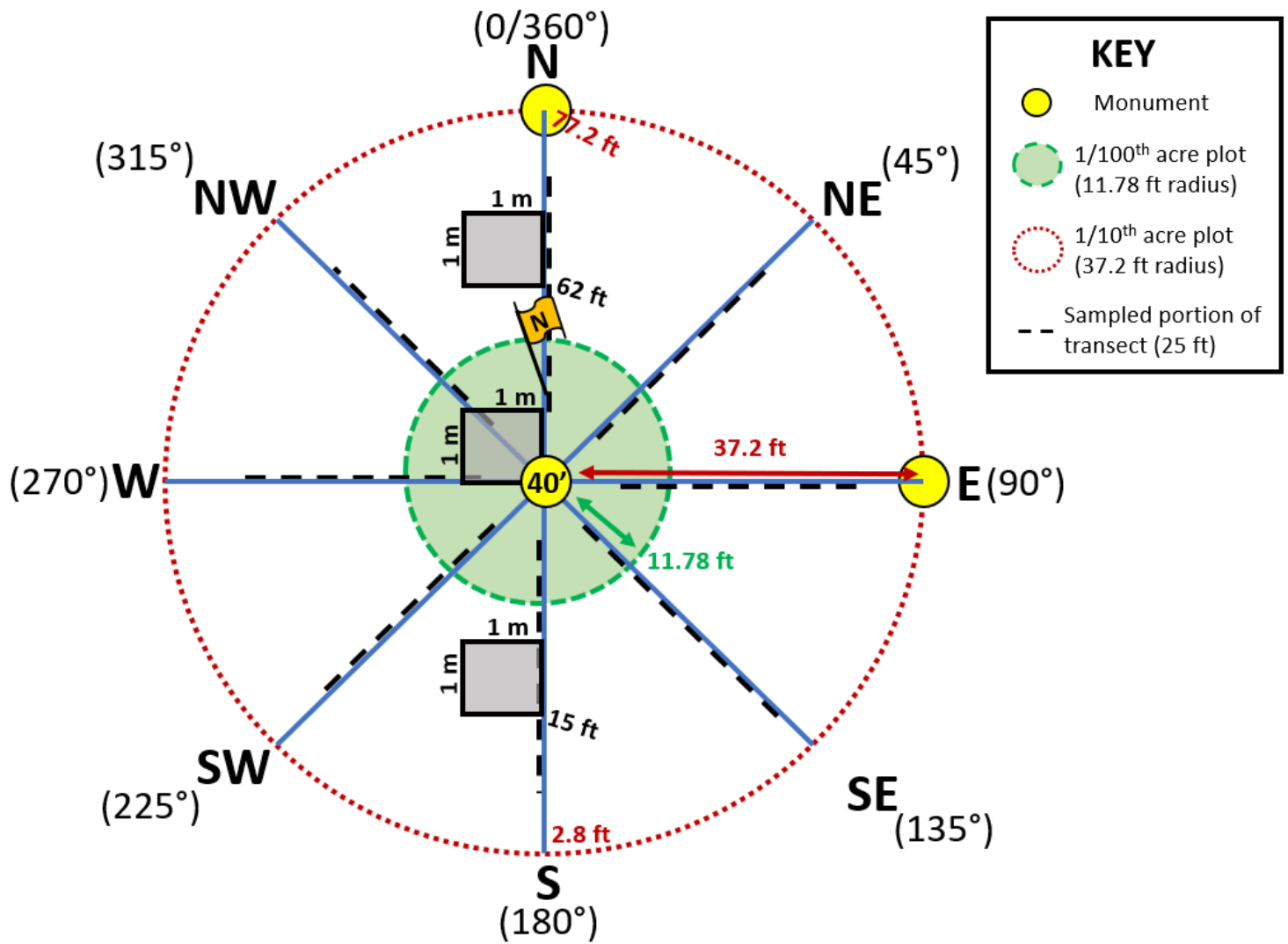


Mothership Plot Protocol:

Field Data Collection to Assess Forest Restoration and Fire Mitigation Effectiveness
Developed by the Colorado Forest Restoration Institute

Sampling Objective:

This protocol is designed by the Colorado Forest Restoration Institute (CFRI) to collect comprehensive data for changes in non-spatial forest structure and composition, fuels and fire potential, and plant species abundance and diversity as a result of management actions in forests and shrublands of Colorado.



