



<i>Title:</i> TOS Protocol and Procedure: VST – Measurement of Vegetation Structure		<i>Date:</i> 03/19/2026
<i>NEON Doc. #:</i> NEON.DOC.000987	<i>Author:</i> C. Meier	<i>Revision:</i> N

TOS PROTOCOL AND PROCEDURE: VST – MEASUREMENT OF VEGETATION STRUCTURE

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	01/10/2014	ECO-01139	Initial release
B	03/20/2014	ECO-01661	Production release, template change, and other changes as detailed in Appendix C
C	04/10/2014	ECO-01792	Added Appendix H with site-specific information
D	10/01/2014	ECO-02287	Migration to new template. Reorganization of content and updates to datasheets. Change to sampling strategy in 40 m x 40 m Tower plots.
E	02/25/2015	ECO-02537	Update of TOS protocol based on 2014 field experience and budget analysis.
F	02/29/2016	ECO-03583	<ul style="list-style-type: none"> • Updated key definitions in Section 2.4 Table 1, and added growth form definitions in Section B.1 Table 7 • Section 4.1: Clarified timing language for fern sampling • SOP B: Reorganized to focus only on classification, mapping, and tagging. Flow charts, figures, and information pertaining to measurements removed and inserted to SOP C when appropriate. • SOP B.1: Classification to growthForm now dependent on stem count, DBH, height, and species-specific knowledge • SOP B.2: Nested subplot text moved from SOP C to SOP B • SOP B.2: Added mechanism to change nested subplot size in consultation with NEON Science Operations. • SOP B.3: ‘Selecting the Optimal Measurement Area’ moved from SOP C to SOP B. • SOP B.5: Added standardized taxonID text to step 9 • SOP C: Broken bole measurement strategy no longer requires confusing data entry into canopy diameter fields. • SOP C: Cactus measurements removed, moved to newly developed Cactus SOP (RD[11]) • SOP C: Calipers now required for diameter measurements on self-supporting stems with lianas. Multi-bole tree measurement strategy now consistent with FIA approach, no longer based on liana guidelines.



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			<ul style="list-style-type: none"> • SOP C: Changed 'stemStatus' to 'status', updated code definitions, added a new code for 'no longer measured' • SOP C: Added paragraph calling out types of 'other' growth forms that require measurement, provided cross-reference to Appendix D for details. • SOP E: Added standardized data entry text • Appendix: Removed <i>Toxicodendron</i> handling appendix, due to imminent release of <i>Toxicodendron</i> handling SOP.
G	03/09/2017	ECO-04408	<ul style="list-style-type: none"> • Sampling completion: Specified that bouts must be completed within 4 months of sampling onset OR onset of next growing season (i.e., leaf-expansion). • Expanded instructions for recording Plot Metadata, and changed to annual basis to improve tracking and reporting of sampling effort. • Updated numerous field names to be consistent with Data Products implementation. • Added more guidance for recording 'identificationReferences' in the Plot Metadata table, and in the growth-form-specific tables. • Added 'tagStatus' to facilitate tracking individuals through time. • Changed 'status' to 'plantStatus' to comply with pre-existing Data Products term definitions, and added new plantStatus choices. • Expanded broken bole guidance. • Appendix D.2: Updated forking guidelines to be consistent with 2016 Forest Service FIA rules. • Appendix D.5: Clarified that ddh is not measured if access is denied along first 30 cm of stem. • Appendix D.6: Added measurement guidelines for 'sap' and 'sms' individuals. • Appendix F: Clarified that agave and other yucca-like growth forms with large basal rosettes should be measured similar to yucca. • Appendix H: Converted dates from DOY to MM/DD • To address problem with consistent field implementation, shrub 'shape' no longer limited to leafy crown, now consider the entire individual. • Appendix I: Added site-specific modifications, including changes to annual Tower Plot measurement frequency at cold/dry sites (identified 'efficiency' required to be implemented in 2017).



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REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
H	07/26/2018	ECO-05698	<ul style="list-style-type: none"> • Sections 1 and 3: Re-organized and simplified text. • Section 3.1: New section with protocol implementation guidelines by plot type, including reference to new Survey Method for Assessment of Vegetation Cover SOP. • Section 4.1: Distributed and all Tower plots sampled every 5 years; each plot type scheduled such that plots of one type or the other are sampled every 2-3 years at each site. A subset of 5 Tower plots are sampled annually. • Section 4.2.1: Clarified that bouts should be completed within 60 d at sites with no distinct growing season. • Section 6: Updated equipment list to support move away from Maximo. • SOP B: Integrated support for digital data collection workflow. • SOP B.1: Clearly called out Shrub Group designation criteria. • SOP B.2, B.3: Added 3 m² nested subplot size. • SOP B.4: Nails no longer used to tag small trees; loose aluminum wire only to avoid damage. • SOP B.6: Added 'Mapping QA/QC' section to integrate use of 'VST Mapper' application into workflow. • SOP C: Integrated support for digital data collection workflow. • SOP C.1: Simplified tagStatus to 'ok', 'replaced', and 'notTagged'. • SOP C.1: Added plantStatus = 'downed'. • SOP C.1.2: Added explicit guidance to avoid sloughing off bark during DBH measurement. • SOP C.3: Combined agave and yucca growthForm into one 'yucca' growthForm, due to identical measurements. • SOP C.3.2: Added guidance for measuring tree ferns. • SOP E: Added content to support digital data workflow • Appendix I: New site-specific appendices for D04, D14; added WREF to list of sites in Appendix I.1.



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J	03/05/2020	ECO-06386	<ul style="list-style-type: none"> • Updated to new template (NEON.DOC.050006vJ) • Reorganized SOPs to better reflect workflow in the field. • Section 4: Re-organized and updated tables to better present scheduling information at different site types and for different event types. • Section 4: Clarified that Tower Plot subset measured annually is 5-10 lowest Morton Order plots with qualifying vegetation. • SOP C.3: Clarified that at sites with both 20m x 20m and 40m x 40m Tower Plots, Vegetation Structure is implemented in the 20m x 20m ‘core’ of the four larger Tower Plots. • SOP C.2: Clarified that the sum of ‘smt’, ‘sap’, ‘sis’, ‘sms’, and shrub groups is used to determine one nested subplot size for all of these growth forms. • SOP C.3: Added Sampling Impractical field. • SOP C.3: Added eventType and dataCollected fields to Plot Meta-Data to account for dendrometer band sampling in Tower Plots. • SOP D.2: Measurement height determination for leaning dead now consistent with leaning live individuals. • SOP D.3: Added recordType field to Mapping and Tagging to identify individuals with dendrometer bands, and better categorize existing record types. • SOP D.4: Added text to clarify error correction strategy for Mapping and Tagging records. • SOP E.1: Clarified when to record a new measurement-Height; added new ‘changedMeasurementLocation’ field to document movement of measurement location along the stem. • SOP E.1: Restored tagStatus = tagRemoved to indicate when an individual drops out of longitudinal dataset. • SOP E.1: Deprecated plantStatus = 14 and restored all codes to previous definitions in earlier protocol versions. • SOP E.1: Added tempID for use with multi-stem smt, sap, sis, and sms growthForms to make records unique. • SOP E.1.2: Added measurementStrategy field for lianas corresponding to illustrated morphologies in SOP E.1.2. • SOP E.1.2: Clarified which ‘other’ complex growth forms may be measured like lianas.



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			<ul style="list-style-type: none"> • SOP E.2: Added canopyPosition and crownDiameter requirements for all woody growth forms except ‘lia’ and shrub groups, and added requirement for recording in all plot types. • SOP E.2.1: For broken multi-stem ‘sap’ and ‘sms’, crown is now measured even if all stems are broken. For broken ‘sis’, a broken individual with all stems now < 130 cm length is measured as a ‘sms’. • SOP E.4: Added tempID for use with ferns and other non-woody growth forms to make records unique. • SOP E.4.2: Clarified that height for decumbent tree ferns is height above ground and not total stem length. • SOP E.4.3: Clarified that measurementHeight is required for non-woody individuals any time a stem diameter measurement is taken. • SOP F: New SOP to document annual measurement of Tower Plot subset within fast-growth and slow-growth increment sites. Includes dendrometer band installation and measurement procedure. • Appendix C: Updated to include site-specific dendrometer band status and added new ‘site type’ column to complement updated Section 4 scheduling table. • Appendix D: Site-specific information added for D03, D06, D14, D20, and all sites implementing dendrometer bands.
K	03/16/2022	ECO-06781	<ul style="list-style-type: none"> • Update to reflect change in terminology from relocatable to gradient sites
L	01/18/2023	ECO-06899	<ul style="list-style-type: none"> • SOP B, Table 8: Updated multi-bole tree qualifying bole criteria as related to resprouts from broken boles. • SOP C: Added biophysicalCriteria field to Plot Meta-Data (published in vst_perplotperyear table). • SOP C: Removed collection and publication of ‘Absence List’ data from Plot Meta-Data. • SOP C: Added Incident-driven ‘partial’ option for dataCollected; used when scheduled sampling is partially completed. • SOP C: Added new ‘nonwoodyCollectDate’ field for plots where ferns/cacti sampled months before woody individuals. • SOP C: Added new targetTaxaPresent options ‘present – sampled’ and ‘present – criteria not met’; these replace previous ‘Yes’ option.



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			<ul style="list-style-type: none"> • SOP C: New eventType option ‘distributedOnly’, applicable to sensitive sites with no annual Tower plot measurements. • SOP C.2 and C.3: Ferns are now split out from the ‘other’ growthForms and are assessed separately for presence/absence and new nestedSubplotAreaFerns to enable clearer totalSampledArea reporting for ferns; new ‘small palm’ and ‘small tree fern’ growthForms to enable accurate reporting of totalSampledArea for these taxa. • SOP D.2, SOP E.1.1: Updated tagging and measurement guidelines for stump resprouts. Resprouts from stumps > 130 cm height must meet same minimum diameter cutoffs as multi-bole trees. • SOP D.3: Added new otherTagID and otherTagOrg fields to document tagIDs assigned by external researchers. • SOP E.1.3: New section consolidating requirements for data collected when individuals no longer qualify and can be relocated. • SOP E.1.4: New section consolidating requirements for data collected when individuals are lost and cannot be relocated. • SOP E.2: Added height re-measurement guidelines when negative height increments are observed. • SOP E.2: Updated guidance for canopyPosition assessment to improve consistency. • SOP E.2.1: Updated measurement guidance for broken boles to make more consistent across growth forms. • SOP E.4.1: Updated text to reflect fern measurements with new nestedSubplotAreaFerns field. • SOP E.4.3: Clarified how meanLeafLength and meanPetioleLength should be calculated for shrub-type palms. • SOP E.4.3: Added option to record a permanent tagID for yucca and agave growth forms.
M	02/21/2023	ECO-06958	<ul style="list-style-type: none"> • Figure 2: Updated to add new 50 m2 nested subplot size for tall-stature 40m x 40m Tower plots. • Table 10: Updated to add new 50 m2 nested subplot size and dimensions for 40m x 40m Tower plots. • Box 3: Updated example to account for new 50 m2 nested subplot size in 40 m x 40m Tower plots.



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N	03/19/2026	ECO-07182	<ul style="list-style-type: none"> • Updated to OS Protocol template revM. • Section 3: Updated text and figure to reflect most recent subplotID naming convention. • SOP A.2: Added daily tablet syncing guidance. • SOP C.2: Updated Box 2 and Box 3 figures with most recent subplotID naming convention. • SOP C.3: Added Sampling Impractical option “Location vulnerable to planned sampling”. • SOP C.3: Added “finalize” workflow for Plot Meta-Data records. • SOP E.1.3 and E.1.4: Clarification and simplification of when to assign tagStatus = ‘tagRemoved’ for individuals with plantStatus = ‘Lost...’ • SOP E.2: Added heightQualifier field and guidance for implementation. • SOP E.2: New figure illustrating height measurement strategies. • SOP E.2: Added clarifying guidance and figure for crown measurements collected from leaning individuals. • SOP E.2: Clarified purpose and relevant details for valid break height measurements and added new figure. • SOP E.4: Added guidance to ignore yucca < 30 cm height. • SOP E.4: Clarified height and stemLength measurements for large tree fern and tree palms, and that tree-palm species do not qualify for measurement when only leaves emerge from the ground. • SOP F.3: Added guidance for replacing “outgrown” dendrometer bands. • Appendix C: Updated sampling windows to use most recent 10 y of MODIS-EVI data, extended sampling window for PUUM site to be consistent with other sites, added DSNY Tower plot sampling. • Appendix D: New subsection for D08 TALL to classify OXAR to growthForm using a 10 cm DBH threshold. • Appendix H: New appendix to document best practices for protocol implementation in the snow. • Equipment List: Replaced TruPulse 360R (obsolete) with newer TruPulse 360i model, added stainless steel wire as an option at sites with burn management.
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1 OVERVIEW

1.1 Background

The measurement of vegetation structure and the mapping of free-standing woody stems within NEON Terrestrial Observation System (TOS) plots enables calculation of per stem, per plot, and site-level woody biomass and productivity. Within Tower Plots, woody biomass increment is often a dominant component of total aboveground net primary productivity. Understanding changes in woody biomass stocks and fluxes is therefore an important prerequisite for predicting ecosystem carbon balance. Recording the types and stature of woody species also provides insight into habitat quality and ecosystem responses to environmental change.

Vegetation Structure data are also an important complement to data streams generated by the NEON Airborne Observation Platform (AOP) and Terrestrial Instrument System (TIS). When combined with AOP data, these ground-collected data will validate LiDAR data used to map the structural complexity of vegetation and will enable mapping of plant biomass at the site scale. In conjunction with TIS carbon flux data, vegetation structure data will facilitate understanding how biomass in different plant growth forms contributes to ecosystem level carbon flux.

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. Documentation of content changes (i.e., changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON’s Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON’s document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

We acknowledge Benjamin Chemel, of the Northern Rockies Conservation Cooperative, who contributed substantially to the initial development and testing of this protocol. Greg Chapman developed liana measurement rules in Appendix G, and additional NEON Field Ecologists have been invaluable with respect to revision and refinement of all aspects of the protocol.



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2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Data Quality Plan
AD[06]	NEON.DOC.000914	NEON Science Design for Plant Biomass and Productivity

2.2 Reference Documents

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

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Data Products Catalog
RD[04]	NEON.DOC.001271	AOS/TOS Protocol and Procedure: DMP – Data Management
RD[05]	NEON.DOC.001573	Datasheets for TOS Protocol and Procedure: Measurement of Vegetation Structure
RD[06]	NEON.DOC.014037	TOS Protocol and Procedure: HBP – Measurement of Herbaceous Structure and Biomass
RD[07]	NEON.DOC.014042	TOS Protocol and Procedure: DIV – Plant Diversity Sampling
RD[08]	NEON.DOC.001025	TOS Protocol and Procedure: PLT – Plot Establishment
RD[09]	NEON.DOC.001717	TOS Standard Operating Procedure: TruPulse Rangefinder Use and Calibration
RD[10]	NEON.DOC.002150	NEON Algorithm Theoretical Basis Document: TOS Vegetation Structure – QA/QC of Raw Field Data
RD[11]	NEON.DOC.001715	TOS Standard Operating Procedure: CAC – Cactus Biomass and Handling
RD[12]	NEON.DOC.001716	TOS Standard Operating Procedure: Toxicodendron Biomass and Handling
RD[13]	NEON.DOC.005023	TOS Standard Operating Procedure: Survey Method for Assessing Vegetation Cover
RD[14]	NA	Manual for Fulcrum Application: TOS Vegetation Structure [PROD] – All SOPs
RD[15]	NEON.DOC.003282	NEON Protocol and Procedure: SIM – Site Management and Disturbance Data Collection
RD[16]	NEON.DOC.005247	AOS/TOS Standard Operating Procedure: NEON Aquatic and Terrestrial Site Navigation



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2.3 Acronyms

Acronym	Definition
BH	Breast height; defined here as 130 cm above the ground. For trees growing on a slope, breast height is measured on the uphill side of the bole.
DBH	Diameter at breast height
ddh	Diameter at decimeter height
FIA	Forest Inventory and Analysis program run by the U.S. Forest Service
Ha	hectare(s)
LAI	Leaf Area Index
LIDAR	Light Detection and Ranging
NEE	Net Ecosystem Exchange
NEP	Net Ecosystem Productivity
NPP	Net Primary Productivity
VST	Vegetation Structure

2.4 Definitions

Common terms used throughout this document are defined here, in alphabetical order. Criteria for defining trees, saplings and shrubs generally follow those outlined and adopted by the USDA PLANTS database.

Table 1. Definitions for common terms used throughout the Vegetation Structure protocol.

Term	Definition
Apparent individual	A stem or group of stems that form(s) an individual with a crown that is discernable from other apparent individuals. Apparent individuals may have multiple stems, provided they are clearly connected above, at, or just below ground level. The word “individual” here does not refer to “genetic” individuals. For example, in an Aspen clone, many apparent individuals are all part of one genetic individual, and each apparent individual is measured.
Bole	Typically, the trunk of a tree. A bole differs from a lateral branch in that it is a primary support structure for the individual, supports lateral branches, and tends toward the canopy at angles < 45° off of vertical (but not true for decumbent growth forms).
Crown	The part of a woody individual that, when drawn in silhouette from branch tip to branch tip, contains the majority of the foliage. Crown implies parts of plants that could (or did) hold leaves (modified FIA definition). Broken boles that do not bear leaves are not included as part of the crown. Sprouts originating from the root point, and small, leafy twigs attached to the main bole are not considered part of the crown.
Emergent bole	Part of a multi-bole tree or shrub that comes out of the ground separate from other boles but is attached either below decimeter height or attached to the same root collar below ground level.
Fulcrum	Software platform used to create NEON electronic data entry applications.
Overstory	The overstory is typically formed by the tallest individuals in the plot, and overstory individuals are often mapped.



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Term	Definition
Primary stem	A stem that supports smaller stems and lateral branches and is not itself connected to a larger branch or bole. Often emerges from the ground and is connected directly to the root system.
Qualifying stem	A stem that meets listed criteria for a given growth form.
ServiceNow	Software platform used for problem/incident ticket tracking and resolution.
stemLength	The length of the stem from the root collar or root pedestal to the base of the leaves.
Understory	Relatively small-stature vegetation, either woody stemmed or herbaceous, that exists in the presence of an overstory.
Woody stem	Lignified aboveground tissue that persists from year to year, typically increasing in diameter due to the addition of new secondary woody growth as the plant ages.



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3 METHOD

The overarching goal of this protocol is to utilize mapping and measurement methods that are robust across a wide variety of field conditions and ecosystem types, are relatively easy to implement in the field, are resistant to user error, and can produce high-quality data.

A combination of NEON Distributed Plots and Tower Plots are employed for collecting vegetation structure data (**Figure 1** and **Figure 2**). Within these plots, this protocol generates data that describe or enable calculation of the spatial location, structure, volume, and biomass of the woody-stemmed plant community, including tree, sapling/shrub, liana, and ‘other’ non-woody growth forms. Data are collected with hand-held tools in the field, using methods with a long, substantiated history in the forestry community. There is no laboratory component to the work. The SOPs provide detailed information and methods related to the following activities:

- SOP A – Preparing for sampling; includes equipment, organizing previously collected data, and dendrometer band fabrication in the laboratory.
- SOP B – Guidelines for classifying woody and non-woody growth forms in the field.
- SOP C – Plot delineation, guidelines for implementing nested subplots, and recording Plot Metadata.
- SOP D – Mapping and tagging requirements by growth form and offset mapping guidance to enable calculation of stem locations.
- SOP E – Vegetation Structure data collected on a 5-year interval; subsections are devoted to stem diameter (E.1); height and crown measurements (E.2); shrub, liana, and fern groups (E.3); and ‘other’ growth forms (E.4).
- SOP F – Vegetation Structure data collected annually in Tower Plots; subsections are devoted to faster-growth sites (F.1), and dendrometer band installation and measurements at slower-growth increment sites (F.2 and F.3).

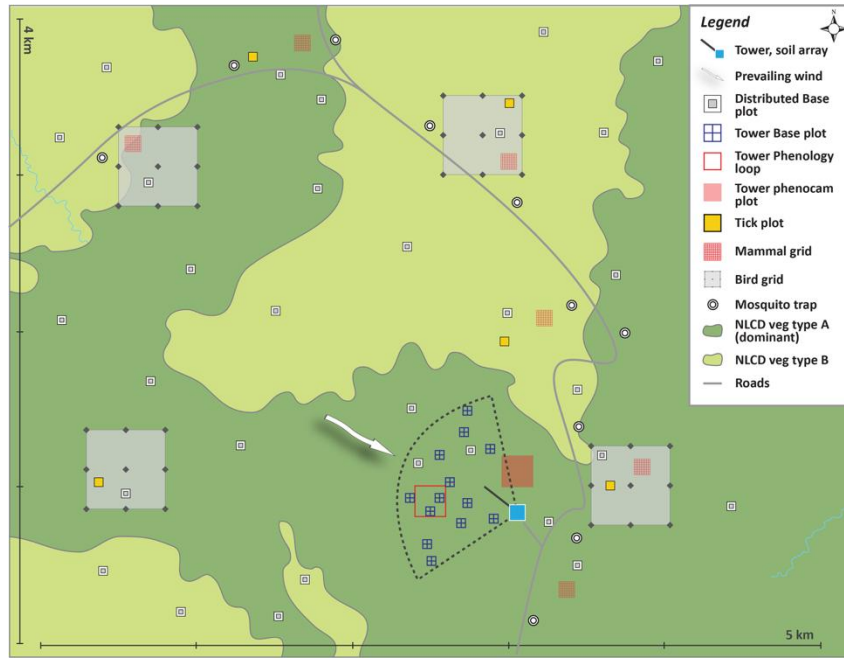


Figure 1. Generalized TOS sampling schematic, showing the placement of NEON TOS plots.

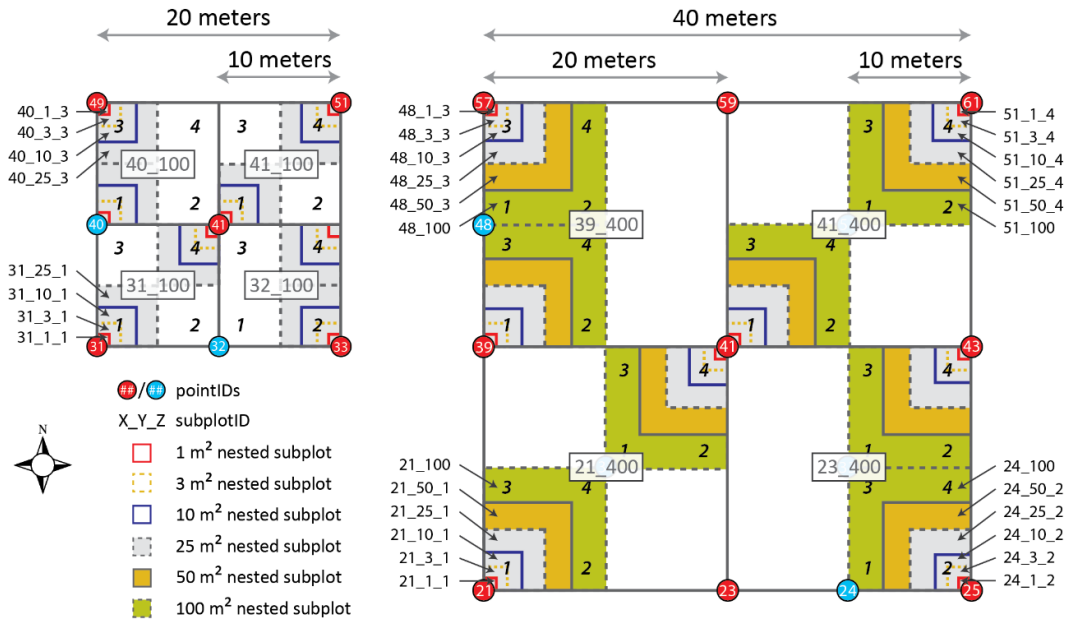


Figure 2. A 20m x 20m base plot (left; larger destructive sampling portion of the plot not shown), a 40m x 40m base plot (right), and associated subplots used for sampling woody vegetation. The 20m x 20m plot size (left) may be used for either Distributed Plots or Tower Plots, and the 40m x 40m plot size is only for Tower Plots. The pointID numbering scheme is illustrated in Appendix F. Numbers in 'X_Y' or 'X_Y_Z' format are subplotIDs or nested subplotIDs, respectively. The 'X' portion of the identifier is derived from the lower-left (southwest) corner of a 10m x 10m subplot, indicated by the red or blue pointIDs. Red pointIDs are used for mapping, while blue pointIDs are not acceptable for mapping. The 'Y' portion of the subplotID is the area (m²), and the 'Z' portion of the ID is the nested corner to which the nested subplot is anchored (indicated by numbers in italic black text).



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Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians **must** follow the protocol and associated SOPs. Use NEON’s problem reporting system to resolve any field issues associated with implementing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document and keep abreast of mid-season changes documented in NEON’s problem-tracking system. In the event local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in NEON’s problem tracking system.

Quality assurance is performed on data collected via these procedures according to the NEON Science Data Quality Plan (AD[05]).

3.1 Protocol Implementation Guidelines by Plot Type

Table 2. Vegetation Structure protocol implementation criteria by plot type.

Plot Type	Guidelines
Distributed	<ul style="list-style-type: none"> • Measurement of Vegetation Structure is determined on a plot-by-plot basis. • Collect data from a plot if any of the following criteria are true: <ul style="list-style-type: none"> ○ NLCD vegetation type is Deciduous Forest, Evergreen Forest, or Mixed Forest. ○ The plot contains at least one single-bole or multi-bole tree individual. ○ Qualifying woody or non-woody perennial vegetation cover is $\geq 25\%$ (visual estimate). • If the above criteria are not met, but qualifying woody or non-woody perennial vegetation is present in the plot: <ul style="list-style-type: none"> ○ Implement the Survey Method for Assessing Vegetation Cover SOP (RD[13]). ○ Collect Vegetation Structure data from the plot if qualifying woody or non-woody perennial vegetation is $\geq 10\%$ cover. • Exceptions: <ul style="list-style-type: none"> ○ Ferns, Xerophyllum, and Yucca growth forms are not measured when NLCD = Deciduous Forest, Evergreen Forest, or Mixed Forest. ○ Ferns are not measured when aerial cover is $< 50\%$ of the plot by visual estimate AND NLCD is not forest. • Data collection: <ul style="list-style-type: none"> ○ <i>If at least one plot contains qualifying vegetation</i> (SOP C.3), create Plot Meta-Data records for all Distributed Plots scheduled for sampling and assigned to the Vegetation Structure protocol.





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Plot Type	Guidelines
	<ul style="list-style-type: none"> ○ ‘Mapping and Tagging’ and ‘Apparent Individual’ records are not created for those Distributed Plots with no qualifying vegetation – i.e., Target Taxa Present = ‘No’ for the entire plot.
Tower	<ul style="list-style-type: none"> ● Collect Vegetation Structure data from all plots if any of the following criteria are true: <ul style="list-style-type: none"> ○ There is at least one single-bole or multi-bole tree in $\geq 10\%$ of plots. ○ Qualifying woody or non-woody perennial vegetation cover is $\geq 25\%$ <i>averaged across all plots</i> (visual estimate). ● If the above criteria are not met, but qualifying woody or non-woody perennial vegetation is present in $\geq 10\%$ of plots: <ul style="list-style-type: none"> ○ Implement the Survey Method for Assessing Vegetation Cover SOP (RD[13]) in all plots. ○ Collect Vegetation Structure data from plots if qualifying woody or non-woody perennial vegetation is $\geq 10\%$ cover <i>averaged across all plots</i>. ● Data collection: <ul style="list-style-type: none"> ○ Create ‘Plot Meta-Data’ records for all Tower Plots scheduled for sampling if Vegetation Structure data are collected from any of the scheduled plots. ○ Create ‘Mapping and Tagging’ and ‘Apparent Individual’ records as above.



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4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

Vegetation Structure is scheduled in a coordinated fashion with other TOS plant protocols to maximize the number of years data are collected from a site, and to minimize spikes in required labor (**Table 3**). The interval between bouts depends on plot type (**Table 4**), and for all plot types, no more than one VST bout is ever scheduled per year. Site specific exceptions are documented in Appendix C.

Table 3. Coordination of Measurement of Vegetation Structure with other TOS plant and soil protocols through time. Years 1 through 7 are shown to illustrate the temporal grouping of protocols, and the pattern repeats beyond year 7. Grey cells indicate synchronized ‘chemistry’ and ‘productivity’ protocol groups; brown cells indicate protocols implemented annually in Tower Plots; orange cells are protocols implemented every 5 y in Tower Plots.

Protocol*	Interval (y)	Plot Type	Plot Number	Year 1	Year 2	Year 3	Year 4	Year 5	Year 6	Year 7
BGB	5	tower	20 or 30 [†]	X					X	
CFC	5	both	16-20	X					X	
LAI	5	distributed	20	X					X	
LTR-bgc	5	tower	20 or 30 [†]	X					X	
NTR	5	both	10	X					X	
SLS-bgc	5	both	10	X					X	
SLS-mb	5	both	10	X					X	
CDW	5	distributed	20		X					X
HBP	5	distributed	20		X					X
VST	5	distributed	20		X					X
HBP	1	tower	5 to 30 [†]	X	X	X	X	X	X	X
LAI	1	tower	3	X	X	X	X	X	X	X
LTR	1	tower	20 or 30 [†]	X	X	X	X	X	X	X
VST	1	tower	5	X	X	X	X	X	X	X
CDW	5	tower	20 or 30 [†]				X			
VST	5	tower	20 or 30 [†]					X		

* Protocol codes and definitions: **BGB** = Belowground Biomass of fine root sampling; **CFC** = Canopy Foliar Chemistry sampling; **DIV** = Plant Diversity sampling; **LAI** = Leaf Area Index sampling; **LTR-bgc** = Litterfall biogeochemistry analysis; **NTR** = soil nitrogen mineralization incubation; **SLS-bgc** = Soil biogeochemistry analysis; **SLS-mb** = Soil microbial biomass analysis (PLFA); **CDW** = Coarse Downed Wood tally sampling; **HBP** = Herbaceous Biomass and Productivity sampling; **VST** = Vegetation Structure sampling; **LTR** = Litterfall sampling (no chemistry).

† The total number of Tower Plots sampled varies by site.

!!! Note that for annual VST sampling in Tower Plots, a spatially balanced subset of Tower Plots is selected based on NLCD class. In addition, at sites with dendrometer bands, all banded trees are measured annually regardless of plotID.

- Lists of annually sampled Tower Plots are available via the SSL.



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Table 4. Scheduling details and SOP implementation on a per site-type and event-type basis. Determine the event type for a given year with reference to the inter-annual schedule and **Table 3**.

Site Type*	Event Type	Plot Number	Field SOPs	Bout Interval	Remarks
Faster-growth*	All Tower Plots	20 or 30 (site dependent)	SOP C SOP D SOP E	5 y	• All growth forms measured
	Distributed and Tower Subset	Dist = 20 (max)	SOP C SOP D SOP E	5 y	• All growth forms measured
		Tower = 5	SOP C SOP D SOP F.1	Annual	• Ferns and fern allies not measured
	Tower Subset	5 plots	SOP C SOP D SOP F.1	Annual	• Ferns and fern allies not measured
Slow-growth*	All Tower Plots	20 or 30 (site dependent)	SOP C SOP D SOP E	5 y	• All growth forms measured
	Distributed and Tower Subset	Dist = 20 (max)	SOP C SOP D SOP E	5 y	• All growth forms measured
		Tower = 5, plus banded trees only in additional plots	SOP C SOP D SOP F.2 SOP F.3	Annual	• Ferns and fern allies not measured • Dendrometer band installation and measurement
	Tower Subset	5 plots, plus banded trees only in additional plots	SOP C SOP D SOP F.2 SOP F.3	Annual	• Ferns and fern allies not measured • Dendrometer band installation and measurement
Sensitive*	All Tower Plots	20 or 30 (site dependent)	SOP C SOP D SOP E	5 y	• All growth forms measured • No annual measurement of Tower Subset.
	Distributed Plots	20 (max)	SOP C SOP D SOP E	5 y	• All growth forms measured • No annual measurement of Tower Subset.
Survey*	All Tower Plots	20 or 30 (site dependent)	RD[13]	5 y	• All plots surveyed • Schedule survey in year prior to potential VST year.
	Distributed Plots	20 (max)	RD[13]	5 y	• Plot-specific survey criteria • Schedule survey in year prior to potential VST year.

* See Appendix C for site-specific designations.



Scheduling Considerations

1. Bout duration:
 - a. All bouts should be complete within 4 months OR before the next growing season begins (i.e., leaf-expansion).
2. Annual Measurements in Tower Plots
 - a. A ‘productivity subset’ of Tower Plots must be sampled annually; these plots are typically the 5 highest priority Tower Plots on the Plot Prioritization list.
 - i. The same subset of five Tower Plots is sampled every year.
 - ii. In the event one of the high priority Tower Plots assigned to annual sampling does not have qualifying vegetation, the subset of Tower Plots sampled annually should be the 5 highest priority plots that do have qualifying vegetation.
 - b. In addition, at slow-growth increment sites:
 - i. Ensure there is enough time in the schedule to measure all banded trees and repair any damaged bands (if necessary).
 - ii. Larger individuals may be banded in additional Tower Plots, and these individuals are also measured annually.
3. Fern measurement
 - a. In years ferns are scheduled for measurement (every 5 years in Distributed and Tower plots), ferns are ideally measured coincidentally with woody-stemmed individuals (i.e., trees, shrubs, lianas) to enable a single sampling effort per year. This idealized sampling schedule means that ferns may not be measured at peak greenness.
 - b. Depending on when woody measurements are scheduled, for those sites with fern species that senesce aboveground every year – e.g., Bracken Fern (*Pteridium aquilinum*) – a separate visit to the plots (and considered part of the same **eventID**) may be required to measure ferns before senescent leaves and stems begin to break apart.
4. ‘Other’ vegetation (e.g., cacti, palms, tree ferns, ocotillo, xerophyllum, yucca)
 - a. Measurement of ‘other’ growth form individuals is ideally coincident with woody stemmed individuals (i.e. trees, shrubs, lianas) to enable a single sampling effort per year for vegetation structure work.
 - b. At sites with *Opuntia spp.* that qualify for measurement (e.g., D14 SRER), a separate early-season bout may be required to enable distinguishing new pads from old pads (see RD[11]).



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4.1.1 Scheduling the Survey Method for Assessment of Vegetation Cover

Section 3.1 describes the vegetation cover criteria that must be met for scheduling Measurement of Vegetation Structure at a site. The Vegetation Cover Assessment SOP (RD[13]) and associated Fulcrum application are used to determine whether a site meets those criteria when a visual assessment is inadequate (Table 2, RD[13]). Sites scheduled for Vegetation Cover Assessment are listed in Appendix C.

Scheduling the Survey Method (for sites listed in Appendix C):

- **All plots:** To enable adequate planning for hiring required staff, schedule the survey the year before a full bout of Vegetation Structure would be needed.
- **Distributed Plots:** Every 5 y, survey scheduled on a per plot basis.
- **Tower Plots:** Every 5 y, survey scheduled for all plots.

4.2 Criteria for Determining Onset and Cessation of Sampling

Sampling Onset

The guiding principle is that vegetation structure measurements should begin after the majority of annual growth in a given growing season has completed. In many systems, the onset of sampling therefore coincides with the end-of-growing-season onset of the senescence phenophase for deciduous and herbaceous plants – i.e., the appearance of colored leaves / needles for trees and shrubs, and reduction in % green for herbaceous plants (Table 5).

Table 5. Sampling onset guidelines for different site and vegetation types.

Site Type	Vegetation Type	Sampling Onset Guideline
Mesic, Temperate	Deciduous forest, Mixed forest, Shrub scrub	<ul style="list-style-type: none"> • Sampling may begin once approximately 50% of the deciduous woody vegetation has begun to senesce. • Use plots with deciduous woody vegetation as a guide for when to sample any evergreen forest plots – sampling onset applies to all vegetation types.
Mesic, Temperate	Evergreen forest	<ul style="list-style-type: none"> • Sampling may begin once approximately 50% of the herbaceous understory plants have begun to senesce. • If any plots at a site are classified into deciduous vegetation types (above row), use deciduous plots to guide sampling onset.
Wet/Dry Seasonality	Multiple	<ul style="list-style-type: none"> • Sampling may begin once the dry season has begun and growth rates are minimal (e.g., D04 GUAN, D14 SRER).

Estimated sampling windows, including estimated sampling onset and cessation dates, are provided on a per site basis in Appendix C.



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- The dates in the appendix are multi-year averages derived from satellite data, and as such, individual future years will vary somewhat with respect to these dates.
- Once a sampling onset date has been selected for vegetation structure measurements at a given site by Field Operations, the onset of sampling in subsequent years should be consistent – i.e. within the same season and vegetation phenophase.
- At each site, the onset of sampling should be the same for all growth forms (except for cacti and ferns, as discussed above).
 - That is, all growth forms should be measured at a given plot when that plot is sampled.
 - Staff should **NOT** sample trees in all plots first, then re-sample plots for saplings/shrubs and lianas.

Sampling Cessation

Measurement of woody stem vegetation structure must be completed within 4 months of sampling onset, OR before the onset of the next growing season – i.e., before new leaves expand.

4.3 Timing for Laboratory Processing and Analysis

Not applicable.

4.4 Sampling Timing Contingencies

When unexpected field conditions require deviations from this protocol, the guidance in **Table 6** must be followed to ensure that basic data quality standards are met.

Table 6. Schedule delays, contingency guidelines, required actions, and possible outcomes for data product quality.

Delay	Action	Outcome for Data Products
Hours to 4 weeks	<ul style="list-style-type: none"> • If delay prevents completion of a plot or sub-plot, track progress using a plot-specific tagID checklist and mark the measurementHeight with a paintstick for individuals for which data have already been collected. • Resume data collection from the plot or subplot ASAP. 	None for woody stem data; ferns may senesce in this time frame, leading to increased uncertainty for this growth form.
	<ul style="list-style-type: none"> • If delay occurs between plots or sub-plots, resume data collection from the next plot or sub-plot ASAP. 	None for woody stem data; ferns may senesce in this time frame, leading to increased uncertainty for this growth form.



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Delay	Action	Outcome for Data Products
≥ 4 weeks, outside scheduled window, within protocol window	<ul style="list-style-type: none"> If delay prevents completion of a plot or sub-plot, track progress using a plot-specific tagID checklist, and attach temporary flagging and mark the measurementHeight with a paintstick for individuals for which data have already been collected. Reschedule data collection within protocol sampling window ASAP. Submit incident ticket if growth is active and measurements not completed within originally scheduled window. 	<ul style="list-style-type: none"> Temporary flagging may be lost, causing duplicate measurements of individuals. Significant wood growth could occur at sites with year-round growth. Increased error in aboveground biomass and NPP estimates if growth is active.
	<ul style="list-style-type: none"> If delay occurs between plots or sub-plots, reschedule data collection within protocol sampling window ASAP. Submit incident ticket if growth is active and measurements not completed within originally scheduled window. 	
≥ 4 weeks, outside scheduled window, AND outside protocol window	<ul style="list-style-type: none"> Submit incident ticket if measurements are not completed within the sampling window defined in the protocol. 	<ul style="list-style-type: none"> Significant wood growth could occur due to onset of next growing season. Increased error in aboveground biomass and NPP estimates if measurements span > 1 growing season.

4.5 Missed or Incomplete Sampling

Sampling according to the schedule is not always possible, and multiple factors may impede work in the field at one or more plots or sampling locations in a given bout. For example:

- Logistics – e.g., insufficient staff or equipment
- Environment – e.g., deep snow, flooding, inclement weather, or
- Management activities – e.g., controlled burns, pesticide application

Instances such as those listed above must be documented for scheduling, tracking long-term plot suitability, and informing end users of NEON data availability. Some types of missed sampling are due to events that should be recorded in the Site Management App; refer to the Site Management and Event Reporting Protocol for more detail (RD[06]).

Missed or Incomplete Sampling Terms

Terms that inform Missed or Incomplete Sampling include:

- **Protocol Sampling Dates:** Bout-specific sampling dates (provided in **Appendix C**).



- **Scheduled Sampling Dates:** Bout-specific sampling dates scheduled by Field Science and approved by Science. These dates coincide with or are a subset of the Protocol Sampling Dates.
- **Missed Sampling:** Incidence of *scheduled sampling* that did not occur. Missed Sampling is recorded at the same resolution as data that are ordinarily recorded.
- **Sampling Impractical:** The field name associated with a controlled list of values that is included in the data product to explain a Missed Sampling event – i.e., why sampling did not occur.
- **Rescheduled:** Missed Sampling is rescheduled for another time according to one of the scenarios documented in **Figure 3**, resulting in no change to the total number of sampling events per year.

The documentation that must accompany missed sampling depends on the timing, subsequent action, and the audience appropriate for numerous scenarios (**Figure 3**).

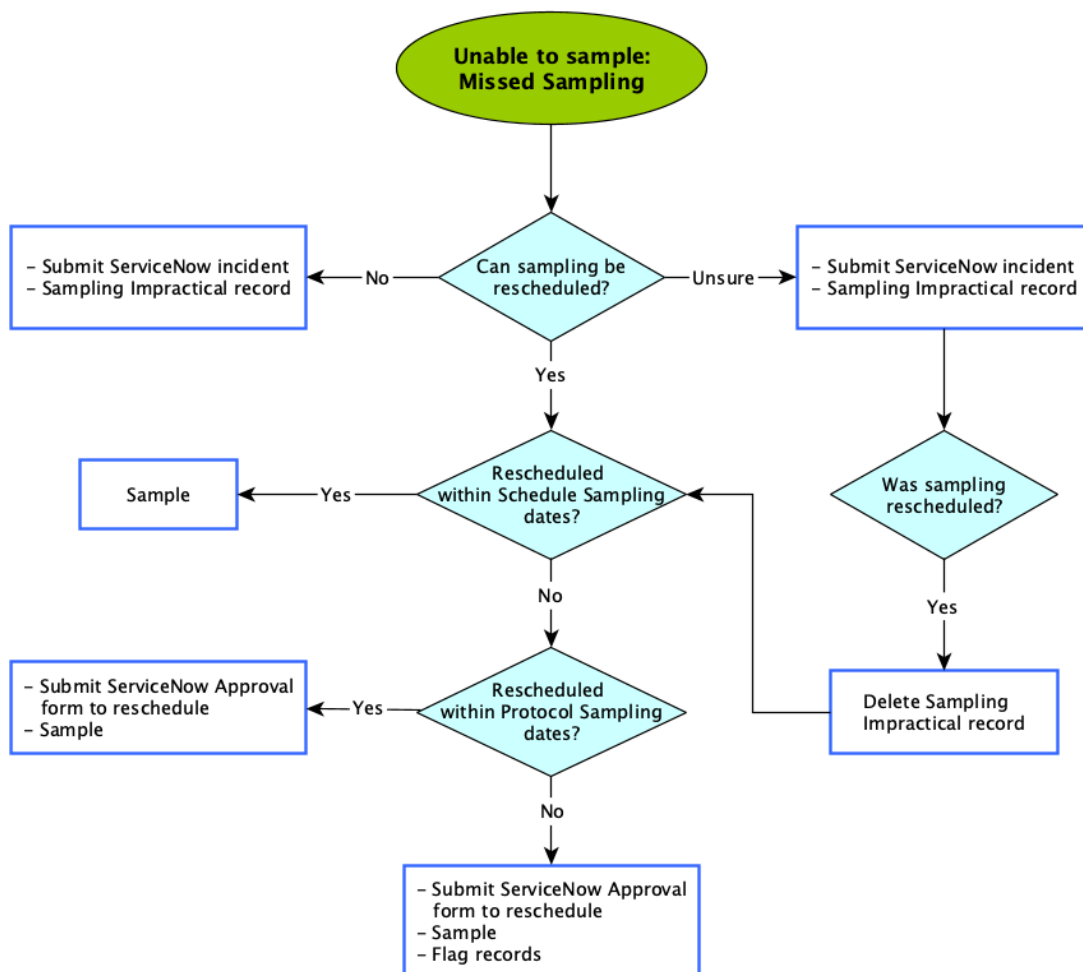


Figure 3. The documentation required for a Missed Sampling event is context dependent. Diamonds represent decision points and boxes describe the required action. Required actions may include: a) Submitting a ServiceNow incident, b) creating a Sampling Impractical record, c) creating a data Flag, d) creating a Site Management record, or e) some combination of (a) – (d).



