Supplemental Verification Methodology

To: **ALL FOREST PROJECT VERIFIERS**
Date: July 03, 2012
Re: Updated Guidance for Verification of sampled pools for Forest Projects

Version 3.3 of the Forest Project Protocol will describe a verification sampling methodology for all sampled pools that employs sequential sampling of the carbon pools reported by the Forest Owner. This supplemental guidance is an excerpt from the draft Forest Project Protocol Version 3.3. Since the draft verification language is not unique for soil carbon, this supplemental guidance includes draft verification language for other carbon pools as well.

All reports that reference carbon stocks must be submitted by the Forest Owner with the oversight of a Professional Forester. If the project is located in a jurisdiction without a Professional Forester law or regulation, then Certified Forester credentials managed by the Society of American Foresters (see http://www.certifiedforester.org) are required so that professional standards and project quality are maintained.

Verifying Carbon Inventories

Verification bodies are required to verify carbon stock inventory estimates of all sampled carbon pools within the Project Area. Inventories of carbon stocks are used to determine the project baseline and to quantify GHG reductions and removals against the project baseline over time. Verification of carbon inventories consists of ensuring the Forest Owner's sampling methodology conforms to requirements listed in the Protocol and that the project's inventory sample plots are within specified tolerances when compared to the verifier's sample plots. Verification is effectively an audit to infer that the inventory estimate is sound. Verification of the project's onsite stocks must occur at each site verification and focus on ensuring that the project's inventory methodology is technically sound and that the methodology has been correctly implemented.

The project must meet the inventory standards in Table 2 prior to the verification body initiating field sampling activities. The verifier will install sample plots or re-measure existing monumented sample plots consistent with the objectives of a random, risk-based and efficient approach[1]. In doing so the verifier may weigh the probability of selecting strata and plots based on various criteria -- including carbon stocking, access difficulty, and vegetation heterogeneity. Verifiers may choose to sample project plots within a given stratum with a cluster design. The selection of a stratum may use probability proportional to carbon stocks or probability proportional to error (as hypothesized by the verifier) risk.

Sequential Sampling for Verification

As a policy to ensure a trend of agreement with sampled data is sustained between the verifier and Forest Owner, Forest Protocol version 3.3 will require a sequential sampling method for verification of sample plots. Sequential sampling is intended to provide an efficient sampling method for verifiers to determine if randomly selected project measurements are within specified tolerance bounds established by the Protocol. Verification using the sequential sampling methodology requires the verification body to

[1] For the purposes of this verification guidance the following terms and definitions apply:

1. Stand: An individual unit or polygon that is relatively homogeneous in terms of the carbon stocking within its borders. For live and dead trees, the determination of stand boundaries is usually based on forest vegetation attributes, such as species, size (age), and density characteristics. For soils, the determination of soil stand boundaries is made on similar soil orders.
2. Stratum: A group of stands that contain a similar attribute, such as vegetation or soils attributes.
3. Strata: Plural of stratum. The set of different groupings for a specific attribute, such as vegetation or soil.

sequentially sample successive plots. Sequential approaches have stopping rules rather than fixed sample sizes. Verification is successful after a minimum number of successive plots in a sequence indicate agreement. Where the stopping rules indicate the potential presence of a bias, additional verification plots may be collected after that time if it is felt that random chance may have caused the test to fail and a convergence towards agreement is expected with additional verification samples. The results of any additional verification plot may also be inconclusive and require additional verification plots for a determination to be made. For effective application of the sequential statistics in the field, the determination of when the stopping rule is met is done at the end of each sampling day, which will include the full set of plots measured in that day.

Worksheets are provided for use by verifiers to assist in verifying sampled data. The verifier will review the descriptive statistics of the carbon stocks independently for each pool or combination of pools that is being reported for crediting (applicable pool) as shown below:

- Standing live and dead trees
- Soil

Separate worksheets have been developed to assess both monumented (paired) and non-monumented (unpaired) plots. Worksheets are found on the Reserve's webpage.

