# Cumberland Forest

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**Forest Carbon Field Inventory Methodology – ACR248 – Highlands IFM**

**November 2019, Updated October 2021**

## Contents

# Introduction

In July 2019 CF Highlands acquired the property that comprised the California Forest Carbon Project known as Finite – Forestland Group Highlands IFM (ACR248/CAFR5198), which was developed and registered under California's Cap and Trade Regulation ("Regulation") which took effect on January 1, 2012, with amendments to the Regulation effective September 1, 2012.

This field inventory methodology document will guide the field data collection for a full re-inventory of the original inventory plots. The OPDR and all other project documentation and reports that reference carbon stocks have been prepared and submitted by Greg Meade, SAF Certified Forester and satisfies the professional forester requirements outlined in the FOP, section 9.1.

# Inventory Overview

This section describes the inventory data collection specifications for use in the field.

CF Highlands, The OPO has commissioned the following forest inventory for the project totaling approximately 97,208 forested acres in Wise, Dickenson, Russell, and Buchanan Counties, Virginia. The inventory will be conducted by LandMark Forestry, LLC, the same company that conducted the initial inventory. The project boundary is defined by the boundary and strata shape files provided with this specification document.

The purpose of this forest inventory is to quantify the forest carbon stocks of the required carbon pools, including live and dead, in the project area.

These procedures shall also be the basis for the collection of future inventory data as needed throughout the project life. This inventory was conducted in a manner that is verifiable, facilitates modeling, and is replicable. All inventory data collected was audited for accuracy.

## Stratification

The Stratification rules and results of the project is unchanged from the initial verification and subsequent full verification (RP1 – RP3). The full detail of the stratification rules and results can be found in the historical Project Inventory Methodology.

### Projects GHG Assessment Boundary

The field inventory will be used to collect data that will be used to calculate the IFM-1 – Standing Live Carbon and IFM -3 – Standing Dead Carbon. The modeling and monitoring documentation, mentioned above, describes the methods used to calculate IFM-7 – Carbon in in-use forest products, IFM-8 – Forest Product Carbon in landfills, IFM-9 – Biological Emissions from site prep, IFM-14 – Biological Emissions/removals from changes in harvesting on forestland outside the Project Area, and IFM-17 – Biological Emissions from Decomposition of Forest Products.

## Project Area Background

The Highlands forest has been managed in the past for coal mining, timber production and outdoor recreation objectives. The forest is currently managed using even-aged and uneven-aged silviculture systems, depending on site conditions and species composition. Natural regeneration is the most prevalent and favorable regeneration method on the landscape.

Review of air photos and satellite imagery reveal a forest dominated landscape with minor agricultural uses in some areas. The forest project lies in the 6a and 6b climate zones as Shown on USDA FS mapping for the region and can be viewed at this link: https://planthardiness.ars.usda.gov/PHZMWeb/Maps.aspx

Further review of a series of publicly available aerial imagery taken over time indicates that land use change pressure in this region is moderately low with limited residential development and little changes to other land uses from forest.

The primary purpose of the inventory is to accurately quantify the onsite forest stocks of the standing living and dead tree carbon pools in the project area for registration and approval as a forest carbon offset project with the California Air Resources Board compliance offset program. This inventory shall be conducted in a manner that can be verified, facilitates growth and yield modeling, and is replicable. The following inventory procedures will be the guiding requirements for future inventory work done on this site to comply with the offset program, including updates of sample data done as forests are affected by management annually and periodically.

Inventory data collected will be audited by the Cumberland's Forest LLC for accuracy. As all carbon claims for this project site will also be independently verified at a later date by an ARB accredited verifier, the accuracy and precision of the data collection for this project is paramount to project success for the landowner.

## Plot Number and Locations

As stated previously this is a re-inventory and will utilize pre-existing plots to the greatest extent possible. The original inventory is comprised of 396 plots and will form the basis for this inventory. Geographic location information was collected during the plot installation as well as monumentation details, both of which will be utilized for this inventory. If an original plot

cannot be located, a new plot will be established according to the geographic location information and the following directions:

### Plot Monumentation

- Using uploaded point locations from ArcGIS or similar software each plot center will be navigated to using the handheld GPS unit. Navigating with a WAAS enabled GPS, the instant the distance to waypoint reads 1-2 yards the plot center is marked by planting the rebar directly in front of the crew member using the GPS.
- Plots that fall in early successional, old fields, brush, or other features such as roads and creeks will be installed as they fall and will not be relocated.
- Where safety is a concern, a plot may be temporarily dropped with justification noted. The plot must be represented as a no-tally plot until conditions or equipment exist to collect the data for the plot.
- All samples shall be monumented with a pink flag hung at or above eye level as close to point center as possible and an orange pin flag placed at plot center. These flags shall be labeled with the following information: Plot #, Cruiser's initials, and Date. The plot center must also be monumented with a sturdy, 10"-12" metal spike or equivalent (e.g. nail) driven flush with the ground. Pink flagging should be tied around the head of the spike prior to being driven into the ground.
- Witness trees. The cruiser shall collect the bearing and distance to two witness trees, generally the best two witness trees on the plot, i.e. the two that could best be used to re-establish plot center if necessary. The witness trees must be painted all the way around at breast height (4.5') and tagged with a metal tag (WT #1, WT #2). Distance shall be the straight line (not slope corrected) distance from the face of the tree at DBH to point center. Bearing shall also be taken from the witness tree to point center. On null or no tally points, this element may be skipped. Information shall be recorded in the notes section on the data recorder indicating it is a no tally point. The species and size of the witness trees will be recorded in the notes section of the tally.

## Equipment List

- Cellphone and emergency contacts list
- First aid kit
- Logger/DBH tape capable of measuring horizontal length and DBH to nearest .1".
- 4.5' DBH pole
- Clinometer and/or laser hypsometer
- Data Recorder
- Field Notebook
- Compass

- Handheld GPS Unit – WAAS Enabled
- Pencils/Markers
- Metal Tags (Plot #)
- Flagging
- Aluminum Nails
- Hammer
- Tree Paint
- Lumber Crayon (for backup use)
- Rebar Posts or 9” nails for plot center
- Paper Tally Sheets (backup)
- Maps and Inventory Protocol
- Digital camera or Smart Phone Camera
- Replacement batteries

## Plot Methodology

Original plots that are being re-inventoried will have fresh flagging hung at eye level and as near plot center as possible. Tags on witness trees will be confirmed to be present as well, if missing they will be replaced.

All trees (live and standing dead) equal to or greater than 5.0” in diameter at breast height (DBH) will be tallied within a 20 basal area factor (BAF) plot. Trees will be numbered with paint to ensure measurements are accurately assigned for the corresponding tree. Pre-existing numbers from original inventory will be re-used to the greatest extent possible. Trees that are no longer part of the inventory but were on the initial inventory will not be part of the data set, however they will be tallied separately and provided to the inventory manager. Each cruiser will have paper tallies (plot cards) from the original inventory. If the cruiser identifies there are missing or additional trees the cruiser will strike the tree from the hard copy tally card. If there is an additional tree the cruiser will write the new tree number, species, and diameter on the plot card.