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To Report Missed or Incomplete Sampling:

1. Missed or Incomplete Sampling that cannot be rescheduled within the Schedule sampling dates must be communicated to Science by a ServiceNow Incident.
 - a. For Missed Sampling that is Rescheduled, there are some cases that require approval by Science and Operations (**Figure 3**).
 - b. Consult **Table 6** above to determine required actions if scheduled activities are delayed or canceled. This protocol is the ultimate source of information should any discrepancy exist between this document and other summary materials – e.g., the ‘Scheduled Field Activities – Delays and Cancellations’ spreadsheet linked via the SSL.
2. Create a Fulcrum record for each Missed Sampling event in the field that cannot be rescheduled. That is, a **Sampling Impractical** record must be created in the *VST: Plot Meta-Data [PROD]* app for each plot missed.
 - a. Missing data in downstream applications are not recorded. For example, no data are recorded in either the *VST: Apparent Individuals [PROD]* app or the *VST: Mapping and Tagging [PROD]* app when a **Sampling Impractical** record is created in the *VST: Plot Meta-Data [PROD]* app.
3. For each Missed Sampling record in the *VST: Plot Meta-Data [PROD]* app, the **Sampling Impractical** field must be populated in the mobile collection device (**Table 7**).
4. For Rescheduled sampling events that occur outside the defined Protocol Sampling Dates, a protocol-specific flag must also be recorded (**Figure 3**).

Table 7. Protocol-specific Sampling Impractical reasons entered into the *VST: Plot Meta-Data [PROD]* Fulcrum application. If more than one is applicable, choose the dominant reason sampling was missed.

Sampling Impractical reason	Description
Extreme weather	Events that compromise safety and access (e.g., thunderstorms, hurricanes).
Location flooded	Standing water > 30 cm depth prevents access to the plot.
Location vulnerable to planned sampling	Location vulnerable to excessive technician impacts during planned sampling. Often related to flooding or recent heavy precipitation. Must be accompanied by a ServiceNow Incident.
Logistical	Site or plot access compromised, staff resources unavailable to support scheduled sampling, issues, errors (e.g., equipment not available in the field).
Management	Management activities such as controlled burn, pesticide applications, etc.
Other	Sampling location inaccessible due to other ecological reason described in the remarks .



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4.6 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframes provided below are estimates based on completion of a task by a skilled two-person team (i.e., not the time it takes at the beginning of the field season) (**Table 8**). Use these estimates as a framework for assessing progress. If a task is taking significantly longer than the estimated time, a problem ticket should be submitted. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 8. Estimated staff and labor hours required for implementation of Vegetation Structure SOPs.

SOP	Estimated time	Suggested staff	Total person hours
SOP A.1: Preparing mobile devices and datasheets	0.25 h	1	0.25 h
SOP A.2: Preparing equipment	1 h	1	1 h
SOP A.3: Preparing previously collected data	5 min per plot	1	5 min per plot
SOP B – SOP C: Classifying vegetation and selecting nested subplot sizes	1 – 3 h per plot ¹	2	2 – 6 h per plot
SOP D: Mapping and tagging apparent individuals	6 – 12 h per plot ²	2 (min)	12 – 24 h per plot
SOP E: Vegetation structure measurements	8 – 10 h per plot ²	2 (min)	16 – 20 h per plot

¹ Dense vegetation contributes to longer plot assessment times by impeding movement, stretching tapes, and making accurate visual assessment of growth form abundance more difficult.

² Actual time requirements to complete vegetation structure measurements will vary greatly between sites and depends on the variety of growth forms present and the stem density within plots.



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5 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the EHS Safety Policy and Program Manual (AD[01]) and Operations Field Safety and Security Plan (AD[02]). Additional safety issues associated with this field procedure are outlined below. If an employee witnesses any unsafe conditions or uncontrolled hazards that present an imminent danger, they should immediately take action to stop work and report such conditions to their manager. Employees must also report all workplace injuries, illnesses, incidents, or releases to the environment as soon as possible, regardless of the severity.

Consult **Appendix H** for safety considerations when collecting Vegetation Structure data in the snow.

Laser Rangefinder Safety

A laser rangefinder/hypsometer/compass instrument is used to map individual woody stems as points, and to measure various stem structural attributes. Safety considerations for this instrument include:

- Avoid staring directly at the laser beam for prolonged periods. The rangefinder is classified as eye-safe to Class 1 limits, which means that virtually no hazard is associated with directly viewing the laser output under normal conditions. However, as with any laser device, reasonable precautions should be taken during operation. It is recommended that you avoid staring into the transmit aperture while firing the laser.
- Never attempt to view the sun through the scope. Looking at the sun through the scope may permanently damage the eyes.

Toxicodendron Exposure

Additional safety issues associated with this field procedure include potential exposure to *Toxicodendron* oils.

- Protocol-specific equipment to mitigate exposure to *Toxicodendron* is listed in **Table 24**.
- Additional general mitigation strategies are discussed in RD[12].



6 PERSONNEL

6.1 Training Requirements

All technicians must complete protocol-specific training as required in the Field Operations Job Instruction Training Plan (AD[04]). Additional protocol-specific required skills and safety training are described here.

Protocol-specific training requirements:

- Proper care and use of the laser rangefinder
 - Metal objects must always be kept ≥ 50 cm from the unit during operation. This includes the mobile data collection device, eyeglasses, watches, rings, earrings, piercings, etc.
 - Although the rangefinder is resistant to dust and water, it is important to seal open ports and use lens caps when not in use.
 - Care must also be taken to avoid scratching lenses.
 - Manufacturer stated accuracy is ± 30 cm for distance measurements. Although measured accuracy may be better than 30 cm, avoid using the laser rangefinder for establishing 1 m², 3 m², and 10 m² nested subplots unless there are no other options.
- Tree-height measurement
 - Training is required to ensure accurate height measurements.
 - Training should emphasize why the rangefinder 3-shot height measurement routine is not suitable for trees. In brief, the 3-shot routine assumes the apex of the crown is directly over the base of the bole; substantial errors in the height calculation are introduced when the apex of the crown is offset from the base of the bole.
- Dendrometer band fabrication, installation, and measurement
 - Repeatability is critical
 - Required to complete online training materials before field work (VST SSL)
 - Individuals should receive OJT and oversight in the field when learning to make dendrometer gap measurements.
 - Individuals should only work independently after demonstrating the ability to make consistent gap measurements.

6.2 Specialized Skills

At least one of the technicians executing this protocol must be able to identify woody plants to species via visual inspection and use of a dichotomous or polyclave key.



7 STANDARD OPERATING PROCEDURES

SOP Overview

SOP A: Preparing for Sampling. Tasks completed in the Domain lab, in preparation for the field campaign. Steps to carry out:

- Equipment preparation: Sync tablets, load plot data onto mobile devices, calibrate the laser rangefinder.
- Prepare previously collected data to aid sampling during the current bout.
- Slow-growth increment sites: Prepare dendrometer band materials.

SOP B: Woody Growth Form Classification.

- Guidelines for classifying woody vegetation based on structural attributes and taxonID.

SOP C: Plot Delineation, Nested Subplots, and Recording Plot Meta-Data

- Guidelines for using nested subplots to standardize sampling effort across plots.
- Instructions for collecting Plot Metadata to scale individual data to the plot level.

SOP D: Mapping and Tagging Apparent Individuals

- Instructions for mapping individuals relative to plot markers, and details for how to tag mapped trees, shrubs and lianas.
- Instructions for assigning appropriate taxonIDs to woody vegetation.

SOP E: Vegetation Structure Data Collected on a 5-year Interval

- Steps to collect Stem Diameter, Height and Crown data, Shrub Group data, and structure data from 'other' non-woody growth forms.
- Implemented when all Tower Plots or Distributed Plots are sampled on a 5-year interval.

SOP F: Vegetation Structure Data Collected Annually in Tower Plots

- Faster-growth sites: Annual structure measurements in the Tower Plot 'productivity subset'.
- Slow-growth increment sites:
 - Dendrometer band fabrication and fitting in the field, as well as initial dendrometer band measurements.
 - Annual structure measurements in the Tower Plot 'productivity subset'.

SOP G: Field Campaign Follow-up. Steps following successful completion of field work.

SOP H: Data Entry and Verification. Guidelines and requirements for successful data entry. This SOP is NOT a substitute for AOS/TOS Protocol and Procedure: Data Management (RD[04]).

- Staff must read RD[04] to understand required data quality procedures.



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SOP A Preparing for Sampling

A.1 Preparing for Data Capture

Mobile applications are the preferred mechanism for data entry. Mobile devices should be fully charged at the beginning of each field day, whenever possible.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should always be carried along with mobile devices to sampling locations.

A.2 Preparing for Field Sampling

1. Plan and save sampling routes for field teams using standard site navigation procedures (RD[16]). Route planning enhances sampling efficiency and helps avoid accidental foot traffic within NEON plots.
2. Load sampling location GPS data to the field tablet, field phone, or recreational GPS receiver (plot centroids, SW corner pointIDs, etc.).
3. Sync tablets daily to ensure Plot Meta-Data records created in the DSF, Mapping and Tagging records created on other tablets, and the most recent TOS Spatial Data are all available in the field on every tablet.
4. Pack pre-labeled tags for tagging newly qualifying individuals. It is CRITICAL that a single series of tagIDs is used for all sites within a domain.
5. Use the hand stamp and die set to pre-label blank aluminum tags with 'A', 'B', 'C', etc. for tagging multi-bole trees ('mbt', if present at site).
6. Pack all tools and equipment required for plot delineation and measurement of individuals (see **Appendix E**).
7. Check the laser rangefinder: Detailed instructions for setting declination, calibrating the tilt-sensor, and calibrating the compass are found in TOS Standard Operating Procedure: Laser Rangefinder Use and Calibration (RD[09]).
 - a. Make sure the lenses on the laser rangefinder are free of dirt and debris and clean with a lens cloth or lens tissue if necessary.
 - b. Declination changes with time at each site, and should be looked up annually using the NOAA Magnetic Field Calculator (<http://www.ngdc.noaa.gov/geomag-web/>)
 - c. TruPulse Declination Offset. Check the current declination against what is entered in the TruPulse.
 - d. Compass Calibration. For optimum performance complete compass calibration each time you change sampling locations (i.e., plots) or after batteries are changed.



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Interference from power lines, indoor magnetic fields, severe drop shock, or nearby ferromagnetic objects can prevent accurate calibration.

- e. TruPulse Tilt-sensor Calibration. In the rare instance that the TruPulse has suffered a severe drop shock, the tilt-sensor requires re-calibration prior to continued field work.

A.3 Preparing Previously Collected Data

To enable accurate and expeditious field measurement of previously measured apparent individuals, it is helpful to:

1. Generate per plot maps and lists of tagIDs, and other key identifying data, for all individuals measured within the plot the previous bout.
 - a. Use the VST QA/QC Shiny application (aka ‘Peregrine’) to create per plot maps and lists of tagged individuals and their previous measurements.
 - i. Data from prior years can be found via the ‘Plot Inventory’ and ‘Site Inventory’ tabs in Peregrine.
 - b. Note that **growthForm** may change from year-to-year for smaller individuals and should be assessed and recorded accurately for each bout.

A.4 Dendrometer Band Fabrication in the Laboratory

Laboratory preparation of dendrometer bands for installation in the field is required when dendrometer bands are installed at NEON sites with relatively slow-growth increment woody vegetation. The list of slow-growth increment sites is provided in **Appendix C**. Once dendrometer bands have been installed at a site, steps below are applicable when new recruits require banding. In addition, guidance below from step (4) onward is applicable for repairing or replacing dendrometer bands in the field that have been damaged.

- Site-specific lists of trees for which bands are required are provided via the SSL.
- VST data are analyzed by Science every 5 y to identify any additional high-biomass trees that may require banding at each slow-growth increment site.
- Dendrometer band components are custom-made in the laboratory using *VST: Apparent Individuals* data from the previous sampling event.
- SOP F.2 describes final fitting and installation of these bands in the field.

Procedure steps:

1. Equipment and materials check: Purchase additional banding, springs, and replacement tools as necessary.
2. Download *VST: Apparent Individual* tree data from the previous sampling event and filter to only those trees that will receive new dendrometer bands.



3. Create list of trees per plot and include the following data fields: plotID, subplotID, tagID, taxonID, growthForm, stemDiameter, templateSize, and springLength.
 - a. See **Appendix G** to assign required templateSize and springLength.
4. Calculate total band length needed for each tree using the appropriate template in **Appendix G**.
 - a. Total length (dcm) = [**stemDiameter** (nearest 0.1 cm) + overlap (from template)]
 - b. *Example:* For a tree with stemDiameter = 30.1 cm, the band length needed is,
Total length (dcm) = [30.1 dcm + 4.5 dcm] = 34.6 dcm (dcm = diameter centimeter equivalent, and can only be measured with a DBH tape)
5. Cut a supply of dendrometer band ‘collar’ pieces; one collar per banded tree plus sufficient extras (**Figure 4**). Collars will be used in the field during band installation.
 - a. Cut 2.5 cm length collar pieces: Length = 2X width of band.

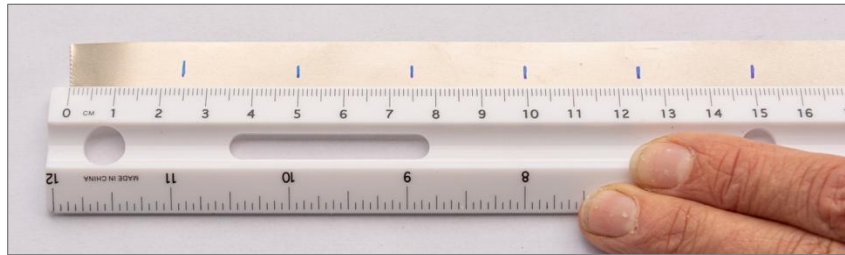


Figure 4. Dendrometer band material marked every 2.5 cm for cutting ‘collars’ in preparation for installation in the field.

6. Pre-fabricate a custom dendrometer band for each tree. For a video tutorial, see [Dendrometer Band Installation and Measurement](#) in the Training Center. *Optional: Wear light gloves for protection.*
 - a. Stretch DBH tape L to R along work surface with diameter centimeter equivalent (dcm) side facing up and ‘0’ on the left. Secure flat to surface with tape.
 - b. Load banding into customized dispenser bucket, and place to left of DBH tape. A bucket with a slit cut in the side at the bottom through which banding may be fed will suffice.
 - c. Cut lengths of lab tape (10-15 cm), and label one per band (plotID, subplotID, tagID, springType).
 - d. Spool out banding from the bucket and lay on table below DBH tape (closer to yourself).
 - e. Use DBH tape and template guidance to cut a custom length of banding for each tree (**Appendix G**).
 - f. Mark the following on the band:
 - i. Tip punch location (**point** centered on band).



- ii. Window start (closest to tip punch point).
- iii. Window end.
- g. Create the tip punch.
 - i. Wiggle gently to remove the band from the punch if the punch is incomplete.
 - ii. Wiggle hanging chad back and forth to break cleanly off from band.
- h. Trim the tip corners.
- i. Cut the window end. Cut perpendicular to the band, width of cut is $\frac{1}{3}$ width of band (do not cut more than $\frac{1}{2}$ the band width). Start over if you make the cut $> \frac{1}{2}$ the band width.
 - i. Cut must be clean. To minimize burring and deforming the metal, place band deep into snips, do NOT use the tips of the snips (**Figure 5**).

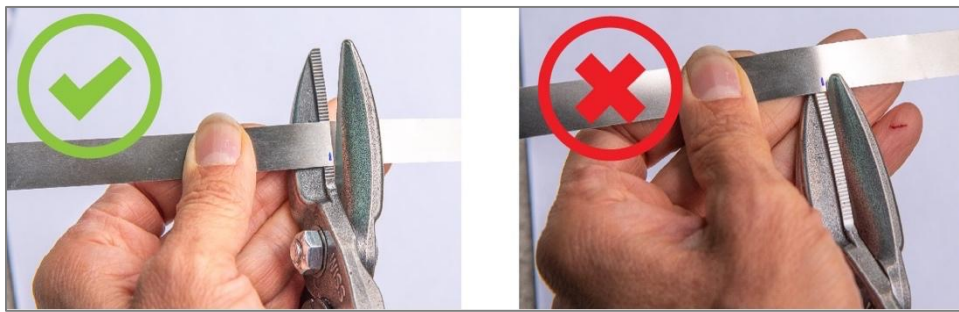


Figure 5. (Left) Correct metal-snip technique for cutting the measurement window in a dendrometer band. (Right) Incorrect technique using the tip of the metal snips will result in burrs and band deformation.

- j. Cut the window (**Figure 6**).
 - i. Begin just before the window start and cut inward toward the window end. The major line of the cut should be $\frac{1}{3}$ of the way into the band. Okay to eyeball.
 - ii. Cut toward the previously made perpendicular window end cut. Intersect at right angles as perfectly as possible to minimize burring and to provide a clean right angle for caliper measurement.
 - iii. Wiggle the window cut-out to break off and remove.





SOP B Woody Growth Form Classification

Consistent classification of woody individuals to growth form is required for:

- SOP C – Implementation of nested subplots; selecting an appropriate nested subplot size depends on the abundance of different growth forms within the plot.
- SOP D – Understanding which woody individuals are mapped within the plot.
- SOP E – Determining a consistent measurement strategy for woody and non-woody apparent individuals.

Woody vegetation is broadly classified to growth form according to [USDA Plants Growth Habits](#). Growth forms assigned to woody individuals are therefore informed by stem diameter (DBH or ddh), height, and site-specific knowledge of the species in question (**Table 9**, **Figure 7**, **Figure 8**, and see **Box 1** for examples). Required measurements for each woody growth form are summarized in **Table 10**. Note that woody individuals may change growth form from one year to the next, due to normal growth or damage (i.e., loss of boles or stems). Additional non-woody growth forms are used for palm, tree fern, fern, and ‘other’ vegetation that is also measured via this protocol (see SOP E.4).

The distinction between ‘apparent individuals’ and ‘groups’ is used when classifying woody vegetation. In general, small trees, saplings, shrubs, small shrubs, lianas, and some ferns can exist either:

- As isolated ‘Apparent Individuals,’ with either single stems or multiple connected stems; or
- As groups of individuals in contact with each other such that crowns of apparent individuals cannot be discerned (e.g. a shrub or vine thicket, hereafter referred to as a ‘Group’).

The ‘Apparent Individual’ designation is always preferable to that of ‘Group’ as allometric equations used for estimating biomass typically depend on basal stem diameter or DBH measurements, and these measurements are not made for Groups. Group measurements allow only for estimation of volume, and translating volume to biomass is often not possible. Nonetheless, the Group designation is warranted when:

- Vegetation forms dense, impenetrable, or thorny thickets.
- Safety concerns are associated with accessing the vegetation (e.g., *Rubus* thickets).
- Excessive damage to vegetation would be required to collect data (e.g., chaparral thickets).

!!! Important: This SOP provides generalized definitions and guidance for determining woody growth forms. However, not every possible situation can be addressed in this generalized format. For example, the line between a multi-bole apparent individual and a shrub group can be difficult to clearly define, especially for clonal species. Following this protocol may lead technicians in different domains to different conclusions. Therefore, it is recommended to create site-specific or species-specific materials within each Domain to maintain consistency through time with respect to how decisions are made to resolve common challenges. Science may review documents and facilitate sharing between Domains.



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Table 9. Growth forms into which woody vegetation is classified and their definitions. Parentheses following terms in the list below indicate the 3-letter code used for each growth form.

Growth Form	Definition
Liana (lia)	Non-self-supporting woody stems with DBH \geq 1 cm. ‘ddh’ is not measured for lianas.
Single-bole tree (sbt)	A self-supporting individual with a single bole that must be \geq 10 cm diameter at breast height. Usually greater than 4 – 5 meters height.
Multi-bole tree (mbt)	A self-supporting individual with multiple boles at breast height. At least one bole must have DBH \geq 10 cm; secondarily, height is usually greater than 4 – 5 meters. To qualify as an additional bole, the fork in question must meet the following criteria: <ul style="list-style-type: none"> • Be at least $\frac{1}{3}$ the diameter of the main stem and $>$ 3.3 cm diameter. See Table 13 for cases involving broken boles and resprouts. • The angle formed with the pith of the main stem must be \leq 45° from vertical. • The pith must intersect the pith of the main stem at or below 130 cm above the ground. • Multiple boles may also emerge independently from the ground, provided they are connected belowground.
Small tree (smt)	Woody individual with the potential to grow into either a single-bole tree or a multi-bole tree. Also includes tree species that, at maturity, never attain the stature of single-bole or multi-bole trees (e.g., <i>Acer pensylvanicum</i> or <i>Picea mariana</i> under some environmental conditions). Of primary importance, diameter at breast height for at least one stem must meet the criteria 1 cm \leq DBH $<$ 10 cm; secondarily, height usually does not exceed 4 – 5 meters. More than one bole may qualify for measurement if the secondary bole(s): <ul style="list-style-type: none"> • Are at least $\frac{1}{3}$ the diameter of the largest bole AND \geq 2.5 cm diameter. • The angle formed with the pith of the main stem must be \leq 45° from vertical. • The pith must intersect the pith of the main stem at or below 130 cm above the ground. A multi-bole small tree is still classified as ‘smt’.
Sapling (sap)	A self-supporting individual with the potential to grow into either a single-bole tree, multi-bole tree, or a small tree. If total height is $>$ 130 cm, DBH is $<$ 1 cm and ddh of at least one stem is $>$ 1 cm; if total height is $<$ 130 cm, ddh of at least one stem is $>$ 1 cm. Individuals that have no stems with ddh \geq 1 cm are not measured with this protocol and may be sampled as part of the herbaceous plant sampling effort
Single shrub (sis)	A self-supporting individual, typically with multiple primary stems; may be single stemmed under certain environmental conditions. Diameter of at least one stem at breast height meets the criteria 1 cm \leq DBH $<$ 10 cm. Usually does not exceed 4 – 5 meters maximum height at maturity. Uncommonly, DBH can be \geq 10 cm; consider the USDA classification and the maximum height potential of the species (see <i>Rhododendron</i> example below).
Small shrub (sms)	A self-supporting individual, typically with multiple primary stems; includes typical ‘subshrub’ species that may never exceed 130 cm height, as well as individuals that will mature into ‘sis’ growth form. The ddh is \geq 1 cm for at least one stem. Individuals that have no stems with ddh \geq 1 cm are not measured with this protocol and may be measured as part of the herbaceous plant sampling effort.



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Growth Form	Definition
Group	<ul style="list-style-type: none"> • Groups are defined as vegetation likely comprised of two or more individuals in contact, such that it is impossible to discern “individuals.” The word “individual” here refers to “apparent” individuals, not “genetic” individuals (e.g., members of an Aspen clone, clumps of clonal fern species, etc). • Groups may contain multiple species (including vine masses), and both live and dead material from one or more species. • Groups that are primarily ‘sms’ individuals should on average have stems with ddh \geq 1 cm; measure a subset of stems to make this determination NOT every stem. If the majority of stems in the Group have ddh $<$ 1 cm, do not measure.

Below, **Figure 7** provides high-level classification information, and **Figure 8** indicates how low-level growth form classifications are informed by structural and taxonomic data. To make a consistent classification, use the flow charts in combination with the definitions in **Table 9**, and use knowledge of species-level growth habits at a site.



Box 1. Woody growth form classification examples.

Example 1: A *Quercus alba* individual in the eastern U.S. may be classified as either a sapling (sap), a small tree (smt), a single-bole tree (sbt), or a multi-bole tree (mbt), depending on life stage and the specific growth habit of the individual. However, a small *Q. alba* individual would not be classified as a small shrub (sms) or single shrub (sis) because this species is broadly recognized as a tree species (e.g., USDA PLANTS), and the biomass of large and small individuals can be estimated using general allometric equations developed for trees (e.g., Jenkins et al. 2004, Chojnacky et al. 2013).

Example 2: An *Acer rubrum* individual has four boles with the following diameters at 130 cm along each bole: 12 cm, 9 cm, 4 cm, and 3.5 cm. This individual is classified as a multi-bole tree growth form because the largest bole is ≥ 10 cm DBH, and there are two secondary boles with diameters $\geq \frac{1}{2}$ the diameter of the largest bole. The smallest bole with DBH = 3.5 cm is not tagged and measured because its diameter is not $\frac{1}{3}$ that of the largest bole.

Example 3: *Rhododendron spp.* may grow large enough that one or more stems have DBH ≥ 10 cm. If only DBH and stem count are considered, **Figure 8** on its own would have large *Rhododendron* individuals classified either as a single-bole tree (multiple stems, but DBH of only one bole ≥ 10 cm) or a multi-bole tree (more than one bole with DBH ≥ 10 cm). However, considering *Rhododendron spp.* are usually < 4 – 5 meters height, these large individuals are classified as single shrubs (sis).

Example 4: A young Interior Live Oak (*Quercus wislizenii*) may split below 130 cm into multiple boles with $10 \text{ cm} > \text{DBH} \geq 1 \text{ cm}$. Because this species routinely achieves single- and multi-bole tree status, smaller individuals are classified as ‘small tree’, rather than ‘single shrub’ (see dashed arrow in **Figure 8**).

Example 5: A Big Sagebrush individual (*Artemisia tridentata*) has multiple emergent boles, with only one such emergent bole having $10 \text{ cm} > \text{DBH} \geq 1 \text{ cm}$; all others have DBH < 1 cm or are < 130 cm height. This species never attains single- or multi-bole tree status, and this individual is classified as a ‘single shrub,’ rather than a ‘small tree.’

Example 6: Species information may not be informative with respect to assigning growth form. For example, *Toxicodendron spp.* commonly exist as lianas, small shrubs, and shrub groups. For *Toxicodendron spp.*, and other similar species, growth form is assigned on a per individual basis according to observed attributes and not species-level tendencies.

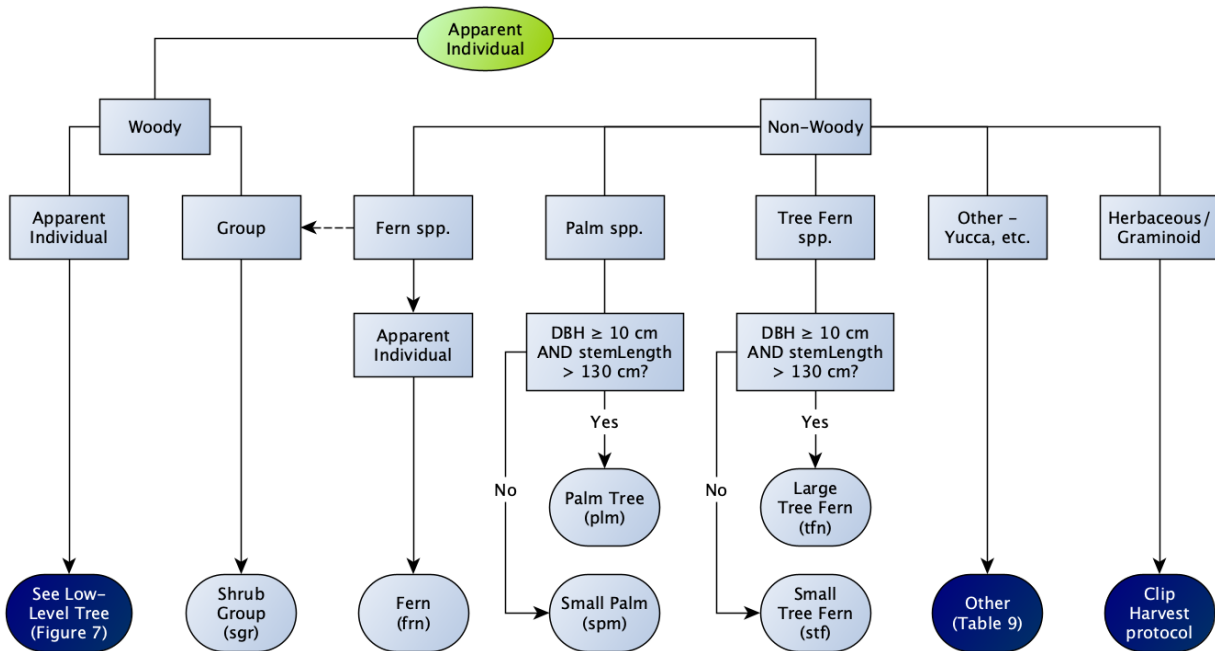


Figure 7. High-level classification tree for assigning vegetation to growth form. Dashed arrow affects D20 PUUM.

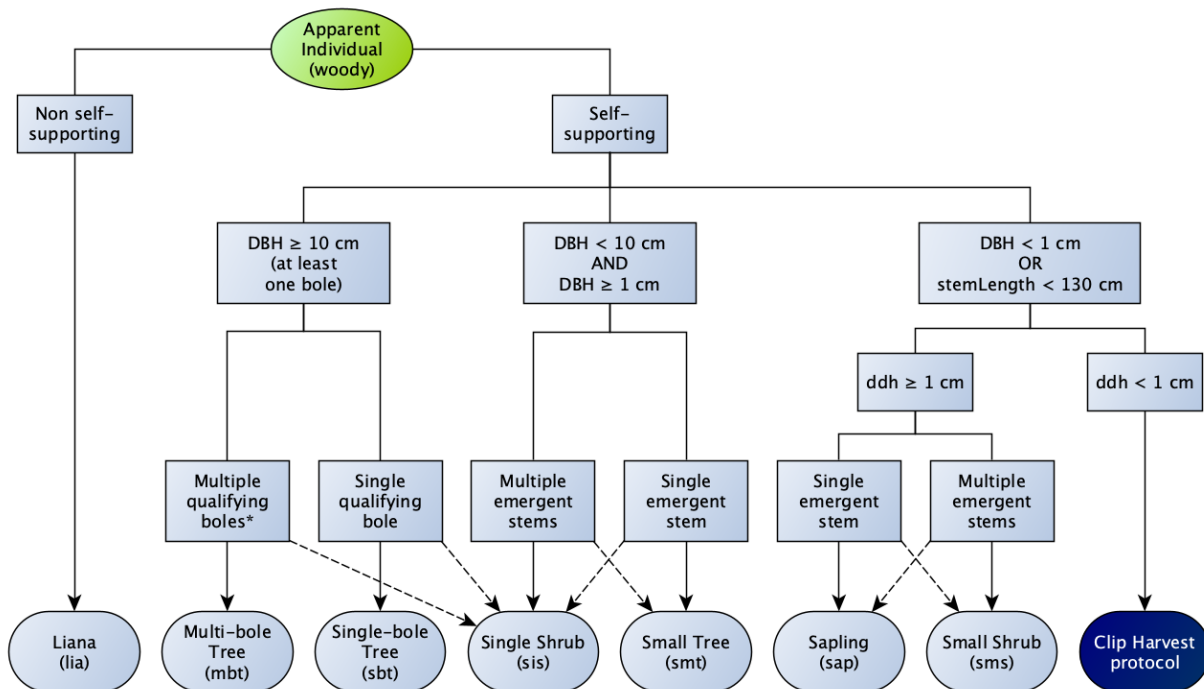


Figure 8. Classification tree indicating how structure and stem diameter inform the growthForm classification of woody apparent individuals. Dashed lines call out points where growth form classification may change after considering height and species-specific information. *Multiple qualifying boles: See Table 9 for qualifying bole criteria.



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Table 10. Summary of required measurements for each growth form. Note that individuals may change growthForm from one year to the next, potentially necessitating different measurements from year-to-year (e.g., a change from ‘sapling’ to ‘small tree’). For required cactus (cac) measurements, see RD[11].

Growth Form	Stem Diameter	Height	Crown Diameter	Additional Measurements
Liana (lia)	<ul style="list-style-type: none"> stemDiameter (DBH) measurementHeight see Appendix E for complex cases 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> plantStatus
Single bole tree (sbt)	<ul style="list-style-type: none"> stemDiameter (DBH) measurementHeight See Table 13 and SOP E.1 for complex cases 	<ul style="list-style-type: none"> vdApexHeight = Maximum height above observer vdBaseHeight = Height from observer to base of tree (typically a negative number) 	<ul style="list-style-type: none"> Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus canopyPosition (Table 17)
Multi-bole tree (mbt)	<ul style="list-style-type: none"> stemDiameter (DBH, per bole) See Appendix D.2 to determine correct measurementHeight 	Measure per individual, not per bole. <ul style="list-style-type: none"> vdApexHeight = Maximum height of tallest bole above observer (not per bole) vdBaseHeight = Height from observer to base of tree (typically a negative number) 	<ul style="list-style-type: none"> Per individual, not per bole Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus (per bole) canopyPosition (per individual, not per bole, Table 17)
Small tree (smt)	<ul style="list-style-type: none"> stemDiameter (DBH) measurementHeight See Table 13 and SOP E.1 for complex cases Measure multiple boles if applicable 	Measure per individual (not per bole). <ul style="list-style-type: none"> vdApexHeight (top) and vdBaseHeight (ground) Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Per individual, not per bole Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus (per bole) canopyPosition (per individual, not per bole, Table 17)
Sapling (sap)	<ul style="list-style-type: none"> basalStemDiameter (ddh) measurementHeight Measure multiple emergent boles if present (SOP E.1) 	Measure per individual, not per bole. <ul style="list-style-type: none"> vdApexHeight = Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> plantStatus (per bole) canopyPosition (per individual, not per bole, Table 17)



Growth Form	Stem Diameter	Height	Crown Diameter	Additional Measurements
Single shrub (sis)	<ul style="list-style-type: none"> basalStemDiameter (ddh, per qualifying emergent bole) stemDiameter (DBH, only on largest diameter fork per emergent bole) measurementHeight for both ddh and DBH See SOP E.1 for complex cases 	Measure per individual, not per bole. <ul style="list-style-type: none"> vdApexHeight = Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Per individual, not per bole Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus (per bole) canopyPosition (per individual, not per bole, Table 17) shape If shape=icn: maxBaseCrown-Diameter, and ninetyBaseCrown-Diameter If shape=elp: height to crown base
Small shrub (sms)	<ul style="list-style-type: none"> basalStemDiameter (ddh, per qualifying emergent stem) measurementHeight Measure multiple emergent stems if present (SOP E.1) Broken emergent stems must be ≥ 30 cm height (or stem length) to qualify for measurement (SOP E.1) 	Measure per individual, not per stem. <ul style="list-style-type: none"> vdApexHeight = Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Per individual, not per bole Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus (per bole) canopyPosition (per individual, not per bole, Table 17) If shape=icn: maxBaseCrown-Diameter, and ninetyBaseCrown-Diameter If shape=elp: height to crown base
Shrub group (sgr)	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> Five points that best represent overall height of the group 	<ul style="list-style-type: none"> Crown area; graph paper method 	<ul style="list-style-type: none"> % contribution to total volume (per species) % live (per species) % dead (per species)
Fern (frn)	<ul style="list-style-type: none"> Species dependent; see SOP E.4 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> plantStatus Species dependent; see SOP E.4
Palm tree (ptr)	<ul style="list-style-type: none"> stemDiameter (DBH) If present, record 'DBH contains leaf base' in remarks field See SOP E.4 	<ul style="list-style-type: none"> Maximum height Typically measure vdApexHeight (top) and vdBaseHeight (ground) Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus canopyPosition (Table 17)



Growth Form	Stem Diameter	Height	Crown Diameter	Additional Measurements
Small palm (spm)	<ul style="list-style-type: none"> See SOP E.4 	<ul style="list-style-type: none"> Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> canopyPosition (Table 17) Species dependent; see SOP E.4
Large tree fern (ltf)	<ul style="list-style-type: none"> stemDiameter (DBH) measurementHeight 	<ul style="list-style-type: none"> Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> stemLength canopyPosition (Table 17)
Small tree fern (stf)	<ul style="list-style-type: none"> See SOP E.4 	<ul style="list-style-type: none"> Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> stemLength canopyPosition (Table 17)
Yucca (yuc)	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> Maximum diameter Perpendicular to max 	<ul style="list-style-type: none"> plantStatus
Bear Grass (xer)	<ul style="list-style-type: none"> Mean basal diameter of tussock 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> Not measured 	<ul style="list-style-type: none"> meanLeafLength
Ocotillo (oco)	<ul style="list-style-type: none"> Not measured 	Measure per individual, not per stem. <ul style="list-style-type: none"> Maximum height Record vdBaseHeight = 0 if total height is measured from the ground with a collapsible ruler 	<ul style="list-style-type: none"> maxBase Crown-Diameter ninetyBase Crown-Diameter 	<ul style="list-style-type: none"> Basal count of stemNumber



SOP C Plot Delineation, Nested Subplots, and Recording Plot Meta-Data

Overview

This SOP describes implementation of nested subplots to standardize sampling effort across plots and growth forms, and recording critical plot meta-data that allows data-users to accurately scale biomass estimates to the plot level (**Figure 9**).

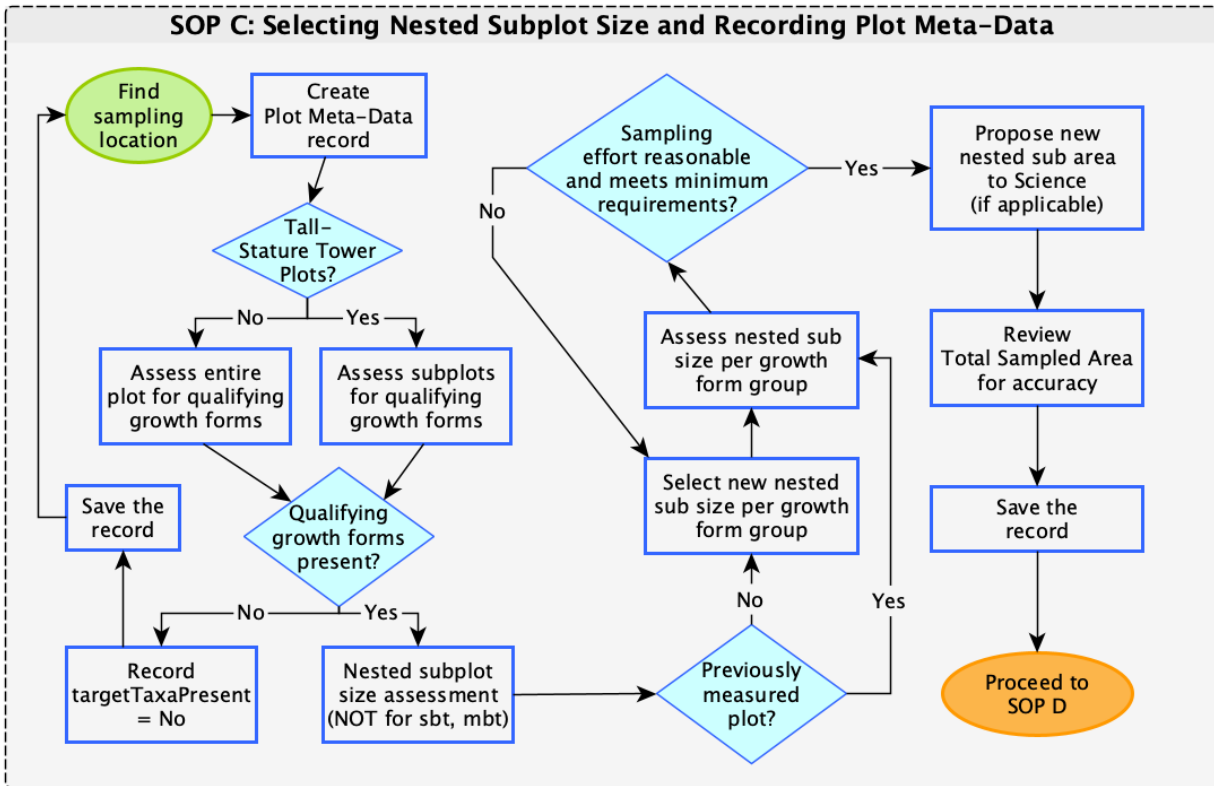


Figure 9. SOP C workflow diagram for growth form survey, nested subplot assessment, and recording Plot Meta-data. The term ‘Tall-Stature Tower Plot’ applies to sites where all Tower Plots are 1600 m². Diagram supports and does not replace protocol text; most common workflow is outlined.

Fulcrum applications used to collect data for this SOP:

- **VST: Plot Meta-Data [PROD]** application. Collect **biophysicalCriteria** data, **targetTaxaPresence** data, and import growth form-specific nested subplot size data (from the TOS Spatial Data Fulcrum app).
- The [Vegetation Structure Fulcrum Manual](#) on the SSL contains detailed data entry instructions.



C.1 Spatially Linked Protocols

Plant Diversity

- Plant Diversity sampling occurs in all Distributed Plots that support Measurement of Vegetation Structure.
- Plant Diversity sampling occurs in 3 selected Tower Plots that support Measurement of Vegetation Structure.
- Plant Diversity and Vegetation Structure utilize many of the same 1 m² and 10 m² nested subplots.
- Mitigate trampling and impact to the vegetation as much as possible when implementing Vegetation Structure in nested subplots that also support DIV sampling. This will ensure that data are of the highest possible quality from these sampling locations.

Leaf Area Index

- Leaf Area Index sampling occurs in 3 Tower plots that also support Measurement of Vegetation Structure.
- Mitigate trampling and impact to the vegetation as much as possible in these plots, especially within 3 meters of the plot centroid.

Litterfall and Fine Woody Debris

- Litterfall collections take place in many Tower Plots that support Measurement of Vegetation Structure.
- Avoid foot traffic through 3m x 0.5m litter ground traps to prevent damage to qualifying particles within the ground traps.

