describe the protocols for locating and sampling the TIS Soil Pit.

4 SAFETY

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined in Job Safety Analysis for Soil Pit Excavation and Sample Collection (RD[03]). All employees and contractors involved in the excavation of the soil pit have the responsibility and right to stop their work in unsafe conditions.

5 REPRESENTATIVENESS OF THE SOIL PIT

Since the soil pit will be used to determine sensor depths in the soil array, measure soil properties, calibrate sensors to site-specific soil conditions, and collect archive soils for future analyses, it must be representative of the soil in the vicinity of the soil array. The FIU Site Characterization Report for each site includes soil information that was used to inform the site design, including the suggested location of the soil pit. Typically the soil pit is located within a few hundred meters of the soil array in an area that most closely mimics the soil array's surroundings. This includes accounting for attributes such as the dominant soil type, topographic position, and vegetation type whenever possible. At most sites soil maps from the USDA NRCS Web Soil Survey were used to ensure that the soil pit location was on the same soil type as the soil array. However, at some sites a NRCS soil map was unavailable so NEON staff determined the location of the soil pit based on topography, vegetation type, and/or input from local researchers. An example of the type of soil-related information included in the site characterization report is shown in Figures 1 and 2 and Tables 1 and 2 (based on the Klemme Experimental Range relocatable site, OK).

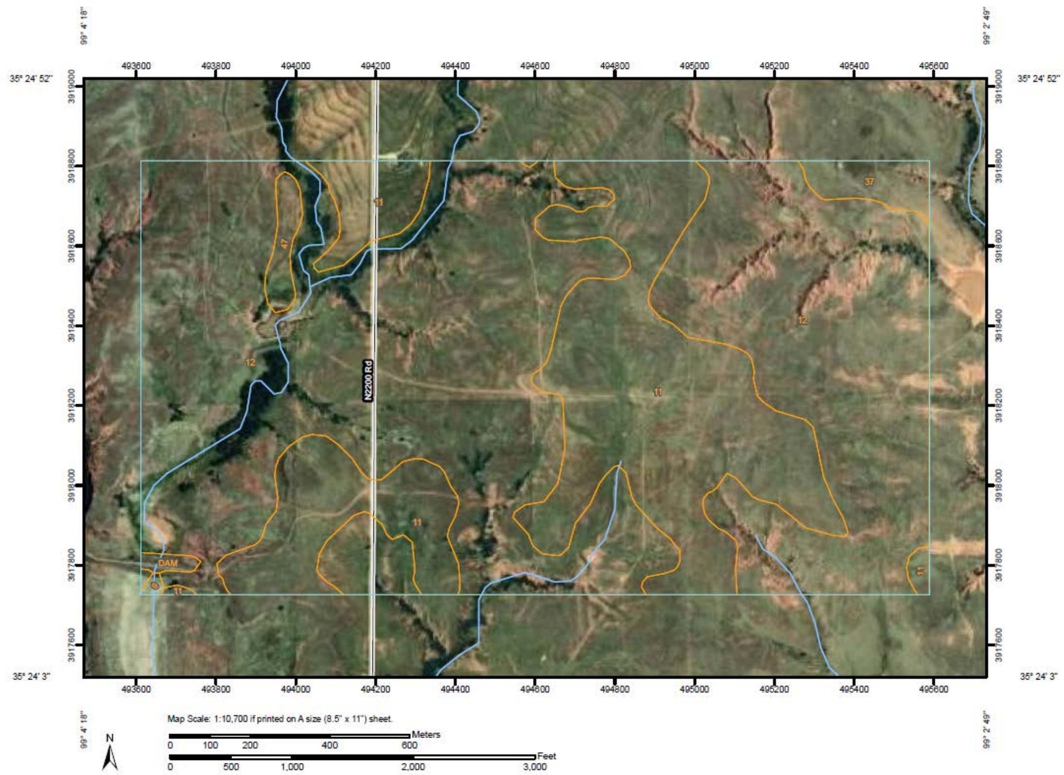

Figure 1. Soil map of the Klemme, OK site and surrounding areas

Figure 1 is from the FIU Site Characterization Report. Source: USDA NRCS Soil Web Survey.