A micro plot of 1/200$^{th}$ acre at the same location will utilized recording all trees from 1.0 – 4.9 inches in DBH. No height measurement is required on micro plot.

Slope adjustments will be implemented according to the USFS FIA procedures as described in the 2014 Field Guide.

**On each tree the following information will be recorded:**

1. Species or Species Code (Appendix A) that is compatible with FVS Growth and Yield Model
    a. Standing Dead that has decomposed to a state in which the species is no longer recognizable may have hardwood or softwood recorded.
    b. Any tree that is not in the pre-determined inventory species list will be given an Other Hardwood, or Other Softwood designations and the actual species will be listed in the comments.
2. Tree Status - shall be recorded for every tallied tree. All standing live trees greater or equal to 1" dbh shall have their tree status recorded as zero (0). Standing dead trees greater than or equal to 1.0" dbh shall only be tallied if they are a minimum 15 feet in total height and their status will be tallied as one (1). All tallied standing dead trees shall be visually evaluated and categorized in one of the following decay class status categories listed below:

Decay class (1-5) for standing dead will be assigned based on the guidance below and included in the hardcopy instructions for each field crew member. Standing dead wood is defined as all dead trees emanating from the original stump which are standing at an angle of less than 45° relative to vertical. Note: The following descriptions were developed on the west coast for softwood species. The color conditions noted in the sapwood and heartwood descriptions will likely not match those of Appalachian Hardwoods. For our purposes a greater reliance on heartwood conditions will be relied upon, as that more directly relates to overall decay of the tree. However, sapwood and branching may also be relied on. % bark remaining and broken tops are not as reliable an indicator. For instance, in Decay Class 2 the Heartwood condition is described as "Sound at base", this is a condition that can readily be tested for, and if meet would likely lead to the snag being classified as Decay class 2, or possibly 1 depending on other characteristics. Decay Class 3 heartwood is described as "Incipient Decay at base", which is another way of saying decay is just beginning, note that decay class 3 also describes the upper bole as having "advanced decay throughout upper bole" in the heartwood.

| Decay class stage (code) | Limbs and branches | Top | % Bark Remaining | Sapwood presence and condition* | Heartwood condition* |
|---|---|---|---|---|---|
| 1 | All present | Pointed | 100 | Intact; sound, incipient decay, hard, original color | Sound, hard, original color |
| 2 | Few limbs, no fine branches | May be broken | Variable | Sloughing; advanced decay, fibrous, firm to soft, light brown | Sound at base, incipient decay in outer edge of upper bole, hard, light to reddish brown |
| 3 | Limb stubs only | Broken | Variable | Sloughing; fibrous, soft, light to reddish brown | Incipient decay at base, advanced decay throughout upper bole, fibrous, hard to firm, reddish brown |
| 4 | Few or no stubs | Broken | Variable | Sloughing; cubical, soft, reddish to dark brown | Advanced decay at base, sloughing from upper bole, fibrous to cubical, soft, dark reddish brown |
| 5 | None | Broken | Less than 20 | Gone | Sloughing, cubical, soft, dark brown, OR fibrous, very soft, dark reddish brown, encased in hardened shell |

*

3. DBH rounded down to the nearest .1” (DBH measured according to FIA guidelines, see Appendix C). Height at which DBH is measured will be marked using paint, chalk, or logger crayon, and will be confirmed using a 4.5’ DBH pole or measuring tape. Attempts will be made to remove vines or other obstructions to DBH measurements.
4. Product Class (Numerical Code may be used)
    a. Sawlog
    b. Tie/Pallet
    c. Pulpwood
    d. Cull
    e. Snag (Standing Dead wood is defined as all dead trees emanating from the original stump which are standing at an angle of less than 45° relative to vertical.) In leaf off season the presence of fine branches in the crown and/or cutting into the cambium will be used to determine if tree is alive or dead if questionable.
    f. Growing Stock (<5.0“ DBH)
5. Merchantable height to nearest ½ log (8’) – Specs for each product detailed in Appendix B
6. Total Height in feet (+/-1’) for trees =>5”DBH – Height measurements will only be taken once timber cruiser has located himself on a 60% or less slope in relation to the top of

the tree. Trees with noticeable lean should be measured perpendicular to the lean. See Appendix D for specifics of Height Measurements.

7. Soundness - deductions for any missing biomass and visible occurrences of rot or cavities in the trunk or bole, including bark shall be considered and recorded as necessary on all trees. Deductions typical in standard merchantable timber cruises will not be made unless the defect has caused visible rot or missing biomass, for example old skidder damage or crook. Deductions should be made using the USDA Forest Service Table provided with this document. For example, a tree that is 80% sound should be recorded as a 20 in the deduction field. See Appendix E for additional information.
8. Forest Health – Any noticeable forest health issue will be described in the comments field. The following will be considered, but is not an exhaustive list:
    a. Hemlock wooly adelgid
    b. Emerald ash borer
    c. Oak decline
    d. Thousand cankers disease
9. Down Woody Debris – Using a Perpendicular Limited Distance Sampling Technique (Ducey 2007) down woody debris will be sampled at each plot. This measurement will not be used for carbon calculations and a detailed methodology has been provided as a stand-alone document.

## Borderline Trees

Any tree that cannot be definitively determined to be in or out from plot center shall be measured for horizontal limiting distance. DBH shall be measured to the nearest 0.1" for the calculation and distance shall be measured with a steel tape. Borderline Trees will be measured from plot center to the geometric center of the tree at ground level to determine if the tree is in or out. The geometric center location will be marked with a paint stripe at ground level. Information for pith location on forked trees can be found in Appendix C, Figures 23-26. If a borderline tree is "out", the tree will be marked with a X facing plot center. If a borderline tree is "in", the tree will be marked by a check.

## Edge Plots

Edge Plots will be collected using the "walk-through" procedure, fully described in Appendix F.

## Special Cases

Live trees on the ground will be treated in the following way. Height will be measured directly with loggers or surveyors' tape. Trees will be determined to be in or out based on the current location of the ground line pith. The first step is to determine where the ground line likely was when tree was upright. Then estimate pith location on the stop of the tree. Measure back to plot center. DBH will be measured in accordance with Appendix C.

# Quality Control/Quality Assurance

All cruisers will have a sufficient level of training as determined by the inventory manager. The tree count will be verified as the last task prior to leaving the plot. Proper training, DBH poles, equipment calibration, and following the attached audit procedure will ensure that the inventory data meets the required accuracy requirement.

All data will be recorded on data recorders with backup paper data sheets available. Data from the data recorders (or paper data sheets if utilized) will be downloaded to an Excel file or similar software nightly, and any anomalous outlier values of dbh or height identified using the data filter - sort function, and as necessary, flagged for re-confirmation/re-measurement the next field day. Downloaded/Transcribed data will be cross-checked against field data sheets, and corrected as necessary, opportunistically by another member of the data analysis team.

## Inventory Audit

The inventory project manager will check a 10% of each cruiser's points for compliance with the protocol, the accuracy of the data collected, and any missed or misunderstood areas of the protocol. Cruisers will be notified as soon as possible as to the results of each check cruise. If initial audits are favorable the intensity may be reduced at project managers discretion. Full audit criteria can be found in Appendix G.