C.2 Subplot Dimensions and Guidelines

Saplings, small trees, shrubs, lianas, and many other woody and non-woody species with DBH < 10 cm that are sampled via this protocol can attain very high stem densities. A nested subplot approach may therefore be employed to standardize the sampling effort across plots. Subplot and nested subplot sizes are shown in **Figure 2**. To ensure sampling effort consistency:

- On a per plot basis, subplot size may be chosen independently for:
 - Small woody individuals: The sum of '*smt + sap + sis + sms + groups*'
 - Lianas
 - Ferns
 - Any '*other*' qualifying vegetation, including 'small palm', 'small tree fern', yucca, etc. (see **Table 18** for a full list of 'other' qualifying vegetation).



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- **For all growth forms, the chosen subplot size must be used for the entire plot.** Subplot size requirements:
 - *In a 20m x 20m Distributed or Tower Plot:* Sample a minimum of 20 individuals across the entire plot (see **Box 2**).
 - *In a 40m x 40m Tower Plot:* Sample a minimum of 20 individuals for at least one 20m x 20m subplot (see **Box 3**). **The other subplot does not need to meet the $n \geq 20$ requirement.**

Subplot and nested subplot details are illustrated in **Figure 2**, and compiled below in **Table 11**. Nested subplots are numbered in sequence beginning with the SW corner of the subplot SW=1, SE=2, NW=3 NE=4 (**Figure 2**).

Table 11. Supported subplot and nested subplot dimensions that vary with plot size. The decision to use nested subplots is made on a per plot basis, and allows standardization of sampling effort across plots.

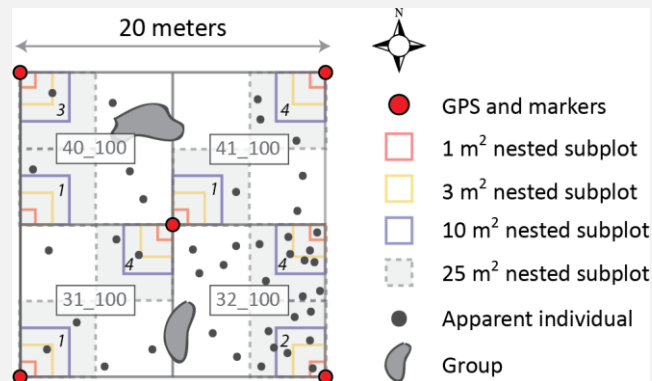
Plot Size	Subplot and Nested Subplot Dimensions (area)	Additional Information
20 m x 20 m (400 m ²)	10 m x 10 m (100 m ²)	The prescribed sampling area when nestedSubplot size = "noneSelected".
	5 m x 5 m (25 m ²)	Nested subplots with these sizes are not utilized for trees with DBH ≥ 10 cm, or for palm trees and large tree ferns with DBH ≥ 10 cm and stemLength > 130 cm; these individuals are sampled throughout the entire plot.
	3.16 m x 3.16 m (10 m ²)	
	1.73 m x 1.73 m (3 m ²)	
	1 m x 1 m (1 m ²)	
40 m x 40 m (1600 m ²)	20 m x 20 m (400 m ²)	Two of the four subplots of this size are randomly selected for sampling by Science. Lists of random subplots are provided in the Fulcrum <i>TOS Spatial Data</i> app. This is the prescribed sampling area when nestedSubplot size = "noneSelected".
	10 m x 10 m (100 m ²)	Smaller nested subplots are established within the two randomly selected 20 m x 20 m subplots. Each nested subplot is anchored to a pre-determined corner as shown in Figure 2 . Nested subplots with these sizes are not utilized for trees with DBH ≥ 10 cm, or for palm trees and large tree ferns with DBH ≥ 10 cm and stemLength > 130 cm; these individuals are sampled throughout the selected subplots.
	7.07 m x 7.07 m (50 m ²)	
	5 m x 5 m (25 m ²)	
	3.16 m x 3.16 m (10 m ²)	
	1.73 m x 1.73 m (3 m ²)	
1 m x 1 m (1 m ²)		



Box 2. Guidelines for selecting nested subplot size in a 20 m x 20 m base plot with heterogeneously distributed vegetation.

In this scenario, we consider whether nested subplots might be appropriate for sampling small tree, sapling, shrub, small shrub, and groups that are heterogeneously distributed throughout the plot (Figure below). Remember that nested subplots are not employed for trees, palm trees, and tree ferns with DBH ≥ 10 cm. In this plot, there are 42 apparent individuals associated with the smaller growth forms listed above, and 2 shrub groups, for a total of 44 (each shrub group is counted as $n=1$). We are required to measure a minimum of $n=20$ per plot, assuming there are at least that many present, so in this case, we should explore whether use of nested subplots can reduce the sampling effort while maintaining a sample size of $n \geq 20$. We assess the number of individuals sampled across the entire plot for each nested subplot size, working upwards from the smallest subplot size to the largest:

- 1 m²: 2 apparent individuals sampled \rightarrow insufficient sample size
- 3 m²: 5 apparent individuals sampled \rightarrow insufficient sample size
- 10 m²: 12 apparent individuals sampled \rightarrow insufficient sample size
- 25 m²: 28 apparent individuals sampled \rightarrow sufficient sampling effort, use 25 m² subplots throughout the entire plot.



A 20 m x 20 m plot with heterogeneously distributed vegetation. Grey numbers indicate 100 m² subplot IDs, and black italic numbers indicate nested corners used to construct IDs for smaller nested subplots (see **Figure 2**).



Box 3. Guidelines for selecting nested subplot size in a 40 m x 40 m base plot with heterogeneously distributed vegetation.

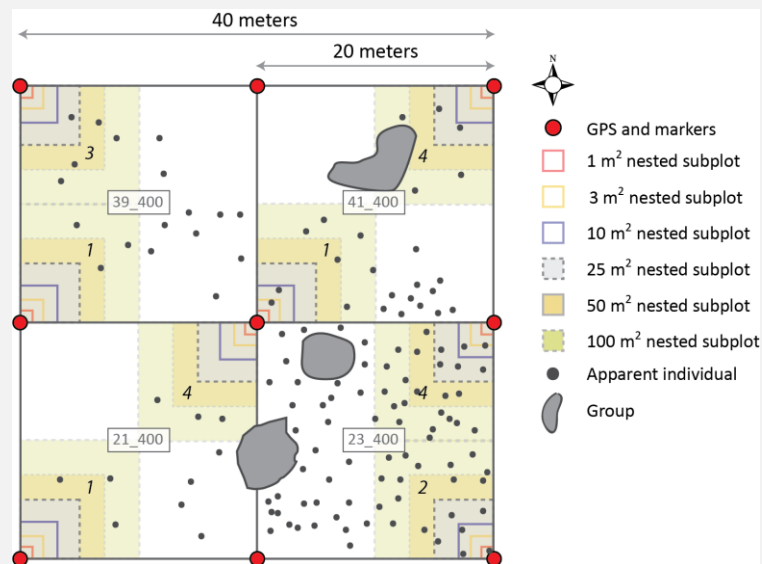
As in Box 2, we consider whether nested subplots can be used for sampling smaller woody individuals that are heterogeneously distributed throughout the plot. Here, assume subplots 23_400 and 41_400 are prescribed for sampling, so we do not consider subplots 21_400 and 39_400 further. An initial survey of the plot indicates that qualifying individuals are relatively dense in subplot 23_400 ($n=81$, including 2 groups), and are less dense in subplot 41_400 ($n=25$, including 1 group). Compared to Scenario 1, the key distinction is that we are only required to sample $n \geq 20$ individuals **for at least one of the two 400 m² subplots randomly selected for sampling; the other subplot does not need to meet the $n \geq 20$ requirement**. Because stem density in subplot 23_400 is high, we begin by assessing whether there is a nested subplot size that will give us $n \geq 20$ individuals for subplot 23_400:

- 1 m²: 1 apparent individual sampled → insufficient sample size
- 3 m²: 2 apparent individuals sampled → insufficient sample size
- 10 m²: 5 apparent individuals sampled → insufficient sample size
- 25 m²: 12 apparent individuals sampled → insufficient sample size
- 50 m²: 20 apparent individuals sampled → sufficient sampling effort ($n \geq 20$), use 50 m² nested subplots throughout the entire plot.
- 100 m²: 45 apparent individuals sampled → do not use, minimum sample size already met

Using the 50 m² nested subplot for both of the two randomly selected subplots, our sampling effort looks like this:

- subplot 23_400, $n=20$
- subplot 41_400, $n=6$. We must also sample the portion of the group that overlaps the nested subplot in corner 4.

*****Note:** If subplot = 23_400 had NOT been randomly selected, the selected nested subplot size would be different for this example plot.



A 40 m x 40 m plot with heterogeneously distributed vegetation. Grey numbers indicate 400 m² subplotIDs, and black italic numbers indicate nested corners used that anchor smaller nested subplots (see **Figure 2**).



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C.3 Plot Delineation and Recording Plot Meta-Data

- Data collected as part of this SOP are recorded in the **VST: Plot Meta-Data [PROD]** application.
- Consult the ‘Manual for Fulcrum Application: TOS Vegetation Structure [PROD] – All SOPs’ for data entry details (RD[14]).

The *VST: Plot Meta-Data [PROD]* application communicates an accurate, detailed per plot per year report of growthForm presence / absence, and the total area sampled for growth forms is clearly documented in the data for end-users. These data are critical for scaling purposes – i.e., calculation of biomass or productivity per unit area.

Procedure steps:

1. Create a record in the *VST: Plot Meta-Data [PROD]* application. Enter required information:
 - a. **siteID**
 - b. **yearBoutBegan**; for bouts that span > 1 calendar year, ALL records should be assigned the year in which the bout began.
 - c. **eventType**; choices correspond to the types of plots scheduled for sampling for the year, as shown in **Table 4**. Select from:
 - i. **allTowerPlots**; all Tower Plots are scheduled for the bout, and NO Distributed Plots are scheduled.
 - ii. **towerSubset**; select when a subset of Tower Plots is scheduled on an annual basis and NO Distributed Plots are scheduled. Also applicable when dendrometer banded trees are measured in additional Tower plots but not all Tower plots are sampled.
 - iii. **distributedAndTowerSubset**; Distributed Plots are scheduled AND the subset of Tower Plots measured annually are scheduled. Also applicable when dendrometer banded trees are measured in additional Tower plots but not all Tower plots are sampled.
DSNY and LAJA sites: Tower plots theoretically could support VST at a future date. When Distributed Plots are scheduled, select this option for Tower plots sampled annually, create records for these Tower plots and select ‘targetTaxaPresent = ‘No’ (see below).
 - iv. **distributedOnly**; only Distributed Plots are scheduled, and no Tower plots are scheduled (only applicable to D13 MOAB, D14 JORN and SRER, and D15 ONAQ).
 - d. **plotID**
 - i. If working in a site with both 20m x 20m and 40m x 40m Tower Plots, implement the Vegetation Structure protocol in the 20m x 20m ‘core’ of the four larger Tower Plots.



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- ii. If working in a site with all Tower Plots = 40m x 40m, the app will display **randomSubplotA** and **randomsubplotB** subplotIDs that have been selected for sampling.
- e. **date**; for plots sampled only once in each **eventID**, record the date that sampling begins.
 - i. **nonwoodyCollectDate**; for plots that support early-season sampling of non-woodies (e.g., cacti, ferns), and woody individuals are sampled later, record the non-woody sampling date here. Record the date woody sampling begins in the **date** field.
- f. **Sampling Impractical**; populate if it is not possible to collect VST data from the plot for the current bout (**Table 7**).
- g. **biophysicalCriteria**; use this field to document the biophysical sampling conditions when sampling occurs and Sampling Impractical = 'OK'.
 - i. **'OK – no known exceptions'** (default); the plot is sampled within the protocol-specified sampling window under typical conditions.
 - ii. **'OK – schedule change but conditions met'**; sampling occurred outside the scheduled sampling window but conditions otherwise met (e.g., plot sampled later than scheduled but leaf-out has not yet occurred).
 - iii. **'schedule change – conditions not met'**; sampling occurred outside the prescribed sampling window and conditions not met (e.g., plot sampled later than scheduled and leaf-out has begun).
 - iv. **'plot disturbance'**; sampling occurred and there is evidence the plot was disturbed after the prior sampling event. Note specifics in the **remarks** (e.g., plot was burned or flooded), and verify that a *Site Management and Disturbance* record has been created.
- h. **dataCollected**; indicates which data are collected in the plot for the current bout. The selected choice controls whether **Nested Subplot Sampling Area** values are used to calculate a **totalSampledArea** for the plot (e.g., **totalSampledArea** is not reported when only dendrometer banded trees are measured).
 - i. **allGrowthForms**; select when all growth forms that exist in the plot are sampled for the current bout.
 - ii. **dendrometerOnly**; select if only trees fitted with dendrometer bands are sampled within the plot for the current bout. Combined with **eventType**, this selection allows end-users to find data needed for annual productivity calculation at slow-growth increment sites.
 - iii. **partial**; scheduled sampling was partially completed. *Submit an Incident to use 'partial'; this option is not available in the mobile ingest application.*



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- a) *Example:* In a 40m x 40m Tower plot, sampling of one subplot was completed but sampling of the second subplot is incomplete.
 - b) *Example:* Sampling for some growth forms was completed (e.g., trees) but sampling for other growth forms is incomplete (e.g., shrubs, saplings).
- i. **samplingProtocolVersion**; the version of the Vegetation Structure protocol used.
2. Delineate the plot or subplot. Use existing plot markers, meter tapes, and chaining pins to carefully delineate the plot / subplot boundaries.
 - a. It is not necessary to pay attention to whether the plot is sloped or flat: The tape is used only to help determine which stems are ‘in’ versus ‘out’ of the plot.
 - b. Individuals are only measured when $\geq 50\%$ of the individual (or $\geq 50\%$ of the stems, for a multi-stemmed individual) are rooted within the measurement area.
 - c. Refer to the Plot Establishment Protocol (RD[08]) for a review of tape wrapping techniques that can be used to delineate subplots.
3. Assess the entire plot or the entirety of the assigned random subplots for **presence/absence** of woody and non-woody growth forms (as defined in **Table 9** and **Table 18**). Per plot presence/absence data recorded here indicate when downstream measurements are expected.
 - a. Presence/absence data are not required when **dataCollected** = ‘dendrometerOnly’.
 - b. If all growth forms are absent from the entire plot or both randomly selected subplots:
 - i. Select **targetTaxaPresent** = ‘No’ in the *VST: Plot Meta-Data* ‘presenceAbsence’ section.
 - ii. Also select **targetTaxaPresent** = ‘No’ if a growth form is present AND the plot is scheduled for sampling, but cover requirements are not met (e.g., a Distributed plot dominated by graminoids has a few saplings and sapling cover does not meet requirements for measurement).
 - iii. Save the record and proceed to the next plot.
 - c. If any woody or non-woody growth forms, as defined in **Table 9** and **Table 18**, are present in the plot or in the assigned random subplots and sampling requirements are met for at least one growth form:
 - i. Select **targetTaxaPresent** = ‘Yes’ in the *VST: Plot Meta-Data* ‘presenceAbsence’ section.
 - d. If **targetTaxaPresent** = ‘Yes’:
 - i. Consider each of the following growth forms or groups of growth forms:
 - a) Trees (sbt, mbt)



- b) Shrubs, Saplings, and Small Trees (includes sum of sis + sms + smt + sap + shrub groups)
 - c) Lianas
 - d) Ferns
 - e) Other – cacti
 - f) Other – palm (sum of ptr + spm)
 - g) Other – tree fern (sum of ltf + stf)
 - h) Other – yucca (sum of agave + yucca)
 - i) Other – ocotillo
 - j) Other – Xerophyllum (Bear Grass)
- ii. For each of the growth forms or group of growth forms listed above, assess presence/absence according to the following options:
- a) **present – sampled**; select if growth form is present and sampling criteria are met. Downstream records for a growth form exist.
 - b) **present – criteria not met** (ferns only); ferns are present and sampling criteria are not met (e.g., due to **eventType**, cover criteria, fern frond length requirements). Downstream fern records do not exist.
 - c) **not present**; select if growth form is absent from the plot. Downstream records for a growth form do not exist.
4. For the ‘Shrubs, Saplings, and Small Trees’ group, ‘Lianas’, ‘Ferns’, and the sum of all ‘Other’ growth forms present in the plot, determine separately whether nested subplots may be employed to constrain the sampling effort (SOP C.2). **Never use nested subplots for ‘sbt’, ‘mbt’, ‘ptr’, or ‘ltf’ growth forms.**
- a. Not required when **dataCollected** = ‘dendrometerOnly’.
 - b. For a plot that HAS been sampled previously: Nested subplot area values are automatically populated from the previous bout. Using the **same nested subplot area each year** ensures that repeat measurements are made on tagged stems.
 - i. Survey for recruitment of newly qualifying individuals. If significant and persistent changes in stem density have occurred over time, due to succession, self-thinning, natural disturbance, or management activities, submit an Incident to discuss with Science whether a change in nested subplot area is warranted.
 - c. For a plot that has NOT been measured previously: Assess vegetation density and select an optimal nested subplot area (SOP C.2). Submit an Incident to document the selected nested subplot area in the *TOS Spatial Data* Fulcrum application.



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5. Delineate nested subplots for each growth form present in the plot that qualifies for nested subplots. Use tapes for smaller nested subplots instead of the laser rangefinder. When using the rangefinder to mark corners for larger nested subplots, use in ‘horizontal distance’ (HD) mode to account for slope.
 - a. Nested subplots are not used when **dataCollected** = ‘dendrometerOnly’.
 - b. Use ‘noneSelected’ if not using nested subplots for a growth form due to low stem density.
 - c. ‘noneSelected’ is also auto-populated for growth forms not present in the plot.
6. Review auto-calculated **Total Sampled Area** values to ensure a match between what is recorded and what was sampled in the field.
 - a. If necessary: Submit an Incident to discuss updating **Nested Subplot Sampling Area** to match the actual sampling effort.
 - b. If nested subplot area is updated in the *TOS Spatial Data* Fulcrum app, the **plotID** must be re-selected in the *VST: Plot Meta-Data* record to propagate the changes.
7. Save the record.
8. Finalize the record only after QC is complete for all growthForms. The Fulcrum record LOAD STATUS will change from “SKIP” to “NONE” when the record is finalized.



SOP D Mapping and Tagging Apparent Individuals

Overview

This section describes the tagging procedure for woody and non-woody perennial individuals and provides the offset mapping procedure for individuals that additionally qualify for mapping.

- See **Table 12** for mapping and tagging requirements by growth form.

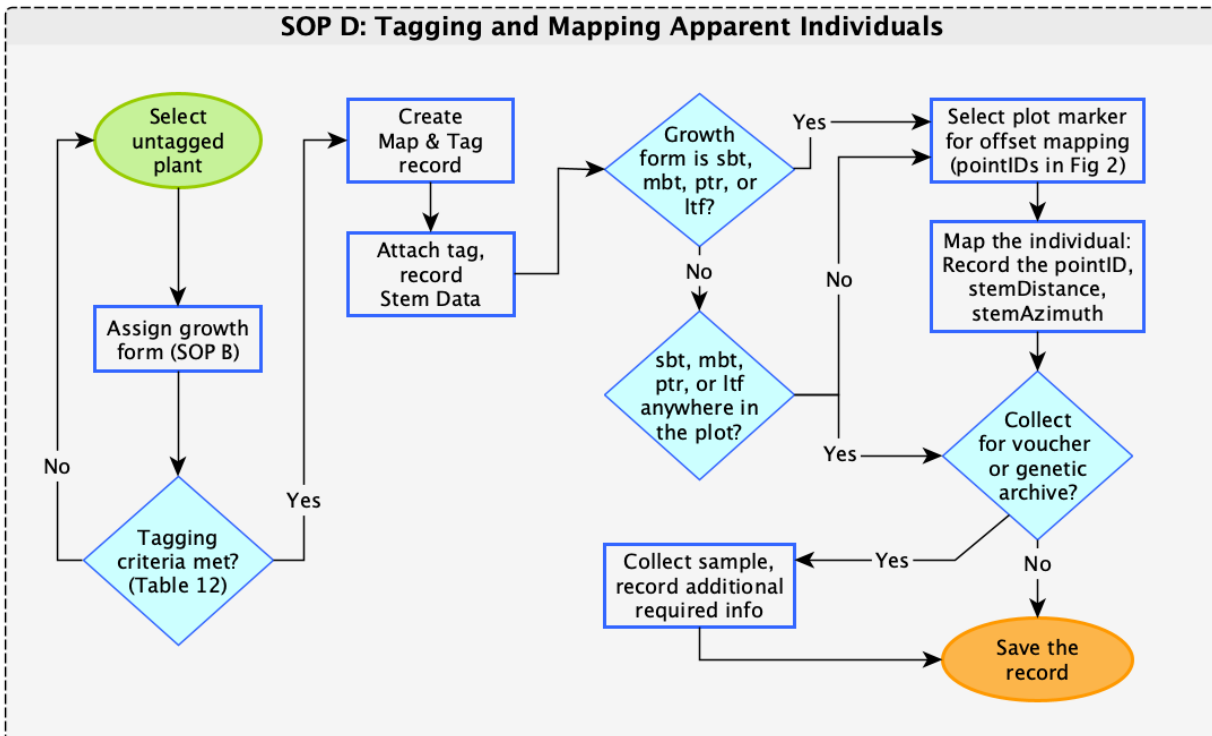


Figure 10. SOP D workflow diagram for tagging and mapping apparent individuals. Diagram supports and does not replace protocol text; most common workflow is outlined.

Fulcrum applications used to collect data for this SOP:

- **VST: Mapping and Tagging [PROD]** application. Collect data that are invariant through time, including **taxonID**, **tagID**, and geolocation data when required (**pointID**, **stemAzimuth**, **stemDistance**).
- If structure measurements are made at the same time as ‘Mapping and Tagging’ data are collected, record structure data in the **VST: Apparent Individuals [PROD]** application (SOP E).
- The [Vegetation Structure Fulcrum Manual](#) on the SSL contains detailed data entry instructions.



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This SOP is implemented every time the Vegetation Structure protocol is implemented to account for recruitment of new qualifying individuals.

- The procedure described here applies to apparent individuals only (i.e., not Shrub Groups or Fern Groups).
- Stems must be $\geq 50\%$ rooted in the plot to be considered 'in' and included in long term monitoring.
- Dead individuals are tagged and mapped if they are leaning $< 45^\circ$ from vertical. However, this criterion does not apply to decumbent growth forms.
- The mapping procedure is completed for:
 - Trees ('sbt' and 'mbt'), palm trees ('ptr'), and large tree ferns ('ltf'). All individuals of these growth forms are mapped throughout the plot.
 - If no trees, palm trees, or large tree ferns are present in the entire plot, smaller woody and non-woody growth forms are mapped ('smt', 'sis', 'sms', 'spm', 'stf'). If nested subplots are used, map smaller woody and non-woody growth forms only within subplots.
- Assigned **tagIDs** must be unique across both the Vegetation Structure and Plant Phenology protocols – i.e., Vegetation Structure tags should not overlap with Plant Phenology tags that are in the 6001-8000 series.
 - To avoid any chance of creating duplicate Vegetation Structure tags, a single series of tags should be used for all sites within a domain.

MAPPING TOOLS

- The steps below assume the use of a laser rangefinder (see RD[09] for detailed rangefinder instructions). However, a meter tape and declination-corrected compass may be used on slopes $< 20\%$ if the tape is not prevented from being stretched straight by understory vegetation.
 - A declination-corrected compass is helpful to check agreement with the rangefinder and ensure the rangefinder unit is calibrated.
 - Training is required to properly set declination and accurately use a compass.
-



D.1 Requirements for Tagging and Mapping by Growth Form

Tagging and mapping requirements vary with vegetation type and are broadly guided by two principles:

- 1) Tags are used when an individual is likely to generate longitudinal data (i.e., persist from bout-to-bout), and
- 2) Individuals are mapped when they are visible to AOP remote sensing instruments.

However, due to logistical constraints, mapping efforts within a given ecosystem are targeted toward those individuals in an ecosystem with the greatest biomass AND that are visible to remote sensing instruments. The following are examples of how this strategy is executed in three common ecosystem types:

- *Closed canopy forest*: Trees, palm trees, and large tree ferns are mapped (all ‘sbt’, ‘mbt’, ‘ptr’, and ‘ltf’). Small trees, saplings, shrubs, small tree ferns, etc. in the understory are not mapped.
- *Rangeland shrub, Pinyon / Juniper, Scrub Oak, short-stature woodlands*: In these systems, it is possible for shrubs like *Artemisia tridentata* or *Prosopis spp.* (mesquite) to make up the overstory in plots that lack trees. Here, these smaller stature growth forms ARE mapped.
- *Early-successional forest and savannah ecosystems*: These systems are a mixture of the previous two examples; trees form the overstory in some parts of the plot, and smaller growth forms (e.g., shrubs, herbaceous plants) form the “overstory” in other parts of the plot. For simplicity only trees (‘sbt’, ‘mbt’, ‘ptr’, and ‘ltf’) are considered the overstory in savannah-like plots because these larger individuals comprise the majority of the plot biomass. Even though smaller growth forms may be visible to remote-sensing instruments throughout much of the plot, these individuals are NOT mapped if there are trees in any part of the plot prescribed for measurement.

Mapping and tagging requirements also vary by growth form:

- *Apparent Individuals*:
 - May be mapped as points. Growth form specific mapping and tagging requirements are provided in **Table 12** (below). See **Table 13** for guidance with complex individuals not covered in **Table 12**.
 - Are tagged with a unique aluminum ID tag for repeat measurements.
 - Mapping and tagging data are recorded in the **VST: Mapping and Tagging [PROD]** application.
 - ‘Other’ non-woody individuals are measured like woody Apparent Individuals but are typically not mapped and tagged (except for large-stature cacti, small palms, and small tree ferns in some Domains).



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- **Groups:** The locations of Groups (shrub, liana, etc.) are mapped relative to the plot with polygons and graph paper (SOP E.3), and location data are NOT entered into the NEON database. Individual stems within the group are not tagged.

Table 12. Summary of tagging and mapping requirements by growth form. For cactus, see the companion *TOS Protocol and Procedure: Cactus Biomass and Handling* (RD[11]).

Growth Form	Map	Stem Diameter Measurement Location	Tag Type, Location, and Method	Additional Required Data
Single bole tree (sbt)	Record stemDistance and stemAzimuth relative to pointID (plot marker)	<ul style="list-style-type: none"> • 130 cm along bole • See SOP E.1 for complex cases 	<ul style="list-style-type: none"> • Unique # • 10 cm above stemDiameter measurement location (preferred) or per site host requirements • Aluminum nail 	<ul style="list-style-type: none"> • taxonID • idQ
Multi-bole tree (mbt)	Record stemDistance and stemAzimuth of largest intact bole relative to pointID (plot marker)	<ul style="list-style-type: none"> • 130 cm along qualifying boles if pith intersection occurs below 30 cm • See SOP E.1 if pith intersection is >30 cm along stem 	<ul style="list-style-type: none"> • Unique # on largest live stem (e.g., 01234); tag most stable dead bole if all boles dead • A,B,C... on additional qualifying stems (e.g., 01234A) • 10 cm above stemDiameter measurement location • Aluminum nail 	<ul style="list-style-type: none"> • taxonID • idQ
Small tree (smt)	Record stemDistance and stemAzimuth relative to pointID if no overstory*	<ul style="list-style-type: none"> • 130 cm along qualifying boles • See SOP E.1 if multi-bole and pith intersection >30 cm along stem 	<ul style="list-style-type: none"> • Unique # • 10 cm above stemDiameter measurement location OR a consistent, visible location • Loose aluminum wire • If multi-bole, Temp ID assigned to qualifying boles (SOP E) 	<ul style="list-style-type: none"> • taxonID • idQ • subplotID (if applicable)
Sapling (sap)	Not mapped	<ul style="list-style-type: none"> • 10 cm along stem 	<ul style="list-style-type: none"> • Unique # • Consistent, visible location • Loose aluminum wire • If multi-bole, Temp ID assigned to qualifying boles (SOP E) 	<ul style="list-style-type: none"> • taxonID • idQ • subplotID (if applicable)
Single shrub (sis)	Record stemDistance and stemAzimuth of shrub center relative to pointID if no overstory*	<p>For each qualifying emergent bole:</p> <ul style="list-style-type: none"> • 10 cm along stem (if possible), AND • 130 cm along stem on largest diameter fork • See SOP E.1 for complex cases. 	<ul style="list-style-type: none"> • Unique # on largest live emergent stem (primary) • No tag on additional qualifying stems. • Mark secondary qualifying stems with lumber crayon • 10 cm above stemDiameter measurement location (nail) OR near ground level (wire) • Aluminum nail or loose wire as appropriate • If multi-bole, Temp ID assigned to qualifying boles (SOP E) 	<ul style="list-style-type: none"> • taxonID • idQ • subplotID (if applicable)



Growth Form	Map	Stem Diameter Measurement Location	Tag Type, Location, and Method	Additional Required Data
Small shrub (sms)	Record stemDistance and stemAzimuth of shrub center relative to pointID if no overstory*	<ul style="list-style-type: none"> 10 cm along each qualifying stem 	<ul style="list-style-type: none"> Unique # Consistent, visible location Loose aluminum wire If multi-bole, Temp ID assigned to qualifying boles (SOP E) 	<ul style="list-style-type: none"> taxonID idQ subplotID (if applicable)
Shrub group (sgr)	Graph paper method used to calculate area only; location not recorded in NEON database	<ul style="list-style-type: none"> Not applicable 	<ul style="list-style-type: none"> Tagging not required, but may be tagged for internal tracking purposes Unique ID assigned per bout if not tagged 	<ul style="list-style-type: none"> subplotID (if applicable)
Liana (lia)	Not mapped, but supporting stem tagID is recorded when applicable	<ul style="list-style-type: none"> 130 cm along stem See SOP E.1 for complex cases 	<ul style="list-style-type: none"> Unique # 10 cm above stemDiameter measurement location, or above the rooting point most proximal to the ascending stem Loose aluminum wire One tag per apparent individual, regardless of branching If multi-stem, Temp ID assigned to qualifying stems (SOP E) 	<ul style="list-style-type: none"> Supporting stem tagID taxonID idQ subplotID (if applicable)
Ferns (frn)	Not mapped or tagged	<ul style="list-style-type: none"> Species dependent, see SOP E.4 	<ul style="list-style-type: none"> Not tagged Temp ID assigned in <i>VST: Apparent Individuals</i> app during data collection (SOP E) 	<ul style="list-style-type: none"> taxonID idQ subplotID (if applicable)
Palm tree (ptr)	Record stemDistance and stemAzimuth relative to pointID (plot marker)	<ul style="list-style-type: none"> 130 cm along stem 	<ul style="list-style-type: none"> Unique # 10 cm above stemDiameter measurement location (nail) OR ground level (wire) Aluminum nail or loose wire as appropriate 	<ul style="list-style-type: none"> taxonID idQ
Small palm (spm)	Record stemDistance and stemAzimuth relative to pointID if no overstory*	<ul style="list-style-type: none"> Species dependent, see SOP E.4 	<ul style="list-style-type: none"> Unique # 10 cm above stemDiameter measurement location (nail) OR ground level (wire) Aluminum nail or loose wire as appropriate 	<ul style="list-style-type: none"> taxonID idQ subplotID (if applicable)
Large tree fern (lrf)	Record stemDistance and stemAzimuth relative to pointID (plot marker)	<ul style="list-style-type: none"> 130 cm along stem 	<ul style="list-style-type: none"> Unique # 10 cm above stemDiameter measurement location (nail) OR ground level (wire) Aluminum nail or loose wire as appropriate 	<ul style="list-style-type: none"> taxonID idQ



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Growth Form	Map	Stem Diameter Measurement Location	Tag Type, Location, and Method	Additional Required Data
Small tree fern (stf)	Record stemDistance and stemAzimuth relative to pointID if no overstory*	<ul style="list-style-type: none"> • stemLength > 130 cm: 130 cm along stem • stemLength < 130 cm: 10 cm along stem 	<ul style="list-style-type: none"> • Unique # • 10 cm above stemDiameter measurement location (nail) OR ground level (wire) • Aluminum nail or loose wire as appropriate 	<ul style="list-style-type: none"> • taxonID • idQ • subplotID (if applicable)
Yucca (yuc)	Not required but may be mapped to enable repeat measurements if desired.	<ul style="list-style-type: none"> • Not applicable 	<ul style="list-style-type: none"> • Tagging not required but may be tagged to enable repeat measurements if desired. 	<ul style="list-style-type: none"> • taxonID • idQ • subplotID (if applicable)

* For mapping and tagging, ‘overstory’ is defined as the presence of at least one tree (‘sbt’, ‘mbt’, ‘ptr’, or ‘ltf’).

D.2 Exceptions to Standard Mapping and Tagging Guidelines

There are numerous instances in which the generalized guidelines provided above in **Table 12** are insufficient when it comes to deciding on an appropriate **measurementHeight** and tagging location. Guidance for determining the **measurementHeight** and tag location for complex and non-standard individuals is summarized in **Table 13** and illustrated in detail in SOP E.1. Site-specific modifications are described in Appendix D.

Note: The the tagging location should never be the same as the **measurementHeight**.

Table 13. Measurement location and tagging guidelines for complex woody stems not covered in **Table 12**.

Measurement location and tagging guidelines for complex woody stems	
Stem/Site Characteristics	measurementHeight and tag location
Growing on sloped or uneven terrain	Measure stem diameter 130 cm from uphill side, tag 10 cm above measurementHeight.
Thickened base	Measure stem diameter 50 cm above the point where the bole becomes ‘regular’ again. The selected measurementHeight must be sample-able and generate high-quality data for a technician of average height.
Leaning or twisted stems	Measure stemDiameter 130 cm along the underside of the stem; diameter measurement is perpendicular to the direction of stem growth, not parallel to ground. Tag 10 cm above measurementHeight.



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Measurement location and tagging guidelines for complex woody stems	
Stem/Site Characteristics	measurementHeight and tag location
Stems with anomalies at 130 cm (e.g., bulge, node/branch, or minor, localized damage).	Measure above the anomaly where stem becomes ‘regular’ again. Tag 10 cm above measurementHeight. When damage is a major feature of the stem, do not move the measurementHeight and tag location. The selected measurementHeight must be sample-able and generate high-quality data for a technician of average height.
Deep litter/duff layer heaped around bole base	The measurementHeight and tagging location are determined from ground level, not the top of the duff layer.
Single-bole individual is broken (applicable to ‘sbt’, ‘sms’, and ‘sis’, with or without re-sprouts)	<ul style="list-style-type: none"> For break points ≥ 130 cm height, follow standard measurementHeight and tagging guidelines. Live or dead broken boles < 130 cm height no longer qualify for tagging and measurement. For a single broken bole < 130 cm height (live or dead) with resprouts: The broken bole does not qualify for measurement. The largest live resprout is tagged, and all resprouts are collectively considered as a single ‘sap’ or ‘smt’ individual and measured accordingly (SOP E).
Multi-bole individual is broken (applicable to ‘mbt’, ‘sms’, and ‘sis’, with or without re-sprouts)	<ul style="list-style-type: none"> For break points ≥ 130 cm height on qualifying boles, follow standard measurementHeight and tagging guidelines. Location of measurementHeight and tag depends on where pith of secondary bole(s) intersects with pith of main bole. See SOP E.1. Live or dead broken boles must be > 130 cm length to qualify for measurement (and for an ‘mbt’ for tagging). Live or dead broken boles < 130 cm height (or stem length) no longer qualify for tagging and measurement. Focus on remaining qualifying boles.
‘sap’ or ‘sms’ individual is broken	<ul style="list-style-type: none"> For a single-stem individual: Follow standard measurementHeight and tagging guidelines if broken stem is ≥ 30 cm length. Broken stems < 30 cm length no longer qualify for measurement (whether live or dead). For a multi-stem individual with one or more broken stems: Tag the largest, live qualifying stem. Broken stems < 30 cm length no longer qualify for measurement (whether live or dead).
Downed live, with vertically growing resprouts	Measurement and tagging strategy depends on whether the pith of the downed bole is above or below the forest floor. See SOP E.1.
Standing dead	<ul style="list-style-type: none"> For standing dead ≥ 130 cm length, follow standard measurementHeight and tagging guidelines. When broken boles are present, follow broken bole guidance above.
Leaning dead	<ul style="list-style-type: none"> If lean is $< 45^\circ$ off vertical, measure and tag same as standing dead. If lean is $\geq 45^\circ$, ignore stem, will be assessed as Coarse Downed Wood (except in the case of decumbent growth forms such as manzanita species, individuals leaning toward available light, etc.).



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Measurement location and tagging guidelines for complex woody stems	
Stem/Site Characteristics	measurementHeight and tag location
Plot burned since previous bout	Do not change measurement strategy. Do not need to search for fallen, tagged individuals for re-measurement.

D.3 Procedure for Mapping and Tagging

Procedure steps:

1. Choose a plot marker with high-resolution GPS coordinates that can be used for offset mapping.
 - a. **Only pointIDs shown in red in Figure 2 may be used for offset mapping.**
 - b. Avoid using pointID = 41 unless absolutely necessary. Mapping from this pointID leads to trampling of subplots used for sampling smaller growth forms.
2. Mount the laser rangefinder on the non-magnetic tripod and position the body of the rangefinder directly over the selected plot marker.
 - a. Use of a tripod ensures the rangefinder is centered over the plot marker. Hand-holding the rangefinder may result in swinging the unit from side-to-side, introducing errors in azimuth (primarily) and distance (secondarily).
 - b. Care should be taken to avoid placing tripod legs within nested subplots.
 - c. A cut length of PVC post may be used as an alternative if a non-magnetic tripod is unavailable.
3. For each individual that requires a tag, create a record in the *VST: Mapping and Tagging* app. See **Table 12** for tagging criteria. Enter the following:
 - a. **CFC-only Tag** status; select ‘Yes’ if the individual is specifically tagged for Canopy Foliar Sampling and is not otherwise measured for Vegetation Structure.
 - b. **domainID** and **siteID**; these fields narrow the list of plotIDs.
 - c. **plotID**; the list of available plotIDs is populated by records created in the *VST: Plot Meta-Data* app. Create Plot Meta-Data records prior to Mapping and Tagging records.
 - d. **yearBoutBegan** and **date**; typically the former is part of the latter. However, the two may be different if the bout began in a previous year and continued over the Dec 31st to Jan 1st transition.
 - e. **samplingProtocolVersion**; the version of the Vegetation Structure protocol used to guide sampling.
 - f. **recordType**; select from the following:



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- i. **Map and Tag**; individual is both mapped and tagged.
 - ii. **Tag Only**; individual is tagged and not mapped.
 - iii. **Band**; individual is mapped, tagged, and dendrometer band is installed.
 - iv. **Temporary**; individual that is measured but not tagged. Applies to approved domains only (see Appendix D); consult with Science if potentially applicable to your site – i.e., chronic loss of tagged individuals before next measurement bout.
4. Determine the **measurementHeight** using **Table 12**, **Table 13**, and figures in SOP E.1. Attach a pre-numbered aluminum tag according to guidelines in **Table 12**; this number is the **tagID**.
 - a. When multi-bole apparent individuals are in close proximity and emergent boles from one apparent individual intermingle with another, it is best to treat each qualifying emergent bole/stem as an individual.
 - b. Mark the **measurementHeight** on the qualifying stem(s) using lumber crayon or equivalent.
 - i. For stemDiameter measurement, the maximum allowed measurement height is 200 cm (all sites but PUUM) or 500 cm (PUUM only).
 - ii. For basalStemDiameter measurement, the maximum allowed basal diameter measurement height is 100 cm.
 - c. **TIP**: It is helpful to mark trees you have just tagged, mapped, and/or measured to track work progress. The lumber crayon marking suffice for tracking purposes, or a small length of flagging may be affixed to track work progress. All temporary flagging must be removed once data have been collected from all trees within a given subplot.
5. Record required **Stem Data** for the individual:
 - a. **fixedSubplotID**; select the subplot that is invariant through time (i.e., the individual will always be rooted in this subplotID regardless of future stem density changes). Helps to relocate individuals in subsequent bouts.
 - i. *Examples*: 31_100 (Distributed, small Tower plot), or 21_400 (large Tower plot) are fixedSubplotIDs.
 - b. **nestedSubplotCorner**; select if sampling occurs within a nested subplot that is anchored to a corner of a fixedSubplot (see **Figure 2**). Helps to relocate individuals in subsequent bouts; may be left NULL for many trees ('sbt', 'mbt') that do not fall within a nested subplot.
 - c. **tagID**; the numeric identifier for the individual. Should be unique within a domain.
 - d. **supportingStemTagID**; required for the liana ('lia') growth form only.





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- e. **previouslyTaggedAs**; enter the previous, incorrect identifier if an individual was previously tagged in the field and associated with an incorrect tagID value in the database.
 - i. The correct tagID value is recorded in the **tagID** field.
- f. **otherTagID**; record any tagID assigned to the individual by a research group other than NEON (e.g., ForestGEO).
- g. **otherTagOrg**; if a non-NEON tagID is present, enter the research organization that applied the tag. Leave blank if not known.
- h. **taxonID**; select from the NEON master list of USDA plant species codes for species present within the domain. Identify to the greatest taxonomic resolution possible.
 - i. Record the USDA plants code rather than the scientific name.
 - ii. If **taxonID** is unknown and the stem is alive, assign a morphospecies ID as indicated in steps below, obtain leaf, bark, and/or reproductive part samples (e.g., cones, nuts), and bring back to the lab to identify.
 - iii. When stem **plantStatus** = '2 – standing dead' or '10 – dead, broken', assign to species if possible. If the species cannot be determined, assign to genus, family, unknown hardwood or unknown softwood, in that order of preference.
- i. **identificationQualifier**; select the appropriate qualifier when identification below a given taxonomic rank (e.g., family or genus) cannot be made (**Table 14**).
 - i. An identification qualifier can be used in combination with a 'sp.' Or 'spp.' In the scientific name. The 'sp.' indicates only one unknown species is involved; the 'spp.' indicates multiple unknown species in the same genus.
 - ii. If the genus of a specimen is obvious, and the specimen is one of up to 3 species, assign the specimen to the best matched species, and then assign 'identificationQualifier = CS'.
 - iii. When a genus- or family-level code is selected, an identification qualifier is not needed, unless for example, the genus is uncertain.

Example: If you record **taxonID** = 'PINUS', do NOT record **idQ** = 'cf. species'; it is already clear that you do not know the species because a Genus-level code was reported in **taxonID**.



