# **Harvesting on Mule Deer Winter Range under General Wildlife Measures for Shallow & Moderate Snowpack Zones:** Approach and Lessons Learned following a Second Harvest Entry after 30 Years

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a place of mind
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## Introduction

Timber harvesting can be conducted on mule deer winter range (MDWR) in such a way as to maintain or enhance the winter habitat for mule deer (*Odocoileus hemionus*) and generate timber values. During winter, mule deer rely upon Douglas-fir (*Pseudotsuga menzesii*) forests that have clumpy stand structure, contain large-diameter trees, and exhibit a fine-scale mosaic of non-uniform microsites that provide food and shelter (Armleder and Dawson, 1992). The clumpy arrangement of trees, pole sized and larger, provides crown closure and thereby intercepts snow. Shallow snow depths reduce the energy required by deer for mobility. Clumps of small-diameter stems also provide thermal and security cover. Additionally, crown abrasion among large trees generate the greatest potential amount of litterfall (Douglas-fir foliage and arboreal lichens), which is the primary winter forage for deer (Waterhouse *et al.*, 1991). Shrubs are preferred winter forage, but are available to deer only before they become covered by snow (Armleder and Dawson, 1992). As snow accumulates, deer move from one high snow interception micro-site area to the next, optimizing their needs for the three different cover types and adjacent forage (R.D. Dawson, pers. comm., May 2015).

In the 1980s, a clumpy single tree selection silvicultural system based on low-volume removal (20%) with long cutting cycles, e.g. 30 years minimum, was developed to integrate mule deer winter requirements with timber harvesting in the Cariboo Region of south-central British Columbia (Armleder *et al.*, 1985). In 1984, the first harvest entry utilizing this system was implemented by the Ministry of Forests Research Section, as an experimental project (EP 903) to evaluate the impact of harvesting on mule deer habitat use (Armleder and Thomson, 1984). Mule deer response to the first harvest entry was evaluated and was comparable to deer use in adjacent, untreated stands (Armleder *et al.*, 1998).

One of the three study areas is situated at the Knife Creek Block of the University of British Columbia Alex Fraser Research Forest (AFRF) and consists of three treated and untreated replicates in stands within the Interior Douglas-fir (IDF) biogeoclimatic zone that had little to no previous commercial harvesting. The AFRF was established in 1987—the inclusion of the Knife Creek Block was largely based on the presence of this long-term research project. The Knife Creek Block is managed under single-tree selection silvicultural system in accordance with the values and objectives established under the Cariboo-Chilcotin Land Use Plan (CCLUP) (Province of British Columbia, 1995).

Under the CCLUP, the Mule Deer Winter Range Strategy contains maps of Mule Deer Winter Ranges and provides plans for each winter range including habitat objectives[1]. The Knife Creek mule deer winter range is within the Shallow and Moderate Snowpack zone, and the trial blocks occur on a part of the winter range with a long-term objective of maintaining High Habitat Stand Structure. To achieve habitat objectives the *Management Plan for Shallow and Moderate Snowpack Zones*, which was first prepared in 2002 and further developed into Land Management Handbook 60 (Dawson *et al.*, 2007), was based upon the results from EP 903 (Armleder *et al*., 1998) and supported by silvicultural interpretations for management of Knife Creek MDWR developed by Day (1998). As of 2006, the Ministry of Environment established *General Wildlife Measures* (GWMs) for MDWRs in the Cariboo-Chilcotin by order of the *Government Actions Regulation* (GAR)[2].

[1] http://www.env.gov.bc.ca/cariboo/env_stewardship/ecosystems/mdwr_strat/mgmtplan.html
[2] http://www.env.gov.bc.ca/wld/documents/wha/Amendment_ShallowModerate_Feb07_Ord.pdf

The GWMs set out many prescriptive elements for the management of mule deer winter range. It is important that those elements be embedded into a systematic approach to stand management. The approach practised on the Alex Fraser Research Forest is based upon the following understandings of stand dynamics at the Knife Creek Block:

1. Disturbance history has changed in the last century, resulting in tremendous ingress of small trees and a reduction of growing space for large trees.
2. Overstocking has led to a general decline in tree vigour, resulting in a reduction of net merchantable growth and an increase in mortality, particularly in large old trees due to bark beetles, and slender supressed trees due to snow press.
3. Interior Douglas-fir is only moderately shade tolerant and requires a gap for successful regeneration and early growth. Small canopy openings alone provide insufficient light to maintain and grow regeneration unless the shade wall of the gap is thinned to allow sunlight to penetrate to the ground. Note that the sun is never directly overhead at this latitude therefore filtered light through the stem assemblage along the south side of gaps is critically important to regeneration; in Williams Lake, the maximum elevation of the sun is about 61° above the horizon at noon on the summer solstice[3].
4. Creation of gaps alone does little to increase growing space generally across the stand, as the extra growing space is quickly dominated by those trees standing immediately adjacent to the gap.

