Final Report for the Ohio Department of Natural Resources Division of Forestry

A COMPLETE FOREST INVENTORY OF EIGHT (8) STATE FORESTS OWNED BY THE ODNR – DIVISION OF FORESTRY TOTALING 156,544 +/- ACRES

By LandMark Systems,
In Cooperation with
Sanborn Solutions and Forest Resource Services

10/27/2009

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I. EXECUTIVE SUMMARY

The State of Ohio required a forest inventory across eight of its state forests for the purposes of forest management activities, database updates, and information to share with the public. To meet these requirements, a **stratified** forest inventory was conducted in spring of 2009. The inventory used proprietary techniques to extrapolate a field sample consisting of 2,209 plots across all the acres of the eight forests. This approach provided a forest level inventory estimate within the allowable budget. As per the project requirements, statistics at a 90% confidence level were calculated for key inventory variables: board feet and tons. This indicates that each variable can be predicted to fall within upper and lower limits shown 90% of the time. At a 90% confidence level, the table below indicates the true population mean (75.9 tons/acre and 10,188 board feet/acre) lies between the lower and upper limit as denoted by the range bars. These range bars represent +/- 6.7% for total tons and +/- 9% for board feet per acre.

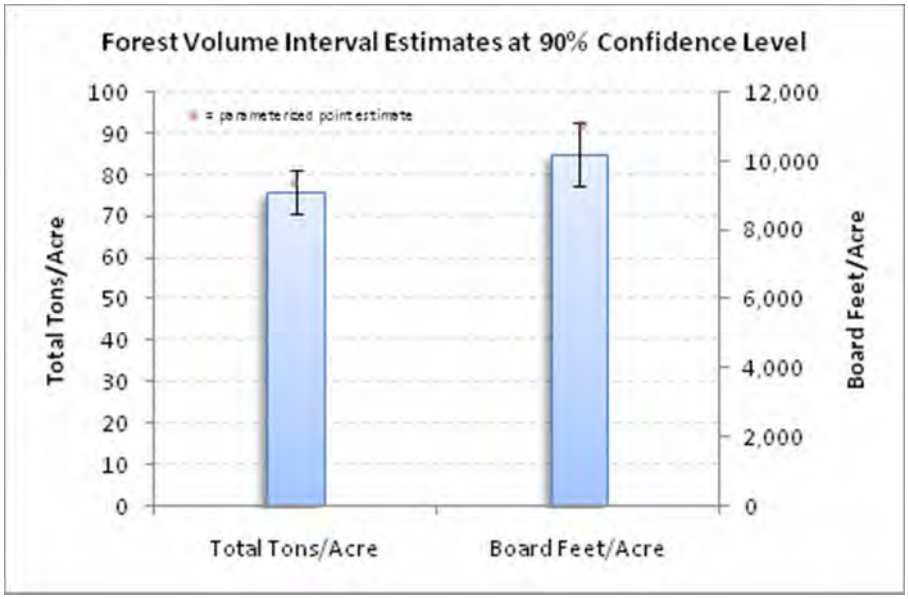


Table 1 - Forest stratified volume statistics

Since the Ohio DOF desires a stand-level inventory, but like most organizations, both public and private, lack the resources to perform such a detailed inventory, the LandMark Team (LandMark Systems, Sanborn Solutions and Forest Resource Services (FRS)) proposed to leverage a number of remotely acquired data sources to arrive at a level that would be more refined than a regular stratified-level inventory. This process, called stand parameterization, results in an inventory that could be classified as a stratified inventory with adjustments made at the stand and sub-stand level. It could also be referred to as a process somewhere between a stratified and stand-based inventory, whereby the stand-level results are more refined than a strata-based inventory, but not as refined as one purely stand-based.

The results show that the parameterized values, when compared to stratified estimates, are about 3.5% higher in basal area (117 vs. 113), 2.8% higher for total tons (78.1 vs. 75.9) and 10.3% higher for sawlog board feet (11,234 vs. 10,188). Since these variances are well within the limits of error (just barely outside the realized standard error for board feet, but well within

the limits of the distribution), they are considered reasonable within the statistical bounds of +/- 10%. This difference with parameterization, while expected, is most likely explained by the reduction of coverage error in that the use of remotely sensed data gathers attributes from the whole forest, while plots gather attributes from samples within a forest. While this difference could either be positive or negative from the stratified estimate, in this case it was found to be positive.

The final parameterized results by State Forest are as follows in Tables 2A (BA) and 2B (Volumes):

Parameterized Basal Area by Forest

Forest	Acres	PWBA	SawBA	LgSawBA	TotalBA
Brush Creek	13,348	36.8	35.1	45.4	117.3
Hocking	9,226	35.5	44.4	52.6	132.6
Pike	11,861	32.7	35.8	50.4	118.8
Richland Furnace	2,430	27.7	41.1	45.1	113.9
Scioto Trail	9,447	32.6	38.9	43.4	114.9
Shawnee	63,200	36.9	35.6	40.1	112.7
Tar Hallow	15,961	27.9	39.3	54.6	121.8
Zaleski	27,352	32.9	37.7	47.5	118.2
Total	**152,824**	**34.4**	**37.2**	**45.3**	**116.8**

Inclusive of all species greater than or equal to 5" dbh.

Table 2A - Basal Area by Forest

Forest Volumes From Parameterization By Forest

		Total				
Forest	Acres*	PWtons	SawTbrBdFt	LgSawTbrBdFt	TotalSawTbrBdFt	TotTons
Brush Creek	13,348	308,780	53,109,249	93,857,164	146,279,794	1,041,189
Hocking	9,226	237,642	53,467,546	76,489,944	130,317,737	887,410
Pike	11,861	254,269	51,347,653	96,998,264	147,183,603	985,475
Richland Furnace	2,430	42,779	11,826,383	16,798,688	28,762,834	187,078
Scioto Trail	9,447	192,146	42,125,431	64,020,046	107,120,887	724,458
Shawnee	63,200	1,425,042	245,276,003	382,645,963	628,456,616	4,595,339
Tar Hallow	15,961	286,414	74,569,091	135,530,284	209,315,204	1,331,805
Zaleski	27,352	589,412	120,431,964	198,515,836	319,366,663	2,190,122
Total	**152,824**	**3,336,483**	**652,153,318**	**1,064,856,188**	**1,716,803,339**	**11,942,877**

		Per Acre				
Forest	Acres	PWtons	SawTbrBdFt	LgSawTbrBdFt	TotalSawTbrBdFt	TotTons
Brush Creek	13,348	23.1	3,979	7,032	10,959	78.0
Hocking	9,226	25.8	5,795	8,290	14,125	96.2
Pike	11,861	21.4	4,329	8,178	12,409	83.1
Richland Furnace	2,430	17.6	4,867	6,913	11,837	77.0
Scioto Trail	9,447	20.3	4,459	6,777	11,339	76.7
Shawnee	63,200	22.5	3,881	6,055	9,944	72.7
Tar Hallow	15,961	17.9	4,672	8,492	13,115	83.4
Zaleski	27,352	21.5	4,403	7,258	11,676	80.1
Total	**152,824**	**21.8**	**4,267**	**6,968**	**11,234**	**78.1**

PWtons=Pulpwood green tons; SawTbrBdFt= Small Sawtimber Board Feet; LgSawTbrBdFt=Medium and Large Sawtimber Board Feet; TotTons=Total green tons; TotalSawTbrBdFt=Total Sawtimber Board Feet. Log rule: International 1/4". All speecies included.

* Excludes stand acres where stratum = DV, ROW, CL, or WA

Table 2B - Volumes by State Forest

For a full listing of deliverables related to this project, please refer to Appendix A – List of Deliverables. All data in the geodatabase include both raw and calculated values as well as supporting GIS data. For a more detailed listing of forest and strata reports, please see Appendix B – Strata and Forest Level Volumes.

If there are any questions or concerns regarding these deliverables, please contact LandMark Systems at 850-385-3667. On behalf of LandMark Systems and the entire LandMark Team, we sincerely thank the Ohio DOF for affording us the opportunity to provide this report and perform this project. We believe it is a product of high value and will have multiple benefits in assisting the DOF in managing their forest resources.

II. PURPOSE OF PROJECT

The purpose of this project was to provide the State of Ohio with an accurate forest inventory at the stand level on eight (8) state forests owned by the Ohio Department of Natural Resources – Division of Forestry. The results were to be used as a decision support tool for forest planning using growth and yield modeling, timber production, and forest certification.

Key components of project included:

- Mapping: stratification, stand polygon delineation with associated inventory attribution
- Inventory: design of a stratified-inventory sampling system, field data collection, and analysis of data.
- Reporting: summary reports for each forest as well as strata, and data configuration to facilitate population of the Division of Forestry's integrated forest information system (Resources, Cengea Solutions, Inc., Vancouver, BC – Canada).
- An inventory that supports forest planning using Growth & Yield Modeling in a format compatible with the USDA Forest Service's Forest Vegetation Simulator.
- An inventory that will allow the calculation of an annual allowable harvest.
- An inventory that will support the DOF timber sale program.
- An inventory that is usable to analysts and field foresters alike.
- An inventory that will support decision-making on silvicultural activities including prescribed burning.

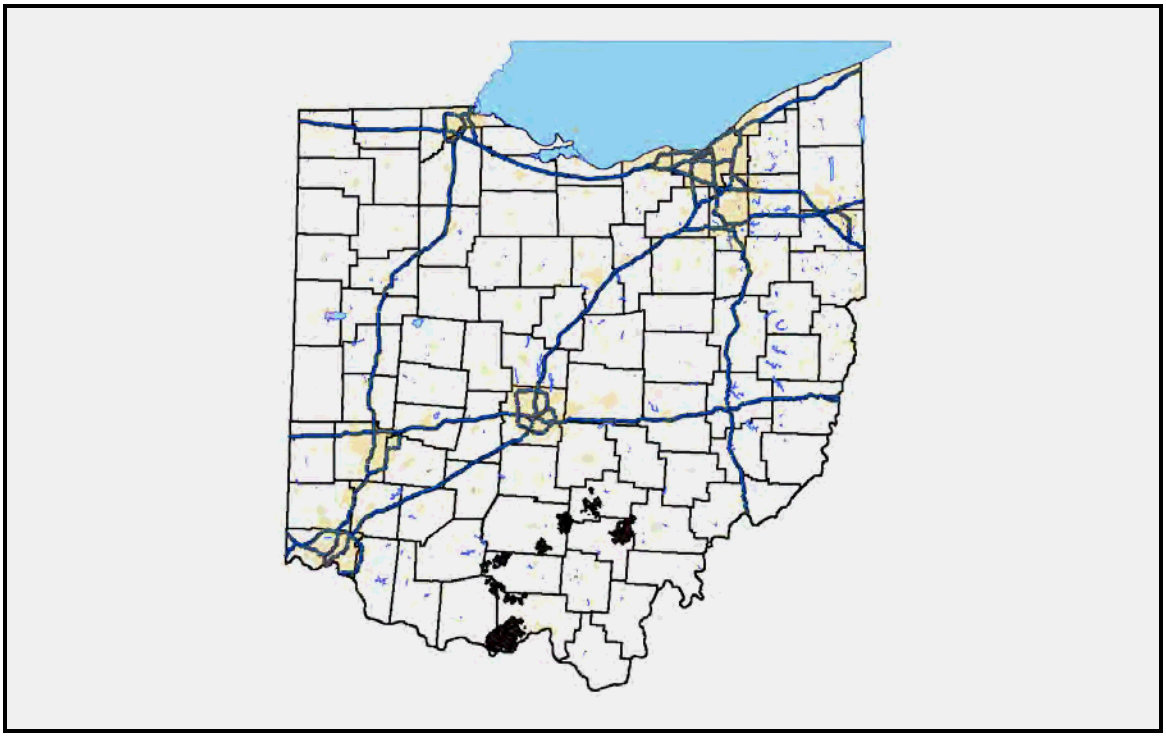
It is LandMark Systems' and the LandMark Team's opinion that this inventory effort meets all of the above component criteria for the project.

The state forests include the following properties and total acres, which are made up of both forest and non-forest areas:

State Forest	Acres	OH County - Location
Brush Creek	13,515	Adams, Scioto
Hocking	9,904	Hocking
Pike	11,861	Pike, Highland
Scioto Trail	9,204	Ross
Shawnee	64,15	Adams, Scioto
Tar Hollow	16,312	Ross, Hocking, Vinton
Zaleski	28,255	Vinton, Athens
Richland Furnace	2,504	Jackson, Vinton
Total	**155,700**	

Table 3 - State Forest Name, Acres and County Location

Figure 1 indicates the approximate location of these state forests in Ohio.



