SITE CLASSIFICATION
AND
FIELD MEASUREMENTS

METHODS MANUAL

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INTRODUCTION

The purpose of this manual is to specify acceptable, uniform methods of obtaining field measurements for the Forest Response Program. The objective statements and descriptive narratives are intended to provide non-experienced field technicians with not only the "hows" of forest inventory work, but the "whys" as well. A basic understanding of theory <u>and</u> practice can only help to elicit a higher level of data quality.

In addition to the primary text, a complete set of field data sheets is provided in the Appendix. Readers of this manual are encouraged to refer to this section often to become familiar with standard data acquisition and formatting procedures.

Even though aimed specifically at Forest Response Program objectives, many of the field procedures described in this manual may be germane to other studies attempting to quantify subtle changes in forest condition over time. The exact methods chosen, sample size measured, and analytical techniques used, however, depend strongly on the objectives of each individual field project.

PERMANENT PLOT ESTABLISHMENT

The $400m^2$ (20 x 20m.) plot serves as the primary sampling unit in which the sampling of all arborescent flora takes place. Since shrub and woody regeneration inventories are taken from subsamples nested within this primary unit, great care must be taken from the start to assure proper plot layout.

Materials List

5 - PVC Pipes (minimum 1/2 inch inside diameter) cut to a minimum length of 60 cm. Because these will serve as plot center and corner stakes, each should be color coded in a consistent manner. eg: center = orange, north = blue, south = red, east = yellow, west = black.
2 - 50m. Fiberglass Surveying Tapes
1 - Light Duty Hammer
1 - Field Transit, Tripod and Plumb-bob (or Staff Compass) with minimum 1^{o} resolution and set to the proper magnetic declination.
1 - Surveying Rod
1 - Clinometer (or equivalent)
1 - Calculator with trigonometric functions

Upon arrival at the site to be sampled, the center PVC stake is driven firmly into the ground. PVC is the material of choice for monumentation since it is durable, inert, and because brightly colored enamels adhere strongly to it. Enough of the stake should protrude above ground level to further increase its visibility. This becomes extremely important when attempting to relocate the plot in subsequent years.

Once established, a tripod-mounted transit is set up and leveled with the plumb-bob positioned directly over the center stake. The instrument operator then sights a direct north bearing and sends technician A out on line with a tape to a horizontal distance of 14.142m., half the diagonal distance of a 20 x 20m. plot (Figure 1). A surveying rod held vertically as a target helps to facilitate the determination of the true north line. A third person may occasionally be needed to push branches or small stems aside to permit a clear line of sight for the instrument operator and to prevent these obstacles from deflecting the tape.

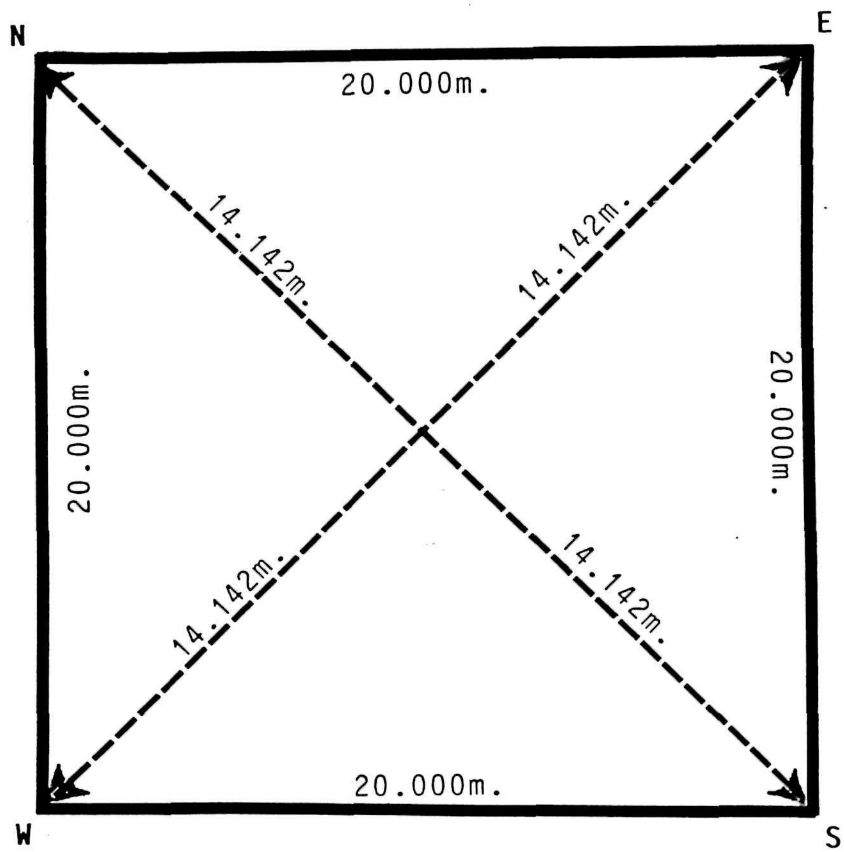


Figure 1. $400m^2$ plot showing half-diagonal distances

Once the bearing and distance have been established precisely, technician A then drives the color-coded north stake firmly into the ground. As with the center monument, the corner stake should protrude well above the forest floor to increase visibility.

The same procedures described above are used to install the three remaining corners. It is strongly recommended, however, that after establishment of the north corner, the instrument operator next shoot the bearing for the south stake. In this way, the transit sighting scope need only be inverted 180° in the vertical plane. The same can be said for laying out the east-west corners. This circumvents having to level the instrument on four separate occasions as would be the case if the cardinal directions were shot in a clockwise or counter-clockwise fashion. (i.e., N-E-S-W)

The final layout procedure is to define the boundaries of the plot by stretching two 50m. fiberglass tapes around the perimeter from corner stake to corner stake. It is customary to travel in a clockwise direction starting at north. Besides delineating the $400m^2$ area, the increments on the tapes will later be used to install the subsampling units. Because of this, it is important that the tapes be pulled snug to avoid sag. Care must also be exercised to make sure that they are as straight as possible and not being deflected by understory vegetation.

Laying Out the Plot in Sloping Terrain: It will be necessary to make adjustments to the plot when sampling in sloping terrain. Corrections for slope are needed to provide a uniform $400m^2$ plot size regardless of topography. In order to make these adjustments it must first be remembered that a taped distance along a slope will always be greater than a given horizontal distance. Because the half diagonal measurement for the plot is 14.142m. on a level surface (Figure 1.), this distance must be increased by a factor related to the degree of slope. The formula used in calculating this factor is:

$$\text{Slope Correction Factor (horizontal to slope)} = \frac{1}{\cos \arctan \frac{(\%\text{slope})}{100}} \qquad \text{(Formula 1)}$$

The result is then multiplied by 14.142 to obtain the slope corrected half diagonal distance.

An example from the field will serve to illustrate this procedure.

While standing at plot center, the instrument operator sends technician A out to a taped distance of 14.142m. Technician A holds the surveying rod vertically and moves it until the operator indicates that the target is directly on the proper bearing. The instrument operator then uses the transit, clinometer or other suitable device to determine the average slope of the ground between plot center and the surveying rod.*

If the slope is determined to be 30 percent, for instance, this value is entered into Formula 1 to obtain the needed slope correction value.

$$\frac{1}{\cos \arctan \frac{(30\%\text{ slope})}{100}} = 1.044$$

This quotient is next multiplied by 14.142 (1/2 diagonal horizontal distance) to calculate the proper slope corrected distance expressed in meters.

$$1.044 * 14.142 = \underline{14.765\text{m.}}$$

Accordingly, technician A extends the tape by that increment. After pulling the tape taut and insuring that it is inclined parallel to the slope of the ground, the cornerstake is installed. The use of a plumb-bob further increases the precision of stake placement. It is advisable that the instrument operator make one final sighting with the transit to insure that the corner is at the proper azimuth. This procedure is repeated (in identical fashion) until all corners are established.

* The slope angle must be determined by sighting the clinometer, transit, Abney level, etc. along a line parallel to the line of average incline or decline. The height of the target must therefore equal the height of the instrument. Since the instrument is read at eye level, the operator should sight on the surveying rod (or technician A's body) at an equivalent height.

To avoid the possibility of arithmetic errors in the field, pre-calculated slope correction tables such as the one found in Table 1 may be used. After determining the half-diagonal slope percent, the corrected distance is obtained at a glance. An even more fail-safe method is the use of a trailer tape. Here the corrected distances for each given slope are permanently marked on the tape itself.

Table 1. Slope Corrections for 14.142m. Half-Diagonal Distance

Slope %	Corr. Dist.	Slope %	Corr. Dist.	Slope %	Corr. Dist.
0	14.142	34	14.937	68	17.102
1	14.143	35	14.983	69	17.182
2	14.145	36	15.031	70	17.263
3	14.148	37	15.079	71	17.344
4	14.153	38	15.129	72	17.426
5	14.160	39	15.180	73	17.509
6	14.168	40	15.232	74	17.593
7	14.177	41	15.285	75	17.678
8	14.187	42	15.339	76	17.763
9	14.199	43	15.394	77	17.849
10	14.213	44	15.451	78	17.935
11	14.227	45	15.508	79	18.023
12	14.244	46	15.567	80	18.111
13	14.261	47	15.626	81	18.199
14	14.280	48	15.687	82	18.289
15	14.300	49	15.749	83	18.379
16	14.322	50	15.811	84	18.469
17	14.345	51	15.875	85	18.561
18	14.369	52	15.940	86	18.653
19	14.395	53	16.006	87	18.745
20	14.422	54	16.072	88	18.838
21	14.451	55	16.140	89	18.932
22	14.480	56	16.209	90	19.026
23	14.511	57	16.278	91	19.121
24	14.544	58	16.349	92	19.217
25	14.577	59	16.420	93	19.313
26	14.612	60	16.492	94	19.409
27	14.649	61	16.566	95	19.506
28	14.686	62	16.640	96	19.604
29	14.725	63	16.715	97	19.702
30	14.765	64	16.790	98	19.801
31	14.806	65	16.867	99	19.900
32	14.849	66	16.945	100	20.000
33	14.892	67	17.023		

Obstacles in Marking the Plot Corners: Occasionally a plot corner will fall precisely in a spot occupied by a large rock, downed tree, or other obstacle. In such cases, the stake should be driven in so that the top of the stake represents the plot corner (Figure 2).

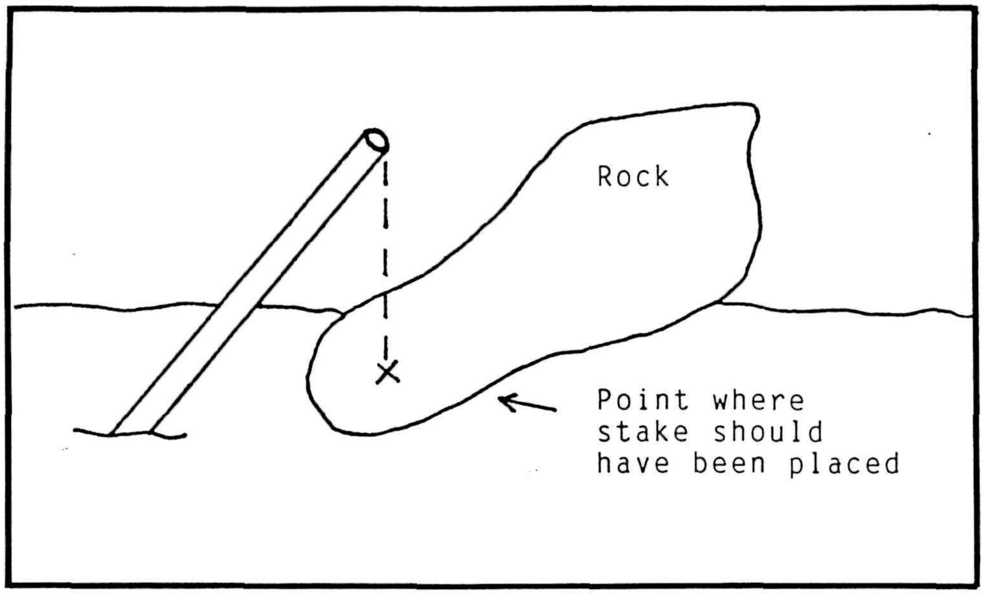


Figure 2. A stake marking plot corner (over a rock).

SITE CHARACTERIZATION

The purpose of the site description is to record the local condition of the site in terms of those topographic features which may influence stand condition and overall productivity. Slope position, landform, microrelief, elevation, aspect, and slope angle have been identified as the features of interest. The first three of these parameters are subjective but can be easily determined after obtaining a grasp of the basic concepts and with proper field training. The latter three are quantifiable. Methodologies for their determination are provided below.

Slope Position

Six distinct slope positions can be identified. They are summit, shoulder, backslope, footslope, terrace, and bottom or floodplain (Figure 3). The summit is the highest point of a landform. It may be narrow or broad but always serves as a drainage divide. The shoulder is defined as the transitional zone between the summit and backslope, It is always convex and is the slope position with the greatest erosional loss. The backslope is the main or mid portion of a landmass and its slope can be linear, concave, or occasionally convex.

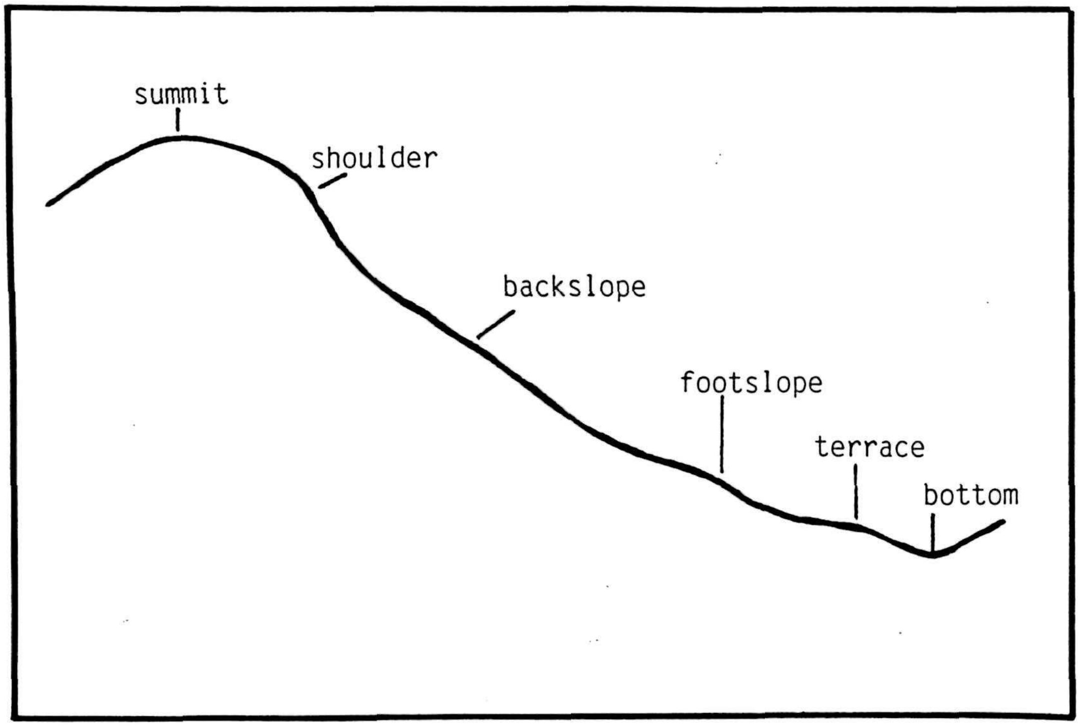


Figure 3. Six slope positions: summit, shoulder, backslope, footslope, terrace, and bottom (floodplain)

The footslope is defined as the zone between a backslope and the terrace. The footslope is normally convex and is the point of greatest colluvial deposition. A terrace is a flat or nearly level area clearly above the bottom of a drainage. The bottom or floodplain is that part of the valley floor, adjacent to the stream, that is built of sediments deposited by the stream. It is an area that is covered by water when the stream overflows its banks.

