Vermont Long-Term Soil Monitoring Study Methods Manual

Version 2.0

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Guide for Participants in the FEMC Long-Term Soil Monitoring Study

This document is written for participants in the FEMC Long-term Soil Monitoring Study. It describes project protocols that have been used in past sampling years, beginning in 2002, and is intended to help future participants plan and execute the rigorous and complex coordination of the multiple tasks involved in this ambitious project during each sampling year. This project calls for mutual respect, coordination, and communication among multiple stakeholders and also calls for a bit of patience and learning on-the-job. Planning for each sampling period must begin several years before the actual summer of sampling. To complete the task of sampling 50 total soil pits across the five study sites will take multiple weeks of fieldwork, and that will follow the completion of other tasks, as laid out in sequence in this document. This guide is intended to be updated after each sampling year.

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Introduction

The long-term impacts of air pollution and climate change on forest soil health and quality are of concern to land managers and the general public. Potential issues include:

- the fate of heavy metals such as mercury deposited from the atmosphere
- loss of available nutrients, especially calcium and magnesium, from acid anion-induced leaching
- changes in nitrogen and organic carbon levels due to nitrogen saturation and the effects of climate change.

Potential implications include loss of biodiversity and forest productivity (regeneration, and growth and mortality rates) and degradation of water quality (increases in heavy metal, aluminum, and nitrate concentrations; decreases in pH, base cations, and alkalinity).

Documentation of temporal changes in forest soil quality is rare and difficult to obtain due to the confounding effect of spatial soil variability, along with the slow rate of change in soils when compared to the relatively short time span of typical scientific studies. To address this information gap, a committee of scientists associated with the Forest Ecosystem Monitoring Cooperative (FEMC), formerly known as the Vermont Monitoring Cooperative, established a long-term forest soil monitoring study.

The study was originally conceived as a 200-year soil study. The initial dialogue began at the Proctor Maple Research Center in April 1998. A working group including Sandy Wilmot (VT-ANR), Deane Wang (UVM), Thom Villars (NRCS), Tim Scherbatskoy (UVM), Don Ross (UVM), Nancy Burt (USFS-GMNF), and Scott Bailey (USFS-NRS) investigated establishing a long-term soil monitoring study to complement above-ground forest health monitoring. This initial work group evolved into a project steering team, with members changing over time due to changes in jobs, work responsibility, and retirements. Current members of the steering team include Alison Adams, FEMC; Carol Adair, UVM; Josh Halman, VT FPR; Jamie Shanley, USGS; Maggie Payne, NRCS; Angie Quintana, USFS. Don Ross and Thom Villars, both retired, are also active as ex officio members.

Monitoring sites were proposed to be within the two FEMC study sites, on forest lands around Mount Mansfield and in the Lye Brook Wilderness Area in the Green Mountain National Forest. After site reconnaissance during 1999 by Thom Villars and Scott Bailey, the group selected three sites around Mount Mansfield and two sites in the Lye Brook Wilderness Area. The sites were chosen to facilitate interactions with other types of forest monitoring and to provide for long-term protection from other, possibly disruptive, land uses.

The five sites represent a range of forest cover types and elevations: subalpine, conifer/hardwood transition, and northern hardwoods at Mount Mansfield and coniferous and northern hardwood at Lye Brook. Sites were selected to be as internally uniform as possible to minimize spatial variability that could compromise detection of temporal trends. They are relatively stone-free and gently sloping to minimize logistical difficulties. Being within the Green Mountain Biophysical Region, the soils at the sites are representative of large, forested areas. Tree species are characteristic of climax forests, but the sites have had logging activity.

Sampling was initially scheduled with lengthening time intervals over a 200-year period, beginning with a 5-year sampling interval, and incrementally increasing to a 50-year sampling interval. Soil samples would be collected, analyzed, and archived at each site in the individual years of field sampling.

Surveyors established a 50x50 m sampling grid at each of the five monitoring locations, with permanent markers at each corner. This size allowed for one hundred 5x5 m sampling plots with similar canopy characteristics to minimize confounding factors. Using a random number generator, 10 sample plots were selected at each site for each sampling year.

In 2000, NRCS established benchmark soil sampling and characterization using a soil pit located just outside of each 50x50 m grid. Soil characterization was conducted at the NRCS Kellogg Soil Survey Laboratory (KSSL) in Lincoln, Nebraska.

The first year of plot sampling, referred to as year zero, was 2002. A team of volunteers from multiple state and federal agencies and University of Vermont personnel excavated, described, and sampled ten soil pits at each of the five study sites. Fifty soil pits and over 200 unique soil horizons were sampled. Subsequent sampling occurred in 2007 and 2012, with fifty more pits sampled each time, again by a large team from multiple entities.

Around 2015, the steering team decided to change the sampling schedule to maintain the 5-year sampling interval throughout the project duration rather than increase the time intervals as originally planned. This would better allow detection of temporal trends. Because this could have shortened the study from a 200-year project to a 45-year project, the team divided the remaining plots into four 2.5x2.5 m *quadrants* to maintain the long-term character of the study.

After consulting with statistician Alan Howard, UVM Statistical Software Support and Consulting Services, the steering team decided to continue with the original plot sampling order set by the random number generation and randomly select a unique quadrant in each plot to be sampled in each sampling year. If the quadrant selected could not be sampled because of a large boulder or tree, the next quadrant choice generated via random generation would be used. It will be important to keep track of the quadrants used and sampled, and those that are rejected.