The scope of this project, as specified by the Ohio DOF, included:

- Mapping, including stratification, stand delineation and production of attributed ESRI ArcMap compatible files.
- The design of a stratified-inventory sampling system that produces the inventory at the lowest cost, most efficient, and most accurate manner possible.
    - While this project requested a complete inventory to the stand level, DOF acknowledged sampling efforts at the stand-level were not cost or time-efficient. DOF requested a **stratified-inventory design**. DOF anticipated that a strata-level inventory can be further split into stands by using the compartment boundaries supplied with the RFP as a guide. However, stands could be produced by other methods mutually determined by the offeror and DOF.
    - The **stratification variables** were estimated in section 6 of the RFP, however, DOF believed this to be a guide and may not fully consider all appropriate variables on the ground. Stratification variables could be added, subtracted, or altered during scoping meetings with the Contractor, and further modified after initial sampling visits.
    - The desired confidence level for the entire project was set at the **90% level**, with associated statistics determined during the project. The sampling size for each stratum should was based on relative importance to DOF and amount of variation. Relative importance and amount of variation determined the coefficients of variation and standard error. This was determined during initial scoping meetings with the Contractor and after initial sampling visits. As a guide,

DOF provided a list of ranking by importance in section 6. In general, strata with high relative importance are where the majority of activities occur and where timber values are high. Where activities are limited and value is low sampling efforts were considerably less intense.

- Sampling according to the sampling system with on-the-ground cruising to collect tree-level data and stand attributes. The number of samples depended on the variability of the strata to the relative importance of the strata. The linking of plot location data using GPS technology with inventory data to produce spatial locations of all samples was used.
- **Optional**: The Contractor was given the option of presenting a solution that leverages other technologies, not specified in the RFP, to improve accuracy of the data. The DOF desired an accurate inventory. Examples of other technologies cited included the use of remote sensing, or other imagery data, or Lidar.
- The Contractor was required to conduct all statistical analyses and produce forest and strata level reports as well as configuration of data so that it is readily available to import into the DOF integrated forest information system (Resources, Cengea Solution Inc., Vancouver, BC – Canada). The Contractor was required to produce a complete data set including the production and attribution of a stand polygon file and a strata polygon file.

III. PROJECT METHODOLOGY

Task 1: Review Scope of Project

This was an internal review among contractor staff in order to verse all those participating in the project on the project requirements, schedule, communication protocols and deliverables. A general task overview was provided such that the creation of the workplan, including the next tasks, could begin.

Task 2: Develop Project Management Workplan

The workplan is a document outlining how each individual project task would be executed as well as scheduling and deliverables if applicable. The workplan was a 38 page document delivered on October 6, 2008 to the DOF. This document was reviewed in a meeting by project team members from both the contractor and the client organizations. The workplan was a collaborative effort which resulted in a working project document.

Task 3: Mapping

Image Acquisition and Stratification

Stratification Scheme

The purpose of this subtask was to create a forest typing, development and stand density system which could classify stands into like strata. This aids stand delineation, sample creation and reporting of inventory. The stratification was created through close collaboration with the client so that the results reflect the understanding of forest structure in the project area. A document outlining the

detail of the stratification is provided in Appendix D – Stratification and Classification Matrix.

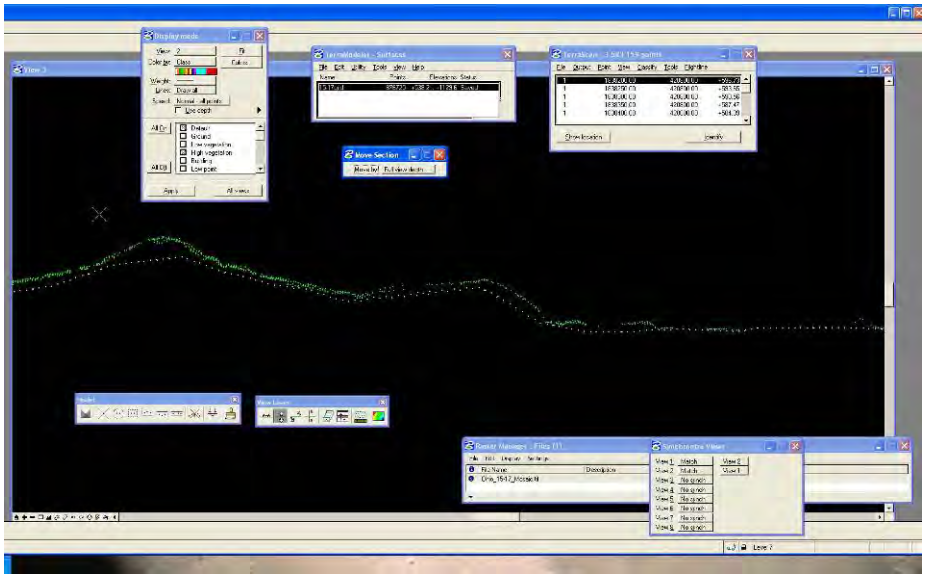
Imagery for creation of stratification layers

The aerial photography was captured using an Intergraph Digital Mapping Camera (DMC), equipped with forward image motion compensation, airborne GPS and a gyro-stabilized camera mount. The imagery was collected as 5-band raw imagery including color (R, G, B), color infrared and panchromatic imagery. The data were then processed into the 4-band imagery in a 16-bit digital format. The digital stereo imagery used was suitable to generate 2 ft ground sample distance (GSD) orthophoto imagery. The area was collected in stereo with 60 percent overlap and 30 percent side lap.

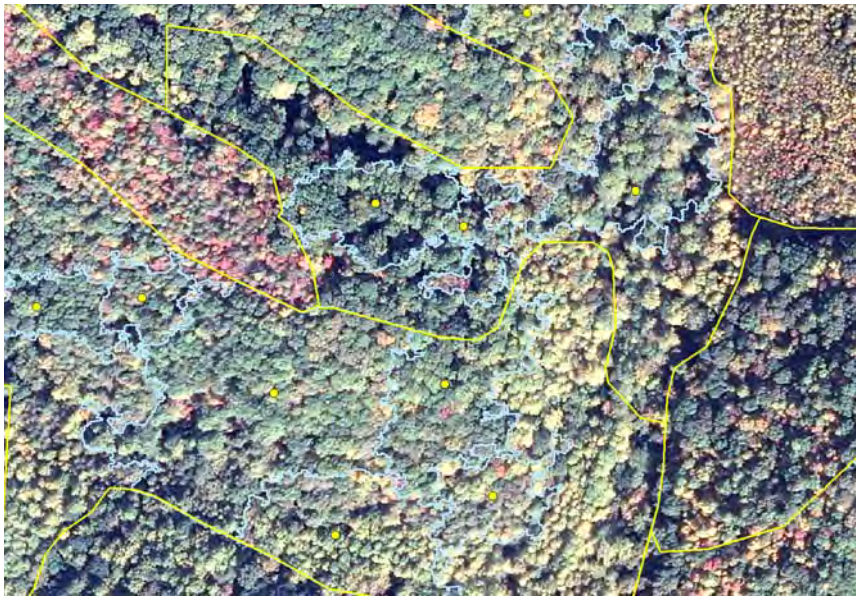
The specifications for the imagery were

1) 2 ft ground resolution
2) Total area 155,700 acres over 8 forests in Ohio
3) Collected between October 25th and October 30th 2008
4) Tiling system based on Ohio DOQQs
5) 4 band digital DMC imagery 12 bit delivery as stacked imagery as uncompressed tiffs, delivered in 16 bit file format.
6) Imagery also processed into 4 band MrSid compressed format 8 bit using same tiling system
7) Digital surface model indicating vegetation height and a digital elevation model indicating bare earth was delivered
8) Orthorectificed mosaics for each forest color balanced with tiling scheme determined with DNR
9) Spatial accuracy of dataset 1":400' scale or RMSE ±13.3'
10) Projection System Ohio State Plane South Zone, NAD 83, US survey feet.
11) DSM was generated to formulate a dense set of mass points with X, Y and Z coordinates with 20 foot spacing. This technique produced over 100 vertical surface measurements per acre. This digital surface model consisted of terrain (bare earth) and non-terrain (tree canopy) features. Sanborn used LiDAR "like" filtering and editing techniques to produce a bald earth, digital elevation model. The DEM was the source to rectify the orthophoto imagery. The tree canopy heights were classified and used to produce a forest height surface that was used for stand delineation and canopy height classes. Both datasets were provided in a raster digital format.

An example of how the DSM was created is shown in the image below



An example of the imagery is shown below with stand boundaries (yellow), segment boundaries (blue) and plot locations (yellow dots).



An example of the imagery draped over the digital surface model (DSM) is shown below.

These datasets were delivered in January 2009 and used for the project for stand delineation, segmentation, navigation, stratification and stand parameterization.

Stand Delineation and Stratification

The LMS team created the stand layer using heads up digitizing over the new leaf on imagery. This work was done using stereo soft copy workstations and 3-D representations of the landscape using the imagery and DSM as well as working in 2-D as appropriate. In addition, slope and aspect data was also used in assisting with the determination of proper stratification. This work resulted in the creation of a provisional stand layer that was reviewed and field verified through a number of back-and-forth iterations. Based upon the feedback from these field verifications (121 independent field verifications in all), adjustments were made both to spatial and labeling attributes. This feedback was crucial in ensuring the stands and stratification calls were as complete and accurate as possible. In all, 6,027 forested stands, with an average stand size of 25.4 acres were created over 55 strata, which resulted in an average forested strata size of 2,780 acres.

Segmentation and Labeling

Please see Task 7: Stand Parameterization for an explanation of how segmentation and labeling was performed for this project.

Task 4: Design of Sampling System

Draft Stratified Inventory Design

Stratification and Sample Size

It was determined that there are 5 broad species types and 4 size classes and up to 4 density classes. Therefore, a total of (5x4x4=80) 80 combinations were possible at the beginning. However, as with all inventories, the final number inevitably ends up being less than the highest possible number after the mapping effort has been completed. The final number of forested strata on Ohio DOF lands came to 55, but there are 59 in total. This resulted in DOF managers having the ability to reassign plots within the budgeted amount to increase the accuracies of selected strata via the sample matrix. This was accomplished in close consultation with the managers. Furthermore, the 4 size classes were later used in conjunction with height classes derived through the Digital Canopy Model provided by the stereo image flight. These classes include: <30', 30-65', 65-100' and >100' and included in Appendix D.

The sample matrix, the final in Appendix H, shows an example of how the plots were distributed. A total of 2,209 plots were installed.

Specific confidence levels as well as limits of error were determined for each stratum depending upon the priorities of forest managers. This was done via a spreadsheet that calculates the required number of samples for each stratum as well as the totals. This gave an interactive way to control both the numbers of plots and in which stratum they were concentrated in given a certain level of desired accuracy. Coefficients of variation were estimated ahead of time for each stratum. However, since the CV's were not known well for these forest types, a two-staged approach was implemented whereby a small number of plots were installed per stratum, focusing on those in Zone III, to derive more accurate CV's for the ownership. This resulted in a more efficient allocation of plots with much more reliability in variance estimations. In addition, these plots served to aid in the production of the stratification of the forest lands as an additional field checking mechanism.

Initial data collection

The initial field campaign lasted around a week and sampled approximately 250 inventory plots across the forests and cover types. The purpose of this field campaign was twofold;

1) The collection of inventory data allowed the creation of draft statistics that supported the inventory design, including allocation of plots to strata.
2) These plots also supported the rest of the stand delineation and stratification effort in providing additional field-based feedback in addition to the field verification visits. This served to further the accuracy and completeness of the mapping deliverable.

This data collection effort occurred in February of 2009, shortly after the on-site scoping meeting.

Final Stratified Inventory Design

Revision of stratified inventory design based on initial field work

Based upon the field data collected during initial data collection and more discussions with the Ohio DOF staff, the stratified inventory design was revised as necessary. This yielded in actual field-observed estimates of the variability represented by coefficients of variation for each strata. By this time, it was also known how many strata were actually present over the state forests. There ended up being 59 strata in all, with 55 of them being forested. Once the actual number and makeup of strata as well as the measured variability of the most important strata were known, the stratification matrix was revised to reflect these conditions and to meet the stated budget for the project. The LandMark Systems team worked closely with Ohio DOF in finalizing the stratified inventory design.

Task 5: Sampling

Sampling Units

For the forest inventory data collection, sample units were related to stand development stage (Pre-commercial, Pole, Sawtimber and Large Sawtimber), and was applied across all state forests, forest type groups (five) and four density categories. These units were stand polygons according to the stratification. Note that all data were presented as stand summaries, although the unit of analysis for the stand parameterization process was the segment. Because of this segmentation approach, each segment within each stand served as the centerpoint for field plot allocation. This was so that each segment could be assigned actual plot data for the stand parameterization process.

General Plot Sampling Philosophy

The purpose of this forest inventory design had three primary goals:

1) To support the stand delineation and accurate attribution at the stratum level, of the stand polygon file.

2) To provide useful forest management planning information for use in the Ohio DNR's integrated forest management system.
3) To accurately capture tree level data and stand attributes in a format that permit growth and yield modeling using the USDA Forest Vegetation Simulator (FVS) software.

As always in forest inventory design – cost is the overriding constraint. Therefore, this approach allowed the LandMark Team to work collaboratively with DOF to meet their objectives while staying within the budget.

