Climate Impacts on the Productivity and Health of Spruce (CIPHS)

Methods Manual

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Part I Introduction

Intent

Since 2001, large portions of the western Canadian interior and specifically Alberta have been notably drier than normal leading to widespread impacts on forests of this region. Trembling aspen, a major commercial species in Alberta, has experienced growth reductions and increased mortality (Hogg et al. 2008). White spruce, another commercial species, has experienced dramatic growth reductions during the past quarter century (Hogg et al. 2017). The decline of both species has been attributed primarily to moisture deficits and, in the case of trembling aspen, insect defoliation. Given climate change projections for continued warming and drying, the future health of Alberta's aspen and white spruce forests is in question.

In 2000 the Canadian Forest Service, in collaboration with provincial agencies and industry, established the Climate Impacts on the Productivity and Health of Aspen (CIPHA) study. In response to the finding of this study and from a concern about the effects of moisture deficit on white spruce, the Canadian Forest Service, in collaboration with Alberta Agriculture and Forestry, established the Climate Impacts on the Productivity and Health of Spruce (CIPHS) study in 2019. The objectives of this study are as follows:

1. Develop a targeted forest health monitoring system to assess climate-related changes in the productivity and health of Alberta's white spruce forests.

2. Determine the impacts of drought, insects and diseases on historic, current and future productivity and health of Alberta's white spruce forests.

3. Provide information and tools in support of forest management practices aimed at minimizing climate impacts on Alberta's white spruce forests.

4. Provide field-based knowledge for including a climate component in models of forest growth and yield, carbon uptake and wood fiber supply.

Study design

The study consists of a balanced system of long-term forest-health research plots in white spruce stands extending throughout the forested "Green Zone". The Green Zone comprises 60 % of the land area of Alberta, is primarily public land owned by the Alberta government and is composed predominantly of forests. The design of this study is as follows:

15 nodes - a node being a geographical area
2 stands/node - 2 white spruce stands within a 40 km of each other

2 plots/stand - variable area plots with a minimum of 25 spruce trees each

There are three phases to the study
1) Site selection
2) Plot establishment
3) Ongoing monitoring

1) Site Selection

Site selection began in 2014 and 2015 with the selection of potential plot locations prior to plot establishment. Site characteristics, such as stand composition, size and suitability were collected. As well, representative trees were cored with increment borers. Tree cores provided information concerning stand age. Although many sites were selected, it is understood that site selection can benefit from the local knowledge of district Forest Health Officers and further GIS analyses. For these reasons, final site selection is left up to the individual Forest Health Officers during the year of establishment.

2) Plot establishment

During this phase, 60 individual plots will be established in 15 geographic areas or nodes. Plot establishment involves the physical marking of plot boundaries, individual trees, and tie points to access roads. At plot establishment initial mensuration and forest health measurements will be collected. Tree cores, and possibly tree disks, will be collected for tree-ring analysis.

3) Ongoing monitoring

The third phase involves repeated measurement of forest health and mensuration. Additional tree cores and/or tree disks will also be collected. Additional surveys, including regeneration surveys, vegetation surveys, soil sampling surveys, etc. will be performed as needed. The frequency of remeasurement and collections will be every four years, however, the frequency can change depending on the health and/or climatic history of the stands as well as resources available including manpower.

Provincial agencies conducting annual aerial surveys of various forest health conditions should consider adding the CIPHS plot locations to their flight paths. In this manner aerially assessed defoliation and dieback can be used to confirm ground measures or conversely ground measures can confirm aerially assessed measures. Aerially derived measures of plot defoliation and dieback are especially relevant in the years between the repeat ground assessments.

Data integrity and quality

Methods utilized in this study are intended to be practical, meaningful, and repeatable. In order to be as efficient as possible, the variables selected for measurement are restricted to only those that meaningfully relate to the projects stated objectives. Although some method changes are inevitable, the benefit of having consistent and well thought out methodology is recognized. For this reason, considerable effort has been made to ensure that right variables and the correct measurement strategies have been adopted from the start.

Given the wealth of knowledge and skill of the field personnel, they are encouraged to review the objectives and methodology and contribute towards improvements. The quality of measurement and the overall results of this project are dependent upon all participants taking an active role in the design and implementation of this project.

At the beginning of the project, all field personnel will engage in training designed to ensure consistency between personnel. Subsequent periodic training ensures consistency is maintained and new staff are trained as needed. Periodically, a subset of plots chosen at random, are to be cross-checked by different field staff. At the end of each collection season, data are checked for incorrectly coded entries and outliers. If these potential errors are not readily correctable they are flagged for reexamination in the following year.

Data is collected using field-ready tablets. These tablets provide run-time error correction by disallowing inappropriate data entries. Further, the tablets contain reference material to assist with forest health measurements including the identification of damage agents. The data collection system also allows for the collection of photographs and specimens which aid in the identification of unknown damage agents.

Permission and entry approval

A number of provincial agencies and Forest Management Agreement holders require research permits and right of entry documents be carried whenever entering lands under their jurisdiction. Some agencies require notification prior to entry. Field staff are provided with appropriate permits, documents and contact numbers for each study site. They are responsible for ensuring that they comply with all obligations and restrictions as specified in the permits.

Part II Procedures

Site Selection

1. Introduction

GIS analyses are used to identify potential sites. Included in these analyses are inventory maps and the below stated selection criteria. Potential sites identified by GIS are then assessed for suitability using on the ground surveys prior to plot establishment. During plot establishment a number of unforeseen circumstances such as stand shape, unfavorable composition, undesirable gaps, bear baiting and other incompatible land use issues may become more apparent and force the selection of a new stand. Therefore, additional potential stands are identified for each node, although only two stands are eventually established.

2. Selection criteria

The following selection criteria are guidelines that represent the ideal stand and it is unlikely that a stand will meet all of these criteria. They are presented in relative order of importance.

Important

1) Stand composition - greater than 70% of trees are white spruce (or 70 % of the basal area).
2) Size - continuous forest (with composition of >70% white spruce) with a minimum size of 250 m × 120 m (~3 ha) required for typical 2 plot layout and 50 m buffer. If a continuous stand of this size can't be found, plots may be placed in two nearby smaller stands each measuring at least 120 m x 150 m provide the nearby stands are within 200 m of each other and they are of the same age.
3) Age - between 40 to 150 years. Where possible one of the two stands should be young (40-80 yrs.) and the other should be old (>100) with an age difference of at least 30 years between the younger and older stand at each node.

Less Important

4) Elevation -all potential stands in a node should be at about the same elevation (within 100m).
5) Access -no stands that require all-terrain vehicles or stands that will be difficult to access during wet weather. Stands must be within a 20-minute walking distance of the access road.
6) Distance from other stands - all stands of a node should be within 25 km of each other and a minimum of ½ km apart.
7) Disturbance -no significant disturbance (e.g., grazing, recent fire, thinning). Stands with recent insect defoliation should be avoided. Stands with extensive historic defoliation should also be avoided.

8) Point source pollution -greater than 1 km away from landfills, emitting industrial sites and flaring oil/gas installations. This restriction does not apply to other oil/gas installations that are not point sources of pollution such as pump jacks, pipelines and compressor stations.

Least Important

9) Slope -no greater than 10%. If stands of slopes greater than 10% are chosen, both the young and the old stand should have a similar slope and aspect.
10) Water bodies -greater than 200 m away from major lakes and rivers. Riparian areas, flood plains and areas where water drainage is likely to have an impact on forest health should be avoided.
11) Agricultural lands, cut blocks, roads and stand edges -greater than 50 m from farmland, roads, cut blocks, and stand edges.
12) Density - crown closure greater than 20%.

Plot Establishment

1. Introduction

Final stand selection is made during plot establishment (usually the year following preliminary stand selection). The best two stands are chosen from previously identified potential stands. If, for any reason, less than two potential stands are determined to be suitable, alternative stands are chosen using the listed selection criteria. GIS maps of suitable stands are used to aid in the selection of new stands. Prior to plot establishment, chosen stands are checked for existing dispositions and notations that might prevent the establishment of CIPHS plots or prevent their protection. Equipment required for plot establishment is listed in Appendix 6.

2. Naming convention

A three-letter code is used to designate the node based on the first three letters of the nearest town name or a nearby dominant geographic feature. Stands are numbered 1 and 2 with number 1 being the most northern. Plots are numbered 1 and 2. Within a stand, the plots are number so that when facing the center point with your back to the tie point, the left plot is Plot 1 and the right plot is Plot 2 (Fig. 1).

3. Locating stand center and plots

GIS maps are used to determine a suitable tie point, bearing and distance to approximate stand center, and approximate bearing of the stand's long axis. Using the appropriate magnetic declination and the predetermined bearing and distance, the stand center is located and marked with a 1 m length of metal electrical conduit. A nearby tree is then flagged and painted. The two plots are laid along the long axis of the stand, one on either side of the center point. If the stand length permits, each plot is located 50 m away from the stand center point with a minimum buffer of 50 m between plot boundaries and the stand edge. If the stand is too small, the distance from the stand center point to each plot is reduced to 25 m (minimum buffer of 50 m is not reduced). Plots are never to be less than 50 m apart.

Certain areas or pockets within a stand are not suitable for plot establishment. These include:

1. Cut lines, clearings, agricultural fields and cut blocks within 50 m of the plot that are significant enough to affect the health or growth of trees in the plot.
2. Deciduous-to-conifer transitions within 50 m of the plot boundaries.
3. Large swamps, wet areas or gaps > 30 m in diameter within 50 m of the plot
4. Areas high in species other than white spruce (>30% of other species by number, consider living trees >7 cm DBH only).

The following conditions are always ignored:

1. Game trails, or old overgrown seismic lines.
2. Changes in stand density and small wet areas or gaps (< 30 m diameter).
3. Changes in tree health or number of dead trees.

If plot areas are unsuitable, as defined above, the distance from the center point is extended by multiples of 25 m until suitable locations are found. If one plot area is not suitable even after extending the distance from the center point or if extending the distance is not possible (i.e., stand too small), a new plot bearing is selected at random (Fig. 1).

4. Determining and marking plot corners

Once a suitable plot area has been found, the appropriate distance to Plot 1 is measured along the long axis of the plot. This point is corner 1 of Plot 1 and is marked with a 1 m length of metal electrical conduit. The next fixed corner is measured and marked at 15 m perpendicular to the long axis (Fig. 2). The plot is always placed on the far side of the long axis, that is, away from the tie point (Fig. 1, 2 and 3). The width (X dimension) of the plot is always 15 m. The length (Y dimension) of the plot varies depending on stand density. Two 50 m tapes are stretched from the fixed corners, keeping 15 m apart, to a length (rounded to the nearest metre) that yields a minimum of 25 living white spruce trees greater than 7cm diameter at breast height. The final two corners are placed at this distance. The plot is then checked to ensure that it is square and that a 50 m buffer exists between any plot border and the stand edge. All plot corner posts are painted fluorescent orange. This procedure is repeated for the second plot.

5. Bearings and compass declination

Recorded latitudes, longitudes, distances and bearings may be use for GIS overlay purposes or may be used to reconstruct the stand following disturbances such as fire. For these reasons, accurate positions, distances and bearing are essential. Accurate bearings depend on the use of the appropriate magnetic declination. Declination changes every year with the Earth's geomagnetic field and is modeled typically for five-year periods. Declination is available from handheld GPS units, however, unless the unit is new the declination provided is likely out of date. A built-in declination calculator, utilizing valid current geomagnetic models, is provided on the Locations Form (Fig. 4). To obtain the declination, the Tie Point latitude and longitude boxes are filled and the Declination box is double tapped. Compass declination must be appropriately set before determining bearings to the Stand Centre and to each Plot.

6. GPS positions

GPS positions are collected using provided GPS USB receivers. Once attached to the tablet, double tapping the Latitude box on the Location Form (Fig. 4) initializes the GPS and starts a collection of GPS positions for 25 seconds. The average of these positions is then automatically entered into the Location Form. This averaging improves the precision but not necessarily the accuracy of the position. In addition a measurement of error, the horizontal dilution of position (HDOP) is automatically entered in to the database.

Although the GPS USB receiver provides the best GPS position, if it is not available or not functional a hand-held GPS units may be used. Smartphone GPS may be used if hand-held units are not available.

7. Tree numbering

Pre-numbered tree tags come in lots of 1 to 1000. Typically a stand with its two plots has no more than 200 trees in total (living and dead spruce and other species). Therefore, the trees in a stand are tagged using lots of 200 tags. A total of 400 tree tags are needed to tag all trees in the two stands of a node. The following procedures are used when numbering trees:

1) All trees of any species, living or dead, greater than 7 cm at DBH and standing under their own support are numbered. Therefore, stumps less than 1.3 m tall and dead trees on the ground or suspended by others are not numbered.
2) Trees are considered in the plot if their point of germination is within the plot boundary.
3) A forked tree is considered to be two trees if the fork is below breast height (1.3 m).
4) Trees in the stands are numbered consecutively (e.g. Fox Creek Stand 1 tagged 1 to 200, Stand 2 tagged 201 to 400, High Level Stand 1 tagged 401 to 600, Stand 2 tagged 601 to 800).
5) Trees in the left plot (Plot 1) are numbered using tags 1 to 100. The process is repeated for the right plot (Plot 2) using tags 101 to 200 (Fig. 2).
6) In the instance where the long axis of the plot is just a continuation of the line from the tie point to stand center, the plot closest to the tie point is Plot 1.

7) When numbering trees, the plot is bisected into two 7.5 m wide strips parallel to the long axis. Trees are numbered along the direction of travel down one strip and back along the other starting with the tree closest to the first corner (Fig. 2).
8) Tags are attached to trees at eye level using aluminum nails. Tree tags are to be nailed tight to the stem for dead trees. Tree tags on living trees are to be loose with at least 1 cm of room between the nail head and the tree stem. Tree tags are place on the side of the tree facing the normal direction of travel through the plot.
9) A horizontal line, 1.3 m above the ground, is painted on each tree facing the normal direction of travel through the plot. This ensures that repeated diameter measurements are always taken from the same point. If stem abnormalities exist at 1.3 m, the line is painted a standard 30 cm above or below 1.3 m (see Appendix 1).
10) Tree numbers are painted as high as possible facing the normal direction of travel through the plot.

