Guidelines and Protocols for Monitoring Upland Forests

Field Manual



New Mexico
Forest and Watershed
Restoration Institute

New Mexico Highlands University

NMFWRI • ECOLOGICAL MONITORING PROGRAM

Guidelines and Protocols for Monitoring Upland Forests Field Manual

Second Edition, 2026

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Dedication

To all who strive for adaptive management.

Feedback

Speaking of adaptive management – do you have feedback on this manual?
Please share it! Contact us through nmfwri.org or call 505-426-2080.

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1.0 Welcome to NMFWRI: About Us



Quaking aspen in autumn, San Pedro Parks Wilderness, NM. *Photo by Jax Gaglianese-Woody*

The New Mexico Forest and Watershed Restoration Institute (NMFWRI) is a Research and Public Service Program (RPSP) based at Highlands University (HU) in Las Vegas, NM. NMFWRI staff with expertise in geospatial information systems, ecological monitoring, outreach, education, and collaboration work alongside partnering organizations around New Mexico to build capacity and develop projects that lead to healthier ecosystems and communities.

NMFWRI Institutional Alliances and Partnerships

NMFWRI is one of three Southwest Ecological Restoration Institutes (SWERI), which also include the Ecological Restoration Institute (ERI) at Northern Arizona University (NAU) and the Colorado Forest Restoration Institute (CFRI) at Colorado State University (CSU). Congress created the SWERI with the Southwest Forest Health and Wildfire Prevention Act of 2004 (SWERI Act) to promote the use of adaptive ecosystem management to reduce the risk of catastrophic wildfire and restore the health of fire-adapted ecosystems in the Interior West.

NMFWRI also participates in the Forest Restoration Triangle (FORT), along with the Department of Forestry at HU and the John T. Harrington Forestry Research Center, operated by New Mexico State University (NMSU) and located in Mora, NM. The three FORT entities share a common board that meets biannually to coordinate and review the activities of the three institutional partners.

SWERIs collaborate with a diverse set of partners and affected entities to build capacity in forest restoration, and the institutes support cooperative efforts such as shared stewardship. The partners that the SWERIs collaborate with, and the affected entities that the SWERIs serve, include land managers and regulators,

such as federal, state, local and tribal agencies; interested or affected stakeholders; concerned citizens; organizations representing natural resource users; traditional groups including land grants and acequias; state and local representatives; and political subdivisions of states, such as soil and water conservation districts. SWERI administrators and staff respond to the current needs of partners and affected entities while also anticipating and preparing for future challenges.

NMFWRI Statutory Purposes and Duties

NMFWRI began operations in 2005. The SWERI Act defines the purposes and duties of the SWERIs and creates a framework for the three institutes to align their operations, cooperate with federal agencies, collaborate with partners, and serve affected entities.

The general purposes and conditions of the SWERIs listed in the SWERI Act are:

1. Promote the use of adaptive ecosystem management.
2. Reduce the risk of wildfires.
3. Restore the health of forest and woodland ecosystems in the interior West.
4. Promote the use of collaborative processes.
5. Prepare an Annual Work Plan that ensures the proposed work of the Institute serves the informational needs of affected entities.

The duties of the SWERIs as defined in the SWERI Act are:

1. Develop, conduct research on, transfer, promote, and monitor restoration-based hazardous fuel reduction treatments to reduce the risk of severe wildfires and improve the health of dry forest and woodland ecosystems in the interior West;
2. Synthesize and adapt scientific findings from conventional research to implement restoration-based hazardous fuel reduction treatments on a landscape scale using an adaptive ecosystem management framework;
3. Translate for and transfer to affected entities any scientific and interdisciplinary knowledge about restoration-based hazardous fuel reduction treatments;
4. Assist affected entities with the design of adaptive management approaches (including monitoring) for the implementation of restoration-based hazardous fuel reduction treatments; and
5. Provide peer-reviewed annual reports.

NMFWRI Mission Statement: The New Mexico Forest and Watershed Restoration Institute works to reduce catastrophic wildfires and restore resilient, fire- and climate-adapted ecosystems. We collaborate with partners and engage communities to bridge scientific and local knowledge and build capacity in landscape-scale adaptive management.

NMFWRI Vision Statement: The New Mexico Forest and Watershed Restoration Institute envisions a fire- and climate-adapted New Mexico that prioritizes cross-boundary collaboration for healthier human and ecological communities, sustainable economies, and social justice.

As of 2026, staff are organized into three programmatic areas: Administration, Coordination & Organizational Development (Education & Outreach; Public Information); Technical and Applied Science Programs (Geospatial Information Systems, Ecological Monitoring); and Civic and Community Action Programs (Collaboration, Conservation Science Center).

NMFWRI Ecological Monitoring Program: Ecological monitoring data provides the scientific basis for restoration treatments and is critical for adaptive management. NMFWRI's Monitoring Program maintains a professionally managed field crew to collect data on short- and long-term ecosystem response to restoration treatments and other disturbances. The field crew also provides hands-on internship opportunities for students and recent graduates to help build New Mexico's forestry workforce. Staff collect data on partner needs and opportunities related to monitoring and adaptive management and respond to those needs through initiatives and projects such as: creating a statewide monitoring data repository and suite of analytical tools, building a network of groups participating in ecological monitoring, and building statewide capacity for ecological monitoring and restoration work through monitoring protocol trainings and technical support.

Our goal is to become a long-term, capacity-building force within the restoration economy with a focus on assisting our partners in overcoming obstacles currently limiting use of the adaptive management model.

In 2026, projects of the Ecological Monitoring Program include:

- Monitor forested and riparian ecosystems throughout New Mexico. Provide quality, hands-on internship opportunities for college students and recent graduates in natural resource management to help build New Mexico's forestry workforce.
- Develop a database of partners working in ecological monitoring statewide; survey needs across partner organizations and develop strategies to meet those needs.
- Establish NMFWRI as a repository for ecological monitoring data collected across the state, building from our own dataset. Develop data pipelines with partners and suites of analytical tools suited to their needs.
- Conduct database analysis to investigate project-, program-, and landscape-level trends in forest and watershed health and the impacts of restoration efforts. We are uniquely situated to do this because of our own long-term monitoring datasets as well as our network of partners.
- Provide on-demand technical assistance and training in restoration and monitoring methods, protocols, and analysis to build capacity among partners and communities.
- Support the development of professional monitoring and restoration capacity across the state by expanding access to formal training (in-house or contracted) and developing accessible training materials (manuals, videos, brochures) on monitoring and restoration methods. We envision a network of professionally trained crews available to contract with agencies.
- Regularly report on and share our findings with partners and the public; set up a library of equipment, technical literature, and herbarium specimens and develop a system for providing managed access to local students and professionals.

INTRODUCTION

1.1 Why We Monitor



Aerial view of the Hermit's Peak fire, San Miguel County, NM, 2022. *Photo by Kathryn Mahan*

Ecological Monitoring efforts have been a vital part of NMFWRI since the Institute's beginning. NMFWRI has hired foresters and forestry students to collect ecological monitoring data on forest restoration treatments since 2007, which established a state-wide network of long-term monitoring sites. Professionally collected and analyzed ecological monitoring data provides the scientific basis for restoration treatments, such as thinning and prescribed burns, and is critical for adaptive management. Monitoring data can help answer questions about what works and what doesn't when forests are managed for a specific outcome such as reducing wildfire risks or increasing wildlife habitat.

More about adaptive management

Adaptive management means learning from experience. Less simply, it is a structured decision-making process that, when implemented by resource managers, should result in more informed management decisions and ecological responses that more closely match the desired and predicted outcomes. The process is defined variously in literature, but it is commonly visualized as an iterative feedback loop.

In theory, resource management should improve as more and more information (experience) becomes available. However, the Department of Interior's Adaptive Management Technical Guide (Williams & Brown, 2012) acknowledges that although adaptive management is frequently referenced by managers and management plans, it is in fact "infrequently implemented" (p. 1). Instead, processes such as trial-and-

error are more common. It is this gap in ecological data that NMFWRI's long-term monitoring seeks to fill, with the recommendation that future re-evaluations should be standard practice as more data becomes available. A goal of the United States Forest Service (USFS) is to develop feedback loops using monitoring data (USDA Forest Service, 2009, p. 28). This monitoring data can provide a basis for adaptive management through crucial insights into monitoring design, project implementation, re-entry, and return intervals for project maintenance; all of which informs future restoration projects. For instance, preliminary field crew observations of the Collaborative Forest Restoration Program (CFRP) suggest that some projects are "escaping" (i.e. returning to pre-treatment conditions in some metrics) the 10-year mark. Program-wide analysis suggests that management of forests, especially dry mixed-conifer forests, may benefit from more-frequent retreatment.

More about what we do

NMFWRI has conducted a number of different ecological monitoring programs utilizing varying techniques and methods such as plot-based protocols, line-point intercept transects, or the New Mexico Rapid Assessment Method (NMRAM). These projects include (but are not limited to) bird/butterfly surveys, wildlife monitoring, rangeland monitoring, riparian monitoring, and the focus of this manual: upland forest monitoring.

Riparian monitoring with GRGWA

NMFWRI has coordinated with the Greater Rio Grande Watershed Alliance (GRGWA) to conduct pre- and post-treatment monitoring on primarily riparian projects since 2011. The Greater Rio Grande Watershed Alliance is a collection of soil and water conservation districts, Pueblos, agencies, and other stakeholders in the Middle Rio Grande watershed. This collaboration is engaged in landscape-scale watershed restoration with a focus on non-native phreatophyte removal from the bosque. A phreatophyte is defined as a deep-rooted plant that obtains a majority of the water that it needs from the phreatic zone (zone of saturation or water table). In New Mexico, those species targeted for removal are most often Russian olive (*Elaeagnus angustifolia*) and Tamarisk (*Tamarix* spp.). They use a variety of treatment techniques such as extraction, mastication, and herbicidal applications alongside native grass, tree, and shrub planting. Collaborators follow community, statewide, and national management and conservation plans and monitor the effectiveness of their restoration efforts.

The riparian field season typically runs from August through leaf-off in November. Re-measurements occur within a 2-week window of the original measurement date. NMFWRI has conducted pre- and post-treatment project monitoring and completed reports for each project monitored. Our website hosts an extensive collection of reports and repeat photographs, a riparian monitoring guide, as well as a GRGWA Projects online map. (https://nmfwri.org/monitoring/riparian-ecological-monitoring/)

The rest of this manual will focus on monitoring methods and protocols used primarily in upland forests. However, many of the techniques outlined in this manual (related to use of tools, etc.) are applicable within the riparian protocol referenced above.

Upland monitoring & CFRP

NMFWRI has partnered with the USFS and other agencies to monitor more than 2,500 plots in the

Collaborative Forest Restoration Program (CFRP) and other restoration projects across the state since 2007, culminating to over 4,500 visits. One of our longest-running upland monitoring projects includes the remeasurement of selected CFRP projects at 5-year intervals.

The CFRP was initiated in 2001. Through this New Mexico-specific program, the USFS provided cost-share grants to many small-scale collaborative forest restoration projects carried out on federal, tribal, state, county, or municipal forest lands. Each year, a Technical Advisory Panel met and selected projects to fund from applications submitted by partnerships representing a variety of interests. Grants were for up to $360,000 with a 20% partner match, and projects lasted 3 to 4 years. Projects could cover pre-treatment planning and carrying out analyses required by the National Environmental Policy Act (NEPA), implementing the actual on-the-ground treatments, and purchasing equipment to assist in carrying out treatments and processing timber removed from treatment sites.

The Community Forest Restoration Act (Title VI, Public Law 106-393), which established CFRP, called for monitoring of "the short- and long-term ecological effects of the restoration treatments" for a minimum of 15 years. In 2008, 20 CFRP projects were identified for long-term monitoring (criteria available here: https://nmfwri.org/wp-content/uploads/2020/07/wp5_-draft_2-1.pdf). NMFWRI has been responsible for long-term vegetation monitoring of selected CFRP projects at 5, 10, and 15-years post-treatment intervals since 2008. Our involvement with CFRP has been supported with federal funds, typically through our congressional appropriations, and at times with additional support from USFS supplemental funding.

In 2021, we completed an analysis of the ecological impacts of the CFRP Program from 2003-2020. This report is available on our website (https://nmfwri.org/wp-content/uploads/2022/02/CFRP_Sustainability-2021_report_final_draft_9_17_21.pdf). Our website hosts a regularly updated collection of individual project reports (https://nmfwri.org/restoration-information/cfrp/cfrp-long-term-monitoring/) as well as an online map (https://www.arcgis.com/apps/webappviewer/index.html?id=1ff53fe01cbd43d9a24657225a24386c&extent=-12406484.6521%2C3666886.861%2C-10850838.2524%2C4481399.8344%2C102100). All data collected on public lands are available upon request.

Post-wildfire

Having a network of long-term project sites across the state allows NMFWRI to monitor not only restoration treatment impacts but also disturbances, such as wildfire. Post-wildfire monitoring provides unique opportunities to build upon our existing knowledge regarding fuel treatments, prioritization, spatial fire planning, and strategies for recovery in a post-fire world. Making the most of the opportunities offered by post-disturbance monitoring allows us to contribute to the landscape-level and statewide understanding of the effectiveness of this type of restoration work in the face of wildfire impacts while learning more about long-term treatment effectiveness and longevity. Generally, this data collection needs to occur immediately post-fire to best capture fire effects – rather than mitigation impacts, monsoon impacts, or some other effect – and the impacts of missing this opportunity are permanent and irreversible.

1.2 Best Practices for Ecological Monitoring



Johnson Mesa, San Miguel County, NM. *Photo by Taryn Schlosser*

What follows is a brief overview of the monitoring process; included are suggestions of things to consider based on our experience in doing this work. We recognize that this list is likely insufficient to support you in designing a monitoring effort from scratch. Fortunately, there are several excellent, detailed guides available for free that exist specifically to help you design a monitoring plan that meets your needs. There are links to a few of our favorites at the end of this section.

Determine project goals

- Determine project goals and interests.
- What are your scientific question(s) of interest?

Determine what indicators to monitor

- What indicators will give you information to evaluate each goal? Examples of indicators may include basal area, seedling density, or surface fuel loads.

Select appropriate data collection procedures

- What methods are needed for the indicators selected?
- What analyses of these results will you use? (use sound statistical principles)

Establish spacing and number of measurements throughout the project (scale)

- Consider the scale at which you are monitoring; project vs landscape, etc. Operate at an appropriate scale. For instance, if your monitoring is intended to quantify landscape-level trends then your sampling design should include randomly selected sites from across the landscape of interest.
- Spacing and density of measurements may be determined by the indicator and analysis method for statistical validity.
- Consider the benefits of randomization and stratification by vegetation communities or treatment units.
- Consider how to minimize impacts of limited access to sites on final sample size.

Determine when and how often to take measurements

- Be aware of the impact of season and sensitivity of your indicator.
- Gather baseline data before the project begins.
- Repeat the same measurements after the project is completed.
- Repeat the same measurements at regular intervals after project completion (5, 10, 15 years).
- Repeat the same measurements post-disturbance (e.g. wildfire).
- If appropriate, stratify your sample area into treatment units or distinct vegetation communities and sample randomly within stratified units. This will reduce unexplained noise in later statistical analysis and facilitate understanding the effects of treatments.
- Have your measurement locations permanently monumented whenever possible.

Establish who will take measurements

- Consistency is key; try to keep the same person or team involved throughout a project.
- Ensure your team has had rigorous training and has access to training materials in the field.
- Have a clear Quality Control (QC) process to identify and address concerns with the data.

Establish when and how to analyze data

- Understand how to analyze your data and when it is useful to do so.
- Consider different analysis options; for instance, when might you want to utilize photo comparisons vs statistics to best communicate a change?
- Use software or coefficient sets appropriate to the project area (for instance, make sure the formulas used in summary calculations include constants developed for the habitat or region in which you are working).

- Seek assistance if needed in interpreting results.
- Preliminary and historic data are useful in identifying trends or immediate treatment impacts; long-term data may highlight other trends or provide information on treatment longevity/need for maintenance.

Establish where and how to store data

- Determine which data points are required for the monitoring methods used by your project, as well as what additional information you will want to collect and document.
- Make sure all relevant information is documented (monitoring methods used, treatment information, etc.) and make it as easy as possible for anyone else to pick up where you've left off.
- Reduce risk of loss through proper data management – work with a data manager to outline a management plan and organizational system for your project.
- Determine how to keep your data safe, available, and understandable to others.



Mountain Spring-Parlsey and Tall Indian Paintbrush in the Pecos Wilderness, NM. *Photo by Jax Gaglianese-Woody*

- Consider uses and limitations of paper data versus electronically collected data. For example, using paper datasheets may be faster in the field, but requires additional labor to enter the data later. Using electronic data collection allows for opportunities to build in QC checks to catch potential entry errors, but is more time- and equipment-intensive.
- Ensure multiple copies of data are stored (e.g. scan your paper datasheets, make backups of electronically collected data, etc.).
- Establish a data-sharing protocol with partners.

Encourage adaptive management

- Monitoring results are useful ONLY when they are analyzed, interpreted, and shared with managers to provide lessons learned and inform future design making.
- Identify target audience(s) and make efforts to share data, reports, and implications with them.

A Sampling of Resources for Monitoring Design

General Design

General Sampling Design Support: https://www.epa.gov/sites/default/files/2015-10/documents/chap2.pdf

Forests

USFS Common Stand Exam: https://www.fs.usda.gov/nrm/fsveg/index.shtml

CFRP Ecological Monitoring Handbook: https://its.nmhu.edu/IntranetUploads/001034-mpm-short-gu-723200822158.pdf

NPS Fire Monitoring Handbook: https://www.nps.gov/orgs/1965/upload/fire-effects-monitoring-handbook.pdf

Photoload Sampling Technique: https://www.fs.usda.gov/rm/pubs/rmrs_gtr190.pdf

CFRI Monitoring Protocols: https://cfri.colostate.edu/publication/?_sf_s=protocol

Riparian

NMED SWQB NMRAM: https://www.env.nm.gov/surface-water-quality/wetlands-rapid-assessment-methods/

NMFWRI Riparian:

https://nmfwri.org/wp-content/uploads/2022/02/Riparian_forest_monitoring_guidelines-1.pdf

Range/ Grassland, Shrubland, Savanna

Monitoring Manual for Grassland, Shrubland,
and Savanna Ecosystems: https://jornada.nmsu.edu/files/bibliography/21-066.pdf

Design for Range: https://www.landscapetoolbox.org/monitoring-design/

2.0 Summary of Plot Protocols

In use in current form since 2016

Note: These protocols are based on the standard procedures of the USFS's Common Stand Exam, DOI's FEAT/FIREMON Integrated, and recommendations for standards made by Derr et al. (2008) for Long-Term Monitoring of New Mexico's Collaborative Forest Restoration Program.

The USFS's Common Stand Exam chapters found here: https://www.fs.usda.gov/nrm/fsveg/index.shtml

DOI's FEAT/FIREMON Integrated information and user guide found here: https://www.frames.gov/ffi/home

Crews, Navigation, & Plot Setup

Plots are most efficiently accomplished with a 3-person crew (*See Supplement A*) but can also be taken with 2 people. More detailed plots, presented here as options, are most efficient with a 4- to 5-person crew. All crews need basic knowledge of monitoring methods and rationale, equipment, plant species, and common tree pests and diseases.

Plots are established using a random point location with project-specific boundaries (e.g., stand boundaries, treatment areas, vegetation types, etc.). For instance, for some upland projects, the following distribution rationale is used based on stand boundaries (more detailed rationale is available upon request):

For Stands 1-50 acres, 1 plot per 10 acres (standard)

For Stands 51+ acres:
51-70 ac – 5 plots
71-90 ac – 6 plots
91-110 ac – 7 plots
111-200 ac – 8-9 plots
201-400 ac – 10 plots

Maps and plot locations are generated in our office with ArcGIS utilities and are loaded onto a high-precision GPS unit (such as a Trimble GeoXT or Juniper Systems Geode GNSS Receiver with tablet) as well as smaller handheld GPS units (such as Garmin GPSMAP units). Unit maps, driving maps, and driving directions are created and sent with the field crew. Once in the project area, navigation to a plot is typically accomplished through paper maps and the handheld units. Paper maps can be easily marked with markers to indicate sequence of plot collection, dates, and teams at work; this information can be stored with the datasheets and may help answer questions that arise later (*See more in Ch. 5*). We use the handheld units because they are user-friendly and can run on AA batteries, which are easily replaced in the field. We use the high-precision unit to more accurately determine plot location and to collect updated plot location coordinates (*See more in Ch. 12*). Plots must be moved one chain (66 ft) at a random azimuth from their original,

intended location if they are within 75 ft of a road. Make sure to document if a plot was moved for future monitoring instances.

A marker – we typically use a 1 ft piece of ½ inch rebar with a plastic mushroom cap – is installed at plot center. Where plots are being re-visited, a good metal detector may be of use to locate the center stake. Copies of the previous plot photos can also be useful. Plots are set up using 8-9 pin flags in addition to the center stake (Figure 1 - pg 19). Preferred colors include blue or orange. Crew members walk cardinal azimuths (N, E, S, W) from plot center and place pin flags at 11.78 ft (11' 9") and 37.24 ft (37' 3") to give visual aids for the two plots (1/10th ac and 1/100th ac) whose purposes are described below.

Photographs, Witness Trees, & Other Plot data

Seven photo points are taken per plot. If more than one Brown's transect is collected, additional photographs are taken in the same format. Typically, a white board with marker is used to tag each photo. The first photo taken at each plot is of the white board on the ground at plot center (PC). This ensures the data technicians are able to read the plot name and number and correctly identify the photos that follow. It is helpful if the camera used can record GPS coordinates.

Additional photos include:

- "C," (center) taken from 75 ft along the North azimuth looking at a crew member holding the white board at plot center.
- Brown's transect photo, "BR_*degrees*" taken from the 75 ft mark of each fuels azimuth looking towards a crew member holding the white board at plot center.



A "center" photo shows a crew member at plot center. *Photo by NMFWRI Field Crew*



Plot photo showing flagged witness. *Photo by NMFWRI Field Crew*

- "N," "E," "S," and "W" photos taken from plot center facing a crew member holding the white board at 37.24 ft at each of the four cardinal azimuth flags. Additional photographs may be taken, but we recommend these be taken after the mandatory seven plot photos, and noted on the data sheets, to avoid confusion for the data technicians.

The photo order must be recorded on the data sheets, for example, PC, C, N, BR75, E, S W. If the data collected on plot is for a revisit, photos should be re-taken in reference to photos from the previous visit. Bring along copies to be sure the frames and landmarks match up. In addition to recording the order of the photo points, record the camera number/model and photo numbers to aid in photo labeling, for example, CAMER001, PC (100-0434), C (100-0435), N (100-0436), etc. (*See more on photos in Ch.16*).

A witness tree or trees (typically not more than two) should be near plot center to assist with finding plot center and ideally should be expected to survive any future thinning, fire, or other disturbance. For example, mature yellow-bark pines near plot center are easy to find and not likely to be thinned. Any healthy tree will work. Don't use saplings. The selected tree(s) could be tagged with metal identifiers at the base or flagged twice around DBH. This tree must be noted as a "witness" in the overstory data table ("tree page") and described on the Plot Description datasheet in the appropriate section. Important characteristics to record include: azimuth from PC, distance from PC, species, status, height, DBH, color of flagging used, and any other notes (e.g. unusual crown shape). The position of the witness relative to the inner and outer circles should also be

indicated with an "x" if recorded on a witness tree diagram. If the witness tree died in-between monitoring instances, record it as dead. If there are other trees on the plot that are still alive, assign one of them to be the new witness. If all trees are dead, no witness will be established or re-established. Record all observations and changes (*See more on witness trees in Ch. 19.13*).

Photo order, hill slope (i.e. wherever slope is steepest), dominant aspect (by circling N/E/S/W and/or writing in the degrees), coordinates and units, elevation and units, date, and time begun are recorded for each plot. Comment fields are available on all datasheets and it is critical that all observations, including dominant species, invasive species, land use impacts, fire history, challenges in taking plot, etc. are documented here. No plot can be so unremarkable as to have a totally blank comments box (*See more in Ch. 15*).

Overstory

All trees and snags are measured within the 1/10th acre (37.24 ft radius), circular, fixed-area sample plot (*See more in Ch. 19*). We typically define a tree as ≥ 4.5 ft in height and ≥ 1.0 in DBH or DRC (wherever its diameter is taken according to protocols), although other cutoffs may be used depending on objectives. Species, condition, DBH or DRC, number of stems, total height, live crown base height, char and scorch height (if any), and other damages (mistletoe, forking, etc. if any) are recorded for each tree located within the plot. Most trees are measured at DBH apart from those multi-stem species with more than two stems at DBH (i.e. *Quercus* spp.*, Juniperus* spp.) (*See Ch. 19.3*). In instances where DBH needs to be taken at a height other than 4.5 ft (i.e. if a large burl was located directly at 4.5 ft), measure above the deformity and indicate the height where the diameter was measured in the comments. Be aware that other trees/large shrubs with multiple stems, such as mountain mahogany or chokecherry, cannot be processed if they are measured at DRC since their conversion formulas are unavailable. Depending upon the project, other information may be collected including snag decay class, crown ratio, and crown class (Blank datasheets with these additional details are available from NMFWRI upon request). Trees are recorded starting from the north azimuth line and moving clockwise, like spokes of a wheel from plot center. Depending upon management objectives and density, it may be helpful to draw a stem map indicating the location of all trees (identified by their number) relative to the cardinal azimuths and the two circles of the plot (i.e. similar to the witness tree diagram) or install metal tree tags (*See Ch. 19.1*). In dense stands, we find it helpful to flag the first tree measured to keep the crew oriented. If appropriate, this first tree may also serve as the witness tree. Do not forget to flag and record your witness tree and remember that you flag the witness tree with ***two*** strips of flagging whereas you might flag the first tree with just one.

Tree regeneration is measured on the nested 1/100th acre circular plot (11.78 ft radius). Species, condition, and height class (>0-0.5 ft; >0.5-1.5 ft; >1.5-2.5 ft; >2.5-3.5 ft; >3.5-4.5 ft) are recorded for each seedling or sprout. Saplings are ≥4.5 ft but under the DBH/DRC cutoff for trees (typically <1.0 in but at other times <5.0 in) are also recorded in this way (See Fig. 2 - pg. 20). Shrubs are measured on the same nested subplot and species, condition, and height/diameter class are recorded for each stem just as with tree species; we typically record cacti in this category as well due to their woody structure. The definition of a "shrub" may vary depending upon management objectives but typically means any woody species which is not a tree. Examples include rose, chokecherry, mountain mahogany, holly, etc. Note that other cutoffs may be used for height and diameter classes depending upon objectives (*See more in Ch. 3, 9, 10, and 18*).

Trees and shrubs are typically recorded using their USDA PLANTS code, which is commonly a four-letter code defined by the first two letters of the genus and first two letters of the species name (e.g. PIPO, ABCO, PIFL, PIED, JUDE, JUSC2, QUGA, etc.). Note that upon entry into a database, it is common for these codes to be followed by various numbers to differentiate between other species whose names would create the same code. It is critical to verify the exact match of the symbol to the species you intend to enter into the database. If a species cannot be identified in the field, crews can employ symbols that include a descriptor of the growth habit. Commonly used examples are "2TREE" or "2S" - for unknown tree or unknown shrub. NMFWRI employs these symbols for individuals that need to be identified later on in the office, or for individuals that are unrecognizable, such as a sapling that was severely burned so as to remove all identifying characteristics. These symbols can be found on the USDA PLANTS website, https://plants.usda.gov/ *(See a Species Code Cheatsheet in Ch. 6).*

Canopy cover (density) is an average of four measurements taken with a spherical densiometer. These four measurements are taken facing out at the four small-plot pin flags along the perimeter of the nested subplot. In this way, each reading is spaced 90 degrees apart. Typically, instructions for use of a densiometer can be found on the underside of the lid. More thorough instructions are provided by Forestry Suppliers (https://www.forestry-suppliers.com/Documents/4283_msds.pdf) *For more on using a densiometer, See Ch. 17.*

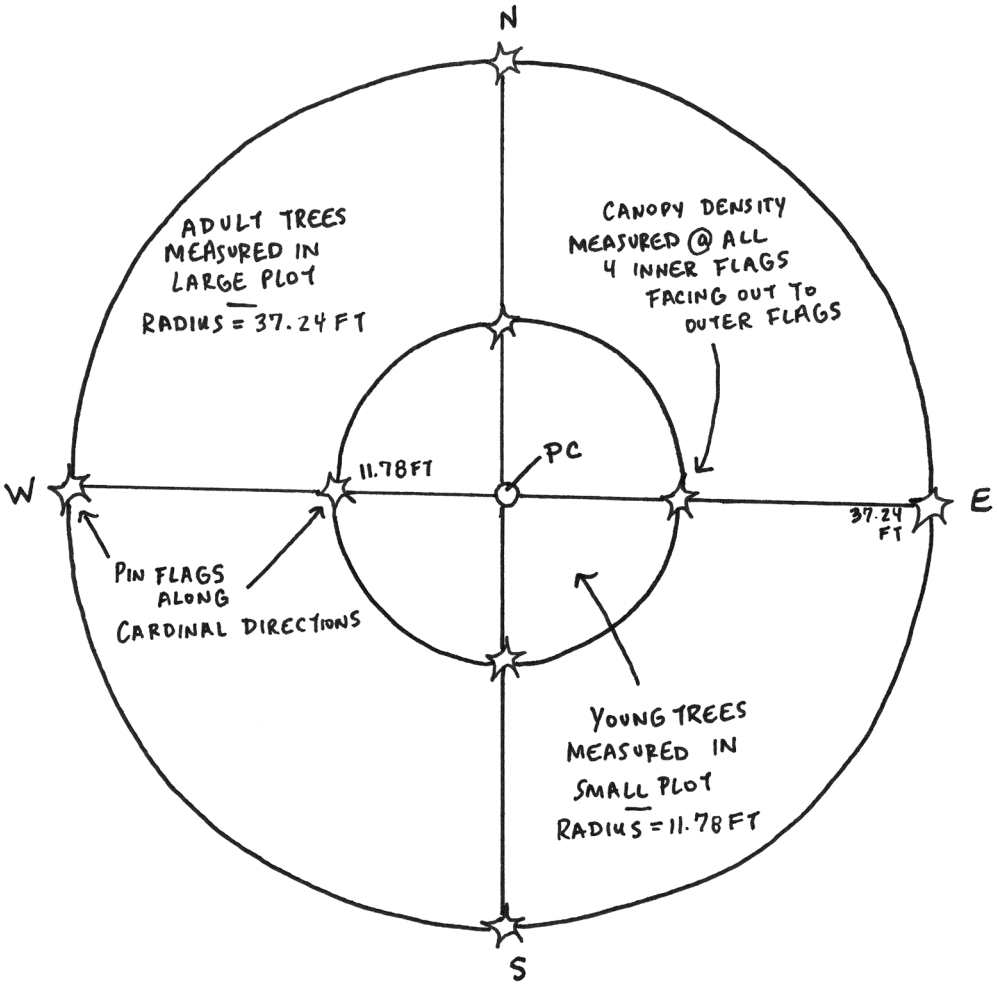


Figure 1. Plot Layout. *Diagram by Meredith Prentice*

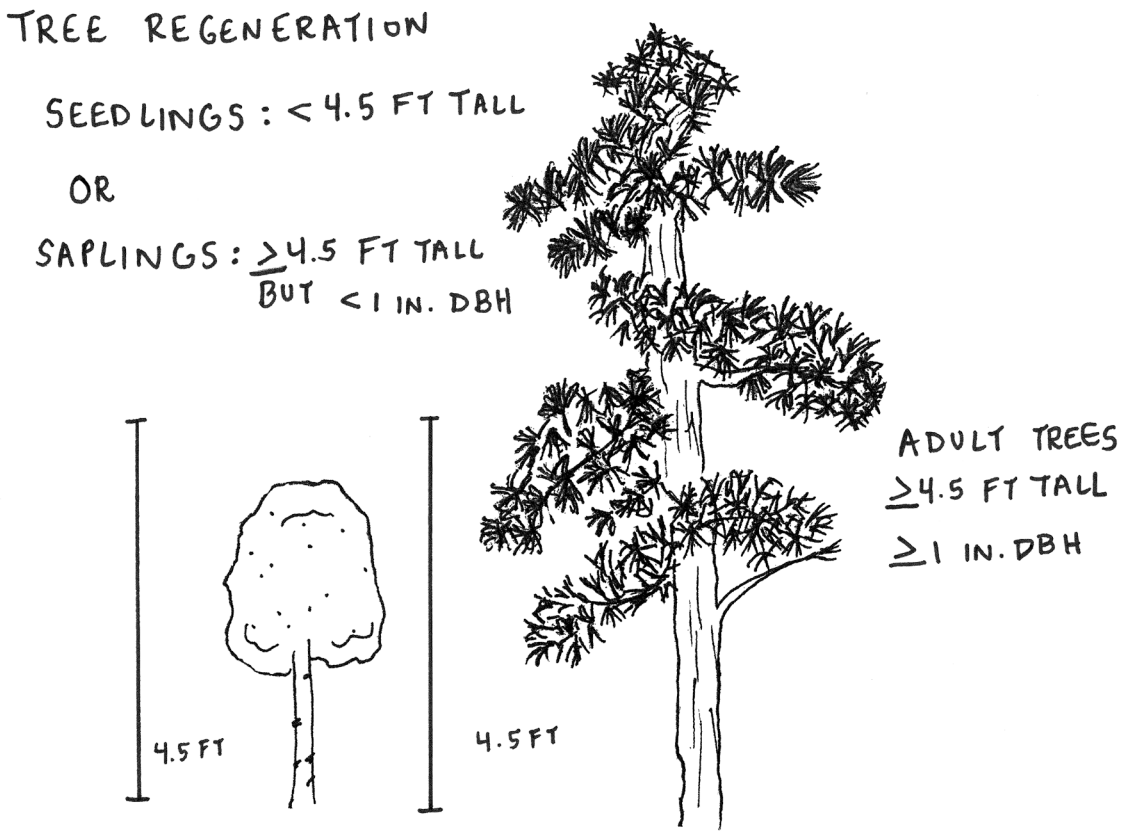


Figure 2. Tree Regeneration & Adult Trees Classifications. *Diagram by Zoe Ahrens & Meredith Prentice*

Fuels (Brown's Transects)

Dead woody biomass and forest floor depth are measured using a planar Brown's transect or transects. These transects may be at fixed or random azimuths. To select a random azimuth, one crew member spins a compass and another decides when to stop. Typically, in our protocol, a fiberglass or steel reel tape is run from the plot center stake out 75 ft and fuels are measured from 15 to 75 ft to account for the expected foot traffic disturbance around plot center. (See Figure 3). Rebar is installed at 75 ft to ensure accurate remeasurement in the future. If you have to offset the Brown's line rebar, be sure to make a note in the comments (e.g., Brown's line rebar placed at 76.5 ft due to rocks at 75 ft). Parameters measured include 1, 10, 100, and 1,000-hr fuels ("time-lag fuels"). Other lengths of transects, including variable lengths for each fuel size, may be used. Note that in our protocol, a piece of coarse woody debris (CWD) must be ≥3 inches in diameter and at least 3 ft long to count as a 1000-hour fuel; if it is >3" in diameter, but under 3 ft long, we count it as a 100-hour fuel. Decay class (1 to 5), species, and sometimes length is collected for each 1000-hr fuel.

Percent cover and height of herbaceous live and dead (HL, HD) material percentage cover and height (up to 6 ft) of shrubby (woody) live (excluding boles of trees) and dead (SL, SD) material are estimated using 6-foot diameter cylinders per Brown's planar intersect method at 45 and 75 ft. Litter and duff depths are measured at 45 and 75 ft. The location, offset, and frequency of these measurements may be modified depending upon management objectives. For more information, see Brown 1974 and subsequent guidelines (https://www.fs.usda.gov/rm/pubs_int/int_gtr016.pdf) (*See also Ch. 20).*

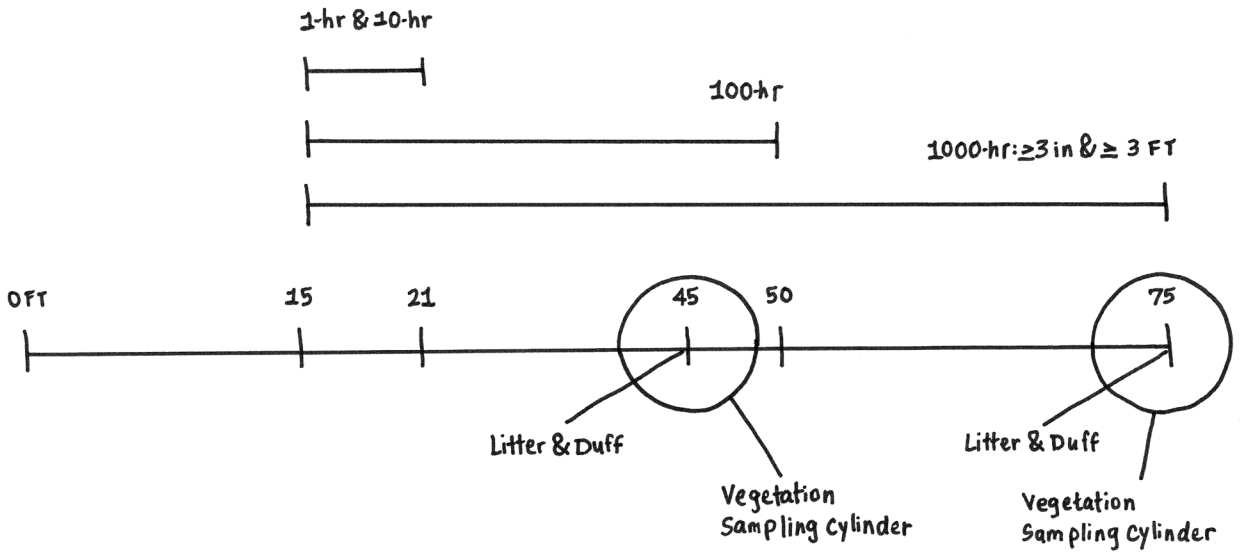


Figure 3. Fuels Transect. *Diagram by Meredith Prentice*

Understory

Vegetation and ground cover are most often estimated within the nested 1/100th acre plot ("small plot"); other project managers may request these measurements be conducted across the entire 1/10th acre area. (See Figure 4). Vegetation measurements include aerial percent cover of seedling/saplings (tree regen), shrubs (woody species which are not trees, including cacti), graminoids (grasses and grass-like plants such as sedges, rushes), and forbs (flowering herbaceous plants which are not grass) and may not necessarily total 100%. Depending upon objectives and field crew skill levels, aerial percent cover may be further stratified by individual species greater than 1% cover. Ground cover measurements include percent cover of plant basal area (cacti is included in this category), boles (trunks of trees and shrubs, anything woody), litter, bare soil, rock, and gravel. Ground cover must logically total 100%. (S*ee Ch. 3 and 18).*

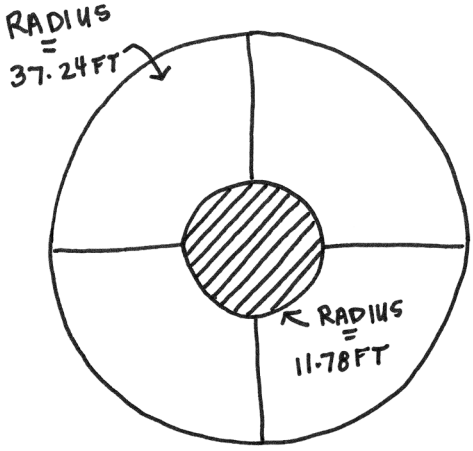


Figure 4. Understory in Small Plot. *Diagram by Meredith Prentice*

Data processing and reporting

At this time, we use Access, FFI software, Excel spreadsheets, SQL, and R to enter and analyze our data. FFI is able to export to FVS and FuelCalc. FFI software and User Guides are available for download

(https://www.frames.gov/partner-sites/ffi/software-and-manuals/). Individual piñons, junipers, and oaks with more than two stems, or whose branch structure made access difficult were measured at DRC instead of DBH. We use DRC conversion equations developed by Chojnacky and Roger (1999) (https://www.usu.edu/beetle/documents2/1999Chojnacky%20Rogers_Converting%20Tree%20Diam.pdf). All our results are typically reported to two significant digits, with exceptions for those metrics we know were measured with either more or less precision. NMFWRI sample reports can be found on our website (https://nmfwri.org/projects/). *(See more on data entry and analysis in Ch. 21).*

General measurement quality standards for plots taken by our professional crews are as follows. For most metrics, our expectation is that 90% or more of all measurements taken by our crews fall within these tolerances when compared against quality assurance checks (Table 1).

MQO

Measurement	Tolerance	MQO Standard %
Slope	± 5% absolute	90%
Azimuth and Aspect	+/- 10°	90%
Cover estimations	± 10% absolute ± 1 class (fuel cylinders)	90%
Heights	± 10% ± 1 class (seedlings) ± 0.5 ft (fuel cylinders only)	90%
Diameters (DBH/DRC)	± 0.1in per 20in ± 1 class (saplings)	95%
Duff/Litter Depths	± 0.1in	90%
Damage Severity	± 10% or 1 class	90%
Decay Class	± 1 class	90%
Seedling/Sapling Count	± 20%	90%
Nail of tagged tree at 4.5ft	± 1in	90%
Canopy cover (w/ Densiometer)	± 10%	90%
1, 10, 100, 1000-hour fuel counts	± 20%	90%
Species/status/tag #/plot #/etc.	No tolerance	90-99%
No trash or equipment left on plot	No tolerance	99%

Table 1. The MQO Standard % represents NMFWRI's expectation of what percentage of measurements taken by our crews falls within these tolerances when compared against quality assurance checks. Please note that these MQOs are intended for professional, experienced crews. We recommend taking the time to evaluate your own crew's performance against these or similar metrics before using your data for analysis and decision-making.

3.0 Terminology Used in Forest Monitoring

Acre (Ac) - Unit of measure for land area, 560 square ft; 10 square chains.

Aerial cover - % of ground covered when viewed from above.

Annual plant - A plant that completes its life cycle within one growing season (one year).

Aspect - The compass direction that a slope faces, expressed as, for example, "northern aspect".

Basal area - A measurement of the cross-sectional area of trees at 4.5 ft (DBH height). Generally expressed in sq ft per acre (typically an open forest is 40-90 sqft/ac, while a dense forest is 100-160 sqft/ac or more).

Biennial plant - A plant that completes its life cycle within two growing seasons (two years).

Breakpoint diameter - Diameter above which trees become measured in detail; below which they are tallied.

Bole - Main trunk of tree or woody plant (see Figure 1 - pg. 27).

Brown's transect - A protocol for monitoring surface fuel loads.

Caliper - A metal or wooden device consisting of an arm and two prongs, one of which is free to slide along a graduated scale on the arm. The prongs are placed against opposite sides of a tree to read its diameter on the scale.

Cactus - Succulent plant with a thick, fleshy stem; commonly with spines. Note: grouped with shrubs in all measurements except aerial cover estimations (see more detail in Ch 18).

Canopy - "Roof" of a forest formed by crowns of tall trees.

Chain - 66 ft.

Clinometer - An instrument used to measure slope and tree height.

Conifer - Trees with needle- or scale-like leaves that also produce cones; many are also evergreen and do not lose their needles every year.

Cool-season vegetation - Term used for grass species that grows better in cooler weather (e.g. early spring and fall); aka C3 vegetation.

Coarse Woody Debris (CWD) - Down woody debris including large branches, logs, snag boles leaning over 45 degrees (1000-hr fuels).

Crown - The part of the tree that includes branches and leaves (see Figure 1 - pg. 27).



Caliper. *Photo by Taryn Schlosser*

Diameter at Breast Height (DBH) - Measured at 4.5 ft, measured on the uphill slope of the tree.

Deciduous - Trees that lose leaves every year (e.g. apple, mountain mahogany).

Densiometer - A device with a spherical mirror used to estimate canopy cover.

Diameter tape - A measuring tape that has a scale calibrated to read a tree's diameter when wrapped around the tree's circumference; uses the value of pi.

Down Woody Debris (DWD) - The remains of fallen trees and branches on the forest floor; encompasses Fine Woody Debris and Coarse Woody Debris.

Diameter at Root Collar (DRC) - Measured close to the ground, above any swell from the roots.



Densiometer. *Photo by Taryn Schlosser*



Clinometer. *Photo by Taryn Schlosser*

Duff - A layer of partially decomposed organic material (e.g. leaves, needles, twigs) found between the mineral soil and the litter layer of the forest floor.

Fine Woody Debris (FWD) - Down woody debris including small pieces of woody material (e.g. twigs, branches) on the forest floor (1 hr – 100-hr fuels).

Foliage - Leaves of a tree or plant (see Figure 1 - pg. 27).

Forb - An herb, a flowering plant, other than grass (see Figure 3 - pg. 28).

Graminoid - grasses or grass-like plants (see Figure 3 - pg. 28).

Global Navigation Satellite System (GNSS) - this includes a range of international location providers such as Glonass, Galileo, and Beidou which are now incorporated into receivers such as Garmins, phones, tablets, and other devices.

Ground cover - % of ground covered by material at point of interception.

Herbaceous plants - Generally, plants with flexible stems (not woody), includes forbs and graminoids.

Hypsometer/Range Finder - Instrument used to measure tree height and distances.

Ladder fuels - Live and dead vegetation that allows fire to travel from the forest floor into the tree canopy. For example, smaller trees or shrubs growing immediately adjacent to taller ones; low branches; tall herbaceous vegetation.

Litter - Small dead plant material such as leaves, bark, and needles.

Live Crown Base Height (LiCrBHt) - Distance from ground to start of live crown.

Overstory - Top layer of cover in a forest (see Figure 2 - pg. 28).

Perennial plant - A plant that lives more than two years.

Planar intercept method - A measurement of ladder fuels typically included as part of a Brown's transect.

Plant basal area - The area of the ground occupied by the base of the plant stem.

Sapling - An individual of a woody species with height over 4.5 ft but with a DBH or DRC (wherever it must be measured) is less than 1 in (this value may change depending upon objectives).

Seedling - An individual of a woody species with height less than 4.5 ft.

Shrub - A woody plant smaller than a tree at maturity; has several main stems arising at or near the ground (which plants are considered "shrubs" vs "trees" may depend upon monitoring objectives).

Slope - A measurement in percent of the steepness of a surface; (rise/run x 100); a slope of 45 degrees equals 100%.

Snag - A standing dead tree.



Diameter tape. *Photo by Taryn Schlosser*

Stand - A group of trees that are sufficiently the same in species composition and arrangement of age classes and condition so that they can be managed as a unit.

Surface Fuels - Vegetative materials near the ground that will carry fire.

Tree - A woody perennial plant; for measurement purposes, an individual that is over 4.5 ft tall and 1 in or over at DBH/DRC (definition may change depending upon monitoring objectives).

Trees per acre (TPA) - A way of quantifying the density of trees.

Understory - The area below the forest canopy that comprises shrubs, snags, and small trees (see Figure 2 - pg. 28).

Warm-season vegetation - Term used for grasses that grow during warmer periods; typically better at withstanding droughts; also known as C4 vegetation.

Woody - A plant containing secondary xylem (wood) as structural tissue; typically perennial.

Acronym, Abbreviation, or Term	Explanation or Definition as used by NMFWRI
AVE and AVG	Average
BA/AC	Basal area per acre
CWD	Course Woody Debris (1000 hr fuels)
DBH	Diameter at breast height (4.5 feet)
DIA	Diameter at root collar (used for woodland species e.g. *Juniperus*)
DRC	Diameter at root collar (used for woodland species e.g. *Juniperus*)
DWD	Down Woody Debris (surface fuels)
FWD	Fine Woody Debris (1-100 hr fuels)
HD	Herbaceous dead (dead non-woody species; herbs)
HL	Herbaceous live (live non-woody species; herbs)
HT	Height
LiCrBHt or LCBH	Live Crown Base Height, distance from ground to start of live crown
QMD	Quadratic mean diameter, always equal to or greater than mean DBH, always an average
SD	Standing dead (dead woody species)
SL	Standing live (live woody species)
TPA	Trees per acre (Trees/acre)

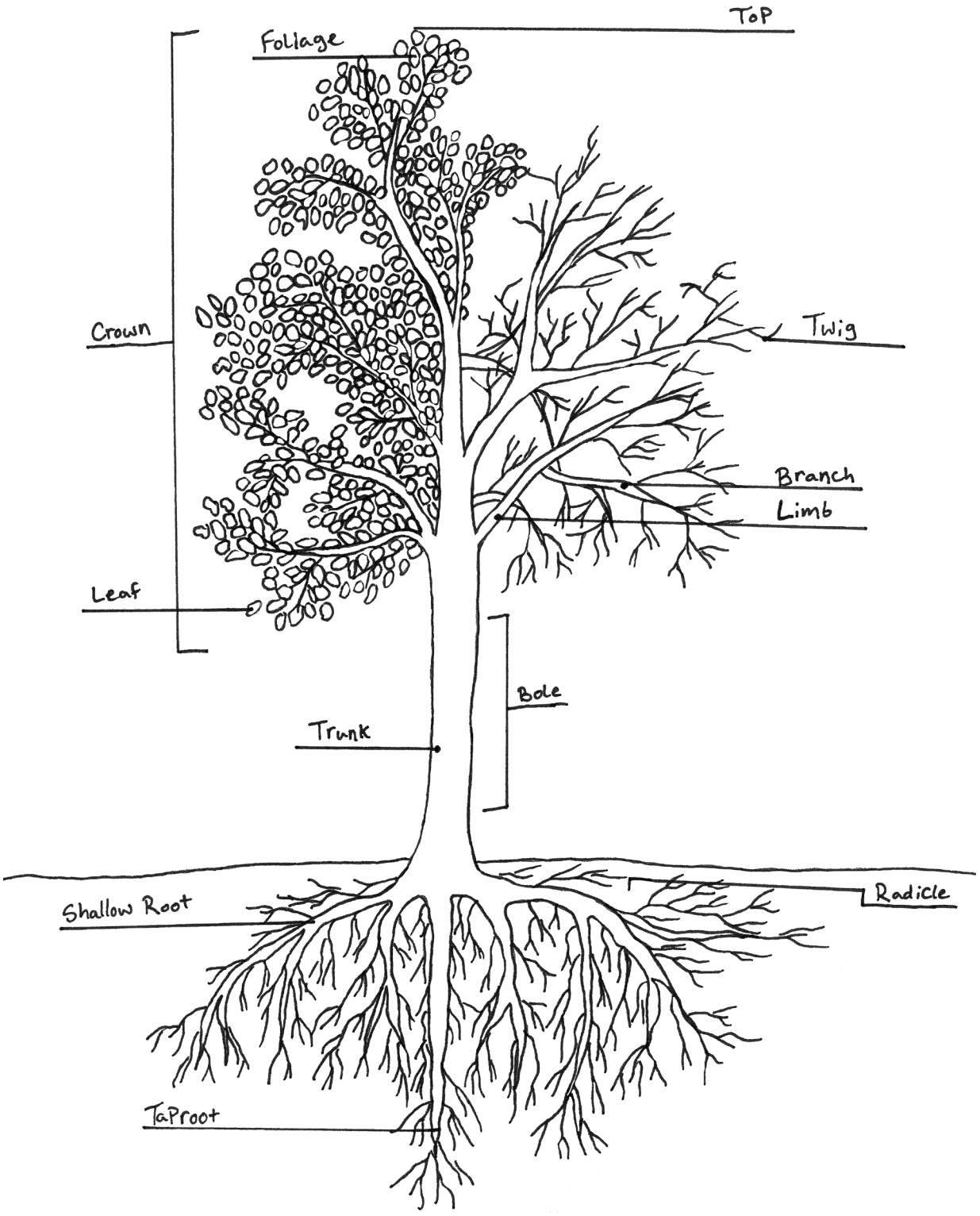


Figure 1. Tree terminology diagram. *Diagram by Zoe Ahrens*

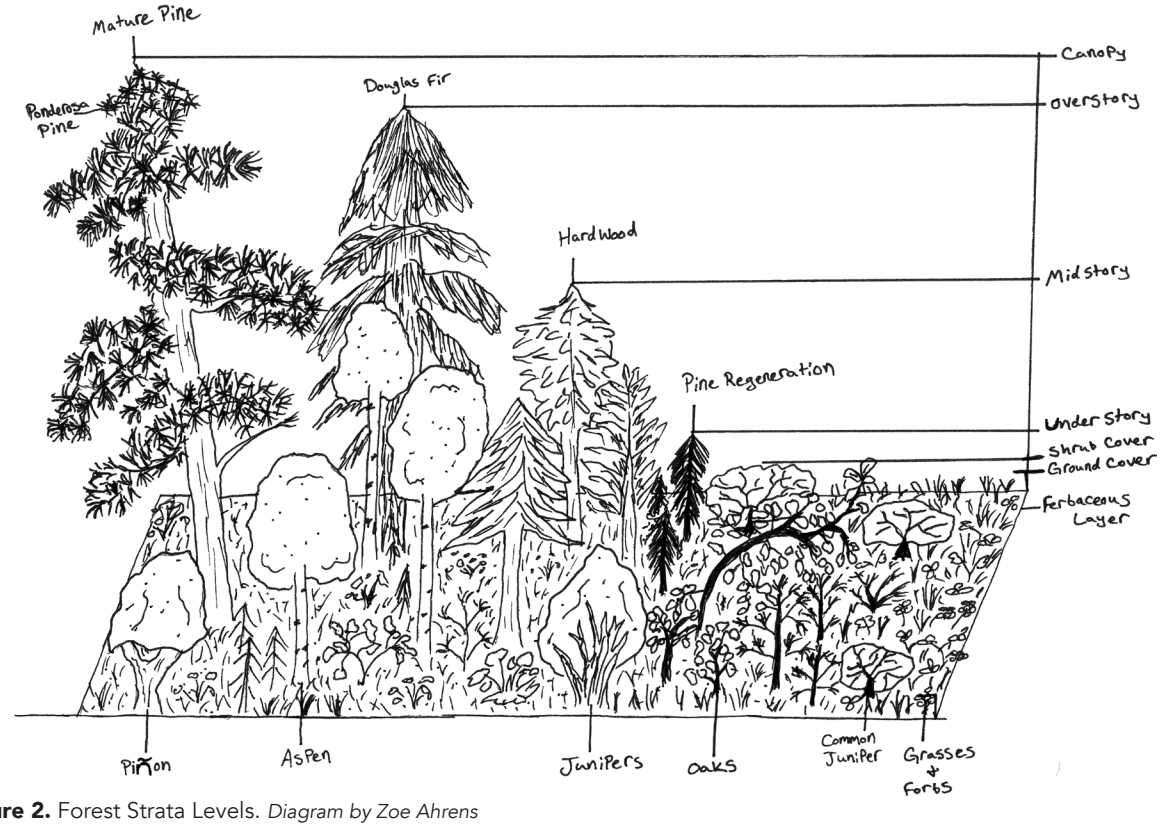


Figure 2. Forest Strata Levels. *Diagram by Zoe Ahrens*

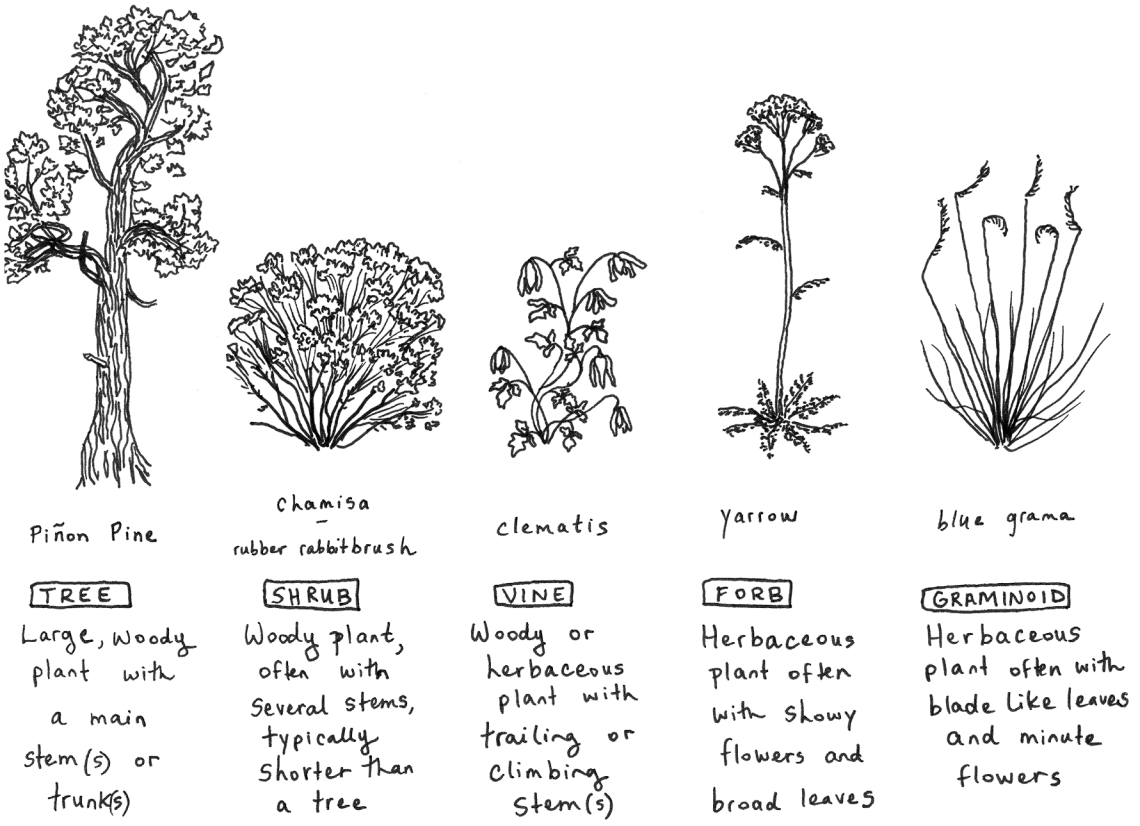


Figure 3. Vegetation Categories. *Diagram by Meredith Prentice*

4.0 Field Safety

Always follow your general field procedures for safety. The section below provides a summary of specific hazards and mitigations to keep in mind while doing forestry field work. See NMFWRI Field Safety and Emergency Action Protocols (available upon request) for more detailed safety information.



Water crossings, steep drop-offs in the road, and signage stashed in trees are all hazards of traveling by vehicle.
Photos by Kathryn Mahan

Traveling by Vehicle

HAZARDS:

- Getting lost or getting the wrong directions
- Remoteness
- Poor access/degraded or impassable roads
- Mechanical problems

MITIGATIONS:

- Prioritize good communication prior to going into the field.
- Have an emergency action plan (EAP) worked out ahead of time, be sure everyone knows it, and keep it with you.
- Bring appropriate maps; ask questions about the route and terrain before heading out into the field.
- Create trigger points for turnarounds/knowing when not to pursue the project.
- Ensure drivers have defensive driving training.
- Follow standard 4WD protocols (FWRI staff have a detailed driving protocol to follow).
- Swap drivers regularly and/or as difficulty of travel demands.
- Use the buddy system and take two vehicles equipped with chains, tow straps, and chainsaws into very remote areas. Make sure you know if your organization requires chainsaw certifications and follow all related safety protocols.
- Communicate from the field if possible: use a radio, personal locator beacon (PLB), cell phone, etc. Keep everyone up to date if plans get changed.



Rocky terrain, steep slopes, downed logs, and body posture when taking transects are all potential hazards of working in the forest. *Photos by Kathryn Mahan*

Traversing and Working in the Forest

HAZARDS:

- Very steep terrain and/or cliffs on plot or encountered traveling between plots
- Traveling through dense understory/areas with lots of downed trees
- Getting poked by limbs of trees trying to measure DBH
- Bending over for long periods of time for certain protocols
- Watching a GPS, map, or datasheet instead of watching the ground you're walking on, etc.

MITIGATIONS:

- Move slowly and cautiously.
- Maintain situational awareness.
- Use topographic maps.
- Wear sturdy boots and proper PPE (eye protection, long sleeves, gloves).
- Take breaks when travel is difficult.
- Maintain awareness of other field crew members to ensure you stay together. When traversing terrain with loose rocks or debris, maintain adequate spacing between crew members.
- Take turns switching up physically taxing tasks.
- Ensure crew members have first aid training and bring appropriate equipment, i.e. radios, first aid kit.



Incoming monsoon rains. *Photos by Kathryn Mahan*

Weather



Improvised rain gear!

HAZARDS:

- Lightning, monsoon, flooding, etc.
- Temperature extremes
- Hypothermia, hyperthermia, etc.

MITIGATIONS:

- Maintain good communication.
- Know the local area and weather patterns.
- Bring rain gear and other PPE suitable for wide variations in weather. Consider bringing a change of clothes and socks.
- Plan ahead; don't park in areas prone to flooding and depart from areas where roads/terrain may become impassable.
- Follow a lightning protocol (e.g. 30/30 rule, know the lightning position):
    - Pay attention to the sky, especially if you hear thunder/see lightning. If thunder follows 30 seconds or less after a lightning strike the thunderstorm poses danger. 5 seconds is equivalent to 1 mile, 30 seconds being equivalent to 6 miles.
    - The safest places to shelter during a thunderstorm are inside vehicles or fully enclosed buildings. If sheltering in a vehicle, keep the windows up. Plan your day accordingly based on weather patterns to ensure the vehicle is in close proximity to your monitoring plots.
    - If unable to seek shelter in a vehicle or building, practice the following safety tips:
        - Avoid exposed ridges, hilltops, and open fields.

- Avoid tall, isolated trees or other objects. Look for a uniform stand of trees to shelter in.
- Avoid bodies of water, metal objects or fences, and shallow caves.
- Spread out your group to reduce the risk of current traveling person to person.
- Assume lightning position: crouch down low to the ground with your feet together. Avoid laying flat on the ground, you want to minimize the amount of contact your body has with the ground. If a foam pad or backpack without metal wiring is available you can sit on top of that for greater comfort.

Always seek shelter whenever possible. Following the safety tips listed above can help minimize the risk of being struck, but you are not safe if you are outdoors during a thunderstorm.



Snake under juniper. *Photo by Kathryn Mahan*

Wildlife

HAZARDS:

- Encounters with venomous snakes, spiders, etc.
- Rabid or aggressive animals
- Hantavirus infection
- Food motivated animals e.g., bears, javelinas

MITIGATIONS:

- Maintain situational awareness.
- Be familiar with local area.
- Secure your food.
- Specific to snakes: sweep under the tree with your caliper before crawling in; use snake chaps.
- Avoid caves, small enclosures, and old structures where mice and other small rodents might live (Hantavirus).





Plants like poison hemlock, cactus, and New Mexico locust all present hazards. *Photos by Kathryn Mahan*

Vegetation

HAZARDS:

- Spiny & sharp plants (e.g. cactus, New Mexico locust, Russian olive)
- Wild edibles: some good, some poisonous; sometimes taste is helpful for ID (e.g. PIEN vs PIPU)
- Skin irritation caused by plants (e.g. poison ivy, stinging nettles) See *Ch. 11.0 Hazardous Plants*

MITIGATIONS:

- Wear protective clothing.
- Wear eye protection.
- Have first aid kits & first aid training.
- Wear sturdy boots with heavy soles.
- Don't put it in your mouth or on your skin unless you're 100% positive about your identification.

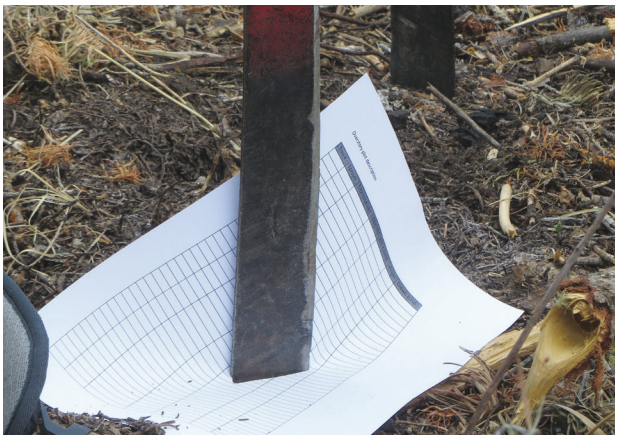
Sharp and Spring-loaded Equipment

HAZARDS:

- Machetes, Spencer (spring-loaded metal-reel) diameter tapes with nails, metal clipboards, papers, etc.

MITIGATIONS:

- Wear personal protective equipment when appropriate (e.g. gloves) and use caution.





Use caution when working with sharp and spring-loaded equipment. *Photos by Kathryn Mahan*

- Be familiar with your equipment.
- Use two people to rewind a Spencer tape.

Burned Areas

HAZARDS:

- Very difficult travel in burned areas
- Ash is slippery, especially if wet
- Stump holes (sunken areas) may exist where tree stumps were consumed by fire. Watch your step.
- Post-fire flooding
- Risk of windthrow and/or falling dead trees and branches
    - Also be aware of trees with less than 50% live foliage, lightning scars, significant root damage, fungal fruiting bodies (indicating root), or a lean over 30%. These are likely to be less stable.
    - Conditions that may increase the associated risk can include strong or gusty winds, rainy weather, steep slopes, diseased or insect-kill areas, fire-weakened timber, or reduced visibility.
    - Trees may fall whether they are dead or alive, and when there is no wind.

MITIGATIONS:

- Create a safety zone where you can get to in the event of high winds. Use extra caution when choosing a campsite, parking spot, or rest area.
- Use proper PPE such as hard hats.
- Establish a wind cutoff and carry a kestrel to measure windspeed. NMFWRI's wind cutoff protocol instructs field crews working in burned areas to wear hard hats when winds are over 15 mph. When there are sustained winds over 40 mph, crews do not work.
- LOOK UP for snags and other hazards. Examine trees for broken tops, dead limbs, signs of decay (cavities, cracks, fungal fruiting bodies, insect damage, etc.).




Stump holes and other hazards are present in burned areas. *Photos by Kathryn Mahan*

- LOOK DOWN for debris and erosion Are there trees that have already fallen? Is there any root damage from equipment, fire, or erosion?
- LOOK AROUND. Does a steep slope increase the risk of rolling debris? Is personnel mobility limited? Plan an escape route.
- *Maintain situational awareness.* Keep your eyes and ears open for movement, cracking, or snapping. Sometimes there is no sound when a limb or bole falls. Do not turn your back on a falling tree or known hazard. Consider using lookouts - assign someone to pay extra attention to hazard trees.
- Maintain good communication and regular check-ins. Discuss and practice medical evacuation procedures and accept risk accordingly. Concurrently, identify, communicate, establish, and monitor No-Work-Zones (NWZ) in all high-risk areas until the hazard has been mitigated. Consider flagging trees that are obvious hazards.
- Check the weather.
- Proceed with caution. See reference materials for more information.