All field work was conducted using the most advanced forestry software and hardware to ensure data integrity and work flow efficiency. Cruise data was collected and processed using the patented Real-Time Inventory (RTI) forestry software system, and a custom designed template specifically for use on this project. All field personnel utilized GPS and GIS to locate pre-plotted sample locations, and recorded the location of any required deviation from the sampling scheme.

Stratum Assignments

The strata are based upon the broad types (planted pine, oak/pine, oak/hickory, cove hardwood and mixed mesophytic), size classes (pre-commercial, pole, sawtimber and large sawtimber), which were also supported by 4 height classes (<30', 30-65', 65-100' and >100'), and four density classes (canopy coverage of 0-25%, 25-50%, 50-75%, 75-100%). The mapping and stratification was mostly completed (only final editing was done during and after the field inventory) before any plots were allocated. There is a total of 59 strata identified with 55 of them being forested covering a total of 152,883 acres. The average acres for each forested strata comes to 2,780 acres.

Development of Strata-Level Polygon Coverage

Once stratum assignments were made for each forested stand polygon, a new coverage was created based on type and stratum. These new polygons were the basis upon which sample locations are chosen. There is a total of 59 strata identified with 55 of them being forested covering a total of 152,883 acres.

Sample Allocation Method

The sample locations were generated using a two-stage, probability proportional to size method. This method has proven to be the most efficient and effective way to perform a stratum-level inventory. The first phase consisted of selecting stands in each stratum with a probability in direct proportion to its size. The second stage

consisted of assigning the selected stands for sampling. There were approximately 153,000 acres to be inventoried. Average mapped forest stand size is approximately 25.4 acres.

The located sample points, placed in the center of each forested segment (sub-stand portions of forest that were deemed homogenous through image processing), were saved as a waypoint along with the condition polygon shapes and transferred to the field data collection devices using LandMark Systems' patented Real-Time Inventory system.

Field Data Collection

Please refer to Appendix C - Plot Specifications and Procedures for specific details regarding field data collection. A total of 2,209 plots were installed in the spring of 2009, including 250 plots that were part of the initial inventory in late 2008.

Task 6: Analysis of Data

A complete set of summary reports for the forest as well as strata are supplied as a deliverable for this project. These include all of the volumetric tree data, both raw and calculated, as well as metadata. In addition, a statistical analysis is provided on a stratum basis to correlate the predicted number of plots/coefficients of variation with the actual numbers found. This also includes confidence level, standard errors and standard deviations.

In addition to the above statistics, a complete audit summary report (please see Appendix K for the audit report details) is supplied comparing the auditor's measurements with those of the cruiser's. This report shows that all cruisers' data were within acceptable ranges.

Site indexes have also been assigned from the existing SSURGO soils data, utilizing tree heights and soil properties. This information is useful in integrating the data into the FVS program for growth and yield purposes.

Since the parameterized results are statistically sound (approximately 3-4% higher than the plot strata-based) and it produced both trees/acre and basal area/acre by strata, the plot & strata-based results, which yielded the same attributes as well as volumes (tons and board feet), VBAR's (Volume-basal area-ratios) were able to be computed for each strata. These VBAR's were then applied to the parameterized results to yield final volume estimates by strata. From there, volumes by stand and forest were also created.

The likely reason the parameterized results are higher than the plot-based results are based on a principal of sampling that cannot be measured – coverage error. Coverage error is simply the error that occurs with sampling when the samples do not cover all of the possible areas that EQUALLY represent the whole population. The stand parameterization is an attempt to reduce that coverage error since attributes are used over the whole forest.

The analysis of data is an interactive process between LandMark, Sanborn, FRS and the Ohio DOF. Additional analysis could be done with the data either internally by the DOF or in cooperation with either LandMark or another contractor.

Task 7: Stand Parameterization

The process of stand parameterization began with the high-resolution imagery collected over the forests of interest in October 2008. The imagery was mosaicked into files representing each forest, and image derivatives were made from the raw imagery. These included:

1. Normalized Difference Vegetation Index (NDVI)
2. Ratio Bands – i.e. Band 3/Band 1

In addition to the high-resolution imagery, information regarding vegetation height was included in the process. These were derived from the aerotriangulation process used to orthorectify the imagery. That process resulted in points representing the tops of the tree canopy at approximately 50 foot intervals. These points contained elevation information as well as location information. To create a Digital Canopy Model (DCM), a portion of the National Elevation Dataset (NED) was subtracted from the tree canopy elevation data, resulting in the DCM.

Ecological differences in the forests of interest are driven to a high degree by aspect, so data relating to aspect was included in the segmentation process. Derivatives relating to image texture were also included. These data were input into the segmentation software, Definiens Professional, along with the analyst-derived stand boundaries. These boundaries were maintained throughout the process, and each stand was segmented into 5-25 sub stands, or segments, depending upon the degree of heterogeneity in the stand. These segments were all given unique identifiers that related them to their parent stand.

Figure 2: Multispectral Aerial Imagery with stand boundaries (yellow), Segment boundaries (blue) and sample plots yellow points

Once complete, segments were given attributes of the stand strata: mean height, average canopy closure, and broad type, resulting in a 4-character identifier for each segment, i.e. OH3A. Each stand retained its stratum as well, and it was possible for a segment to have a different stratum than its parent stand. In this manner, heterogeneity of the stand would be accounted for in the process. Segments were used to summarize independent variables of interest derived from the height, high resolution imagery and Landsat datasets. See list below:

1. High-resolution imagery (4 bands)
2. High-resolution imagery ratios (3 bands)
3. NDVI
4. Image texture (2 bands)
5. Aspect
6. Mean Canopy Height
7. Maximum Canopy Height
8. Standard deviation of canopy height
9. Proportion of canopy height > 30 feet
10. 7 dates of Landsat 5 data (Tasseled Cap derivatives):

a. 17 April 2007
b. 12 Oct 2008
c. 06 July 2007
d. 23 August 2007
e. 24 Sept 2007
f. 06 June 2008
g. 10 Sept 2008

These data were compiled into a single database of independent variables. The dependent variables for the regression analyses were the plot data collected by LandMark Systems in the spring of 2009. Plot locations were overlaid on the segments, and variables values for segments for which plot (ground) data existed were used to build regression models. Out of 175,000 segments covering the 8 forests, 2,209 segments contained plot data, and were the training data for the regressions models.

Plot data were summarized at two levels:

Level 1: Broad Forest Categories

1. Conifer
2. Broadleaf

Level 3: Species and Species Group Categories

1. Basswood
2. Beech
3. Black Cherry
4. Black Oak
5. Chestnut Oak
6. Hemlock
7. Hickory
8. Northern Red Oak
9. Other Hardwood
10. Other Lowland Hardwoods
11. Other Pine
12. Other Softwood
13. Red Maple
14. Sugar Maple

15. Sweetgum
16. Sycamore
17. White Oak
18. White Pine
19. Yellow Poplar

In addition each species or species group had 3 size classes:

1. Poles 5- 11.5” dbh
2. Sawtimber 11.6-17.5” dbh
3. Large Sawtimber 17.6” + dbh

This stratification of the target classes resulted in 6 predicted variables at level 1 (2 x 3), and 57 at level 3 (19 x 3).

Predicted parameters of interest were:

1. Basal Area per acre (BA)
2. Per-Area Conversion Factor (PACF)
3. Quadratic Mean Diameter (QMD) – this would be derived from BA and PACF

The plot measured variables, and their associated independent variables, were analyzed for each forest stratum separately. The plot measured variables were regressed using regression tree analysis against the independent variables listed above. Out of 80 possible strata (Broad type x Height class x Canopy Closure class), 47 were found to have sufficient ground plots to conduct an analysis, accounting for 99.4% of the land area. For each parameter of interest at level 3 there were 2,679 regression models created, and at level 1, 282 regression models were created.

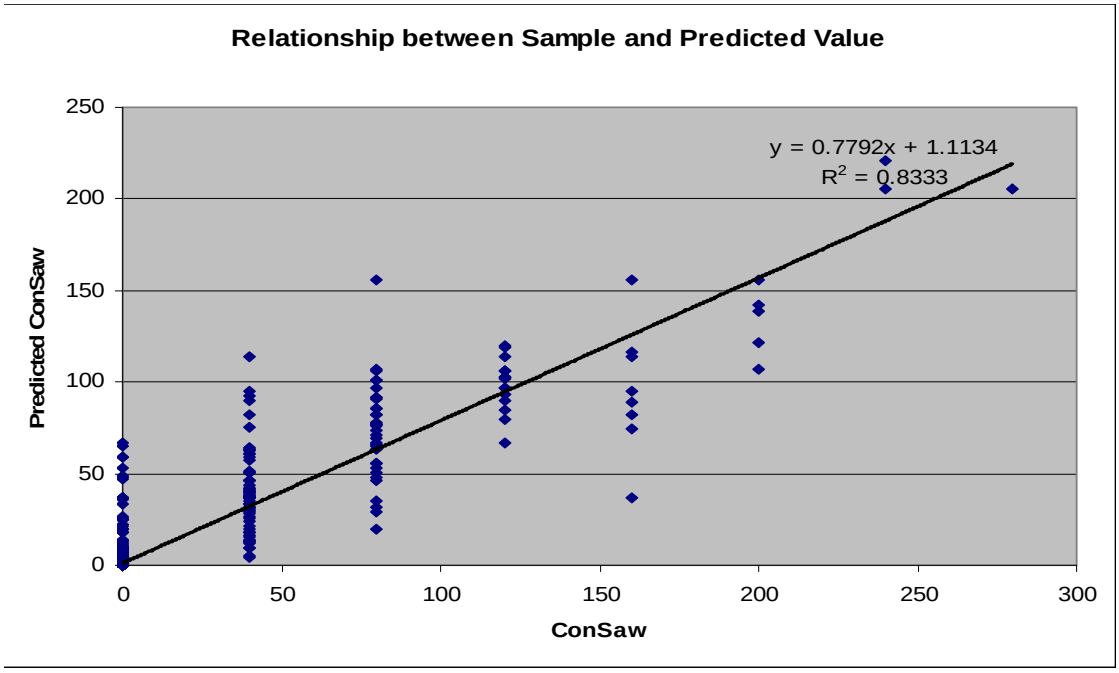


Figure 3: An example of the relationship between predicted and measured conifer saw log basal area for Ohio State Forests

Once the models were developed, the relationships were run for unsampled segments. This process produced a predicted parameter value for each segment across the 8 forests. These values were assembled into a database format and joined to their respective spatial representation that provides the area of each segment (Figure 4).

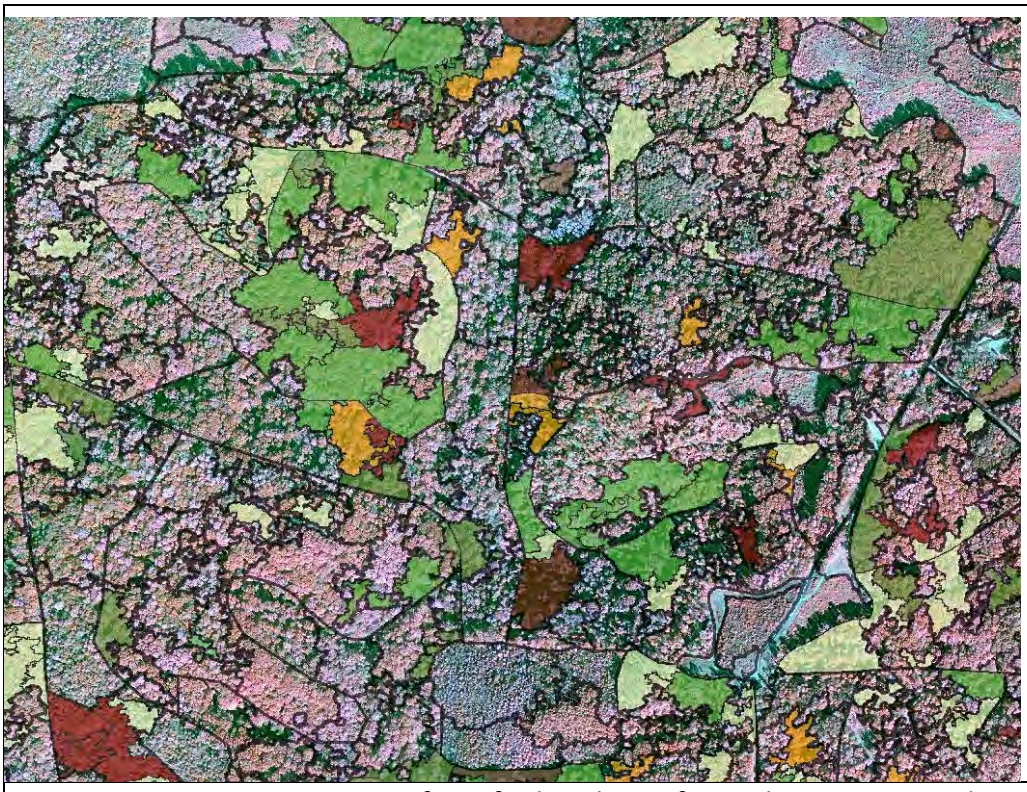


Figure 4: Estimate of conifer basal area for each segment overlain on the aerial imagery

This information enabled the results to be summarized to a stand level using an area-weighted average method for each stand. The output of the process was a single value for each parameter of interest for each stand.