Table 1. Soil series and percentage of soil series within 2.1 km2 at the Klemme site based on the soil map

Washita County, Oklahoma (OK149)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
9	Clairemont silt loam, 0 to 1 percent slopes, occasionally flooded	0.5	0.1%
11	Cordell silty clay loam, 3 to 5 percent slopes	147.8	27.9%
12	Cordell-Rock outcrop complex, 2 to 15 percent slopes	368.0	69.3%
37	Quinlan-Obaro complex, 5 to 12 percent slopes	8.1	1.5%
47	St. Paul silt loam, 1 to 3 percent slopes	4.8	0.9%
DAM	Large dam	1.5	0.3%
Totals for Area of Interest		**530.8**	**100.0%**

The source for Table 1 is the USDA NRCS Soil Web Survey.

Table 2. Summary of soil array and soil pit information at Klemme from the FIU Site Characterization Report

Soil plot dimensions	5 m x 5 m
Soil array pattern	B

Distance between soil plots: x	40 m
Distance from tower to closest soil plot: y	21 m
Latitude and longitude of 1st soil plot OR direction from tower	35.41040, -99.05875
Direction of soil array	165°
Latitude and longitude of FIU soil pit 1	35.410596, -99.060444 (primary location)
Latitude and longitude of FIU soil pit 2	35.410259, -99.060845 (alternate 1)
Latitude and longitude of FIU soil pit 3	35.409968, -99.061308 (alternate 2)
Dominant soil type	Cordell silty clay loam, 3 to 5 percent slopes-Cordell-Rock outcrop complex, 2 to 15 percent slopes
Expected soil depth	0.25-0.51 m
Depth to water table	>2 m

Expected depth of soil horizons	**Expected measurement depths***
0-0.15 m (Silty clay loam)	0.08 m[a]
0.15-0.25 m (Silty clay loam)	0.20 m[a]
0.25-0.36 m (Very gravelly silty clay loam)	0.31 m[a]
0.36-0.43 m (Bedrock)	

0° represents true north and accounts for declination.

*Actual soil measurement depths will be determined based on measured soil horizon depths at the NEON FIU soil pit and may differ substantially from those shown here.