If crew size permits, three observers should independently categorize slope position. Uniform training prior to field measurements should insure consistent categorization.

Landform

Landform may be categorized into seven distinct forms (Figure 4). Ridgetop refers to the primary ridge of a mountain system. A spur ridge is a secondary, lateral ridge emanating from the primary ridge. A noseslope is a slope with a diverging drainage pattern; headslopes have converging drainage; sideslopes have parallel drainage. A cove is a bowl-like depression at the head of a drainage. It is bounded at one end by steep-sided headslopes and open at the other. A draw is a depression open at both ends and bounded by steep sideslopes or noseslopes.

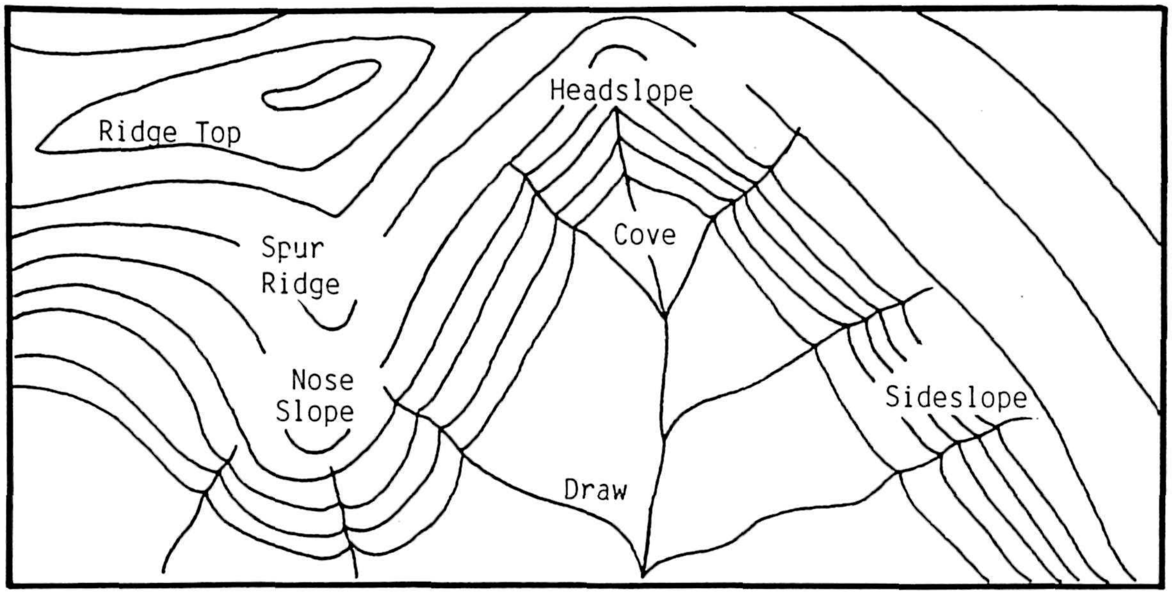


Figure 4. Seven types of landforms: ridgetop,spur-ridge,noseslope,headslope, sideslope, cove, and draw.

Microrelief

Materials List

1 - 30m. Fiberglass Surveying Tape

Microrelief is a descriptor used to convey the shape of the landscape within the plot itself. Microrelief normally can be categorized as either planar, concave or convex although some plots may need to be classed as doubly concave or doubly convex.

It is important that this determination be made both along the slope contour and perpendicular to it. In most instances microrelief will be readily apparent via quick ocular estimation. Occasionally, however, it will be necessary for two technicians to stretch a tape across the plot so that it crosses at the plot center stake. Each end of the tape must be held at equal height. The distance, at plot center, between the ground surface and the tape (center height) determines the microrelief (Figure 5). If the center height is within 1.0m. of the height of the tape at the ends, the microrelief is planar. If center height is more than 1.0m. greater than the height at the ends, it is concave. If the height at the ends is more than 1.0m. greater than the center height, or if the tape touches the ground between the two ends and therefore cannot be held straight, microrelief is convex.

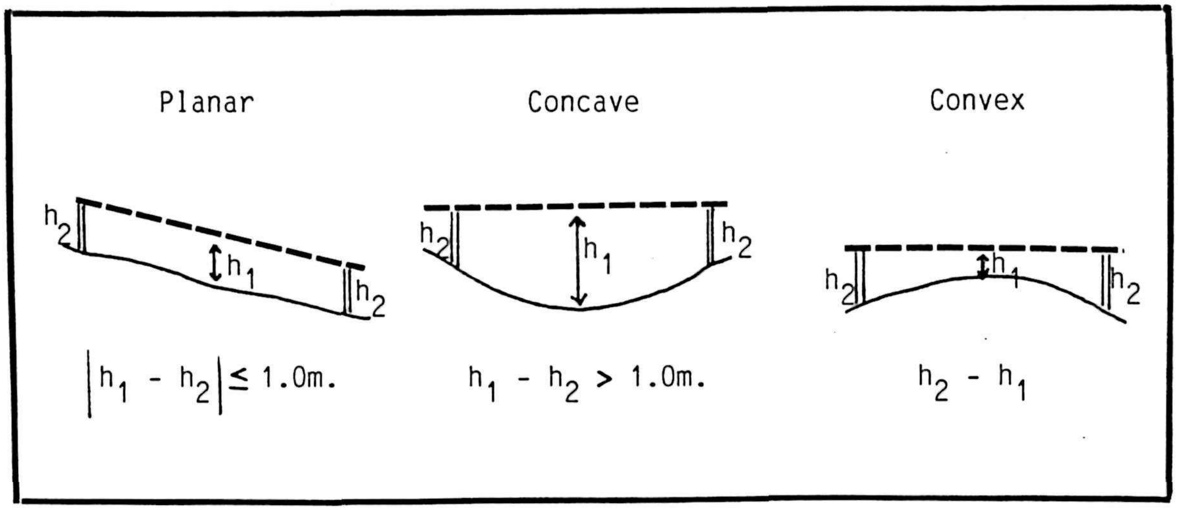


Figure 5. Three types of microrelief: planar, concave, convex

Elevation

Materials List

1 - Altimeter (minimum 20 ft. graduations)
1 - 7 1/2 Minute Topographic Map

Stand elevation may greatly influence forest condition and productivity by affecting a wide variety of site factors, the most important of which are temperature and precipitation. Perhaps of even greater consequence to the current study are orographic "cloud caps" which form near the summits of the tallest mountains. Such clouds bathe the highest elevation forests for up to 50% of the time and are known to be highly acidic.

Each day before going to the field, the altimeter should be calibrated at a point of known elevation (such as a benchmark). Calibrations should continue throughout the day whenever the technician is at a point of known elevation.

Plot elevation is determined by locating the center of the plot and standing in place with the altimeter for several minutes. The instrument should be gently tapped periodically to encourage "settling" of the indicator needle. Holding the altimeter with the needle in the 3 o'clock position will help to foster this process. Carefully read and record elevation to the nearest 10m. Comparisons should always be made on site with appropriate 7 1/2 minute series topographic maps to assure that the determination is reasonable.

Aspect

Materials List

1 - Hand Compass

Aspect is important for stand evaluation because it strongly influences the amount of solar radiation received at the plot. It will also influence exposure to prevailing winds and weather patterns; factors which may be linked to levels of atmospheric deposition.

Stand at plot center holding the compass level so that the needle swings freely. First sight on an object directly downhill, perpendicular to the contour, and record the bearing. Then sight directly uphill perpendicular to the contour. Add 180^{o} to the uphill bearing (then subtract 360 if this results in a total ½ 360^{o}). Add this adjusted uphill bearing and the downhill bearing and divide by 2 to calculate the average aspect for the plot.

When using the compass avoid proximity to any iron and steel objects including belt buckles, jewelry or wristwatches.

Slope Angle

Materials List

1 - Clinometer

The slope angle of a plot can greatly impact site attributes and thereby influence the plant community growing there. Most often affected are soil profile development, moisture retention and runoff. Insolation may be increased during certain times of the year if the plot is inclined toward the direct rays of the sun.

Several devices can be used to determine plot slope by means of measuring vertical angles. The clinometer, which is easy to obtain and relatively inexpensive, will serve in the following description. Slope is determined by sighting the clinometer along a line parallel to the line of average incline, or decline of the plot. Two technicians are needed. Technician A determines equivalent eyelevel on technician B. Technician A stands at plot center and sends technician B uphill on a line perpendicular to the contour for a distance, of at least 10m. Using the clinometer, technician A sights on B to obtain the uphill slope. The same procedure is used to measure the slope to the downhill side of the plot. The two readings are then averaged and recorded.

Clinometers are available that measure at various scales. Percent, degree, and topographic are the most common. The percent scale, however, has been denoted as the standard for slope determination by the Forest Response Program. Direct measurement of slope can, therefore, only be made with a clinometer that reads in percent. Many clinometers include two of the above mentioned scales on the same dial. When using an instrument with more than one scale, care must be taken to always read the percent scale. The use of other slope units will require that the data be converted to percent. (Formulas 2 and 3)

Degrees to Percent

$$\tan \text{slope angle in degrees} * 100 = \text{percent slope} \qquad \text{(Formula 2)}$$

Topographic to Percent

$$\text{angle in Topographic Units} * \frac{100}{66} = \text{percent slope} \qquad \text{(Formula 3)}$$

STAND CHARACTERIZATION

A thorough understanding of local stand characteristics are necessary when making inferences about the relative condition and productivity of a forest community. The primary determinants of vigor and growth are the amount of site resources (e.g. water, nutrients, and light) available to the trees. The availability of these resources is determined not only by the external conditions of the climate and site (site characteristics) but also by conditions within the stand itself. Factors such as species composition, spatial distribution, intra- and interspecific competition, and size and age distribution all influence how much water, light, and nutrients may be available for any one tree. In addition, insects and disease may play a significant role in determining nutrient allocation.

The initial phase of characterizing the forest stand is to assess individual trees within the 400m^2 plot. For the current study, trees are defined to be any arborescent flora, living or dead, which measure 5cm. in diameter at a point on the bole, 1.37m. above ground level. A total inventory of stems 1.37m. tall, or greater, regardless of diameter, may be taken depending on the goals of the investigation.

Species Composition and Spatial Distribution

Materials List

4 - PVC Pipes (minimum 1/2" inside diameter) cut to a minimum length of 35cm.
2 - 30m. Fiberglass Surveying Tapes
1 - Light Duty Hammer
  - Plastic Flagging (two colors)

The location of individual trees within the plot, as well as their species type, are required for subsequent periodic reevaluation of the sampling units. This will allow investigators to ascertain changes (growth, vigor, mortality, etc.) that take place in individuals or among taxonomic groups over time. To accomplish this, tree locations are plotted in the appropriate position on a Plot Map (Figure 6).

From the map, observe that special symbols, drawn to scale, are used to depict each species type. Circles, for example, represent red spruce while squares represent Fraser fir. Open symbols indicate living trees while dead ones are indicated by closed symbols. These symbols, along with their corresponding six letter species codes, can be found near the right margin of the Plot Map for easy reference. Identification of individual trees is further promoted by affixing them with a uniquely numbered aluminum tag.* This number is placed in parentheses next to the symbol.

The position of a tree on the ground is not easily transposed to the appropriate map position, especially when working on large-size plots. This process, however, may be facilitated by breaking the plot down into more manageable subunits. The 400m^2 area is first divided into four equal 100m^2 (10 x 10m.) "subplots" which are numbered consecutively in a clockwise fashion starting at north. Boundaries of the subplots are delineated in the field by

* For more detailed instructions see "Diameter measurement" p. 13.

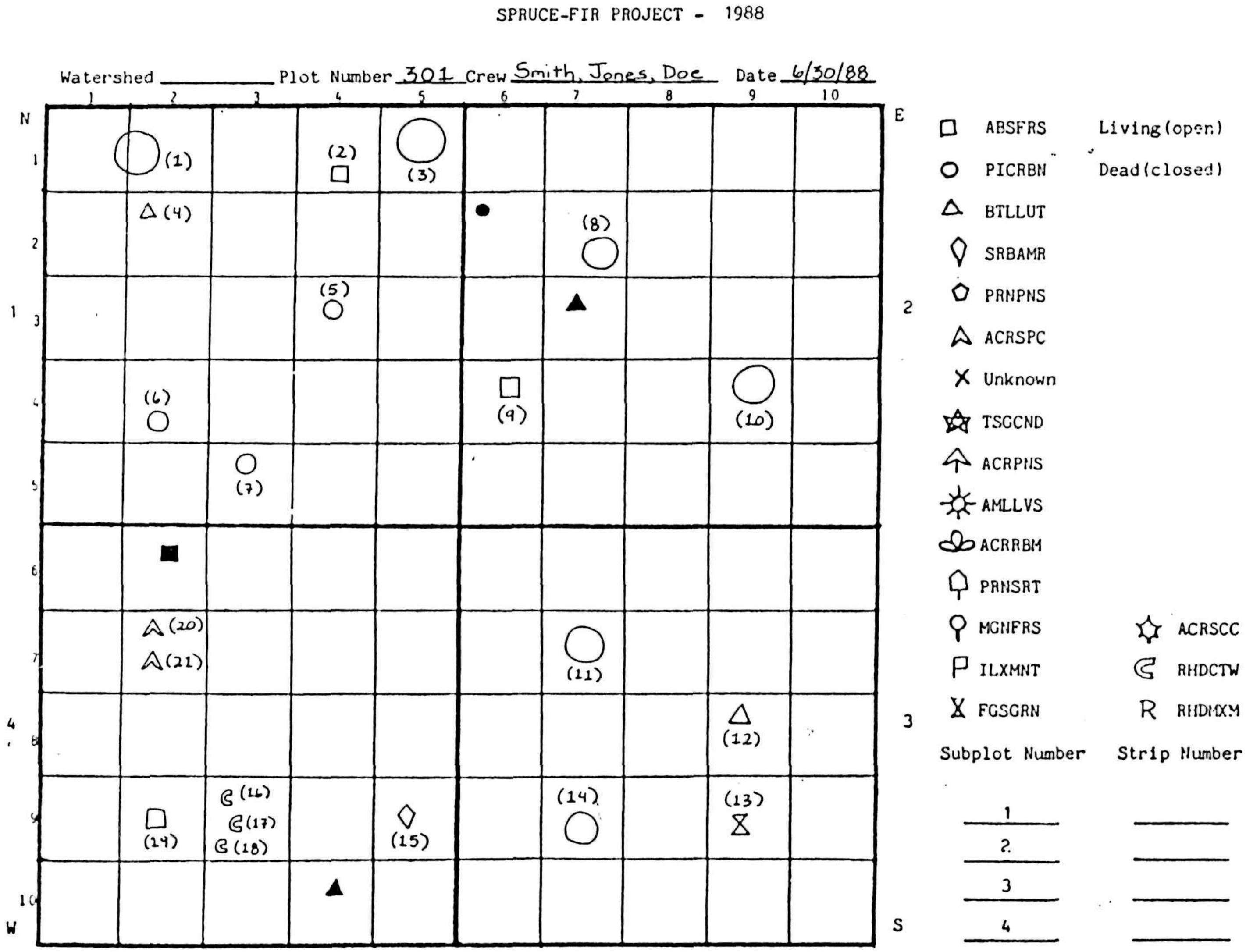


Figure 6. 400m² plot showing examples of individual tree mapping

stretching a 30m. tape across the plot from the midpoint of the N-E perimeter line to plot center and then to the midpoint of the S-W perimeter line. A second 30m. tape is next layed out from the midpoint of the S-E perimeter line, across plot center to the midpoint of the N-W perimeter line. These subplot boundaries are depicted on the plot map as boldface "crosshairs." (Note: perimeter midpoints are always permanently monumented with PVC stakes.)