Overnight Stays

HAZARDS:

- Heavy backpacks, carrying lots of equipment, loading & unloading that equipment
- Front-country communications options may not work (e.g. no cell service)
- Improper campsite selection could result in exposure to high winds, lightning, flooding
- Increased chance for encounters with wildlife (importance of proper food storage)
- Importance of group and personal hygiene especially when getting water, preparing food, and using the restroom
- Team members face more challenges trying to stay warm and dry
- Distance to medical help makes prevention much more critical
- General hazards in kitchen and campsite (knives for food preparation, fire for cooking, guylines, etc.)
- Operating in the dark



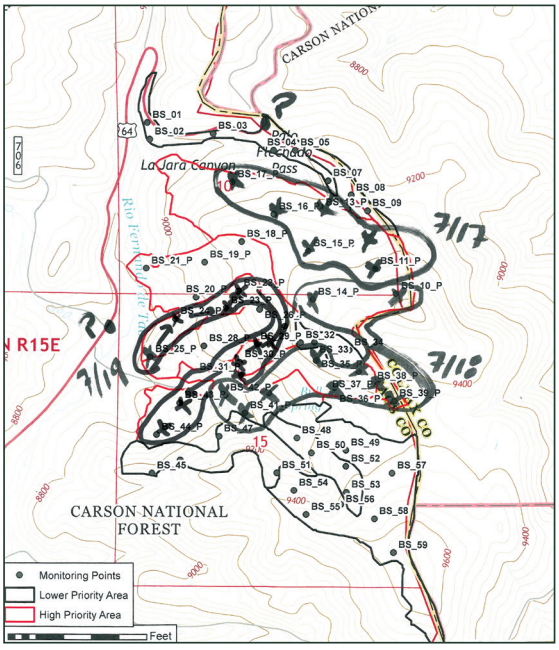
Heavy backpacks, wind impacting tents, extra equipment to load, and livestock at camp are all common hazards when staying overnight. *Photos by Kathryn Mahan*

- Emotional stresses intensify

MITIGATIONS:

- Ensure everyone in the group follows standards for hygiene, etc.
- Wear the proper PPE to avoid burns, cuts, sunburns, etc.
- Properly treat all drinking water (by boiling, Aqua Mira/chlorine treatment, iodine, etc).
- Pay attention to campsite selection and weather forecasts.
- Keep all equipment in good condition and bring extra warm/dry clothes.
- Keep camp clean and secure food properly to reduce the draw for wildlife (in a locked car or trailer at night and when away from camp during the day).
- Ensure personal and collective gear is safely packed away and that your camps can withstand extreme weather conditions such as wind or rain (put away all equipment in tents or vehicles, zip up tents and rain flies, and thoroughly stake down tents when leaving camp).
- Prepare equipment beforehand to ensure nothing is left behind.
- When moving lots of heavy equipment, use proper posture and lift with a partner.
- Bring extra/backup batteries for field equipment and keep equipment in bags when there is risk of exposure to moisture. Sleep with batteries in your sleeping bag to keep them warm.
- Be courteous and communicate with team members. Be prepared to practice psychological first aid.

5.0 Planning Your Day – Tips & Reminders



Example master map showing crew progress on project.
Credit: NMFWRI Field Crew

- Begin each day with a plan for each crew:
  - What time they're heading out and returning.
  - How often they'll check in and with who.
    - We often use a radio check-in every 2 hours on the hour with the other crew in the area.
  - What plots they're covering and in what order.
    - Consider access, topography, skill, and speed of the crew.
  - What safety hazards they're watching for and what they'll do in case of emergency.
  - Be sure everyone goes through their checklists and has everything they need (equipment, food, raingear, first aid, etc.).
- At the end of each day:
  - Finalize QC and make sure all data was completed.
  - Take notes on the day and the project. For instance, did you learn anything about access to plots, or encounter any partners while working? Include in your notes anything that would benefit a future crew in working more safely and efficiently.
  - Record the route each crew took and what plots they finished that day on one master map. Be sure that map stays with the datasheets or project information. Having a master record of the sequence in which things happened allows for the data entry team to solve the mystery that may arise if a detail isn't recorded in the field.

5.1 Sample Equipment Checklist

FIELD SUPPLIES – PER CREW

- ☐ SPOT device for check-ins (1 per crew or sat phone)
- ☐ Sat phone for emergencies (1 per crew or SPOT)
- ☐ Folder with emergency action plans (EAPs) and group medical history/confidential info
- ☐ Hypsometer (Rangefinder), packed carefully with extra battery & charger (1 per crew)
- ☐ Spherical densiometer with flagging tied around it (1 per crew)
- ☐ Handheld walkie-talkie radio with extra batteries and/or charger (1 per crew)
- ☐ Camera with space on memory card, spare charged batteries, spare memory card, & charger (1 per crew)
- ☐ Inverter (for car charging; 1 per crew)
- ☐ External GNSS receiver and tablet unit with points loaded & charger (1 per crew)
- ☐ Mini-Tripod for Geode (1 per crew)
- ☐ Samsung tablet for use with Geode with points loaded & charger (1 per crew)
- ☐ Tablet or Toughbook laptop with data entry software set up and charger/battery pack (if using; 1 per crew)
- ☐ Fiberglass 100 ft or longer tape (2 per crew)
- ☐ Pin flags (10+ per crew)
- ☐ Flag bags for carrying pin flags and/or rebar (1 per crew)
- ☐ Whiteboard, whiteboard markers, & whiteboard wipes (1 set per crew)
- ☐ Chaining Pins (2 per crew)
- ☐ Rebar cut to length & caps to match (number of plots needed + 5)
- ☐ Clipboard (1 regular and 1 waterproof per crew)
- ☐ Paperwork: emergency contacts, driving directions, driving maps, field maps, authority contacts, datasheets and EXTRA datasheets (including some on waterproof paper), plot photos, and data from previous trip
- ☐ Tree calipers (if using; 1 per crew)
- ☐ Fuels gage (min 1 per crew)
- ☐ Plant ID guides (e.g. Trees and Shrubs by Jack Carter)
- ☐ Training manual, tree codes, and protocol cheat sheets (min 1 per crew)
- ☐ Calculator (1 per crew)
- ☐ Field plant press (1 per group) and blank voucher collection sheets

- ☐ Metal detector & spare batteries (if using, 1 per group)
- ☐ Scribes (if using, 1 per crew)
- ☐ Kestrel and fire weather kit (1 per group)
- ☐ Tree tagging machine + tagging kit (extra metal tape reels, nails, hammer, pocket knife, etc) (1 per crew)

FIELD SUPPLIES – PER PERSON

- ☐ Field packs (1 per person)
- ☐ Compass (1 per person)
- ☐ Clinometer & case (1 per person)
- ☐ Garmin GPS with extra AA batteries and points loaded (1 per person)
- ☐ Diameter tape (logger's tape) (1 per person)
- ☐ Arctic Vinyl orange glo heavy duty flagging (1 roll per person)
- ☐ Pencil, pen, & Sharpie (min. 1 each per person)
- ☐ First aid kit (1 per person)
- ☐ Angle gauge (if using; 1 per person – do not share)
- ☐ Field vests (optional; 1 per person)
- ☐ Rattlesnake chaps (optional)
- ☐ Hardhats (if working in windy or burned areas) (1 per person)
- ☐ Field notebook (1 per person)
- ☐ Hand lens (1 per person)
- ☐ Safety sunglasses (1 per person)
- ☐ Sun hat (1 per person)
- ☐ Leather gloves (1 per person)
- ☐ Bandanas (min 1 per person)
- ☐ Lunch & snacks (mandatory per person)
- ☐ Raincoat & rain pants (1 set per person)
- ☐ Small flashlight or headlamp with extra batteries (1 per person)
- ☐ Durable watch with alarm setting – NOT cell phone (1 per person)
- ☐ Sturdy hiking or wildland fire boots – no tennis shoes or sandals when doing fieldwork (1 per person)
- ☐ More water & Gatorade than you think you will drink (recommended 10 L/day/person)
- ☐ Toiletries – toilet paper/trowel/hand sanitizer, sunscreen, etc. (1 kit per person)
- ☐ Tree codes & protocol cheatsheets
- ☐ Pack cover or contractor trash bag

6.0 Species Code Cheat Sheet

Common Upland Tree Codes

Code	Scientific Name	Common Name
ABCO	*Abies concolor*	white fir
ABLAA	*Abies lasiocarpa* var. *arizonica*	corkbark fir
ARTR2	*Artemisia tridentata*	big sagebrush
CEMO2	*Cercocarpus montanus*	alderleaf mountain mahogany
FRVE2	*Fraxinus velutina*	velvet ash
JUCO6	*Juniperus communis*	common juniper
JUDE2	*Juniperus deppeana*	alligator juniper
JUMO	*Juniper monosperma*	one-seed juniper
JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper
PIAR	*Pinus aristata*	bristlecone pine
PIED	*Pinus edulis*	two-needle piñon *piñon pine**
PIEN	*Picea engelmannii*	Engelmann spruce
PIFL2	*Pinus flexilis*	limber pine
PIPO	*Pinus ponderosa*	ponderosa pine
PIPU	*Picea pungens*	blue spruce
POTR5	*Populus tremuloides*	quaking aspen
PSME	*Pseudotsuga menziesii*	Douglas-fir
QUGA	*Quercus gambelii*	Gambel oak
QUGR3	*Quercus grisea*	gray oak
QUPA4	*Quercus pauciloba*	wavyleaf oak
QUTU2	*Quercus turbinella*	Sonoran scrub oak *desert scrub oak**
RONE	*Robinia neomexicana*	New Mexico locust

Common Riparian Codes

Code	Scientific Name	Common Name
AIAL	*Ailanthus altissima*	tree of heaven
ACGL	*Acer glabrum*	Rocky Mountain maple
ACNE2	*Acer negundo*	boxelder
BASA4	*Baccharis salicifolia*	seepwillow *mule-fat**
COSE16	*Cornus sericea*	redosier dogwood
ELAN	*Elaeagnus angustifolia*	Russian olive
FOPU2	*Forestiera pubescens*	stretchberry *New Mexico olive**
PODEW	*Populus deltoides* ssp. *wislizeni*	Rio Grande cottonwood
PRVI	*Prunus virginiana*	chokecherry
SAEX	*Salix exigua*	narrowleaf willow *coyote willow**
TAMAR2	*Tamarix* spp.	tamarisk *salt cedar**, species unknown
ULPU	*Ulmus pumila*	Siberian elm

Common Cacti Codes

Code	Scientific Name	Common Name
CYIM2	*Cylindropuntia imbricata*	tree cholla
CYLIN2	*Cylindropuntia* sp.	cholla, species unknown
OPEN3	*Opuntia engelmannii*	cactus apple *desert prickly pear**
OPPH	*Opuntia phaeacantha*	tulip prickly pear
OPUNT	*Opuntia* sp.	prickly pear, species unknown

Common Upland Shrub Codes

Code	Scientific Name	Common Name
AMCA6	*Amorpha canescens*	lead-plant
AMFR	*Amorpha fruitcosa*	false indigo bush
ARPU5	*Arctostaphylos pungens*	point-leaf manzanita

Code	Scientific Name	Common Name
ARUV	*Arctostaphylos uva-ursi*	kinnickinnick
ATCA2	*Atriplex canescens*	fourwing saltbush
CEFE	*Ceanothus fendleri*	Fendler's ceanothus
DAFR6	*Dasiphora fruticosa*	shrubby cinquefoil
ERNA10	*Ericameria nauseosa*	rubber rabbitbrush
FAPA	*Fallugia paradoxa*	Apache plume
FOPU2	*Forestiera pubescens*	stretchberry *desert olive**
GUSA2	*Gutierrezia sarothrae*	broom snakeweed
KRLA2	*Krascheninnikovia lanata*	winterfat
MARE11	*Mahonia repens*	creeping barberry
NOGR5	*Nolina greenei*	woodland beargrass *Greene's beargrass**
PAMY	*Paxistima myrsinites*	Oregon boxleaf *mountain-lover **
RHTR	*Rhus trilobata*	skunkbush sumac *three-leaved sumac **
RIBES	*Ribes* sp.	currant, species unknown
RICE	*Ribes cereum*	wax currant
RIIN2	*Ribes inerme*	whitestem gooseberry
ROWO	*Rosa woodsii*	Woods' rose
RUID	*Rubus idaeus*	American red raspberry
SHCA	*Shepherdia canadensis*	russet buffaloberry
SYAL	*Symphoricarpos albus*	white snowberry
SYMPH	*Symphoricarpos* sp.	snowberry, species unknown
SYRO	*Symphoricarpos rotundifolius*	roundleaf snowberry
VAMY2	*Vaccinium myrtillus*	whortleberry
YUBA	*Yucca baccata*	banana yucca
YUCCA	*Yucca* sp.	yucca, species unknown

**Italic common name* represents an alternative common name that differs from the common name found in the USDA plant database.

7.0 Forest Types of New Mexico

Forest Type – A designation or name given to a forest based on the most abundant tree type or types in the stand.

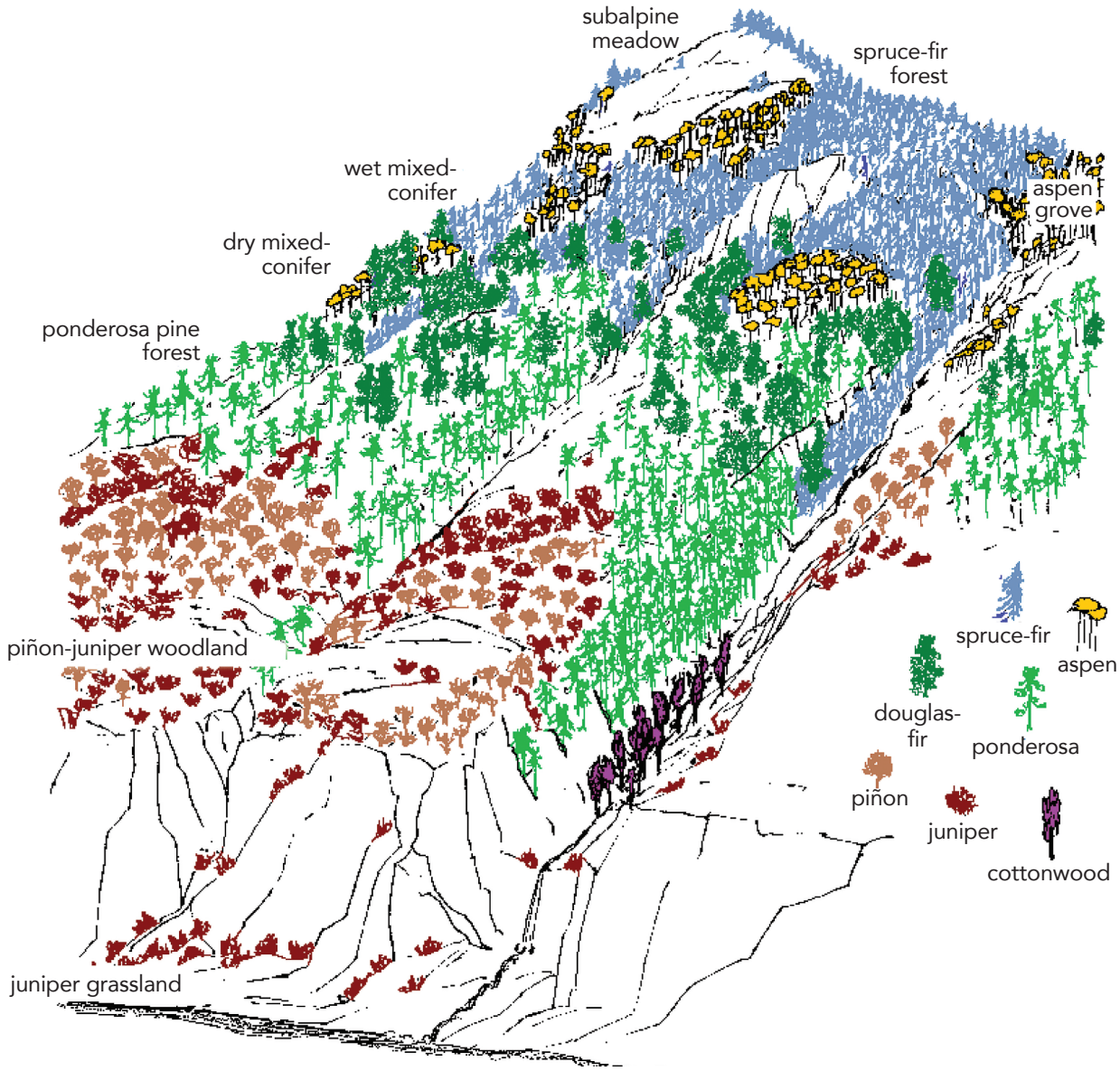


Figure 1. Illustration of changes in forest type by elevation and aspect (adapted from LANL 2011).
Diagram credit: Rocky Mountain Research Station, USDA Forest Service
(https://www.fs.usda.gov/rm/pubs/rmrs_gtr310.pdf)



Photo by Carolina May

1. **Piñon-Juniper** – Forest type consisting mainly of piñon and juniper species, often one-seed juniper and/or rocky mountain juniper. Generally found in elevations ranging from 4,000 to 8,000 ft.



Photo by Carolina May

2. **Bosque/Riparian Forest** – Bosque is dominated by cottonwoods and willows, as well as non-natives such as salt cedar and Russian olive. Typically, found below 6,000 ft, at higher elevations smaller willows/shrubby/high-elevation species dominate.



Photo by Carolina May

3. **Ponderosa** – Forest type consisting mainly of ponderosa pine (more than 26% of total tree species by NMFWRI definition). Other trees species found in ponderosa pine forests in New Mexico includes oak, juniper, and piñon. Understory composition includes numerous bunchgrass, forb, and shrub species. Common from 7,000 to 9,000 ft.



Photo by Kathryn Mahan

4. **Dry Mixed-Conifer** – Forest that is dominated by ponderosa pine but with a large component of Douglas-fir, limber pine, aspen, and occasionally white fir and blue spruce. Dry mixed-conifer forests are found in the drier, warmer, and lower elevations of mixed-conifer forest types. Generally, occurs from 5,000 to 9,500 ft.



Photo by Carolina May

5. **Wet Mixed-Conifer** – Forest type consisting of an assortment of species including Douglas-fir, limber pine, white fir, blue spruce, and aspen. Occurs from 5,500 to 10,000 ft.



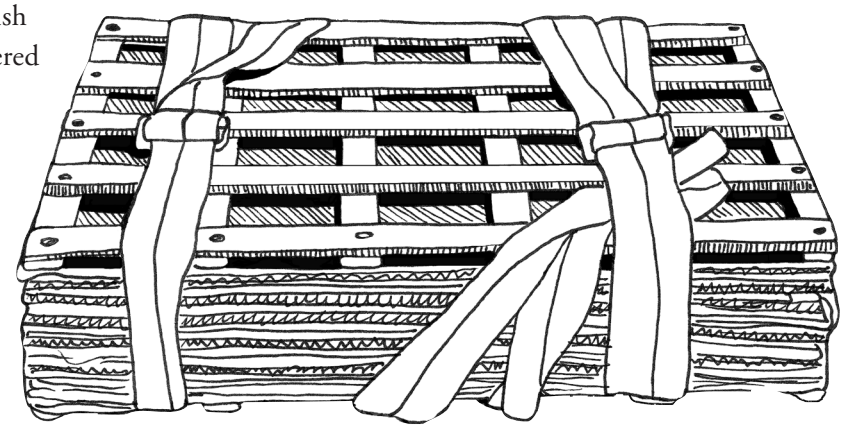
Photo by Carolina May

6. **Spruce-fir** – Forest dominated by Engelmann spruce, Douglas-fir, aspen, corkbark or subalpine fir. Usually occurs from 8,000 to 12,000 ft.

8.0 Herbarium Voucher Collection Protocol

Purpose

Plant collections are used to establish physical records of plants encountered in the field and to aid in the identification of unknown species. A specimen collected in the field is known as a voucher. Along with collecting a voucher, photographs and observations of the plant and its habitat are documented to provide pertinent details that aid in identification and contribute to generalized knowledge of the species.



Field plant press. *Diagram by Meredith Prentice*

Main Steps

1. Photographing & Collecting
2. Pressing & Preserving
3. Mounting & Labeling
4. Filing

1. Collecting

Collection Materials:

- Hand lens
- Identification keys and field guides
- Clippers
- Gloves
- Soil knife and/or trowel
- Wooden plant press with newsprint, blotting paper, cardboard ventilators, and press straps
- Paper bags
- Gallon Ziploc bags
- Envelopes
- Field press bag
- Paper string tags
- Voucher datasheets
- Sharpie/pen/pencil
- Camera

Cactus Specific Materials (in addition to materials above):

- Knife
- Large paper bags
- 95% ethanol solution
- Small cooler
- Tongs
- First aid kit equipped with i.e. tweezers, ultra-sticky heavy-duty tape, and Elmer's glue

Ecological and Cultural Considerations:

Be familiar with any rare or endangered species in the area you are collecting from. Do not collect any species with a sensitive conservation status. Collecting threatened, endangered, or rare plants may be illegal depending on local laws. It is recommended to carry a list of rare, threatened, endangered, etc. plants for a field site you are traveling to. If there is a chance the plant you are thinking of collecting may be rare or endangered, be sure to identify first to confirm the species. If not 100% certain about the identification and there is a chance the species might be rare, err on the side of caution and don't collect. Take detailed observation notes and photographs. A list of rare plants in New Mexico can be found at: https://nmrareplants.unm.edu/rarelist.php.

Plant collections may or may not be permitted on certain land depending on the jurisdiction, i.e. tribal, federal, state or private. Be aware of restrictions on making collections and obtain any necessary permits ahead of time. Any permits obtained will need to be carried with you out into the field.

Many plants are culturally and medicinally important for the Indigenous and Nuevomexicano communities that have deep ancestral relationships to the land. Educate yourself about the land you are working in and peoples who call that land home. To learn more about indigenous territories, Native Land Digital has an online interactive map that can be found here: https://native-land.ca/.



Photo by Meredith Prentice

Scientific collections played a significant role in the colonial and imperialist practices of objectification, extraction, commodification, and expansion. The taxonomic system used to categorize and divide all of life arose from Carolus Linnaeus, a 18th century Swedish botanist. Linnaeus was inspired by Aristotle's "Great Chain of Being", a conceptual framework that ranked matter according to its perceived evolutionary advancement. Linnaeus adopted a hierarchical approach to categorizing life to organize his classification system. Linnaeus's classification schema was also used to categorize and rank human communities. His work influenced





Photos by Meredith Prentice

scientific racism, perpetuating the oppressive regimes of colonial genocide, slavery, and the eugenics movement.

Though the current educational and research aims of many herbariums differ from the original intentions of early colonialists, imperialists, and scientists, we can easily perpetuate harmful ways of perceiving and interacting with the land and the peoples who call that land home if we don't examine our positionality. Plants, and the ecosystems they reside in, have an inherent right to exist outside their benefit to humans and science. We can begin to untangle and rewrite our relationship to plants and the land at large by learning their stories and various names, by learning about the people who have close ties to them, and approaching them with respect, integrity, and curiosity.

This is by no means an exhaustive list, but before collecting, think through the following considerations:

- What is the conservation status of the plant I am considering collecting?
- Is collecting permitted? Do I have a copy of the permit with me?
- What is the cultural or ecological importance of this plant or the site it is growing in?
- Would a photograph suffice in place of a collection?
- Is the plant population stable? (Minimum of 20-30 plants in the general area for herbaceous plants, i.e. forbs and grasses)
- Is this plant already in the herbarium? If it is, does this particular plant display interesting morphological features or immaturities useful for education and training purposes?

Special Considerations for Non-native Plants:

Collection of common non-native plants are useful for education and training purposes. However, these types of plants should be handled with care and caution to avoid dispersal of seeds. Keep fragment bags handy to capture seeds that may become loose during the collection and pressing process. Clean collection equipment after collection of non-natives. There are laws at the federal, state, and local level regulating the transportation and possession of plants considered to be noxious. Be aware of regional regulations before handling and transplanting certain plants that may fall into this category.

What to Look for in a Voucher:

Vouchers should be as complete as possible, meaning the collected plant has leaves, flowers and/or fruits depending on the phenology. Depending on the purpose of a plant collection, vouchers may or may not need to include roots. Certain considerations to think through on whether to include roots or not include:

- Are roots needed for identification?
- Is the plant annual or perennial? Just taking an above ground clipping of a perennial allows the plant to survive
- What is the size of the plant population?

Regardless of whether the roots are collected or not, make sure to collect enough of the plant so that the voucher includes the necessary anatomical features needed for identification. A good voucher is healthy and representative of typical plant morphology. There are some cases in which immature or atypical plants would be desirable for collection. For monitoring purposes, it is helpful to have samples of common trees or shrubs in their seedling stage to aid identification in the field. Unhealthy or atypical plants may also be collected to display morphology impacted by forest pathogens.

Vouchers should ideally fill a good portion of the herbarium sheet (29 x 43 cm). If you are unable to identify the species in the field, collect two vouchers. One will be used for identification and the other will be the primary mounted specimen. If a plant encountered on plot is needed or desirable for collection, make sure to collect the plant from outside of the plot boundaries. Collecting inside the plot can impact species richness counts.



Photo by Meredith Prentice

What to Collect: Photographs + Voucher + Field Observations

Photographing

Always photograph a plant before collecting. This can aid in identification and capture details of the plant, i.e. size and color that usually become obscured in the pressing process.

Several photographs of the plant should be taken to capture enough details. Photograph the plant from a reasonable distance to capture the entirety of the plant. Additionally, take close up photos of the leaves, flowers, fruits, etc. Close up photos capture the smaller details of the plant needed for identification. To indicate the size of these certain features its recommended to include an object next to the leaf, flowers, etc. to show scale. Use tapes, rulers, or commonly known objects such as coins.

Make sure photographs are in focus with nothing obscuring the plant. If collecting a plant voucher associated with a certain plot, take photos of the plant after all other plot photos have been taken. Record the photo number on the voucher collection datasheet and the plot description photo order section.

Small Plants (grasses, forbs, etc.):

Ensure there are at least 20-30 plants in the area. Include the leaves, flowers, and/or fruits, and potentially the underground structure. If the plant is small, collect a couple vouchers (as long as they all come from one population and the population is big enough). If collecting the roots, carefully dig them up and remove as much dirt as possible.



Photo by Meredith Prentice

Bryophytes (liverworts, hornworts, and mosses) **& Lichen:**

Use your best judgment on whether you should collect certain species or not, considering conservation status and population size. If you are not seeing a lot of the species in the general area, opt to take pictures, sketches, and extensive notes. With these types of plants, you don't need to fill a whole herbarium sheet. Collect the whole specimen, grabbing enough plant material to fill the palm of your hand. Be careful not to include other species that may grow interspersed with the desired sample. When collecting bryophytes, collect specimens that include sporophytes if possible, as it is often needed for proper identification. If the plant is growing on a tree, additionally collect some of the outer bark it's growing on and include the tree species in observation notes. When collecting bark be careful not to damage the cambium layer located underneath the outer/inner bark layers. Before collecting lichen, if the specimen is dry or brittle, spray or dab some water on it to avoid damaging the voucher. These types of plants are air dried, so they can be placed in paper bags or envelopes right away when collecting.

Trees, Shrubs, & Vines:

When whole plants cannot be collected, collect the essential features; leaves, twigs, flowers, bark (from either trunk or ground, being careful not to expose the cambium; or snap a close-up photo), and fruit as a cutting. Use clippers to make a clean cut through the stem approximately one foot back from the tip. To minimize danger to the parent plant, twigs should be cut off cleanly with a pruner and not torn. The stem should be cut diagonally to display the color of the wood and the pith. If the stem is very thick it can be sliced lengthwise to reduce its bulkiness.

Cactus:

Many cactus species are rare or illegal to collect. Be certain of an ID before collecting. Assuming the cactus is allowed to be collected, be certain that a voucher is actually needed or necessary. Include flowers and fruits of cactus as this is often necessary for identification. Using gloves and a sharp tool, cut off a section of the plant. For *Opuntia* species (prickly pear) this could mean several cladodes or pads depending on the size of the plant. Flowers should be collected when the tepals are completely opened. Be aware that cuttings will shrink after



Photo by Meredith Prentice

processing. Cacti hold a significant amount of water and thus can be challenging to dry. Cactus cladodes will need to be processed in the herbarium. Place the voucher in a larger paper bag for temporary storage. Flowers should be pressed immediately.

Labeling:

Collections will need to be assigned a collection number. Follow this format when establishing a collection number: Site_Year_#. Numbers should start with 001 and increase in consecutive order with each new collection. Record the collection number on a paper tag and attach that to plant (if collecting two samples make sure each sample has a label and additionally indicates which plant is 1 of 2 and 2 of 2). Also write the collection number on the newsprint or bag that plant is stored in, in case the tag is lost.

Field Observations:

In addition to collecting the voucher sample, we will also need to collect pertinent information about the plant and the specifics of its habitat. It's important to record any features of the plant that could be obscured after the pressing and mounting process. This includes features such as flower color, texture, scent, height, the presence of latex (i.e. usually located in the stem; examples include *Apocynum* and *Asclepias* species), type of bark, stickiness, etc.

Fill out a voucher datasheet to record the following information:

- Collection No.
- Associated Plot ID
- Collection date
- Collectors' name
- Identifier's name
- Location:
    - Country
    - State

County

Locality: e.g. distance and direction from nearest town or other landmark, hwy intersection, National forest or name of land, etc. in drainage along FS road 252, in Santa Fe National Forest, San Miguel, County, New Mexico)

- Latitude and longitude or UTMs
- Elevation
- Scientific name
- USDA Plants symbol
- Common name(s)
- Family
- Lifeform (forb, shrub, graminoid, tree, bryophyte)
- Plant description:

  Height, flower color, texture, smell, habit (annual, biennial, perennial), etc. Any features likely to be obscured in the pressing/ drying process. The more details the better.

- Habitat:

  Slope
  Aspect
  Type of habitat (prairie, marsh, piñon-juniper woodland, associated plants in the area. For epiphytes include the type of substrate: rock, log, tree, etc.)
  Soil type or parent material
  Extent of species population



Photo by Meredith Prentice

2. Pressing

The keys to achieving well-pressed plants are:

- Pressing them quickly;
- Attending to the specimens as they dry and not allowing them to mold under moist conditions.

Pressing is the process of applying pressure to a plant specimen to dry and preserve it. Ideally plants are pressed directly into the wooden plant press to reduce the amount of handling vouchers receive. There may be certain situations where you don't have immediate access to the wooden press and may store samples temporarily in a field press bag with cardboard, newsprint, and blotter paper or in a plastic bag/water bottle with a small amount of water to keep the sample moist. Vouchers will not press properly in the field press and will come out wrinkly. It is crucial to transfer the voucher to the wooden press as soon as possible.

As mentioned before, if you have an unknown plant you will collect two vouchers. One of these will be used for identification. It is best to try to identify the plant while plant material is still fresh. If you anticipate being able to identify a plant in the field, you can temporarily store the plant in a plastic bag with a small amount of moisture until you are able to identify it. If you do not anticipate being able to identify the plant in the field, press both samples and label them clearly.

Using the Plant Press:

1. Place the plant in between a sheet of newsprint. The sample should not hang over edges of the newsprint. If necessary, fold the specimen so it will fit on the sheet. Some specimens, such as grasses, sedges, and certain forbs can be arranged into a zigzag to fit onto the newsprint. If needed, cut the specimen in half and press it in two separate sheets of newsprint. It is better to cut or fold the specimen rather than bending to achieve the proper size. Cutting and folding are more noticeable and indicate that the shape of the specimen was altered during the pressing process. Arrange the plants in a way that displays both the front and backside of the leaves. Flowers should be arranged to display a front, back, and side profile. If a voucher was too large to fit on a single sheet of newsprint or multiple smaller samples were collected for a voucher, make sure all samples have labels and note the total numbers of samples per voucher (i.e. 1 out of 2, 2 out of 2).
2. Once the plant is folded in the newsprint, place the newsprint in between two sheets of blotting paper. The blotting paper helps to absorb the moisture from the specimen. Place the blotting paper, newsprint, plant, newsprint, blotting paper arrangement between two sheets of ventilated cardboard. Using ventilated cardboard allows for air to flow through the press. If you are utilizing the field press bag without a wooden press, secure the field press in the field bag until you are able to transfer the collection to the wooden press. Before you place the collected voucher into the wooden field press, it is a good idea to reposition the sample if need be (the sample may have moved around during the day in the field press).
3. Make sure the sample:
    a. Is spread out flat and fully on the newsprint.
    b. Both the bottom and front sides of leaves are displayed.
    c. Has some of the flowers pressed open and some flat.
    d. Will fit on the mounting card when dry, remembering to leave space in the bottom right hand corner for the label.
    e. Is not crowding the sheet; if you need to you can snip off some of the leaves, just make sure you leave part of the petiole so it is evident you removed the leaves.
4. Once checked, place the stack of collected vouchers (cardboard ventilators, blotting paper, newsprint, plant, newsprint, blotting paper, cardboard ventilator sandwich) in between the top and bottom lattices of the wooden field press.
5. Wrap the straps around the press. While applying pressure to the press, tie or fasten the straps so the press is compressed. The press should be evenly compressed so that specimens dry quickly and press flat. Specimens with bulky parts may require thick folds of newspaper around the bulky parts so that pressure is transferred to the less-bulky leaves and flowers. Vouchers should be arranged in the press so

that the bulky parts of the vouchers are alternating in orientation so as not to disproportionately make one side or corner of the press dramatically larger than the rest.

6. Make sure the datasheet is filled out correctly and fully and is stored nearby the samples for safe keeping.

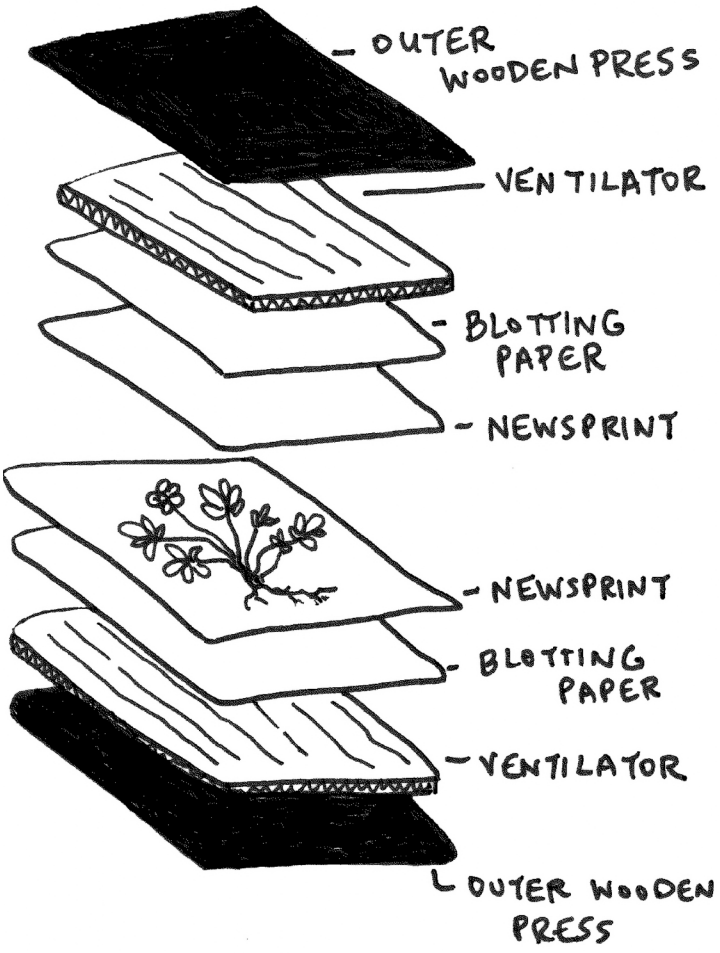


Diagram by Meredith Prentice

Pressing Considerations:

Specimens typically take one to two weeks to dry depending on temperature, humidity and the dampness and/or succulence of the plants. Presses should be kept in a warm, dry location with good air circulation while drying.

Check vouchers regularly to ensure potential moisture, insect, and fungal spore build up is avoided. Checking the specimens regularly also provides the chance to reposition the sample if need be. Please refer to the positioning guidelines mentioned above to ensure the plant is drying in a desirable manner. In the Southwest it is rarely necessary to replace the newsprint or blotting paper during the drying process. Specimens that are fleshy or contain a lot of water may need to be checked on and placed within fresh newsprint or blotting paper. Be sure to handle samples with care, as the plant continues to dry it will become more fragile and more likely to break. If any piece of the voucher breaks off, save and store the fragments in an envelope to be stored next to the voucher. Label this envelope in case it happens to be separated from the voucher.

Pressing Cactus:

Collections placed in a large paper bag can be stored for two to four days. Store in the bag in a dark place in the interim. It is best to process samples within one to two days after collecting. Once the collected sample is ready to be pressed, it is cut with a knife lengthwise. If the cactus species is especially thick, it may be necessary to cut lengthwise three to four times. Opuntia species (prickly pear) should be cut through the middle lengthwise. For *Cylindropuntia* species (cholla), slice through the joints lengthwise to preserve the branching pattern.



Plant press. *Photos by Meredith Prentice*

To aid in the cutting process, wear gloves and press cardboard or a piece of wood against the sample while you cut. After cutting, scoop out the parenchyma (fleshy inside) of the plant. Place the sample in a 95% ethanol solution for eight to twenty-four hours in a sealed container such as a cooler. Weigh down the sample with a heavy object to ensure it is totally submerged. This will also help with keeping the sample flat. Cacti can be removed from the ethanol bath when the parenchyma tissue has shrunk back from the vasculature. Time in the ethanol bath will differ depending on the size of the sample and type of cactus. *Echinocactus* species (barrel) take around twenty-four hours, whereas *Opuntia* species will take around eight hours.

Flowers should be pressed immediately as they deteriorate more rapidly and lose their color quickly. Cut the flowers longitudinally and make small incisions in the ovary wall to aid in drying the sample. Make sure flowers stored in the press are assigned the sample collection number as the cladode or pad portion of the voucher.



Once the sample is ready, place the voucher in the wooden press. Place a sheet of parchment or wax paper on the side of the cactus pad or flower that was cut. This helps to ensure the plant material doesn't stick to the newsprint. Place the sample and the parchment paper inside a sheet of newsprint. Place the newsprint in between two sheets of blotter paper and ventilated cardboard. When tightening the press straps apply enough pressure so that cactus spines lay flat but not too much pressure to avoid damage to the soft tissue. Newsprint and blotting paper may need to be changed periodically depending on the thickness of the sample.

3. Mounting

Collections should be stored in the freezer for at least 48 hours before being mounted. Freezing specimens reduces the introduction of pests into the herbarium. Samples should be stored in the newsprint sheet and staked flat in the freezer.

After freezing, the pressed voucher is mounted on a 29 x 43 cm archival quality (acid free) white mounting card. It is best to mount several vouchers

(15-20) in the same session as set up/cleanup is time consuming.

Guidance on NMFWRI mounting technique was provided by the University of New Mexico Herbarium located at the Museum of Southwestern Biology. For more detailed information about mounting, reference "Mounting Specimens at the UNM Herbarium."



Photo by Meredith Prentice

Mounting Materials:

- Voucher
- Voucher datasheet
- Voucher label
- Pen (archival ink)
- Acid free herbarium glue
- Paper towels
- Flat surface to spread out glue, i.e. glass plate/lunch tray
- Plastic containers w/ lid (for watered down herbarium glue)
- Foam paint brush (various sizes)
- Forceps
- Acid free herbarium mounting paper (29 x 43 cm)
- Foam squares
- Wax squares
- Cardboard ventilators
- Heavy objects/books for weights
- Metal washers

Arranging the specimen:

- Vouchers should be arranged and mounted in portrait orientation (vertical).
- Center the voucher on the mounting card, placing it vertically or diagonally across the paper.
- If there are multiple small plants collected for a voucher, arrange them in evenly spaced rows across the mounting paper.
- Placement of the voucher should reflect its growth habit, i.e. flowers at the top and roots the bottom.
- Make sure morphological characteristics are showcased (both sides of leaves displayed, some flowers open, some closed) and that specimen lies flat on the mounting card.
- Leave a 1 cm border around the edge of the mounting card to allow space for holding or picking up voucher.

- Leave space in the lower right-hand corner of the mounting card for the voucher label.
- Leave space in the upper left-hand corner if a fragment envelope needs to glued to the mounting card.

Gluing & Attaching the Specimen:

1. Prepare a workspace by laying down used newspaper and gathering the supplies listed above.
2. Create a diluted glue mixture containing water and herbarium glue. The mixture is mostly glue. It should be a runny consistency that will easily spread over the working surface. Add water little by little to achieve the desired consistency.
3 Pour the diluted mixture on the surface of a plate/tray and spread the mixture around with a large foam brush. The surface of the plate should be semi-translucent. Too much glue and it will seep out the bottom of the specimen and label card.
4. Carefully dip the backside of the plant into the glue to ensure all parts of the plant have contacted the glue. It may be necessary to dip the plant from several angles to ensure total coverage. Use a small paintbrush to dab glue on areas not initially covered.
5. Place specimen in predetermined orientation on the mounting card. Dab away any excess glue that may seep out after attaching it to the paper.
6. Use heavy metal washers to hold down bulky plant materials that do not lie flat or do not stay in place. Place a small sheet of wax paper between the plant and the washer to ensure the washer doesn't stick to the plant. Certain plants may be too delicate to dip directly into glue. For these types of plants dab and /or brush glue on the backside.

Fragment Envelopes:

As mentioned previously, any loose seeds or plant parts that broke off during the drying/mounting process are kept in a fragment envelope. Fragment envelopes should be labeled with the voucher ID number of the specimen it is associated with. Don't place fragment parts in the envelope until they are completely dry. Brush the diluted glue mixture on the backside of the envelope and attach it to the mounting card in the top left-hand corner. Use metal washers to hold the envelope down until it is dry.

Labels:

After the specimen has been glued to the mounting card, fill out and glue the voucher label. Make sure hand writing is legible and written in archival ink for long-term preservation. NMFWRI uses Micron pens to fill out labels.

Labels include the following information:

- No. (ex. SITE_YEAR_#)
- Herbarium (NMFWRI)
- Scientific Name i.e. *Pinus ponderosa* Lawson or Pinus ponderosa Lawson
- Common Name
- Family
- Location (include collection site, habitat, state, county, UTMs, elevation, etc.)
- Collected By
- Date
- Identified By

Brush glue on the backside of the label (glue should be thinner than the glue used for the plant specimen and fragment envelope). Make sure all corners and edges are covered with glue. Place in the lower right-hand corner of the mounting card. The label should be one cm from the bottom and righthand edges of the mounting paper. Smooth out any wrinkles or air bubbles that may form and wipe away any excess glue. Hold down the label with metal washers until dry.

Stacking & Drying:

Ten to 15 vouchers can be easily stacked in a pile to dry after gluing. After the voucher and label have been glued to the mounting paper, place a sheet of wax paper on top of the mounting card. Place a sheet of foam on top of the wax paper. Next, place a sheet of cardboard on top of the foam. Build up the stack with the additional mounting cards in this order. After building the stack, place a plywood square on top weighted down with heavy books or sandbags. Place a sticky note on the stack indicating the name of person who mounted the specimens and the date mounted. Allow to dry for at least 48 hours.

Remove specimens from the stack one by one, handling carefully. If any major parts of the plant did not successfully attach with the initial mounting, repeat the process above again to glue them down. Not every leaf or small section of the plant needs to be glued down, just ensure the main parts of the plant are attached to ensure they don't get lost.

4. Filing

Once the voucher is completely dry, place it in a clear voucher envelope. This sealed envelope will be filed in the herbarium cabinet. The cabinet is arranged in alphabetical order by family and then by genus. Each letter has its own shelf. Within the shelf, there are folders organized by genus. If the voucher collected belongs to a genus that doesn't currently have an existing folder, establish a folder and label the folder with the genus in the right-hand corner.



Herbarium cabinet. *Photo by Meredith Prentice*

Vouchers should be handled delicately to ensure their longevity. They should always remain in a horizontal flat position with the specimen facing towards the ceiling. Use both hands to pick up and move the voucher. Never turn them upside down or flip them over like pages of a book.

8.1 Mushroom Collection Protocol

Safety

Mushroom collection should not be scary! Mushrooms are not dangerous to touch or pick up. That said, some mushrooms are very poisonous if ingested, and caution should be exercised. Gloves are not needed to collect mushrooms because mycotoxins cannot be absorbed through skin, but touching the face or eating while handling mushrooms should be avoided, in case of micro-mycotoxin or bacterial transfer to the mouth. Always wash your hands with soap and water (not hand sanitizer) after handling mushrooms. Even if the mushrooms are not poisonous, pathogenic bacteria can live on them. Never eat a mushroom unless it has been properly identified and is a known edible. In most circles, it is recommended to never consume a mushroom unless its identification is confirmed using **two sources**, such as two different field guides. There is no one specific trait to determine if a mushroom is edible or poisonous, and many mushrooms have look-a-likes with different traits. If an edible mushroom is identified, always cook wild picked mushrooms. It is not necessary to wash edible mushrooms before cooking them, unless they are particularly dirty, because washing them may make them slimy and the heat from cooking them will kill any bacteria. Also note, do not eat wild mushrooms looking for a psychedelic trip. *Amanita muscaria* (fly agaric) is poisonous and is a native psilocybe species (magic mushrooms) which have many toxic look-a-likes. Edible, poisonous, or anything in between, mushroom collecting and identification should be fun!

A brief introduction on fungi

Mushroom classification gets complicated. There are over 100,000 types of fungi described, with thousands more yet to be discovered. There are seven phyla of fungi: Chytridiomycota, Blastocladiomycota, Neocallimastigomycota, Microsporidia, Glomeromycota, Ascomycota, and Basidiomycota, with the latter two groups being lumped together in a subkingdom called dikarya, or higher fungi, and these kingdoms are the only two mushroom-producing phyla. Even dikarya can be broken down into microscopic and macroscopic groups. Microscopic fungi are comprised of yeasts, molds, etc. and macroscopic fungi are usually mushrooms. Fungi can also be grouped by ecological roles, which span across the seven phyla. The three major ecological roles are saprobic, which are decomposers, mycorrhizae, which are symbiotes, usually plant mutualists, and pathogens, which tend to be parasitic.

Mushrooms are the fruiting bodies of the underground mycelium, and the mycelium is the main body of the fungus made up of microfilament networks called hyphae. Mushrooms are the apparatus that spreads the spores of the fungus and they can last only hours up to many months. The mycelium, hidden underground, can last much longer and can sometimes regrow mushrooms for years. The mycelium, hidden underground, can last much longer and can sometimes regrow mushrooms for years. Mushroom anatomy starts with the mycelium underground, which sprouts an egg-shaped cup (volva) that will become the base of a mature mushroom. The stem/stalk (stipe) grows from the cup, with the cap (pileus) being the top of the mushroom. On or under the cap there can be gills (lamellae), pores, ridges, teeth, or more, all of which produce the spores. Some mushrooms also have a ring (annulus) around the stem or a veil around the gills.

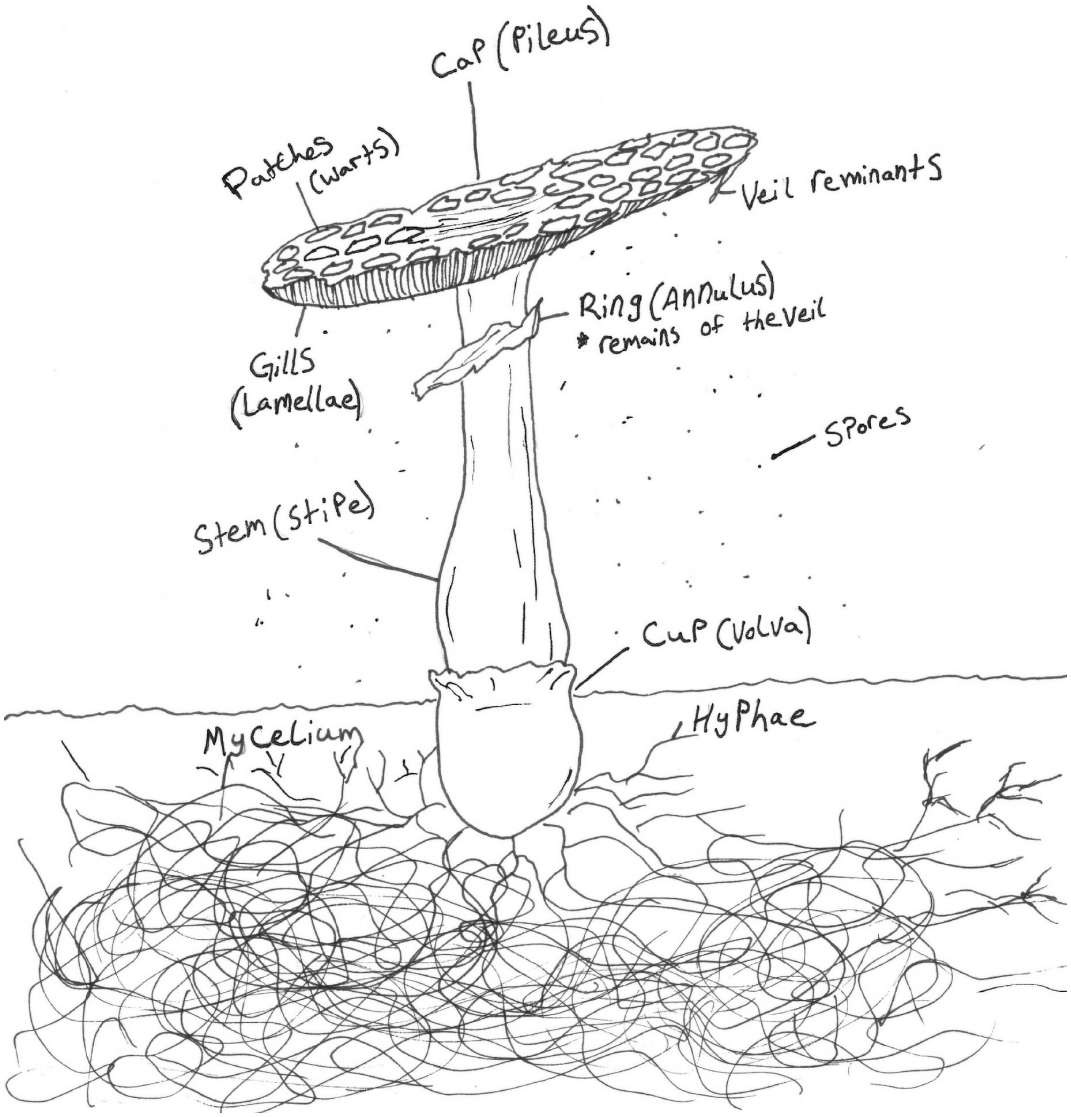


Diagram by Zoe Ahrens

To collect samples, you will need

- Pen and notepad
- Mushroom ID book
- Camera
- Pocketknife with brush
- A basket, empty tackle box, cooler, large mesh bag or burlap sack
- Wax paper, paper sack, small mesh bags or plastic bags with paper towel
- Tin foil, white paper or spore print paper
- A plastic box with a lid or bowl
- Magnifying glass
- Ruler

Where to find mushrooms

Though mushrooms can be found virtually anywhere there is warmth, water, and plants, usually the best way to find mushrooms is after a steady rain in the summer near dead and living trees. Mushrooms of different species can grow in the Rocky Mountains year-round and from semi-arid grasslands to alpine regions. Many species grow on living trees, such as cottonwood trees by streams, pine tree roots in the shade, and aspen trees high up on their trunks. Other mushrooms survive on dead things, and many can be found on the underside of rotten logs, growing from the branches of snags, and in patches of litter. You can also find them in grassy fields, recently burned areas, flowerpots, in animal dung, growing out of a dead insect, really, anywhere!

How to collect mushrooms

Since mushrooms are so fleeting and sometimes difficult to preserve, take or draw lots of pictures. Take a picture of where it was found before collecting it. Take a photo of the side profile, and the top. Later, remove the cap and take a picture of the underside of it, then take photos specifically of the cap, stem and ring if present, and the cup. Cut the mushroom in half vertically and photograph the transect and take a picture of the spore print if that is successfully collected.

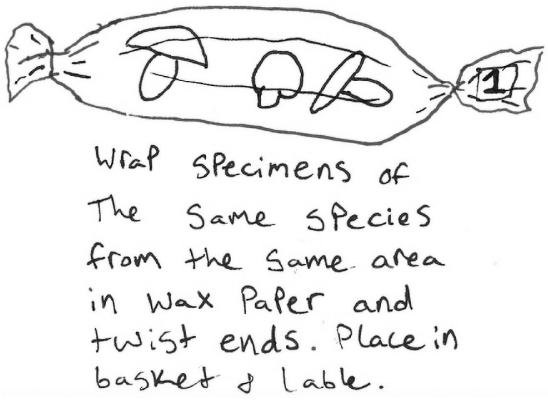


Diagram by Zoe Ahrens

If you find a mushroom on a stalk growing in the soil, use a knife to cut around the soil around the cup and scoop up the whole mushroom. Avoid breaking the stem from the base as the entire shape of the stem is sometimes important to the identification. The cup is usually just slightly buried in the soil, so it should not be necessary to dig very deep in the soil.

If you find a mushroom attached to a live tree, cut the mushroom closest to the wood without cutting the bark. You can do the same for a mushroom attached to a dead tree; though you can try to cut it out of the wood, it can sometimes be gently pulled off the log or branch. Mushrooms like puffballs can be gently picked up, with little attachment to the ground.

Try to collect multiple of the same species if there are more than one in the same area, especially if there are some varying in age. If multiple specimens can be found, try to collect three, unless they are the only three you see, then only collect the best one. If three of the same species can be found, then keep the best one to preserve, use one with a good cap to take a spore print, and cut one in half to see what it looks like internally for identification. Avoid collecting endangered species, or over collecting a species, as some mushrooms don't grow back if picked. Try to collect complete samples that are not too old, broken or missing parts.

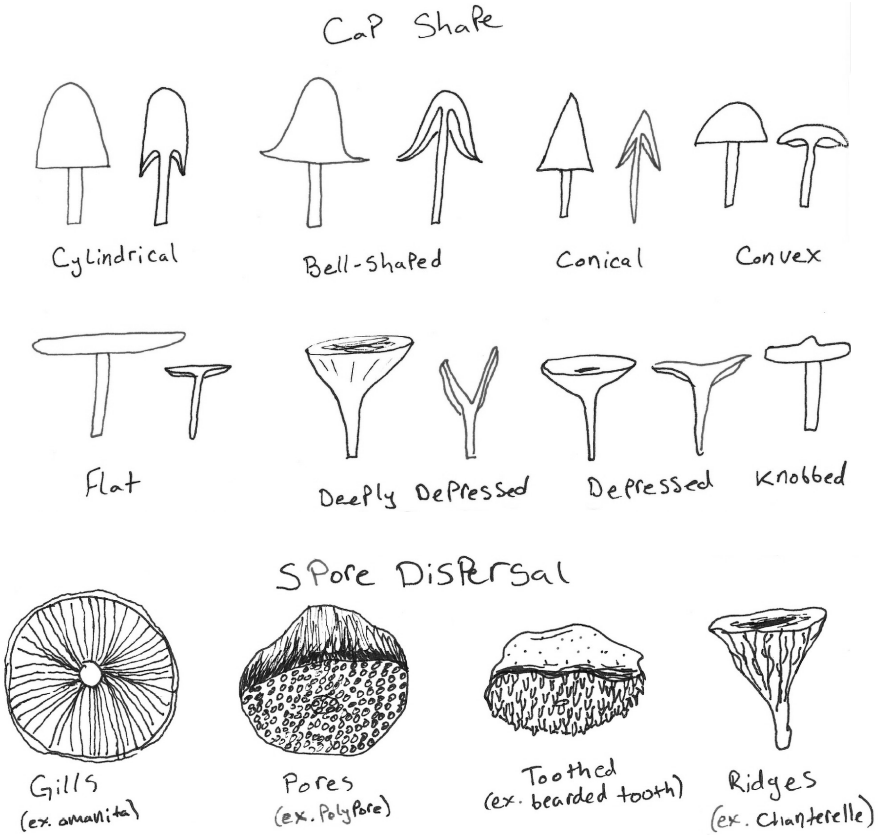
Take note of where your mushroom was found. Write down the date collected, the geographical location (ex. The Jemez Mts, NM; bonus points for coordinates and elevation), the ecological description (ex. montane, mixed coniferous forest, near a creek), and where the mushroom was growing (ex. on a rotten log, in the grass that was part of a fairy ring, next to a cottonwood, on a recently burned hillside) and it may help to even record the weather, as some species only grow in specific conditions, such as rain and shade.

When a specimen is collected, wrap it individually—or multiple of the same species collected from the same

area together—in wax paper and twist the ends of the paper around the mushroom leaving some air around the mushroom and taking care not to squish them. Label the wax paper, even if it is a corresponding number to the note of where it was found on a notepad, then gently place the mushrooms collected into a basket or burlap sack. This is better than plastic to prevent the mushrooms from getting slimy. Plastic bags can work, but it is best to add some air and paper towels to absorb moisture and avoid keeping them in plastic for long periods of time. It is best to keep them in a cool dry place, such as a cooler, for longer transportation. It is best to identify them within the same day of collection.

After the mushroom hunt, examine the collections one at a time within a few hours of collection. Record as much detail of each specimen as possible.

- Smell, (ex. sweet, rotten, earthy, fishy, medicinal, nutty, anise like, corn like)
- Texture (ex. fuzzy, slimy, smooth, scaley, dry, waxy, spiney, hairy, firm, soft, spongey)
- Size (measure total height, length of stem, width of cap, width of stem)
- Anatomy (are there multiple parts or one, is there a cup, stalk, ring, cap, warts, veil?)
- Shape (typical, round, wrinkly, phallic, coral-like, star shaped, shelf-like)
- Color (brown, white, colorful, different colors, spots, gradient, staining)
- Cap shape (flat, bell, knobbed, conical, cylindrical, convex, concave, depressed)
- Stalk shape (thin, fat, tapering towards base or cap, equal, club shaped, bulbus, with cup)
- Gill type/attachment to stalk (pores, ridges, teeth, gills/free, narrowly attached, broadly attached, notched, descending, veiled)



Diagrams by Zoe Ahrens

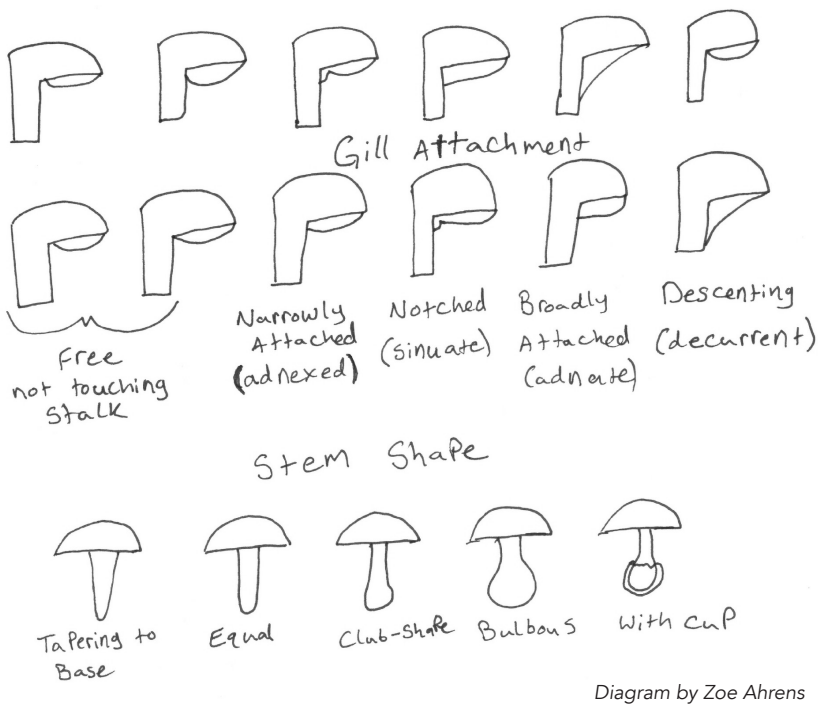


Diagram by Zoe Ahrens





Sample 1

09/08/22

Found near Cuchara, CO. 8,000 ft elevation. Mixed coniferous, hilly, found in a damp, shaded area near lake, one solitary mushroom found in litter near many downed decomposing trees. Sunny 63˚ F, recent rain.

Large, dark purple mushroom. Cap 4" diameter, convex, dark purple, dry almost velvety. Total height 5", stalk bulbous, 1" diameter, and pink at base, fibrous, cream color, brown staining. Gills present, fleshy, yellowish white to brown, free from stalk. Inner flesh white, spongey, not hollow. No cup or ring present. Lightly fishy smelling. Orange spore print.

ID'd as Shrimp Russula (*Russula xerampelina*)

Great edible, but many poisonous look alikes.

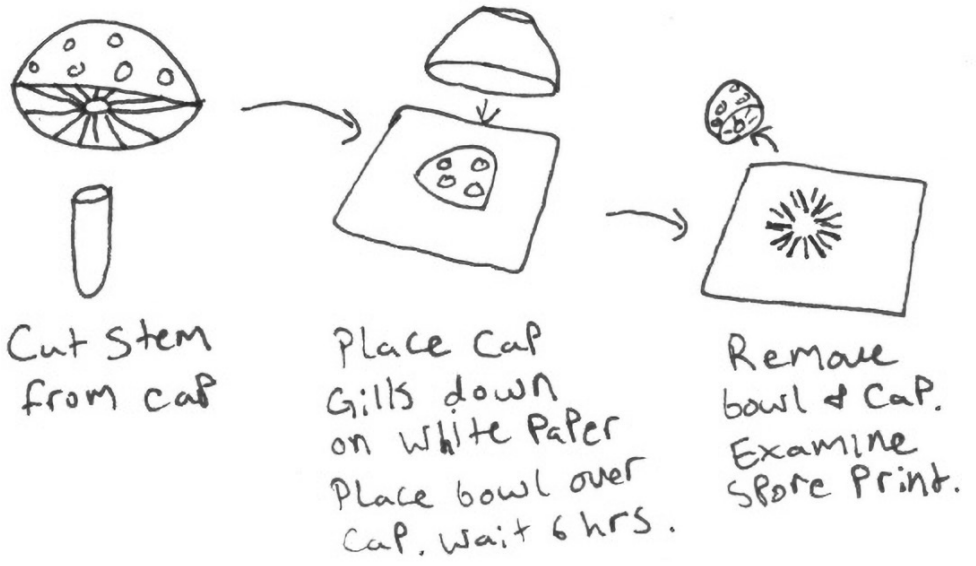


Diagram by Zoe Ahrens

- Spore print (pattern, color; white, grey, black, brown, pink, purple, yellow, green, etc.)
- Spore shape under a microscope (circular, smooth, ridged, pointed)
- Taste *not recommended for beginners* taste a small amount raw, and spit out (spicy, fishy, earthy, bitter, mild)

How to collect a spore print

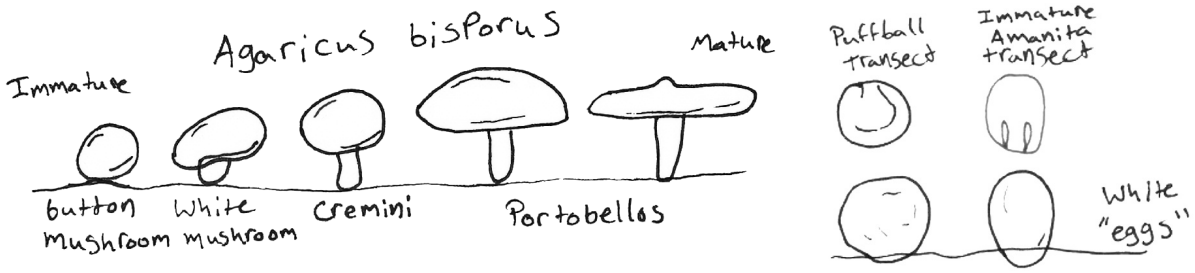
When the mushroom is fresh, cut the stem from the cap so that the cap can sit flat, gills facing down. Place the cap, gills down, on a piece of foil or white paper (even alternating black and white striped paper to be fancy). Place the cap and paper in a plastic box and cover with a lid or place a bowl over the cap on the paper on a table. Leave it alone for 2-24 hours (6 hours is a good target wait time), and carefully remove the mushroom from the paper to reveal the spore print. A mushroom may not provide a spore print if it is too young, or old, sits too long, doesn't have gills, or air blows the spores away. The color and pattern of the spore print is often vital to identifying a species or at least can help to determine if it is poisonous or edible. The spore print can also be preserved when covered with plastic and kept with the description label and photographs or drawings. The spores are also important to collect to view under a microscope to aid in identification. Some species cannot be properly identified without using a microscope to determine the spore shape. Sometimes the spores can also be used later for cultivation of some species.

How to dry mushrooms

Carefully clean dirt or debris from the mushroom using a brush. If it is still dirty, then a paper towel or cloth can be used, using very little, if any, water. If it is small, it can be dried whole. If it is large, it may need to be cut in half lengthwise or quartered to allow a better view and to dry faster. It is best to use a dehydrator but a mushroom can potentially be dried out in a warm dry room with adequate airflow over a few days. Keep track of the mushrooms while they are being dried by making sure a label is near them. Do not press the mushrooms; it will not preserve them. Place the dried mushrooms in plastic baggies or boxes, ideally with a silica packet, and keep them dry and free of pests. Keep a logbook with the dried sample and/or spore print labeled with a number corresponding to a notebook and/or computer spreadsheet with the location and physical description.

Identification challenges

All this information is vital to identification because mushrooms can vary so widely in color, shape, and age within their own species. The fly agaric mushroom is usually red and white around most of the northern hemisphere, except in Washington and Montana where it is yellow and white. Mushrooms also have many look-a-likes that can be from entirely different genus' with very different ecological characteristics that can't be obviously seen. A golden morel can vary in color and shape enough to easily be mistaken for a false morel, but a true morel can be identified by its hollow stalk. Age plays a huge part in identification too because a new mushroom of many species, called a button, looks like a white egg and can easily be mistaken for a puff ball unless cut in half. Common mushrooms in grocery stores, such as button mushrooms, white mushrooms, creminis, and portobellos are actually all the same species, *Agaricus bisporus*, they are just at different levels of maturity. Multiple identification books, talking to other more experienced mycophiles and lots of practice is the best way to become proficient in mushroom identification.



Other types of mushrooms



Diagrams by Zoe Ahrens

9.0 Common Trees of New Mexico



Photo by Carolina May

What is a tree?