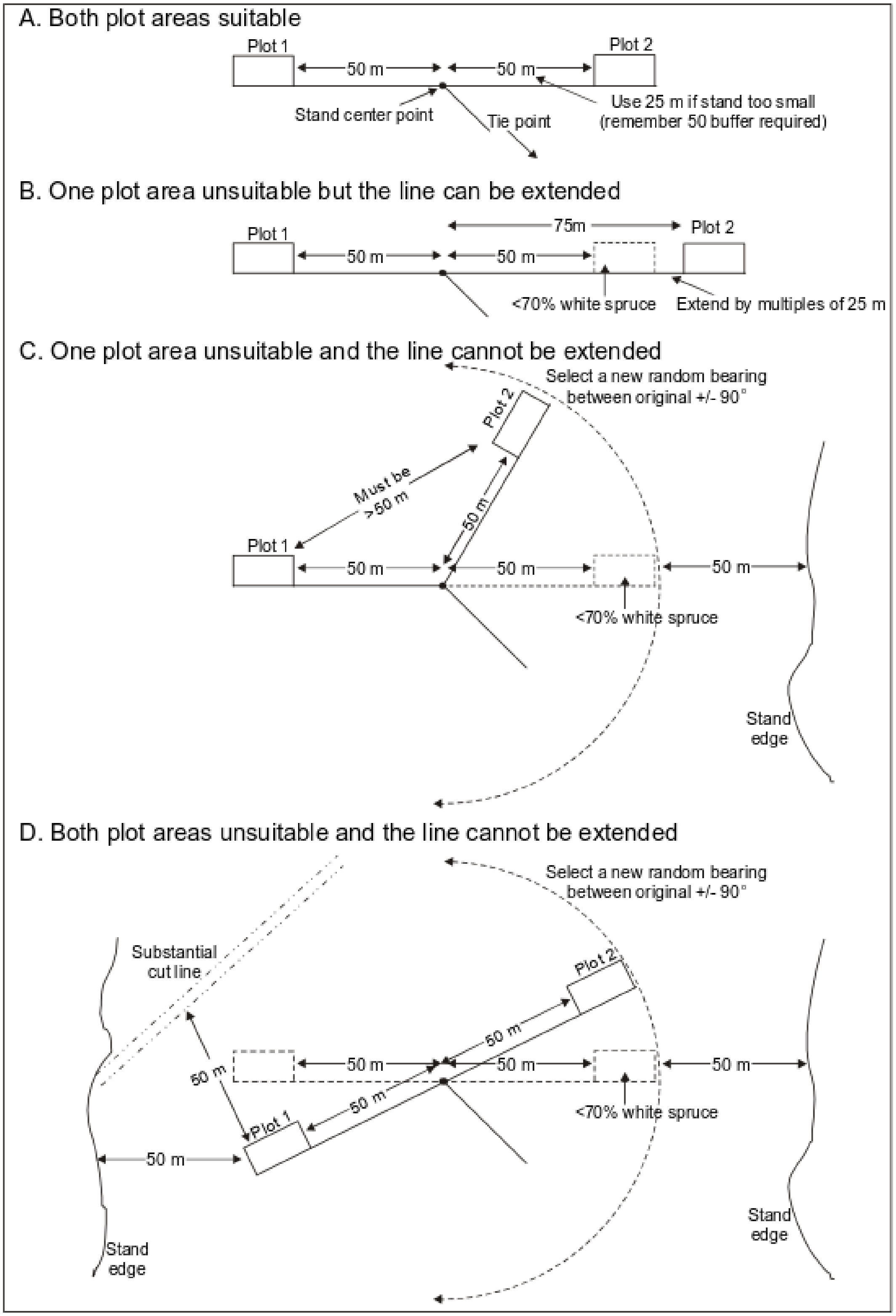
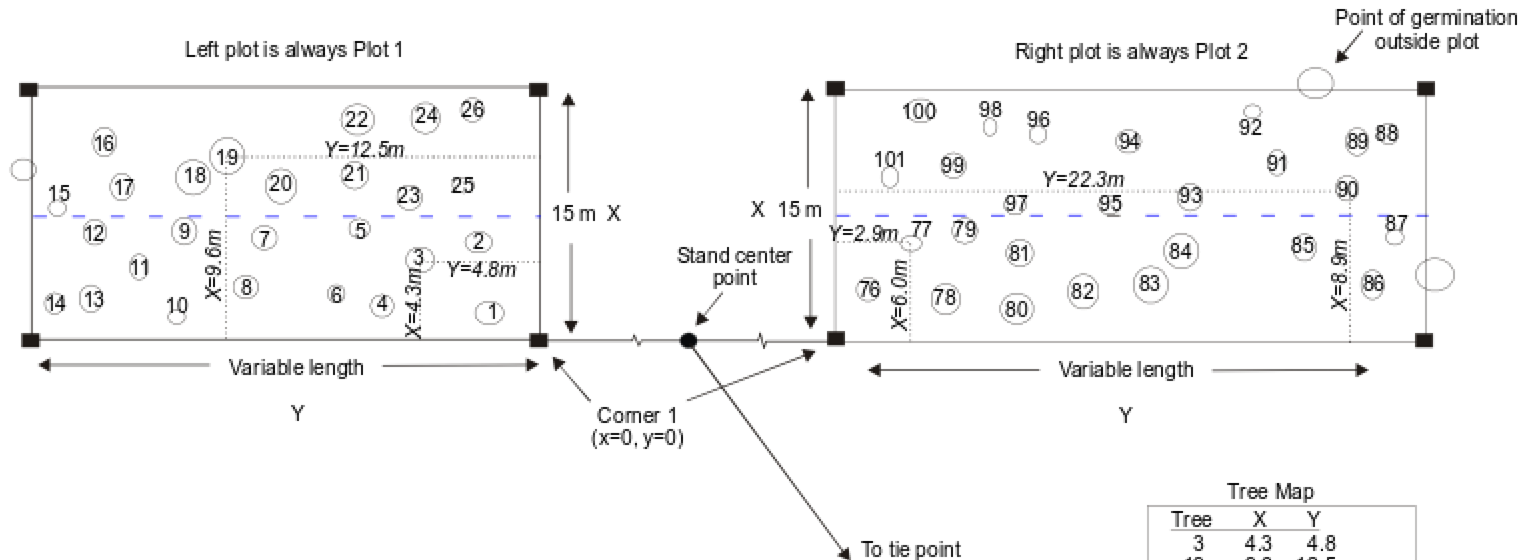


Figure 1. Determining plot locations within stands



Tree Map

Tree	X	Y
3	4.3	4.8
19	9.6	12.5
77	6.0	2.9
90	8.9	22.3

Note: No negative values

Notes:
1) Y distance is variable and is the length to the nearest metre at which point the plot contains 25 live white spruce trees
2) The plot may have slightly more than 25 live white spruce trees
3) Always start numbering the left plot (Plot 1) trees first
4) Number the trees of the second plot starting with tag number 101
5) Within each plot, always measure distances from Corner 1 (no negative values)

Figure 2. Numbering and mapping trees within a stand.

8. Stand sketch map

A detailed stand sketch map is made depicting stand boundaries, tie point, center point, plot locations and dimensions, locations of unsuitable gaps or pockets, road names and distances to major intersections. The orientation of the map is indicated by including an arrow pointing to the north. An example of a completed sketch map is provided in Figure 3. Blank sketch map forms are available in Appendix 2 and may be printed as needed.

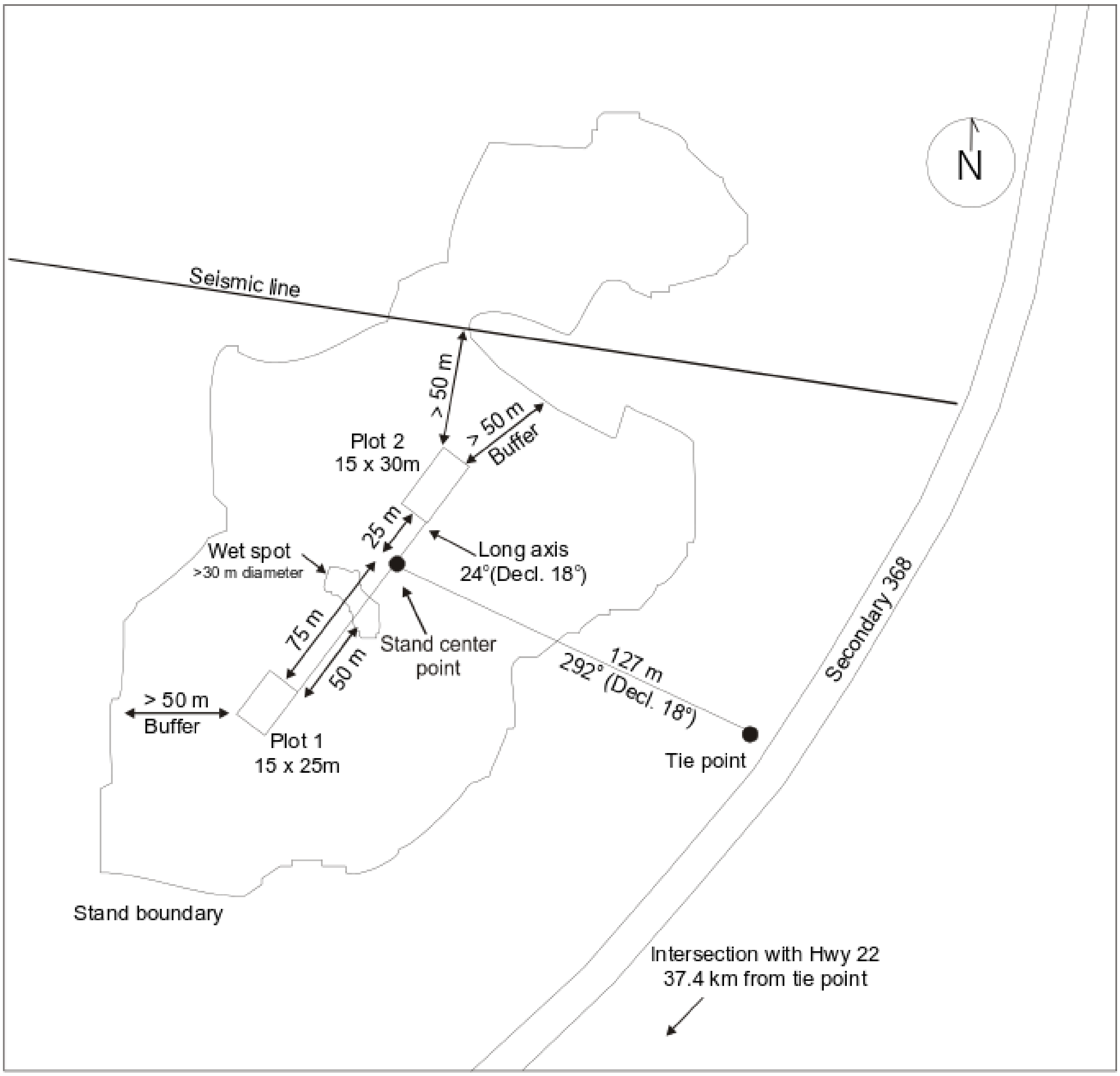


Figure 3. Example of a thorough stand and plot sketch map.

Location Form: Basic Stand and Plot Information

1. Introduction

The Location Form provides basic stand and plot information. Information is entered into this form during plot establishment. All distances, bearings, plot dimensions, and latitude and longitude coordinates are recorded. GPS coordinates are collected from the road-side tie point, the stand center and corner 1 of each plot. Contact information of the person/s who have jurisdiction over the land is also recorded. This may include FMA company representatives, Alberta Environment and Parks personnel, etc.

2. Variable descriptions

Location Form: Stand Tab **(See Fig. 4)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2
Tie Point[2]	Latitude and longitude to 5 decimal points. Elevation is recorded to the nearest metre.
Stand Center[3]	Latitude and longitude to 5 decimal points. Elevation is recorded to the nearest metre.
Distance[4]	Distance from the Tie Point to the Stand Center (in metres)
Bearing[5]	Bearing from the Tie Point to the Stand Center
Declination[6]	Declination in degrees for the year of establishment.
Owner[7]	FMA holder, park or private land holder.
Stand Number[8]	AVI Stand number or other if available.
Size[9]	Stand size to nearest ha.
Location[10]	Description of the location of the stand and tie point by reference to distances traveled along named roads.
Comment[11]	Any other relevant information not previously captured.

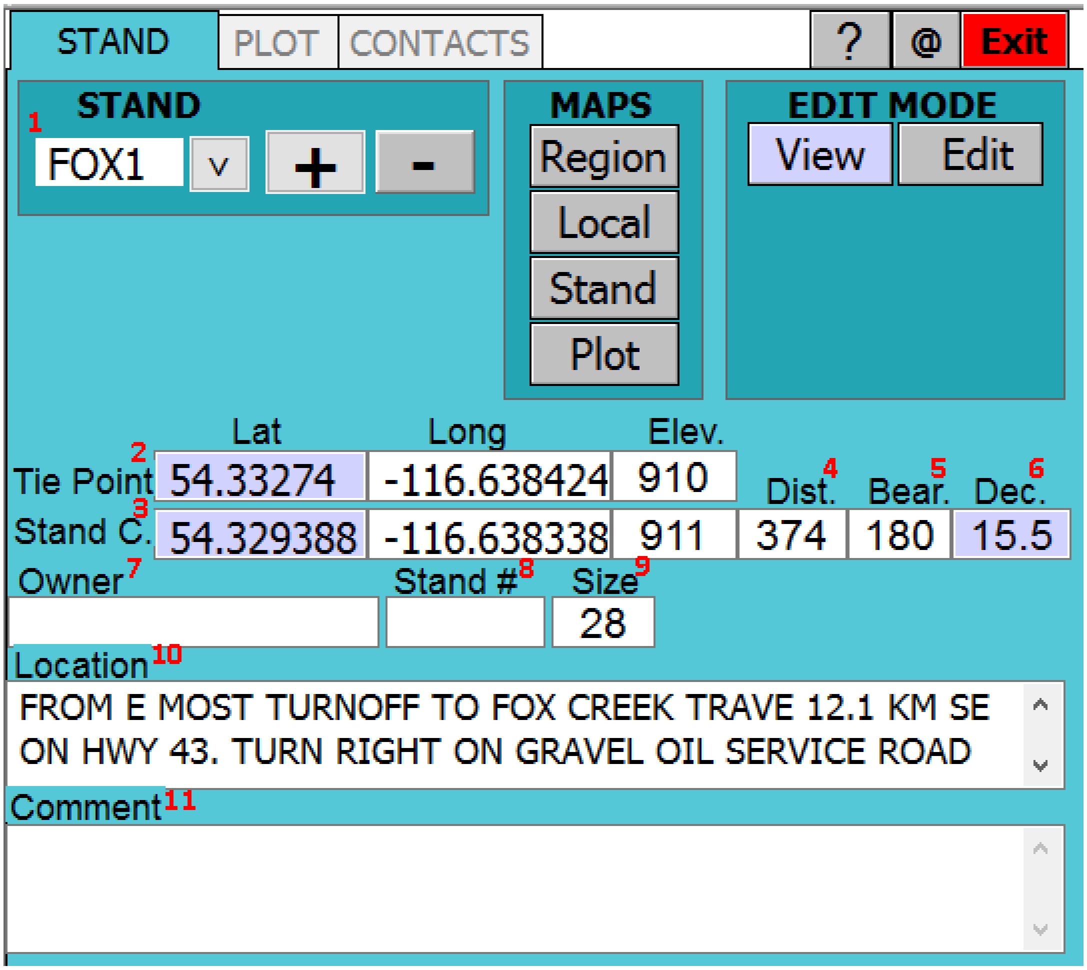


Figure 4. Location Form, Stand Tab

Location Form: Plot Tab **(See Fig. 5)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2
Plot[2]	Plot number 1 or 2.
Latitude[3]	Corner 1 latitude to 5 decimal points.*
Longitude[4]	Corner 1 longitude to 5 decimal points*
Elevation[5]	Elevation to the nearest metre.
Distance[6]	Distance (nearest metre) from Stand Center to corner 1 of the plot.
Bearing[7]	Bearing from Stand Center to corner 1 of the plot.
Plot Bearing[8]	Bearing of the long axis of the plot (usually the same as the bearing from Stand Center to the plot)
Width[9]	Plot width along the X axis (nearest metre, almost always 15m).
Length[10]	Plot length along the Y axis (nearest metre).
Slope[11]	Slope in degrees (use compass clinometer)

Aspect[12]	Aspect of the slope as N, NE, E, SE, S, SW, W or NW. Blank if slope is 0.
Composition[13]	Species composition of the codominant trees using Alberta inventory codes. For example SW8FB2 = 80% white spruce and 20% balsam fir. Understory species can be recorded in the Comment field.
Distrubance[14]	Evidence of disturbance, past or present, such as cattle grazing, logging, seismic, industrial activity (e.g., oil and gas), fire, flooding.
Comment[15]	Any other relevant information not previously captured.