PLOT LAYOUT:

1. **Navigate to the plot.** If resampling an area, use the site map, GPS coordinates, and/or plot photos to navigate to the plot. If establishing a plot, use Collector, Avenza map, GPS coordinates, or a random number table with numbers 0-359 to choose a random direction and distance. When establishing a plot, make sure that the GPS point falls in an area that is suitable (e.g. not on a road, riparian, treatment boundary, etc.) and characteristic of the surrounding area. If the plot needs to be moved, use the random number table to choose a direction and distance to move the point to a suitable area. Before proceeding, be sure that the *edge of the plot is at least 100 feet from a treatment boundary.*

Helpful hints for relocating a plot:

- *Use the metal detector.*
 - *Plug coordinates into the GPS – occasionally points on the map can be off.*
 - *Match the plot location using previous plot photos. Look for distinctive rocks, branches, snags, topography, etc.*
 - *Speak with RAs – occasionally we have multiple sources for plot coordinates.*
2. **Lay out the plot.** From plot center, establish 8 transects in the cardinal (0°, 90°, 180°, 270°) and ordinal directions (45°, 135°, 225°, 315°) using a **declinated** compass (set - 8.5° east for the Front Range) and four 100 ft tapes. Center the 40 ft mark of all 4 tapes over the plot center and extend tapes to 80 ft. Clip tapes together with a binder clip at plot center to ensure they stay in place. Be sure the 0 ft mark is on the south and west ends of the transects (the reel should be on the north and east ends). Colored tape marks the plot center and transect ends, as well as the understory plant measurement areas on each 100-ft tape. Place the 1 m² quadrat in the northwest corner of plot center. To avoid trampling vegetation and woody fuels, walk on the right side of the transect as much as possible. [Note that this protocol can be implemented with 50 ft tapes, but care must be taken to ensure measurements happen at the correct locations.]
 3. **Monument.** Install three permanent markers, or monuments, using a nail, yellow painted washer, and a silver “CFRI Long-term Monitoring Plot” tag. Inscribe plot name and location (“N,” “Center,” or “E”) on the tag with a pen and write it on the washer with a permanent marker. Monuments should be located at plot center, 37.2-ft north of plot center (North), and 37.2-ft east of plot center (East). Wrap a piece of pink flagging around each washer. Re-flag nails on each revisit or once a year.

PLOT SET-UP:

1. Basic Plot Info-

- a. **Plot Name:** Triple check that the plot is named correctly! Look at the map and compare tablets. Errors in plot names cascade to all data and are very difficult to fix in the lab.
- b. **Aspect:** Using a **declinated (8.5°E)** compass, measure the hillslope aspect in degrees (0-359) within the 1/10th acre plot. This is NOT along the transect, but where a ball would roll down the hill. If revisiting, record the previously measured aspect unless it is outside of revisit standards. *Revisit aspect accuracy standards: ± 15°*
- c. **Slope:** Using a clinometer, record the slope of the hillside along the aspect to the nearest percent within the 1/10th acre plot. Take slope measurements from plot center both downhill and uphill and record the average slope of the two measurements. In general, new plots should not be installed when slope >40%. If revisiting, record the previously recorded slope unless it is outside of the revisit standards. *Revisit slope accuracy standards: ± 5%*
- d. **Coordinates:** Record the location (UTM) and elevation (ft) using the built-in function on the Survey123 form. *Revisit UTM accuracy standards: ± 5 m E & N*
- e. **Fuel Model:** (Crew Leader/Senior Technician) assign a fire behavior fuel model to the plot using the Fuel Model Key¹, found in the clipboard.
- f. **Plot Notes:** Record any plot notes in the *complete* Survey123 form, including notes on plot location (near road, near treatment boundary), making specific notes of past disturbances (e.g. fire, insect outbreaks, stumps from logging, animal signs/grazing, human disturbance, etc.). *Notes should only be recorded on the *complete* Survey123 form.*