# Appendix A – Species List and Codes

| **Species Code** | **Common Name** |
|---|---|
| POP | Yellow-Poplar |
| SM | Red Maple |
| AB | American Beech |
| CO | Chestnut Oak |
| HM | Sugar Maple |
| HE | Eastern Hemlock |
| WO | White Oak |
| NRO | Northern Red Oak |
| BSW | American Basswood |
| PH | pignut hickory |
| BO | Black Oak |
| BB | Sweet Birch |
| SW | Sourwood |
| SO | Scarlet Oak |
| CUC | Cucumbertree |
| MH | mockernut hickory |
| BG | Blackgum |
| MAG | Magnolia |
| WA | White Ash |

| | |
|---|---|
| SYC | Sycamore |
| BUC | Yellow Buckeye |
| BH | bitternut hickory |
| SH | shagbark hickory |
| BW | Black Walnut |
| BL | Black Locust |
| SE | slippery elm |
| BC | Black Cherry |
| PP | Pitch Pine |
| SAS | Sassafras |
| WP | Eastern White Pine |
| SB | serviceberry |
| YB | Yellow Birch |
| MW | American hornbeam; musclewood |
| PA | Paulownia, empress-tree |
| BN | Butternut |
| AE | American elm |
| VP | Virginia Pine |
| IR | Eastern Hophornbeam, Ironwood |
| BWIL | black willow |
| DW | Flowering Dogwood |
| ERB | Eastern Redbud |
| HAK | Hackberry |

# Appendix B – Product Specs and Definitions

| SOFTWOOD PRODUCT | MINIMUM DBH | MAXIMUM | MINIMUM TOP DOB | MINIMUM LENGTH | | COMMENTS |
|---|---|---|---|---|---|---|
| PULPWOOD | 5.00 | 26.59 | 4.00 | 16 | | MUST CONTAIN GREATER THAN 50% SOLID MATERIAL. NOT EXCESSIVELY CROOKED. |
| SAWTIMBER | 9.60 | + | 8.00 | 8(1/2 Log) | | FREE OF EXCESSIVE KNOTS; DEAD KNOTS ≤ 2" LIVE KNOTS ≤ 3," STRAIGHT, SOUND |
| **HARDWOOD PRODUCT** | **MINIMUM DBH** | **MAXIMUM** | **MINIMUM TOP DOB** | **MINIMUM LENGTH** | **MINIMUM CLEAR SIDES** | **COMMENTS** |
| PULPWOOD | 5.00 | 26.59 | 4.00 | 16 | | MUST CONTAIN GREATER THAN 50% SOLID MATERIAL. NOT EXCESSIVELY CROOKED. |
| GRADE SAWTIMBER | 12.60 | + | 12.00 | 8(1/2 Log) | 2 | MUST BE FREE OF ROTTEN BRANCHES, HOLES AT STUMP, BAD SWEEP OR CROOK. |
| MERCH TIE/PALLET | 12.60 | + | 12.00 | 8(1/2 Log) | None | STRAIGHT, SOUND, NOT MEETING GRADE SPEC |

| | | | | | | |
|---|---|---|---|---|---|---|
| POPLAR PEELER | 10.60 | + | 10.00 | 9 (1/2 Log in | None | STRAIGHT, SOUND, NOT MEETING GRADE 32 SPEC |
| CULL | 5.10 | + | | 8 | | CALL IN EIGHT FOOT SECTIONS ACCOUNTING FOR BAD SWEEP, ROT, FIRE SCARS, |

Sawtimber -

- Hardwood
    - Grade – Minimum small end diameter inside bark of 12”, minimum of .5 log (8’). 2 clear sides
    - Tie/Pallet - Minimum small end diameter inside bark of 12”, minimum of .5 log (8’). No clear side requirement
- Softwood – Minimum small end diameter inside bark of 8”, minimum of 1 log (16’). Logs must be sound and not have excessive sweep or crook to make log unusable.

Pulpwood – Minimum small end diameter inside bark of 4”, minimum of 1 log (16’). Tree must be sound, and reasonably manufactured into pulpwood using regional norms.

Cull – Live tree with no merchantability due to defect, rot, excessive crook, or excessive size.

Growing Stock – Any tree between 1.0 DBH and 4.9 DBH. Total Height will be measured for growing stock

Snag – Standing dead tree at least 5.0 inches and at least 15’ tall. Total Height will be measured for snags.

## Appendix C – DBH Measurements

Measure DBH 4.5 feet above the groundline on the uphill side of the tree. Round the measurement down to the nearest .1 inch. For example 3.68 would be recorded as 3.6. For special DBH situations such as forks, butt swell, irregularities at DBH, etc, the FIA National Core Field Guide, V 6.0 – October 2012 will guide all measurements and is included in this methodology. Height sticks are encouraged to ensure that DBH is being measured at the appropriatte location. A vertical mark (paint or lumber crayon) will be placed at the location DBH is measured.

Page 1 of the FIA guidance is below, by double clicking on that page the entire document will open. *The entire document (page 101-107)will be included in the hard copy instructions the*

6.9.2 DIAMETER AT BREAST HEIGHT (DBH)
Unless one of the following special situations is encountered, measure DBH at 4.5 feet above the ground line on the uphill side of the tree. Round each measurement down to the last 0.1 inch. For example, a reading of 3.68 inches is recorded as 3.6 inches.

Special DBH situations:

1. Forked tree. In order to qualify as a fork, the stem in question must 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. Forks originate at the point on the bole where the piths intersect. Forked trees are handled differently depending on whether the fork originates below 1.0 foot, between 1.0 and 4.5 feet, or above 4.5 feet.

   - Trees forked below 1.0 foot. Trees forked below 1.0 foot are treated as distinctly separate trees (fig. 23). Distances and azimuths are measured individually to the center of each stem where it splits from the stump (fig. 26 A-C). DBH is measured for each stem at 4.5 feet above the ground. When stems originate from pith intersections below 1 foot, it is possible for some stems to be within the limiting distance of the microplot or subplot, and others to be beyond the limiting distance. If stems originating from forks that occur below 1.0 foot fork again between 1.0 and 4.5 feet (fig. 26-E), the rules in the next paragraph apply.

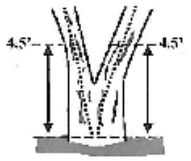


Figure 23. Forked below 1.0 ft.

   - Trees forked between 1.0 foot and 4.5 feet. Trees forked between 1.0 foot and 4.5 feet are also counted as separate trees (fig. 24), but only one distance and azimuth (to the central stump) is recorded for each stem (fig. 26 D-F). Although a single azimuth and distance applies to all, multiple stems should be recorded as they occur in clockwise order (from front to back when one stem is directly in front of another). The DBH of each fork is measured at a point 3.5 feet above the pith intersection. When forks originate from pith intersections between 1.0 and 4.5 feet, the limiting distance is the same for all forks—they are either all on, or all off the plot.

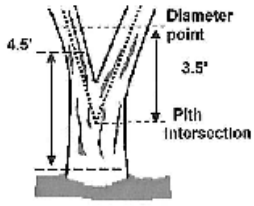


Figure 24. Forked between 1.0-4.5 ft.

