Foothills Growth and Yield Association
Regenerated Lodgepole Pine Trial

FIELD MANUAL
for
REGENERATION PHASE
MEASUREMENTS AND MAINTENANCE

Version 4.3

June, 2014

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1   General

This document is intended primarily for use by FGYA contractors engaged in ongoing measurement and maintenance of the trial. For these purposes it replaces all previous versions as of July 1, 2013. (Amendments since the 2010 version 3.1 are summarized in Appendix 1.)

The remainder of this section summarizes the ecological and treatment categories by which installations and plots are classified, and the layout of installations. Sections 2, 3 and 4 describe procedures for measurements, maintenance and quality control respectively.

Each installation is uniquely referenced by a sequence of 3 digital codes representing its eco-class (see Table 1), group (valid codes are 1 – 5), and planting density (see Table 2). Treatment plots within each installation are further referenced by vegetation management treatment (see Table 3).

Table 1. Eco-Classes

Code	Eco-class (and Edatope)
1	Bearberry / lichen / hairy wild rye (submesic / subxeric, medium – low)
2	Labrador tea – mesic (mesic – poor)
3	Billberry / cranberry / sarsaparilla / rhododendron (mesic / medium)
4	Honeysuckle / fern (subhygric – rich)
5	Labrador tea – hygric (hygric – poor)

Table 2. Installation Planting Densities

Code	Spacing (m²)	Target Planting Density (stems/ha)	Target Trees/plot (0.25 ha/0.1 ha)
0 or 9	Control	0	0
816	3.5	816	204/82
1111	3.0	1111	278/111
1600	2.5	1600	400/160
2500	2.0	2500	625/250
4444	1.5	4444	1111/444

Table 3. Plot Vegetation Management Treatments

Code	Plot #	Treatment	Treatment Description
C	1	Control	No vegetation management treatments
W	2	Weeding	Remove competing vegetation
WT	3	Weeding & Thinning	Treatments 2 & 4
T	4	Thinning	Pre-commercially thin to target density

Figure 1 portrays a standard non-split installation. In some installations treatment plots have been re-aligned or separated to fit into the targeted site. Before carrying out any measurement or treatment on any plot, treatment plot post demarcation and field notes should be checked.

Figure 1. Installation Diagram

Figure 1. Installation Diagram
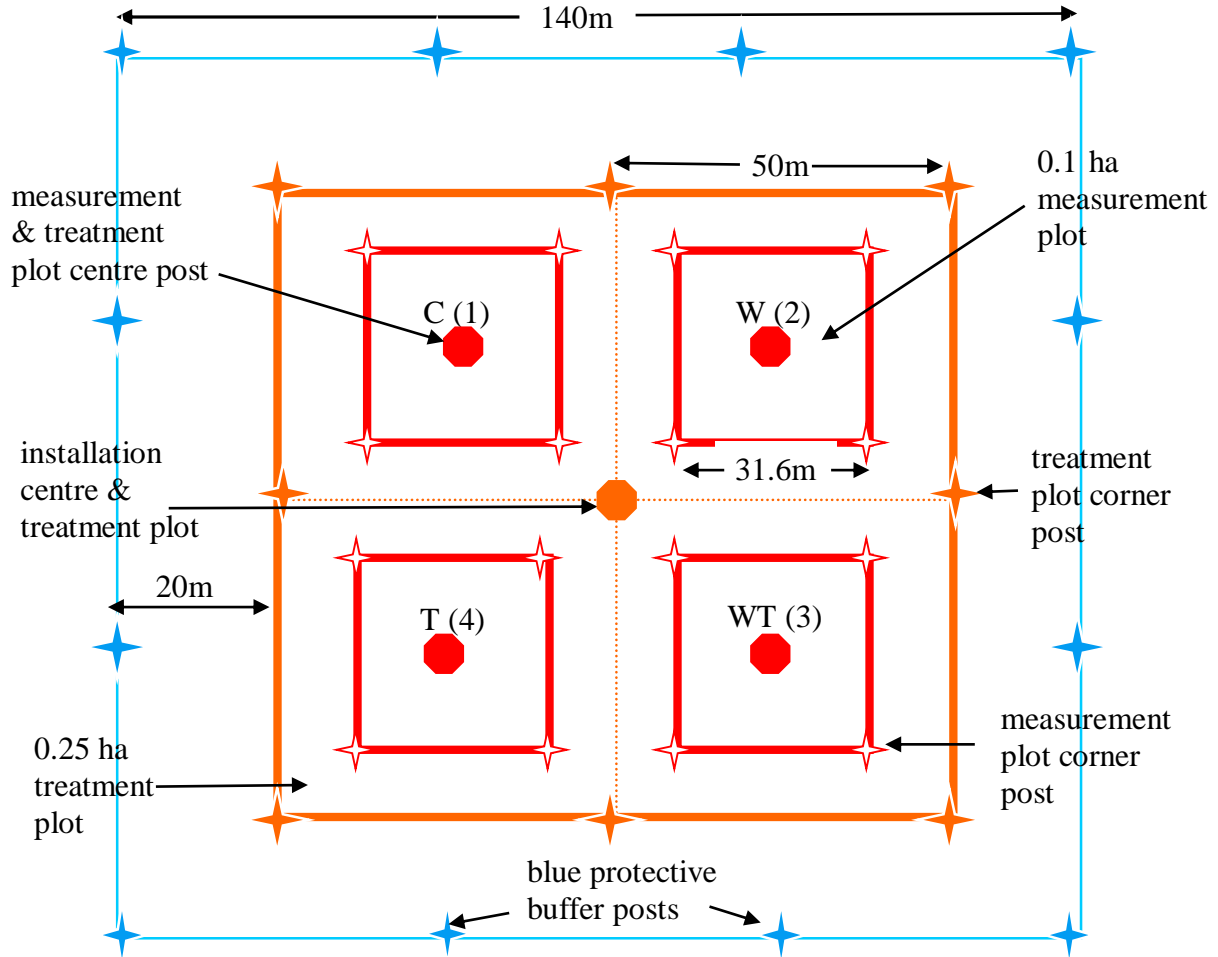
In every measurement plot there are 16 circular regeneration sub-plots (radius 1.78m) marked with green plot centers. They are laid out on a 7.90 m square grid as shown in Figure 2.

Figure 2. Regeneration Plot Layout

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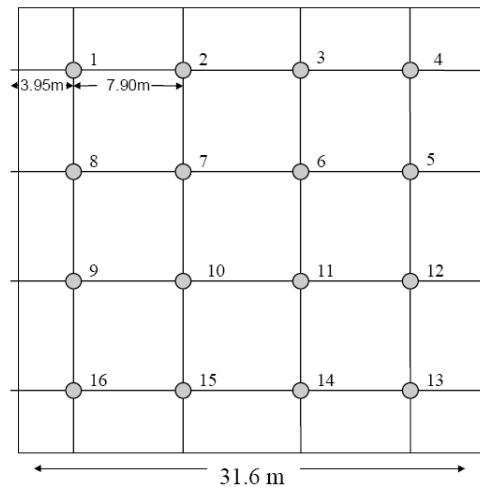
2   Measurements

2.1   Numbering, Type and Timing of Measurements

A unique and sequential measurement number will be assigned by the database manager to each scheduled measurement of a treatment plot. Measurements are of 2 types: full measurements and vigour checks (see Table 4).