A new sampling design will be needed after 2047. Thirty plots at each site were sampled before quadrants were established (plots sampled in 2002, 2007, and 2012). Those 30 plots are likely unusable for future sampling. This leaves up to 210 quadrants available at each site to sample beyond 2047, counting the 70 remaining plots at each site with 3 unsampled quadrants within each plot.

The field tasks outlined below require 6 to 8 weeks to complete during summer, including plot surveying and marking, vegetation inventories, soil pit digging, and soil sampling. Digging soil pits, describing and sampling horizons, bagging the samples, collecting mercury samples, and refilling the takes 2–3 weeks and requires up to twenty participants, including a crew to dig soil pits. Several of the sites have lengthy approaches by hiking trails that add to the time and logistical requirements. Inclement weather often delays sampling, especially for the high-altitude Mount Mansfield Forehead site. Post-sampling processing usually takes months. The laboratory analysis extends into subsequent years.

Future field observations and laboratory analyses may encompass additional parameters. For the vegetation inventory work, this could include the presence or lack of various invasive plants, observable signs of various diseases, occurrence or lack of signs of fires and any storm damage (wind, ice, hurricane, etc.). For soils, fieldwork should note the presence or absence of earthworms (by species if possible), and laboratory work can address pollutants or nutrients of emerging concern. The sample archive will allow analysis of trends over time.

Locate Sampling Grid Corners

2002	In this first sampling year, soil grid corners were established using a wooden dowel to mark each corner, then stretching baling twine along each side for field sampling orientation. The plot diagonals were measured to ensure that side lengths and corner angles were square.
2003	Surveyors installed permanent metal monuments at each of the four corners, consisting of 1 m metal stakes with a round brass survey marker on top with the words, "VMC 200 Soil Plot" and the specific corner. At the Lye Brook Wilderness Area plots, the tops of corner markers were installed below the duff layer. At the Mount Mansfield sites, corner marker stakes protrude just above the soil surface. At each corner, 2 witness trees were marked using two diagonal bark scribes at DBH and one scribe below ½ m, with distance and azimuth (magnetic) to the corner recorded. GPS points were recorded with a Trimble GPS unit. It is anticipated that GPS coordinates will be used to find the general corner locations. Witness tree markings and rock piles should be maintained during each sampling to aid precisely locating the markers.
2007	Corner markers and soil sampling grids were flagged to facilitate sampling. Small rock cairns were maintained around the corner markers to aid locating the site. All sites were accessed on foot.
2012	Same as 2007
2017	Surveyors located and flagged corner markers, selected soil plots, and selected quadrants, to facilitate sampling work. Small rock cairns were maintained around the corner markers for future use in locating the site. All sites were accessed on foot.
2022	Same as 2017

Set Up Sampling Plots or Quadrants

2002	Each of the five 50x50 m sites were split into grids of 100 potential 5x5 m plots to be sampled. A random numbers system was used to determine which of the 100 potential plots would be sampled in 2002. Each of the five sites had its own array of random sample plot numbers. To establish the grids, the south and north sides were flagged every 5 meters, with twine stretched perpendicular to the sides to use as a guide for measuring to each sample plot. Flags were labeled and placed at each of the 4 plot corners. Soil pits were dug as near to the center of each plot as possible, depending on the location of trees and boulders.
2007	At each of the 50x50 m sites, a 10x10 grid of 5x5 m sampling plots was temporarily established for sampling 10 of the potential 100 plots. To establish the grids, the south and north sides of each site were flagged every 5 meters, and baling twine was stretched perpendicular to the sides as a guide for locating each sample plot. A random number generating program selected which of the 100 potential plots were to be sampled, and this was done individually for each site. At each of the 10 sample plots, flags were labeled (NE, NW, SE, SW) and placed at the 4 plot corners.
2012	Same as 2007
2017	At each of the 50x50 meter sites, surveyors located and flagged the corners of the 10 randomly selected plots for this year. Within each plot, the designated sampling *quadrant* (2.5x2.5 m) was also marked. Quadrants were introduced this sampling year to extend the potential life of the project. For each plot, the order of use of the quadrants was randomized. At each of the 10 quadrants to be sampled, flags (with a plastic stake) were labeled (NE, NW, SE, SW) and placed at the 4 quadrant corners, along with a flag (plastic stake) in the center saying "*Dig here.*" If a large boulder or other obstruction prevented a pit from being dug in that quadrant, the next quadrant in the list was used, and a note was recorded of the quadrant that couldn't be sampled.
2022	Same as 2017

Inventory Trees within Sampling Grids

2002	Trees at each 50x50 m site were tallied by species and DBH class. All standing dead trees were included as one group (not by species).
2007	All trees >= 2-inch DBH were measured over the entire 50x50 m at each site. Measurements included: DBH, species, live/dead. An exception was the Forehead site where only 1/4 of the site was inventoried as a representative sample.
2012	All trees >= 2-inch DBH were measured over the entire 50x50 m for each site. Measurements included: DBH, species, live/dead. An exception was the Forehead site where only 1/4 of the site was inventoried as a representative sample.
2017	All trees >= 2-inch DBH were measured over the entire 50x50 m site, and the inventory is conducted and tracked by quarters of the site. Measurements included: DBH, species, live/dead.
2022	All trees >= 2-inch DBH were measured over the entire 50x50 m site, and the inventory is conducted and tracked by quarters of the site. Measurements included: DBH, species, live/dead.

