FOREST AND RANGE INVENTORY MANUAL

CHAPTER EIGHT

GROWTH AND YIELD

1983

MINISTRY OF FORESTS
INVENTORY BRANCH
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INVENTORY BRANCH

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FOREWORD

The British Columbia Forest Act (1978) states that the Chief Forester shall develop and maintain an inventory of the land and forests in the Province, and shall assess the land in the Province for its potential for growing trees continuously, providing forest oriented recreation, producing forage for livestock and wildlife, and for accommodating other forest uses. Also, the Ministry of Forests Act (1978) requires a periodic resource analysis report containing a description of the inventory of the forest and range resources in the Province, a description of the location and extent of areas of forest land in the Province that have been denuded of timber through harvesting or otherwise and have not become re-stocked with a commercially valuable species of timber, or are producing timber at the rate that is substantially lower than their potential. In addition, the Minister of Forests is required to submit to the Lieutenant-Governor in Council an annual report which must include a summary of forest land in the Province, showing areas denuded of forest during the year, areas re-stocked during the year and areas the productivity of which has been improved during the year.

In order to implement the requirements of the new forest legislation, the Inventory Branch of the Ministry of Forests has acquired new technology and has developed new approaches for conducting forest and range inventory. The Forest and Range Inventory Manual, consisting of eleven chapters, the Five-year Plan for Forest and Range Inventory in British Columbia: 1981-1985, and the inventory handbooks, namely the Field Handbook, the Helicopter Camera Boom Instruction and Operation Handbook, the Colour Stereogram Handbook, and the Stereocord Handbook, describe the procedures for planning, conducting and auditing provincial forest and range inventories.

F. HEGYI, R.P.F.
DIRECTOR

CHAPTER EIGHT

GROWTH AND YIELD

1983

Chapter eight, "Growth and Yield", of the Forest and Range Inventory Manual is a description of the methods used for the establishment and remeasurement of permanent samples in natural and managed stands, for the assessment of site capability and site productivity, and for the construction of empirical yield tables in natural stands and the simulation of growth based upon permanent sample data. This chapter was prepared by H.A.O. Magdanz, R.P.F., F. Szy, R.P.F., J. Viszlai, R.P.F., E. Andody, R.P.F., G.P. Bourdon, R.P.F., J. Braz, R.P.F., M.J. Faliszewski, R.P.F., A.J. Hughes, R.P.F., A.E. Kivari, R.P.F., L.W. Stanley, R.P.F., and C.C. Martins, C.E.T., and it was edited by A.A. Britneff, R.P.F.

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SECTION 8.1

NATURAL STANDS

8.11 ESTABLISHMENT OF PERMANENT GROWTH SAMPLES IN NATURAL STANDS

Growth plots in natural stands are established to monitor the rates of growth, mortality, changes in stand structure, and stand development to maturity or cutting age. Stands are selected for sampling by means of a detailed analysis of previous surveys of the management unit. Required growth plots are located as a sub-sample of the six-point ground sample. Growth plots are usually established on the second, fourth and sixth points of the six-point phase 2 sample in the desired stratum. The standards of measurement for permanent samples are listed in Appendix 8-1.

8.111 Office Preparation and Field Reconnaissance

Obtain the most recent forest cover maps and status maps and note possible areas for sample establishment. Then collect the latest air photos which cover those possible areas for sample establishment. A growth sample receives the same sample number as its respective six-point phase 2 (ground) sample. The provincial sample list enumerates samples consecutively by region and compartment. Do not duplicate numbers within a compartment.

For a list of equipment used in growth and yield natural stands, see Appendix 8-2.

To attain operational efficiency, carry out a field reconnaissance of the possible areas for sample establishment. Discard unsuitable areas, examples of which in even-aged forests are:

A. Stands containing more than six to eight veterans per hectare,

B. Stands in which site and species composition vary extremely, and

C. Stands which may be too old for at least two remeasurements.

Examples of unsuitable areas for sample establishment in all-aged or residual forests are:

A. Stands too small to accommodate a six-point sample, and

B. Stands in which site and species composition vary extremely.

Further details on strata selection are to be agreed to by the regional Inventory Officer and the Growth Monitoring Sub-section of the Inventory Branch.

8.112 Field Training

All personnel involved in growth sample establishment are to attend a short training course to familiarize them with the field procedures. Then crews should work under direct guidance of senior personnel for a period of time sufficient to gain a full understanding of the different phases of the work and to obtain reasonable efficiency in the collection of field measurements.

8.113 Plot Location and Marking

8.1131 Location and Access Description

For the benefit of future remeasurement crews, describe in detail the access to, and the location of, the plot. When describing routes and distances to a tie point, always start from an easily identifiable point, the location of which is likely to remain unchanged during the intervening ten-year period between measurements. Describe the starting point (for example, bridge crossing or main road junction) and from there note distances to road junctions, creek crossings, or to other prominent features on route to the tie point. Describe the species, diameter and location of the tie tree.

8.1132 Tie Point

As growth samples will be remeasured every ten years, the reference point or tie point should be a permanent topographic feature distinguishable on air photos and on the ground. Topographic features such as a road junction, a bend in the road, a creek junction, or a road crossing a creek, are good examples of a reference point. Choose a tie tree as close to the reference point as possible and mark it well. Blaze both sides of the tie tree in the direction of the tie line. Above the blazes, nail aluminum growth plot markers (see Appendix 8-3) and on them inscribe the sample number, plot number, region number, compartment number, bearing and distance to the first plot, and the date of sample establishment. The aluminum marker is designed for use in the natural stands and managed stands growth and yield programs. To identify a natural stands sample, place a check mark in the space provided under "natural". Each aluminum marker is divided into three sections. When used as a tie point marker, complete only the middle and bottom sections of the marker.

In addition to the two aluminum plot markers and the two blazes, mark the tie tree with two strands of red plastic flagging tape, one above and one below the aluminum markers.