The Reserve has established a 10% allowance as an acceptable level of agreement between the verifier and the Project Developer, without adjusting the project estimates for uncertainty. The Reserve will accept applying up to a 20% allowance, meaning that the verifier can infer that their estimates indicate an agreement within 20% of the Project Developer's estimates, with an adjustment applied for the higher uncertainty. The rules for determining the adjustment are as follows:

- Where project estimates can be verified within a 10% allowance level, no adjustment will be applied to the project submission.

  If the project data do not agree with the verifier data at the 10% allowance level, the allowance level shall be incrementally adjusted upwards by 1%until the data display a stopping rule indicating agreement. Due to the inherent variability present in larger allowance levels, the average value of the project developer's carbon estimates for project sites shall be adjusted proportional to the adjusted allowance level.
- This proportion will be applied to each stratum according to the following table (Table 1).

Table 1. Adjustment Factors for associated allowance levels.

Passing Allowance Level	**Project Site Carbon Average Adjustment Factor**
11%	0.98
12%	0.96
13%	0.94
14%	0.92
15%	0.90
16%	0.88
17%	0.86
18%	0.84
19%	0.82
20%	0.80

- If the project's inventory is stratified, the adjustment shall be applied to the entire project estimate by applying the adjustments as a proportion to the project inventory. Equation 1 below demonstrates how strata level adjustments are to be applied to project inventories.

Equation 1. Adjustment to Project Inventory Using Strata Level Adjustments

$$\frac{\sum_{i=1}^{n} STRv_i STRvadj_i}{\sum_{i=1}^{n} STRv_i} \times STR_{total}$$

Where,

n	=	number of strata verified
$STRv_i$	=	CO_2-e in verification stratum i
$STRvadj_i$	=	adjustment factor used from Table 1 for verification stratum i
STR_{total}	=	the total sum of CO_2-e in all project strata

- If the carbon estimate does not pass the sequential sampling methodology at a 20% allowance level for the project or any given stratum, then the carbon for that specific carbon pool shall be considered unverifiable.

- This guidance will be incorporated into the sequential sampling guidance for the Forest Project Protocol Version 3.3.

Inventory Estimates
The items in Table 2 are measures that need to be taken before the verifier goes to the field and analyzes the plots.

Table 2. Inventory Methodology Verification Items

Verification/Evaluation Standards		Insert a 'Failure to meet Standard' in any category below where the standards on the left are not met or clearly have not been implemented as described in the inventory methodology
1.a	Inventory methodology describes the methodology for plot location in the field. The plot locations are either random or systematic with a random initial point.	X
1.b	If inventory methodology describes a stratification design: The stratification methodology, including rules for stratification, is clearly defined. The stratification design is relevant for the sampling of biomass. Checks for correct implementation can be made through comparison of stratification rules to strata polygons with inventory reports, field checks to stated strata, aerial photos, etc.	X
1.c	Inventory methodology states how the inventory is updated on an annual basis to reflect growth, harvest, and other disturbances. The methodology includes a process to: 1. Update the inventory for harvest and other disturbances. 2. Update the inventory for growth using and approved growth model or a stand table projection, as described in Appendix B. The inventory being verified is determined to be current using the update methodology.	X

1.d	The inventory methodology has been implemented in a consistent manner since the project's inception. If changes have been made to the inventory methodology, such changes have been discussed and approved in writing by the Reserve.	X
1.e	The inventory methodology describes the volume and biomass equations used to compute the project's carbon stocks and these equations are consistent with those required by the protocol. Appropriate use of biomass equations is demonstrated.	X

Each applicable pool/combination of pools must meet the minimum precision threshold stated in the Forest Project Protocol of +/- 20% at the 90% confidence interval. Project Developers can improve the precision of their estimates through additional inventory effort, but can only include it in their reporting after the confidence estimate has been verified. Projects must include the uncertainty adjustment associated with their most recent verification effort. The emissions associated with site preparation activities (soil, shrubs, and herbaceous understory) are not subject to the same sequential sampling requirements and shall be verified according to Section 6.1.1.(2) for Reforestation Project types which requires the Forest Owner to measure site preparation emissions using 1 of the following methods - sample 20 plots located in the portion of the Project Area containing the greatest amount of biomass in the pool that will be affected; stratifying the Project Area into similar densities and measuring stocks within the carbon pools using 20 sample plots per density class.; and measuring the affected carbon stocks based on a grid system across the Project Area.