[a]Soil CO_2 probes

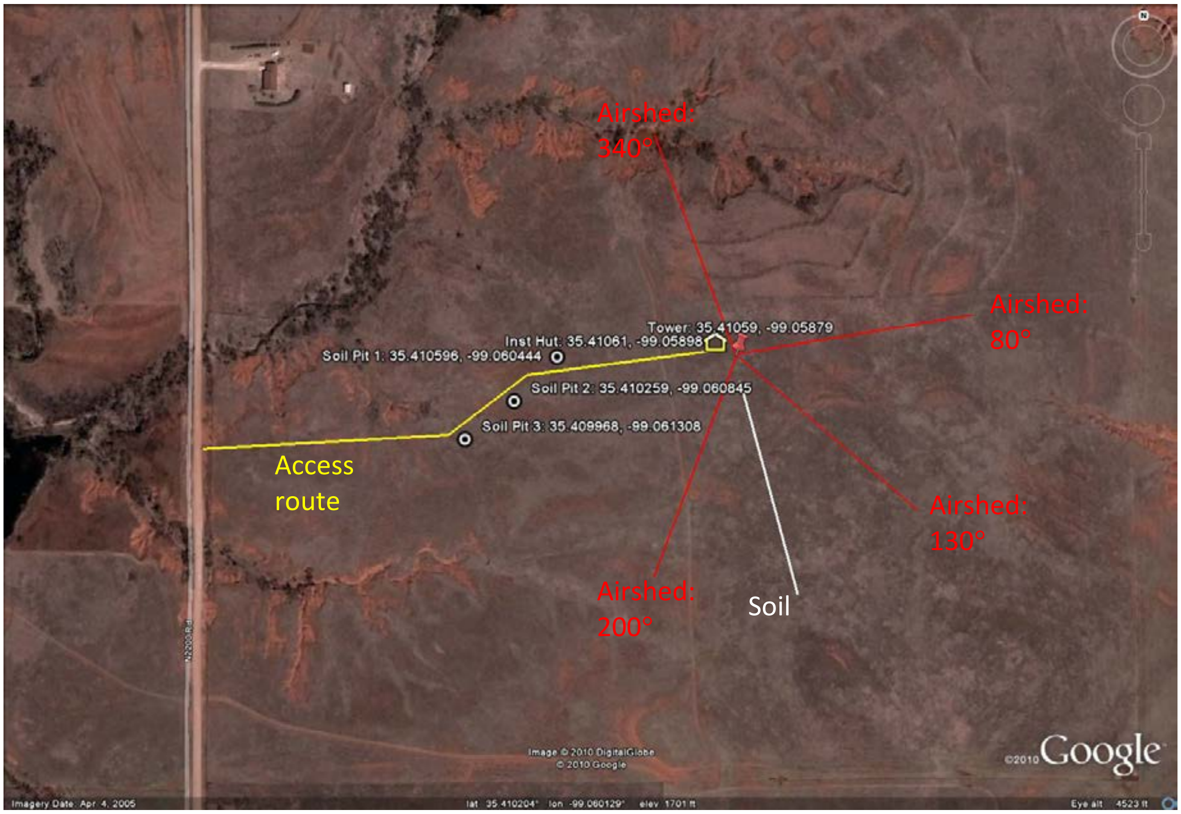

Figure 2. NEON site layout at Klemme from the FIU Site Characterization Report showing soil array and suggested location of the FIU soil pit

5.1 Location of the soil pit

A primary soil pit (Soil Pit 1) location was included in the FIU Site Characterization Report for each site and this is expected to be the location of the soil pit at most sites. In addition, two alternative locations were selected in case the primary location cannot be used. These locations were based on a number of factors, including maximizing the similarity of soils at the soil pit location with the soil array location, accessibility with a small backhoe, locating the soil pit outside the expected tower airshed to minimize disturbance to the tower source area, and a location that the site host permits.

At many sites the location of the soil pit was chosen after the site visit because, for example, the tower location was microsited after the visit, soil maps were not available at the time of the visit, and/or the location selected during the site visit was not permitted by the land owner. Therefore, the soil pit location is a best estimate by FIU of a location that is representative, accessible, outside of the tower airshed, and permitted for sampling.

Shortly before digging the soil pit a representative from FIU determines whether the pit location is suitable during a visit to the site. If the location is deemed unsuitable a new location is selected by the FIU representative. Prior to April 2015, at sites where choosing a representative location for the pit was deemed difficult by FIU, assistance was sought from local NRCS soil scientists. From April 2015 onward, FIU seeks assistance from local NRCS soil scientists when locating all subsequent soil pits whenever possible.

Features that shall result in a location being deemed unsuitable include, but are not limited to:

- being in a (ephemeral) drainage channel or pond (unless this is representative of the soil array);
- being in, or within the zone of influence of, a path or road;
- excessive human disturbance (relative to the soil in the vicinity of the soil array);
- excessive abundance of rocks (relative to the soil in the vicinity of the soil array);
- unusual vegetation (relative to the area in the vicinity of the soil array);
- excessive trampling and/or compaction by livestock (relative to the soil in the vicinity of the soil array);
- excessive erosion or deposition of material (relative to the soil in the vicinity of the soil array); and
- other unusual features (relative to the soil in the vicinity of the soil array).

5.2 Depth of the soil pit

At non-permafrost sites the soil pit will be 2 m deep or extend to bedrock (or restrictive feature), whichever is shallower. At sites with permafrost, the soil pit will be 3 m deep or extend to the bedrock (or restrictive feature), whichever is shallower, since soil sensors will be placed up to 3 m deep to monitor changes in permafrost at these site.

For the purposes of the soil pit sampling, permafrost sites are:

- D19 Caribou Creek
- D19 Poker Flats
- D19 Delta Junction
- D19 Healy
- D18 Toolik
- D18 Barrow

If the bedrock (or restrictive feature) is reached at a depth of <2 m (<3 m at permafrost sites) FIU will decide whether the depth is representative of the soil in the vicinity of the soil array. Deciding whether the depth of the soil pit is representative of the soil in the soil array location is not trivial. Ultimately the FIU representative will be required to use their expert opinion to reach a decision.