2. Photos-

- a. Standing at the plot center, take 6 photos. Fill out a white board with the plot name and date. Hold whiteboard 10 ft from plot center. Take photos in the landscape orientation, frame photos so the white board is legible, and exclude gear and people in the shot. *For post-treatment plots, check pre-treatment photos to ensure the same view is captured.* The photo sequence is:
 1. *Ground, North:* Face the north transect and hold the tablet at eye level while standing about 5 ft back from plot center. Angle the tablet downward to include the entire 1 m² sampling frame and plot center in the photo; making sure that the transect is in the center of the photo.
 2. *Eye level, North:* Hold the tablet over plot center, looking along the north transect at eye level.
 3. *Canopy, North:* Hold the tablet over plot center, looking along the north transect towards the upper tree canopy.
 4. *Eye level, East:* Hold the tablet over plot center, looking along the East transect at eye level.

5. *Eye level, South:* Hold the tablet over plot center, looking along the South transect at eye level.
6. *Eye level, West:* Hold the camera over plot center, looking along the West transect at eye level.

PLOT MEASUREMENTS:

For all plot measurements, begin sampling on the north transect and moving clockwise though the plot.

1/100th Acre Plot (11.78 ft radius)

Tree Seedlings and Saplings

1. **Tree Seedlings:** individuals within the 1/100th acre plot (11.78 ft radius) that are less than 4.5 ft tall. Add a note if Class 1 seedlings are recent germinants.

Record the species and number of individuals in each height class:

Class 1: 0 - 4 in

Class 3: 18.1 - 30.1 in

Class 2: 4.1 - 18 in

Class 4: 30.1 - 54 in

2. **Tree Saplings:** individuals within the 1/100th acre plot (11.78 ft radius) that are 4.5 ft or taller with DBH < 5 in. For each individual record:

Species	Record species of each tree.
Status Class	L= Live trees with green needles. 1a <i>with needles</i> = Recently dead trees, top intact, needles/ foliage and fine branches present. <i>Record CBH for trees with needles.</i> 1b <i>without needles</i> = Recently dead trees, top intact, fine branches present. 2 = Snags with coarse branches, but fine branches and foliage have fallen off. 3 = Rotten snags. Very few if any branches remain. Usually short (<20 ft) due to decay status.
Diameter at Breast Height (DBH)	Measure the distance from the top of mineral soil to breast height (54 inches) with a measuring tape on the uphill side of the tree. Mark this measuring location with timber crayon. If a tree is leaning, arrange the tape so that it goes along the length of the tree and measure DBH perpendicular to the central axis. <i>Measure to the nearest 0.1 inch.</i>
Height	Ocular estimate up to 10 ft. Use rangefinder/ hypsometer for heights taller than 10 ft, making sure that the value returned seems reasonable.
Crown Base Height (CBH)	Lowest height of continuous needles/leaves for all live saplings and <i>class 1a snags.</i>

Tag Number	<p>Only if tagging trees (primarily sites where treatment involves prescribed burning). Angle the head of an aluminum nail downwards and leave about 1" of nail exposed so that tree growth does not close over the tag. Saplings with a small DBH (roughly < 1 inch) should be tagged with wire and not a nail to avoid damaging the tree. Tree tags should be sequentially numbered in the order trees are measured.</p>
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Variable Radius Plot

Tree Overstory

1. **Prism size:** Record the basal area prism (BAF) size. *The same BAF should be used throughout the entire site. If the site has been previously sampled, use the same prism size used in previous visits.*
2. **Flag trees in plot:** While holding the prism over plot center, note all trees that are in the variable radius plot. Tree overstory includes all live and dead trees 4.5 ft or taller with a diameter at breast height (DBH) ≥ 5.0 in. Flag all trees meeting these requirements using alternate pin flag colors, starting to the east side of the north transect and working clockwise. Since trees are not always tagged, **it is essential that trees are recorded in order** to understand changes in tree overstory. If two trees are in the same location, measure the furthest from plot center first.
3. *When conducting **post-treatment measurements**, check for any new or missing trees prior to beginning measurements and make note of any changes in tree order in the notes for each tree.*
4. **Measurements for each tree:**