The level of field review during the verification of the project's onsite stocks is based on the programmatic risk (risk of inaccuracy to the entire forest offset program) and project risk (risk of inaccuracies at the project level). Small projects with low levels of reported reductions/removals are verified with a smaller number of plots than large projects with high levels of reported reductions/removals. All projects must be within the maximum acceptable error of 10% (verifier estimates compared to project estimates).

Measurement Specifics for Verifiers:

Verifiers must use the highest standard to conduct measurements during field measurements. Measurements utilized by verifiers during field inspections shall be consistent with the tolerance standards for measurements identified in Appendix A, with the following exceptions:

1. Verifiers shall measure the heights of all trees according to the height measurement used for the species-specific biomass equation on the Reserve's Forest Resource webpage.
2. The use of regressions to estimate heights is allowable for Forest Owners; verifiers should measure each height for comparisons with Forest Owner estimates.
3. Tools and methods used for distance measurements for plot boundaries should be accurate within 1"/30'.
4. Tools and methods used for distance measurements for height measurements must be able to obtain an accuracy of 6"/100'.
5. All borderline tree should be measured to determine their status as an 'in' or 'out' tree.

Verifying a Stratified Inventory: Where the Forest Owner's inventory is stratified, the strata to be verified may be selected by the verifier according to the presumed risk of measurement error or presumed risk of the effects of measurement error on the overall inventory estimate, as described above. Individual stands and plot locations must be independently selected using a random selection design. The verifier shall select three strata (or the maximum number of strata present) based on the verifier's evaluation of risk. The minimum number of passing plots varies by project size and number of strata verified. (Table 3).

Verifying a Non-Stratified Inventory: If the project is not stratified for each applicable pool, the verifier shall allocate the plots systematically or in clusters for efficiency. The plots shall be located on a randomized basis. If the verifier uses a cluster design, the mean of the cluster accounts for one

observation (plot). Plots may be measured and assessed one at a time or in reasonable batches that correspond to logistical realities such as crew-days of effort.

Verification within a Stand: Plots or clusters must also be independently selected using a random or systematic design. No more than 6 plots or clusters can be assigned to a stand, unless the groups of plots required for verification exceed the number of stands that exist for the project.

Table 3. Number of passing plots in sequence, as a function of project size.

Test	Number of Strata Verified	Project Acres				
		<100	100 – 500	501 - 5,000	5,001-10,000	> 10,000
Paired/Unpaired	3	2	3	4	5	6
	2	4	6	8	10	12
	1	8	12	16	20	24

There are two possible statistical procedures that can be applied to the stratum-level verifications. A paired test can be applied when plot locations can be found and it is statistically appropriate to use a paired test (i.e. plot measurements can be replicated). An unpaired test can be applied when plots cannot be relocated. The range of acceptable error (δ, delta) is fixed at 10 percent for both tests.

Paired Plots

The statistical test is based on a comparison of the verifier's measurements of plots within a selected stratum, calculated as CO_2-e compared to Forest Owner's measurements of plots, which may include any adjustments for growth.

Use α=0.05 and β=0.20 to control for error.
The null hypothesis (H_0) is that the verification and project plots are equal.

1) Perform verification sampling on at least the minimum number of passing plots required in a sequence from Table 3
2) If $n \geq ((Z_\alpha + Z_\beta)^2 \times S_n^2) / D^2$ then stop and evaluate. Otherwise take another sample.

   n = Number of verification plots measured,

   Z_α = α% N(0,1) = 1.645
   Z_β = β% N(0,1) = 0.8416

   S_n^2 = sample variance of the differences,
   D = δ × project average estimate.

3) If stopped, then evaluate.

   If $X_N \leq$ K then accept H_0,
   If $X_N >$ K then reject H_0.

   X_N = sample mean of the differences,
   N = total number of plots measured,
   $K = (Z_\alpha \times D) / (Z_\alpha + Z_\beta)$.