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Table 14. Taxon identificationQualifier (idQ) codes. Leave this field blank if the person making the identification is confident in the species ID.

idQ code	identificationQualifier	Description
CS	<i>cf. species</i>	Roughly equals but “not sure” about the species
AS	<i>aff. species</i>	“Similar to, but is not” the species
CG	<i>cf. genus</i>	Roughly equals but “not sure” about the genus
AG	<i>aff. genus</i>	“Similar to, but is not” the genus
CF	<i>cf. family</i>	Roughly equals but “not sure” about the family
AF	<i>aff. family</i>	“Similar to, but is not” the family
CV	<i>cf. variety</i>	Roughly equals but “not sure” about the variety
AV	<i>aff. variety</i>	“Similar to, but is not” the variety

6. Map the individual if it qualifies for mapping (see **Table 12**). Skip this step if the individual is only tagged. See RD[09] for rangefinder operation instructions.
 - a. Make sure **recordType** = ‘Map and Tag’ or ‘Band’ in the *VST: Mapping and Tagging [PROD]* app.
 - b. Record the **pointID**; this is the plot marker number over which the laser rangefinder is positioned. **Only pointIDs identified in Figure 2 may be used for mapping**. Refer to Appendix F if plot markers are not numbered.
 - c. Record the **stemDistance**; nearest 0.1 m. This is the horizontal distance from the plot marker to the base of the main stem, or the center of a shrub.
 - i. Note that tapes are preferred for measuring distances < 3 m due to rangefinder accuracy.
 - d. Record the **stemAzimuth**; nearest 0.1 degree. This is the angle relative to True North from the chosen plot marker to the base of the main stem or center of shrub.
 - i. Always keep metal objects > 50 cm (2 feet) from the rangefinder during operation; metal objects interfere significantly with compass accuracy. This includes watches, earrings, rings, glasses, etc.
7. Record additional **Stem Data** for the individual:
 - a. **identificationReferences**; for unknown species that must be keyed out, record the references used (e.g., dichotomous keys, regional flora guides) on a per individual basis the first time the species is encountered. It is not necessary to record the identificationReferences the next time the species is encountered.
 - i. Only required when a species at a site has been keyed out with that reference for the first time. Consult with the lead Field Ecologist if you are unsure.



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- b. **morphospeciesID**; enter a concise, descriptive ID that will be possible to link to this species at a later time – e.g., ‘hirsute palmate decumbent’ instead of ‘green fuzzy’.
 - i. Record the **taxonID** to the best of your ability IN ADDITION to the morphospeciesID.
 - ii. If domain staff cannot identify a given morphospecies prior to data entry, the morphospecies ID must be recorded in the morphospecies ID list (found in the ‘morphospeciesTracking’ folder of the FOPS / TOS Sharepoint library).
 - iii. *Cryptic species*: To aid in identifying cryptic species at a site, members of cryptic pairs or groups should be added to NEON master taxon lists. New pairs / groups may be entered in the ‘crypticSpeciesGroups’ spreadsheet in the ‘taxonTables’ folder of the ‘Sampling Support Documentation’ Sharepoint library.
8. Enter optional **Plant Voucher or Genetic Archive Data** if:
 - a. Adding the sample to a domain-specific reference collection would be helpful (see RD[07] for procedure), or
 - b. Collecting a specimen from the individual for Genetic Archive (see RD[07]).
9. Save the record and proceed to the next individual.

D.4 QA/QC for Mapping and Tagging Data

Ensuring that mapping and tagging data are accurate is important because:

- Mapping data are used by researchers to link ground-based measurements with airborne remote-sensing data.
- Mapping data reveal whether larger trees are accurately classified ‘in’ or ‘out’ of the plot; accurate ‘in/out’ classification can have significant downstream consequences for biomass and productivity per unit area estimates.
 - Mapping QA/QC is particularly important in steep terrain or dense brushy vegetation when it is difficult to determine plot boundaries.
- Correct taxonIDs are necessary for accurate biomass estimation via allometric equations. For example, different parameters are used for estimating biomass of hard maples vs. soft maples.

Use the ‘Peregrine’, the VST QA/QC Shiny application, to review mapping data as soon as the data are entered into Fulcrum. Pay particular attention to:

- Mapped stems that appear to reside outside of plot boundaries. It is important to verify mapping data for these individuals in the field.



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- Mapped stems that appear to be located in a different part of the plot than where you remember the rooting point. Verify mapping data for these individuals in the field.
- The VST QA/QC Shiny application is only available within the NEON network (and via VPN) to prevent external access to raw data that have not been QA/QC'd.

To Correct Errors in Mapping and Tagging Data:

1. If the record is locked *and was originally created in a different year than the current one*:
 - a. Create a new *VST: Mapping and Tagging* record and enter all required fields. Enter updated information into those fields that require correction. Data in other fields should remain unchanged.
2. If the record is locked *and was created in the current year*:
 - a. Request deletion of the Fulcrum record and the loaded data.
 - b. Create a new Fulcrum record and enter updated information into only those fields that require correction. Data in other fields should remain unchanged.
3. If the record is not locked:
 - a. Edit the existing record and enter updated information into only those fields that require correction. Data in other fields should remain unchanged.
 - b. Downstream *VST: Apparent Individuals* records will need to be updated to reflect taxonID changes made in *VST: Mapping and Tagging*; that is, changes to the *VST: Mapping and Tagging* record do not push automatically to downstream records.



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SOP E Vegetation Structure Data Collected on a 5-Year Interval

Overview

In this SOP, we describe measurements collected on a 5-year interval for all qualifying woody and non-woody growth forms (**Figure 11**). All qualifying woody and non-woody individuals are sampled every 5 years in Distributed Plots (**eventType** = distributedAndTowerSubset) and Tower Plots (**eventType** = allTowerPlots). Importantly, the full complement of VST Distributed Plots is sampled in a different year than the full complement of VST Tower Plots (**Table 3**). Additional measurements performed annually in a subset of Tower Plots are described in SOP F. Subsections of this SOP address the following:

- **SOP E.1:** The procedure for measuring stemDiameter and guidance for recording plantStatus, measurementHeight, and other critical data.
 - SOP E.1.1 illustrates stemDiameter measurement for complex scenarios.
 - SOP E.1.2 describes strategies for determining liana stemDiameters.
 - SOP E.1.3 provides guidance for individuals that no longer qualify.
 - SOP E.1.4 describes required data when a previously sampled individual is lost.
- **SOP E.2:** Guidance for determining individual shape ('sis' and 'sms' only), measuring height, crown diameters, and assessing canopyPosition.
 - SOP E.2.1 describes strategies for measuring broken individuals when either all or a subset of boles are broken.
- **SOP E.3:** The procedure for measuring 'grouped' individuals that cannot be sampled separately due to dense stems that cannot be accessed without damaging either vegetation or staff.
- **SOP E.4:** Guidance for sampling other non-woody growthForms for which vegetation structure data are appropriate, including ferns, tree ferns, palms, and others.
 - SOP E.4.1: Fern sampling guidance.
 - SOP E.4.2: Tree fern sampling guidance.
 - SOP E.4.3: Guidance for sampling palms, small palms, ocotillo, xerophyllum, and yucca (and agave).
 - SOP E.4.4: A summary table of required measurements for all 'other' growthForms.

Woody stemmed vegetation may exhibit numerous growth forms – from single, straight boles to multiple curved, branched stems, and more. The measurement strategy for woody individuals depends on growth form because allometric equations that relate structure to biomass require growth-form dependent input data. This protocol modifies guidelines established by the U.S. Forest Service (2012) for measuring tree species. Shrubs are measured according to Lutz et al. (2014) and Conti et al. (2019), and liana measurements are derived from Gerwing et al. (2006) and Schnitzer et al. (2008).



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Goals

1. Accurately classify individuals to growth form and thoroughly assess each plot for the presence of qualifying growth forms.
 - a. Review current bout **VST: Plot Meta-Data [PROD]** records for each plot and update if any qualifying growth forms were missed during the initial survey (see SOP C).
 - b. Communicate with Science if changes to nested subplot size are required.
2. Map and tag new stems that now meet mapping and tagging requirements (see SOP D).
 - a. Collect new mapping and tagging data in the **VST: Mapping and Tagging [PROD]** app.
3. Determine which structure measurements are required for each qualifying individual in the plot and collect repeatable data from consistent locations on stems.
 - a. The measurements required for an individual are dependent on the assigned growth form (**Table 10**). Check for changes in required measurements based on changes in growth form through time – e.g., ‘sap’ grows to ‘smt’.
 - b. Collect data from all individuals with DBH \geq 10 cm, regardless of stem density – i.e., do NOT use nested subplots for trees (‘sbt’ or ‘mbt’), palm trees (‘ptr’), or large tree ferns (‘ltf’).
 - c. Record data in the **VST: Apparent Individuals [PROD]** and **VST: Shrub Groups [PROD]** applications.
 - d. Consult the ‘Manual for Fulcrum Application: TOS Vegetation Structure [PROD] – All SOPs’ for data entry details (RD[14]).

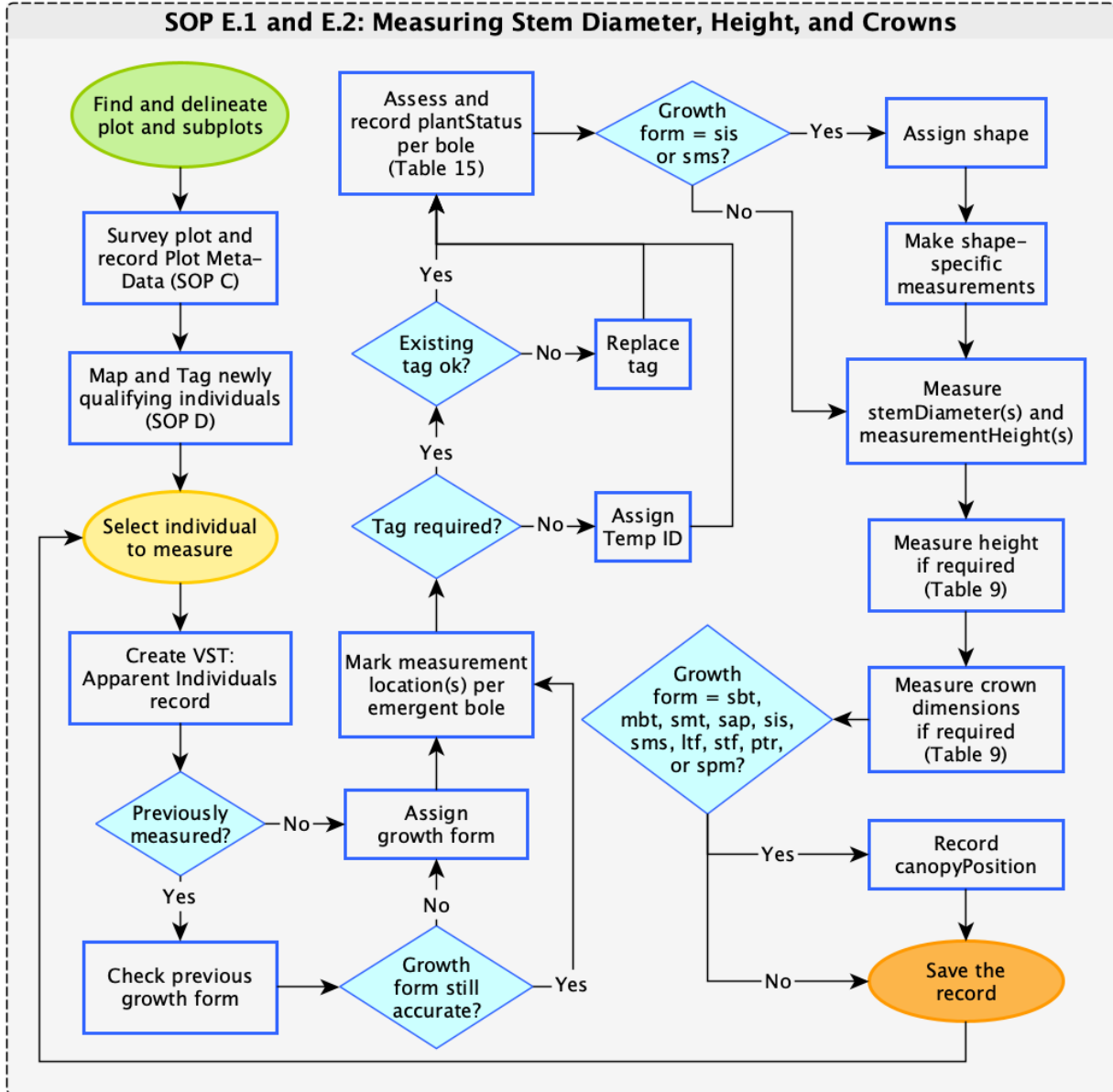


Figure 11. SOP E.1 and E.2 workflow diagram for stem diameter, height, and crown dimension measurements collected from apparent individuals. Diagram supports and does not replace protocol text; most common workflow is outlined.



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E.1 Stem Diameter Measurements

This section describes collecting diameter at breast height (DBH) measurements and basal stem diameter (ddh) measurements that are required inputs for allometric equations used to estimate woody biomass. This section also describes assessment of plant status (live, dead, etc.) and other variables that are required for accurate biomass estimation.

- Bring per plot checklists (SOP A.3) of previously tagged individuals to the field to ensure that repeat measurements are obtained for as many apparent individuals as possible. Missed individuals significantly impact plot-level productivity estimates.
- (Optional) It is helpful to mark trees to track work progress. One method is to use temporary flagging that is removed once data have been collected.

Procedure steps for each qualifying apparent individual:

1. (If necessary) Create a parent record in the *VST: Apparent Individuals* app for the plot and enter required information.
2. Select an individual and determine the **growthForm** (see **Table 9**).
 - a. A quick, initial assessment of **stemDiameter** (DBH or ddh) may help guide classification.
 - b. Remember that **growthForm** values may change from year to year.
 - i. *Example:* A ‘sap’ grows into a ‘smt’.
 - ii. *Example:* A ‘sbt’ breaks below 130 cm and becomes a ‘sap’ due to resprouts from the root collar.
3. Determine the **measurementHeight**(s) for each of the qualifying stems of the individual – i.e., the distance along the bole(s) at which the **stemDiameter** is measured, beginning from the root collar – i.e., typically where the bole emerges from the ground (see **Table 12**, **Table 13**, and SOP E.1).
 - a. The **measurementHeight** is determined independently for multiple emergent boles that are part of the same individual.
 - b. In many cases, the measurement location will already be marked with lumber crayon.
 - c. Re-use previously measured **measurementHeight** values if within ± 5 cm of the observed height in the current year.
 - i. If re-measuring indicates the previous measurementHeight is more than ± 5 cm different from the actual measurementHeight, update with the new value.
 - ii. **!!!** Do NOT move the actual location on the bole at which the DBH is measured unless absolutely necessary: A meaningful time-series depends on this location staying constant.



- d. DO move the actual measurement location on the bole and record a new **measurementHeight** if the previous measurement location becomes unusable.
 - e. Consult **Appendix H** when determining **measurementHeight** in snow.
4. Select a bole to measure. For a multi-bole individual, the steps below are repeated per bole.
5. Use the **changedMeasurementLocation** field to document when the actual measurement location on the bole must be moved.
 - a. **noChange**; measurement location is consistent with previous measurement location.
 - b. **deformityGrowth**; growth of a deformity compromises past measurement location.
 - c. **branchGrowth**; growth of a branch compromises past measurement location.
 - d. **damage**; localized damage compromises past measurement location.
 - e. **newRootingPoint**; the measurement location is shifted relative to a new rooting point (typically applied to lianas).
 - f. **boleChange**; a different emergent bole is selected for measurement and the measurementHeight may or may not be different than previously recorded (e.g., the thickest fork of a 'sis' changes, the previously measured fork of a 'sis' is broken or absent, or an 'sbt' breaks below 130 cm and re-sprouts are then measured).
 - g. **protocolChange**; measurement requirements changed between protocol versions, or as described in 2.c.i above, the previous measurementHeight is incorrect and is more than ± 5 cm from the correct measurementHeight.
6. Mark (or re-mark) the bole at the desired **measurementHeight** with lumber crayon or equivalent to enable repeat measurements at the exact same location.
 - a. Mark boles with $DBH \geq 30$ cm at multiple points around the bole to ensure accurate re-measurement.
 - b. (Optional) For forked 'mbt' and 'smt', mark the pith intersection point(s) for future reference (SOP E.1.1, **Figure 13**).
7. Assess whether a diameter tape or calipers should be used to measure stem diameter.
 - a. **Use a diameter tape for**: Self-supporting stems or large lianas with $DBH \geq 5$ cm, AND that do NOT have lianas, fungal growth, etc. that will interfere with accurate diameter measurement.
 - b. **Use calipers for**:
 - i. Self-supporting stems or lianas with $DBH < 5$ cm; use Vernier calipers to measure the stem at its widest point, and perpendicular to its widest point. Calculate the average and record. Diameter tapes are less accurate for small stems.



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- c. **tagStatus**; select from the following options:
 - i. **ok**; select if:
 - a) Previously attached tag exists, is legible, and value is consistent with previously entered value, OR
 - b) A new tag has been attached because the individual did not previously qualify for measurement, OR
 - c) A new tag has been attached because the previous tagID value could not be determined with $\geq 90\%$ certainty and the previous tagID was swapped for a new tagID.
 - ii. **replaced**; tag no longer attached, readable, etc., and the previously recorded tagID value can be surmised with $\geq 90\%$ certainty (via VST Mapper, process of elimination, or other means). Tag has been re-made with previous number.
 - iii. **notRequired**; applicable to many non-woody ferns, yucca, and cactus for which longitudinal data are not collected (see **Table 12**).
 - iv. **tagRemoved**; tag has been removed, and individual will not be measured in future years (see SOP E.1.3 and SOP E.1.4). Also applicable if tag is found not associated with any individual (e.g., after a fire).
 - d. **taxonID**; for reference only. Update in *VST: Mapping and Tagging* if needed.
9. Assess and record the **plantStatus** for the selected bole (**Table 15**).
- a. See SOP E.1.1 for guidance for multi-bole individuals with mixed plantStatus.
 - b. If **plantStatus** = 8 or 16: Skip to Section E.1.3
 - c. If **plantStatus** = 3, or 11-15: Skip to Section E.1.4

Table 15. List of **plantStatus** codes and definitions.

Code	Definition
1	Live – any live Apparent Individual that is of typical healthy status for the site. If minor insect damage or foliar disease is typical on most individuals, use this code rather than code 4 or 5 below.
2	Standing dead – any dead individual, or standing dead bole within a multi-bole individual, regardless of cause of death. The entire tree or bole must be dead, and the bole is NOT broken. For dead, broken boles see additional code below. Indicate factors associated with death in order of importance in the remarks field. Only record a specific cause of death when observable evidence indicates the cause: <ul style="list-style-type: none"> • Unknown: It is common to have no observable evidence as to the actual cause of death. • Biotic: Suppression, animal damage, mistletoe • Disease: Blister rust, rot, canker, other (specify), unknown • Insect: Bark, defoliating, other; specify insect species if possible • Physical: Crown damage, crushed, lightning, other (specify if possible) • Fire: Crown scorch, crown combustion, bole/stem scorch, bole/stem combustion, burned through at base (for small trees, due to litter & duff burning around base), other (describe).



Code	Definition
3	Removed – an individual that has been cut and removed by direct human activity related to harvesting, silviculture or land clearing (re-measurement plots only). If the individual is a species that may resprout and eventually qualify again for measurement record ‘no longer qualifies’ rather than ‘removed’.
4	Live, insect damaged – Visible damage caused by insects that exceeds trace amounts that may be present on typically healthy trees; note ‘crown’ or ‘bole’ damage in remarks , and indicate type of insect causing damage if there is evidence (e.g., Mountain Pine Beetle, Spongy Moth, etc.)
5	Live, disease damaged – Visible damage caused by disease that exceeds trace amounts that may be present on typically healthy trees; note ‘crown’ or ‘bole’ damage in remarks and indicate type of disease causing damage if there is evidence (e.g., Blister Rust, rot, canker, other (specify), unknown).
6	Live, physically damaged – Visible damage not caused by insects or disease, but of known origin; note ‘crown’ or ‘bole’ damage in remarks , and indicate type of physical damage (e.g., partial break, bole scar, girdling, snow/ice damage, crushed, lightning, crown scorch, bole scorch, ungulate herbivory, human damage).
7	Live, other damage – Visible damage of other origin, e.g. biotic suppression; note ‘crown’ or ‘bole’ damage in remarks and note cause of damage if there is evidence.
8	No longer qualifies – note reason in remarks ; record in multiple years if individual is still alive and may qualify in the future. Reasons for not measuring include: Individual no longer qualifies (e.g., broken and remaining live shoots do not qualify), change in nested subplot size, etc. See SOP E.1.3
9	Live, broken bole/stem – individual with broken top, with broken main bole and ascending leaders (that may or may not be taller than the break point), or that is broken and dead at top but live below, etc. If known, indicate factors that may have caused the break and other damage in order of importance in the remarks field. When damage does not result in a clean break in the bole/stem, record ‘Live, physically damaged’.
10	Dead, broken bole/stem –all parts of the broken bole or stem are dead; may have broken spike top, or dead leaders ascending beyond the break point. Use ‘2 – Standing dead’ above if the break is not complete. If known, indicate factors associated with death and the source of damage in order of importance in the remarks field.
11	Lost, burned – A previously measured individual that is not measured in the current bout because the plot has been burned, and the individual could not be re-located for measurement. Cause of loss is presumed to be fire.
12	Lost, herbivory – A previously measured individual that is not measured in the current bout because the individual could not be re-located for measurement. Cause of loss is presumed to be herbivory.
13	Lost, presumed dead – A previously measured individual that is not measured in the current bout because it could not be re-located for measurement. The individual is presumed dead based on evidence within the plot. If known, note presumed cause of death in the remarks field (e.g., blowdown event). Also applicable when a tag is found on the ground unassociated with an individual.
14	<i>Deprecated – no longer in use</i>
15	Lost, fate unknown – A previously measured individual that is not measured in the current bout because the individual could not be found. For small individuals, a status of ‘lost’ may be temporary. Also applicable when a tag is found on the ground unassociated with an individual and there is no evidence to suggest death.
16	Downed, dead – A previously measured individual that is not measured in the current bout because it is > 45° from vertical and is dead. Also applicable when: <ul style="list-style-type: none"> • Most of the individual has fallen and the remaining rooted, dead bole is broken completely and has height < 130 cm and there are no re-sprouts, or • When an individual has broken completely and begun to fall but has become supported by other vegetation before reaching the ground.



10. Record the **growthForm** determined in step (2).
11. Measure the **stemDiameter** at the required **measurementHeight(s)**. See **Table 10** for growth-form-dependent requirements (DBH, ddh or both). All diameter cutoffs that determine measurements are hard cutoffs – do not round.
 - a. Place the diameter tape or calipers directly over the marking(s) from step (3).
 - i. Take care to avoid sloughing bark when collecting data. Negative growth can be perceived due to bark loss. (Optional) Record in **remarks** if peeling/flaking bark results in negative growth increment.
 - ii. For large boles, the tape must not slip above or below the desired **measurementHeight**.
 - b. QC in the field: Check current measurement against previous measurements if prior year data are available. Repeat the measurement if necessary and optionally record “diameter verified” in **remarks** if current measurement is significantly different from the previous measurement.
12. Record in the *VST: Apparent Individuals* app:
 - a. **stemDiameter** (growthForm dependent): The diameter of the bole perpendicular to the pith, typically 130 cm along the bole for DBH; nearest 0.1 cm. Not recorded when growthForm = ‘sap’ or ‘sms’.
 - b. **basalStemDiameter** (growthForm dependent): The basal diameter of the bole, typically 10 cm above the ground; nearest 0.1 cm. Recorded only when growthForm = ‘sap’, ‘sis’, or ‘sms’.
 - c. **measurementHeight(s)**: Distance along the bole at which the **stemDiameter** or **basalStemDiameter** is measured; nearest 1 cm. Both DBH and ddh are required for ‘sis’ individuals.
 - i. If the desired measurementHeight is out of reach for all but the tallest foresters, adjust downward to ensure that repeat measurements can be made by the average person (see SOP E.1.1 Case B for how to deal with compound splits that often lead to this situation).
 - d. **changedMeasurementLocation**; select from the drop-down if the actual location along the bole where the measurement is made moves relative to its position in previous years. See step (4) for definitions.
 - e. **measurementStrategy (lia only)**; select the liana morphology from SOP E.1.2 that best informs the measurement strategy for the individual.
 - i. If multiple measurement strategies are combined, select the most relevant from the drop-down.



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- ii. You may record **remarks** to help ensure a consistent measurement strategy if multiple strategies are combined.

13. To record **stemDiameter** for individuals with multiple qualifying boles:

- a. For trees (growthForm = 'mbt'):
 - i. Create a new child record for each qualifying bole, each of which has a *unique tagID* – e.g., 01234 (largest bole), 01234A (next largest), 01234B (etc.).
 - ii. Keep tagIDs constant through time – i.e, do not change the tagID if what was initially the second largest bole becomes the largest.
- b. For all others (growthForm = 'smt', 'sap', 'sis', 'sms', or 'lia'):
 - i. Create a new child record for each qualifying bole, each of which has the *same tagID*.
 - ii. Assign a **tempID**; this ID is an incremented integer assigned to each qualifying stem. Combined with the tagID, the tempID uniquely identifies the stem in the database within a year. Incrementing starts over for each individual. Within an individual, it is not important which tempID is assigned to a given bole from year to year.

14. Measure and record required **height** and **crown** measurements according to SOP E.2.

- a. For multi-bole individuals, complete height and crown diameter measurements considering all boles together and record the data in the child record associated with the largest bole.



E.1.1 Stem Diameter Measurement Guidelines

In the sections below, guidelines for tree measurement were adapted from the U.S. Forest Service Forest Inventory and Analysis National Core Field Guide (U.S. Forest Service 2012). The approach for measuring shrubs was developed in collaboration with researchers from the ForestGEO network (Lutz et al. 2014).

Irregular Boles

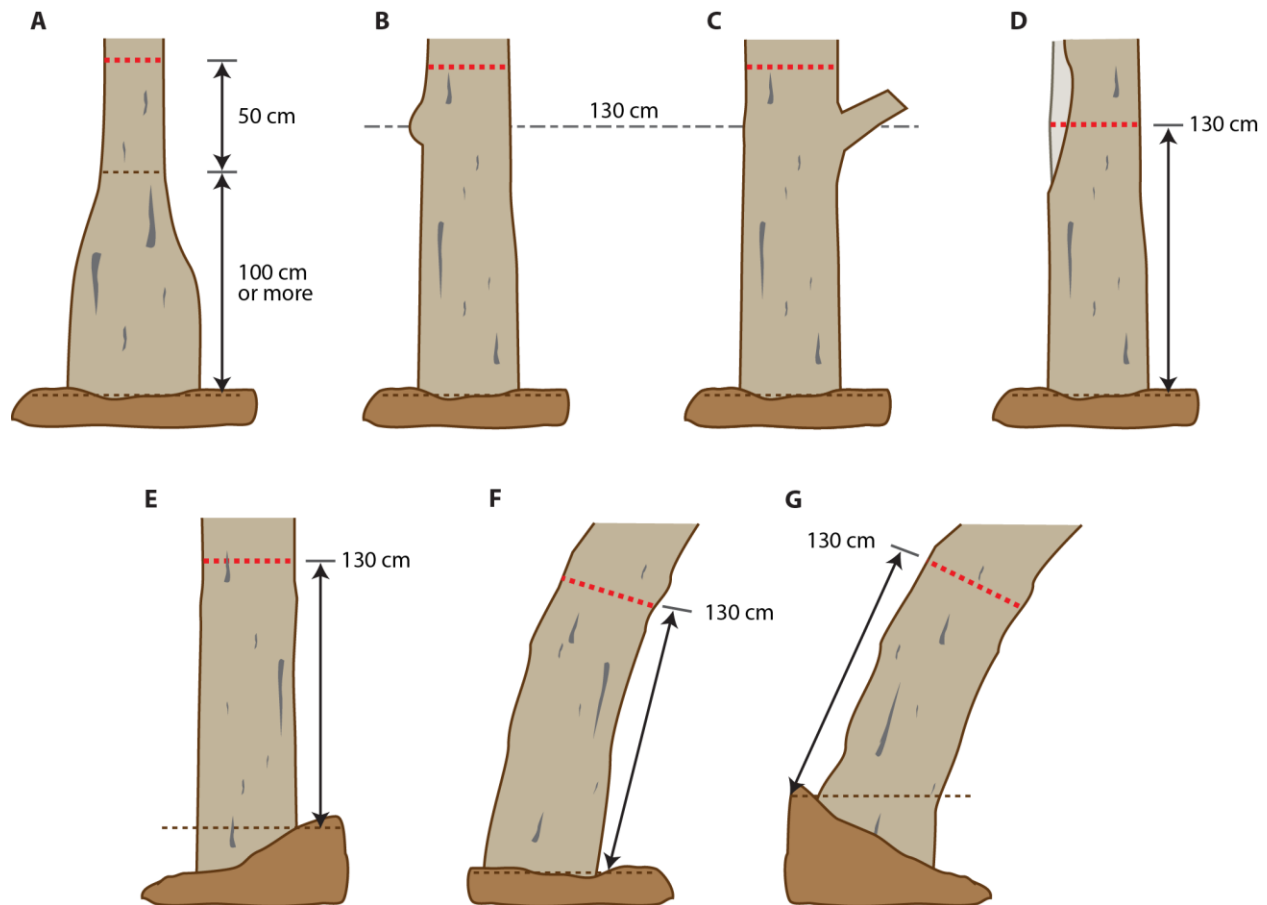


Figure 12. Stem diameter measurement guidelines for irregular single-bole trees. The lowest dashed line represents ground level from which the desired measurement height is referenced. The thick dashed red line shows the desired measurement height above ground level. Tags are typically placed 10 cm above the measurement height.

- (A) Pronounced thickening near the base. If the point at which swelling returns to normal is ≥ 100 cm above the ground (top dashed line), measurementHeight for bole diameter is 50 cm **ABOVE** this point. Also applicable if the root collar is elevated 100 cm or more above the ground – i.e., the individual is growing upright on a stump, boulder, etc. with roots extending to the ground.



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- (B) Irregularities at breast height. If swelling, bumps, depressions or other irregularities occur at breast height, move the measurementHeight **ABOVE** the irregularity to a point where the bole becomes regular again.
- (C) Branches at breast height. Similar to (B), move the measurementHeight **ABOVE** the branch to a point where the branch no longer affects bole diameter and the bole is “regular.”
- (D) Missing wood or bark. If a tree is missing substantial wood or bark at the desired measurementHeight (light grey indicates exposed wood and missing bark), do not attempt to reconstruct the diameter as it would appear without the damage. Measure the DBH of the wood and bark that is present, and optionally note in the **remarks** that bark is missing. However, if the damage is localized, treat it as an irregularity, and measure as in (B).
- (E) Sloped ground. Consider ground level to be the uphill side of the bole and measure DBH 130 cm above this point.
- (F) Leaning tree. Measure diameter 130 cm along the bole on the underside face.
- (G) Leaning tree on a slope. Consider ground level to be on the uphill side of the bole as in (E) and measure diameter 130 cm along the bole on the uphill face.



Multi-Bole Trees

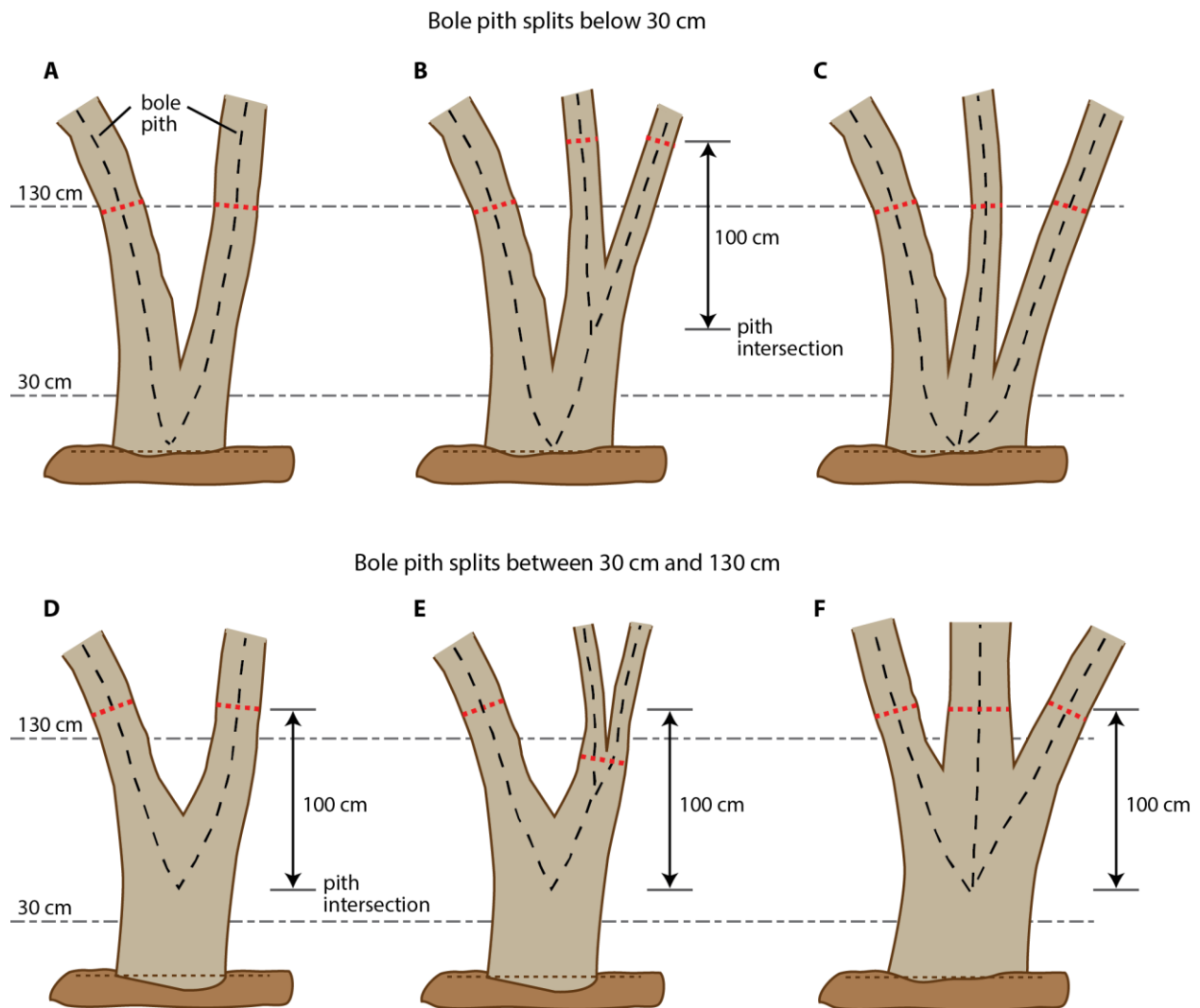


Figure 13. Stem diameter measurement guidelines for multi-bole trees with pith splits. See **Figure 16** for Shrub guidance.

- (A)** Simple split. Piths intersect ≤ 30 cm above the ground. Measure stemDiameter on each bole 130 cm above the ground, or 130 cm along the stem if curved.
- (B)** Compound split. Primary piths intersect ≤ 30 cm above the ground. Because each of the two main boles are measured separately, stemDiameter on the left bole is measured 130 cm above the ground. However, the right bole forms a secondary split between 30 cm and 130 cm. Here, the stemDiameter of the secondary splits are measured 100 cm above the point of the secondary pith intersection*.



- (C) Multiple boles. Multiple piths originate from the same point ≤ 30 cm above the ground. Measure stemDiameter on each bole 130 cm above the ground, or 130 cm along the stem if curved.
- (D) Elevated simple split. Simple split with piths intersecting > 30 cm and ≤ 130 cm above the ground. Forks originating between 30 cm and 130 cm are measured 100 cm above the pith intersection point*.
- (E) Elevated compound split. Primary piths intersect > 30 cm and ≤ 130 cm above the ground. The left primary fork is assessed independently from the right one. On the left, stemDiameter is measured 100 cm above the primary pith intersection point*. The right bole forms a secondary split between 30 cm and 130 cm; in this case, once a stem is tallied as a fork originating from a primary split between 30 cm and 130 cm, ignore any additional forks, and measure just below the base of stem separation. That is, do not measure stemDiameter the full 100 cm above the primary pith intersection point.
- (F) Elevated multiple boles. Multiple piths originate from the same point > 30 cm and ≤ 130 cm above the ground. To qualify, multiple boles must originate from roughly the same point along the main bole. Each bole is assessed independently, and stemDiameter is measured 100 cm above the pith intersection point.

In the figure above, all individuals are either 'mbt' or multi-bole 'smt' growthForms (not Shrubs, see **Figure 16** for Shrub guidance). Furthermore:

- * For (B), (D), and (E): In the event the pith intersection for the secondary fork on the right occurs close to 130 cm, the resulting desired measurement location may be out of reach for all but the tallest foresters. Adjust the measurementHeight downward to a maximum of 200 cm, if necessary, to ensure that repeat measurements can be made by the average person. Repeatability is more important than reaching exactly 100 cm above the fork in the pith.
- The lowest, finely dashed line represents ground level from which the 30 cm and 130 cm reference heights are drawn (multi-dashed background lines).
- The thick dashed red line shows the desired measurement height above ground level.
- If the bole is not growing vertically, measure 130 cm along the bole, rather than 130 cm above ground. Diameter is measured perpendicular to the pith.
- Large dashed black lines indicate the pith of each bole.
- Tag 10 cm above the measurementHeight (ideally) or according to site host specifications.
- To qualify as a split, or fork, the stem in question must be at least $\frac{1}{4}$ the diameter of the main bole and must branch out from the main bole at an angle of $< 45^\circ$.
 - The presence of a qualifying fork may require shifting the measurement height (cases B, D, E, and F). Moving the measurement height upward to the required height may cause one or both forks to no longer qualify for measurement.



- **Exception:** Forks that are < 2.5 cm diameter are NOT sampled, even if they meet the $\frac{1}{2}$ diameter requirement. This exception holds for 'mbt' and multi-bole 'smt' individuals.
- Forks originate at the point on the bole at which the piths intersect.

Live Downed Trees

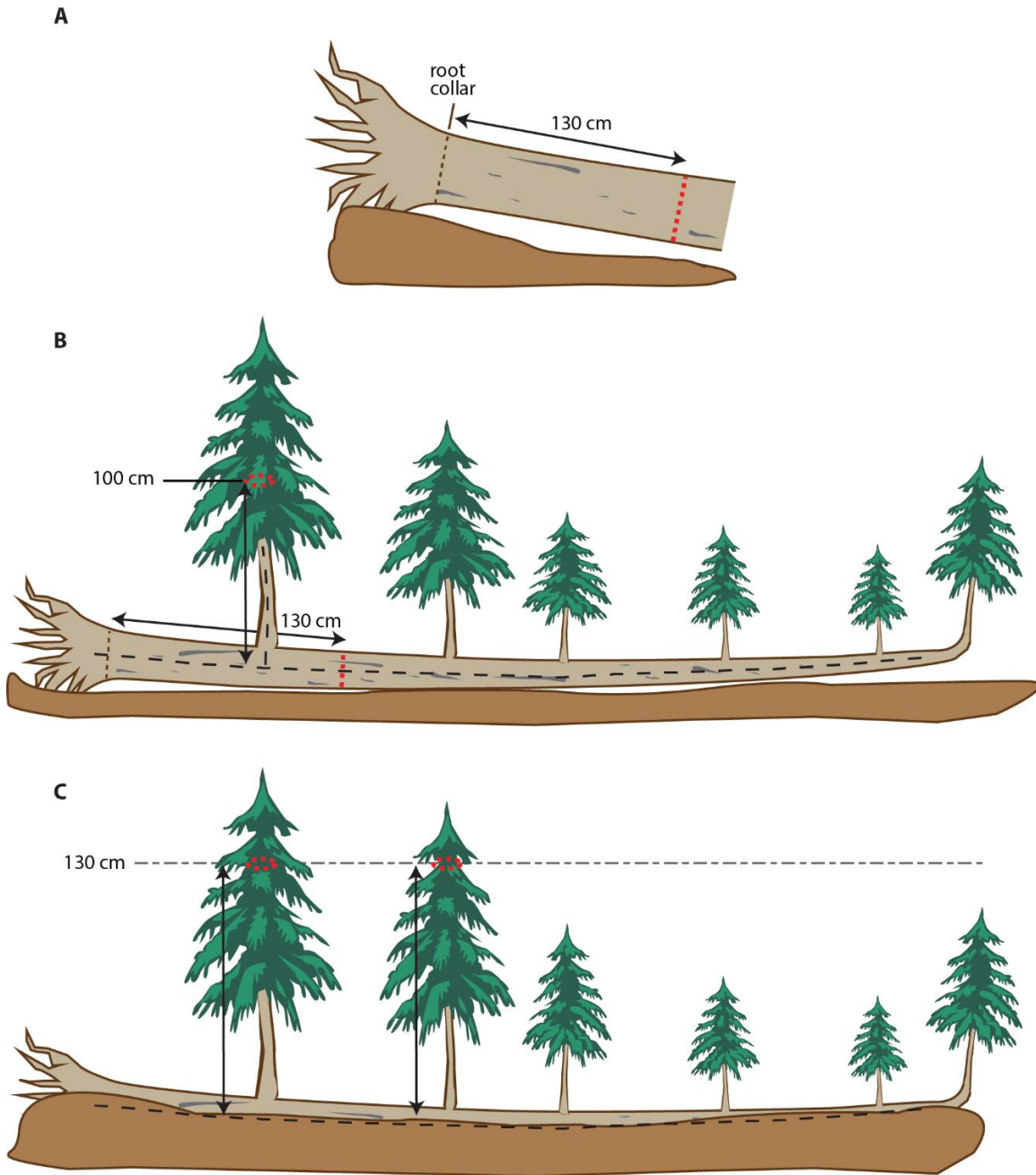


Figure 14. Stem diameter measurement guidelines for live, downed trees.



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For **(B)** and **(C)**, consider a downed live tree, touching the ground, with tree-like branches that originate from the main bole, AND are less than 45° off the vertical. If the pith of the main bole (black dashed line) is above the duff layer, assess according to **(B)**, and if the pith is below the duff layer, assess according to **(C)**.

- (A) Live windthrown tree.** Measure 130 cm along the bole from the top of the root collar. Tag 10 cm above the measurement location.
- (B) Pith above duff.** Use the same forking rules specified for a forked tree (**Figure 13D**), and measure and tag accordingly. If the intersection between the main downed bole and the tree-like branch is > 130 cm along the main bole, treat that branch as part of main bole – i.e., ignore it.
- (C) Pith below duff.** Ignore the main bole of the tree and assess each tree-like branch individually to determine whether it qualifies for measurement. In the figure, the two left-most tree-like branches are ≥ 10 cm DBH and are measured 130 cm above the ground (not necessarily equal to measuring from the top of the main downed bole). The other, smaller tree-like branches may qualify for measurement if they lie within the desired measurement area (i.e., nested subplot size).