8.1133 Tie Line

From the tie point, the tie line is run to the three plot centres with a hand compass, clinometer (Suunto), and measuring tape. Follow the bearing set on the hand compass for the required distance. On broken terrain it may be necessary to advance by 20-metre intervals, otherwise use 40-metre intervals. Measure slope with the clinometer and make the required correction for horizontal distance. Mark the tie line with a blaze on each side of the trees along it as well as with flagging tape, both at approximately 10-metre intervals: in stands with heavy undergrowth, decrease the interval; whereas in stands with light or no undergrowth, increase it.

8.1134 Plot Centre

When the required distance has been chained, mark the three plot centres with tubular aluminum stakes. Drive the stake into the ground for at least half of its length and build a cairn around its base to support it firmly. For plots that are not to be stem mapped, select three trees around each plot centre, and in the appropriate stem map columns, record the bearing and distance from the plot centre stake to each tree. This information will aid future remeasurement crews in relocating the position of a centre stake that has been pulled out. Each respective plot centre coincides with the centre of the second, fourth and sixth point of the six-point ground sample. Mark the closest living tree (15 cm d.b.h. or greater) to the aluminum plot centre stake as the plot centre tree. Nail two aluminum growth plot markers to the plot centre tree approximately two metres above the ground. Inscribe the top section of each aluminum growth plot marker (see Appendix 8-3) with the sample number and the plot number.

Record, on the bottom section of the aluminum marker, the region number, the compartment number and the date of sample establishment, and place a check mark in the space provided under "natural". If the plot centre is also the tie point for the next plot on the tie line, then fill out the middle section of the aluminum growth plot marker. Flag the centre tree with two strands of flagging tape, one above and one below the aluminum growth plot markers.

8.114 Plot Establishment

8.1141 Plot Shape and Size

Growth plots established in natural stands are fixed-radius circular plots. The plot radius is measured from the plot centre stake and all trees of measurable size are tagged inside the plot. To accommodate the density of different stands being sampled, variation in plot size is permitted. The objective of the sampling design is to obtain 70 living stems (minimum number accepted is 60) that are 7.5 cm + d.b.h. in a sample (3 plots). The basic plot size is 0.025 ha with a radius of 8.92 m (0.075 ha sample size).

In open stands, increase the plot size to 0.03 ha with a radius of 9.77 m (0.09 ha sample size) or to 0.035 ha with a radius of 10.56 m (0.105 ha sample size). In dense stands, decrease the plot size to 0.02 ha with a radius of 7.98 m (0.06 ha sample size), to 0.015 ha with a radius of 6.91 m (0.045 ha sample size), or to 0.01 ha with a radius of 5.64 m (0.03 ha sample size). Only these variations in plot size are permitted.

In very dense young stands, there may be few, if any, trees 7.5 cm d.b.h. and greater. If the maximum plot size is used, the result would be too many ingrowth trees (7.5 cm d.b.h. or greater) at the first and second remeasurements (10 and 20 years after establishment, respectively). For these stands, use the minimum plot size (0.01 ha) and ignore the minimum tree requirement for stems 7.5 cm d.b.h. and greater. However, the sub-sample size must be increased by an amount sufficient to obtain a total of 100 trees for the sample and sub-sample together (see Section 8.1151). As a guide, stands less than 41 years of age with a density of 10,000 stems per hectare or greater qualify for the minimum plot size.

As density can vary among the three plots of a sample and because the three plots have to be the same size, do not choose the plot size until each plot has been examined. Therefore, go to the last plot on a tie line and then work back to the tie point.

8.1142 Plot Radius and Circumference

Having established the plot centre, mark the plot circumference with plot string. Measure the selected plot radius from the plot centre stake. On level terrain, hold the tape horizontally. On sloping terrain, hold the tape parallel to the slope, measure the slope with the Suunto using the percent scale, and apply a slope correction to the radius (see Appendix 8-4). Measure the plot radius at a minimum of eight locations while playing out the plot string to mark the circumference. Check trees close to the circumference with the plot tape. Line trees are those on the circumference and are included in the plot when at least half of their base is inside the plot.

8.1143 Division of the Plot into Sectors

To simplify tree numbering and to reduce the number of tagging errors, each plot is divided into sectors. The number of sectors depends upon the density of the stems within the plot. Eight sectors are usually sufficient but twelve or even sixteen may be necessary in dense stands. To lay out the sectors, follow this procedure:

A. Set the hand compass to north 0^{o} Azimuth and from plot centre follow this bearing to the perimeter of the plot while playing out the plot string.

B. Repeat this procedure in a clockwise direction with the hand compass set at 45° intervals (that is, 45°, 90°, 135°, 180°, and so on) for 8 sectors, at 30° intervals for 12 sectors, or at 22.5° intervals for 16 sectors. When the plot is divided into sectors, the string radiates from the centre stake as do the spokes from the hub of a wheel. Sector number 1 is always the first sector clockwise from the north bearing.

8.1144 Tree Tagging

Having divided the plot into sectors, tag all living trees with a d.b.h. of 7.5 cm or larger with round, blue, plastic tags. These tags come embossed with white numbers in sets of 1 to 300. Do not duplicate tag numbers on any one plot. To have more than 300 living stems tagged on one plot is unlikely because plot size is selected according to stand density.

In sector 1, all tags must face plot centre. Begin tagging in sector 1 near the plot centre and continue by passing back and forth across the pie-shaped sector. The last pass near the circumference of the plot is always made in the direction of sector 2 so that the last tree tagged in sector 1 is as near as possible to the first tree tagged in sector 2.

In sector 2, all tags must face the circumference. Start tagging in sector 2 near the circumference and as close as possible to the last tree tagged in sector 1 and continue by passing back and forth across the sector so that the last tree tagged is close to plot centre.

Repeat the procedures used for sector 1 and 2 alternately for the remaining sectors. Remember that tags in odd numbered sectors face plot centre while those in even numbered sectors face the circumference.