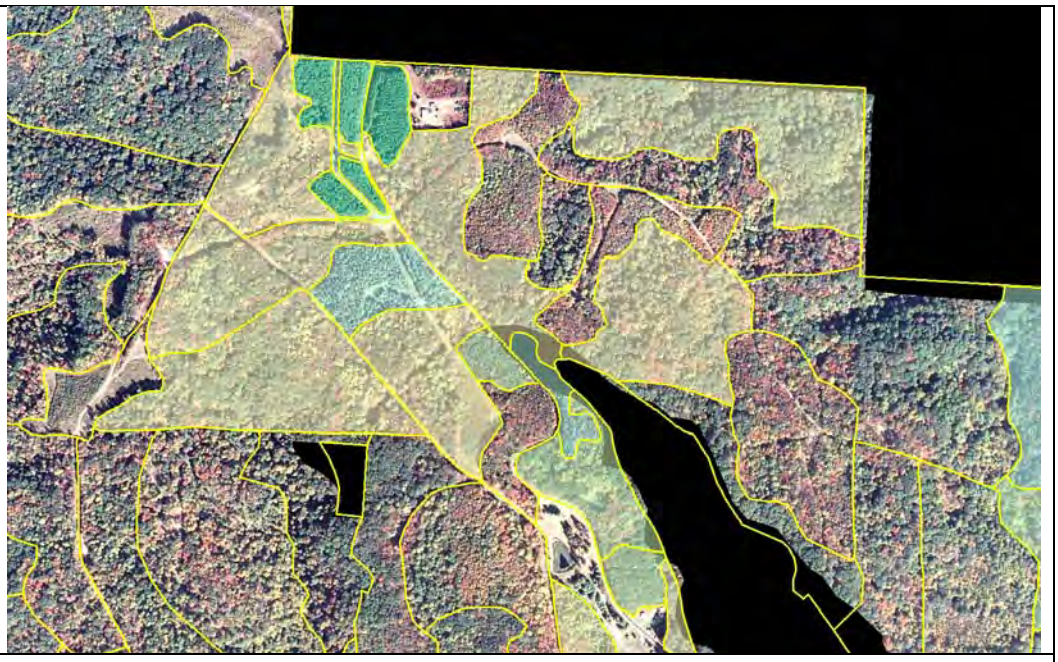


Figure 5: Stand conifer basal area for unsampled stands

This process was run for all desired variables for all stands across the forest providing estimates of the forest variables for unsampled stands.

Task 8: Reporting

In addition to the geodatabase supplied with the deliverables, there are a number of strata and stand reports in Appendix B and even more that can be found with the deliverables.

IV. Schedule of Work

Given the need for new imagery and the complexities of incorporating the new process of stand parameterization as well as the size and scope of the project combined to require the project taking just over one year to complete. The schedule below outlines each task along with start/finish dates, what was required to be completed before (predecessors) and the resources assigned to each.

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
1	**Tasks 1 and 2: Project Management**	**195 days**	**Tue 9/2/08**	**Mon 6/1/09**		
2	Develop Draft Work Plan	10 days	Tue 9/2/08	Mon 9/15/08		
3	Deliver Draft Work Plan	0 days	Mon 9/15/08	Mon 9/15/08	2	
4	Onsite Meeting	2 days	Wed 9/17/08	Thu 9/18/08		
5	Develop Final Workplan	10 days	Fri 9/19/08	Thu 10/2/08	4	
6	Deliver Final Work Plan	0 days	Thu 10/2/08	Thu 10/2/08	5	
7	Detail data flow within project	1 day	Wed 10/1/08	Wed 10/1/08		
8	**Progress Reports**	**174 days**	**Wed 10/1/08**	**Mon 6/1/09**		
18						
19						
20	**Task 3 and 4: Mapping and Design of Sampling System**	**152 days**	**Tue 9/2/08**	**Wed 4/1/09**		
21	**Task 4 Step 1: Draft Inventory Design**	**94 days**	**Tue 9/2/08**	**Fri 1/9/09**		
22	Develop Stratification Schema	10 days	Fri 9/19/08	Thu 10/2/08	4	LandMark
23	Draft Stratified Inventory Design	94 days	Tue 9/2/08	Fri 1/9/09		LandMark & FRS
24	Sampling Procedures Document	10 days	Mon 9/22/08	Fri 10/3/08		LandMark & FRS
25	Deliver Draft Stratified Inventory Design	0 days	Fri 1/9/09	Fri 1/9/09	23	LandMark
26	**Task 3 Step 1: Image Acquisition and Stratification**	**94 days**	**Mon 10/13/08**	**Thu 2/19/09**		
27	Image Aquisiton & Initial Processing	74 days	Mon 10/13/08	Thu 1/22/09		Sanborn
28	Image Delivery to LandMark	0 days	Thu 1/22/09	Thu 1/22/09	27	Sanborn
29	Remote Sensing Training Fieldwork	5 days	Mon 10/20/08	Fri 10/24/08	4FS+20 days	Sanborn
30	**Create Draft Stratification Layers**	**20 days**	**Fri 1/23/09**	**Thu 2/19/09**		
31	Sanborn Acquire Imagery From its vendor	5 days	Fri 1/23/09	Thu 1/29/09	27	Sanborn
32	Gather and QC Other Data (slope, aspect, soils, events)	10 days	Fri 1/30/09	Thu 2/12/09	31	Sanborn
33	Preprocess Imagery	5 days	Fri 1/30/09	Thu 2/5/09	31,27	Sanborn
34	Create Draft Layers (height, canopy closure, species)	10 days	Fri 2/6/09	Thu 2/19/09	33,29	LandMark
35	Identify and digitize initial sample locations	7 days	Fri 1/23/09	Mon 2/2/09	28	LandMark
36	Allocate Initial Samples (use imagery, slope, aspect, soils, veg	7 days	Tue 2/3/09	Wed 2/11/09	35	LandMark
37	**Task 4 Step 2: Final Inventory Design**	**30 days**	**Wed 2/18/09**	**Tue 3/31/09**		
38	Initial Field Inventory Data Collection	5 days	Wed 2/18/09	Tue 2/24/09	36FS+4 days	LandMark & FRS
39	Analysis of Field Data	5 days	Wed 2/25/09	Tue 3/3/09	38	LandMark
40	Stand Parameterization	10 days	Wed 3/4/09	Tue 3/17/09	39	Sanborn
41	Draft Inventory Design	5 days	Wed 3/18/09	Tue 3/24/09	40	LandMark & FRS
42	Final Stratified Inventory Design	5 days	Wed 3/25/09	Tue 3/31/09	41	LandMark
43	Deliver Final Stratified Inventory Design	0 days	Tue 3/31/09	Tue 3/31/09	42	LandMark
44	**Task 3 Step 1: Finalize Stratification Layers**	**15 days**	**Wed 3/4/09**	**Tue 3/24/09**		
45	QC of Layers Against Field Data	5 days	Wed 3/4/09	Tue 3/10/09	39	Sanborn
46	Rerun Models and Produce Final Data Layers	10 days	Wed 3/11/09	Tue 3/24/09	45	Sanborn
47	**Task 3 Steps 2 and 3: Stand Delineation and Segmentation**	**44 days**	**Fri 1/30/09**	**Wed 4/1/09**		
48	Manually Create Stand Polygons	30 days	Fri 1/30/09	Thu 3/12/09	31,5,27	LandMark
49	Deliver Draft Stand Boundaries	0 days	Fri 3/20/09	Fri 3/20/09	48	LandMark
50	Segmentation within Polygons	5 days	Mon 3/23/09	Fri 3/27/09	49	Sanborn
51	Final Stand Delineation with Strata Label and Segments	3 days	Mon 3/30/09	Wed 4/1/09	46,50	LandMark
52	Deliver Final Stand Boundaries	0 days	Wed 4/1/09	Wed 4/1/09	51	LandMark
53						
54	**Task 5: Sampling**	**30 days**	**Thu 4/2/09**	**Wed 5/13/09**		
55	Organize and Train Cruisers	2 days	Thu 4/2/09	Fri 4/3/09	51	LandMark & FRS
56	Collect Field Data	18 days	Mon 4/6/09	Wed 4/29/09	55	FRS
57	Audit	18 days	Mon 4/6/09	Wed 4/29/09	55	LandMark
58	Complete Inventory	10 days	Thu 4/30/09	Wed 5/13/09	57	LandMark & FRS
59	Deliver Inventory Database	0 days	Wed 5/13/09	Wed 5/13/09	58	LandMark & FRS
60						
61	**Task 6: Analysis of Data**	**30 days**	**Thu 5/14/09**	**Wed 6/24/09**		
62	Analyze Data Products	5 days	Thu 5/14/09	Wed 5/20/09	59	LandMark
63	Draft Stratified Inventory Report	10 days	Thu 5/21/09	Wed 6/3/09	62	LandMark
64	Review of Report by Ohio DNR	10 days	Thu 6/4/09	Wed 6/17/09	63	Client
65	Finalize Report	5 days	Thu 6/18/09	Wed 6/24/09	64	LandMark
66	Deliver Statistical Analysis	0 days	Wed 6/24/09	Wed 6/24/09	65	LandMark
67	Delivery of data for import into Genus	0 days	Wed 6/24/09	Wed 6/24/09	66	LandMark
68						

ID	Task Name	Duration	Start	Finish	Predecessors	Resource Names
69	**Task 7: Stand Parameterization**	**50 days**	**Thu 5/14/09**	**Wed 7/22/09**		
70	Develop Models	20 days	Thu 5/14/09	Wed 6/10/09	58	Sanborn
71	Test Models	10 days	Thu 6/11/09	Wed 6/24/09	70	Sanborn
72	Evaluate Outliers	10 days	Thu 6/25/09	Wed 7/8/09	71	Sanborn
73	Rerun Models	10 days	Thu 7/9/09	Wed 7/22/09	72	Sanborn
74	Deliver Stand Database	0 days	Wed 7/22/09	Wed 7/22/09	73	Sanborn
75	Delivery of data for Import into Genus	0 days	Wed 7/22/09	Wed 7/22/09	74	
76						
77	**Task 8: Reporting**	**49 days**	**Thu 7/23/09**	**Wed 9/30/09**		
78	Revision of models	5 days	Thu 7/23/09	Wed 7/29/09	75	
79	Finalize Stand Database	5 days	Thu 7/30/09	Wed 8/5/09	78	
80	Ohio Review	10 days	Thu 8/6/09	Wed 8/19/09	79	
81	Revisions	8 days	Thu 8/20/09	Mon 8/31/09	80	
82	On-Site Wrapup Meeting	2 days	Tue 9/1/09	Wed 9/2/09	81	
83	Delivery of all final reports	0 days	Wed 9/2/09	Wed 9/2/09	82	
84						
85	Sign off	0 days	Wed 9/30/09	Wed 9/30/09		

V. Analysis and Summary of Results

The results of the stratified inventory were used to calculate a VBAR (volume-basal area-ratio = volume/basal area) for each species group and product class. This VBAR was then multiplied by the basal area from the parameterized results for each stand in order to derive final parameterized volumes for each stand.

As stated before, here are the final overall volumes per acre, which indicate a mature forest with well-stocked stands of large trees:

		Per Acre				
Forest	**Acres**	**PWtons**	**SawTbrBdFt**	**LgSawTbrBdFt**	**TotalSawTbrBdFt**	**TotTons**
Brush Creek	13,348	23.1	3,979	7,032	10,959	78.0
Hocking	9,226	25.8	5,795	8,290	14,125	96.2
Pike	11,861	21.4	4,329	8,178	12,409	83.1
Richland Furnace	2,430	17.6	4,867	6,913	11,837	77.0
Scioto Trail	9,447	20.3	4,459	6,777	11,339	76.7
Shawnee	63,200	22.5	3,881	6,055	9,944	72.7
Tar Hallow	15,961	17.9	4,672	8,492	13,115	83.4
Zaleski	27,352	21.5	4,403	7,258	11,676	80.1
Total	**152,824**	**21.8**	**4,267**	**6,968**	**11,234**	**78.1**

PWtons=Pulpwood green tons; SawTbrBdFt= Small Sawtimber Board Feet; LgSawTbrBdFt=Medium and Large Sawtimber Board Feet; TotTons=Total green tons; TotalSawTbrBdFt=Total Sawtimber Board Feet. Log rule: International 1/4". All speecies included.

* Excludes stand acres where stratum = DV, ROW, CL, or WA

It is important to note that Large Sawtimber (LgSawTbrBdFt) includes both medium and large sawtimber tree categories from the inventory. The parameterization process could not provide reliable numbers when these categories are separated.