Table 4. Measurement Types and Associated Measurement Requirements

Measurement Variables	Measurement Type	
	Full measurement (FM)	Vigour check (VC)
Coniferous ingress	Required	Not required
Competition – shrubs and herbs	Required	Not required
Competition – deciduous trees	Required	Not required
Tree size and growth	Required	Not required
Vigour	Required	Required
Health	Required	Required[1]

[1] Required for trees that have died since the last measurement to indicate probable cause of mortality.

Full measurements will continue to be required every 2 years until 12-14 years have elapsed since harvest, and will alternate with vigour checks to be conducted in the intervening years. Detailed measurement schedules will be provided annually. Full measurements will be made between July 15 and September 15. Vigour checks may be made any time between July 1 and September 15.

For each tree in the database (i.e.: all tagged trees within measurement plots), a sample type must be correctly assigned. Some changes to sample type are valid, others not. Valid sample types and changes are shown in Table 5.

Table 5. Tree Sample Types

Code	Sample Type	Valid & Invalid Changes			
		B	S	C	N
B	Both crop and sample		OK	No	No
S	Sample	OK		No	No
C	Crop	No	No		OK
N	Neither[1]	No	No	OK	

Procedures for selecting sample trees are described below. Procedures for identifying crop trees are described in Section 2.6.

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[1] Tree, tagged and assessed for health and vigour, which are neither crop or sample trees.

Sample Tree Selection - Planted Installations
(This procedure should have been followed in previous measurements for all planted installations.)
The selection and tagging of sample trees provides the basis for tracking an unbiased sample of approximately 50 trees individually on each treatment plot. The selection of sample trees for planted installations is carried out only once. After their initial selection they remain the same year to year. (Exception: during a fill plant, dead sample trees may have been replaced, given unique numbers, and assessed as new sample trees). Other than in a fill-planting situation, sample trees are <u>not</u> to be replaced. Where mortality of sample trees has occurred and no fill-plant has taken place there will be less than 50 sample trees.

To select the sample trees in planted installations, start by selecting all tagged trees within each regeneration plot until 50 sample trees have been selected. On lower density installations, you may not have 50 trees within the 16 regeneration plots, in this case, go back to the first plot and select the closest pine outside the regeneration plot, go to the next plot and do the same, continue doing this until you've achieved the required 50. <u>Sample trees must be flagged on their respective pigtails with BLUE ribbon (alternatively, pigtails may be painted blue)</u>

Sample Tree Selection - Non-Planted "0 density" Installations
(This procedure should have been initiated in non-planted installations having natural regeneration.)
For each treatment plot, start in regeneration plot # 1, measure out one metre, <u>due North</u>, from the regeneration plot center, and at this location, tag and number the closest lodgepole pine volunteer > 10 cm in height, within the 1.78 metre radius regeneration plot. Next, in the same regeneration plot, follow the same procedure twice more but measuring out one metre <u>due East</u> and then one metre <u>due South</u>, from the regeneration plot center, tagging and numbering the closest lodgepole pine volunteer > 10 cm in height. Once you have selected the three sample trees in regeneration plot #1 as noted above, move to the next regeneration plot and follow the same procedure starting with your first tree being the closest lodgepole pine volunteer > 10 cm in height as measured from a point 1 metre <u>due West</u> from the regeneration plot centre. If three sample trees are located at each regeneration plot (16), two extra sample trees will have to be selected to achieve a total of 50, these can be located in any regeneration plot. As you proceed with the selection process, alternate the selection location in order from N to E to W to S, this will result in an unbiased selection method. The regeneration plots need not be divided into theoretical quadrants for the selection process, simply select the lodgepole pine volunteer > 10 cm in height which is closest to the 1 metre point in the particular cardinal direction that you are using. By doing this instead of using a "quadrant", we can select two or more sample trees which are located right next to each other in the same cardinal direction where clumping of trees is occurring. A maximum of 4 sample trees per regeneration plot, and 50 sample trees per measurement plot may be selected. Unlike on the planted plots, sample trees in non-planted installations WILL NOT be selected from outside the regeneration plot. Where less than 50 trees are located within the 16 regeneration plots, the additional sample trees will be tagged if and when further ingress occurs.

The identification and tagging of sample trees should be continued at each full measurement until there are 50 sample trees tagged per plot. Following full measurements any regeneration plot that has three or more naturals greater than 10 cm must have three trees tagged.

The plot measurement type and tree sample type define what tree measurements are required as follows:
VC (vigour check) measurement type:

- Valid vigour code required for all tagged trees, regardless of sample type.
- If tree has died since last measurement, a health code is also required to explain cause of death if known.

FM (full) measurement type:

- If sample type = S or B: all tree size and growth information, plus vigour and health, must be recorded;
- If sample type = C: vigour and health codes are required, plus height is recorded in the regeneration plot table;
- If sample type = N: vigour and health codes only are required.

Details of required measurements are provided below. Quality control checks that must be passed before data are loaded into the master database are listed in Appendix 2.

2.2 Density of Coniferous Natural Regeneration (Coniferous "Ingress")

- Required for FM (Full Measurements) only.

- In each 1.78 meter radius regeneration plot (16), record the number of live naturally regenerated coniferous trees >10.0 cm in height, by species. (Valid species codes are shown in Table 6.)

- Partition the counts by height into <30cm and 30cm+.

Note: "height" is defined as the vertical distance between ground level and the base of the terminal bud, as in Section 2.3.1.

For trees 30cm+ in height: If the count is less than or equal to 10, the exact number of trees should be recorded. However, if the stem count exceeds 10, an estimate (accurate to +/- 10%) is acceptable.

For trees <30cm in height: If the count is less than or equal to 10, the number of trees should be recorded to a required accuracy of +/- 2 trees. However, if the stem count exceeds 10, an estimate (accurate to +/- 20%) is acceptable.

Table 6. Coniferous Species Codes

Code	Species
Fa	Sub-alpine Fir
Fb	Balsam Fir
Lt	Tamarack (Larch)
Pj	Jack pine
Pl	Lodgepole Pine
Sb	Black Spruce
Se	Englemann Spruce
Sw	White Spruce

2.3 Size and Growth (Sample Trees)

For each Sample Tree measure/collect the following information during scheduled full (FM) measurements.

2.3.1 Tree Height:

- Record the tree height from tree stem ground level to the base of the bud. If identification of "stem ground level" is uncertain because of uneven slope, litter etc., measure on the side of the stem where the ground level appears closest to the germination point.   Leaning trees are to be measured from the base of the bud plumb to the ground level. E.g.; If a tree had an extreme lean of about 45º you would measure from the base of the terminal bud straight down to the ground, in other words, you <u>do not</u> measure the *length* of the tree, only the *height* above ground level.

- Precision: record to nearest 0.1cm on trees < 2 m tall, trees over 2 m are recorded to nearest cm. Accuracy required for trees < 2 m to within +/- 1 cm or 1%, whichever is greater, and for trees > 2 m +/- 2%.
- Trees up to 5 m tall should be measured with a stiff tape or height pole. Trees taller than 5 m should be measured using a vertex.