4) If H_0 was rejected then additional samples may be taken as long as the verifier is of the opinion that there is a chance that H_0 may be accepted based on the variability and trend observed.

Unpaired Plots

The statistical test is based on comparing the average CO2-e estimates for each stratum from the verifier plots to the Forest Owner plots.

Use α=0.05 to control for error; the β is not specified because we are constructing a confidence interval not a test. The null hypothesis (H_0) is that the verification and stratum averages are equal. The following procedure is appropriate for the unpaired test.

1) Perform verification sampling on at least the minimum number of plots required in a sequence from Table 3. Calculate n as the sum of the number of plots from both the stratum and the verification.

2) Calculate the following:

   $T_n = X_P - X_n$ where, X_P = stratum mean,
   X_n = verification mean after sample n.
   S_n^2 = sample variance of the verification plots,
   S_P^2 = sample variance of the stratum plots,
   D = δ × stratum average estimate.

3) If $n \geq (a^2/D^2) \times (S_n^2 + S_P^2)$ then stop and evaluate. (Note: $n = n = n_P + n_V$). Otherwise take another sample.

4) If stopped, then evaluate. Construct a confidence interval $T_n \pm D$.
   If the confidence interval includes zero then accept H_0,
   Otherwise reject H_0.

5) If H_0 was rejected then additional samples may be taken until as long as the verifier is of the opinion that there is a chance that H_0 may be accepted based on the variability and trend observed.

If the stopping rule in step (3) above cannot be attained within 100 plots then apply a standard unpaired t-test comparison using alpha of 0.05 and beta of 0.80.

Step by Step Guidelines to Performing the Verification Guidance

Step1: Assigning Risk to Strata

The verifier must determine for standing live and standing dead trees if the Forest Owner has stratified the Project Area into strata that reflect common characteristics that influence carbon stocks. The verifier may presume risk exists in the highest stocked strata, strata that are unique or difficult to access due to topographical, vegetative, or other physical barrier, strata that represent a large portion of the project's inventory due to the area they represent, or any other risk perceived by the verifier. The determination of risk must be applied to the stratum as a unit and not individual stands of a given stratum.

Step 2: Selecting Strata based on Risk

Based on the assessment of risk, the verifier will query or request that the Forest Owner query the set of stands that are associated with the strata selected. The queried stands must have an identifier which can be based on the Forest Owner's identification convention or one assigned by the verifier. Three strata must be selected, or the maximum number of strata stratified by the Forest Owner for each pool. Table 4 displays an example of ordered strata for standing live and dead trees selected by stratum with random numbers assignments.

Table 4. Stands selected by vegetation strata and risk class with random number assignments.

Stand Number	Stratum (from Forest Owner or Verifier)	Risk Class	Order of Random Selection
2	Dense Intermediate Conifers	High Stocking	5
3	Dense Intermediate Conifers	High Stocking	3
4	Dense Intermediate Conifers	High Stocking	1
8	Dense Intermediate Conifers	High Stocking	8
9	Dense Intermediate Conifers	High Stocking	2
10	Dense Intermediate Conifers	High Stocking	1
15	Dense Intermediate Conifers	High Stocking	4
18	Dense Intermediate Conifers	High Stocking	7
Stand Number	**Stratum (from Forest Owner or Verifier)**	**Risk Class**	**Order of Random Selection**
8	Dense Mature Conifers	High Stocking	4
9	Dense Mature Conifers	High Stocking	3
10	Dense Mature Conifers	High Stocking	5
15	Dense Mature Conifers	High Stocking	2
18	Dense Mature Conifers	High Stocking	1
Stand Number	**Stratum (from Forest Owner or Verifier)**	**Risk Class**	**Order of Random Selection**
13	Medium Dense Mature Riparian	Difficult Access	2
14	Medium Dense Mature Riparian	Difficult Access	1
17	Medium Dense Mature Riparian	Difficult Access	3

Step 3: Planning and Implementing Field Verification Sampling

The selected stands should be mapped and labeled with the random number to assist in developing a strategy to perform field sampling activities. Up to 6 plots or clusters may be re-measured in a stand (if plots are monumented by the Forest Owner) or installed (if plots are not monumented) in each stand. If the Project Area has not been stratified or there are less than 3 strata, the verifier shall locate the plots or clusters using a random process of their own design. For efficiency, it is acceptable for the verifier to relocate to a new area at the beginning of a day without having completed all the plots in the previous day.