A tree is usually defined as a woody plant having one erect perennial stem (trunk) and a definitely formed crown of foliage. USDA PLANTS is the authority NMFWRI uses to determine the growth habit of a plant species. If there are multiple listed, use the most robust of the growth forms. There are several species listed as trees in this section that may never reach the stature of a "tree" in the state of New Mexico, remaining short and shrub-like. For example, common juniper (*Juniperus communis)*, may grow up to 10ft tall in the northeastern US, whereas it rarely reaches a height above 4ft in the southwest. *See Supplement H for resources and guidance on plant identification.*



Photo by Kathryn Mahan

JUNIPERS

Juniperus communis, common juniper
Juniperus deppeana, alligator juniper
Juniperus monosperma, one-seed juniper
Juniperus osteosperma, Utah juniper
Juniperus scopulorum, Rocky Mountain juniper

PINES

Pinus aristata, bristlecone pine
Pinus edulis, two-needle piñon
Pinus flexilis, limber pine
Pinus ponderosa, ponderosa pine

FIRS

Abies concolor, white fir
Abies lasiocarpa var. *arizonica*, corkbark fir
Pseudotsuga menziesii, Douglas-fir

SPRUCE

Picea engelmannii, Engelmann spruce
Picea pungens, blue spruce

POPLARS

Populous tremuloides, quaking aspen

OAKS

Quercus gambelii, Gambel oak
Quercus grisea, gray oak
Quercus turbinella, desert scrub oak
Quercus × pauciloba, wavyleaf oak

ASSORTED

Acer glabrum, Rocky Mountain maple
Alnus incana ssp. *tenuifolia*, thinleaf alder
Amelanchier alnifolia, Saskatoon service-berry
Artemisia tridentata, big sagebrush
Cercocarpus montanus, mountain mahogany
Cornus sericea, redosier dogwood
Cylindropuntia imbricata, tree cholla
Prunus virginiana, chokecherry
Purshia stansburyana, cliffrose
Robinia neomexicana, New Mexico locust
Salix exigua, coyote willow
Sambucus nigra ssp. *caerulea*, blue elderberry
Sambucus racemosa, red elderberry
Senegalia greggii, catclaw acacia
Tamarix spp., salt-cedar

JUNIPERS

Juniperus communis, common juniper





Left photo by Carolina May, right by Grace McCartha, used with permission

Common Name: common juniper

Family: Cupressaceae or cypress

USDA PLANTS Code: JUCO6

Habitat: Wide habitat range. Typically, found in mixed conifer forests. Northwest and southwest New Mexico.

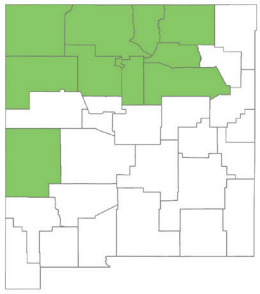
Elevation: 7,000 to 11,500 ft

Common/Similar Species: none

ID: Typically, grows to about 3-5 ft in height. Sometimes taller depending on location. Dense, spreading. Bark is shreddy, peels into thin strips.

Leaves: Awl-shaped. Simple. 5-15 mm long. Whorl arrangement.

Fruits: Cones are fleshy, berry-like, contain 1 to 3 seeds. Less than 1.5 cm in diameter.



Map by Emily Yannayon

JUNIPERS

Juniperus deppeana, alligator juniper



Photo by Carolina May





Center photo and above by Grace McCartha, used with permission

Common Name: alligator juniper

Family: Cupressaceae or cypress

USDA PLANTS Code: JUDE2

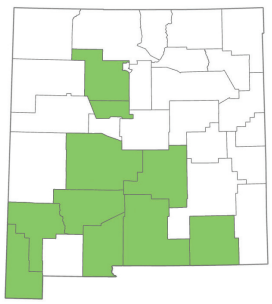
Habitat: Dry, rocky slopes. Grows in association with piñon pine, oaks, and ponderosa pine. Throughout most of the state, most commonly found in central and southern New Mexico.

Elevation: 6,000 to 8,000 ft

ID: 20-40 ft in height, occasionally taller. Typically, single stem. Platy, grayish bark resembles alligator skin.

Leaves: Blue-green, scale-like, 1-4 mm long, glandular.

Fruits: Pollen and seed cones on separate trees. Pollen cones 3 mm long, seed cones are 8-15 mm long. Reddish brown-bluish, bearing 3-6 seeds per cone.



Map by Elizabeth Becker

JUNIPERS

Juniperus monosperma, one-seed juniper



Photo by Carolina May

Common Name: one-seed juniper

Family: Cupressaceae or cypress

USDA PLANTS Code: JUMO

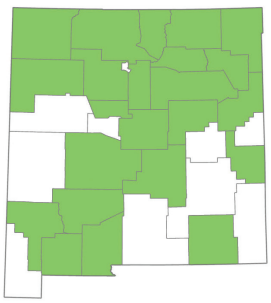
Habitat: Dry, rocky slopes. Grows in association with piñon pine and ponderosa pine. Very widespread throughout New Mexico.

Elevation: 4,000 to 8,000 ft

ID: 7-23 ft in height. Typically, with a rounded crown and multiple stems. Bark is grayish-brown, shreddy in appearance.

Leaves: 1-3 mm long, bright green. Scale like, elongate, glandular.

Fruits: Pollen and seed cones on different plants. Pollen cones are 3-4 mm long, seed cones are 4-7 mm long. Seed cones typically bare 1 seed per cone, occasionally bearing 2 or 3 seeds. Dark blue, glaucous.



Map by Elizabeth Becker

JUNIPERS

Juniperus osteosperma, Utah juniper





Photos by Wendy McCrady, (https://inaturalist.nz/observations/124210218), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Name: Utah juniper

Family: Cupressaceae or cypress

USDA PLANTS Code: JUOS

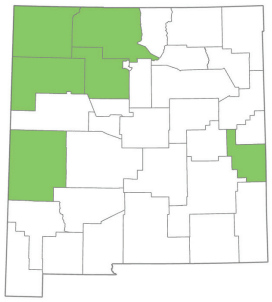
Habitat: Rocky slopes and hills. Found in western and northwestern New Mexico.

Elevation: 6,200 to 7,500 ft

ID: 20-30 ft in height. Typically single-stemmed, can have multiple stems. Rounded or conical crown. Shreddy, gray bark.

Leaves: Scale-like. Bright yellow-green. 1-2 mm long. Glandular.

Fruits: Pollen and seed cones on same plant. Pollen cones 2-3 mm, seed cones 6-12 mm long. Brownish-blue, glaucous. Typically contains 1 seed per cone.



Map by Elizabeth Becker

JUNIPERS

Juniperus scopulorum, Rocky Mountain juniper



Photo by Carolina May



Photo by Grace McCartha, used with permission

Common Name: Rocky Mountain juniper

Family: Cupressaceae or cypress

USDA PLANTS Code: JUSC2

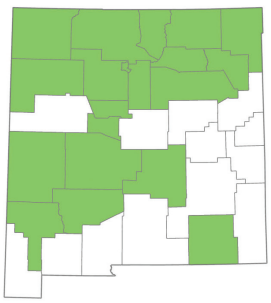
Habitat: Mixed conifer forests, dry slopes. Common throughout New Mexico. Found at higher elevations than *Juniperus monosperma* (one-seed juniper).

Elevation: 5,700 to 9,000 ft

ID: 10-35 ft in height. Most commonly with a single trunk. Has a "lacy" or "droopy" appearance. Bark is reddish-brown or grayish-brown, shreddy.

Leaves: Blue-green, scale-like, 1-4 mm long, and glandular.

Fruits: Pollen and seed cones on separate plants. Seed cones 4-6 mm in diameter, typically bearing 2 seeds. Bluish-purple.



Map by Elizabeth Becker

PINES

Pinus aristata, bristlecone pine





Photo above and center by Carolina May



Photo by Kathryn Mahan

Common Name: bristlecone pine

Family: Pinaceae or pine

USDA PLANTS Code: PIAR

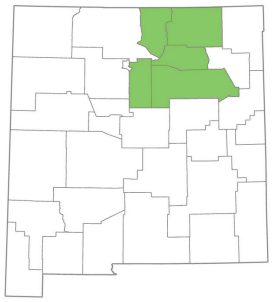
Habitat: High elevation mixed conifer to subalpine. Mountainous areas in northern New Mexico.

Elevation: 9,000 to 12,500 ft

ID: 40-50 ft in height. Needles on branches are bottlebrush in appearance. Mature trees have shallowly furrowed bark, reddish-brown in coloration.

Leaves: 4 cm long, 5 needles per fascicle, sticky, and curved.

Fruits: Pollen and seed cones on same plant. Pollen cones are 1 cm long. Seed cones 5-9 cm long. Scales bearing curved prickles.



Map by Elizabeth Becker

PINES

Pinus edulis, two-needle piñon





Photos by Carolina May

Common Name: two-needle piñon

Family: Pinaceae or pine

USDA PLANTS Code: PIED

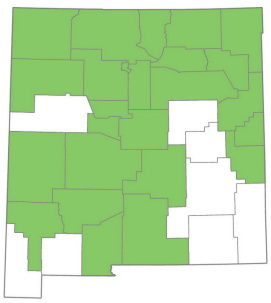
Habitat: Dry slopes, mesas, grows in association with juniper, oaks, and ponderosa pine. Common throughout New Mexico.

Elevation: 4,500 to 7,500 ft

ID: 15-60 ft in height. Yellowish-brown bark, irregularly fissured, and resinous.

Leaves: Two needles per fascicle, 2-4 cm long. Slightly curved upwards. Stomatal lines on both surfaces.

Fruits: Pollen and seed cones on the same tree. Seed cones 3.5-5 cm long. Golden, yellowish-brown in coloration. Spherical, stout in shape.



Map by Elizabeth Becker

PINES

Pinus flexilis, limber pine





Photos above and center by C. Rothfels (https://inaturalist.nz/observations/131156876), licensed by CC-BY(https://creativecommons.org/licenses/by/4.0/)



Photo by Carmen Melendez

Common Name: limber pine

Family: Pinaceae or pine

USDA PLANTS Code: PIFL2

Habitat: Mixed conifer forests to subalpine. Mountainous areas in northern New Mexico.

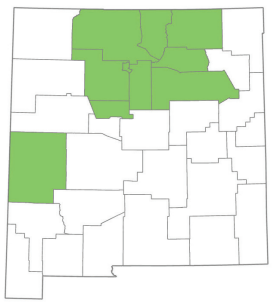
Elevation: 7,500 to 12,000 ft

ID: 26-85 ft in height. Spreading to ascending branches. Brownish-gray bark forms scaly plates with maturity.

Leaves: 3-7 cm long. 5 needles per fascicle. Stomatal lines on both needle surfaces but more distinct on upper surface of needle.

Fruits: Pollen and seed cones on same tree. Seed cones 7-15 cm long, slightly reflexed, and truncate at the apex. Unarmed. Wider and shorter than *Pinus strobiformis* (southwestern white pine).

Note: *Pinus strobiformis* looks very similar to *flexilis*. Has been known to hybridize. *Strobiformis* only has stomatal lines on upper needle surface. Strobiformis seed cones are 15-25 cm long and recurved.



Map by Elizabeth Becker

PINES

Pinus ponderosa, ponderosa pine



Photo by Carolina May



Photo by Meredith Prentice

Common Name: ponderosa pine

Family: Pinaceae or pine

USDA PLANTS Code: PIPO

Habitat: Mid to high elevation forests. Common throughout New Mexico in mountainous regions.

Elevation: 5,000 to 9,500 ft

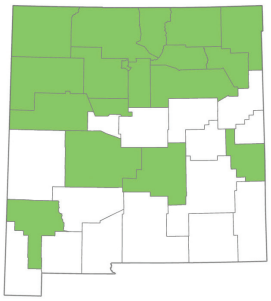
ID: 20-100 ft in height, can be taller. Bark puzzle piece shaped. Referred to as "blackjacks" when young due to grayish-black or brown coloration of bark. With maturity bark takes on golden-brown coloration and is referred to as "yellow bellies".

Leaves: 10-20 cm long, 3 needles per fascicle. Bright yellow-green. All needle surfaces have stomatal lines.

Fruits: Pollen and seed cones on same tree. Seed cones 5-15 cm long, ovoid to elliptic. Reddish-brown in coloration, scales tipped with sharp prickle.



Photo by Carolina May



Map by Elizabeth Becker

FIRS

Abies concolor, white fir





This photo and left by Carolina May



Photo by Kathryn Mahan



Photo by Carmen Melendez

Common Name: white fir

Family: Pinaceae or pine

USDA PLANTS Code: ABCO

Habitat: Mixed conifer forests, common throughout mountainous regions of New Mexico.

Elevation: 7,000 to 9,000 ft

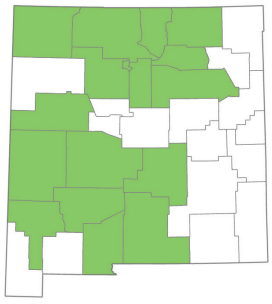
ID: 30-100 ft tall or more. Bluish-green in coloration. Symmetrical conical shape. Branches perpendicular to trunk. Bark is whitish-gray and smooth on young trees, dark gray and furrowed with maturity.

Leaves: Needles are 3 cm or more long. Spiraled upwards.

Fruits: Seed cones grayish, 7-12 cm long. Fall apart at maturity/ before they drop to the ground.



Photo by Kathryn Mahan



Map by Elizabeth Becker

FIRS

Abies lasiocarpa var. *arizonica*, corkbark fir





Photos by Claire Gentry, used with permission

Common Name: corkbark fir

Family: Pinaceae or pine

USDA PLANTS Code: ABLA

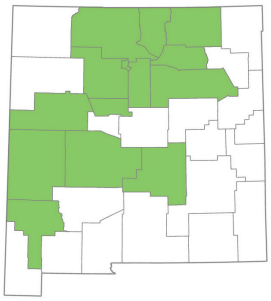
Habitat: Subalpine mixed conifer forests throughout mountainous regions in New Mexico.

Elevation: 8,500 to 12,000 ft

ID: Up to 65 ft in height. Bark is smooth, grayish-white, with resin blisters. Spongy upon touch, resembling a corkboard in texture.

Leaves: 1.8-3 cm long. Flattened and typically turned upward. Bluish-green and waxy on upper surface.

Fruits: Seed cones erect. Dark purple, 6-12 cm long, and 2-4 cm wide. Seed cone bracts.



Map by Elizabeth Becker

FIRS

Pseudotsuga menziesii, Douglas-fir





Photos by Carolina May

Common Name: Douglas-fir

Family: Pinaceae or pine

USDA PLANTS Code: PSME

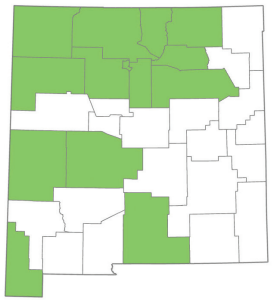
Habitat: Foothills, mixed coniferous forests. Common throughout New Mexico.

Elevation: 6,500 ft to treeline

ID: Up to 200 ft in height. Bark is dark brown, deeply furrowed. Crown shape conical to rounded.

Leaves: Flat, 2-4 cm long, tapering to a short petiole. Two stomatal lines on the underside. Needles form an angle at the point of attachment with the twig, shaped like a hockey stick.

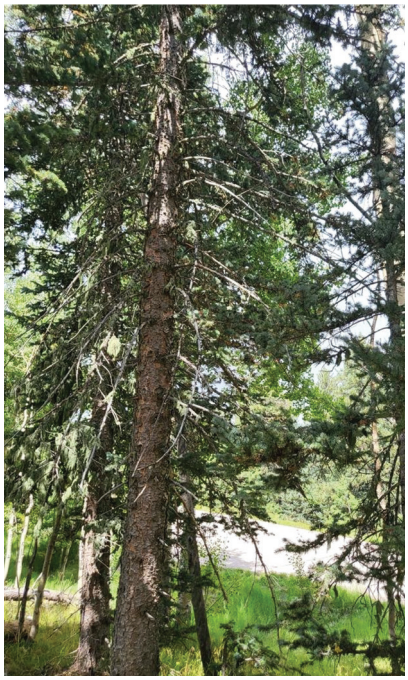
Fruits: Seed cones 5-9 cm long. 3 pointed bracts extend out past the scales, resembling a mouse tail.



Map by Elizabeth Becker

SPRUCE

Picea engelmannii, Engelmann spruce









Photos by Grace McCartha, used with permission

Common Name: Engelmann spruce

Family: Pinaceae or pine

USDA PLANTS Code: PIEN

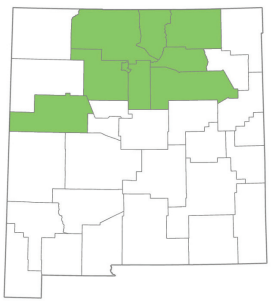
Habitat: Mixed conifer, subalpine forests to treeline. Typically, found at elevations higher than Picea pungens.

Elevation: Above 8,500 ft

ID: Up to 190 ft in height. Bark is reddish-brown, scaly. Branches typically horizontal to somewhat drooping.

Leaves: 1.6-3.5 cm long. Typically, 4-sided or square. Borne singly from all side of the twig, 4-angled. Needles and pegs acutely attached to twig. Somewhat flexible, not spine-tipped, and not as sharp to the touch as Picea pungens. Stems pubescent on new growth.

Fruits: Seed cones are 6 cm long or less. Papery and flexible. Ellipsoid.



Map by Elizabeth Becker

SPRUCE

Picea pungens, blue spruce



Photo by Carolina May

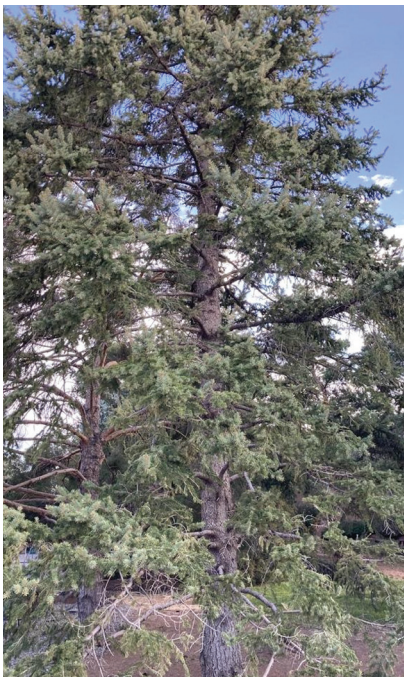




Photo by Carolina May



Center and above photos by Claire Gentry, used with permission

Common Name: blue spruce

Family: Pinaceae or pine

USDA PLANTS Code: PIPU

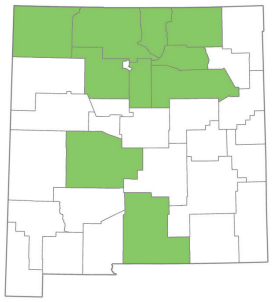
Habitat: Drainage, moist canyons. Foothills, mixed conifer, and subalpine forests in mountainous regions throughout New Mexico.

Elevation: 7,500 to 10,500 ft

ID: Up to 160 ft in height. Whorled branches, slightly to strongly drooping. Bark is gray, brown, and more furrowed/ridged than scaly.

Leaves: 1.5-3 cm long, rigid and sharp to the touch. Typically 4-sided or square. Needles and pegs attached to twig at right angles.

Fruits: Seed cones are typically 6-8 cm long. Ellipsoid, scales elliptic to diamond-shaped.



Map by Elizabeth Becker

POPLARS

Populous tremuloides, quaking aspen



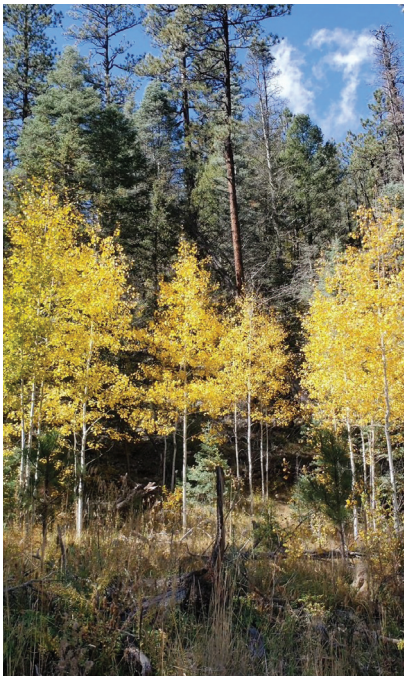




Photo by Carolina May

Center photo and above by Kathryn Mahan

Common Name: quaking aspen

Family: Salicaceae or willow

USDA PLANTS Code: POTR5

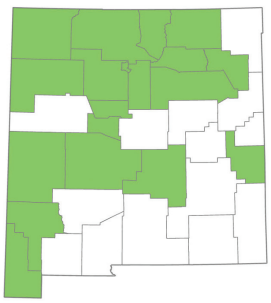
Habitat: Mountainous slopes and valleys throughout New Mexico.

Elevation: 6,500 to 10,500 ft

ID: 16-100 ft in height. Bark is white, smooth, and powdery to the touch. Bark around base becomes grayish-black and furrowed with maturity.

Leaves: 4-6 cm long. Ovate to nearly round. Margins have small, rounded teeth. Long, flatted petiole. Dark green and shiny above, pale green below.

Fruits: Narrowly ovoid to flask-shaped capsules. 5-7 mm long. Seeds 2 mm long, each with a tuft of long, silky white hairs.



Map by Elizabeth Becker

OAKS

Quercus gambelii, Gambel oak









Photos by Carolina May

Common Name: Gambel oak

Family: Fagaceae or beech

USDA PLANTS Code: QUGA

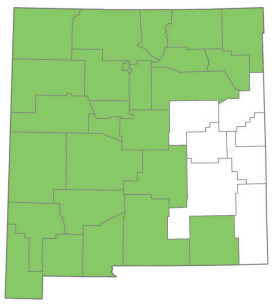
Habitat: Grows in association with piñon-juniper woodlands, ponderosa pine forests, and dry mixed conifer forest. Hills, canyons, and mountain slopes. Common throughout New Mexico.

Elevation: 6,000 to 8,500 ft

ID: Up to 60 ft in height. Growth form can also be shrubby.

Leaves: 3-15 cm long, with 5-9 lobes. Lobes rounded to obtuse. Bright green upper surface, dull green and tomentose on underside. Elliptic.

Fruits: Acorns 8-20 mm. Acorns grow solitary or borne in clusters of 2 or 3. Cup covers one-third to one-half of the total length of the acorn.



Map by Elizabeth Becker

OAKS

Quercus grisea, gray oak



Photo by Grace McCartha, used with permission



Photo by CK Kelly, https://www.inaturalist.org/observations/77524775, licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)

Common Name: gray oak

Family: Fagaceae or beech

USDA PLANTS Code: QUGR3

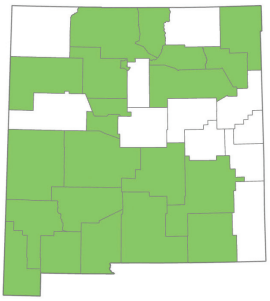
Habitat: Piñon-juniper woodlands, ponderosa pine forests, and savanna. Common throughout New Mexico.

Elevation: 4,700 to 7,200 ft

ID: Up to 32 ft in height. Can be shrubby in appearance.

Leaves: 1.5-5.5 cm long, 9-30 mm wide. Margins slightly revolute to dentate. Leaf tip rounded to pointed, base cordate to rounded. Pubescent on both the upper and lower surface. Gray-green, elliptic to ovate.

Fruits: Acorn solitary or borne in pairs. 1-1.2 cm long. Cup covers about one-third to one-half of the total length of the acorn. Peduncle, if present, 30 mm.



Map by Elizabeth Becker

OAKS

Quercus turbinella, desert scrub oak



Photo by Grace McCartha, used with permission



Photo by Michael Tidwell, (https://www.inaturalist.org/observations/172600835), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)

Common Name: desert scrub oak

Family: Fagaceae or beech

USDA PLANTS Code: QUTU2

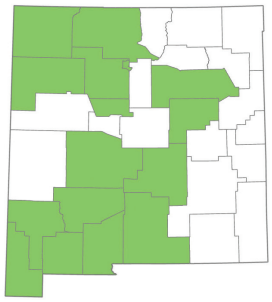
Habitat: Grassland, deserts, and piñon-juniper woodlands. Common throughout New Mexico.

Elevation: 4,000 to 8,000 ft

ID: Up to 13 ft in height.

Leaves: 1.5-3 cm long and 5-30 mm wide. Spinose margins, 3-7 spines per side of the leaf. Thick and leathery, ovate to elliptic, oblong. Base cordate to rounded.

Fruits: Acorns 1-3.5 cm long. Cup covers one-fourth to one-half of total acorn. Peduncles 10 mm.



Map by Elizabeth Becker

OAKS

Quercus × pauciloba, wavyleaf oak



Photo by Grace McCartha, used with permission



Photo by CK Kelly, (https://www.inaturalist.org observations/34744058), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)

Common Name: wavyleaf oak

Family: Fagaceae or beech

USDA PLANTS Code: QUPA4

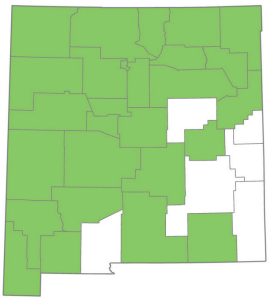
Habitat: Dry slopes and canyons, common throughout New Mexico.

Elevation: 5,500 to 8,500 ft

ID: Typically low growing 3-5 ft in height, up to 22 ft.

Leaves: 1.5-6.5 cm long, 0.6-3 cm wide, margins coarsely toothed. Shallow, pointed lobes. Pubescent surfaces.

Fruits: Acorns less than 2.5 cm long.



Map by Elizabeth Becker

ASSORTED

Acer glabrum, Rocky Mountain maple



Photo by Carolina May



Photo by Aaron Gunnar, (https://www.inaturalist.org/observations/181249758), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)



Photo by Lindsey Salmonson, (https://www.inaturalist.org/observations/48583464), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)

Common Name: Rocky Mountain Maple

Family: Aceraceae or Acer

USDA PLANTS Code: ACGL

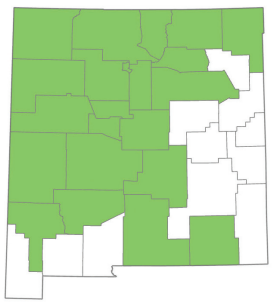
Habitat: Streams and canyons, foothills, mixed conifer, and subalpine forests. Common throughout New Mexico.

Elevation: 7,000 to 9,500 ft

ID: Up to 26 ft in height, with numerous slender shoots. Bark is smooth and reddish-brown.

Leaves: 10 cm or less long, 7.5 cm wide. Trifoliate or palmately lobed, with 3-5 lobes. Toothed or serrated margins. Long red petioles. Shiny green above, paler below.

Fruits: Samaras (winged nutlets) arranged in pairs, 4-6 cm long. Tinted red with maturity.



Map by Elizabeth Becker

ASSORTED

Alnus incana ssp. *tenuifolia*, thinleaf alder



Photo by Kalvin Chan, (https://www.inaturalist.org/observations/166974804), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)



Photo by John Doyle, (https://www.inaturalist.org/observations/1818050), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0)

Common Name: thinleaf alder

Family: Betulaceae or Birch

USDA PLANTS Code: ALINT

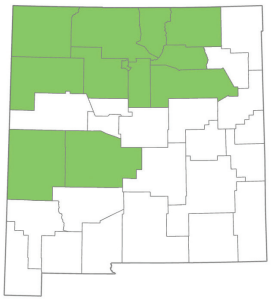
Habitat: Canyons and riparian areas. Common in mountainous regions throughout northern and western New Mexico.

Elevation: 6,500 to 8,500 ft

ID: Up to 32 ft in height. Bark smooth, grayish-brown to reddish-brown.

Leaves: 4-11 cm long, 2.5-7.5 cm wide. Margins doubly serrated, ovate to elliptic, oblong. Rounded or cordate at the leaf base.

Fruits: Catkins elliptic, arranged in clusters of 2-5, 1-2 cm long.



Map by Elizabeth Becker

ASSORTED

Amelanchier alnifolia, Saskatoon service-berry





Photos by Carolina May

Common Names: Saskatoon service-berry, Service-berry, juneberry, shadbush

Family: Rosaceae or rose

USDA PLANTS Code: AMAL2

Habitat: Coniferous forests and wet meadows. Upper limits of piñon-juniper communities. Occurs in northern NM counties.

Elevation: 6,000 to 9,000 ft

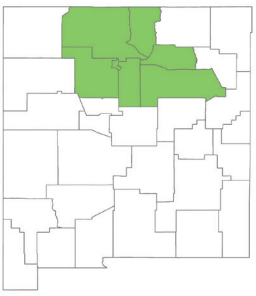
Common/Similar Species: *Amelanchier utahensis* (Utah serviceberry) has shorter leaves and typically occurs at lower elevations/ southern portion of New Mexico.

ID: Up to 22 ft tall. Forming thickets, mats, or clumps. Bark thin, light brown, and tinged with red. Smooth or shallowly fissured.

Leaves: Simple, alternate, ovate to nearly round. 2.5-6 cm long, 1.5-4.2 cm wide, with lateral, parallel veins in 8-13 pairs. Glabrous with age, margins coarsely serrate to dentate.

Flowers: Short, dense, 5-15 flowered, upright racemes. White petals, 1-2 cm long. Sepals with long hairs on the inside, reflexing in age. About 20 stamens, 5 styles, and ovary is persistently tomentose at the top. Flowers from May to June.

Fruits: 5-15 mm long. Smooth, purple-black, slightly gray-blue waxy. Pulp fleshy and sweet. 4-10 seeds.



Map by Emily Yannayon

ASSORTED

Artemisia tridentata, big sagebrush









Middle photo by Carolina May all others by Claire Gentry, used with permission

Common Name: Big Sagebrush

Family: Asteraceae or aster

USDA PLANTS Code: ARTR2

Habitat: Open, dry plains, hills, slopes, mesas, or rocky areas with deep soils. Often grows in cold desert shrub or piñon-juniper woodlands. Most commonly found in western/ northwestern New Mexico.

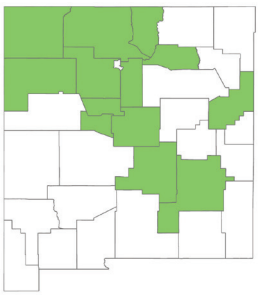
Elevation: 4,500 to 8,500 ft

Common/Similar Species: Many *Artemisia* species.

ID: 2-13 ft tall, spreading branches with numerous main stems.

Leaves: Blue-gray to blue-green due to dense gray hairs. Typically, cuneate (wedge-shaped, triangular, and gradually tapering to the base) or flabelliform (fan shaped). 0.5-5 cm long, 3 lobed, sometimes 5. Spirally arranged with internodes making the leaves very dense.

Flowers: 5-12 flowers per head. Arranged in panicle. Flowers July to October. Very aromatic with the smell being described as bitter, pungent to pleasant.



Map by Emily Yannayon

ASSORTED

Cercocarpus montanus, mountain mahogany



Photo by Grace McCartha, used with permission



Photo by Carolina May

Common Names: mountain mahogany, alderleaf mountain mahogany, silverleaf mountain mahogany

Family: Rosaceae or rose

USDA PLANTS Code: CEMO2

Habitat: Rocky hillsides, cliffs, open woods, mesas, piñon- juniper woodlands, coniferous forests. Most commonly found in northern New Mexico but has a wide range throughout the state.

Elevation: 5,500 to 8,500 ft

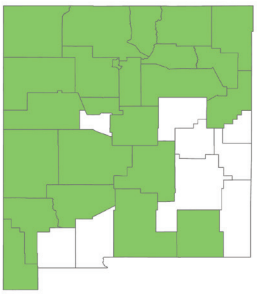
Common/Similar Species: *Cercocarpus ledifolius* (curl-leaf mountain mahogany) leaves are linear to elliptic. Found in the northwest corner of New Mexico.

ID: Up to 15 ft in height. Erect growth habit with numerous branches.

Leaves: Simple, alternate, ovate to obovate. Crenate to dentate margins. Deep venation. 2-4 cm in length, 1.5-3 cm in width.

Flowers: Can be in clusters (2-3) or solitary.
No petals. 5 sepals, stamens 20 or more, 1 pistil. Flowers May to July.

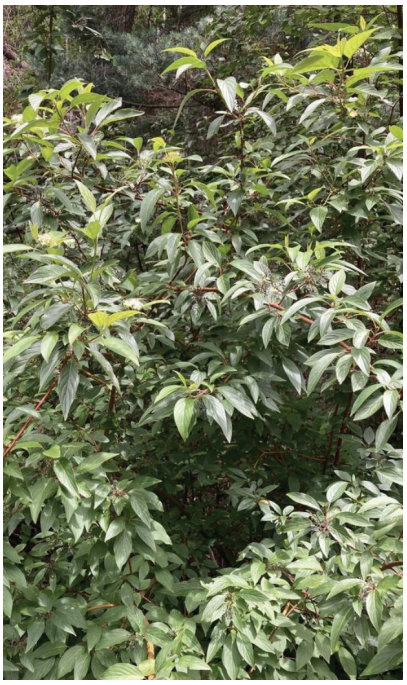
Fruits: Achene 4-8 cm in length. Tapers to a slight spiral, covered in white hairs.



Map by Emily Yannayon

ASSORTED

Cornus sericea, redosier dogwood





Photos by Claire Gentry, used with permission

Common Names: redosier dogwood, American dogwood, red willow, redstem dogwood

Family: Cornaceae or dogwood

USDA PLANTS Code: COSE16

Habitat: Edges of lake, ponds, within wetlands, along streams. Prefer soils that are saturated for at least a portion of the growing season. Found throughout New Mexico generally excluding the eastern and central portion of the state.

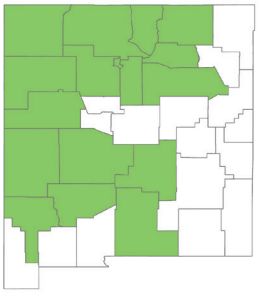
Elevation: 5,500 to 9,000 ft

ID: Generally, 4.6-20 ft tall. Bark and twigs are reddish to purple and smooth from autumn to spring after leaves have fallen. Bark and twigs green in spring and summer.

Leaves: Simple, opposite, 2-4 in long, dark green above and hairy and lighter-colored below. Smooth margins, rounded bases, pointed tips, falsely parallel veins.

Flowers: Cyme inflorescence of small white to cream-colored flower. Four petals, four stamens. Flowers May to July.

Fruits: White berries with smooth exterior faces and furrowed interiors.



Map by Emily Yannayon

ASSORTED

Cylindropuntia imbricata var. *imbricata*, tree cholla









Photos by Grace McCartha, used with permission

Common Names: tree cholla, walking stick cholla, rope pear, cane cholla

Family: Cactaceae or cactus

USDA PLANTS Code: CYIM2

Habitat: Grassland, scrubland, woodland, and hillsides. Common throughout New Mexico.

Elevation: 3,600 to 7,500 ft

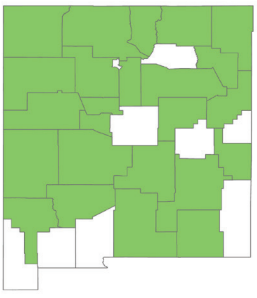
Common/Similar Species: Varieties include *imbricata* and *spinosior*. *Spinosior* has smaller tubercles (mound/enlarged leaf base), more tubercles per row. Typically found in the southeastern portion of New Mexico.

ID: 4 ft or taller in height. Several stems arising from one to several main trunks.

Leaves: Tubercles 2 cm long. 3 to 4 rows visible on one side of the stem. Areoles (area of cactus bearing spines and/or flowers) contain 10-20 spines, roughly 15-18 mm long.

Flowers: Pink to magenta. Flowers May to June.

Fruits: Yellow when mature. With 18-20 areoles.



Map by Emily Yannayon

ASSORTED

Prunus virginiana, chokecherry



Photo by Carolina May



Photo by Will McFarland, (https://inaturalist.nz/observations/133760478), licensed by CC-BY (https:/ creativecommons.org/licenses/by/4.0/)

Common Names: chokecherry, common chokecherry, black chokecherry, red chokecherry, California chokecherry, Virginia chokecherry, eastern chokecherry, western chokecherry, rum chokecherry, whiskey chokecherry, wild cherry, wild blackcherry, bird cherry, jamcherry, chokeberry, cabinet cherry, chuckleyplum, sloe tree, bitter-berry, capulin

Family: Rosaceae or rose

USDA PLANTS Code: PRVI

Habitat: Moist forests and canyons, along streamsides. Common throughout New Mexico.

Elevation: 5,500 to 8,000 ft

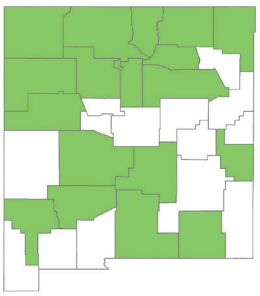
Common/Similar Species: There are 3 recognized varieties of *Prunus virginiana*. *Prunus virginiana* var. *demissa* (western chokecherry) produces dark red fruit. Prunus virginiana var. *melanocarpa* produces black fruit. *Prunus virginiana* var. *virginiana* produces crimson to deep red fruit. This variety can be found in two forms, one with red and one with white fruit.

ID: Up to 25 ft. Stems numerous and slender. Bark gray to reddish brown when young, turning darker brownish black and furrowed with maturity. Distinctly marked with horizontal rows of lenticels (raised air pores).

Leaves: Alternate, simple, glabrous, oval to broadly elliptic in shape, 4-12 cm long. Margins toothed. Dark green and glossy above, paler below.

Flowers: Perfect, aromatic, five white petals. Arranged in cylindrical racemes, 7-15 cm long. Start appearing before leaves are fully developed. Flowers April to June.

Fruits: Spherical drupes with 1 seed. Dark red or purple to almost black.



Map by Emily Yannayon

ASSORTED

Purshia stansburyana
cliffrose







Photos by Rachel Stringham (https://inaturalist.nz/observations/149382208) licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: cliffrose, Stansbury cliffrose

Family: Rosaceae or rose

USDA PLANTS Code: PUST

Habitat: Dry, rocky slopes, grasslands, piñon-juniper woodlands. Found in western New Mexico.

Elevation: 3,000 to 8,000 ft

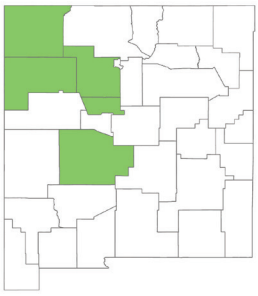
Common/Similar Species: *Fallugia paradoxa* (Apache plume) flowers are more than 2 cm in diameter, with 20 carpels per flower. Styles are reddish.

ID: Up to 6 ft in height.

Leaves: Alternate, simple, pinnately lobed with 3-9 lobes per leaf. Think, resinous, margins rolled under. Dark green, glandular above, white tomentose below.

Flowers: Solitary. Yellow or cream color. Less than 1.5 in diameter. Five petals, 5-10 carpels per flower. Flowers April to July.

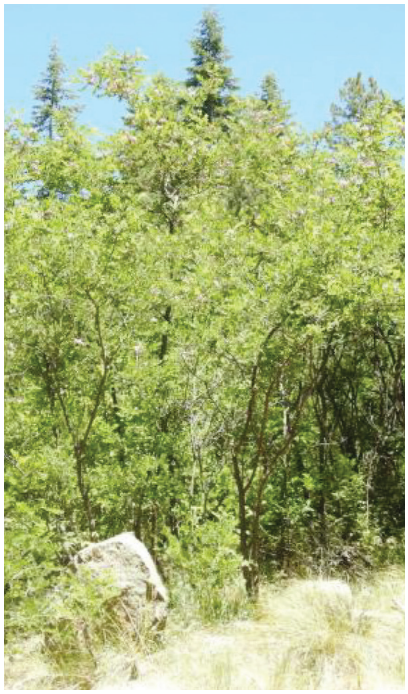
Fruits: Achenes 4-7. Silvery, pubescent, feather like styles.



Map by Emily Yannayon

ASSORTED

Robinia neomexicana, New Mexico locust







Photos by Rachel Stringham, (https://inaturalist.nz/observations/121054463),licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: New Mexico locust, Southwestern locust, hojalito

Family: Fabaceae or pea

USDA PLANTS Code: RONE

Habitat: Arroyos, stream banks, canyons. Widespread throughout New Mexico.

Elevation: 5,500 to 9,500 ft

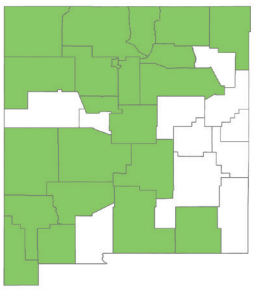
Common/Similar Species: none

ID: Can reach up to height of 25 ft. Pair of spines present at base of each leaf node. Bark reddish brown, turning gray with maturity.

Leaves: Pinnately compound, 8-20 cm long. Leaflets, 9-21 per leaf, 1.5-3 cm long. Elliptic to oval. Margins entire.

Flowers: Raceme of pink- pinkish purple flowers. Covered in gland tip hairs. Flowers May to July.

Fruits: Flat legume pod, brown, 6-10 cm long, covered in gland tipped hairs. Contains 4-8 seeds.



Map by Emily Yannayon

ASSORTED

Salix exigua, coyote willow







Photos by Carolina May

Common Names: coyote willow, sandbar willow, gray willow, narrow-leaved willow, dusky willow, pussywillow

Family: Salicaceae or willow

USDA PLANTS Code: SAEX

Habitat: Near water, wetlands, alluvial bottomlands, streamsides, riparian forest, stabilized gravel bars. Common throughout New Mexico.

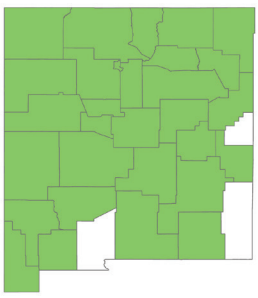
Elevation: 3,500 to 7,500 ft

ID: Up to 20 ft tall. Spreads clonally by root-sprouting.

Leaves: Mature blades are 3-16 cm long, 2-10.2 mm wide, linear, with an acuminate leaf top or either a serrate or entire leaf edge. Petioles 2-10 mm long.

Flowers: Catkins inflorescence appears with or after the leaves in the spring. Staminate (male) flowers 0.9-9 cm long, two stamens, yellow anthers, hairy filaments. Carpellate (female) flowers 2-9 cm long. Flowers March to July.

Fruits: 4-8 mm long, glabrous capsule.



Map by Emily Yannayon

ASSORTED

Sambucus nigra ssp. *caerulea* blue elderberry





Photo by Joe Rojas-Burke, (https://inaturalist.nz/observations/137883640), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: blue elderberry, Elder, blue elder, Arizona elderberry, American elder, sweet elder, wild elder, flor sauco, tree of music, Danewort, Walewort, New Mexican elderberry, velvet-leaf elder, hair blue elderberry, dwarf elder

Family: Caprifoliaceae or honeysuckle

USDA PLANTS Code: SANIC5

Habitat: Common along stream banks, riverbanks, and open places in riparian zones and forested ecosystems.

Elevation: 7,000 ft to 9,000 ft

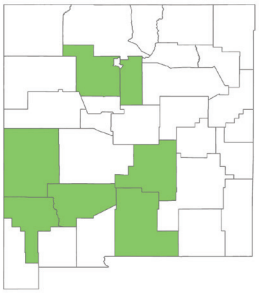
Common/Similar Species: Other *Sambucus* spp., can look like *Juglans* spp., and *Fraxinus* spp. *Sambucus caerulea* is synonymous with *Sambucus nigra* ssp. *caerulea*. Note that the spelling *cerulea* in some sources is synonymous.

ID: Height ranges from 6 to 26 ft. Multiple stems sprouting from base. Bark typically grayish to brown with ridges.

Leaves: Opposite, odd pinnate. Leaves about 15-35 cm long, made up of 3-9 serrated leaflets about 2-15 cm long. Distinctive scent.

Flowers: Flat-topped clusters of tiny, creamy white scented flowers Inflorescence is 4-30 cm across, broader than high. Bisexual flowers have five lobed corollas. Flowers May to July.

Fruits: Dark bluish-purple berries that hang in large clusters from September-October. 5-6 mm wide. Contains 3-5 nutlets.



Map by Emily Yannayon

ASSORTED

Sambucus racemosa
red elderberry






Photos by Grace McCartha, used with permission,

Common Names: Scarlet elder, stinking elderberry, stinking elder, red-berried elder, bunchberry elder, and red elder

Family: Caprifoliaceae or honeysuckle

USDA PLANTS Code: SARA2

Habitat: Streambanks, ravines, swamps, moist forest clearings and higher ground near wetlands. Shade tolerant but prefers a sunny exposure. Found in northern, central, and western New Mexico.

Elevation: 7,000 to 12,000 ft

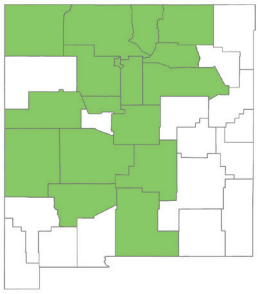
Common/Similar Species: Other *Sambucus* spp.

ID: Grows to height of 10-20 ft tall. Broad arching form. Twigs are pithy, dark red or purple to reddish-brown in color, covered with numerous small pumps (raised pores).

Leaves: Opposite, compound, 5-7 leaflets. Oval to oblong or lance shaped, 5-10 cm long. Finely toothed margins. Foliage has strong distinctive odor.

Flowers: Conical or pyramidal shaped clusters of small, creamy white flowers. Flowers April to July.

Fruits: Arranged in clusters of small bright red, fleshy berries, bearing 2-5 seeds per fruit. Fruits in summer.



Map by Emily Yannayon

ASSORTED

Senegalia greggii
catclaw acacia





Photos by Alex Wentworth, (https://inaturalist.nz/observations/147926410),licensed by CC-BY(https://creativecommons.org/licenses/by/4.0/)

Common Names: Catclaw, devilsclaw, Gregg acacia, Gregg catclaw, long-flower catclaw, Texas catclaw, wait-a-minute bush

Family: Fabaceae or pea

USDA PLANTS Code: SEGR4

Habitat: Chaparral communities, flats, along streams, stream banks and washes. Found in southern New Mexico.

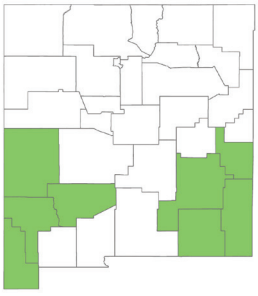
Elevation: 3,500 to 5,500 ft

ID: Can reach height of 22 ft with curved/ hooked spines, rarely reaching 4 cm in length.

Leaves: Alternate, compound; bipinnate. Leaves less than 5 cm long, leaflets 3-6 mm long.

Flowers: Cream to pale yellow, dense, fragrant, cylindrical spike. Flowers April to September.

Fruits: Twisted, legume pod. 1.2-1.8 cm wide and 4-10 cm long.



Map by Emily Yannayon

ASSORTED

Tamarix spp.
salt-cedar





Photos by Adriana Nelly Correa Sandoval, (https://inaturalist.nz/observations/139171161), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: tamarisk

Family: Tamaricaeae or tamarisk

USDA PLANTS Code: TAMAR2

Habitat: Dunes, scrub, wetlands, rivers, desert washes. Non-native. Common throughout New Mexico.

Elevation: 3,000 to 5,500 ft

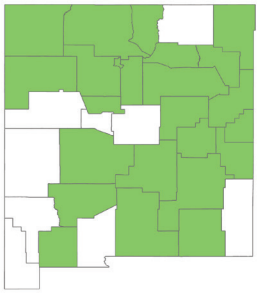
Common/Similar Species: Species in New Mexico include *Tamarix parviflora* (small-flowered tamarisk), *Tamarix gallica* (French tamarisk), and *Tamarix chiensis* (salt-cedar). These species are known to hybridize so identification to species can be problematic.

ID: Up to 26 ft in height. Reddish bark when immature.

Leaves: Alternate, green, scale-like. Rarely more than 1 mm long.

Flowers: Raceme of white or pink flowers. 5 sepals, 4-5 petals, 5-10 stamens, Superior ovary with 2-5 united carpels. Flowers April to October.

Fruits: Capsule with numerous hairy seeds. Capsules 3-4 mm long.



Map by Emily Yannayon

10.0 Common Shrubs of New Mexico



Photo by Kathryn Mahan

What is a shrub?

A woody plant that is smaller than a tree and has several main stems arising at or near the ground. USDA PLANTS is the authority NMFWRI uses to determine the growth habit of a plant species. If there are multiple listed, use the most robust of the growth forms. *See Supplement H for resources and guidance on plant identification.*

Amorpha canescens, leadplant
Amorpha fruticosa, indigo bush
Arctostaphylos pungens, pointleaf manzanita
Arctostaphylos uva-ursi, kinnikinnick
Atriplex canescens, four-wing saltbush
Atriplex confertifolia, shadescale saltbush
Baccharis salicifolia, seepwillow
Ceanothus fendleri, Fendler's ceanothus
Dasiphora fruticosa, shrubby cinquefoil
Ephedra viridis, green ephedra
Ericameria nauseosa, rubber rabbitbrush
Fallugia paradoxa, Apache plume

Forestiera pubescens, New Mexico olive
Gutierrezia sarothrae, broom snakeweed
Hymenoxys richardsonii, pingue rubberweed
Jamesia americana, five-petal cliffbush
Krascheninnikovia lanata, winterfat
Larrea tridentata, creosote bush
Lonicera involucrata, twinberry honeysuckle
Lycium pallidum, pale wolfberry
Mahonia repens, creeping Oregon-grape
Nolina greenei, Greene's beargrass
Opuntia engelmannii, cactus apple
Opuntia phaeacantha, tulip prickly pear cactus
Paxistima myrsinites, mountain-lover
Petradoria pumila, rock goldenrod
Physocarpus monogynus, mountain ninebark
Psorothamnus scoparius, broom dalea
Rhus trilobata, skunkbush sumac
Ribes cereum, wax currant
Ribes inerme, whitestem gooseberry
Rosa woodsii, Woods' rose
Rubus armeniacus, Himalayan blackberry*
Rubus idaeus, red raspberry
Rubus parviflorus, thimbleberry
Shepherdia canadensis, russet buffaloberry
Sorbus dumosa, Arizona mountain-ash
Symphoricarpos rotundifolius, roundleaf snowberry
Vaccinium myrtillus, whortleberry
Yucca baccata, banana yucca

***non-native**

Amorpha canescens

Common Names: leadplant, leadplant amorpha, downy indigobush, prairie shoestrings, buffalo bellows

Family: Fabaceae or pea

USDA PLANTS Code: AMCA6

Habitat: Dry grasslands, sandy, hillsides, roadsides, open woodlands, and distributed areas. Primarily found in northeastern and eastern New Mexico.

Elevation: 4,000 to 6,000 ft

Common/Similar Species: *Amorpha fruticosa* (indigo bush) is a larger plant as a whole and leaflets are larger. Fewer leaflets per leaf. Typically occurs in central, western, and southern New Mexico.






Photos by Grace McCartha, used with permission

ID: Erect, up to 3.3 ft tall. Woody at base.

Leaves: Pinnately compound. 4-10 cm long with 15-47 leaflets. Lanceolate to elliptic or oblong. Leaflets 7-15 mm long and 3-6 mm wide. Stems and leaf underside densely woolly.

Flowers: Tiny purple flowers, grouped in several terminal spikes. Florescence is 6-10 cm long. Single petal is about 4-5 mm long. Flowers June to August.

Fruits: Densely woolly, about 4 mm long. Seeds are orange-brown, elliptic.

Amorpha fruticosa







Photos by Claire Gentry, used with permission

Common Names: false indigo bush, desert false indigo, river-locust, false indigo, indigo amorpha, indigobush

Family: Fabaceae or pea

USDA PLANTS Code: AMFR

Habitat: Open woods, canyons, and stream margins. Found in central, western, and southern New Mexico.

Elevation: 4,500 to 6,000 ft

Common/Similar Species: Similar to *Amorpha canescens* (leadplant) which has smaller leaves and more leaflets per leaf. *Amorpha canescens* is typically found more in the eastern portion of New Mexico.

ID: Height between 3-10 ft

Leaves: Compound leaves, 7-20 cm long. Leaflets 2-4.5 cm long, 9-25 per leaf, ovate to oblong. Shape of leaf and pubescence can be highly variable.

Flowers: Purplish-blue with orange anthers. Upright spikes 7-15 cm long. Flowers May to June.

Fruits: Curved, containing 1-2 seeds. Glabrous or slightly hairy.

Arctostaphylos pungens





Photos by Carolina May

Common Names: pointleaf manzanita, Mexican manzanita

Family: Ericaceae or heath

USDA PLANTS Code: ARPU5

Habitat: Pine-oak woodlands, piñon-juniper woodlands, chaparral, mixed conifer forests, foothills, canyons. Typically occurs in western and southwestern New Mexico.

Elevation: 4,500 to 8,000 ft

Common/Similar Species: May appear similar to *Arctostaphylos pringlei*, but *A. pringlei* has much more pubescence and is usually found in lower elevations in AZ/CA.

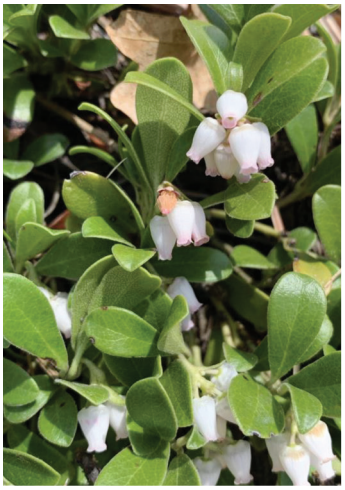
ID: Large, erect, reaching 3-10 ft.
Bark is smooth, red to brown.

Leaves: Covered with fine hairs.
Thick, leathery, oblong to elliptic, and pointed at the apex. 12-30 mm long, 10-20 mm wide.

Flowers: Raceme of perfect, urn-shaped, terminal flowers, roughly 6 mm long. Pink to white.
Flowers March to July.

Fruits: Smooth round berry, 5-8 mm in diameter. Red to brown. Contains several seeds.

Arctostaphylos uva-ursi





Top left photo by Carmen Melendez, top right and above by Claire Gentry, used with permission

Common Names: kinnikinnick, bearberry

Family: Ericaceae or heath

USDA PLANTS Code: ARUV

Habitat: Dry mountain slopes in coniferous and subalpine forests. Typically found in northern and west central New Mexico.

Elevation: 6,500 to 10,000 ft

Common/Similar Species: Can get confused with *Paxistima myrsinites* (mountain-lover). *Paxistima myrsinites* leaves are opposite and toothed.

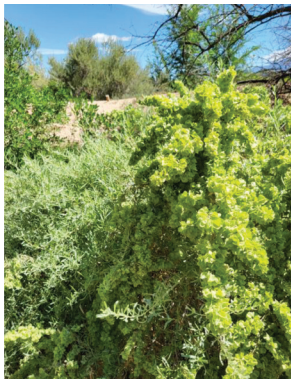
ID: Rarely exceeds 10 cm in height, typically grows in dense mats sending out trailing stems.

Leaves: Glossy dark green, reddish in the winter. Alternate, simple, entire, and obovate. Roughly 2 cm long.

Flowers: Shaped like an urn. White and pink. 5 petals and sepals, 10 stamens. Flowers from April to July.

Fruits: Bright red, glabrous, drupes. 6-12 mm in diameter. Contains 1 to 5 seeds. Stays attached to plant into early winter.

Atriplex canescens



Photos by Grace McCartha, used with permission

Common Names: fourwing saltbush, chamize, chamise, chamiso, white greasewood, fourwing shadescale, bushy atriplex

Family: Chenopodiaceae or goosefoot

USDA PLANTS Code: ATCA2

Habitat: Salt-desert scrub, alkali bottoms, sand dunes, piñon-juniper woodlands, sandy to gravely soil. Common throughout the entirety of New Mexico.

Elevation: 3,000 to 6,800 ft

Common/Similar Species: highly variable in appearance; may hybridize with *A. confertifolia* in NM

ID: Multi-branched stems that are stout and whitish in appearance. Mature plants up to 8 ft in height.

Leaves: Simple, alternate, entire, sessile, linear-spatulate to narrowly oblong, canescent (covered with fine whiteish hairs). 1-4 cm long and 3-8 mm wide.

Flowers: Yellow, brown, or cream colored flowers arranged in small clusters. Panicles 3-15 cm long. Flowers May to September.

Fruits: Bracts have four flat, entire, or fringed wings from which the plant gets its name.

Atriplex confertifolia

Common Names: shadscale saltbush, spiny saltbush

Family: Chenopodiaceae or goosefoot

USDA PLANTS Code: ATCO

Habitat: Can be found in warm and cold desert shrub-steppe environments. Populations occur in low valleys, foothills, and mesas. Can also be found in sagebrush and piñon-juniper communities. Found in western and northwestern portions of New Mexico.

Elevation: 4,500 to 7,000 ft

ID: 1-3 ft tall with spine-tipped branches.

Leaves: Gray-green, ovate, alternate. 10-20 mm long. Typically width is equal to length. Sessile or attached by short petiole.

Flowers: The staminate flowers are yellow and gathered in clusters or spikes. Perianth divided into 5 parts. Flowering date varies.

Fruits: Two-winged, small utricle (inflated, dry fruit). 4-12 mm long and wide that typically bears one seed.





Photos by Bobby McCabe, (https://inaturalist.nz/observations/131767327)licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Baccharis salicifolia

Common Names: seepwillow, mule fat

Family: Asteraceae or aster

USDA PLANTS Code: BASA4

Habitat: Found along streams and drainages, disturbed sites, dry washes. Typically found in southeastern New Mexico and a small portion of the state in the northeast.

Elevation: 3,500 to 5,000 ft

Common/Similar Species: May resemble true willows, but is not a member of the willow family.

ID: 3-10 ft in height. Woody at base. Stems subtly hairy.

Leaves: Margins entire to coarsely toothed. 3-nerved. 3- 15 cm long, 3-20 mm wide. Linear-lanceolate to oblong- obovate. Apex tapering to a point.

Flowers: Inflorescence is a round, large, terminal corymb. Phyllaries 2-4 mm long. Flowers March to October.

Fruits: Achenes 0.8-1.5 mm in length, glabrous, 5 nerved on short petiole.







Photos by Guillermo Debandi, (https://inaturalist.nz/observations/148055000) licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Ceanothus fendleri





Photos by Jackson Irvin, (https://inaturalist.nz/observations/132328835), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: Fendler's ceanothus, Fendler's buckbrush

Family: Rhamnaceae or buckthorn

USDA PLANTS Code: CEFE

Habitat: Coniferous forests. Common throughout New Mexico.

Elevation: 5,000 to 9,500 ft

ID: Spreading to erect shrub. Rarely exceeds 3 ft in height. Thorny. Often can form dense thickets.

Leaves: Alternate, simple, margins typically entire. 3 prominent veins. Green to grayish green, pubescent on the upper surface. Lower surface white-tomentose. Oblong, elliptic, oblanceolate. Roughly 2 cm long.

Flowers: Inflorescence borne in dense panicle. White flowers with 5 sepals, 5 petals, and 5 stamens. Style 3-lobed. Flowers April to October.

Fruits: Small, 3-lobed dry capsule.

Dasiphora fruticosa









Photos by Grace McCartha, used with permission

Common Names: shrubby cinquefoil, golden hardhack, potentilla

Family: Rosaceae or rose

USDA PLANTS Code: DAFR6

Habitat: Open forests, moist meadows, subalpine. Most likely found in north central, northwestern, and western portions of New Mexico.

Elevation: 6,000 to 11,000 ft

Common/Similar Species: There are many cultivars used in landscaping.

ID: Typically 3 ft in height. Dense, upright. Shredding bark is reddish brown.

Leaves: 3 to 7 leaflets per leaf. Compound, alternate. Leaflets obovate to lanceolate. Margins entirely, slightly revolute.

Flowers: Perfect. Yellow. Five petals, five sepals, 20-25 stamens. Flowers June to July.

Fruits: Long, hairy brown achene, not showy. Roughly 1-2 mm in length.

Ephedra viridis




Photos by Carolina May

Common Names: green ephedra, Mormon tea, jointfir

Family: Ephedraceae or ephedra

USDA PLANTS Code: EPVI

Habitat: Rocky or sandy slopes and plains. Piñon-juniper woodland, sagebrush desert, and desert grasslands. Can occur throughout many regions, most typically northwestern and southwestern New Mexico.

Elevation: 3,000 to 7,000 ft

Common/Similar Species: Many *Ephedra* species. Evidence of hybridization between species. Mostly similar in appearance to *Ephedra cutleri* (sticky joint fir) but the twigs are not sticky.

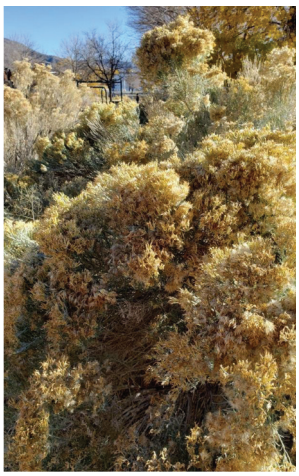
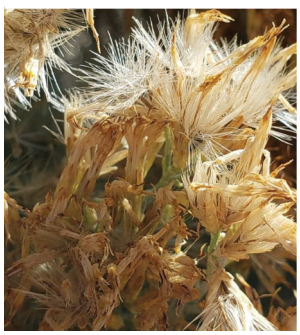
ID: Typically, about 3 ft in height. Branches green and irregularly fissured, practically leafless.

Leaves: Scale-like, 0.2-0.3 cm long, bases and middle portion conspicuously dark brown, the rest light green. Tends to be membranous.

Flowers: On staminate plants, flowers are yellow clusters of pollen sacs. Pollen cones are spheroidal and 0.3-0.4 mm in diameter. Pollen sacs are 0.5 mm long and 0.5-0.6 mm broad, practically lacking stalks.

Fruits: Cones of 2 to several present at nodes. 6-10 mm long. Either sessile or on short peduncles.

Ericameria nauseosa


Photos by Grace McCartha, used with permission

Common Names: rubber rabbitbrush, gray rabbitbrush, golden rabbitbrush, chamisa, chamiso blanco

Family: Asteraceae or aster

USDA PLANTS Code: ERNA10

Habitat: Dry, open areas on plains, valley bottoms, foothills, and mountains. Common throughout New Mexico.

Elevation: 4,000 to 8,000 ft

ID: 1-8 ft tall. Rounded crown with stems originating from its base. Stems and leaves covered with dense white hairs.

Leaves: Bluish green, gray. Alternate, linear to spatula shaped with entire margins. 2-10 cm long and 1-6 mm wide. Commonly covered in felt like hairs.

Flowers: Arranged in cymes or corymbs. Involucres 6-11 mm. Heads typically contain 5-6 tubular flowers. Phyllaries in 4-5 series. No ray flowers. Flower July to October.

Fruits: Achenes topped with a pappus.

Fallugia paradoxa

Common Names: Apache plume

Family: Rosaceae or rose

USDA PLANTS Code: FAPA

Habitat: Dry/ rocky slopes, arroyos. Common throughout New Mexico.

Elevation: 3,000 to 8,000 ft

Common/Similar Species: *Purshia stansburiana* (cliffrose), flowers are less than 1.5 cm in diameter. 5-10 pistils per flower. More common in western half of New Mexico.

ID: Grows up to 6 ft.

Leaves: Alternate, 3- 7 lobes. 0.6-1.4 cm long. Lower surface covered in white tomentose hairs. Some leaves are fascicled, revolute.

Flowers: Perfect, white. Over 2 cm in diameter. 20 carpels or more, with slender pistils, numerous stamens. Flowers April to October.

Fruits: Achene with exserted style. Red, feathery. 2.5-5 cm in length.







Top photo and bottom right by Kathryn Mahan
Bottom left photo by Michele Jones, (https://inaturalist.nz/observations/127441522), licensed by CC-BY(https://creativecommons.org/licenses/by/4.0/)

Forestiera pubescens

Common Names: New Mexico olive, stretchberry, New Mexico privet, New Mexico forestiera, desert olive

Family: Oleaceae or olive

USDA PLANTS Code: FOPU2

Habitat: Along streams, moist valleys, hillsides, and mesas. Common throughout New Mexico.

Elevation: 3,000 to 7,000 ft

Common/Similar Species: F*orestiera neomexicana* is a synonym of *Forestiera pubescens*. Sometimes get separated out as two species.

ID: Multi-stemmed, typically 6 ft in height. Occasionally reaching a mature height of 12-15 ft. Capable of sprouting from the base.

Leaves: Light green to grayish green oblong, simple, opposite. Rounded at both base and leaf apex. Attached to stem by short petiole. 1.4-5.5 cm long and 0.5-2 cm wide.

Flowers: Cluster of inconspicuous yellow flowers are borne along bare stem. Typically, in bloom before the leaves are present. Petals are absent from flowers.









Photos above left by Grace McCartha, right by Claire Gentry, used with permission

Four to six small sepals. Flowers April to June.

Fruits: Dark bluish black to black, round to oblong drupe. 5-7 mm long.

Gutierrezia sarothrae

Common Names: broom snakeweed, snakeweed, stinkweed, turpentine weed

Family: Asteraceae or aster

USDA PLANTS Code: GUSA2

Habitat: Open, dry plains and upland sites, disturbed areas or areas with overgrazing. Common throughout New Mexico.

Elevation: 3,000 to 8,000 ft

Common/Similar Species: Often gets confused with *Ericameria nauseosa* (rubber rabbitbrush). *Gutierrezia sarothrae* is smaller. Also gets mixed up with *Hymenoxys richardsonii* (pingue rubberweed), *richardsonii* flowers are significantly bigger. *Gutierrezia microcephala* (thread-leaf snakeweed) can be difficult to distinguish. In the past it has been grouped into the same species as *Gutierrezia sarothrae* and treated as a variety. *Microcephala* flowers are more tightly clustered, and involucres are typically less than 1.5 mm in diameter.

ID: Up to 3 ft tall. Stems are bushy and branch upwards from woody base. Non-woody stems range from smooth to having some short hairs. Stems may be resinous and sticky.



Photos by Grace McCartha, used with permission

Leaves: Alternate, linear, and threadlike in shape. 0.5-7 cm long and 1-4 mm wide. Gland dotted.

Flowers: Bright golden yellow with sticky resin. 3-8 ray and disk florets per cluster. Involucres typically 2-3 mm in diameter. Bracts are narrow and green in color at apex and along mid-nerve.

Fruits: Achenes have a modified calyx consisting of 8-10 acute scales. The acute scales of the ray achenes are about one-half as long as those of the disk achenes.

Hymenoxys richardsonii

Common Names: pingue rubberweed

Family: Asteraceae or aster

USDA PLANTS Code: HYRI

Habitat: Ponderosa pine and piñon-juniper forests, upland sites. Common throughout New Mexico.