Any trees which have "shrunk" significantly in height since the last measurement should have a valid health code or comment explaining shrinkage. Contractors should have previous measurements available in data collectors or on tally forms to assist in identifying these trees.

2.3.2 Ground Line Diameter / Stump Diameter / Breast-Height Diameter:

- For each sample tree, record stem diameter in cm at ground level (GLD). Be careful not to damage trees with the calipers when taking measurements.

- Tree diameter is measured at ground line only until the sample tree has reached 2.0m in height. Once a tree is 2.0m in height, diameter will also be measured at 1.3m (DBH) and 0.3m (DSH).
- For one measurement only (when the tree first reaches 2.0m in height) all 3 diameters will be required (GLD, DSH, DBH); thereafter GLD can be dropped.
- Precision: record all diameters to the nearest 0.1cm, accurate to within +/- 0.2cm or 2%, whichever is greater.
- Diameters greater than 3.0 cm should be measured using a D-tape. Smaller diameters should be measured using calipers.

2.3.3 Crown Diameter:

- For each sample tree, record the crown diameter at the widest point. Disregard "rogue" branches which would give a false assessment of crown diameter.

- Precision: record to the nearest cm. Accuracy required to within +/- 5 cm for trees < 3 m, +/- 10 cm for trees > 3 m.

2.3.4 Crown Length:

- For each sample tree, record the crown length in cm. Start at the bottom where the live crown starts and measure up to the tip of the terminal bud. Disregard "rogue" branches which would give a false assessment of crown length.

- Precision: record to the nearest cm. Accuracy required for trees < 2 m to within +/- 1 cm or 1%, whichever is greater, and for trees > 2 m +/- 2%.

2.4 **Health**

Health assessments are required on all tagged trees during full (FM) measurements). They are also required during vigour (VC) checks for any tagged tree that has died since the last measurement. When vigour checks are conducted prior to thinning, health codes are also required for trees that are alive an unlikely to survive (vigour code "AU").

For each tagged tree within the measurement plot, record up to two of the valid health codes listed in Table 7. If no health issues are apparent, record "NONE" for the first health code.

Table 7. Health Codes

Code	Description	Code	Description	Code	Description
AB	Fire	DEG	Grey Mold	IDC	Cankerworms General
AC	Chemical Pollutants (not pesticides)	DEM	Powdery Mildew	IE	Engravers/IPS
AD	**Drought**	DF	Needle Diseases	IM	Seed and Cone Insects
AE	Winter Damage	**DFB**	**Needle Cast General**	IMD	Coneworms
AES	Snow or Ice	DFE	Needle Rusts General	IME	Eastern Pine Seedworm
AEW	Winter Desiccation	DM	Lodgepole Pine Dwarf Mistletoe	IMS	Cone Maggots
AF	**Frost**	**DRA**	**Armillaria Root Disease**	**IP**	**Pitch Blister Moths**
AFC	Frost Crack	DS	Stem Diseases	IR	Wood Borers
AFH	Frost Heaved	**DSA**	**Atropellis Canker**	IRF	Flathead Borers
AFK	Shoot/Bud Frost Damage	DSB	White Pine Blister Rust	IRM	Clearwing Moth
AHM	**Hail-main stem**	**DSC**	**Comandra Blister Rust**	IRW	White Spotted Sawyer Beetle
AHL	Hail-lateral	DSD	Sphaeropsis (Diplodia) Blight	IRY	Northeastern Sawyer Beetle
AL	Lightning	DSF	Sweet Fern Blister Rust	**ITT**	**Lodgepole Terminal Weevils**
AO	Flooding	DSG	Scleroderris Canker	ITS	White Pine Weevil
AR	Redbelt	**DSH**	**Hypoxylon Canker**	ITT	Lodgepole Terminal Weevil
AWS	Soil Failure	DSR	Diplodia Gall and Rough Bark	IW	Root Weevils
AWT	Treatment or Harvesting Related	**DSS**	**Stalactiform Blister Rust**	IWA	Northern Pine Weevil
AX	Scarring/Rubbing	**DSW**	**Western Gall Rust***	IWP	Couper Collar Weevil
CL	Condition - Leaning	**DSW 50**	**DSW, gall encircles >%50 of stem**	IWS	Yosemite Bark Weevil
CCK	Crook	IAG	Gall Forming Aphids	**IWW**	**Warren Root Collar Weevil**
CDT	Dead Top	IAO	Open feeding Aphids and Adelgids	TC	Chemical
CFT	Fork Top	IAP	Pine Needle Scale	TL	Logging
CNL	New Leader	IB	Bark Beetles	TM	Mechanical
CSP	Sweep	IBA	Ambrosia Beetles	TP	Planting
CSM	Settling Mound (microsite)	IBL	Lodgepole Pine Beetle	TPJ	J Root
DB	Broom Rusts	IC	Defoliators – Coniferous	TPM	Poor Planting Microsite
DD	Stem Decays	ICA	Needle Miners General	UNS	Seedling Shrinkage – Unexplained
DDP	Red Ring Rot	ICG	Black Army Cutworm	VP	Vegetation Press
DED	Damping off Disease	ICN	Sawflies General	**WB**	**Browsing Damage**

* NOTE alternative code added 2011: If the gall encircles more than 50% of the main stem, enter the code "DSW50" instead of "DSW"

Pay particular attention to the codes listed in Table 7 that are bolded. These are factors that are known or expected to be significant causes of mortality or damage that could pre-dispose tree to other mortality factors in young lodgepole pine growing in west-central Alberta, and differentiation of which might lead to different management interpretations. Identification aids for these "key" factors are provided under separate cover.[2] If cause of death is not apparent, dig up dead trees to determine if they were affected by IWW or DRA.

In cases where **live** trees are affected by more than two coded health factors, record the two highest priority codes according to the following priority rules.
1. If any are present, record pests or health factors which are likely to cause mortality in the short term: DRA, DSW50, IWW, or AHM.
2. Record pests or health factors that reduce vigour but which will not cause mortality in the short term. This includes the remainder of the bolded items in Table 7.
3. Record non-bolded items in Table 7 last.

When choosing between pests within the same priority rule, choose the one that appears to be having the greatest impact on the tree's health. If a tree is **dead**, record the health factor that is most likely to have caused mortality.

If a condition is observed which is not listed in Table 7, record as a comment and notify the Operations Director.

2.5 **Vigour and Source**

Assessment of vigour is required in all scheduled measurements (measurement types FM, VC). For each tagged tree within the measurement plot, record one of the four vigour codes indicated in Table 8.

Table 8. Vigour Classes

Code	Description
AL	Alive and likely to survive
AU	Alive but unlikely to survive
D	Dead
M	Missing
MT	Mechanically thinned (i.e. removed by thinning)

Trees confirmed as missing for 2 consecutive years will be assigned as Dead. It is very important that every effort is made to locate missing trees before this re-assignment is made.

All trees recorded for vigour must be correctly differentiated by source: "P" for Planted and "N" for Natural.

2.6 **Competition and Crop Tree Assessment**

Competition and crop tree assessments are required during full measurements.

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[2] (a) Alberta Sustainable Resource Development, 2009. *Pest ID Cards 2009*. Unpublished. Edmonton, Alberta.