     Multiple forks are possible if they all originate from approximately the same point on the main stem. In such cases, measure DBH on all stems at 3.5 feet above the common pith intersection (fig. 26-F).

     Once a stem is tallied as a fork that originated from a pith intersection between 1.0 and 4.5 feet, do not recognize any additional forks that may occur on that stem. Measure the diameter of such stems just below the base of stem separation as shown in figure 26-E (i.e., do not move the point of diameter the entire 3.5 feet above the first fork).



# Appendix D – Height Measurements

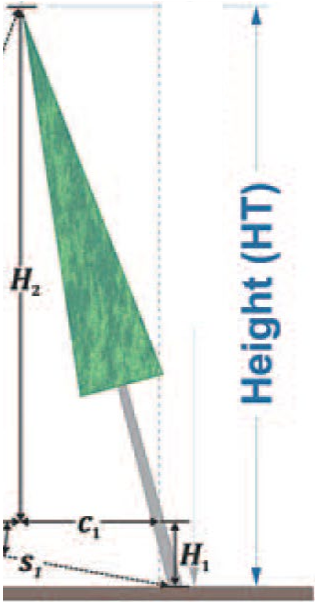
If the top of the tree is broken or missing, the measurement should be at the point it is broken unless a new leader has developed. If a new leader has developed the measurement should include the height of the new leader should be measured.

For dead trees close to the 15 feet total height cut-off for tallying, careful measurement is encouraged and the use of a guide stick or measuring tape should be used if possible.

Laser Hypsometers will be the primary tool for measuring tree heights, using the Height Function built into the hypsometer.

The hypsometer will be calibrated at the beginning of each day of field work, and re-calibrated during the day after significant changes in temperature and humidity or when odd readings are obtained. Field crews will not carry the hypsometer inside their jackets to avoid changes in temperature (outside pocket of vest is okay).

Height measurements should be taken at a horizontal distance that is at least 85% of the height of the tree. For example a tree that is 70' tall should be measured from a horizontal distance of at least 59.5' (70 X .85 = 59.5). Total height is measured as the distance from ground level to the highest visible point on the crown (or apical meristem). Total height requires sighting the level point on the trunk, the top, and the base of the tree at ground level. Care will be taken to be certain that the correct top is being sighted, being aware that part of the crown leaning toward or away from the observer may give the false appearance of being the highest points of the tree. For leaning trees, total height should be measured perpendicular to the lean and sighted by drawing a horizontal line from the tree top to a point over the tree base (see figure below). A minimum of two height measurements will be obtained, from different vantage points if necessary, and the recorded height taken as the average of the two measurements.



Demonstration of height measurement of a leaning tree, “Height (HT)” Height should be measured from the oblique (or perpendicular to the lean) perspective of the reader, and sighted with the hypsometer drawing a horizontal line (blue horizontal line) from the tree top to a point over the tree base (adapted from Bragg 2014[1])

# Appendix E – Biomass Deduct

Defect adjustments on live and dead trees will be made by **visually** assessing the tree and assigning percent defect in percentage. For example, a tree that is 80% sound should be recorded as 20%. Defect estimates will be guided by the accompanying USFS Technical Note for Percent allocation by log or bolt. Sweep or crook is **not** considered defect in this case – remember that merchantable defect may involve no missing biomass and therefor no carbon defect.

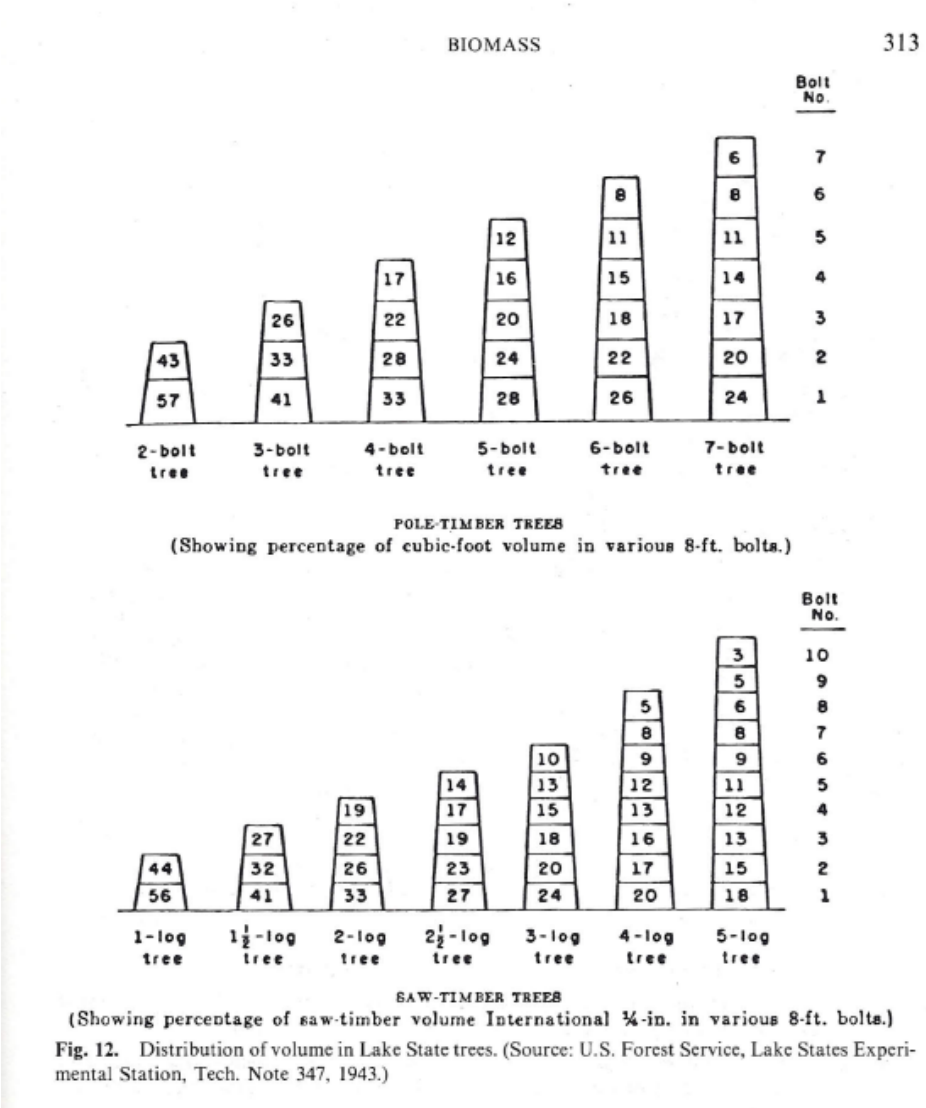


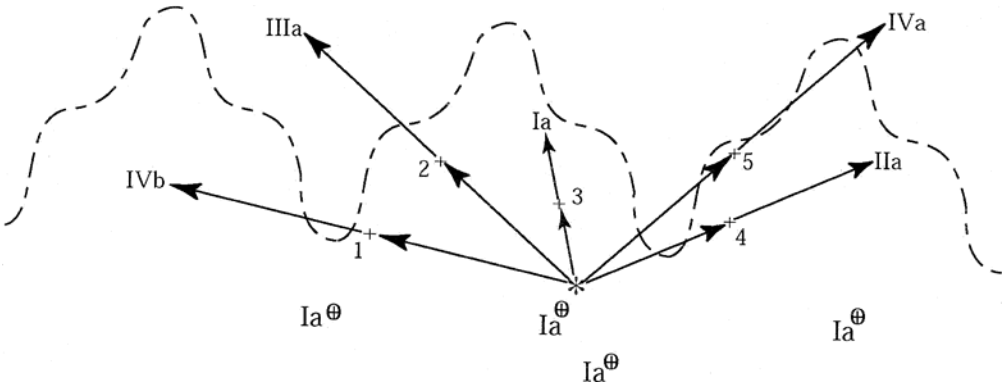

**Fig. 12.** Distribution of volume in Lake State trees. (Source: U.S. Forest Service, Lake States Experimental Station, Tech. Note 347, 1943.)