Inventory Regeneration within Sampling Grids

2002	
2007	Tree seedlings were counted by species on each of the 10 sampling plots at each site. All seedlings with true leaves (more than just cotyledons) and all saplings less than 2" DBH were tallied. For root sprouted seedlings (e.g. beech) each individual stem branching below ground was counted separately.
2012	Tree seedlings were counted by species on each of the 10 sampling plots at each site. A 5 m^2 PVC square was placed on the perimeter of each plot and all seedlings whose stems originated in the square were counted. All seedlings with true leaves (more than just cotyledons) and all saplings less than 2" DBH were tallied. For root sprouted seedlings (e.g., beech) each individual stem branching below ground was counted separately.
2017	Tree seedlings were counted by species on each of the 10 plots with sampling quadrants at each site. A 5x5 m PVC square was placed on the perimeter of each plot and all seedlings whose stems originated in the square were counted. A 2.5x2.5 m square was nested inside the 5x5 m plot square to overlap the sampling quadrant. The crew tallied seedlings in the quadrant and the plot. All seedlings with true leaves and all saplings less than 2" DBH were tallied. For root sprouted seedlings (e.g., beech) each individual stem branching below ground was counted separately.
2022	Tree seedlings were counted by species on each of the 10 plots with sampling quadrants at each site. Surveyors flagged corners of each 5x5 m plot, and all seedlings whose stems originated in the square were counted. A 2.5x2.5 m square was nested inside the 5x5 m plot to overlap the sampling quadrant. The crew tallied seedlings in the quadrant and for the plot. All seedlings with true leaves (more than just cotyledons) and all saplings less than 2" DBH were tallied. For root sprouted seedlings (e.g., beech) each individual stem branching below ground was counted separately.

Inventory Understory Plant Cover within Sampling Grids

2002	All herbaceous plants across each of the entire 50x50 m sites were identified to species (where possible) and listed. No abundance data was recorded.
2007	Using the list of herbaceous plants identified in 2002, a casual inventory of plants present across each 50x50 m site was completed in the process of other inventory work.
2012	The protocol was changed from a presence/absence by species at each site to an abundance measure (percent cover) at each of the plots. A 5 m^2 PVC square was placed on the perimeter of each plot and all plants whose stem originated in the square were recorded by species and percent cover.
2017	Understory plant cover data were not collected in 2017.
2022	Understory plant cover data were not collected in 2022.

Dig Soil Pits

2002	Within each sample plot, a 0.7 to 1 m per side soil pit was dug at roughly the center (depending on obstacles). Pit contents were placed on tarps to avoid contaminating surrounding surface soil. The upper organic layer was separated from the mineral soil to facilitate replacing this layer after sampling. Pits were of variable depth (typically, a few cm into the C horizon). Where bedrock prevented adequate sampling of multiple horizons, the pit was relocated within the 5x5 m sampling point if possible.
2007	Within each 5x5 m sample plot, a 0.7-0.9 m per side (27-36 in) soil pit was dug at roughly the center point, with some adjustment for stones and boulders. All excavated material from the soil pit was placed on plastic tarps to avoid contamination of surrounding surface soil. The upper organic layer was stockpiled separately from the excavated soil to facilitate replacing this layer following sampling. Pits were generally dug to 75 cm where possible, but the depth of the pits varied. Large stones and boulders limited excavation depth at a few sample plots.
2012	Same as 2007
2017	All 10 soil pits were dug by a separate crew. Within each 2.5x2.5 m sample quadrant, a soil pit was dug at roughly the center point, adjusting for stones and boulders. All excavated material from the soil pit was placed on plastic tarps to avoid contaminating surrounding soil. The upper organic layer was stockpiled separately from the excavated soil to facilitate replacing this layer after sampling. The pits were 0.7-0.9 m per side (27-36 in) and 75 cm deep from the soil-air interface where possible. Large stones and boulders limited excavation depth at a few sample plots.
2022	Same as 2017

Identify Soil Horizons

2002	Once all 10 pits were dug at a site, pit examinations were made to determine which horizons would be sampled. At a minimum, an organic layer sample and several other soil horizons were sampled. Not all horizons could be sampled in each pit, based on presence and volume of soil at each horizon.
2007	All 10 soil pits at each site were dug and observed concurrently by the soil sampling crew before the profiles at individual pits were described to increase consistency in horizon delineation and designations among the teams of soil describers working on the site. There were no criteria for minimum horizon thickness (and extent, for discontinuous horizons like E horizons). However, enough soil material was needed for splitting into sub-samples for submission to several labs and for the archives. For this reason, horizons less than two cm thick were described but not sampled.
2012	At Lye Road, all 10 soil pits were dug and observed concurrently by the soil sampling crew before the profiles at individual pits were described. The reason for this was to assure consistency in horizon delineation and designations among the teams of soil describers working on the site. At other sites, several teams worked on digging pits and as they finished, others began describing and sampling the soil profiles. This method was found to be more time-effective than digging all ten of the pits before beginning to describe any of the soil profiles. There were no criteria for minimum horizon thickness (and extent, for discontinuous horizons like E horizons). However, enough soil material was needed for splitting into sub-samples for submission to several labs and for the archives. For this reason, horizons less than two cm thick were described but not sampled.
2017	The soil sampling crew observed the soil pits the same day or the day after pits were before describing the profiles at individual pits. This was to improve consistency in horizon delineation and designations among the soil describers at the site. There were no criteria for minimum horizon thickness (and extent, for discontinuous horizons like E horizons). However, enough soil material was needed for splitting into sub-samples for submission to several labs and for the archives. For this reason, horizons less than two cm thick were described but not sampled.