A "Crop tree" is defined as the coniferous tree with the best overall height, diameter[3], and health within each (1.78 m radius) regeneration plot. Each treatment plot will have a maximum of 16 crop trees. Initially, on planted installations, the crop tree should be a planted pine. However, if a naturally regenerated conifer in a regeneration plot exceeds the height and diameter of an existing crop tree, and is at least as healthy and vigorous as the crop tree, then that natural seedling is to be tagged and numbered as the new crop tree. Moreover, any *planted* pine in a regeneration plot, which exceeds the height, diameter, and health of an existing crop tree will also replace the existing crop tree. (It will be tagged and numbered already so just record that number as the new crop tree). Crop trees will continue to be replaced by better candidates throughout the life of the plots, often more than once. Once a crop tree has been replaced by a better candidate, the replaced crop tree is no longer measured for any size and growth measurements (unless it is a sample tree).

Crop trees must have their respective pigtails flagged with GREEN ribbon. Once a crop tree has been replaced with a better candidate the ribbon must be removed and placed on the new crop tree.

In non-planted plots, the best natural coniferous (ingress) seedling within each regeneration plot is selected as the crop tree (minimum 10cm height). This "natural" crop tree must be tagged and given a unique number.

Collect the following information at each regeneration plot. Note that deciduous competition and shrub and herb competition are all assessed using the regeneration plot post as the plot centre.

2.6.1 Crop Tree Data

Record the number, species and source of the crop tree, plus all size and growth measurements i.e. "Crop" trees will have exactly the same information collected as described for "Sample" trees in Section 2.3.

2.6.2 Deciduous Competition

Number of Stems >30cm in Height, by Species:
- Record for each deciduous species the number of stems 30cm+ in height within 1.78 m of the regeneration plot centre.
- If the number of deciduous trees in the plot is less than or equal to 10, the exact number of trees should be recorded. However, if the stem count exceeds 10, an estimate (+/- 10%) is acceptable. This may be obtained by estimation from a representative segment of the circular plot (e.g. counting trees in a ¼ segment, and multiplying by 4 to obtain the estimate for the plot).

> Suckered deciduous stems are counted as individuals if the suckering has occurred under ground and is not visible. A "group" of stems visibly suckered and/or originating above ground may be counted as a single stem.

Height and Diameter for Deciduous Species:
- In the 1.78 m radius regeneration plots, record the modal height and modal ground-line diameter for each deciduous species[4]. Modal height or diameter is the most frequently occurring height or diameter in a plot, not necessarily the average.

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[3] Use the highest recorded diameter for this assessment i.e. DBH if measured, otherwise stump diameter if measured, otherwise ground-line diameter.
[4] Valid species codes are AW (aspen), PB (black poplar) and BW (white birch).

- Also record the species, height, ground-line diameter and (for trees over 2m in height) DBH of the tallest deciduous tree over 30 cm height. For one measurement only (when the tree first reaches 2.0m in height) both GLD and DBH will be required; thereafter GLD can be dropped.

- Precision: record heights to the nearest cm and diameters to the nearest 0.1cm. Required accuracies:

  - Modal height: +/- 2 cm on trees < 1 m tall, auditor's discretion on trees > 1 m tall

  - Diameters: +/- 0.2 cm.

  - Height of tallest deciduous: for trees < 2 m to within +/- 1 cm or 1%, whichever is greater, and for trees > 2 m, +/- 2%.

2.6.3   Shrub and Herb Competition

During full plot measurements, provide estimates for every regeneration plot (1.78m radius) of the percent of ground covered by each of the vegetation categories listed in Table 9. Table 10 indicates the area and some dimensions associated with various cover percentages, to assist in estimation. Record modal (predominant and most frequently occurring) heights of shrubs, herbs and grasses. Record percent cover and heights consistently regardless of whether the vegetation appears to be competing with crop trees. Percent cover must always be between 0 and 100 for each vegetation category. Heights must be recorded for any category where the percent cover is greater than zero.

Table 9. Assessment of Shrub and Herb Competition

Variable	Description
WillowAlderGE30PctCover	Percent cover of willow and / or alder equal to or taller than 30cm in height
WillowAlderGE30Ht	Modal height of willow and alder equal to or taller than 30cm in height
OtherShrubGE30PctCover	Percent cover of shrubs equal to or taller than 30cm, other than willow or alder
OtherShrubGE30Ht	Modal height of shrubs equal to or taller than 30cm, other than willow or alder
ShrubLT30PctCover	Percent cover of ground shrubs (any species) less than 30cm in height
ForbPctCover	Percent cover of all non-graminoid, non-woody vascular plant species
ForbHt	Modal height of all non-graminoid, non-woody vascular plant species
GrassPctCover	Percent cover of all graminoid species (including grasses, sedges, rushes)
GrassHt	Modal height of all graminoid species (including grasses, sedges, rushes)
MossPctCover	Percent of forest floor (including advanced decayed downed wood) covered by moss
LichenPctCover	Percent of ground covered by lichens

Table 10. Dimensions for Cover Percentages of a Regeneration Plot

Percent Cover	Area (cm²)	Radius (cm)	Diameter (cm)	Side of square (cm)
1	1,000	18	36	32
5	5,000	40	80	71
10	10,000	56	113	100
20	20,000	80	160	141
30	30,000	98	195	173
40	40,000	113	226	200
50	50,000	126	252	224
60	60,000	138	276	245
70	70,000	149	299	
80	80,000	160	319	
90	90,000	169	339	
100	100,000	178	357	

The species indicated in Table 11 must be noted **where they are the predominant species** within their vegetation category on the plot. Only one species can be noted in each vegetation category.

Table 11. Shrub and Herb Species of Interest

Vegetation Category	Species and Code
WillowAlder (GE 30 cm)	Willow (SALIX), Alder (ALNUS)
OtherShrubGE30Ht	Honeysuckle (LONICER), Labrador tea (LEDUM), rhododendron (RHODALB)
Forbs	Fireweed (EPILANG)
Grasses	Calamagrostis (CALAMAG)

- Precision: Record percent cover to the nearest percent and heights to the nearest cm. Required accuracies:
  - Percent covers: +/- 10%

  - Modal height: +/- 2 cm on plants < 1 m tall, auditor's discretion on plants > 1 m tall

2.7 Photographs

Now that all installations are established, the taking of photographs will be optional (at the discretion of the plot owner), unless specifically requested for defined research or demonstration purposes. If the option is selected, the following methodology applies:

At each treatment plot center (4 per installation), take one landscape orientated photo toward each treatment plot corner. This will give four photos per treatment plot and therefore 16 photos per installation. Photographs should be digital and labeled accurately. Contractors will confirm the photograph submission format and protocol with the database manager prior to any collection of data.

2.8 Stocking of Regeneration Plots by Planted Trees

Stocking of regeneration plots by natural regeneration can be computed from the regeneration plot data collected as described in Section 2.2. It is important that, in addition to determining whether each regeneration plot is stocked with natural regeneration (ingress), a record is made of whether the plot is stocked with a planted tree. This is the purpose of the "Regen Plot Number" field in the Tree Information Table. If a tagged tree is INSIDE a regeneration plot, record the plot number in this field. This information should be checked and recorded at every measurement, including during vigour checks. **Contractors are asked to pay particular attention to checking that the correct information is entered in this field, since some inconsistencies have been observed in the data from previous years.** If a tagged tree does not lie within a regeneration plot, the closest regeneration plot should be recorded in the adjacent "Closest Regen Plot" field to assist in finding the tree in future.