Tags are fastened to the trees at breast height (1.3 m above germination point) with 5-centimetre aluminum nails (see Appendix 8-5). Angle the nail slightly upward so that the tag hangs away from the tree and drive it in just enough to hold the tag securely and yet allow for radial growth. Use a 1.3-metre long d.b.h.-stick to locate tagging height (a hair-broom handle on the property list is the correct length). Raise or lower the tagging height only when abnormal swelling occurs at breast height but record the actual tag height on the tally sheet.

Special rules govern the tagging of forked trees:

A. If the fork occurs at or above 1.3 m, tag the stem as a single tree provided it has a d.b.h. of at least 7.5 cm.

B. If the fork occurs below 1.3 m, and two or more stems of the fork are 7.5 cm or greater in d.b.h., tag each stem separately using consecutive numbers. When the diameters are recorded on the tally sheet, bracket the numbers of the stems making up the fork(s).

C. If the fork occurs below 1.3 m, and only one of the stems is 7.5 cm or greater, tag it as a single tree.

8.115 Sub-plot Establishment

To have some representation from trees below the tagging limit, that is, trees less than 7.5 cm d.b.h., a sub-plot is established within each of the three plots in the sample. The objective is to obtain a total of 30 trees (minimum number accepted is 20) in all three sub-plots.

8.1151 Sub-plot Shape and Size

Each of the three sub-plots is also fixed radius and circular, and its size is dependent on density. For a list of sub-plot sizes and sub-plot radii, see Appendix 8-4.

Note: When it is impossible to obtain the 70 trees (7.5 cm d.b.h. and greater) in the maximum size for the sample (see Section 8.1141), then increase the size of the sub-sample by an amount sufficient to obtain a total of 100 trees for the sample and sub-sample together. For example, if a sample has only 34 trees 7.5 cm d.b.h. or greater, then the sub-sample size must be large enough to include 66 trees less than 7.5 cm d.b.h.

8.1152 Sub-plot Radius and Circumference

Choose the sub-plot size and, using the procedure described in Section 8.1142, mark the sub-plot circumference with string.

8.1153 Division of the Sub-plot into Sectors

Sectors were laid out when the main plot was established. For the sub-plot, use the same sector divisions.

8.1154 Tree Tagging

Tag with nails all living trees (within the three sub-plots) between 2.0 cm and 7.4 cm d.b.h. as described in Section 8.1144.

In addition, tag all living trees at least 0.3 m in height but less than 2.0 cm d.b.h. but, for these trees, wire the blue plastic tag onto a branch. The procedure for tagging is the same as that described in Section 8.1144. Special rules govern the tagging of forked trees between 2.0 cm d.b.h. and 7.4 cm d.b.h. inclusive within the sub-plots:

A. If the fork occurs at or above 1.3 m, tag the stem as a single tree.

B. If the fork occurs below 1.3 m, tag each fork as a tree provided each is 2.0 cm d.b.h. and greater.

Give special attention to the method of tagging forked trees less than 2.0 cm d.b.h. To avoid tagging numerous leaders of trees that have been severely browsed, for example, tag as a tree only the tallest leader (see Appendix 8-6).

8.116 Tree Measurements and Miscellaneous Remarks

8.1161 Tree Description

For each tagged tree, record these measurements or observations in the relevant columns of the growth sample record sheet (F.S. 820, see Appendix 8-7): tree number, species, sector number, d.b.h. or small tree height, tree class, decay indicators for trees 2.0 cm d.b.h. and greater, and crown class. In addition, for sub-plot trees (tagged trees less than 7.5 cm d.b.h.), record 1 in the sub-plot tree column of the growth sample record sheet. Leave two spaces after each tree to allow the recording of two more measurements.

8.1162 D.B.H., or Small Tree Height, Measurement

Diameter at breast height is measured to the nearest millimetre for all tagged trees 2.0 cm d.b.h. and greater in the sample. Measure the diameter just above the nail and make sure that the diameter tape is perpendicular to the bole of the tree and it is pulled tight (see Appendix 8-5). The smallest possible diameter measurement that can be obtained at the nail is the correct one. For tagged trees less than 2.0 cm d.b.h., a total height (small tree height) measurement is taken instead of a diameter measurement. Measure the small tree height from the germination point to the tip of the terminal bud (see Appendix 8-6). For small trees with drooping leaders, such as cedar and hemlock, measure the height to the highest point of the droop.

Now and then unusual live trees are found within the sub-plot. Special rules apply to the measurement of the height of these abnormal trees that are less than 2.0 cm d.b.h. (see Appendix 8-6).

8.1163 Tree Class

Each tagged tree is classed as either tree class 1 (residual), tree class 2 (suspect), or tree class 5 (veteran):

Tree Class 1 Residual

Record tree class 1 if none of the decay indicators is present on the tree.

Tree Class 2 Suspect

Record tree class 2 if one or a combination of several decay indicators is present on the tree. Each of the decay indicators including a dead or broken top must be recorded on the field sheet under "Path Remarks" giving its occurence in the lower, middle, and/or upper third of the total height of the tree. The decay indicator position codes are listed in Appendix 8-8. These examples illustrate the relationship between the decay indicator and its position code:

A. A suspect tree has scars in the lower and middle third, and a fork in the middle third. In the pathological remarks section under "SCAR" enter 4, and under "FK/CK" enter 2.

B. A suspect tree has a dead top, conks in the lower third, and a crook in the middle third. In the pathological remarks section under "D/B T", enter 3; under "CONK" enter 1; and under "FK/CK", enter 2.

Tree Class 5 Veteran Tree

Record tree class 5 if a tree proves to be at least 30 years older than the oldest bored tree of the main stand. In addition, record V in the layer column of the growth sample record sheet.

Trees in this class are in a distinctly older age class than that of the main stand being sampled. Use an increment borer to determine the ages of trees that appear to be veterans. A veteran is not always an old tree: for example, a 20-year old stand could have 60-year old veterans which are remnants of a stand destroyed by fire.