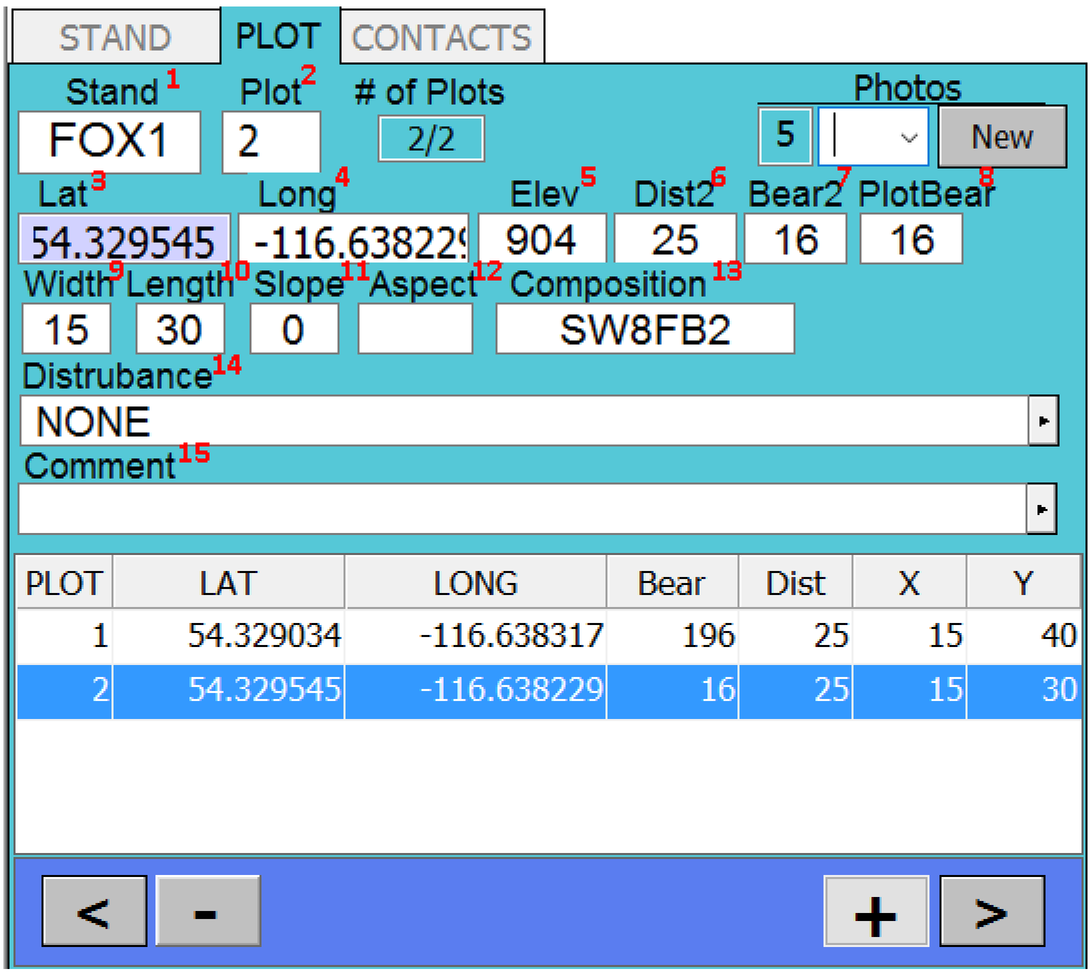


Figure 5. Location Form, Plot Tab

Location Form: Contacts Tab **(See Fig.6)**

Name[1]	Name of contact person responsible for the FMA or park
Organization[2]	Company or park
Position[3]	Job title
Email[4]	
Phone[5]	

Cell[6]
Fax[7]
Address[8]
Comment[9] Details of contact. Some stands may require a notification be sent to the land owner prior to entering the stand. This information is entered in this box.

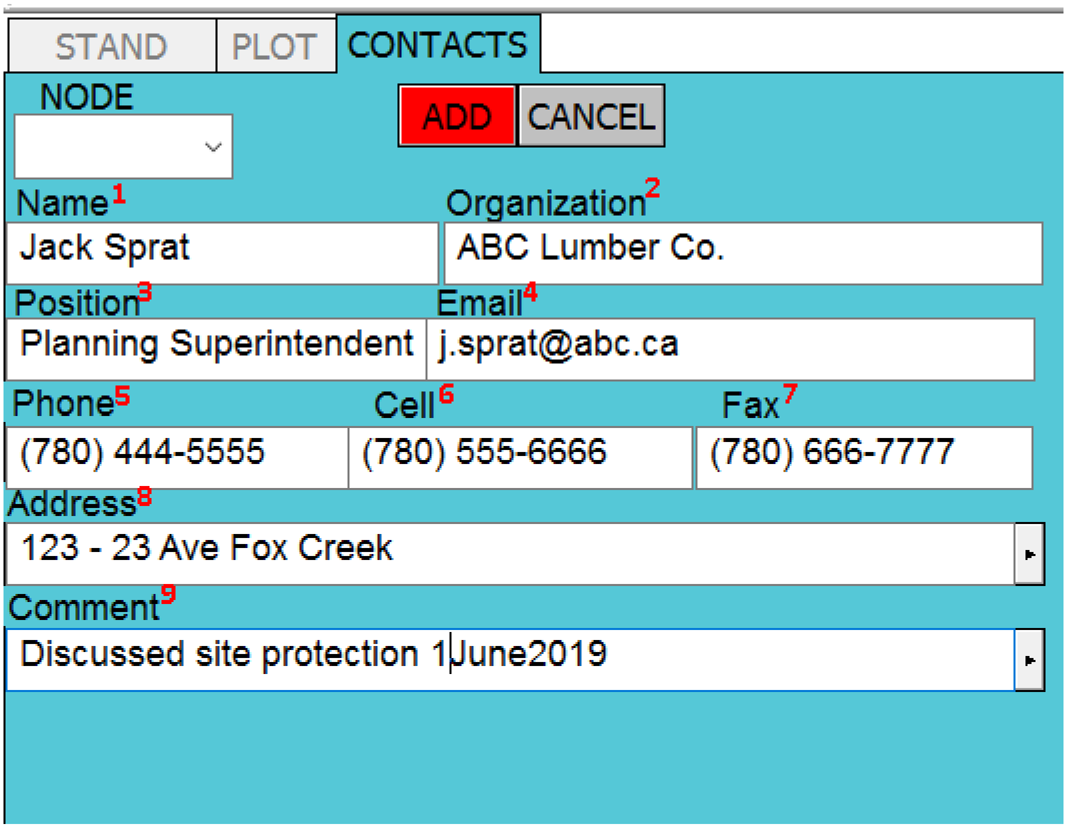


Figure 6. Location Form, Contacts Tab

Health Form: Tree Position, Mensuration and Health

1. Introduction

Tree position, mensuration and health data are recorded in the Health form. Tree positions are recorded once immediately after plot establishment. Tree health is assessed every 3 years. Diameters and heights of all tagged trees and stumps are assessed at plot establishment and at every major remeasurement (every 6 years). At each major remeasurement, ingrown trees (those that have surpassed the 7 cm minimum diameter requirement) are tagged, mapped, and measured. Equipment required for completing Health form is listed in Appendix 6.

2. Measuring tree positions

Tree locations are always measured as the distance from corner 1 of each plot (Fig. 2). The X distance is always measured perpendicular to the long axis of the plot. The Y distance is always measured along the long axis of the plot. Negative numbers are never recorded even if the plots are on opposite sides of the long axis. Distance may be measured using tape measures or vertex hypsometers. If hypsometers are to be used they must be calibrated just prior to use.

3. Measuring diameters

Diameters are measured for each tree of any species, live or dead, as long as they are above 1.3m. Dead trees on the ground and dead trees supported by others are not tagged or measured. Tree diameters are measured at the breast height marker lines painted on the tree during plot establishment. The dbh painted line, usually 1.3 m, should be in an area free of branch stubs or other anomalies that may affect the measurement of diameter. If the diameter can't be measured at 1.3 m due to a branch stub or other anomalies, the painted line may be moved to a new position (see Appendix 1) but the new diameter height must be entered as well as the diameter. The diameter measuring position for leaning trees is at a point 1.3m parallel to the lean. Diameters are recorded to the nearest 1/10 centimeter.

4. Measuring heights

Tree heights are measured for each tree of any species, live or dead, as long as they are above 1.3m. Dead trees on the ground and dead trees supported by others are not tagged or measured. Tree heights are measured to the nearest 1/10 metre. Three heights are measured; total height, highest live foliage and lowest live foliage. Tree heights are measured using Haglof Vertex® ultrasonic hypsometer consisting of a range finder and a target transponder. The following guidelines are applied when using ultrasonic hypsometers:

1) The instrument must be calibrated daily before use.

2) The instrument must reach ambient temperature before calibration and use. The unit cannot be stored in a warm jacket or pant pocket between height measurements.
3) The top of the tree must be clearly visible from the measurement position. If not, move to another position. Often, it is helpful to have someone shake the tree.
4) The measurement position must be perpendicular to the lean of the tree. Depending on the direction and severity of the lean, the height measurement can be erroneously high or low.
5) The measurement position must be a horizontal distance away from the tree equal to or greater than the height of the tree.
6) Normally the transponder is placed at 1.3 m above ground. Thick understory vegetation, however, may obscure it from view. In such cases, the transponder is attached to a tall stick, at a known height, and leaned against the tree above the understory vegetation. The range finder's offset DBH height must be changed before measuring the tree height.
7) A manual clinometer is used in situation when the ultrasonic hypsometer malfunctions.

5. Assessing tree health

All living trees, of any species, are assessed for level of dieback, total defoliation and current foliage complement. In addition, damage agents are also assessed but only for white spruce trees (damage agents are not assessed for non-white spruce trees). When assessing damage agents, the type and amount of damage caused by biotic and abiotic agents is determined. Health assessments are conducted in June and July when the maximum level of damage due to the season's insect and disease activity is evident. The causal agent may no longer be present, therefore, all signs and symptoms are carefully considered before ascribing an agent. Trees stems are examined for wood boring insects and diseases, roots and the lower bole are examined for root disease, and tree crowns and foliage examined for defoliating insect and diseases. Trees must be viewed from a number of vantage points using binoculars.

White spruce trees that have died since the last health assessment are included in health assessments in order to determine the damage agents that likely contributed to death.

Destructive sampling of living trees is not permitted. Off-plot trees and recently dead on-plot trees may be destructively sampled.

6. Quantifying damage

Many damage agents are quantified in terms of percent foliage or crown affected or percent of stem girdled. These include defoliating insects, foliar diseases, woody tissue insects and diseases, abiotic conditions, and mechanical damage (Appendix 4). If a stem wound is closed the appropriate agent type and name is recorded and the agent level is coded as not applicable ("99"). If a tree has multiple cankers or wounds, the greatest amount of stem girdling, at a given cross section, is recorded. Other agents, such as decay fungi and wood borers are quantified by recording the number of conks or bore holes up to a maximum of 10. A number of pests, however, are difficult to quantify. The level of Armillaria root disease, for example, is related to the time and effort spent looking for it, while agents such as root collar borers defy quantification. These types of agents are assessed on a presence/absences basis. Presence is recorded by entering the appropriate agent type and name. The agent level is coded as not applicable ("99").

Equipment required for completing mensuration and health assessments is listed in Appendix 6.

7. Variable descriptions

Health Form: Health Tab **(See Fig.7)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2
Plot[2]	Plot number 1 or 2.
Tree[3]	Tree number
Species[4]	Three-digit tree species code (see Appendix 3)
X distance[5]	Distance perpendicular to the long axis, from the Y axis (long axis) to the **center** of the tree (to the nearest tenth of a metre). It cannot be greater than 15 m (Fig. 2).
Y distance[6]	Distance parallel to the long axis, from the X axis to the **center** of the tree (to the nearest tenth of a metre).
DHT[7]	Diameter height. Height (measured to nearest 1/10 m) at which the diameter is measured (painted line usually at 1.3 m).
DBH[8]	Diameter at breast height (measured to nearest 1/10 cm).
Total Height[9]	Highest point of tree (measured to nearest 1/10 m).
Top of Live[10]	Highest level of live foliage (measured to nearest 1/10 m). Note: if the tree is dead Top of Live = 0
Bottom of Live [11]	Lowest level of live foliage (measured to nearest 1/10 m). Note: if the tree is dead Bottom of Live = 0
Dieback[12]	Estimated percent of the crown that is dead. Branches in the lower bole or interior crown that died as a result of shading are not included in the assessment. Record as follows: 5 = 0 to9%, 15= 10 to 19%, 25 = 20 to 29%, 95 = 90 to 99%, "99" indicates a dead tree. "199" indicates a dead tree on the ground snapped below 1.3 m. "299" indicates a dead snag tree snapped above 1.3 m.
Total Defoliation[13]	Estimated current missing and/or non-functional current years foliage caused by biotic and abiotic damage agents. Missing/nonfunctional foliage of previous years is excluded. Also excluded is the portion of the tree showing dieback (this is already captured by the Dieback field). Record as follows:

5 = 0 to9%, 15= 10 to 19%, 25 = 20 to 29%, … 95 = 90 to 99%, If the tree is dead Total Defoliation is 99.

Foliage Compliment[14] Estimated relative amount of functional foliage compared to a similarly sized healthy tree. Consider needle retention of current as well as past years. Exclude dieback and defoliation. Record as follows:

0 = 80 –100% of normal foliage compliment.
1 = 50 – 79% of normal foliage compliment.
2 = less than 50% of normal foliage compliment.

Remark[15] Any other remark relevant to the tree.