Clumpy single tree selection, as with the selection silvicultural system more generally, is intended to provide a continuous supply of large trees to provide both forage and snow interception as well as harvest opportunities. For this to occur over time, there needs to be a periodic recruitment of regeneration via the creation of canopy openings throughout the stand, as well as thinning of all size classes to release growing space so that the residual trees can grow and remain vigorous. Where competition for growing space is high (e.g. IDF stands) stagnation is likely to occur in the absence of management or regular, low severity fire. Such stands under high competition stress are also vulnerable to pests and disease. Thinning from below is thus a very important process that improves stand vigour and ultimately contributes to the likelihood that there will be healthy trees to provide mule deer winter range into the future. The premise that single tree selection combines the creation of canopy gaps with thinning from below is well supported in silviculture texts (e.g. Daniel et al. 1979, Matthews 1991, Nyland 1996, Smith et al. 1997).

In addition to achieving a recruitment objective, the shrub and tree regeneration that develops within the small canopy openings referred to in GWMs of the GAR Order is also intended to increase forage production and lead to enhanced security and thermal cover compared to stands composed mostly of larger stems. Thinning from below, as described in the GWMs, is not considered inherent to the single tree selection silvicultural system. It can be implemented on its own or in conjunction with the creation of small canopy openings in stands with a dense intermediate canopy layer. As both habitat and timber growth objectives must be balanced on winter ranges, higher residual basal areas are required than for stands without a habitat objective.

[3] http://www.sunearthtools.com/dp/tools/pos_sun.php

Basal area targets, as generated by BDq[4] values stipulated in the GWMs relating to thinning from below and clumpy single tree selection, are the ultimate control for harvesting decisions, i.e. target removals are from diameter classes with surplus basal area as derived from stand tables. The intent of applying BDq is to establish a target towards achieving a "balanced uneven-aged" condition where equal space is allocated to each diameter class—this condition is one that can be approached but is almost never perfectly attained in practice (British Columbia Ministry of Forests Forest Practices Branch, 2003). It may take several cutting cycles before a given stand approaches the long-term target stand structure. Land Management Handbook 13 (Armleder, 1986) recommends selecting existing individual clumps (small groups) for removal. Trees selected for harvest for gap creation need only be of merchantable size—removal of smaller diameter trees to create gaps can be as effective as removal of clumps of mature trees.

In 2014, the second harvest entry was scheduled at the Knife Creek site of EP 903 by AFRF to continue the original research project in collaboration Research staff at the Ministry of Forests, Lands and Natural Resource Operations. This is the first of the study areas to enter a second cutting cycle in accordance with the GWMs. The objectives of the second harvest entry are to demonstrate harvest planning and operational implementation according to the GWMs for high stand structure targets.

Given the long re-entry period (30 years) identified in the GWMs for clumpy single tree selection in shallow and moderate snow pack zones it was considered important to implement both the creation of gaps and thinning from below (as the blocks contained an over-abundance of stems in the intermediate diameter classes) at this entry for both habitat and silvicultural reasons. The limited harvest opportunity available at this second cutting cycle aimed to achieve regeneration of trees and shrubs, thin the residual stand so as to maintain vigourous stands that will continue to grow large trees important to mule deer, and maintain sufficient snow interception, and thermal and security cover.

In the short-term it is expected that there will be a loss of habitat value as the stands will have reduced snow interception capacity. However, there will be higher rooted forage production and in the longer term there will be recovery of crown closure on healthy, resilient trees. Growth and yield is also expected to improve as a result of ongoing implementation of the silvicultural strategy utilized at the Knife Creek Block.

The purpose of this report is to:

1. Document the pre-harvest stand conditions in 1984 and 2014
2. Describe the harvesting criteria based on small group removal and thinning from below
3. Interpret the GWMs as they relate to the project
4. Describe the mark-to-cut process
5. Describe the harvesting equipment and timing
6. Document the production costs and market value of the wood

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[4] B=Residual Basal Area, D=Maximum Diameter to be Retained, q=Structural Regulation across Diameter Classes. See https://www.for.gov.bc.ca/hfp/publications/00085/silvsystemshdbk-web.pdf for explanations of Basal Area and BDq.