Mixed Status Trees and Single Shrubs

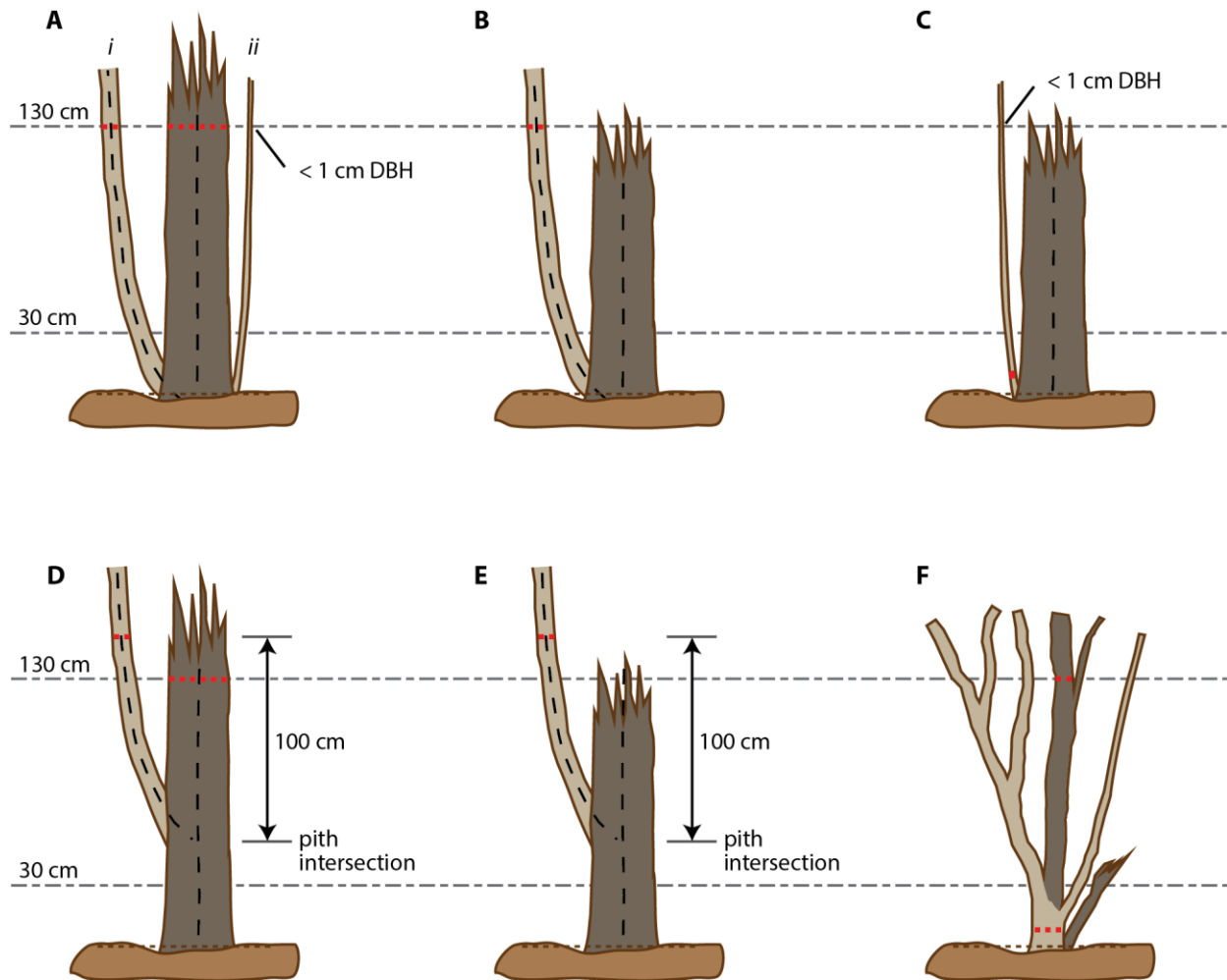


Figure 15. Stem diameter measurement guidelines for multi-bole individuals with mixed plantStatus (live/dead).

The figure above deals with trees (**A – E**) and shrubs (**F**) that have both living (light brown) and dead (dark brown) boles or portions of stems. The lowest, finely dashed line represents ground level from which the desired measurement height is referenced. The thick dashed red line shows the stemDiameter measurement location. For (**A – E**):

- Stump sprouts originate between ground level and 130 cm above the ground.
- Measure stump sprouts the required distance along the bole if it is growing off the vertical.
- If the broken stump is > 130 cm height: Stump sprouts are handled the same as forked trees; resprouts must be $\frac{1}{3}$ the DBH of the broken stump and ≥ 2.5 cm diameter to qualify.
- If the broken stump is < 130 cm height: Stump sprouts are treated as the same individual and are measured as either ‘sap’ or ‘smt’, depending on size.
- For multi-stemmed woodland species, treat all new sprouts as part of the same new tree.



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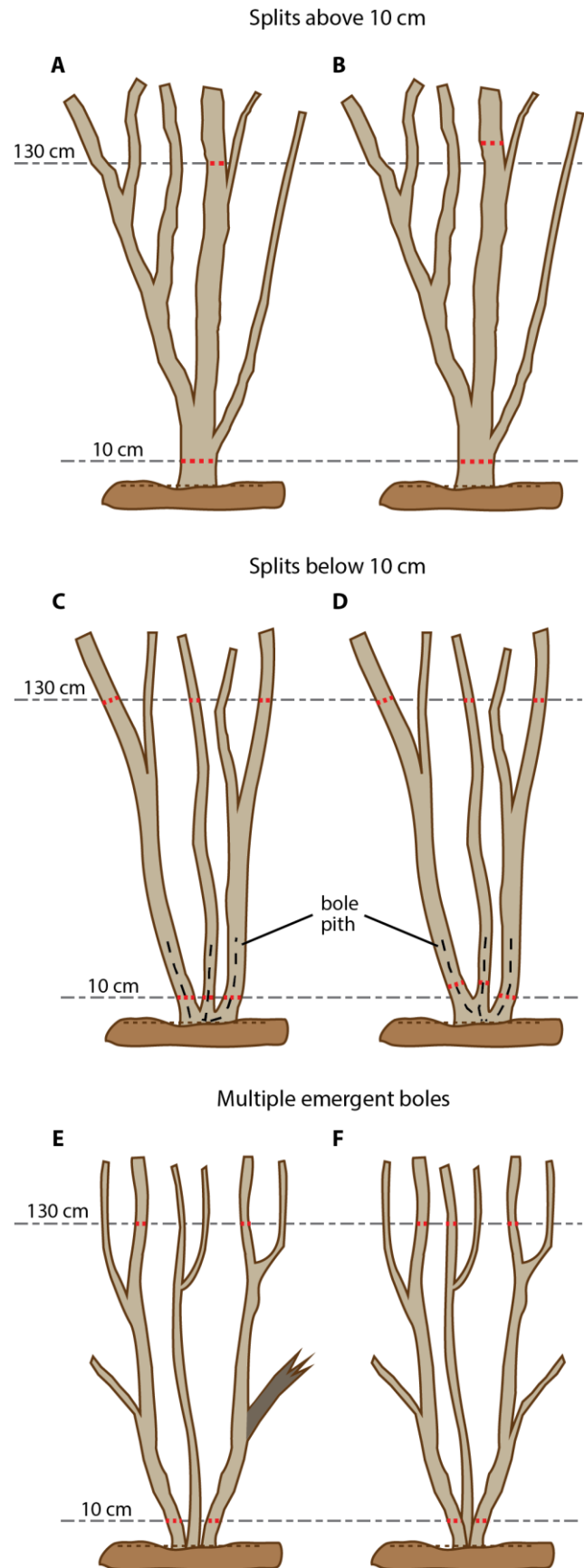
- (A) Dead main bole that is > 130 cm height with resprouts (*i* and *ii*) that have piths intersecting with the main dead bole somewhere below the ground. Growth form is a multi-bole tree (mbt). Similar to when the main bole is alive, measure the DBH of each qualifying bole 130 cm above the ground. (*i*) Resprouts with DBH > $\frac{1}{3}$ the DBH of the main bole and ≥ 2.5 cm diameter qualify for sampling; (*ii*) resprouts that do not qualify are not sampled but their presence may be noted in the **remarks** of the record associated with the main dead bole. For the dead bole, record the break height, and record the diameter at the break height as well as DBH.
- (B) Resprout ≥ 1 cm DBH with dead main bole that is < 130 cm height. Measure DBH of the resprout 130 cm above the ground; ignore the dead main bole. The diameter of the resprout determines the growth form (sbt or smt); if growthForm = smt, only measure if the individual falls within the desired measurement area.
- (C) Resprout < 1 cm DBH with dead main bole that is < 130 cm height. Measure the diameter of the resprout 10 cm above the ground (ddh); ignore the dead main bole. The growthForm = sap, the tag is moved to the resprout (the largest if there are many), and the individual is only sampled if it falls within the desired measurement area (i.e., nested subplot).
- (D) Resprout ≥ 1 cm DBH with pith intersecting that of the main bole between 30 cm – 130 cm above the ground. The DBH of the resprout is > $\frac{1}{3}$ the DBH of the main bole and ≥ 2.5 cm diameter. Growth form is a multi-bole tree (mbt). Similar to when both boles are alive, measure the diameter of the resprout 100 cm above the pith intersection point. Measure the dead bole as in (A).
- (E) Resprout ≥ 1 cm DBH with pith intersecting main dead bole ≥ 30 cm above the ground, and the dead bole is < 130 cm height. Measure the DBH of the resprout 100 cm above the pith intersection point, and ignore the main dead bole. The growthForm is determined by the DBH of the resprout and may be 'smt' or 'sbt'.
- (F) Shrub with plantStatus = '2 – standing dead' for largest emergent stems and broken dead stems with plantStatus = '10 – dead, broken'. If the individual has multiple qualifying emergent stems > 130 cm height (or total length) with different status, DO record status separately for each emergent stem. Measure DBH at 130 cm on largest fork and measure ddh. Ignore broken emergent stems (alive or dead) that are < 130 cm height (or total length if growing off the vertical). Refer to **Figure 17** for Sapling and Small Shrub guidance.



Single Shrubs

Figure 16. Shrub stem diameter measurement guidelines. Simple dashed black lines represent stem piths. Light brown shows live tissue, and dark brown indicates dead.

- (A) Simple shrub with unified base. Measure DBH at 130 cm (or along the pith for decumbent growth forms) on the **thickest** fork only, and measure diameter at decimeter height (ddh).
- (B) Irregular at DBH. Similar to (A), but with a branch point at 130 cm on the largest fork. Move the measurement height up on the largest fork so the DBH is not influenced by the branch.
- (C) Multiple stems connected above ground. Piths intersect below 10 cm and originate from a visible root collar. Consider emergent stems separately for **stemDiameter** and assess stems together for height and crown diameter(s). Measure DBH at 130 cm on the thickest fork of each emergent stem and measure ddh for each emergent stem with qualifying DBH.
- (D) Irregular at ddh. Similar to (C), but the base of stem separation for the left two stems occurs right at 10 cm above ground. Because the piths intersect below 10 cm, the left two stems are still considered separately, but the stemDiameter is measured higher where the diameters are not affected by the fork.
- (E) Multiple stems connected below ground. If stems emerge independently from a buried root collar, consider each emergent stem separately for stemDiameter. Measure DBH on the thickest fork of each emergent stem at 130 cm height; the thickest fork on the right stem is dead/broken and ignored because it does not reach 130 cm. Measure ddh for each emergent stem with qualifying DBH; center stem does not qualify for DBH and is not measured for ddh.
- (F) **Access denied.** Similar to (E), but middle stem now qualifies at DBH, and desired ddh measurement height is no longer accessible. For the middle stem, DBH is measured and ddh is not measured if a measurement location cannot be accessed within the first 30 cm along the stem.



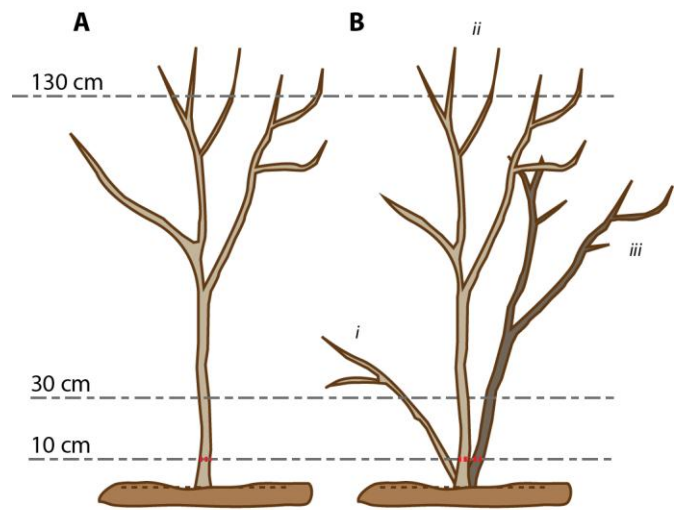


Saplings and Small Shrubs

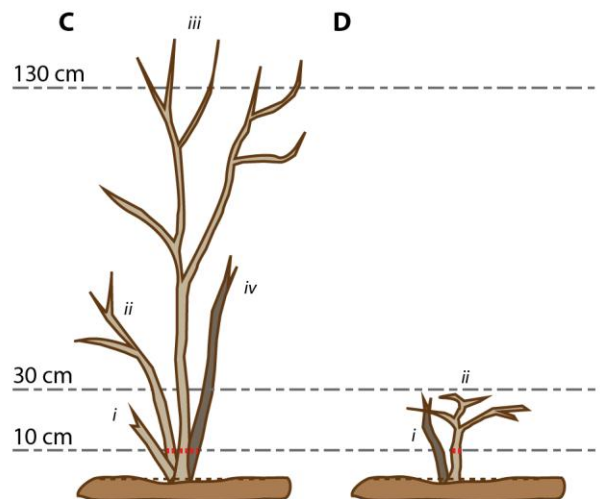
Figure 17. Stem diameter measurement guidelines for saplings and small shrubs that have no qualifying DBH. Light brown shows live, and dark brown indicates dead tissue. For all cases, consider emergent stems separately for basal stem diameter measurements, and consider all intact stems together when measuring crown diameter(s).

- (A) Simple sapling or small shrub with unified base.** Measure ddh 10 cm above the ground, or 10 cm along the stem for decumbent growth forms.
- (B) Multiple intact stems connected below ground.** (i) Ignored: ddh < 1 cm; (ii) Measure ddh, plantStatus = '1 – live'; (iii) Measure ddh, plantStatus = '2 – dead'.
- (C) Multiple intact and broken stems, connected below ground.** (i) Ignored: ddh ≥ 1 cm, but broken, and total length < 30 cm; (ii) Measure ddh, plantStatus = '1 – live'; (iii) Measure ddh, plantStatus = '1 – live'; (iv) Measure ddh: broken, but total length ≥ 30 cm, plantStatus = '10 – broken, dead'.
- (D) Mixed status dwarf small shrub.** (i) Ignored: ddh ≥ 1 cm, but broken, and total length < 30 cm; (ii) Measure ddh for live stems < 30 cm length if stem meets qualifying diameter and is not broken.

Intact Saplings and Small Shrubs



Broken Saplings and Small Shrubs



- (E) Multiple stems connected above ground (not depicted).** Determine the ddh measurement location as in C or D for “Single Shrubs” above in **Figure 16**, and collect basalStemDiameter and plantStatus data for each stem with ddh ≥ 1 cm.

Note: Saplings and small shrubs with a relatively decumbent growth habit may have multiple rooting points for one or more emergent stems. When this occurs, determine the diameter measurement location relative to the secondary rooting point (as in Case “D” for lianas in SOP E.1.2, **Figure 18**).



E.1.2 Liana Measurement Guidelines

The guidelines below support consistent measurement of complex liana growth forms (adapted from Schnitzer et al. 2008). Other complex ‘liana-like’ morphologies that are often adopted by *Vitis spp.*, *Smilax spp.*, *Parthenocissus quinquefolia*, etc. may also be measured according to these strategies.



Figure 18. Guidelines for determining where to measure liana stem diameter (red line) across a variety of complex growth forms. Different growth forms correspond to capital letters.

- (A)** Individuals that simply ascend into the canopy are measured 130 cm along the stem from the main rooting point.
- (B)** Twining individuals are measured 130 cm along the stem from the rooting point, including all twists and curves.
- (C)** Individuals that split below 130 cm from the rooting point are measured 20 cm below the branching point:
 - (1).** If the branch point is less than 40 cm from the ground, measure half-way between the branch point and the ground, where the stem is regular.
 - (2).** If the stem is not regular anywhere between the branch point and the ground, measure according to **(G)** below.
- (D)** Individuals that loop to the ground and root again before ascending to the canopy are measured 130 cm from the last rooting point.
- (E)** Like **(D)**, but the loops have branches that ascend to the canopy. Each rooted ascending stem with a leafy canopy branch is recorded separately as part of a multi-bole individual.



- (F) Individuals with rooted adventitious roots further than 80 cm from the main rooting point are measured 50 cm past the last root.
- (G) Individuals that branch below 130 cm but have a very irregular main stem or branch close to the ground. Measure branches separately at 130 cm and record as part of a multi-bole individual.
- (H) Ignore branches < 1 cm diameter and measure the principal stem 130 cm from the roots.
- (I) Exclude individuals that branch below 130 cm from the roots if none of the stems are ≥ 1 cm diameter at 130 cm above the roots.
- (J) Similar to (G) above.
- (K) Multiple rooting points in a small area: Measure each branch ≥ 1 cm diameter 130 cm from the roots of the most proximal rooting point.
- (L) Exclude “ground-to-ground” individuals that loop from one rooting point to another and do not ascend to the canopy. Also exclude those individuals that are prostrate on the soil, even if they are ≥ 1 cm in diameter.
- (M) Include “ground-to-ground” individuals if they have a resprout or branch, even if the branch is < 1 cm diameter. If the branch is < 1 cm, measure the principal stem 130 cm from the roots, ignoring the branch. If the branch is ≥ 1 cm diameter, and within 130 cm of the roots, the point of measurement should be on the ascending branch.
- (N) Exclude individuals growing prostrate on the soil if they do not have a stem ≥ 1 cm diameter ascending towards the canopy.
- (O) Exclude multiple branches that originate within 130 cm of the main roots if they are smaller than 1 cm diameter.
- (P) *Deprecated: Refer to Case (F)*
- (Q) If the stem is anomalous and not uniform below 130 cm from the root, measure 20 cm above the point where it becomes uniform; if there is no uniform area within reach, measure the stem 130 cm from the roots.
- (R) If the stem is flat and wide, include the individual if the mean of its wide and narrow axes is ≥ 1 cm diameter.

Implementing Liana Measurement Guidelines

From the cases presented in the figure above, generalized implementation strategies may be derived.

1. For any liana to qualify for measurement, at least one stem that is ascending toward the canopy must be greater than 1 cm diameter at a distance of 130 cm from the most proximal rooting point to ascension (rules **A, D**).
 - a. Lianas lacking any ascending branches do not qualify, regardless of their size (rule **L**).



- b. Measurements are taken 130 cm along the stem, including all twists and curves (rule **B**).
 - c. Oblong stems qualify if the average of the wide and narrow axes is greater than 1 cm (rule **R**).
 2. Exceptions to the above rules:
 - a. Individuals that loop from one rooting point to another (“ground to ground”) with an ascending branch < 1 cm diameter at a distance of 130 cm are measured along the principal stem 130 cm from the roots, ignoring the branch (rule **M**).
 - b. If a “ground-to-ground” individual has an ascending branch \geq 1 cm diameter at a distance of 130 cm, measure the ascending branch and do not measure below the split.
 - c. If a “ground to ground” individual does not have any ascending branches, the individual is not measured (rule **L**).
 - d. Lianas completely prostrate on the ground are ignored (rule **N**).
 3. Stems that branch below 130 cm may be measured with an altered measurement height depending on the following conditions:
 - a. Confirm more than one branch is > 1 cm diameter at 130cm before considering an altered measurement height. If only one branch qualifies at 130 cm, do not alter the measurement height (rules **H, I, O**).
 - b. If multiple branches qualify at 130 cm:
 - i. Measure 20 cm below the branching point (rule **C**).
 - ii. If the branching point is < 40 cm from the roots, measure halfway between rooting point and branch (rule **C**).
 4. Multi-bole individuals may be recorded in the following conditions:
 - a. If no regular point of measurement exists below a branching point (due to general stem irregularity, or branching very close to the ground), measure each branch separately at 130 cm (rule **G**).
 - b. If an individual has one or more branches that loop to the ground and re-root before ascending, measure each qualifying branch 130cm from its most proximal rooting point to ascension (rules **E, K**).
 5. Measurement heights may be altered on an individual stem or branch:
 - a. If a stem is irregular below 130 cm, measure 20 cm above the point where the stem becomes uniform. If no uniform area is within reach, measure at 130 cm regardless of the irregularity (rule **Q**).
 - b. Individuals with rooted adventitious (aerial) roots > 80 cm from the main rooting point are measured 50 cm past the last root (rule **F**).



E.1.3 Apparent Individuals That No Longer Qualify

Procedure steps for apparent individuals that no longer qualify for measurement and that can be relocated – e.g., the individual is not lost but is no longer measured due to a change in nested subplot size, wind-throw, damage, or other change.

1. Create a record in the *VST: Apparent Individuals [PROD]* app. Enter the following:
 - a. **tagID**; select the individualID value from the list of previously created *VST: Mapping and Tagging* records. Verify that the taxonID associated with the tagID is correct.
 - b. **plantStatus**; select plantStatus = '8 – no longer qualifies' or '16 – downed, dead'.
2. For **plantStatus** = '8 – no longer qualifies', record:
 - a. **tagStatus**; record as in SOP E.1. The tag may be left in place if there is a chance the individual will be measured again in the future; remove the tag if the individual was clearly tagged in error (e.g., it is clearly outside the plot). Examples of when a tag should be left:
 - i. Individual may be measured again if nested subplot size changes.
 - ii. Non-qualifying living shoots of a downed or broken individual may grow to qualify in the future.
 - b. **growthForm**; leave blank.
 - c. **remarks**; record 'change in nested subplot size' or a pithy phrase that describes the situation for end-users.
 - d. No additional data are collected.
3. For **plantStatus** = '16 – downed, dead', individuals should be dead and downed (> 45° from vertical) and not likely to produce re-sprouts that may eventually qualify for sampling. For dead, downed individuals, record:
 - a. **tagStatus**; select 'tagRemoved'. The 'tagRemoved' option should be selected even if the tag is left on the log for potential inclusion in the CDW Tally dataset; in this case "removed" means removed from the Vegetation Structure dataset.
 - b. **growthForm**; leave blank.
 - c. **remarks**; enter any brief observations relevant to a data end-user (e.g., a disturbance event already recorded in the *Site Management and Disturbance* app likely downed the individual).
 - d. No additional data are collected.



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E.1.4 Lost Apparent Individuals

Procedure steps for apparent individuals that cannot be relocated for measurement. Steps below apply to **plantStatus** = '3 – removed' or 11-15 (any variation of 'lost').

1. Create a record in the *VST: Apparent Individuals [PROD]* app. Enter the following:
 - a. **tagID**; select the individualID value from the list of previously created *VST: Mapping and Tagging* records.
 - b. **plantStatus**; select from '3 (removed)' or 11-15 ('Lost...') using guidance in **Table 15**.
 - c. **tagStatus**; while in the field:
 - i. Leave blank if the individual and its tag cannot be relocated and there is a chance the individual may be found again. Otherwise select 'tagRemoved'.
 - ii. Select 'tagRemoved' for any tags found not attached to an individual.
 - d. **growthForm**; leave blank.
 - e. **remarks**; enter any brief observations relevant to a data end-user or to NEON staff who may attempt to relocate the individual in a future sampling event.
Example: "Not found in 2025 or 2020, individual dead in 2018."
 - f. No additional data are collected.
2. While performing QAQC, use the VST QAQC Shiny application to review records with **plantStatus** = 'Lost...' to determine whether **tagStatus** should be set to 'tagRemoved' and they should be dropped from the dataset and not looked for in future bouts.
 - a. For plots sampled every 5 years: Set tagStatus = 'tagRemoved' for individuals not found for two consecutive bouts (including the current one).
 - b. For plots sampled annually: Set **tagStatus** = 'tagRemoved' for individuals not found for three consecutive bouts (including the current one).



E.2 Height and Crown Diameter Measurements




This section describes measurement of height, crown diameters, and assessment of ‘shape’ that informs these measurements for some growth forms.





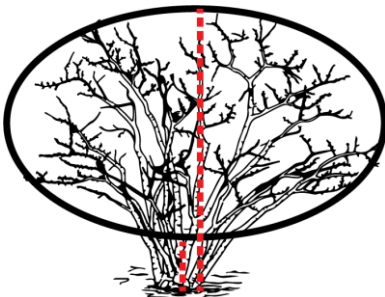
NOTE: NEON employs a 2-shot height routine for measuring height of individuals > 2 m tall. The 3-shot height routine built into the laser rangefinder is NOT used because the assumptions of the 3-shot routine cannot be easily verified in the field.

6. (For growthForm = ‘sis’ and ‘sms’ only) Determine the **shape** of the individual (**Table 16**). Shrub crown dimensions and height can be used to estimate volume according to idealized shapes.
 - a. For previously measured individuals, refer to the previously recorded **shape** for guidance. The **shape** can legitimately change through time, but it is desirable to re-use the previously recorded value if it is plausible (use the VST QAQC Shiny app to find previously recorded data).
 - b. Not all shrubs match an idealized shape: Choose the best fit and consider the stems and branches as they emerge from the ground level, not just the leafy crown.
 - c. There will not necessarily be a ‘correct’ shape to assign for a given shrub; that is, more than one shape can conceivably apply.
 - i. Shape may be relatively consistent from year-to-year, so use the previous year’s **shape** as a starting point (if available).
 - ii. Calibrate your judgement as a team prior to beginning work to enable consistent data collection through time and across teams.

Table 16. Idealized shapes for shrub volume estimation.

Shape	Example	Additional measurements
Half-sphere (hsp)*		None
Oblate half sphere (ohs)*		None
Cone (cne)		None



Shape	Example	Additional measurements
Inverted cone* (icn)		<ul style="list-style-type: none"> • maxBaseCrownDiameter (dashed red line); the maximum width of the shrub base, including ground-level branches or boles emerging from the ground for multi-bole individuals. • ninetyBaseCrownDiameter
Cylinder (cyl)		None
Ellipsoid or sphere (elp)		<ul style="list-style-type: none"> • baseCrownHeight (short dashed red line); the average height above the ground at which crown leaves begin. • height (long dashed red line) is already recorded

* Images from Ludwig et al. (1975)

7. Measure the **height** (if required for the growthForm). See **Table 10** for growthForm dependent requirements.

In select domains with very tall trees (D06, D08, D16, D17, D20), the **height** is not populated (and input **vdApexHeight** and **vdBaseHeight** are not recorded) if the top of a single- or multi-bole tree ('sbt' or 'mbt') cannot be seen from any angle. When this occurs, record **heightQualifier** = "No height recorded, treetop not visible".

Otherwise, record in the *VST: Apparent Individuals* app:

- a. **vdApexHeight**; the definition depends on the measurement method:
 - i. *Rangefinder*: The vertical distance between the top of the crown and the rangefinder (typically a positive number, **Figure 19A**); nearest 0.1 m. When using the rangefinder, make measurements until two measurements match within 1%, then record the mean.
 - ii. *Collapsible ruler, surveyor level rod, measuring stick, metal measuring tape, or equivalent*: If the individual is shorter than the measuring rod/tape, record the vertical distance between the top of the canopy and the ground (**Figure 19C**); nearest 0.1 m. If the individual is taller than the measuring device but the



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rod/tape can be held up so that it reaches the apex height, record vdApexHeight relative to an elevated point along the bole (**Figure 19B**) – e.g., breast height – and record to the nearest 0.1 m.

- b. **vdBaseHeight**; *Do NOT leave blank when vdApexHeight is populated!* The definition depends on the measurement method:
- i. *Rangefinder*: The vertical distance between the rangefinder and the tree base where it emerges from the ground (typically a negative number, **Figure 19A**); nearest 0.1 m.

NOTE: If the base of the tree is completely obscured to the person operating the rangefinder – due to debris, vegetation, CDW, etc. – hold the reflector a known height above the ground where it can be seen (e.g., 1.3 m), then measure vertical distance to the reflector and manually add the offset to obtain the correct **vdBaseHeight** value.
 - ii. *Collapsible ruler, surveyor level rod, measuring stick, metal measuring tape, or equivalent*: If the individual is shorter than the measuring rod/tape and vdApexHeight was measured relative to the ground, enter '0', since **vdApexHeight** already represents total **height** above ground (**Figure 19C**). If vdApexHeight was measured with a rod/tape relative to an elevated position (e.g., breast height, **Figure 19B**), enter vdBaseHeight as the inverse of the elevated position (e.g., –1.3 m).
- c. **height** (auto-calculated); if possible, compare with a previously measured height.
- i. For trees, palm trees, and large tree ferns ('sbt', 'mbt', 'ptr', 'ltf'), remeasure if observed height is > 1.0 m shorter than the previously observed value and no damage is obvious.
 - ii. For all other smaller growth forms, remeasure if observed height is > 5% shorter than previously observed value and no damage is obvious.
 - iii. To verify a measurement, check height from a few different locations around the tree. It is not necessary to match or exceed the previous **height**, only to verify to the best of your ability that the current measurement is accurate. Verification should not take more than a few minutes. When complete, add the **remark** "height verified".
 - iv. If height is uncertain due to foliage/understory in front of or behind the crown apex and the rangefinder, set the rangefinder Target Mode to "Closest (CLO)" or "Farthest (Far)" depending on the vegetation (see RD[09] for details), and collect additional measurements until a repeatable, convincing height is attained.



- v. When height remains uncertain after multiple measurement attempts, record the best estimate of **vdApexHeight** and **vdBaseHeight**, and record **heightQualifier** = “uncertain height measurement”. The “uncertain height measurement” qualifier may also be recorded if persistent water droplets form on the rangefinder lens.
- d. See SOP E.2.1 for strategies to deal with broken individuals.

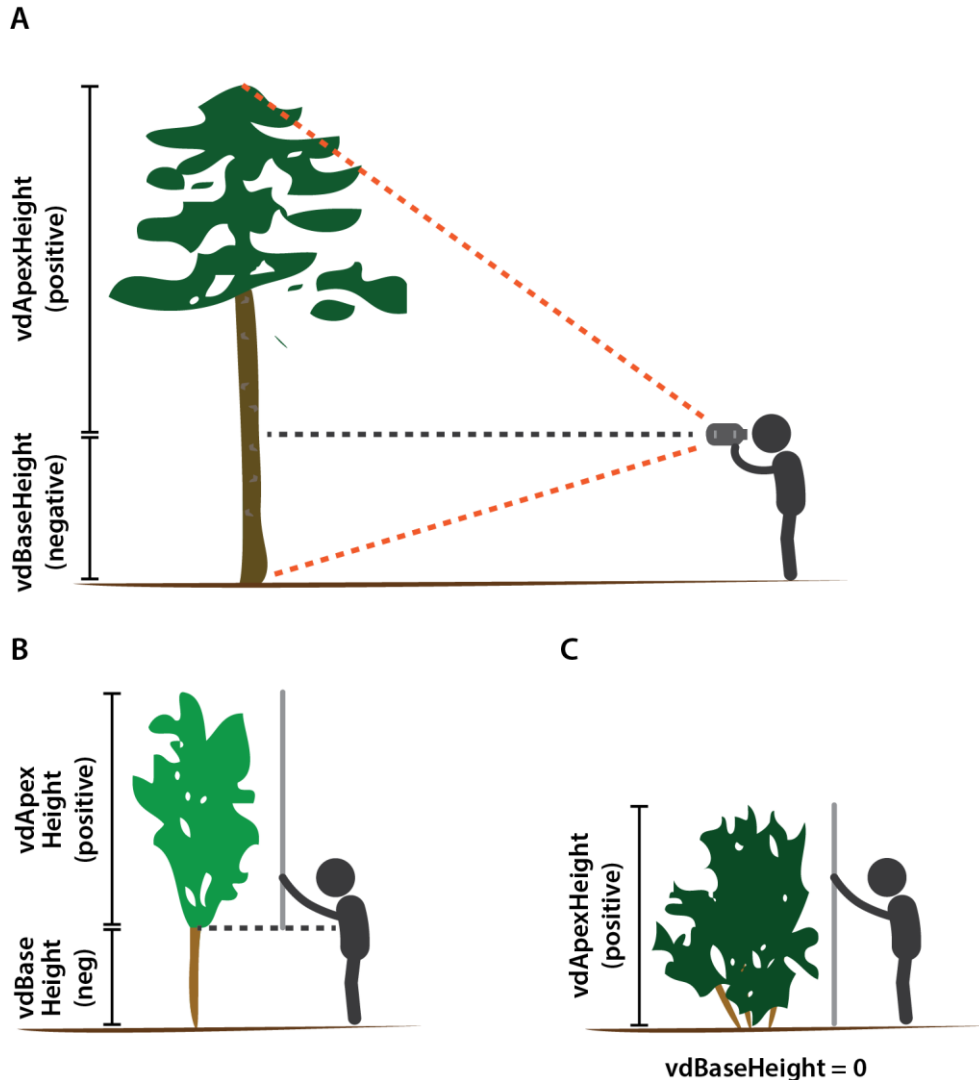


Figure 19. Strategies to collect **height** data from woody individuals. (A) For tall individuals, a rangefinder may be used with the 2-shot height routine to sight along the orange dashed lines and generate **vdApexHeight** and **vdBaseHeight**, which are positive and negative, respectively, relative to the observer height (the black dashed line); (B) For mid-stature individuals that are taller than the measuring rod but whose height can be reached when the rod is elevated, **vdApexHeight** can be measured relative to an elevated position – e.g., the dashed black line at breast height (1.3 m), and **vdBaseHeight** is entered as the inverse (e.g., -1.3 m); (C) For individuals shorter than the measuring rod, **vdApexHeight** is the height of the crown above the ground and **vdBaseHeight** = 0.



8. Measure **crown** dimensions (if required). See **Table 10** for growthForm-dependent requirements. When measuring crown diameter, the purpose is to record diameter data that approximate the area of the crown as seen from above.
- a. The **crown** dimensions may include live and dead material from both intact and broken boles / stems. Individual branches that are abnormally long, or individual boles for multi-stem 'smt', 'sis', or 'sms' that are abnormally long or stick out at abnormal angles relative to the majority of the crown, may be ignored. *Do not record crown dimensions for broken individuals with no remaining branches.*
- i. *Example:* A 'sbt' with a broken bole supports both live and dead branches below the break. Include all branches that contribute to the general shape of the crown.
- ii. *Example:* A 'mbt' has one bole that is broken, and this bole supports branches and foliage below the break that contribute to the general shape of the crown. Include the branches and foliage on this bole in your assessment of the individual's crown.
- iii. *Example:* A 'sis' has one broken emergent bole sticking out at an angle such that it is well removed from the remaining crown of the individual. Ignore this broken bole when measuring the individual's crown.
- b. For individuals that lean such that the crown is not over the rooting point, ignore the bole(s) that extends beyond the main crown volume (see **Figure 20**). Sprouts originating from the root point are not considered part of the crown, and small, leafy twigs attached to the main bole are similarly ignored.

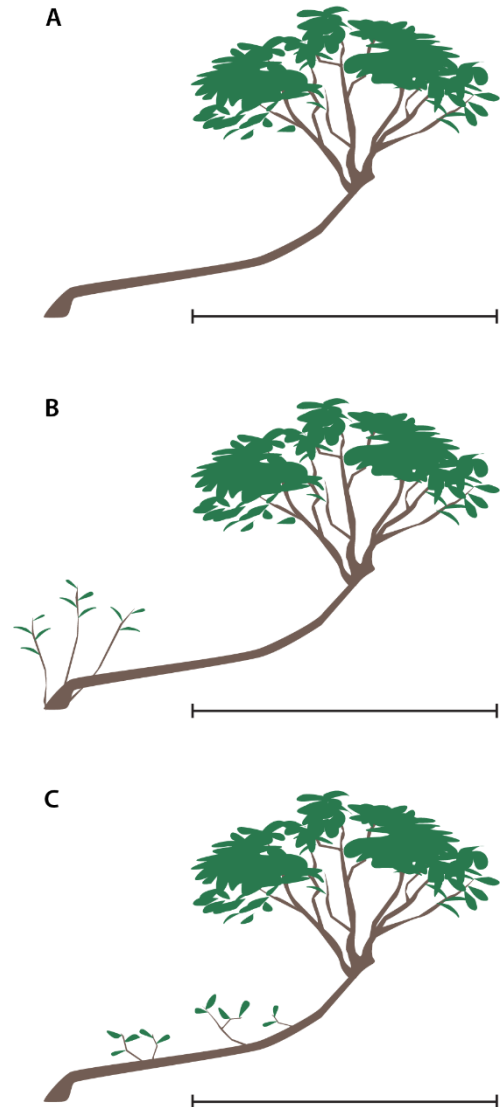


Figure 20. Crown diameter measurements for leaning individuals (A), leaning individuals with root sprouts (B), and leaning individuals with leafy twigs emerging from the bole (C). For all cases, crown diameter measurements are focused on capturing the area of the crown as seen from above (black bars) and the portion of the bole extending beyond the crown is ignored.



- c. Measure crown diameters with the technique that works best given the constraints of the vegetation:
 - i. Large calipers ('sms')
 - ii. Rigid collapsible meter stick ('sms', some 'sis', 'smt')
 - iii. Meter tape (some 'sis', 'smt', 'sbt', 'mbt')
 - iv. Laser rangefinder (some 'sis', 'smt', 'sbt', 'mbt')
9. Record in the *VST: Apparent Individuals* app:
 - a. **maxCrownDiameter**; The maximum extent of the crown; nearest 0.1 m.
 - b. **ninetyCrownDiameter**; The diameter at 90° to maxCrownDiameter; nearest 0.1 m.
10. Measure and record additional growthForm-dependent crown data (if required). See **Table 10** for growthForm-dependent requirements. Use methods as described above.
 - a. For **shape** = inverted cone (icn):
 - i. **maxBaseCrownDiameter**; nearest 0.01 m. The maximum diameter of the base of the crown (dashed red line in **Table 16**), always measured at ground level. For an inverted cone with only one stem, this diameter is the diameter of the stem. Record to 0.01 m (highest precision) for small individuals where the stem itself forms the very narrow base; nearest 0.1 m is acceptable for larger individuals.
 - ii. **ninetyBaseCrownDiameter**; nearest 0.01 m. The diameter at the crown base that is perpendicular to maxBaseCrownDiameter.
 - iii. If using paper datasheets: maxBaseCrownDiameter = 'aDatum'; ninetyBaseCrownDiameter = 'bDatum'.
 - b. For **shape** = ellipsoid (elp):
 - i. **baseCrownHeight**; nearest 0.01 m. Should be a positive number. Use a rigid, collapsible meter stick to measure the height above the ground surface for the lowest portion of the crown (short dashed red line in **Table 16** above). Nearest 0.1 m is acceptable for tall 'sis' individuals with a baseCrownHeight that is overhead.
 - ii. If using paper datasheets: baseCrownHeight = 'aDatum'; 'bDatum' = null.
11. Assess and record the **canopyPosition** (see **Table 17, Figure 21**).
 - a. Required for all 'sbt', 'mbt', 'smt', 'sap', 'sis', and 'sms' growth forms in all plots. Not required for 'lia' and shrub groups.



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- b. Include both live and dead branches when assessing the crown and its position but ignore individual branches that are abnormally long and do not represent the general shape of the crown.
- c. Assess **canopyPosition** relative to other trees.
- d. The **canopyPosition** data are **critical** for selecting representative individuals visible to remote sensing for sampling via the NEON TOS Canopy Foliar Chemistry protocol.
- e. *Example:* A closed canopy, northern hardwood forest. A young Red Oak (*Quercus rubra*) with DBH = 12.2 is growing at the center of a narrow gap in the canopy caused by a blow-down that occurred some years before. Assign canopyPosition = 3, because the top of the tree’s crown is dominating a small canopy gap, and receiving direct sun. The sides receive little direct light, since the gap is narrow.

Table 17. Canopy position definitions. Modified from USFS Forest Inventory Analysis program Crown Class definitions to emphasize an individual’s visibility to AOP remote-sensing instruments (U.S. Forest Service 2012).

Code	Canopy Position Definition
1	Open Grown – Full sun, not touching other plants, with crowns that have received full light from above and from all sides throughout most of its life, particularly during its early developmental period.
2	Full sun/dominant – crowns receiving full light from above and partly from the sides. These trees are taller than the average trees in the stand and their crown form or shape appears to be free of influence from neighboring plants.
3	Partially shaded/co-dominant – crowns receive full light from above, but little direct sunlight penetrates their sides. These trees are average height with respect to the canopy and are somewhat crowded from the sides. May also apply to a relatively shorter tree growing in a small canopy gap.
4	Mostly shaded – individuals that receive little direct light from above and none from the sides. These trees are shorter than dominants and co-dominants, and hence shorter than the average canopy height. However, crowns of these trees do extend into the canopy formed by dominants and co-dominants.
5	Full shade – individuals that receive no direct sunlight either from above or the sides. These trees have crowns that are entirely below the canopy formed by dominants and co-dominants.

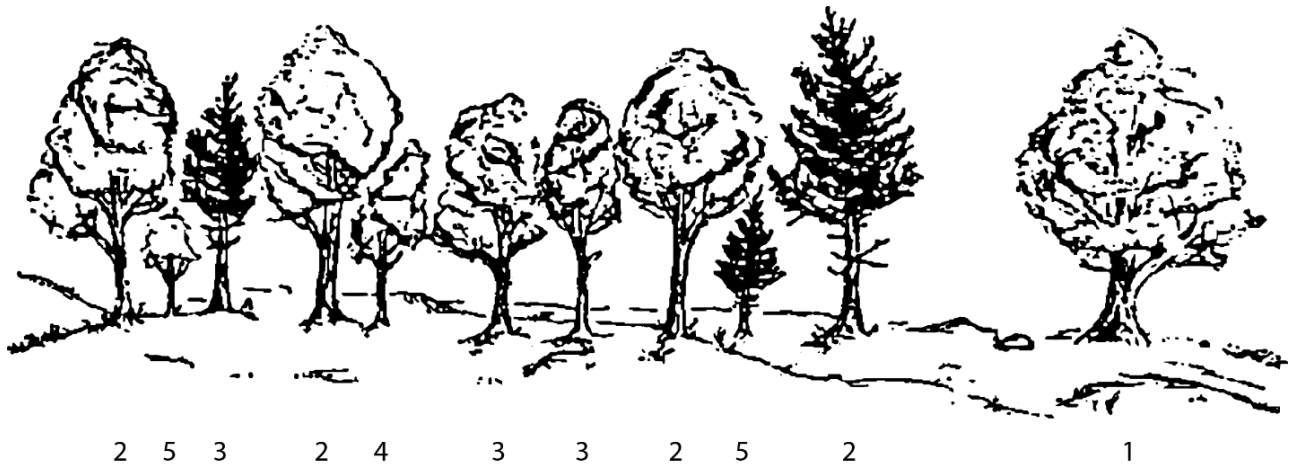


Figure 21. Illustration of relative canopy positions defined in **Table 17**; numbers (1-5) correspond to codes. 1 = open grown, 2 = full sun/dominant, 3 = partially shaded/co-dominant, 4 = mostly shaded, 5 = full shade. Modified from (U.S. Forest Service 2012).