Each $100m^2$ subplot is further divided into 25 2 x 2m. "quadrats." These appear as a small, square grid system on the map. The quadrat boundaries are not actually installed in the field with measuring tapes as are the boundaries for the other sampling units. This would require too much time. Instead, flagging may be tied along both the outside perimeter and inner crosshair tapes at slope-corrected, 2m. intervals. Using this system, the technician can easily determine the relative position of a tree within a subplot by counting flags along the tape.

Quadrats are used in a similar fashion to plot the location of standing dead trees. Since dead trees do not receive aluminum tree tags, their precise field position must be fixed through the use of an address system. This entails matching the tree symbol with the appropriate row and column numbers in much the same way mathematical relationships are plotted graphically using x-y coordinates. In this case, the N-W perimeter line represents the x-axis 10 columns (quadrats) wide, and the N-E perimeter line represents the y-axis 10 rows (quadrats) high. Referring once again to the plot map, our sample shows a dead fir in subplot 4. The proper address for the tree would be column 6, row 2. This would be entered on the tree data sheet simply as: (6,2).

Size and Age Parameters

Diameter at Breast Height (dbh)

Materials List (per person)

1 - Steel Diameter Tape, calibrated in centimeters (cm) and millimeters (mm)
1 - Measuring Pole, permanently marked at 1m. and 1.37m.
1 - Grease Pencil, Lumber Crayon, or China Marker
1 - Light Duty Hammer
  - Aluminum Tree Tags (uniquely numbered)
  - Aluminum Nails (#7 siding nails)

Tree diameter measurements are the most commonly collected size parameters in forest inventory work. Diameters can be used to predict basal area, density, volumes, and product potential of trees, as well as being used for inventories to establish change in these parameters over time.

Diameter measurements are taken at breast height and are therefore commonly referred to as dbh. Dbh is taken at 1.37m. above the ground level since this is a convenient working height for most people. These measurements are made outside bark (dob).

The initial step in measuring dbh is to determine the appropriate point on the bole from which to take the measurement. Remember that the only trees of interest are those which are living, are 1.37m. tall, and have a dbh of 5cm. or greater. The measuring pole is placed against the tree, and the technician uses a grease pencil to carefully mark the 1m. and 1.37m. levels directly on the bark. When in sloping terrain, it is imperative that the pole be placed on the tree's uphill side. The diameter measurement is obtained by stretching the tape around the trunk precisely at the 1.37m. mark. It should be positioned so that it encircles the stem in a plane perpendicular to the tree's vertical axis. The tape should be pulled taut and checked to see that there are no sags before reading the measurement. Dbh is recorded to the nearest mm.

With any kind of plot work where dbh is periodically re-evaluated, it is important that future technicians be able to easily identify each individual tree and that measurements are taken at precisely the same place on the trunk. Consistency is crucial in obtaining meaningful biological data. As has been seen, mapping trees is one way of assuring relocation. Permanently marking them with aluminum tags is another. Furthermore, if these tags are placed at equivalent heights on all tallied trees, it is also possible to assure that dbh's are obtained from the same spot on the tree each year.

In spruce-fir sampling, for instance, the technician uses a measuring pole and grease pencil to mark the stem at 1m. on the uphill side. The aluminum tag is installed with an aluminum nail at exactly that spot. Succeeding workers can then simply use a 0.37m. long measuring stick, place it atop the aluminum nail and be assured that the top of the stick indicates the exact point where the original dbh was taken. For the most accurate results the nail must be oriented perpendicular to the vertical axis of the tree and pounded in no more than 2.5cm.

In cases where stem abnormalities such as swellings, burls, depressions, or branches prevent an accurate dbh measurement, diameters are taken immediately above the irregularity at a place where it ceases to affect the normal stem form.

If a tree forks above the dbh level, diameter is measured below the swelling at a place where the fork no longer distorts the bole. When the stem forks below dbh, the tree is considered as two or more distinct individuals. Each stem is measured at 1.37m. and given a separate aluminum tag. Tagging does not present a problem as long as the fork occurs below both dbh and the 1m. point. Standard tagging procedures apply. On rare occasions, however, where a tree forks below dbh but the fork occurs above the 1m. mark, special rules must come into play. In such instances, tags are affixed 15cm. below the diameter point.

Leaning trees, no matter how severe the lean, are measured and tagged as long as they are still living. In super-humid climates even partially uprooted trees may survive for long periods of time and therefore continue to play a role in the dynamics of the plot.

Figure 7 illustrates procedures for dbh measurements in a variety of situations. Figure 8 shows how tags should be placed when stems are forked below breast height.

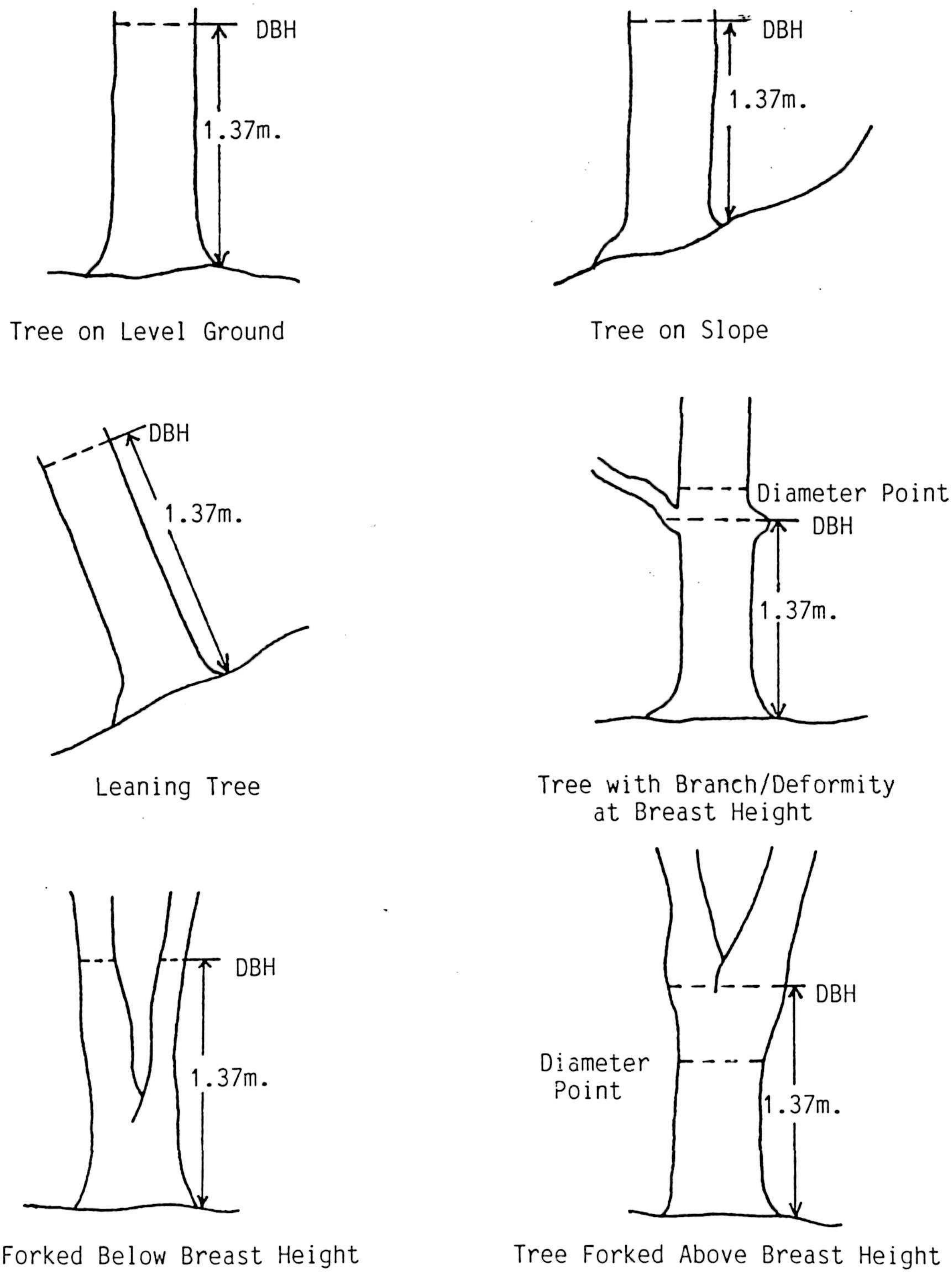
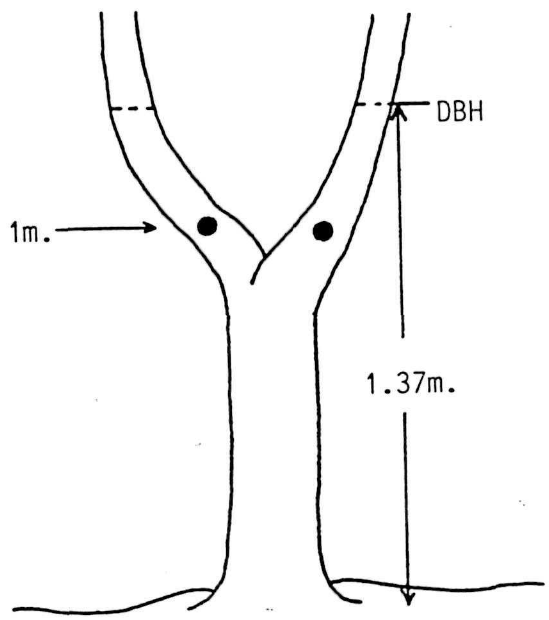


Figure 7. DBH measurements and determination of proper diameter point

Situation I:

When the tree forks below the 1.37m. diameter point and below 1m., tags are affixed to both stems at the 1m.



Situation II:

When the tree forks below the 1.37m. diameter point but the fork occurs above the 1m. mark, tags are placed 15cm. below the diameter point.

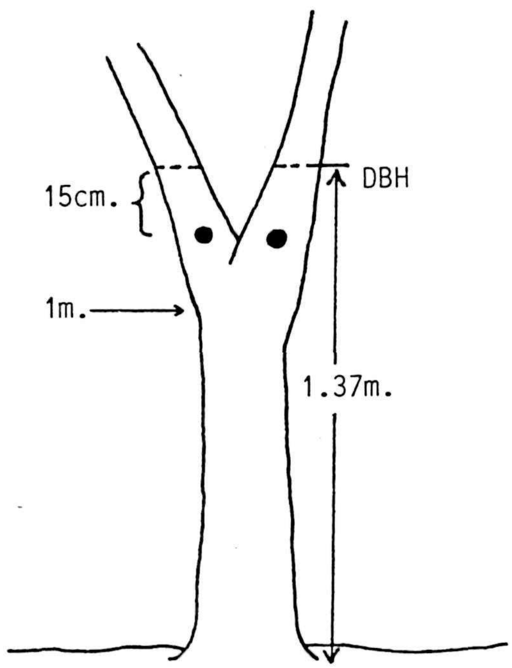


Figure 8. Tagging rules for forked stems

Tree Height

Materials List

1 - 50m. Fiberglass Surveying Tape
1 - Clinometer (or equivalent)
1 - Telescoping Fiberglass Height Pole (optional)

Tree height is used to establish site index, calculate volume, ascertain live crown ratio and to determine height growth over time. It is an ambiguous term unless clearly defined. Generally, tree height means the vertical distance between ground level and some point on the tree. Total live height refers to the distance between the ground and the top of the live crown. Other height variables such as merchantable height, bole height, height to dead top, etc. must otherwise be specified by the individual investigator.

In the current study, ten tagged trees are selected at random on each permanent plot and measured for total height. The heights of small trees can be measured directly through the use of telescoping height poles. While very accurate, the poles are often cumbersome to use. One technician positions the pole as close as possible to the uphill side of the stem while an observer walks to a point where both the top of the tree and pole are clearly visible. When the height of the extended pole coincides exactly with that of the tree, the observer informs the first technician and the scale is read.

Height measurements of tall trees are most easily obtained through indirect methods using instruments called hypsometers. Hypsometer measurements are based on trigonometric principles and employ the relationships which exist between the sides and angles of right triangles. Perhaps the most commonly used hypsometer in forest assessment work is the clinometer. With this device, the vertical angles 1 and 2 depicted in Figure 9 are determined by sighting first to the top of the crown and secondly to the base of the trunk. If the horizontal distance (D) is also known, the vertical segments BC and CA can easily be calculated.

When determining tree heights in the field, the first step is to locate an appropriate point from which to sight the tree with the clinometer. For most accurate results: 1) the sighting point should offer a clear view of the entire tree, 2) whenever possible, the point should lie on approximately the same topographic contour as the tree of interest, 3) trees should not lean more than 10% from the vertical, 4) leaning trees should be measured at right angles to the direction of the lean, and 5) clinometer readings to either the top or base of the tree should never exceed 90% due to the inaccuracies of the instrument at such steep angles.

Once this has been accomplished the horizontal distance (D) from the tree to the sighting point must be determined. Technician B holds the "zero end" of the 50m. surveying tape on the midpoint of the side of the tree at eye level, while the instrument operator walks with the "smart end" of the tape to the pre-determined sighting point. After making sure the tape is perfectly straight, the instrument operator holds the tape at an equivalent eye level, pulls it taut, and reads the distance. Technician B then records the measurement.

In nearly all cases, except where the terrain is completely level, the taped distance between the tree and the sighting point will have to be converted from slope distance to an equivalent horizontal distance. The average slope (obtained via clinometer measurement) is first entered into Formula 4 to derive the appropriate correction value.