2022	Some of the pits were observed by the full soil sampling crew before the profiles at individual pits were described. This was done primarily on the first day of soil description and sampling. Thom Villars led a discussion of sampling and description protocols at the beginning of work at the two major locations, Mount Mansfield and Lye Brook. This was to improve consistency in horizon delineation and designations among the soil describers at the site. There were no criteria for minimum horizon thickness (and extent, for discontinuous horizons like E horizons). However, enough soil material was needed for splitting into sub-samples for submission to several labs and for the archives. For this reason, horizons less than two cm thick were described but not sampled. **Horizon designations – guidelines for consistency among soil describers**: 1. **O horizons – Record all O horizons**, starting with the **Oi** comprised of relatively new leaf litter, followed by slightly decomposed organic material designated as **Oe**, and if present, highly decomposed organic material designated as **Oa**. It is critical to be consistent across all pits at each site in your descriptions of O horizons. Unless there has been some sort of surficial disturbance, all pits will typically have both **Oi** and **Oe** horizons. The **Oa** may not be present, with an **A** horizon observed instead. 2. How to distinguish an **Oa** vs. an **A** horizon? This can be a tough call. Use judgment, based on smeariness and sense of higher OM content vs higher mineral content. These two horizons are sampled together in the bulk sample process. Lab analysis of organic carbon percentage will ultimately indicate if **Oa** or **A**. 3. **Do not use transitional or mixed horizon designations**, such as AE, EB or E/Bs. 4. The **B horizon designations** will be based on the Munsell moist color: • **Bhs** (has appearance of having spodic properties) – has hue 7.5YR or redder, with value and chroma of 3 or less, plus hue of 10YR below an E horizon, with value/chroma of 2/1, 2/2, or 3/1. • **Bh** horizon designation will not be used. • **Bs** (has appearance of having spodic properties) - has hue 7.5YR or redder, with value or chroma greater than 3. • **Bw** - other B horizons with hue of 10YR or yellower shall be identified as **Bw** horizons (non-spodic). • The **BC** horizon designation will not be used. The **Bw** designation shall be used for all lower B horizons not meeting color criteria for **Bhs** or **Bs** horizons.

Record Soil Descriptions (see Field Description Form on page 16)

2002	Used standard NRCS protocols
2007	Soils were described using NRCS procedures in the **Field Book for Describing and Sampling Soils**, **version 2.0, September, 2002**. The Soil Profile Description Form was based on the form on p. 2-75. **The following soil physical properties were described** (with page numbers following): • Horizon Designation and lower Boundary (pp. 2-2 to 2-6) • Depth of horizon (upper and lower) in centimeters • Matrix color, moist, Munsell notation • Texture (pp. 2-29 to 2-31) • Percent rock fragments by volume (shape- p. 2-40, note basic Percent Chart on p. 2-9 – some Munsell color books also have a Percent Chart) • Structure; grade, size, and type (pp. 2-41 to 2-48) • Consistence, moist (also referred to as Rupture Resistance, pp. 2-49 to 2-50)

	• Redoximorphic features; quantity, size, contrast – and Munsell color (pp. 2-14 to 2-17; see also quantity, size and contrast charts under Mottles on pp. 2-9 to 2-12) • Roots (pp. 2-56 to 2-58) • Other features such as: organic streaks and stains, type of organic material, moisture status, slope percent, aspect and horizons sampled Soil chemical properties (such as pH) were not recorded in the field. They were analyzed later in a lab.
2012	Same as 2007
2017	Same as 2007 and 2012
2022	Soils were described using NRCS procedures referenced in the **Field Book for Describing and Sampling Soils**, **version 3.0, September, 2012** (reprinted 2021). The Soil Profile Description Form is based on the form in the Field Book, pp. 2-93 and 2-94. **The following soil physical properties were described** (with page numbers following): • Horizon Designation and lower Boundary (pp. 2-2 to 2-7) • Depth of horizon (upper and lower) in centimeters o Do not use the '+' symbol for lower horizon depths. The lowest depth shown for the deepest horizon should equal the total depth of the soil pit. • Matrix color, moist, Munsell notation • Texture (pp. 2-36 to 2-45) • Percent rock fragments by volume (shape- p. 2-47, note - some Munsell color books also have a Percent Chart) • Structure; grade, size, and type (pp. 2-52 to 2-61) • Consistence, moist (also referred to as Rupture Resistance, pp. 2-62 to 2-69) • Redoximorphic features; quantity, size, contrast – and Munsell color (pp. 2-10 to 2-17; see also quantity, size and contrast charts under Mottles on pp. 2-18 to 2-27) • Roots (pp. 2-70 to 2-72) • Other features such as: organic streaks and stains, type of organic material, moisture status • Horizons that are sampled should also be noted Soil chemical properties (such as pH) were not recorded in the field. They were analyzed later in a lab.

Label Soil Sample Bags

2002	No standard
2007	No standard
2012	No standard
2017	The group agreed on standard labeling on the sample bags to avoid confusion. **Genetic samples** were labeled with: ***Site - plot & quadrant – year – horizon - upper/lower depths;*** Example: • LT-028NE-2017-Oa-3-10cm **Bulk samples** were collected from one of 4 depths, and labeled with: ***Site - plot & quadrant – year – horizon and/*****or depth increment;** Examples: • LT-028NE-2017-Oi/Oe • LT-028NE-2017-Oa/A • LT-028NE-2017-top10cmB • LT-028NE-2017-60–70cm
2022	Same as 2017, except some staff used numbers for quadrants instead of letters (1 = NW, 2 = NE, 3 = SW, 4 = SE).