12. Review all *VST: Apparent Individuals [PROD]* record fields for completeness and accuracy.
 - a. It is valuable to spend a minute to identify missing data, missed individuals, or other errors while still in the field where the individual can be checked against measurement requirements (see **Table 10**, **Table 16**).
 - b. Collecting missing data later and / or correcting errors without access to the measured individual is time-consuming and costly.
13. Save the record and repeat steps for additional qualifying individuals.



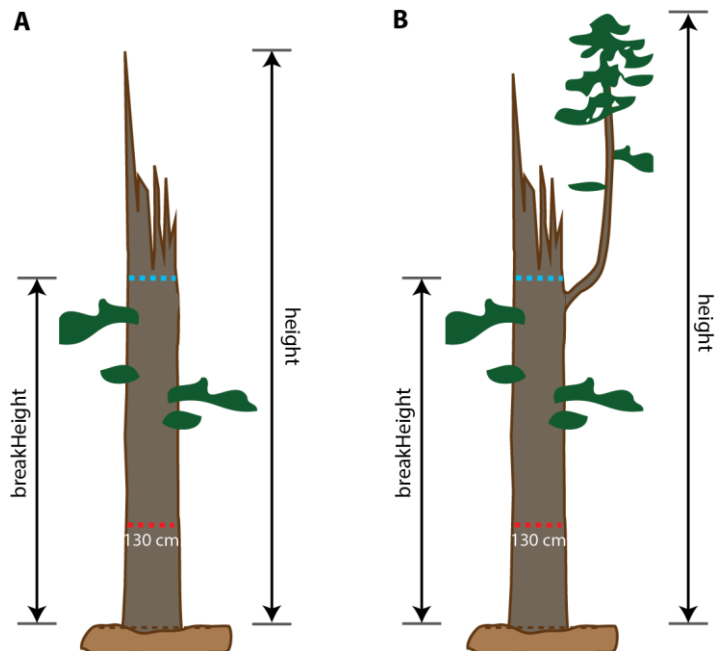
E.2.1 Measuring Broken Individuals

I. Broken boles: sbt

When either live or dead completely broken ‘sbt’ individuals > 130 cm height are encountered:

- a. Record **plantStatus** = ‘9 – live, broken’ or ‘10 – dead, broken’ (see **Table 15**). Partial breaks are assigned to **plantStatus** = ‘6 – live, physically damaged’ and are not covered here.
- b. Record **stemDiameter**, **breakDiameter**, **vdApexBreakHeight** and **vdBaseBreakHeight**. The purpose of these data is to enable estimating the mass of a cylinder that approximates the dimensions of the broken bole (**Figure 22**).
 - i. Measure **breakDiameter** below the break at the last point the bole is regular.
 - ii. For broken decumbent boles, **breakHeight** data correspond to the length of the bole between the break and the root collar.
 - iii. If leader branches ascend higher than the break height, **vdApexHeight** will be larger than **vdApexBreakHeight**.
 - iv. If the break height is the highest point and the break is clean and horizontal, the value recorded for **vdApexBreakHeight** will be the same as that recorded for **vdApexHeight**.
 - v. **vdBaseBreakHeight**; often the same as **vdBaseHeight**. May be different than **vdBaseHeight** for a broken ‘mbt’ bole growing on a slope, or when a different viewpoint is needed to make the separate height/breakHeight measurements.

Figure 22. Broken bole measurements for an individual with a “spear” break (A), and an individual with an ascending leader above the break (B). The dashed red line represents DBH, and the dashed blue line is the **breakDiameter**.





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- c. *If the broken top of the bole can be found nearby on the ground:*
 - i. Measure the **breakDiameter** of the entire bole as near the break point as possible, nearest 0.1 cm. Measure two diameters with tree calipers and record the average if a diameter tape cannot be used.
- d. *If the broken top cannot be found, or it cannot be determined which broken top matches the broken bole of interest: Two people may use tree calipers to estimate the diameter at the breakpoint.*
 - i. Person 1: Stand away from the broken bole at a sufficient distance such that you can see the breakpoint AND the base of the bole (i.e., the same distance required for measuring the height of the break).
 - ii. Person 2: Stand in front of the broken bole with the caliper jaws open and pointing up.
 - iii. Person 2 directs Person 1 to open the calipers until the jaw gap appears to match the diameter at the breakpoint (squinting may help).
 - iv. Record to the nearest 1 centimeter and note in the **remarks** that “break diameter is estimated”.
- e. Record **maxCrownDiameter**, **ninetyCrownDiameter**; see SOP E.2, step 3 (above).
- f. For a completely broken ‘sbt’ < 130 cm height, the individual does not qualify, do not sample. **Note:** See SOP E.1 **Figure 15** if resprouts are present.

II. Broken boles: mbt

When either live or dead broken boles > 130 cm length are part of a multi-bole tree:

- a. *If a subset of the boles is broken:*
 - i. Record data for the largest, intact bole first. Crown dimensions and height data should not be associated with a broken bole, even if the broken bole is largest.
 - ii. Record **plantStatus** individually for each bole (see **Table 15**).
 - iii. Record **crown diameter** measurements once per tagged individual and enter the values in the crown diameter fields for the largest, unbroken bole. Measurement of **crown diameter** may include broken boles as described above in SOP E.2, step 3.
 - iv. Record mapping data in a new *VST: Mapping and Tagging* record if the largest, intact bole was not previously mapped.



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- v. Separately measure and record **stemDiameter**, **breakDiameter**, **vdApexBreakHeight**, and **vdBaseBreakHeight** for the broken bole(s) as described above for broken 'sbt.'
- b. *If all of the boles are broken:*
 - i. Record **plantStatus** individually for each bole (see **Table 15**).
 - ii. Record **crown diameter** data as described above in SOP E.2 step 3 if broken boles continue to support a crown.
 - iii. Separately measure and record **stemDiameter**, **breakDiameter**, **vdApexBreakHeight**, and **vdBaseBreakHeight** for each broken bole as described above for broken 'sbt.'
 - iv. Height data (**vdApexHeight** and **vdBaseHeight**) should be collected from the tallest broken bole.

III. **Broken boles: smt**

- a. When a single-bole 'smt' has broken, or all boles of a multi-bole 'smt' have broken, and length of all boles is now < 130 cm:
 - i. Consider the individual as a 'sap' and measure accordingly if it qualifies for this growth form and the individual lies within the accepted measurement area – i.e., the individual is within a nested subplot if nested subplots are employed.
 - ii. If individual does not qualify as a 'sap', assign **plantStatus** = '8 – no longer qualifies' and do not measure. Leave the tag in place and monitor in future years as the individual may again qualify for measurement.
- b. When one or more boles of a multi-bole 'smt' have broken and now have length < 130 cm, and at least one bole still qualifies for measurement at 130 cm:
 - i. For broken boles that do not qualify, no data collected.
 - ii. Continue to measure emergent boles that qualify at 130 cm as normal.
 - iii. Measurement of **crown diameter** may include broken boles as described above in SOP E.2, step 3.
- c. When one or more boles of a multi-bole 'smt' have broken, and length is > 130 cm:
 - i. Record **plantStatus** = '9 – live, broken' or '10 – dead, broken' per broken bole.
 - ii. Measure **crown diameter** as described above in SOP E.2, step 3 (above).
 - iii. Measure **breakDiameter**, **vdApexBreakHeight**, and **vdBaseBreakHeight** as for 'sbt', above.



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IV. **Broken boles: sap and sms**

- a. Emergent stem has $ddh \geq 1$ cm, and is broken and < 30 cm stem length:
 - i. Do not measure ddh .
 - ii. For 'sms', measurement of **crown** diameter may include broken stems as described above in SOP E.2, step 3 (above). Crown diameters are not measured for 'sap'.
- b. Emergent stem has $ddh \geq 1$ cm, and is broken and ≥ 30 cm stem length:
 - i. Assign **plantStatus** = '9 – live, broken' or '10 – dead, broken'
 - ii. Measure ddh .
 - iii. For 'sms', measurement of **crown** diameter may include broken stems as described above in SOP E.2, step 3 (above). Crown diameters are not measured for 'sap'.
 - iv. **breakDiameter** and **breakHeight** data are not required.
- c. If all qualifying emergent stems are broken and ≥ 30 cm stem length, measure extent of 'broken' crown.
- d. If all qualifying emergent stems are broken and < 30 cm stem length, individual does not qualify and no measurements are made.



V. Broken boles: sis

- a. When an emergent bole is broken and is < 130 cm stem length:
 - i. No data collected.
 - ii. Measurement of **crown** diameter may include broken stems as described above in SOP E.2, step 3 (above).
- b. When an emergent bole is broken and is \geq 130 cm stem length:
 - i. If the individual is a multi-bole 'sis', record data for the intact bole with the largest DBH first, as this bole will be associated with height and crown dimensions.
 - ii. Record **plantStatus** = '9 – live, broken' or '10 – dead, broken' per broken bole.
 - iii. Measure **crown** diameter as described in SOP E.2, step 3 (above).
- c. When all emergent boles are broken and \geq 130 cm stem length:
 - i. Record **plantStatus** = '9 – live, broken' or '10 – dead, broken' per broken bole.
 - ii. Measure the extent of the 'broken' crown as described above.
- d. When all previously qualifying emergent boles are broken and are < 130 cm stem length:
 - i. Leave the tag in place, treat the individual as a 'sms', and measure as described above for broken 'sms'.
 - ii. If the individual does not qualify as a 'sms' and is still alive, create one record for the individual with **plantStatus** = '8 – no longer qualifies' and do not measure. Continue to monitor in future years in the event the individual again qualifies for measurement.
 - iii. If all boles are broken, dead, and < 30 cm stem length, create one record for the individual with **plantStatus** = '16 – downed, dead'.



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E.3 Shrub Groups, Liana Groups, Fern Groups, and Cactus Groups

- Data collected as part of this section are recorded in the *VST: Shrub Groups [PROD]* application.
- Fern Groups are reserved for certain fern species at the D20 PUUM site.
- Cactus Group measurement is described in ‘TOS Standard Operating Procedure: CAC – Cactus Biomass and Handling’ (RD[11]).
- Consult the ‘Manual for Fulcrum Application: TOS Vegetation Structure [PROD] – All SOPs’ for data entry details (RD[14]).

Classifying vegetation as a ‘Group’ is a measure of last resort, as Group measurements are the least useful with respect to allometric biomass estimation (**Figure 23**, see SOP B for explanation and classification guidelines). Vegetation groups are not mapped relative to a plot marker, and it is not required that they be tagged; however, you may tag Groups to better enable repeat measurements if you wish. Groups are measured so that the volume of the group may be estimated as ‘canopy area’ x ‘average height’.

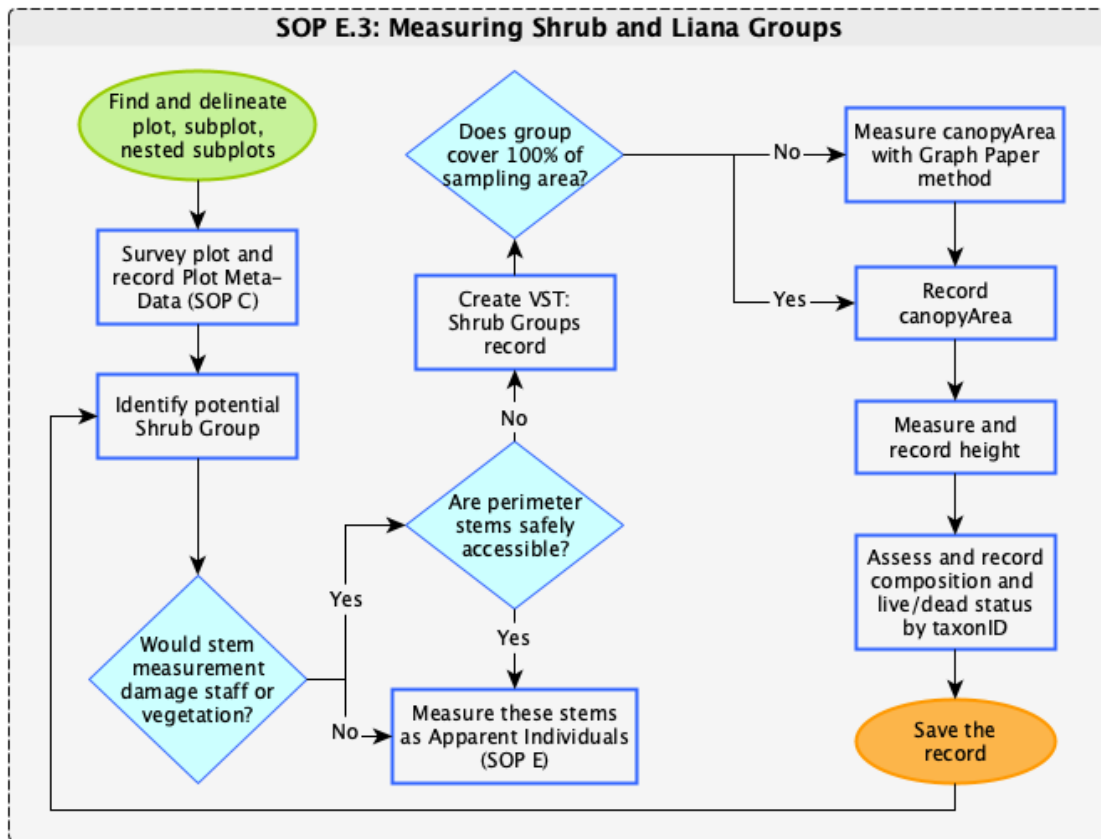


Figure 23. SOP E.3 workflow diagram outlining measurement of shrub, liana, fern, and cactus groups; boxes indicating ‘Shrub Group’ in the diagram also apply to other group types. Diagram supports and does not replace protocol text; most common workflow is outlined.



Canopy area is estimated using the graph paper mapping technique, with the area covered by the group determined by counting the number of graph squares within the group (**Figure 24**).

Each group receives a **groupID** that is unique within the plot. This number is not necessarily a permanent assignment; it is a temporary ID used to link data related to multi-species groups.

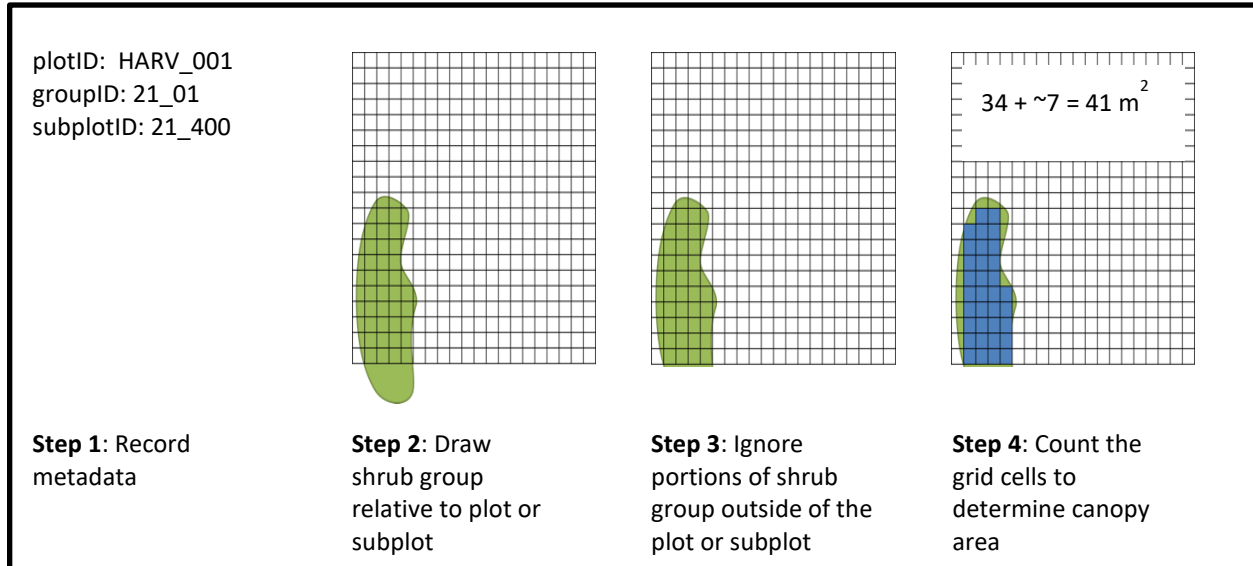


Figure 24. Example of graph paper method for estimating shrub group area within a 20 m x 20 m subplot. In this example, **canopyArea** = 41 m².

For each Shrub, Liana, or Fern Group:

1. Assess the % cover of the Group relative to the measurement area:
 - a. Do not map the group if cover is 100% for a given subplot or nested subplot – i.e., stems are very dense, and a more-or-less continuous group covers the entire measurement area. When this occurs, record the area of the nested subplot in the canopyArea field. E.g., if the nested subplot area = 25 m² and cover is 100%, record canopyArea = 25.
 - b. If the group covers <100% of the measurement area, map the area of the group using the graph paper method.
2. Measure Group **canopyArea** with the graph paper method (**Figure 24**):
 - a. Label plotID and subplotID or nested subplotID on the graph paper.
 - b. Draw the measurement area boundaries, (1 cm² = 1 m²).
 - c. Draw the shape of the shrub group to scale within the measurement area.
 - d. Count the number of grid cells contained within the sketched group, begin with whole cells then add up partial cells: the sum is the **canopyArea** for the group.



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3. Measure Group average height:
 - a. Use either the laser rangefinder (> 2 m), a meter tape (< 2 m) or collapsible ruler (< 2 m).
 - b. Measure the height at 5 locations (**aGroupHeight**, **bGroupHeight**, etc.); nearest 0.1 m.
 - i. Choose heights that you feel best represent the average maximum height of the shrub group. Bear in mind that the goal is to estimate the volume of the entire group as accurately as possible.
 - ii. For groups that include lianas, measure height for the majority of the group, do not account for climbing stems extending to the canopy.
4. Create a record in the *VST: Shrub Groups [PROD]* application. Enter the following:
 - a. **siteID** and **plotID**; select a plotID from the list generated by the *VST: Plot Meta-Data* app. Return to *VST: Plot Meta-Data* and create record for the current bout if one does not yet exist.
 - b. **Date**; enter the correct date, *YYYY-MM-DD* format.
 - c. **fixedSubplotID**; select the subplot that is invariant through time (i.e., the group will always be rooted in this subplotID regardless of future stem density changes). Helps to relocate groups in subsequent bouts.
 - i. *Examples*: 31_100 (Distributed, small Tower plot), or 21_400 (large Tower plot) are fixedSubplotIDs.
 - d. **nestedSubplotCorner**; select if sampling occurs within a nested subplot that is anchored to a corner of a fixedSubplot (see **Figure 2**). Helps to relocate groups in subsequent bouts; may be left NULL when sampling groups throughout the entire plot (i.e., nested subplot = 'noneSelected').
 - i. If a single group spans > 1 nested subplot, record additional nested subplotIDs in the **remarks** field.
 - e. **eventID**; a unique identifier for the sampling event, '*vst_SITE_YYYY*' format, where *YYYY* is the year the bout began. If an auto-populated value is incorrect, return to *VST: Plot Meta-Data* and update the record.
 - f. **groupID**; unique identifier *within a plot* for the shrub group, using the form '*XX_YY*' where *XX* is the subplotID, and *YY* is an incremental number (01, 02, 03...) assigned in the field, starting over for each plot.
 - g. **canopyArea**; the area of the shrub group, nearest 1 m².
 - h. **aGroupHeight**, **bGroupHeight**, etc.; enter 5 representative height measurements, nearest 0.1 m.



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5. Assess the Group to determine taxonomic composition and per taxon live/dead status.
 - a. Determine the % contribution by volume (ocular estimation) of each species within the group (sum of live + dead biomass).
 - i. Ignore herbaceous species that are quantified via the Herbaceous Biomass protocol.
 - ii. It is okay to include woody individuals with ddh < 1 cm in the estimate that, were they not within the group, would be quantified via the Herbaceous Biomass protocol.
 - b. For each species present, assess the % live and % dead within the total group volume. The sum of % live and % dead should = 100 for each taxonID, though see below if the %volume is < 5% for a given taxonID.
 - i. Do not include dead, downed individuals that would be measured via the Litterfall or Coarse Downed Wood protocols.
 - ii. Dead decumbent individuals should be assessed using site- and taxon-specific criteria to determine if they are 'downed'.
 - c. Create a child record in the *VST: Shrub Groups* app for each taxonID within the shrub group and record:
 - i. **taxonID**; select from the NEON master list of USDA plant species codes for species present within the domain. Identify to the greatest taxonomic resolution possible.
 1. If **taxonID** is unknown and the stem is alive, assign a morphospecies ID as indicated in steps below, obtain leaf, bark, and/or reproductive part samples (e.g., cones, nuts), and bring back to the lab to identify.
 - ii. **identificationReferences**; for unknown species that must be keyed out, record the references used (e.g., dichotomous keys, regional flora guides) on a per individual basis the first time the species is encountered. It is not necessary to record the identificationReferences the next time the species is encountered.
 - iii. **identificationQualifier**; select the appropriate qualifier when identification below a given taxonomic rank cannot be made – e.g., taxonID = family- or genus-level (**Table 14**).
 - iv. **morphospeciesID** (if applicable); enter a concise, descriptive ID that will be possible to link to this species later. Follow all guidance in SOP D.3.
 - v. **volumePercent**; visually estimated % volume of the group for a taxonID, nearest 10%. If a taxonID is < 5% of total group volume, record volumePercent = 1%



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- vi. **livePercent**; the estimated percent of the biomass that is alive for a taxonID in the group, nearest 10%.
 - vii. **deadPercent**; the estimated percent of the biomass that is dead for a taxonID in the group, nearest 10%. Sum of livePercent + deadPercent must = 100%.
 - d. Save the child record and repeat for additional taxa present in the group. The sum of the % volume contributions from all taxa must equal 100%.
6. Save the parent Shrub Group record and proceed to the next group.



E.4 Measuring ‘Other’ Growth Forms

E.4.1 Ferns and Fern Allies

Ferns and fern allies are one of the most common ‘other’ growth forms encountered across the Observatory. As a group, ferns and fern allies have a range of shapes and sizes. However, there are a limited number of fern allometries available for estimating biomass for this group. Measurements required for common fern species are provided in **Table 18**.

For Distributed Plots: Ferns may be ignored and recorded as ‘present – criteria not met’ (SOP C.3) when sampling Distributed plots if the NLCD class for the plot is forested (of any type), or if the visually estimated aerial cover of ferns is < 50% of the entire plot area (**Figure 25**). That is, visually estimate the fern cover as seen by AOP and ignore those individuals that are not visible because they are growing beneath the tree canopy.

For Tower Plots: Sampling ferns within Tower Plots is determined by Science and is based on analysis of Site Characterization data.

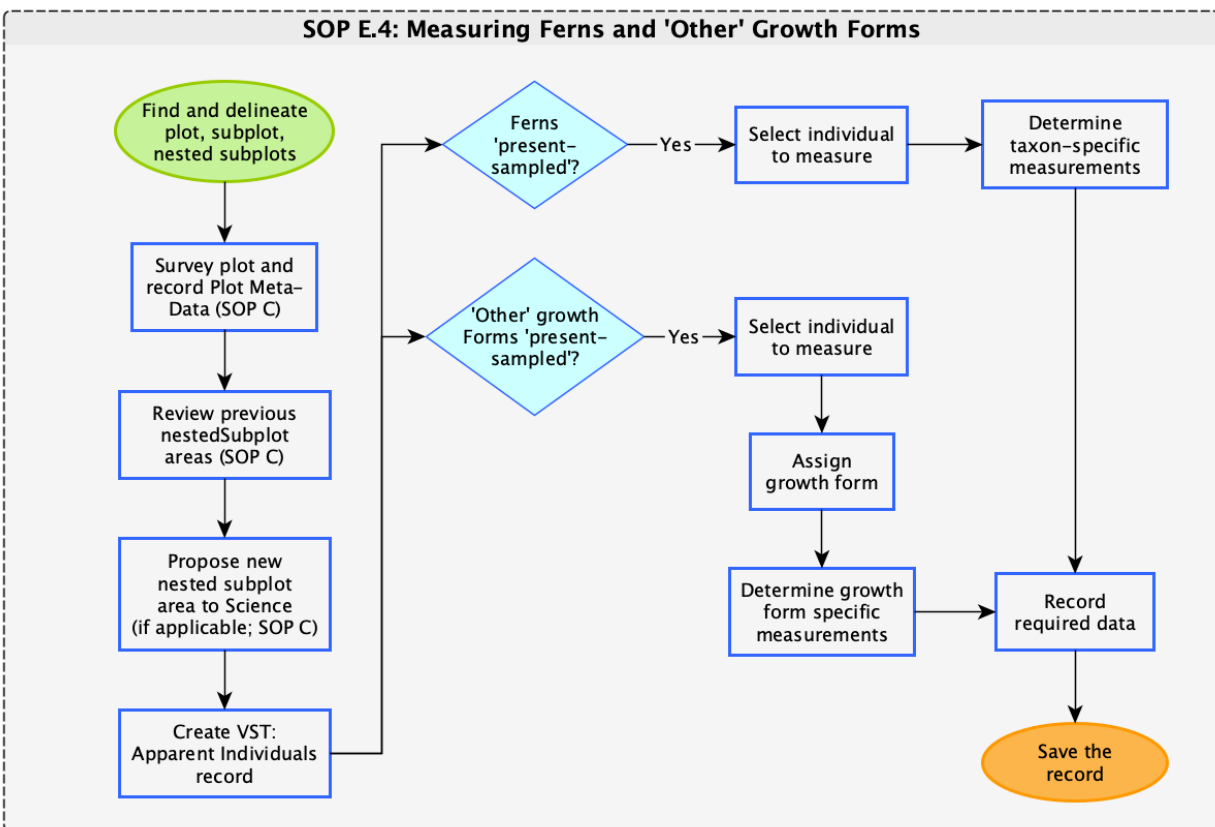


Figure 25. SOP E.4 workflow diagram outlining measurement of ferns and ‘other’ non-woody growthForms. Diagram supports and does not replace protocol text; most common workflow is outlined.



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To Measure Ferns and Fern Allies:

1. Determine the appropriate measurement area for ferns – i.e., whether nested subplots should be employed to standardize the sampling effort (SOP C.2).
 - a. The **nestedSubplotAreaFerns** may be informed by the area selected in a prior bout for a given plot. For each bout, confirm that the fern sampling effort is adequate, and if applicable, request a new **nestedSubplotAreaFerns** for a plot by submitting an Incident.
2. Ignore all individuals with average frond length < 30 cm.
 - a. **!!! Note:** This will likely disqualify many fern allies from consideration for this protocol.
 - b. For individuals close to the cutoff and with fronds of very different lengths, use the ‘Mean Leaf Length Calculator’ in the *VST: Apparent Individuals* app.
3. Create a record in the *VST: Apparent Individuals* app and create a non-woody child record for each fern.
4. Assign a **tempID** to each individual fern that is measured. The tempID auto-increments within each plot.
 - a. If multiple teams are working within the same plot, one team should begin the auto-incrementing tempID sequence with ‘1’ and the other team should begin the tempID sequence with a much higher number (e.g., ‘500’) to avoid overlap and duplicates within the data. Note that tempIDs cannot exceed ‘999’ so consider the number of teams working in the plot and plan the appropriate starting values accordingly.
 - b. **Note:** Use flagging (or equivalent) to keep track of which ferns have been sampled.
5. For densely clustered ferns that form an impenetrable mass (e.g., some D20 PUUM species):
 - a. Consider dense patches as ‘groups’ similar to Shrub Groups (SOP ii) and create a *VST: Shrub Groups [PROD]* record.
 - b. Groups count as ‘1’ when determining the correct nested subplot size to use.
6. Determine species or morphology group and measure accordingly (**Table 18**). If a species is not listed in the table, record:
 - a. Average frond length, nearest 1 cm (select 5 representative fronds to measure). Measure fronds from the rooting point to the tip with the frond extended (laid flat) on a ruler.
 - b. Number of total fronds.



E.4.2 Tree Ferns

Tree fern species are measured similarly to woody individuals: Large tree ferns ('ltf') are sampled throughout the plot (individuals with DBH \geq 10 cm and stemLength > 130 cm), and small tree ferns ('stf') may be sampled with nested subplots, if applicable (stf are individuals with DBH < 10 cm or stemLength < 130 cm). See **Table 18** for a summary of required measurements.

1. For small tree ferns ('stf'), select a **nestedSubplotAreaOther** using guidelines in SOP C.2:
 - a. Small tree ferns are considered along with 'Other' growth forms in the plot when determining nested subplot area. That is, if any additional 'Other' growth forms are present in the plot, use the tally of small tree ferns + additional 'Other' individuals to determine the appropriate **nestedSubplotAreaOther** for the plot.
 - b. The **nestedSubplotAreaOther** may be informed by the area selected in a prior bout. If nested subplots are utilized, confirm the selected area meets guidelines in SOP C.2 and submit an Incident if a new nested subplot area is desired.
 - c. Large tree ferns with DBH \geq 10 cm and stemLength > 130 cm: Do NOT use nested subplots. Measure these individuals throughout the plot.
2. Mapping tree ferns:
 - a. Map all large tree fern ('ltf') individuals (i.e., DBH \geq 10 cm and stemLength > 130 cm). Map the root point, not the crown.
 - b. Do not map small tree ferns ('stf').
3. Measure and record the **measurementHeight**:
 - a. For all 'ltf' individuals, and 'stf' with stemLength > 130 cm, measure diameter 130 cm along the stem from the 'root collar' or 'root point'.
 - i. For downed individuals that are still growing, find the rooting point, and measure 130 cm along the downed stem to find the measurement location.
 - ii. For individuals with pedestals, define the zero point as the top of the pedestal, then measure 130 cm along the stem from the top of the pedestal.
 - iii. For individuals with the frond attachment point at 130 cm (or close to it):
 - 1) Move the measurement location down the stem until the stem is regular.
 - 2) Record the modified **measurementHeight**.
 - b. For 'stf' with stemLength < 130 cm, select a **measurementHeight** above the root collar or root pedestal where the stem is regular.
 - c. Guidance in SOP E.1 may help with other complex situations.



4. Measure and record the **stemDiameter** (DBH at 130 cm for 'ltf' and 'stf' with stemLength > 130 cm) or the **basalStemDiameter** (ddh at 10 cm for 'stf' with stemLength < 130 cm):
 - a. Use calipers when boles are extremely furrowed, moss-covered, or there are other irregularities like roots / shrubs / lianas that prevent accurate use of tapes.
 - b. Avoid sloughing off bark to ensure repeat measurements do not yield negative changes in **stemDiameter** or **basalStemDiameter**.
5. Measure the **stemLength**. The stemLength is the length of the stem from the root collar or root pedestal to the base of the leaves.
 - a. For decumbent individuals the stemLength is used to allometrically estimate biomass, whereas height is meaningless.
 - b. At the apex of the plant, the stem terminates at the point where woody parts stop and fronds emerge.
 - i. The point at which woody material stops and fronds emerge is often obscured. When possible, probe by hand to determine where woody parts stop.
 - ii. For very tall individuals for which manual probing is not possible, use experience with shorter individuals to consistently visually estimate the correct **stemLength**.
 - c. Use a measuring stick or a rangefinder to measure the required length.
6. Measure the **vdApexHeight** and **vdBaseHeight** (i.e., the required inputs for **height**).
 - a. The total **height** should be the vertical distance between where the individual emerges from the ground and the highest point of the fronds.
 - b. As above, use a measuring stick or a rangefinder to measure the required vertical distances.

E.4.3 Additional 'Other' Growth Forms

1. 'Other' growth forms that are also measured according to this protocol are listed below. Required measurements are unique to each growth form, and are listed in **Table 18**.
 - a. Palm trees ('ptr') with DBH \geq 10 cm AND stemLength > 130 cm:
 - i. Measure throughout the sampling area, do not use nested subplots.
 - ii. Create a mapping and tagging record in the *VST: Mapping and Tagging* app to track the same individuals through time. All 'ptr' individuals should be mapped.
 - iii. For tree-palm-like species (e.g., *Arecaceae*), measure **stemLength** and **height** as described above for large tree ferns.
 - b. Small palm trees ('spm').



- i. Nested subplots may be used to standardize sampling effort. Use prior values of **nestedSubplotAreaOther** as a guide and request a new nested subplot area via an Incident if the old value does not meet guidelines in SOP C.2.
 - ii. Create a tagging record in the *VST: Mapping and Tagging* app to track the same individuals through time. Individuals may also be mapped if no 'sbt', 'mbt', 'ptr' or 'ltf' are present in the plot.
 - iii. Distinct measurements are required for:
 - 1) Shrub-type palms (e.g., *Serenoa repens*); ignore individuals with < 30 cm mean total leaf length.
 - 2) Small tree-type palms (e.g., *Butia capitata*) with DBH < 10 cm or stemLength < 130 cm.
 - iv. Small individuals from tree-palm-like species do not qualify for measurement when only leaves emerge from the ground and no bole is yet visible.
- c. *Fouquieria splendens* (i.e., Ocotillo)
- i. Stem count is basal stem count, not terminal stem count.
- d. Xerophyllum species (i.e., Bear Grass)
- e. Yucca species
- i. Include agave species with yucca-like growth form in this group.
 - ii. Ignore all individuals with height < 30 cm.
 - iii. Ignore the flower stalk for flowering individuals.
 - iv. (Optional): Create a tagging record in the *VST: Mapping and Tagging* app to track the same individuals through time.
- f. Cactaceae species:
- i. The Cactus SOP is implemented concurrently with this protocol. Measurement of Cactaceae species is described in the companion Cactus SOP (RD[11]).
2. As above, create a *VST: Apparent Individuals* record for each plot that contains non-woody growth forms, then create a child Non-Woody record for each individual.
 3. For most non-woody individuals, assign an auto-incrementing **tempID** to each non-woody 'other' individual within the plot as described above for ferns in SOP E.4.1.
 4. Measure and record the **measurementHeight** any time a **stemDiameter** or **basalStemDiameter** measurement is made.



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5. To measure **meanBladeLength** and **meanPetioleLength** for shrub-type palms (e.g., *Serenoa repens*):
 - a. Ignore young fronds not fully expanded.
 - b. Ignore dead fronds that have started to break apart due to decomposition; otherwise include dead fronds.
 - c. If individual has ≤ 5 qualifying fronds: Measure all fronds and use the *VST: Apparent Individuals* app calculator to determine mean **lengths**. Record to the nearest 1 cm.
 - d. If the individual has > 5 qualifying fronds:
 - i. Number all qualifying fronds at the petiole base with a sharpie.
 - ii. Use the random number generator and mean length calculator in the *VST: Apparent Individuals* app to randomly select 5 fronds for measurement. Record the mean **lengths** to the nearest 1 cm.



E.4.4 Summary of Required Measurements for ‘Other’ Growth Forms

Table 18. Summary of required measurements for ferns, tree ferns, palms, and additional non-woody ‘other’ growth forms.

Growth Form	taxonID	leafNumber/ stemCount	maxCrown Diameter	ninetyCrown Diameter	height	stem Diameter	measurement Height	stemLength ¹⁰	meanPetiole Length	meanBlade Length	meanLeaf Length	canopy Position
Ferns ¹ (frn)	<i>Athyrium filix-femina</i> ⁴	leaf									x	
	<i>Blechnum spicant</i> ⁴	leaf									x	
	<i>Dryopteris austriaca</i> ⁴	leaf									x	
	<i>Polystichum munitum</i> ⁴	leaf									x	
	<i>Pteridium aquilinum</i> ⁴					basal ²	x					
Large Tree Fern (ltf)	<i>Cibotium spp.</i> ⁵ , <i>Cyathea spp.</i> ⁶				x	DBH	x	x				x
Small Tree Fern (stf)	<i>Cibotium spp.</i> ⁵ , <i>Cyathea spp.</i> ⁶				x	DBH or basal	x	x				x
Palm tree (ptr)	<i>Areaceae spp.</i> ⁸				x	DBH	x	x				x
Small Palm (spm)	<i>Leucothrinax morrisii</i> ⁷	leaf	crown	crown	x				x	x		x
	<i>Serenoa repens</i> ⁷	leaf	crown	crown	x				x	x		x
	<i>Sabal etonia</i> ⁷	leaf	crown	crown	x				x	x		x
	<i>Areaceae spp.</i> ⁸ (i.e., small tree palms)				x	DBH or basal	x	x				x



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Growth Form	taxonID	leafNumber/ stemCount	maxCrown Diameter	ninetyCrown Diameter	height	stem Diameter	measurement Height	stemLength ¹⁰	meanPetiole Length	meanBlade Length	meanLeaf Length	canopy Position
<i>Fouquieria splendens</i> ⁹ – Ocotillo (oco)		basal stem	basal ³	basal ³	x							x
<i>Xerophyllum tenax</i> ⁴ – Bear Grass (xer)						basal ²	x				x	
<i>Yucca sp.</i> (yuc) ¹¹ <i>Includes agave, and species with yucca-like, large basal rosette growth forms</i>			crown	crown	x							

¹ Fern species not mentioned in this table should be measured similarly to *Athyrium filix-femina*. To qualify for measurement according to this protocol, ferns must have an average frond length ≥ 30 cm.

² basalStemDiameter for *Pteridium aquilinum* and ‘xer’ is measured at the surface of the litter layer (measurementHeight = 0); for ‘xer’, average the max and min diameter at the base of the tussock (i.e., the ‘tussock’ includes leaves, and for flowering individuals, also the stem).

³ See the ‘icn’ shape in **Table 16** for illustration of the maxBaseCrownDiameter and ninetyBaseCrownDiameter measurement location.

⁴ Allometry from Gholz et al. (1979).

⁵ Allometry from Ostertag et al. (2014), Selmants et al. (2014)

⁶ Allometry from Alves et al. (2010).

⁷ Allometry from Gholz et al. (1999).

⁸ Allometry from Morel et al. (2011).

⁹ Allometry from Bobich and Huxman (2009).

¹⁰ **stemLength** definition: See SOP E.4.2; measure to 0.01 m. For vertical individuals, stemLength is equivalent to height. For decumbent individuals, height cannot be used to allometrically determine biomass.

¹¹ To qualify for sampling, yucca must have height ≥ 30 cm. When measuring ‘height’, ignore flower stalks on flowering individuals.



SOP F Vegetation Structure Data Collected Annually in Tower Plots

Overview

In this SOP we describe measurements made annually in a subset of Tower Plots. Subsections of this SOP are focused on sites with and without dendrometer bands.

- **SOP F.1:** For relatively fast-growth increment sites without dendrometer bands.
- **SOPs 0 and 0:** For relatively slow-growth increment sites with dendrometer bands.

This SOP assumes working knowledge of SOP E: ‘Vegetation Structure Data Collected on a 5-year Interval’.

Goals

- Collect annual Vegetation Structure data from a productivity subset of Tower Plots.
- At slow-growth increment sites, fit selected trees in the ‘productivity subset’ with dendrometer bands. Collect annual band gap data in addition to standard DBH data from banded trees.
- At slow-growth increment sites, fit large trees $\geq 95^{\text{th}}$ %-tile biomass in additional Tower Plots with dendrometer bands. Collect annual band gap data in addition to standard DBH data from banded trees.

F.1 Annual Measurements at Faster-Growth Increment Sites

- Annual Tower Plot measurement at faster-growth sites involves implementation of SOP E in a ‘productivity subset’ of 5 plots identified in the Plot Prioritization list provided via the SSL.
- The list of plots in the productivity subset is determined by Science and the plot list is provided via the SSL.
- All qualifying woody and non-woody vegetation is measured annually within the productivity subset, *with the exception of ferns and fern allies*.
- See Appendix C for a list of faster-growth and slow-growth increment sites.

Procedure steps:

1. Navigate to one of the selected plots and delineate according to SOP C.
 - a. Classify individuals to growth form according to SOP B when determining nested subplot size.
2. Create a record in the *VST: Plot Meta-Data [PROD]* application. Enter required information as described in SOP C.3. Ensure the following two fields are entered correctly:



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- a. Enter the **eventType**:
 - i. **allTowerPlots**; do NOT select. This option only applies when all Tower Plots are measured on a 5-year interval.
 - ii. **distributedAndTowerSubset**; select if Distributed Plots are scheduled for measurement in the same year that the Tower Plot ‘productivity subset’ is measured.
 - iii. **towerSubset**; select when only the productivity subset is scheduled for measurement for the current sampling year.
- b. Enter the type of **dataCollected**:
 - i. **allGrowthForms**; select when all woody growth forms are measured within the plot. This is the only option to select for faster-growth sites.
 - ii. **dendrometerOnly**; do NOT select. Dendrometer bands are not currently installed at faster-growth sites.
3. Survey the plot for newly qualifying woody and non-woody individuals.
 - a. Tag and map (if required) according to SOP D.
 - b. Do NOT consider ferns and fern allies for annual measurement in Tower Plots.
4. Collect and record required vegetation structure data for woody individuals according to SOP E.
 - a. Do NOT measure ferns and fern allies annually in Tower Plots.



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F.2 Dendrometer Band Field Installation at Slow-Growth Increment Sites

Overview

At slow-growth increment sites, measurement of banded individuals provides high-resolution woody growth-increment data on an annual frequency that is not possible using standard DBH tapes. Annual growth increment data are used to calculate annual changes in aboveground Net Primary Productivity (NPP) for the site.

Dendrometer band installation in the field requires preparation of the tree, diameter measurements and data recording, custom fitting the tree-specific metal band prepared in the lab (SOP A.4), collar fabrication, installing the band on the tree, and finally, initial gap measurement (**Figure 26**).

Identifying Trees to Band:

- Trees selected for banding are initially identified by Science and a list is provided via the SSL.
- Banded trees are concentrated in a subset of spatially-balanced Tower Plots (typically n=5). The subset is chosen to match the biomass distribution from the full set of plots.
- The largest trees are banded in additional plots (those trees $\geq 95^{\text{th}}$ percentile biomass); these trees are identified by Science every 5 years.
- Trees with DBH < 5 cm are never banded, and the minimum banding diameter cutoff varies by site. Site-specific banding guidance is provided via the SSL.
- When re-measuring banded trees at a site, follow the steps in this SOP to band and collect initial band data from new recruits that now meet the minimum banding diameter.

Fulcrum applications used to collect data for this SOP:

- **VST: Mapping and Tagging [PROD]** application. Collect dendrometer band installation data, as well as mapping, tagging, and taxonID data for individuals in the plot.
- The [Vegetation Structure Fulcrum Manual](#) on the SSL contains detailed data entry instructions.