## Study Area

The experimental cut blocks are situated on the Knife Creek block of the Alex Fraser Research Forest (AFRF), about 18 km south-east of Williams Lake, B.C. and within the Knife Creek Mule Deer Winter Range (Ungulate Winter Range Plan No. U-5-002, Unit No. dwl_50). The topography is gently rolling and interspersed with short ridges, steep slopes and gullies. Elevations range from 740 m – 860 m along aspects facing south to west. Block 1/CB 229[5] has complex topography with numerous short ridges and topographic breaks while Blocks 2/CB 222 and 3/CB 232 are more level. Each is within the Interior Douglas-fir biogeoclimatic zone (IDF), with Blocks 1/CB 229 and 2/CB 222 in the very dry, mild subzone (IDFxm), and Block 3/CB 232 within the Fraser variant of the dry, cool subzone (IDFdk3) (Steen and Coupe, 1997; Klinka *et al*., 2004). The dominant tree species is Douglas-fir with a minor component of trembling aspen (*Populus tremuloides*), paper birch (*Betula papyrifera)*, and lodgepole pine (*Pinus contorta*). Untreated control areas adjacent to each cut block have been maintained since 1984.

The original timber cruise plots from 1984 were re-measured in 2013 in all treatment and control units to provide pre-harvest stand condition estimates. Stand tables in which BDq was applied were created for the treatment units (Appendix 2: Stand Tables and Diameter Distribution by Cut Block). Diameter distribution using 5-cm diameter classes were graphed according to stems per hectare and basal area (BA) and plotted against the long-term target and prescribed post-harvest stand structures. Prescriptions for removal by diameter class were made based on the relative surplus or deficit of stems as compared to the long-term targets. In the diameter classes in which there was less BA than the target, more retention in smaller diameter classes was prescribed to make up the deficit over time. In classes that exceeded target levels, most of the surplus was prescribed for removal at this harvest entry.

All cut blocks had irregular, clumpy, multi-layered stand structures prior to the second harvest entry. Diameter distributions of stems per hectare typically followed the “reverse J” curve[6] indicative of uneven-aged stands with abundant, unmerchantable Douglas-fir regeneration and poles, small-diameter merchantable Douglas-fir (15-cm and 20-cm diameter classes) and a range of stems in larger diameter classes (though trees in the smallest merchantable size classes in Block 3/CB 232 were relatively scarce according to the 2013 cruise data). Abundance of large-diameter Douglas-fir (≥37.5 cm) varied by cut block. Planning units for each cut block are summarized in Table 1 and Appendix 1: Maps. Zones dominated by sub-merchantable diameter classes were delineated as “unmerchantable.” “Inoperable” zones include steep, rocky slopes. Varying degrees of Douglas-fir beetle (*Dendroctonus pseudotsugae*) salvage has occurred in all cut blocks and the control for Block 2/CB 222 by AFRF managers since 1987. Average stand structures for each cut block are summarized in Table 2 and described in Appendix 2: Stand Structure Tables and Charts.

[5] Nomenclature represents “EP 903/AFRF cut block #” values.
[6] Diameter distribution where more stems are found in the smaller diameter classes than in the larger classes. See Appendix 3.

**Table 1: Planning units by cut block (hectares) on MDWR treated with a second harvest entry (2014).**

| **Cut Block** | **Gross Area** | **Standards Units** | | | | | |
|---|---|---|---|---|---|---|---|
| | | **Wildlife Tree Patch** | **Non-productive** (permanent access, landings) | **Net Harvestable Area** | | | |
| | | | | **Silviculture Strategy:** creation of small canopy gaps as well as thinning from below | **No Work Zone** (wildlife/danger trees, dens) | **Unmerch -antable** | **Inoperable** (steep, rocky) |
| **Block 1/ CB 229** | 38.9 | 3.5 + dispersed | 2.1 | 24.7 | 0.2 | 2.3 | 6.1 |
| **Block 2/ CB 222** | 43.4 | 5.0 + dispersed | 2.7 | 31.6 | 0.3 | 3.8 | - |
| **Block 3/ CB 232** | 17.9 | Dispersed | 0.6 | 16.5 | 0.8 | - | - |

**Table 2: Timber cruise summaries of merchantable pre-harvest stand structure estimates (≥12.5 cm dbh) and prescribed and cruised post-harvest stand structure for cut blocks on MDWR treated with a second harvest entry (2014).**

| **Parameter** | **Block 1/CB 229** | | | | **Block 2/CB 222** | | | | **Block 3/CB 232** | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Pre-Harvest | *Target Residual | Prescr. Residual | Post-Harvest | Pre-Harvest | *Target Residual | Prescr. Residual | Post-Harvest | Pre-Harvest | *Target Residual | Prescr. Residual | Post-Harvest |
| **B** - Min. post-harvest residual BA ≥12.5 cm dbh ($m^2$/ha; ) | | 27 | | | | 27 | | | | 29 | | |
| **D** - Max. residual diameter class in target stand structure (cm) | | 65.0 | | | | 65.0 | | | | 70.0 | | |
| **q** – Diameter distribution constant | | 1.25 | | | | 1.25 | | | | 1.25 | | |
| **Merch. Volume** ($m^3$/ha) | 235 | | 177 | 212 | 282 | | 198 | 228 | 290 | | 204 | 205 |
| **BA** - Total Basal Area ($m^2$/ha) | 37.4 | 27 | 27 | 32.9 | 38.0 | 27 | 27.0 | 30.0 | 39.5 | 29 | 29.0 | 28.0 |
| **BA≥37.5 cm dbh** - Min. post-harvest residual BA ($m^2$/ha) | 12.9 | 15 | 13.1 | 12.6 | 17.2 | 15 | 15.1 | 15.8 | 23.0 | 16 | 18.9 | 20.5 |
| **BA>D** – Large tree reserve ($m^2$/ha) | 4.9 | 0-2.7 | 4.6 | 4.9 | 4.3 | 0-2.7 | 3.0 | 4.3 | 2.0 | 0-2.2 | 2.0 | 2.0 |