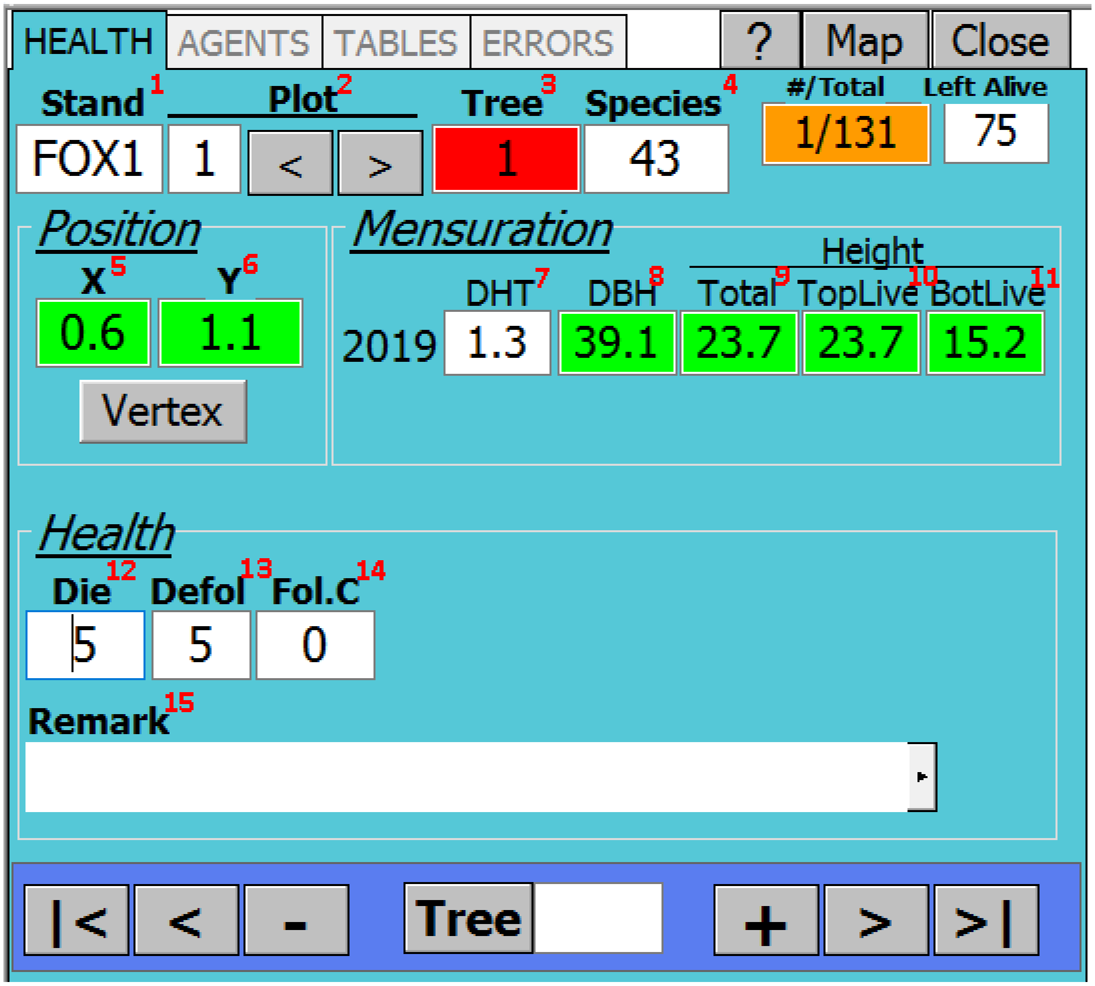


Figure 7. Health Form, Health Tab

Health Form: Agent Tab **(See Fig. 8)**

Type[1]	Damage agent type (see Appendix 4).
Name[2]	Damage Agent Name. Standard six- to eight-character abbreviation for the damage agent is used (see Appendix 4).
Level[3]	Damage Agent Level. The following three agent level scales, are used to record the appropriate agent level (see Appendix 5) as indicated: 1) % Crown foliage affected or % stem girdled: 5 = 0 to 9%, 15 = 10 to 29%, …95 =90 to 100%. 2) Count of conks or bore holes: 1 to 10, where 10 represents ten or more. 3) Use "99" for closed wounds, root rot, branch/stem galls, bark beetles and ants.
Validation[4]	Verification of the agent using a three-digit code as follows: Digit1 – Primary indicator*, 0 = not observed, 1 = observed Digit2 – Photograph, 0 = not taken, 1 = taken Digit3 – Voucher specimen, 0 = not collected, 1 = collected * Primary indicators include signs such as fruiting bodies, tendrils, hyphal pegs, etc., that is, features distinctive to a specific species. Primary indicators do not include symptoms such as sunken or discolored bark, bore holes, sap flow, etc., that is, features common to a number of species.
Remarks[5]	Any other information relevant to the damage agent.

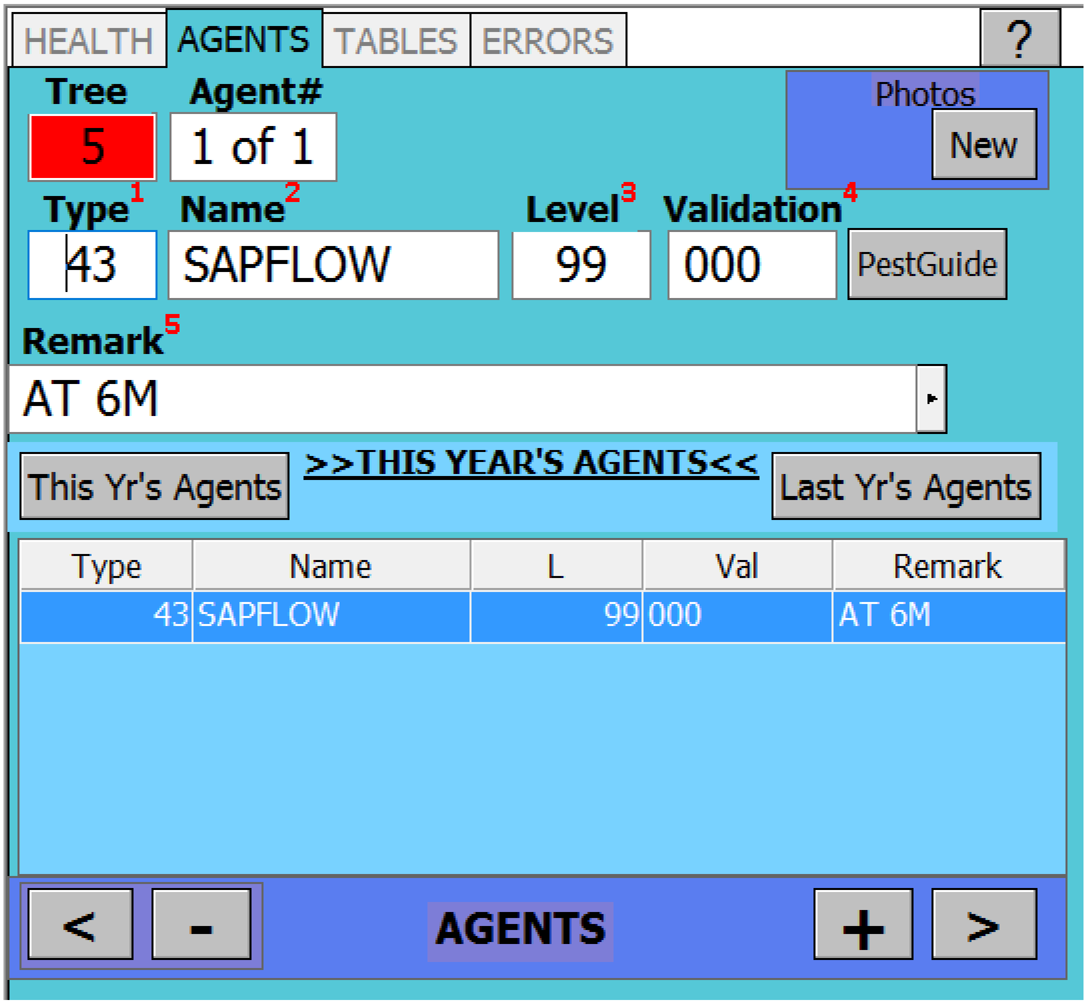


Figure 8. Health Form, Agent Tab

<u>Photo Form</u>: Photograph and Voucher Specimen Log

1. Introduction

An essential part of health assessments is the identification of damage agents. A voucher specimen is collected when there is doubt as to the species, if the pest is rare or if it is unique to the area. These specimens are then identified in the laboratory. If a damaging agent cannot be collected as a voucher specimen (e.g., insect may be long gone, stem canker on an on-plot tree) photographs of the damage or agent are required as substitutes. Photographs are also taken of unidentified voucher specimens since many organisms quickly loose shape and color. Finally, photographs are also taken of each plot during the year or establishment and at each health assessment. These photographs provide visual documentation of changes in each plot. The Photo Form functions to collect data for both photographs and collected voucher specimens. Each photograph and voucher specimen is labeled with a unique identification number that links to individual pest agents entered in the Health Form. Equipment required for completing the Photo Form is listed in Appendix 6.

2. Collecting voucher specimens

Insect and disease specimens are collected from within plot boundaries only if the tree is dead or if destructive sampling is not required. If destructive sampling is required, samples are collected from similarly affected off-plot trees. Voucher labels are placed in specimen vials and sample bags. The voucher labels are marked with pencil only because many inks are water/alcohol soluble**.** The voucher number is also recorded on paper bags or envelopes with a permanent marker.

3. Preserving voucher specimens

The following procedures are used for preserving and transporting voucher specimens:

Insect

- Eggs or larvae - placed in alcohol vial with voucher label
- Adult, hard bodied – placed in alcohol vial with voucher label
- Adult, soft bodied – placed in killing jar, then placed in tightly sealed envelope with voucher label

Disease

- Foliage – placed with voucher label in stapled paper bag or vegetation envelope marked with voucher number.
- Stem or root – placed with voucher label in stapled paper bag marked with voucher number. Specimen is also marked with voucher number.

Plastic bags are never used to store samples. Foliage specimens are refrigerated when possible. Once back at the laboratory, specimens and photographs are identified and the species are recorded in the Health Form, if required, as soon as possible. Voucher specimens and photographs are then archived.

4. Taking photographs and entering data

The Photo Form is accessed from the:

i) Stand Tab of the Location Form (useful for taking off-plot photos)
ii) Plot Tab of the Location Form (useful for taking general photos of a plot)
iii) Agent Tab of the Health Form (useful for taking photos of a specific agent).

Photographs are taken either with the built-in tablet camera or a digital camera. If the tablet camera is used the photo file is automatically tied to the given agent and the Photo Form is not opened. If a digital camera is used, the photo file name must be manually entered in the Photo Form and the photographs themselves must be copied manually from the camera to the backup memory stick. The tablet camera has limited resolution and zoom capabilities. For this reason it is often preferable to use a hand held camera of greater capabilities.

5. Variable descriptions

Photo Form **(See Fig. 9)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2
Tree[2]	Tree number (use “X” for off-plot tree).
Type[3]	Damage agent type (see Appendix 4).
Name[4]	Damage Agent Name. Standard six- to eight-character abbreviation for the damage agent is used (see Appendix 4).
Voucher#[5]	Automatically filled voucher number. Composed of Date/Stand/Tree/Photo# or Date/Stand/Tree/Specimen#. If specimen is collected the Voucher# is recorded to a label and attached to the specimen.
Photo#[6]	Number of photos of this agent (automatically filled).
Photo ID[7]	Camera photograph file name.
Remark[8]	Any other information relevant to the photograph.

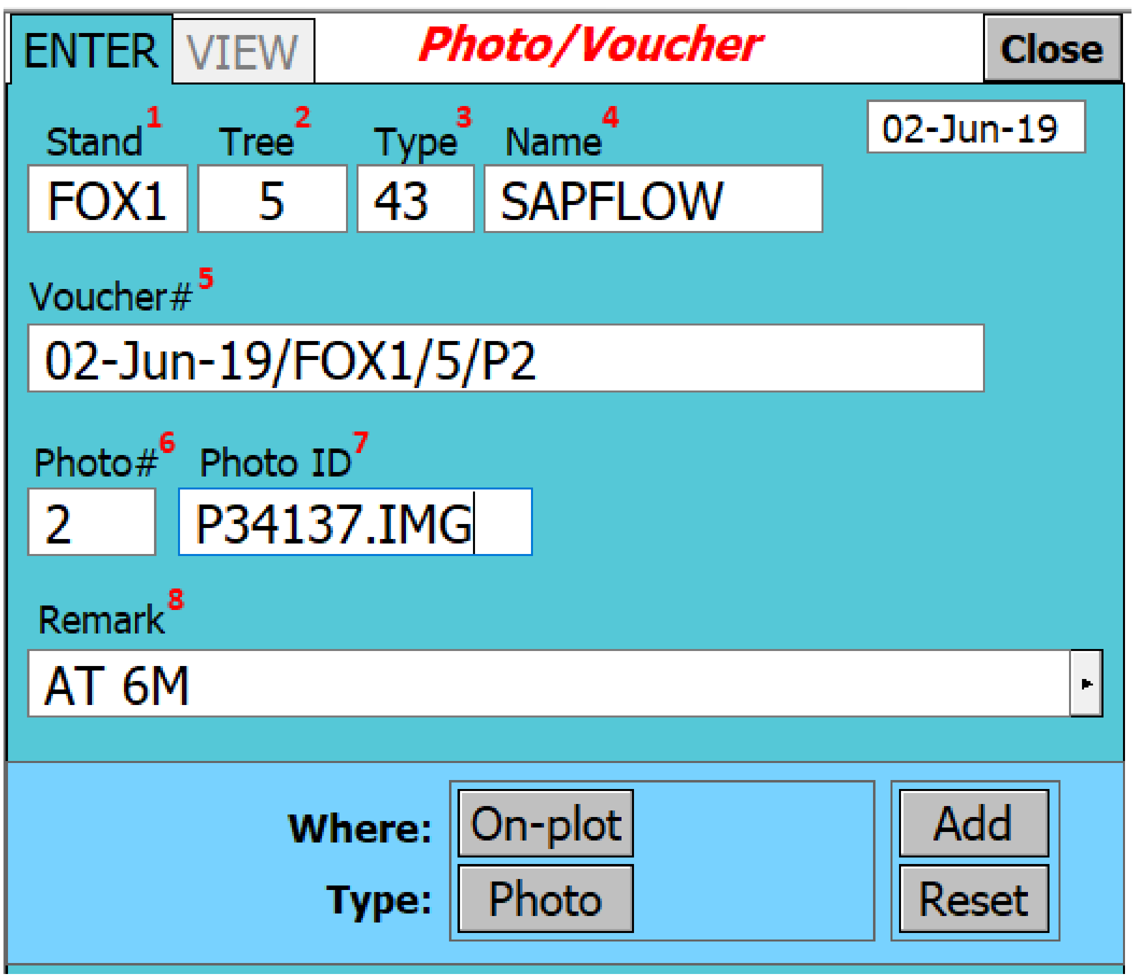


Figure 9. Photo Form

Core Form: Tree coring

1. Introduction

Six trees are cored from each plot (12 trees per stand). Two radii are collected from each tree and the relevant data is recorded in the Core Form. Tree coring is preferably completed during the fall, after the season's radial growth has occurred. Tree cores are collected at plot establishment and at every major remeasurement (at least every 6 years). Equipment required for completing the Core Form is listed in Appendix 6.

2. Determining diameter classes and tree selection

Selection of trees is based on diameter classes. In general, two small, two medium and two large off-plot spruce tree are selected near each plot. During the year of establishment, the selection of trees is subjectively based on the range of tree sizes found on-plot. During subsequent core collections the selection is based empirically on the measured on-plot tree diameters such that each class, small medium and large, contributes an equal amount to the total plot basal area. The purpose of this structured selection process is to provide a statistically efficient means of sampling the stand for its annual growth in terms of basal area.

Trees are selected from the off-plot area surrounding each plot preferably a tree length away from the plot. To ensure tree-rings chronologies from individual trees can be properly matched (cross-dated) with other trees from the plot it is essential to avoid coring trees that are not representative of the plot. Trees that are on a stand edge or opening are excluded. Lone or solitary trees, often called wolf trees, are excluded. Trees with unusual stem forms or trees with a large lean are excluded. Unless they make up a significant portion of the plot, dominant and suppressed trees are avoided. Where possible, trees with significant mechanical damage, insect boring, obvious decay or disease are avoided.

3. Coring

Trees to be cored are painted with a mark at breast height (1.3 m unless affected by abnormalities as described in Appendix 1). The diameter at breast height is measured and recorded in Core Form. Two cores are collected from each tree either by collecting a single, diametric core running through the center of the tree, or by collecting two separate cores from different sides of the tree. Cores are taken perpendicular to the tree stem and care is taken to ensure that the pith is included in each core.