Elevation: 3,000 to 8,000 ft

Common/Similar Species: Often gets confused with *Gutierrezia sarothrae* (broom snakeweed), which has smaller flowerheads and lacks distinctive basal rosette.

ID: Roughly 1-1.5 ft in height. Erect with numerous stems. Woody caudex.

Leaves: Alternate, both basal and cauline. Simple or lobed (3-7). Gland dotted, glabrous to slightly pubescent. Linear. Tufts of soft hair located at leaf base axis.

Flowers: Corymbs of yellow flowers with both ray and disk flowers. 7-9 ray flowers, 7-15 mm long. Disk flowers 25-50, 3-4 mm long. Phyllaries arranged in two series, the outer phyllaries keeled.

Fruits: Pubescent achene, 2 mm long.



Photos by Bobby McCabe, (https://www.inaturalist.org/observations/92153066), licensed byCC-BY(https://creativecommons.org/licenses/by/4.0/)

Jamesia americana

Common Names: five-petal cliffbush, cliffbush, cliff Jamesia, waxflower

Family: Hydrangeaceae or hydrangea

USDA PLANTS Code: JAAM

Habitat: Moist, sunny canyons and forests. Common throughout mountainous regions across New Mexico.

Elevation: 6,500 to 9,500 ft

Common/Similar Species: When trying to identify can key out to several species of *Viburnum*. These are found in the southeast and require more moisture than what's typically available in the Southwest.

ID: Up to 6 ft in height. Peeling reddish bark.

Leaves: Margins serrate, crenate, or dentate. Green above, underside is white tomentose. Deep venation. Ovate to elliptic. 7- 40 mm long, 6-32 mm wide.

Flowers: Arranged in a small cyme, with white, hairy flowers. Five sepals, five petals, with typically about 10 stamens. Ovary half inferior. Flowers June to July.

Fruits: Capsule.







Photos by Claire Gentry, used with permission

Krascheninnikovia lanata

Common Names: winterfat, white sage, winter-sage, feather-sage, sweet sage, lambstail

Family: Chenopodiaceae or goosefoot

USDA PLANTS Code: KRLA2

Habitat: Occurs in salt desert shrub, piñon-juniper woodlands, sagebrush grass and near the edges of some forest plant communities. Found in every county in New Mexico.

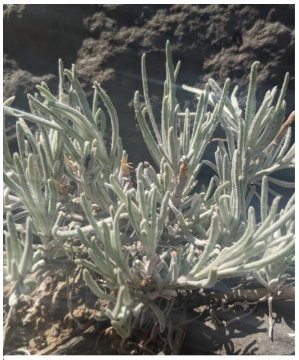
Elevation: 4,700 to 6,500 ft.

ID: Erect to spreading, low-growing. Up to 3 ft in height, sometimes taller. Wooly and branched.

Leaves: Simple, alternate, mostly linear, and revolute margins (rolled back from the margin). 1-4 cm long and 5 mm or less wide.

Flowers: Inflorescence is a spike. Plants are monoecious with staminate flowers above the pistillate ones or occasionally they are dioecious. Perianth is 4 parted with 4 stamens on staminate flowers. Flowers from May to July.

Fruits: Seed is an utricle. Seed coat is thin and covered with fine white, silky pilose hairs. About 1 cm long.



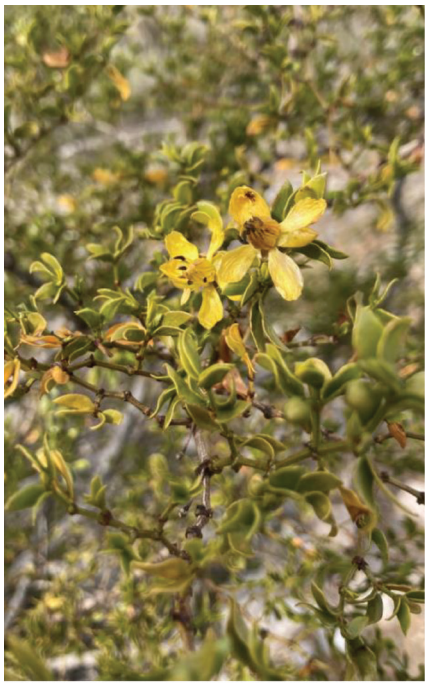


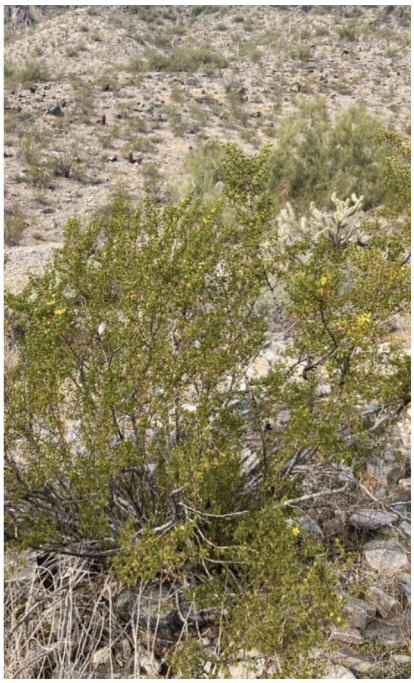




Top left photo by Carolina May, top right by Grace McCartha, used with permission, bottom photos by Carmen Melendez

Larrea tridentata





Photos by Meredith Prentice

Common Names: creosote bush, greasewood, chapparal

Family: Zygophyllaceae or caltrop

USDA PLANTS Code: LATR2

Habitat: Well-drained slopes and plains, particularly those with a layer of caliche. Central and southern portions of New Mexico.

Elevation: 3,000 to 5,500 ft

ID: Typically, 6 ft in height. Mature bark gray. Dark swollen nodes persist along the stems.

Leaves: Thick, resinous, waxy. Bifoliate, with two small leaflets. Opposite.

Flowers: Yellow, solitary. 5 petals and sepals, 10 stamens. Flowers April to June.

Fruits: Hairy capsule with 1 seed. 4.5 mm wide.

Lonicera involucrata





Photos by Carolina May

Common Names: twinberry honeysuckle, bearberry honeysuckle, twinberry, black twinberry, bush honeysuckle, bracted honeysuckle

Family: Caprifoliaceae or honeysuckle

USDA PLANTS Code: LOIN5

Habitat: Moist or wet soils, open woods, riparian. Mostly found in shaded areas in the mountainous regions throughout New Mexico.

Elevation: 7,500 to 10,500 ft

ID: Typically, 6 ft in height, sometimes taller.

Leaves: Arranged in opposite pairs along the stem. Egg or broadly lance shaped, pointed, and often hairy beneath. 5-15 cm long.

Flowers: Tubular, yellow. Solitary or borne in twos or threes in the leaf axis. Flowers June to July.

Fruits: Grows two, "twin" black, shiny berries. Cupped by purplish-red bracts.

Lycium pallidum







Photos by Carolina May

Common Names: pale wolfberry, pale-desert thorn, boxthorn, rabbit thorn

Family: Solanaceae or nightshade

USDA PLANTS Code: LYPA

Habitat: Piñon-juniper woodlands, riparian zones, savannah, desert grasslands, ruins. High salinity soils. Common throughout New Mexico.

Elevation: 2,000 to 7,000 ft

Common/Similar Species: Can get confused with *Lycium torreyi* (Torrey's wolfberry). *Torreyi* has shorter flowers, 1.6 cm long or less, usually found along river drainages.

ID: Dense, thorny shrub, up to 3-9 ft tall. Typically, erect. Mature branches reddish-brown.

Leaves: Pale green, hence, the name. Alternately arranged along the branch. Oblanceolate to spatulate, waxy and glabrous. Apex can be acute to rounded. 1-4 cm long and 4-15 cm wide.

Flowers: Solitary or arranged in 2-3. Funnel shaped flowers can be creamy-yellow, yellow-green, or creamy-green. Sometimes can present with a tinge of purple. Fragrant. Roughly 2 cm long or longer. Flowers May to June.

Fruits: Resemble tiny tomatoes. Shiny, oval shaped bright red berries. Can contain up to 50 seeds.

Mahonia repens



Photo by Carolina May

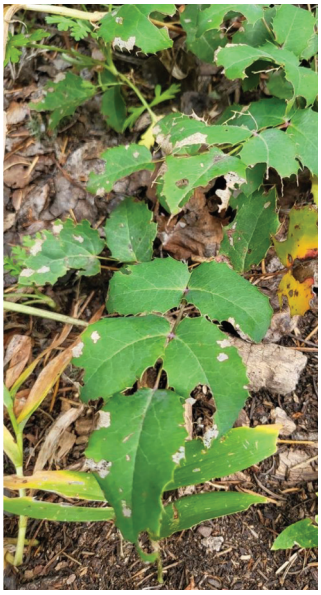


Photo by Grace McCartha, used with permission

Common Names: creeping Oregon-grape, creeping mahonia, truckee barberry, ash barberry, creeping holly grape, holly grape, mountain holly, creeping western barberry

Family: Berberidaceae or barberry

USDA PLANTS Code: MARE11

Habitat: Primarily found in high elevation coniferous forests. Dry, open woods and hills. Common throughout New Mexico.

Elevation: 6,200 to 10,000 ft

Common/Similar Species: *Mahonia aquifolium* (Oregon grape) can grow to height of 9 ft. *Mahonia repens* can take on appearance of *aquifolium* and grow taller if water resources are more abundant. *Aquifolium* has 5-9 leaflets per leaf.

ID: Less than 1 ft in height.

Leaves: Alternate, leaflets 3-7 per leaf. Toothed margins. Blue green above, grayish green on the underside.

Flowers: Yellow, arranged in racemes. Flowers April to July.

Fruits: Bluish-black berries, 6-10 mm.

Nolina greenei

Common Names: Greene's beargrass, woodland beargrass

Family: Liliaceae or lily

USDA PLANTS Code: NOGR

Habitat: On rocky limestone slopes, over lava flows, piñon-juniper woodlands and grasslands. Most commonly found in central New Mexico.

Elevation: 4,000 to 6,500 ft

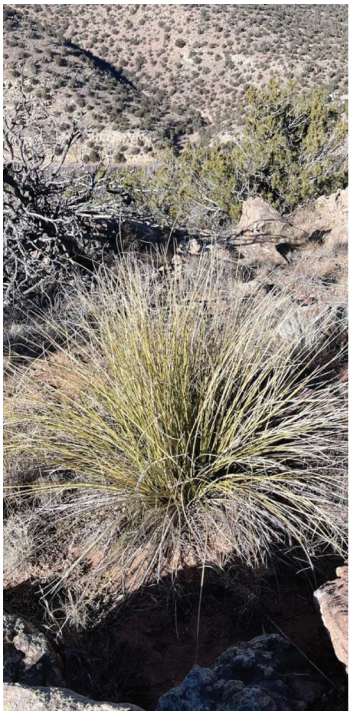
Common/Similar Species: Has been synonymous with *Nolina texana* (Texas beargrass) in the past.

ID: Typically, 3 ft in height. Rosette forming plant.

Leaves: Long and narrow, up to 100 cm long, up to 1 cm wide. Toothed margins, sometimes entire.

Flowers: Panicle of white flowers with purple midveins. Up to 20 cm in length.

Fruits: Dry, inflated capsule, 5 mm in diameter.





Photos by Teresa Mayfield, (https://inaturalist.nz/observations/145721978), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Opuntia engelmannii

Common Names: Engelmann prickly pear, cactus apple

Family: Cactaceae or cactus

USDA PLANTS Code: OPEN3

Habitat: Sandy soils, plains, arroyos, deserts, grasslands. Found in central and southwestern New Mexico.

Elevation: 3,000 to 7,000 ft

Common/Similar Species: *Opuntia phaeacantha* (tulip prickly pear) has a lower spine that is longer than the others. Pads 10-25 cm long.

ID: Up to 6 ft in height.

Leaves: Mature spines white or light gray, reddish at base. 1-5 spines per areole, 2-5 cm long. Pads 20-40 cm long, usually longer than wide. Orbicular to elliptic.

Flowers: Yellow, sometimes pink or orange. Flowers April to July.

Fruits: Purple-red, 3.5-9 cm long. Obovoid.







Photos by Theo Summer, (https://inaturalist.nz/observations/146664036), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Opuntia phaeacantha





Photos by Grace McCartha, used with permission

Common Names: tulip prickly pear cactus, dark-spined prickly pear, desert prickly pear

Family: Cactaceae or cactus

USDA PLANTS Code: OPPH

Habitat: Found on sandy to rocky soils. Found throughout the entirety of New Mexico.

Elevation: 3,000 to 7,500 ft

Common/Similar Species: *Opuntia engelmannii* (cactus) spines are all the same length. Pads 20-40 cm long.

ID: Up to 3 ft in height. Stems sprawling to flat on the ground.

Leaves: Reddish brown or dark yellow-red spines. Often lighter at the tip. 3-8 cm long. Three to eight spines per areole. One single lower spine longer than the other. Pads obovate to circular, 10-25 cm long.

Flowers: Yellow, rarely pink or red. Flowers April to July.

Fruits: Wine color to purple.

Paxistima myrsinites







Top photo by Aaron Gunnar,(https://www.inaturalist.org/observations/178345428), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)
Bottom photos by Ken-ichi Ueda,(https://www.inaturalist.org/observations/1303042),licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: mountain-lover, Oregon boxleaf

Family: Celastraceae or bittersweet

USDA PLANTS Code: PAMY

Habitat: Coniferous forests; piñon-juniper to spruce fir. Primarily found in north central and northwest New Mexico. Range extends to southern border.

Elevation: 6,000 to 10,000 ft

Common/Similar Species: Can get confused with *Arctostaphylos uva-ursi* (kinnikinnick), kinnikinnick has alternate leaves, leaves entire.

ID: Up to 20 cm in height. Growth form spreading to upright.

Leaves: Opposite, toothed above middle portion of leaf. Elliptic to obovate. Dark green, leathery.

Flowers: Red to reddish brown. Solitary or groups of 2-3 cymes. 4 petals. Flowers May to July.

Fruits: 2-celled dehiscent capsule. Sessile in leaf axis.

Petradoria pumila







Photos by Jim Morefield, (https://www.inaturalist.org/observations/146098285), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: rock goldenrod

Family: Asteraceae or aster

USDA PLANTS Code: PEPU7

Habitat: Piñon-juniper woodlands, open woods, roadsides.

Elevation: 4,500 to 8,000 ft

Common/Similar Species: Looks like *Gutierrezia sarothrae* (broom snakeweed) and *Hymenoxys richardsonii* (pingue rubberweed), richardsonii flowers are significantly bigger. *Pumila* leaves are wider than *Gutierrezia sarothrae*.

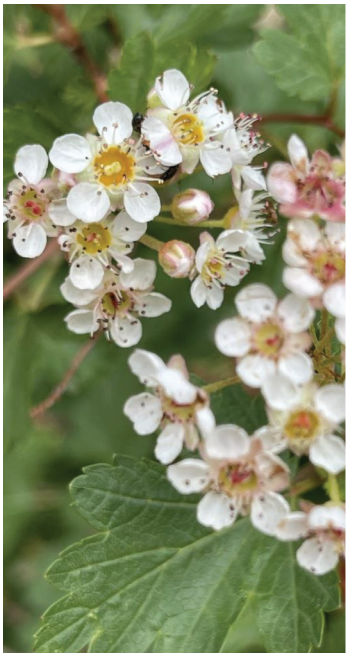
ID: Less than 1 ft in height. Base of plant typically has dead leaves from previous years still attached.

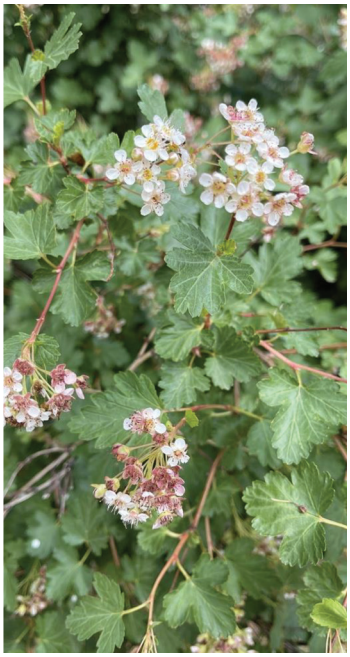
Leaves: 7-12 mm long, 4-7 mm wide. Bright green. Primarily grow at base. Margins entire.

Flowers: Dense, flat-topped cluster, yellow. Phyllaries arranged in vertical lines, light yellow to brownish. Slightly darker towards the tips. 2-3 pistillate ray florets, 2-4 staminate ray florets. Flowers May to August.

Fruits: Pappus of capillary bristles. Glabrous seeds.

Physocarpus monogynus





Photos by Christine Laney, (https://www.inaturalist.org/observations/84453509), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: mountain ninebark

Family: Rosaceae or rose

USDA PLANTS Code: PHMO4

Habitat: Dry, rocky slopes in the mountain, open woods. Can be found across New Mexico in high elevation to subalpine mixed coniferous forests.

Elevation: 6,500 to 10,000 ft

Common/Similar Species: Looks like *Ribes spp.*, *Ribes spp.* flowers are tubular shaped.

ID: Typically, 3 ft or taller. Bark often shreddy.

Leaves: Three lobed, arranged alternately. 2.5-4.5 cm long. Margins double crenate.

Flowers: Nine-25 white flowers arranged in a corymb. Five petals, five sepals. Petals 2-4 mm long. Flowers June to July.

Fruits: Inflated capsule with 2-3 carpels. 3-4 mm long. Reddish brown.

Psorothamnus scoparius





Photos by Katja Seltmann, (https://www.inaturalist.nz/observations/131421252), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: broom dalea, feather dalea, broom smokebush

Family: Fabaceae or pea

USDA PLANTS Code: PSSC6

Habitat: Sandy soils, arroyos. Can be found throughout New Mexico, mostly the central portion of the state.

Elevation: 3,500 to 5,300 ft

Common/Similar Species: Other *Psorothamnus spp.*, other species less shrubby, contain spines, or can be more pinnately compound.

ID: Broom shaped shrub, growing up to 3 ft tall. Stems yellowish green, with amber colored glands.

Leaves: Linear, alternate, sparsely arranged along stems. 1 mm wide, 0.5-1.9 cm long. Row of glands grow along the leaf margins. Leaves are sometimes, but rarely tri-foliate.

Flowers: Dark purple and blue. 1 cm wide, growing at the tip of the branches. Typical pea flower morphology; 5 hairy sepals fused together forming a tube. Flowers July to September.

Fruits: Legume, obovate, gland dotted and pubescent, less than 0.5 cm long.

Rhus trilobata





Photos by Grace McCartha, used with permission



Photo by Claire Gentry, used with permission

Common Names: skunkbush sumac, skunkbrush, polecat bush, stinking sumac, ill-scented sum ac, quailbush, basketbush, lemonade sumac, three-lobed sumac, three-leaved sumac, lemita

Family: Anacardiaceae or sumac

USDA PLANTS Code: RHTR

Habitat: Prairies to shrublands and oak woodlands and in a variety of sites including dry rocky slopes, streamsides, seasonal drainages, canyon bottoms, sand dunes and sandhills, pastures, and roadsides. Widespread throughout New Mexico.

Elevation: 5,000 to 7,500 ft

Common/Similar Species: Sometimes treated as a variety of *Rhus aromatica* (fragrant sumac). There seems to be regional distinctions when it comes to the classification. Historically, *Rhus trilobata* has been in the classification used in western states and *Rhus aromatica* has been the classification used in the east.

ID: Up to 8 ft tall. Rounded, mound-like, or upright thicket growth form.

Leaves: Alternate, compound with three leaflets, variable in size and shape. Margins crenate, usually shiny-glabrous above. Terminal leaflet 3-6.5 cm long. Green in summer, becoming orange to reddish in fall.

Flowers: Pale yellow or a soft cream color. Dense clusters on short lateral shoots. Bisexual and unisexual, both types borne on the same plant. Flowers April to July.

Fruits: 5-7 mm in diameter. Red at maturity and sparsely hairy, each fruit containing a single nutlet.

Common name derived from odor of the leaves, especially when bruised.

Ribes cereum

Common Names: wax currant, wild wax currant, Western red currant

Family: Grossulariaceae or currant

USDA PLANTS Code: RICE

Habitat: Pine forests, wood openings, dry slopes, ridges, rocky places, and forest edges. Common throughout New Mexico.

Elevation: 6,000 to 9,000 ft

ID: Typically, 3-6 ft in height. Erect to spreading. Unarmed, lacking spines.

Leaves: Alternate, 3-5 lobes, crenate. Length and width roughly equal. Glandular, pubescent.

Flowers: Tubular, pink, pubescent. 6-8 mm long. Anthers have a cup shaped gland at the apex. Flowers May to July.

Fruits: Bright red or orange-red berry containing several seeds. 5-12 mm. Stipulate-sglandular or spiny.

Ribes cereum has a noticeable "spicy" odor.



Left photos by Grace McCartha, right photos by Claire Gentry, used with permission

Ribes inerme

Common Names: whitestem gooseberry, klamath gooseberry

Family: Grossulariaceae or currant

USDA PLANTS Code: RIIN2

Habitat: Moist, often in shaded places, in woodland. In riparian, grassy meadows, under willows, and cool, rocky seeps. Found in mountainous regions throughout New Mexico.

Elevation: 6,000 to 10,500 ft

ID: Can reach height of 9 ft. Can be armed with 3 spines at the node or unarmed. Younger bark has smooth, whitish stems with black, sessile glands. When spines present 1-12 mm long.

Leaves: Deeply lobed, 1.5-6 cm wide. Glabrous to sparsely pubescent. Petiole equal or longer than leaf blade.

Flowers: Arranged in raceme of up to 5 flowers. Green to greenish-purple, shorter than the sepals which are reflexed. Anther lacks cup shaped gland at apex. Stamens two times longer than the petals. Style pubescent. Hypanthium 2-3.5 mm long. Flowers April to May.



Photos by Don Loarie, (https://inaturalist.nz/observations/3981182),licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Fruits: Glabrous, greenish purple to black, roughly 7-8 mm in diameter.

Rosa woodsii

Common Names: Woods' rose, wild rose, common wild rose, mountain rose

Family: Rosaceae or rose

USDA PLANTS Code: ROWO

Habitat: Riparian and wetland sites, disturbed sites, especially along roadsides and south-facing cutbanks. Bluffs, dry grassy slopes, prairie sandhills, in clearings in boreal and subalpine forests. Ponderosa pine, cottonwood, and Douglas-fir dominated forests. Common throughout New Mexico.

Elevation: 4,500 to 9,500 ft

Common/Similar Species: Can be distinguished from other species of rose by its shrubby, thicket-forming habit, stems with straight prickles, and leaves and sepals without glands.

ID: 0.5-9 ft tall. Can form dense thickets. Stems reddish-brown to gray, with straight or slightly curved prickles.

Leaves: Alternate, odd-pinnately compound, leaflets 5-11 cm long, obovate to ovate or elliptic. Finely toothed.

Flowers: Can grow in clusters at the stem tip or less; commonly grow solitary. Five petals, 15-25 mm long, pink to lilac-pink or lavender. Sepals lanceolate, 1-2 cm long, erect or usually persistent, tomentose on the margins and inner surface. Flowers June to September.



Photos by Claire Gentry, used with permission

Fruits: Fleshly, red, globose to ellipsoid "hip", 5-12 mm wide, derived from the base of the sepals and petals. Nutlets 15-25, 3-4 mm long.

Rubus armeniacus

Common Names: Himalayan blackberry, Himalaya-berry, Armenian blackberry

Family: Rosaceae or rose

USDA PLANTS Code: RUAR9

Habitat: Grows in open weedy sites, stream sides, and along roadsides.

Elevation: 2,700 to 6,000 ft

ID: Canes (mature stems) arching, may be up to 32 ft long. Thorns are typically reddish color later in the summer and may be up to 20 mm long. Canes can intertwine forming dense thickets as tall as 6 ft.

Leaves: Compound leaves with 3-5 leaflets. Underside is white. Roughly oval shaped, with toothed margins and a pointed apex. All leaflets attached to a common point.

Flowers: Flowers perfect. Five white or pale pink petals. Borne in loose clusters. Roughly 2 cm in diameter.

Fruits: Drupe, consistently of 15-40 tiny drupelets. Dark blue at maturity. Each drupelet contains one seed.



Photo by Sam Beaumont (https://inaturalist.nz/observations/136975993), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Rubus idaeus

Common Names: American red raspberry, raspberry, grayleaf red raspberry, red raspberry

Family: Rosaceae or rose

USDA PLANTS Code: RUID

Habitat: Edges of swamps and bogs, especially common after burnings, clearings, or other disturbances. Common throughout New Mexico.

Elevation: 6,500 to 10,000 ft

ID: Grows up to 5 ft tall. Slender. Covered in sharp hairs.

Leaves: Pinnately compound with three to five leaflets. White tomentose on the underside. Terminal leaflet 5-7 cm long, ovate. Toothed margins.

Flowers: Five white petals, five sepals, numerous stamen and carpels. Sepals covered with gland tipped hairs. Flowers May to July.

Fruits: Red to white rounded, aggregate. 2 cm long and broad. Maturing between July to September.





Photos by Agnieszka Łubian, (https://www.inaturalist.org/observations/96285403), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Rubus parviflorus

Common Names: thimbleberry, western thimbleberry

Family: Rosaceae or rose

USDA PLANTS Code: RUPA

Habitat: Forest edges and stream banks. Found in mountains across New Mexico.

Elevation: 7,000 to 10,000 ft

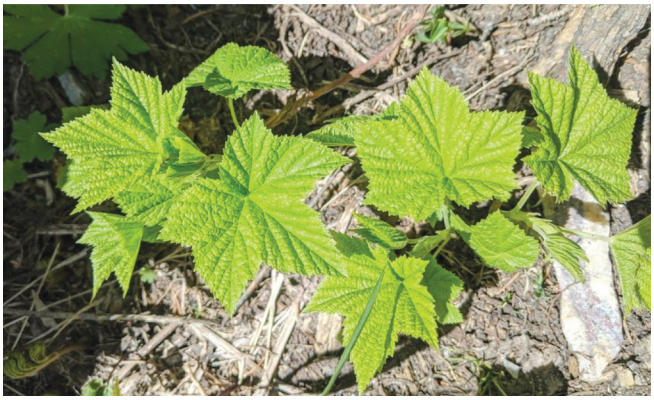
ID: 3-6 ft in height. Erect, slender. Older bark shreddy. Unarmed.

Leaves: Alternate, large, palmately lobed. Three to five lobes per leaf. 9-30 cm wide, roughly as long as wide. Long, hairy, petioles, 2- 11 cm. Deep palmate venation. Margins irregularly serrated. Bright green above, paler below.

Flowers: White, borne in cymose. Typically, three to seven flowers per cluster. Five petals, five sepals. Sepals are reflexed and spreading. Glabrous styles. Flowers June to August.

Fruits: Red, aggregate, 2-3 cm wide. Drupelets numerous.





Photos by Carolina May

Shepherdia canadensis





Photos by Kathryn Mahan

Common Names: russet buffaloberry, buffaloberry, soapberry, russet red buffaloberry, Canadian buffalo-berry

Family: Elaeagnaceae or oleaster

USDA PLANTS Code: SHCA

Habitat: Dry to moist open woods and thickets from lowlands to mid-elevation forests. Generally found on rocky, sandy, or gravelly soil. Found in northcentral New Mexico.

Elevation: 8,000-9,800 ft

Common/Similar Species: *Shepherdia argentea* (silver buffaloberry) has silvery leaves on both sides with stellate scales. Twigs are also thorny.

ID: Reaches 3-6 ft in height. Branches stellate-hairy. Not armed.

Leaves: Opposite, oval to elliptic. Green, slightly pubescent on upper surface, undersides rusty, scaly, with brown spots. 2-6 cm long, 1-2.5 cm wide.

Flowers: Small, yellowish or brownish, male and female flowers on separate shrubs. Arranged in raceme of a few to several flowers. Flowers May to June.

Fruits: Drupelike, red or yellowish, 4-6 mm long. Ovoid achenes.

Sorbus dumosa





Top photo by Wendy McCrady, (https://inaturalist.nz/observations/145476083), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/ Bottom photos by Valerie Norton, (https://inaturalist.nz/observations/141648419), licensed by CC-BY-NC-ND (https://creativecommons.org/licenses/

Common Names: Arizona mountain ash

Family: Rosaceae or rose

USDA PLANTS Code: SODU2

Habitat: Moist coniferous forests. Found in western and northwestern New Mexico.

Elevation: 7,500 to 10,000 ft

Common/Similar Species: *Sorbus scopulina* (cascade mountain ash) has leaves and leaflets that are longer (leaves: 10-25 cm, leaflets: 35-70 mm). Rachis (stems) only slightly hairy as opposed to dumosa which is densely hairy.

ID: Up to 16 ft. Bark reddish to gray, densely white pubescent, smooth with maturity.

Leaves: Odd-pinnate leaves, 7-15 cm long. Leaflets 9-15 per leaf, oval to lanceolate, 4-45 mm long, serrated leaf margins. Dark green, glabrous above, paler, glabrous to pubescent on the underside.

Flowers: Cyme of numerous small, white flowers (10-40). 5 petals (1-2 mm long), 5 sepals (1-2 mm long). Flowers May to June.

Fruits: Small, red, berry-like pome (an apple-like fruit), arranged in terminal clusters, each 8-10 mm in diameter.

Symphoricarpos rotundifolius





Photos by Claire Gentry, used with permission

Common Names: roundleaf snowberry

Family: Caprifoliaceae or honeysuckle

USDA PLANTS Code: SYRO

Habitat: On ridges, slopes, open places in woods. Found in western and northern New Mexico.

Elevation: 6,000 to 10,000 ft

Common/Similar Species: *Symphoricarpos oreophilus* (mountain snowberry) is a synonym of *Symphoricarpos rotundifolius* (roundleaf snowberry). *Symphoricarpos albus* (white snowberry) and *Symphoricarpos occidentalis* (western snowberry) are uncommon, only found in north central and northeastern New Mexico. Corollas on both species are bell shaped, corolla lobes are equal to or longer than the corolla tubes.

ID: 1-6 ft in height. Erect to arching.

Leaves: Opposite, entire, oval to ovate. 1-3 cm long. Bright green, paler on the underside. Petioles 1-3 mm long.

Flowers: Arranged in pairs or separately. White to pink. Tubular flowers. Corolla lobes one-third or less compared to length of corolla tube. Corolla 8-25 mm long. Flowers May to June.

Fruits: Drupe, white to pink.

Vaccinium myrtillus





Photos by Mitch Van Dyke, (https://inaturalist.nz/observations/50600171), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Names: whortleberry, myrtle whortleberry, dwarf bilberry, bilberry, wimberry, European blueberry, blueberry, whinberry

Family: Ericaceae or heath

USDA PLANTS Code: VAMY2

Habitat: Found in coniferous forests. Found in northcentral and western New Mexico.

Elevation: 8,000 to 11,500 ft

Common/Similar Species: *Vaccinium scoparium* (grouse whortleberry) and *Vaccinium myrtillus* (whortleberry) have been known to hybridize. *Scoparium* berries are smaller in diameter, 3.5-6 mm. Branches are also broom-like, numerous, and glabrous. Leaves are 0.7-1.2 cm long and 4-6 mm wide. Most commonly found in tundra ecosystems.

ID: Up to 1.5 ft in height. Slender and spreading. Twigs are green and sharply angled. Grooves of branches typically puberulent. Rhizomatous; usually occurs in colonies.

Leaves: Alternate, 1.9-2.8 cm long, 7-12 mm wide. Serrated margins. Bright green, elliptic to lanceolate. Broadest from the middle of the leaf to the base.

Flowers: Pink, cream or greenish white urn-shaped flowers. 3-5 mm long.

Fruits: Deep purple, purplish-black, to bluish black berry. 7-9 mm in diameter.

Yucca baccata

Common Names: banana yucca, blue yucca, fleshy-fruited yucca, datil

Family: Asparagaceae or asparagus

USDA PLANTS Code: YUBA

Habitat: Dry plains; hilly grasslands, in piñon-juniper, sagebrush and ponderosa pine forests. Common throughout New Mexico.

Elevation: 3,500 to 7,500 ft

ID: Up to 8 ft in height. Grows in colonies.

Leaves: Forms basal rosettes. 30-100 cm long, more than 2 cm wide at widest point. Margins produce fiber strings. Spine tipped apex, 1.5-7 mm long.







Left photo by Carolina May, right photos by Grace McCartha, used with permission

Flowers: Creamy colored tepals with hints of purple. 4.5-13 cm long. Inflorescence a panicle, usually somewhat tucked within the basal rosette, 130 cm long. Flowers April to May.

Fruits: Indehiscent, fleshy, succulent type fruit. Roughly 12 cm or more long. Seeds are black, obovate.

11.0 Hazardous Plants of New Mexico



Photo by Nick Kleinschmidt
(https://inaturalist.nz/observations/145109744)
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NMFWRI has compiled this section on plants that can pose hazards to our crews working in the field. Our field work takes place primarily in the state of New Mexico; thus, this section does not include hazardous plants that may occur in other locales. Do your own research on hazardous plants that may occur at your field sites, and ensure your crew is trained in identification and mitigation of these hazards.

HAZARDOUS PLANTS

Conium maculatum, poison hemlock
Toxicodendron rydbergii, western poison ivy
*Urtica dioic*a, stinging nettle

HAZARDOUS PLANTS

Conium maculatum



Photo by Joe Dillon, (https://inaturalist.nzobservations/145032427),licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)





Photos by Quinten Wiegersma, (https://inaturalist.nz/observations/144997863), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Name: poison hemlock, hemlock, wild hemlock

Family: Apiaceae or carrot

USDA PLANTS Code: COMA2

Habitat: Moist areas, streams, roadsides, ditches, and disturbed areas.

Elevation: 5,000 to 7,500 ft

Common/Similar Species: *Ligusticum porteri* (oshá) looks very similar to poison hemlock. Oshá has a distinct spicy-celery smell while poison hemlock is reported to have a musty smell. Oshá tends to not grow in excessively moist soil due to the plant's relationship with mycorrhizal fungi, thus it is never found growing in standing water.

ID: 3-7 ft tall. Stalks are hollow, glabrous, and dotted with purple spots or stripes.

Leaves: 3-4 times pinnately compound, triangular. Bright green and toothed, resembling a fern.

Fruits: Green, ribbed, ovoid, and 2-2.5 cm long.

Interaction: VERY TOXIC. All plant parts are poisonous, and toxins can be absorbed into the skin. If working in area where its presence is confirmed or suspected, wear gloves. Wash your hands with soap and avoid contact with your mouth if touched. Ingestion can result in the following symptoms: dilated pupils, salivation, rapid weak pulse, dizziness, ataxia, and shaking or trembling. May result in depression of the central nervous systems, respiration rhabdomyolysis, acute renal failure, and even death.

HAZARDOUS PLANTS

Toxicodendron rydbergii



Photo by Quinten Wiegersma, (https://inaturalist.nz/observations/144997863), licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)



Photo by Nick Kleinschmidt, (https://inaturalist.nz/observations/145109744) licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)



Photo by CKY, stock.adobe.com

Common Name: western poison ivy, poison ivy, poison oak

Family: Anacardiaceae or Sumac

USDA PLANTS Code: TORY

Habitat: Widespread throughout disturbed sites, woodlands and forests, rocky slopes, wetland/riparian areas, and canyon bottoms.

Elevation: 4,500 to 8,500 ft

Common/Similar Species: Looks similar to *Toxicodendron radicans* (eastern poison ivy), which generally grows as a vine in the east. *Radicans* and *rydbergii* can hybridize where their ranges overlap.

ID: Low growing shrub/subshrub. Occasionally grows as a vine. Typically, up to 3 ft in height.

Leaves: Alternate, compound leaves. Each leaf has 3 leaflets (trifoliate). Leaves are longer than wide, measuring 3-15 cm long and 2-11 cm wide. Prominent mid vein. Leaf margins are broadly toothed or serrated, with an acute apex. Glabrous on both sides.

Flowers: Inflorescence arranged in a panicle. Greenish sepals are deltoid in shape.
The 5 petals are creamy white to yellowish, oblanceolate in shape. Flowers May to September.

Fruits: Yellowish-white drupes, arranged in an axillary panicle. Glabrous.

Interaction: Can result in painful itching, rashes, blistering, and swelling. The chemical urushiol, the cause of the reaction, is located throughout the plant. Confident ID and avoidance help to prevent contact. If contact occurs or is suspected, thoroughly wash objects or parts of body that came into contact with the plant with liquid dish soap.

HAZARDOUS PLANTS

Urtica dioica

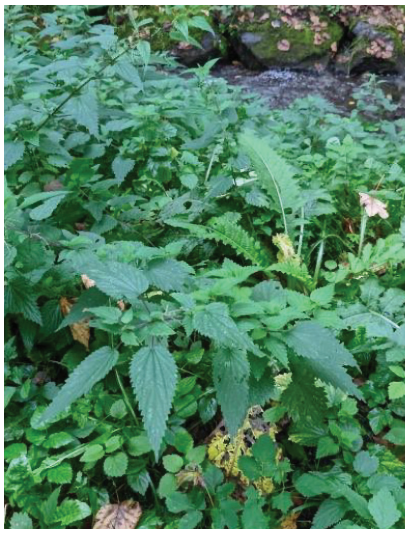


Photo by Nick Kleinschmidt (https://inaturalist.nz/observations/145109744)licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)



Photo by montypeter, stock.adobe.com



Photo by Nick Kleinschmidt (https://inaturalist.nz/observations/145109744)licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)

Common Name: stinging nettle, California nettle, slender nettle, tall nettle

Family: Urticaeae or nettle

USDA PLANTS Code: URDI

Habitat: Moist areas, streams, and meadows. Disturbed sites.

Elevation: Up to 10,000 ft

Common/Similar Species: Other *Urtica* species.

ID: Low growing shrub/ subshrub. Occasionally grows as a vine. Typically up to 3 ft in height.

Leaves: Opposite arrangement with 2 leaves per node. Margins serrated or doubled serrated. Elliptic, lanceolate, to ovate. Apex acute, base rounded or cordate. 7-20 cm long, 2.5-6.5 cm wide. Stem relatively square. Covered in stinging hairs.

Flowers: Arranged in a panicle, sprouting throughout the length of the stem near the leaf axils and atop stem tip. White to green in coloration.

Fruits: Ovoid, flattened achene, and 1-1.4 mm in length and width.

Interaction: Contact with the plant results in rash and burning/ stinging sensation. Wash irritated area with soap and water. Can apply a cold compress for pain relief. In certain cases, contact may result in an allergic reaction.

12.0 Using GNSS/GPS Devices

Global Positioning System (GPS) is a satellite-based navigation system made of at least 24 satellites. It works in various weather conditions, 24 hours a day. Global Navigation Satellite System (GNSS) includes a range of international location providers (such as Glonass, Galileo, Beidou) and is incorporated into receivers (such as Garmins, phones, tablets, etc).

The following guidelines are for Garmin handheld receivers, which NMFWRI and many partners commonly use. Please note that specific instructions will vary by device.

Calibrating GPS Units

Most GPS units need to be calibrated on occasion. On Garmin units, navigate to the compass, select 'Menu', and then select 'Calibrate Compass'. Follow instructions on screen.

Navigating to a Pre-loaded Point

On Garmin units, select 'Find' and then 'Waypoints'. Scroll until the waypoint of interest is located.

Navigating to GPS Coordinates

On Garmin units, select 'Find' and then 'Coordinates'. Type in GPS coordinates in decimal degrees.

Recording a Waypoint

On Garmin units, select 'Mark'. Use up and down arrows to input point name and notes. Use a standardized point naming system to avoid confusion (i.e. Plot Name).

GPS Tips & Troubleshooting

- Ensure all necessary GPS points are loaded onto all GPS devices before heading into the field.
- In deep canyons, GPS access to satellites may be obscured. GPS units need a clear view of the sky to be used with accuracy.
- Satellite locations will vary throughout the day, and therefore GPS accuracy will vary.
- Low battery warnings are frequent on Garmin GPS units, but often battery life will continue long after low battery warnings. Always bring plenty of spare batteries along.

13.0 Using a Compass

Getting set up

For each project, you must know the declination for the area where you are working. Make sure everyone on your crew sets their compasses to the same declination. You may use any style of compass for your work. Most of the following instructions and photos use Silva Ranger compasses. *See 13.1 Compass Declination*

Walking a line

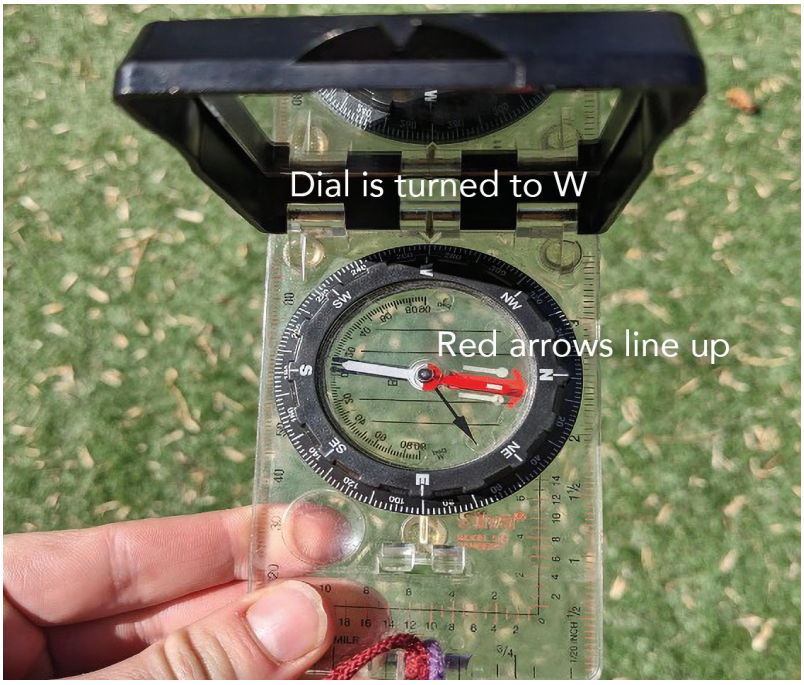


Photo by Carolina May

1. To walk a straight line, for instance, to the West, turn the dial on the top of your compass so the "W" is lined up with the center mark.
2. Next, rotate yourself and your entire compass so that the red arrow lines up with the painted red lines. See photo above. Be sure you are not holding any metal near the compass.
3. Hold the compass level. Keep the red arrow aligned and look through the sights at either the top of the cover or at the base until you find an object you can recognize. In the picture on the next page, we can see a tree through the sights.
4. Walk toward this object, keeping the red arrow aligned with the painted lines at all times. You can continue looking through the viewer or look at the real-life object. One other option is to walk every step with your eyes on your compass needle, and make sure it stays aligned.

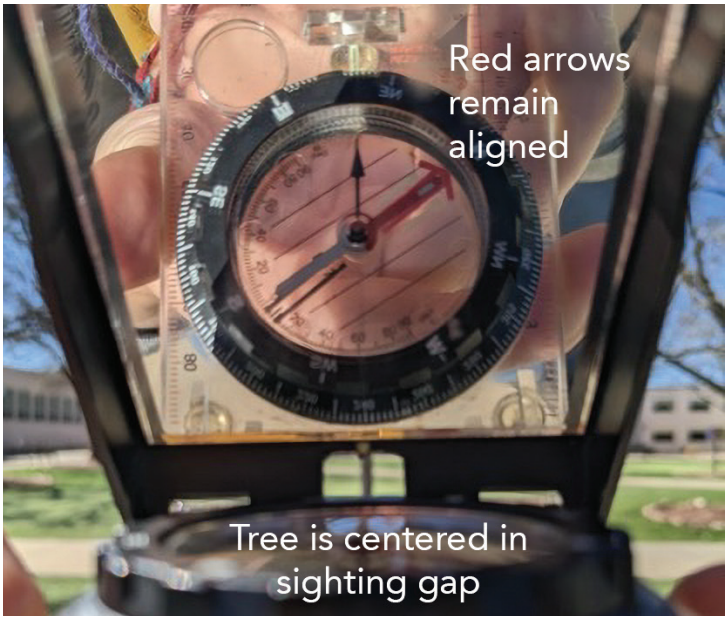


Photo by Carolina May

5. Walk out the appropriate distance (bring your tape along) and stop.
6. Turn around and use the sights on the compass to look back at where you came from. This time, the WHITE arrow should line up with the red lines (you are looking backwards). Step right or left as needed until the alignment is perfect.
7. To double-check yourself, have someone stand where you started and sight to you with their own compass. If your declination was set the same, you should both agree on the right position.

Common errors and troubleshooting

1. If you are sighting with one eye open and one eye closed, it does make a difference, depending on which eye is dominant for you. Be sure you know this for yourself, or sight with both eyes open.
2. Be sure you are holding your compass level while sighting with it.
3. If you are holding something metal such as pin flags or a metal tape, these will attract the compass needle and your line will be off.
4. If you are consistently off, double-check your declination setting. These tic marks are very hard to read, so it is easy to make a mistake initially.
5. In very dense stands, have someone stand at plot center (PC) and guide you around trees and brush.
6. Try to keep your compass protected from extreme temperatures or rapid changes in elevation to reduce the chance of getting bubbles in the liquid inside. These bubbles, if they are large enough, can make the compass very difficult to use.
7. If compass liquid is gone, large bubbles are present, or if needle is spinning loosely, the compass is unusable.

13.1 Compass Declination

Declination is the difference between magnetic north and true north. Declination changes over time and differs depending on location, so it is important to know the current declination of your monitoring site. We must correct for this difference when working from a map or when re-taking plots over time so that, for instance, the "north" photo of the plot remains in the same location.

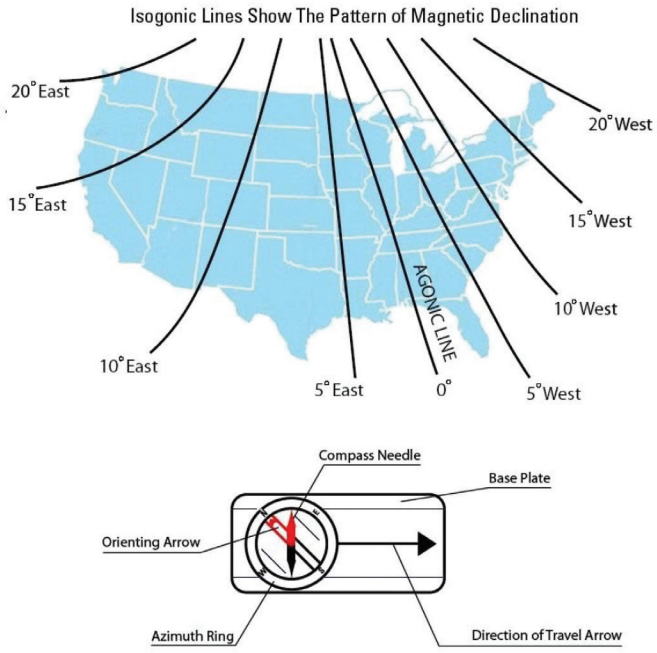


Diagram by USGS Educational Resources

Looking Up Declination

To look up the declination for your area, this link to the NOAA website is useful: https://www.ngdc.noaa.gov/geomag/calculators/magcalc.shtml#igrfwmm. You will need to know the latitude and longitude of your monitoring site to look up the declination.

Correcting for Declination – Method 1

One way of correcting for declination is to set the wheel on your compass.

1. Locate the small metal key included along your lanyard.
2. Turn your compass over.
3. Insert the metal key into the adjustment screw on the wheel on the back of your compass to set the declination on your compass.

4. Turn the screw until the declination indicator matches the declination you looked up for your area of work (make sure you are going the correct direction - east or west!).
5. Make sure everyone on your crew sets their compasses to the same declination and test this by sighting a line.

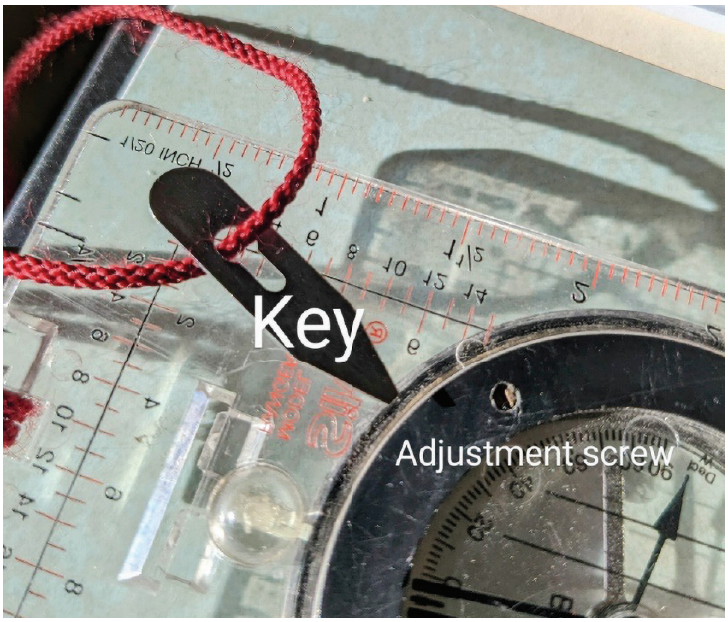


Photo by Carolina May

Correcting for Declination – Method 2

If you do not have a compass with adjustable declination, you can adjust with addition and subtraction. One method is to use the formulas:

True reading – east declination = magnetic reading

True reading + west declination = magnetic reading

So, for example, if your declination is 10 degrees East and you want to walk a line north for your plot:

True reading – east declination = magnetic reading

360 – 10 = 350, so you would need to set your compass for 350 degrees to get a true north line.

14.0 Reading Tape Measures

Many kinds of tape measures may be used on a plot. It's very important to pay attention to what each tape is, and how to read it.

Caution! Tapes built with a hook on the end are designed to be read only if the hook is attached to something and the tape is pulled taught. The end of the tape is NOT zero. Zero is at the end of the hook.





All Photos in this chapter by NMFWRI Field Crew

Types of Tapes

1. **Fiberglass/Reel Tapes**

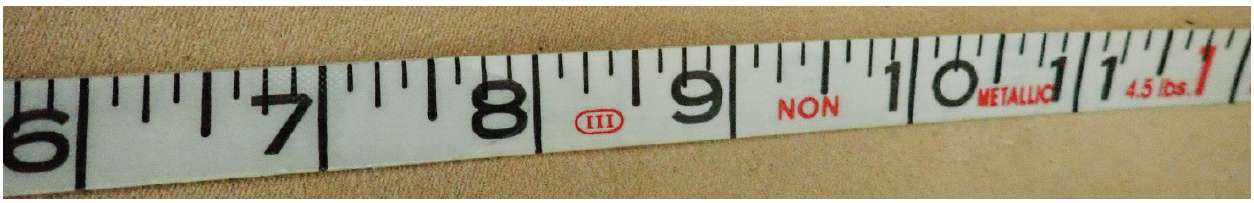
   Sometimes these tapes have one side, and sometimes two. Read the tape to know what units it uses (see pictures below). For instance:



This tape is in feet and tenths. You know this because it only counts to 10 (you only see numbers up to 9).



This tape is the same, but the tenths are marked with a decimal point.



This tape, however, is marked in feet and inches. Notice how it has twelve divisions (you see numbers up to 11).

Note: it's common to find fiberglass tapes with both a metric side and a side with inches. Typically, the sides are two different colors.

2. Diameter/Logger Tapes

If you use a Spencer tape, it is commonly also two-sided. For example:



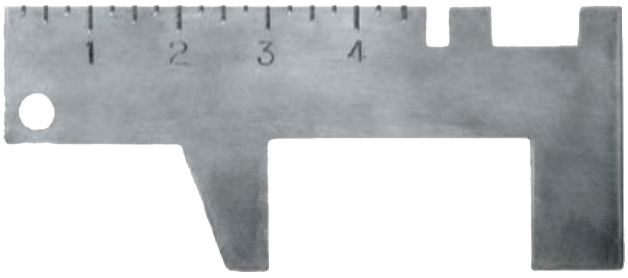
Side 1 – in feet and tenths, designed to be read from the end of the hook. This side is useful for measuring length of logs or measuring your distance from a tree when measuring height by clinometer and laying out the East and South lines of your plot.



Side 2 – in inches and tenths BUT adjusted for the value of pi. This side is meant to be read when measuring the diameter of a tree or 1000-hour fuel. It is read where the number and the zero-mark line up (see more detail on reading this side of the tape in *19.31 Rules for Measuring DBH*).

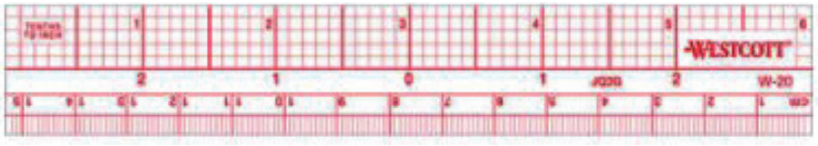
3. Fuels gauge

Some go/no-go fuels gauges also come with a measuring side. This is useful for measuring litter and duff depth. This one is marked in inches and quarter inches, so each small mark represents 0.25 inches.



4. Flat tape/ruler

Sometimes rulers are also used, especially if your fuels gauge doesn't have a ruler, or if you are checking plant ID by measuring the lengths of parts of the plant. Be sure you check your units.



Abbreviating Measurements

Remember, there are standard abbreviations for inches and feet. Always indicate what units you're using on your datasheets and be careful not to confuse inches and tenths of feet!

Unit	Inches	Feet
Acceptable ways to record	2.1 in, 2.1 inches, 2.1"	6 ft, 6 feet, 6'

Table 1. Guidelines for recording measurement units - Always indicate units!

For example, the datasheet below uses both kinds of abbreviations for inches and feet. Both forms are acceptable.

Similarly, both decimal and fractions are acceptable (e.g, ½ inch or 0.5 inches) as long as they can be clearly and easily read.

Transect	Sample Location	Litter Depth	Duff Depth
1	45'	0.1 in	0 in
1	75'	1.5 in	0.2 in
2	45'		
2	75'		
3	45'		
3	75'		

Veg Item	% Veg Cover	Veg Hgt (d.d')
HD	0.5	1.0ft
HL	3.0	0.5ft
SD	0	—
SL	0	—
HD	0.5	0.5ft
HL	3.0	1.0ft
SD	0	—
SL	0	—
HD		
HL		
SD		
SL		
HD		
HL		
SD		
SL		
HD		
HL		
SD		
SL		
HD		
HL		
SD		
SL		

Surface Fuels-Vegetation
Item Code and Description
HD dead non-woody vegetation
HL Live non-woody vegetation
SD Dead woody vegetation
SL Live woody vegetation

Code	% Veg cover Cover
0	No cover
0.5	>0-1 % cover
3	>1-5 % cover
10	>5-15 % cover
20	>15-25 % cover
30	>25-35 % cover
40	>35-45 % cover
50	>45-55 % cover
60	>55-65 % cover
70	>65-75 % cover
80	>75-85 % cover
90	>85-95 % cover

Comments:

14.1 Measuring by Tenths of a Foot

1. Place your tape measure on a flat surface where you can clearly read it.
2. Reading from left to right, you will see your tape measure has the numbers 1 through 9 (in black). Each one of the nine vertical dashes (in black) between the foot marks (in red) represent 1/10th of a foot (or 0.10 feet).
3. Remember that if your tape begins with a hook or loop, it is designed to be read **from** a stake (see the picture below).

For example, if the measurement from the stake to the pin flag (below) comes out to 1 foot (red) with 2 black numbers after the 1 foot mark, then your measurement would be 1.2 feet.



Photo by Ernesto Sandoval

Example 1 (above): The measurement from stake to pin flag is 1.2 feet.

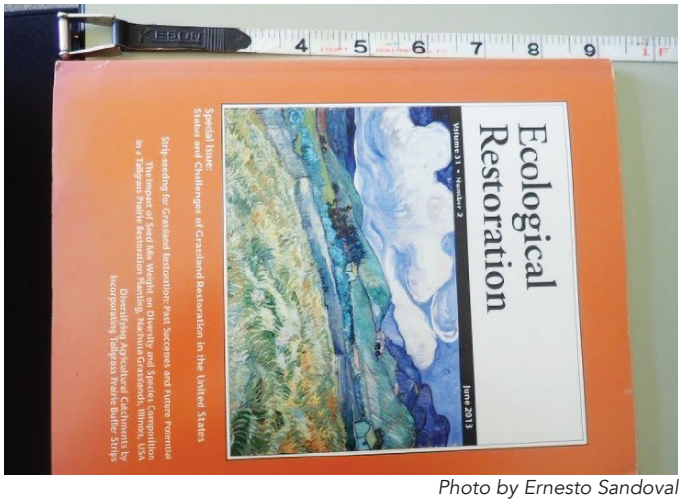


Photo by Ernesto Sandoval

Example 2 (above): The measurement of the book is 0.9 feet (we round to the nearest tenth of a foot or 0.10).

15.0 Plot Layout & Description



Setting up a plot. *Photo by NMFWRI Field Crew*

1. Use GPS to locate plot center (PC).
2. At PC, drive rebar into ground at a height of 4-6" and add a mushroom cap.
3. Run tape in each cardinal direction to 37.24 ft. Have another crew member direct you from PC with a compass to ensure your line matches the correct azimuth.
4. Use pin flags to mark smaller diameter circle at 11.78 ft and larger circle at 37.24 ft (pin flags correspond to stars in the image below).
5. Run a tape at the specified azimuth for the Brown's line(s). Again, have another crew member direct you with a compass, and use photos of the previous Brown's line to get the tape as close as possible to the previous tape layout.
6. Drive another rebar into the ground at the end of the Brown's line (75') and add a mushroom cap. If you have to offset the Brown's line rebar, be sure to make a note in the comments. (i.e., Brown's line rebar placed at 76.5 ft due to rocks at 75 ft)
7. Record the information found in the highlighted boxes of your datasheet, following page.
   Observer: The initials of people calling out data.
   Recorder: The initials of the person recording the data on the datasheet.
   Latitude, Longitude, and Elevation: Record from your high-precision GNSS receiver in the appropriate format. Be sure to indicate units for elevation.
   Administrative Unit: Landowner or Land Manager (i.e. Santa Fe National Forest, New Mexico State Land Office).
   Project Unit: Name of the sub-unit of the project.
   Macroplot: Number of the plot.
   Date: Date monitored.

Time: Time you begin working on the plot.
Hill Slope: % slope wherever it is steepest within your plot (at least 37.24 ft distance). *See also Ch 15.1*
Aspect: Overall orientation/ direction of the plot (N, E, S W). *See also Ch 15.2*
Aspect azimuth: The direction of the aspect in degrees.
Magnetic declination: The amount you adjusted your compass to account for the difference between true north and magnetic north. *See more Ch 13.1*
Plot comments: Include information useful for finding the plot again, a description of conditions at the site, and any other pertinent information about the collection of data. Record conditions and history of disturbance at the plot. *See also Ch 15.3*

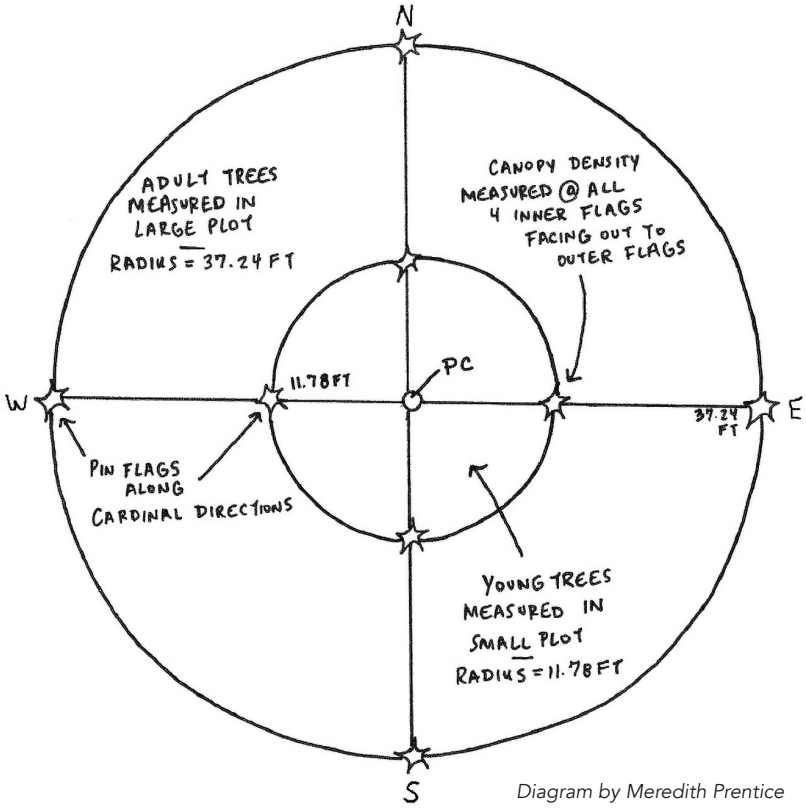


Diagram by Meredith Prentice

Plot Description

Observer: KM, ES, RP, PD	Administrative Unit: USFS
Recorder: CB,	Project Unit: Gnego. 1.
Latitude (dd.dddddd): 35.7373926	Macroplot: 06
Longitude (ddd.dddddd): 105.38561700	Date (MM/DD/YYYY): 4/10/18
Elevation: 7931 ft	Time: 11:48
Photo Azimuths: (1) of whiteboard at PC (2) from 75 feet N looking south to PC (4) from PC in all four cardinal directions; (3) from each Brown's transect looking toward PC.	Hill Slope (% where steepest): 28 %
ORDER TAKEN: PC, BD, C, B270, B135, NESW	Aspect (circle one): N (E) S W
	Aspect azimuth (degrees): 70 °
	Mag Declination: 8 °

Comments: Many many mullein, Burned a while back, some fire killed, a few snags. large woody debris, open Ponderosa Pine forest, a few ABCO & PSME Dead PIPA seedlings fire-killed.

15.1 Slope with a Clinometer

Choosing a Clinometer

Clinometers are tools that can be used for measuring slopes, angles, or heights of objects, including trees. There are many different scales available, such as secant, percent, degree, topographic, 15- and 20-meter, and more. Each clinometer comes with two scales. We recommended using a percent and topographic clinometer, also known as PM5/1:66, when measuring plot slopes and tree heights, because this allows you to take height measurements from a chain away. The following instructions are based on Suunto clinometers.

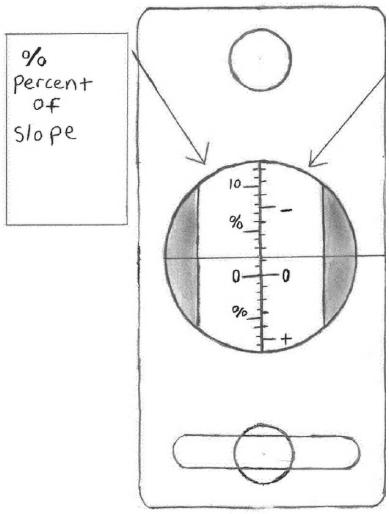
Using a Clinometer:

1. Hold the clinometer to your eye. Generally, the recommendation is to look with both eyes open, one eye looking through the lens at the wheel and the other looking at the object or landscape. For some people, however, it may be necessary to close one eye.

2. Aim the red dot at the target and imagine a horizontal sighting line from the lens wheel to the object you are measuring.

3. Raise or lower the clinometer by tilting your head until the imaginary sighting line crosses the wheel like a target.

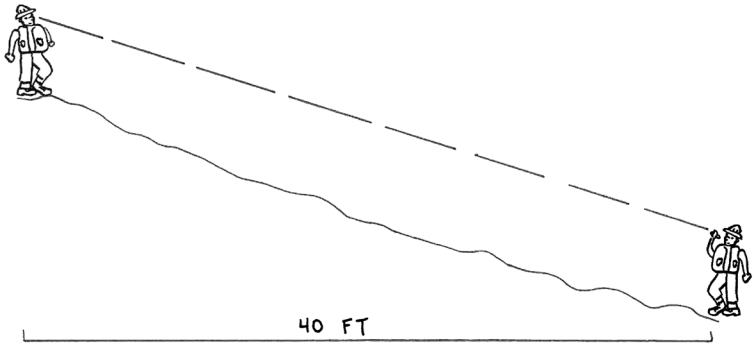
4. Read the number closest to the sighting line on the correct side of the wheel - remember that two scales appear through the clinometer lens. If you forget which side to read, look at the wheel on the side of the clinometer to see the units, or look through the lens and tip the wheel until you can see symbols. On a PM5/1:66 clinometer, the scale on the left indicates percent slope (rise/run x 100), while the scale on the right measures height in feet if you are 66 feet away from your target.



Use the scale on the left for percent slope measurements. *Diagram by Raymundo Melendez*

Taking plot slope:

- Find a partner and establish where your eye level falls on them.
- Stand at least 37.24 ft apart on the steepest part of the plot. The slope measurement should pass through plot center.
- Raise or lower the clinometer to the point you established as eye level on your partner. The number at the sighting line is your percent slope.

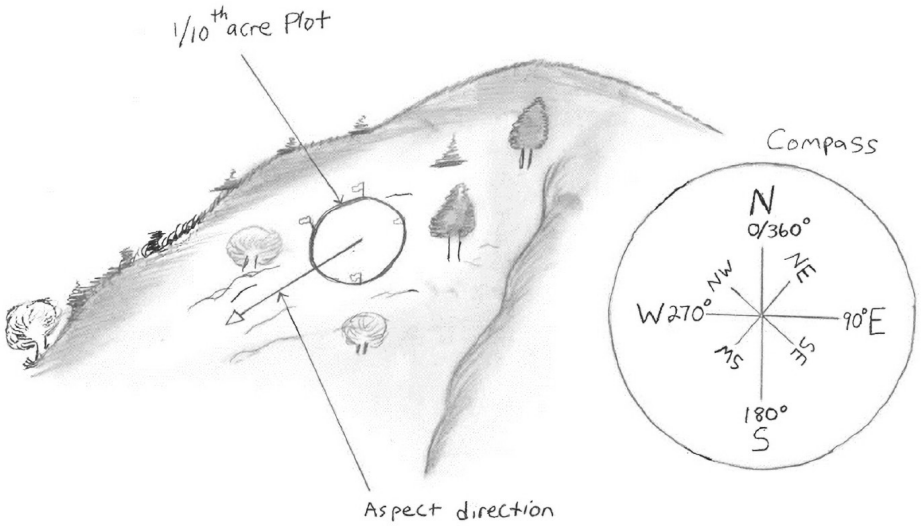


The technician on the right measures slope uphill by angling the clinometer to eye level on their partner. *Diagram by Raymundo Melendez and Carolina May*

15.2 Aspect with a Compass

Aspect is the general orientation or direction of your plot. To determine aspect, it's helpful to conceptualize which direction water would flow through your plot. For each plot, aspect is recorded with a specific azimuth (degrees) and a cardinal direction (N, E, S, W).