* Shallow and Moderate Snowpack MDWRs General Wildlife Measures

# Planning and Operations

## 1. The First Harvest Entry, 1984

The objective was to remove 20% of the volume across all merchantable diameter classes from each of the three cut blocks (Table 3) according to Armleder *et al.*, 1985. Faller selection was guided by a list of criteria with explanatory diagrams. An example of mark-to-leave trees was also marked to help guide the loggers across the balance of the cut blocks. Hand falling with line-skidder was the harvesting method. Contractor Carl Hennig, RPF, (Single Tree Holdings, Williams Lake) carried out the logging.

Sixteen percent volume was actually removed (Armleder *et al.*, 1998), mostly from access roads, skid trails, and landings (A. Vyse, unpublished data, Nov. 1984). Consequently, the skid trail density was very high in comparison to the GWMs. Little harvesting occurred between skid trails and no thinning from below was applied to the matrix (this practice was not part of the harvesting criteria in 1984). A substantial volume of pine remained on Block 3/CB 232 which was subsequently salvaged by AFRF during the mountain pine beetle epidemic prior to 2010.

**Table 3: Pre-harvest merchantable basal area and net volume (≥17.5 cm dbh) by cut block at first harvest entry, 1984. Note that values do not include the 15-cm diameter class as 2014 values do.**

| Cut Block | 1984 BA ($m^2$/ha) | 1984 Net Volume ($m^3$/ha) |
|---|---|---|
| Block 1/CB 229 n=(17) | 27 | 190 |
| Block 2/CB 222 (n=19) | 32 | 210 |
| Block 3/CB 232 (n=9) | 34 | 226 |

## 2. Second Harvest Entry Objectives

The harvesting objective is to create small canopy openings while maintaining and promoting a vigourous, multi-layered stand dominated by Douglas-fir in clumpy distribution at high crown closure (Dawson, *et al*., 2007). Small gap creation across the blocks involves the removal of all diameter classes of trees in which there is surplus. This is distinct from thinning from below which focuses on thinning of trees less than 37.5 cm dbh. Small openings benefit mule deer by increasing shrub forage production and natural regeneration of Douglas-fir that will provide security and thermal cover and be essential to mule deer winter survival in the future by promoting the clumpy stem distribution essential for snow interception in uneven-aged stands. The residual stand surrounding the openings will provide snow interception, thermal and security cover.

The creation of small canopy openings is balanced with some thinning from below. Thinning across diameter classes increases growing space for the remaining matrix by removing lower-vigour stems and stems with poor snow-interception capability. Isolated mature trees that are not functioning as part of a clump or providing effective snow interception can also be harvested (Armleder, 1986). Thinning provides increased growing space (light, moisture, etc.) to Douglas-fir regenerating within the openings and increases stand vigour. Increased vigour is associated with increased resilience to stressors in IDF forests, such as drought, fire and insect pests. Such resilience will be critical to ongoing maintenance of mule deer winter range habitat values into the future. Snow interception will improve in thinned stands over time as crowns of the residual trees expand.

## 3. Implementation of GWMs

The interpretations of the GWMs as they relate to this project are as follows:

### *Additional 20% basal area of Douglas-fir*

**GWM 1** stipulates an additional 20% basal area of Douglas-fir post-harvest, except where Douglas-fir exceeds 80% of the pre-harvest basal area as was the case here.

### *No construction of roads/landings within topographic buffers*

Under **GWM 2**, roads and landings would not have been possible to place in the topographically complex Block 1/CB 229 as it is entirely contained within a topographic buffer. However, we were able to re-use an existing road and landing that pre-dated the GWM.

### *Skid trails 30 m from ridges or topographic breaks; trails limited to 10% of the net harvested area*

An exemption from **GWM 3**, that specifies skid trails to be located at least 30 m from ridges or topographic breaks, was also requested for the topographically complex Block 1/CB 229. Rather than creating new skid trails, this exemption allowed us to re-use existing skid trails that in some cases did not satisfy the GWM. Skid trails were armoured with tree tops and branches from logs processed on site and that were left afterwards as woody debris (except below Big Meadow Road in Block 1/CB 229 where fuel management was also a management objective). Under **GWM 10**, the GAR order limits skid trails to 10% of the net harvested area in stands managed to high and moderate stand structure objectives. The skid trail density from 1984 exceeds this on two cut blocks (Table 4; see Figure 1 for an example). The 30-year harvest entry was to re-use existing trails (though not all of them were expected to be utilized). Because the trail network already existed, an exemption to this limitation in GWM 10 was requested.