A number of issues must be adhered to when coring:

a) Cores must be collected with a standard **5.15 mm** diameter increment borer. Smaller or larger diameter borers are not to be used.
b) Increment borers must be sharp. Dull borers shred the wood fibers making assessment impossible. If a borer becomes dull it must either be sharpened or replaced by a new one.

c) If the core breaks apart during extraction it must be ensure that a) no parts are missing and b) the orientation of the broken piece has not been flipped and the order of the pieces has not changed. If this can't be ensured, a new core must be taken.
d) If the core breaks into more than 4 pieces a new core must be collected.
e) If the core contains evidence of a branch (see Figure 10) a new core must be collected.
f) The straws are not to be labeled directly with a permanent marker because these marks often rub off the plastic straws. Instead, preprinted labels are used. If labels are not available, masking tape is used.
g) Collected cores are not to be stored or transported in cruise vests because they are likely to break. Instead, a mailing tube or other such device is used.
h) Care must be taken to ensure the cores do not develop mold. Staples, not tape, are used to block the ends of the straws because taped straws do not allow the cores to dry.
i) Cores should be stored on the dashboard of the vehicle. This ensures they dry as fast as possible. Cores are not stored in the fridge or freezer because this traps moisture and eventually promotes mold.
j) As soon as possible upon return from the field, cores are placed in a drying oven (minimum 60^o C, maximum 70^o C for 1week).
k) If a drying oven is not available the cores must be sent to the Canadian Forest Service as soon as possible. Cores should be packed in a sturdy mailing tube and send by courier to the address below. Before sending the cores notify the CFS, by phone or email, that cores are on the way and whether or not they have been dried.

Attn: Trisha Hook
Canadian Forest Service
5320 – 122 St.
Edmonton, AB
T6H 3S5
Email: Trisha.Hook@NRCan-RNCan.gc.ca
Phone: 825-510-1199

Figure 10. Tree core with evidence of branch on left side

4. Variable descriptions

Core Form **(See Fig. 11)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2.
Plot[2]	Plot number 1 or 2.
DBH[3]	Diameter at breast height (measured to nearest 1/10 cm).
Dom[4]	Tree dominance defined as: D = Dominant – crown extends above general canopy level. Receives full light from above and sides. C = Codominant – crown makes up the general canopy level. Receives direct light from above but little light from the sides. I = Intermediate – crown reaches into the general canopy level but most of the crown is below. Receives some direct light from above but no direct light from the sides. S = Suppressed – crown is below the general canopy level. Receives no direct light.
Comment[5]	Any comment relevant to the tree including tree health conditions and information relating to collected cores.

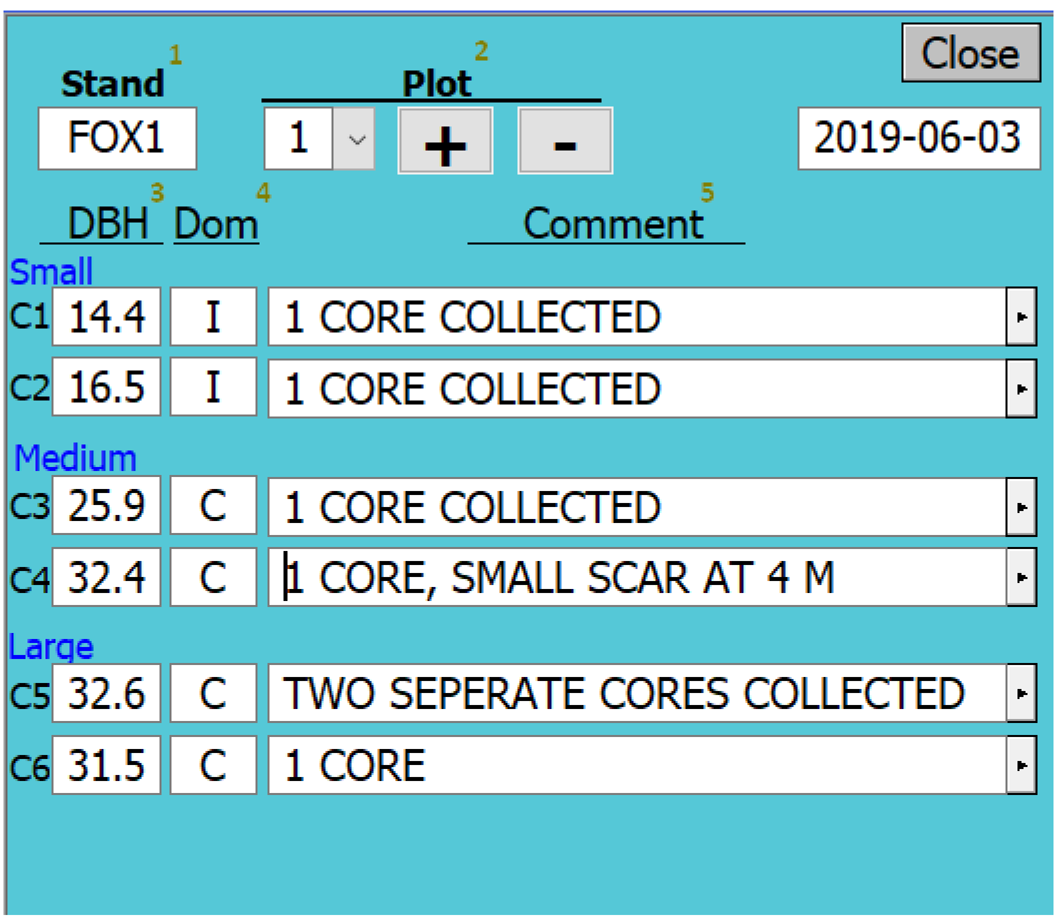


Figure 11. Core Form

Regen Form: Regeneration, shrub and vegetation surveys

Regeneration, shrub and vegetation surveys are intended to document ecological changes that may accompany white spruce forest mortality in the CIPHS network. Assessments of regeneration are essential to determining white spruce forest sustainability and succession. These surveys are to start in the year after plot establishment and are repeated every three years. Surveys are to be completed from late June to mid-August, the period at which vegetation species composition and cover is most stable and complete. The layout of these surveys is provided in Figure 12. To aid the determination of ecological change, the same regeneration and vegetation plots, as well as shrub transect lines are to be assessed at each survey. Therefore, the boundaries and marker points are to be permanent.

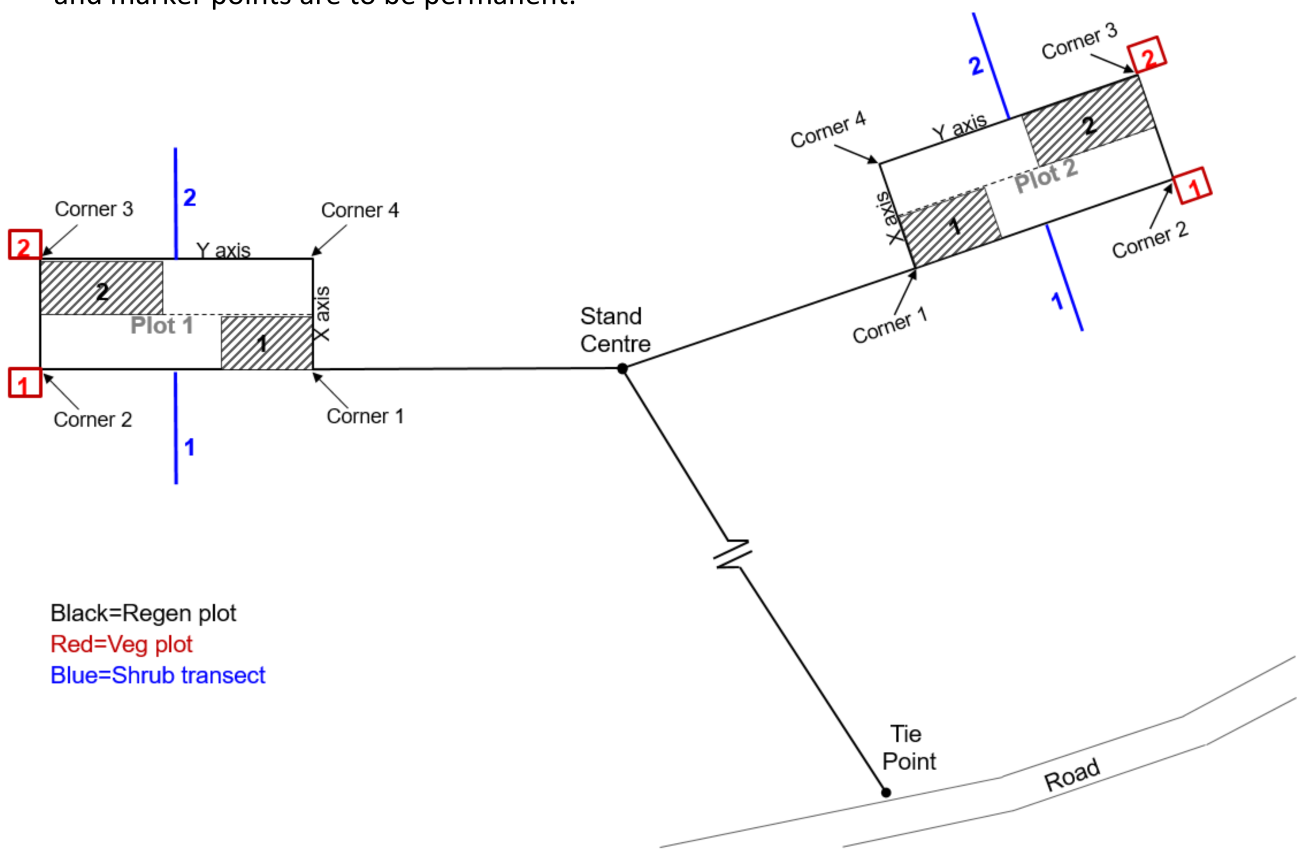


Figure 12. Regeneration compartment, shrub line and vegetation plot arrangement

A. Regeneration Survey

1. Introduction

Regeneration is assessed by surveying only a portion of each plot. Basal diameter, DBH, and tree height are measured on a subset of the regeneration in a plot. Trees considered as regeneration are those trees, of all species, not previously counted, measured and tagged, that is, those less than 7 cm dbh. There are two size classes measured, large (L: >1.3m tall) and small (S: <1.3m tall). Data is entered using the field tablets and the CIPHS data program. Equipment required for completing of the regeneration survey is listed in Appendix 6.

2. Establishing regeneration compartments

Each plot is divided in half along the shorter axis (X axis) into two compartments as shown in Figure 2. Both compartments will be 7.5 meters wide and will have a variable length along the Y axis. A measuring tapes are placed down both Y axis sides of the plot as shown in Figure 13. A third tape or hip-chain string is placed down the center of the plot to separate the compartments. Seedlings and saplings of **ALL species** are recorded but the length of the compartment is determined only by the number of living white spruce. A maximum of 10 **live** white spruce trees of each size class, L and S, are measured in each compartment. Dead white spruce and trees of other species, although recorded, are not counted as part of the minimum live 10 tree of each size class. Once 10 **live white spruce** trees of each size class are marked and measured, the total distance along the Y axis is recorded for each size class. **Make sure the distance is measured from the appropriate direction** as shown in Figure 13. This distance becomes the compartment length. Trees of all species outside of the longest compartment length (the large or the small) are ignored.

To make the process easier 10 pigtail markers will be flagged with orange and one is place beside each white spruce regen of the small class. Another 10 will be flagged with blue and one place beside each white spruce regen of the large class. As the heights and diameters of these regen are recorded the pigtail is removed to avoid counting the regen twice.

Often a compartment will have less than 10 regeneration trees of one or both size classes. For example, compartment #1 has 10 small regeneration trees (<1.3m tall) in 6.5 m but only 2 large (>1.3 m tall) regeneration trees along the entire length of the plot. In this case the length for the S class is 6.5m and the length for the L class is the total length of the plot.

3. Rules for counting saplings and seedlings

The design of the regeneration surveys is intended to minimize the time and effort required to adequately assess regeneration. There may be cases where the number of the target species, in this case white spruce, is less than 10 in the entire compartment however there may be hundreds of non-target species such as balsam fir. In this case, it is impractical in inefficient to measure and record all balsam fir in the entire compartment. The following rules will be followed to maximize sampling efficiency:

- Stop collection the of all large class saplings of any species, alive or dead once 10 large alive white spruce saplings have been recorded.
- Similarly, stop collection the of all small class seedlings of any species, alive or dead once 10 small alive white spruce seedlings have been recorded.
- If 10 large alive white spruce saplings are not found in the entire compartment then stop recording large saplings of other species, dead or alive, once 10 of each type have been recorded.
- Similarly, if 10 small alive white spruce seedlings are not found in the entire compartment then stop recording small seedlings of other species, dead or alive, once 10 of each type have been recorded.

In other words the recording of large saplings of any species, alive or dead, stops when a total of 10 of that type have been reached OR when 10 large white spruce saplings have been recorded, whichever comes first. Similarly, the recording of small seedlings of any species, alive or dead, stops when a total of 10 of that type have been reached OR when 10 small white spruce seedlings have been recorded, whichever comes first.

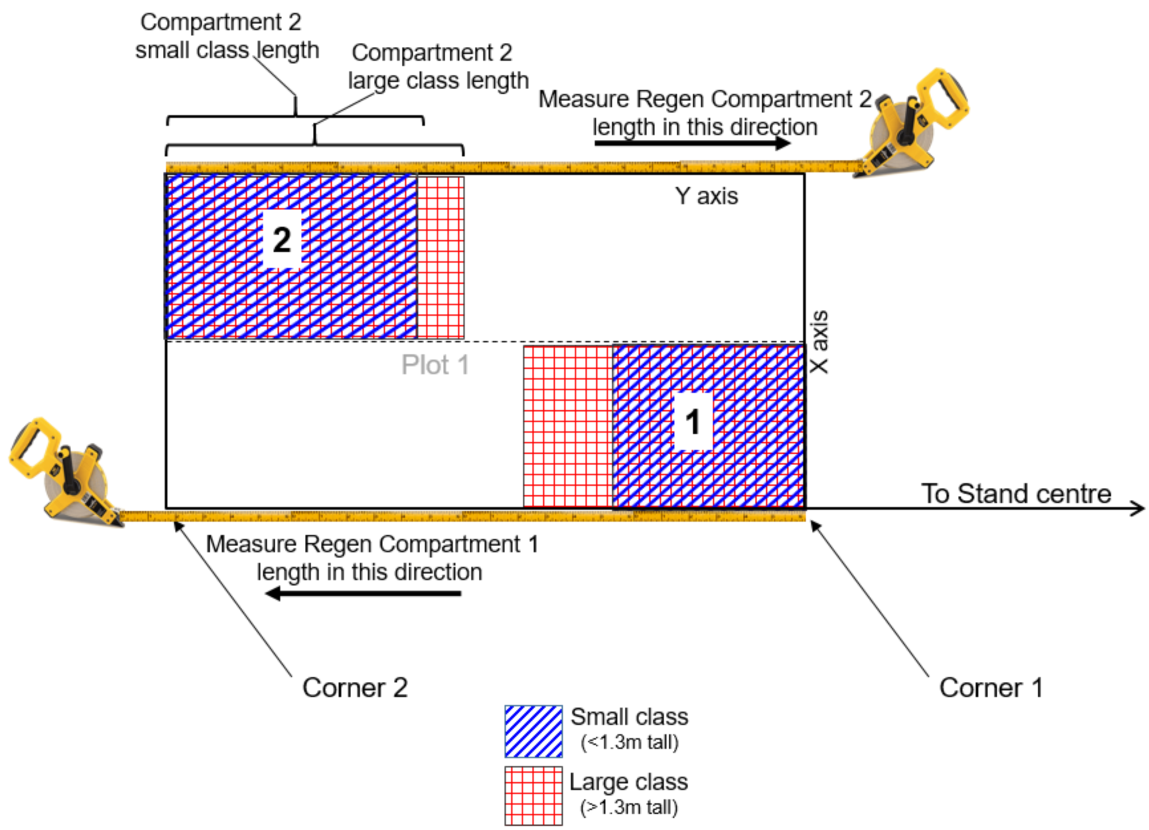


Figure 13. Regeneration compartment details

4. Measurements

Heights and diameters of all trees < 7 cm dbh are to be recorded regardless of species and status (alive or dead). Heights of all regeneration trees are measured with a height pole or other measuring device. Basal diameters (diameter at ground level) are measured for all trees in either height class using calipers. Breast height diameters are measured only for tree in the L class. Status of each tree, alive or dead is also recorded.