Species	Record species of each tree.
Status Class	<p>L= Live trees with green needles. 1a <i>with needles</i> = Recently dead trees, top intact, needles/foilage and fine branches present. <i>Record CBH for trees with needles.</i> 1b <i>without needles</i> = Recently dead trees, top intact, fine branches present. 2 = Snags with coarse branches, but fine branches and foliage have fallen off. 3 = Rotten snags. Very few if any branches remain. Usually short (<20 ft) due to decay status.</p>

Diameter at Breast Height (DBH)	Measure the distance from the top of mineral soil to breast height (54 inches) with a measuring tape on the uphill side of the tree. Mark this measuring location with timber crayon. If a tree is leaning, arrange the tape so that it goes along the length of the tree and measure DBH perpendicular to the central axis. <i>Measure to the nearest 0.1 inch.</i>
Height	Ocular estimate up to 10 ft. Use rangefinder/ hypsometer for heights taller than 10 ft, making sure that the value returned seems reasonable. <i>Measure to the nearest foot.</i>
Crown Base Height (CBH)	Lowest height of continuous needles/leaves for all live trees and <i>class 1a snags</i> . <i>Measure to the nearest foot.</i>
RX Burn only: Tag Number	Only at sites where treatment involves prescribed burning. Tag trees at breast height (4.5') facing plot center. Angle the head of an aluminum nail downwards and leave about 1" of nail exposed so that tree growth does not close over the tag. Tree tags should be sequentially numbered in the order trees are measured.
RX Burn only: Bark Beetle Evidence	Only at sites where treatment involves prescribed burning. Look for small holes, frass (looks like sawdust), and pitch tubes (blobs of sap). Mark "Yes" if there is evidence of bark beetle attack in the lowest 6' of the tree stem.

Special cases:

- *Multiple qualifying stems:* If a single tree has multiple stems that divide below DBH (4.5 ft or 54 inches) – very common in juniper species – consider each qualifying stem (DBH < 5 in) as its own tree (take all measurements and tag if tagging trees).
- *Borderline tree:* If it is unclear with the prism if the tree is in or not, use the borderline tree equation below to calculate and measure if a tree is in. The distance measured from plot center to the center of the tree should be shorter or the same as the calculated distance.

Borderline tree limiting distance calculations:

10 BAF prism: $DBH \times 2.75$

20 BAF prism: $DBH \times 1.94$

1 m² Quadrats

1 m² sampling quadrats are located at 15, 40, and 62 ft on the north-south transect with the sample frame positioned on the left (west) side of the transect when looking north. If the

quadrat contains masticated fuels (combined litter/duff/woodchips), select “Forest Floor” and refer to the masticated fuels protocol addendum; otherwise, select “Photoload.”

1. **Quadrat Photo:** Standing on the opposite side of the transect tape, take a downward-looking photo of the quadrat, include the whiteboard to the side of the quadrat with plot code, date, and quadrat location (e.g. “40 ft”).
2. **Photoload Estimates:** Using the Photoload² estimating technique, estimate fuel loading for 1 hr, 10 hr, and 100 hr fuels in tons/acre within the 1 m² sample frame. Estimate as close to the picture as possible or chose an intermediate loading between pictures if appropriate. A go-no-go fuel gauge should be used to help classify fuels in the frame. Fuel sizes are as follows:

1 hr: 0 to 0.24 inch diameter
10 hr: 0.25 to 0.99 inch diameter
100 hr: 1.00 to 2.99 inches diameter

3. **Biomass Collection:** If treatment included mastication and at least one quadrat falls on a masticated fuelbed, collect biomass in a 30 cm PCP frame. See Sampling Masticated Fuels Addendum for collection methods.

North-South Transect

For the following measurements, measure along the north-south transect, beginning at the start of the south transect at 3 ft, measuring every foot and finishing at the 77 ft mark. Note that the following two measurements (tree cover and tree group transect) are typically measured in tandem.