In complex-layered stands, a tree is called a veteran (tree class 5) only when the tree is:

A. A remnant of a much older stand.
B. At least 100 years older than the oldest sample trees of the main stand.
C. Of a much larger diameter than those of the trees in the main stand. This criterion is necessary because of the subjectivity in determining what constitutes the main stand owing to the wide range of ages possible in it.

Growth samples established in complex-layered stands rarely contain trees belonging to tree class 5. Record decay indicators for veteran trees in the same way as for other trees.
For a veteran component to be recognized, the veterans must have an estimated crown closure of less than 6 percent (average of all plots) for the sample. Veterans are not recognized in stands 121 years or older except in lodgepole pine stands which may have a veteran component of Douglas-fir or larch.

8.1164 Decay Indicators

The eight indicators of decay (pathological remarks) are defined and illustrated in Appendix 8-9 and are:

Conk - In immature stands, its occurence is mainly on deciduous trees.

Blind Conk - It very seldom occurs on immature trees.

Scar - It must be weathered and may be grown over or open.

Fork or Crook - It includes multiple leaders.

Frost Crack - It may resemble a scar but it always follows the grain.

Mistletoe - It can occur on the trunk or on branches. Record a branch swelling that extends to the trunk of the tree as mistletoe. Because mistletoe may be an inhibitor of growth, also record it if present on swollen limbs even if at some distance from the trunk.

Rotten Branch - It must have a minimum diameter of 10 cm and in immature stands should only be present on veteran trees.

Dead or Broken Top - It includes a broken or dead leader (see Appendix 8-6).

These abnormalities are not indicators of decay and are illustrated in Appendix 8-9: butt rot, flute, candelabra branch, branch fan, black knot, butt and gall, sweep, exposed root, spiral grain, dry side, sapsucker hole, and insect boring. Record their occurrence in the remarks section of the growth sample record sheet.

A tree can only be properly classified when it is viewed from all sides. Because most defects in the upper portion of a tree are not visible to an observer standing at the base of the tree, it is important that the recorder move around until each tree crown being classified is clearly visible to him. The person measuring d.b.h. should move far enough away from the tree to be able to classify the lower third of the stem; whereas the recorder is responsible for classifying the upper two thirds of the tree.

8.1165 Crown Class

Crown class refers to the position of the crown of a tree relative to all other trees within the general plot area (not the whole stand). Each tagged tree classed as tree class 1, 2 or 5 is assigned a crown class code. The four crown classes are dominant, codominant, intermediate, and overtopped, and their respective crown class codes are 1, 2, 3 and 4 (see Appendix 8-10).

Record the crown class in column 36 of the growth sample record sheet (F.S. 820).

8.1166 Stand Structure

Stand structure is the physical arrangement or pattern of organization of the stand. Stand structure is described and classified according to recognizeable differences in age and in height.

The stand structures recognized are:

A. Single layer

1. Simple structure (even age, even height)

a) Without veterans
b) With veterans

2. Complex structure (uneven age, uneven height)

a) Without veterans
b) With veterans

B. Multi-layer

A multi-layered stand has two distinct layers:

1. Layer 1 (top layer)

2. Layer 2 (bottom layer)

For further details on stand structure, see Appendix 8-11.

For each tagged tree, identify the layer to which it belongs. For single-layered stands, only record the veteran layer code (V) in column 61 (F.S. 820) if veterans are present; for multi-layered stands, record the layer code for each tagged tree in column 61: codes 1, 2, and V for layer 1, layer 2, and a veteran layer, respectively.

8.1167 Sample Trees

Sample Trees for Age

In even-aged stands (pure and mixed) average age is determined by boring ten dominant and/or codominant trees of the leading major species on the sample, that is, ten trees selected from the three plots (see Figure 8-1). Note that the sample trees from the codominant class are taken from the taller ones. A major species comprises 20 percent or more of the gross sample volume. In mixed stands, take one additional age for each major species to determine if each species is in the same age class. If the second major species belongs to a different age class, and its volume is within 10 percent of the leading species, then also take 10 ages for it. The age of the second major species is not included in the calculation of average sample age, but the presence and the age of it are noted in the stand description, and the main stand age is still calculated by averaging the 10 ages of the leading major species.

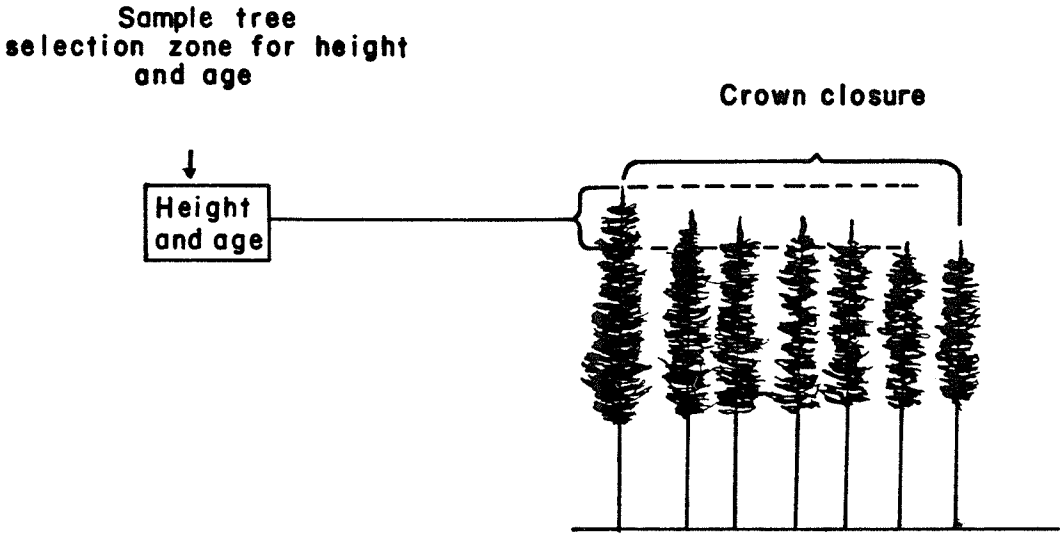

Figure 8-1 Sample tree selection in a single-layered, simple stand

Trees which appear to be veterans must be bored for age to determine if they are indeed veterans. The ages of veteran trees are not used in the calculation of the main stand age.