5. Photographs

Photographs are useful when documenting stand canopy and understory changes. Photos are taken from the start points of each regen compartment. Photos should be collected before the regen survey begins. Photos are also taken of any regen seedling or sapling whose species can't be determined.

6. Variable Descriptions

Regen Form: Regen Tab **(See Fig. 14)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2.
Plot[2]	Plot number 1 or 2.
Length[3]	Length of plot, automatically populated.
Compartment[4]	Compartment number 1 or 2
Photo[5]	Photos taken. Photographs are taken by pressing the "Regen" button. Photographs are viewed by selecting from the dropdown box.
Class[6]	Height class L or S (Large>1.3m, Small<1.3m).
Species[7]	Species of the tree. First 4 letters of the genus and first 3 letters of the species is entered. If only the genus is known the first 4 letters of the genus is recorded and "SPP" entered for the species. If only the common name is known the common name is entered. If the common name is unknown "UNK" is entered. If the species is unknown a photograph is taken.
Status[8]	Status of the tree (Alive or Dead).
Distance[9]	Total distance of the 10 living large trees (>1.3 m) along the Y axis (to nearest 0.1 m). The direction of measurement is shown in Figure 13. Distance may be entered for each regen sapling or once on the tenth tree as the maximum distance of the total 10 saplings of each class and species.
Diameter Basal[10]	Basal diameter measured at the base (to the nearest mm)
Diameter Breast[11]	Breast height diameter measured at 1.3m (to the nearest mm).
Height[12]	Total height of tree (to the nearest 0.1 m).
Remark[13]	Any comments relevant to the sapling or seedling.

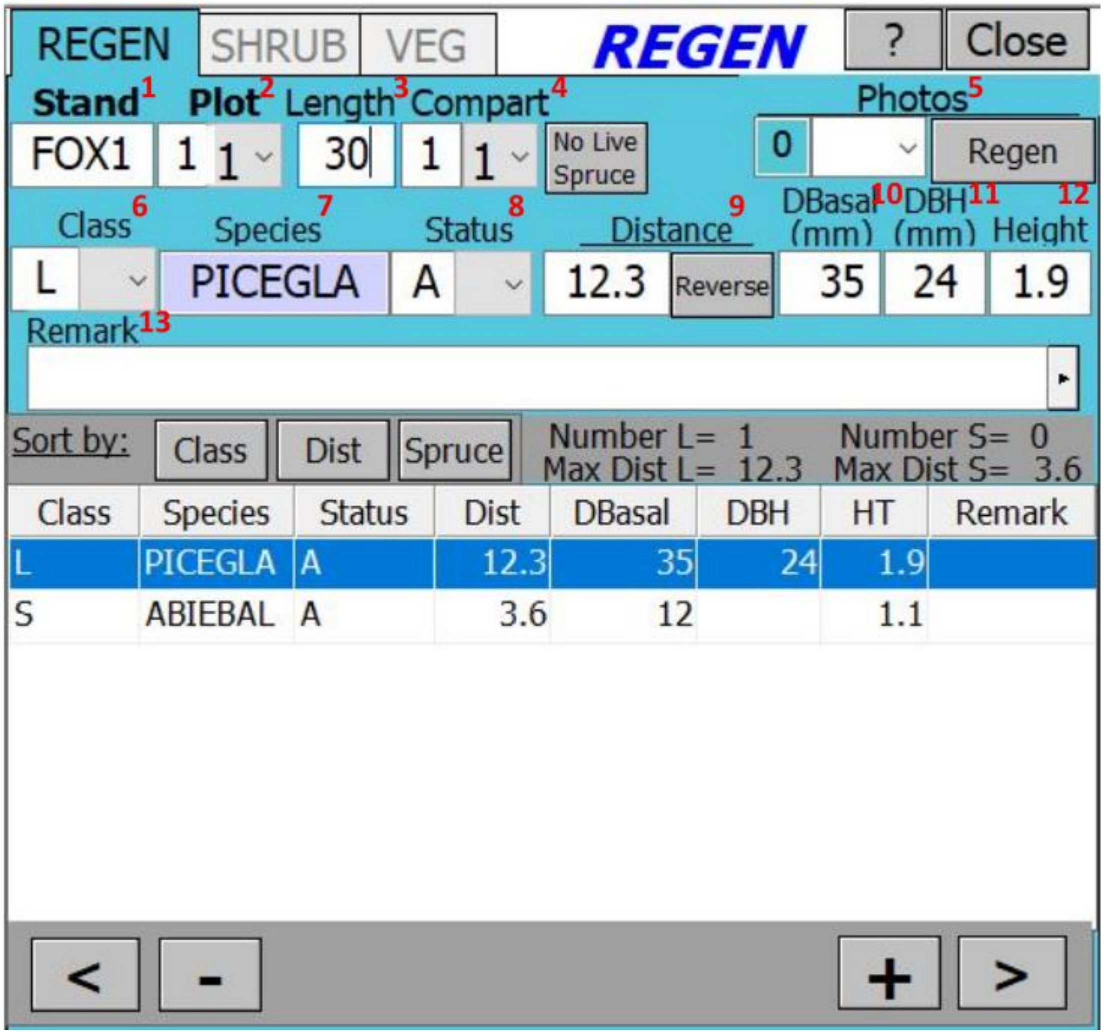


Figure 14. Regen Form, Regen Tab

B. Shrub Survey

1. Introduction

Shrub surveys are conducted to assess changes in shrub cover and include species composition and percent cover assessments. Data is entered using the field tablets and the CIPHS data program. Equipment required for completing of the shrub survey is listed in Appendix 6.

2. Establishing shrub transects

Shrub surveys are conducted using two 10m transect lines established at each CIPHS plot. The transect start position is located at the halfway point of each Y axis boundary. The transect end position is 10 m away on a bearing perpendicular to the Y axis as shown in Figure 12. If, for any reason, the perpendicular bearing can't be used a bearing as close as possible to perpendicular is chosen. A pigtail marker is placed at the start and end points of the transect. Pigtail markers are left in the ground for the next shrub survey. The transect closest to Corner 1 of the CIPHS plot is always numbered 1. A measuring tape is placed along the transect with the 0 measure at the transect start and the 10m measure at the transect end.

3. Measurements

The species of each **living** shrub above 0.5 m tall is recorded. A shrub is considered to be any plant with a woody stem. Dead shrubs are not recorded. The start and end distance of each shrub is recorded. Two shrubs of the same species are recoded separately unless they overlap. If two shrubs of the same species overlap a single entry is made for the species and single start and end distances are recorded. If two shrubs of differing species overlap, a start and end distance is recorded for each shrub species. The maximum height of each shrub is measured with a height pole or other measuring device. Start and end distances, as well as heights, are measured **directly over the tape measure** as shown in Figure 15.

4. Photographs

Photos are taken of the shrub transect from a number of vantage points (from the start point facing the end, from the midpoint facing the start, from the midpoint facing the end and from the end point facing the start). Photos are taken before the shrub line is disturbed by the measurement of individual shrubs.

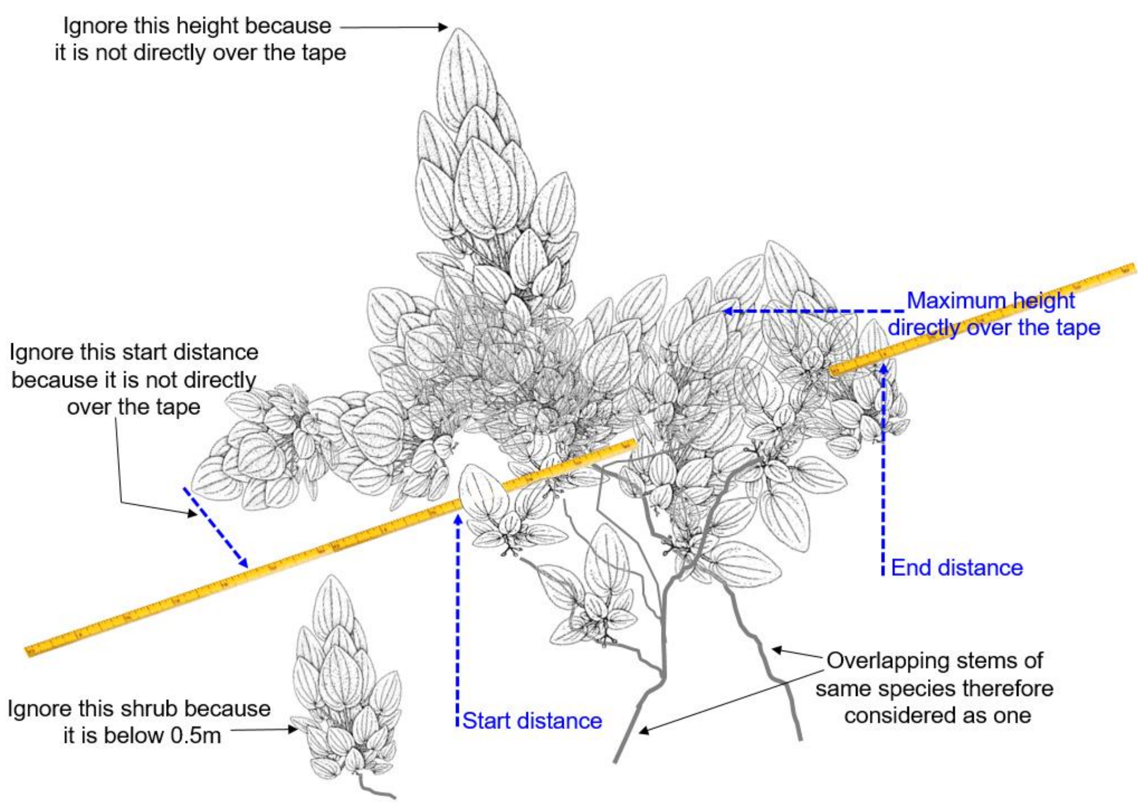


Figure 15. Shrub distance and height measurement details

5. Variable Descriptions
Regen Form: Shrub Tab **(See Fig. 16)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2.
Plot[2]	Plot number 1 or 2.
Line[3]	Line number 1 or 2.
Bearing[4]	Bearing of the transect line from the start point.
Photos[5]	Photos taken. Photographs are taken by pressing the "Shrubline" button. Photographs are viewed by selecting from the dropdown box.
Number[6]	Shrub number, automatically populated.
Species[7]	Species of the shrub. First 4 letters of the genus and first 3 letters of the species is entered. If only the genus is known the first 4 letters of the genus is recorded and "SPP" entered for the species. If only the common name is known the common name is entered. If the common name is unknown "UNK" is entered. If the species is unknown a photograph is taken.
Distance1[8]	Start position of the shrub (to the nearest 0.1 m)
Distance2[9]	End position of the shrub (to the nearest 0.1 m)
Height[10]	Maximum height of the shrub (to the nearest 0.1 m)
Remark[11]	Any comments relevant to the shrub

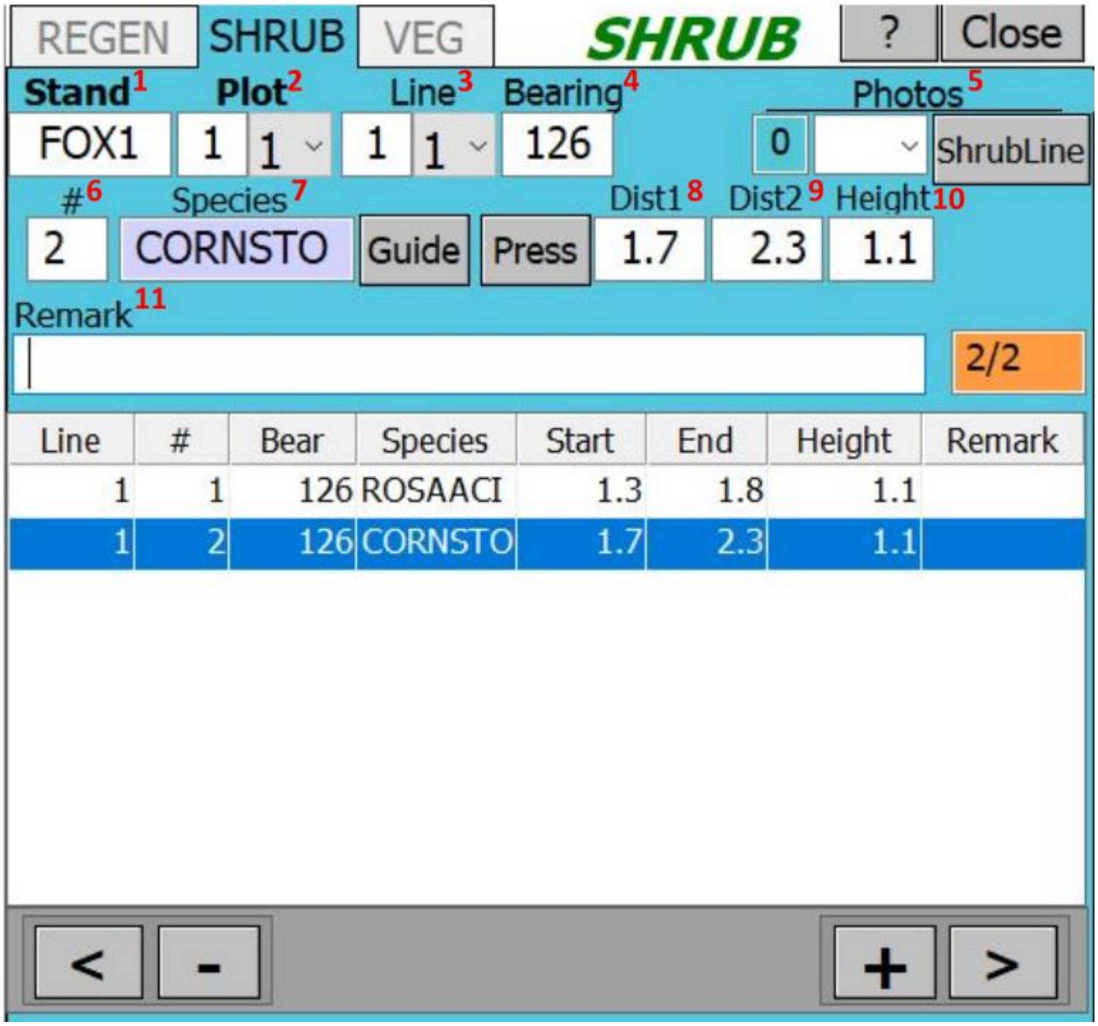


Figure 16. Regen Form, Shrub Tab

C. Vegetation Survey

1. Introduction

Vegetation surveys are conducted to assess changes in understory vegetation and include species composition and percent cover assessments. Data is entered using the field tablets and the CIPHS data program. Equipment required for completing of the regeneration survey is listed in Appendix 6.