**Percent volume allocation chart for soundness deductions** (USDA Forest Service Tech Note 347, 1943)

# Appendix F – Walk Through Method for Plots Affected by Boundary Edge

- For plots that are within 200' of the project boundary careful examination and care should be taken to implement the Walk-Through Method as necessary.
- Walk through points shall be taken on the edges of GIS delineated non-forest areas only.

- The procedure is the same for every plot.
  - Measure the distance from the plot center to every "in" tree
  - Duplicate the distance on the other side of the tree
  - If the end of the duplicated distance is outside the sample area then record that tree twice, painting two numbers on the face of the tree
  - See figure below for examples of how this is implemented
- [Source: A Walk-Through Solution to the Boundary Overlap Problem.]




**Graphic illustration of the walkthrough method. Five sample objects (+), lying close to the boundary, have been tallied from a sample point (*). The arrows indicate the layout of the walk- through points for each object; the outcome on the key in Table 1 is indicated for each walkthrough point. Objects 1, 3, and 4 are tallied normally; objects 2 and 5 are double-tallied. Four objects ((±) ) lie "close to the boundary" but in positions where they would be single-tallied, and no measurements would be needed as the duplicated distance moves away from the boundary.**

# Appendix G – Audit Procedures

CF Highlands LLC
Check Cruise Procedures
December 2019

- Each cruiser (or crew) will have 10% of the plots randomly selected for audit. The plots will be audited by TNC forestry staff or a qualified forestry consultant
    - Audits will begin as soon as possible to provide more immediate feedback
    - Inventory Manager at his discretion can reduce the percentage audited if early audits result in high levels of accuracy
- Check Cruise Standards
    - General Procedures that will be audited include:
        - Reasonable plot location based on GPS and Topo information
        - Plot monumentation procedures followed (if new plot)
        - Witness trees correctly marked/measured (if new plot)
        - Inventoried trees correctly marked
        - Data entry free from errors
    - There should be no errors in General Procedures
    - Measurement Standards
        - 95% or greater of the measurements must fall within the tolerance range for a cruise to be acceptable.
        - If less than 95% of the measurements fall within the tolerance all plots for that cruiser must be re-measured for the measurement in which the error(s) exist. For example, if Total Height Measurements is identified to be the issue, only Total Height would need to be re-measured. See attached example for pass and fail audit plots.

Measurement Tolerances

| **Measurement** | **Tolerance** |
|---|---|
| Tree I.D. (Genus) | One error per plot permitted |
| Tree Count | Exact (***errors count double in calcs***)<br>If Limiting Distance is Measured in Field 1'<br>Tolerance is allowed |
| Diameter (DBH) | +/- .3 " |
| Total Height | +/- 8% |
| Actual Height (Snapped Trees Only) | +/- 8% |
| Deduct (Biomass Only) | +/- 20% |
| Decay Class (Snags Only) | +/-1 Decay Class |

**Examples of errors:**

Missed trees or tallied "out" trees ***Note – These errors are doubled in calculations***

DBH tallied as 10.5, actually 10.1

Tree Height tallied 85', actually 76'

Yellow Poplar incorrectly tallied as White Oak

**These are not errors:**
Northern Red Oak tallied as Black Oak
DBH tallied as 10.5, actually 10.3
Tree Height Tallied 85', actually 80'

95% Pass Rate will be averaged across the number of plots audited, likely 2 plots in the first audit. Each audit period will be independent of the others and will only consider plots taken since the last passing audit.

**Example 1 Summary Audit Data on 2 plots:**
25 live trees correctly tallied as "in"
1 live tree missed that should have been tallied (2 errors) ***note double error rate***
24 of 25 DBH measurements within tolerance (1 error)
22 of 25 HT measurements within tolerance (3 errors)
25 of 25 trees correctly identified
25 of 25 trees correct deduct assigned

Calculations: 125 measurements and 6 errors or 6/125 = 4.8% error or 95.2% acceptable – Audit passes

**Example 2 Summary Audit Data on 2 plots:**
30 live trees correctly tallied as "in"
2 live trees missed that should have been tallied (4 errors) ***note doubled error rate***
1 live tree tallied that should have not been (2 errors) ***note doubled error rate***
27 of 30 DBH Measurements within tolerance (3 errors)
26 of 30 HT measurements within tolerance (4 errors)
30 of 30 trees correctly identified
28 of 30 trees correct deduct assigned (2 errors)

Calculation: 150 measurements and 15 errors or 15/150 = 10% error or 90% correct measurements – Audit Fails

In Example 2, many different errors combined to fail the audit, effectively meaning all plots represented by this audit would need to be re-cruised. If only in/out trees had failed the plot each plot would still need to be checked, however new measurements on each parameter would not be required, only a re-check for in/out trees. Professional judgement of the auditor will determine which elements are required to be re-measured in the case of a failed audit.

# Appendix H – Confidence Deduction

A confidence deduction is required to be calculated each year and applied to the inventory of actual onsite carbon stocks based on the inventory.

The confidence Deduction will be calculated according to the COP, section A.4 and outlined below:

To determine the appropriate confidence deduction, perform the following:

1. Compute the standard error of the inventory estimate (based on the carbon in all carbon pools included in the forest carbon inventory).

2. Multiply the standard error by 1.645

3. Divide the result in (2) by the total inventory estimate and multiply by 100. This establishes the sampling error (expressed as a percentage of the mean inventory estimate from field sampling) for a 90 percent confidence interval.

4. Consult Table A.4 to identify the percent confidence deduction that must be applied to the inventory estimate for the purpose of calculating GHG reductions and removals (i.e. variable CDy in Equation 6.1 in Section 6).