8.1167 cont.

For complex-layered stands, average age is calculated by averaging the 10 sample tree ages (of the leading major species) selected from trees in the top third of the stand (see Figure 8-2). To show the variation in age, take one additional age (of the leading major species) from the youngest portion of the stand. Do not select a tree smaller than 2.0 cm d.b.h. For each additional major species in complex-layered samples, take one age in addition to the 11 ages for the leading species.

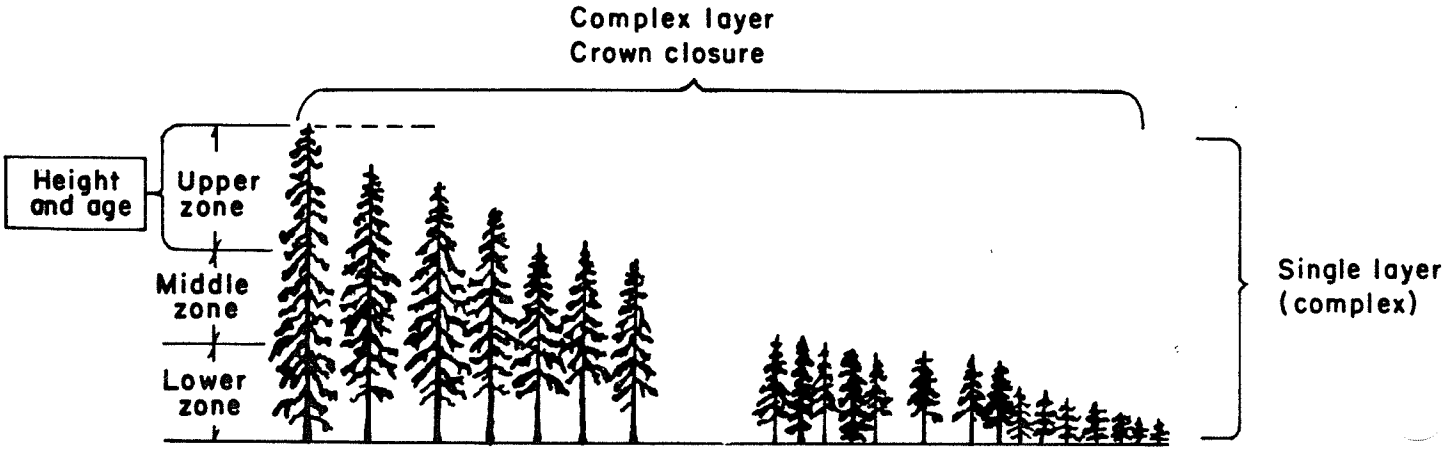

Figure 8-2 Sample tree selection in a single-layered, complex stand

Whenever possible, bore trees selected for age at 0.3 m above the germination point. Half the cores taken must include the pith. If the pith is included, record 1 in the pith column of the growth sample record sheet. If the pith is missed by more than an estimated three years on a tree under 100 years old, or by five years on a tree over 100 years old, then rebore the tree. Count ages in the field and record them on the field sheet. Then, for samples established in complex-layered stands, measure the radial increment for the last 10 and 20 years (to the nearest millimetre) and record the measurements in the radial increment section of the growth sample record sheet. In addition, put the accepted cores in plastic straws, which must be properly labelled with region number (R#), compartment number (Co#), sample number (G#), plot number, tree number, species, counted age, and boring height. Collect these straws and return them to the Inventory Branch for further analysis.

8.1167 cont.

Because trees are bored for age above the germination point, a correction must be made to obtain total age. Calculate the average boring age and average height of the 10 sample trees selected (from the leading major species) provided that all 10 were bored for age at the same location above the germination point. If some of the 10 sample trees were bored higher than 0.3 m above the germination point, exclude them temporarily until the age correction has been calculated. From the appropriate species site curve in the Field Handbook, establish a temporary site class based on the average age and average height of the sample trees. Using the pertinent species correction table from the Field Handbook, select the relevant age correction factor based on boring height and temporary site class. Then add this age correction factor to the average boring age to give total average age. Using this total average age, check the site curve again to make sure that the site class has not changed owing to the addition of the age correction factor. If the site class has changed, select the appropriate age correction and repeat the procedure.

Note: If it is not possible to bore a small tree for age without damaging it, select an outside-plot tree and bore it. Assign tree numbers 980 to 999 to outside-plot trees.

Sample Trees for Height

All trees within the plot measured for age must be measured for height. Local height-diameter curves are constructed from growth sample data before samples are compiled. To construct reliable curves, we therefore need a substantial number of heights.

Fourteen heights are required for each major species in the sample (that is, on the three plots), of which 10 are to be taken from the dominant and codominant classes using a ratio of two codominants to one dominant, while the other four are to cover the remaining range of stand diameters (down to 2.0 cm d.b.h.). Note that the sample trees from the codominant class should be taken from the taller portion of the codominant class.

For each minor species, take four heights from trees covering the full range of diameters for the particular species (down to 2.0 cm d.b.h.). A minor species is one which comprises from 10 to 19 percent of the gross sample volume. One height is required for each scattered species. A scattered species comprises less than 10 percent of the gross sample volume. If veteran trees are present within the sample, take at least one height for each species and estimate, to the nearest metre, the total heights of all other veterans in the sample. Record each estimated height in the curve height column of the growth sample record sheet (F.S. 820).

When possible, select residual sample trees for height measurements (tree class 1), otherwise select trees that do not have suspect characters occuring in the upper third of the tree. For each height measurement, the top and bottom of the tree must be clearly visible and the reading on the Suunto percent scale should not exceed 90 percent. The bottom reading may be taken on a hard hat held at the tree-tag height for which the correction is 1.3 m.