1. **Tree Cover:** Use a densiometer scope to record cover of any live or dead tree 4.5 ft (breast height) or taller at each foot. Begin recording near the start of the south transect at 3 ft and record cover every foot until the 77 ft mark for a total of 75 measurement “hits.” Stand directly over each point along the tape, making sure that the scope is level and look to see what species (if any) is present in the crosshairs of the scope. If any part of a tree is observed, use the appropriate clicker counter to make note of the observation. After looking up at 75 separate points, look to the clicker counters for your species totals and record in Survey123 form.

Notes:

- All dead trees are lumped recorded as their own species (“DEAD”).
- If a dead branch on a live tree is encountered, it is recorded as the live tree species.
- If multiple species are encountered at one point, record the species first encountered (species closest to the ground).

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- 2. **Tree Group Transect:** Use the densiometer scope beginning at 3 ft and ending at 77 ft on the north-south transect to measure the distance of closed canopy and tree openings. While standing directly over each point along the tape with a level densiometer, observe if the crosshairs of the scope meet canopy cover (*live tree cover with DBH \geq 1 inch*) or canopy opening (open sky). If closed canopy is encountered, note the size of that canopy clump. Canopy clumps are determined by the number of interlocking **live trees (DBH \geq 1 inch)** or trees with canopies **within 5 ft**. Canopy classes are as follows:

Open: 0 trees	Class 3: 5 – 9 trees
Class 1: 1 tree	Class 4: 10 – 15 trees
Class 2: 2 – 4 trees	Class 5: 15+ trees

Openings of > 5 ft must be observed along the transect to transition from one cover type to another (i.e. 3 ft: canopy, 4 ft: canopy, 5 ft: open, 6 ft: canopy = canopy from 3-6 ft). Each start point should begin at the same location as the previous end point and canopy classes should be assigned for the entire length of the transect (i.e. 3-5 ft = Class 1, 5-14 ft = Open, 14-77 ft = Class 5).

1/10th Acre Plot (37.2 ft radius)

1. 1000 Hour Fuels (\geq 3 inches diameter):

- a. *Plot size:* Plot sizes are: Mini (1/100th acre; 11.78 ft radius), Whole (1/10th acre; 37.2 ft radius), Half (half of 1/10th acre plot with 37.2 ft radius), or Quarter (quarter of 1/10th acre plot with 37.2 ft radius). Newly established plots should be Mini plots unless otherwise directed. If remeasuring a plot, use Mini only if it was used pre-treatment. If 1000 hr fuel volume is homogenously distributed across the large 1/10th acre plot, consider using a Half or Quarter plot – and note in beginning of Survey123 form.
- b. *Measure and record* the following, starting from the transect azimuth towards 50 ft and working clockwise:
 - i. *Type:* conifer or hardwood
 - ii. *Rotten or sound.* Consider pieces rotten when it is obviously punky, can be easily kicked apart, or buckles under weight.
 - iii. *Diameter* at each end to nearest 0.1 inch. If diameter drops below 3 in on the log, stop measuring at that point.
 - iv. *Length* to the nearest 0.1 foot.
 - v. *Stumps:* Measure all stumps with a DBH \geq 3 in. Diameter 1 is diameter of the base, diameter 2 is diameter at tallest point, and

length is the height of the stump. Make sure to select “Stump” on the Survey123 form.

Notes:

- When a log travels outside of the plot boundary, stop measuring the log at the plot boundary.
- If the center point of the log is below the duff, stop measuring at that point.

2. Jackpots or Burn Piles:

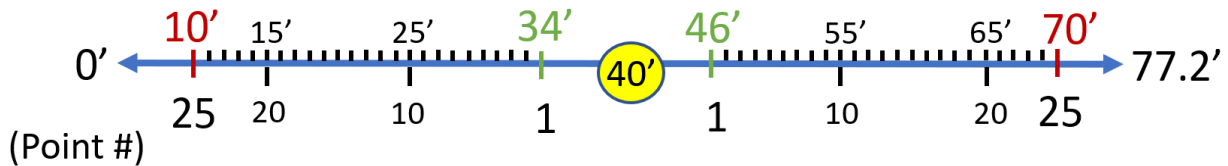
Managers often pile large woody fuels for later burning or removal. Because logs are often inaccessible for measuring, piles that fall within the 1000 hr fuel plot should be measured as a single volumetric unit.