**Table A.4.** Forest carbon inventory confidence deductions based on level of confidence in the estimate derived from field sampling.

| Sampling Error (% of Inventory Estimate) | Confidence Deduction |
|---|---|
| 0 to 5% | 0% |
| 5.1 to 19.9% | (Sampling Error – 5.0%) to the nearest 1/10$^{th}$ percentage |
| 20% or greater | 100% |

# Appendix I –Change Log

Any changes to the methodology, once the inventory is underway or in future implementations will be listed and dated here.

| A unique number associated with change log record | Date change was made | This indicates the file that was updated | A full description of the update made |
|---|---|---|---|
| Change_ID | Change_Date | Change_Reference | Change_Description |
| 1 | April 2016 | Appendix A. ACR248 Project Inventory Methodology Proprietary | Appendix was created to combine the project inventory specifications document with the required sections detailing data management, analytical systems, and the full monitoring plan. |

| | | | |
|---|---|---|---|
| 2 | November 2017 | Appendix A. ACR248 Project Inventory Methodology Proprietary | The 'Events' portion of the 'Monitoring Plan' section of this appendix was updated to reflect the method by which the inventory was grown forward at the plot-level (and not at the level of the individual tree records) to represent onsite carbon stocks at the end of RP2. |
| 3 | December 2017 | Appendix A. ACR248 Project Inventory Methodology Proprietary | The 'Spatial Data' and 'Stratification Rules' sections of this appendix were expanded to better describe the process implemented by the landowner prior to the initiation of the project and to support replicability. |
| 4 | December 2017 | Appendix A. ACR248 Project Inventory Methodology Proprietary | The 'IFM-3: Standing Dead Carbon' section of this appendix was expanded to better describe the process as it pertains to trees < 5" DBH. |
| 5 | | Appendix A. ACR248 Project Inventory Methodology Proprietary | The 'Monitoring Plan' section of this appendix was expanded to better describe the procedure for updating project carbon stocks in the case of natural disturbance, as well as the procedure for retiring sample plots. |
| 6 | July 2019 | Ownership Change | CF Highlands LLC Purchased underlying property that comprises the Highlands II Project |
| 7 | October 2019 | OPO Change | Listing Forms were filed to change the OPO from prior owner to CF Highlands |

| | | | |
|---|---|---|---|
| 8 | November 2019 | Inventory Methodology Nov 2019_Highlands II | Original inventory methodology was updated to include additional guidance around collecting tree heights |
| 9 | April 2020 | Project Name Change | OPDR submitted that changed the name of the project to the current name |
| 10 | April 2020 | Inventory Plot Allocation | 200 additional (new) inventory plots were installed on the pre-existing grid that the previous/original inventory plots had be taken. |
| | April 2020 | Inventory Methodology Nov 2019_Highlands II | Methodology updated to reflect that plots cannot be permanently dropped due to safety concerns. Plot must be represented as a no-tally plot until conditions exist to allow for the measurement of the plot. |
| 11 | March 2021 | Carbon Stock Reporting | Interpolation was utilized to arrive at EORP4 Stocking. See RP4 Stocking summary for details. |
| 12 | October 2021 | Inventory Methodology Nov 2019_Highlands II_CahngeLogEdited_Oct2021 | Appendix J – Monitoring Plan, and Appendix K – Quantification Procedures have been added to the Inventory Methodology |

# Appendix J – Monitoring Plan

**Monitoring Plan**

This portion of the Inventory Methodology describes the Project's annual monitoring plan. The primary purpose of the project's annual monitoring plan is to ensure up-to-date estimates of project carbon stocks and provide assurance that GHG reductions or removals achieved by a project have not been reversed.

**Components of the Monitoring Plan**

The major components of the property's monitoring plan are:

1. Continuous forest inventory and carbon stock updates: This component focuses on updating the forest carbon inventory and includes conducting forest carbon inventories by following the *Sampling Methodology*. It also encompasses the process of recording any timber harvests or other activities that affect the overall carbon stocks. The output of this process is used to complete the Annual Forest Monitoring Report, as well as the ROC/ARBOC Monitoring Calculation Worksheet and the Harvested Wood Product Calculation Worksheet.

2. Forest Stewardship Council certification under the NEPCon (formerly RainForest Alliance) forest certification program. Each year, the forest owner will undergo an audit conducted by NEPCon. Principles and criteria are compared against indicators observed from activities that occurred, including timber harvesting, to ensure that the forest is in compliance with the FSC U.S. Forest Management Standard. As part of the FSC principles and criteria, the forest owner must also demonstrate on annual basis it is not violating any regulations or legal agreements, including the conservation easement and project implementation agreement. The certification license is renewed every five years. The current certificate was issued on March 10, 2018 and is valid until March 9, 2023. The license can be validated on the FSC Public Certificate Search website.

3. Forest carbon project verification by an ARB accredited verifier. Each year, the project is required to be verified by an accredited third-party auditor. This audit will serve to provide assurance to the ARB that the project is operating in compliance with the Forest Offset Protocol.

**Forest Health**

As per the requirements of the FOP Appendix A.3 this subsection of the monitoring plan identifies potential insect or disease infestations that may affect the health of the project's inventory, specifically above-ground standing live and dead trees.

Hemlock Wooly Adelgid is a threat to the eastern hemlock on the property. This tree species comprises less than 6% of the basal area within the Project Area. Control of the Adelgid is not currently being pursued. Hemlock is harvested when it is within a timber sale area.

In 2011 gypsy moth infestations were mostly found in the eastern half of West Virginia. Current quarantine and control methods have been unable to completely stop the spread, though occurrences in western Virginia remain limited.

**Updating Forest Carbon Stocks**

There are three major inputs for updating forest carbon stocks: activity data, emissions factors, and the confidence deduction.

**Activity Data**

Activity data is defined as the aerial extent of a land-use category. It is the "area data" in units of acres. In this case, land-use will be stratified across the property in order to classify forest versus non-forest, and within forests, the forest type based on the dominant tree species or representative vegetative community. These strata are described in the earlier Stratification Rules section, and all changes to the activity data should follow these stratification criteria. Activity data can change for several reasons including growth, timber harvests, conversion for mining by sub-surface rights holders, natural disturbances and succession or selling property within the project area; these changes in activity data are collectively labeled as *events*. For this project, activity data will be monitored and reported over time using spatially explicit datasets, also known as a Geographic Information System or GIS. On a continuous basis throughout the year, changes in activity data will be mapped, attributed and recorded by professional foresters during timber harvest operations and timber cruises. Harvest boundaries should be confirmed with GPS and edited as necessary in GIS following the completion of any harvest operation so that the final harvest area is accurately reflected in the GIS dataset. Changes will be submitted to and edited by the forest owner's GIS controller. Further information relevant to this process is included in the 'Events' section below. A collection of digital ortho photography is also used to update stand typing and plan timber cruises; such datasets include a seamless, color mosaic of various commercial and government imagery sources, including Aerials Express 0.3 to 0.6m resolution imagery for metropolitan areas and the best available United States Department of Agriculture (USDA) National Agriculture Imagery Program (NAIP) imagery and enhanced versions of United States Geological Survey (USGS) Digital Ortho Quarter Quad (DOQQ) imagery for other areas. For more information on this imagery, visit: http://goto.arcgisonline.com/maps/World_Imagery. Edits to the activity data will be compiled and delivered to the project developer at the end of each reporting period. The project developer will store and archive all activity data by year in the project's geodatabase in the "stands" feature class, which will also serve as the activity data change log.

**Emissions Factors**

Emissions factors are defined as the emissions/removals of greenhouse gases per unit area. In this case, metric tons of CO2 equivalents (tCO2e) will be used to express emission factors as a result of changes in forest carbon stocks. Emission factors vary based on the category of activity data (i.e. strata) and are derived from forest inventory plots.