1. Stand at plot center and hold the compass facing up with the sights facing away from you.
2. Hold the compass flat and parallel to the ground.
3. Turn your body so that you aim the sights of the compass in the direction the slope is facing. (Another way to visualize this is to position yourself as if you were downhill skiing the fastest route off your plot).
4. Without moving yourself or the main body of your compass any more, turn the round dial to align the painted red lines with the red needle.
5. Read the number that now aligns with the sights.
6. Record this number exactly as you see it (aspect azimuth) and also as whatever cardinal direction it is closest to (aspect). For example: 230 degrees, West.



The plot shown on the hillside has an aspect azimuth of 230 degrees. Aspect direction would be listed as West. *Diagram by Raymundo Melendez*

15.3 Site Condition & History

Often, there are important aspects of a site that may not be captured by other metrics described in this manual. This may include wildlife utilization, human activities such as logging, or wildfire impacts. Disturbance History is a protocol adapted from FFI that NMFWRI utilizes to capture these events or conditions as well as their timing and severity. The intention is for this protocol to be used as a supplement to your plot comments, not a replacement for any field data.

The components of this protocol are:

- **Change Agent** – the primary cause of the change on plot
- **Change** – additional detail on the Change Agent
- **Percent of Plot Affected / Severity** – Depending on the Change Agent, this should be denoted by a 900 code (used in other Damage/Severity assessments, such as in *Ch. 19.5 Damage Codes and Statuses*).
- **Dates** – provide your best estimate for start/end dates of disturbance. Ideally, month and day should be entered, but years MUST be estimated.

All Change Agents and accompanying details, as well as blank and example datasheets, are included in *Supplement C, Disturbance History Change Agent (Pg 250)*.

16.0 Taking Photos



Crew member taking photo from plot center (PC). *Photo by Kathryn Mahan*

Plot Photo Points

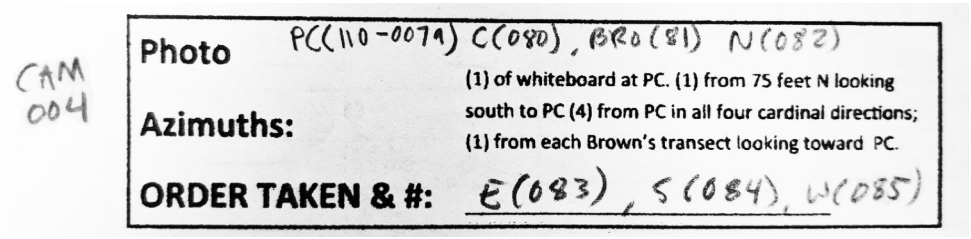
Plot photos are an important aspect of ecological monitoring. Photos are powerful visual tools for documenting change over time. Photos are included in reports and professional publications meant for diverse audiences including land managers and the public.

Seven photo points are taken per plot. If more than one Brown's transect is collected, additional photographs are taken in the same format. Typically, a white board with marker is used to tag each photo. The first photo taken at each plot is of the white board on the ground at plot center (PC). This ensures the data technicians are able to read the plot name and number and correctly identify the photos that follow. It is helpful if the camera used can record GPS coordinates.

Additional photos include:

- "C," (center) taken from 75 ft along the North azimuth looking at a crew member holding the white board at plot center.
- Brown's transect photo, "BR_*degrees*" taken from the 75 ft mark of each fuels azimuth looking towards a crew member holding the white board at plot center.
- "N," "E," "S," and "W" photos taken from plot center facing a crew member holding the white board 37.24 ft away at each of the four cardinal azimuth flags. Additional photographs may be taken, but we recommend these be taken after the mandatory seven plot photos, and noted on the data sheets, so that there is no confusion for the data technicians.

The photo order must be recorded for each plot, for example, PC, C, N, BR75, E, S,W. If photos are being re-taken from a previous year, it is critical to bring along copies of the previous photographs to be sure the frames and landmarks match up. In addition to recording the order of the photo points, record the camera number/model and photo numbers to aid in photo labeling. For example: CAMER001, PC (100-0434), C (100-0435), N (100-0436), etc.



Recording photo numbers. *Photo by NMFWRI Field Crew*

Taking Photos – Tips & Reminders

- Be sure GPS tracking is enabled on your camera (if available).
- Do NOT turn the camera vertically.
- Do NOT zoom in or out at all.
- Try to use the same kind of camera that was used before (aspect ratio/frame should match).
- If previous photos were taken from a different azimuth than you measured (i.e., azimuth was incorrectly recorded in previous measurements, or declination was not set perfectly), match the photos to the previous azimuth (i.e, make a perfect visual match). Make notes of major deviations from the previously identified azimuth. If the azimuth was off for the initial picture, after retaking the photo to match the previous year's, take a photo of what the correct orientation should be. Be sure to label which photo is which when jotting down the order.
- If you are taking photos on a plot for the first time, do so after flagging your witness tree, and try to have a landmark in every photo if it's easy to do so.
- Center the frame on the person with the whiteboard (right-to-left). The person holding the whiteboard should hold the board directly in front of their body, to take up as little space in the photo as possible. If a tree or obstacle is in the way, try to hold the board in a way that it is visible.
- All crew members should wear proper clothing and PPE in photos and appear professional.
- You may not be able to center on the person up-and-down because you will always keep your camera level (even if shooting on steep slopes).
- If you take extra photos of "cool stuff" or unknown plants, try to do this after you have completed the series required for your plot, and be sure to document these extras on your datasheet.
- Double-check your photos by using the playback function on your camera before you leave the plot.

- When you're looking through them, remember that photos should NOT:
    - be blurry or include fingers over photo.
    - include vehicles.
    - include highly visible backpacks/gear or other crew members.
    - include tapes that are "wiggly" – straighten them up or remove them!

Sample Photos:



Griego Unit 1 Plot 6 PC


Griego Unit 1 Plot 6 Center


Griego Unit 1 Plot 6 Brown's 0


Griego Unit 1 Plot 6 Brown's 270


Griego Unit 1 Plot 6 Brown's 135


Griego Unit 1 Plot 6 North


Griego Unit 1 Plot 6 East


Griego Unit 1 Plot 6 South


Griego Unit 1 Plot 6 West

17.0 Canopy Cover with a Densiometer

Spherical densiometers are tools developed for estimating overstory canopy density in forests. They are available with concave and convex mirrors; NMFWRI crews use the concave models. You should be aware that, in addition to the methods described below, there are a number of other ways to use spherical densiometers, such as the Strickler modification, that you may encounter in other monitoring protocols or jobs.

When working on plot, the tree canopy cover for each plot will be an average of four measurements, collected while standing at each inner plot flag (North, East, South, West), facing out to the outer plot flag. Equations for calculating canopy cover can also be found in *Ch. 21.3*.

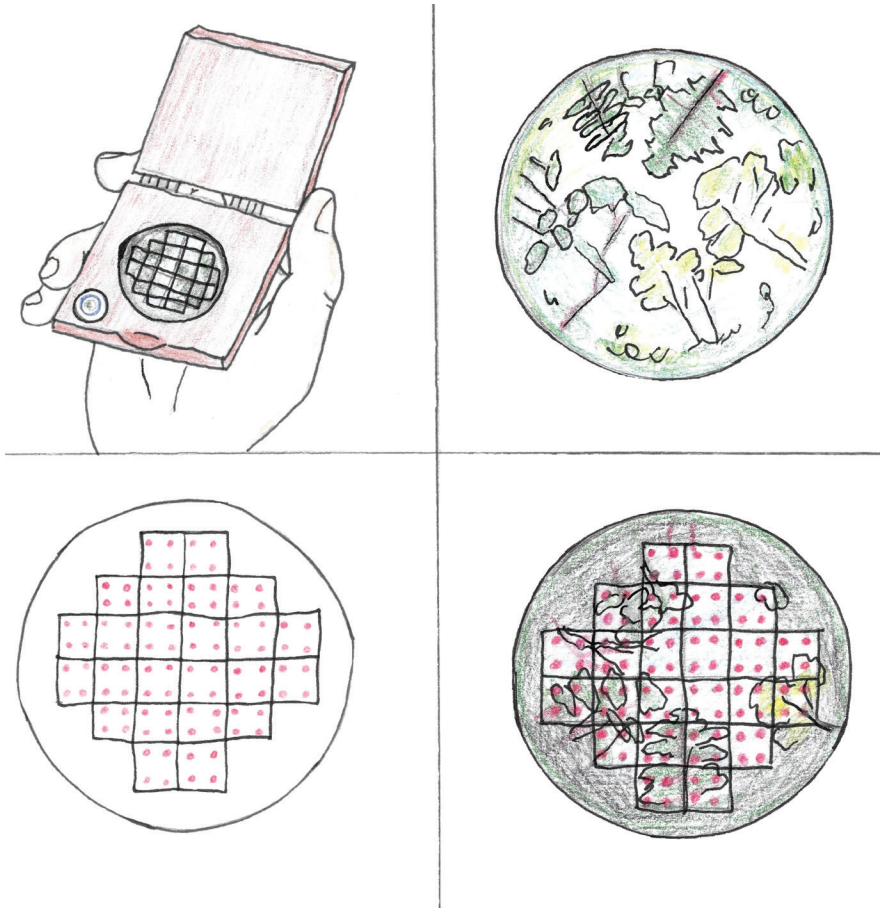


Diagram by Zoe Ahrens

To begin,

1. Stand at your first flag.
2. Open the densiometer and hold it about waist high, level, and just far enough away from your body so that you cannot see yourself in it. Typically, your elbow should be pressed against your waist.

3. To ensure the densiometer is level, make sure the bubble is centered in the black circle in the lower right corner.

4. Proceed, using either the Squares or Dots methods outlined below.

Squares Method:

- In the mirror, you will see 24 engraved squares.
- Count the number of squares which are NOT occupied by canopy. Half squares can be combined within a single measurement, but each measurement should be reported in a whole number of squares.
- Subtract the number of open squares from 24 to get the number of covered squares.
- Record this number and move on to the next measurement. Repeat this process until you have four numbers from each inner flag. Record each measurement on your datasheet individually for each cardinal direction.
- In the analysis, the four measurements will be added together and multiplied by 1.04 to obtain percent canopy cover.

Square Method Example:

North Inner Flag: 6 squares were open.
24 – 6 = 18 = canopy
East Inner Flag: 18 squares were open.
24 – 18 = 6 = canopy
South Inner Flag: 0 squares were open.
24 – 0 = 24 = canopy
West Inner Flag: 11 squares were open.
24 – 11 = 13 = canopy

Next, I add up my numbers
18 + 6 + 24 + 13 = 61
Next, I multiply by 1.04 to correct for only having a total of 96 squares (24 x 4).
61 * 1.04 = 63.44 = 63
So, I have an average of 63% canopy cover on my plot.

Dots Method:

- In the mirror, you will see 24 engraved squares. Mentally, you can add 4 dots per square, for a total of 96 dots. (See diagram on previous page for an illustration of these dots.)
- Count the number of dots which are NOT occupied by canopy.
- Subtract the number of open dots from 96 to get the number of covered dots.
- Record this number and move on to the next measurement. Repeat this process until you have four numbers from each inner flag. Record each measurement on your datasheet individually.
- In the analysis, the four measurements will be averaged and multiplied by 1.04 to obtain percent canopy cover.

Dot Method Example:

North Inner Flag: 44 dots were open.
96 – 44 = 52 = canopy
East Inner Flag: 32 dots were open.
96 – 32 = 64 = canopy
South Inner Flag: 70 dots were open.
96 – 70 = 26 = canopy
West Inner Flag: 51 dots were open.
96 – 51 = 45 = canopy

Next, I add up my numbers
52 + 64 + 26 + 45 = 187
Then, I divide by 4, since I took 4 measurements
187 / 4 = 46.75
Finally, I multiply by 1.04 to correct for only having 96 dots.
46.75 * 1.04 = 48.62 = 49
So, I have an average of 49% canopy cover on my plot.

Special Cases:

Cliff/Ground providing cover in measurement on steep slopes:

- Include this as "cover" but leave a note estimating the percent coverage that was ground/rock rather than canopy.

Burned/dead canopy:

- Squares with dead branches without leaves can make for difficult canopy estimations as it is not always clear how many dots would actually be covered by thin branches. In these cases, estimate the amount of sky visible in each square (I.e. 50% sky and 50% coverage would be half a square or 2 dots of coverage).

Calibration/Troubleshooting:

- Crew members using the densiometer can come up with a wide variation in readings. To become consistent, it's important to agree upon a method (dots vs squares) and to spend time practicing with all crew members taking the same readings from the same point and comparing readings. Always record the method you are using, and use the same method across the entire project. As a crew, you will need to calibrate yourselves so you can share the same judgment in counting dots and squares, especially with small, irregular openings. Have the same crew member measure all four directions within one plot.

- When working in forests with deciduous trees, such as riparian areas, you need to make sure you are taking canopy readings during the same season each time as leaf-off will impact readings.

- Sunglasses are recommended when using the instrument in open canopy on sunny days.

18.0 Small Plot Measurements

Aerial cover and ground cover are estimated within the nested 1/100th acre plot along with tallies of seedlings, saplings, and shrubs. Some project managers may request that these measurements are conducted across the entire 1/10th acre area. In Table 1, you will find a cover estimation guide that may assist in visualizing and quantifying cover measurements.

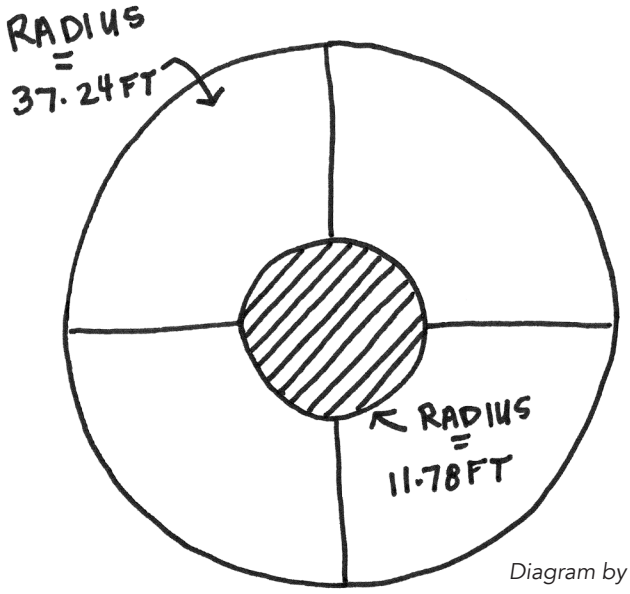


Diagram by Meredith Prentice

%	Area (acres)	Area (sq ft)	Diameter (ft)	Square (ft)
1	0.0001	4	2.4	2.1
5	0.001	22	5.3	4.7
10	0.001	44	7.4	6.6
20	0.002	87	10.5	9.3
30	0.003	131	12.9	11.4
40	0.004	174	14.9	13.2
50	0.005	218	16.7	14.8
60	0.006	261	18.2	16.2
70	0.007	305	19.7	17.5
80	0.008	348	21.1	18.7
90	0.009	392	22.3	19.8
100	0.01	435	23.6	20.9

Table 1. Small plot (11.78ft radius) Cover Estimation Guide.

18.1 Estimating Aerial Cover

Aerial cover refers to cover as viewed from above. Aerial cover includes the percentage of the ground covered by a perimeter of leaves/ branches/ etc., from a viewpoint above the plot. In our protocol, aerial cover is for ocular estimations of the cover of seedling/saplings ("tree regen"), shrubs, graminoids, and forbs, and may not necessarily total 100%. When vegetation overlaps, cover values greater than 100% are possible. When vegetation is sparse, aerial cover may be much less than 100%. Depending upon objectives, aerial percent cover may be further stratified by individual species greater than 1% cover and/or by growth habit.

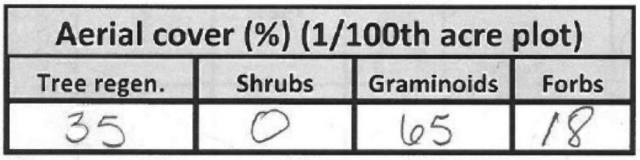


Photo by NMFWRI Field Crew

Terms:

- **Aerial cover** - Percent of ground covered when viewed from above.
- **Tree regen** - A term covering, for our purposes, all individuals meeting the definition of seedling (<4.5 ft tall) and sapling (≥4.5 ft tall but under the breakpoint diameter at DBH).
- **Shrub** - A woody plant smaller than a tree at maturity; has several main stems arising at or near the ground (which plants are considered "shrubs" vs "trees" may depend upon monitoring objectives); cacti are lumped into the shrub category for aerial cover.
- **Graminoids** - Grasses or grass-like plants.
- **Forb** - An herb, a flowering plant, other than grass.

Steps:

1. Be sure all four flags of your inner circle/small plot are in place.
2. Visualize the circle you are estimating for; walk around it and look up and down.
3. Imagine you are looking down from above at your inner circle.
4. Estimate the percentage of your circle covered by each item in the table. Break the circle down into quadrants and sum up the cover in each quadrant if needed. Consult with others if you are unsure.
5. To stay consistent, have the same person do the estimation for all plots in a project.

18.2 Estimating Ground Cover

Ground cover measurements include percent cover of plant basal (including cacti), bole, litter, bare soil, rock, and gravel, and **must total 100%**.

Ground cover (%) (1/100th acre plot) (total 100 %)						
Plant basal	Bole	Litter	Bare soil	Rock (>2.5in)	Gravel (< 2.5 in)	Total (%)
70	2	7	18	1	2	100

Photo by NMFWRI Field Crew

Terms:

- **Plant basal** - Area of the ground occupied by the base of the plant stem. Plant basal includes mosses, cactus, lichen, and cryptobiotic crust.
- **Bole** - Main trunk of tree or woody plant.
- **Litter** - Small dead plant material such as leaves, bark, and needles. For ground cover estimations, this also includes down woody debris (DWD) such as sticks and logs, and other non-living organic materials including ash.
- **Bare soil** - Exposed mineral soil.
- **Rock** - Material greater than or equal to 2.5 inches in diameter.
- **Gravel** - Material under 2.5 inches in diameter but larger than a grain of sand.

Steps:

1. For this estimation, imagine you cut off everything in your plot at less than an inch above the ground to estimate how the surface is covered.
2. Estimate the percentage of your circle covered by each item in the table. Sometimes it is easiest to divide your circle into quarters between the inner flags and PC. Remember that if something fills up an entire quarter, it would be 25%. It also may help to remember that 1% of your area is about the size of a large pizza.
3. To stay consistent, have the same person do the estimation for all plots in a project.
4. To begin with, estimate your plant basal area. This is basically the area where the plant stem intercepts the ground surface. So, for instance, if you estimated graminoids and forbs at a total of 83% in your

aerial cover table, you might expect the basal area to be less than this. This number does not include any part of the plant except what is right on the soil surface. The stems of cacti are included in basal area.

5. Next, do your bole estimation. A bole is the part of a woody stem (the main trunk) that goes into the ground. It doesn't include branches or twigs, and it doesn't include any pieces of wood that are not stuck into the ground. Cut stumps do count, however.

6. Your litter estimation will capture all needles, sticks, logs, loose pieces of dead grass, etc., that may be on your plot. Only include material that is in direct contact with the ground. For example, some logs may be partially in contact with the ground and partially suspended in the air.

7. Bare soil means an area is totally bare. Don't forget that gravel or pine needles are not bare soil.

8. Rock is a piece of solid mineral material ≥ 2.5 inches in diameter, while gravel is under 2.5 inches.

9. Use a calculator to check your total. Make sure your ground cover totals 100%.

18.3 Tallying Seedlings, Saplings, and Shrubs

Tree regeneration (seedlings and saplings) is measured on the nested 1/100th acre circular plot (11.78 ft. radius). The species, condition, and height class (>0-0.5 ft; >0.5-1.5 ft; >1.5-2.5 ft; >2.5-3.5 ft; >3.5-4.5 ft) are recorded for each **seedling** or sprout. **Saplings** (≥ 4.5 ft but <1.0 in or other breakpoint diameter) at diameter at breast height (DBH) are also recorded in this way. **Shrubs** are measured on the same nested subplot and species, condition, and height/diameter class are recorded for each stem just as with tree species; we typically record **cacti** as well, since they were considered "shrubs" in the aerial cover measurements. Other cutoffs may be used for height and diameter classes depending upon project and monitoring objectives.

USDA PLANTS (https://plants.usda.gov/) is the authority NMFWRI uses to determine the growth habit of a plant species. If there are multiple listed, use the most robust of the growth forms. For example, USDA PLANTS denotes alderleaf mountain mahogany (*Cercocarpus montanus*, CEMO2) to have a growth habit of a shrub or a tree. NMFWRI classifies this species as a tree.

Some other protocols consider vining plants, such as *Clematis columbiana* (CLCO2), to be shrubs. USDA PLANTS denotes this species to be a vine; therefore, it is not considered when tallying seedlings and saplings.

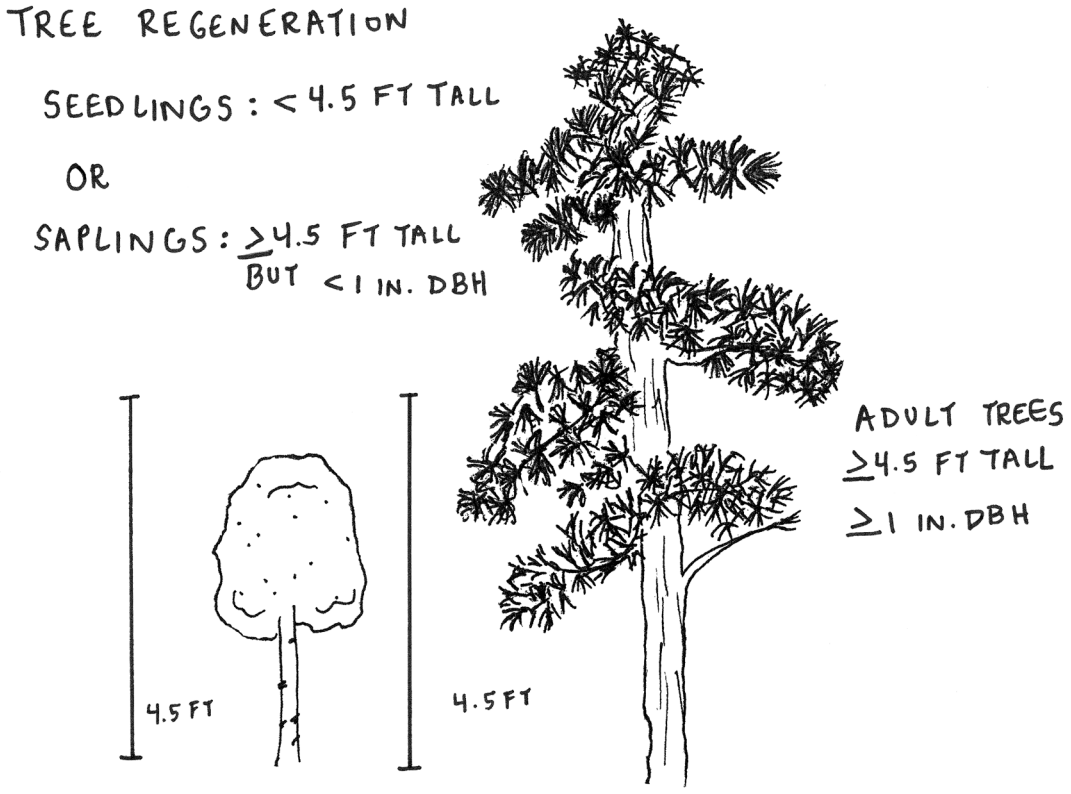


Diagram by Zoe Ahrens & Meredith Prentice



Above: Former crew logistics support Carmen Melendez counts seedlings of Woods' rose using a wooden dowel that is marked with the height cutoffs for seedling classes. Note pin flags marking conifer seedlings, and the transect tape. The transect tape is used to be certain which seedlings are in or out of the small plot, as well as to keep track of what has been counted circumferentially.
Photo by Kathryn Mahan

Right: Quaking aspen (*Populus tremuloides*) sprouts readily from its roots, especially in response to disturbance. These sprouts are often quite close together. *Source: https://www.fs.usda.gov/wildflowers/beauty/aspen/decline.shtml | "B. Campbell, Utah"*



Above: Young aspen suckers, appearing to originate from the charred aspen in the center of the photo. According to NMFWRI protocols, only two of these stems would be considered part of the same individual. Recall that stems must be visually connected, with no soil, duff, or litter between them. *Photo by Vincent Vispo*



Taking the Measurements:

1. It is helpful to measure these cutoffs on your body, just as you did to find 4.5 feet for DBH. This way you can simply walk up to a seedling and know which height category it falls in. Another option would be to make marks on sticks or hiking poles.

2. In dense areas, it also helps to break up the small plot into smaller sections, using transect tapes, and do one section at a time. Having a helper might also be a good idea.
    - Species such as conifers that are single-stemmed, sprout from seed, and may be inconspicuous, can be difficult to keep track of. It's suggested to mark these individuals with pin flags as you work. This also helps to avoid trampling these sensitive seedlings.

3. If unsure if a seedling, sapling, or shrub is in the inner circle, pull the tape out from plot center.

4. Be careful to look for sprouts or very young seedlings that may be hiding in the brush or litter layer. Don't forget that subshrub species such as *Mahonia repens*, which is low-growing and small, also count. So do any cacti found on the plot.

5. For shrubs and seedlings prone to multistem growth or resprouting (such as aspen), count stems individually if the ground or litter is visible between sprouts. The connected rootstock must be visible above ground in order to be counted together. Do not disturb soil or plant material to reveal connections. See the example below. List the status of each individual stem (live, dead, or sick).

6. For shrubs prone to creeping growth (i.e kinnikinnick or snowberry, which will produce roots laterally along their stems as they come into contact with soil), identify clumps with main rooting stems and count these as individuals. If a creeping stem is rooted again further from the main rooted stem, do not count it again. A single leaf sprout with no visible stem is not counted – one needs to see a stem to tally a plant.



Above: Kinnikinnick (*Arctostaphylos uva-ursi*) has a creeping growth habit that can amass to dense carpets of foliage. The stems will produce additional roots as the lateral shoots come into contact with soil. Only count a stem once when this occurs. *Source: SEINet, Botanical Research Institute of Texas, Philecology Herbarium*

7. Tally your seedlings by height class and condition, such as the example below. Multiple tally systems exist. Tally marks or dot and line tallies (aka Tukey tallies) may be used, but when the recording is complete, the final count should be recorded in Arabic numerals. This is to avoid confusion (for instance, 2 tally marks look similar to 11), and make data entry simpler. If tallies are present on the datasheet, circle the numerals of your final count. *(See an example of this in Supplement E.)*

8. Tally your saplings by diameter class. If you are only working with saplings under 1" (i.e. this is your breakpoint diameter), then you will only have one class of saplings. If there were no saplings found, place a line through the box. See the example below.

Species	Condition (Live, Dead, Sick)	Small Plot—Tree Regen & Shrubs				
		Height classes—Seedlings (<4.5', <1" dbh/drc)				
		> 0 - 0.5	> 0.5—1.5'	> 1.5' - 2.5'	>2.5 - 3.5	>3.5 - 4.5
Quga	D			25		
Quga	L			5		
Abco	D					1

Small Plot—Tree Regen & Shrubs		
Species	Condition (Live, Dead, Sick)	Saplings >4.5', < 1"

Photo by NMFWRI Field Crew

19.0 Measuring Trees

Information about trees is captured for every plot in overstory measurements. There are many rules and parameters for what to record and how to properly take tree measurements (i.e. DBH, height, live crown base height, etc.).

19.1 What Trees to Record

All **trees and snags** are measured within the 1/10th acre circular, fixed-area sample plot (37.24 ft. radius).

By Diameter:

Trees and snags are recorded in the macroplot if they have one stem greater than or equal to the established breakpoint diameter for the protocol. In the following examples, we will use a 1" breakpoint diameter. If there is more than one stem per tree or snag you will collect multiple diameters if they meet certain criteria. (See Figure 1, below.) See *19.33 Measuring Multi-Stem Trees* for more information on defining multi-stem trees and special circumstances you may encounter. First determine what stem has the largest diameter. This is considered your main stem.

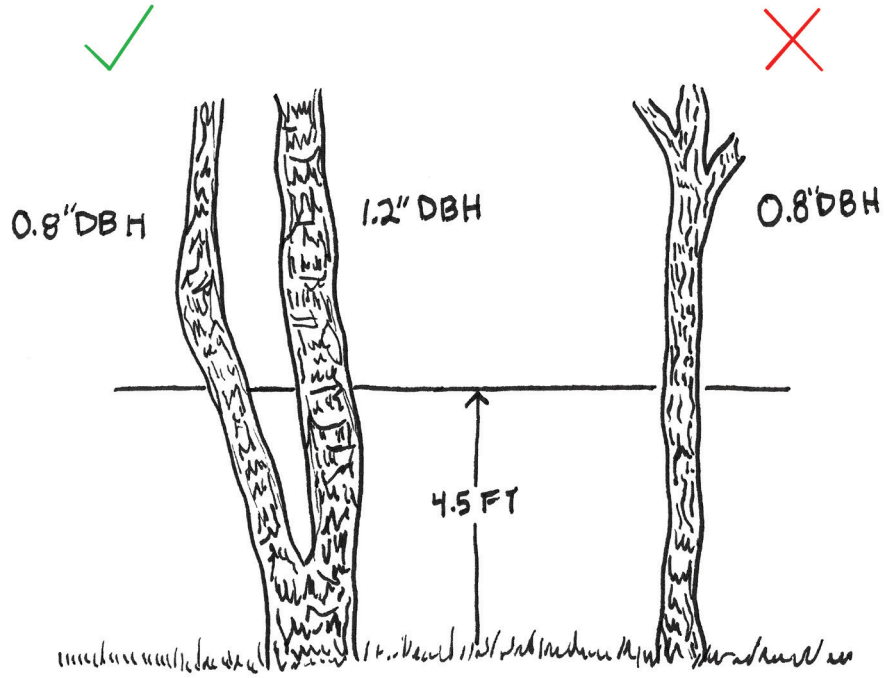


Figure 1. Record both stems of the tree on the left, as the main stem is over 1" DBH. Do not record the tree on the right as the diameter is below 1" DBH and it is not connected to any stems over 1". *Diagram by Raymundo Melendez and Meredith Prentice*

By Distance from PC:

All trees should be determined to be in or out of the plot by their horizontal distance from plot center (PC), not the slope distance. In a sloping plot, have a crew member help you hold the transect tape horizontally

while measuring tree distance from PC. For example, if the tree of interest is uphill from plot center you will have to raise the tape above DBH at plot center so that the tape is level when measuring if the tree is in. *See Ch. 19.24 Slope Corrections* for information on slope distance vs. horizontal distance.

Trees and snags are determined to be in or out of the plot by the location of the bole at DBH height (4.5 feet, Figure 2). A tree or snag rooted in the plot that leans out of the plot at DBH should not be recorded and vice versa.

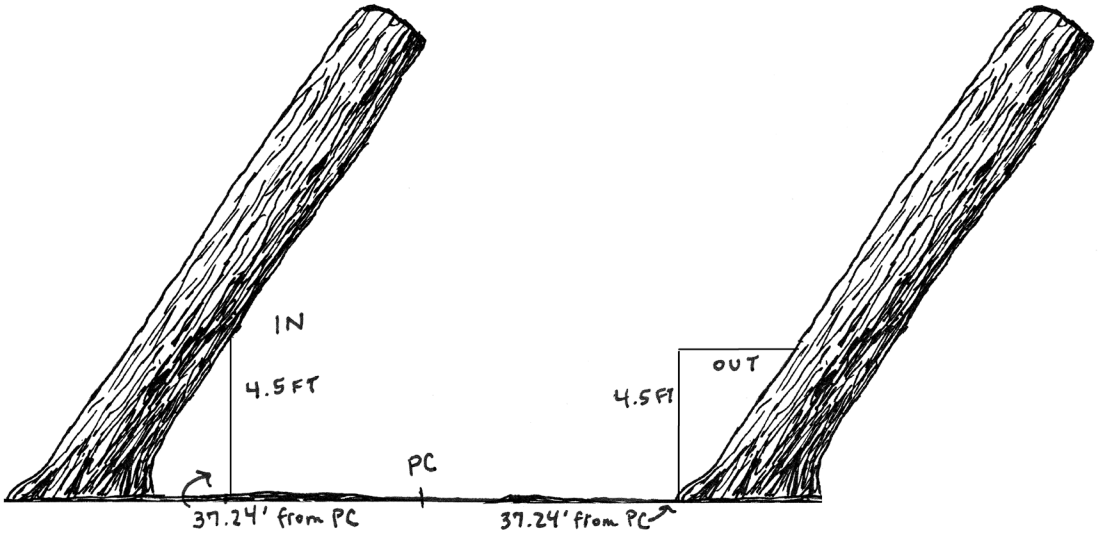


Figure 2. The tree on the left is rooted out of the plot, but leans into the plot at DBH height, and therefore should be recorded. The tree on the right is rooted in the plot, but leans out of the plot at DBH, and therefore should not be recorded. *Diagram by Zoe Ahrens*

By Angle:

Snags leaning at an angle greater than 45 degrees should not be recorded in the tree data, and instead will be captured in fuel measurements (Figure 3). Live or sick trees should be recorded regardless of angle (along with appropriate damage code/severity, see *Ch. 19.5*).

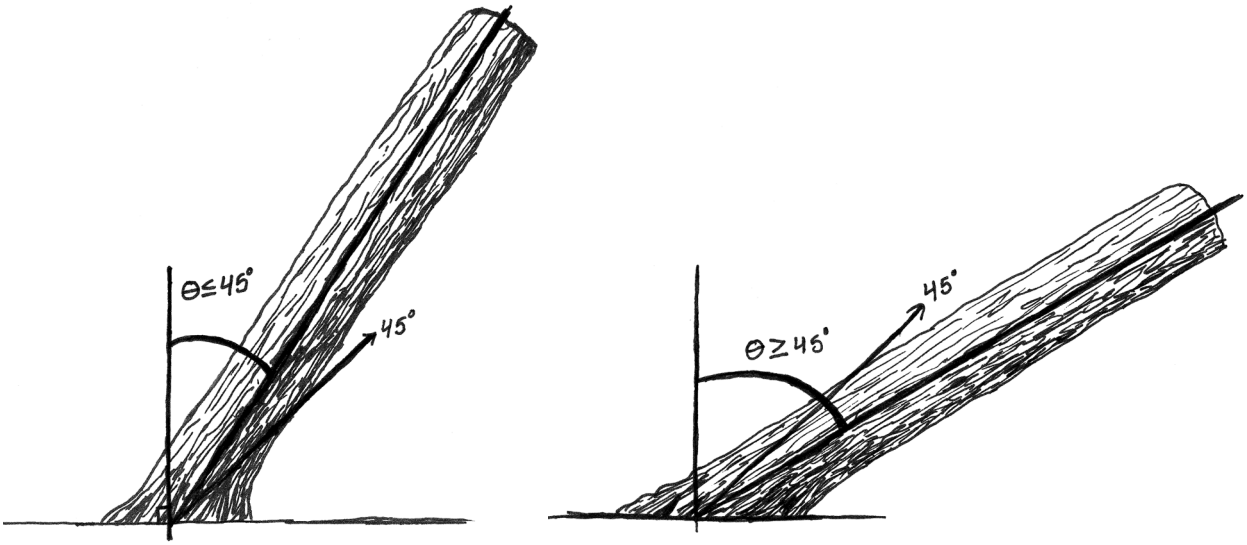


Figure 3. The snag on the left is leaning at an angle less than 45 degrees, and therefore should be recorded as a tree (with a lean noted as a damage code). The snag on the right is leaning at an angle greater than 45 degrees, and therefore should not be recorded as a tree, but instead be recorded in the fuel transect if applicable. *Diagram by Zoe Ahrens.*

19.11 Recording Trees

Trees are recorded using their USDA PLANTS code, a four-letter code defined by the first two letters of the genus and first two letters of the species name (e.g. PIPO, ABCO, PIFL, PIED, JUDE, JUSC, QUGA, etc) *See Ch. 6*. Trees are recorded starting from the north azimuth line and moving clockwise, like spokes of a wheel, from plot center. In dense stands, we find it helpful to flag the first tree measured to keep the crew oriented. If appropriate, this first tree may also serve as the witness tree. *See Ch. 19.13 Witness Trees for more details.*

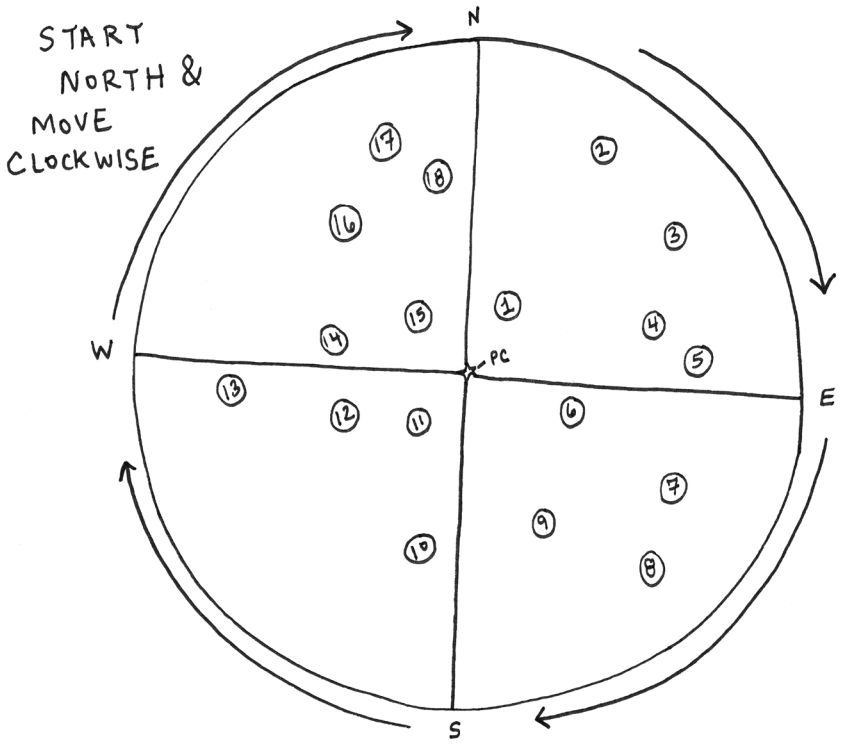


Diagram by Meredith Prentice

What Gets Recorded:

For each tree located within the plot collect the following:

- Species *See Ch. 9*
- Condition (live, dead, or sick) *See Ch. 19.5*
- DBH or DRC *See Ch. 19.3*
- Number of stems *See Ch. 19.33*
- Total height *See Ch. 19.2*
- Live crown base height *See Ch. 19.2*
- Snag decay class *See Ch. 19.4*
- Damage codes and severity ratings *See Ch. 19.5*
- Any comments—for information such as: details on damages/severities, estimation of how long the tree has been dead (i.e. needles gone, well-rotted, etc.) or anything unusual or interesting.

19.12 Tagging Trees

Tagging trees is recommended for long-term monitoring projects, with multiple site revisits. This practice increases consistency of measurements across time, allowing for tree growth analysis and tracking of tree-level pathology, mortality, and decay. Tagging reduces errors and time spent on quality control, by ensuring that all revisits are using the same tag numbers for each individual tree. After initial tag installation, this practice drastically reduces time spent on plot set-up on subsequent revisits.

That being said, the initial time and labor required to tag trees, especially in dense stands of trees, can be costly. Additionally, tagging requires field crews carry extra equipment, and your program is responsible for the cost and maintenance of extra materials.

Tag Numbers/Devices

During initial tagging, tag numbers should follow traditional numbering protocols as described in *Ch. 19.11 Recording Trees and Ch. 19.33 Measuring Multi-Stem Trees*. Trees should be tagged with consecutive numbers moving clockwise from north, with stems of the same tree starting with the same tag number. For example, if the 5th tree in the plot has four stems, tags will read: 5.1, 5.2, 5.3, 5.4.

Considerations for working in areas likely to be thinned or harvested for fuelwood:

- Use aluminum rather than stainless steel to protect loggers and logging equipment. If using stainless steel tags, make them as small as possible.
    - If working in juniper or other forest types where you find that aluminum nails do not work well, consider alternative materials and methods described below.
- Standard forest inventory methods call for trees to be tagged at their base for forest worker safety and buffering for tree growth. However, unlike placing nails at breast height, this does not provide a reliable re-measure marker for DBH.

Tag Installation

- Install tree tags at DBH (4.5'), so that DBH measurements can be taken consistently just above the nail at each recurring measurement (see left photo opposite page).
- Tags should be installed on the uphill side of the tree, where DBH is taken.
- If DBH is offset due to an abnormality, such as a burl, tag at whatever height the diameter was taken.
- Thread the tag through a long nail (at least 2.5-3") and hammer the nail until it is secure.
    - Leave at least 1.5" of nail exposed to allow for tree growth before the next measurement period. Angle the nail down slightly towards the ground to allow the tag to easily slide away from the tree as it grows. When remeasuring tagged trees, use the claw of a hammer





Above left: DBH should be measured just above the nail on tagged trees. **Above right:** A ponderosa pine tree with an aluminum tag and nail installed at 4.5′, angled downward and not flush with the tree to allow for growth. *Photos by Kathryn Mahan*

to loosen and extend the nail to allow for further growth before the next measurement period. (See above right photo)

- To minimize harm to trees, keep the nail in the sapwood. According to Bartlett Tree Experts Consulting, "at this depth, the tree can rapidly compartmentalize the [nail], causing no significant harm to the tree" (2023).

- Small trees are more vulnerable to damage from tagging methods. This may be especially meaningful for young aspen trees, which can be more vulnerable to subsequent infections. Consider using an alternative tagging method for trees less than 2" DBH. See below.
- Snags, especially burned snags, can be much harder than living trees. This, along with the potential instability of snags, make hammer and nail installation difficult and hazardous. This can be circumvented by alternative tagging methods. NMFWRI employs a nail gun for this purpose. This installation method results in a tag flush with the bole, therefore, it is not appropriate for living trees (see photo on next page). This also requires purchase of additional materials, as well as additional weight for a crew to carry to-and-from monitoring plots.

Equipment & Materials

NMFWRI Tagging Materials:

- Aluminum nails
  - Stainless steel nails are hazardous to loggers and logging equipment.
  - Copper nails are toxic to trees.

- Aluminum or stainless steel tags: Pre-numbered series of tags may be fine, but to reduce waste and ensure compatibility with plot inventories, NMFWRI uses a DYMO-brand Embossing Label Maker with aluminum tape.
- Hammer

Alternative Tagging Materials:

- Nail gun: see snag considerations above.
- 22-24 gauge wire: be extremely mindful not to girdle the tagged tree with this method – consider time between remeasures and tree growth rate when deciding on the size of wire loops.
- Lumber crayon: Typical advertisements for these products state that marks last 3-5 years. However, there are recorded instances of marks lasting for over 15 years. Longevity is likely highly correlated with local climate conditions and tree species.
    - Note this method works well on aspen, but the bark must first be wiped clear of the farinose powder usually found on these trees for writing to be visible.
- Other traditional timber marking methods such as a paint marker or aerosol paint
- RFID (Radio Frequency Identification) tags "involve a wireless, non-contact system that uses radio-frequency electromagnetic fields to transfer data from a tag for automatic identification and/or tracking. A typical RFID system consists of an interrogator, and a transponder." (Farve, 2014)



A dead gambel oak tagged with a nail gun. Note that this method is only appropriate for dead trees that will not consume their tags with growth. *Photo by Emily Yannayon*

General Workflow Recommendations

- Usually, NMFWRI field crews split themselves into a tagging or data collection roles. Crews can accomplish tree tagging and data collection all at once, in one rotation around the plot. However, this isn't always the most suitable method, and this depends on crew size, tree density, and other unique plot variations.
- For sparse stands:
    - Tree tagging/marking: 1-2 crew members start after accomplishing other tasks, such as collecting inner plot or fuels data.

- ◊ One person stands at Plot Center (PC), directing the "tagger" on which order to tag the trees.
- ◊ The other person, or the "tagger," will tag or mark trees in the designated order (*see Ch. 19.11 Recording Trees*). Since the tree tagger will be checking DBH for breakpoint diameter cutoffs, it may be appropriate for the person standing at PC to record these measurements simultaneously.

- Individual tree data collection: 3-4 crew members. It is most efficient to have two crew members taking tree measurements and one crew member recording data.

- For dense stands: The process is similar, but can be adjusted depending on crew size.
  - 4+ people: start two crew members on tree tagging immediately after plot set-up.
  - It can be extremely difficult to visually determine the correct order of trees on some dense stands. Some plots require laying out transect taps from PC to section off trees and determine the correct numerical order of trees.
  - With a 2- or 3-person crew, it may be best to save tagging and data collection until the end, once all crew members are available to tackle the task together.

Tagged Tree Remeasures

When remeasuring plots with tagged trees, it is imperative to bring a copy of previous data to the field to check that all previously tagged trees were either located, noted as fallen on the ground, or were plausibly removed by fire/thinning. Record fallen trees with visible tags in data notes, and enter a damage code that describes this condition *(See Ch. 19.5 Damage Codes and Statuses)*.

- 70000: Affected by human activities. Use this if a tagged tree was cut, and include notes. Record the true height of the stump.
- 99001/BROK: The tree broke to a height below 4.5'. Record the true height of the stump.
- GONE: Previously tagged tree is missing; its fate is unknown.
- UPROOT: Previously tagged tree has been completely uprooted, but crew was able to locate the bole.

Be sure to check for trees that have grown into the tree class since the last measurement and add a tag with the next tree number available for this plot. Verify what the next tree number should be for your specific plot based on the previous dataset. Include in the comments: notes about the azimuth and/or which tree tags this tree occurs between to minimize confusion on the next remeasure. For example, say a ponderosa pine was recorded as a sapling at the last visit, five years prior, because it had a DBH of 0.9". It is located on plot between trees 5 and 6, and now has a DBH of 1.3". There are a total of 12 previously tagged trees on plot, so this young ponderosa pine will be assigned tag 13. The comment field may read "located between trees 5 & 6."

If a tree is missing a tree tag, but is large enough to have been present in the previous measure, and is within the plot boundaries, tag the tree and make a note of this in the data so that additional quality control work can be done.

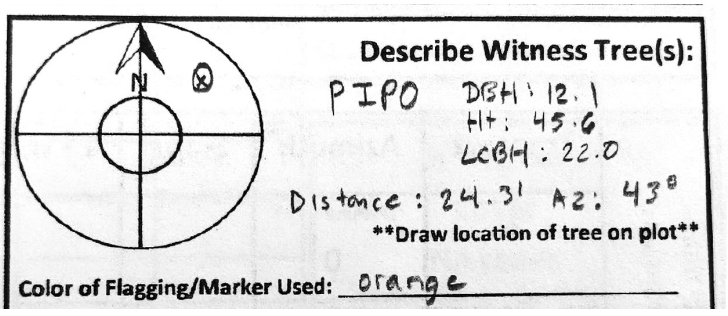
19.13 Witness Trees

On every plot, a witness tree is established to aid in locating plot center for future measurements. Witness trees should be close to the plot center, should be expected to survive any future thinning, fire, or other disturbances, and ideally have some notable visual characteristics (i.e., yellowbelly, forked top, etc.). Witness trees are double flagged, noted in the overstory tree data comments, and described in plot description. Measure and record the distance and azimuth of the witness tree from the plot center.

Observer/Recorder: CJM/MJP Project/Site/Plot: GU3_03 Griego Date: 4/22/2026 Plot Number: 03 Page 1 of 1

1/10th acre plot (37' 3" radius)

Tree Tag #	Species	Tree cond. (L, D, S)	DBH/DRC (add down arrow if DRC was taken)	# stems	Total Tree Ht	LiCrBHt	Damage 1	Severity 1	Damage 2	Severity 2	Char Ht	Scorch Ht	Comments (witness tree, etc.)
1	PIPO	L	14.6"	1	51.5'	22.4'					13.4'	24.7'	Witness tree, oozing sap
2	PIPO	L	1.1"	1	6.0'	1.5'					0.8'	5.5'	
3	PIPO	L	10.4"	1	46.7'	23.4'	99004	903			1.0'	—	3.1 U shaped fork
3	PIPO	L	13.5"	1	49.8'	24.5'	99004	903			1.0'	—	3.2 at 15'
4	PIPO	S	10.2"	1	43.2'	18.0'	41010	412	11000	906	8.0'	—	
5	QUGA	D	2.9"	1	9.0'	—					0.5'	—	Decay class 2
6	PIPO	L	11.2"	1	49.1'	29.3'					9.0'	30.3'	
7	QUGA	L	4.6"	2	18.2'	5.0'					1.1'	—	
8	QUGA	L	3.3"	2	10.8'	4.7'	99001	901			—	—	





Examples of witness tree flagging. *Photos by NMFWRI Field Crew*

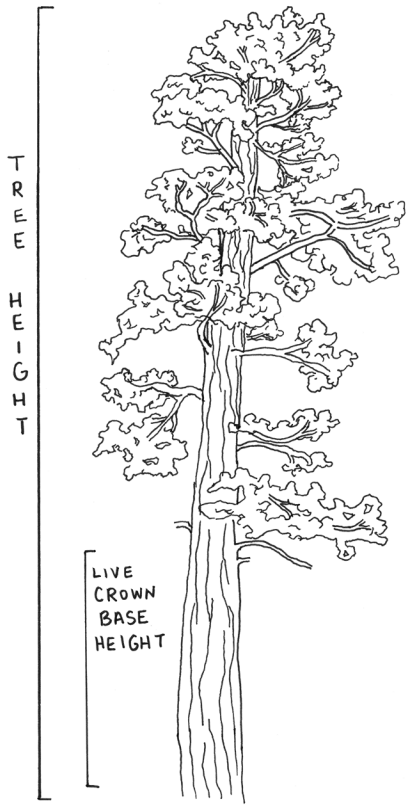
19.2 Tree Heights

The following sections explain how to take tree heights: the rules, tools, and methods we use.

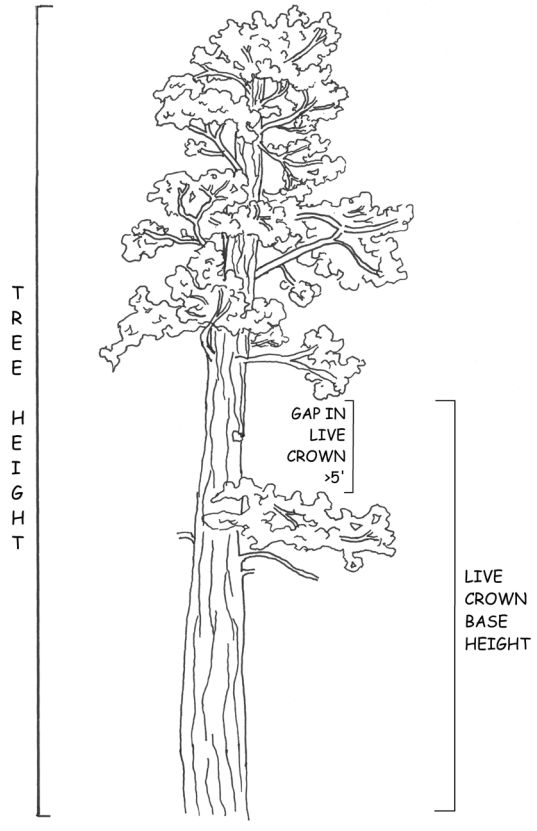
19.21 Rules for Measuring Tree Heights

Rules for Measurements

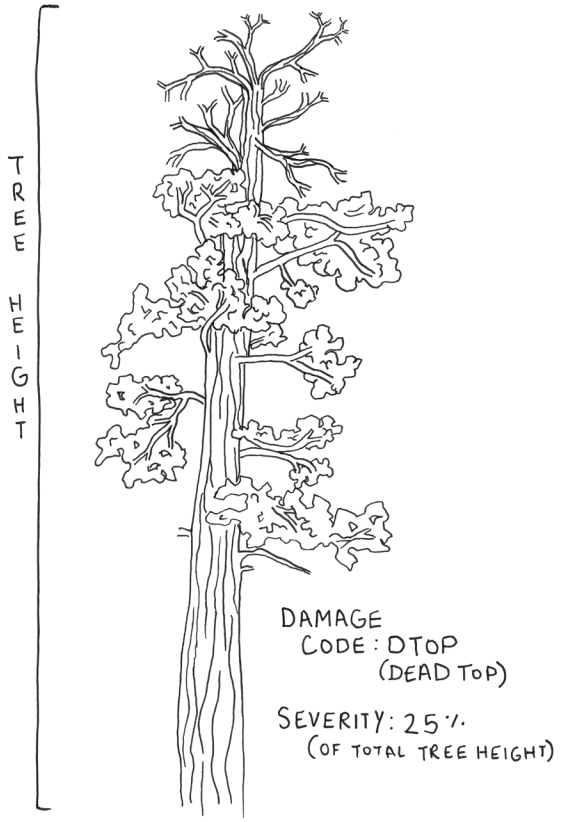
- *Tree Height:* Record height from ground to highest part of the tree. For multi-stem trees with a Diameter at Breast Height (DBH) for each stem, record individual heights for each stem.
- *Live Crown Base Height (LiCrBHt or LCBH):* Record the height from the ground to the start of continuous live foliage. If the lowest live branch whorl is more than 5ft lower on the bole than the next live whorl, do not include in your measure of LCBH (see Example 2 below). For multi-stem trees with a DBH for each stem, record individual LCBH for each stem.
- *Leaners:* Measure from ground to highest point, even though the tree would measure taller if it were standing up straight.(See Example 6).



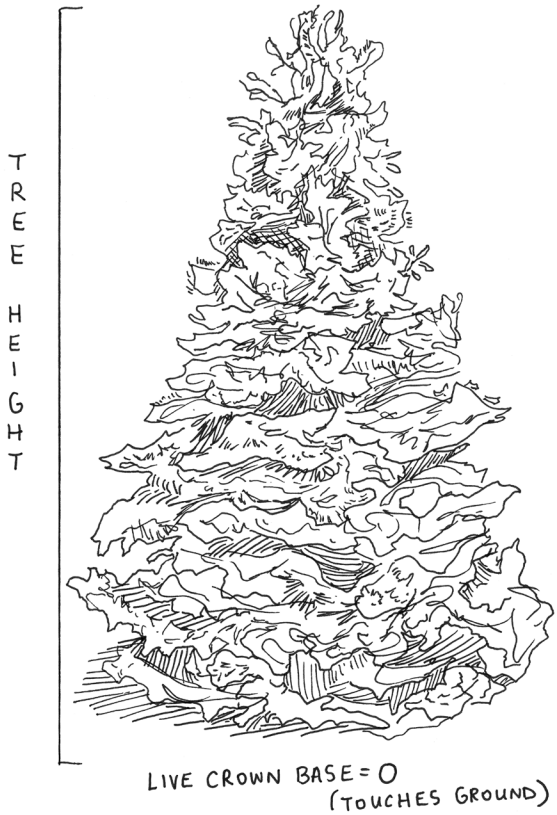
Example 1. Note that branch bends lower to ground a few feet out than it does where it connects to the tree. Use the distance from the ground to the lowest live foliage for your Live Crown Base Height measurement.
Diagram by Meredith Prentice



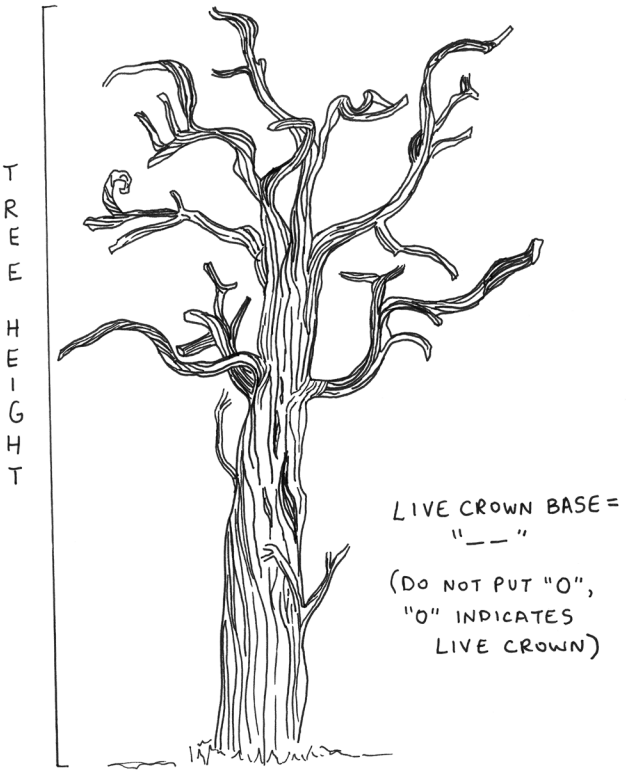
Example 2. The live crown of this tree is discontinuous – there is a low branch that is more than 5' lower than the rest of the crown. The height of the live crown begins where there is continuous foliage.
Diagram by Meredith Prentice, Alex Withnall



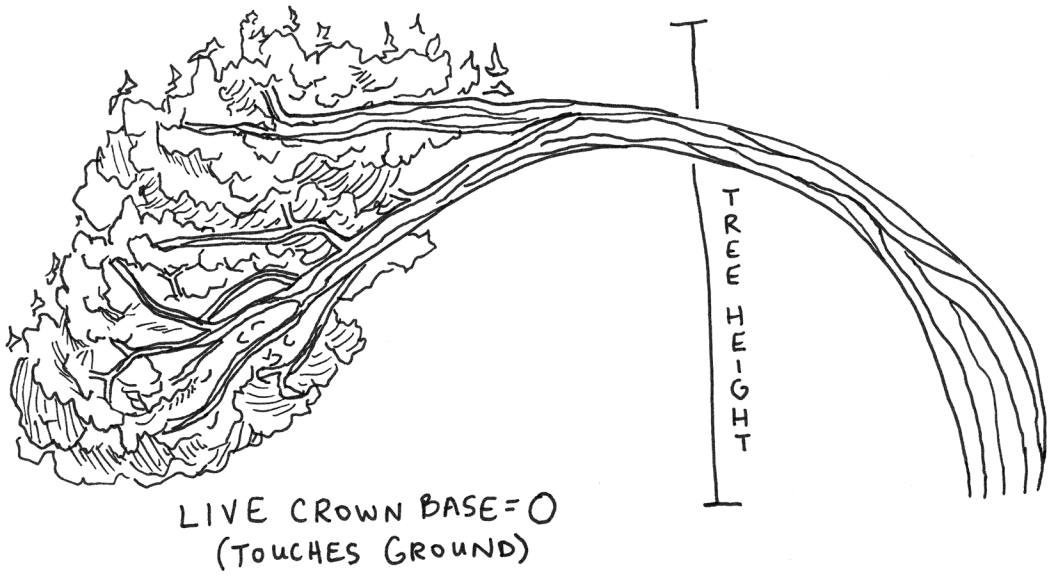
Example 3. The treetop is dead. However, for our Tree Height, we measure from the ground to the highest part of the tree. Remember to add a damage code and severity indicating the dead top.
Diagram by Meredith Prentice



Example 4. The live crown base height is 0, because the foliage touches the ground.
Diagram by Meredith Prentice



Example 5. The tree is dead (a snag). For tree height, measure from the ground to the highest part of the tree. The tree's condition will be a "D" for dead. The Live Crown Base Height should be left blank for electronic data entry or recorded as "---" on the datasheet. Do NOT enter or record a "0" because a value of "0" indicates the crown is present and touching the ground. For absent live crown, always leave the field blank or use dashes.
Diagram by Meredith Prentice



Example 6. The tree is bent over. For tree height, measure from the ground to the highest part of the tree. Since the crown touches the ground, record a live crown base height of 0. Also record a damage code and severity to indicate a lean.
Diagram by Meredith Prentice

19.22 Measuring Tree Heights Using a Hypsometer

A hypsometer (or rangefinder) is a tool that uses a laser to calculate height/distance of an object. In the case of this protocol, hypsometers are used to measure the height and live crown base height of trees. Laser hypsometers can make taking tree heights fast work, as they typically handle slope distance adjustment calculations for you and do not require you to stand a chain away from your target. Make sure the hypsometer your crew is using is accurate; many models operate outside the recommended +/- 0.5ft precision standard for height. One model NMFWRI crews use is a TruPulse 360R.

Instructions:

1. Power on the hypsometer and ensure it has been recently calibrated.
2. Ensure the hypsometer is in the correct mode. Tree height measurements will be taken with a "3-point height routine", which uses a horizonal distance, a base angle, and a top angle to calculate heights.
3. Stand at least 30 feet away from the tree you are measuring, until you are able to clearly see the top. Taller trees will need to be measured from a further distance.

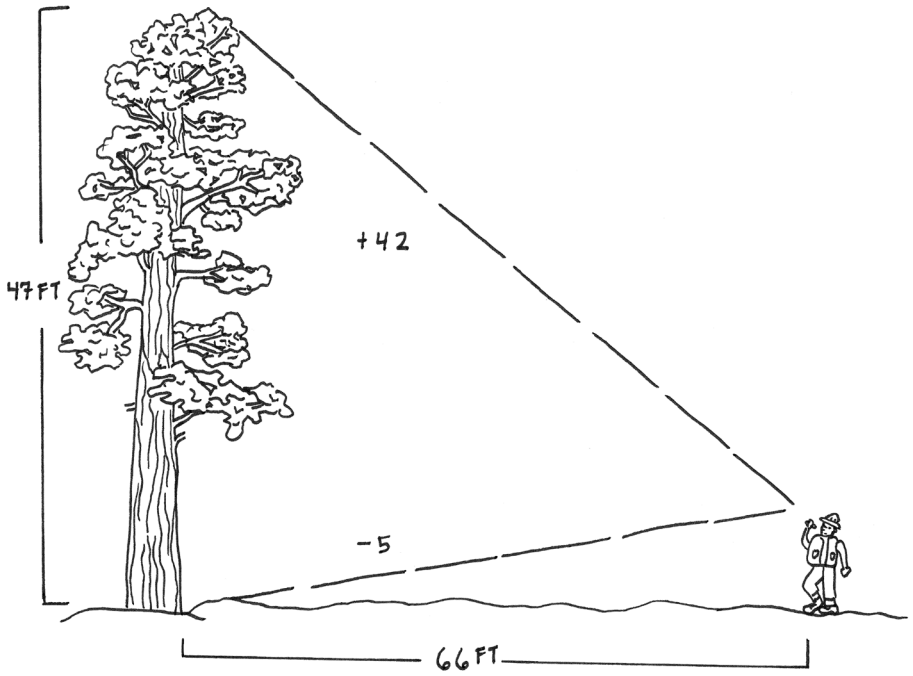


Figure 1. Technician uses hypsometer to shoot 1) the distance to the bole of the tree, 2) the angle to the base of the tree, and 3) the angle to the top of the tree.
Diagram by Raymundo Melendez and Meredith Prentice

4. Look through the eyepiece and aim the crosshairs at eye level on the bole of the tree you are measuring. Press the button to activate the laser. You should see a distance value appear. If this number is unreasonably high or low, the bole may not have been hit by the laser.
5. Direct the crosshairs to the base of the tree. Activate the laser. An angle reading will appear.
6. Direct the crosshairs to the very top of the tree. Activate the laser. An angle reading will appear, followed by a height measurement for the tree.

Hypsometer Tips and Troubleshooting

- The hypsometer is not usable in rain or heavy fog, and can be challenging to use in windy conditions.
- Do not point the hypsometer into direct sunlight.
- Similarly to a compass, hypsometers are sensitive to magnetic materials and magnetic fields. Keep pin flags, nails, computers, spare batteries, etc. away from the hypsometer while in use.
- If height measurements seem incorrect, check:
    - Is the hypsometer in the correct mode for a 3-point height routine?
    - Is the measurement starting with horizontal distance?
    - Is the laser able to hit the bole of the tree, or is it hitting other vegetation in the way?
    - Is the user standing too close to see the true top of the tree?
    - Is the hypsometer low on battery?
    - Is the hypsometer properly calibrated? Calibration is key to keeping these sensitive instruments functioning as they should. See user manual for information on calibrating.

19.23 Measuring Tree Heights Using a 1:66 Clinometer

A clinometer is an instrument commonly used in forestry to measure slope and heights. The instructions that follow are based on a Suunto clinometer.

Instructions:

1. Confirm your clinometer has a 1:66 scale. For 1:66 scale clinometers, % slope is on the left side and the 1:66 scale used to measure tree heights is on the right. If uncertain about which side of the scale to read, you can tilt your head back while looking through the clinometer and reference the unit labels at the bottom of the scale.

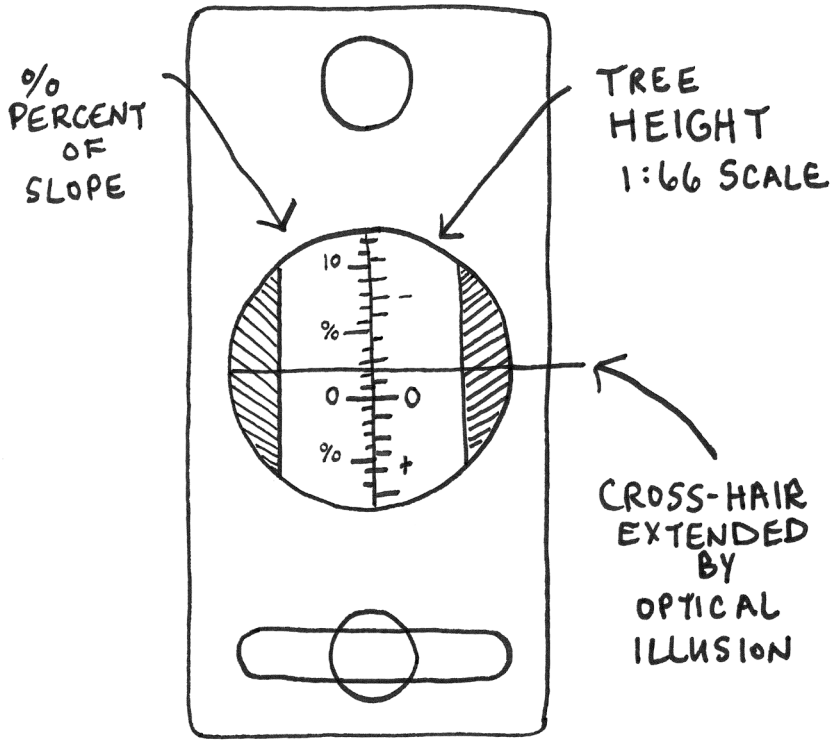


Figure 1. Use the scale on the left if you are measuring percent slope, and the scale on the right if you are measuring tree height.
Diagram by Raymundo Melendez and Meredith Prentice

2. Determine the tree you want to measure and move 66 feet away.
   You can either measure with a DBH tape (nail stuck in tree), or pace off a chain.