2.9 Top Height

Top height and associated attributes will be measured on all installations scheduled for full measurement.

In order to emulate assessment of top height in RSA (Reforestation Standard of Alberta) performance surveys, tag and measure the largest diameter at breast-height live (AL or AU) tree, by species group, within 5.64m of the centre post of each of the following regeneration plots: 1, 4, 13, 16.

Follow RSA tree selection and measurement procedures as quoted in Appendix 3, treating the above 4 centre posts as the centres of RSA detailed performance survey plots.

If the selected tree already is tagged, use the existing tree number; otherwise tag the tree with a new number, series 4000. Record for each tree:

- Regeneration plot number: 1, 4, 13 or 16;
- Health (do not select any tree with a broken top that has not been replaced by a new leader, or a tree whose main stem is more than 50% encircled by western gall rust);
- Species (note that if more than one species group is present within the 5.64 plot radius, one tree for each group should be measured);
- Source (note that age need not be measured if the tree was planted);
- Height (this is height to the base of the terminal bud, consistent with height measurement of sample trees);
- Top height (this is height to the top of the terminal bud, as in RSA protocols);

- DBH;
- Total age: if the selected tree is naturally regenerated, follow the RSA procedure for estimating total age (see Appendix 3);
- Distance to the regeneration plot centre;
- Azimuth from the regeneration plot centre;
- Whether the tree falls outside the 0.1 ha staked measurement plot.

3   Maintenance

The items indicated in Table 12 must be checked at each plot measurement visit, and the listed requirements met.

Pinning, numbering and regeneration plot assignment of trees will be checked and maintained at each measurement. All seedlings planted within measurement plots, plus naturally regenerated trees designated as sample or crop trees, should be pinned and numbered, using 9-gauge 45 cm painted wire pins, aluminum tags and wires. Any tagged tree within 1.78 m of a regeneration plot centre stake should be correctly assigned to that regeneration plot. Do NOT assign regeneration plot numbers to trees that are outside the regeneration plot.

Unlike in measurements, where errors are tolerated within specified limits, no errors or omissions are acceptable in installation and plot maintenance.

Table 12. Installation and Plot Maintenance Requirements

Item	Requirement
Access Maps	Accurate, and updated if access has changed.
Installation Tie-point	Clearly visible. Marked with the azimuth and distance to installation center.
Installation Buffer	Clearly visible around the entire installation. Conduit poles pounded securely into the ground and blue paint refreshed as required. As trees begin to approach 2m tall, blue ribbon should be tied to the lateral branches (never to the main stem!) of regenerating trees to make the buffer easier to see.
Installation Centre Post	Pounded securely into ground. Orange paint clearly visible. Flagged with orange ribbon. As neighbouring trees reach 2m tall, witness trees should be flagged on lateral branches only. Tagged with the installation number.
Treatment Boundary Corner Posts	Pounded securely into ground. Orange paint clearly visible. As neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only.
Measurement Boundary Corner Posts	Pounded securely into ground. Red paint clearly visible. As neighbouring trees reach 2m tall, witness trees should be flagged on lateral branches only.
Measurement and Treatment Plot Centre Post	Pounded securely into ground. Red paint clearly visible. Tagged with the installation number and treatment type.
Regeneration Plot Centre Post	Every measurement plot must contain 16 green regeneration plot centre posts properly positioned and securely pounded into ground.
Tree Demarcation	Number on tags is clear & legible and clearly displayed (i.e. off the ground). Pigtails are utilized ONLY until trees are robust enough to allow for either: • Placement of a big-loop-tag to the main stem (providing a minimum of 4 inches of diameter slack to allow for growth) or • Tagging a lateral branch Trees tagged with a big-loop or tagged on lateral branch will be flagged appropriately (green/blue/both) on a lateral branch. If utilized, pigtails are placed 20cm North of their assigned tree and are marked with the appropriate color ribbon (sample tree = blue, crop tree = green, both = blue/green) If pigtails are utilized and there is ANY doubt as to which tree is represented, the tree itself may be flagged with the appropriate color and/or tagged (flagging and/or tagging tree stem must be done in a non-restrictive manner, and, will be only utilized until transfer to main stem big loop tag or lateral branch demarcation

4 Quality Control

4.1 Measurements and Maintenance

Required accuracies of measurements are specified in Section 2. Note the distinction made between precision and accuracy. "Precision" refers to how the data should be recorded. Quality control audits will be made to check whether measurements are within the "required accuracy" (i.e. acceptable error limit) specified for each variable. No errors or omissions are acceptable in plot maintenance.

Field contractors are encouraged to submit completed data to the Operations Director as soon as possible to allow for quick audits. Installation maintenance and measurements will be checked by the Field Auditor in consultation with the applicable company technical representative. Failures will be placed in one of 3 categories:

1. Minor outage: an issue that can be rectified during the next regularly scheduled field visit.
2. Moderate outage: an issue that can be rectified during the next regularly scheduled field visit; however additional measurements may need to be taken.
3. Major outage: an issue that cannot be fixed at the next regularly scheduled field visit.

Identified outages will be regarded as potentially applying to all plots measured by the contractor within the sample year. The Operations Director will discuss observed problems with the respective company technical representative and notify the field contractor of any required remedial action. Major outages (and some systemic moderate outages) will require the field contractor to ensure that all plots visited for that sample year have been fixed. The Field Auditor will re-audit corrected plots, and the Operations Director will provide a recommendation for payment to member companies only when satisfied that all quality control issues have been addressed.

4.2 Data Loading

All data must be submitted using the Contractor Loading Database (CLDB). The CLDB is a Microsoft Access database provided to each of the contractors engaged to undertake measurements. Contractors receive a personalized version of the database that contains all the installations they are scheduled to measure. It includes previous measurement data and error-checking routines.

Regardless of how data is collected in the field, it must be loaded into this database. Prior to submission of data, all error checking routines must be run and any problems identified must be corrected. On receipt of the data, the database manager and / or Operations Director will verify whether the data passes the quality control checks, and will notify the contractor and company representative to this effect within 2 weeks of receiving the data.

The error checks incorporated into the CLDB and applicable for the 2013 field season are described in Appendix 2.

4.3 Field Audit Procedures

Field audit procedures are described in Appendix 4.

Appendix 1. Latest Amendments

The following changes and additions have been made since 2010 (version 3.1 of this Manual). Contractors must ensure that they have noted and understood the revised manual sections referenced below before commencing field work.