8.1168 Crown Closure

Crown closure is the percentage of ground area covered by the vertically projected tree crowns. Estimate crown closure for each plot by layer to the nearest 10 percent and record it in the crown closure column of the growth sample record sheet. Record crown closure for the veteran component to the nearest percent.

8.1169 Topography and Main Ground Cover

Make a brief description of landform, slope, surface conditions, soil type, and soil texture. Record minor vegetation in order of occurrence by botanical or common name.

8.116.10. Stump Measurements

For each stump found on growth plots established in selectively logged stands, measure and record by sector: stump tree-number (900 to 979), species, height, diameter, and tree number of the closest tagged tree.

Note: Stump tree-numbers range from 900 to 979 and are assigned to stumps, but tags are not affixed to them.

8.117 Stem Mapping

For use in distance-dependent growth modelling studies, 10 percent of the growth samples established in natural stands are stem mapped. The Inventory Branch designates the stratum (type group, site, age class) and the number of samples to be stem mapped. To establish the location of trees on these circular plots, measure and record on the stem mapping section of the growth sample record sheet, the bearing and distance from a point, usually plot centre, to each tagged tree. For a list of equipment needed for stem mapping, see Appendix 8-12.

To stem map growth samples, follow this procedure:

A. Set up the staff compass directly over the aluminum plot centre stake, and level the instrument. Record 1 in column 13 (card type 6) on the back of the growth sample record sheet (F.S. 820).

   If a tree of large diameter interferes with sightings on a considerable number of trees in the plot, then set up the instrument in an opening close to plot centre, but measure and record the bearing and the distance from the instrument to the plot centre. Record these measurements on the back of the growth sample record sheet in columns 14 to 21 (card type 6); also record 2 in column 13.

B. Adjust the staff compass for magnetic declination, and raise the sighting vanes. In Western Canada, magnetic declination is east of true north. Obtain the correct magnetic declination from an isogonic chart (see Appendix 8-13).

C. Systematically sight along to each tagged tree on the sample. To avoid sighting on the wrong tree, place the d.b.h. stick, wrapped with flagging tape to make it more visible, in front of the tree being sighted. To avoid false compass readings, keep sources of magnetic interference such as steel tapes, axes, knives, steel datum holders, eye glasses with steel frames, and most metal objects away from the staff compass. To simplify recording and possibly to minimize errors, use a staff compass that has Azimuth bearings, when available.

D. Measure the slope distance between plot centre (staff compass) and the centre of the tree.

E. Measure the slope with the clinometer (Suunto) using the percent scale.

F. Read the staff compass bearing on the scale at the north end of the compass needle.

G. Record the measurements in the respective columns alongside each tree number on the plot sheet.

As with tree tagging, begin stem mapping in sector 1 and continue in a clockwise direction until all the tagged trees are stem mapped.

All stem-mapped plots should be photographed on low level (70 mm) photos. To aid the photography crew and to obtain complete coverage of the plot, raise a flag on the tallest tree near the plot centre.

8.118 Growth Sample Record Sheet (F.S. 820)

Front of the Growth Sample Record Sheet (see Appendix 8-7)

Column	Item	Instruction
Card Type 1 - Sample Data		
1 to 2	Region No.	- Enter the provincial inventory reference region number obtained from inventory maps.
3 to 5	Compt. No.	- Enter the provincial inventory reference compartment number obtained from inventory maps.

8.118 cont.

Column	Item	Instruction
6	Compt. Letter	- Enter the provincial inventory reference compartment letter. Only a few areas in B.C. have a compartment number followed by a letter, and they are mainly on the Coast. If the compartment letter does not exist, use a dash.
7 to 9	Sample No.	- Enter the consecutive sample number for the compartment.
10	Plot No.	- Enter the plot number.
11	Card Type	- Card type 1 is entered.
12	Measurement No.	- Enter 0, which is the code for the initial sample measurement.
13 to 15	Sample Size	- Enter the sample size in hectares (i.e. the sum of the three plot sizes).
16 to 19	Sample per Hectare Factor	- Enter the factor, which varies with sample size; see Appendix 8-4.
20 to 23	Sub-sample Size	- Enter the sub-sample size in hectares (i.e. the sum of the three sub-plot sizes).
24 to 29	Sub-sample per Hectare Factor	- Enter the factor, which varies with sub-sample size.
30 to 32	Mean Age (Layer 1)	- Enter the mean age for layer 1.
33 to 35	Mean Age (Layer 2)	- Do not use and enter 0.
36 to 38	Mean Age (Layer V)	- Enter the mean age for the veteran component. If layer V does not exist, enter 0.
39 to 44	Age Range	- Enter age range (youngest and oldest age) for samples established in complex-layered stands.
45 to 47	Damage to Sample	- Do not use for establishment.

8.118 cont.

Column	Item	Instruction
48	Stem Map	- If the sample is not stem mapped, enter 0 and if it is stem mapped, enter 1.
49 to 51	Inventory Sample Number	- Enter the T.S.A. number. Note that columns 49 to 51 are titled "Inventory Sample No."; instead, read "T.S.A. Number".
52	F.I.Z.	- Enter the forest inventory zone (letters A to L).
53 to 56	Special Cruise Number (P.S.Y.U. or T.F.L.)	- Enter the special cruise number.
11	Card Type 2 - Plot Data	
12	Measurement No.	- Enter 0 which is the code for the initial sample measurement.
13 to 15	Plot Size	- Enter the plot size in hectares (see Appendix 8-4).
16 to 19	Plot Radius	- Enter the plot radius in metres (see Appendix 8-4).
20 to 23	Sub-plot Size	- Enter the sub-plot size in hectares (see Appendix 8-4).
24 to 27	Sup-plot Radius	- Enter the sub-plot radius in metres (see Appendix 8-4).
28 to 29	Aspect	- Enter the plot aspect (e.g. N.SW.), left-justified.
30 to 31	Slope	- Enter the average slope of each plot in percent.
32 to 35	Elevation	- Enter elevation above sea level obtained from a contour map.
36 to 38	Crown Closure (Layer 1)	- Enter the crown closure of each plot (for layer 1) to the nearest 10 percent.