The 8 forests appear to be relatively evenly stocked for the most part, with Shawnee the lowest at 72.7 tons/acre and Hocking the highest a 96.2 tons/acre. This results in a range of 23.5 tons/acre and an average stocking of 78.1 tons/acre. The tons/acre figures include both pulpwood and sawtimber products while the board feet, calculated in International ¼", are just for sawtimber products only. These averages also include only commercially viable species. There are a number of other species, as well as submerch-sized trees, that were included in the inventory and data deliverables that are not included in the volume summaries.

As noted in the executive summary, the results show that the parameterized values, when compared to stratified estimates, are about 3.5% higher in basal area (117 vs. 113), 2.8% higher for total tons (78.1 vs. 75.9) and 10.3% higher for sawlog board feet (11,234 vs. 10,188). Since these variances are well within the limits of error (just barely outside the error limits for board feet, but well within the limits of the distribution), they are considered reasonable within the statistical bounds of +/- 10% and even lower.

LandMark Systems and Sanborn are making plans to follow up with Ohio DOF in the coming months in order to provide additional analysis on the accuracy and usefulness of the parameterized stand volumes. Based upon what we have seen thus far in preliminary analyses, this inventory should provide the DOF with a more useful set of data over a traditional strata-based inventory. While it is not a stand-based inventory, it is one that should offer better and more practical data when performing stand analyses, growth and yield modeling, as well as harvest planning.

VI. Appendices - Reports and Deliverables Documentation

Appendix A – List of Deliverables

Geodatabase

1. Stand feature class- 'Stands'
2. Inventory tables – constructed from field inventory plots
    - Stand summary – 'StandSummary'
    - Strata_Summary
    - Plot summary – 'PlotTreeTally'
    - T-Cruise Tree table – 'Tree'
    - T-Cruise Plot table- 'Plot'
    - Summary of tree tally species – 'PlotTreeTally'
    - Site index by Soil – 'SibySoils'
    - Stand age – 'StandAge_SI'
    - Species group and DBH summary – 'StrataGroupDBH_Summary'
    - Volume summary by stand – 'StandSummary'
3. Parameterization inventory tables
    - QMD_byStandSpp
    - BA_byStandSpp
    - TPA_byStandSpp
    - Volume_byStandSpp
4. Plots feature class – 'CruisePlots'
5. Elevation Contours
6. Metadata on stands and plots
7. Soils
8. Photo Grid
9. Forest boundaries
10. Ownership boundary

Other Data

1. TCruise files(tcd's), templates
2. Landmark export Access database of raw inventory data – 'Ohio_TcruiseExport.mdb'
3. FVS tables

Reports

1. Project Report - Ohio DOF_Final Report.doc
2. Stand inventory reports – pdf stand level report.

Documentation (as part of report and as documents)

1. Field procedure document
2. Stratification and sample documents
3. LandMark Export DB Table Definitions
4. TCruise Species List and Groups
5. SI Index Curve Documentation

Appendix B – Strata and Forest Level Volumes

Forest Volumes From Parameterization By Forest

		Total				
Forest	Acres*	PWtons	SawTbrBdFt	LgSawTbrBdFt	TotalSawTbrBdFt	TotTons
Brush Creek	13,348	308,780	53,109,249	93,857,164	146,279,794	1,041,189
Hocking	9,226	237,642	53,467,546	76,489,944	130,317,737	887,410
Pike	11,861	254,269	51,347,653	96,998,264	147,183,603	985,475
Richland Furnace	2,430	42,779	11,826,383	16,798,688	28,762,834	187,078
Scioto Trail	9,447	192,146	42,125,431	64,020,046	107,120,887	724,458
Shawnee	63,200	1,425,042	245,276,003	382,645,963	628,456,616	4,595,339
Tar Hallow	15,961	286,414	74,569,091	135,530,284	209,315,204	1,331,805
Zaleski	27,352	589,412	120,431,964	198,515,836	319,366,663	2,190,122
Total	**152,824**	**3,336,483**	**652,153,318**	**1,064,856,188**	**1,716,803,339**	**11,942,877**

		Per Acre				
Forest	Acres	PWtons	SawTbrBdFt	LgSawTbrBdFt	TotalSawTbrBdFt	TotTons
Brush Creek	13,348	23.1	3,979	7,032	10,959	78.0
Hocking	9,226	25.8	5,795	8,290	14,125	96.2
Pike	11,861	21.4	4,329	8,178	12,409	83.1
Richland Furnace	2,430	17.6	4,867	6,913	11,837	77.0
Scioto Trail	9,447	20.3	4,459	6,777	11,339	76.7
Shawnee	63,200	22.5	3,881	6,055	9,944	72.7
Tar Hallow	15,961	17.9	4,672	8,492	13,115	83.4
Zaleski	27,352	21.5	4,403	7,258	11,676	80.1
Total	**152,824**	**21.8**	**4,267**	**6,968**	**11,234**	**78.1**

PWtons=Pulpwood green tons; SawTbrBdFt= Small Sawtimber Board Feet; LgSawTbrBdFt=Medium and Large Sawtimber Board Feet; TotTons=Total green tons; TotalSawTbrBdFt=Total Sawtimber Board Feet. Log rule: International 1/4". All speecies included.

* Excludes stand acres where stratum = DV, ROW, CL, or WA

Forest Volumes From Parameterization By Strata

		Total				
Stratum	Acres	PWtons	SawTbrBdFt	LgSawTbrBdFt	TotSaw	TotTons
CH1B	20	0	0	0	0	0
CH1D	50	1,743	0	0	0	2,081
CH2A	695	19,305	2,043,359	2,776,495	4,562,353	43,145
CH2B	678	18,188	3,028,871	3,053,236	6,034,541	47,905
CH2D	53	1,901	27,584	0	62,167	2,202
CH3A	1,370	31,530	5,387,462	10,468,553	16,060,084	110,701
CH3B	537	12,354	3,141,403	4,552,720	7,850,282	51,200
CH4A	235	4,336	964,290	3,811,206	4,696,533	27,396
MX1A	295	0	0	0	0	0
MX1B	59	0	0	0	0	0
MX1C	29	0	0	0	0	0
MX1D	69	0	0	0	0	0
MX2A	3,016	66,313	9,787,495	10,887,012	19,616,552	166,680
MX2B	2,485	65,388	7,353,576	15,019,522	22,788,863	179,045
MX2C	92	2,812	0	0	0	3,934
MX2D	107	4,174	0	0	0	5,578
MX3A	13,016	270,254	53,530,490	106,781,298	158,886,733	1,055,932
MX3B	7,842	159,594	25,819,754	69,471,819	97,235,049	629,023
MX3C	51	975	118,985	500,635	661,747	4,160
MX4A	2,102	36,294	8,736,287	25,875,443	33,929,158	200,787
MX4B	270	8,948	536,665	2,586,948	2,925,226	23,336
NF1A	21	0	0	0	0	0
NF1D	9	0	0	0	0	0
NF2A	28	0	0	0	0	0
NF2B	21	0	0	0	0	0
NF2D	33	0	0	0	0	0
OH1A	444	10,336	0	0	0	25,011
OH1B	173	0	0	0	0	0
OH1C	15	0	0	0	0	0
OH1D	119	0	0	0	0	0
OH2A	23,797	573,227	88,776,953	99,875,483	184,456,194	1,528,593
OH2B	2,772	63,733	10,804,911	15,296,218	26,545,469	198,209
OH2C	74	2,650	185,065	322,585	509,754	5,332
OH2D	45	1,876	0	0	0	2,258
OH3A	73,001	1,530,135	324,877,767	526,825,520	854,327,068	5,802,092
OH3B	9,577	184,195	38,317,968	76,806,483	116,058,259	752,612
OH3C	20	481	113,576	167,945	277,274	1,895
OH4A	4,992	79,576	23,187,322	45,890,159	69,111,787	439,396
OH4B	434	9,047	1,711,337	4,950,949	6,717,760	41,597
OP1A	9	0	0	0	0	0
OP1B	10	0	0	0	0	0
OP2A	152	6,273	831,523	588,162	1,402,782	14,795
OP2B	63	1,547	282,549	120,893	435,257	3,648
OP2C	5	128	34,218	30,205	76,917	472
OP3A	630	21,911	5,174,662	3,848,531	9,161,008	66,840
OP3B	145	3,755	945,965	0	2,228,631	14,271
PP1A	34	0	0	0	0	0
PP1B	14	0	0	0	0	0
PP2A	385	15,606	2,632,447	0	3,653,117	35,453
PP2B	186	10,897	1,747,928	492,129	2,212,470	23,839
PP2C	3	182	37,818	8,070	45,462	455
PP3A	1,454	66,435	16,615,021	17,692,948	32,217,926	229,622
PP3B	866	37,447	13,418,273	12,286,308	25,135,651	159,311
PP3C	11	733	28,147	31,105	57,273	993
PP4A	167	6,733	1,635,934	3,171,817	5,913,115	35,196
PP4B	40	5,470	317,713	665,794	950,873	7,880
Total	**152,824**	**3,336,483**	**652,153,318**	**1,064,856,188**	**1,716,803,339**	**11,942,877**

Forest Volumes From Parameterization By Strata						
		Per Acre				
Stratum	Acres	PWtons	SawTbrBdFt	LgSawTbrBdFt	TotSaw	TotTons
CH1B	20	0.0	0	0	0	0.0
CH1D	50	35.2	0	0	0	42.0
CH2A	695	27.8	2,939	3,994	6,563	62.1
CH2B	678	26.8	4,465	4,501	8,896	70.6
CH2D	53	36.0	522	0	1,177	41.7
CH3A	1,370	23.0	3,932	7,640	11,721	80.8
CH3B	537	23.0	5,852	8,481	14,623	95.4
CH4A	235	18.5	4,111	16,248	20,023	116.8
MX1A	295	0.0	0	0	0	0.0
MX1B	59	0.0	0	0	0	0.0
MX1C	29	0.0	0	0	0	0.0
MX1D	69	0.0	0	0	0	0.0
MX2A	3,016	22.0	3,245	3,609	6,504	55.3
MX2B	2,485	26.3	2,959	6,045	9,171	72.1
MX2C	92	30.7	0	0	0	42.9
MX2D	107	38.9	0	0	0	52.0
MX3A	13,016	20.8	4,113	8,204	12,207	81.1
MX3B	7,842	20.4	3,292	8,859	12,399	80.2
MX3C	51	19.0	2,317	9,750	12,888	81.0
MX4A	2,102	17.3	4,156	12,310	16,142	95.5
MX4B	270	33.2	1,990	9,592	10,846	86.5
NF1A	21	0.0	0	0	0	0.0
NF1D	9	0.0	0	0	0	0.0
NF2A	28	0.0	0	0	0	0.0
NF2B	21	0.0	0	0	0	0.0
NF2D	33	0.0	0	0	0	0.0
OH1A	444	23.3	0	0	0	56.4
OH1B	173	0.0	0	0	0	0.0
OH1C	15	0.0	0	0	0	0.0
OH1D	119	0.0	0	0	0	0.0
OH2A	23,797	24.1	3,731	4,197	7,751	64.2
OH2B	2,772	23.0	3,897	5,517	9,575	71.5
OH2C	74	35.9	2,508	4,371	6,907	72.2
OH2D	45	41.4	0	0	0	49.8
OH3A	73,001	21.0	4,450	7,217	11,703	79.5
OH3B	9,577	19.2	4,001	8,020	12,118	78.6
OH3C	20	24.3	5,752	8,505	14,042	96.0
OH4A	4,992	15.9	4,645	9,194	13,846	88.0
OH4B	434	20.8	3,943	11,408	15,479	95.8
OP1A	9	0.0	0	0	0	0.0
OP1B	10	0.0	0	0	0	0.0
OP2A	152	41.1	5,453	3,857	9,199	97.0
OP2B	63	24.4	4,457	1,907	6,866	57.5
OP2C	5	25.4	6,779	5,984	15,239	93.5
OP3A	630	34.8	8,207	6,104	14,530	106.0
OP3B	145	25.9	6,512	0	15,341	98.2
PP1A	34	0.0	0	0	0	0.0
PP1B	14	0.0	0	0	0	0.0
PP2A	385	40.5	6,833	0	9,482	92.0
PP2B	186	58.5	9,380	2,641	11,873	127.9
PP2C	3	58.5	12,126	2,588	14,577	146.0
PP3A	1,454	45.7	11,426	12,167	22,156	157.9
PP3B	866	43.2	15,488	14,182	29,013	183.9
PP3C	11	67.1	2,574	2,845	5,239	90.9
PP4A	167	40.4	9,812	19,025	35,467	211.1
PP4B	40	136.4	7,920	16,596	23,702	196.4
Total	**152,824**	**21.8**	**4,267**	**6,968**	**11,234**	**78.1**

PWtons=Pulpwood green tons; SawTbrBdFt= Small Sawtimber Board Feet; LgSawTbrBdFt=Medium and Large Sawtimber Board Feet; TotTons=Total green tons; TotalSawTbrBdFt=Total Sawtimber Board Feet. Log rule: International 1/4". All speecies included.