Step 4: Determination if the Stopping Rules have been met

The verifier must determine if the stopping rules have been met for each stratum after the measurement of each plot or at a minimum the end of each day. The Reserve provides tools to assist verifiers with determining if the stopping rules have been met or not. The tools are Microsoft Excel based and are distinct for paired designs and for unpaired designs.

The verifier must enter their data into the appropriate spreadsheet based upon use of a paired or unpaired test). It is required that the verifier apply the random order selection in the sampling process. The verifier is free to measure the set of plots that were randomly selected in any order that provides the greatest efficiency while sampling in the field, but when the verifier inputs data into the spreadsheet, the verifier must follow the random selection order in order to properly conduct the analysis and maintain the integrity of sequential analysis. . This may provide significant efficiencies when selected stands and/or plots are in close geographic proximity and it is hypothesized that the stopping rules will require the full number of plots. Table 4 displays a hypothetical sampling schedule planned by the verifier and the hypothetical verification results. In this case, the sequential sampling is conditionally satisfied after Day 3 but requires the full set of randomly selected stands to be sampled up to the point of satisfying the sequential statistics, which is met after sampling Stand 3 on Day 4.

Table 5- Example of Randomly Selected Plots

Stand	Stratum (from Forest Owner)	Risk Class	Order of Random Selection	Sampling Schedule (Planned)	Verification Effort	Verification Results
4	Dense Intermediate Conifers	High Stocking	1	Day 3	Day 1	Inconclusive. Stand 9 sampled. Sequential sampling criteria not satisfied - More plots are needed
9	Dense Intermediate Conifers	High Stocking	2	Day 1	Day 2	Inconclusive. Stand 15 sampled. Sequential sampling criteria not satisfied - More plots are needed
3	Dense Intermediate Conifers	High Stocking	3	Day 4	Day 3	Inconclusive. Stand 4 sampled. Sequential sampling criteria satisfied but stand order must be satisfied. Stand 3 must be sampled
15	Dense Intermediate Conifers	High Stocking	4	Day 2	Day 4	Conclusive. Stand 3 sampled. Sequential sampling criteria is met and adherence to random selection is maintained
2	Dense Intermediate Conifers	High Stocking	5	Day 6	Further Verification Effort not Necessary	
10	Dense Intermediate Conifers	High Stocking	6	Day 5		
18	Dense Intermediate Conifers	High Stocking	7	Day 7		
8	Dense Intermediate Conifers	High Stocking	8	Day 8		

Finally, in addition to evaluating and verifying adherence to the Forest Owner's inventory methodology, the verification body must verify the items in Table 6.

Table 6. Additional Verification Items for Inventory Methodology and Implementation

Verification Items		Apply Professional Judgment?
1. Inventory Update Processes	1.a Forest Owner's inventory document describes methodology for updating inventory data resulting from growth, harvest, and disturbances. Methodology adheres to acceptable forestry practices.* 1.b Harvest/Disturbance updates in inventory management system are implemented per the specified methodology and are representative of the harvest or disturbance. 1.c Growth is accounted for using an approved growth model or using a stand table projection, as described in Appendix B.	Yes

2. Biomass Equations and Calculations	2aThe carbon tonnes per acre for a representative sample plot, computed using the Forest Owner's calculation tools, replicate output computed by the verification body.** 2.b All conversions and expansions are accurate.	Yes

*A forest biometrician employed by the state in which the project is located, or a consulting forest biometrician may be consulted in the event of a dispute between the verification body and Forest Owner. The written opinion of the forest biometrician, submitted to the Reserve as part of the verification report, shall be considered the authoritative word.

**The verification body must provide an (idealized) 'verification plot' consisting of all tree species in Project Area with varying heights and diameters existing within the Project Area. The plot need not correspond to an actual plot within the Project Area.