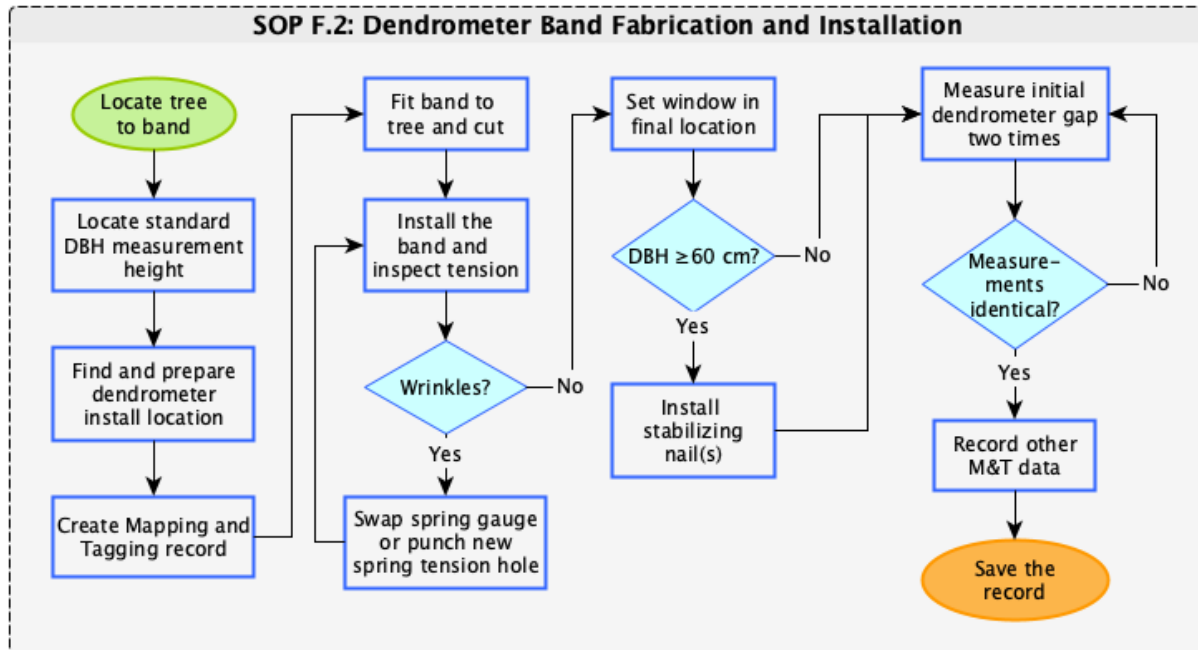


Figure 26. SOP F.2 workflow diagram for dendrometer band installation in the field, and initial measurements. Diagram supports and does not replace protocol text; most common workflow is outlined.

Procedure Steps:

1. Locate a tree to be banded. If the individual is a multi-bole tree, all boles that meet the minimum banding diameter for the site will be banded.
2. Prepare the tree for dendrometer band installation.
 - a. Locate the standard DBH measurement location on the bole – i.e., the **measurementHeight**. This location is often marked with orange lumber crayon.
 - b. (Optional) Tie flagging around the standard measurement location.
 - c. Locate the dendrometer band installation height. The goal is to situate the band high enough above the standard DBH measurement location that bark removed during smoothing does not affect the standard DBH measurement.
 - i. For smooth-barked trees that require minimal surface preparation: Situate band approximately 10 cm above the standard DBH measurement location.
 - ii. For trees with rough, deeply fissured, or loosely attached bark: Situate band approximately 20-30 cm above the standard DBH measurement location.
 - iii. Assess the desired band location for branches, burls, knobs, etc. that may interfere with band placement. Move up the bole if necessary. It is possible to move below the standard DBH measurement location, but this is not desired.



- d. Prepare dendrometer band location on the bole. The goal is to create as much smooth surface as possible on which the band will be flush and appressed to the bole.
 - i. Use a knife to clear moss and smooth a 6-10 cm width swath around the circumference of the tree.
 - ii. Inspect the bark and remove any loose pieces using either your hand and/or the knife. Smoothing the bark is an iterative process that typically requires several trips around the circumference of the tree.
 - iii. For deeply fissured bark, gaps between band and bark are common and should be minimized where possible (**Figure 27**).



Figure 27. Preparation of the bole surface for dendrometer band installation on a deeply fissured Douglas Fir (*Pseudotsuga menziesii*) at the D16 WREF site.

3. Make initial diameter measurements and record in the *VST: Mapping and Tagging [PROD]* application. Create a new entry and record:
 - a. **Dendrometer Installation Date**; YYYYMMDD format.
 - b. **Initial Band Stem Diameter**; the diameter of the bole at the exact, smoothed location where the band will be installed, nearest 0.1 centimeters. **!!! This measurement is not the same as DBH.**
 - c. **Dendrometer Height**; the height above ground at which the dendrometer band is installed, nearest 1 centimeter. For decurved stems, this is the distance along the stem rather than the height above ground.



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4. Cut the band to fit the tree.
 - a. Select the labeled, pre-cut band that was sized for the current tree.
 - b. In your left hand, hold the tip-punched end with the window pointing down and the tip-punch pointing to the right.
 - c. Take the other end of the band and wrap it clockwise around the tree so it is taut around the prepared surface. It should overlap the tip-punched end and all of the window.
 - d. Mark the overlying band approximately 1 cm left of the window. Draw a dash/dot/star just to the right of the mark to indicate the outer face of the band.
 - e. Remove band.
 - f. Clip the band to length at the marked location and responsibly discard the clipped waste metal.

5. Fabricate the buckle (**Figure 28**).
 - a. Hold the collar perpendicular to the tree side of the band (i.e. the unmarked side) approximately 1 cm from the cut end and centered on the band (**A**).
 - b. Fold each wing of the collar around the band. They should not overlap. Pinch tightly with fingers (**B, C**).
 - c. Fold the cut end of the band over the collar wings so that the cut end does not extend beyond the lower edge of the collar. Make sure the fold is square with the band and tight. Use fingers to pinch tightly (**D**).
 - d. Fold the cut end again, in the same direction. Make sure the fold is square and tight. Use fingers to pinch tightly (**E, F**).
 - i. (*Optional*) Gloves may be worn to protect against cuts. Thin, golf-style gloves or equivalent are recommended in order to retain finger dexterity.
 - e. The tip-punch end of the band should slide freely through the buckle (**G, H**).
 - f. Smooth any burrs that may prevent the tip-punch end of the band from passing through the buckle.

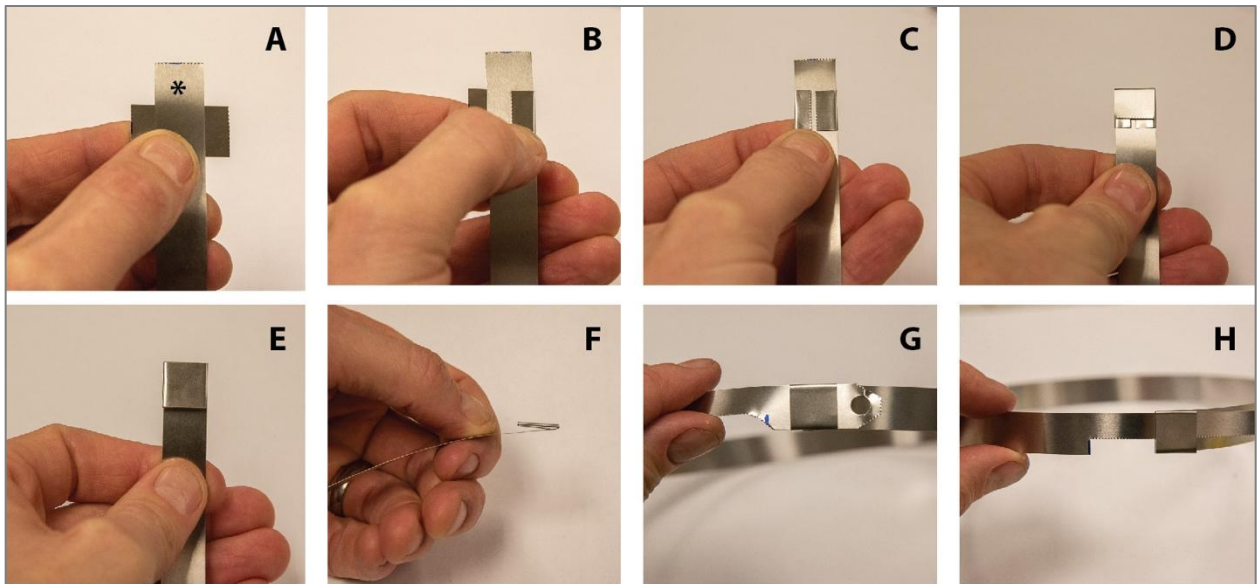


Figure 28. Fabricating the dendrometer band buckle with the collar after fitting the band to the tree and cutting to the desired length. The asterisk in **A** denotes the outward-facing side of the band marked in the previous step.

6. Install the band (**Figure 29**).

- a. Select a measurement location on the prepared surface of the bole where the window, buckle, and the extended spring can be fully appressed to the bark surface.
- b. Hold the leading tip-punched end with the window pointing down in your left hand, with the tip-punch end pointing to the right as you face the tree.
- c. Take the other end of the band and wrap it clockwise around the tree.
- d. Slide the tip-punched end through the buckle.
- e. Hook a spring of the required size and gauge through the tip punch from the tree side of the band (see Appendix G for spring requirements).
- f. Rotate the band to place the window, buckle, and the extended spring in the desired measurement location.
- g. Pull the band taut and stretch the spring to an appropriate tension.
 - i. The spring should be tight enough that it is snug all the way around the tree, but not so tight that the band crumples or wrinkles from the tension.
 - ii. Mark the band at the location where the free end of the spring will be attached.
- h. Release the band tension.
- i. Punch the hole. This may be done with the band still on the tree. Be sure to collect the chad and discard responsibly.
- j. Pull the band taut and hook the spring through the newly punched hole.
- k. Situate the band in its final location:
 - i. Rotate so window, buckle, and spring are fully appressed against the bole.



- ii. Check that the entire band is perpendicular to the pith of the bole and centered within the prepared surface all the way around the tree (**Figure 27**).
- iii. Make sure the spring is resting on the band, not the bark.
- l. Check the **Initial Dendrometer Gap**. The gap between the buckle and the right-angled end of the window should be approximately 1-2 cm.
- m. Add stabilizing nail(s) if needed.
 - i. Boles with DBH > 60 cm require at least one nail on the side opposite the window and underneath the band.
 - ii. Tapering boles require at least one nail above the band to prevent the band from slipping upward.
 - iii. **!!! Nails may be omitted for deciduous species that are known to swell around the nail.**



Figure 29. Installed dendrometer band with a 1–2 centimeter initial gap in the measurement window. The band is rotated such that the entirety of the measurement window and the spring are fully appressed to a smoothed section of the bole.



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7. Measure and record the **Initial Dendrometer Gap**; the initial width of the dendrometer band window, nearest 0.1 mm.

!!! *This measurement is ideally made after a settling period of 4 weeks or longer. Record on the day of installation and return and update after the settling period.*

- a. Use the inside jaws of metal calipers to measure the gap. Specific calipers are required, see **Table 22**.
 - b. Hold calipers level with the band and perpendicular to the bole.
 - c. Place left jaw point in the upper left window corner (see **Figure 29**).
 - d. Expand the caliper jaw to the upper buckle edge, stopping before the caliper dial begins to “click”.
 - i. Stopping before the dial clicks ensures that the caliper does not deform the window, resulting in inaccurate measurement of the growth increment.
 - e. Remove caliper, read value.
 - f. Reset to calipers to zero and repeat the measurement.
 - i. If the two values are the same, record the **Initial Dendrometer Gap**.
 - ii. If values differ, repeat measurement until obtaining two equal measurements.
8. Record **Initial Gap Measurement Date**; YYYYMMDD format.

!!! *Record the current date on the day of installation and return and update after the settling period.*
 9. Save the record.
 10. Record standard **stemDiameter** and **measurementHeight** data for the banded individual as described in SOP E.



F.3 Annual Measurements at Slow-Growth Increment Sites with Dendrometer Bands

Overview

- A spatially balanced productivity subset of 5 Tower Plots is selected for sampling (based the Plot Prioritization list available on the SSL, same as at fast-growth increment sites).
- All qualifying woody and non-woody vegetation is measured annually within the productivity subset, *except for ferns and fern allies*.
- Additionally, dendrometer band gap data are collected from trees within the productivity subset that are fitted with a dendrometer band for annual measurement.
- Collect dendrometer band gap data from large trees with biomass $\geq 95^{\text{th}}$ %-tile that are banded in other Tower Plots; only banded trees are measured annually in these additional plots.
- Replace existing bands that trees have outgrown. The maximum **dendrometerGap** that can be entered is 110 mm (11 cm).
- The list of initially banded trees is provided via the SSL. VST data are analyzed by Science every 5 years to identify any changes to per site minimum banding diameters, changes to the 95th %-tile biomass threshold, and any new trees to be banded that meet the 95th %-tile biomass threshold.
 - Outside of this 5-year assessment cycle, banded trees that die and/or fall down are not replaced with new banded trees (except for new recruits).
- Survey trees in the Tower plot annual productivity subset for new recruits that meet the site-specific minimum banding diameter and fit with new dendrometer bands; record initial dendrometer band data in the *VST: Mapping and Tagging* app (SOP F.2).
- See Appendix C for a list of faster-growth and slow-growth increment sites.

Fulcrum applications used to collect data for this SOP:

- *VST: Mapping and Tagging* [PROD] application. Collect initial dendrometer installation data.
- *VST: Apparent Individuals* [PROD] application. Collect dendrometer band gap data, as well as other required structure data for individuals in the plot.
- The [Vegetation Structure Fulcrum Manual](#) on the SSL contains detailed data entry instructions.

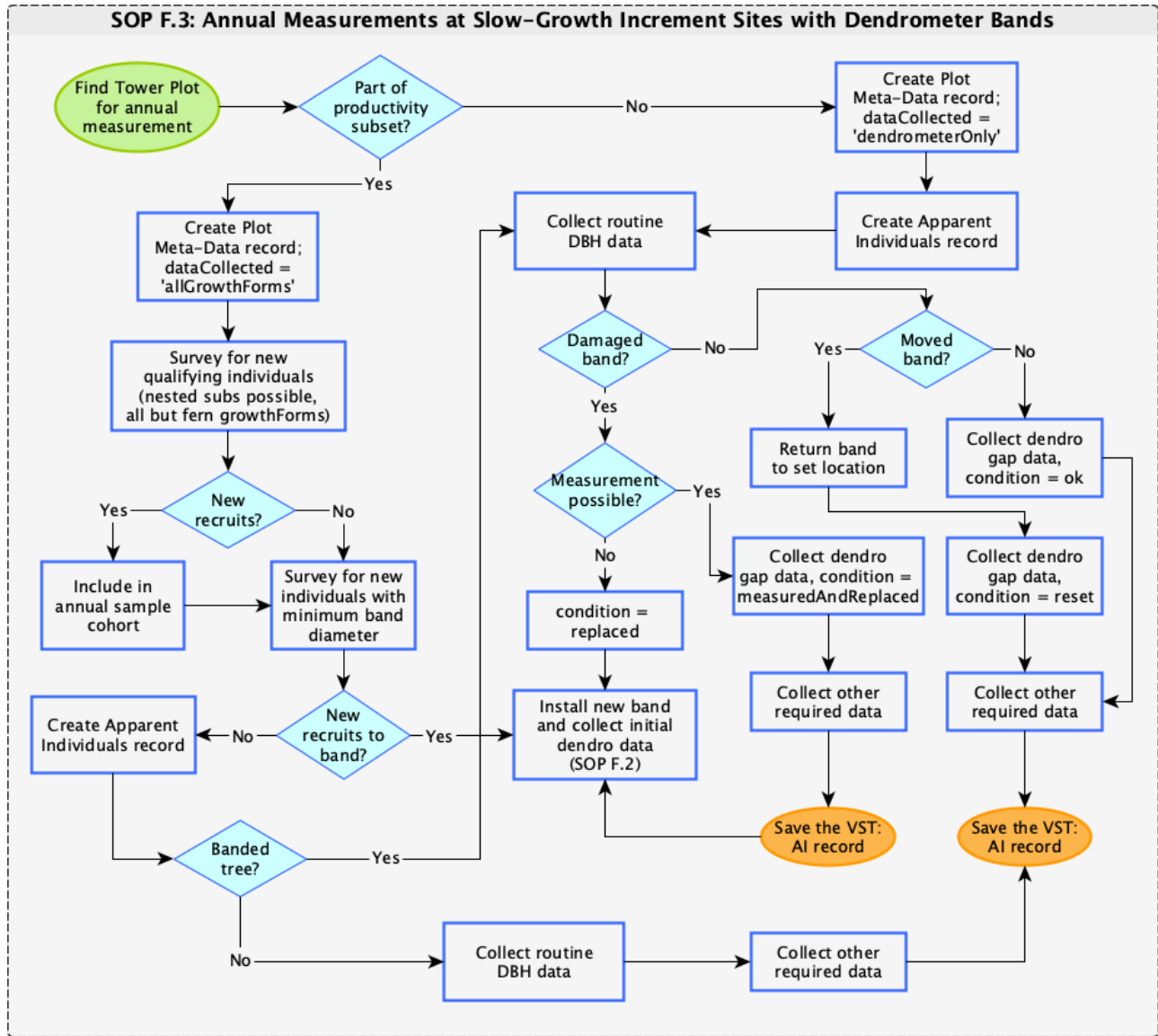


Figure 30. SOP F.3 workflow diagram for annual measurements in Tower Plots at slow-growth increment sites with dendrometer bands. Diagram supports and does not replace protocol text; most common workflow is outlined.



Procedure steps:

1. Navigate to one of the selected plots and delineate according to SOP C.
 - a. Classify individuals to growth form according to SOP B when determining nested subplot size.
2. Create a record in the *VST: Plot Meta-Data [PROD]* application. Enter required information as described in SOP C.3. Specific to this SOP, ensure the following field is entered correctly:
 - a. Enter the type of **dataCollected**:
 - i. **allGrowthForms**; select when all woody growth forms are measured within the plot. This option applies when the plot is part of the annual ‘productivity subset’.
 - ii. **dendrometerOnly**; select when only large, banded individuals with $\geq 95^{\text{th}}$ %-tile biomass identified by Science are sampled in the plot. The ‘totalSampledArea’ is NULL for the plot when this value is selected because biomass data cannot be scaled to the plot level since only the banded subset of trees in the plot are sampled for the bout.
3. If the plot is part of the ‘productivity subset’, survey the plot for newly qualifying woody and non-woody individuals.
 - a. Tag and map if required (SOP D).
 - b. If the individual is a tree, install a dendrometer band if the DBH now meets or exceeds the site-specific minimum banding diameter, and collect initial dendrometer band data (SOP F.2).
 - c. Do NOT consider ferns and fern allies for annual measurement in Tower Plots.
4. If the plot is part of the ‘productivity subset’, collect and record required vegetation structure data for qualifying woody and non-woody individuals according to SOP E.
 - a. Do NOT measure ferns and fern allies annually in Tower Plots.
5. For qualifying trees fitted with a dendrometer band in a previous bout:
 - a. Determine if the tree has “outgrown” the band. A **dendrometerGap** up to 110.0 mm may be recorded; gaps larger than this are not recorded because bole curvature leads to increasingly inaccurate data.
 - i. If the gap is between 90 – 110 mm (9 – 11 cm) and past data indicate the gap will be > 110 mm by the next bout, proceed to the next step and collect dendrometer gap data. Replace the band when finished and collect **Initial Dendrometer Gap** data (SOP F.2).



- ii. If the gap is > 110.0 mm (11 cm), do not collect **dendrometerGap** data, replace with a new band and collect Initial Dendrometer Gap data (SOP F.2).
- b. Inspect the dendrometer band for damage:
 - i. If the window is damaged or the band is damaged such that it is no longer appressed flat to the bole at the set location, replace with a new band and collect **Initial Dendrometer Gap** data (SOP F.2).
 - ii. If the band is damaged, a measurement is possible, and the data quality is questionable, proceed to the next step and acquire dendrometer gap data. Replace the band when finished and collect **Initial Dendrometer Gap** data (SOP F.2).
- c. Inspect the dendrometer band for movement. If the band is no longer at the original set location – i.e., the **Dendrometer Height** has changed from the initial installation height:
 - i. Carefully slide the band back and forth and move the band to the bole location at which it was originally set.
 - ii. If helpful, install additional nails to prevent future band movement.

!!! Be aware that nails may cause some deciduous species to swell around the nail, so adding nails is not universally useful.
- d. Measure and record the **Dendrometer Gap**; the width of the dendrometer band window, nearest 0.1 mm. ‘Dendrometer Gap’ measurements allow precise estimation of growth increment and woody productivity.
 - i. Use the inside jaws of metal calipers to measure the gap. Specific calipers are required, see **Table 23**.
 - ii. Hold calipers level with the band and perpendicular to the bole. In this position you will not be able to read the calipers, thus removing any visual bias from the measurement.
 - iii. Place left jaw point in the upper left window corner (see **Figure 29**).
 - iv. Expand the caliper jaw to the edge of the buckle, stopping before the caliper dial begins to “click”.
 1. Stopping before the dial clicks ensures that the caliper does not deform the window, resulting in inaccurate measurement of the growth increment.
 - v. Remove caliper, read value.
 - vi. Reset to calipers to zero and repeat the measurement.
 1. If the two values are the same, record the **Dendrometer Gap**.
 2. If values differ, repeat until two equal measurements are obtained.



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- e. Record the **Band Condition**:
 - i. **ok**; select if a regular, high-quality measurement was made. That is, the band is not damaged and has not moved relative to the initial installation location.
 - ii. **measuredAndReplaced**; select if the band was damaged but a lower-quality measurement could be made and the band was replaced afterward.
 - iii. **replaced**; select if the band was damaged, a measurement could not be made, and a new band was installed. For example, the window itself was damaged by falling debris and could not be measured.
 - iv. **reset**; select when a band has moved from the initial **Dendrometer Height** and was undamaged; the band was moved back to the original location and a lower-quality measurement was made.
6. Record standard **stemDiameter** and **measurementHeight** data as described in SOP E.
7. Review all *VST: Apparent Individuals* record fields for completeness and accuracy.
 - a. It is valuable to spend a minute to identify missing data or errors while still in the field.
 - b. Collecting missing data at a later date and / or correcting errors without access to the measured individual can be time-consuming and costly.
8. Save the record and repeat steps for additional qualifying individuals in the plot.



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SOP G Post-Field Sampling Tasks

G.1 Document Incomplete Sampling Within a Site

Measurement of Vegetation Structure sampling is scheduled to occur at all prescribed sampling locations according to the frequency and timing described in Section 4 and Appendix C. The protocol should be implemented at up to 20 selected Distributed Plots, and up to the total number of Tower Plots per site. Ideally, sampling will occur at these sampling locations for the lifetime of the Observatory (core sites) or the duration of the site’s affiliation with the NEON project (gradient sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced.

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions – e.g., a terrestrial sampling plot is compromised after road-building activities. Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that is biologically meaningful – e.g., the plot is extremely far from a road and requires an extended hike to access.

For measurement of Vegetation Structure, criteria for considering a plot compromised depend on plot type:

- Distributed Plots: If sampling cannot be completed for 2 consecutive bouts then the plot should be considered compromised.
- Tower Plots: If sampling cannot be completed for any 2 out of 3 scheduled bouts then the plot should be considered compromised.
- Not sampling lower-priority plots due to staffing constraints does not count toward qualifying as compromised.

If sampling at a given plot is not possible during a given bout, the **Sampling Impractical** field must be populated in *VST: Plot Meta-Data [PROD]* (SOP C.3) and a problem ticket should be submitted by Field Science staff.

To document locations not sampled during the current bout:

1. Review the completed sampling effort and create **Sampling Impractical** records as described in Section 4.5 for plots at which sampling was scheduled but not completed.
2. To document whether a location is compromised according to the criteria above:
 - a. Review **Sampling Impractical** records from the *VST: Plot Meta-Data [PROD]* application and Portal data to identify locations where sampling was scheduled but was not completed due to environmental or site management factors.
3. Create an Incident with the following naming convention to document the missed sampling: and compromised location: ‘TOS Sampling Location Compromised: VST – [Root Cause Description]’.



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- a. Example: ‘TOS Sampling Location Compromised: VST – Could not access plot for two consecutive bouts due to permanently closed road’

Staff scientists review incident tickets annually to determine whether a sampling location is compromised.

G.2 Sample Preservation

- Place plastic bags with leaf samples from unknown species in a refrigerator until they are identified and/or placed in a plant press and dried for identification at a later date.
- **Specimens should not be left in the refrigerator for more than two days.**
- Identification often requires a variety of dichotomous keys, a dissecting microscope, a dissecting kit, and a herbarium with voucher specimens for verification.

G.3 Refreshing the Sample Kit

- Recharge batteries on the GPS unit.
- Make sure there are either 1) adequate supplies of fresh replacement batteries for the TruPulse 360R (type CR123A); or 2) rechargeable AA batteries needed for the TruPulse 360i are re-charged.
- Check that supplies of lens tissue are adequate.
- Check that supplies of consumable materials are adequate, particularly data sheets.

G.4 Equipment Maintenance, Cleaning, and Storage

- If necessary, clean the lenses on the laser rangefinder with a lens cloth or lens tissue.
- Remove plot location information that is no longer needed from mobile devices.



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SOP H Data Entry and Verification

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible; alternatively, devices should be synced immediately upon return to the Domain Support Facility.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times. Data collected on paper data sheets must be transcribed within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

Quality Assurance

Data Quality Assurance (QA) is an important part of data collection and ensures that all data are accurate and complete. Certain QA checks can be conducted in the field (i.e., before a field team leaves a plot or site), while others can be conducted at a later date in the office (typically within a week of collection). Field QA procedures are designed to prevent the occurrence of invalid data values that cannot be corrected at a later time, and to ensure that data and/or sample sets are complete before the sampling window closes. Invalid metadata (e.g., collection dates, plotIDs) are difficult to correct when field crews are no longer at a sampling location.

Office QA procedures are meant to ensure that sampling activities are **consistent** across bouts, that sampling has been carried out to **completion**, and that activities are occurring in a **timely** manner. The Office QA will also assess inadvertently duplicated data and transcription errors to maintain data **validity** and **integrity**. See the Data Management Protocol (RD[04]) for more discussion of QA measures.

Before digital records load to the NEON database, the data must undergo thorough quality checks.

The steps needed to accomplish this are outlined in the VST QC Checklist, which is available on the [NEON SSL](#).

H.1 QA/QC and Digital Data Workflow

The 'Manual for Fulcrum Application: TOS Vegetation Structure [PROD] – All SOPs' provides a detailed description and illustration of the workflow (RD[14]). A summary is provided here.

1. VST: Plot Meta-Data

- a. Records created here inform which plots are subsequently available in all downstream apps for selection in **plotID** fields for the current bout.
- b. All growth forms measured in downstream applications must be documented here first.



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2. **VST: Mapping and Tagging**

- a. Records created here inform which **tagIDs** are available for measurement in *VST: Apparent Individuals*.
- b. All **tagIDs** that will be measured must be entered here first.
- c. Published taxonID values for Apparent Individuals on the Data Portal are derived from this application.
- d. Verify mapping and tagging efforts immediately after field work is complete using the VST QAQC ‘Peregrine’ application.

3. **VST: Apparent Individuals**

- a. Records created here rely on previously created **plotID** and **tagID** records in upstream applications – *VST: Plot Meta-Data* and *VST: Mapping and Tagging*, respectively.

4. **VST: Shrub Groups**

- a. Records created here rely on previously created **plotID** records in the upstream *VST: Plot Meta-Data* application.
- b. The **groupID** does NOT need to be created first in *VST: Mapping and Tagging*.

H.2 Field Data Sheets

Paper data sheets for Vegetation Structure data collection may be used if the mobile application ingest platform is unavailable or compromised.

1. Transcribe data from the ‘Plot Meta-Data’ data sheet into the *VST: Plot Meta-Data [PROD]* app.
2. Transcribe data from the ‘Mapping and Tagging’ data sheet into the *VST: Mapping and Tagging [PROD]* app.
3. Transcribe data from the ‘Apparent Individuals,’ ‘Other non-cactus,’ and ‘Cactus’ data sheets into the *VST: Apparent Individuals [PROD]* app.
4. Transcribe data from the ‘Shrub Groups’ data sheet into the *VST: Shrub Groups [PROD]* app.



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SOP I Sample Shipment

Not applicable to the Measurement of Vegetation Structure protocol.



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APPENDIX A QUICK REFERENCES

Making Quality Measurements of Vegetation Structure

Step 1 – Calibrate laser rangefinder compass. Check/set current declination for site.

Step 2 – Carefully delineate measurement area and ensure all tagged individuals fall within plot boundaries.

Step 3 – Survey vegetation for presence/absence of growth forms and assess need for nested subplots (typically for new plots only).

Step 4 – Record Plot Meta-Data and save.

Step 5 – Tag and identify each newly qualifying individual (new plots and as needed in existing plots), and map individuals as required.

Step 6 – Record Mapping and Tagging data.

Step 6 – Take and record Apparent Individual and Shrub Group measurements; optional: use temporary flagging as you go to mark progress.

Step 7 – Remove temporary flagging (if applicable).

For directions on using the laser rangefinder, see TOS Standard Operating Procedure: TruPulse Rangefinder Use and Calibration (RD[09]).



APPENDIX B REMINDERS

Making Quality Measurements of Vegetation Structure

Measurement Area: Make sure to know...

- Size of plot and subplots.
- Number of subplots in the plot.
- Size of nested subplots (if any) for plots previously measured.
- How to determine whether nested subplots are needed for new plots, and how to determine whether a new nested subplot size is warranted.

Taking Measurements: Remember to...

- Include stem in tally if > 50% of the individual (or > 50% of stems for multi-stemmed plants) are rooted in the measurement area.
- (Optional) Use temporary flagging or clothes pins to distinguish between measured and unmeasured stems.
- Carefully record all metadata, measurements, and observations in digital application or data sheet.
- Mark, map, and tag new individuals that meet minimum size cutoff.
- Identify previously tagged stems that have died since last measurement.
- Remove temporary flagging when measurements are completed

Using the laser rangefinder: Pay close attention to...

- Declination – Is it set for your current location?
- Calibration – for optimum performance, complete compass calibration each time you change sampling locations (i.e., plots), after changing batteries. After a severe drop shock, both the compass and the inclinometer require calibration.
- Selection choices in drop-down menu – in what measurement mode has the instrument been set?.
- Battery charge – Replace when low-charge indicated.
- Transcription of measurements into digital application or data sheet.
- Metal objects – Keep them at least 2 feet away from instrument when using the compass.

Directions for the laser rangefinder are in TOS Standard Operating Procedure: TruPulse Rangefinder Use and Calibration (RD[09]).



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APPENDIX C SITE-SPECIFIC SCHEDULING INFORMATION

The dates in the table below are estimated from satellite MODIS-EVI phenology data averaged from 2012-2021 (Didan 2023), with the exception that dates for D04 and D20 are derived from precipitation data, as these sites are relatively invariant with respect to greenness. Dates presented here are only a guide and are derived according to the logic presented in Section 4. Because individual years may vary widely from the average dates provided below, it is essential that domain staff monitor real-time conditions to determine when to start (and stop) sampling, as described in Section 4 of this protocol.

“Start Date” definition: Below, values in the “Start Date” field correspond to the average day of year at which greenness begins to decrease. Use these dates as a guide for when to begin monitoring for senescence. The goal is to begin vegetation structure sampling when approximately 50% of deciduous woody plants and/or herbaceous plants have begun to senesce.

“Start Date” and “End Date” fields are relevant to vegetation structure measurement windows in both Distributed and Tower plots and represent the period during which vegetation photosynthetic activity is minimal following a growing season. The “Protocol Implementation” field indicates qualifying vegetation is present based on satellite imagery and on-the-ground feedback, and therefore the Vegetation Structure protocol should be implemented. If you feel this assessment is inaccurate for your site, please submit a problem ticket to Science Operations. It will not necessarily be possible to record vegetation structure data throughout the entire measurement window, due to snow, site access issues, etc. If provided measurement windows are not logistically feasible, changes to “Start Date” may be made in consultation with Science. Unless indicated otherwise, “End Date” values are in the next calendar year.

Table 19. Site-specific scheduling information for vegetation structure measurements.

Domain Number	Site ID	Site Type	Start Date	End Date	Protocol Scheduling by Plot Type	Dendro-bands	Remarks
01	BART	Faster-growth	07/01 (ferns) 08/16 (woody)	04/21	Dist = Yes Tower = Yes	N	Access problems may exist during proposed measurement window.
	HARV	Faster-growth	07/01 (ferns) 08/13 (woody)	04/22	Dist = Yes Tower = Yes	N	Access problems may exist during proposed measurement window.
02	BLAN	Faster-growth	08/19	03/23	Dist = Yes Tower = Yes	N	Start date visually estimated from MODIS timecourse data.
	SCBI	Faster-growth	08/04	04/02	Dist = Yes Tower = Yes	N	
	SERC	Faster-growth	08/11	03/27	Dist = Yes Tower = Yes	N	



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Domain Number	Site ID	Site Type	Start Date	End Date	Protocol Scheduling by Plot Type	Dendro-bands	Remarks
03	DSNY	Faster-growth	05/01 (ferns) 07/28 (woody)	03/07	Dist = Yes Tower = Yes	N	
	JERC	Faster-growth	06/01 (ferns) 08/18 (woody)	04/05	Dist = Yes Tower = Yes	N	
	OSBS	Faster-growth	05/01 (ferns) 07/25 (woody)	03/12	Dist = Yes Tower = Yes	N	Not all Distributed plots may have qualifying stems.
04	GUAN	Faster-growth	11/21	04/15	Dist = Yes Tower = Yes	N	Dates correspond to the dry season and are derived from Ensenada precipitation data (2005-2021). Dry season months are those averaging < 60 mm precipitation.
	LAJA	Faster-growth	11/21	04/15	Dist = Yes Tower = No	NA	Dates correspond to the dry season and are derived from Ensenada precipitation data (2005-2021). Dry season months are those averaging < 60 mm precipitation.
05	STEI	Faster-growth	08/01 (ferns) 08/12 (woody)	04/26	Dist = Yes Tower = Yes	N	Not all Tower plots may have qualifying stems.
	TREE	Faster-growth	08/01 (ferns) 08/12 (woody)	04/26	Dist = Yes Tower = Yes	N	
	UNDE	Faster-growth	07/15 (ferns) 08/13 (woody)	04/29	Dist = Yes Tower = Yes	N	
06	KONA	Not scheduled	NA	NA	Dist = No Tower = No	NA	Ag site, no qualifying individuals
	KONZ	Survey (D) Faster-growth (T)	08/11	04/14	Dist = No Tower = Yes	N	Dist: Survey indicates no qualifying individuals; schedule survey every 5 y.



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Domain Number	Site ID	Site Type	Start Date	End Date	Protocol Scheduling by Plot Type	Dendro-bands	Remarks
	UKFS	Faster-growth	08/11	03/28	Dist = Yes Tower = Yes	N	
07	GRSM	Faster-growth	08/09	04/03	Dist = Yes Tower = Yes	N	
	MLBS	Faster-growth	07/01 (ferns) 08/11	04/15	Dist = Yes Tower = Yes	N	
	ORNL	Faster-growth	07/23	03/24	Dist = Yes Tower = Yes	N	
08	DELA	Faster-growth	07/22	03/14	Dist = Yes Tower = Yes	N	Sampling discontinued after the 2025 season due to planned site decommissioning.
	LENO	Faster-growth	07/25	03/18	Dist = Yes Tower = Yes	N	
	TALL	Faster-growth	07/20	03/24	Dist = Yes Tower = Yes	N	
09	DCFS	Survey	08/19	05/04	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y
	NOGP	Survey	08/14	04/20	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y
	WOOD	Survey	08/24	05/12	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y
10	CPER	Survey	07/22	04/06	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y; <i>Opuntia</i> cover is critical for Tower Plot survey. Start date visually estimated from MODIS timecourse data.
	RMNP	Slow-growth	08/06	05/01	Dist = Yes Tower = Yes	Y	Start date visually estimated from MODIS timecourse data.
	STER	Not scheduled	NA	NA	Dist = No Tower = No	NA	Ag site, no qualifying individuals
11	CLBJ	Faster-growth	03/15 (ferns) 11/01 (woody)	03/13	Dist = Yes Tower = Yes	N	Start date later than MODIS based on Field Science feedback.
	OAES	Survey	NA	NA	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y



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Domain Number	Site ID	Site Type	Start Date	End Date	Protocol Scheduling by Plot Type	Dendro-bands	Remarks
12	YELL	Slow-growth	07/23	See Remarks	Dist = Yes Tower = Yes	Y	Dist Plots: Complete data collection before snowfall and road closure. MODIS end date not meaningful due to winter snow cover. Tower Plots: Measurements must be completed before Bear Management closure.
13	MOAB	Sensitive	09/11	04/30	Dist = Yes Tower = Yes	N	Short shrubs, widely spaced; many may not be qualifying stems. Sensitive soil/veg site: No annual Tower Plot measurement, every 5-year for all plots only. Visual interpretation of MODIS timecourse data.
	NIWO	Slow-growth	08/17	05/04	Dist = Yes Tower = Yes	Y	Complete data collection before snowfall and road closure. Tower Plots meet Science Design criteria for implementation. MODIS end date not meaningful due to winter snow cover.
14	JORN	Sensitive	09/07	03/22	Dist = Yes Tower = Yes	N	Tower Plots: Sensitive soil/veg site, no annual Tower Plot measurement, every 5-year for all plots only. Start and end dates visually estimated from MODIS timecourse data.
	SRER	Sensitive	09/13	04/01	Dist = Yes Tower = Yes	N	Dist Plots: Schedule survey every 5 y in year before anticipated VST effort. Tower Plots: Sensitive soil/veg site, no annual Tower Plot measurement, every 5-year for all plots only. End date visually estimated from MODIS timecourse data.
15	ONAQ	Sensitive	06/10	03/31	Dist = Yes Tower = Yes	N	Tower Plots: Sensitive soil/veg site, no annual Tower Plot measurement, every 5-year for all plots only. Start date visually estimated from MODIS timecourse data.
16	ABBY	Faster-growth	07/01 (ferns) 07/29 (woody)	03/28	Dist = Yes Tower = Yes	N	Not all plots may have qualifying stems due to logging management.



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Domain Number	Site ID	Site Type	Start Date	End Date	Protocol Scheduling by Plot Type	Dendro-bands	Remarks
	WREF	Slow-growth	07/01 (ferns) 08/01	03/21	Dist = Yes Tower = Yes	Y	Not technically a slow-growth site but large trees lead to small growth increment.
17	SJER	Slow-growth	07/01	04/30	Dist = Yes Tower = Yes	Y	Tree senescence does not align with Mediterranean rainy season.
	SOAP	Slow-growth	07/01 (ferns) 07/11 (woody)	03/26	Dist = Yes Tower = Yes	Y	Ferns may not persist after fire.
	TEAK	Slow-growth	06/27 (woody) 07/27 (ferns)	04/17	Dist = Yes Tower = Yes	Y	Start date earlier than standard MODIS-EVI window to mitigate smoke exposure and access problems. MODIS-derived end date may not be meaningful due to winter snow cover.
18	BARR	Survey	08/13	05/21	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y
	TOOL	Survey	08/07	05/07	Dist = No Tower = No	NA	Survey indicates no qualifying individuals; schedule survey every 5 y
19	BONA	Slow-growth	08/03	05/03	Dist = Yes Tower = Yes	Y	Complete data collection before snowfall and road closure.
	DEJU	Slow-growth	08/05	05/01	Dist = Yes Tower = Yes	Y	Complete data collection before snowfall and road closure.
	HEAL	Slow-growth	08/07	04/25	Dist = Yes Tower = Yes	Y	Complete data collection before snowfall and road closure.
20	PUUM	Faster-growth	06/15	10/15	Dist = Yes Tower = Yes	N	Start Date should be consistent from year to year (\pm 2 weeks).



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APPENDIX D SITE-SPECIFIC SAMPLING INFORMATION

D.1 D03 – DSNY – Disney Wilderness Preserve

Modification Type	Modification	Standard Rule	Rationale for Change
Tagging requirements	<p>Root (re)sprouts from some species are only tagged once they graduate to ‘smt’ or ‘sis’.</p> <p>DSNY species are:</p> <ul style="list-style-type: none"> • <i>Quercus spp.</i> • <i>Lyonia spp.</i> • <i>Ilex spp.</i> • <i>Vaccinium spp.</i> • <i>Crataegus spp.</i> • <i>Gaylussacia spp.</i> • <i>Persea spp.</i> • <i>Aronia arbutifolia</i> • <i>Asimina reticulata</i> • <i>Diospyros virginiana</i> • <i>Gordonia lasianthus</i> • <i>Morella cerifera</i> • <i>Rhus copallinum</i> • <i>Sassafras albidum</i> • <i>Hypericum brachyphyllum</i> • <i>Bejaria racemosa</i> • <i>Callicarpa americana</i> <p>Create VST: Mapping and Tagging record with recordType = ‘temporary’ to record taxon data.</p>	Tag qualifying ‘sap’ and ‘sms’ with DBH < 1 cm and ddh ≥ 1 cm.	<ul style="list-style-type: none"> • Implementation of standard guidance does not result in longitudinal data per tagID. • Fire management results in repeat tagging of resprouts with little data value. • Protocol clarification: Apparent individuals drive nested subplot size, not number of resprouts from same individual.

D.2 D03 – JERC – Jones Ecological Research Center

Modification Type	Modification	Standard Rule	Rationale for Change
Tagging requirements	<p>Root (re)sprouts from some species are only tagged once they graduate to ‘smt’ or ‘sis’.</p> <p>JERC species are:</p> <ul style="list-style-type: none"> • <i>Acer spp.</i> • <i>Asimina spp.</i> 	Tag qualifying ‘sap’ and ‘sms’ with DBH < 1 cm and ddh ≥ 1 cm.	<ul style="list-style-type: none"> • Implementation of standard guidance does not result in longitudinal data per tagID. • Fire management results in repeat tagging of resprouts with little data value.



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Modification Type	Modification	Standard Rule	Rationale for Change
	<ul style="list-style-type: none"> • <i>Carya spp.</i> • <i>Celtis spp.</i> • <i>Quercus spp.</i> • <i>Sideroxylon spp.</i> • <i>Ulmus spp.</i> • <i>Vaccinium spp.</i> • <i>Diospyros virginiana</i> • <i>Rhus spp.</i> • <i>Sassafras albidum</i> • <i>Liquidambar styraciflua</i> • <i>Callicarpa americana</i> • <i>Aesculus pavia</i> • <i>Magnolia grandiflora</i> • <i>Ilex vomitoria</i> • <i>Crataegus spp.</i> • <i>Prunus spp.</i> <p>Create VST: Mapping and Tagging record with recordType = 'temporary' to record taxon data.</p>		<ul style="list-style-type: none"> • Protocol clarification: Apparent individuals drive nested subplot size, not number of resprouts from same individual.
Tagging requirements	Tags from the 6001 – 8000 series are used for Vegetation Structure.	Tags from the 6001 – 8000 series are reserved for Plant Phenology.	<ul style="list-style-type: none"> • Tags in the 6001 – 8000 series were originally allocated to Vegetation Structure and do not overlap with the Plant Phenology tag series.