* Excludes stand acres where stratum = DV, ROW, CL, or WA

Parameterized Basal Area by Forest					
Forest	Acres	PWBA	SawBA	LgSawBA	TotalBA
Brush Creek	13,348	36.8	35.1	45.4	117.3
Hocking	9,226	35.5	44.4	52.6	132.6
Pike	11,861	32.7	35.8	50.4	118.8
Richland Furnace	2,430	27.7	41.1	45.1	113.9
Scioto Trail	9,447	32.6	38.9	43.4	114.9
Shawnee	63,200	36.9	35.6	40.1	112.7
Tar Hallow	15,961	27.9	39.3	54.6	121.8
Zaleski	27,352	32.9	37.7	47.5	118.2
Total	**152,824**	**34.4**	**37.2**	**45.3**	**116.8**

Inclusive of all species greater than or equal to 5" dbh.

Parameterized Basal Area by Strata

Stratum	Acres	PWBA	SawBA	LgSawBA	TotalBA
CH1B	20	41.5	17.2	9.2	67.9
CH1D	50	58.5	7.3	4.0	69.8
CH2A	695	42.0	30.0	27.6	99.6
CH2B	678	43.2	33.8	28.1	105.2
CH2D	53	76.3	7.2	0.0	83.5
CH3A	1,370	36.0	32.0	46.1	114.0
CH3B	537	37.1	43.2	44.4	124.6
CH4A	235	29.4	33.3	89.8	152.6
MX1A	295	35.6	34.1	8.1	77.8
MX1B	59	36.6	29.5	10.9	77.0
MX1C	29	59.7	20.4	15.9	96.0
MX1D	69	51.0	20.8	12.3	84.1
MX2A	3,016	38.8	30.8	24.7	94.3
MX2B	2,485	38.3	31.4	35.9	105.7
MX2C	92	51.0	8.4	12.0	71.3
MX2D	107	53.9	5.4	12.7	72.1
MX3A	13,016	32.0	33.2	47.6	112.8
MX3B	7,842	32.2	29.6	50.3	112.0
MX3C	51	29.2	23.6	56.4	109.3
MX4A	2,102	27.2	32.1	66.7	126.1
MX4B	270	32.1	27.1	67.2	126.4
NF1A	21	0.0	0.0	0.0	0.0
NF1D	9	0.0	0.0	0.0	0.0
NF2A	28	0.0	0.0	0.0	0.0
NF2B	21	0.0	0.0	0.0	0.0
NF2D	33	0.0	0.0	0.0	0.0
OH1A	444	39.7	41.4	14.9	96.0
OH1B	173	52.5	48.9	21.0	122.4
OH1C	15	36.5	34.8	12.5	83.8
OH1D	119	31.0	3.4	3.0	37.5
OH2A	23,797	41.0	36.5	31.7	109.1
OH2B	2,772	37.1	33.7	37.1	107.8
OH2C	74	57.9	21.7	29.4	109.0
OH2D	45	70.5	0.0	14.3	84.8
OH3A	73,001	33.3	39.0	47.5	119.8
OH3B	9,577	32.1	34.6	52.0	118.6
OH3C	20	30.1	40.8	52.3	123.2
OH4A	4,992	24.5	36.7	65.4	126.6
OH4B	434	28.3	33.6	70.7	132.6
OP1A	9	72.1	0.0	16.9	89.0
OP1B	10	37.4	0.0	0.0	37.4
OP2A	152	47.0	43.1	28.7	118.8
OP2B	63	46.2	25.7	19.6	91.5
OP2C	5	48.1	39.1	61.4	148.6
OP3A	630	44.4	48.3	40.9	133.6
OP3B	145	37.6	33.1	44.8	115.5
PP1A	34	39.7	35.4	14.4	89.5
PP1B	14	69.4	62.4	33.7	165.5
PP2A	385	38.1	56.0	21.7	115.8
PP2B	186	56.3	72.4	19.0	147.7
PP2C	3	56.3	93.6	18.6	168.5
PP3A	1,454	36.2	65.1	60.1	161.3
PP3B	866	20.7	92.3	79.8	192.8
PP3C	11	64.6	19.9	20.4	104.9
PP4A	167	38.1	46.1	127.3	211.5
PP4B	40	65.4	47.2	93.4	206.0
Total	**152,824**	**34.4**	**37.2**	**45.3**	**116.8**

Inclusive of all species greater than or equal to 5" dbh.

Appendix C – Plot Specifications and Procedures

Table of Contents

Forest Inventory

Personnel Contact Information

Harrison Peterson will be the primary contact and Mike Berzinis will be secondary contact for LandMark Systems. Chad Sanders is the ODNR for the project. Jerry Lambert will be the contact person for Forest Resource Services. Appendix E.1 lists contact information.

A. Equipment

The RTI software package is a requirement for all data collection on this project, and will be supplied by the contractor. All forestry tools necessary for the accurate and complete collection of sample plot data will be supplied by the contractor.

B. Scope

This inventory is designed as a stratum level estimate of five primary Broad Types. Since the reporting level is to be the entire managed area, the actual inventory across the ownership needs to provide reliable volume estimates, but also needs to be accomplished within a reasonable time frame and cost. The five broad types are; **Oak/Pine, Planted Pine, Oak/Hickory, Cove Hardwoods, and Mixed Mesophytic.** For each broad type, twelve strata have been identified that are differentiated by a combination of development and stocking level. Presented in the form of a matrix (Appendix E.2), sample size for each stratum and type group is a function of an estimated coefficient of variation and a stated acceptable allowable error at the 90% confidence level (could go up or down depending upon specific requirements). The number of samples is calculated based on the probability that 9 times out of ten the sample estimate of total volume per acre will be within the stated allowable error.

The assigned coefficients of variation for each broad type/stratum combination are the product of many years of sampling and archival datasets that cover many parts of the country. While we believe these estimates to be realistic, changes will be necessary as data from the preliminary cruise are compiled. The preliminary cruise will include all of the data collection of the larger inventory, except that the sample will be focused on deriving a more accurate coefficient of variation for desired strata. There are 5 broad types, 3 development (size) types and 4 density classes that will be focused on for the forest inventory. Therefore, a total of 60 combinations are possible at this point, however, there will inevitably end up being less than 60 strata after the mapping effort. This will result in Ohio DNR managers having the ability to reassign plots within the budgeted amount to increase the accuracies of selected strata via the sample matrix. This will be accomplished in consultation with the managers.

All plots will utilize a 40 BAF prism for the variable plot size sample for merchantable trees (>= 5.0" DBH). All merchantable tallied trees on plot will be measured to the nearest 0.1" DBH. Saplings will be measured on a nested 1/500th acre fixed radius plot and will be put into 1" DBH classes and heights to the nearest 5 foot class. Seedlings will be measured on a nested 1/500th acre fixed radius plot and will be plot counts by species. Down Woody Debris (DWD) will be measured with a 1/100th acre fixed radius plot.

C. Sample Allocation

The sample locations will be generated using a two-stage, probability proportional to size method. This method has proven to be the most efficient and effective way to perform a stratum-level inventory. The first phase consists of selecting stands in each stratum with a probability in direct proportion to its size. The second stage will consist of assigning the selected stands with a minimum of 10 plots in each stand. The number of samples will be accumulated by selecting additional polygons until the total sample size is reached. At this point the next stratum will be processed in the same fashion. The located sample points will be saved as a shapefile along with the condition polygon shapes and transferred to the field data collection device.

D. Handheld Templates and Waypoint Files

The RTI system requires a template (.tcc) for TCruiseField and a waypoint file (.way) for SoloField. The TC template is Ohio_DNR_.tcc and the Solo waypoint file is Ohio_DNR.way.

E. Data Collection Procedure

Plot Monumentation

Once the worker reaches plots center an orange piece of flagging will be hung from the nearest permanent branch with plot number and workers initials. An additional piece of orange flagging will be placed in the ground to mark plot center. Plot locations are to be taken with Real-Time Inventory (RTI – www.landmarksystems.org) units. The worker needs to pay special attention to the placement of the ground flagging, for it will be used as the plot center for the audit cruise.

Boundary Correction

Correction for boundary overlap of stands or property boundaries will be accomplished by the Walkthrough Method. This is similar to the Mirage Method, but statistically more correct. It simply entails doubling the critical distance to a tree near a boundary. If the doubled distance goes over the boundary line, the tree is counted twice. Specific instructions and information regarding this method will be covered in the training session for the cruisers. See Appendix E.3.

Timber Specifications

Products recognized for this inventory will include Poles/Pulp, Small Sawtimber , Medium Sawtimber , and Large Sawtimber. See Appendix E.4, Product Specifications.

Plot Measurements

All measured tree diameters will be recorded with either diameter tapes or calipers reading to the nearest one tenth inch. Heights will be measured to the nearest foot using a calibrated laser or clinometer. Limiting distances will be measured with a Haglof DME or measuring tape. All measured heights will be recorded to the nearest foot at total height. Limiting distances will be measured with a Haglof DME or measuring tape. Product assignments need to be kept at AutoAssign, AA, unless a tree is downgraded to pulpwood. **All points will be tallied starting from the first tree to the north and working in a clockwise direction. The first tree tallied will also**

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require flagging. This needs to be strictly adhered to in order for the audit cruise to accurately reflect the plot tally. See Appendix E.5 to view "TCruise Data Input Screen".

Small Tree Sub Plots

Our objective is to provide a relatively straightforward method of collecting regeneration data to yield reasonable estimates of species composition and development. These nested small tree plots will be "plot count" samples rather than "stocked quadrat" samples. This means that all trees by species will be counted. Measurements for downed woody debris will also be made on a small subplot.

Seedling Plots:* A "seedling" shall be defined as any tree species which is greater than 1.0 feet in height, but less than 4.6 feet in height (1.0' to 4.5'). The 1/500 acre fixed plot has a radius of 5.3 feet. In the interest of efficient data collection, a maximum of 5 of each species will be counted and recorded from each plot. Record "1" for seedlings in the **R** column.

Sapling Plots:* A "sapling" shall be defined as any tree species that is greater than 4.5 feet in height, but less than 5.0 inches in diameter (4.6" to 4.9" DBH). The 1/500 acre fixed plot has a radius of 5.3 feet. For saplings we will record species, DBH to the nearest one inch diameter class, and average total height to the nearest 5 foot height class. In the interest of efficient data collection, a maximum of 5 of each species/DBH combination will be counted and recorded from each plot. In situations where more than one species/DBH combination is recorded, we will record the average height of counted trees to the nearest 5 foot class.

Downed Woody Debris:* Our objective is to gather DWD information in such a manner as to allow the calculation of DWD cubit foot volume on a per acre basis. This will be accomplished through the use of 1/100th acre plot on the initial 250 plots to determine cost effectiveness. DWD is characterized by having a stems large end originate within the plot radius; having a minimum diameter of 5.0" at 4.5'; and at least 5 feet in length. The DWD must not crush under the weight of the cruiser. The following values will be measured and recorded:

Species (SPC) *: Appendix E.4, Species List.

*DBH **: Ocular Estimates to the nearest 1.0 inch.

*Total Tree Height (TTH)**: Ocular estimates to the nearest 1 foot for all DWD on the plot. Measure the DWD stem to the right of north.

*Broken Top Diameter (DOB)**: This field is only used for DWD with a broken top before it reaches 4 inches – this will be used to modify the profile equation.

Growing Stock Status (GSS):* Record all DWD as GSS 8. See Appendix E.6.

Large Tree Main Plot

With the use of a 40 BAF variable radius plot, we anticipate recording an average of 2-5 large "in" trees per plot in unthinned stands, and 1-2 trees in the thinned stands. A "large tree" shall be defined as any tree species which is 5.0 inches DBH or larger. This description in meant to include all classes of merchantable, live cull, and standing dead trees. The following values will be measured and recorded for all classes of large trees that are "in" on the plot:

Species (SPC) *: Appendix E.4, Species List.

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*DBH **: Measured and recorded to the nearest 0.1 inch

*Product (PROD)** : Product assignments need to be kept at AutoAssign, AA, unless a tree is downgraded to pulpwood.

*Total Tree Height (TTH)** : Measured and recorded to the nearest 1 foot for the first of each species on the plot. Measure the first tree of each species to the right of north – in other words, only one height per species will be measured per plot. TCruise will automatically perform a height regression based on the measured trees to populate the non measured trees for volume calculation and reporting.

*Log Stopper Height (LSH)**: This field is only used for sawlog trees that exhibit a defined "stopper". Above this stopper height diameter may be large enough for sawlogs, but because of excessive defect will not meet quality log specifications (crook, seams, knots, etc.). In this situation the log sized volume above the stopper will be downgraded to pulpwood.

*Broken Top Diameter (DOB)**: This field is only used for trees with a broken top – this will be used to modify the profile equation.

*Percent Defect (DEF)**: This field is only used for trees which contain a defect that must be deducted from the gross volume calculated for the tree. Recorded as a % volume deduct applied to the entire stem volume.