5.3 Other factors affecting representativeness

Besides the suitability of the location and the depth of the soil, other factors will influence the representativeness of the soil pit. These factors shall also be considered by the FIU representative when deciding whether the soil pit is suitable and in many cases the FIU will not be able to determine this until the soil pit has been dug.

Other factors that influence the suitability of the soil pit include, but are not limited to:

- Excessive rocks in the soil profile (relative to expert opinion of soils in the vicinity of the soil array);
- Excessive voids in the soil profile (relative to expert opinion of soils in the vicinity of the soil array);
- Excessive disturbance caused by burrowing animals; and
- Unusual features, e.g. mineral deposits, in the soil profile (relative to expert opinion of soils in the vicinity of the soil array).

5.4 Ability to collect TIS samples from the soil pit

In addition to being representative, the TIS soil pit must provide access to sufficient soil to allow FIU to collect the soil samples needed. Therefore, soil sample collection must not be limited by the presence of:

- Large rocks or boulders (e.g., greater than approximately 10 cm in diameter throughout the collection area)
- Large roots (e.g., greater than approximately 3 cm in diameter throughout the collection area)
- Any other obstacle

If obstacles are encountered, FIU will initially attempt to collect the soil sample from a different location at the same depth on the exposed face of the soil pit. However, if the samples cannot be collected from any location within the TIS soil pit a new soil pit will be needed.

6 SOIL PROFILE CHARACTERIZATION AND SAMPLE COLLECTION

The following measurements and samples will be collected from each soil pit:

- Soil profile description
- Photos showing entire soil profile, as well as close-ups of each horizon
- TIS Soil Archive samples collection from each horizon
- Biogeochemistry sample collection from each horizon
- Bulk density sample collection from each horizon
- Intact soil block sample collection (≤6 per soil pit)

Details on the procedure for each measurement/sample are provided below.

6.1 Soil profile description

The soil profile description is performed by a local soil expect familiar with the soils within the region. This is typically performed by a USDA NRCS Soil Scientist.

The description should extend to 2 m (3 m at permafrost sites) or less if the restrictive feature if shallower. At a minimum, the description should include soil taxonomy, soil horizon names, and horizon depths. Whenever possible, additional information should be provided, including horizon color, texture, structure, occurrence of coarse fragments and roots.

6.2 Photos of the soil profile

Photographs of the soil profile, as well as significant features within the profile, are taken prior to sample collection. A scale (e.g., tape measure or wooden ruler) shall be visible in all the photographs and it shall be possible to determine the depth from the soil surface on the scale in each photo (e.g., legible numbers on the tape measure). Whenever possible include markers at the top and bottom of each horizon, as well as a label showing the horizon name, in the photo (Figure 3). It should be noted that the initial soil horizon names assigned during the soil profile description in the field are sometimes changed by the soil scientist after considering additional information. As a result the horizon names shown in soil pit photos and on the field data sheets may not match the horizon names in the final soil profile description.

At each site, photos of the entire profile are taken (or large sections of the profile if it is not possible to fit it all into a single photo). In addition, close-up photos of each horizon are taken.

Figure 3. The soil pit at the Smithsonian Conservation Biological Institute, VA

In Figure 3, the small pins identify the soil horizon boundaries, while yellow markers display the soil horizon name. Additionally, two scales with different granularities are shown here (meter/centimeter units). Subsequent photos were taken to capture additional details.

6.3 TIS Soil Archive and Biogeochemistry sample collection

Two similar samples representing the soil from each horizon are needed, one for the TIS Soil Archive and one for various biogeochemical and physical analyses (hereafter Biogeochemistry sample). The biogeochemistry sample shall consist of ~4 liters of mineral soil (i.e., any horizon with a name where the first letter is not “O”) or ~12 liters of organic soil (i.e., any horizon with a name where the first letter is “O”) are needed for each sample. The archive sample shall consist of ~12 liters of mineral soil or ~36 liters of organic soil are needed for each sample.

Since the archive and biogeochemistry samples are similar to each other they are collected simultaneously. This is done by collecting soil from each horizon in a large tray. To ensure the samples are representative of the horizon they are composed of soil from the entire horizon. For example, if a soil horizon is 20 cm thick, the sample should include soil from the entire 20 cm depth, not only soil from the top 10 cm of the horizon. If the bottom of the soil horizon exceeds 2 m (or 3 m at permafrost sites), soil should be collected from the top of the horizon to 2 m (or 3 m at permafrost sites).