**Table 4: Skid trail area and percent area, by cut block.**

| Cut Block | Area (ha) | NP / No Harvest (ha)[7] | Net Area (ha) | Skid Trail Total Length (km) | Skid Trail Area (ha)[8] | Skid Trail Area (%) |
|---|---|---|---|---|---|---|
| Block 1/CB 229 | 38.9 | 5.9 | 33.3 | 5.9 | 2.4 | 7 |
| Block 2/CB 222 | 43.4 | 7.7 | 35.7 | 16.8 | 6.6 | 18 |
| Block 3/CB 232 | 21.6 | 4.3 | 17.3 | 7.6 | 3.0 | 17 |
| **TOTAL** | **103.9** | **17.6** | **86.3** | **30.3** | **12.0** | **14** |

[7] No-harvest areas include WTP areas and reserves established to protect permanent sample plots previously established in the harvest area. NP areas are those areas non-productive due to permanent access structures (roads and landings).

[8] Skid trail area was estimated with the assumption that trails are 4 m wide on average.

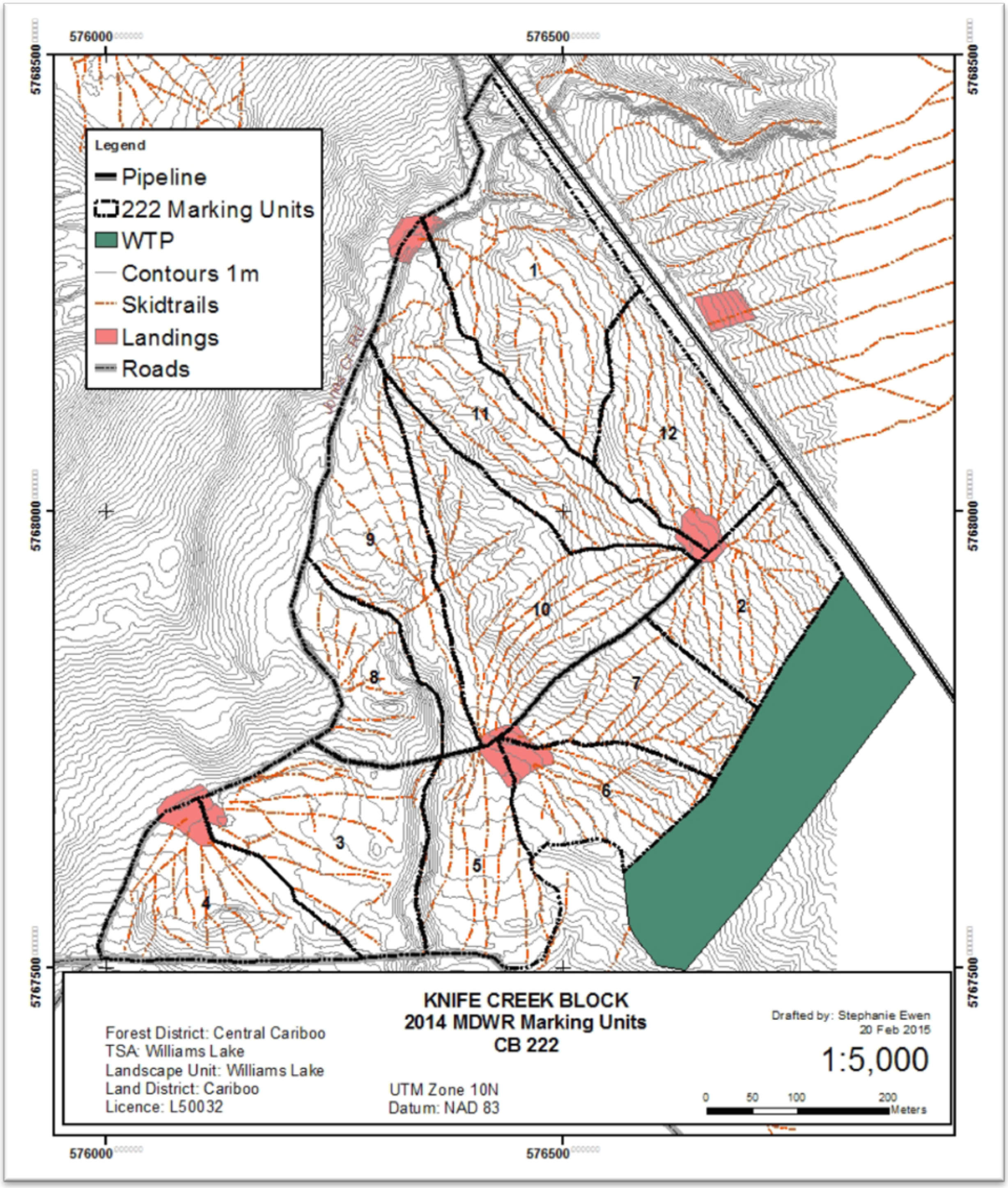


**Figure 1: Original 1984 skid trail layout and 2014 marking units for Block 2/CB 222.**

### *No construction of roads in Old Growth Management Areas*

**GWM 4** was not applicable in this project.

### *Protection of Douglas-fir regeneration, retention of Douglas-fir in juvenile spacing treatments, higher than average basal area within 30 m of ridge or topo break*

Protection of Douglas-fir regeneration as stipulated in **GWM 5** was accomplished by implementing directional falling during mechanical harvesting and re-using existing skid trails. Regarding ridges and topographic breaks in Block 1/CB 229 we found that several had poor stocking and did not support the minimum post-harvest basal area in the first place, especially on the warm aspects. When marking to cut, markers regularly conducted prism sweeps to ensure basal area targets were being maintained and marked only those trees under threat of imminent mortality or trees to be thinned from below.

No pre-commercial thinning (PCT) in existing advanced regeneration was conducted at this harvest entry, however doing so will further improve the development of structure important to mule deer winter range by selecting out poor-vigour specimens and increasing growing space for Douglas-fir regeneration exhibiting better form. Thermal and security cover for mule deer must also be maintained, however. Upon declaration of free growing one year post-harvest (2015), a stocking survey will be conducted and an application for funding support via British Columbia's Forests For Tomorrow program pursued if possible. PCT will not be required uniformly—cut blocks will be stratified according to areas that require it and those that do not.

### *Douglas-fir bark beetle sanitation*

The requirements of **GWM 6** were incorporated into the overall harvest planning and marking strategy for the three cutblocks. In early 2014, an active Douglas-fir beetle (*Dendroctonus pseudotsugae*) infestation was identified near the northern boundary of Block 1/CB 229 originating within the adjacent untreated control area, which is also an old-growth management area (OGMA). MCH (anti-aggregation pheromone) was applied to the infestation centre and 15 trap trees were felled within the treatment area in an attempt to drive the beetles out of the untreated