*Growing Stock Status (GSS)**: This may be the single most important tree value to describe forest health, quality, and future value of forest products. GSS field includes 3 classes of "acceptable" (GSS 1, 2 , & 3) and 2 classes of "unacceptable" (GSS 4 & 5), along with the standing dead tree with bark (GSS 6) and without (GSS 7). This one "Growing Stock Status" evaluation for each tree includes all of the items of interest such as form, vigor, decay, crown class, risk of loss, lean, growth potential, grade potential, etc. Specific instructions and information regarding this method will be covered in the training session for the cruisers. See Appendix E.6.

*Live Crown Ratio (LCR)**: This field is only used with GSS 'A" & "U" trees and is record as a percent of the total height.

F. Auditing Procedure

One of the largest sources of problems with large inventories results from the failure of many organizations to perform a proper audit of the process. No matter how experienced the cruisers, it has been our experience that there will inevitably be some problems that need correcting from day one on the ground. Therefore, an internal audit of primary data collection accuracy will be conducted on 5% of the samples during primarily the early phases of the inventory. Any plots taken by Landmark Systems contractors will be audited by Landmark Systems. Using the same GIS plot layout from the initial sample, the auditor will navigate to the original plot locations. During the audit, the plot will be tallied according to the initial specifications. Plot by plot comparisons can then be made at any time after the audit is completed. Accuracy weighting sheets can be provided if desired. Appendix E.7 lists the audit specifications.

G. Data Handling and Storage

Data transfer from the field to Landmark Systems will have guidelines, set forth below, to ensure accurate and timely information flow. Also, file naming schemes will be set forth to provide consistent information.

Spatial Data Format

The projection for all field and office spatial data will be NAD 1983, State Plane Ohio South FIPS 3402, Feet.

Raw Field Data

The raw field data will consist of two files for each cruiser per week; a Solo project file (.udf) and a T-Cruise file (.tce). File naming schemes for both files will use the numeric date (mm, dd, yr; 6 characters) and the field workers initials (3 characters). The 2 character number that represents the day in the numeric date will always be the Monday of that week (ex. 021207HJP.udf, 021207HJP.tce). This format will be strictly adhered to throughout the project. Field data will not be accepted for payment unless each field workers solo file has the same number of points as their TCruise file(s), with matching PlotID's per week.

The subcontractor will be required to submit a weekly report to LandMark Systems on the number of plot samples collected. The format of this report will be left up to the subcontractor as long as the information is clear and concise. Additionally, two files per field worker will be submitted, a Solo project file (.udf) and a T-Cruise file (.tce). This weekly information will be transferred to LandMark Systems, via e-mail, in a .zip file or in person to LandMark personnel.

It is **recommended** that the subcontractor perform daily back-ups of the raw data from the handhelds to a PC for each field worker.

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APPENDIX E.1 – CONTACT INFORMATION

LandMark Systems

Harrison Peterson	850-385-3667, ext 3960 office 850-528-2192 cell
Mike Berzinis	850-385-3667, ext 3950 office 850-320-2522 cell

Ohio DNR

Chad Sanders	614-265-6701 office
Greg Guess	740-774-1596 ext 3 office

FRS

Jerry Lambert	989-732-7188 office 989-619-2882 cell
Luke Gilner	616-430-0746 cell
Chad Fate	989-619-2167 cell

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APPENDIX E.2

LandMark

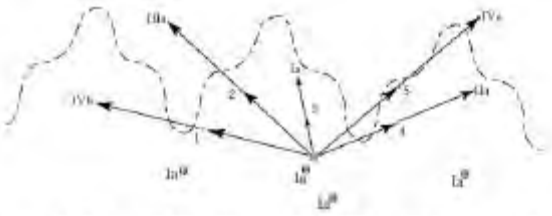
APPENDIX E.3

Walkthrough Method

The Walkthrough Method is unbiased and easy to implement in the field since it does not actually require the cruiser to cross the boundary. The figure on the next page depicts instances where sample 'in' trees are counted once and locations where they are counted twice. Simple instructions for each 'in' tree near the boundary are presented below:

Procedure:

1. *Measure the distance from the point center to the sample 'in' tree.*
2. *While maintaining the same bearing, double the distance. If the endpoint falls outside the boundary, the sample 'in' tree is counted twice. All other 'in' trees are counted once.*



Graphic illustration of the walkthrough method. Five sample objects (1-5), 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.

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APPENDIX E.4

Species List and Product Specs

Sp code	Species name	Sp code	Species name
802	White Oak	261	Hemlock
832	Chestnut Oak	931	Sassafras
422	Chinkapin Oak	331	Buckeye
898	Other White Oak	731	Sycamore
806	Scarlet Oak	611	Sweet Gum
837	Black Oak	693	Black Gum
833	N. Red Oak	901	Black Locust
899	Other Red Oak	521	Persimmon
621	Yellow Poplar	972	Elm
318	Sugar Maple	379	Black Birch
316	Red Maple	373	River Birch
317	Silver Maple	221	Cypress
440	Tight Hickory	391	Hornbeam
415	Loose Hickory	701	Ironwood
540	Ash	712	Paulownia
531	Beech	711	Sourwood
951	Basswood	040	Cedar
762	Black Cherry	299	MiscSftwd
602	Black Walnut	999	MiscHdwd
743	Bigtooth Aspen	341	Allanthus
742	Cottonwood		
129	White Pine		
125	Red Pine		
132	Virginia Pine		
110	Shortleaf Pine		
126	Pitch Pine		
131	Loblolly Pine		

Product	Minimum DBH's		Min Top Dia	Min Log Length
	Pine	Hwd		
Pulp	5.0"	5.0"	4.0"	8'
Small Saw	11.6"	11.6"	10.0"	8'
Medium Saw	NA	17.6"	10.0"	8'
Large Saw	NA	23.6"	10.0"	8'

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APPENDIX E.5

TCRUISE DATA INPUT SCREEN

Ohio DNR Forest Inventory

TCruise Data Input Screen

Species Code		Product	Seedling Class	Tree Count	HM	HS	TM	Percent Defect	Growing Stock Status	Live Crown Ratio
SPC	DBH	PROD	R	##	TTH	LSH	DOB	DEF	GSS	LCR
Only tree species listed are recorded	Measured and recorded to the nearest 0.1 inch (no entry for Seedling class)	Product code determines need to be kept or NOT kept, MA, unless a tree is downgraded to pulpwood	Record "1" for seedlings less than 4.5' tall from the 1/1,000th acre fixed radius plot	Used primarily with Seedling and Sapling tree counts, but can be used with merch trees	Total Tree Height - measured on only first tree of each species, from each plot	Log Stocker Height - only used for sawlog trees with definable stocker - no logs calculated above this height	Top diameter outside bark to nearest 1 inch class - used only for broken top	Only used with GSS "A" & "U" trees - % volume deduct applied to entire stem (v/o% = Cull)	"A" = Acceptable, "U" = Unacceptable, "Sngl" = Standing Dead W/Bark, "SngB" = Standing Dead W/O Bark, & "DWD" = Down Woody Debris	Only used with GSS "A" & "U" trees - Live Crown Height as a Percent of TTH
							Default Value:	0	-0-	0
							Drop Down Option 1:	10	1A	10
							Drop Down Option 2:	20	2A	20
							Drop Down Option 3:	30	3A	30
							Drop Down Option 4:	40	4U	40
							Drop Down Option 5:	50	5U	50
							Drop Down Option 6:		6Cul	60
							Drop Down Option 7:		7SngB	70
							Drop Down Option 8		8Sng	
							Drop Down Option 9:		9DWD	

GSS 6, 7, & 8 are not truly part of the GSS they are used as tree categories. *** Adjust langue as you see fit***

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APPENDIX E.6 Growing Stock Status (GSS)

Growing Stock Status (GSS): Growing Stock Status is a method to predict future timber quality and value increases - as a result of diameter growth - for trees of all size classes. GSS is the ranking of each tree's current condition in relation to risk of loss, anticipated growth response, potential sawlog height, and predicted grade improvement *(hardwoods only)*. Determination of Growing Stock Status requires a thorough evaluation of all aspects that effect tree health, growth, and quality. These criteria should not be considered all-encompassing, other biological factors may be present which should have an influence on each tree's designation.

In application, evaluate all sampled trees *(hardwoods and conifers)* which are 4.6" D.B.H. and larger. Growing stock evaluations should be based on each tree's individual characteristics - not in relation to the quality of adjacent trees, current diameter class, or market preferences. These criteria must be applied in a consistent manner to permit an equal basis evaluation through space and time.

Growing Stock Status - Evaluation Criteria **Forest Resource Services, LLC*

GSS Quality Rank *Marking Rule*	1 Superior *Crop Tree*	2 Very Good *Crop Tree*	3 Good *Could Cut*	4 Fair *Should Cut*	5 Poor *Must Cut*
Poorest of the following four criteria determines the best quality ranking					
Risk of Loss or Degrade	No risk of volume or value loss (degrade) anticipated before ROTATION AGE	Low risk of volume or value loss (degrade) anticipated before ROTATION AGE	Minor volume or value loss (degrade) anticipated within the next 10 YEARS	Moderate volume or value loss (degrade) anticipated within the next 10 YEARS	Major volume or value loss (degrade) anticipated within the next 10 YEARS
Growth Potential	Displays superior growth potential. Will respond well to release.	Displays very good growth potential. Will respond well to release.	Displays good growth potential. Should respond well to release.	Displays fair growth potential. May not respond well to release.	Displays poor growth potential. Will not respond well to release.
Log Height Potential	Should produce 3 or more 16 foot sawlogs (48'+) at financial maturity.	Should produce at least 2 16 foot sawlogs (32') at financial maturity.	Should produce at least 1 16 foot sawlog (17') at financial maturity.	Should produce at least 1 8 foot sawlog (9') at financial maturity.	Will likely not produce any sawlogs at financial maturity.
Hdwd Grade Potential	Should produce One or more 16 foot Grade 1 or better sawlogs (17') at financial maturity.	Should produce at least one 16 foot Grade 1 or better sawlog (17') at financial maturity.	Should produce at least one 8 foot Grade 2 or better sawlog (9') at financial maturity.	Will likely produce only Grade 3 sawlogs at financial maturity.	Will only produce pulpwood or cull.
Use the following criteria for further clarification					
Crown Class	Dominant	Codominant	← →	Intermediate	Suppressed
Crown Condition	Well developed symmetrical crown. Occasional dead branches in the outer crown. Healthy leaves and densely foliated.	← →	Less than well developed, or oblong crown. Some dead branches in the outer crown. Good leaf condition. Indications of minor crown competition.	← →	"Flat topped" or poorly developed "basket" crown. Considerable dieback in outer crown. Poor leaf condition. Indications of major crown competition.
Bole Form	Superior form, with no crook, sweep, seams, or spiral grain.	← →	Good form, with only minor crook, sweep, seams, or spiral grain.	← →	Poor form with major crook, sweep, seams, or spiral grain.
Forking	Free of acute forking in the main stem and crown.	← →	Acute forking confined to the upper bole and crown.	← →	Acute forking on the lower bole.
Rot and Decay	No cull loss present. No indications of heart rot or staining.	← →	Cull loss less than 10%. Minor indications of heart rot or staining in the early stages.	← →	Cull loss greater than 20%. Obvious indications of major heart rot or staining.
Lean	No noticeable lean.	← →	Less than 20 degrees.	← →	Greater than 30 degrees.

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APPENDIX E.7

AUDIT SPECIFICATIONS

Quantitative Variables to be Evaluated:

Plot Location - Must be within 25 feet of audit location.

Limiting Distance - ± 1% of distance as measured with tape.

DBH (0.1 in.) - ± 2% of diameter as measured with steel tape.

Plot stem count - 1 pulpwood stem missed for every 25 stems tallied.
1 sawlog stem missed for every 50 trees tallied.

Height (total) - ± 3% from height measured with laser, Vertex 3 or Suunto clinometer.

Product class - Pulpwood/CNS – 1 error per 50 trees tallied.
Sawlog - ± 1 product per 100 trees vs. audit.

Audited Plot Volumes:

≥ 90% of original total plot volume MUST be within ± 3% of the audited plot volume.

All Audited Plots:

Average variation in total volume measured by Standard Error MUST be within ± 3% of audited plots variation in total volume Standard Error.