3. From 66 feet away, sight through the glass eyepiece of the clinometer with both eyes open to the very top of the tree. Remember to point the red dot at the tree; the dot represents your line of sight. Record this number and its sign (+ or -).

4. From exactly the same location, and while trying not to move your head, tilt the clinometer downward until the red dot is lined up with the base of the tree. Sight through the clinometer with both eyes open to the base. Record this number and its sign (+ or -).

5. You will now use the equation "top" – "bottom" to get tree heights. For example,
   "top" – "bottom" = 42 – (-5) = 42 + 5 = 47 ft tall
   If you are on a very steep slope and both numbers are negative, stick to the formula.
   (Obviously a tree cannot be -15 feet tall!) Remember, always: "top" - "bottom."

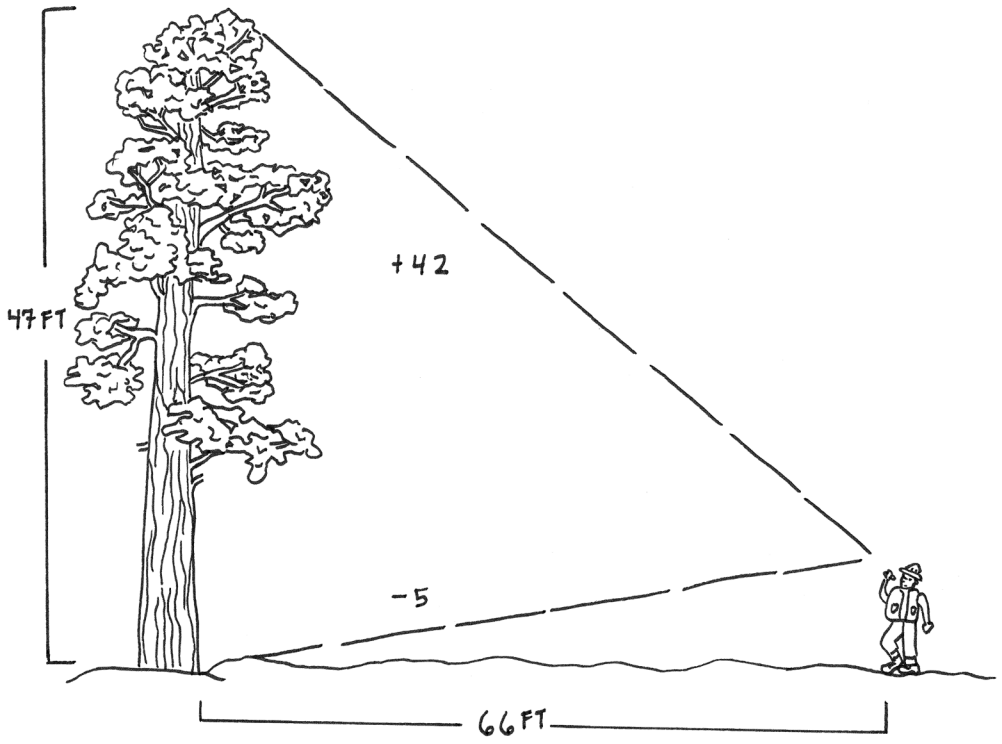


Figure 2. Example of using a clinometer to calculate tree height.
Diagram by Raymundo Melendez and Meredith Prentice

Chains

1 chain = 66 feet
80 chains = 1 mile
You can determine how many paces (one pace = two steps) your chain is by laying out a tape and counting the paces required to reach 66 ft. When determining your chain pace number, always take multiple (at least three) and average them.

How does the terrain change your pace?

- Shorter in tall vegetation than in short vegetation.
- Shorter walking uphill than walking downhill.

- Shorter walking on sloping ground than on flat ground.
- Shorter walking on soft ground than on hard ground.
- Level vs uphill vs downhill?
  - In general, when slope is >5%, your "level" pacing is no longer accurate.

Common sources of error when using the clinometer:

- The distance between you and the tree was not perfectly measured and/or paced. This is a common challenge in very dense or very steep areas. Remember that slope distance is not always the same as horizontal distance. *See Ch. 19.24 Slope Corrections* for using a clinometer to measure tree heights in areas with slope.
- The tree is taller than 66 feet, which means using a 1:66 scale is less accurate.
  - Ideally the trees you measure should be less than 66 feet, or you should consider alternate scales. For example, you could use the percent (left) side of the clinometer if you were standing 100 feet away, since this is a 1:100 scale.
- Arithmetic errors, such as mixing up signs.
- You cannot see the top and bottom of the tree and are estimating. This is a common challenge in very dense areas.
  - Try moving to another area.
  - Do not move between sighting the top of the tree and the base.

19.24 Slope Corrections

When using clinometers, it is sometimes necessary to correct the difference between slope distance and horizontal distance. Slope distance is always longer than horizontal distance. When possible, always try to walk the contour so that you are not going uphill or downhill from the tree you are measuring. Another option for slope correction would be to calculate the slope distance needed to reach one chain (66 ft) in horizontal distance.

Use this formula to calculate slope distance:

Slope distance = horizontal distance/cos α *(slope in degrees)*

To convert your measured percent slope (grade) to degrees α, reference the conversion table provided on the back of your clinometer. Do not use percent slope in this equation. Horizontal distance will always equal 66 ft.

Grade	Angle	Grade	Angle	Grade	Angle	Grade	Angle	Grade	Angle
2%	1.15	22%	12.41	42%	22.78	62%	31.80	82%	39.35
4%	2.29	24%	13.50	44%	23.75	64%	32.62	84%	40.03
6%	3.43	26%	14.57	46%	24.70	66%	33.42	86%	40.70
8%	4.57	28%	15.64	48%	25.64	68%	34.22	88%	41.35
10%	5.71	30%	16.70	50%	26.57	70%	34.99	90%	41.99
12%	6.84	32%	17.74	52%	27.47	72%	35.75	92%	42.61
14%	7.97	34%	18.78	54%	28.37	74%	36.50	94%	43.23
16%	9.09	36%	19.80	56%	29.25	76%	37.23	96%	43.83
18%	10.20	38%	20.81	58%	30.11	78%	37.95	98%	44.42
20%	11.31	40%	21.80	60%	30.96	80%	38.66	100%	45.00

Table 1. Slope conversion table for percent grade and degrees.

Example: A crew comes across a tree that can only be accurately and safely measured from uphill. First, slope percent is taken at 40%. Using a conversion table, this converts to 21.8 degrees. Using the formula below, a slope distance of 71.3 ft is calculated.

Slope distance = horizontal distance/cos α *(slope in degrees)*
Slope distance = 66 ft/ cos(21.8)
Slope distance = 71.3

Using a tape, the crew pulls out to 71.3 ft uphill (in the direction the slope was taken) from the bole of tree across the ground. Standing here, the technician is at a distance of 66 horizontal feet. To measure multiple trees occurring across the same slope, the technician could count and remember the number of paces required to reach 71.3 ft uphill and use this as a chain pacing for this plot.

Important Takeaways:

On this 40% slope, taping out 66 ft parallel to the slope does not result in a run (horizontal distance) of 66 ft. Measuring tree heights from a slope distance of 66 ft would result in an error of nearly 10 percent. Always calculate slope correction before using a clinometer to measure tree heights on a slope. Alternatively, pacing along the contour and maintaining the same elevation as the tree, or using a hypsometer, removes the need for this calculation.

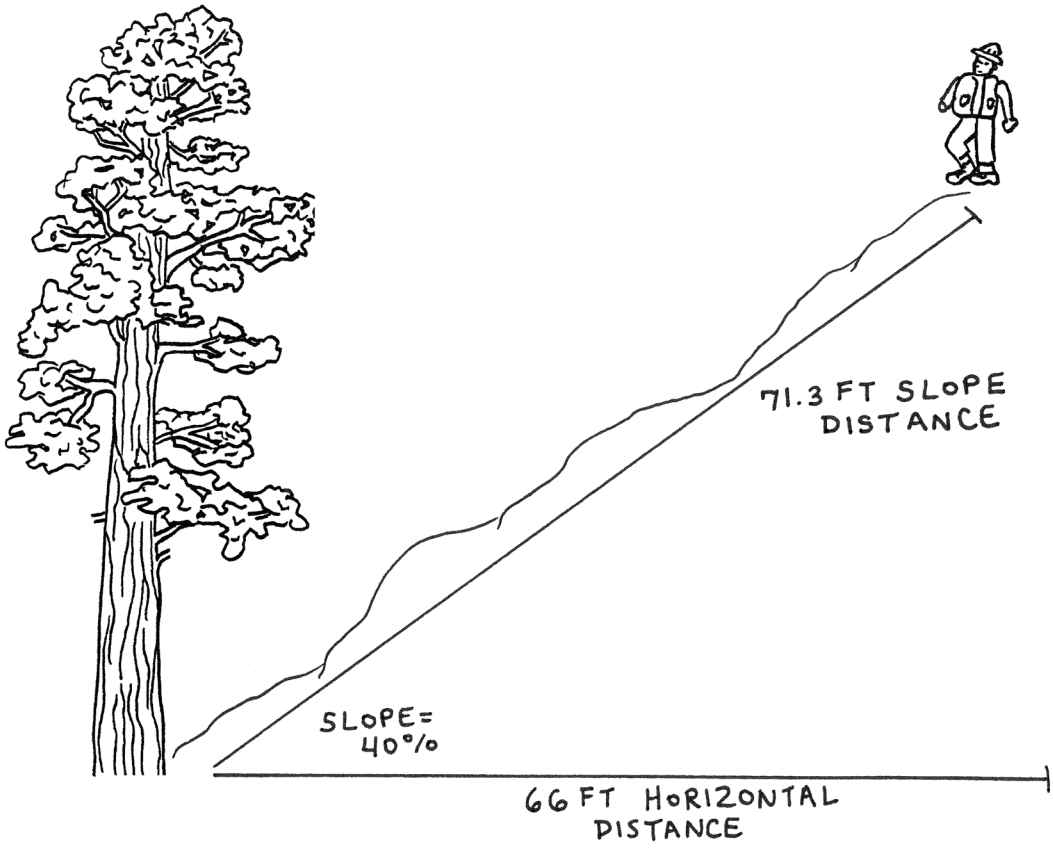


Figure 1. Example of the difference between slope distance and horizontal distance.
Diagram by Raymundo Melendez, Meredith Prentice, and Carolina May

19.3 Tree Diameters

The following chapters outline methods of taking tree diameters: measuring a diameter at breast height, diameter at root crown, and how to handle multiple stems.

19.31 Rules for Measuring DBH

DBH, or diameter at breast height, is a standard measurement in forestry. This measurement is the diameter of a tree at 4.5 feet. It is important to measure all trees at the same height, to the extent possible, to keep forest inventory consistent. Diameter tapes (aka Logger's Tape or D-tape) are adjusted by the value of *pi* to provide the diameter of the tree.

The Basics:

To measure DBH, first determine where 4.5 ft is on yourself. You will use this spot to determine where to take DBH on a tree. Remembering this position saves lots of time when you are taking DBH on numerous trees. If trees were previously tagged, measure DBH just above the nail to maintain consistency between measurements.

DBH is always taken on the uphill/ upslope side of the tree being measured. Make sure the tape is level and straight around the bole. Tapes can easily get twisted around the bole and the DBH can get inflated by a branch or burl. For larger DBH trees get someone to help you wrap the tape around the tree to ensure it is straight and taut. To read the tape, look at the number where the zero crosses. Round to the nearest 0.1 inch, as the diameter tape is in tenths. For example, the tape in the picture below on the right reads 45.7 inches.



Measure DBH on yourself. *Photo by Kathryn Mahan*



Diameter of 45.7 inches. *Photo by Carolina May*

Reminders & Special Situations

1. Always measure from the uphill side. See Figure 1, below.

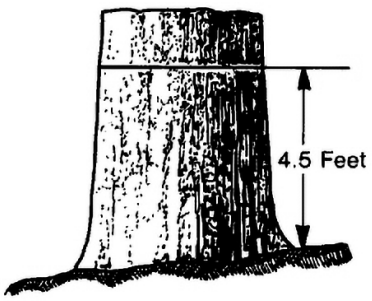


Figure 1. Measure from the uphill side.

*** Sketches from Forest Service Washington*
FSH 2409.12 – Timber Cruising Handbook

2. Always measure height to DBH vertically, not diagonally with the lean of the tree. If a tree leans so severely that it does not reach 4.5 feet vertically, it will not be measured as a tree in our protocol.

3. Once DBH height is established, measure diameter perpendicularly to the lean of the tree. See Figure 2, below.

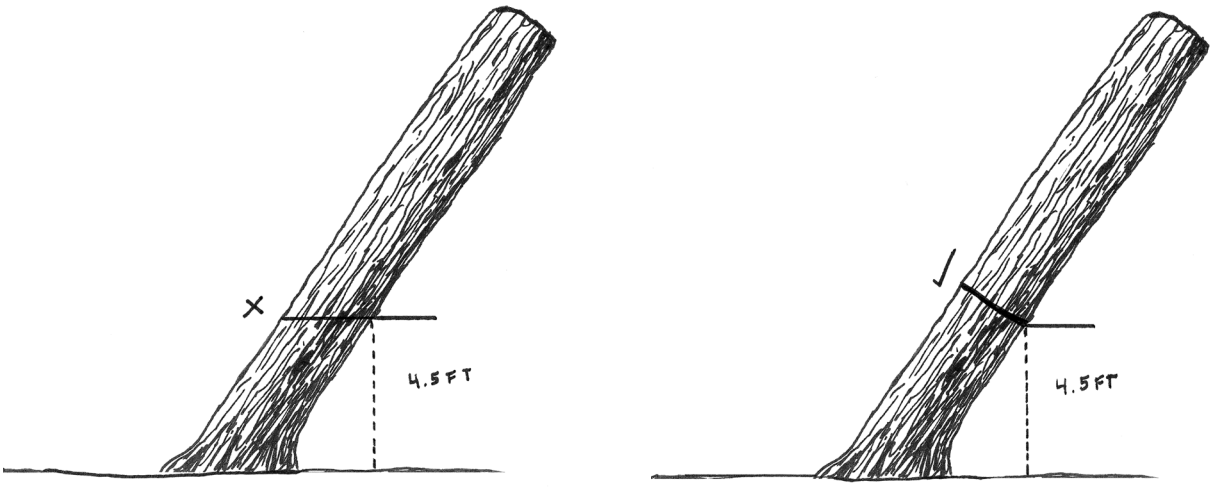


Figure 2. The tree on the left is not measured perpendicular to the lean of the tree, and therefore is measured incorrectly, overestimating the diameter. The tree on the right depicts the correct orientation of the DBH tape on a leaning tree.
Diagram by Zoe Ahrens

4. If the tree is forked below 4.5 feet but is determined to have common rootstock and a unified crown, record as a single tree with two stems. If unsure, apply the ankle-height rule. If there is light between the two stems at ankle height, record as two trees. If there is no light at the ankle, record as one tree with two stems and two DBH's with the same tag number. See Figure 3 below and *19.33 Measuring Multi-Stem Trees* for more information.

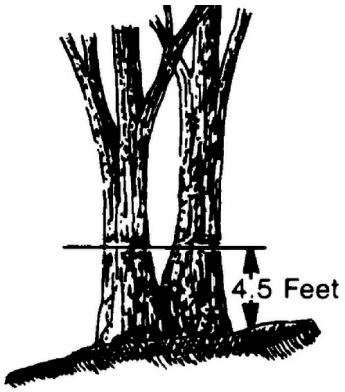


Figure 3. Fork occurs below 4.5 feet.

5. If a tree is forked above 4.5 feet, but the stems are together at DBH, measure it as one tree with one stem, and record one DBH. Record in the comments that the tree is forked and at what height, and what percentage of the total length of the bole is forked. See Figure 4.

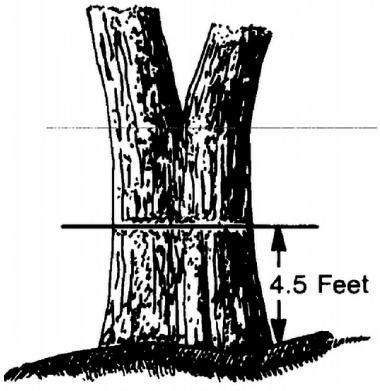


Figure 4. Fork occurs above 4.5 feet.

6. Abnormalities: For abnormalities, measure at the first place **above** 4.5 feet where the tree appears normal. Be sure you note where you measured DBH in the comments field on the datasheets. See Figure 5.

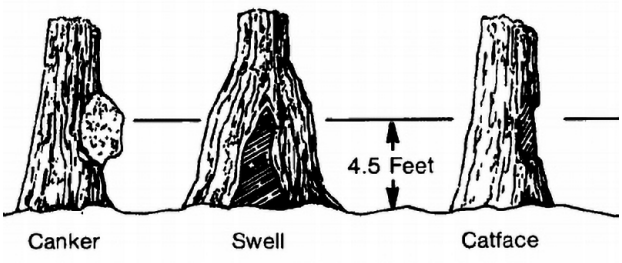


Figure 5. Abnormalities at 4.5 feet.

7. For trees growing on objects, measure at 4.5 feet from the root crown, not the forest floor. See Figure 6.

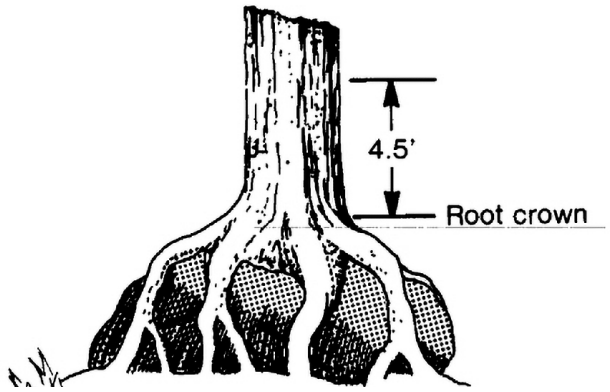


Figure 6. Measuring DBH on Trees Growing on Objects.

8. If DBH is at A, measure normally. If DBH is at B, measure just above on broken portion where tree appears normal, i.e. at C. Make note of the tree abnormality in the comments, but as the bole is vertical at the original DBH height, the 45 degree lean cutoff for dead trees is not a concern here. See Figure 7.

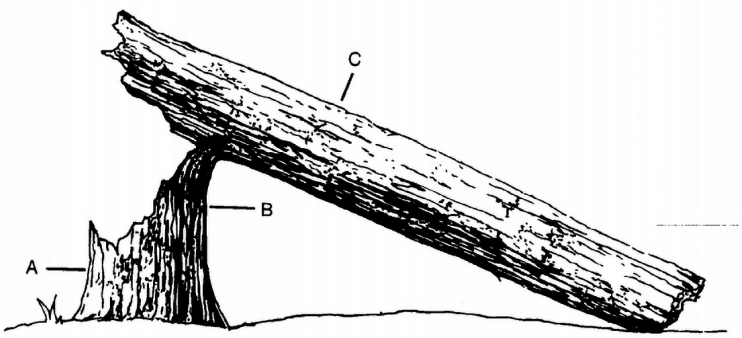


Figure 7. Measuring DBH on Broken Trees.

9. Unable to measure above: If it is not possible to measure at or above breast height because of the vertical extent of the irregularity, or because the top of the tree is missing entirely, then adjust the DBH measurement to better reflect the diameter of a regular bole: if 50% or more of the circumference of the bole is intact, reconstruct the diameter at DBH. If less of the bole is intact, record the measurement of the remaining bole and explain in the comments.

In Summary:

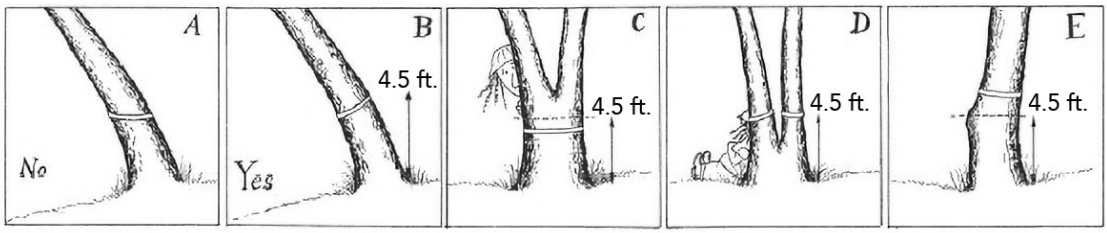


Figure 8. DBH measurements. A) Diameter tape is not perpendicular to the tree stem. B) Correct way to measure tree diameter is with tape perpendicular to tree stem. C) If the tree splits above breast height measure tree diameter below any swell caused by the separation. D) If the tree splits below breast height measure as two trees. E) Measure the most representative diameter above or below any deformity.

19.32 Rules for When and How to Measure at DRC

When to take DRC measurements:

Measuring diameter of root collar (DRC) may be used for multi-stemmed trees in some situations. Measuring diameter at breast height (DBH) generally provides a better estimate of tree size than measuring DRC. Use DRC only in scenarios where taking DBH measurements of individual stems for all trees on a plot would be very prohibitive. Using the Chojnacky and Rogers conversions, DRC should only be taken on junipers, oaks, and piñon pine.

See the below flowchart for when DRC can be measured:

Flow Chart for DRC

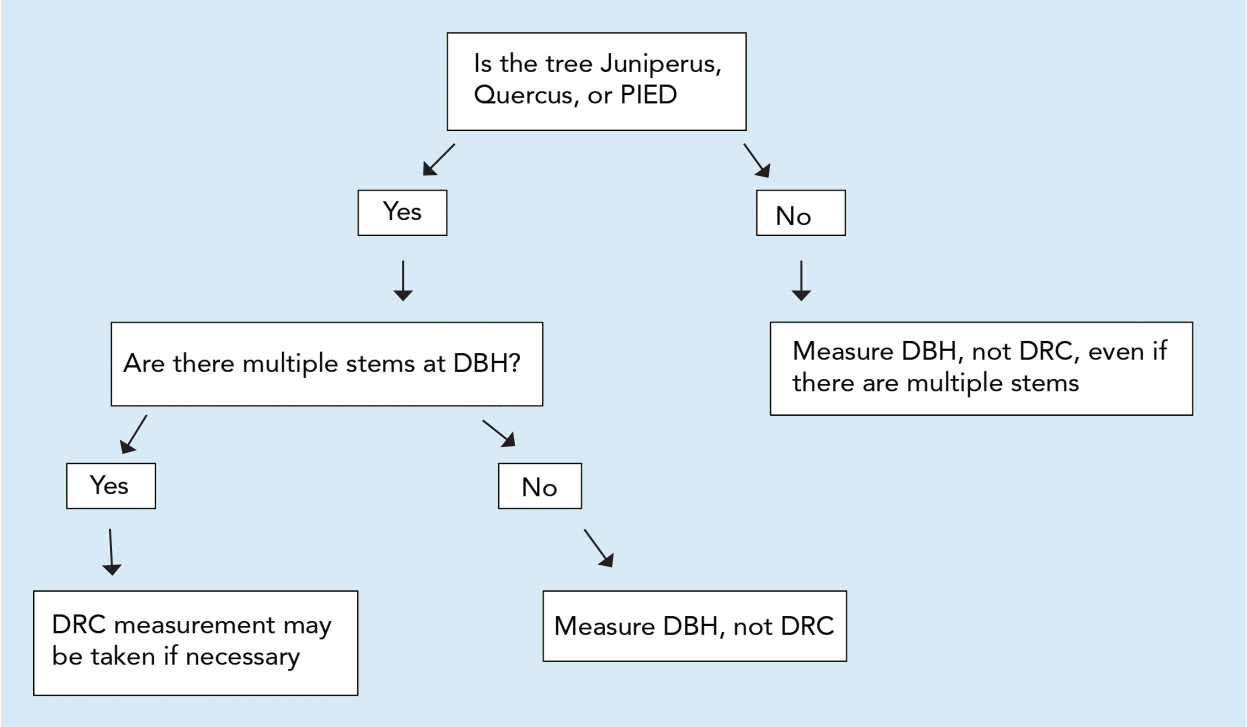


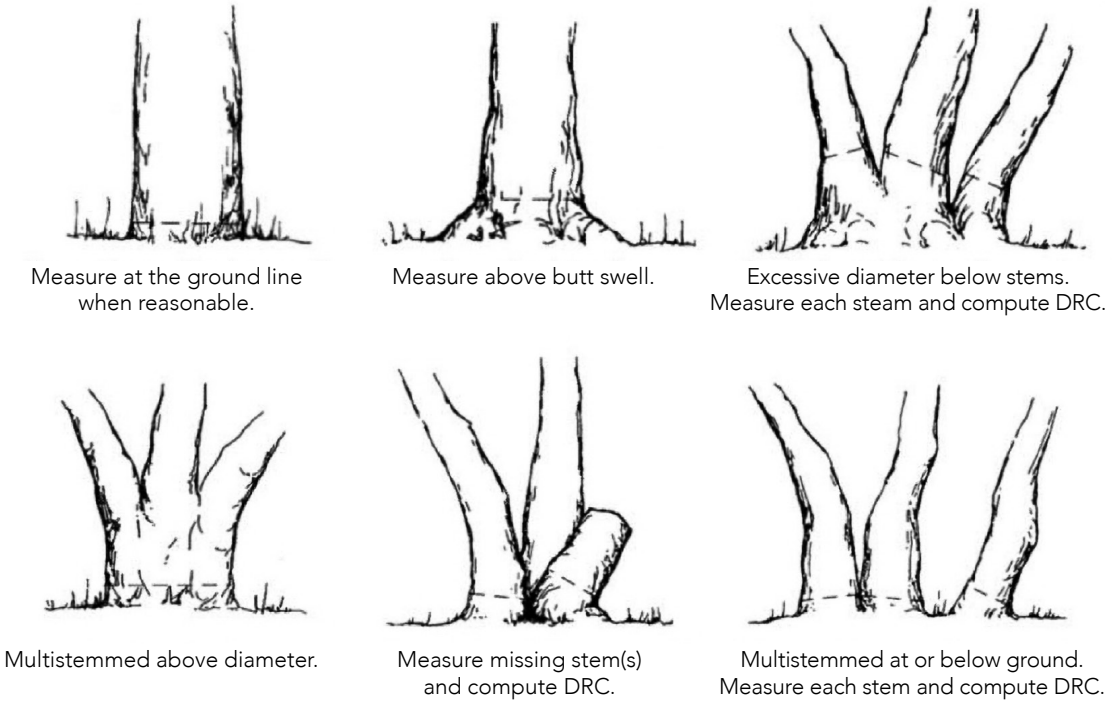
Figure 1. Flow Chart for determining whether it is more appropriate to measure DRC or DBH on a tree.

How to take DRC Measurements:

1. Remove loose material on the ground, but DO NOT remove mineral soil. Watch for snakes when reaching under trees.

2. Measure at ground line when ***reasonable***.

3. Measure DRC just above any swells present.
4. Must be measured in a location that is a good representation of the volume in the stems.
5. If excessive diameter exists at the base, measure the stems occurring above the base individually.
6. If a tree has unified crown and common rootstock, but has several separate stem clumps with soil in between, take multiple DRC measurements for the same tree tag number. Do not include any soil or open spaces at ground level between stems in a single measurement.
7. If using tree tags, tag at the height DRC is taken. If re-measuring tagged trees, take DRC just above nail.



Credit: Bonfantine, K., J. Zebrowski, and Egan, A. (2011). *Guidelines and protocols for monitoring riparian forest restoration projects.* New Mexico Forest and Watershed Restoration Institute. https://nmfwri.org/wp-content/uploads/2020/07/Riparian_forest_monitoring_guidelines-1.pdf

Figure 2. Guidelines for taking DRC.

DRC/DBH conversion protocols:

DRC values must be converted to equivalent diameter DBH values for analysis. Table 2 below from Chojnacky & Rogers, 1999 shows established DRC to DBH conversion equations. These conversions are done after field data collection, and both the original DRC value and converted DBH value are reported.

Table 2 Parameters and equation[1] to convert drc to dbh for pinyon pine, Utah juniper, and Gambel oak

Measurement	Parameter estimates							No. of	Fit statistics	
units	β_0	β_1	β_2	β_3	β_4	β_5	β_6	trees	R^2	CV (%)
English	–2.6843	1.0222	0.7433	0.7469	–0.0399	1.2244	–0.0689	224	0.98	13
Metric	–6.8180	1.0222	1.8879	1.8971	–0.0399	3.1100	–0.0689	224	0.98	13

[1] Conversion equation:

$$dbh = \beta_0 + \beta_1 drc + \beta_2 stm + \beta_3 Pied + \beta_4 drc_P + \beta_5 Quga + \beta_6 drc_Q$$

where

dbh = diameter at 1.3m above groundline of all live and dead stems 2.5 cm and larger (cm or in.)

drc = diameter at root collar above groundline of all live and dead stems 2.5 cm and larger (cm or in.)

$$diameter = \sqrt{\sum_{i=1}^{n} d_i^2}$$

n = number of live and dead stems at dbh or drc with diameter 2.5 cm or larger

d_i = stem diameter (cm or in.)

stm = 1 for trees with one stem (n = 1) at drc, 0 otherwise

Pied = 1 for pinyon pine species, 0 otherwise

drc_P = drc for pinyon pine species, 0 otherwise

Quga = 1 for Gambel oak species, 0 otherwise

drc_Q = drc for Gambel oak species, 0 otherwise

Figure 3. DRC to DBH conversion formulas from Chojnacky and Rogers, 1999.

19.33 Measuring Multi-Stem Trees

What defines a single multi-stem tree vs. multiple trees?

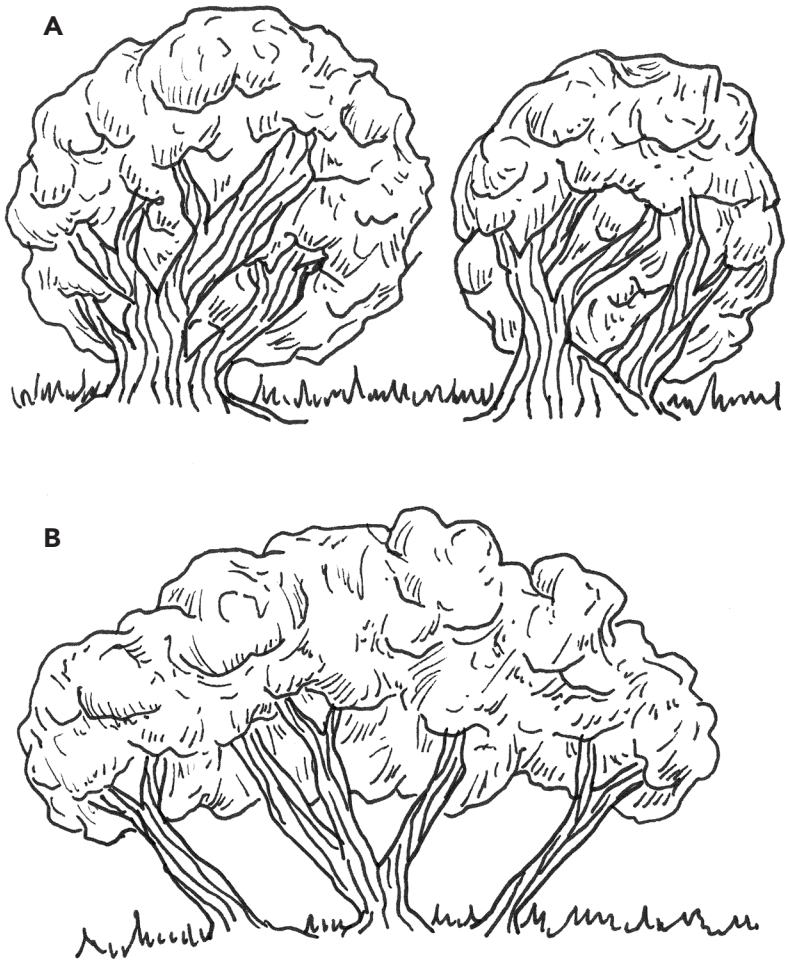


Figure 1A shows two trees with distinct crowns, which should be recorded as separate trees. **Figure 1B** shows a single tree with a unified crown and assumed common rootstock, which should be recorded as a single tree with multiple stems.
Diagram by Raymundo Melendez and Meredith Prentice

Definitions:

**Unified crown: S*tems come together to form a contiguous crown, often teardrop or vase shaped, without large gaps. See Figure 1B, above.

***Common rootstock:* A **rootstock** is part of a plant, often an underground part, from which new above-ground growth can be produced. Stems which are of the same species and originate from the same place in the ground can be considered to have common rootstock. See Figure 1B, above.

Flow Chart for Defining Multi-Stem Trees

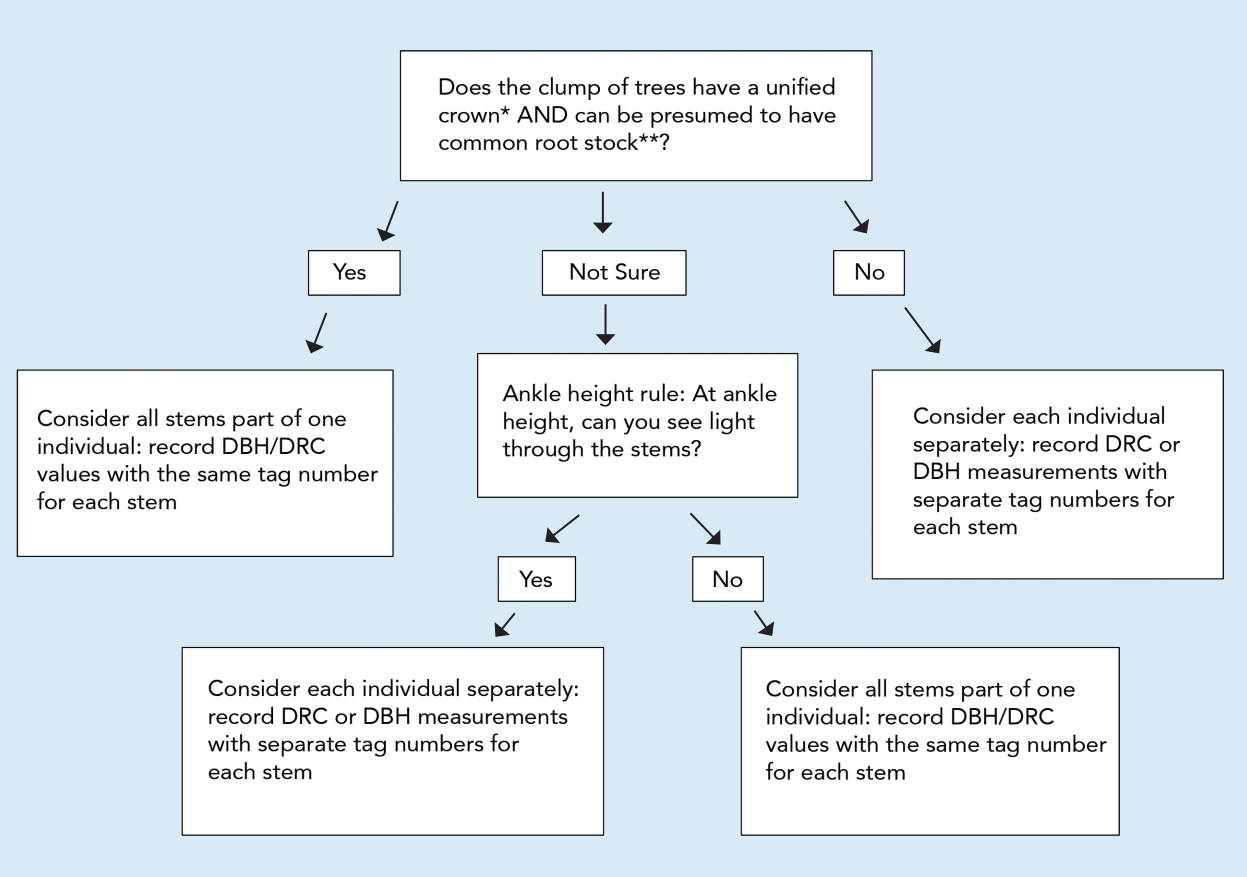


Figure 2. Flow Chart for Defining Multi-Stem Trees.

Special Circumstances

STUMP SPROUTS

Stump sprouts originate between ground level and 4.5 ft on the boles of trees that have died or been cut. Stump sprouts are handled the same as trees with multiple stems. For multi-stemmed woodland species, treat all new sprouts as part of the same new tree. (Use 99000 code, see *Ch. 19.5*)

EXTREMELY HIGH DENSITY

In cases of extremely high density multi-stemmed species (e.g. 40-stemmed Rocky Mountain maple with many tiny stems below the breakpoint diameter, see photo on opposite page), it may be possible to use a stem-level diameter cutoff instead of a tree-level for efficiency. In such cases, this protocol should be implemented consistently for a given species across an entire project. The counts of live and dead stems recorded should reflect all stems present (including those below breakpoint) that are part of the individual. In no case should part of an individual tree or shrub be recorded as Tree and another part of the same individual as Sapling or Seedling; if any part of the individual qualifies as a Tree, the rest of the stems will be counted with that Tree. Leave detailed explanations in the comments.



Rocky Mountain maple (*Acer glabrum*) can have dozens of stems attributed to one individual, many of which are likely below breakpoint diameter.
Source: SEINet, Dan Beckman

What is a stem vs a branch?

- A stem generally grows in an upright position and contributes to the main structural support of a tree crown.
- When working with bushy tree species with multiple curved limbs and no clear main upright stems, (e.g. some oneseed juniper) consider applying a rule such as this: when determining whether something is a stem or a branch, stems captured need to be at least 1/3 the diameter of the main stem AND must branch out from the main stem at an angle of 45 degrees or less. Note that this rule MAY NOT be used broadly to exclude smaller stems, only in cases where it is unclear whether something is a stem or a branch.

Other recommendations for measuring trees with multiple stems

- Record each stem of a multi-stem tree as a separate line of data with an individual diameter, height, live crown base height, and condition status (live, dead, or sick). Multi-stem trees should start with the same tag number followed by a decimal and its respective consecutive number. Certain databases may not allow you to record tag numbers with decimals. In these cases indicate the specific tag numbers in the comment form. We recommend this method over the square-of-squares method for multi-stem trees. More information on the square-of-squares method can be found in Chojnacky and Rogers (1999). See example below.
    - Protocols that use the square-of-squares or other methods for quantifying multi-stem trees require that a tree's condition should be listed as sick if dead stems outnumber live stems. This rule does not apply to NMFWRI protocols. Individual living stems within a multi-stem tree do not need to be recorded as sick when they are outnumbered by dead stems. The condition of each is assessed individually.

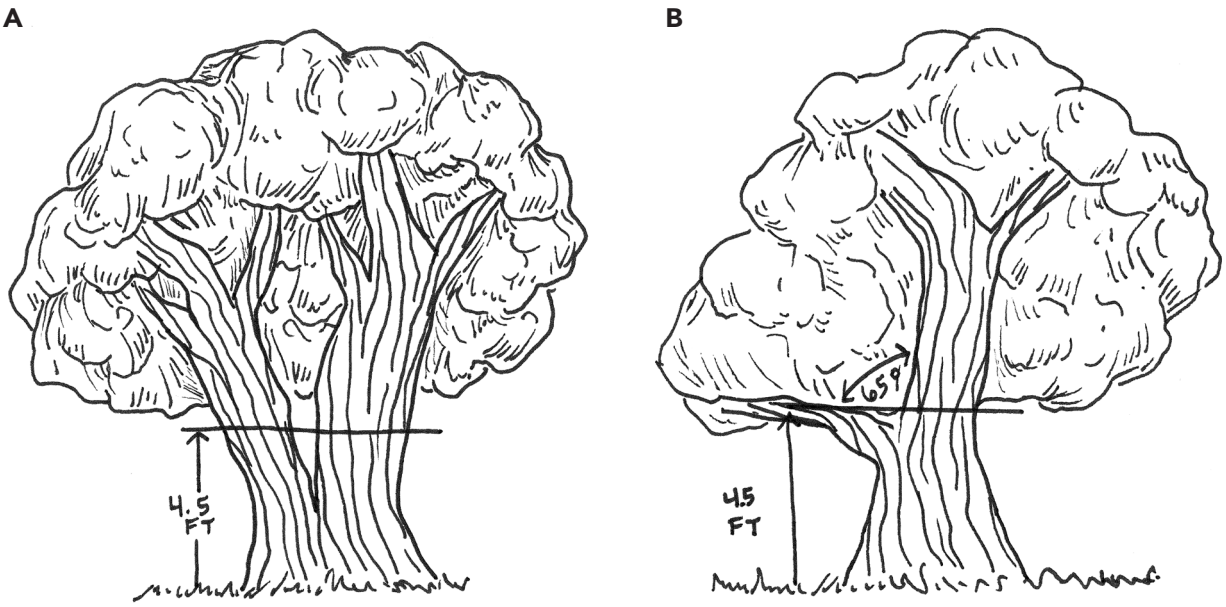


Figure 2A shows a tree with two stems at DBH. **Figure 2B** shows a single stem tree with a branch.
Diagram by Raymundo Melendez and Meredith Prentice

- Maintain the same clockwise progression within the multi-stemmed tree that is maintained in the plot as a whole while recording stems.
- Onion-shaped junipers are common, and getting past the outer branches of a large specimen to measure the stems at the root collar can be a challenge. The crew member doing this must wear eye protection and work gloves as protection from sharp branch stubs and watch for rattlesnakes.
- Multi-stemmed oaks are more often defined using the ankle-height rule, as common root stock and unified crown can be hard to determine due to the size of colonies and the depth of litter.
- If trees were previously tagged, maintain the same stem definitions of previous crew for consistency over time. However, check for any new stems that may have grown into measurable size since the last measurement period and add tags as needed.

Tree #	Species	Tree cond. (L, D, S)	DBH (in)	No. stems	Total Tree Ht	LiCrBHt
1.1	JUMO	L	12.1	3	17.5	2.5
1.2	JUMO	L	8.6	3	9.6	3.1
1.3	JUMO	D	5.7	3	8.8	—
2.1	PIED	L	3.6	2	9.5	4.0
2.2	PIED	L	4.5	2	8.5	2.2

Figure 3. Sample record of multi-stemmed trees. *Photo by NMFWRI Field Crew*

19.4 Snag Decay Classes

A dead tree, that which has no sign of living tissue, is also known as a snag. NMFWRI records the decay class of snags, assigned as a numerical category from one to five. Decay class is determined through several factors, including remaining branches/twigs, bark integrity, and wood decay. Collecting data on decay class can inform many aspects of forest management. The decay class of a snag can help characterize habitat potential for species such as cavity-nesting birds, or woodpeckers that feed on the insects in a decaying tree. A range of decay classes in a forest is ideal, as each stage of decay provides habitat for several life forms. Decay classes can also provide insight into the progression of decay post-disturbance, such as after a wildfire or disease outbreak. This then can help to project the future of the surface fuels in a forest. In the case of resource assessment, snag

Snag Decay Classes

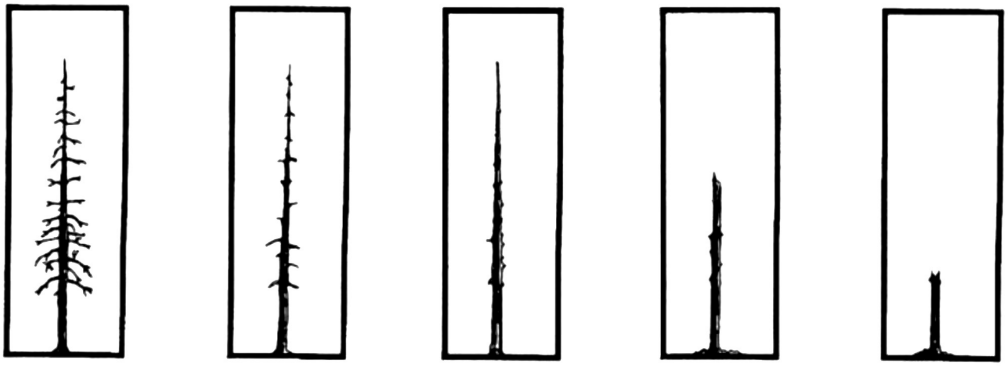


Diagram *by Kathryn Mahan, Alex Withnall. Version 1/29/2026*

Snag Decay Classes

Code	Bark	Heartwood Decay	Sapwood Decay	Limbs	Top Breakage	Bole Form	Time Since Death
1*	Tight, intact	Minor	None to incipient	Mostly present	May be present	Intact	≤5 years
2	50% loose or missing^	None to advanced	None to incipient	Small limbs missing	May be present	Intact	>5 years^
3	75% missing^	Incipient to advanced^	None to 25%^	Few remain	Approx. 1/3	Mostly intact	>5 years^
4	75% missing^	Incipient to advanced^	25%+^	Few remain	Approx. 1/3 to 1/2	Losing form, soft^	>5 years^
5	75% missing^	Advanced to crumbly ^	50%+^ advanced	Absent	Approx. 1/2+	Form mostly lost	>5 years^

**Implies resent mortality, within the last 5 years.*
^Decay may progress differently in burnt snags, especially with high burn severity.

decay class also informs the harvest potential of snags, especially in the case of large tree die-off events. In turn, it also informs decisions regarding workforce safety and hazard mitigation.

Decay class one is reserved for trees that have died recently, within the past five years. These snags often have needles or leaves remaining on their branches, and/or have most of their twigs and branches remaining. Active decay is limited. Decay class five is the furthest progression of decay. Snags have lost most of their height, bark, and branches. In addition, the structural integrity of the wood is poor; the wood is crumbly and falling from the bole.

Please note that the characteristics for decay classes (previous page) are not mutually exclusive: decay occurs continuously, not necessarily in neat stages. In addition, there are environmental factors that affect the way decay proceeds, such as local climate. For example, a tree that died within the past two years has most of its twigs, branches, and bark remaining. A large wind event passes through and breaks the snag at the approximate midpoint of its bole. What decay class should one assign? This is, in part, determined by the ultimate goal of collecting decay class data: this event may improve the habitat suitability for an endangered species, but may decrease the amount of marketable timber in an area. Use your best judgement and weigh characteristics against the purpose of the project.

Assigning decay class in burned snags is often more complex than with unburned snags due to the destructive function of fire. In addition, the effects of fire can alter the process of decay: the heat of fire removes moisture, which is a critical component of decay. Char also possesses some antifungal and antimicrobial properties. As a result, the rules described above will vary in application. Some considerations:

- A snag in a high severity burn area was hollowed out by wildfire, has no branches or bark left, is missing three-quarters of its previous height, but the mortality occurred in the past 6 months. In this example the snag would be recorded as a class five, despite not having been dead for over five years.
- Limbs and top breakage are good indicators of class in both burned and unburned snags.
- Bark and bole form are also important indicators in burned snags, but the missing bark and bole may have burned away rather than rotted.
- Heartwood decay, sapwood decay, and time since death are categories that will likely be poor indicators in burned snags, particularly in areas that burned with high fire severity.
- Use your best judgement when assigning decay class to burned snags. There are many variables that can make determining class difficult, so choose the decay class that matches most closely with the greatest number of categories.

The following pages show photographic examples for all snag decay classes, burned and unburned.



Class 1 Unburned. All *photos by NMFWRI Field Crew unless otherwise marked.*

CLASS 1



Class 1 Unburned



Class 1 Unburned



Class 1 Burned

Code	Bark	Heartwood Decay	Sapwood Decay	Limbs	Top Breakage	Bole Form	Time Since Death
1*	Tight, intact	Minor	None to incipient	Mostly present	May be present	Intact	≤5 years
2	50% loose or missing^	None to advanced	None to incipient	Small limbs missing	May be present	Intact	>5 years^

**Implies resent mortality, within the last 5 years.*
^Decay may progress differently in burnt snags, especially with high burn severity.

CLASS 2



Class 2 Unburned



Class 2 Burned



Class 2 Burned

CLASS 3

Code	Bark	Heartwood Decay	Sapwood Decay	Limbs	Top Breakage	Bole Form	Time Since Death
3	75% missing^	Incipient to advanced^	None to 25%^	Few remain	Approx. 1/3	Mostly intact	>5 years^

^Decay may progress differently in burnt snags, especially with high burn severity.



Photo right, Class 3 Unburned



Class 3 Burned



Class 3 Burned



Class 3 Burned

CLASS 4

Code	Bark	Heartwood Decay	Sapwood Decay	Limbs	Top Breakage	Bole Form	Time Since Death
4	75% missing^	Incipient to advanced^	25%+^	Few remain	Approx. 1/3 to 1/2	Losing form, soft^	>5 years^

^Decay may progress differently in burnt snags, especially with high burn severity.

Photos right and far right, Class 4 Unburned



Class 4 Burned







Class 4 Burned

CLASS 5

Code	Bark	Heartwood Decay	Sapwood Decay	Limbs	Top Breakage	Bole Form	Time Since Death
5	75% missing^	Advanced to crumbly ^	50%+^ advanced	Absent	Approx. 1/2+	Form mostly lost	>5 years^

^Decay may progress differently in burnt snags, especially with high burn severity.

Photos this page by Kathryn Mahan except where noted.



Class 5 Unburned



Class 5 Unburned



Class 5 Unburned



Class 5 Burned



Class 5 Burned, *Photo by NMFWRI Field Crew*



Class 5 Burned

19.5 Damage Codes and Statuses

Status:

Status denotes whether the trees, shrubs, saplings, or seedlings are live, dead, or sick.

Live (L):

Tree or shrub has green foliage, green or wet cambium when cut, and is healthy, with no severe damage or significant disease. Some dead stems or branches may be present, but there are more live stems than dead stems. If burned, the tree has greater than 30% live canopy remaining.

Dead (D):

Tree has no green foliage or sign of living tissue. Branches and twigs snap with no flexibility and do not have a green or wet cambium when cut. For *Quercus spp.* where the main stem is dead with resprouts from roots, record the status as dead and record "sprouts at base" in the comments. Damages to dead trees such as insect or bird damage are part of the natural process of snag decay. For this reason, NMFWRI does not report insect or bird damage on snags, unless said damage is expected to be the cause of the tree's mortality. These damages can inform the advancement of tree decay, but a better indicator is snag decay classes (*see chapter 19.4*).

Sick (S):

In general, sick trees have extensive biotic or abiotic damages that will ultimately cause death within 5-10 years (FIREMON). Designation of sick status is ultimately subjective as it may vary by management objectives, site conditions, and crew expertise with specific damage agents. For instance, in our practice, because research shows that most trees with less than 30% live crown remaining unscorched following fire are more likely to die than survive, we designate all these trees as sick when recording data immediately post-fire. Note that damage codes and severity should be recorded on any tree with damage agents present, even if the tree is not marked as sick. It is critical that any tree designated as sick must also have supporting documentation such as damage codes, severity, and any relevant comments recorded. For our reports, we find it more useful to analyze and report by damage agent/severity across growing stock (live + sick trees considered together) vs dead trees, because of the subjectivity of defining sick trees.

Damage Code Systems

Damage codes are used to record signs of illness, injury, and abnormalities in overstory trees. These codes can be entered directly into FFI or written into the comments of the tree data sheet.

NOTE: All damage codes should also be recorded with a severity measure (minor/severe or % damage).

Multiple code systems are available to record damage. We will cover and provide references for two of the most common systems. The table below includes common damages and how they are represented by each system. Where damage equivalencies exist between the two systems, codes are displayed side by side. In cases where no equivalencies exist, "---" will be displayed.

Letter-based system

The letter-based system, used by the National Park Service, uses 4-letter abbreviations to represent various damage codes. This system is easy to use for those new to monitoring but has a much smaller set of possibilities

than the numeric system and is less commonly used. More comprehensive information on the letter-based system can be found here:
https://www.nps.gov/orgs/1965/upload/fire-effects-monitoring-handbook.pdf

Number-based system

The number-based system, used by the United States Forest Service (USFS) and others, uses a 5-number system to indicate damage. The format is Category/Agent. The Damage Category is a 2-digit code (see table below), and the Damage Agent is a 3-digit code. (Note that some programs may combine the Damage Category/Agent code with Tree Part (letter code)/Severity(numeric) to create a single alphanumeric code, such as 10000BO1, where the severity is rating scale associated with specific degrees of damage. Our datasheets and FFI encourage separate entry of the Damage Category/Agent and the Severity, and we recommend using the severity assessment suggested in the table below. FFI includes a suggestion of the following minimum numeric Damage Category/Agent codes, shown in the table below, but it is possible to type in and use any of the Damage Category/Agent codes found in the expanded list. More comprehensive information on the number-based system can be found here:
https://www.fs.usda.gov/nrm/documents/fsveg/cse_user_guides/userguide_fsveg_apdx_k_damages.docx

The table below includes common damages encountered in the field. The letter and number-based systems have been grouped together to compare equivalencies. Severity codes listed for damages are based on the USFS number system. The most common damages also have photographic examples below the table.

Common Tree Damage Codes

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
10000	**INSE**	General Insects	**101 - Minor:** bottlebrush or shortened leaders, 0-2 forks on stem, OR <20% of branches affected, OR <50% of bole with visible larval galleries OR **102 - Severe:** 3 or more forks on bole, OR 20% or more branches affected, OR terminal leader dead, OR 50% or more of bole with visible larval galleries	Beetles, moths, sawflies, ants, wasps.
11000	---	Bark Beetles	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	The presence of small holes, usually exuding frass and galleries (tunnels beneath bark).

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
17000	**GALL**	Gallmarker Insects	**171 - Minor** OR **172 - Severe**	Abnormal growths on stems, roots, or leaves. Formed by pathogen/ parasitic infection.
19000	---	General Disease	**191 - Minor** OR **192 - Severe**	Blister rust, etc.
21000	**ROTT**	Root/Butt Disease	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	The presence of fungi other than shelf-like fruiting bodies/ conks. Indicate specific fruiting body or its general morphology in the comments.
22000	**CONK**	Stem Decay/ Canker	220: 0-4% rotten 221: 5-15% rotten 222: 16-25% rotten 223: 26-35% rotten 224: 36-45% rotten 225: 46-55% rotten 226: 56-65% rotten 227: 66-75% rotten 228: 76-85% rotten 229: 86-100% rotten	The presence of shelf-like fruiting bodies/ conks. If not shelf-like fungus, use ROTT/2100. Specify presence of conk in the comments.
23000	--- **OR** **EPIC/** **LICH/**	Parasitic/ Epiphytic Plants	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Epiphytic plants: lichen Parasitic plants: dodder *(Cuscuta spp.)*, pinedrop *(Pterospora andromedea)*, bearcorn *(Conopholis americana)*, pinesap *(Monotropa hypopitys)*, etc. Make a note in the comments whether plant is an epiphyte or parasite and record the specific species if able to identify.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
23001	**MISL**	Mistletoe	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Parasitic plant that often forms a dense cluster of shoots. Can sprout from bole or branches. Affects PIPO, PIFL, PIED, PSME, PIEN, PIPU, JUxx.
25000	--- **OR** **BROM**	Foliage Diseases	**251 - Minor:** <20% of foliage affected or <20% of crown in brooms OR **252 - Severe: >**20% of foliage affected or >20% of crown in brooms	Needle cast, needle blight, witches' broom. Note the specific damage in the comments.
25001	**BLIG**	Blight	**251 - Minor:** <20% of foliage affected or <20% of crown in brooms OR **252 - Severe:** >20% of foliage affected or >20% of crown in brooms	Discoloration of needles, stunted growth. Needles stay attached to the tree in comparison to needle cast where they are shed.
27000	---	Broom Rusts	**271 - Minor:** <20% of crown in brooms OR **272 - Severe:** >20% of crown in brooms	Dense cluster of growth. More yellow than brooms caused by mistletoe and lacks mistletoe shoots.
30000	**FIRE**	Fire	Maximum scorch height (foliage) & char height (bark)	No % or severity needed, assessed by recording the maximum height of scorch and char.
40000	**MAMM**	Animal Damage, Source Unknown	**401 - Minor** OR **402 - Severe**	Bear claw marks, porcupine or beaver chewings, and deer/elk rubbings. Make a note in the comments about specific damage.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
41010	**BIRD**	Woodpecker	**411 -Minor:** <20% of crown affected, bole damage is <50% circumference OR **412 - Severe:** >20% of crown affected, bole damage is >50% circumference, upper 1/3 of crown is killed	Holes are larger, more chiseled than beetle holes. 41010 code indicates woodpecker, NPS letter code not as specific.
50000	**--** **OR** **OZON/ FRST**	Abiotic Damage	**501 - Minor:** <20% or crown affected, bole damage is <50% of circumference OR **502 - Severe:** >20% of crown affected, bole damage is >50% of circumference, upper 1/3 of crown is killed	Air pollutants, chemical damage, drought, frost. Note the specific damage in the comments.
50008	**LIGT**	Lightning Scar	**501 - Minor:** <20% of crown affected, bole damage is <50% circumference OR **502 – Severe:** >20% of crown affected, bole damage is >50% circumference, upper 1/3 of crown is killed	Narrow vertical scar/ wound running down the length of the bole.
70000	**UMAN**	Human Activities	**701 - Minor** OR **702 - Severe**	Markings, girdling, cuttings, etc. Note the specific damage in the comments.
90000	---	Unknown	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Used when damage cannot be identified.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
99001	**BROK**	Broken Top	% of original height missing: 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Live, sick, and dead trees can all have broken tops. If a previously tagged tree broke below 4.5ft, record broken top code with true height of tree.
99002	**DTOP**	Dead Top	% of total tree height that is dead: 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Only live and sick trees can have a dead top.
99004	**FORK/ TWIN**	Forked Top	% of total tree height above fork 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Uncharacteristic, forked top (not applicable for POTR5, *Quercus spp.*, etc.). NPS letter codes use FORK for forking above DBH and TWIN is used for forking below DBH. Indicate whether fork is V-shaped or U-shaped in the comments in addition to recording the height of where the bole forks.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
99006	**CROK**	Crook or Sweep	% of total tree height, which contains the crook or sweep 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Use when crooked bole or sweep is uncharacteristic for tree species.
99016	**SPAR**	Foliage Loss	**1 = Minor** OR **2 = Severe**	Unusually sparse foliage.
99026	**WOND**	Open Wound	% of bole affected: 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Opening or cavity on bole with the outer bark missing.
99036	**FIRE**	Fire Scar	% of bole covered by fire scar	Scar that forms at the base of the tree, usually triangular in shape.
99037	**LEAN**	Leaning tree	% lean from vertical: 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Should be greater than 15%, use 900 severity rating. In the comments, specify the exact %. Snags (dead trees) with a lean greater than 45 deg or 50% lean severity are not recorded as trees. They instead are recorded as CWD in the fuel measurements.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
99000	--- **OR** **ABGR/** **BURL/** **EPIC/** **HOLW/** **ROOT/** **SRPT**	Physical Effects	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Large, exposed roots, hollowed out bole, abnormal growth pattern, burl, epicormic sprouts from bole/ limbs, sprouts at base, etc. Make a note in the comments of the specific damage.
---	X	Not assessed	-1	
NMFWRI Custom Damage Code				
GONE		Tree missing	---	Previously tagged tree is missing; its fate is unknown.
UPROOT		Tree uprooted	---	Previously tagged tree has been completely uprooted, but crew was able to locate the bole.

NMFWRI Damage Codes Reference Chart

NMFWRI uses 900 percentage codes to indicate severity for several damage codes. *Refer to "USFS Damage Code Reference Chart" in Supplement D, pg 253 to compare to the standardized USFS severity ratings.*

Damage Description & Photos

10000 General Insects

Insects to note include beetles, moths, ants, wasps, sawflies, etc. Depending on the insect, you might notice tree impacts such as pitch tubes, frass (insect excrement), or galleries. If insect signs can be identified to a beetle species, use 11000 (Bark Beetles).

11000 Bark Beetle

As the name indicates, these insects live in the bark of trees. Bark beetles bore small, D-shaped holes through



Insect damage on trees (10000/11000). *Photos by Carolina May*

the trunk, creating tunnels (egg galleries) where they lay eggs on the inner surface of the bark. You will likely notice frass around the bore holes or at the base of the tree and pitch tubes. Advanced stages of infestation result in foliage discoloration, appearing yellow to reddish brown. Note that trees infested with bark beetle will have browning foliage from the top down, as opposed to fire scorch, which causes needle browning from the bottom up. Bark Beetle damage can be distinguished from bird damage as the holes are smaller. It is common to encounter trees with advanced bark beetle damage that also have bird damage. Bark beetles impact tree health by disrupting water and carbohydrate transport systems which can result in tree mortality. Bark beetles typically attack stressed, sick, or old trees.



Bark beetle damage (11000). *Photo by Carmen Melendez*







Galls are abnormal growths (17000). *Photos by Grace McCartha, used with permission*

17000 Gallmarker Insects

Galls are abnormal growths that form on plant branches, stems, roots, and vegetation. Infection caused by fungi, bacteria, insects, genetics, or environmental stress can result in the formation of galls. Galls come in many different shapes and sizes and it is often difficult to determine the specific cause of the growth. *Quercus* spp. often present with galls as they can host hundreds of insect species that can produce them. Most of the galls NMFWRI encounters in the field are on *Quercus* spp., thus we use the damage code 17000 (Gallmarker Insects) to record the damage.







Fungi on trees (21000). *Photos by Grace McCartha, used with permission*

21000 Root/Butt Disease

The presence of fungi is indicated by the growth of the fruiting body/mushroom. Fungi enter trees through wounds or cracks or directly through the roots, causing rot. Fungi release enzymes that decay wood and weaken wood fibers. With advancing decay, impacted trees can start to lose branches and limbs and break. Use the 21000 (Root/Butt Disease) damage code to indicate the presence of fungi other than conks/cankers.



Conks (22000). *Left and middle photos by Carolina May, above by Carmen Melendez*

22000 Stem Decay/ Canker

Conks (polypores) are the shelf-like fruiting bodies of decay fungi. Some decay fungi attack the heartwood (inner dead core) of trees while the other types attack the sapwood (living wood). The presence of a conk typically indicates a tree in an advanced stage of decay. For our purposes it is not necessary to ID the kind of decay fungi or their fruiting bodies. For recording purposes, use the 22000 (Stem Decay/Canker) code and record conk in the comments.

23000 Parasitic/ Epiphytic Plants

Epiphytes

Epiphytes, often referred to as "air" plants, are photosynthetic. They obtain their water and nutrients directly from the atmosphere. Though they grow on other plants they are not parasitic. Lichens are a type of epiphyte.



Epiphytes/lichen (23000). *Photos by Carolina May*

Lichen

Lichens are symbiotic organisms comprised of both fungi and algae or cyanobacteria (blue-green algae). Contrary to popular opinion, lichen does not cause damage to the tree it lives on. An abundance of lichen can indicate poor tree growth, environmental stress, damage, etc. Lichen thrives with increased sun exposure. Dead or declining trees open the forest canopy, increasing the amount of sunlight available. Use the damage code 23000 (Parasitic/ Epiphytic Plant) and recorded lichen in the comments.

Parasitic Plants

Parasitic plants lack chlorophyll, getting their water, nutrients, and carbohydrates from a host organism. Two types of parasitic plants are typically recognized. Heterotrophic plants, meaning "other feeding," get their growth requirements directly from host plants. Mycotrophic plants, meaning "fungus feeding," get their growth requirements from the mycorrhizal fungi that have a symbiotic relationship to host plants. Mycotrophic plants disrupt the mycorrhizal association by redirecting the carbon and nutrients that would have otherwise been exchanged between the fungi and the host plant. Use 23000 (Parasitic/ Epiphytic Plant) if a parasite is present and indicate that the specific damage is a parasite in the comments. If able to ID, indicate the type of parasite in the comments as well.



Parasitic plants, including pinesap, pinedrops, dodder, and cancer root (23000).
Top left photo by Carolina May, top right by Meredith Prentice,
bottom right by Alina Martin, (https://www.inaturalist.org/observations/189176588),
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Dwarf and true mistletoes (23001). *Left and middle photos by Carolina May, right photo by Carmen Melendez*

23001 Mistletoe

Mistletoes are parasitic plants that rely on woody hosts for most of their nutrients and water requirements. In NM we have both dwarf mistletoe, Arceuthobium, (found on coniferous trees) and true mistletoe, Phoradendron, (also call broadleaf or leafy mistletoe; found on deciduous trees). Mistletoe embeds its root system into the bark and wood tissue of trees. The size of mistletoe shoots can vary from 1⁄2 inch to 3 inches depending on the host tree. Colors range from yellowish orange to yellowish green. Mistletoe infection often results in the formation of witches' broom. Mistletoe infection can reduce tree growth; usually the tree height is more impacted than the diameter growth. Dwarf mistletoe has sticky seeds that are shot out from the plant and can land as far as 50 ft from the host tree. Birds also contribute to the dispersal of mistletoe seeds. After the tree is initially infected, it can take 3 to 4 years for the infection to reach maturity.

NM species susceptible to dwarf mistletoe: PIPO, PIFL, PIED, PSME, PIEN, PIPU, *Juniperus* spp.

NM species susceptible to true mistletoe: hardwoods such as cottonwoods, elms, ash, willows, oaks, and locusts.

25000 Foliage Diseases

Foliage diseases include needlecast, blight, broom rusts, leaf spots, and blisters. Foliage diseases are caused by pathogens that penetrate the cuticle, epidermis, or stomates of the foliage. Foliage diseases impact conifers especially as they cannot re-foliate as easily or quickly as hardwoods. NMFWRI uses the general 25000 (Foliage Diseases) damage code when a tree has witches' broom(s). Indicate the specific kind of disease in the comments if known.

Witches' Broom

Witches' brooms are abnormal tree growths resulting in a dense spherical cluster of branches and twigs. Sometimes these clusters have lighter colored and smaller needles than the rest of the tree. The growth of brooms is a stress response caused by several diseases or pathogens including rusts, mistletoe, needle cast, insects, environmental conditions, etc. Witches' broom caused by mistletoe often form a few years after infection. Use damage code 25000 (Foliage Diseases) when witches' broom is present. Use codes 25000 and 23001 (Mistletoe) when both damages are present. Always make a note in the comment of witches' broom as the 25000 code indicates a non-specific foliage disease.



Examples of witches' broom (on left due to mistletoe) (25000) (23001).
Photos by Carmen Melendez

Needlecast

Needlecast is the premature "cast" or loss of needles. Prior to being cast, needles will brown. Discoloration can impact the entire length of the needle or just a portion. Most needlecast infections are caused by a specific family of fungi, Rhytismataceae, or pathogens belonging to phylum Ascomycota. There is one infection period annually. If needlecast is caused by fire scorch, use 30000 (Fire) code instead.



Foliage discoloration due to needlecast (in this case, from Rhizosphaera) (25000).
Photo by Forest Health Protection, Forest Service, USDA, Alaska Region (https://www.flickr.com/photos/194703066@N07/51812376577/in/album-72177720296192422/), licensed by PMD https://creativecommons.org/publicdomain/mark/1.0/)

25001 Blight

Blight is a foliage disease that produces discoloration, stunted growth, wilting, rapid death, or dieback. Blight can be the result of a variety of rusts or canker diseases. In contrast to needlecast, dead needles caused by blight can remain attached to twigs. If discoloration is caused by fire scorch, use 30000 (Fire) code instead.