2. Establishing vegetation plots

Two 1 x 1 m vegetation plots are established at the distal end of each CIPHS plot as shown in Figure 12. A plastic vegetation frame is placed on the ground. Pigtail markers are to be placed at each corner on the inside of the frame. These markers are left in the ground to help locate the plot at the next vegetation survey. Trees and shrubs can be included inside the vegetation plot and therefore the plot is not moved because of trees or shrubs. In the extreme event that a vegetation plot can't be placed in the position shown in Figure 12 then a new position is chosen but the exact location must be recorded on the field tablet. The vegetation plot closest to Corner 1 of the CIPHS plot is always numbered 1.

3. Measurements

Each plant in the plot is classified by layer (combination of plant type and height) and the percent cover of all species is recorded. Included are "non-species" such as bare ground, leaf litter, woody debris, water, etc. Woody debris such as downed logs are counted if they are directly on the ground or if they likely have had a significant impact on the vegetation below. If downed logs are well above the ground and have not had a significant impact on the vegetation below they are ignored. Upright tree stems, alive or dead, are included and the percent cover for these trees is entered as the stem basal area as a percent of the total vegetation plot area.

Percent cover is assessed to 5 % categories if the total cover of the species is over 5 % and to 1% if the total cover of the species is less than 5 %. Since plant species may overlap the total percent cover can be over 100 percent. An individual plant species may have a cover of up to 100 percent. If the total percent cover is less than 100, individual species percent values are reassessed.

Plant identifications are made to the species level. Where this is not possible identifications are made to the genus. If genus is not possible identifications are made to the vegetation type (tree, shrub, forb, grass, lichen or other). Plant specimens that can't be identified are collected and pressed using provided blotting paper and specimen envelopes. The stand number, plot number, vegetation plot number, date, collector name as well as the plant number (obtained from the field tablet) are recorded on the envelope. Only one species type per envelope is allowed. Collected specimens are submitted to the Northern Forestry Centre if they can't be identified by field personnel or their colleagues.

4. Photographs

Photos are taken of the vegetation plot from directly overhead and a number of other vantage points. Photos are taken **before the plot is disturbed** by the assessment of individual percent cover. Photos are taken of individual plant species especially if the genus and/or species are unknown. Photos should include dorsal and ventral leaf views.

5. Variable Descriptions

Regen Form: Veg Tab **(See Fig. 17)**

Stand[1]	Three-letter node abbreviation plus the stand number 1 or 2.

Plot[2]	Plot number 1 or 2.
Vegetation Plot[3]	Vegetation plot number 1 or 2.
Photos[4]	Photos taken. Photographs are taken both of the entire vegetation plot and of individual plant species. Photographs are taken by pressing the “VegPlot” or “Species” buttons. Photographs are viewed by selecting from the dropdown box.
Plant Number[5]	Plant number automatically populated.
Layer[6]	Layer of the plant: A =Tree>10m, B1 =Tall shrub or tree >2m and <10m B2 =Low shrub or tree <2m C =Herb (forbs, ferns, grasses, sedges, rush, horsetails, mushroom) D =Bryoid (mosses, liverworts, lichens) E =Other (bare ground, leaf litter, woody debris, water)
Species[7]	Species of the plant. First 4 letters of the genus and first 3 letters of the species is entered. If only the genus is known the first 4 letters of the genus is recorded and “SPP” entered for the species. If only the common name is known the common name is entered. If the common name is unknown “UNK” is entered. If the species is unknown a photograph is taken.
Percent Cover[8]	Estimated percent of the 1 x 1m vegetation frame taken up by the plant species. Since plant species may overlap the total percent cover may be over 100%.
Remark[9]	Any comments relevant to the plant species

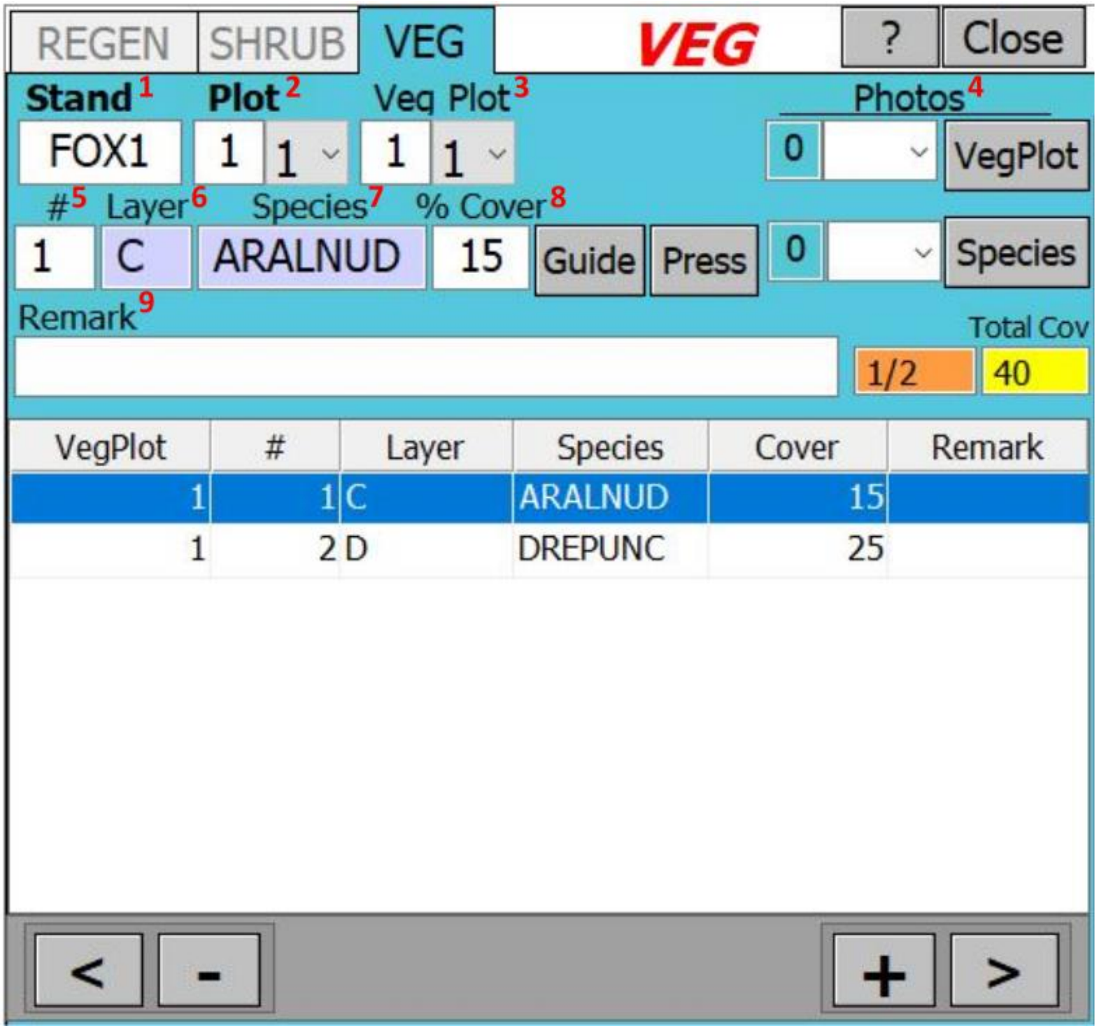


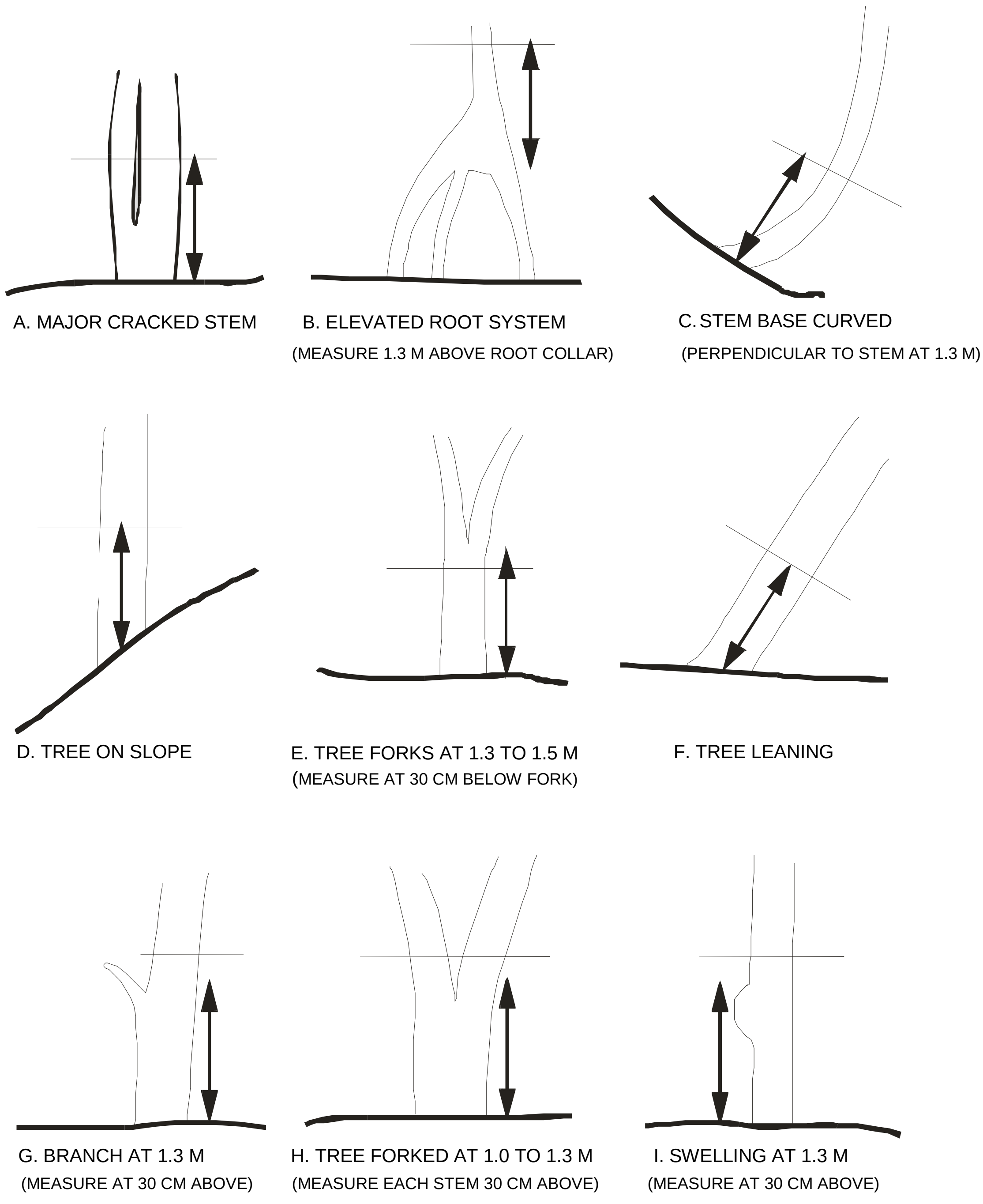
Figure 17. Regen Form, Veg Tab

References

Hogg EH, Brandt JP, Michaelian M. 2008. Impacts of a regional drought on the productivity, dieback, and biomass of western Canadian aspen forests. Can. J. For. Res. 38(6): 1373-1384

Hogg, E. H., Michaelian, M., Hook, T. I., & Undershultz, M. E. 2017. Recent climatic drying leads to age-independent growth reductions of white spruce stands in western Canada. Global Change Biology, 23(12), 5297– 5308.

Appendix 1. Measurement of DBH on abnormal trees



From ARNEWS Information Report PI-X-117

Appendix 2. Printable blank stand sketch map (front)

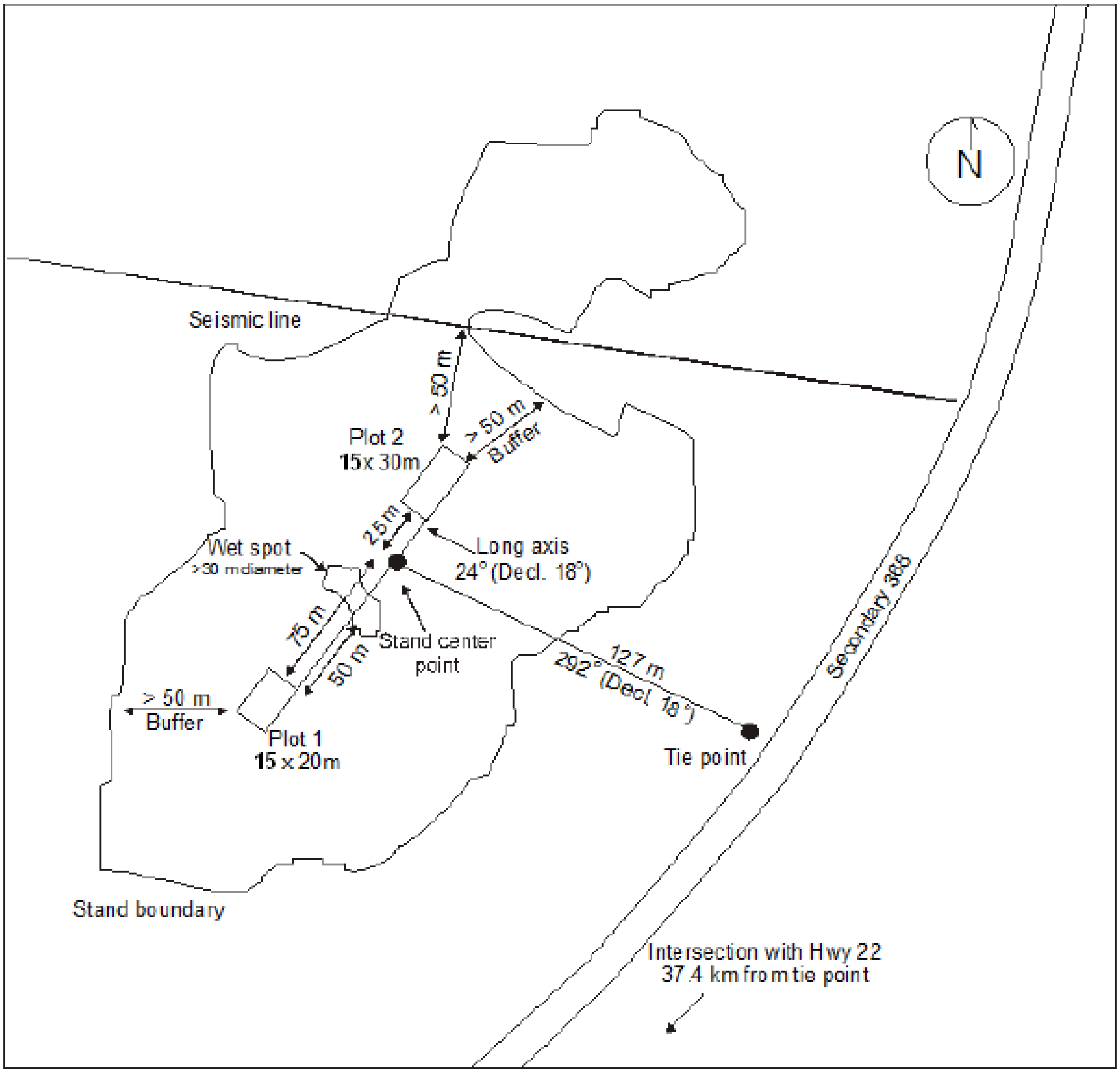
CIPHS Stand Sketch Map

Node: ____ Stand: ____ Initials: ____ Date: ____

N

Stand Sketch (see back for example)