8.118 cont.

Column	Item	Instruction
39 to 41	Crown Closure (Layer 2)	- Do not use for establishment.
42 to 44	Crown Closure (Layer V)	- Enter the crown closure of each plot for the veteran component.
45 to 50	Date of Measurement	- Enter the date of plot measurement (year-month-day).
51 to 58	Map No.	- Enter the B.C.G.S. map sheet number.
59 to 66	Photo No.	- Enter the B.C. flight number and photo number.
11	Card Type 3 - Tree Data	
12	Meas. No.	- Enter 0, which is the code for the initial sample measurement.
13 to 15	Tree No.	- Enter the tag number of the tree being examined.
16 to 17	Species	- Enter the species code of the tree being examined. For species codes, see Appendix 8-14.
18 to 19	Sector No.	- Enter the sector in which each tagged tree is located.
20 to 23	D.B.H. (1.3 m)	- Enter the diameter at breast height (1.3 m above germination point) of each tagged tree 2.0 cm d.b.h. and greater to the nearest millimetre.
24 to 26	Small Tree or Curve Height	- Enter small tree height to the nearest decimetre for tagged trees (trees 0.3 m in height but less than 2.0 cm d.b.h. at 1.3 m). Also, record the estimated height for veterans.
27	Tree Class	- Enter the pertinent tree class code, of which three are recognized: residual (1), suspect (2), and veteran (5).

8.118 cont.

Column	Item	Instruction
28 to 35	Pathological Remarks	- Record decay indicators present on each tree (see Appendices 8-8 and 8-9).
36	Crown Class	- Record the crown class of each tree (see Appendix 8-10).
37 to 45	Stem Mapping	- Record the stem-mapping information for each tree.
46 to 52	Stumps	- Record the required information.
53 to 55	Near Tree No.	- Record the tree number of the closest numbered living tree to the stump (for selectively logged samples) or to the sub-plot tree being measured.
56	Sub-plot Tree	- If the tree is located in the sub-plot and is less than 7.5 cm d.b.h., record 1.
57 to 60	D.B.H. (1.37 m)	- Leave blank for new samples.
61	Layer	- If the stand has more than one layer, enter the layer to which that tree belongs (layer 1 is assumed if the column left blank).
62 to 66	Remarks	- Enter pertinent tree information not recorded in preceding columns.

Back of the Growth Sample Record Sheet (see Appendix 8-7)

Card Type 4 - Sample Tree Data

1 to 10	Plot Identity	- Enter this information in the same way as on the front side (region no., comp. no., letter, sample no., plot no.).
11	Card Type	- Card Type 4 is entered.

8.118 cont.

Column	Item	Instruction
12	Meas. No.	- Enter 0, which is the code for the initial sample measurement.
13 to 15	Tree No.	- Enter the tree number of the sample tree.
16 to 17	Species	- Enter the species of the sample tree.
18 to 21	D.B.H.	- Enter the d.b.h. of the sample tree.
22 to 23	Top	- Enter the top Suunto reading (% scale).
24 to 26	Bottom	- Enter the bottom Suunto reading (+ or - , % scale).
27 to 29	Total	- Enter the total of top and bottom readings.
30 to 32	Slope Dist.	- Enter the slope distance from the tree to the measurer.
33 to 34	Slope %	- Enter the slope percent.
35 to 37	Horiz. Dist.	- Enter the horizontal distance between the tree and the measurer.
38 to 40	Height	- Enter the calculated height.
41 to 42	Height Correction	- Enter the height correction.
43 to 45	Total Height	- Enter the total height.
46 to 48	Boring Age	- Enter the boring age.
49 to 50	Boring Height	- Enter the boring height.
51 to 52	Age Correction	- Enter the age correction.
53 to 55	Total Age	- Enter the total age.
56	Pith (1)	- If the pith is included, enter 1.
57 to 62	Rad. Inc. (mm)	- Record the radial increment during the last 10 and 20 years (for complex stands only).

8.118 cont.

Column	Item	Instruction
	Tree Count	- Do not use for establishment.
Card Type 5 - Tree Count Summary Data		
	Tree Count Summary	- Do not use for establishment.
Card Type 6 - Stem Mapping Data		
(11 to 21)	Stem Mapping	- Record the necessary information for stem mapped samples.
11	Card Type	- Card type 6 is entered.
12	Measurement No.	- Enter 0, which is the code for the intial sample measurement.
13	Compass at Plt. Centre Y = 1 N = 2	- If the staff compass was set up at plot centre, record 1; if it was set up elsewhere, record 2.
14 to 16	Bearing From Compass to Plot Centre (0 to 360°)	- If the compass was not set up at plot centre, record the bearing (0 to 360°) from the compass to the plot centre.
17 to 18	Slope (%)	- If the compass was not set up at plot centre, record the slope % from the compass to plot centre. If the slope is zero, enter 0.
19 to 21	Slope Distance (0.01 m)	- If the compass was not set up at plot centre, record the slope distance from the compass to plot centre.
	Sector Diagram	- Sketch the layout of the plot sectors for future reference.
	Topography	- Give a brief description of landform, slope (e.g. uniform or variable), and surface conditions in the vicinity of the plot.
	Main Ground Cover	- List the minor vegetation in order of occurrence.
	Location and Access	- Describe in detail the location of the sample and the access to it.
	Notes	- Record remarks in this area.

8.119 Quality Control, Sample Mapping, and Return of Field Sheets

Refer to Appendix 8-1 for the standards of measurement, which state the non-sampling error or variation allowed. Sampling crews should emphasize accuracy of measurement and then production.

To ensure that crews continue to work efficiently and they follow and understand the application of recommended procedures, regular inspections must be carried out on each crew. Inspect at least 10 percent of all samples established, and where the inspection shows that a growth sample has been poorly done, the original crew may be required to redo it.