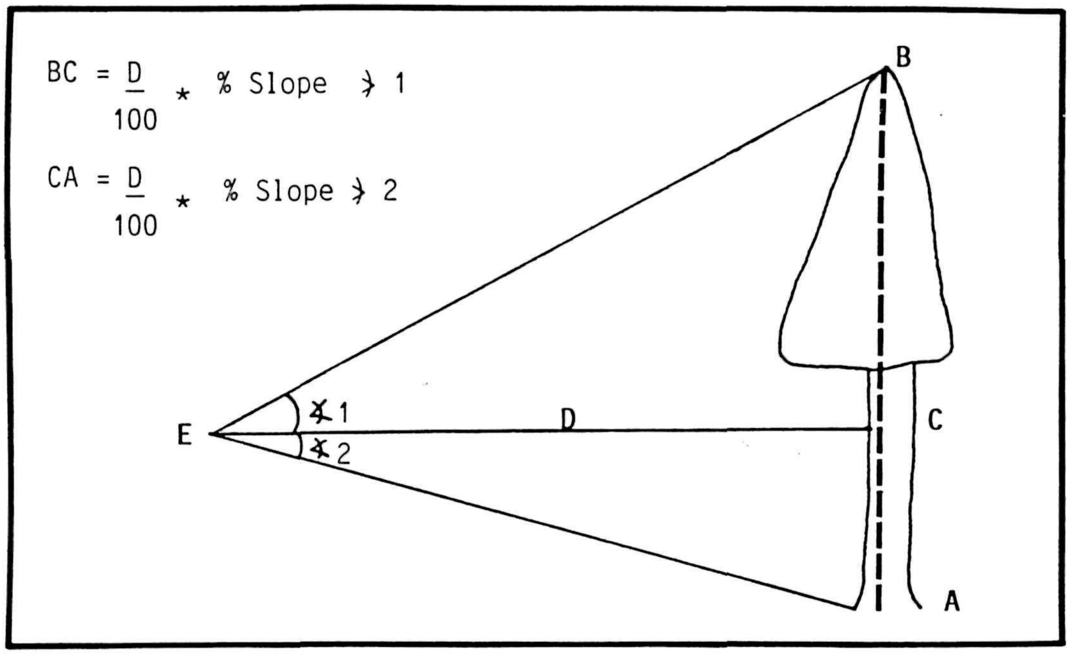


Figure 9. Application of trigonometric relationships of right triangles pertinent to tree height measurement (After Husch, Miller, Beers 1972)

$$\text{Slope Correction Factor (slope to horizontal)} = \cos \ \arc\tan \frac{(\%\ \text{slope})}{100}$$

(Formula 4)

The result is then multiplied by the slope distance to obtain the corresponding horizontal distance.

$$\text{Horizontal Distance} = \text{Slope Correction Factor (slope to horiz.)} * \text{Slope Distance}$$

(Formula 5)

The final set of measurements needed for height calculation are the angles to the top and base of the tree. While standing perfectly erect at the sighting points, the instrument operator uses the clinometer to carefully shoot both angles. Technician B then records the values. Once in from the field, the data for each individual tree is entered into a calculater equipped with trigonometric functions and the height determined. Final figures should be reported to the nearest 0.1m.

Two examples are provided below to illustrate the procedure.

Example 1

Assuming the following results from the field, what is the total height of the tree?

Slope distance = 18m.
Slope angle = -11%
Angle to top of tree (∠1) = +28%
Angle to base of tree (∠2) = -19%

Step 1 - Horizontal Distance Determination:

$$\text{Slope Correction Factor (slope to horiz.)} = \cos\ \arctan \frac{-11\%}{100} = 0.994$$

Horizontal Distance = 0.994 * 18m. = 17.89m.

Step 2 - Tree Height Determination:

From formulas in Figure 8,

$$BC = \frac{17.89\text{m.}}{100} * 28 = +5.01\text{m.}$$

$$CA = \frac{17.89\text{m.}}{100} * -19 = -3.40\text{m.}$$

Since the calculated values have opposite signs they must be added to obtain total height. Total height of the tree in Example 1 is therefore 8.41m. This figure is rounded to 8.4m.

Example 2

Slope distance = 22m.
Slope angle = -35%
Angle to top of tree = -6%
Angle to base of tree = -44%

Step 1 - Horizontal Distance Determination:

$$\text{Slope Correction Factor (slope to horiz.)} = \cos\ \arctan \frac{-35\%}{100} = 0.944$$

Horizontal Distance = 0.944 * 22m. = 20.77m.

Step 2 - Tree Height Determination:

$$BC = \frac{20.77\text{m.}}{100} * -6 = -1.25\text{m.}$$

$$CA = \frac{20.77\text{m.}}{100} * -44 = -9.14\text{m.}$$

Since the calculated values have like signs (in this case both negative) the smaller is subtracted from the larger to arrive at a total height of 7.89m. The reported value would then be 7.9m.

Cannot View Base of Tree from Sighting Point: Occasionally the lower portion of the tree bole will be obscured by dense understory vegetation. In such situations, an accurate measure of the angle to the base of the tree is difficult to obtain. A brightly colored target waved at ground level will sometimes allow the clinometer operator to get a sighting, but more often a height pole or other vertical target of known length must be used. Referring to Figure 10, technician B holds a vertical target next to the tree such that the top of the target is visible to the clinometer operator. The angle to the top of the tree (1) is taken using standard methods. This is followed by a determination of the angle to the top of the target (2) in order to derive the height of segment BC. BC is then added to the known height of the target to obtain total tree height.

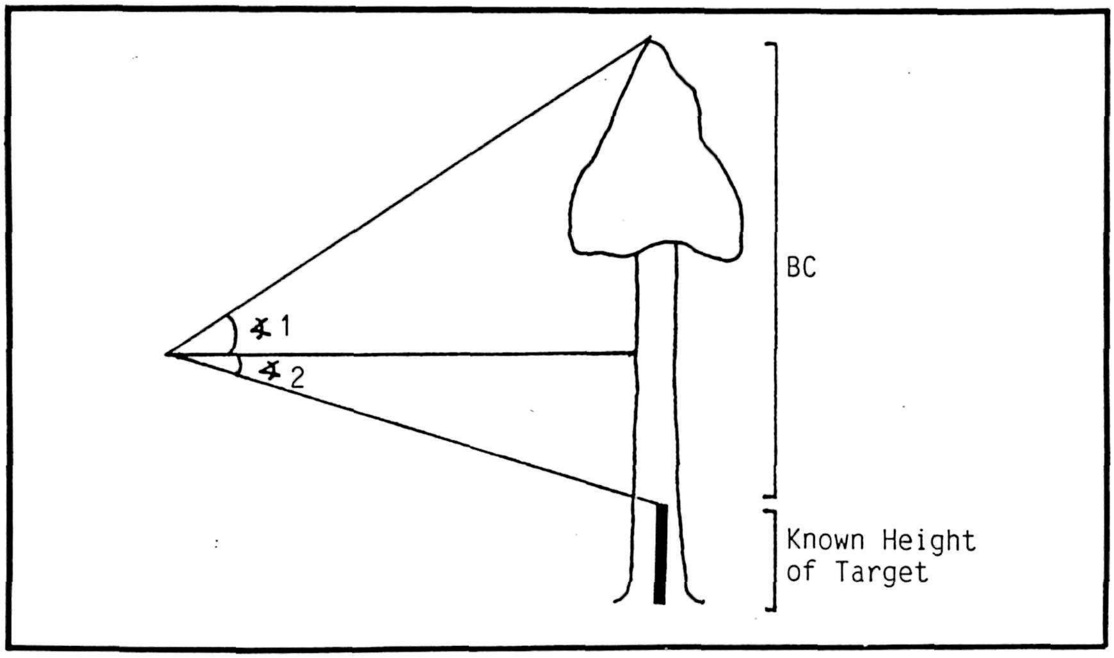
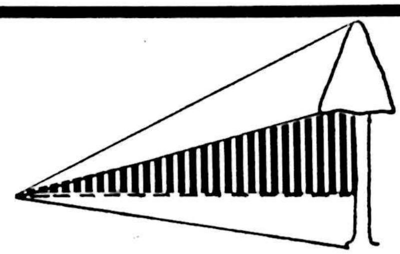
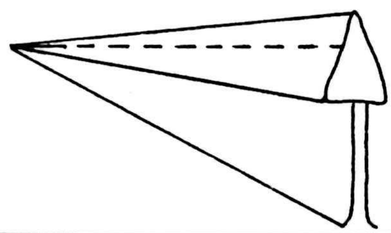
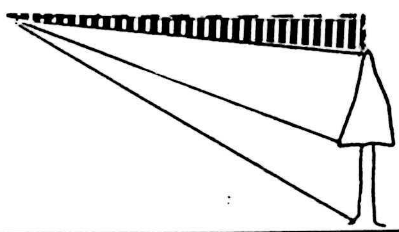


Figure 10. Use of sighting targets as an aid for measuring tree heights in dense cover

Crown Height

Live crown height along with crown width measurements (see p.) are necessary for biomass determinations and for ascertaining the photosynthetic potential of individual trees. Trees having large crowns are able to produce greater quantities of carbohydrate and are therefore more productive than their smaller-crowned counterparts. Crown heights are easily derived by using the same field methods described for tree height. Crown height determinations, however, require obtaining an additional clinometer measurement - angle to the crown base. The crown base is defined as the point at which the lowermost limb intersects the bole of the tree. Small limbs which contribute little to the tree's productivity are disregarded. Table 2 details the relationship necessary to calculate crown height. The table is followed by an example from the field.

Table 2. Rules for Crown Height Determination

Situation		Solution
	When Angle to the Crown Base is Positive	Height to the Top Minus Height to the Crown Base
	When Angle to the Crown Base is Negative	Height to the Top Plus Height to the Crown Base
	When Angle to the Top and Crown Base Both are Negative	Height to the Crown Base Minus Height to the Top

<u>Example 3</u>

Slope distance = 31m.
Slope angle = +2%
Angle to top of tree = +74%
Angle to bottom of tree = -3%
Angle to crown base = +35%

<u>Step 1</u> - Horizontal Distance Determination:

Slope Correction Factor (slope to horiz.) = $\cos \arctan \frac{+2\%}{100} = 0.99$

Horizontal Distance = 0.99 * 31m. = 30.99m.

Step 2 - Tree Height Determination:

$$\text{Height to Top} = \frac{30.99\text{m.}}{100} * +74 = +22.94\text{m.}$$

$$\text{Height to Base} = \frac{30.99\text{m.}}{100} * -3 = -0.93\text{m.}$$

opposite signs therefore add the two values

Tree Height = 23.87m. or 23.9m.

Step 3 - Crown Height Determination:

$$\text{Height to Crown Base} = \frac{30.99\text{m.}}{100} * +35 = +10.85\text{m.}$$

Since the height to the crown base is positive, subtract this value from height to the top to derive crown height (refer to Table 2.)

Crown Height = 22.94m. - 10.85m. = 12.09m. or 12.1m.

Occasional trees will be found to have dead tops owing to a variety of biotic and abiotic factors. In these instances it is necessary to calculate tree height to both the live and dead top. To accomplish this, shoot the angles to each of these points and use standard procedures to make the appropriate calculations.

Crown Width

Materials List

1 - 30m. Fiberglass Surveying Tape
1 - Hand Compass

Total crown width is determined by measuring the tree crown in the north-south and east-west planes and then averaging the two values. Technician 1, while standing at the base of the tree to be measured, uses the compass to determine a north-south line. A second technician then aides technician 1 in stretching a tape out along the north-south line until each has reached the outer extremity ("drip line") of the crown. The same procedure is then repeated for the east-west line. When taking these measurements it is important to assure that the tape is being held horizontally and that the position of "drip line" has been accurately determined. The use of a third technician standing some distance away can greatly facilitate this process.

Tree Age

Materials List

1 - Increment Borer (minumum 18 in. length)
  - Beeswax
  - Plastic Storage Straws

Increment cores are used to determine tree age, growth dynamics, to assess factors affecting growth or to establish climatological patterns. Cores may also be used for chemical analysis. In the current study the primary use of the cores is to approximate stand ages, and further, to determine regional growth trends among southern Appalachian red spruce. To meet this end, cores are extracted from five (5) dominant or codominant spruce trees per plot. These are trees whose diameter, total height, and crown width dimensions have been determined. Annual growth rings are tallied and growth increments are assessed by qualified personnel.

When attempting to determine tree age it is desirable to sample the tree's center ring. It is rare, however, that the geometric center of the tree is also where the pith is positioned. This often makes sampling difficult, especially for beginners. For those readers who have never taken increment cores, Phipps (1985) provides a very helpful and thorough description of the process. For the more experienced, a generalized discussion of the procedure is provided below.

Before starting, beeswax is applied to the threaded end of the increment borer bit to reduce friction. Excess heat can cause metal fatigue and eventual bit breakage. The borer is inserted into the tree 15cm. below the dbh point in order to prevent resin flow or stem swelling from interfering with future diameter measurements. Coring is always done perpendicular to the vertical axis of the tree. If the tree being sampled is on a slope, the core should be taken parallel to the slope (on slope contour) to reduce, as much as possible, growth distortions caused by tension or compression wood. Similarly, if a tree is leaning, the core should be extracted 90 degrees from the direction of the lean to diminish the effect of irregular growth rings.

Rarely is it possible to hit the tree's pith with the first core sample. This first core though can provide very useful information that allows the technician to "zero in" on the pith on the second attempt. Before extracting the first core, turn the borer handle counter-clockwise 360 degrees. This not only loosens the core but also leaves it in the same position it was when attached to the tree. When the core is removed, the arc of the growth rings near the tree's heart indicate whether the botanical center is to the left or right of the original core hole. The distance to the biological center can also be approximated by studying the arcs. Remove the first core from the extractor and place it back in the tree. On the second attempt orient the borer to compensate for the initial distance and directional errors. Be sure though that the second core hole does not intersect with the first. This will result in a core that is either broken or missing several pieces. It is always prudent to take the second core up or down the stem a few centimeters to ensure there is sound wood into which the borer can dig.

Whenever a core is removed from a tree it must be carefully examined. Close inspection may reveal defects which make them unsuitable for laboratory analysis. Distorted growth rings due to embedded branch traces or adventitious buds are typical of such defects. Other factors such as fungal infection or insect infestation may also be present. It is better to discover an unsuitable core in the field than in the laboratory.

One person should be designated to be in charge of sample custody until the cores have been delivered to the laboratory. It is this person's responsibility to make sure that each collected core is securely placed into a protective plastic straw or commercial core holder and marked with the appropriate information including date, plot and tree tag numbers. (Throughout the entire procedure it is imperative that all cores be maintained in good condition and with no mixup.)

Once in from the field the core samples are removed from their holders and mounted on sturdy cardboard sheets to allow them to air dry. It is advisable to use plenty of tape when attaching them to the cardboard to reduce warping. After the cores have dried thoroughly (3-5 days) each is removed from the cardboard and glued into a grooved, wooden mounting block. Mounting blocks can easily be made using 1/2 x 1/2 in. pine laths and routing them to fit the cores. This should be done in such a way that approximately 1/2 to 1/3 of the core's diameter is raised above the level of the mounting block. This will allow the cores, once firmly glued in place, to be sanded down flush with the block to permit easier increment analysis.

Tree Condition

The bulk of the information presented thus far has been aimed at characterizing overall stand parameters in terms of species composition, spatial distribution and size and age parameters. The next section focuses on the topic of individual tree condition with respect to pollution injury and how to assess the damage.

Although the mechanisms by which atmospheric pollutants harm trees have not yet been fully explained, they are assumed to interact through both direct and indirect pathways. Indirect pathways might, for example, include altered water and nutrient balances due to acid leaching of nutrients from the rooting zone. Apart from such soil mediated processes, direct pathways involve degradation of plant tissues which are in direct contact with the polluting agent. Acids which occur in rainfall and are commonly found in cloud mist, result in damage to exposed tissues and leaching of foliar nutrients.