control/OGMA and reduce the overall risk of further loss of large-diameter Douglas-fir. Removal of the trap trees and sanitation of all green-attack trees within the cut block was conducted at the time of harvest. In keeping with being an untreated control area, sanitation did not occur within the OGMA. Likewise, five trap trees were felled at the site of a small lightning-strike fire from 2012 along the eastern-most ridge of Block 1/CB 229 where another bark beetle infestation was active. To compensate for the 11 stems lost to spill-over green-attack at trap tree sites, the approximate equivalent basal area of stems that would otherwise have been marked to cut were retained in the immediate vicinity of the infestations. Other scattered green attack was marked to cut as part of the marking process.

### *Mixed-species stands*

All stands were dominated by Douglas-fir and would not be considered to be "mixed species" so the criteria regarding diameter classes <37.5 cm dbh in **GMW 7** were non-applicable. Rather, post-harvest basal area retention was based on stand structure tables implementing BDq values listed in Table 2. **GWM 7** also stipulates maintenance and recruitment of snags. Wildlife Tree Patches (WTP) were established in Block 1/CB 229 and Block 2/CB 222 and scattered individual wildlife trees were assessed for retention across all blocks (Table 1). Due to the small area of Block 3/CB 232 and the fact it is surrounded on two sides by an Old Growth Management Area, no additional WTP was created there.

### Wildlife and Danger Trees

There is a risk of overcutting dead standing trees even using wildlife and danger tree (WDT) assessment methodology. Assessors should be very experienced with evaluating veteran Douglas-fir (Fd) growing in MDWR. Safe trees could possibly be interpreted as being dangerous if using the field cards for decision-making alone. For example, evidence of structural weakness is required to classify dead limbs or tops as being hazardous and this definition includes, stem scars and breakage. In the IDF, old fire scars and broken branches are very common among old Fd. Since doing a detailed assessment of each old tree is time and cost prohibitive, inexperienced assessors might err on the side of caution and mark them as dangerous, even though they may actually not be dangerous. Likewise, the small conk fungus that grows out of the exit holes of Douglas-fir beetle (*Cryptoporus volvatus*) and is a sapwood fungus would default a perfectly sound tree into the dangerous category if the assessor did not know that that particular conk is not evidence of advanced heartrot. Of course, some of the dead standing will be dangerous—in this project they tended to be in Tree Class 5 and greater and exhibited presence of carpenter ants or advanced decay. The most dangerous trees in the study blocks were in fact the <20 cm diameter class stems that were weakly hung up or so rotten they were about to collapse with the slightest nudge. Marking is the perfect time to identify and pinpoint those dangerous stems, even if the marker is not a certified WDT assessor. A certified assessor can follow up using GPS coordinates.