Forest inventory plots will be updated according to the Sampling Methodology and processed by the OPO using the data management and analytical systems outlined under Analytical Methods and Biomass Equations. In

years when new inventory data is not collected the forest owner will use the permanent inventory plots to update the project's forest carbon stocks by growing these plots forward using the approved growth and yield model (FVS). No forest inventory plot data greater than 12-years old will be used. Measuring the same plots through time will reduce sampling variability and provide reliable estimates of actual growth through time. New permanent plots

will be used where previous plots are not able to accurately represent a particular change in activity data. Permanent plots may be retired if the plot location has experienced a shift to a non-forest use, such as through new road construction. Inventory plots input to growth & yield modeling, as well as tracking harvest volumes, will be used to account for the changes in carbon stocks.

**Events**

Events are activities that occur within the project area that affect activity data or emission factors. Events will require spatial and tabular updates to the carbon database. A list of events including harvest volume summaries will be submitted by the Forest Owner at the end of each reporting period for the previous year and prepared for verification by completing a monitoring report.

1. Just Growth

Just growth events are assumed to occur in all areas of the project where no other event is assumed to occur. In this event, the activity data and emissions factors are updated by projecting inventory data using FVS growth and yield software, or with new inventory data when available, assuming that accretion and mortality are only a function of the stand's structure and condition from the previous reporting period. Furthermore, growth also occurs in other areas where other events take place, e.g. a timber harvest. In this case, the activity data and emissions factors are updated in the same fashion as just growth events, but accretion and mortality are adjusted based on the other event's effects, e.g. timber harvesting will reduce the carbon stocking, but may increase growth rates while reducing mortality because crop trees are free to grow.

Annual growth is represented at the plot-level by growing the inventory forward five years (the default cycle length for the SN variant) and adding the annual growth, calculated at the plot-level, to each individual plot.

2. Land Sales

Land sales activity has a tremendous bearing on every carbon project. Should all or a portion of the area committed to the carbon project be sold while under the project's commitment terms, ARB will need to be notified as soon as possible. The forest owner will be required to provide digital mapping and possibly other documentation for the area affected by the sale. Please note that any Land Sales taking place on the Project Area will remain subject to the Forest Offset Protocol and Regulations, and therefore remain part of the Project. Should any portion of the Project Area be sold and wish to terminate the Project, the whole project will be considered terminated, as there is no provision which currently allows the Project Area to be divided into multiple projects.

3. Natural Disturbances

Natural disturbance events can include windstorms, tornadoes, ice storms, floods, land-slides, earthquakes, insect or disease infestations, or other impacts of weather or nature on the forest carbon stocks. The forest owner will be required to supply mapping of the damaged area, and in some cases, a re-inventory of any original sample locations affected by the event performed to the specifications in the Inventory Methodology. The severity of the disturbance will dictate whether such a re-inventory is required, and if such an effort should include the use of temporary plots to better capture the extent of the impact. There is no established threshold for the scale of a natural disturbance event that would trigger such a response. Consultation with the property manager will allow a determination to be made as to whether the potential impact on onsite carbon stocks requires additional inventory work and updates to the project accounting.

4. Harvests

IFM projects typically encounter planned timber harvests and thinnings on a regular basis. When these events occur, the forest owner is required to provide a digital (GPS or GIS) polygon file of the affected area. This data is typically generated by the forest manager during the planning stage for any harvest or other activity, and the data is logged by the forest owner in their forest information system. Where harvest activities affect permanent plots, a re-inventory of those samples affected by the action may be required.
All areas of timber harvest will be associated with a harvest volume summary. Harvest volume summaries are logged by the forest owner in their forest information system and will be submitted to the project developer by species group (Hardwood/Softwood) and product (Sawtimber/Pulpwood), at a minimum. All harvest volume summaries must be verifiable from mill/contractor receipts (pay-as-cut sales) and/or prospectus cruises (lump-sum sales).
Post-harvest updates to inventory data and onsite carbon stocks will be undertaken in one of two ways depending on the verification needs of the project for the current reporting period:
• During reporting periods subject to full site visit verifications all harvest-affected plots will be re-inventoried. At the discretion of the forest owner these updates may follow the original specifications at the beginning of this document for a complete inventory; or a modified version by which they may tally trees removed and update the status for remaining trees (i.e. live versus dead). When the modified version is used for post-harvest updates, the OPO will apply the annual growth increments specific to each tree record as is referenced in the 'Just Growth' section above and described in 'Data and FVS Settings.' All new inventory plot data should be submitted electronically in Excel or Access formats.
• During reporting periods subject to less intensive verifications, onsite carbon stocks may be depleted based on the carbon represented in the harvest volume summary for that reporting period. Actual project carbon in harvested wood delivered to mills is used to quantify actual project carbon in trees harvested for wood products in the 'Harvested Wood Products Calculation Worksheet' for that reporting period.
5. Land Use Conversions

If there is a conversion to non-forest use, such as new road construction, these areas will be mapped by the forest manager, who will provide the data to the OPO to make the correct adjustment to the strata acreage and total carbon stocks.
In the special case where actions by a sub-surface rights holder initiates a land use change to non-forest use, the area subject to the change will be removed from the current strata. When a sub-surface rights holder receives a permit for mining activity, they will notify the forest owner and provide a digital (GPS or GIS) polygon file of the affected area to the forest manager. This information will be logged by the forest owner and provided to update the strata acreage and total carbon stocks. The volume harvested *will not* contribute to the quantification of carbon sequestered in wood products. If a plot is removed from a forested stratum as a result of this activity, it will be removed from the inventory completely. Additional plots may be allocated randomly along the existing grid during the next full project inventory, though this will be done at the discretion of the forest owner.
For all events described above, ongoing monitoring by the forest owner and its forest managers will ensure Unintentional Reversals will be reported to ARB and where necessary, an inventory of affected portions of the forest will be performed to account for unintentional reversals that create a need for ARBOC replacement from the Forest Buffer Account. Inventory design to account for unintentional losses will depend on the extent and intensity of the reversal should one occur.

**Monitoring Quality Control**
Quality Control for this project is defined as a series of activities and documented procedures that serve to maintain an acceptable level of data quality for monitoring forest carbon stocks and demonstrating compliance with the Forest Offset Protocol. Quality control success will be measured by whether or not the project passes annual verifications.

*Organization and Responsible Individuals*
Individuals responsible for maintaining project operations have been defined in the Listing Form and listed under the forest owner's account information in both the Offset Project Registry account and the CITSS account. Any changes, including new contact information, will be updated to the account information immediately.

*Document Control*
Forest Owner will be responsible for maintaining critical documents and files that support forest carbon data collection and processing. All documents will be stored on company computers and back-up servers, as well as cloud-based backup through Box.com, for a minimum of 15 years following the issuance of ARB Offset Credits related to each OPDR. The most critical documents and files necessary to be maintained include:
1. Offset Project Data Reports;
2. Project Inventory Methodology, including all requirements from the FOP Appendix A.3 (Appendix A);
3. Project geodatabase (GIS file geodatabase, Attachment I);

4. ROC/ARBOC Monitoring Calculation Worksheet; and
5. Harvest Wood Product Calculation Worksheets;

A change log specific to this monitoring plan to show updates made to raw inventory field data, inventory specifications, and data management and analytical systems will be recorded in the table below. When an update is made to the raw inventory field data or to the inventory methodology and calculations, it should be recorded in the Inventory File and Data Change Log. Modifications to inventory methodologies must be approved in advance by a third-party verification body and by ARB.