In addition to sample inspections, make spot checks as the work progresses to be sure that tie points have been properly marked and that tie lines have been run on the designated bearings. So that their performance can be observed, occasionally visit each crew on the sample. After sample inspection, correct on the field sheet all errors greater than the allowable standard .

8.1191 Office Checking of Samples

All field sheets must be office checked before sending them to the Manager, Growth and Yield, at the Inventory Branch. To office check properly:

A. Check that all information recorded is legible and dark enough for clear photo copying.

B. Check that the region number, the compartment number, the compartment letter, the sample number, and the plot number have been recorded on every page and the tree information is complete, has been recorded in the proper column, and has been correctly justified.

C. Check that for each plot the bearing and distance from plot centre to three tagged, living trees have been recorded in the stem map columns.

D. For samples that were stem mapped, check that the required information on the location of the staff compass has been recorded for card type 6.

E. If the distance measured is the horizontal distance, check that a zero has been recorded in the slope percent column, that is for stem map and height measurement.

F. Check that the tree class meets these criteria:

Tree class 1 - Tree has no decay indicators.
Tree class 2 - Tree has one or more decay indicators.
Tree class 3 - Not used.
Tree class 4 - Not used.
Tree class 5 - Tree is a veteran.

G. Check that the sample trees have been selected in accordance with the specifications in this manual (see Section 8.1167).

H. Check height calculations.

I. For stem-mapped samples, check that the tree number of the tree to which the flag is attached for 70 mm photography was recorded on the back of the growth sample record sheet.

J. Check that 1 has been recorded (in the sub-plot column) for each tagged tree less than 7.5 cm d.b.h. within the sub-plot.

K. Check that mean sample age and mean sample height have been calculated correctly and have been recorded only on the first sheet of each plot.

L. Check that the measurement number, the sample and sub-sample sizes and per hectare factors, the age range (if applicable), the stem map code, the T.S.A. number, the F.I.Z., the special cruise number, the plot and sub-plot sizes and radii, the aspect, the slope, the elevation, the crown closure, the date of measurement, the map number, and the photo number have been recorded only on the first sheet of each plot.

M. Check that the pages have been numbered properly and the tally person has signed the sample.

8.1192 Plot Inspection Procedures

Pre-field Inspection

A. Randomly select one plot that has been office checked according to the procedures in Section 8.1191.

B. Randomly select six trees from the tree detail section (card type 3) of the growth sample record sheet and transcribe their respective measurements onto the top section of the natural stands plot inspection report (F.S. 822(1), see Appendix 8-15).

C. Randomly select three trees for height from the sample tree section (card type 4) of the growth sample record sheet and transcribe their height measurements onto the sample tree section of the natural stands plot inspection report.

D. Select one tree for age, which may be one of the three selected for height, from the sample tree section and transcribe the age measurements into the sample tree section of the natural stands plot inspection report.

E. Transcribe the crown closure, aspect, and slope of the plot onto the appropriate section of the plot inspection report.

F. Enter the sample identity (region, compartment, sample, plot), plot and sub-plot sizes, plot and sub-plot radii, inspection date, original tally crew, and the date of measurement in the section at the top of the plot inspection report.

8.1192 cont.

Field Inspection

A. Use the access notes to get to the plot.

B. Check that the tie point is marked as specified in Section 8.1132.

C. Verify that the tie line bearing and distance were run within the allowable standards.

D. Check that the aluminum plot centre markers are inscribed correctly and the plot centre stake is protected with a cairn.

E. Check that the bearings and distances from plot centre to three trees are correct.

F. Check the plot and sub-plot radii each at a minimum of three different locations on the perimeter for trees that should have been included or excluded from the plot or sub-plot. Also, check that trees away from the perimeters, but within the plot and sub-plot that are larger than the tagging limits, were not missed. Flag with a circled asterisk any tree missed or tallied when it should have been included or excluded, respectively.

G. Carefully measure all the selected trees recorded on the plot inspection report for:

1. Tree identification

   Check that the genus or species of each tree inspected is correct and place a circled asterisk beside a tree that was incorrectly identified.

2. Tree tag height

   Check the tag height of the six selected trees to verify that breast height has been located at 1.3 m above the germination point. At the same time, make sure that the nails have been securely driven into the trees and the nail with the tag has been driven in at a slight angle so that the tag hangs away from the tree.

3. Diameter and pathological remarks (decay indicators)

   Measure the six selected trees for d.b.h. and classify them.

4. Sample tree heights

   Measure the three selected trees for height.

5. Stem mapping

If the sample was stem mapped, check the six selected trees for bearing, distance, and percent slope.

Also, assess crown closure for the plot. Compare all of the check measurements with the crew's measurements and give the crew the benefit of the doubt on any slight discrepancy.

H. Check that the results conform to the standards of measurement (see Appendix 8-1).

I. Use an asterisk in the margin to indicate that the difference between the two measurements is greater than the allowable error.

J. Use a circled asterisk in the margin to indicate that the error is greater than one and a half times the allowable error.

K. Complete the inspection items section of the inspection report.

L. Rate the quality of the work on the plot using the system of weighting in Appendix 8-16.

M. Record the plot rating and any other comments in the remarks section of the plot inspection report.

Post Field Inspection

A Discuss the results of the plot inspection with the original tally crew.

B. Make recommendations to the original field crew, when necessary, for improvement of their work.

C. Change, on the original field sheets, all data flagged with an asterisk or a circled asterisk.

8.1193 Mapping of Samples

Having established the samples, plot them on the forest cover maps at the Forest District office. Send copies of the maps showing the location of all the samples to the Forest Region and to the Inventory Branch.

8.1194 Return of Field Sheets

Once the field sheets have been office checked and corrected, make good legible photo copies of them before sending the originals to the Manager, Growth and Yield, at the Inventory Branch. Store the photo copies in the Forest Region for security and reference. Send a covering letter with the originals that lists the samples sent, and keep a duplicate of the covering letter for field office records. If the data are being sent by mail, register them.