Needle loss (crown thinning) has, for over a decade, been used as a tool by forest ecologists to assess the relative decline of coniferous forests in relation to both direct and indirect pollution injury. This is due almost entirely to the fact that needle loss is a readily observable trait and is therefore quick and easy to quantify. Major drawbacks, however, are encountered with assessments of this kind since they are highly subjective and open to much interpersonal bias. Furthermore, needle loss cannot always be correlated with pollution injury alone. A large number of other perturbing factors including wind, ice, drought, insects and pathogens can all produce similar effects. It is because of such limitations that needle loss ratings are applied only in a general sense to describe changes in tree condition over time. Only after a thorough study of all other intervening factors is made can pollution injury be considered to have occurred.

Crown Condition (Coniferous species only)

Because of the subjective nature of crown condition assessments, it is imperative that well-defined decline classes be established and clearly understood before field work begins. The current study uses a classification system that was originally developed by the Germans for their appraisal of "Waldsterben" in The Black Forest region. It has been modified somewhat to accommodate the different decline symptomology and speciation found in our eastern spruce-fir forests.*

Table 3. Crown Decline Classes for Eastern Spruce-fir Forests

Crown Class	Notation	% of Crown Exhibiting Needle Loss
1	None or Slight	0 - 10%
2	Moderate	11 - 50%
3	Severe	½ 50%
4	Recent Dead	-
5	Old Dead	-

To promote the "mental imaging" of each decline class, field personnel should be provided with a set of standard color photographs. The photo standards ideally should depict the entire range of defoliation possibilities. In addition, trees should be photographed over a wide variety of lighting conditions since their appearance can change quite dramatically depending upon whether they are viewed in full sun, overcast skies, or in dense fog. Similarly, the time of day or even the time of year at which the tree is observed may affect the appearance of the crown. Although these variables cannot be controlled, an awareness of them, in conjunction with a strong training program prior to the initiation of field work, will greatly reduce the potential for error.

Once on site a visual assessment of each tagged spruce and fir tree crown is made by two trained observers. Observers should have an unobstructed view of the crown from a distance of no less than one tree length away. They should also view the tree from as many different locations as possible to get a true picture of the crown. In sloping terrain, assessments should be made from the uphill side of the tree. At no time are downhill vantage points acceptable. If the observers' initial estimates do not fall within the same class, the crown is reevaluated until they are in agreement. If a concensus cannot be reached a third observer should be called in to break the tie.

* Very little is known about pollution symptomology of high elevation broad-leaved species. Because meaningful decline classifications currently do not exist, crown condition assessments on these taxa were omitted from the study.

Crown Position

Crown position is a parameter which describes the relative placement of each individual tree crown within the forest canopy. Trees are normally thought of as falling into one of four crown position classes - dominant, codominant, intermediate, and suppressed. A description of each of these classes is provided in Table 4. Figure 11 illustrates the classes.

The position of a tree's crown in relation to that of its neighbors reflects its status in the intense competition for light, moisture, and nutrients. Such factors become important when trying to ascertain the productivity and health of forest ecosystems. Suppressed stems for example, even those of shade tolerant species such as spruce and fir, are less productive than their dominant counterparts. Understory trees, if suppressed for long periods of time possess crowns which become increasingly misshapen and restricted in size. Reduction in photosynthetic area results in small root systems and the diminution of diameter growth. Reduction in height growth may also occur through these same mechanisms and also through physical barriers presented by overtopping vegetation.

Table 4. Crown Position Classification (after Smith 1962)

Dominant: (D)	Trees with crowns extending above the general level of the crown cover and receiving full light from above and partly from the side; larger than the average trees in the stand, and with crowns well-developed but possibly somewhat crowded on the sides.
Codominant: (C)	Trees with crowns forming the general level of the crown cover and receiving full light from above but comparatively little from the sides; usually with medium-sized crowns more or less crowded on the sides.
Intermediate: (I)	Trees shorter than those in the preceding classes but with crowns extending into the crown cover formed by codominant and dominant trees; receiving a little direct light from above but none from the sides; usually with small crowns considerably crowded on the sides.
Suppressed: (Overtopped) (S)	Trees with crowns entirely below the general level of the crown cover, receiving no direct light, either from above or from the sides.

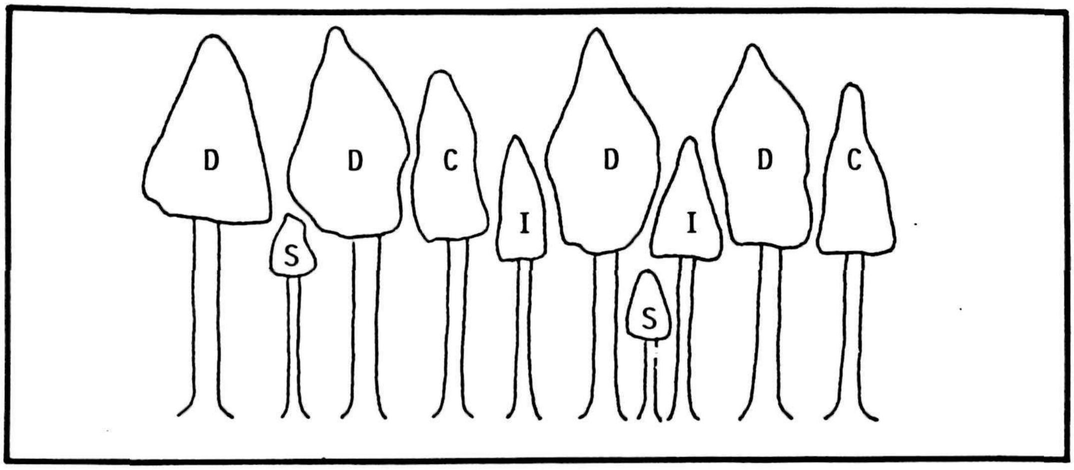


Figure 11. Crown position classes. D = dominant, C = codominant I = intermediate, S = suppressed

In uneven-aged stands another very important relationship exists between crown position and appearance of the crown. Typically, suppressed spruce and fir possess not only short, misshapen crowns, but also have a totally different needle morphology than dominant and codominant individuals. Overtopped trees growing in deep shade exhibit long, thin needles which tend to give their crowns a naturally sparse appearance. Dominant and codominants, whose crowns are exposed to direct sunlight and dessicating winds, develop tightly packed needles which are thick-bodied and rather short by comparison. This needle form tends to make these trees appear more densely foliated, and to the untrained eye, perhaps more "healthy."

It is critical that all field personnel be trained to recognize the confounding influences that crown position can impose on tree physiognomy and take these into account whenever crown condition classes are assigned. The temptation to automatically give small crowned, thin needled trees inferior condition rankings should be avoided since this may be their normal state.

Biotic and Abiotic Disturbance Factors (All Species)

In the effort to relate tree crown degradation with pollution injury it has been shown how the effect of crown position can complicate the analysis. Similarly, a wide spectrum of other biotic and abiotic perturbations which lead to significant foliar loss must be considered in order to yield meaningful crown condition data. Technicians need to be trained to recognize disturbance factors and constantly keep them in mind during the evaluation process. Whenever they occur, the nature and extent of injury should be carefully recorded so that these may be considered in the final interpretation of the data.

While it is not the intent of this manual to describe in detail all possible factors leading to tree decline, the following table provides some of the most commonly encountered causes of damage found in southern Appalachian spruce-fir forests.

Table 5. Common Abiotic and Biotic Perturbances in Southern Appalachian Spruce-Fir Forests Causing Symptom Complexes Similar to Those Induced by Air Pollutants

Source of Damage	Affected Species	Nature of Damage
Frost/Wind Crack	All species	Continuous or intermittant stem cracks and seams running either spirally or straight. Copious resin flow often present.
Lightning Crack	All species	Bark stripping, cracking, or exploded stem with damage running spirally or straight from strike point normally to the ground. Tops deteriorate from root damage or breakage.
Ice/Snow Breakage	All species	Broken twigs, limbs and occasionally entire stems. Most commonly occurs on windward side of trees situated on exposed sites. Damage is often widespread over a given area. Also includes tree "flagging" where one side of the stem may be completely sheared of branches by the abrading action of wind blown ice crystals and dessication.
Cold Injury	All hardwoods (Occurs in eastern spruce and fir but not confirmed in southern Appalachians)	Symptoms vary depending on species when freezing temperatures occur. Spring frosts normally cause succulent twigs and foliage to turn black or brown. Fall frosts may cause premature autumn coloration, wilting, or abscision of green leaves. Remaining foliage may have light brown margins. Dead wood usually persists in crown for several years.
Drought Injury	All species	Various wilting symptoms such as drooping or cupped leaves, pendant needles, and tip dieback. In severe instances, reduced leaf and needle retention and eventual defoliation.

Table 5. (continued)

Source of Damage	Affected Species	Nature of Damage
Balsam Woolly Adelgid	Fraser Fir	Minute sucking insect which produces small white masses that are evident on mid and upper trunk. Stem and crown feeding gives rise to gouting syndrome which results in swollen stems and enlarged nodes and buds. Gouting reduces growth of new foliage by inhibiting the conduction of water and nutrients. Affected trees often assume a flat-topped appearance. Heavy and repeated infestation causes mortality in 2-6 years. Recently killed trees normally retain fire-red needles for 1-2 years.
Mountain-Ash Sawfly	Mountain Ash	Small, light yellowish-green larvae (to 2.5cm.), marked dorsally with black spots. Causes partial to complete defoliation. Only leafy tissue is consumed so rachises and leaflet midveins persist. Frass often present beneath infested trees. Persistent, severe attacks weaken trees and may cause eventual mortality.
Miscellaneous Animal Damage	All Species	Bark rubbed away from lower portion of stems either in patches or entire girdling of small diameter trees (deer). Succulent leaves and shoots clipped off or broken (deer, red squirrel). Bark stripped away usually in a single patch 1-1.5m. above ground level; tooth and claw marks present (black bear). Horizontal rows of small holes often encircling stems primarily of black cherry, pin cherry, beech, sugar maple, and birch (sapsucker).

Understory Sampling

Shrubs and Saplings

Detailed community characterization measurements are dependent not only on evaluating canopy class individuals but woody understory components as well. Changes in understory species composition, density, and productivity are major areas of interest for this study, particularly in light of the transformations which could occur here due to degradation of the overstory. Since change can only be detected through precise periodic reevaluations, much emphasis needs to be placed on laying out the sampling units to insure that the same area is studied from one year to the next.

Sub-sampling Layout

Because of the large number of stems which may be involved, it is impractical to conduct a total inventory. Instead, understory shrubs and saplings are systematically sub-sampled within the $400m^2$ plot. Before going to the field, three of the four subplots are randomly selected for sampling. From Figure 12 it can be seen that each subplot potentially contains five 2 x 10m. strips. (In most instances their linear dimensions will be somewhat greater due to corrections for slope.) This is reduced to four 2 x 8m. strips since a 2m. wide band on either side of the inner cross-hair tapes is reserved as a "travel lane." This allows technicians to move freely about without the worry of trampling vegetation which is to be sampled. Of these four strips only one strip per subplot is actually chosen for inventory. Again, this selection is randomly made.

To permanently mark the strips, 1/4" PVC pipes, cut to approximately 35cm., are hammered into the ground at the proper slope-corrected locations. Thirty meter tapes can easily be stretched from the interior strip stakes positioned along the cross-hairs and out to the opposite stakes on the plot perimeter.

Again referring to the example presented in Figure 11, note that subplots 1,2 and 4 containing strips in positions 1,3 and 4 have been randomly chosen for sampling. Closer inspection reveals that each 2 x 8m. strip is further subdivided into four 2 x 2m. quadrats. Each plot is therefore composed of 12 2 x 2m. units equalling $48m^2$ or 12% of the total plot area. Delineating the quadrats in the field is best accomplished by laying height poles, dbh poles or other suitable markers perpendicularly across the strips at slope-corrected 2m. intervals. Numbering of these quadrats, as with the strips, originates from plot center and proceeds outward towards the periphery.

The quadrat represents the primary sampling unit from which shrub and sapling characterizations are derived. Each live woody stem which is ½ 1.37m. tall and ¼ 5cm. dbh is evaluated for species and measured for total height, crown height, average crown width and basal diameter or dbh. Dead individuals are assessed for species, total height and stem diameter only. A brief description of the methodology used to obtain each of these parameters is provided below.

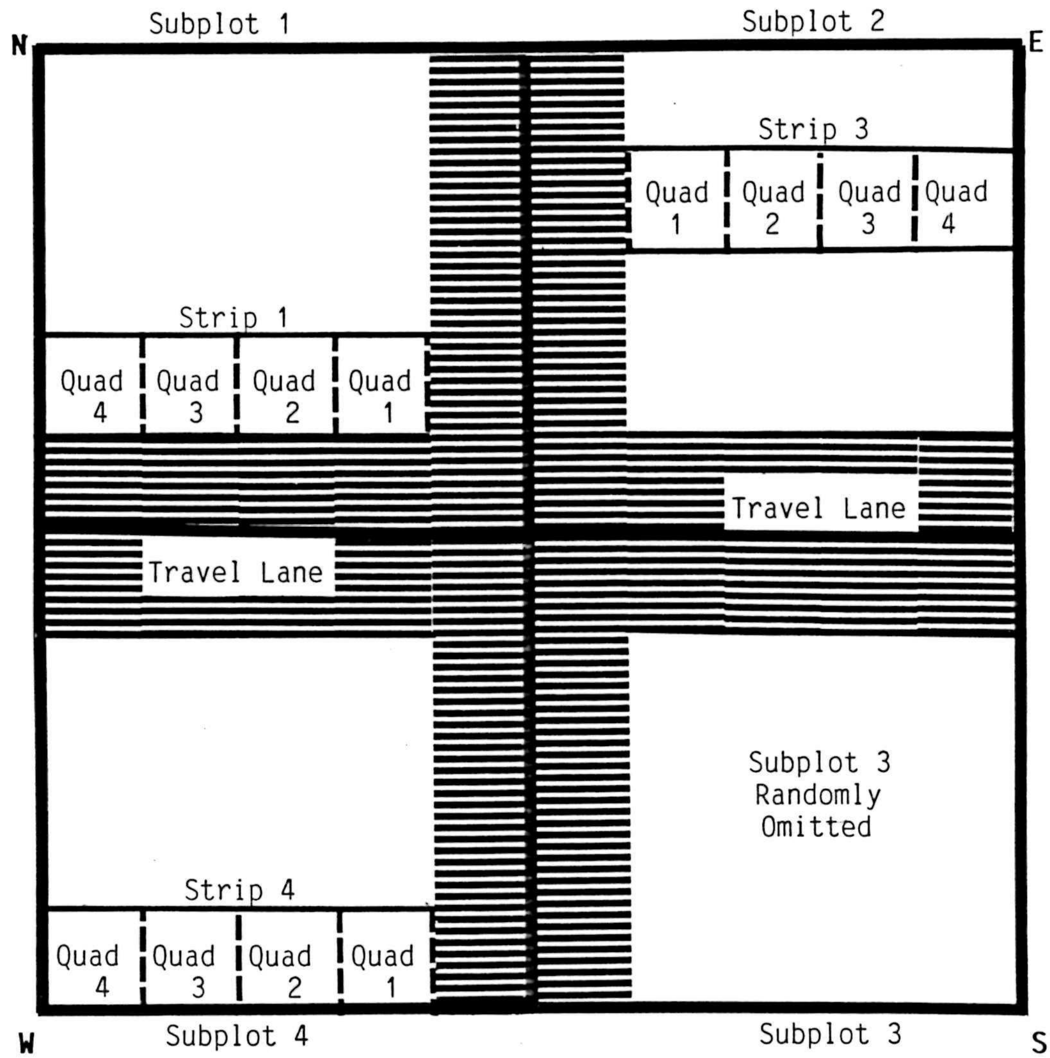


Figure 12. Example of randomized sub-sampling units within the 400m² plot

Species - Sapling and woody shrub identification can be readily taught to inexperienced personnel if proper initial training is provided by the field supervisor. Additionally, Table 6 of this manual provides a list of the most common species indigenous to the southern Appalachian mountains, along with their six letter species codes.