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Appendix D – Stratification and Classification Matrix

LandMark SYSTEMS

Ohio Department of Natural Resources

Forest Inventory

Appendix B--Forest Inventory Stratification & Initial Sample Size

Sample Computation Inputs	
Variable	*Value*
Confidence Level:	90%
Coeff. Variation on:	Total Tons
Prob. Level:	0.10
t-Value:	1.652508101

STRATUM NUMBER	STRATUM DESCRIPTION	INPUT DATA	*OP* OAK/PINE	*PP* PLANTED PINE	*OH* OAK/HICKORY	*CH* COVE HARDWOOD	*MX* MIXED MESOPHYTIC	*Total Rec. Samples By Stratum*
1D	Precommercial development	**Coeff. Var. %**						
	CrownClosure 0-25%	**Allow. Err.%**	35	35	35	35	35	
	Understocked	**Recommended Samples**	0	0	0	0	0	**0**
		ActualSamples						0
1C	Precommercial development	**Coeff. Var. %**						
	CrownClosure 26-50%	**Allow. Err.%**	35	35	35	35	35	
	Slightly Understocked	**Recommended Samples**	0	0	0	0	0	**0**
		ActualSamples						**0**
1B	Precommercial development	**Coeff. Var. %**						
	CrownClosure 51-75%	**Allow. Err.%**	25	25	25	25	25	
	Adequately Stocked	**Recommended Samples**	0	0	0	0	0	**0**
		ActualSamples				4		4
1A	Precommercial development	**Coeff. Var. %**						
	CrownClosure 76-100%	**Allow. Err.%**	25	25	25	25	25	
	Overstocked	**Recommended Samples**	0	0	0	0	0	**0**
		ActualSamples			**1**		**6**	**7**
2D	Pole development	**Coeff. Var. %**	90.0	60.0	90.0	90.0	90.0	
	CrownClosure 0-25%	**Allow. Err.%**	50	50	30	30	30	
	Understocked	**Recommended Samples**	9	4	25	25	25	**87**
		ActualSamples			18			18
2C	Pole development	**Coeff. Var. %**	80.0	**50.7**	80.0	80.0	80.0	
	CrownClosure 26-50%	**Allow. Err.%**	50	40	30	30	30	
	Slightly Understocked	**Recommended Samples**	7	4	19	19	19	**70**
		ActualSamples		9	55		4	**68**
2B	Pole development	**Coeff. Var. %**	65.0	45.0	65.0	**94.7**	**52.4**	
	CrownClosure 51-75%	**Allow. Err.%**	50	30	15	20	15	
	Adequately Stocked	**Recommended Samples**	5	6	51	61	33	**157**
		ActualSamples	20	15	146	57	61	299
2A	Pole development	**Coeff. Var. %**	**44.1**	40.0	**98.1**	50.0	**63.9**	
	CrownClosure 76-100%	**Allow. Err.%**	35	30	15	20	15	
	Overstocked	**Recommended Samples**	4	5	117	17	50	**193**
		ActualSamples	37	42	310	104	92	**585**
3D	Sawtimber development	**Coeff. Var. %**	70.0	60.0	**102.5**	70.0	75.0	
	CrownClosure 0-25%	**Allow. Err.%**	50	20	20	20	20	
	Understocked	**Recommended Samples**	5	25	72	33	38	**174**
		ActualSamples			**0**		**0**	0
3C	Sawtimber development	**Coeff. Var. %**	60.0	55.0	**57.4**	60.0	75.0	
	CrownClosure 26-50%	**Allow. Err.%**	35	20	15	20	15	
	Slightly Understocked	**Recommended Samples**	8	21	40	25	68	**162**
		ActualSamples		**18**	**17**		**21**	**56**
3B	Sawtimber development	**Coeff. Var. %**	**37.5**	**32.5**	**63.8**	**58.2**	**80.0**	
	CrownClosure 51-75%	**Allow. Err.%**	35	20	10	15	10	
	Adequately Stocked	**Recommended Samples**	3	7	111	41	175	**337**
		ActualSamples	**13**	**35**	**138**	**75**	**80**	341
3A	Sawtimber development	**Coeff. Var. %**	45.0	**56.2**	**51.5**	**48.9**	75.0	
	CrownClosure 76-100%	**Allow. Err.%**	35	20	10	15	10	
	Overstocked	**Recommended Samples**	5	22	72	29	154	**281**
		ActualSamples	**33**	**33**	**297**	**128**	**102**	**593**
4D	Large Sawtimber development	**Coeff. Var. %**	70.0	60.0	75.0	70.0	75.0	
	CrownClosure 0-25%	**Allow. Err.%**	50	20	20	20	20	
	Understocked	**Recommended Samples**	5	25	38	33	38	**140**
		ActualSamples						0
4C	Large Sawtimber development	**Coeff. Var. %**	60.0	55.0	75.0	60.0	75.0	
	CrownClosure 26-50%	**Allow. Err.%**	35	20	15	20	15	
	Slightly Understocked	**Recommended Samples**	8	21	68	25	68	**190**
		ActualSamples						**0**
4B	Large Sawtimber development	**Coeff. Var. %**	55.0	**75.6**	**44.7**	60.0	**34.9**	
	CrownClosure 51-75%	**Allow. Err.%**	35	**20**	**10**	15	10	
	Adequately Stocked	**Recommended Samples**	7	39	55	44	33	**177**
		ActualSamples		**0**	**0**	**3**	**22**	25
4A	Large Sawtimber development	**Coeff. Var. %**	45.0	**38.7**	**40.4**	**42.0**	**68.1**	
	CrownClosure 76-100%	**Allow. Err.%**	35	20	10	15	10	
	Overstocked	**Recommended Samples**	5	10	45	21	127	**207**
		ActualSamples	**20**	**0**	**161**	**20**	**12**	**213**
	TOTAL RECOMMENDED SAMPLES:		**70**	**188**	**713**	**374**	**829**	**2173**
	ACTUAL SAMPLES:		**123**	**152**	**1143**	**391**	**400**	2209

Document Notes

CV's can be changed by user to impact recommended samples

Values highlighted in red are actuals from initial sample effort

Revised: 4/30/2009

LandMark SYSTEMS

Ohio Department of Natural Resources
Forest Inventory

Appendix A--FOREST COVER TYPE CLASSIFICATION SCHEMA

BROAD TYPES:

Code	Short Description	Long Description
OP	Oak/Pine	Any Natural Pine, or Virginia or Pitch dominanted, may contain Oak, dry ridge tops, knobs
PP	Planted Pine	Obvious plantation: White Pine, Red Pine, Shortleaf, Loblolly. Or Mix pine species
OH	Oak/Hickory	South and West slopes. Xeric. Dominanted by oak (Chestnut Oak / Scarlet Oak / Black Oak). 60% BA oaks. Maple, poplar present
CH	Cove Hardwoods	Drainages and coves. 50% BA poplar. White Oak lower third, poplar, maple. Basswood other misc species present
MX	Mixed Mesophytic	North and east slopes. Mesic. 60% BA Dominated by poplar, ash, and maple. Oak and hickory components

***The difference between OH and MX is mostly aspect…the stands may look somewhat similar as oak will be on both sides. Chestnut oak a key on xeric sites. Poplar/Map/Ash key on mesic sites.*

OVERSTORY SPECIES COMPOSITION:

Code	Species Cover Type	Code	Species Cover Type
102	Red pine	510	Scarlet oak
103	Eastern white pine	511	Yellow-poplar
105	Eastern hemlock	515	Chestnut oak/blk oak/scrlett oak
161	Loblolly pine	519	Red maple / oak
163	Virginia pine	520	Mixed upland hardwoods
181	Eastern redcedar	702	River birch / sycamore
401	Eastn WP/N. red oak/wht ash	705	Sycamore / pecan / American elm
405	Virginia pine / southern red oak	707	Silver maple / American elm
502	Chestnut oak	801	Sgr maple/beech/yel.birch
503	White oak / red oak / hickory	803	Cherry-ash-yellow poplar
504	White oak	805	Hard maple / basswood
506	Yellow-poplar/white oak/N.red oak	807	Elm-ash-locust
507	Sassafras / persimmon	809	Red maple / upland
508	Sweetgum / yellow-poplar	997	Other Hardwoods

[Source: As calculated from inventory data processed using FVS and Appendix B in "Essential FVS: A User's Guide to the Forest Vegetation Simulator"]

HEIGHT CLASSES:

Code	Description
1	< 30 ft
2	>= 30 ft and < 65 ft
3	>= 65 ft and < 100 ft
4	>= 100 ft

STAND DENSITY CLASSES:

Code	Description
A	Crown closure 76-100%
B	Crown closure 51-75%
C	Crown closure 26-50%
D	Crown closure 0-25%

DEVELOPMENT CLASSES:

Code		Description	
1	Seedlings/Saplings	<5" DBH	Determined by selecting the class with the greatest proportion of total basal area (exceptions: seedling/sapling had to occupy 50% or greater of total basal area; in event of a tie, the larger development class was selected)
2	Poles	5 - 11.5" DBH	
3	Sawtimber	11.6 - 17.5" DBH	
4	Large Sawtimber	17.6"+ DBH	

Appendix E – Stand Mapping Protocols

Ohio DOF
Stand protocols utilized by LandMark Systems
10/1/08

Minimum Stand Size – 10 acres
Exceptions:
- Pine plantations
- Admin areas (Offices, Buildings, Airfields, mowed areas)
- Recreational (campgrounds, fire towers, etc)
- Special or Geologic feature (rocks, cliffs, water body, etc)
- Recent clearcuts should be mapped down to 5 acre minimum

Maximum Stand Size – 100 acres
Exceptions:
- Pine plantations
- Non-forested areas (there are only a few significant non-forest areas that will be over 100 acres).

Target Stand Size – 25-30 acres

Stand Delineation priorities in order of importance
1. Aspect - NE, NW, SE, SW
2. Slope Position - divide into thirds; upper third, middle third, lower third
3. Topographic feature - ridgetop, creek, draw, cove
4. Compartment Boundary
5. Admin barrier – a road, utility ROW, or property line

Rules of thumb:
Long, skinny stands OK on broad ridgetops, creek bottoms, and road-side buffers that are un-harvested. Avoid long, skinny stands in the middle of the slope.

Appendix F – Field Plot & Audit Summary

FOREST RESOURCE SERVICES

Ohio DNR Forest Inventory, 2008 - 2009

Cruiser	2/16/2009	Audit		4/6/2009	4/13/2009	4/20/2009	Audit	Total	Total Audit	%Audit
GJL	87	3						87	3	0.03
LLG	85	4		173	229	90	14	577	18	0.03
CMF	83	5		119	193	45	8	440	13	0.03
CDW				72			15	72	15	0.21
CEC				56			13	56	13	0.23
PTJ				105	211	80	18	396	18	0.05
SGR				87	160	60	14	307	14	0.05
TEM				88	132	54	17	274	17	0.06
Totals	**255**	**12**		**700**	**925**	**329**	**99**	**2209**	**111**	**5%**

5% audit of ~2000 Plots

111 Audited Plots

Ohio DOF - Inventory Audit Results

Characteristic	Original Data	Audit Data	% Difference [Original to Audit]
Merch. Trees/Ac.	99.9	101.6	-1.7%
Merch. Basal Area/Ac.	85.4	83.6	2.2%
Quad. Mean DBH	12.5	12.3	1.6%
Total Pulpwd. (Cubic Feet/Ac.)	580.2	595.5	-2.6%
Total Pulpwd. (Tons/Ac.)	17	17.4	-2.3%
Sawtimber (Cubic Feet/Ac.)	1421.8	1354.6	5.0%
Sawtimber (Tons/Ac.)	41.6	39.6	5.1%
Total Cubic Volume/Ac.	2001.9	1950.1	2.7%
Total Green Tons/Ac.	58.6	57	2.8%
Percent Sampling Error @ 9:1 on Total Tons	10.7	11	-2.7%
Coefficient of Variation as % on Total Tons	67.8	70	-3.1%

Appendix G – Probability-Proportional-To-Size Sampling

Probability Proportional to Size Sampling
A Brief Background and Description

July 10, 2009

With simple random sampling or systematic sampling, the size of the sampling units (i.e. trees) does not affect the probability of being selected for the sample. Point sampling is an unequal-probability-selection sampling method. The larger trees (sampling units) have a higher probability of selection so that point sampling can be called a probability-proportional-to-size (PPS) sampling method. The probability of selection is proportional to tree basal area. The idea behind this method is to focus sampling on the larger, more valuable trees, thereby making the inventory more efficient.

In this same manner, PPS is also applied to stratified sampling, which is referred to specifically as a two-stage list sample. At the first stage of sampling, stands are selected with probability of selection proportional to some measure of size of the stand. Size is typically referred to as acres, as in the case with the Ohio DNR. However, if the data exists, it could alternatively consist of measures such as volume, basal area, value, etc.

The required number of plots is estimated for each stratum, given available budget and statistical goals. Once a stand is selected in the first stage, plots (or points) are randomly or systematically located throughout the stand at a normal grid spacing for stand-level inventories (i.e. 5x10, 8x8, etc.). The same process is repeated for subsequent stands in each strata until the required number of plots are reached for each stratum.

PPS is employed for a wide variety of sampling needs in government, research and business. The techniques employed for the Ohio DNR were primarily based upon the work of Shiver and Borders (1996), *Sampling Techniques for Forest Resource Inventory*, University of Georgia. Some additional references PPS can be found at the following sources:

- Chambers, R L, and Skinner, C J (editors) (2003), *Analysis of Survey Data*, Wiley, ISBN 0-471-89987-9
- Cochran, William G. (1977). *Sampling Techniques* (Third ed.). Wiley. ISBN 0-471-16240-X.
- Deming, W E (1975) On probability as a basis for action, *The American Statistician*, 29(4), pp146–152.