### *Removal of mountain pine beetle-affected stems will follow GWM 7*

The presence of mountain pine beetle-killed pine was negligible so **GWM 8** did not apply.

### *Thinning from below*

**GWM 9** primarily focusses on stems less than 37.5 cm dbh (with harvest or damage to Douglas-fir >37.5 cm not exceeding 10% of pre-harvest basal area) and to 25% of the pre-harvest merchantable basal area. The first harvest entry in 1984 did not apply thinning from below with the intent to improve stand vigour. This cutting cycle is the first to fully implement the combination of small canopy openings with thinning from below in these stands. Thinning was implemented via marking-to-cut (see Section 4 below) and targeted stems from diameter classes with surplus basal area as derived from stand structure tables (see Appendix 2: Stand Structure Tables and Charts). The selection of which trees were cut will affect stand vigour into the future.

Within the study blocks there were sections, especially in Block 1/CB 229, dominated by trees <37.5 cm, e.g. areas that had previously undergone selective logging in the 1950s, or were stagnating due to a lack of natural disturbance. Thinning from below in those uniform areas at this harvest entry will function as a preparatory cut to focus growth on the best specimens over the next cutting cycle (Figure 2). Gaps can be introduced in the next entry or the following one.

Thinning from below *within clumps* in the short-term will reduce snow interception and improve tree growth when retention favours Douglas-fir with relatively deep, wide crowns. In clumps consisting of intermediate or small diameter stems, inter-tree distance can be more intensively managed to achieve both good tree form and effective clump arrangement, and over time snow interception will improve. Keep in mind that naturally occurring mature clumps typically have inter-tree distances from 2 to 5 m. The sweep and lean that is prevalent in these stands means that interlocking crowns within a clump may be standing on trees that are widely spaced when looking at the rooting locations. The post-thinning condition should be such that the crowns of intermediate trees within a clump are almost touching each other. By the subsequent harvest entry, they should be touching and functioning at intercepting snow to reduce snow depths and providing litterfall for deer forage. It is very important for habitat purposes to manage for these values in the near-term, i.e. there should be some crown contact within clumps, even at expense to tree form and wood quality. Further thinning in a given clump can be done at the next entry if required. Thermal and security cover also needs to be maintained in microsites between cutting cycles. This approach was taken as necessary across the study blocks as well as in the north-west portion of Block 1/CB 229 that had been pre-commercially thinned using clumpy spacing (Armleder, 1999), in the mid-1990s.

Thinning within mature clumps with interlocking crowns is unlikely to improve tree form or wood quality in the remainder of the clump, and would reduce the snow-interception function of the clump. That said, stems with poor crowns may be selected for removal from the edges of clumps if falling damage to the residuals can be avoided.

**Figure 2: Thinning from below, Block 2/CB 222.**

### *Creation of small canopy gaps, clumpy single-tree selection approach*

**GWM 10** specifies that clumps are to contain four to 10 or more mature trees with interlocking crowns. Openings can range in diameter from 0.3 to 1 times the average height of adjacent mature trees and should average half that height. Target BDq values are listed by cut block in Table 2. The q value of 1.25 was selected for these sites based on Day (1997). For these particular stands, gap diameters were permitted to range from 9-30 m with an average of 15 m (Figure 3). The trees removed from gaps fell within the diameter classes in which there was surplus. There is no specific guidance in the GWM as to gap density. However, given the expected average gap size (15 m diameter) and the target stand structures stipulated by values in Table 2 and using BDq arithmetic, Ken Day, Manager AFRF determined that for these stands there should be four small canopy openings per hectare. It is important to not overcut gaps so as to ensure sufficient mature tree canopy development over time when applying the clumpy single-tree selection silvicultural system. The placement of small canopy openings in this study was focussed on clumps of trees in diameter classes that were over-represented and that would generate revenue (e.g. 20-35 cm classes).

**Figure 3: Examples of small canopy openings, ground and crown views, Block 3/CB 232.**

### Minimum Post-harvest Residual Basal Area, Stems ≥37.5 cm dbh

The GAR order specifies a minimum post-harvest residual basal area. As of the 2013 timber cruise, the BA of stems ≥37.5 cm dbh in Block 1/CB229 was 13.1 $m^2$/ha (Table 2), which was less than the minimum allowable post-harvest BA of 15 $m^2$/ha. The marking tally does indicate that 0.2 $m^2$/ha was marked for removal in diameter classes ≥37.5 cm (Table 5). These trees would have been selected due to bark beetle infestation or safety reasons. The prescription for trees ≥37.5 cm in the other blocks appear undercut as fewer of those stems were actually present within the small groups marked to cut than the cruise indicated were available.