Taxa not considered in the present study are those which commonly classify as short-lived semi-woody shrubs. Examples include the biennial primocanes and florocanes produced by members of the genus *Rubus* or suffrutescent stems which are periodically killed back to the root collar during harsh winters (*Hydrangea*, *Diervilla*).

Table 6. Common and Occasional Woody Plant Species Native to the Southern Appalachian Spruce-Fir Forests.

Trees

ABSFRS	Abies fraseri	Fraser Fir
ACRPNS	Acer pensylvanicum	striped maple
ACRRBR	Acer rubrum	red maple
ACRSCC	Acer saccharum	sugar maple
ACRSPC	Acer spicatum	mountain maple
ASLOCT	Aesculus octandra	yellow buckeye
AMLLVS	Amelanchier laevis	smooth serviceberry
BTLLUT	Betula lutea	yellow birch
FGSGRN	Fagus grandifolia	American beech
ILXMNT	Ilex montana	mountain holly
MGNFRS	Magnolia fraseri	Fraser magnolia
PICRBN	Picea rubens	red spruce
PRNPNS	Prunus pensylvanica	pin cherry
PRNSRT	Prunus serotina	black cherry
SRBAMR	Sorbus americana	mountain-ash
TSGCND	Tsuga canadensis	eastern hemlock

Shrubs

ARNMLN*	Aronia melanocarpa	black chokeberry
CRNALT*	Cornus alternifolia	alternate-leaved dogwood
DRVSSS+	Diervilla sessilifolia	bush-honeysuckle
HYDARB+	Hydrangea arborescens	hydrangea
MNZPLS	Menziesia pilosa	minnie-bush
RHDCTW*	Rhododendron catawbiense	Catawba rhododendron
RHDMXM*	Rhododendron maximum	rosebay rhododendron
RIBGLN	Ribes glandulosum	skunk current
RIBRTN	Ribes rotundifolium	round-leaved current
RBSCND+	Rubus canadensis	thornless blackberry
SMBPBN+	Sambucus pubens	red-fruited elderberry
VBRALN	Viburnum alnifolium	witch-hobble
VBRCSS	Viburnum cassinoides	northern wild raisin
VCCCNS	Vaccinium constablii	tall woodland blueberry
VCCERY	Vaccinium erythrocarpum	mountain cranberrybush

* occasionally reaching tree-size in spruce-fir forests
\+ sub-shrubs tallied only in regeneration inventories (see p. 37)

Total Height

Total height of woody understory flora is best obtained through the use of telescoping height poles. The procedure is generally the same as those described for tree height on page 17 except understory sampling often requires measuring many more leaning and convoluted stems. In the case of Rhododendron spp. or Mountain Maple (Acer spicatum) it is not unusual even to encounter individuals which trail along the ground.

Regardless of form, stems are measured for their absolute linear component only, starting from the root collar and ending at the tip of the terminal bud. They should never be measured in segments in order to compensate for crook or sweep. Figure 13 provides an example illustrating proper pole placement for measuring height. Notice that the pole is positioned as close as possible to the main stem and parallel with it. Measurements should be recorded to the nearest cm.

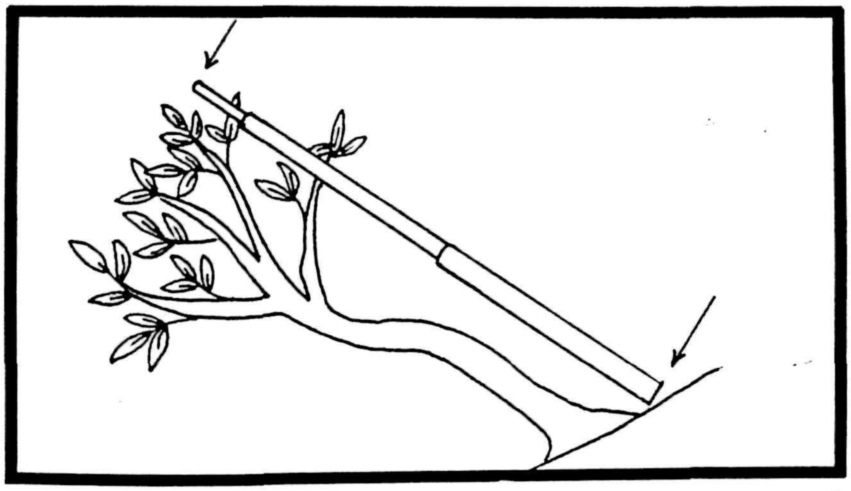


Figure 13. Use of telescoping pole to measure shrub/sapling height

Crown Height

As with total height, live crown height is best determined using height poles. Fiberglass tapes can be substituted for poles when appraising small individuals. Measurements are taken from the point where the lower most primary branch intersects the main stem to the tip of the terminal bud. Small, inconsequential sprouts not associated with crown proper are disregarded since they contribute little to the photosynthetic potential of the plant.

Crown Width

Crown width determinations are made by measuring across a plant's major (widest) crown axis and minor (narrowest) crown axis. The two are then averaged to derive mean crown width. It is important that the height pole, or other suitable measuring device, is held in a plane which parallels the axis being measured and is extended to coincide exactly with the drip line of the crown.

Diameter

Whereas all tree species within the 2 x 2m. quadrats are measured for diameter at 1.37m. (dbh) using conventional procedures, woody shrubs within the quadrats are measured at the 15cm. level. This diameter point is referred to as "basal diameter." Basal diameters more accurately predict stem biomass in small vegetation than does dbh. Choosing to measure at 15cm. also avoids two other problems in the field. First, if basal diameters were taken at ground level, stem swelling in the area of the root collar would distort the accuracy of the measurements. Secondly, since shrub species typically develop a multiple-fork or deliquescent habit and normally possess a single defineable trunk only near the lower portion of the plant, taking diameters at 1.37m. would necessitate having to measure each fork as a single individual.

Basal diameters and dbh's of small trees are most conveniently and accurately obtained using small, inexpensive calipers capable of measuring to a minimum 150mm. Instruments of this kind are typically graduated to 0.1mm. even though the project requires accuracy to the level of the nearest 1mm. When irregular or strongly elliptical stems are encountered, both major and minor diameter measurements should be taken and the two averaged. When saplings are forked below 1.37mm. and shrubs are forked below 15cm. each stem is considered as a separate individual and will yield its own independent set of measurements (including diameter, total height, crown height and crown width).

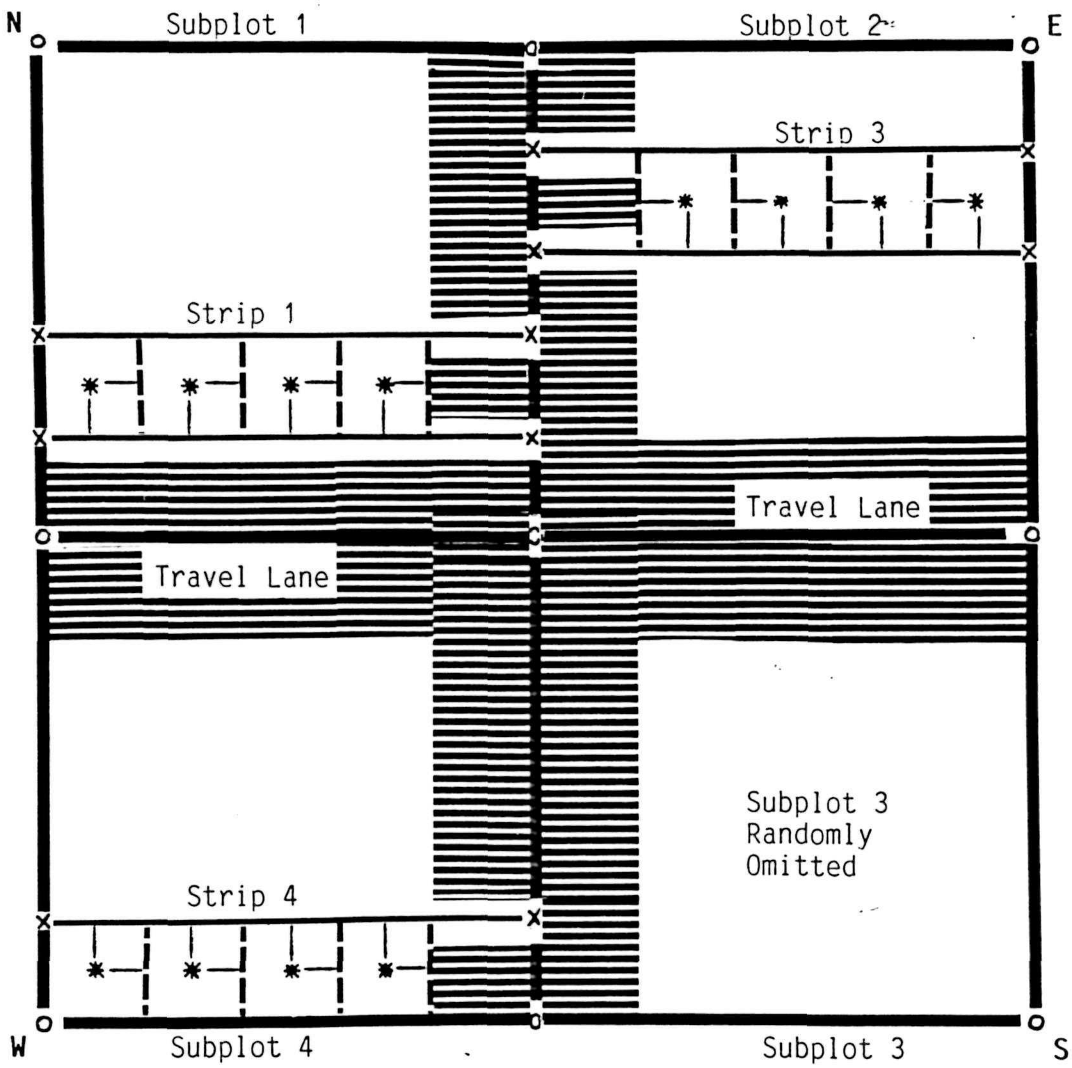
Woody Seedlings and Germinals

The final phase of the study involves an inventory of woody germinals and woody seedlings. As with tree, sapling, and shrub class stems, the general aim of this inventory is to better understand the role which atmospheric pollutants may play in altering the composition and productivity in the stratum over time.

Embedded within this general foundation are two additional parameters of specific interest. The first involves an assessment of the affect which habitat changes have on seedling survivability. The second examines the influence of atmospheric perturbations on the reproductive capacities of trees and shrubs.

Sampling for regeneration-class individuals and categorizing substrate types takes place within the same subplots, strips, and quadrats established when inventorying saplings and woody shrubs. However, because of the potential of a great number of stems being involved, the basic sampling unit is further reduced to a 1 x 1m. area. The 1 x 1's are always nested in the interior corner of each 2 x 2m. quadrat (i.e. corner closest to plot center.) (See Figure 14)

To facilitate the relocation of the 1 x 1 sampling areas from one year to the next, it is strongly recommended that precise documentation and monumentation be used. Not only should 1 x 1 locations be depicted on the plot map, but tape distances recorded as well. PVC stakes consistently and permanently installed in the field are also very important for future relocation.



o = location of permanent PVC center, corner, and midpoint stakes
x = location of permanent PVC strip stakes
* = location of permanent PVC 1 x 1m. corner stakes

Figure 14. Example of randomized sub-sampling units within the $400m^2$ plot including depiction of proper 1 x 1m. placement

An invaluable tool which permits technicians to accurately define the boundaries of the 1 x 1 unit is the three-sided PVC sampling frame. The light weight frames are easily constructed by cutting 1/4" PVC to the prescribed length and joining them together using elbows. It is advisable not to glue the entire apparatus together since this would make transportation in the field awkward. Instead, elbows are secured only to the two vertical beams of the frame. The single top beam can then be slid into the open elbow ends to complete the assembly, whenever needed. Once together, be sure that the <u>inside</u> dimensions of the frame equal one square meter.

Figure 15 provides an example showing the proper placement of the 1 x 1m. frame within a given strip and quadrat. Note that the frame is hooked around the PVC marking stake and the tubing at the open end of the frame is flush with the interior strip tape.

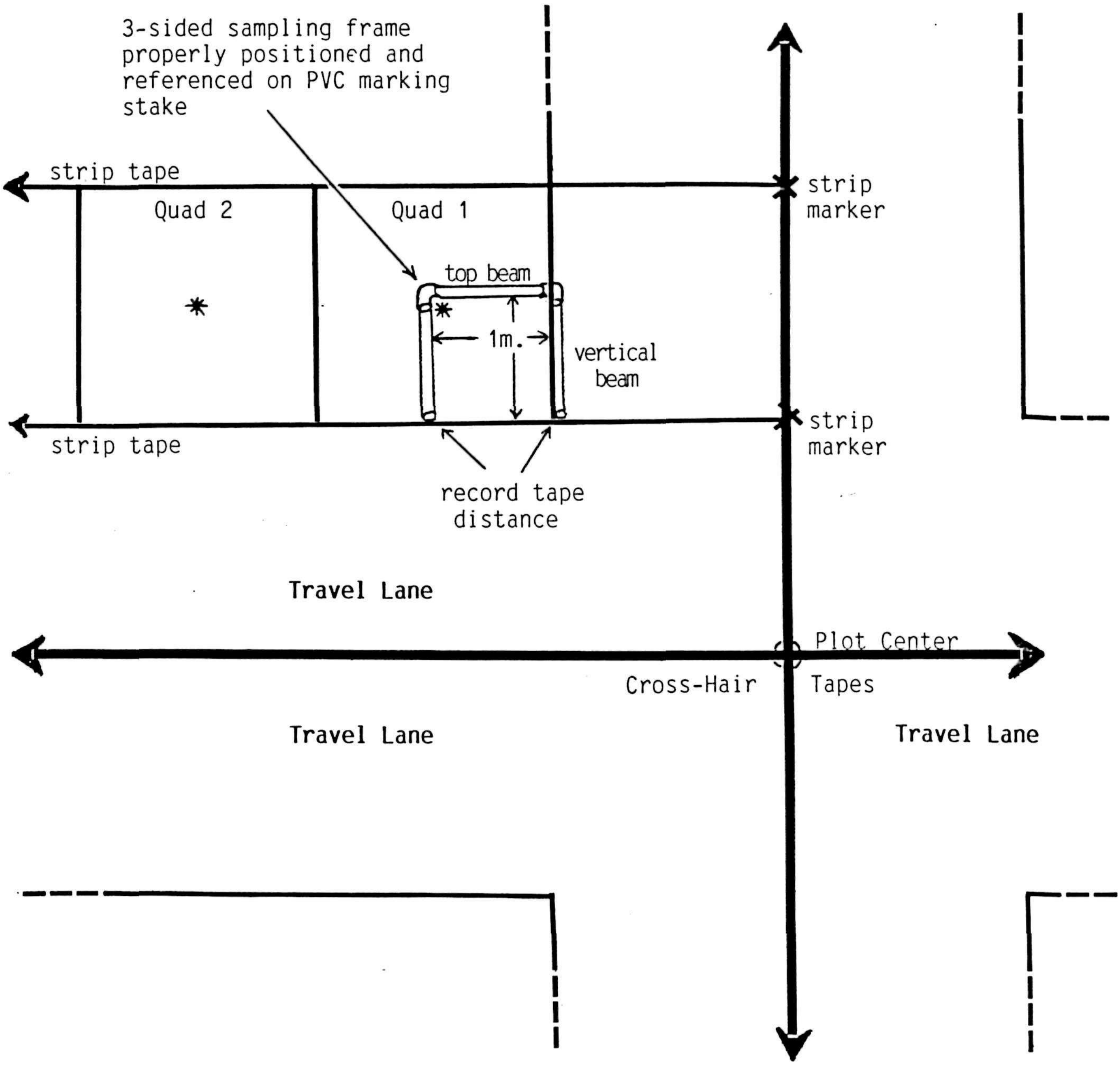


Figure 15. Portion of $400m^2$ plot showing proper positioning of 1 x 1m. sampling frame within a given strip and quadrat

Within each 1 x 1, the forest floor is first characterized by assigning relative percent cover to each class of substrate that is present. These assessments are made by looking down on the 1 x 1 from directly overhead. Because percent cover of herbaceous plants is also included in the tally, that portion of the substrate lying beneath the herbs and obscured from view is not considered.* Cover estimates can therefore never exceed 100 percent.