D.3 D03 – OSBS – Ordway Swisher Biological Station

Modification Type	Modification	Standard Rule	Rationale for Change
Tagging requirements	<p>Root (re)sprouts from some species are only tagged once they graduate to 'smt' or 'sis'. OSBS species are:</p> <ul style="list-style-type: none"> • <i>Asimina spp.</i> • <i>Quercus spp.</i> • <i>Lyonia spp.</i> • <i>Ilex spp.</i> • <i>Magnolia spp.</i> • <i>Persea spp.</i> 	Tag qualifying 'sap' and 'sms' with DBH < 1 cm and ddh ≥ 1 cm.	<ul style="list-style-type: none"> • Implementation of standard guidance does not result in longitudinal data per tagID. • Fire management results in repeat tagging of resprouts with little data value. • Protocol clarification: Apparent individuals drive nested subplot size, not



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Modification Type	Modification	Standard Rule	Rationale for Change
	<ul style="list-style-type: none"> • <i>Vaccinium spp.</i> • <i>Decodon verticillatus</i> • <i>Diospyros virginiana</i> • <i>Gordonia lasianthus</i> • <i>Morella cerifera</i> • <i>Rhus copallinum</i> • <i>Sassafras albidum</i> • <i>Crataegus spp.</i> <p>Create VST: Mapping and Tagging record with recordType = 'temporary' to record taxon data.</p>		number of resprouts from same individual.
Tagging requirements	Tags from the 6001 – 8000 series are used for Vegetation Structure.	Tags from the 6001 – 8000 series are reserved for Plant Phenology.	<ul style="list-style-type: none"> • Tags in the 6001 – 8000 series were originally allocated to Vegetation Structure and do not overlap with the Plant Phenology tag series.

D.4 D06 – KONZ – Konza Prairie

Modification Type	Modification	Standard Rule	Rationale for Change
Tagging requirements	<p>Root (re)sprouts from some species are only tagged once they graduate to 'smt' or 'sis'. KONZ species are:</p> <ul style="list-style-type: none"> • <i>Cornus drummondii</i> <p>Create VST: Mapping and Tagging record with recordType = 'temporary' to record taxon and mapping data.</p>	Tag qualifying 'sap' and 'sms' with DBH < 1 cm and ddh ≥ 1 cm.	<ul style="list-style-type: none"> • Implementation of standard guidance does not result in longitudinal data per tagID. • Fire management results in repeat tagging of resprouts with little data value. • Protocol clarification: Apparent individuals drive nested subplot size, not number of resprouts from same individual.



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D.5 D08 – TALL – Talladega National Forest

Modification Type	Modification	Standard Rule	Rationale for Change
Growth form classification	At TALL, OXAR individuals (<i>Oxydendrum arboreum</i>) with DBH < 10 cm should be classified to shrub-type growthForms ('sms', 'sis'), and individuals with DBH ≥ 10 cm should be classified to tree-type growthForms ('sbt', 'mbt').	The growthForm for OXAR would typically be assigned to either shrub-type OR tree-type growthForms within a site.	<ul style="list-style-type: none"> • OXAR growing in areas at TALL that are frequently burned adopt 'sms' and 'sis' growthForms, are multi-stemmed, and do not transition to trees. • OXAR growing in wetter areas at TALL that do not burn have fewer stems, on average, and will transition to a larger tree growthForm once DBH ≥ 10 cm.

D.6 D10 – RMNP – Rocky Mountain National Park

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot 'productivity subset', including banded trees. Dendrometer band measurements in additional Tower Plots for large trees (≥ 95 th percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> • Annual measurement frequency in Tower Plot 'productivity subset' plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.7 D12 – YELL – Yellowstone National Park

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot 'productivity subset', including banded trees. Dendrometer band measurements in additional Tower Plots for large trees (≥ 95 th percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> • Annual measurement frequency in Tower Plot 'productivity subset' plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.



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D.8 D13 – NIWO – Niwot Ridge

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.9 D13 – MOAB

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement frequency	All Tower Plots measured on 5 y interval; no annual measurements	Annual measurements in a subset of Tower Plots.	<ul style="list-style-type: none"> Dendrometer band installation not applicable for vegetation. Annual measurement with calipers causes adverse site impacts due to sensitive vegetation, soils.

D.10 D14 – JORN – Jornada LTER

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement frequency	All Tower Plots measured on 5 y interval; no annual measurements	Annual measurements in a subset of Tower Plots.	<ul style="list-style-type: none"> Dendrometer band installation not applicable for vegetation. Annual measurement with calipers causes adverse site impacts due to sensitive vegetation, soils.



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D.11 D14 – SRER – Santa Rita Experimental Range

Modification Type	Modification	Standard Rule	Rationale for Change
Mapping guidelines	Map large-stature cacti	Cacti not mapped	<ul style="list-style-type: none"> • Ensure data completeness. • Speed locating individuals for repeat measurements.
Measurement frequency	All Tower Plots measured on 5 y interval; no annual measurements	Annual measurements in a subset of Tower Plots.	<ul style="list-style-type: none"> • Dendrometer band installation not applicable for vegetation. • Annual measurement with calipers causes adverse site impacts due to sensitive vegetation, soils.
Measurement guidelines	2020 onward: <i>Prosopis velutina</i> and <i>Parkinsonia florida</i> measured as 'sis'	2019 and prior: These two species measured as 'sbt' or 'mbt'	<ul style="list-style-type: none"> • Published biomass allometries for these two species require basal diameter as input. • Both 'shrub' and 'tree' growth forms are consistent with USDA Plants designation.
eventID		Same eventID for <i>Opuntia</i> measured in spring as for woody vegetation measured in autumn	<ul style="list-style-type: none"> • Clarification of standard rule, given large temporal gap between <i>Opuntia</i> and woody measurement events in same calendar year.

D.12 D15 – ONAQ – Onaqui / Ault

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement frequency	All Tower Plots measured on 5 y interval; no annual measurements	Annual measurements in a subset of Tower Plots.	<ul style="list-style-type: none"> • Dendrometer band installation not applicable for vegetation. • Annual measurement with calipers causes adverse site impacts due to sensitive vegetation, soils.



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D.13 D16 – WREF – Wind River Experimental Forest

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.14 17 – SJER – San Joaquin Experimental Range

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.15 D17 – SOAP – Soaproot Saddle

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.



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D.16 D17 – TEAK – Teakettle

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.17 D18 – BARR – Utqiagvik (Barrow)

Modification Type	Modification	Standard Rule	Rationale for Change
Diameter cutoff	Reduce ddh cutoff from 1 cm to 0.7 cm.	For apparent individuals with no DBH, measure basal stem diameter for all individuals with ddh ≥ 1 cm.	<ul style="list-style-type: none"> The mean ddh of the dominant small shrubs at the site (<i>Betula nana</i>) is approximately 1 cm, with a significant number of individuals having ddh smaller than 1 cm. Using a 1 cm ddh cutoff at this site therefore arbitrarily splits the <i>B. nana</i> population such that roughly half is measured via the VST protocol, and half is measured via the HBP protocol. Reducing the ddh cutoff from 1 cm to 0.7 cm ensures that > 90% of the ‘sms’ individuals are measured with only the VST protocol.
Mapping requirements	Do not map ‘sms’ growth forms even if trees with DBH ≥ 10 cm are not present (mainly applies to <i>Betula nana</i>).	Map ‘sis’ and ‘sms’ if no trees with DBH ≥ 10 cm are present in the plot.	<ul style="list-style-type: none"> Mapping <i>B. nana</i> is not consistent with the goals of the Plant Productivity Science Design (NEON.DOC.000914)



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D.18 D18 – TOOL – Toolik LTER

Modification Type	Modification	Standard Rule	Rationale for Change
Diameter cutoff	Reduce ddh cutoff from 1 cm to 0.7 cm.	For apparent individuals with no DBH, measure basal stem diameter for all individuals with ddh \geq 1 cm.	<ul style="list-style-type: none"> • Mean ddh of the dominant small shrubs at the site (<i>Betula nana</i>) is approximately 1 cm, with a significant number of individuals having ddh smaller than 1 cm. • A 1 cm ddh cutoff at this site arbitrarily splits the <i>B. nana</i> population such that roughly half is measured via the VST protocol, and half is measured via the HBP protocol. • Reducing the ddh cutoff from 1 cm to 0.7 cm ensures that > 90% of the ‘sms’ individuals are measured with only the VST protocol.
Mapping requirements	Do not map ‘sms’ growth forms even if trees with DBH \geq 10 cm are not present (mainly applies to <i>Betula nana</i>).	Map ‘sis’ and ‘sms’ if no trees with DBH \geq 10 cm are present in the plot.	<ul style="list-style-type: none"> • Mapping <i>B. nana</i> is not consistent with the goals of the Plant Productivity Science Design (NEON.DOC.000914)
measurement Height	When thick bryophytes form the ground layer, the mean height of the bryophyte layer surrounding the base of the stem is used as the zero-point for determining measurement Height .	Mounded or heaped organic material around the base of a stem is removed, and the ‘true’ ground surface is exposed before determining measurement Height .	<ul style="list-style-type: none"> • Bryophytes grow in a mounded, clustered manner around the base of stems, and often grow up stems 10 cm+ • It is destructive and not possible to remove bryophytes and uncover the ‘true’ surface of the ground because of the mat-like bryophyte growth form that slowly transitions to peat with depth. • It is functionally consistent with other sites to consider the surface of the bryophyte layer the ground, and the zero-point for determining measurement Height.



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D.19 D19 – BONA – Bonanza Creek LTER

Modification Type	Modification	Standard Rule	Rationale for Change
Mapping requirements	Do not map 'sms' growth forms even if trees with DBH \geq 10 cm are not present (mainly applies to <i>Betula nana</i>).	Map 'sis' and 'sms' if no trees with DBH \geq 10 cm are present in the plot.	<ul style="list-style-type: none"> Mapping <i>B. nana</i> is not consistent with the goals of the Plant Productivity Science Design (NEON.DOC.000914)
Diameter cutoff	Reduce ddh cutoff from 1 cm to 0.7 cm.	For apparent individuals with no DBH, measure basal stem diameter for all individuals with ddh \geq 1 cm.	<ul style="list-style-type: none"> Mean ddh of the dominant small shrubs at the site (<i>Betula nana</i>) is approximately 1 cm, with a significant number of individuals having ddh smaller than 1 cm. A 1 cm ddh cutoff at this site arbitrarily splits the <i>B. nana</i> population such that roughly half is measured via the VST protocol, and half is measured via the HBP protocol. Reducing the ddh cutoff from 1 cm to 0.7 cm ensures that > 90% of the 'sms' individuals are measured with only the VST protocol.
measurement Height	When thick bryophytes form the ground layer, the mean height of the bryophyte layer surrounding the base of the stem is used as the zero-point for determining measurement Height .	Mounded or heaped organic material around the base of a stem is removed, and the 'true' ground surface is exposed before determining measurement Height .	<ul style="list-style-type: none"> Bryophytes grow in a mounded, clustered manner around the base of stems, and often grow up stems 10 cm or more. It is destructive and not possible to remove bryophytes and uncover the 'true' surface of the ground because of the mat-like bryophyte growth form that slowly transitions to peat with depth. It is functionally consistent with other sites to consider the surface of the bryophyte layer the ground, and the zero-point for determining measurement Height.



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Modification Type	Modification	Standard Rule	Rationale for Change
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.20 D19 – DEJU – Delta Junction

Modification Type	Modification	Standard Rule	Rationale for Change
Mapping requirements	Do not map ‘sms’ growth forms even if trees with $\text{DBH} \geq 10$ cm are not present (mainly applies to <i>Betula nana</i>).	Map ‘sis’ and ‘sms’ if no trees with $\text{DBH} \geq 10$ cm are present in the plot.	<ul style="list-style-type: none"> Mapping <i>B. nana</i> is not consistent with the goals of the Plant Productivity Science Design (NEON.DOC.000914)
Diameter cutoff	Reduce ddh cutoff from 1 cm to 0.7 cm.	For apparent individuals with no DBH, measure basal stem diameter for all individuals with ddh ≥ 1 cm.	<ul style="list-style-type: none"> Mean ddh of the dominant small shrubs at the site (<i>Betula nana</i>) is approximately 1 cm, with a significant number of individuals having ddh smaller than 1 cm. A 1 cm ddh cutoff at this site arbitrarily splits the <i>B. nana</i> population such that roughly half is measured via the VST protocol, and half is measured via the HBP protocol. Reducing the ddh cutoff from 1 cm to 0.7 cm ensures that $> 90\%$ of the ‘sms’ individuals are measured with only the VST protocol.
measurement Height	When thick bryophytes form the ground layer, the mean height of the bryophyte layer surrounding the base of the stem is used as the zero-point for	Mounded or heaped organic material around the base of a stem is removed, and the ‘true’ ground surface is exposed before determining measurement	<ul style="list-style-type: none"> Bryophytes grow in a mounded, clustered manner around the base of stems, and often grow up stems 10 cm or more. It is destructive and not possible to remove bryophytes



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	determining measurement Height.	Height.	and uncover the ‘true’ surface of the ground because of the mat-like bryophyte growth form that slowly transitions to peat with depth. <ul style="list-style-type: none"> It is functionally consistent with other sites to consider the surface of the bryophyte layer the ground, and the zero-point for determining measurement Height.
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees ($\geq 95^{\text{th}}$ percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.

D.21 D19 – HEAL – Healy

Modification Type	Modification	Standard Rule	Rationale for Change
Diameter cutoff	Reduce ddh cutoff from 1 cm to 0.7 cm.	For apparent individuals with no DBH, measure basal stem diameter for all individuals with ddh ≥ 1 cm.	<ul style="list-style-type: none"> Mean ddh of the dominant small shrubs at the site (<i>Betula nana</i>) is approximately 1 cm, with a significant number of individuals having ddh smaller than 1 cm. A 1 cm ddh cutoff at this site arbitrarily splits the <i>B. nana</i> population such that roughly half is measured via the VST protocol, and half is measured via the HBP protocol. Reducing the ddh cutoff from 1 cm to 0.7 cm ensures that $> 90\%$ of the ‘sms’ individuals



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			are measured with only the VST protocol.
Mapping requirements	Do not map ‘sms’ growth forms even if trees with DBH \geq 10 cm are not present (mainly applies to <i>Betula nana</i>).	Map ‘sis’ and ‘sms’ if no trees with DBH \geq 10 cm are present in the plot.	<ul style="list-style-type: none"> Mapping <i>B. nana</i> is not consistent with the goals of the Plant Productivity Science Design (NEON.DOC.000914)
measurement Height	When thick bryophytes form the ground layer, the mean height of the bryophyte layer surrounding the base of the stem is used as the zero-point for determining measurement Height .	Mounded or heaped organic material around the base of a stem is removed, and the ‘true’ ground surface is exposed before determining measurement Height .	<ul style="list-style-type: none"> Bryophytes grow in a mounded, clustered manner around the base of stems, and often grow up stems 10 cm or more. It is destructive and not possible to remove bryophytes and uncover the ‘true’ surface of the ground because of the mat-like bryophyte growth form that slowly transitions to peat with depth. It is functionally consistent with other sites to consider the surface of the bryophyte layer the ground, and the zero-point for determining measurement Height.
Measurement method	Annual measurement of qualifying stems in Tower Plot ‘productivity subset’, including banded trees. Dendrometer band measurements in additional Tower Plots for large trees (\geq 95 th percentile biomass).	DBH tape used for annual measurement of diameter in Tower Plot subset.	<ul style="list-style-type: none"> Annual measurement frequency in Tower Plot ‘productivity subset’ plus dendrometer band measurements required to estimate annual aboveground net primary productivity for slow-growth-increment site.



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D.22 D20 – PUUM – Pu’u Maka’ala

Modification Type	Modification	Standard Rule	Rationale for Change
Measurement guidelines	Uluhe (<i>Dicranopteris emarginata</i>) and group-forming fern allies (e.g., <i>Lycopodiella spp.</i>) are measured as shrub groups.	Ferns and fern allies are measured as apparent individuals.	<ul style="list-style-type: none"> • Dense groups of Uluhe and other fern allies are impenetrable without significant damage to the vegetation. • Lack of physical access to individuals of these species makes Apparent Individual measurements impractical.



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APPENDIX E EQUIPMENT

- Equipment in the tables below is needed to implement the procedures in this document.
- Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.
- Item quantities are provided for a single team of two people collecting data.
- Suppliers and item numbers may be suggested for equipment with Exact Brand = ‘N’ but availability is not guaranteed.
- Suppliers and item numbers are provided for equipment with Exact Brand = ‘Y’ and these data are accurate at the time of protocol release.

Table 20. Equipment list – Preparing for Sampling (SOP A).

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Amazon	N	GPS receiver, recreational accuracy	Pre-load sampling locations	1
Forestry Suppliers 92496	Y	TruPulse 360i Laser Rangefinder, ± 20 cm accuracy	Map and measure apparent individuals and shrub groups.	1
	N	Hammer	Label blank tags	1
Forestry Suppliers 57522	N	Hand stamp steel die set OR battery- powered cordless engraver	Label blank tags	1 set
	N	All weather copy paper	Print datasheets	As needed
National Band and Tag	N	Round unnumbered aluminum tag, silver, 1.25” diameter, 0.05” thickness, or equivalent.	Pre-label for tagging multi-stemmed individuals.	50

Table 21. Equipment list – Field Sampling: Classification, Plot Meta-Data, Mapping and Tagging (SOP C and SOP D).

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
	N	Mobile data collection device (tablet or equivalent), and spare battery	Collect and record data in the field.	1
	N	Cardboard ventilator	Press collected individuals for identification	



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Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Forestry Suppliers 39167	N	Chaining pins or other suitable anchor	Anchor measuring tapes	4
	N	Compass with mirror and declination adjustment	Determine nested subplot boundary	1
	N	Cooler	Chill perishable samples in field	1
Forestry Suppliers 59422	N	Lufkin Diameter tape, 200 cm	Measure stem diameter. Stems present with diameter > 64 cm	1
Forestry Suppliers 39379	N	Spencer metric logger's tape, or equivalent	Measure stem diameter. Stems present with 5 cm < diameter < 64 cm	1
	N	Field guide, regional flora reference guide and/or key	Identify unknown species	1
Forestry Suppliers 91079	Y	TruPulse i-series foliage filter	Allow laser rangefinder use in dense vegetation	1
	N	GPS receiver, recreational accuracy	Navigate to sampling location	1
	N	Site map	Navigate to sampling location	1
	N	Hammer	Nail tags to trees, label blank tags	1
Forestry Suppliers 57522	N	Hand stamp steel die set OR battery-powered cordless engraver	Label blank tags	1 set
	N	Block of wood or equivalent hard surface	Tag stamping	1
	N	Handheld caliper, 0.1 cm precision	Measure stem diameter < 5 cm; lianas prevent accurate diameter measurement with tape	1
Thermo Fisher	N	Ice pack	Chill perishable samples in field	As needed



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Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Forestry Suppliers 92496	Y	TruPulse 360i Laser Rangefinder, ± 20 cm accuracy	Determine nested subplot boundary; map stems; measure stem height and crown diameter. Individuals with relatively large canopies; plots with slopes > 20%	1
Forestry Suppliers 39945	N	Measuring tape, minimum 50 m	Determine nested subplot, subplot boundary	4
Herbarium Supply 223	N	Paper blotters	Press collected individuals for identification	As needed
Bioquip 3115	N	Plant press	Press collected individuals for identification	As needed
Forestry Suppliers 37250	N	Tripod, non-magnetic	Hold laser rangefinder directly over plot marker	1
Grainger 5B317	N	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1
	N	Wire cutter	Cut wire to desired length	1
	N	Rod, dowel, pipe, or equivalent; 1.4 m length, max 1" diameter, marking at 1.3 m	Quickly find measurementHeight and tag height for straight boles	1
	N	Rod, dowel, pipe, or equivalent; 0.1 m length, max 1" diameter	Quickly find measurementHeight for ddh	1
	N	AA battery	Spare battery for GPS receiver	4
Forestry Suppliers 79121	N	Aluminum nail	Affix tag to stems with DBH ≥ 5 cm	As needed
Grainger 16Y067	N	Aluminum wire, 20 gauge	Affix tag to stems with DBH ≥ 5 cm	As needed
Grainger 16Y049	N	Stainless steel wire, 20 gauge (0.032 in diameter)	Affix tag to stems with DBH < 5 cm at sites with fire management	As needed

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
	N	CR123A battery or 2X AA batteries	Spare battery for TruPulse 360R and TruPulse 360i, respectively	2
Forestry Suppliers 57880	N	Flagging tape or orange clothes pins	Temporarily mark stems after measurement	2
Grainger 9TA07	N	Fluorescent lumber crayon	Mark DBH measurement location on stem. A black crayon may be used to cover mistakes.	1
Grainger 8YAT5, 5CNK5	N	Resealable plastic bag, 1 gal	Collect voucher specimens	20
National Band and Tag	N	Round numbered aluminum tag, silver; 0001-6000 and 8001-9999	Tag qualifying stems	As needed
National Band and Tag	N	Round unnumbered aluminum tag, silver	Tag multi-stemmed individuals.	50
	N	Survey marking flag, PVC or fiberglass stake	Delineate sampling area	12
	N	Tabloid newspaper pages	Press collected individuals for identification	As needed
	N	Field datasheet	Record data	As needed

Table 22. Equipment list – Dendrometer band fabrication and installation (SOP A.4 and SOP F.2).

Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
McMaster 1598T62	Y	½” stainless steel label tape, 21 foot length	Band material	per SSL
Amazon	N	Small plastic bucket with slit cut in side at ground level – e.g., large yogurt container or equivalent	Organize and dispense band material for initial cutting and prep	2



Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Lee Spring LE 026C 05 S	Y	1.5" stainless steel spring	Band 5-10 cm DBH trees	per SSL
Lee Spring LE 026C 11 S	Y	3" stainless steel spring, wire diameter = 0.026 inch	Band 10-50 cm DBH trees	per SSL
Lee Spring LE 031C 11 S	Y	3" stainless steel spring, wire diameter = 0.031 inch	Band DBH > 50 cm trees	per SSL
Roper Whitney	Y	Heavy duty metal hole punch	Punch spring attachment points in band material	2
Amazon	N	Tin snips	Cut band material to length	2
Knife Center	N	Mora knife	Prepare tree bole surface for band	8
Forestry Suppliers	N	Hatchet; use existing CDW equipment if available	Prepare tree bole surface for band if knife is inadequate	2
Mitutoyo 500-723-20	Y	Stainless steel Mitutoyo digital caliper, 0-150 mm measuring range, 0.025 mm increment	Measure initial dendrometer band gap	4

Table 23. Equipment list – Measuring Apparent Individuals (SOP E).

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
	N	Mobile data collection device (tablet or equivalent), and spare battery	Collect and record data in the field.	1
Bioquip 3127	N	Cardboard ventilator	Press collected individuals for identification	
Forestry Suppliers 39167	N	Chaining pins or other suitable anchor	Anchor measuring tapes	4
	N	Cooler	Chill perishable samples in field	1



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Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Forestry Suppliers 59422	N	Lufkin DBH tape, 200 cm	Measure stem diameter. Stems present with diameter > 64 cm	1
Forestry Suppliers 39379	N	Spencer metric logger's tape, or equivalent	Measure stem diameter. Stems present with 5 cm < diameter < 64 cm	1
Forestry Suppliers 59763	Y	Haglof Mantax Black tree calipers, 95 cm	Measure stem diameters up to 95 cm when lianas are attached and a DBH tape will not work.	1
Forestry Suppliers 59714	Y	Haglof Mantax Black tree calipers, 50 cm	Measure stem diameters up to 50 cm when lianas are attached and a DBH tape will not work.	1
	N	Field guide, regional flora reference guide and/or key	Identify unknown species	1
Mitutoyo 500-723-20	Y	Stainless steel Mitutoyo digital caliper, 0-150 mm measuring range, 0.025 mm increment	Measure dendrometer band gap	4
Forestry Suppliers 91079	Y	TruPulse i-series foliage filter	Allow laser rangefinder use in dense vegetation	1
Amazon	N	GPS receiver, recreational accuracy	Navigate to sampling location	1
	N	Site map and plot list	Navigate to sampling location	1
	N	Hammer	Nail tags to trees, label blank tags	1
Forestry Suppliers 57522	N	Hand stamp steel die set OR battery-powered cordless engraver	Label blank tags for multi-stem trees	1 set
	N	Vernier caliper, 0.1 cm precision	Measure stem diameters < 5 cm	1
Thermo Fisher	N	Ice pack	Chill perishable samples in field	As needed
Forestry Suppliers 92496	Y	TruPulse 360i Laser Rangefinder, ± 20 cm accuracy	Map stems recruited into the minimum size class; measure stem height, crown diameter. Brushy; trees with relatively large canopy diameters; slopes ≥ 20%	1



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Supplier/ Item No.	Exact Brand	Description	Purpose	Quantity
Forestry Suppliers 71112	N	Measuring stick, 2 m folding	Measure heights of small-stature woody vegetation	1
Forestry Suppliers 39428 (one example)	N	Aluminum or fiberglass measuring rod, 5 m telescoping (e.g., Bosch GR500), metal retractable 5 m tape (Keson 25 mm tape, PGPRO8MV; Milwaukee wide blade tape, 48-22-1226), or equivalent.	Measure heights of medium-stature woody vegetation, measure crown dimensions for some shrubs	1
Forestry Suppliers 39945	N	Measuring tape, minimum 50 m	Determine nested subplot, subplot boundary	4
Forestry Suppliers 53740	N	Paper blotters	Press collected individuals for identification	As needed
Bioquip 3115	N	Plant press	Press collected individuals for identification	1
Grainger 5B317	N	White reflector or reflective tape	Reflective target for laser rangefinder; aids in measuring distance to target accurately	1
	N	Wire cutter	Cut wire to desired length. Stems present with DBH < 5 cm	1
	N	Compass with mirror and declination adjustment	Delineate nested subplots if markers are removed or disturbed	1
	N	Rod, dowel, pipe, or equivalent; 1.4 m length, max 1" diameter, marking at 1.3 m	Quickly find measurementHeight and tag height for straight boles	1
	N	Rod, dowel, pipe, or equivalent; 0.1 m length, max 1" diameter	Quickly find measurementHeight for ddh	1
	N	Retractable metal measuring tape, 25 mm W x 10 m L, metric demarcations	Quickly measure mid-stature shrub crown dimensions	1
	N	AA battery	Spare battery for GPS receiver	



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Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Forestry Suppliers 79121	N	Aluminum nail	Affix tag to stems with DBH ≥ 5 cm	As needed
Grainger 16Y067	N	Aluminum wire, 20 gauge (0.032 in diameter)	Affix tag to stems with DBH < 5 cm	As needed
Grainger 16Y049	N	Stainless steel wire, 20 gauge (0.032 in diameter)	Affix tag to stems with DBH < 5 cm at sites with fire management	As needed
	N	CR123A battery or 2X AA batteries	Spare battery for TruPulse 360R or TruPulse 360i, respectively	2
Forestry Suppliers 57880	N	Flagging tape	Temporarily mark stems after measurement	2
Grainger 9TA07	N	Fluorescent lumber crayon	Mark DBH measurement location on stem	1
	N	Graph paper	Estimate area of shrub groups	As needed
National Band and Tag	N	Round numbered aluminum tag, silver; 0001-6000 and 8001-9999	Tag new qualifying stems	As needed
National Band and Tag	N	Round unnumbered aluminum tag, silver	Tag new multi-stemmed individuals	50
	N	Survey marking flag, PVC or fiberglass stake	Delineate sampling area	12
	N	Newspaper pages, tabloid size	Press collected individuals for identification	As needed
	N	Cordless Power drill, 18V Li-ion	Pre-drill nail holes into trees with dense wood; prevent bending of aluminum nails	1
	N	Field data sheets	Record data in event of device failure	As needed



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Table 24. Equipment list – Equipment and materials required for a team of two to minimize exposure to toxic oils from *Toxicodendron spp.*

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan- tity
Forestry Suppliers 59763	Y	Haglof Mantax Black tree calipers, 95 cm	Measure stem diameters up to 95 cm when lianas are attached; label for use with <i>Toxicodendron</i> to minimize spread of oils. Accurate enough to also measure <i>Toxicodendron</i> diameter.	1
Forestry Suppliers 59714	Y	Haglof Mantax Black tree calipers, 50 cm	Measure supporting stem diameters up to 50 cm when lianas are attached; label for use with <i>Toxicodendron spp.</i> to minimize spread of oils to other equipment.	1
	N	Pruning shear	Label for use with <i>Toxicodendron spp.</i> to minimize spread of oils to other equipment. Used to gain access to woody stems surrounded by <i>Toxicodendron</i> .	1
Ben Meadows 32577	N	Cleanser, urushiol-specific, Tecnu or equivalent	Clean equipment after use with <i>Toxicodendron spp.</i>	As needed
	N	Nitrile or cotton gloves	Prevent oil contact with skin	As needed
	N	PPE outer-wear	Prevent oil contact with skin, normal clothing	As needed
	N	Trash bag	Dispose of used gloves and PPE to minimize toxic oil transfer	2
	N	Cleanser, urushiol-specific, Tecnu or equivalent	Clean equipment after use with <i>Toxicodendron spp.</i>	As needed



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APPENDIX F PLOT MAP

Plot pointIDs are numbered according to the largest possible plot size, 80 m x 80 m, such that a plot of any size will use a consistent numbering scheme. A pointID is defined for every point on a 10 m grid within this framework; this design is used in initial plot establishment, but permanent, primary, and secondary markers are placed at 20 meter intervals. Plot subplotIDs are determined by the pointID of the SW corner of the subplot area. Plot center will always be pointID 41.

- During stem mapping, technicians must only use the approved points shown in **Figure 2** that are associated with high-resolution GPS data.

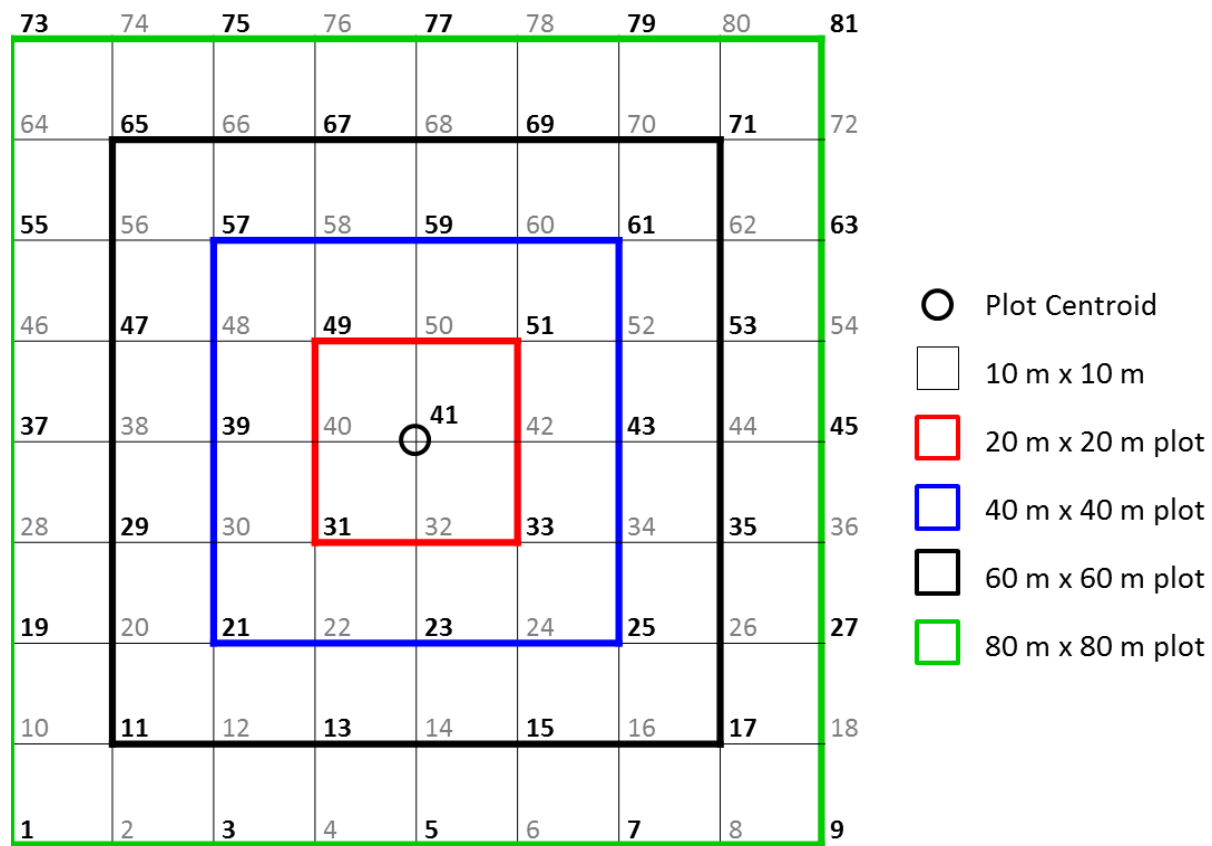


Figure 31. Plot map illustrating how NEON base plots of various sizes are constructed from 10 m x 10 m ‘modules.’ The SW corner of each ‘module’ receives a pointID number; bold numbers indicate pointIDs that may receive physical markers.

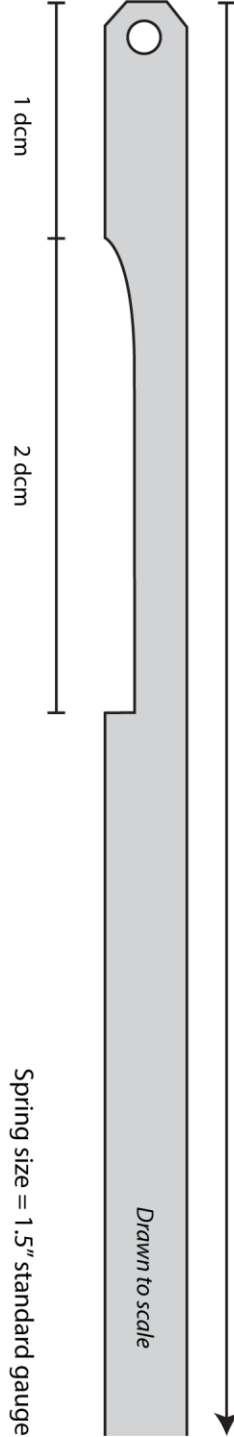


APPENDIX G DENDROMETER BAND CUTTING TEMPLATE

1 dcm = 3.14 cm
dcm = 1 cm on dbh tape

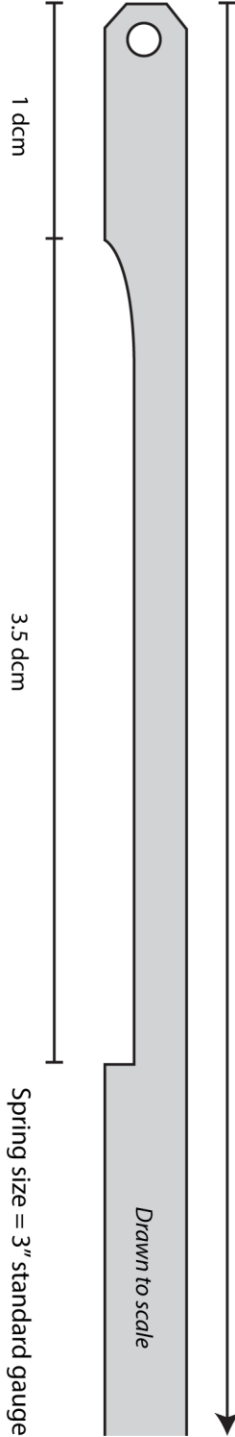
Dendrometer Template: 5 - 10 cm DBH

Total length = tree diameter + 3 dcm



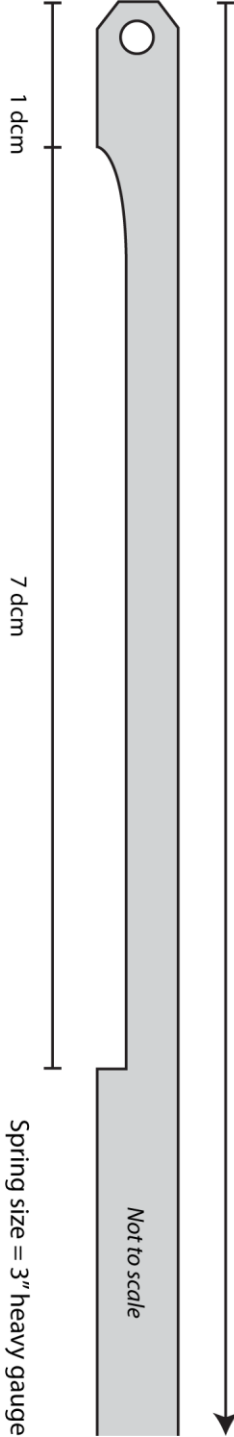
Dendrometer Template: 10 - 50 cm DBH

Total length = tree diameter + 4.5 dcm



Dendrometer Template: > 50 cm DBH

Total length = tree diameter + 8 dcm





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APPENDIX H IMPLEMENTING VEGETATION STRUCTURE IN THE SNOW

Environment, scheduling, and weather sometimes dictate that snow is encountered while implementing this protocol. Guidance in this appendix identifies common challenges experienced while sampling vegetation in snowy conditions and outlines best practices to ensure safety and high-quality data collection. Feasibility of carrying out this protocol in the snow varies with conditions and the growth forms present at the site. Safety is the primary objective, and this protocol should not be implemented if snow depth or other winter conditions compromise safety.

The guidance presented here assumes there is enough snow to make measurement of smaller growth forms difficult, and that individuals in the plot are already tagged (i.e., the plot has been sampled before in a prior year). If the plot has never been sampled, contact Science about priorities because accurate mapping will be difficult or impossible in the snow.

General Guidance

- Sampling vegetation and standing relatively still is significantly different from hiking in the snow. Prevent a safety issue by making sure all staff have sufficient layers.
- Collecting Vegetation Structure measurements is difficult to do while wearing gloves. Expect to take more breaks than usual to don gloves and keep fingers warm. Keep hand warmers in pockets.
- Keep toe warmers dry or do not use them. Toe warmers do not work when wet.
- Snowshoes can be useful. By distributing weight over a larger area, snowshoes prevent foot damage to plants buried under snow, and they help to conserve energy while moving to and within plots.
- Objects dropped into snow are difficult find. Tie flagging tape to your tools so they are easier to find when inevitably dropped. Attach writing utensils to clipboards with string or flagging tape.
- Use a stylus with the tablet so the data recorder can wear gloves.
- Scheduling considerations:
 - If the schedule is flexible and there is a good weather forecast, sample ‘sap’ and ‘sms’ in plots before snowstorms arrive. Return to plots to sample the overstory after the snowstorm has passed.
 - It is difficult to find tags for smaller ‘sap’ and ‘sms’ individuals in the snow, as wire loops may slide to the base of these individuals and tags may become buried. These individuals are also difficult to measure in the snow because, when they are not buried, the required ddh/d10 measurements require excavation.



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- Larger ‘sis’ individuals are easy to locate in the snow but collecting a ddh measurement can be difficult. It may be possible to clear snow from the base of ‘sis’ individuals and collect ddh, but collecting ddh may be impossible.
- Submit an Incident if snow depth is such that it is not possible to sample ‘sap’ and ‘sms’ growth forms. Rooting in the snow to find small individuals may be damaging to the vegetation and the plot.

Plot Setup

Plot markers installed close to the ground are difficult to find in the snow. If this applies to your site:

- Use GPS to get as close to the SW corner of the plot as possible. Use a boot to gently brush snow aside and look for the marker. Then, even if the marker cannot be found, lay tapes and outline the plot using tags on trees as guides.
- Do not add new trees to the *VST: Mapping and Tagging* app when setting up the plot under snowy conditions unless you are absolutely sure new apparent individuals are in the plot.
- Do not map individuals (e.g., a ‘smt’ graduates to a ‘sbt’ and requires mapping) unless a plot marker associated with high-resolution GPS data can be found.
- Snow cover results in increased potential for trampling the plot. Tread as lightly as possible and leave as wide a buffer as is feasible around 1 m² sampling areas given their exact location will be difficult to determine.

Taxon Identification

- Evergreen species should retain leaves and identification should be straightforward.
- For deciduous species, ensure at least one member of the crew is capable of identifying species without foliage. Bring a winter twig guide if one is available.

Plant Status

Focus on distinguishing dead individuals from dormant individuals:

- Broken, snapped-off twigs, peeling bark, and or fungal growth can indicate an individual is dead but inference may be species dependent.
- A “bend test” can reveal if an individual is alive and flexible or dead and brittle.
- For some species, a small scratch in the bark can reveal if the phloem is green and the individual is alive. However, this approach should be avoided if there is significant disease pressure at your site.



Stem Diameter and Measurement Height

- Probe near the base of the tree with a meter stick or measuring rod to find the ground and determine where on the bole the measurement height should be found.
- If a mark from a prior year cannot be found, it is necessary to clear snow from around the base of the tree to acquire an accurate measurement height.
- Given the increased uncertainty of determining the measurement height in the snow, assume the observed measurement height is correct if it is within ± 10 cm of the previous value (normal guidance is within ± 5 cm).
- If the observed measurement height is > 10 cm different from the previous value:
 - Verify you are on the correct side of the tree (relevant if on a slope) and probe again with the meter stick or measuring rod.
 - Clear snow from around the base of the tree and try again. Clearing snow in this manner is a last resort.
- Lumber crayons do not work well with wet boles. Grease paint or spray paint may be more suitable. Make sure any proposed marking method is consistent with the NEON permit.
- If possible, scrape away any ice on the bole that may affect an accurate diameter measurement.

Tree Height

- For **vdBaseHeight**, attach a reflector to the end of a 1 meter measuring stick or rod and record the base height 1 meter above the ground.
 - The added 1 meter MUST be subtracted before the **vdBaseHeight** value is recorded.
 - Vocalize the 1 meter offset to the data recorder – e.g., “Base height is -0.1 m, which is -1.1 m with the offset”.
 - Err on the side of being overly clear and redundant.
- For **vdApexHeight**, the rangefinder can give inaccurate measurements when treetops are snow covered.
 - Check the observed value against the previously recorded value and remeasure according to protocol guidelines (SOP E.2).



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Downed, Missing, and Decumbent Individuals

Downed trees and their tags may be easily hidden under snow. If you suspect a tree has fallen since the last bout, do the following:

- Record **plantStatus** = “Lost, fate unknown” and **tagStatus** = “notRequired”.
- Do not assume an individual that cannot be found is dead unless there is evidence.