1. Section 2.1. Table 5 amended to include clarification of valid and invalid changes to tree sample type. Invalid changes to tree sample types, previously accepted with a warning, are now treated as unacceptable errors in data loading.
2. Section 2.3.1. Added guidelines for choosing tools to measure trees at different heights and diameters.
3. Section 2.4. Note alternative health code added. If the gall encircles more than 50% of the main stem, enter the code "DSW50" instead of "DSW".
   New condition codes added for sweep and crook. Some insect and disease codes were removed from the list to reflect the most likely pests.
   Added priority rules for determining which Forest Health codes to record when more than two are present.
   When vigour checks are conducted prior to thinning, health codes are also required for trees that are alive and unlikely to survive
4. Section 2.5. Additional vigour class added to Table 8 to accommodate removal of trees by thinning.
5. Section 2.8. New section on stocking of regeneration plots by planted trees. Contractors are asked to pay particular attention to checking that the correct information is entered, since some inconsistencies have been observed in the data from previous years.
6. Section 2.9. New section on selection and measurement of top height trees, consistent with Government of Alberta RSA procedures. Relevant extracts from the Government RSA manual are included in Appendix 3.
7. Appendix 2. Quality control checks for loading data collected in 2013.
8. Appendix 4. Field audit procedures that will be followed by the Operations Director and Field Auditor in 2013.

Appendix 2. Quality Control Checks for Loading Data – 2013

Measurement Plot Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
2	Missing or Invalid Plot Measurement Type			0	0	
3	Missing / Invalid Start Date	15/07/2013	15/09/2013	0	0	Measurement type FM
4	Missing / Invalid End Date	01/07/2013	15/09/2013	0	0	
5	Missing Contractor			0	0	
6	Missing Crew Initial			0	0	
7	Excessive Days Between Start and End (warning)			0	10	
8	Missing / Invalid Start Date	01/07/2013	15/09/2013	0	0	Measurement type VC

Regeneration Plot Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	Invalid Crop Tree Number			0	0	
2	Invalid Crop Tree Height	0.1	900	0	0	Tree Sample Type C or B
9	Invalid Ingress Species 1			0	0	
10	Invalid Ingress Species 2			0	0	
11	Invalid Ingress Species 3			0	0	
35	Missing / Invalid Start Date	15/07/2013	15/09/2013	0	15	
36	Missing / Invalid End Date	15/07/2013	15/09/2013	0	15	
37	Invalid Contractor			0	0	
38	Excessive Days Between Start and End (warning)			0	20	
39	Missing IngressCount1_LT30	0		0	0	
40	Missing IngressCount1_GT30	0		0	0	
41	Missing IngressCount2_LT30	0		0	0	
42	Missing IngressCount2_GT30	0		0	0	
43	Missing IngressCount3_LT30	0		0	0	
44	Missing IngressCount3_GT30	0		0	0	
45	Invalid WillowAlderGE30 PctCover	0	100	0	0	
46	Invalid WillowAlderGE30 Ht	30		0	0	WillowAlderGE30 PctCover >0
47	Invalid WillowAlderGE30 Species Code			0	0	
48	Invalid OtherShrubGE30 PctCover	0	100	0	0	
49	Invalid OtherShrubGE30 Ht	30		0	0	OtherShrubGE30 PctCover >0
50	OtherShrubGE30 Invalid Species Code			0	0	
51	Invalid ShrubLT30 PctCover	0	100	0	0	
52	Invalid Forb PctCover	0	100	0	0	
53	Invalid Forb Ht	>0		0	0	Forb PctCover >0
54	Forb Invalid Species Code			0	0	
55	Invalid Grass PctCover	0	100	0	0	
56	Invalid Grass Ht	>0		0	0	Grass PctCover >0
57	Grass Invalid Species Code			0	0	
58	Invalid Moss PctCover	0	100	0	0	
59	Invalid Lichen PctCover	0	100	0	0	

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
61	IngressCount1_LT30 > 25 (warning)	0	25	0	0	
62	IngressCount2_LT30 > 25 (warning)	0	25	0	0	
63	IngressCount3_LT30 > 25 (warning)	0	25	0	0	
64	IngressCount1_GT30 > 25 (warning)	0	25	0	0	
65	IngressCount2_GT30 > 25 (warning)	0	25	0	0	
66	IngressCount3_GT30 > 25 (warning)	0	25	0	0	

Regeneration Plot Information (Deciduous)

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	InValid Decid Species 1			0	0	
2	InValid Decid Species 2			0	0	
3	InValid Decid Species 3			0	0	
4	Missing / Invalid Start Date	15/07/2013	15/09/2013	0	15	
5	Missing / Invalid End Date	15/07/2013	15/09/2013	0	17	
6	Too Long Between Start and End (warning)			0	10	
7	Missing DecidCount1	0		0	0	
8	Missing DecidCount2	0		0	0	
9	Missing DecidCount3	0		0	0	
10	Missing /Invalid DecidModalHt1	>0		0	0	DecidCount1 >0
11	Missing /Invalid DecidModalHt2	>0		0	0	DecidCount2 >0
12	Missing /Invalid DecidModalHt3	>0		0	0	DecidCount3 >0
13	Missing /Invalid DecidModalDiam1	>0		0	0	DecidCount1 >0
14	Missing /Invalid DecidModalDiam2	>0		0	0	DecidCount2 >0
15	Missing /Invalid DecidModalDiam3	>0		0	0	DecidCount3 >0
16	Missing /Invalid DecidSelectSp			0	0	DecidCount1 >0
17	Missing /Invalid DecidSelectHt	>0		0	0	DecidSelectSp Is Not Null
18	Missing /Invalid DecidSelectAge	>0		0	0	DecidSelectSp Is Not Null
19	Missing /Invalid DecidSelectDBH	>0		0	0	DecidSelectSp Is Not Null
20	Missing GLD (warning)			0	0	
21	Invalid GLD (warning)			0	0	
22	Suspect DBH/Ht Ratio (warning)	0.001	0.05	0	0	
23	Invalid Decid Select Height (warning)		1000	0	0	
24	Invalid Decid Select DBH (warning)		25	0	0	
25	Suspect Modal1 DBH/Ht Ratio (warning)	0.001	0.05	0	0	
26	Suspect Modal1 Height (warning)		1000	0	0	
27	Suspect Modal1 DBH (warning)		25	0	0	
28	Suspect Modal2 DBH/Ht Ratio (warning)	0.001	0.05	0	0	
29	Suspect Modal2 Height (warning)		1000	0	0	
30	Suspect Modal2 DBH (warning)		25	0	0	
31	Suspect Modal3 DBH/Ht Ratio (warning)	0.001	0.05	0	0	
32	Suspect Modal3 Height (warning)		1000	0	0	
33	Suspect Modal3 DBH (warning)		25	0	0	
34	Ingress Count1 > 50 (warning)	0	50	0	0	
35	Ingress Count2 > 50 (warning)	0	50	0	0	
36	Ingress Count3 > 50 (warning)	0	50	0	0	