Similarly, substrate types often "piggy-back" on one another. Bryophytes growing on woody ground debris such as a fallen log is an example of such an occurrence. Again, substrate cover estimates should be based on those components clearly visible from above. The portion of the log obscured by the bryophyte cover is not considered in the estimate otherwise double-counting would result.

Once substrate cover estimates have been established, woody germinals and woody seedlings less than 1.37m. tall are inventoried by species and a series of size/age parameters. The tally includes both living and dead stems. Substrates in which each stem is growing are also designated since substrate type often reflects the seedling's ability to withstand drought and other environmental stresses such as extremes in temperature.

While size parameters can easily be derived by measuring the height of each seedling from the root collar to the tip of the terminal bud, age class assignments require closer scrutiny.

First year germinals can be identified by a combination of their small size and often by the presence of cotyledons or embryonic seed leaves. Because cotyledons are morphologically distinct from true leaves they are readily identifiable. Broad-leaved, deciduous species such as birch, mountain-ash, and the maples all possess two cotyledons which lack the serrations found in true leaves. The three dominant conifers found at high elevation: spruce, fir and hemlock, are, by contrast, polycotyledonous and produce a whorl of cotyledons that vary from 4-8 in number. No true leaves are produced by these trees during the first growing season.

Identification of 1-3 year old seedlings can be made in virtually all species by counting annual growth flushes or bud scale scars. Because this is a skill which requires strong powers of observation, some initial training of inexperienced personnel will be needed. Counting, however, is usually not necessary in the case of red spruce and Fraser fir in the southern Appalachians. Both of these species consistently produce only a single unbranched stem for the first three years of their existence. It is not until the fourth year that lateral branches begin to appear. By default, therefore, any spruce or fir seedling bearing one or more lateral branches cannot fall into the 1-3 year age class.

* The current study does not require that the herb cover be typed by species. The only instances in which the identity of an herb is cited occurs when the species is considered to be rare or threatened either in the state or nationally.

PLOT DISASSEMBLY

After all phases of sampling have been completed, the plot is carefully dismantled. Perimeter, crosshair, and strip tapes should be taken up so that vegetation is not harmed and none of the plot monumentation is disturbed. All equipment used in the inventory should then be accounted for so that nothing is left behind. Oversights such as this can be avoided by assigning each crew member responsibility for bringing specific pieces of equipment to and from the field each day. These same people should also be responsible for the care and maintenance of the equipment that is assigned to them.

PLOT LOCATION SURVEY

One of the most important duties for a field crew is to provide clear but detailed directions to all plots within the study area. Because the plots are meant to be permanent and their purpose is to provide long-term ecological data, clear directions are an absolute necessity for future investigators.

Those personnel responsible for generating field directions should always bear in mind that the people for which they are intended may be totally unfamiliar with the area or may not be particularly adept at orienteering. Information should include trail and road names and precise bearings and distances of off-trail routes. Descriptions should, whenever possible, reference intermediate landmarks that are easily discernable. These might include creek confluences, distinctive rock formations, trail signs and intersections, or even tagged "witness trees." Additional information in the form of hand drawn maps and photocopied sections of topographic maps are also essential. The Appendix contains an example of a typical plot location survey.

LITERATURE CITED

Phipps, R.L. 1985. Collecting, Preparing, and Measuring Tree Increment Cores. U.S. Geologic Survey, Water Resources Investigations. Report 85-4148. Reston, Va. pp. 1-48.

Smith, D.M. 1962. The Practice of Silviculture. John Wiley and Sons, Inc., New York. 578 pp.

APPENDIX

Field Data Sheets Used in Permanent Plot Sampling

PLOT LOCATION   SPRUCE-FIR PROJECT - 1988   PLOT LOCATION

Vegetation Section __________ Plot Number 301

General directions to plot: Travel to Indian Gap via the Clingman's Dome Road. Near the paved parking area on the Tennessee side of the road, locate a N.P.S. historical marker entitled "The Old Indian Gap Road." At this marker begin taping down the steep Indian Gap (Road Prong) trail. At 910m. you will encounter a large 102cm. DBH birch immediately to the left of the path. This tree is easily distinguished by its heavy covering of moss, and by the 30cm. DBH beech which has fallen into it. The large birch has been tagged #52 low on the reverse side. From #52 continue taping down the trail for an additional 60.5m. until reaching a 40cm. DBH spruce which has fallen diagonally across the trail. The spruce has been severed to allow easy passage. Note too, numerous other downed trees and sawn boles adjacent to the trail nearby. From the severed spruce shoot a 20° azimuth and tape up the sideslope 199m. to plot center.

SEE REVERSE SIDE FOR MAP
AND ADDITIONAL DETAILS

Landmark Description:

Witness Tree (From witness tree to landmark)

Species	DBH	Tag #	Azimuth	Distance	Tree Description

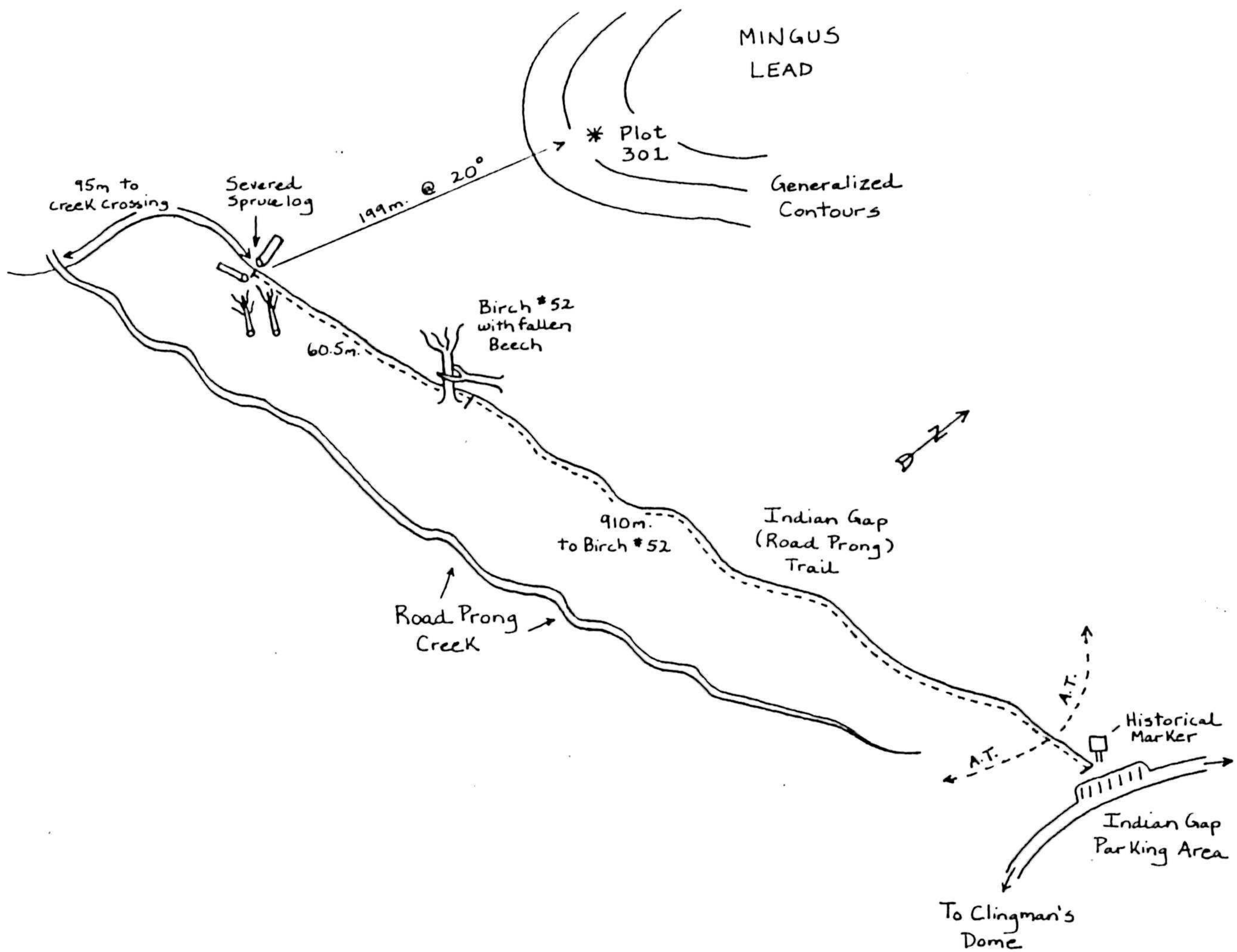
Photographs of Landmark: Roll Number ________ Frame Numbers ________ ________

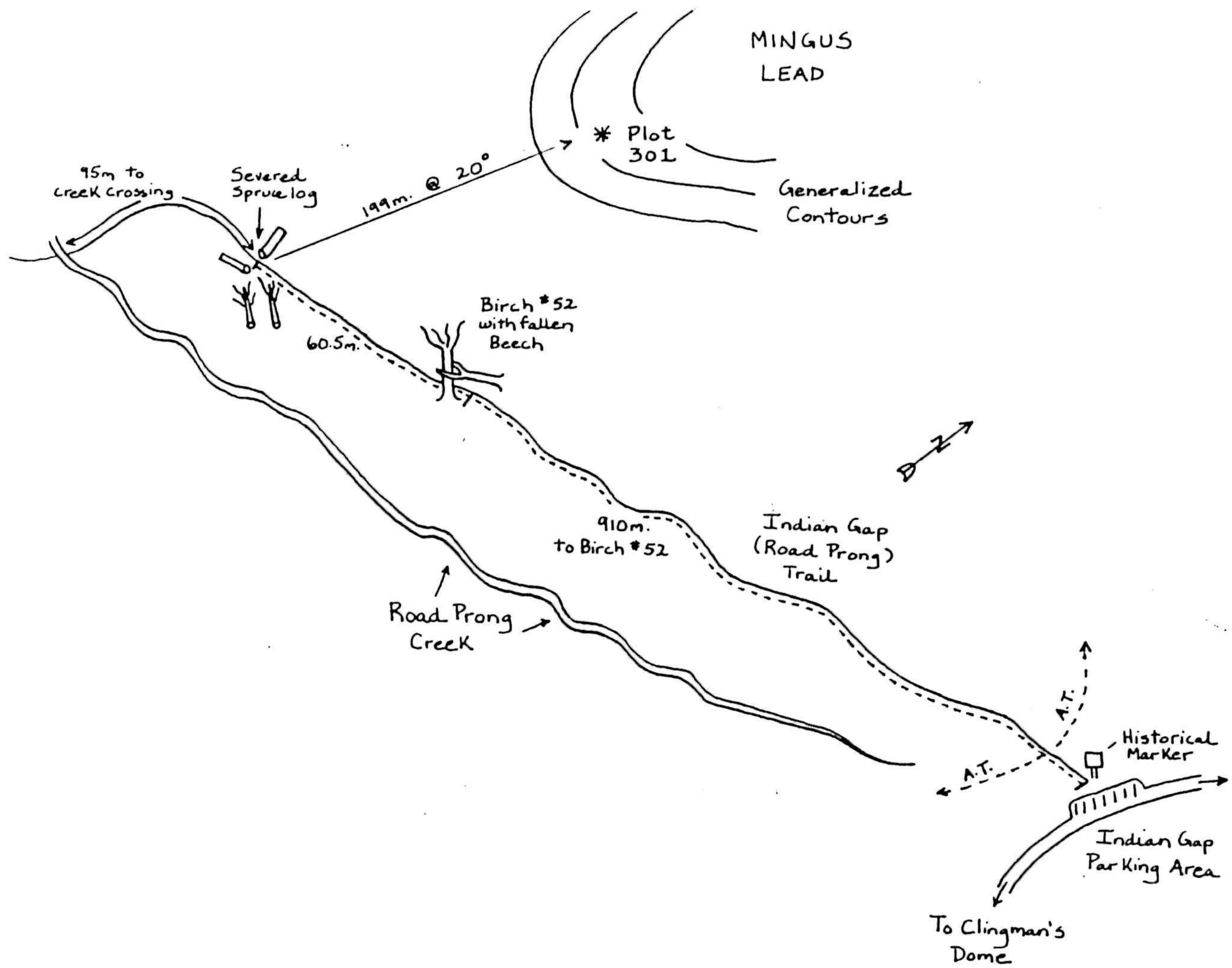
Plot extension for SARRMC related work:

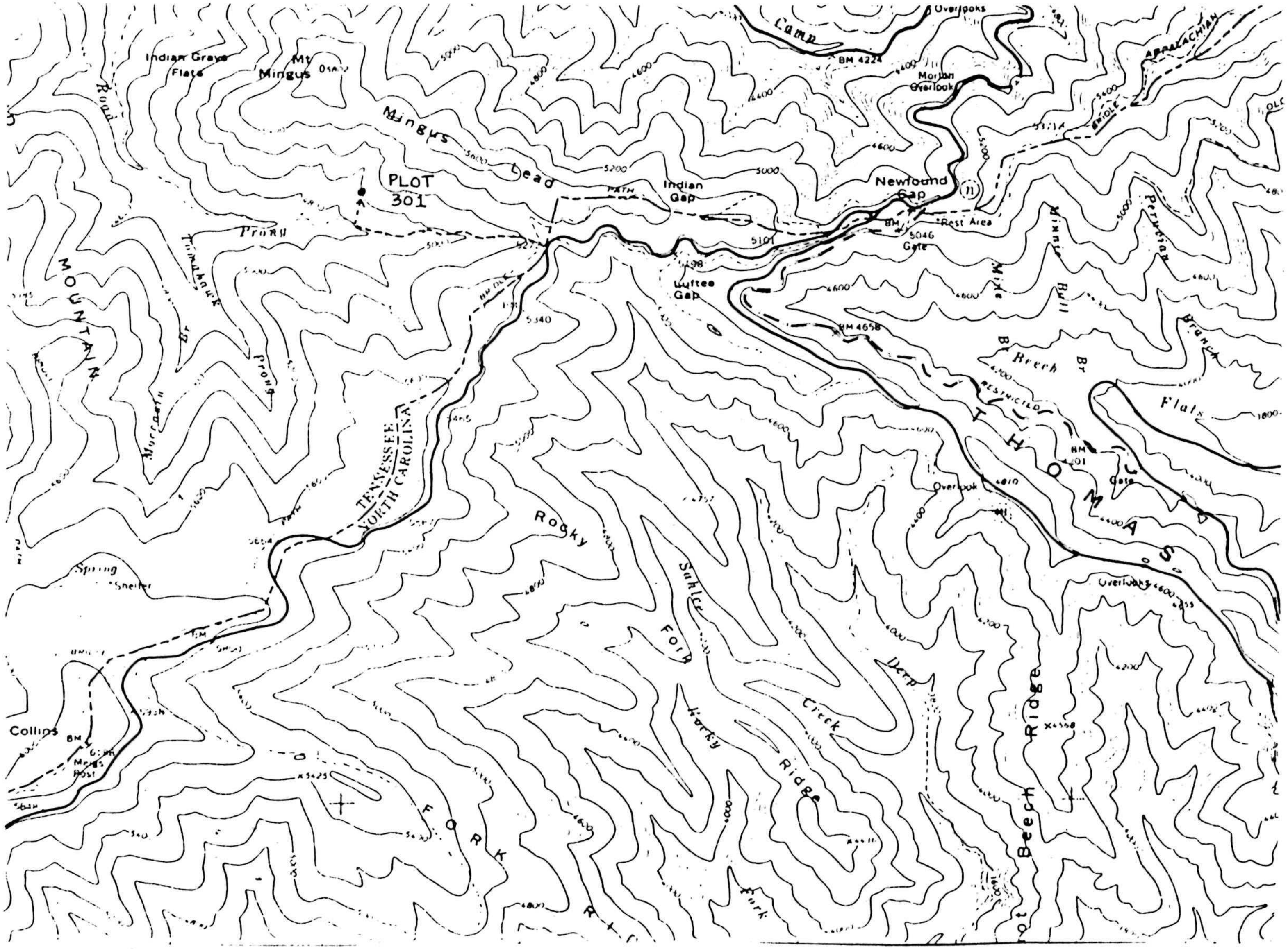
Plot Placement

Witness Tree (From witness tree to plot center stake)

Species	DBH	Tag #	Azimuth	Distance	Tree Description


MINGUS LEAD
Plot 301
Generalized Contours
199m. @ 20°
95m to creek crossing
Severed Spruce log
60.5m.
Birch #52 with fallen Beech
910m. to Birch #52
Indian Gap (Road Prong) Trail
Road Prong Creek
A.T.
A.T.
Historical Marker
Indian Gap Parking Area
To Clingman's Dome


MINGUS
LEAD
Plot
301
Generalized
Contours
95m to
creek crossing
Severed
Spruce log
199m. @ 20°
60.5m.
Birch #52
with fallen
Beech
N
910m.
to Birch #52
Indian Gap
(Road Prong)
Trail
Road Prong
Creek
A.T.
A.T.
Historical
Marker
Indian Gap
Parking Area
To Clingman's
Dome


Indian Grave Flats
Mt Mingus
Mingus Lead
PLOT 301
Prong
Road
MOUNTAIN
Camp
BM 4224
Overlooks
Morton Overlook
APPALACHIAN
Indian Gap
Newfound Gap
Rest Area
BM
5046
Gate
5101
Luftee Gap
BM 4658
5340
RESTRICTED
Beech Br
Flats
Overlook
Gate
THOMAS
TENNESSEE
NORTH CAROLINA
Rocky
Spring
Shelter
Overlooks
Collins
BM
Deep
Creek
Ridge
Beech Ridge
FORK

Plot Number 301 Date 6/30/88 Crew Smith, Jones, Doe

Elevation 5000 Slope Angle - 38 (Rdg.1) 42 (Rdg.2) 40% ($\bar{x}$) Aspect 225°

Weather Conditions overcast, scattered rain

*** *** *** ***

MACRO-RELIEF

Landform:
1. Ridge Top
2. Spur Ridge
3. Nose Slope
4. Head Slope
5. Side Slope
6. Cove
7. Draw

Slope Position:
1. Summit
2. Shoulder
3. Back Slope
4. Foot Slope
5. Terrace
6. Bottom

MICRO-RELIEF

Plot Slope:
1. Planar
2. Convex
3. Concave
4. Doubly Convex
5. Doubly Concave

*** *** *** ***

CANOPY OPENNESS

Subplot	Reading 1 ($\frac{x}{15}$)	Reading 2 ($\frac{x}{10}$)	Total ($\frac{x}{25}$)
1			
2			
3			
4			

*** *** *** ***

Balsam Woolly Aphid Damage:

Major infestation 1980-82. Aphids still active in residual canopy class fir. Seedlings and saplings exhibiting prior damage but appear to be recovering.

Comments:

Large area (approx. 2 hectares) of windthrown trees 80m. directly upslope of plot.

TREES
20x20

SPRUCE-FIR PROJECT - 1988
(Arborescent Flora ≥ 5cm. DBH)

TREES
20x20

PLOT 301 DATE 6/30/88 DATA COLLECTOR Smith

Sub-Plot	Tree#	Species	DBH	L/D	Crown Class	Crown Cond	Comment Code
1	1	PICRBN	64.8	L	D	1	5,15
1	2	ABSFRS	26.3	L	I	2	1
1	3	PICRBN	72.1	L	D	1	15
1	4	BTLLUT	8.3	L	S		22,23
1	5	PICRBN	20.5	L	I	2	20,21
1	6	PICRBN	22.6	L	I	1	14
1	7	PICRBN	18.2	L	I	1	16
2		PICRBN	12.8	D	S	4	(2,6) 5,15
2	8	PICRBN	51.1	L	C	1	0
2		BTLLUT	24.3	D	S	5	(3,7) 5
2	9	ABSFRS	23.0	L	I	3	1
2	10	PICRBN	60.2	L	D	2	2,6,21
3	11	PICRBN	58.4	L	C	1	0
3	12	BTLLUT	25.7	L	I		20,22
3	13	FGSGRN	21.1	L	I		10
3	14	PICRBN	59.9	L	C	1	9
4	15	SRBAMR	18.4	L	I		4
4		BTLLUT	12.6	D	I		(10,4) 23

0 - No comment
1 - BWA Occurrence/Impact
2 - Lightening Damage
3 - Dieback/Dead Top
4 - Insect Feeding/Defoliation
5 - Stem Disease/Lesions/Burls
6 - Top Missing
7 - Lean >45o
8 - Wind Shearing/Krummholtz
9 - Terminal Replacement
10- Root Rot/Fruiting Bodies
11- Fire Scar
12-
13 - Animal Damage
14 - Misc. Mechanical Injury
15 - Stem Crack
16 - Crown Ratio ≤ 25%
17 - Recently Released
18 - Open Grown
19 - Super-Dominant
20 - Strong Crown Red./Lat Comp.
21 - Recent Needle Loss
22 - Crook/Sweep
23 - Stilted
24 - Forked Below DBH
25 - Ice Breakage
26 - Witch's broom
27 - Special Comm. (Detail above)

Crown Cond. Codes

1. 100-90% intact
2. 89-50% intact
3. 49- 1% intact
4. Recent dead
5. Old dead

TREES
20x20

SPRUCE-FIR PROJECT - 1988
(Arborescent Flora ≥ 5cm. DBH)

TREES
20x20

PLOT 301 DATE 6/30/88 DATA COLLECTOR Smith

Sub-Plot	Tree#	Species	DBH	L/D	Crown Class	Crown Cond	Comment Code
4	16	RHDCTW	5.3	L	S		7
4	17	RHDCTW	5.6	L	S		7
4	18	RHDCTW	5.0	L	S		7
4	19	ABSFRS	20.0	L	I	3	1
4	20	ACRSPC	7.6	L	S		22,23
4	21	ACRSPC	8.1	L	S		22
4		ABSFRS	16.7	D	I	4	(6,2) 1
			.				
			.				
			.				
			.				
			.				
			.				
			.				
			.				
			.				
			.				

0 - No comment
1 - BWA Occurrence/Impact
2 - Lightening Damage
3 - Dieback/Dead Top
4 - Insect Feeding/Defoliation
5 - Stem Disease/Lesions/Burls
6 - Top Missing
7 - Lean >45o
8 - Wind Shearing/Krummholtz
9 - Terminal Replacement
10- Root Rot/Fruiting Bodies
11- Fire Scar
12-

13 - Animal Damage
14 - Misc. Mechanical Injury
15 - Stem Crack
16 - Crown Ratio ≤ 25%
17 - Recently Released
18 - Open Crown
19 - Super-Dominant
20 - Strong Crown Red./Lat Comp.
21 - Recent Needle Loss
22 - Crook/Sweep
23 - Stilted
24 - Forked Below DBH
25 - Ice Breakage

26 - Witch's broom
27 - Special Comm. (Detail above)

Crown Cond. Codes

1. 100-90% intact
2. 89-50% intact
3. 49- 1% intact
4. Recent dead
5. Old dead

PLOT NUMBER 301

TREE HEIGHT
AND CROWN MEASUREMENTS

Date 6/30/88
Data Collector Smith

Tree #	Crown Width			Horizontal Distance			Tree and Crown Height					Comments	
	N-S	E-W	$\bar{x}$	Slope%	SlopeDx	HorizDx	%Angle Top	%Angle Base	%Angle CrBase	Total Height	Crown Height	Dead Top	
	13.5	12.1	12.80	-55	24.7	21.64	+68	-64	-21	28.56	19.25		
	11.4	8.7	10.05	-46	23.7	21.53	+40	-53	+15	20.82	5.38		
	11.4	8.3	9.85	-50	28.3	25.31	Dead +53 / Live +39	-58	-2	D. 28.09 / L. 24.55	D. 13.92 / L. 10.38	3.54	
	7.7	6.1	6.90	-17	33.7	33.22	+65	-25	+12	29.91	17.61		
	2.3	1.8	2.05	-60	11.4	9.77	-8	-72	-25	6.26	1.66		
	7.4	7.6	7.50	-42	25.1	23.14	+56	-50	+5	24.53	11.80		
	9.9	9.7	9.80	+1	30.5	30.50	+88	-7	+45	28.97	13.12		
	5.6	6.3	5.95	-48	17.4	15.69	-8	-56	-35	7.53	4.24		
	3.0	3.8	3.40	0	13.7	13.70	+66	-10	+40	10.41	3.56		
	7.5	5.4	6.45	-65	19.3	16.18	+46	-72	+14	19.09	5.17		

WOODY STEMS
2x2

SPRUCE-FIR PROJECT - 1988
Basal Diameters
(Woody Stems > 1.40 m. Tall and < 5cm. DBH)

Subplot	Strip
1	4
2	3
~~3~~	
4	3

Plot 301 Date 6/30/88 Data Collector Jones

Sub-Plot	Quad#	Species	L/D	Tree/Shrub Basal Dia.	Sub-Plot	Quad#	Species	L/D	Tree/Shrub Basal Dia.
1	1	ABSFRS	L	3.28					.
1	1	ABSFRS	L	2.19					.
1	2	VBRALN	L	2.08					.
1	3	———		.					.
1	4	PICRBN	L	4.56					.
2	1	ACRSPC	L	1.92					.
2	2	ABSFRS	D	4.82					.
2	2	ABSFRS	L	3.66					.
2	3	ABSFRS	L	2.37					.
2	4	———		.					.
4	1	RHDCTW	L	4.76					.
4	1	RHDCTW	L	3.49					.
4	1	RHDCTW	L	3.33					.
4	2	VBRALN	L	2.50					.
4	3	———		.					.
4	4	RHDCTW	L	3.69					.
4	4	RHDCTW	L	3.91					.
4	4	SRBAMR	L	4.64					.
				.					.
				.					.
				.					.
				.					.
				.					.

* Does not include Rubus or Hydrangea

HERBS
1x1

SPRUCE-FIR PROJECT - 1988

PERCENT COVER OF 1x1 m. QUADS
(Herbaceous Stems Only)

Subplot	Strip
1	4
2	3
~~3~~	
4	3

HERBS
1x1

Plot 301 Date 6/30/88 Data Collector Doe

Sub-Plot Number	1	1	1	1	2	2	2	2	4	4	4	4
Quadrat Number	1	2	3	4	1	2	3	4	1	2	3	4
Bare Soil	–	–	–	–	–	–	–	–	–	1	–	–
Leaf/Twig Litter	1	10	20	5	10	5	10	30	5	15	5	20
Bare Rock	–	–	–	–	–	–	–	–	–	1	–	–
Bole (Living or Dead)	–	–	–	–	–	1	–	–	5	–	–	1
Bryophyte/Lichen	1	20	20	1	1	5	5	1	5	10	35	5
Woody Debris (Ground)	10	5	10	5	5	10	10	–	–	5	–	5
Woody Debris (Aerial)	–	–	–	35	–	–	–	–	–	5	30	–
Stream/Seep	–	–	–	–	–	–	–	–	–	–	–	–
Herb	90	70	50	60	95	80	75	70	85	65	30	70
Rare/Threatened Species												

*Includes Rubus and Hydrangea

TREES
1x1

SPRUCE-FIR PROJECT - 1988

Seedling Density

TREES
1x1

PLOT 301 DATE 6/30/88 DATA COLLECTOR Doe

Sub-Plot	Quad. No.	Species	Subst.	L or D	Germinal	1 year to 4 years	4 yr. to .25m tall	.25m to 1 m.	1 m. to 1.4 m.
1	1	ABSFRS	1	L		•	•••		
1	1	PICRBN	1	L	••	⊓••	•••		
1	2	ABSFRS	4	L		•	••	•	
1	2	ABSFRS	1	L		••••	••		•
1	3	ABSFRS	4	L			••		
1	3	ABSFRS	4	D		•			
1	3	ABSFRS	1	L			•		
1	3	ACRSPC	1	L		•			•
1	4	———							
2	1	ABSFRS	1	L		••	••••		
2	1	PICRBN	1	L	••	⊠ ⊠ •••	•••		••
2	2	ABSFRS	1	L		•			
2	3	ABSFRS	1	L		•••		••	
2	3	PICRBN	1	L	•••		⊏		
2	4	———							
4	1	———							
4	2	ACRSPC	1	L		••			
4	2	ABSFRS	1	L	•	•			
4	3	BTLLUT	6	L		•	•		
4	3	BTLLUT	6	D		•			
4	3	PICRBN	6	L		•	⊠		
4	3	VCCERY	6	L		•			
4	4	ABSFRS	1	L		•	•		
4	4	BTLLUT	1	L			•		
4	4	PICRBN	4	L		•	•		

SUBSTRATE TYPES: 0 - FOREST FLOOR, 1 - ROCK, 2 - WOODY DEBRIS (GROUND), 3 - WOODY DEBRIS (AERIAL), 4 - STUMP, 5 - STREAM-GULLY