- a. Record length, width, and height of pile to nearest 0.1 ft.
 - a. if only part of the pile is within the 1000 hr fuel plot, record the total pile measurements as well as the percentage of the pile that falls within the plot area in Notes.
- b. Note if the feature is a burn pile (most material <3” diameter) or jackpot (most material >3” diameter).
- c. If no piles are present, enter ‘NONE’ in species name.

Transects

For all of the following measurements, measure along each of the 8 transects in cardinal and ordinal directions from plot center:

(Transect ft)



1. **Points/ Pin Flag Drops:** Using the line-point intercept method, record any plant present at each point on all 8 transects. Begin counting at 6 ft from the center and collect data every foot for a total of 25 points per transect (see diagram). At each point record:

a. Understory Vegetation:

- i. *Plant hits:* Record every plant hit on the vertical drop of the pin flag from DBH (4.5 ft) downward, entering plants using the USDA PLANTS database 4-letter code. If more than one species is visible at a sampling point record them all (i.e. kinnickinnick, mountain

mahogany, Douglas-fir). Record the top-most vegetation as the first hit, and then other species of shorter stature as bottom hits. Each transect can have no more than 25 top vegetation counts, i.e. 1 top hit at every point measured. Multiple bottom hits may be recorded at each point.

1. *Record only live plants, or plants that were living during the growing season and have since cured.*
- ii. *Plant heights:* If shrubs are recorded, measure the maximum height of the top plant to the nearest inch. Do not straighten bent-over herbaceous vegetation unless it has been trampled.

Unknown plants: If unable to identify a plant, give the plant an unknown name (i.e. InitialsMMDDYY[A/B/C...], ex: KEM061819A). Collect a specimen from outside the plot for later identification in the lab and place in a plastic bag with a completed unknown plant label. The specimen will be pressed at the end of the day with this unknown label for identification in the lab. Record relevant information on the Unknown Plant Description *Survey123* form AND the crew member who named the plant should add it to their unknown list.

- b. **Woody Fuels:** record any woody fuels hit by the pin flag drop. Woody fuels that should be recorded *in addition* to forest floor substrate are:
 - **Fine Woody Fuels (“1/10/100 hr fuel”):** Unattached, non-rooted, non-living woody structures smaller than 3 inches in diameter. No minimum size, but does NOT include needles, bark, and pinecones (these are classified as litter/duff).
 - **1000-Hour Fuel in Air (“1KINAIR”):** Fuels ≥ 3 inches diameter that are suspended above the ground. Fuels are considered to be suspended in the air if there is space for plants to grow underneath.
- c. **Forest Floor Substrate:** After recording plant and woody fuels (if present), record the underlying forest floor substrate. If the point of the pin flag hits multiple substrates, choose the dominant substrate at that particular point. Substrate categories are the following:
 - **Litter/Duff:** non-woody; includes pine needles, bark, and pinecones
 - **Bare Soil/Gravel:** mineral particles that are < 0.5 inches
 - **Rock:** mineral particles > 0.5 inches
 - **1000-Hour Fuels:** Woody fuels with a diameter ≥ 3 inches and NOT suspended from the ground

- **Moss/Lichen:** any moss or lichen that is growing on the ground; moss or lichen growing on a rock is counted as rock
 - **Woody Basal:** Large, rooted woody vegetation that is larger than a branch; primarily tree trunks, stumps, and roots
 - **Herbaceous Vegetation Basal:** dead bunchgrasses; dead plant material that suppresses growing space for other plants; rarely encountered
2. **Litter and Duff Depths:** On each cardinal transect (N, E, S, and W), measure litter and duff depths at 10 ft, 20 ft, and 30 ft from plot center. Measure to the nearest 0.25 inch.

Distinguishing between litter and duff:

- **Litter:** Loose layer made up of needles, dead grasses detached from the plants, recently fallen leaves, twigs not visible from above where the individual pieces are still identifiable and little altered by decomposition.
 - **Duff:** Layer below the litter layer and above the mineral soil. It is made up of litter material that has decomposed to the point that the individual pieces are no longer identifiable. [Per FIREMON protocol (RMRS-GTR-164-CD)]
3. **Species Richness (Plant Walk):** Systematically search for and record any additional plant species present in the 1/10th acre plot (37.2 ft radius) that were not previously recorded on the point measurements.
- a. If any noxious species of concern are found during this search, estimate their cover in the 0.1-acre plot as rare (>0 – 1%), common (2 – 10%), abundant (11 – 50%), or very abundant (51% +). Species that are noxious are written in bold and noted as such on the species list.