Tree Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	Missing Species or Change			0	0	
2	Missing/invalid Height	0.1	1000	0	0	Sample Type S or B
3	Shrinking Height (warning)			0	10	
4	Missing/invalid Ground Line Diameter	0.1	20	0	0	Height < 200
5	Shrinking Ground Line Diameter (warning)			0	0.1	
6	Missing/invalid DBH	0.1	20	0	0	Height >= 200
7	Shrinking DBH (warning)			0	0.1	
8	Suspect DBH/Ht Ratio (warning)	0.002	0.04	0	0	
9	Suspect GLD/Ht Ratio (warning)	0.002	0.04	0	0	
10	Shrinking Crown Length (warning)			0.05	0	
11	Shrinking Crown Diameter (warning)			0.05	0	
27	Dead to Live			0	0	
28	Missing Vigour/Health Code Information			0	0	
29	Invalid Tree Species			0	0	
30	Missing/Invalid Crown Length	0.1	900	0	0	
31	Missing/Invalid Crown Diameter	0.1	500	0	0	
32	Crown Length > Height (warning)	0	0	0.1	10	
33	Invalid SampleType Code			0	0	
34	Invalid Source Code			0	0	
35	Invalid Vigour Code			0	0	
36	Invalid Health Code 1			0	0	
37	Invalid Health Code 2			0	0	
38	Missing Regen Plot Number/Closest Regen Plot (warning)			0	0	
39	Missing DSH	0.1		0	0	Height >= 30 AND < 200
40	Missing/ Invalid Stem Map Information (warning)			0	0	
41	DBH > GLD (warning)			0	0	
42	DBH > Stump Diameter (warning)			0	0	
43	Missing or Changed Source			0	0	
44	Possible Missing/invalid Ground Line Diameter (warning)			0	0	
45	Suspect DSH/Ht Ratio (warning)	0.002	0.04	0	0	
46	Missing or Changed SampleTree Code			0	0	
47	Regen Plot Number Change			0	0	

Top Height Information

Error ID	Error Description	Minimum Value	Maximum Value	Tolerance Percent	Tolerance Absolute	Criteria
1	Missing Species			0	0	
2	Missing/invalid Height	0.1	1200	0	0	
3	Missing/invalid Top Height	0.1	1200	0	0	
4	Missing/invalid DBH	0.1	20	0	0	
5	Invalid Health Code			0	0	
6	Missing/invalid Age			0	0	
7	Invalid Regen Plot Number			0	0	
8	Suspect DBH/Ht Ratio (warning)	0.002	0.04	0	0	
9	InValid Tree Species			0	0	
10	Missing Stem Map			0	0	
11	Height > Top Height			0	0	
12	Age Not Required (Planted)			0	0	

Appendix 3. Extracts from Reforestation Standard of Alberta

(Government of Alberta Publication T/245, May 2011)

Top Height

A top height tree is the largest diameter at breast height (DBH) tree by species group present with in the 5.64 m radius Detailed plot.

The species groups are:
- Aw = Aw + Pb;
- Pl = Pl + Pj + Lt;
- Sw = Sw + Se + Fb + Fa; and,
- Sb = Sb.

Top height trees shall be selected based on the rules outlined below:

Primary tree species to select	Secondary tree species to select (if primary tree species is absent from the 5.64m radius plot)
Aspen	Balsam poplar
Pine	Larch
White spruce	Engelmann spruce, then fir species
Black spruce	None

If the largest DBH tree has a lost or broken top that has not yet been replaced by a new leader, then the next largest DBH tree of that species shall be selected.

ADV trees and SDL trees classified as having western gall rust (≥50% of the stem encircled by gall) are not eligible as top height trees.

If there are no coniferous trees taller than breast height (130 cm) within the Pine, White spruce, and Black spruce species groups, then select and measure the height of the tallest tree below breast height to a minimum height of 30 cm.

The minimum height for deciduous trees is 130 cm. Thus, if there are no deciduous trees taller than breast height (130 cm) within the Aspen species group, then no deciduous top height trees shall be selected.

Total Age

Total age is the number of years since germination. To field-age a tree:
- Count the number of branch whorls on coniferous trees or bud scars on deciduous trees from the current season's growth (i.e., terminal leader) down to the root collar node;
- Add one year (germination to cotyledon); and,
- Record age.

Appendix 4. Field Audit Procedures

The Operations Director (OD) has the lead responsibility to ensure that the field installations have been properly maintained and measured. She will be assisted by a Field Auditor (FA). Company technical representatives are encouraged to be actively involved in maintaining the integrity of the data collected within their respective FMA areas. This can be done by visiting installations (with the FA or independently) and alerting the OD of any suspected problems.

The FA will annually audit 10% of the full measurement installations and 5% of the vigour check installations. Selection of the installations to be audited will be done by the OD. Each year a representative sample should be audited on each of the participant FMA areas. The FA will attempt to visit each contractor early in the season, in a mentoring/audit role. Subsequently, most of the installations to be audited should be randomly selected each field season, but this may be modified for logistical purposes. The OD may also select sample locations to improve access efficiencies; however this must be done carefully to ensure that predictable auditing does not occur.

The OD may also select installations for audit by the FA that have not been QC'd for an extended period or to ensure that locations (or contractors) with potential problems are given emphasis.

QC audits must examine:

- installation maintenance;

- measurement plot data (one measurement plot will be randomly selected within each audited installation), and;

- regeneration plot data (2 out of 16 regeneration plots will be randomly selected within each audited measurement plot).

Table 13 (below) lists the sampling intensities and permitted measurement thresholds that the FA will reference. Where the FA finds measurements and maintenance outside the acceptable thresholds, he will conduct additional checks within the plot to determine if the issue is isolated or extends throughout the plot. If necessary, additional checks will be conducted on the rest of the installation or on additional installations measured by the same contractor to determine the extent of the problem.

Figure 3 provides a schematic for the field auditing process.

Table 13. Field audit sampling intensity and accuracy targets

Measurement / Maintenance Item	Sampling Intensity	Target Accuracy Standard*	Maximum Permitted Deviation †
Installation Maintenance Audit			
Access Maps	Check for all audited	Must be 100% accurate	None
Installation Tie-point	Check on audited installations	All Tie-points must: • be clearly visible • be marked with the azimuth and distance to installation center	None
Installation Buffer	Thoroughly examine one side of the buffer	The blue buffer must be well maintained and clearly visible around the entire installation. Conduit poles should be pounded securely into the ground and the blue paint refreshed as required. As trees begin to approach 2m tall, blue ribbon should be tied to the lateral branches (never to the main stem!) of regenerating trees to make the buffer easier to see.	None
Installation Centre Post	Check on audited installations	Centre post must be: • pounded securely into the ground • painted orange • flagged with orange ribbon. As neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only. • tagged with the installation number	None
Treatment Boundary Corner Posts	Thoroughly examine posts for at least one treatment zone	Corner posts must be: • pounded securely into the ground • painted orange. • as neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only.	None
Measurement Boundary Corner Posts	Thoroughly examine posts for at least one measurement plot	Corner posts must be: • pounded securely into the ground • painted red. • as neighbouring trees reach 2m tall, witness trees should be flagged (when possible) on lateral branches only.	None
Measurement and Treatment Plot Centre Post	Check on audited plots.	Centre post must be: • securely pounded into the ground • clearly painted red • tagged with the installation number and treatment type	None