Collect Soil Samples

2002	After soil descriptions were completed, samples were taken from the side of the pit that was described, using a knife and trowel. If Oe was sampled, a larger area of soil surface was peeled backwards and "mined". All samples were collected into 60-ounce clear polyethylene sterile bags (Fisher Scientific), and labeled with soil site, soil pit number, and date (?) Sample size was dependent on the thickness and continuity of the described horizons.
2007	As the 10 soil pits were initially reviewed, evaluations were made to determine which horizons to sample at each soil pit. At a minimum, an organic horizon and several mineral soil horizons were sampled. If Oe was sampled, a larger area of soil surface was peeled backwards and "mined." Not all horizons were sampled in each pit, due to the minimal thickness of some horizons. Samples were taken from the side of the pit that was described, using a knife or trowel. All samples were collected into 60-ounce clear polyethylene sterile bags (Fisher Scientific), and labeled with plot name, subplot number, and date. Sample size depended on the thickness and continuity of the described horizon. In addition to the genetic horizon sampling, similar to the 2002 sampling, a depth increment sampling was completed at each pit. The genetic horizon samples will be kept as reference samples and the depth increment samples were used for all analytical work. Depth increment sampling consisted of collecting one gallon of material from: • the Oi and Oe horizons together • the Oa and A horizons together • the upper 10 cm (4 inches) of uppermost B horizon(s); • and between the depths of 60 to 70 cm below ground surface.
2012	The 2012 sampling included genetic horizon sampling and bulk depth increment sampling, as in 2007. The genetic horizon samples were kept as reference samples and the bulk depth increment samples were used for all analytical work. Genetic horizon samples were taken from the side of the pit that was described, using a knife or trowel. They were placed into small clear polyethylene sterile bags (e.g., sandwich bags), and labeled with a two-letter site initial, plot number, horizon label, and depth. Sample size was generally sufficient to fill the small bags but depended on the thickness and continuity of the described horizon. Bulk depth increment samples, for all but the MM Forehead site, were one gallon of material from: • the Oi and/or Oe horizons, mixed together if both were present • the Oa and/or A horizons, mixed together if both were present • the upper 10 cm (4 inches) of the uppermost B horizon(s) • between the depths of 60–70 cm below the **mineral soil surface**. For the MM Forehead site, bulk depth increment samples consisted of one gallon of material from: • the Oi and/or Oe horizons, mixed together if both were present; • the Oa and/or A horizons, mixed together if both were present; • the upper 10 cm (4 inches) of the uppermost B horizon(s), if a B horizon was present. If a B horizon was not present, the E horizon, if present, was sampled in its entirety; • between 60–70 cm below the **mineral soil surface**, if the soil pit was deep enough.

<table>
<tr><td>2017</td><td>Same as 2012, with some exceptions:
Bulk depth increment samples for all but the MM Forehead site were one gallon of material from:
the Oi and/or Oe horizons, mixed together if both were present;
the Oa and/or A horizons, mixed together if both were present;
the upper 10 cm (4 inches) of the uppermost B horizon(s); and
between the depths of 60–70 cm below the soil surface
For the MM Forehead site, bulk depth increment samples consisted of one gallon of material from:
the Oi and/or Oe horizons, mixed together if both were present;
the Oa and/or A horizons, mixed together if both were present;
the upper 10 cm (4 inches) of the uppermost B horizon(s), if a B horizon was present. If a B horizon was not present, the E horizon, if present, was sampled in its entirety; and
between 60–70 cm below the soil surface, if the soil pit was deep enough.</td></tr>
<tr><td>2022</td><td>Same as 2017</td></tr>
</table>

Collect Separate Soil Samples for Mercury Analysis

<table>
<tr><td>2002</td><td>After the general soil sampling was completed, additional samples were collected for Hg analysis using sampling methods that prevent atmospheric contamination of the samples (plastic utensils, gloves). Separate samples for total mercury (THg) were taken in 20-mL polyethylene scintillation vials from a fresh pit face. The uppermost sampleable humified soil horizon was taken, either an Oa or A horizon.

Five of the 50 samples were identified as Oe, and 10 additional B horizon samples were collected for a total of 60 samples. Samples were frozen as soon as feasible.</td></tr>
<tr><td>2007</td><td>After the general soil sampling was completed, additional samples were collected for Hg analysis using sampling methods that prevent atmospheric contamination of the samples (plastic utensils, gloves). Separate samples for THg were taken in 20-mL polyethylene scintillation vials from a fresh pit face. The uppermost sampleable humified soil horizon was taken, either an Oa or A horizon.