Blight (25001). *Photo by Carolina May*

25002 Broom Rust

Broom rust is a systematic disease caused by fungi. Similar to mistletoe, broom rust results in the formation of witches' broom. Witches' broom caused by broom rust can be distinguished from those caused by mistletoe because they are denser, more yellow, and lack mistletoe shoots. The yellow needles of broom rust are shorter and thicker than needles on unimpacted branches. Broom needles are shed during the fall and new yellow foliage is produced in the spring.



Broom rust (25002). *Photo by Carolina May*

Broom rust can also result in cankers, growth abnormalities, stunted growth (diameter and tree height), top-kill, and tree mortality. Trees impacted by broom rust are weakened and thus more susceptible to other pathogens or diseases.

Susceptible species: *Abies* spp., *Picea* spp.

30000 Fire

Trees can be impacted by fire through radiant heat or direct burning. Fire is recorded by noting char (charring of the bole) and scorch (discolored/dead needles) that may be present on the tree. We note the presence of char and scorch and the height of each to indicate the fire severity. Char can run up the entirety of the bole to the top of the tree. Scorch can also impact the entirety of the crown but should only be recorded if at least some dead needles are still present. If either or both situations occur, the char/scorch height would be the same as the tree height.



Fire impacts on trees (30000). *Photos by Meredith Prentice*

Note that post-fire needle browning that occurs *from the top down* with green needles at the base is caused by bark beetle impacts, not scorch.

40000 Animal Damage, Source Unknown

The most common animals that cause damage include elk, deer, beavers, porcupines, squirrels, and birds. Damage can appear as removal or alteration of wood, bark, vegetation, etc. Bird damage (woodpecker) can be differentiated from insect damage as the holes they produce are larger and appear chiseled. If woodpecker damage is detected, use the specific 41010 (Woodpecker) code. If the type of animal that caused the damage can be identified, make a note in the comments.



Animal damage (40000). *Left photo by Carolina May, right by Carmen Melendez*

41010 Woodpecker

Holes vary by type of bird. Woodpeckers usually create deep holes with jagged edges. Depth can vary from 1" to boring all the way through to the interior of the trunk. Woodpeckers, such as the Pileated Woodpecker, can bore though trees to forage on insects living inside the bole. Often you will find bird damage in conjunction with insect damage, indicating a potentially sick or dying tree.

Sapsuckers are a type of woodpecker that create numerous uniform horizontal rows of round to semi-round holes that are shallow. Indicated by the name, sapsuckers bore into trees to access insects attracted to sap secretions. Typically, the damage created by their boring isn't enough to weaken or kill trees unless the feeding is intensive, as the holes can act as an entry point for pathogens.



Damage caused by woodpecker (41010), note the deep irregular patterns of holes. *Photos by Carmen Melendez*

50008 Lightning Scar

Lightning damage often presents as a long, narrow scar that runs down the length of the tree trunk, often curling around the bole. Often the scar can reach down into the soil. Sometimes lightning strikes result in the trees being blown apart. Damage caused by lightning can result in tree mortality, but more often the damage is slight. Lightning scars can encourage insects such as bark beetles and diseases to enter the tree.





Lightning Scar (50008). *Photos by Carolina May*

99001 Broken Top

Can be found on live, sick, or dead trees. This code can be utilized when a tag that had been tagged in a previous measure is broken to a height below 4.5 ft. This tree will not be included in reports of growing stock trees, but can be used to determine decay progress and fates of individual trees. See *Ch. 19.12* for more information on this process.



Broken Top (99001). *Photo by Carolina May*



Dead Top (99002). *Photo by Meredith Prentice*

99002 Dead Top

Noted for live trees. Foliage will appear brown or may be absent.

99004 Fork

Forks are splits in the tree bole, resulting in several leaders of vertical growth which are distinguishable from branches. For some species of trees, such as oaks, aspens, and junipers, the forking of the bole is characteristic of typical growth patterns.

When recording a fork, make a note of the height of where the bole forks in the tree comments and indicate whether the fork is V-shaped or U-shaped. U-shaped forks or "doglegs" are most often caused by injury or damage to the main stem when the tree was younger. They are generally considered to be stable. V-shaped forks often have two



Fork (99004). *Photo by Meredith Prentice*



Crook or Sweep (99006). *Photo by Meredith Prentice*



Fire Scar (99036). *Photo by Carolina May*



Leaning tree (99037). *Photo by Carolina May*

stems with no lateral connection, which are significantly more prone to splitting under stress (e.g. weight or wind). Noting the location of the fork is also relevant, as forks near the middle of the tree are more likely to result in breakage than a fork near the top of the crown.

99006 Crook or Sweep

Crooked or twisted boles are noted for species in which this growth form is uncharacteristic, such as PIPO or PIED.

99036 Fire Scar

Fire scars, often called catfaces, are the result of cambial death at the base of the bole. Trees respond to fire related injury by developing calloused edges around the edge of the wound. These callouses help to close the wound, thus helping to minimize vulnerability to infections.



Foliage Loss (99016). *Photo by Bryn, (https://www.inaturalist.org/observations/184732082) licensed by CC-BY (https://creativecommons.org/licenses/by/4.0/)*

99037 Leaning Tree

A leaning tree bole can result from a variety of factors including shading, crowding, poor soil structure, weather, or damage to the root structure. Leaning snags (dead trees) are hazards; be cautious around them. Snags with a lean greater than 45 degrees or 50% lean severity are not recorded as trees and are instead recorded as coarse woody debris (CWD) in the fuel measurements.

99016 Foliage Loss

Loss of foliage or sparse foliage can be the symptom of many foliage diseases.

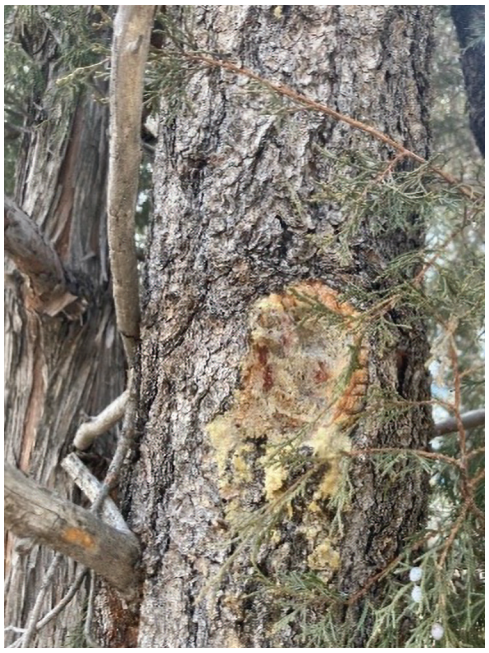
70000 Human Activities

Human-caused damage includes embedded objects such as nails or wire fencing, vandalism, inscriptions, etc. Trees are resilient and can survive a lot of instances of human-induced damage. In the case of embedded objects, the bole of a tree will often grow around the object. If damage is excessive or leads to infection, trees can sicken or eventually die. Indicate the specific kind of human-caused damage in the comments, if known.



Human activities (70000). *Photo by Carolina May*





Open Wound (99026). *Left photo by Carmen Melendez, right by Carolina May*

99026 Open Wound

Wounds and cracks secrete substances such as gums and resin to protect the wound from outside infections. Note the kind of substance, if any, that is being secreted from the wound or crack.



Examples of burls (99000). Left photo by Carmen Melendez, middle and right photos by Kathryn Mahan

99000 Physical Effects

Burl

A burl is a large, hard, woody abnormal growth presenting on the stem or branch of a tree. A burl can be caused by bacteria, insects, fungus, pathogens, or environmental stress. On some species of trees and shrubs, burls naturally develop. Since 99000 (Physical Effects) indicates general effects, indicate the presence of a burl in the comments.

Sprouts from bole/limb

Epicormic sprouts, also called adventitious shoots, are shoots that emerge in atypical places, typically the bole or branches. These shoots result from some kind of injury, stress, or disease (i.e., thinning, girdling, etc.), where the apical buds die or their dominance is impacted (apical buds are located at the tip of a shoot or stem). When they are dominant, the central leader of the tree is the longest. A helpful way to envision this concept is to consider the growth form that rises from trimming a basil plant to encourage the plant to develop a more bush-like shape. Epicormic branching is more common on some species, such as blue spruce, than others. Since 99000 (Physical Effects) indicates general effects, indicate the presence of sprouts in the comments.



Sprouts from bole (99000).
Photo by Carolina May



Hollowed out (99000). *Left and middle photos by Carolina May, right photo by Caremen Melendez*

Hollowed out

Hollows form when a tree's core rots out but remains surrounded by some amount of bark. Reoccurring fire can cause hollows. In most cases, evidence of char will also be present. Since 99000 (Physical Effects) indicates general effects, indicate that the tree is hollowed out in the comments.

Large, exposed roots

Tree roots can become exposed due to many factors including significant erosion, growth requirements, poor soil quality, or compaction. With roots exposed, there is an increased potential for wounds and thus infections. Since 99000 (Physical Effects) indicates general effects, indicate the presence of exposed roots in the comments.

Sprouts at base

Certain trees such as *Quercus* spp. and POTR5 will have sprouts growing from the base. Since 99000 (Physical Effects) indicates general effects, indicate the presence of sprouts at base in the comments.



Exposed roots (99000).
Photo by Taryn Schlosser



Sprouts at base (99000).
Photo by Carolina May

20.0 Fuels Transects for Restoration Monitoring

Fuels, or down woody debris (DWD), are a key component of forest ecosystems. Quantifying amounts and stages of decay can help managers evaluate potential fire behavior, forest structural diversity, wildlife habitat quality, carbon storage, nutrient cycling, and other ecological processes. A common measurement method is the fuels transect, also called the Brown's transect.

The primary method was presented by James K Brown in the GTR INT-16 in 1974. Below, we present the particular fuel sampling protocol NMFWRI follows. Be aware that various adaptations and explanations of the details of the protocol exist and are used by different programs. For further reading, we recommend resources such as:

Handbook for Inventorying Downed Woody Material, https://www.fs.usda.gov/rm/pubs_int/int_gtr016.pdf

FIREMON Fuel Loading Protocol, https://www.fs.usda.gov/rm/pubs_series/rmrs/gtr/rmrs_gtr164.pdf

Sampling protocol, estimation, and analysis procedures for the down woody materials indicator of the FIA program, https://research.fs.usda.gov/treesearch/13164

Because of the complexity of these protocols, we encourage you to keep this section nearby for reference when sampling in the field.

The Basics

The components sampled to estimate fuel loading include dead and down woody debris (DWD) and litter and duff depths. Pieces of DWD are tallied in the standard fire size classes: 1-hour (0 to 0.24 in.), 10-hour (0.25 to <1.0 in.), and 100-hour (1.0 to <3.0 in.). Pieces 3 inches or greater in diameter and over 3 feet in length are recorded as 1000-hour fuels and additional diameter and decay class information is collected for those pieces. Duff and litter depth are measured at two points along each 60-foot sampling plane (transect). Biomass of DWD, duff, litter, and vegetation can be calculated using computer software, or by hand using the calculation sheets in *Ch. 21.3 Data Analysis Calculations*. Additional, and optional measures for fuel loading can be found in *Supplement G.*

Definitions

The following definitions need to be understood so that data gathered is consistent between field crews.

Litter is the loose layer of freshly fallen plant material on the forest floor, including leaves, needles, small twigs (<0.25 inch), cones, bark fragments, dead moss and lichens, herbaceous stems, and small pieces of decayed wood. It is minimally decomposed and readily identifiable.

Because it is exposed to the air, litter acts as flash fuel that can ignite quickly and carry surface fire. It does not include material still attached to logs, rotten wood contained within a log, or animal manure.

Duff is the layer beneath litter, composed of dark, decomposed organic matter with no recognizable plant parts, derived from the decomposition of plant and animal litter (pine straw, leaves, twigs, etc.) and deposited on either an organic or a mineral surface. When moss is present, the duff begins just below the green moss layer and extends down to the mineral soil.

In the Southwest, duff depth rarely exceeds a few inches. It is much denser than litter—often weighing more than six times as much for the same volume—which can help distinguish the two layers.

Fuelbed is the accumulated mass of dead woody material on the forest floor surface. It begins at the top of the duff layer and includes litter, fine woody debris (FWD), coarse woody debris (CWD), and dead woody shrubs, but excludes dead hanging branches on standing trees. Fuelbed depth is not measured in this protocol but can be a useful term to understand.

Woody refers to a plant with stems, branches or twigs that persist from year to year. These structural components support leaves, needles, cones, and similar parts, and are the elements tallied along the Brown's transect.

Dead material has no live foliage or is completely severed from the plant where it grew. Sampling in the dormant season should only be done by crews with the expertise to distinguish dormant from dead trees and shrubs. (See more tips on identifying dead vs live trees in *19.5 Damage Codes and Statuses.*) Importantly, material can be classified as "dead" even if green foliage remains attached if it has been severed from the parent plant—for example, fresh slash or newly broken branches.

Down Woody Debris (DWD) includes snags with the main stem on the ground or supported by branches. A tree is considered down if it is leaning more than 45 degrees from vertical, is not self-supporting, and/or in contact with the ground.

Fine Woody Debris (FWD) includes down, dead branches, twigs, and small woody boles within 6 feet of the forest floor that are not attached to their original plant, are suspended by other material, or are attached to plants that are themselves dead and down. FWD may be connected to larger downed material, but only pieces that intersect the sampling transect are counted. Piece angle is not important for determining whether material is down.

FWD does not include any pieces over 3 inches in diameter at the transect intersection, dead branches still attached to live or standing dead trees or shrubs, dead foliage, needles, cone scales, bark fragments, or other non-woody litter, or small chunks of highly decomposed wood (i.e. cubical rot).

Coarse Woody Debris (CWD) includes down, dead tree and shrub boles, large limbs, and other woody pieces that are detached from their original source and lying on the ground. It also includes dead trees leaning more than 45 degrees from vertical (whether root-supported, severed, or uprooted) and round wood such as fence posts and cabin logs.

CWD does *not* include any pieces less than 3 inches in diameter at the transect intersection, dead trees leaning 0–45 degrees from vertical, dead shrubs that remain self-supported by roots, any trees showing signs of life,

rooted stumps, and dead foliage, bark, or other non-woody material not integral to a bole or limb (note that bark attached to a portion of a piece *is* considered an integral part).

Sampling Procedure:

Monitoring for fuel loading requires 5 groups of specific tasks for each sampling plane:

1. Lay out the measuring tape, which defines the sampling plane.
2. Measure the slope of the sampling plane.
3. Count and measure DWD
4. Measure the fuelbed (litter and duff)
5. Planer Intercept Cylinders for Ladder Fuels

Dead Woody Class			Piece Diameter (in.)
DWD	FWD	1-hr	0 to 0.24
		10-hr	0.25 to 0.99
		100-hr	1.0 to 2.99
	CWD	1000-hr and greater	3.0 and greater

Table 1. Characterization of down woody debris (DWD) as fine woody debris (FWD) and coarse woody debris (CWD).

Locating and Establishing Line Transects

The location of the transects depends on the protocol. In our standard protocol we use one transect that extends out from plot center at random azimuth which will be remeasured at that same azimuth during subsequent visits.

Another common arrangement is to use three transects originating from plot center at azimuths of 0, 135, and 270 degrees. Using three transects can help reduce sampling bias on sloped terrain, where coarse woody debris (CWD) may be aligned in a particular direction, by increasing the likelihood of capturing logs positioned parallel, perpendicular, and across the slope.

NMFWRI's default is to sample over a 60-foot distance with an additional 15 feet of buffer from plot center to minimize the impact of disturbance from plot set-up. (In other words, the tape will go from plot center out to 75 feet, and sampling will occur from 15 to 75 feet.) In instances of high fuel loads, such as in slash, the transect length may be shortened to 35 feet. Note the slope of the fuels transect—both will be needed for the analysis (*see more in 15.1 Slope with a Clinometer*). Always record the transect azimuth, and monument both ends of the transect if possible, so you can repeat measurements in the future.

Laying Out the Measuring Tape

A measuring tape laid close to the soil surface defines the sampling plane. The sampling plane extends from the top of the forest floor to a height of six feet. When laying out the tape, crew members need to step so that they minimize trampling and compacting fuels.

The process of laying out the tape is typically more difficult than it sounds because the tape needs to be straight (Figure 1). If the tape zigzags, the selection of pieces is biased, and remeasurement of transect lines and tally pieces for future change detection cannot be done properly. Take your time when laying out the tape.

Note: If photos of previous fuel transects are available, use these to align the measuring tape so that the photos match exactly (even if the azimuth appears to be slightly different from what was recorded).

Tips for getting the straightest tape:

Two crew members need compasses. One crew member can stand at plot center holding the zero end of the tape and the other can advance along the azimuth with the tape reel.

Before leaving plot center, the crew member with the tape should sight a bearing (*see more in Ch. 13 Using a Compass*) to follow. The crew member remaining at plot center will also sight a bearing. The crew member with the tape will move away from plot center, following both their own bearing and the directions of the

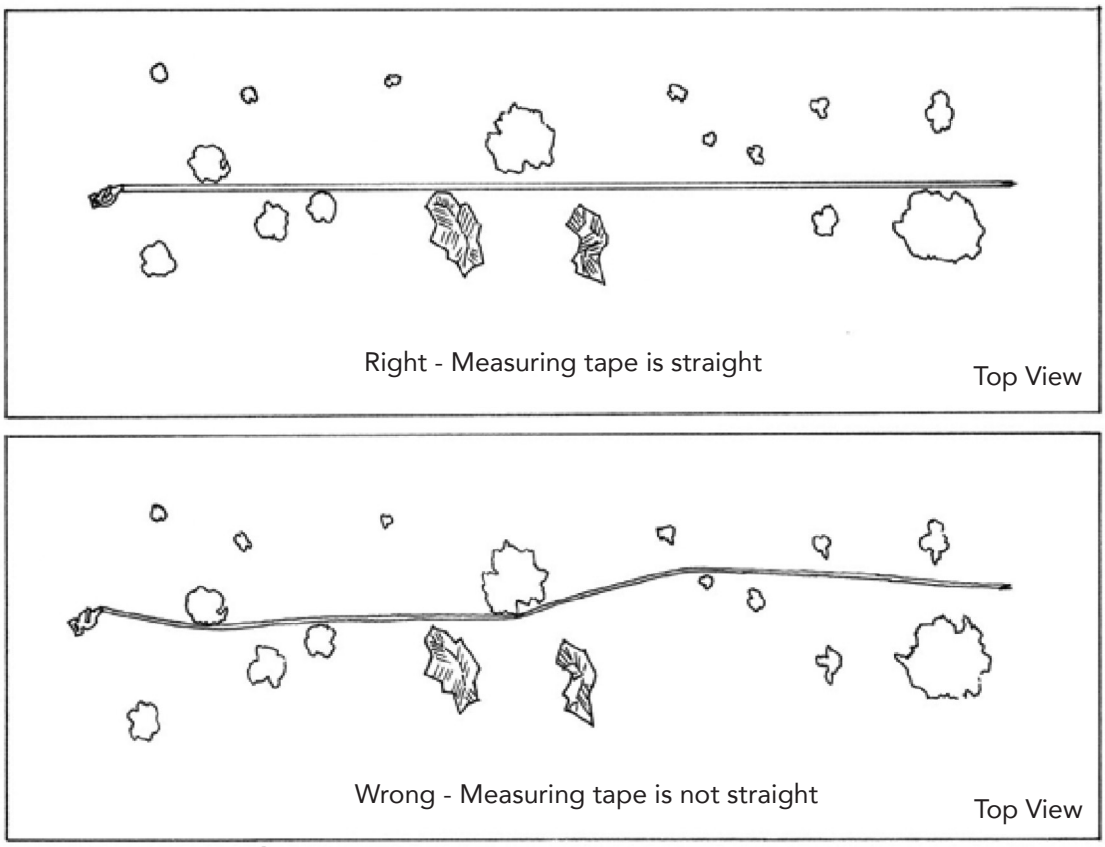


Figure 1. The measuring tape, which represents the lower portion of the sampling plane, should be as straight as possible. If the tape is not straight it needs to be offset left or right until it can be established without kinks or bends. *Image by FIREMON*

other crew member until they reach the 75-foot mark on the tape. At this point, they should be able to sight with their compass back to plot center and be exactly 180 degrees off their original mark. The crew member at plot center should hold the zero end of the tape over the plot center while the other crew member pulls the tape tight. They should work together to lower the tape as close to the ground as possible without disturbing the debris being measured. In most cases, the tape will rest on some DWD and low vegetation but remain below the crowns of shrubs and seedlings.

After the tape is positioned, secure it in place so it does not move until all sampling is complete. Most tapes have a loop at the zero end that can be secured at plot center with rebar or a chaining pin. A chaining pin can be inserted through the tape handle to secure the opposite end. On roll-up tapes, the winding crank can usually be flipped so the knob faces the reel which locks the reel and prevents the tape from unwinding.

We recommend adding a piece of rebar to the 75-foot mark for reliable resurvey of the fuels transect. If mastication is planned, the rebar can be pounded close to ground level and marked with a plastic cap. NMFWRI also collects photopoint from the 75-ft mark looking along the transects toward plot center to help in re-establishing the transects.

Sampling DWD

DWD is sampled along specific transect segments based on piece size (Figure 2). One- and 10-hour fuels are tallied from 15–21 ft, 100-hour fuels from 15–50 ft, and pieces ≥3 inches from 15–75 ft. FWD uses shorter distances because it is more abundant so can be adequately sampled over shorter lengths. The first 15 feet of the tape are excluded from sampling due to expected disturbance near plot center.

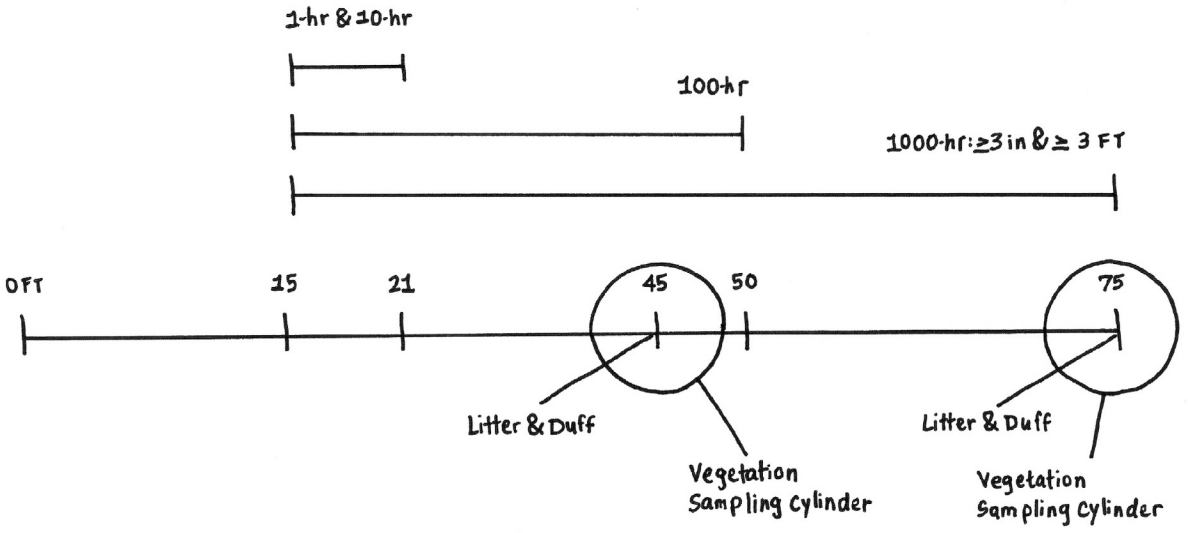


Figure 2. Dead fuels, duff/litter, and vegetation data are recorded at specific locations on or along each sampling plane. The 1-hour and 10-hour fuels are sampled from the 15-foot to the 21-foot marks along the plane, the 100-hr fuels are sampled from the 15-foot to the 50-foot marks and pieces 3 inches and larger are sampled between the 15-foot and 75-foot marks along the plane. Duff/litter measurements are made in a representative area within a 6-foot diameter circular area at the 45-foot and 75-foot marks. The cover of live and dead vegetation is estimated within an imaginary 6-foot diameter by 6-foot high sampling cylinder at the 45-foot and 75-foot marks. *Diagram by Meredith Prentice*

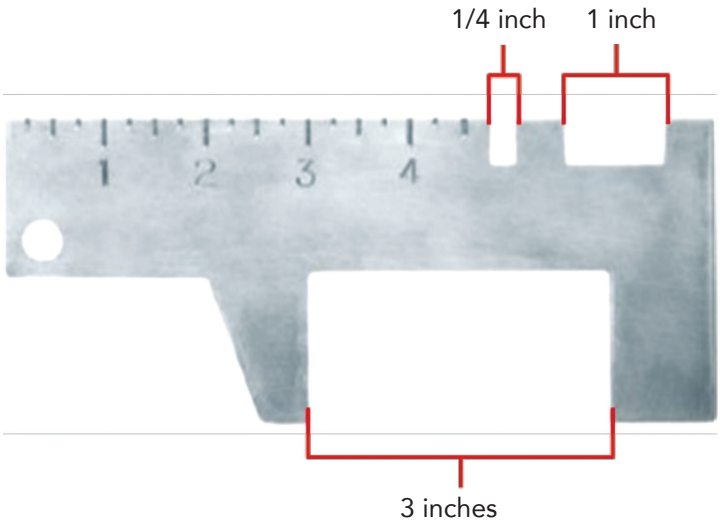


Figure 3. A go/no-go gauge can help samplers tally 1-hr, 10-hr and 100-hr fuels quickly and accurately. *Image by FIREMON*

Sampling FWD Using a Fuels Gauge

FWD is tallied in three size classes: 1-hour, 10-hour, and 100-hour. A go/no-go gauge (Figure 3) has slots match the three fuel-size thresholds, allowing for rapid classification of pieces.

Count 1-, 10-, and 100-hour fuels that intersect the transect between the 15- and 21-ft marks; from 21 to 50 ft, tally only 100-hour fuels. Remember the sampling plane extends 6 feet above the ground along the transect tape. Classify each piece by its diameter at the point of intersection to one edge of the tape, using the go/no-go gauge. Check carefully for hidden pieces to ensure accurate counts – pieces can overlap or be hidden by vegetation.

Sampling CWD using a diameter tape

Tally pieces that intersect the transect and meet the dead, down, and woody criteria, from 15 to 75 feet along the transect, up to 6 feet above the ground. Record the diameter and decay class for each piece (see more on decay class in Table 2); under some protocols additional measurements are taken, including char, log length,

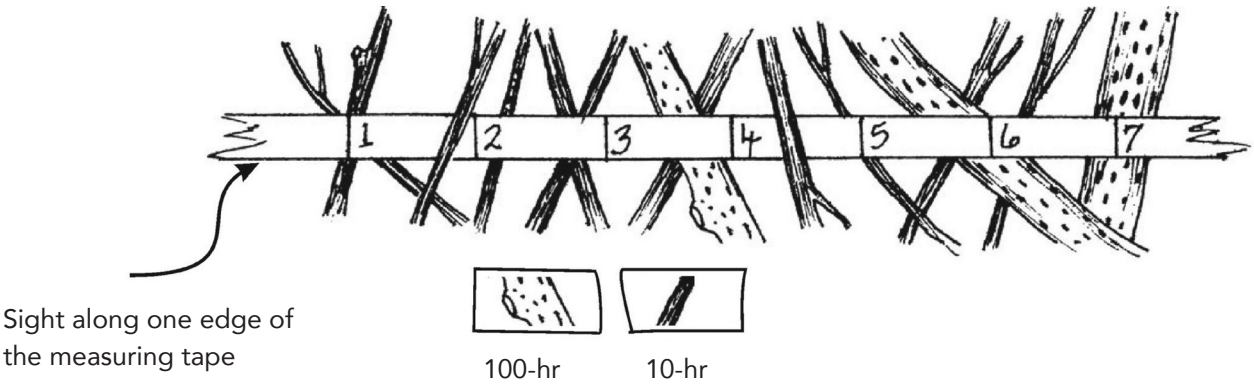


Figure 4. Tally pieces that intercept the sampling plane both above and below the measuring tape. Focus on one edge of the tape to make counting easier. Be sure to note any lower fuels that are hidden by pieces above. In this illustration there are 11 10-hour and three 100-hour fuels. *Image by FIREMON*

large-end diameter, species, intersection point, or estimated volume loss to decay. Recall that CWD is at least 3 inches in diameter, and must be at least 3 feet in length.

Wrap a diameter tape around the bole to measure the diameter where the piece's central axis intersects with the transect, perpendicular to the axis, to the nearest 0.1 inch. If a piece crosses the transect more than once, record each intersection separately (Figure 5). For irregular shapes (e.g. logs with missing chunks of wood or splintered ends), take two measurements and average them to get the diameter. Do not sample a piece of CWD if the central axis of the piece is in or below the duff layer where it crosses the transect (Figure 8).

Angle rule: CWD that intersects the sampling plane at more than 45° above horizontal is considered down only if it is part of a broken dead bole with at least one end touching the ground (not supported by branches or other vegetation). CWD at 45° or less above horizontal is considered down regardless of whether it is broken, uprooted, or otherwise supported (Figures 6 and 7).

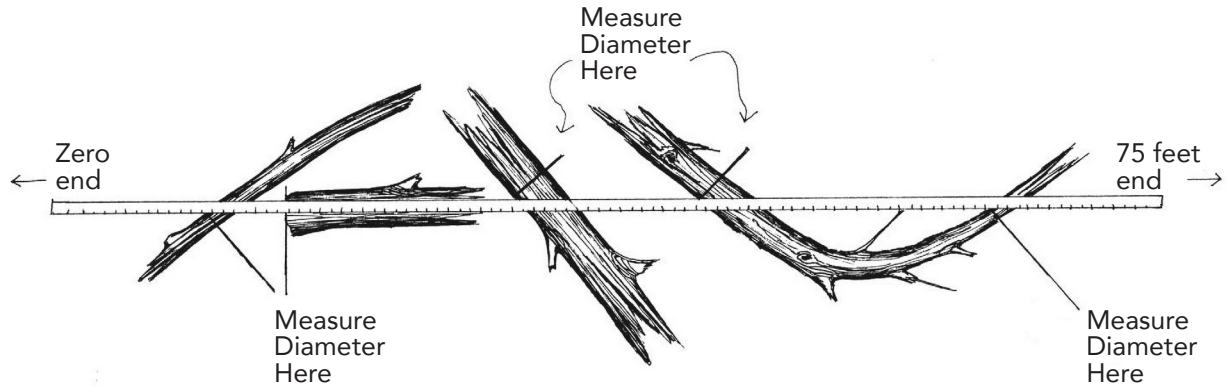


Figure 5. Measure the diameter of CWD crossing through the sampling plane perpendicular to the central axis of the piece. If a curved piece passes through the plane more than once, measure its diameter at each intersection. *Image by FIREMON*

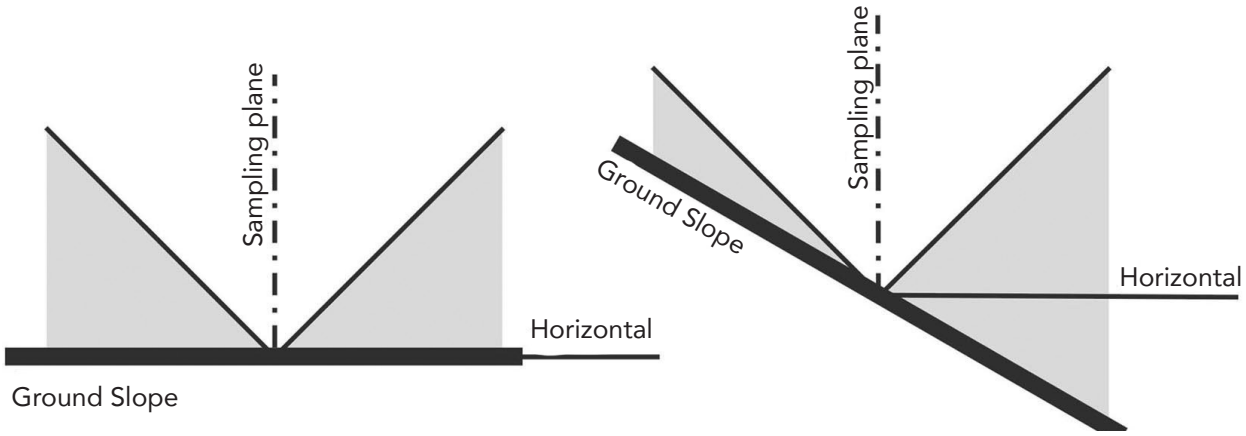


Figure 6. CWD pieces crossing through the sampling plane at an angle less than 45 degrees from horizontal (represented by the shaded areas in the figure) are always considered to be "down." Some CWD leaning greater than 45 degrees may be considered "down." See the text for details. *Image by FIREMON*

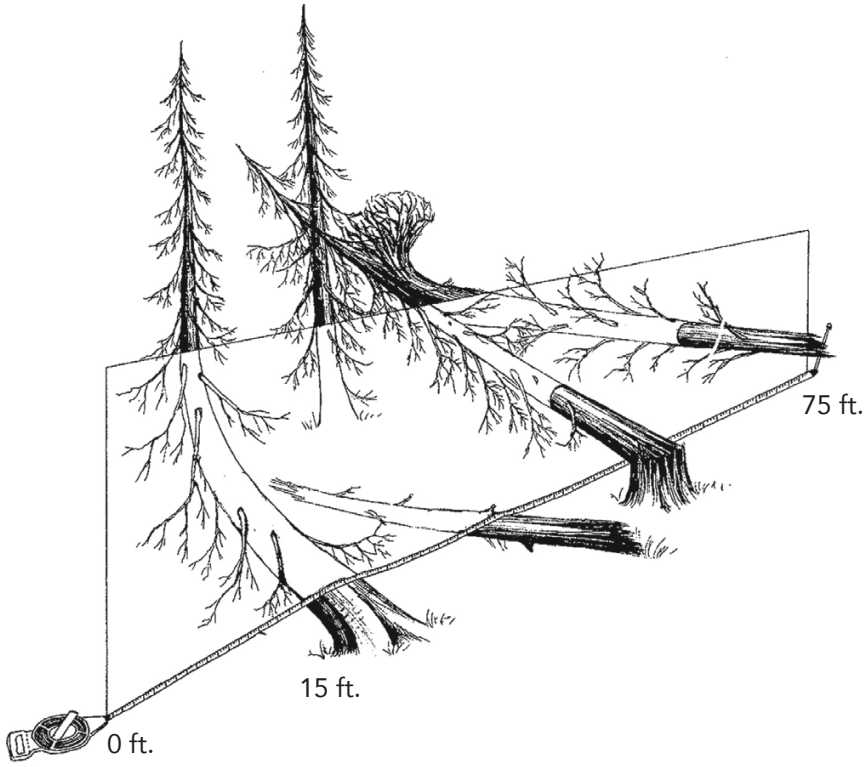


Figure 7. All of the pieces crossing through the sampling plane in this illustration would be considered "down." *Image by FIREMON*

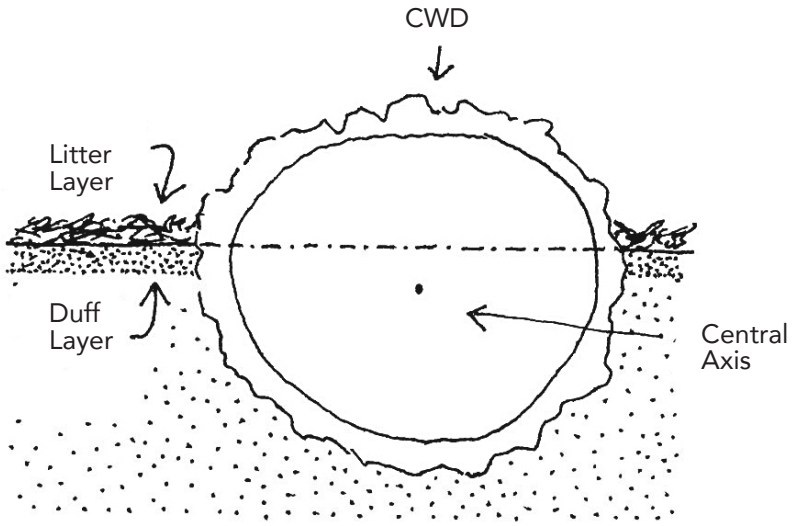


Figure 8. Do not sample CWD when the central axis of the piece lies in or below the duff layer. *Image by FIREMON*

Decay Classes

Decay class can vary along a single piece of CWD, and the condition at the diameter measurement point may not represent the entire log. However, recording decay class at the measurement point provides a consistent and representative sample along the transect.

Note that class 5 logs can blend into duff and litter, but must still resemble a log to be tallied.

Decay Class	Description
1	All bark is intact. All but the smallest twigs are attached. Old needles are probably still present. Solid, freshly fallen, intact logs, hard when kicked.
2	Some bark is missing, as are many of the smaller branches. No old leaves still on branches. Hard when kicked.
3	Most of the bark is missing. Most of the branches less than 1 inch in diameter are also missing. Still hard when kicked, still supports its own weight.
4	Looks like a class 3 log but the sapwood is rotten. Sounds hollow when kicked and you can probably remove wood from the outside with your boot. Pronounced sagging if suspended for even moderate distances.
5	Entire log is in contact with the ground. Easy to kick apart but most of the piece is above the general level of the adjacent ground. If the central axis of the piece lies in or below the duff layer then it should not be included in the CWD sampling as these pieces act more like duff than wood when burned.

Table 2. Use these descriptions to determine the decay class where the log crosses the sampling plane.

Duff and Litter Depth Measurements

Depth of the duff and litter layers—and the overall fuelbed—is used in fire models to estimate fire behavior, effects, spread, and smoke, and to calculate fuel loads. Measure duff and litter depth at the 45- and 75-ft points on each transect.

Sampling Duff and Litter

The duff and litter layers occur below the transect so cannot be measured using the planar intercept method. Instead, two or more points are collected along each transect by exposing an undisturbed profile of duff and litter.

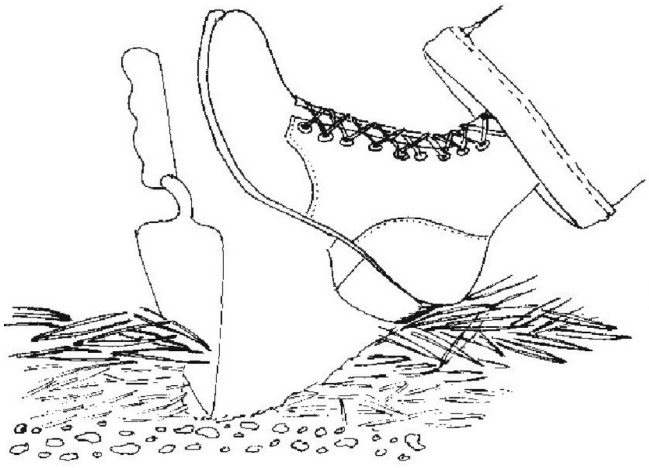


Figure 9. Use your boot to carefully pull the litter and duff layers away, until you are down to mineral soil. *Image by FIREMON*

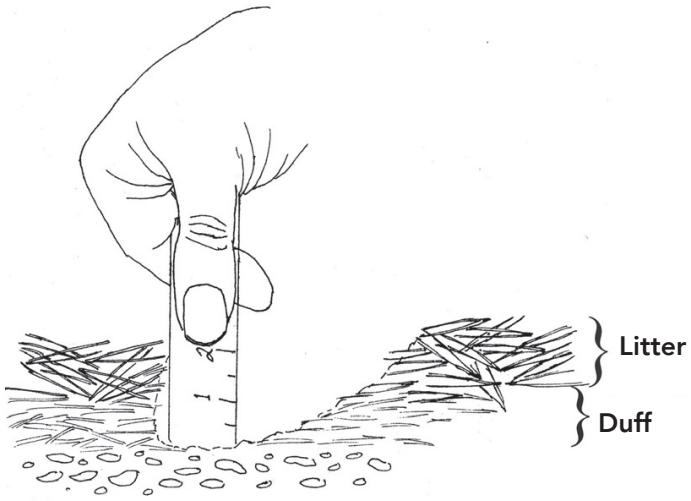


Figure 10. Use a clear plastic ruler to measure duff and litter depth. Here, both measurements are about 1 in. *Image by FIREMON*

Take measurements within 3 feet of the 45-ft and 75-ft marks. At each location, choose a point that best represents the litter/duff conditions within a 3-foot radius. Walk carefully to avoid trampling the area.

Expose the profile carefully by digging with a trowel or boot heel down to mineral soil (Figure 9). Be careful not to compact or otherwise disturb the profile. Measure litter and duff depths separately to the nearest 0.1 in. using a ruler (Figure 10). Measurements are most accurate on the most vertical, undisturbed face of the profile. When measuring deep duff layers, take extra care to make sure the duff bottom is correctly identified.

Biomass of Understory Material (Planar Intercept Cylinders)

The final component of the total fuel loading on a plot to be sampled is the biomass of live and dead understory material, which is useful in approximating ladder fuels. A 6-foot diameter cylinder will be used to estimate the percent cover and height of live and dead woody species, live and dead herbs (including grasses), and litter.

Both trees and shrubs are woody species. They are easily identified because their stems persist and growth does not have to start at ground level each growing season. Trees generally have a single, unbranched stem near ground level. Shrubs, which include woody vines, generally have multiple stems near ground level. Herbs are non-woody herbaceous plants, but also include ferns, mosses, lichens, sedges, and grasses. Although the aerial portions of many forbs and grasses die by the end of the growing season, an estimate of live and dead biomass on a given date will help fire modelers predict the life stage of herbaceous material during the year, allowing them to estimate fire danger patterns across the landscape. One way to identify non-woody plants is to remember that, in general, factors like wind, rain, snow, and so forth, collapse herb foliage and stems back to or near the ground between growing seasons. If unsure, use the USDA PLANTS growth habit designation to determine whether a plant is woody or herbaceous.

Small trees, shrubs, and herbs influence fire behavior because their branches and foliage are suspended above the ground, allowing efficient heating and burning of these parts. Dense, suspended fuels can lead to fires that are difficult or impossible to control. By estimating the cover and heights of woody and non-woody vegetation, fire managers can estimate the volume, density, and biomass of vegetation. All three of these characteristics are strongly associated with fire behavior.

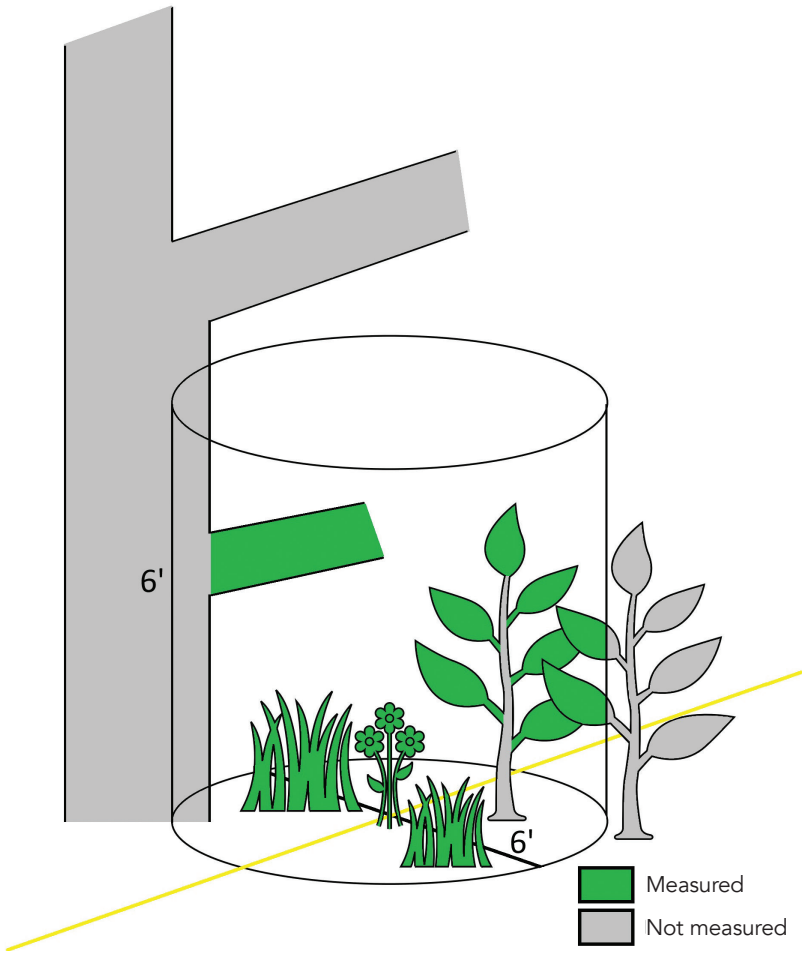


Figure 11. A fuel cylinder is 6′ in diameter and 6′ in height. The yellow line represents a fuels transect. Only vegetation within the cylinder is included in height and cover estimates. Upright stems are not measured.
Image by Alex Withnall

Sampling Vegetation Cover and Height

Estimate vegetation cover and height at the 45-foot and 75-foot marks on the measuring tape. Field crews will estimate the vertically projected cover of vegetation within a 6-foot tall by 6-foot diameter imaginary sampling cylinder. Use the marks on the measuring tape to help visualize the 6-foot diameter. For instance, when standing at the 45-foot mark, the 42-foot and 48-foot marks will identify the boundary of the cylinder along the tape. Use that measurement to get a good idea of the distance needed on each side, perpendicular to the tape, required to form the imaginary base of the cylinder. Most people have an arm's width spread (or wingspan) that is about six feet. Each sampler should measure their arm span and use that measurement to help them visualize the sampling cylinder.

The cover of plants, especially of the foliage, is a function of the life stage of the plant. Early in the season many plants may not have completely leafed out, in mid-season plant cover reaches its maximum, and in late season plant material, especially herbaceous vegetation, moves from the live to dead class. Clearly, where herbaceous vegetation is concerned, it is important to sample at the same life stage when repeat monitoring, and this should be taken into account when designing a monitoring program. For example, in the Southwest, fires historically burned in May-June, so the best assessment of surface fuels, in terms of potential fire fuels, would be made during the fire season. However, other factors may keep monitoring crews from working during fire season, making life stage only one of many factors considered in designing a monitoring program.

%	Area (sq ft)	Diameter (ft)	Square (ft)
1	0.28	0.60	0.53
10	2.83	1.90	1.68
20	5.65	2.28	2.38
30	8.48	3.29	2.91
40	11.31	3.79	3.36
50	14.14	4.24	3.76
60	16.96	4.65	4.12
70	19.79	5.02	4.45
80	22.62	5.37	4.75
90	25.45	5.69	5.04
100	28.27	6.00	5.32

Table 3. Planar intercept cylinder (3 ft radius) Cover Estimation Guide (Tip: 8.5" x 11" = about 2.3% coverage)

Eight attributes are measured at each vegetation sampling point. These values are four cover estimations for vegetation: 1) live woody species (trees and shrubs), 2) dead woody species, 3) live non-woody species (herbs/forbs) and 4) dead non-woody species; and the corresponding height measurements for each component.

Similar to aerial cover (*see Ch. 18.1*), estimate by imagining a bright light directly above the microplot, causing vegetation to cast shadows on the ground. The percent of the ground covered by the vegetation shadows inside the 6-foot (2-meter) diameter sampling area is being estimated. Use Table 3 to aid you in estimating cover. Do not include the cover of the cross-sectional area of upright stems in the live or dead woody cover estimate. Fire acts upon upright stems differently than it does upon the more horizontal fuels; thus, upright stems are not included in cover estimates. An alternative method is estimating cover by visualizing an outline around the live or dead material and accumulating this across the microplot.

For live fuels, estimate the percent of the microplot area that is covered by live plant material. Include whole plants that are entirely green (or alive) and the live branches on plants that are a mixture of live and dead plant parts. Include live branches or leaves that extend into the microplot area from a plant that is actually rooted outside of the microplot. Do not include material above 6 feet.

For dead fuels, estimate the percent cover using the same procedures as live fuels, but include plants that are entirely dead and branches or leaves that are dead but still attached to a live plant. Dead plant material must be clearly visible. Do not include dead material that has fallen to the ground or that is unrooted.

Two conditions make cover estimations difficult and, frequently, inaccurate. First, the equations used to estimate biomass assume that all of the plant parts for each species are included in the cover and height estimation. In other words, when looking at the cover of a woody shrub species, samplers need to estimate

Code	Cover
0	No cover
0.5	>0-1 percent cover
3	>1-5 percent cover
10	>5-15 percent cover
20	>15-25 percent cover
30	>25-35 percent cover
40	>35-45 percent cover
50	>45-55 percent cover
60	>55-65 percent cover
70	>65-75 percent cover
80	>75-85 percent cover
90	>85-95 percent cover
98	>95-100 percent cover

Table 4. Cover of each of the four vegetation categories is recorded in one of the following classes.

the cover of all the parts, even things like the foliage, which are not "woody." Second, estimating cover is not something people do very often; it is only with practice and experience that good estimations of plant cover can be made. Fortunately, the cover classes used here are typically 10 percent, so the precision of cover estimates are secondary to accuracy (Table 4).

In addition to the cover estimates, samplers will make four height estimates at each vegetation sampling location—two for the average heights of the live and dead woody species and two for the average heights of the live and dead non-woody species. Make your height estimate by noting the maximum height of all the plants in the class and then recording the typical or average of all the maximum heights. Some people like to envision a thin sheet covering just the plants in one class, then they estimate the average height of the sheet above the ground. A fast way to make accurate height assessments is for samplers to measure their ankle, knee and waist heights then estimate vegetation height based on those points. Estimate height to the nearest 0.1 foot (0.2 m). Recall that the maximum height is 6 feet.

Wrapping Up

Before picking up the transects, take notes of anything that might be helpful. For example, evidence of flood, fire, browsing, or treatments that could be impacting the fuel loading, or any notes that will help future crews exactly recreate the transect.

21.0 Using the Data

As we mentioned back in Chapter 1.1, the ultimate goal of most of our monitoring efforts is to provide critical information for the adaptive management, decision-making process. Not only can monitoring data help to understand a site's current conditions when considering a treatment, it can also be used to evaluate the impact and effectiveness of a particular treatment or disturbance and inform planning for the future. To support this goal, the following sections walk through ways to make sure the data collection and analysis processes are reliable, how to perform some common analyses, and a brief overview of what management implications may be drawn from those results.

21.1 Data Quality Assurance in the Field

Ensuring quality data collection requires taking steps to check data during collection and before leaving the plot. This practice applies to both paper datasheets and electronic data entry. Assign two crew members to look over the data to ensure completion and accuracy before removing flags and leaving the plot. Some best practices for on-plot quality assurance (QA) are listed below:

1) Is data being collected consistently?

- ☐ Ensure all technicians are following all established protocols (i.e., DBH is taken from the correct height; any trees located near the edge of a plot are carefully measured with a tape; fuels transects are laid out to match photos of previous transects).
- ☐ Train on practice plots and conduct an error analysis before collecting project data can highlight any areas of inconsistency where crew members need further practice. See the section on measurement quality objectives (MQOs) on the following page for more information.

2) Are all protocols completed?

- ☐ If using paper datasheets, ensure every box is filled in. If no trees/seedlings/fuels were present, a line through the box or comment should indicate that this protocol was completed. Do not leave anything blank!

3) Within protocols, are all required data present?

- ☐ Are the plot center coordinates and elevation recorded?
- ☐ Does the witness tree have distance and azimuth recorded?
- ☐ Do all trees have a height, DBH, and status recorded? Do all live trees have a crown base height?
- ☐ Are all tree damages recorded (char/scorch, diseases, abnormal growth) with appropriate severities?
- ☐ Do all 1000-hr fuels have a diameter listed?

- ☐ Are all surface vegetation coverage values recorded? Does each have a height? Has the slope of the fuel transect been recorded? Ensure there was no height entered if the aerial cover for that category was zero.
- ☐ On paper datasheets, are final tallies counted and circled?
- ☐ Is all plot description info filled in? Does anyone else on the crew have anything to add to the comments sections?

4) Scan through data. Do data values make sense?

- ☐ Are there any trees that are too tall or wide? (Do DBH and height measurements make sense?)
- ☐ If a total is supposed to equal 100%, do all the percentages add up?
- ☐ Can you notice any outliers, strangely large or small numbers?
- ☐ Are the appropriate units used and labeled for surface fuel vegetation heights, litter, duff depths, and other measurements?
- ☐ Is all written data legible?

Measurement Quality Objectives (MQOs) are established threshold values for the accuracy of parameters you choose to measure. Monitoring crews use MQOS as practical guidelines to collect data that are complete, accurate, and reproducible. These standards, set during the planning phase, increase data reliability and ensure your results can confidently support management decisions. MQOs also help confirm that your monitoring methods are suitable for meeting project goals and objectives. When evaluating the effectiveness of restoration practices, it is important to remember that long-term datasets often span different time periods, site locations, and involve multiple crews. By adhering to consistent MQO metrics, you ensure you can reliably compare and analyze your data. MQOs might be specific to protocols or generalized for all monitoring activities.

Cross-checking the accuracy of data collected by a production crew should be conducted during training, as described above. NMFWRI operates a part-time Quality Assurance (QA) crew throughout the regular field season. This crew is made up of the most experienced and dependable field staff. NMFWRI aims to re-sample at least ten percent of data collected by a production crew, distributed evenly across the sampling period for a project. The data from the production crew is then weighed against the metrics from the QA crew to determine whether these values are within the set tolerance. This tolerance is usually a percentage of the QA crew's value, unless otherwise stated. For example, cover data is recorded as a percentage; thus, the tolerance refers to the absolute value of the metric. NMFWRI data must be within the tolerance 90% or more of the time in order to meet MQOs.

NMFWRI recommends that QA re-sampling should take place within a few days of the initial production crew sampling, up to two weeks at a maximum. This is to ensure that areas of concern can be addressed and corrected as soon as possible, but also that metrics such as tree seedling count are not skewed by the natural progression of the growing season. Similarly, lightweight surface fuels components may shift during precipitation events, especially during monsoon season in the southwestern US. If it is at all possible that an observed metric has been altered, consider excluding from your MQO evaluations.

MQO

Measurement	Tolerance	MQO Standard %
Slope	± 5% absolute	90%
Azimuth and Aspect	+/- 10°	90%
Cover estimations	± 10% absolute ± 1 class (fuel cylinders)	90%
Heights	± 10% ± 1 class (seedlings) ± 0.5 ft (fuel cylinders only)	90%
Diameters (DBH/DRC)	± 0.1in per 20in ± 1 class (saplings)	95%
Duff/Litter Depths	± 0.1in	90%
Damage Severity	± 10% or 1 class	90%
Decay Class	± 1 class	90%
Seedling/Sapling Count	± 20%	90%
Nail of tagged tree at 4.5ft	± 1in	90%
Canopy cover (w/ Densiometer)	± 10%	90%
1, 10, 100, 1000-hour fuel counts	± 20%	90%
Species/status/tag #/plot #/etc.	No tolerance	90-99%
No trash or equipment left on plot	No tolerance	99%

Table 1 The MQO Standard % represents NMFWRI's expectation of what percentage of measurements taken by our crews falls within these tolerances when compared against quality assurance checks. Please note that these MQOs are intended for professional, experienced crews. We recommend taking the time to evaluate your own crew's performance against these or similar metrics before using your data for analysis and decision-making.

21.2 Data Quality Control

Following field quality assurance, quality control practices are necessary to ensure all data errors are corrected before analysis. There are multiple methods that can be employed in the quality-control process, and the most effective quality control employs a combination of these methods.

Quality control by visual review:

QC can be done by doing a visual review of data in the database, sorting by values, and comparing entered data to paper datasheets. Reviewers should check for missing data, data values that are unlikely or incompatible with other data, typos, and incorrect plot sizes/transect lengths. For example, a PIPO with a 1.5" DBH with a height of 60' would warrant additional review and checking paper datasheets. Likewise, a dead tree with a live crown base height listed indicates an error in either tree status or live crown base height.

An example of complete visual review QC checklist can be provided by NMFWRI upon request.

Quality control by script:

Programming languages can be used to write a script that detects potential errors in a dataset and flags them for review. Using a script allows for the efficient checking of all data for established errors, such as heights, DBH values, plot sizes, or transect lengths entered outside of set parameters. It can also detect errors that are harder to find with visual review, such as a damage code entered that does not match any established codes, or ground cover values that do not sum to 100%. However, not all error detection can be automated, and additional visual review is needed to detect errors such as incorrectly identified plant species or mis-entered sampling dates.

An example of a complete QC script can be provided by NMFWRI upon request.

Quality control by data analysis:

Data analysis can be a powerful tool for detecting potential errors missed in initial quality control. Large changes in data values across measurement periods that have no obvious ecological cause warrant additional investigation into the data. For example, a large drop in basal area or tree density following no treatments or fires may indicate missed trees or a plot size error. Plot photos can often be used to validate data trends or expose potential errors.

21.3 Data Analysis Calculations

This chapter intends to present some common analyses that can be performed with the data collected on plots according to the protocols outlined in this manual. These are not all the analyses that can be done, and many programs will do this work for you. However, it may be helpful to understand the math and be able to perform the calculations by hand if needed.

Overstory and Regen Calculations

Canopy Cover Calculations:

See *Chapter 17.0* for details on NMFWRI's protocol for estimating overstory canopy density using a spherical concave densiometer. There are 2 methods for estimating canopy density: the squares and the dots method. Both of these methods involve taking 4 measurements, facing each of the 4 cardinal directions (North, east, south, and west).

Squares method:

For each measurement: 24 - (squares NOT occupied by canopy) = Canopy

Total Percent Closed Canopy = (North + East + South + West) * 1.04

Dots method:

For each measurement: 96 - (dots NOT occupied by canopy) = Canopy

Total Percent Closed Canopy = ((North + East + South + West) / 4) * 1.04

Mean height/live crown base height:

The mean height and live crown base height of trees may be reported at the plot or project level. When calculating mean heights (H_{plot}) at the plot level sum all individual tree heights (H_i) within a plot and divide by the number of trees in the plot (n) following equation 1. When reporting mean heights at the project level ($H_{project}$) we typically average the means of the plots by summing the mean heights across the plots and dividing by the number of project (p). Note that taking the mean of the plot means may yield a different project level value when there different numbers of trees among the different plots (not shown).

$$H_{plot} = \frac{\sum_i^n H_i}{n} \qquad \text{Equation 1}$$

$$H_{project} = \frac{\sum_i^p H_{plot}}{p} \qquad \text{Equation 2}$$

Mean basal area:

Basal area represents the area of a forest that is covered by tree boles, and is calculated based on DBH (diameter at 4.5 ft off the ground). Typically, basal area is reported as the square feet of tree bole per acre of forest. To calculate the basal area for a plot we first calculate the basal area (in inches) of each tree (measured in inches) as the DBH squared times 0.005454 (equation 3). Then we sum basal area of trees within the plot, and divide by the area of the plot in acres – for reference the area of a 37' 3" plot radius is 0.1 acres. Finally, to get a project mean DBH we average across the plots (not shown).

$$Basal\ Area = DBH^2 * 0.005454 \quad \text{Equation 3}$$

Quadratic mean diameter:

The quadratic mean diameter (QMD) is meant to represent the average tree diameter and is used over an arithmetic mean for historical reasons (see: https://www.fs.usda.gov/pnw/olympia/silv/publications/opt/436_CurtisMarshall2000.pdf)

The QMD for a plot is calculated by summing the squared DBH values, dividing by the number of trees and taking the square root as in equation 4. To calculate the QMD at the project level we then take the arithmetic mean of the QMD for the plots (not shown).

$$QMD = \sqrt{\frac{\sum_i^n DBH_i}{n}} \quad \text{Equation 4}$$

Density (trees per acre):

The density of trees is generally reported as the number of trees per acre (TPA). This is first calculated at the plot level as the number of individual trees divided by the area of the plot in acres (equation 5). To calculate a project level mean the plot level TPA is averaged (not shown).

$$TPA = \frac{n}{area} \quad \text{Equation 5}$$

Species composition:

Species composition compares the abundance of different species within a forest. It is typically calculated based on either TPA or basal area of species, and could be graphed as a bar graph.

General notes on forest measurement metrics.

When comparing forest measurement metrics between projects or sampling periods it is important to understand the underlying methods that were used to collect and summarize the data. A few considerations are discussed here.

1. Breakpoint diameters that determine whether a tree is counted as a “tree” or “sapling” are an important part of a classification scheme. Two sampling protocols that use different breakpoints can end up

having different values for these metrics because changing the breakpoint can change how trees are counted, and how many small trees affect the values like average height and QMD.

2. How multi-stem species are treated. When species have multiple stems, they are sometimes treated differently by different protocols. Sometimes the DBH of each stem is measured and reported as an individual tree, sometimes math is done so that one DBH is reported that corresponds to the basal area of both stems, and sometimes the diameter at the root collar (DRC) is measured and reported. These decisions can all effect summary metrics – and are particularly important in woodlands where multi-stem species are common. NMFWRI handles each stem separately when possible.

3. Averaging. At NMFWRI, to get project level averages, we typically average at the plot level and then average across plots. Metrics such as height, live crown base height, and QMD may also be reported as grand means at the project level. There is not a right and wrong way to do this but that the values of these two methods can differ so be aware of this when comparing to values collected on different protocols.

Fuel Load Calculations

Downed Woody Debris (from Brown 1974):

Formula for Computing Tons per Acre:

1, 10, 100-hr size classes: 0-3 in: (tons/acre) = $(11.64 * n * d^2 * s * a * c)/N_t$

1000-hr size classes: 3+ inches: (tons/acre) = $(11.64 * \sum d^2 * s * a * c)/N_t$

Where:

c = slope correction factor

$$c = \sqrt{1 + \left(\frac{\text{Percent slope}}{100}\right)^2}$$

No slope correction is needed for samples taken using the Jacob's staff.

Table 1.--*Slope correction factors for converting weight/acre on a slope basis to a horizontal basis*

Slope	Correction factor	Slope	Correction factor
Percent	*c*	*Percent*	*c*
0	1.00	60	1.17
10	1.00	70	1.22
20	1.02	80	1.28
30	1.04	90	1.35
40	1.08	100	1.41
50	1.12	110	1.49

(From Brown 1974)

n = total number of intersections over all sample points (for each of the 1-hr, 10-hr and 100-hr samples), aka the number of pieces you tallied

d^2 = squared average diameters

- For 1, 10 and 100-hr fuels these have been measured in the field and constants for different species and systems have been derived. For our purposes, we use the following (nonslash composite values from Brown 1974):

Hour Category	1-hr	10-hr	100 -hr
Diameter class (inches)	0 – 0.25	0.25 - 1	1 - 3
d^2 (inches^2):	0.0151	0.289	2.76

- For 1000-hr fuels (3+ in), the actual diameters of each piece are squared and added together to get $\sum d^2$

s = specific gravity of the materials

Approximate Specific gravities for conifers given by Brown (1974) were:

Hour Category	1-hr	10-hr	100 -hr	1000-hr sound	1000-hr rotten
Diameter class (inches)	0 – 0.25	0.25 - 1	1 - 3	3+, decay class 1, 2, or 3	3+, decay class 4 or 5
specific gravity	0.48	0.48	0.40	0.40	0.30

a = the nonhorizontal angle correction factors

- The correction factor adjusts weight estimates for the fact that all particles do not lie horizontally as assumed in the planar intersect theory.
- Brown provides the following:

0 to 3 inches: 1.13
3+ inches: 1.00

N_l = the total length of the sampling line

These lengths are different for different protocols. In our protocol:

Fuel Size Class	Length of Transect Sampled
1-hr	6ft
10-hr	6ft
100-hr	35ft
1000-hr	60ft

Litter and Duff:

Litter and Duff loadings are calculated by multiplying the average depth by the bulk density of litter (or duff). Use bulk density values of 2.75 lbs/ft^3 for litter and 5.5 lbs/ft^3 for duff. Note that you will need to convert to tons/acre.

Full formulas:

$$Fuel\ loading\ \left(\frac{tons}{ac}\right) = avg.depth(in)x\ bulk\ density(\frac{lb}{ft^3})(\frac{1ft}{12in})(\frac{1ton}{2000lb})(\frac{43560ft^2}{1ac})$$

Or

$$Fuel\ loading\ \left(\frac{tons}{ac}\right) = \frac{avg.depth(in)xbulk\ densityx43560}{24000}$$

Or

$$Fuel\ loading\ \left(\frac{tons}{ac}\right) = avg.depth\ (in)xbulk\ densityx1.815$$

Calculate average depth in inches for your entire site.

Live and Dead Herbaceous and Woody Loads:

For each transect, average the planar intercept cylinder microplot estimates for live shrub cover, dead shrub cover, live herbaceous cover, and dead herbaceous cover. Find the average shrub height and average herbaceous height. Biomass of live and dead shrubs and biomass of live and dead herbaceous plants are calculated using the equation. Note that you may need to convert to metric units to be able to use this formula!

B=H*C*BD

Where:

B = biomass (kg/sq. m)

H = height (m)

C = percent cover/100

BD = bulk density (kg/cu. m)

Bulk density used for the herbaceous and shrub components are 0.8 kg/m^3 and 1.8 kg/m^3, respectively.

21.4 Reporting & Ecological Management Implications

The final steps in the monitoring process are creating accessible summaries of the data, interpreting the results in the context of the project ecosystem, and discussing the implications of these results for adaptive management with those responsible for decision-making. In this section, we focus on discussing the management implications of monitoring results in an ecological context, but similar metrics are used in stands managed for timber production.

Reporting metrics

Mean height/live crown base height:

Mean tree height provides information on site quality, tree growth, and wildlife habitat. An increase in tree height can indicate growth, or when paired with a decrease in tree density following thinning or fire, can indicate selective retention of taller trees. Similarly, decreases in mean tree height may be caused by an increase in the number of small trees at the site.

Mean live crown base height provides information about the susceptibility of a stand to crown fire, and an increase in mean live crown base height can indicate decreased risk of crown fire in the measured project area, usually following treatments or fire. A decrease in live crown base height over time often indicates the ingrowth of smaller trees with lower live crown base heights drawing the overall stand mean lower.

Basal area:

Basal area incorporates stand density and tree diameters and can be used with other metrics to assess forest trends. For example, if basal area increases while tree density decreases five years after a fire, remaining trees can be assumed to be gaining diameter, likely due to decreased competition. Basal area values can be compared to historic ranges of variability to assess risk of high-severity fire, inform treatments, and assess treatment effectiveness.

Quadratic mean diameter (QMD):

Quadratic mean diameter provides information about the average tree size in a project and is directly related to basal area. An increase in quadratic mean diameter over time may indicate tree growth or the selective removal of smaller trees. As retaining fewer, larger trees is generally the target of thinning treatments, an increase in QMD immediately post-treatment is expected.