Measurement / Maintenance Item	Sampling Intensity	Target Accuracy Standard*	Maximum Permitted Deviation †
Tree Tags	Check tags on trees checked as described below.	The tags should be: • legible • clearly displayed (i.e. off the ground) • located 20cm to the north of their assigned tree (if possible)when pigtails are used Trees 2m+ tall should be tagged either by affixing a tag to a lateral branch or if the tree is less than 4m tall the tag can be affixed to the main stem by a big-loop-tag that provides a minimum of 4 inches of diameter slack to allow for growth.	None
Audit 1 of the 4 Measurement Plots (Randomly Selected)			
Dead and Missing Trees [vigour code = 'D' or 'M']	5 trees	Confirm the status of trees that have been identified as either dead or missing during the last measurement (to a maximum of 10 trees).	No errors allowed
Dead Tree Causal Agent	5 trees	Confirm the causal agent for trees that have been identified as dead during the last measurement (to a maximum of 10 trees).	A maximum of 20% of the measurements are allowed to be outside the target standard.
Health Assessment	10 trees	Field Auditor must agree that the assessment is plausible.	A maximum of 20% of the measurements are allowed to be outside the target standard.
Sample or Crop Tree Height	10	For trees <2m tall: within 1cm or 1% whichever is higher For trees >2m tall: within 2%. Shrinking trees must have a health code/comment to explain the cause.	A maximum of 10% of the measurements are allowed to be outside the target standard.
Sample or Crop Tree Diameter	10	Within 0.2cm or 2% whichever is higher	A maximum of 10% of the measurements are allowed to be outside the target standard.
Sample/Crop Tree Crown Diameter	10	For trees <3m tall: within 5cm For trees >3m tall: within 10cm.	A maximum of 30% of the measurements are allowed to be outside the target standard.
Sample/Crop Tree Crown Length	10	For trees <2m tall: within 1cm or 1% whichever is higher For trees >2m tall: within 2%.	A maximum of 20% of the measurements are allowed to be outside the target standard.

Measurement / Maintenance Item	Sampling Intensity	Target Accuracy Standard*	Maximum Permitted Deviation †
Sample/Crop Tree Tree Species Code	10	All must be correct.	None
Sample/Crop Tree Planted / Natural	10	All must be correct.	None
Audit 3 of the 16 Regeneration Plots (Randomly Selected)			
Deciduous Modal Height	Check	For trees <1m tall: within 2cm For trees >1m tall: auditor's discretion	None
Species of Tallest Deciduous Tree	Check	Species correctly identified	None
Height of Tallest Deciduous Tree	Check	For trees <2m tall: within 1cm or 1%, whichever is greater For trees >2m tall: within 2%	None
Diameter of Tallest Deciduous Tree	Check	within 0.2cm	None
Shrub and Herb Percent Cover	Check for each category	Within 10%	None
Shrub and Herb Modal Heights	Check for each category	For plants <1m tall: within 2cm For plants >1m tall: auditor's discretion	None
Density of Coniferous Natural Regeneration (Ingress)	Count all stems within regeneration plot. Stratified by species	For trees >=30cm tall: If there are 10 or less trees– the exact number If there are more than 10 trees total – within 10% For trees <30cm tall: If there are 10 or less trees– with 2 stems If there are more than 10 trees total – within 20%	None
Density of Deciduous Competition Trees >= 30cm	Count all stems within regeneration plot. Stratified by species	For trees >=30cm tall: If there are 10 or less trees – the exact number If there are more than 10 trees total – within 10%	None
Top Height	For each species on regen plot	Protocol for top height tree selection and measurement as described in Section 2.9 of the manual are followed.	None

* - Deviation is calculated from true measurement: for example a tree height measurement of 2.50m (10% deviation allowed) would have an acceptable measurement tolerance of 2.25m to 2.75m.

† - "Maximum Permitted Deviation" is the maximum amount of field measurements that are permitted to not comply with the "target standard". The total observed deviation is calculated for each measurement/maintenance item on each plot by dividing the total number of QC measurements by the total number of QC samples taken (for that specific item).
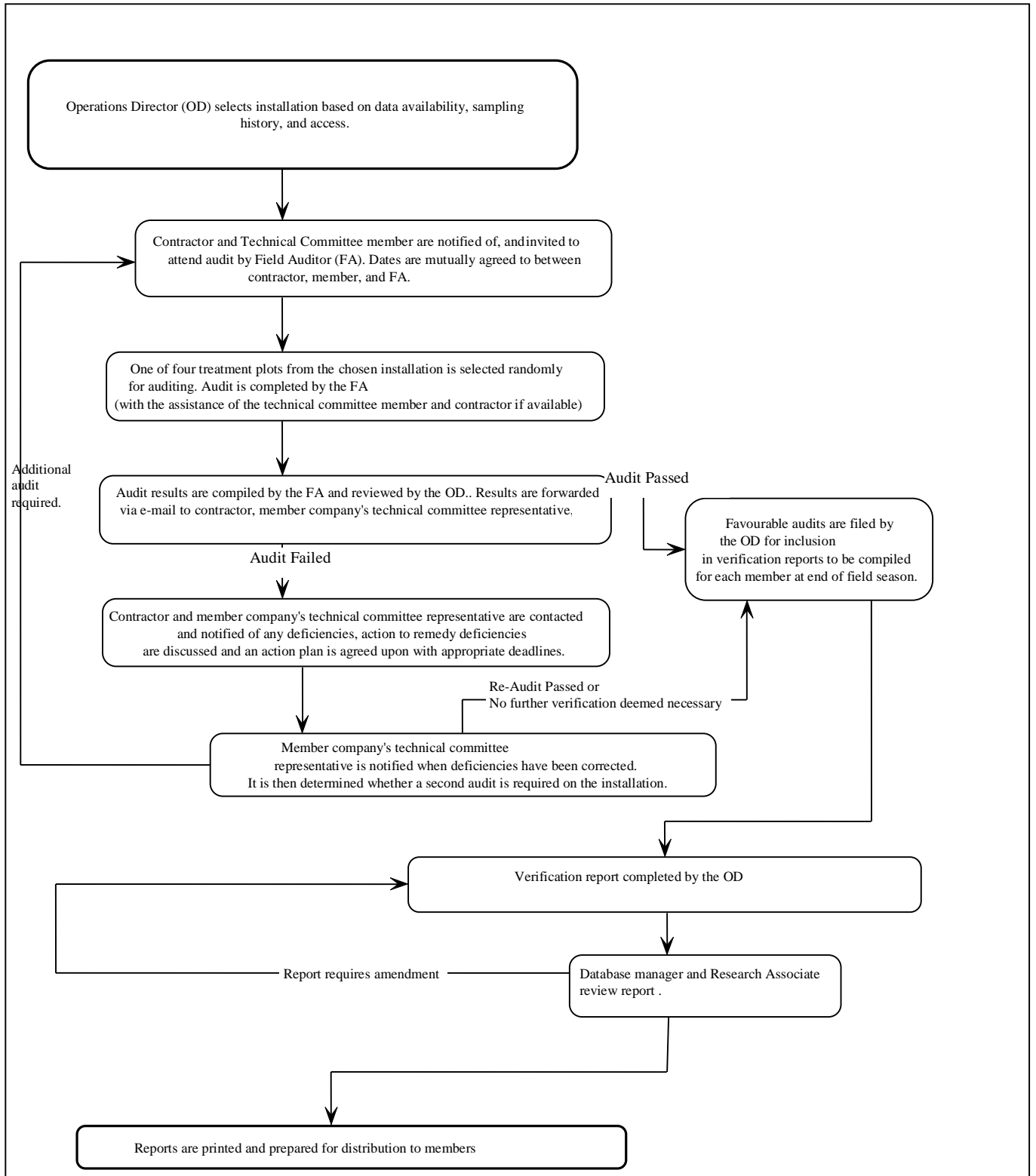
Figure 3. Field Audit Flow Chart