Appendix 2. Printable blank stand sketch map (back)



Example of a completed Stand Sketch

Appendix 3. Tree species codes

Species Code	Common Name
3	Balsam fir
7	Alpine fir
32	Tamarack
42	Engelmann Spruce
43	White spruce
45	Black spruce
52	Jack pine
54	Lodgepole pine
60	Red pine
62	Eastern white pine
72	Douglas fir
104	Manitoba maple
130	Alder species
168	White birch
253	Black ash
254	Red ash
304	Balsam poplar
308	Largetooth aspen
311	Trembling aspen
357	Bur oak
400	Willow species

Appendix 4. Damage agent names and type codes (Health Form – Agent Tab)

AGENT NAME	COMMON NAME	SCIENTIFIC NAME	AGENT TYPE
Foliar Insects			
ACLVAR	Eastern blackheaded budworm	*Acleris variana*	1
CARDIV	Gray spruce looper	*Caripeta divisata*	1
CEPFAS	Spruce webspinning sawfly	*Cephalcia fascipennis*	1
CHICON	Gelechiid moth	*Chionodes continuella*	1
CHOBIE	Two-year-cycle budworm	*Choristoneura biennis*	1
CHOFUM	Spruce budworm	*Choristoneura fumiferana*	1
CHOOCC	Western spruce budworm	*Choristoneura occidentalis*	1
CLALIM	Yellowlined forest looper	*Cladara limitaria*	1
CLEPER	Whitetriangle leafroller	*Clepsis persicana*	1
COLATR	Coleotechnites atrupictella	*Coleotechnites atrupictella*	1
DASGRI	Pine tussock moth	*Dasychira grisefacta*	1
DOLTHY	Spruce needleworm	*Dolichomia thymetusalis*	1
ECTCRE	Saddleback looper	*Ectropis crepuscularia*	1
ENYVEN	Variable girdle	*Enypia venata*	1
EPIAUT	Green velvet looper	*Epirrita autumnata*	1
EPIPUL	Whitelined looper	*Epirrita pulchraria*	1
EPIRAD	Spruce tip moth	*Epinotia radicana*	1
EUPANN	Larch pug moth	*Eupithecia annulata*	1
EUPLAR	Fir needle inchworm	*Eupithecia lariciata*	1
EUPPAL	Small pine looper	*Eupithecia palpata*	1
FERCOM	Comstock's sallow	*Feralia comstocki*	1
FERJOC	Redlined conifer caterpillar	*Feralia jocosa*	1
GILHER	European spruce sawfly	*Gilpinia hercyniae*	1
HYPPIN	Pine measuringworm moth	*Hypagyrtis piniata*	1
LAMFIS	Western hemlock looper	*Lambdina fiscellaria lugubrosa*	1
LEP	Unknown lepidopteran species		1
MACSIG	Spruce fir looper	*Macaria signaria dispuncta*	1
MELIMI	Greenstriped forest looper	*Melanolophia imitata*	1
NEMRES	Filament bearer	*Nematocampa resistaria*	1
NEOABI	Balsam fir sawfly	*Neodiprion abietis*	1
ORTHIB	Speckled green fruitworm	*Orthosia hibisci*	1
PERBEH	Behr's pero	*Pero behrensaria*	1
PERMOR	Pero moth	*Pero morrisonaria*	1
PIKALA	Yellowheaded spruce sawfly	*Pikonema alaskensis*	1

PIKDIM	Greenheaded spruce sawfly	*Pikonema dimmockii*	1
PROPOR	Porcelain gray	*Protoboarmia porcelaria*	1
SAWFLY	Unknown sawfly species		1
SYNALI	Spruce climbing cutworm	*Syngrapha alias*	1
SYNCEL	Western conifer looper	*Syngrapha celsa*	1
SYNPAL	Synaxis pallulata	*Synaxis pallulata*	1
TETCAC	White slaut	*Tetracis cachexiata*	1
THAHYP	Northern thallophaga	*Thallophaga hyperborea*	1
XESMUS	Xestia mustelina	*Xestia mustelina*	1
ZERUNF	Purplestriped shootworm	*Zeiraphera unfortunana*	1
APHID	Unkinown aphid species		2
ELAABI	Spruce aphid	*Elatobium abietinum*	2
MITE	Unknown mite species		2
OLIUNU	Spruce spider mite	*Oligonychus ununguis*	2
ADEABI	Eastern spruce gall adelgid	*Adelges abietis*	3
ADECOO	Cooley spruce gall adelgid	*Adelges cooleyi*	3
COLPIC	Orange spruce needleminer	*Coleotechnites piceaella*	4
ZEICAN	Spruce bud moth	*Zeiraphera canadensis*	5
CYDSTR	Spruce seed moth	*Cydia strobilella*	6
DIOABI	Fir coneworm	*Dioryctria abietivorella*	6
DIOREN	Spruce coneworm	*Dioryctria reniculelloides*	6
Foliar Diseases			
CHRARC	Spruce broom rust	*Chrysomyxa arctostaphyli*	10
CHRLED	Spruce-Labrador tea needle rust	*Chrysomyxa ledicola*	10
LIRMAC	Lirula needle blight	*Lirula macrospora*	11
LOPPIC	Spruce needle cast	*Lophodermium piceae*	11
SIRCON	Sirococcus Shoot Blight	*Sirococcus conigenus*	11
HERJUN	Brown felt blight	*Herpotrichia juniperi*	12
CHRPIR	Inland spruce cone rust	*Chrysomyxa pirolata*	13
Woody Tissue Insects			
APHCRI	Pine spittlebug	*Aphrophora cribrata*	20
PISSTR	White pine weevil	*Pissodes strobi*	21
HYLPAL	Pales weevil	*Hylobius pales*	22
HYLWAR	Warren's rootcollar weevil	*Hylobius warreni*	22
DENRUF	Spruce beetle	*Dendroctonus rufipennis*	24
IPSTYP	European Spruce Bark Beetle	*Ips typographus*	24
MONSCU	Whitespotted sawyer	*Monochamus scutellatus*	25
TRYLIN	Striped ambrosia beetle	*Trypodendron lineatum*	25
ANTSPP	Unknown ant species		26
CAMHER	Boreal carpenter ant	*Camponotus herculeanus*	26
CAMSPP	Carpenter ant	*Camponotus spp.*	26

Woody Tissue Disease			
CYTKUN	Cytospora canker	*Cytospora kunzei*	30,31
ARCPUS	Eastern dwarf mistletoe	*Arceuthobium pusillum*	32
FOMPIN	Pinicola brown crumbly rot	*Fomitopsis pinicola*	34
GANAPP	White mottled rot	*Ganoderma applanatum*	34
GLOSEP	Brown cubical sap rot	*Gloeophyllum sepiarium*	34
PHEPIN	Red Ring Rot	*Phellinus pini*	34
STESAN	Red heart rot	*Stereum sanguinolentum*	34
TRIABI	Pitted sap rot	*Trichaptum abietinum*	34
VELFIM	Brown cubical pocket rot	*Veluticeps fimbriata*	34
ARMSPP	Armillaria root disease	*Armillaria spp.*	35
GROWAG	Black stain root disease	*Grosmannia wageneri*	35
INOTOM	Tomentosus root rot	*Inonotus tomentosus*	35
RHIUND	Rhizina root rot	*Rhizina undulata*	35
ROOTROT	Unknown root disease		35
Other			
HERBICI	Herbicide damage		40,41,42
HYDCARB	Hydrocarbons		40,41,42
NOX	Nitrogen oxides		40,41,42
OZONE	Ozone flecking		40,41,42
SO2	Sulfur dioxide		40,41,42
FROST	Frost crack, frost damaged foliage		40,41,42,43
WINDRY	Winter drying		40,41,42
STRESSCK	Stress crack		43
SUNSCALD	Sun scalding		43
MECHSCAR	Mechanical scars		43,44
FIRE	Fire scar		43,44
HAIL	Hail damage		41,42,43,44,45
WIND	Windthrow or broken branch/stem		43,44,45,47
WHIPPING	Whipping		43,44
DROUGHT	Drought		40,41,42
SAPFLOW	Sap flow of unknown cause		43
SNOW	Snow damage broken branch/stem, leaning stem		43,44,47
LOGGED	Logged	*Homosapien*	45
ALCALC	Moose	*Alces alces*	43,44
ODOVIR	White-tailed deer	*Odocoileus virginianus*	43,44
URSARC	Grizzly bear	*Ursus arctos*	43,44
URSAME	Black bear	*Ursus americanus*	43,44
CASCAN	Beaver	*Castor canadensis*	43,44
EREDOR	Porcupine	*Erethizon dorsatum*	43,44
DRYPIL	Pileated woodpecker	*Dryocopus pileatus*	43,44

PICSPP	Woodpecker species	*Picoides spp.*	43,44
SPHVAR	Yellow-bellied Sapsucker	*Sphyrapicus varius*	43,44
TAMHUD	Red Squirrel	*Tamiascurus hudsonicus*	43,44,49
TREE	Damage/lean caused by other tree		43,44,45,47
FLOOD	Flooding causing chlorotic or dead foliage/tree		40,41,42
CASCAN	Beaver	*Castor canadensis*	43,44,45
ROTFORK	Rotten fork usually at base		49

Appendix 5. Agent type and agent level codes (Health Form - Agent Tab)

AGENT TYPE	DAMAGE AGENT OR SYMPTOM	EXAMPLES	AGENT LEVEL
Foliar Insects			
1	Free foliage feeders	Spruce budworm	% Crown affected
2	Aphids/mites	Spruce aphid	% Crown affected
3	Adelgids	Spruce gall adelgid	% Crown affected
4	Needle miners	Spruce needle miner	% Crown affected
5	Bud feeders	Spruce bud moth	% Crown affected
6	Cone/seed feeders	Spruce coneworm	% Crown affected
9	Other foliage insect		% Crown affected
Foliar Diseases			
10	Needle rusts	Spruce broom rust	% Crown affected
11	Needle blight/casts	Spruce needle cast	% Crown affected
12	Foliage blight	Brown felt blight	% Crown affected
13	Cone diseases	Spruce cone rust	% Crown affected
19	Other foliage disease		% Crown affected
Woody Tissue Insects			
20	Branch/twig feeders	Pine spittlebug	"99" not applicable
21	Terminal borers	White pine weevil	"99" not applicable
22	Root collar borer	Warren's rootcollar weevil	"99" not applicable
24	Bark beetles	Spruce beetle	Count holes to a max. of 10
25	Wood borer	Whitespotted sawyer	Count holes to a max. of 10
26	Ants	Carpenter ant	"99" not applicable
29	Other woody tissue insect		Choose appropriate
Woody Tissue Diseases			
30	Twig or branch canker	Cytospora canker	% Crown affected
31	Stem canker	Cytospora canker	% Stem Girdled
32	Twig and branch broom	Dwarf mistletoe	Count brooms to a max. of 10
34	Stem rot	Red ring rot	Count conks to a max. of 10
35	Root rot	Armillaria	"99" not applicable
39	Other woody disease		Choose appropriate
Other			
40	Chlorotic foliage	flooding, drought	% Crown affected
41	Damaged foliage	flooding, drought, hail	% Crown affected
42	Dead foliage	flooding, drought	% Crown affected
43	Stem wounds	mechanical, hail, fire	% Stem Girdled, 99 if closed

44	Broken branch	mechanical, wind, snow	% Crown affected
45	Broken stem/top	mechanical, wind, snow	% Crown affected
46	Logged	human, beaver	"99" not applicable
47	Leaning stem	wind, snow, other tree	"99" not applicable
49	Other damaging agents		Choose appropriate

Appendix 6. Equipment Lists

Plot establishment:

a) Tablet, spare battery, USB GPS puck
b) GIS maps, inventory maps, or other maps
c) Hand held GPS unit plus extra batteries
d) Compass
e) 2 ultrasonic hypsometers plus extra batteries
f) Fiberglass tapes (two 50 m tapes, and at least one 30 m tape)
g) DBH tape
h) Flagging – orange (1 roll/stand)
i) Tree paint - orange (2 cans/stand)
j) Tree tags (200/stand)
k) 1 ½" or 2" aluminum nails for tree tags (200/stand)
l) 1 m x ½" electrical conduit for plot makers (10/stand)
m) Sledge hammer, or axe
n) Hammer for tree nails
o) Camera
p) Blank stand sketch map sheet (1/stand, see Appendix 2)
q) Pencils and permanent markers

Health Assessment, Specimen and Photograph Collection:

- Conducted every 3 years

a) Tablet and spare battery
b) Reference texts for damage agent identifications
c) Binoculars
d) Ultrasonic hypsometers plus extra batteries (for measuring height of new snags)
e) Pole pruners for foliage collection
f) Knife for sample collections
g) Collection envelopes or paper bags (5/stand)
h) Insect collection vials with alcohol (5/stand)
i) Stapler
j) Camera
k) Tree paint - orange (2 cans/stand)
l) Pencils and permanent markers

Mensuration Assessment:

- Conducted at plot establishment and every major remeasurement (every 6 yrs.)

a) Tablet and spare battery
b) Ultrasonic hypsometers plus extra batteries
c) DBH tape
d) Fiberglass tapes (one 50 m tape and one 30 m tape)

e) Tree paint - orange (2 cans/stand)

Core Collections:

- Conducted at plot establishment and every major remeasurement (every 6 yrs.)

a) Tablet and spare battery
b) Increment corer (must be sharp)
c) Straws (12/stand, 24/node)
d) Stapler
e) DBH tape
f) Flagging orange (1 roll/node)
g) Tree paint (1 can/node)
h) Preprinted core labels
i) Pencils and permanent markers

Regeneration Survey:

- Conducted a year after plot establishment and every 3 years there after

a) Field tablet and portable extra battery
b) Diameter caliper
c) Height pole or other height measuring device
d) DBH tape
e) Pigtails (20) and flagging (2 different colors)
f) Compass
g) Fiberglass tapes (two 50 m tapes)
h) Hip chain string or a third tape measure
i) Metre stick

Shrub Survey Equipment:

- Conducted a year after plot establishment and every 3 years there after

a) Field tablet and portable extra battery
b) Compass
c) Fiberglass tape (30 m)
d) Pigtail markers (8 per stand) and flagging
e) Height pole or other height measuring device
f) Vegetation reference guide
g) Camera
h) Metre stick

Vegetation Survey Equipment:

- Conducted a year after plot establishment and every 3 years there after

a) Field tablet and portable extra battery

b) Pigtail markers (16 per stand) and flagging
c) 1 x 1 m vegetation frame
d) Vegetation reference guide
e) Vegetation collection envelopes
f) Knife for collecting vegetation samples
g) Sample collection envelopes (10 per stand)
h) Camera