Density:

Tree density, reported as trees per acre, reflects the degree of tree crowding within a project area. It can be used to assess the level of tree competition, risk of high-severity fire, and vulnerability of insect and disease

outbreaks within a stand. Reporting tree density provides the number of trees per acre irrespective of size, so considering basal area alongside density gives further information on stand trends. High tree densities can be predictive of an increased risk of high-severity fire, insect or disease outbreaks, and stagnated growth. Similarly to basal area, tree density values can be compared to historic ranges of variability to inform treatments and assess outcomes.

Species composition:

Species composition, and changes in species composition over time, are important parameters to report to understand forest type classification, assess wildlife habitat factors, and determine impacts of treatments and fire on forest biodiversity. Shifting species dominance in a stand is often included in management goals when planning forest treatments. For example, a thinning treatment may target the removal of white fir to increase the dominance of ponderosa pine to reflect historic species compositions in the area or increase resilience to fire. Species compositions of the regeneration class can provide valuable information about the trajectory of the stand species composition over time.

Surface fuel loads:

Surface fuel loads, most often reported in tons/ac can tell you a lot about not only expected fire behavior but also forest structural diversity, quality of wildlife habitat, carbon sequestration, nutrient cycles, and more. Surface fuel loads typically increase after thinning, and decrease after fire. Very low fuel loads may suggest recent fire, and/or heavy fuelwood utilization. Paying attention to the distribution of 1000-hour fuel decay classes can give information on habitat diversity, fire history, and recruitment. For instance, if the majority of logs are decay classes 1-2 this would suggest they have been recently recruited (e.g. thinning, blowdown).

Ladder fuel loads:

Ladder fuel loads (approximated by the planar intercept cylinders) can be useful for predicting fire behavior. Increased biomass—for instance, in the standing dead categories—can indicate more ladder fuels on the landscape, which could increase the likelihood of crown fire. This can also tell us about the structural diversity of the forest – an absence of biomass in the planar intercept cylinders may be associated with an absence of understory shrubs/regeneration.

Best practices for reporting

Make reports accessible:

If reporting results for a general audience, avoid technical terms and jargon that may be inaccessible to the average reader. Define any acronyms or technical terms that are used. Create clear and simple figures that show data trends visually and refer to these figures when describing results. Provide a general summary of data trends and management implications at the beginning of the report. Try to integrate your understanding across the different types of data to create a common-language narrative of what is happening in the forest.

Provide context:

When reporting, it is important to make results relevant in the context of the history and geography of a project area. Provide maps of treatments, plots, and project boundaries. Include a timeline of treatments,

fires, and other disturbances, with details on the intended outcomes and goals of any treatments completed. Consider any other information needed to understand the report's results in an ecological context, and if reporting to a general audience, do not assume prior knowledge.

Note limitations:

When reporting monitoring results, always clearly describe any limitations in the data analysis or data quality. For example, if only a subset of monitoring plots were re-measured in a particular year, this could influence results and should be noted clearly in the report wherever applicable. If monitoring protocols changed over time, detail these changes and any effects they may have on data trends. Note where direct comparisons should not be made over time due to changing protocols or seasonal effects.

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21.4 Reporting and Ecological Management Implications

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SUPPLEMENTAL INFORMATION

A Basic CSE Plot Workflow with a 3-person crew

This workflow is one option for efficient plot data collection for a 3-person crew. This workflow assumes that a crew is not performing certain optional monitoring protocols, such as tagging trees and recording disturbance history.

Task	Person 1	Person 2	Person 3
Navigate w/ GPS, update point & record coordinates/elevation with Geode and a paired mapping application	1		
Install rebar at plot center (PC)		1	
Plot slope (take & record)	2		
Aspect (take & record)	3		
Regeneration (small plot seedlings/saplings)	5		
Aerial/ground cover (small plot)	6		
Take canopy with densiometer at all 4 inner flags		4	
Record canopy from Person 2	7		
Take PC photo of whiteboard			1
Layout plot to E & S		2	
Layout plot to N/B0, W/B270, B135 (if applicable)			2
Take photos from 75' facing PC on Brown's transects			4
Take slope on Brown's transect			3
Hold whiteboard for Brown's photos	8		
ID tree species, condition, & take DBH			6
Flag witness tree		3	
Record witness tree	4		
Measure tree Ht & LiCrBHt		5	
Record trees from Person 2 and Person 3	10		
Count Brown's transects, cylinders, and litter & duff			5
Record Brown's counts, cylinders, slope & fuelbed	9		
Take NESW photos from PC & pick up inner flags			7
Hold whiteboard for NESW photos at 37.24' & pick up outer flags		6	
Write down the photo order and photo numbers, the group's comments on plot, & double-check datasheets are completely filled out	11		
Double-check all photos with camera playback			8
Mark off plot on master map & confirm next destination		7	

Basic CSE Plot Workflow – Tasks by Person

Person 1

1. Navigate w/ Garmin GPS, update point & record coordinates/elevation with Geode and a paired mapping application, such as Field Maps
2. Plot slope (take & record)
3. Aspect (take & record)
4. Record witness tree
5. Regeneration (small plot seedlings/saplings)
6. Aerial/ground cover (small plot)
7. Record canopy from Person 2
8. Hold whiteboard at PC for Brown's photos
9. Record Brown's counts, cylinders, slope, & fuelbed
10. Record Trees from Person 2 and Person 3
11. Write down the photo order and photo numbers, the group's comments on plot, & double-check datasheets are completely filled out

Person 2

1. Install rebar at plot center
2. Layout plot to E & S
3. Flag witness tree
4. Take canopy with the densiometer at all four inner flags
   **** Help Person 1 with the small plot tally if needed ***
5. Measure tree Ht & LiCrBHt (clinometer or hypsometer/rangefinder)
6. Hold whiteboard for NESW photos at 37.24' & pick up outer flags
7. Mark off plot on master map & confirm next destination

Person 3

1. Take PC photo of whiteboard
2. Layout plot to N/B0, W/B270, B135
3. Take slope on Brown's transect
4. Take photos from 75' facing PC on Brown's transects
5. Count Brown's transects, cylinders, and litter & duff
   ***If Person 1 is busy, record your Brown's transect in your own field book or whiteboard and give it to them when they are free ***
6. ID tree species, condition & take DBH
7. Take NESW photos from PC & pick up inner flags
8. Double-check all photos with camera playback

SUPPLEMENTAL INFORMATION

B Species Code Cheat Sheet

Common Upland Tree Codes

Code	Scientific Name	Common Name
ABCO	*Abies concolor*	white fir
ABLAA	*Abies lasiocarpa* var. *arizonica*	corkbark fir
ARTR2	*Artemisia tridentata*	big sagebrush
CEMO2	*Cercocarpus montanus*	alderleaf mountain mahogany
FRVE2	*Fraxinus velutina*	velvet ash
JUCO6	*Juniperus communis*	common juniper
JUDE2	*Juniperus deppeana*	alligator juniper
JUMO	*Juniper monosperma*	one-seed juniper
JUSC2	*Juniperus scopulorum*	Rocky Mountain juniper
PIAR	*Pinus aristata*	bristlecone pine
PIED	*Pinus edulis*	two-needle piñon *piñon pine**
PIEN	*Picea engelmannii*	Engelmann spruce
PIFL2	*Pinus flexilis*	limber pine
PIPO	*Pinus ponderosa*	ponderosa pine
PIPU	*Picea pungens*	blue spruce
POTR5	*Populus tremuloides*	quaking aspen
PSME	*Pseudotsuga menziesii*	Douglas-fir
QUGA	*Quercus gambelii*	Gambel oak
QUGR3	*Quercus grisea*	gray oak
QUPA4	*Quercus pauciloba*	wavyleaf oak
QUTU2	*Quercus turbinella*	Sonoran scrub oak *desert scrub oak**
RONE	*Robinia neomexicana*	New Mexico locust

Common Riparian Codes

Code	Scientific Name	Common Name
AIAL	*Ailanthus altissima*	tree of heaven
ACGL	*Acer glabrum*	Rocky Mountain maple
ACNE2	*Acer negundo*	boxelder
BASA4	*Baccharis salicifolia*	seepwillow *mule-fat**
COSE16	*Cornus sericea*	redosier dogwood
ELAN	*Elaeagnus angustifolia*	Russian olive
FOPU2	*Forestiera pubescens*	stretchberry *New Mexico olive**
PODEW	*Populus deltoides* ssp. *wislizeni*	Rio Grande cottonwood
PRVI	*Prunus virginiana*	chokecherry
SAEX	*Salix exigua*	narrowleaf willow *coyote willow**
TAMAR2	*Tamarix* spp.	tamarisk *salt cedar**, species unknown
ULPU	*Ulmus pumila*	Siberian elm

Common Cacti Codes

Code	Scientific Name	Common Name
CYIM2	*Cylindropuntia imbricata*	tree cholla
CYLIN2	*Cylindropuntia* sp.	cholla, species unknown
OPEN3	*Opuntia engelmannii*	cactus apple *desert prickly pear**
OPPH	*Opuntia phaeacantha*	tulip prickly pear
OPUNT	*Opuntia* sp.	prickly pear, species unknown

Common Upland Shrub Codes

Code	Scientific Name	Common Name
AMCA6	*Amorpha canescens*	lead-plant
AMFR	*Amorpha fruitcosa*	false indigo bush
ARPU5	*Arctostaphylos pungens*	point-leaf manzanita

Code	Scientific Name	Common Name
ARUV	*Arctostaphylos uva-ursi*	kinnickinnick
ATCA2	*Atriplex canescens*	fourwing saltbush
CEFE	*Ceanothus fendleri*	Fendler's ceanothus
DAFR6	*Dasiphora fruticosa*	shrubby cinquefoil
ERNA10	*Ericameria nauseosa*	rubber rabbitbrush
FAPA	*Fallugia paradoxa*	Apache plume
FOPU2	*Forestiera pubescens*	stretchberry *desert olive**
GUSA2	*Gutierrezia sarothrae*	broom snakeweed
KRLA2	*Krascheninnikovia lanata*	winterfat
MARE11	*Mahonia repens*	creeping barberry
NOGR5	*Nolina greenei*	woodland beargrass *Greene's beargrass**
PAMY	*Paxistima myrsinites*	Oregon boxleaf *mountain-lover **
RHTR	*Rhus trilobata*	skunkbush sumac *three-leaved sumac **
RIBES	*Ribes* sp.	currant, species unknown
RICE	*Ribes cereum*	wax currant
RIIN2	*Ribes inerme*	whitestem gooseberry
ROWO	*Rosa woodsii*	Woods' rose
RUID	*Rubus idaeus*	American red raspberry
SHCA	*Shepherdia canadensis*	russet buffaloberry
SYAL	*Symphoricarpos albus*	white snowberry
SYMPH	*Symphoricarpos* sp.	snowberry, species unknown
SYRO	*Symphoricarpos rotundifolius*	roundleaf snowberry
VAMY2	*Vaccinium myrtillus*	whortleberry
YUBA	*Yucca baccata*	banana yucca
YUCCA	*Yucca* sp.	yucca, species unknown

**Italic common name* represents an alternative common name that differs from the common name found in the USDA plant database.

SUPPLEMENTAL INFORMATION

C Disturbance History Change Agent Code Reference Chart

CHANGE AGENT CODE	CHANGE AGENT DESCRIPTION	CHANGE CODE (Used To Add Additional Info About The Change Agent)	DEFINITIONS/USE CASES	SEVERITY All Severities Are Approximations Use 900 Codes For All %S
AVAL	Avalanche			% of plot impacted
CHIP	Chipping	**CHIPADD** **CHIPLEFT**	Chips/mulch present on site (not just sawdust from chainsaw cuts). If possible, indicate whether these came from trees on site (CHIPLEFT) or were dropped as part of re-seeding or erosion control efforts (CHIPADD) in the Change description.	% of plot covered in chips
CCUT	Clearcut	**CCUTRX** **CCUTHAZ**	All or nearly all trees were cut on plot. Most commonly done with live trees to create a fuelbreak (CCUTRX) but can also be a type of hazard tree mitigation (e.g. removal of all standing dead trees) (CCUTHAZ).	% of plot clear cut
DICH	Ditching/ Draining		Use for manmade ditches or hydrologic modifications present on plot.	If this occurred on plot, report 100%
FIEX	Fire Exclusion		Can be used on sites with a unique history of fire exclusion, such as RNAs.	If this occurred on plot, report 100%
FLOD	Flood		Use when wrack lines/debris present on plot. Please note in the comments height of wrack/ debris, and observations about erosion.	If this occurred on plot, report 100%
GRAZ	Grazing	**GRAZLIV** **GRAZWIL** **BROW**	Use when grazing or browsing has impacted the plot. Although we know wildlife (GRAZWIL) or livestock grazing (GRAZLIV) likely occurs on every plot, this code does not need to be recorded unless there is noticeable grazing/ browsing. If the primary impact is browsing of woody species, use the Change Code BROW.	% of vegetation on plot impacted by grazing/ browsing
ICE	Ice Storm		Used if several trees show ice damage.	% of vegetation on plot impacted
INDI	Insect and Disease		Use when insect/disease is impacting plot vegetation. Note that most of the detail will be captured in the regen/ overstory data.	% of vegetation on plot impacted by
EXSP	Introduction of Exotic Species		Use when exotic species (herbaceous, woody, or other) noted on plot. List the species in the Comments if possible!	% of plot covered in exotic species

CHANGE AGENT CODE	CHANGE AGENT DESCRIPTION	CHANGE CODE (Used To Add Additional Info About The Change Agent)	DEFINITIONS/USE CASES	SEVERITY All Severities Are Approximations Use 900 Codes For All %S
LNDS	Landslide		Use if significant slope movement or debris encountered on plot.	If this occurred on plot, report 100%
LOG	Logging Methods/ Equipment Damage	**TRACK** **DRAG**	Use if heavy equipment tracks (TRACK) or skid trails (DRAG) have disturbed plot. If extraction occurred, see STUM.	% of plot covered in tracks or trails
MAST	Mastication	**MASTLEFT** **MASTREM**	Trees were masticated on plot as evidenced by the distinctive stumps. Note if chips/ masticate was removed (MASTREM) or left (MASTLEFT).	% of plot masticated % of plot masticated + masticated materials remaining on plot
NOCH	No Change		No new disturbances observed on plot since last sample event.	If this occurred on plot, report 100%
PAVE	Paving		Not typically encountered.	
PILE	Pile Burn	**PILE** **JACK** **BARE** **PREP**	Use for pile burns (PILE) that occurred as part of prescribed fire. If you know they were jackpot burns, use JACK. Use BARE if bare patches exist. If piles exist on plot but have not yet been burned, use PREP.	% of plot burned in pile burn (PILE, JACK) % of plot bare due to presence of burn piles (BARE) % of plot covered in burn piles (PREP)
PRUN	Pruning		Use if trees were pruned for some reason.	% of vegetation on plot pruned
PFIRE	Prescribed Fire	**BROAD**	Use for broadcast burns (BROAD) that occurred as part of prescribed fire. Also appropriate to use (along with Pile Burn) if fire was allowed to run between/ among piles. If crown fire resulted or the burn escaped, see CFIRE and GFIRE.	% of plot burned in broadcast burn
OTHR	Other		Use for disturbances not otherwise represented here. Add detail to comments.	% of plot impacted
REFR	Residual Fertilizer		Not typically encountered.	

CHANGE AGENT CODE	CHANGE AGENT DESCRIPTION	CHANGE CODE (Used To Add Additional Info About The Change Agent)	DEFINITIONS/USE CASES	SEVERITY All Severities Are Approximations Use 900 Codes For All %S
RSTN	Restoration work	**PLANT** **SEED** **ERCO** **OTHER**	Use to reflect restoration activities such as planting of seedlings (PLANT), seeding (SEED), or erosion control structures (ERCO) or other activities (OTHER). Add details about seeding, seedlings, types of erosion control structures, and more to the Comments.	If this occurred on plot, report 100%
SALV	Salvage Logging	**SALVDROP** **SALVREM**	Standing dead (insect- or fire-killed) trees were cut on plot. Indicate whether trees were removed (SALVREM) or left on plot (SALVDROP).	If this occurred on plot, report 100%
SCUT	Selection cut		Selection cuts are often intended to create an uneven-aged structure, so trees of all sizes/ classes will be harvested. For other types of thinning, see THIN, CCUT or SALV.	If this occurred on plot, report 100%
STUM	Stumpwooding		Use for removal or harvest of stumps, including extraction.	If this occurred on plot, report 100%
THIN	Thinning (thin from below)	**THINBELOW** **FUEL** **OTHER**	Thinning from below focused on removing the smaller diameter or suppressed trees, leaving the largest trees. If you are sure this is what was happening, use THINBELOW. If all diameters of trees were taken, see SCUT above. If you believe the cutting happened for fuelwood harvesting, use FUEL. For other types of thinning, see SALV and CCUT. If you are unsure why a particular thinning effort occurred, use OTHER and leave comments.	If this occurred on plot, report 100%
TURP	Turpentining		Not typically encountered.	
WFIRE	Wildland Fire	**WILD** **ESCAPE**	Use for wildfire only (WILD) or escaped prescribed fire (ESCAPE).	% of plot burned in wildfire
CFIRE	Wildland fire (crown)		Used when several crowns have been burned. Do not use for isolated or very small groups of trees (this is torching).	% of plot that saw crown fire
GFIRE	Wildland fire (ground)		Use for ground fire as a result of wildfire or escaped prescribed fire. Ground fire as a part of typical prescribed fire can be captured under PFIRE.	% of plot burned in ground fire
WFUS	Wildland Fire Use [suppression]	**RETD** **LINE** **OTHER**	Can be used to capture fire suppression activities, such as retardant drops (RETD), fireline (LINE), other (OTHER) etc. Add notes in the Comments.	If this occurred on plot, report 100%
WIND	Windthrow		Used to capture microbursts or other windthrow on plot. Not necessary when a single tree or two falls.	% of trees on plot impacts by windthrow

D USFS Damage Codes Reference Chart

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
10000	**INSE**	General Insects	**101 - Minor:** bottlebrush or shortened leaders, 0-2 forks on stem, OR <20% of branches affected, OR <50% of bole with visible larval galleries OR **102 - Severe:** 3 or more forks on bole, OR 20% or more branches affected, OR terminal leader dead, OR 50% or more of bole with visible larval galleries	Beetles, moths, sawflies, ants, wasps.
11000	---	Bark Beetles	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	The presence of small holes, usually exuding frass and galleries (tunnels beneath bark).
17000	**GALL**	Gallmarker Insects	**171 - Minor** OR **172 - Severe**	Abnormal growths on stems, roots, or leaves. Formed by pathogen/ parasitic infection.
19000	---	General Disease	**191 - Minor** OR **192 - Severe**	Blister rust, etc.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
21000	**ROTT**	Root/Butt Disease	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	The presence of fungi other than shelf-like fruiting bodies/ conks. Indicate specific fruiting body or its general morphology in the comments.
22000	**CONK**	Stem Decay/ Canker	220: 0-4% rotten 221: 5-15% rotten 222: 16-25% rotten 223: 26-35% rotten 224: 36-45% rotten 225: 46-55% rotten 226: 56-65% rotten 227: 66-75% rotten 228: 76-85% rotten 229: 86-100% rotten	The presence of shelf-like fruiting bodies/ conks. If not shelf-like fungus, use ROTT/2100. Specify presence of conk in the comments.
23000	--- **OR** **EPIC/** **LICH/**	Parasitic/ Epiphytic Plants	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Epiphytic plants: lichen Parasitic plants: dodder *(Cuscuta spp.)*, pinedrop *(Pterospora andromedea)*, bearcorn *(Conopholis americana)*, pinesap *(Monotropa hypopitys)*, etc. Make a note in the comments whether plant is an epiphyte or parasite and record the specific species if able to identify.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
23001	**MISL**	Mistletoe	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Parasitic plant that often forms a dense cluster of shoots. Can sprout from bole or branches. Affects PIPO, PIFL, PIED, PSME, PIEN, PIPU, JUxx.
25000	--- **OR** **BROM**	Foliage Diseases	**251 - Minor:** <20% of foliage affected or <20% of crown in brooms OR **252 - Severe: >**20% of foliage affected or >20% of crown in brooms	Needle cast, needle blight, witches' broom. Note the specific damage in the comments.
25001	**BLIG**	Blight	**251 - Minor:** <20% of foliage affected or <20% of crown in brooms OR **252 - Severe:** >20% of foliage affected or >20% of crown in brooms	Discoloration of needles, stunted growth. Needles stay attached to the tree in comparison to needle cast where they are shed.
27000	---	Broom Rusts	**271 - Minor:** <20% of crown in brooms OR **272 - Severe:** >20% of crown in brooms	Dense cluster of growth. More yellow than brooms caused by mistletoe and lacks mistletoe shoots.
30000	**FIRE**	Fire	Maximum scorch height (foliage) & char height (bark)	No % or severity needed, assessed by recording the maximum height of scorch and char.
40000	**MAMM**	Animal Damage, Source Unknown	**401 - Minor** OR **402 - Severe**	Bear claw marks, porcupine or beaver chewings, and deer/elk rubbings. Make a note in the comments about specific damage.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
41010	**BIRD**	Woodpecker	**411 -Minor:** <20% of crown affected, bole damage is <50% circumference OR **412 - Severe:** >20% of crown affected, bole damage is >50% circumference, upper 1/3 of crown is killed	Holes are larger, more chiseled than beetle holes. 41010 code indicates woodpecker, NPS letter code not as specific.
50000	**--** **OR** **OZON/ FRST**	Abiotic Damage	**501 - Minor:** <20% or crown affected, bole damage is <50% of circumference OR **502 - Severe:** >20% of crown affected, bole damage is >50% of circumference, upper 1/3 of crown is killed	Air pollutants, chemical damage, drought, frost. Note the specific damage in the comments.
50008	**LIGT**	Lightning Scar	**501 - Minor:** <20% of crown affected, bole damage is <50% circumference OR **502 – Severe:** >20% of crown affected, bole damage is >50% circumference, upper 1/3 of crown is killed	Narrow vertical scar/ wound running down the length of the bole.
70000	**UMAN**	Human Activities	**701 - Minor** OR **702 - Severe**	Markings, girdling, cuttings, etc. Note the specific damage in the comments.
90000	---	Unknown	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Used when damage cannot be identified.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
99001	**BROK**	Broken Top	% of original height missing: 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Live, sick, and dead trees can all have broken tops. If a previously tagged tree broke below 4.5ft, record broken top code with true height of tree.
99002	**DTOP**	Dead Top	% of total tree height that is dead: 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Only live and sick trees can have a dead top.
99004	**FORK/ TWIN**	Forked Top	% of total tree height above fork 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Uncharacteristic, forked top (not applicable for POTR5, *Quercus spp.*, etc.). NPS letter codes use FORK for forking above DBH and TWIN is used for forking below DBH. Indicate whether fork is V-shaped or U-shaped in the comments in addition to recording the height of where the bole forks.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
99006	**CROK**	Crook or Sweep	% of total tree height, which contains the crook or sweep 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Use when crooked bole or sweep is uncharacteristic for tree species.
99016	**SPAR**	Foliage Loss	**1 = Minor** OR **2 = Severe**	Unusually sparse foliage.
99026	**WOND**	Open Wound	% of bole affected: 900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Opening or cavity on bole with the outer bark missing.
99036	**FIRE**	Fire Scar	% of bole covered by fire scar	Scar that forms at the base of the tree, usually triangular in shape.
99037	**LEAN**	Leaning tree	% lean from vertical: 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Should be greater than 15%, use 900 severity rating. In the comments, specify the exact %. Snags (dead trees) with a lean greater than 45 deg or 50% lean severity are not recorded as trees. They instead are recorded as CWD in the fuel measurements.

USFS Damage Category	NPS Damage Code	Damage Description	Severity	Notes
99000	--- **OR** **ABGR/** **BURL/** **EPIC/** **HOLW/** **ROOT/** **SRPT**	Physical Effects	900: 0 – 9% affected 901: 10 – 19% affected 902: 20 – 29% affected 903: 30 – 39% affected 904: 40 – 49% affected 905: 50 – 59% affected 906: 60 – 69% affected 907: 70 – 79% affected 908: 80 – 89% affected 909: 90 – 100% affected	Large, exposed roots, hollowed out bole, abnormal growth pattern, burl, epicormic sprouts from bole/ limbs, sprouts at base, etc. Make a note in the comments of the specific damage.
---	X	Not assessed	-1	
NMFWRI Custom Damage Code				
GONE		Tree missing	---	Previously tagged tree is missing; its fate is unknown.
UPROOT		Tree uprooted	---	Previously tagged tree has been completely uprooted, but crew was able to locate the bole.

E Completed Example Datasheets

Plot Description

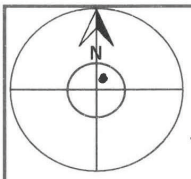
Observer:	LM, AR
Recorder:	KS
Latitude (dd.dddddd):	35.5453933°
Longitude (ddd.dddddd):	-105.1520001°
Elevation (ft):	8,438ft

Administrative Unit:	Santa Fe National Forest
Project Unit:	Maestas Northridge
Macroplot:	M_4
Date (MM/DD/YYYY):	07/06/2023
Time:	2:14 P.M.

Photo Azimuths:	(1) of whiteboard at PC. (1) from 75 feet N looking south to PC (4) from PC in all four cardinal directions; (1) from each Brown's transect looking toward PC.
ORDER TAKEN & #:	PC(100-0985), N(0985), E(0986), S(0987), W(0988), BR2∞(0289), C(0990)

Hill Slope (% where steepest):	10 %
Aspect (circle one):	N E (S) W
Aspect azimuth (degrees):	195 °
Mag Declination:	8 °

Comments: Tree #4 fell since last visit
Lots of mulein on plot
Ravine to the south
open w/ mainly ponderosa pine and aspen
Large boulders at edge of plot to the West



Describe Witness Tree(s):
@25° azimuth
5' from PC
Tree#5, 17.5" DBH
55.1' HT, 23.1' Live crown HT
Draw location of tree on plot

Color of Flagging/Marker Used: double orange flagging

Aerial cover (%) (1/100th acre plot)			
Tree regen.	Shrubs	Graminoids	Forbs
2%	7%	10%	12%

Macroplot Sizes		
Size (Acres)	1/100	1/10
Radius (Feet, Decimal Feet)	11.78	37.24
Radius (Feet, Inches)	11' 9"	37' 3"

Squares →

Canopy (%)	
N 7	S 10
E 5	W 2

Ground cover (%) (1/100th acre plot) (total 100 %)						
Plant basal (including cacti)	Bole (woodies)	Litter	Bare soil	Rock (>2.5in)	Gravel (< 2.5 in)	Total (%)
15%	9%	30%	20%	15%	1%	100%

Species	Condition (Live, Dead, Sick)	Small Plot—Tree Regen, Shrubs & Cacti: Height classes—Seedlings (<4.5', <1" dbh/drc) > 0 - 0.5'	> 0.5'—1.5'	> 1.5' - 2.5'	>2.5'- 3.5'	>3.5' - 4.5'
ARUV	L	II (2)		IIII (6)		(1)
BOWO	L	III (3)	II (2)	IIII (4)	II (2)	
BOWO	D	IIII (5)	(1)			
POTR5	L	III (3)			IIII (4)	II (2)
PIPO	L		(1)			

Small Plot—Tree Regen, Shrubs & Cacti: Species	Condition (Live, Dead, Sick)	Saplings ≥4.5', < 1"
POTR5	L	II (2)

New Mexico Forest and Watershed Restoration Institute

Version: 3/13/24, km

Observer/Recorder: AR/NL Project/Site/Plot SFNF, Maestas Date 7/6/23 Plot Number M-4 Page 1 of 1

1/10th acre plot (37' 3" radius)													
Tree Tag #	Species	Tree cond. (L, D, S)	DBH/DRC (add down arrow if DRC was taken)	# stems	Total Tree Ht	LiCrBHt	Damage 1	Severity 1	Damage 2	Severity 2	Char Ht	Scorch Ht	Comments (witness tree, etc.)
1	PIPO	L	3.8 inches	1	16.9 ft	10.1'							
2	PIPO	D	9.2 in.	1	32.2'	—	99001	901					
3	POTR5	L	5.0"	1	31.1 ft	22.6'	30000	—			0.5'	24'	
5	PIPO	L	17.5"	1	55.1'	23.1'							Witness tree
6	PSME	L	10.2 in.	1	45.9'	25.5'	23001	902					
7	POTR5	L	6.4"	1	33.4'	18.6'							
8	PIPO	L	13.1"	1	48.9'	17.9'	30000	—			6.5'		
9	PIPO	L	12.7"	1	49.8'	15.3 ft							
10	PIFL2	D	7.6"	1	28.6'	—							
11.1	PIPO	L	4.9"	2	30.2'	11.0 ft	99004	909					V fork at 3'
11.2	PIPO	L	5.7"	2	33.7	10.5'	99004	909					V fork at 3'
12	PIFL2	S	9.0"	1	30.0'	22.3'	11000	908	23001	909	10'	22.3'	Damage 3: 30000
13	POTR5	L	1.2"	1	9.1 feet	6.4'							Reached Cutoff in past 5 years, 15° azimuth between #2 + #3

Version: 3/13/24

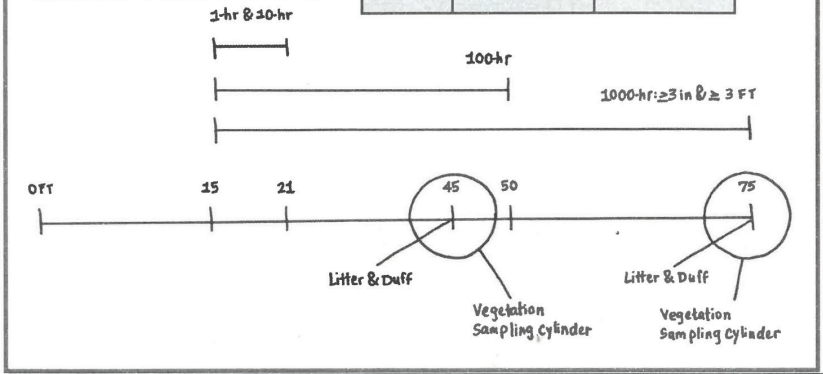
Surface Fuels

Sheet 1 of 2: Fine Woody Debris—Coarse Woody Debris

Observer	LM
Recorder	LM
Number of Transects	1

1-hour Transect Length - 6'	
10-hour Transect Length - 6'	
100-hour Transect Length - 35'	
1000-hour Transect Length - 60'	

Class		Diameter (in)
FWD	1-hr 10-hr 100-hr	0 to 0.25 0.25 to 0.9 1.0 to 2.99
CWD	1000-hr +	3.0 and greater



Admin Unit:	Santa Fe National Forest
Project Unit:	Maestas Northridge
Macroplot:	M_4
Date (MM/DD/YYYY):	07/06/2023
Time:	2:45 P.M.

Fine Woody Debris (1, 10, 100 hr fuels)	Transect	Azimuth	Slope	1 - Hr Count	10 - Hr Count	100 - Hr Count	Comment
	1	* Random for CFRP or (0°) 20°	4	III (3)	II (2)	—	
	2	135°					
	3	270°					

Coarse Woody Debris (1000 hr fuels)	Transect	Log No.	Log Diameter	Decay Class	Comment (e.g. spp)
	1	1	7.2"	2	Tree tag #4, PIPO
	1	2	10.0"	5	

Precisions: Diameter: ±0.5 in ; decay class ±1 class ; Slope ±5 percent

Decay Class Description

1 All bark is intact. All but the smallest twigs are present. Old needles probably still present. Hard when kicked
2 Some bark is missing, as are many of the smaller branches. No old needles still on branches. Hard when kicked
3 Most of the bark is missing and most of the branches less than 1 in. in diameter also missing. Still hard when kicked
4. Looks like a class 3 log but the sapwood is rotten. Sounds hollow when kicked and you can probably remove wood from the outside with your boot. Pronounced sagging if suspended for even moderate distances
5 Entire log is in contact with the ground. Easy to kick apart but most of the piece is above the general level of the adjacent ground. If the central axis of the piece lies in or below the duff layer then it should not be included in the CWD sampling as these pieces act more like duff than wood when burned.

Surface Fuels

Sheet 2 of 2: Duff, Litter, and Vegetation

Observer	LM
Recorder	LM
Number of Transects	1
Transect Length: 75 '	

Administrative Unit:	Santa Fe National Forest
Project Unit:	Maestas Northridge
Macroplot:	M_4
Date (DD/MM/YYYY):	07/06/2023
Time:	2:50 P.M.

Transect	Sample Location	Litter Depth	Duff Depth
1	45'	1.5"	0.5"
1	75'	1"	0"
2	45'		
2	75'		
3	45'		
3	75'		

Veg Item	% Veg Cover	Veg Hgt (d.d')
HD	0.5	0.3'
HL	3	1'
SD	0	—
SL	3	1.5'
HD	3	0.5'
HL	10	1.2'
SD	0	—
SL	0	—
HD		
HL		
SD		
SL		
HD		
HL		
SD		
SL		
HD		
HL		
SD		
SL		
HD		
HL		
SD		
SL		

Surface Fuels-Vegetation Item Code and Description

HD dead non-woody vegetation
HL Live non-woody vegetation
SD Dead woody vegetation
SL Live woody vegetation

% Veg cover

Code	Cover
0	No cover
0.5	>0-1 % cover
3	>1-5 % cover
10	>5-15 % cover
20	>15-25 % cover
30	>25-35 % cover
40	>35-45 % cover
50	>45-55 % cover
60	>55-65 % cover
70	>65-75 % cover
80	>75-85 % cover
90	>85-95 % cover

Comments:

New Mexico Forest and Watershed Restoration Institute
Surface Fuels
Sheet 2 of 2: Duff, Litter, and Vegetation

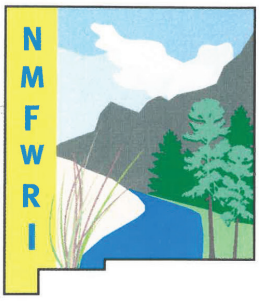
Version: 04/03/2018

Observer/Recorder: VV Project/Site 17.2 Plot Number 003 Date 5/25/26 Page 1 of 1

Disturbance History				
Change Agent	**Change Code**	**Percent of Plot Affected / Severity (Use 900 Codes)**	**Start & End Date**	**Comment**
THIN	THINBELOW	909	9/2025 11/2025	Crew met FS employee who said that thinning was completed last fall.
CHIP	CHIPLEFT	906	9/2025 11/2025	Chips likely from thinned trees.
FLOD		909	5/15/26 5/16/26	Heavy rain occured 10 days before visit. Arroyo on edge of plot shows some erosion and debris 1.5' above bottom.
WFIRE	ESCAPE	905	4/2022 8/2022	Signs of fire on plot, likely HPCC.

F Completed Herbarium Voucher Collection Datasheet

NMFWRI Herbarium Voucher Collection



Collection No.: Soil Value Added_2022_009

Associated Plot ID:

Date: 7-19-2022

Collected by: Sarah Smith

Identified by: Sarah Smith

Location (site, country, state): Cibola National Forest, Tijeras, NM - Sandia District

Latitude (dd.dddddd): 34.968163

Longitude (ddd.dddddd): -106.358029

Elevation (ft): 7,245ft

Scientific Name: Teucrium laciniatum

USDA PLANT Symbol: TELA

Common Name(s): lacy germander

Family: Lamiaceae

Lifeform (forb, shrub, graminoid, tree, mushroom, bryophyte): forb

Species Description (height, flower color/scent, stickiness, texture, gill type, cap shape, etc.):

Long root, white irregular flowers. Linear leaves feathery appearance, opposite leaves.

Habit (annual, biennial, perennial):

perennial

Habitat (ex. P-J, Ponderosa Pine, associated plants in the area, note any disturbance):

Ponderosa Pine, JUSC, GUSA, bottom of canyon next to road

Extent of Species Population: 12 **approx. # of individuals in** 1/10th acre **approx. area**

Slope: 3

Aspect: North

Soil Info (texture, parent material, other): Sandy soil texture

SUPPLEMENTAL INFORMATION

G Optional Measures For Fuel Loading

These variables are not usually measured, but could be collected in special cases. Only use these measures if specifically stated. Some of the text in the following section takes text verbatim from the cited sources to ensure clarity.

Sampling Residue Piles

The line transect method is not practical when sampling CWD within piles and windrows. Piles and windrows are located and sampled on the plot, whether or not they intersect a transect.

Piles and windrows created directly by human activity, and log piles at the bottom of steep-sided ravines in which individual pieces are impossible to tally separately, are more efficiently sampled by using the following instructions. However, loose CWD in piles created by wind throw, landslides, fires, and other natural causes should be tallied using line transects unless it is physically impossible to measure the pieces in the natural pile.

For a pile to be tallied, the following criteria must be met:

• The pile's center must be within 24.0 horizontal feet of plot center, and

• It contains pieces of CWD ≥3 inches diameter that would be impossible to tally separately.

Use the PILE DENSITY variable to estimate the percent of the pile that contains woody material ≥ 3 inches. The pile is assigned to the condition class in which the pile center lies.

Apply the following steps to determine the center of a pile or windrow:

1. Determine the longest axis of a pile.
2. Determine the midpoint of this axis.
3. Project a line through this midpoint that is perpendicular to the axis determined in step 1.
4. Determine the midpoint of the segment of this projected line that crosses the pile.
5. This is the center of the pile.

Piles that cross the 24.0-foot fixed-radius subplot boundary: If the center of a pile is within 24.0 horizontal feet of plot center, tally the pile, recording the dimensions of the entire pile even if part of the pile is beyond 24.0 feet. If the center of a pile is more than 24.0 horizontal feet of subplot center, do not tally the pile or any portion of the pile.

Diameter at the Small End of the Log

Record the code indicating the diameter at the piece's small end. The diameter is recorded to the nearest inch.

The DIAMETER AT THE SMALL END occurs either at (1) the actual end of the piece, if the end has a diameter ≥ 3.0 inches, or (2) at the point where the piece tapers down to 3.0 inches in diameter. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume.

Diameter at Large End of the Log

Measured for wildlife concerns. Record the diameter of the large end of the log to the nearest 0.1 inch. The large end will occur either at a broken or sawn end, at a fracture, or at the root collar. If the end is splintered or decomposing (sloughing off), measure the diameter at the point where it best represents the overall log volume. If a piece is broken but the sections are touching, consider that one log. If the broken sections are not touching, then consider them two logs and record the diameter of the large end of the piece that is passing through the sampling plane.

Log Length

Important for wildlife concerns and useful for rough determination of piece density. CWD TOTAL LENGTH is the length of the piece that lies between the piece's recorded DIAMETER AT THE SMALL END and DIAMETER AT THE LARGE END. For curved logs, measure along the curve. The minimum log length is 3.0 feet before it is a valid tally log. Record length of CWD to the nearest 0.1 feet. If a piece is broken but the two parts are still touching, then record the length end-to-end (A) or sum the lengths for broken pieces not lying in a straight line (B). If piece is broken and the two parts are not touching, then only measure the length of the piece that intercepts the sampling plane (C).

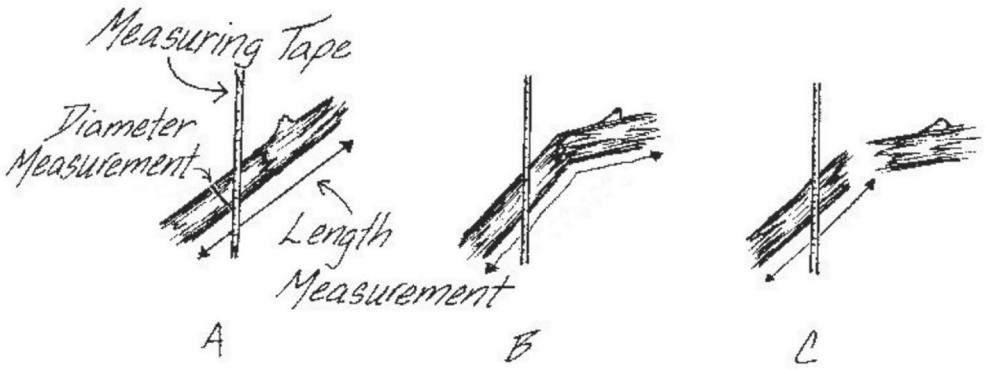


Figure 13. Log length and diameter measurement for optional CWD data. In each case the diameter measurement is made at the same point. In A and B the broken pieces are touching so length includes both pieces. In C, only the piece crossed by the measuring tape is measured for length. *Image by FIREMON*

Distance from Beginning of Transect to Log

This measurement makes relocation of specific logs easier. Frequently, logs that were included in pre-fire sampling roll away from the sampling plane during a fire while other logs, not originally sampled, roll into the plane. Recording the distance from the start of the line, in addition to permanently marking the logs with tags, will make post-fire sampling easier. Record the distance from the start of the measuring tape to the point where the diameter was measured.

Proportion of Log That is Hollow

This characteristic is important for wildlife concerns but also allows more accurate estimates of carbon. Estimate the percent diameter and percent length that has been lost to decay.

A piece is considered hollow if a cavity extends at least two feet along the central longitudinal axis of the piece, and the diameter of the entrance to the cavity is at least one-quarter of the diameter of the piece where the entrance occurs. The entrance occurs at the point where the circumference of the cavity is whole – the point where wood is present completely around the circumference of the cavity. The length of the cavity begins at this point.

Class	Lost to decay
0	No Loss
0.5	>0-1 percent lost
3	>1-5 percent lost
10	>5-15 percent lost
20	>15-25 percent lost
30	>25-35 percent lost
40	>35-45 percent lost
50	>45-55 percent lost
60	>55-65 percent lost
70	>65-75 percent lost
80	>75-85 percent lost
90	>85-95 percent lost
98	>95-100 percent lost

Table 5. Use these classes for recording the percent of diameter and length lost to rot in CWD

References

Brown, J.K., R.D. Oberheu, and C.M. Johnston. (1982). *Handbook for Inventorying Surface Fuels and Biomass in the Interior West.* U.S. Department of Agriculture. Forest Service (General Technical Report INT-129.) https://www.fs.usda.gov/research/treesearch/29401

Down Woody Materials Indicator. (2004). U.S. Department of Agriculture. Forest Service. Northern Research Station. https://www.nrs.fs.usda.gov/fia/topics/dwm/documents/DWM_Training_Plan_04.doc

Fuel Load Sampling Methods. FIREMON. https://www.frames.gov/firemon/sampling-methods#:~:text=The%20Fuel%20Load%20methods%20(FL,transect%20method%20(Brown%201974).

SUPPLEMENTAL INFORMATION

H Plant Identification Resources

The following list of online and print resources are recommended by the authors. Identifying plants can be intimidating, and requires a high level of attention to detail. For true beginners, the book *Botany in a Day* is a lesson in training your mind to observe plants. There are specific details and patterns that, if you can recognize them, make plant identification feel much easier.



Canadian bluejoint, *Calamagrostis canadensis*. A hand lens, or loupe, can be helpful when working with plants with minute identifying features. *Photo by Emily Yannayon*

Another recommended resource for beginners is the New Mexico Wildflowers app. This is available for androids and IOS devices. Users can search for plants based on botanical characteristics such as flower color or leaf orientation. This app can be used offline, and contains photos, range maps, and descriptions of all 3,262 plant species in the app. There are also links to other websites, including those listed below, for a given species (this feature requires internet connection). Versions for most other US states are also available.

Thirdly, iNaturalist is an invaluable tool for identifying and documenting plants. This website and app have an automated plant identification feature. However, the identification provided can be flawed depending on photo quality and the taxa. For example, iNaturalist is unable to correctly identify many grasses due to the nuances required for identification. On the other hand, iNaturalist is a social platform that many experts and hobbyists frequent, who can provide, confirm, or deny identifications.

Online Resources

Field Guide to Diseases and Insects of the Rocky Mountain Region, U.S. Department of Agriculture, Rocky Mountain Research Station, U.S. Forest Service
https://www.fs.usda.gov/r02/natural-resources/forest-health/insects-and-disease-rocky-mountain-region
Tool for field identification of biotic and abiotic agents that damage native trees in the USDA Forest Service's Rocky Mountain Region. Focus on tree diseases and insects that have significant economic, ecological, and/or aesthetic impacts.

A Field Guide to the Grasses of New Mexico
https://nmfwri.org/wp-content/uploads/2019/12/grasses-field-guide-nm.pdf
Third Edition, by Kelly W. Allred

iNaturalist https://www.inaturalist.org/home
Online nonprofit social network and citizen science project. Offers a website and mobile applications. Includes an automated species identification tool, though accuracy for certain taxa is unreliable.

Minnesota Wildflowers: a field guide to the flora of Minnesota
https://www.minnesotawildflowers.info/
Many southwest plants have ranges that extend into the Midwest. By Katy Chayka and other contributors.

New Mexico Department of Agriculture Memorandum on additions to the New Mexico Noxious Weed List
https://nmdeptag.nmsu.edu/media/pdf/noxious-weed-memo-and-list-june-2020.pdf
Latest update to the NM Noxious Weed List, current to July 2, 2020.

New Mexico Rare Plants
https://nmrareplants.unm.edu/rarelist
Information on rare plants listed under varying jurisdictions in the state. Maintained by the New Mexico Rare Plant Technical Council.

New Mexico Thistle Identification Guide
https://www.npsnm.org/wp-content/uploads/2016/02/NM_Thistles_screen_or_8.5x11_2162016.pdf
Thistles are notoriously difficult to identify. Some species native to the US are rare or endangered, and there are non-native species that are noxious weeds. Produced by Robert Sivinski for the Native Plant Society of New Mexico.

New Mexico Wildflowers
https://wildflowersearch.org/search?page=Apps
Smartphone app – available on Google Play Store and Apple App Store. Users can search by plant name, as well as botanical features such as flower color, leaf orientation, and location. App versions are also available for most US states, most Canadian provinces and Northern Mexico.

Plants of the Gila Wilderness
https://www.gilaflora.com/
by Dr. Russ Kleinman, Associate Botanist, Dale A. Zimmerman Herbarium. Presented in Association with the Western New Mexico University Department of Natural Sciences & the Dale A. Zimmerman Herbarium

Plants of the Middle Rio Grande Bosque Field Guide
https://yerbamansaproject.org/field-guide/
Free field guide from the Yerba Mansa Project, based in Albuquerque, NM, an ongoing project created using the iNaturalist platform.

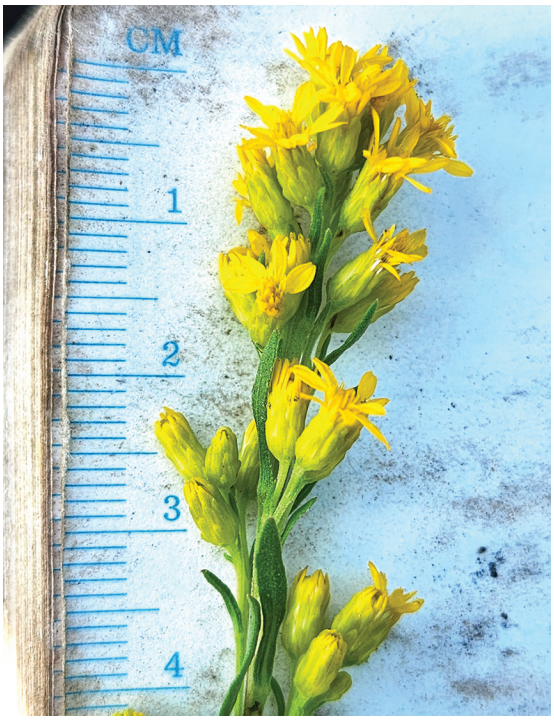
Plants of the World Online
https://powo.science.kew.org/
Online taxonomic database published by the Royal Botanic Gardens, Kew.

Plant Term Glossary
https://gobotany.nativeplanttrust.org/glossary/a/
Glossary of plant terms by the New England Native Plant Trust's Go Botany initiative. Some entries have images or illustrations.

Recognizing Plant Families of the West Field Guide
https://www.blm.gov/colorado/blm-library/blm-library/recognizing-plant-families-west
By Carol Dawson and Phil Krening for U.S. Department of the Interior, Bureau of Land Management, 2021. Print copies available from the BLM Printed Materials Distribution Services.

SEINet New Mexico-Arizona Chapter
https://swbiodiversity.org/seinet/index.php
Database portal containing digitized herbarium collections, including spatial data. Also contains "taxon pages, checklists, and other tools to help you understand the plants in your region of interest." The SEINet network also includes other regional databases.

Southwest Colorado Wildflowers
https://www.swcoloradowildflowers.com/#WEBSITECONTENTS
by Al Schneider



Velvety goldenrod, *Solidago velutina*. A ruler or another way to measure plant specimens may be crucial to identifying features, such as the size of a flower head. *Photo by Emily Yannayon*

USDA PLANTS
https://plants.usda.gov/
US Government databased with standardized information on kingdom Plantae. "Includes names, plant symbols, checklists, distributional data, species abstracts, characteristics, images, crop information, automated tools, web links, and references."

Weeds of the West, 9th edition by Tom D. Whitson. 2006.
https://wyoextension.org/agpubs/pubs/wsws-1.pdf

Wildflowers of New Mexico
https://npsnm.org/wildflowersnm/
by George Miller

World Wide Flowering Plant Family Identification
https://www.colby.edu/info.tech/BI211/PlantFamilyID.html
Electronic form developed from Hansen and Rahn (1969) punched card system for flowering plant family identification. By Ray Phillips for Taxonomy of Flowering Plants course.

Print Resources

Botany in a Day: The Patterns Method of Plant Identification by Thomas J. Elpel. 2004.
https://mountain-press.com/products/botany-day

Diseases of Trees and Shrubs by Wayne Sinclair and Howard H. Lyon. 2005.
https://www.cornellpress.cornell.edu/book/9780801443718/diseases-of-trees-and-shrubs/#bookTabs=1

A field guide to the Plants and Animals of the Middle Rio Grande Bosque
https://publiclands.org/products/a-field-guide-to-the-plants-and-animals-of-the-middle-rio-grande-bosque?srsltid=AfmBOoqODALq_tUndNe3LAOvSw_qni1CcsH_BDJ5mLUOkgczfwfr-fXb



Spreading sandwort, *Arenaria lanuginosa*. *Photo by Emily Yannayon*

Flora Neomexicana III: An Illustrated Identification Manual, 2nd Edition. By Kelly W. Allred, Eugene M. Jercinovic, & collaborators. Illustrated by Robert DeWitt Ivey. https://floraneomexicana.org/flora-neomexicana-series/ Also available for free download as PDFs.

Flowering Plants of New Mexico by Robert DeWitt Ivey. 5th Edition published 2008. https://www.lulu.com/shop/robert-dewitt-ivey/flowering-plants-of-new-mexico/paperback/product-1qn85y9v.html?page=1&pageSize=4

A Guide to Plants of the Northern Chihuahuan Desert by Carolyn Dodson. 2012. https://www.unmpress.com/9780826350213/a-guide-to-plants-of-the-northern-chihuahuan-desert/

Identification of Trees and Shrubs in Winter using Buds and Twigs by Bernd Schulz. 2nd edition, 2025. https://press.uchicago.edu/ucp/books/book/distributed/I/bo257334147.html

Meet the Natives: A Field Guide to Rocky Mountain Wildflowers, Trees and Shrubs by Walter M. Pesman. 2018

Mountain Wildflowers of the Southern Rockies by Carolyn Dodson and William W. Dunmire. 2007. https://www.unmpress.com/9780826342447/mountain-wildflowers-of-the-southern-rockies/

Plant Identification Terminology: An Illustrated Glossary by James G. Harris. 2001. https://upcolorado.com/university-press-of-colorado/plant-identification-terminology

Plant Names Explained: Botanical Terms and their Meaning by Julia Britton. 2005.

The Sunflower Family: A guide to the family Asteraceae in the contiguous United States by Richard Spellenberg and Naida Zucker, 2019. https://shopbritpress.org/products/sunflowerfamily

Trees and Shrubs of New Mexico Revised and Expanded by Jack L. Carter. 2020. Available from Gila Native Plant Society: https://gilanps.org/books/

Vascular Plants of New Mexico by Kenneth Heil and Steve L. O'Kane Jr. 2024. https://press.uchicago.edu/ucp/books/book/distributed/V/bo237308748.html

Wildflowers of the Northern and Central Mountains of New Mexico by Larry J. Littlefield and Pearl M. Burns. 2015. https://www.unmpress.com/9780826355478/wildflowers-of-the-northern-and-central-mountains-of-new-mexico/

Winter Botany: An Identification Guide to Native Trees and Shrubs by William Trelease. 3rd edition, 2011. https://store.doverpublications.com/products/9780486218007?srsltid=AfmBOoq7Ue4Wdgc71F1EYS9GLfdMqhCxS8cbjAVUKZvCjh_QOQNJWwvT

Blank Forms for Field Work

The following pages have blank forms to be used for field work. Reference the preceding pages to view samples of filled out forms.

Equipment Checklist

FIELD SUPPLIES – PER CREW

- ☐ SPOT device for check-ins (1 per crew or sat phone)
- ☐ Sat phone for emergencies (1 per crew or SPOT)
- ☐ Folder with emergency action plans (EAPs) and group medical history/confidential info
- ☐ Hypsometer (Rangefinder), packed carefully with extra battery & charger (1 per crew)
- ☐ Spherical densiometer with flagging tied around it (1 per crew)
- ☐ Handheld walkie-talkie radio with extra batteries and/or charger (1 per crew)
- ☐ Camera with space on memory card, spare charged batteries, spare memory card, & charger (1 per crew)
- ☐ Inverter (for car charging; 1 per crew)
- ☐ External GNSS receiver and tablet unit with points loaded & charger (1 per crew)
- ☐ Mini-Tripod for Geode (1 per crew)
- ☐ Samsung tablet for use with Geode with points loaded & charger (1 per crew)
- ☐ Tablet or Toughbook laptop with data entry software set up and charger/battery pack (if using; 1 per crew)
- ☐ Fiberglass 100 ft or longer tape (2 per crew)
- ☐ Pin flags (10+ per crew)
- ☐ Flag bags for carrying pin flags and/or rebar (1 per crew)
- ☐ Whiteboard, whiteboard markers, & whiteboard wipes (1 set per crew)
- ☐ Chaining Pins (2 per crew)
- ☐ Rebar cut to length & caps to match (number of plots needed + 5)
- ☐ Clipboard (1 regular and 1 waterproof per crew)
- ☐ Paperwork: emergency contacts, driving directions, driving maps, field maps, authority contacts, datasheets and EXTRA datasheets (including some on waterproof paper), plot photos, and data from previous trip
- ☐ Tree calipers (if using; 1 per crew)
- ☐ Fuels gage (min 1 per crew)
- ☐ Plant ID guides (e.g. Trees and Shrubs by Jack Carter)
- ☐ Training manual, tree codes, and protocol cheat sheets (min 1 per crew)
- ☐ Calculator (1 per crew)
- ☐ Field plant press (1 per group) and blank voucher collection sheets
- ☐ Metal detector & spare batteries (if using, 1 per group)
- ☐ Scribes (if using, 1 per crew)

- ☐ Kestrel and fire weather kit (1 per group)
- ☐ Tree tagging machine + tagging kit (extra metal tape reels, nails, hammer, pocket knife, etc) (1 per crew)

FIELD SUPPLIES – PER PERSON

- ☐ Field packs (1 per person)
- ☐ Compass (1 per person)
- ☐ Clinometer & case (1 per person)
- ☐ Garmin GPS with extra AA batteries and points loaded (1 per person)
- ☐ Diameter tape (logger's tape) (1 per person)
- ☐ Arctic Vinyl orange glo heavy duty flagging (1 roll per person)
- ☐ Pencil, pen, & Sharpie (min. 1 each per person)
- ☐ First aid kit (1 per person)
- ☐ Angle gauge (if using; 1 per person – do not share)
- ☐ Field vests (optional; 1 per person)
- ☐ Rattlesnake chaps (optional)
- ☐ Hardhats (if working in windy or burned areas) (1 per person)
- ☐ Field notebook (1 per person)
- ☐ Hand lens (1 per person)
- ☐ Safety sunglasses (1 per person)
- ☐ Sun hat (1 per person)
- ☐ Leather gloves (1 per person)
- ☐ Bandanas (min 1 per person)
- ☐ Lunch & snacks (mandatory per person)
- ☐ Raincoat & rain pants (1 set per person)
- ☐ Small flashlight or headlamp with extra batteries (1 per person)
- ☐ Durable watch with alarm setting – NOT cell phone (1 per person)
- ☐ Sturdy hiking or wildland fire boots – no tennis shoes or sandals when doing fieldwork (1 per person)
- ☐ More water & Gatorade than you think you will drink (recommended 10 L/day/person)
- ☐ Toiletries – toilet paper/trowel/hand sanitizer, sunscreen, etc. (1 kit per person)
- ☐ Tree codes & protocol cheatsheets
- ☐ Pack cover or contractor trash bag

Plot Description

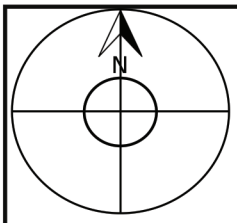
Observer:	_____
Recorder:	_____
Latitude (dd.dddddd):	_____
Longitude (ddd.dddddd):	_____
Elevation (ft):	_____

Administrative Unit:	_____
Project Unit:	_____
Macroplot:	_____
Date (MM/DD/YYYY):	_____
Time:	_____

Photo Azimuths:	(1) of whiteboard at PC. (1) from 75 feet N looking south to PC (4) from PC in all four cardinal directions; (1) from each Brown's transect looking toward PC.
ORDER TAKEN & #:	_____

Hill Slope (% where steepest):	_____%
Aspect (circle one):	**N E S W**
Aspect azimuth (degrees):	_____°
Mag Declination:	_____°

Comments:



Describe Witness Tree(s):

Draw location of tree on plot

Color of Flagging/Marker Used: _____

Aerial cover (%) (1/100th acre plot)

Tree regen.	Shrubs	Graminoids	Forbs

Macroplot Sizes		
Size (Acres)	1/100	1/10
Radius (Feet, Decimal Feet)	11.78	37.24
Radius (Feet, Inches)	11' 9"	37' 3"

Canopy (%)

N	S
E	W

Ground cover (%) (1/100th acre plot) (total 100 %)

Plant basal (including cacti)	Bole (woodies)	Litter	Bare soil	Rock (>2.5in)	Gravel (< 2.5 in)	Total (%)

Species	Condition (Live, Dead, Sick)	Small Plot—Tree Regen, Shrubs & Cacti: Height classes—Seedlings (<4.5', <1" dbh/drc)				
		> 0 - 0.5'	> 0.5'—1.5'	> 1.5' - 2.5'	>2.5'- 3.5'	>3.5' - 4.5'

Small Plot—Tree Regen, Shrubs & Cacti		
Species	Condition (Live, Dead, Sick)	Saplings ≥4.5', < 1"

Observer/Recorder: _____ Project/Site/Plot_____ Date_____ Plot Number_____ **Page_____of_____**

1/10th acre plot (37' 3'' radius)													
Tree Tag #	**Species**	**Tree cond. (L, D, S)**	**DBH/DRC** (add down arrow if DRC was taken)	**# stems**	**Total Tree Ht**	**LiCrBHt**	**Damage 1**	**Severity 1**	**Damage 2**	**Severity 2**	**Char Ht**	**Scorch Ht**	**Comments** (witness tree, etc.)

Version: 3/13/24

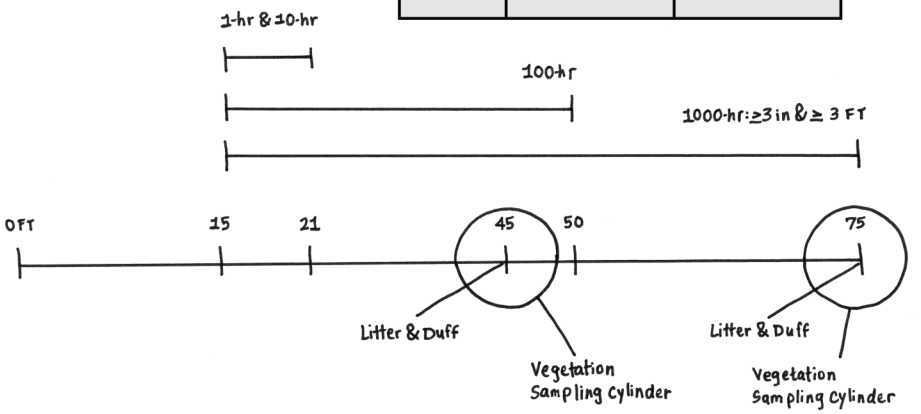
Surface Fuels

Sheet 1 of 2: Fine Woody Debris—Coarse Woody Debris

Observer	
Recorder	
Number of Transects	

1-hour Transect Length - 6’
10-hour Transect Length - 6’
100-hour Transect Length - 35’
1000-hour Transect Length - 60’

Class		Diameter (in)
FWD	1-hr 10-hr 100-hr	0 to 0.25 0.25 to 0.9 1.0 to 2.99
CWD	1000-hr +	3.0 and greater



Admin Unit:	
Project Unit:	
Macroplot:	
Date (MM/DD/YYYY):	
Time:	

Fine Woody Debris (1, 10, 100 hr fuels)	Transect	Azimuth	Slope	1 - Hr Count	10 - Hr Count	100 - Hr Count	Comment
	1	* Random for CFRP or (0°)					
	2	135°					
	3	270°					

Coarse Woody Debris (1000 hr fuels)	Transect	Log No.	Log Diameter	Decay Class	Comment (e.g. spp)

Precisions: Diameter: ±0.5 in ; decay class ±1 class ; Slope ±5 percent

Decay Class Description

1 All bark is intact. All but the smallest twigs are present. Old needles probably still present. Hard when kicked
2 Some bark is missing, as are many of the smaller branches. No old needles still on branches. Hard when kicked
3 Most of the bark is missing and most of the branches less than 1 in. in diameter also missing. Still hard when kicked
4. Looks like a class 3 log but the sapwood is rotten. Sounds hollow when kicked and you can probably remove wood from the outside with your boot. Pronounced sagging if suspended for even moderate distances
5 Entire log is in contact with the ground. Easy to kick apart but most of the piece is above the general level of the adjacent ground. If the central axis of the piece lies in or below the duff layer then it should not be included in the CWD sampling as these pieces act more like duff than wood when burned.

Plot Description

Observer:	_____
Recorder:	_____
Latitude (dd.dddddd):	_____
Longitude (ddd.dddddd):	_____
Elevation (ft):	_____

Administrative Unit:	_____
Project Unit:	_____
Macroplot:	_____
Date (MM/DD/YYYY):	_____
Time:	_____

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ORDER TAKEN & #:	_____

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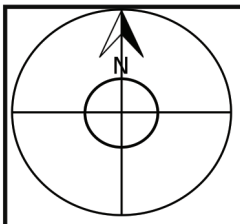
Aspect (circle one):	N E S W
Aspect azimuth (degrees):	_____°
Mag Declination:	_____°

Comments:



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		Height classes—Seedlings (<4.5', <1" dbh/drc)				
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Small Plot—Tree Regen, Shrubs & Cacti		
Species	Condition (Live, Dead, Sick)	Saplings ≥4.5', < 1"

Observer/Recorder: _____ Project/Site_____ Plot Number_____ Date_____ **Page_____of_____**

Disturbance History				
Change Agent	**Change Code**	**Percent of Plot Affected / Severity (Use 900 Codes)**	**Start & End Date**	**Comment**

Data Quality Assurance Checklist

Ensuring quality data collection requires taking steps to check data during collection and before leaving the plot. This practice applies to both paper datasheets and electronic data entry. Have two crew members look over the data to ensure completion and accuracy before removing flags and leaving the plot. Some best practices for on-plot quality assurance are listed below:

1) Is data being collected consistently?

- ☐ Ensure all technicians are following all established protocols (i.e., DBH is taken from the correct height; any trees located near the edge of a plot are carefully measured with a tape; fuels transects are laid out to match photos of previous transects).
- ☐ Training on practice plots and conducting an error analysis before collecting project data can highlight any areas of inconsistency where crew members need further practice.

2) Are all protocols completed?

- ☐ If using paper datasheets, ensure every box is filled in. If no trees/seedlings/fuels were present, a line through the box or comment should indicate that this protocol was completed. Do not leave anything blank!
- ☐ If using computer/tablet data entry, ensure every protocol tab is filled out completely.
- ☐ Confirm all photos are present on the camera.
- ☐ Confirm GPS location is recorded on GPS unit and in datasheets/data entry forms.

3) Within protocols, are all required data present?

- ☐ Are the plot center coordinates and elevation recorded?
- ☐ Does the witness tree have distance and azimuth recorded?
- ☐ Do all trees have a height, DBH, and status recorded? Do all live trees have a crown base height?
- ☐ Are all tree damages recorded (char/scorch, diseases, abnormal growth) with appropriate severities?
- ☐ Do all 1000-hr fuels have a diameter listed?
- ☐ Are all surface vegetation coverage values recorded? Does each have a height? Has the slope of the fuel transect been recorded? Ensure there was no height entered if the aerial cover for that category was zero.
- ☐ On paper datasheets, are final tallies counted and circled?
- ☐ Is all plot description info filled in? Does anyone else on the crew have anything to add to the comments sections?

4) Scan through data. Do data values make sense?

- ☐ Do any live crown base heights exceed tree heights?
- ☐ Do ground cover percentages add up to 100?
- ☐ Do trees with small diameters have excessive heights listed? Do trees with large diameters, and no damages, have abnormally short heights?
- ☐ Are the appropriate units used and labeled for surface fuel vegetation heights, litter, duff depths, and other measurements?
- ☐ Is all written data legible?

NMFWRI Herbarium Voucher Collection

Collection No.:

Associated Plot ID:

Date:

Collected by:

Location (site, country, state):

Latitude (dd.dddddd):

Longitude (ddd.dddddd):

Elevation (ft):

Scientific Name:

USDA PLANT Symbol:

Common Name(s):

Family:

Lifeform (forb, shrub, graminoid, tree, mushroom, bryophyte):

Species Description (height, flower color/scent, stickiness, texture, gill type, cap shape, etc.):

Habit (annual, biennial, perennial):

Habitat (ex. P-J, Ponderosa Pine, associated plants in the area, note any disturbance):

Extent of Species Population:_____ approx. # of individuals in _____ approx. area

Slope:

Aspect:

Soil Info (texture, parent material, other):



Mora County, NM. *Photo by Vincent Vispo.*



Douglas-fir seedling, *Pseduotsuga menziesii*. *Photo by Emily Yannayon.*

New Mexico
Forest and Watershed
Restoration Institute
New Mexico Highlands University

NMFWRI • ECOLOGICAL MONITORING PROGRAM



Guidelines and Protocols for Monitoring Upland Forests Field Manual