All edits and revisions to documents after project registration will be clearly marked and identified by placing a revision date or version number at the beginning of the document or within the name of the file. Outdated versions of documents will be archived. Other forms and documents required by ARB will be maintained and stored in the forest owner's account on the OPR software.

*Central Data Repository*

The ESRI personal geodatabase format will be used to store spatial and tabular project data. Built-in features of the geodatabase structure, such as domains (i.e. field value validation) and relationships, will help control data quality. Edits and updates will occur at the beginning of each reporting period to account for activities in the previous year unless an event such as a reversal occurs, in which case updates will take place and be reported to ARB in the required time frame. All results will be summarized in the Offset Project Data Reports.

## Appendix K - Quantification Procedures

Gross cubic foot volume of stem wood (VOLCFGRS) was calculated using equations referenced by Woodall et al 2011[2], using coefficients consolidated in the ARB database "Gross Cubic Foot Volume Equation Coefficients.xls", see biomass equations below in Table 1. Sound volume of stem wood (VOLCFSND) was calculated by multiplying gross volume by (1 – percent defect in stem wood). Sound volume of stem wood and dbh were then used to produce estimates of biomass using the Component Ratio Method (CRM), per Woodall et al 2011, and referencing coefficients consolidated in the 2014 protocol ARB database "biomass_coefficients_for_use_with_crm_45states.xls"

[2] Woodall, Christopher W.; Heath, Linda S.; Domke, Grant M.; Nichols, Michael C. 2011. Methods and equations for estimating aboveground volume, biomass, and carbon for trees in the U.S. forest inventory, 2010. Gen. Tech. Rep. NRS-88. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 30 p.

Wood density of standing dead wood was adjusted by multiplying by species-specific density reduction factors (DRF), corresponding to a given decay class, referenced from Harmon et al 2011[3], and then a structural loss adjustment (SLA) factor applied (Domke et al 2011[4]).

Biomass was converted to carbon applying a carbon fraction of 0.5, and carbon converted to carbon dioxide equivalent (CO2e) applying a conversion factor of 3.664. All estimates of carbon dioxide equivalent per unit area are converted to metric tons (1000 kg) per acre.

## Table 1. Biomass Equations Volume and Biomass Equation Assignments by Species

| Name | FIA Code | ARB Volume FIA Code | Equation Reference |
|---|---|---|---|
| Shortleaf Pine | 110 | 110 | McClure, J. and Cost, N. 2010 |
| Pitch Pine | 126 | 126 | McClure, J. and Cost, N. 2010 |
| Eastern White Pine | 129 | 129 | McClure, J. and Cost, N. 2010 |
| Virginia Pine | 132 | 132 | McClure, J. and Cost, N. 2010 |
| Eastern Hemlock | 261 | 260 | McClure, J. and Cost, N. 2010 |
| Striped Maple | 315 | 999 | McClure, J. and Cost, N. 2010 |
| Red Maple | 316 | 316 | McClure, J. and Cost, N. 2010 |
| Sugar Maple | 318 | 318 | McClure, J. and Cost, N. 2010 |
| Buckeye, Horsechestnut | 330 | 330 | McClure, J. and Cost, N. 2010 |
| Ailanthus | 341 | 999 | McClure, J. and Cost, N. 2010 |
| Serviceberry Spp. | 356 | 999 | McClure, J. and Cost, N. 2010 |
| Yellow Birch | 371 | 371 | McClure, J. and Cost, N. 2010 |
| Sweet Birch | 372 | 371 | McClure, J. and Cost, N. 2010 |
| River Birch | 373 | 370 | McClure, J. and Cost, N. 2010 |
| Am Hornbeam, Musclewood | 391 | 999 | McClure, J. and Cost, N. 2010 |
| Hickory Spp. | 400 | 400 | McClure, J. and Cost, N. 2010 |
| Shagbark Hickory | 407 | 400 | McClure, J. and Cost, N. 2010 |
| Eastern Redbud | 471 | 999 | McClure, J. and Cost, N. 2010 |
| Flowering Dogwood | 491 | 491 | McClure, J. and Cost, N. 2010 |
| American Beech | 531 | 531 | McClure, J. and Cost, N. 2010 |
| White Ash | 541 | 540 | McClure, J. and Cost, N. 2010 |
| Green Ash | 544 | 540 | McClure, J. and Cost, N. 2010 |
| American Holly | 591 | 591 | McClure, J. and Cost, N. 2010 |
| Butternut | 601 | 601 | McClure, J. and Cost, N. 2010 |
| Black Walnut | 602 | 602 | McClure, J. and Cost, N. 2010 |
| Yellow-Poplar | 621 | 621 | McClure, J. and Cost, N. 2010 |
| Cucumbertree | 651 | 651 | McClure, J. and Cost, N. 2010 |
| Mountain Magnolia | 655 | 651 | McClure, J. and Cost, N. 2010 |
| Apple Spp. | 660 | 999 | McClure, J. and Cost, N. 2010 |
| Red Mulberry | 682 | 680 | McClure, J. and Cost, N. 2010 |
| Blackgum | 693 | 693 | McClure, J. and Cost, N. 2010 |
| E. Hophornbeam | 701 | 999 | McClure, J. and Cost, N. 2010 |
| Sourwood | 711 | 999 | McClure, J. and Cost, N. 2010 |
| Paulownia, Empresstree | 712 | 999 | McClure, J. and Cost, N. 2010 |
| Sycamore | 731 | 731 | McClure, J. and Cost, N. 2010 |
| Black Cherry | 762 | 762 | McClure, J. and Cost, N. 2010 |
| White Oak | 802 | 802 | McClure, J. and Cost, N. 2010 |
| Scarlet Oak | 806 | 806 | McClure, J. and Cost, N. 2010 |
| Chestnut Oak | 832 | 832 | McClure, J. and Cost, N. 2010 |
| Northern Red Oak | 833 | 833 | McClure, J. and Cost, N. 2010 |
| Black Oak | 837 | 837 | McClure, J. and Cost, N. 2010 |
| Black Locust | 901 | 901 | McClure, J. and Cost, N. 2010 |
| Sassafras | 931 | 999 | McClure, J. and Cost, N. 2010 |

[3] Harmon, Mark E.; Woodall, Christopher W.; Fasth, Becky; Sexton, Jay; Yatkov, Misha. 2011. Differences between standing and downed dead tree wood density reduction factors: A comparison across decay classes and tree species. Res. Pap. NRS-15. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station. 40 p.

[4] Domke, Grant M., Christopher W. Woodall, and James E. Smith. 2011. Accounting for density reduction and structural loss in standing dead trees: Implications for forest biomass and carbon stock estimates in the United States. Carbon balance and management 6.1: 1-11.

| | | | |
|---|---|---|---|
| American Basswood | 951 | 950 | McClure, J. and Cost, N. 2010 |
| Elm Spp. | 970 | 970 | McClure, J. and Cost, N. 2010 |
| Slippery Elm | 975 | 970 | McClure, J. and Cost, N. 2010 |

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