Eight B horizons were also sampled, along with one A under an Oa, for a total of 59 samples. Samples were frozen as soon as feasible.</td></tr>
<tr><td>2012</td><td>After the general soil sampling was completed, additional samples were collected for Hg analysis using sampling methods that prevent atmospheric contamination of the samples (plastic utensils, gloves). Separate samples for THg were taken in 20-mL polyethylene scintillation vials from a fresh pit face. The uppermost sampleable humified soil horizon was taken, either an Oa or A horizon. Samples were frozen at 0 ^{o}C as soon as feasible, usually the same day.</td></tr>
<tr><td>2017</td><td>Same as 2012</td></tr>
<tr><td>2022</td><td>Same as 2012</td></tr>
</table>

Refill Soil Pits

2002	Once all the soil samples were collected, soil from the tarps was replaced into the pits, and topped off with the original organic layer.
2007	Once all the soil samples were collected, soil from the tarps was replaced into the pits, and topped off with the original organic layer. The goal was to not leave any soil material extracted from the pit remaining on the soil surface around the pit.
2012	Once all the soil samples were collected, soil from the tarps was replaced into the pits, and topped off with the original organic layer. The goal was to not leave any soil material extracted from the pit remaining on the soil surface around the pit.

	At Mount Mansfield sites, plastic coated (surveyor) magnets were left in soil pits to indicate their location for future site visits (using a magnet detector). Magnets were placed against the lateral center of the sampling face, in the upper mineral soil. Because of Wilderness restrictions, these were not used at Lye Brook sites.
2017	Once all the soil samples were collected, soil from the tarps was replaced into the pits, and topped off with the original organic layer. The goal was to not leave any soil material extracted from the pit remaining on the soil surface around the pit. Although placement of magnets at the Mansfield sites was mentioned in Version 1.0 of this document in 2017, it is unclear if this actually occurred.
2022	Once all the soil samples were collected, soil from the tarps was replaced into the pits, and topped off with the original organic layer. The goal was to not leave any soil material extracted from the pit remaining on the soil surface around the pit.

Process Soil Samples at Off-Site Locations

2002	Samples were air-dried on black plastic on lab benches out of direct sunlight at the University of Vermont Plant and Soil Science Department. After drying, samples were stored in their original field bag if viable. Samples were then sieved through a 2-mm polyethylene sieve and separated into four 8-ounce containers using a riffler. Some horizons had insufficient volume/weight for four containers.
2007	Same as 2002
2012	Samples were kept in Jeffords Hall basement room 013 in boxes until space was available to dry samples on metal shelving units. Each sample bag was dried individually on 15"x12" black plastic sheets. Small samples were spread out on one sheet while bulk samples were dried on two overlapping sheets. Moist samples were laid out as space became available by re-bagging of dried soil. Each black plastic sheet was wiped down with a damp paper towel before laying out a new sample to dry to avoid contamination between samples. Sieving and riffling was completed under the grinding hood in Jeffords basement room 010 in a specific order to minimize contamination between samples by the equipment. Dry samples were sieved and riffled starting with the top of a pedon, working through the horizons by increasing depth, then beginning at the bottom of the next pedon working upwards (example: Oa, A, Bw, C, of one pit then C, Bs, E, Oa of a different pit). Each sample was put through a plastic 2mm sieve and then riffled into archive jars using a metal Humboldt riffle sampler. Aggregates were crushed using moderate hand pressure against the side (not the grating) of the sieve using an extra plastic jar. Anything >2 mm was discarded, except in the case of Oa and A samples which formed soil aggregates that could not be crushed with moderate hand pressure against the side of the sieve. These aggregates sometimes made up a large portion of the sample in A or Oa horizons. In this case, rocks, roots, and other 'non-soil aggregate' materials were removed by hand and aggregates were crushed with as little force possible using a ceramic mortar and pestle, taking care to use only enough pressure to break up aggregates and not grind the soil particles. Equipment was cleaned between samples under the hood using an air compressor to blow off any remaining dust. Samples were split with the riffler as few times as possible to avoid losing small particles as dust. Samples were also split to produce at least four jars, making sure to have at least one 8-oz jar and splitting the rest into 16-oz jars (if the sample was too small to fill 16-oz jars, 8-oz were used instead). Jars were temporarily labeled using a permanent marker until a full inventory was made and each sample given a reference number. Oi/Oe bulk samples were air dried and then ground using a Thomas-Wiley Laboratory Mill with a 2-mm screen. The milled sample was then riffled into plastic jars using the same method as the mineral horizons, and the mill was cleaned meticulously between samples.

2017	Samples were air-dried on black plastic on metal shelves in Jeffords Hall basement room 010. After drying, samples were stored in their original field bag if viable. Subsequent processing included sieving through a 2-mm polyethylene sieve and separating into four 16- or 8-ounce containers using a riffler.
2022	Samples were stored in Jeffords Hall basement room 010 in boxes for 1–3 weeks until space was available to dry them. Both metal shelving units and metal racks of drying trays were used. Each sample bag was dried individually on a black plastic sheet, wiped down with a damp (reverse osmosis water) paper towel before laying out a new sample. Processing of dry samples was done by horizon and subhorizon, starting with all A horizons, then working down the soil profile (for example, all Bs horizons for all pits were sieved, then Bhs horizons, followed by Bw horizons etc.). Each sample was put through a plastic 2-mm sieve and then riffled into archive jars using a metal Humboldt riffle sampler. Aggregates were crushed using moderate hand pressure against the side of the sieve. Anything >2 mm was discarded, except in the case of Oa and A samples which formed soil aggregates that could not be crushed with moderate hand pressure against the side of the sieve. These aggregates sometimes made up a large portion of the sample in A or Oa horizons. In this case, rocks, roots, and other 'non-soil aggregate' materials were removed by hand and aggregates were crushed with as little force possible using a ceramic mortar and pestle. Equipment was cleaned between samples under the hood using an air compressor to blow any remaining dust off. Samples were split to produce five jars, one set of 4-oz polypropylene jars was prepared for shipment to the NRCS KSSL in Lincoln, NE and four sets were prepared for archiving, consisting of either 4-oz, 8-oz (polyethylene) and 16-oz (polyethylene) jars. Some samples had insufficient volume for more than three 4-oz jars. Oi/Oe bulk samples were air dried and then ground using a Wiley Mill with a 2-mm screen at the UVM Horticultural Research Center, cleaned thoroughly between samples. The milled sample was then riffled into plastic jars using the same method as the mineral horizons. Temporary labels were replaced with a permanent one including the year, inventory number, study name, sampling year, location, site number, sample name, and number of the replicate jar (see example below). These labels were then covered with clear plastic tape to protect them from wear. **2022-067** 200 Year Soil Study, Year 20 Lye Brook Trail Plot 80 Q3 **top 10 cm B** 1 of 4