Citations:

¹ Scott, Joe H.; Burgan, Robert E. 2005. Standard fire behavior fuel models: a comprehensive set for use with Rothermel's surface fire spread model. Gen. Tech. Rep. RMRS-GTR-153. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 72 p.

² "The Photoload Sampling Technique: Estimating Surface Fuel Loadings From Downward Looking Photographs of Synthetic Fuelbeds." Robert E. Keane and Laura Dickinson. USFS General Technical Report RMRS-GTR-190, pages 15-17. April, 2007. http://www.fs.fed.us/rm/pubs/rmrs_gtr190.pdf

Mothership Gear List

Main Compartment – Gear Bag:

- 4 – 100 ft tape
- 1 – 10 BAF prism
- 1 – Hammer
- 1-2 – Clinometer
- 1 – Hypsometer/ Rangefinder
- 1 – Fuel gauge
- Several – Litter/Duff ruler
- 1 – Sapling calipers (mini)
- 1 – Clicker counter
- 1 – Densitometer
- 1 – Clipboard
- 1 – Whiteboard
- 1 – Ziploc with timber crayon, Litter/Duff ruler, pens/pencils, dry erase marker
- 1 – Tape measure
- Several – Orange lanyards
- 1 – First Aid kit mini
- 1 – Flagging tape (pink)
- Several – paper bags (for unknown plants)
- *For masticated sites:* 1 hand saw
- *For masticated sites:* small (10), med (10), and large (3) brown paper biomass bags
- *For prescribed fire sites:* Numbered tree tags and aluminum nails
- 12 – Plot tags, large aluminum nails, and washers (3 each per plot)
- 1 – Garmin e-trex GPS device
- Batteries: AAA (4), AA (4), 9V(1), 123A (2) [*AAA for walkie talkies, AA for GPS, 123A for hypsometer/rangefinder, 9V metal detect*]

Individual Gear (for each person in each pod):

- 1 – Compass
- 1 – Logger’s tape

Clipboard:

- Datasheets
- Protocol
- Photoload
- Fuel Model key & photos

- Random number table
- Species list
- Unknown plant sheets
- Plant guides sheets
- Maps of the site
- Plot list

Shoulder Sheath:

- 1 - 18-inch Calipers
- 1 - 1 m² Quadrat
- 10 - Chaining pins
- 30+ - Pin flags of 3 different colors
- Yard sticks w/ seedling class marks

Vehicle:

- Food cooler
- Water jug
- Metal detector
- Plant press
- Plant ID books
- Monument box (nails, washers, tags)

Vehicle Form Box:

- Datasheets
- Protocols
- Photoload
- Fuel Model key & photos
- Random number table
- Kat/Katarina's business cards
- Unknown plant sheets
- Species lists

Vehicle Folder:

- Enterprise rental agreement
- Emergency contact sheet
- Vehicle maintenance protocol
- Vehicle tracking log
- CO counties map
- Workers' compensation protocol
- Vehicle parking permission sign

Vehicle Bag:

- Brown paper bags
- Duct tape
- CO atlas
- Jumper cable
- Tow strap
- First Aid Kit
- PPE (masks, hand sanitizer, gloves, disinfecting wipes & spray, Ziploc bags, trash bags)

Electronics Box:

- Samsung tablets & charger
- Portable charger
- Extra batteries
- Walkie talkie & charger
- Binder clips

Camp Box:

- Stove
- Propane
- Lighter(s)
- Toilet paper
- Trowel
- Trash bags
- Paper towels
- Biodegradable camp soap
- Pan(s)
- Tarp

Refill each day from vehicle:

- 3 per plot – Painted nails, washers, stamped tags
- 2 of each size / plot – Paper bags for fuels
- Forms
- PPE