Clods of soil and root mats are broken up by hand, rocks larger than 2.5 cm are removed, and large roots/root clusters are removed after the soil is brushed off of them. The soil is then thoroughly hand mixed in the field and subsamples are collected for the TIS Soil Archive and for biogeochemical analyses.

The soil for the archive and biogeochemistry samples is usually collected from the face of the soil pit. However, if the soil horizon is very thin (e.g., less than ~5 cm) the area where the soil would be collected from could interfere with the collection of the soil block, which also requires a large area (see below). In these cases, soil for the archive and biogeochemistry samples may be collected from a location within ~10 m of the soil pit that appears similar to the soil pit location, thereby allowing the soil block to still be collected from the soil pit.

Note that prior to 24 June 2013, rock fragments smaller than 2.5 cm were also removed from these samples (most rocks larger than approximately 1 cm were removed). However, the lab performing the analyses on the biogeochemistry sample requested that these be left in the samples from future sites. The samples where rocks smaller than 2.5 cm may have been removed are all archive and biogeochemistry samples collected from the following soil pits:

- Pit 1 D01 Harvard (HARV)
- Pit 1 D02 Blandy (BLAN)
- Pit 1 D02 SCBI (SCBI)
- Pit 1 D03 Ordway (OSBS)
- Pit 1 D03 Disney (DSNY)
- Pit 1 D03 Jones (JERC)
- Pit 1 D08 Dead Lake (DELA)
- Pit 1 D09 Woodworth (WOOD)
- Pit 1 D09 Dakota Coteau (DCFS)
- Pit 1 D09 NGPRL (NOGP)
- Pit 1 D10 CPER (CPER)
- Pit 1 D10 Sterling STER)
- Pit 1 D10 Castnet (RMNP)
- Pit 1 D11 Klemme (OAES)
- Pit 1 D14 Jornada (JORN)

6.4 Bulk density sample collection

One bulk density sample is collected from each horizon described in the soil pit. The bulk density sample is typically collected as a single vertical soil core (10 cm long, 4.8 cm diameter or 5 cm long, 8 cm diameter). However, where it is not possible to collected a single 10 cm core (e.g., because of rocks or horizon thickness), two or more cores can be collected and combined. For very shallow soil horizons or where it is difficult to insert the soil corer, a known volume of soil can be collected from a specified area (e.g., using the 40 x 40 cm soil box as a guide).

Collecting a single, vertical soil core is the preferred method since the sample volume can be determined with greater accuracy than any of the other methods. Whatever method is used to collect the bulk density sample, it is essential that the volume of the sample is recorded.

6.5 Intact soil block collection

Up to 6 intact blocks of soil (40 x 40 cm horizontally x 16 cm tall) are collected from each soil pit to calibrate NEON's soil water content sensor to the local soil type and to measure the rate of CO_2 diffusivity through the soil. The soil block is collected within a stainless steel box with a removable top and bottom plate. The soil block is collected by exposing a ~70 x 70 cm area of soil at the upper depth of the intended sample, placing the box (without top or bottom plate) on the exposed soil, and excavating around the edge of the sample while lowering the sides of the box into place. Once the top of the box walls are level with the top of the sample, the bottom plate is inserted beneath the sample, the sample is removed, and sealed up (Figure 4).

Figure 4. Intact block of soil during (left panel) and after (right panel) collection at D09 Woodworth

Ideally one block of soil is collected from each soil horizon. For horizons less than 16 cm thick (i.e., the required height of the sample), the soil block should be vertically centered on the soil horizon unless that would raise the top of the sample above the soil surface. Note that the uppermost soil block collected from each soil pit often contains several soil horizons since the horizons near the soil surface tend to be thin.

If there are more than 6 horizons in the soil profile there are two options when collecting the soil block: 1) one or more soil blocks have to contain 2+ soil horizons; or 2) a soil block from one horizon is assumed to be representative of another soil horizon. With either option the affected soil horizons should be as similar as possible. For example, if a soil profile is comprised of the following horizons Oi, A, Ap, Bt1 Bt2, BC, C, it would likely be best to collect one soil block to represent the Bt1 and Bt2 horizons, since these horizons are probably more similar to one another than any other pair of horizons. The FIU personnel collecting the samples base the sample collection depths on their best judgment, which is informed by the soil profile description as well as discussions with the local soil scientist.