Send Soil Samples for Laboratory Analysis

2002	**NRCS-Kellogg Soil Survey Laboratory (KSSL).** The NRCS steering team member coordinates necessary approvals and submission of soil samples to the Kellogg SS Lab in the year preceding field sampling. All 204 samples were sent to NRCS-KSSL in 20-mL vials, weighing 3.2-33.3 g. Six replicates (B horizons from LR and LT) were also included. (No Oi or Oe or C horizons were collected.) The NRCS lab determined total C, N, S by combustion; pH 3 NH_4-oxalate optical density (ODOE), Fe, Al, Mn, Si, P; pyrophosphate Fe, Al, Mn; and pH 7 NH_4-acetate Ca, Mg, K, CEC. The detection limit on the exchangeable cations was not sufficient to determine the low concentrations in the E and B horizons. Methods from Kellogg Soil Survey Laboratory Methods Manual, Soil Survey Investigations Report No. 42, Version 3 or 4. **UVM**. All B and BC horizons (n = 104) were analyzed for exchangeable cations by a batch extraction. Cations included Al, Ca, Mg, K, Na, Fe and Mn. The method was 20 mL of 1 molar NH_4Cl to 2.00 (+ or - 0.01 but usually closer) g in "50" mL Oak Ridge polyethylene centrifuge tube, shaken for 2 hours (30 s on 30 s off), Eberbach reciprocal shaker at high (160 back and forths per minute), centrifuged on Beckman J-21 with JA-20 rotor at 12000 rpm (RCF 17400). The NH_4Cl was Fluka 09725, Lot and Filling code: 1140885 14704256, >99.5%, Ca<0.00005%. Other sources of NH_4Cl were found to be relatively high in Ca. The same 104 samples had pH determined in 0.01 molar $CaCl_2$, 2:1 V:V (10 mL solution: 5 mL soil). These were rerun in 2019 by Emily Piersiak as part of a UVM Honors College thesis: The Effects of Aging on pH in Forest Soil Samples (2020), available at UVM ScholarWorks. **UVM and USFS, Durham NH.** In 2010 (with reruns in 2012), all 204 Year-0 samples were analyzed for exchangeable cations by mechanical vacuum extraction (MVE) with 1 molar NH_4Cl. The extraction was done at UVM and the cations were determined by ICP at the Forest Service Lab in Durham, NH. Cations included Al, Ca, Mg, K, Na, and Mn. Each batch was 24 samples included a blank, a reference soil, and one sample run in triplicate. Method was from: Blume et al. 1990. Handbook of methods for acid deposition studies laboratory analyses for soil chemistry. EPA/600/4-90/023. US EPA, Environmental Monitoring Systems Laboratory, Las Vegas, Nevada, USA. **Reference soils.** The UVM lab used two reference soils, an Oa horizon and a Bs horizon, collected near the Mansfield Underhill site and described in Ross et al., 2015, Ecosphere 6(5):73. http://dx.doi.org/10.1890/ES14-00209.1 **Mercury analysis.** Samples were overseen by the USGS, and Hg analysis provided by the Vermont Dept. of Environmental Conservation (VT DEC) laboratory using an aqua regia/permanganate hot block digestion and cold vapor atomic absorption spectroscopic analysis. Carbon was not determined on the separate samples taken for Hg but, instead, results from the larger horizon sample were used.
2007	**NRCS-KSSL.** The NRCS steering team member coordinates necessary approvals and submission of soil samples to the Kellogg SS Lab in the year preceding field sampling. Small (20-mL) subsamples of 142 'large' horizons were sent, including all but the Oi/Oe layer. The same analyses were performed on all samples as done in 2002 (total C, N, S; NH_4-oxalate; pyrophosphate) except CEC and exchangeable 'base' cations were only run on the 60–70 cm samples. Again, the detection limits were not low enough. Also, on only the 60–70 cm samples, particle size was determined. Methods used were from the current KSSL methods manual. **UVM.** All 'small' B horizon samples (n = 129) were run for C and N by elemental analyzer. The instrument was calibrated with reference soil from the North American Proficiency Testing program (NAPT) and both an NAPT soil (Saugeen) and the Underhill Bs were used as QCs. **UVM and USFS.** As described above for 2002, exchangeable cations were determined by MVE on all samples, excluding the Oi/Oe horizons.

	Mercury. Samples were overseen by the USGS, and Hg analysis provided by the VTDEC lab using an aqua regia/permanganate hot block digestion and cold vapor atomic absorption spectroscopic analysis. C was not determined on the samples taken for Hg—results from the larger horizon sample were used.
2012	**NRCS-KSSL.** The NRCS steering team member coordinates necessary approvals and submission of soil samples to the Kellogg SS Lab in the year preceding field sampling. Subsamples of all 197 'large' horizon samples were sent to the Lincoln lab, including the Oi/Oe. The same analyses as in 2007 were performed on all but the Oi/Oe. This included Total C, N, S; NH_4-oxalate extractable elements; and pyrophosphate extractable elements. A total digestion (HF and aqua regia) was done on the Oi/Oe and 60–70-cm samples, with a suite of elements determined by ICP. Particle size distribution and CEC were both done on the 60–70-cm samples. **UVM.** The MVE procedure for exchangeable cations was performed on all 'small' B horizons (n = 123) and all top-10cm-B 'large' samples (n = 47). ICP cations were run at UVM and included Al, Ca, Mg, K, Na, and Mn. Some samples that were very low in Ca were also sent to the Forest Service lab in Durham NH to verify the results. **Mercury.** Samples were air dried, put through a polyethylene 2-mm sieve, and split into two 20-mL vials. One set was delivered to the State of Vermont Agricultural Lab in the Hills Building at UVM where samples were digested, and Hg determined by EPA 7471A (cold vapor). The other set of samples had total carbon determined by elemental analyzer at the UVM Agricultural and Environmental Testing Lab.
2017	**NRCS-KSSL.** The NRCS steering team member coordinates necessary approvals and submission of soil samples to the Kellogg SS Lab in the year preceding field sampling. Somewhat larger subsamples (4-oz, or 118-mL, polyethylene jar) of all 193 'large' horizon samples were submitted and the same analyses as 2007 performed on the same sample types, except that no CEC measurements were done. Methods from 2014 KSSL version 5.0 Manual—Particle size: 3A1a1a pipet analysis with standard pretreatments and dispersion (air dry); C, H, S: 4H2a dry combustion, thermal conductivity detector; sodium pyrophosphate: 4G3; ammonium oxalate: 4G2 in manual but listed as 4G4 in results; total elemental: 4H1b, HF + HNO_3 + HCl. **UVM.** The MVE procedure for exchangeable cations was performed only on all the top-10-cm-B 'large' samples (n = 46). ICP cations included Al, Ca, Mg, K, Na, Fe, and Mn. **Mercury.** Samples were air dried, put through a polyethylene 2-mm sieve, and split into two 20-mL vials. Glass vials were delivered to the Vermont Agricultural and Environmental Lab in Randolph, VT. Hg was determined, without further drying, by SW 3050B (digestion) and SW 6020B (ICP-MS). Anne Charbonneau was the analyst. Total carbon was run on the other split by elemental analyzer at the UVM Agricultural and Environmental Testing Lab.
2022	**NRCS-KSSL.** The NRCS steering team member coordinates necessary approvals and submission of soil samples to the Kellogg SS Lab in the year preceding field sampling. Subsamples (4-oz polycarbonate jar) of all 'large' horizons were submitted to the KSSL on 1/24/2023. Identical analytical scheme as 2017 was requested, but the lab no longer performs the Na-pyrophosphate extraction. They have substituted citrate-dithionate extraction (4G1) instead. **UVM.** No analyses have been performed to date (10/30/2023) **Mercury.** Samples were sent to the Center for Environmental Systems Engineering (CESE) laboratory at Syracuse University (Mario Montesdeoca, lab manager; Charley Driscoll, faculty). Analysis will include soil elemental carbon analysis with an Elemental Analyzer (50 @$22.12) and soil prep and Hg content with a Direct Mercury Analyzer (50@$88.25)

Record of Revisions to version 1.0 of this Document:

- April 2023 – Thom Villars updated document with some 2022 sampling notes and recommendations.
- April 2023 – Josh Halman, VT FPR, updated the Vegetation Survey sections.
- July, August 2023 – Don Ross updated the Soil sampling and Processing sections with input from Jenny Bower. Added section on Lab Analyses.
- August 2023 – Thom Villars did revision to Introduction and formatting of document
- Sept 2023 – Jamie Shanley made slight edits on Hg parts.
- October 2023 – Thom Villars did quick review of document, made minor edits, and sent to Don Ross for final review.
- November 2023 – Angie Quintana edited for length, clarity, and plain language.

USDA-NRCS & FEMC	LONG TERM SOIL MONITORING PROJECT - SOIL DESCRIPTION FORM - 20______ Pedon ID (Site, subplot, quadrant) :			
Series or Component Name:		Classification:	Date:	
Describer(s):	Location:			
Pedon ID Info:	Elevation:	Slope:	Aspect:	Any un-samplable quadrants in the subplot?
Other Features/Comments:			Soil Moisture Status:	

MISCELLANEOUS FIELD NOTES / SKETCH

SOIL HORIZON INFORMATION

Layer Number	Sampled (Yes/No)	Horizon Designation	Depth (cm) (top-bottom)	Lower Bndry	Matrix Color Moist	Texture	Rock Frag % & Size (note all sizes)	Structure Grade Size Type	Consistence Moist
1									
2									
3									
4									
5									
6									
7									
8									

Layer Number	Redoximorphic Features - 1 % Size Contrast Color	Redoximorphic Features - 2 % Size Contrast Color	Roots Quantity & Size (note all sizes)	Earthworms Quantity	Other Features and Notes
1					
2					
3					
4					
5					
6					
7					
8					