Note that the soil blocks collected from the first soil pit that was sampled (Pit 1 D03 Ordway) were 4 cm shorter (i.e., 40 x 40 cm horizontally x 12 cm tall) than the blocks collected at the remaining sites.

7 SAMPLING STRATEGY WHEN A SOIL PIT IS NOT APPROVED

At some sites a soil pit may not be approved by the host or the disturbance caused by sampling the pit may be greater than NEON can tolerate. In these cases soil sampling will be attempted via boreholes if possible. In order to maximize the amount of information that can be collected under these conditions soil samples should be extracted using a coring machine (i.e., resulting in intact soil cores), rather than an augur, which mixes the soil as it is extracted.

The process for determining the location of the sampling shall be the same as described for a soil pit (see above), however it is likely that the boreholes shall be collected from a wider area than the size of a soil pit. The boreholes shall be located as close to one-another as possible pending host approval and sampling feasibility.

Due to the constraints imposed by using boreholes, not all the sampling activities described for soil pit sampling can be achieved. This is described for each activity below.

7.1 Soil profile description

The soil profile can still be described from an intact soil core, however the uncertainty in all properties associated with that description will be larger than if the description was generated from a pit due to the small area from which the sample was collected. If samples can only be collected by augering, which disturbs the soil prior to extraction, the uncertainties will be even greater than for a description from an intact core.

The profile shall be described from a single core that is deemed most representative of all the cores collected. The selection of the most representative core shall be based on expert opinion of FIU personnel and/or the local soil scientist.

7.1.1 Impact

Coring reduces accuracy of soil taxonomy, horizon names, and horizon top and bottom depths. Since the horizon names and depths guide the collection of all other soil samples collected from the pit, this will also reduce the accuracy of data generated from those samples by an unquantifiable amount.

7.2 Photos of the soil profile

Photos will be taken of a representative profile as determined by FIU personnel and/or the local soil scientist.

7.2.1 Impact

Due to the relatively small width of the sample some features that are spatially variable will likely not be visible in the photos.

7.3 TIS Soil Archive and Biogeochemistry sample collection

Given the quantity of soil that is needed for these samples, the expected diameter of the boreholes (≤10 cm), and the likely number of boreholes that are feasible (≤60), it is unlikely that it will be possible to collect sufficient material for many soil horizons.

7.3.1 Impact

Reducing the amount soil per sample may mean that there is not enough material for some analyses to be performed; as a result the data products (NEON.DP1.00096 and NEON.DP1.00097) that result from these analyses may be incomplete. In addition, the quantity of soil that is archived in the NEON Megapit Soil Archive may have to be reduced for these samples, which may result in these samples being fully used up before the end of NEON's 30-year lifespan. The magnitude of these impacts will depend on the quantity of soil that can be collected for each horizon.

7.4 Bulk density sample collection

Bulk density samples can be collected from intact soil cores, however, if the soil is compacted during the extraction it will result in an overestimation of bulk density. Collecting the intact cores when the soil is frozen is expected to minimize compaction of the mineral soil horizons and reduce compaction of organic soil horizons, however, some compaction may still occur and it will be impossible to fully quantify as compaction may not be uniform over the intact soil core.

If the boreholes are created by augering it will not be possible to collect bulk density samples due to the disturbance caused to the soil structure.

7.4.1 Impact

Without reliable bulk density data it will not be possible to create reliable estimates of the amount of soil constituents on an area basis. Other data products that rely on bulk density, such as soil porosity, will also be impacted.

7.5 Intact soil block collection

This sampling activity is not feasible using boreholes, therefore intact blocks of soil will not be collected.

7.5.1 Impact

An empirical site- and depth-specific calibration will not be generated for NEON's soil water content sensor, which will reduce the accuracy of data products from this sensor and other data products that have a dependency on soil moisture. An empirical estimate of the rate of CO_2 diffusivity through the soil will not be generated, which will reduce the accuracy of soil CO_2 flux estimates.