### Large Tree Reserve

The GAR order recommends a range of retention of large trees greater in diameter than recommended D values but does not provide guidance on how to make that decision. In Block 2/CB 222 and Block 3/CB232 where the basal area ≥37.5 cm dbh far exceeded the post-harvest minimums and there was considerable basal area greater than D (65 cm and 70 cm, respectively), at least 75% were prescribed for retention for the purpose of stand structure diversity (Table 2).

**Table 5: Cruise-based and marking tally-based basal area values ($m^2$/ha) prescribed for removal on the net harvestable cutblock areas**

| Parameter | Block 1/CB 229 | | | Block 2/CB 222 | | | Block 3/CB 232 | | |
|---|---|---|---|---|---|---|---|---|---|
| | **Prescribed Removal** (Cruise) | **Prescribed Removal** (Marking Tally) | **Actual Post-Harvest Removal** (Cruise) | **Prescribed Removal** (Cruise) | **Prescribed Removal** (Marking Tally) | **Actual Post-Harvest Removal** (Cruise) | **Prescribed Removal** (Cruise) | **Prescribed Removal** (Marking Tally) | **Actual Post-Harvest Removal** (Cruise) |
| **DBH Class** | | | | | | | | | |
| 15 | 3.1 | 1.10 | 1.4 | 2.5 | 1.9 | 2.0 | 0.0 | 1.1 | 0.0 |
| 20 | 3.3 | 1.26 | 1.4 | 1.7 | 1.5 | 2.0 | 0.0 | 1.1 | 0.5 |
| 25 | 1.5 | 0.91 | 0.9 | 2.1 | 0.9 | 1.1 | 0.6 | 0.9 | 2.0 |
| 30 | 2.0 | 0.61 | 0.6 | 2.0 | 0.6 | 0.9 | 1.6 | 0.8 | 3.5 |
| 35 | 0.7 | 0.35 | 0.0 | 0.6 | 0.3 | 0.7 | 4.3 | 0.6 | 3.0 |
| 40 | 0.0 | 0.09 | 0.0 | 0.0 | 0.1 | 0.4 | 0.0 | 0.4 | 0.0 |
| 45 | 0.0 | 0.02 | 0.0 | 0.1 | 0.1 | 0.0 | 5.5 | 0.4 | 1.5 |
| 50 | 0.0 | 0.02 | 0.0 | 0.1 | 0.1 | 0.2 | 0.6 | 0.3 | 0.0 |
| 55 | 0.1 | 0.00 | 0.3 | 0.3 | 0.0 | 0.7 | 0.0 | 0.2 | 0.5 |
| 60 | 0.1 | 0.01 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.1 | 0.5 |
| 65 | 0.2 | 0.01 | 0.0 | 0.2 | 0.0 | 0.0 | 0.4 | 0.1 | 0.0 |
| 70 | 0.1 | 0.00 | 0.0 | 0.6 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 |
| 75 | 0.1 | 0.01 | 0.0 | 0.2 | 0.1 | 0.0 | 0.2 | 0.0 | 0.0 |
| 80 | 0.0 | 0.00 | 0.0 | 0.2 | 0.1 | 0.2 | 0.0 | 0.0 | 0.0 |
| 85 | 0.0 | 0.02 | 0.0 | 0.2 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 90 | 0.0 | 0.00 | 0.0 | 0.0 | 0.1 | 0.0 | 0.1 | 0.0 | 0.0 |
| **Basal Area** ($m^2$/ha) | 12.2 | 4.4 | 4.5 | 11.0 | 6.0 | 8.0 | 10.5 | 6.0 | 12.0 |
| **BA≥37.5 cm dbh** ($m^2$/ha) | 0 | 0.2 | 0.3 | 2.1 | 0.8 | 1.4 | 4.1 | 1.5 | 2.5 |
| **BA>D** ($m^2$/ha) | 0 | 0 | 0 | 1.3 | 0.5 | 0.0 | 2.0 | 0 | 2.0 |
| **% Total BA Removal in Second Entry** | 31 | 11 | 12 | 28 | 16 | 22 | 27 | 15 | 21 |

### *Apply IDFxm/xw targets for portions of particular units within IDFdk when applying GWM 10*

**GWM 11** did not apply to the blocks in this project.

### *Practices in GWM 10 are limited to specific winter ranges until 2026; 80% of pre-harvest merchantable Douglas-fir basal area to be retained after GWM 10 harvesting until 2026*

The research design established in 1984 (Armleder *et al.* 1998) studied the effectiveness of Clumpy Single-tree Selection with 30-year cutting cycles. Subsequent MDWR planning defined the area as High Habitat Stand Structure Objectives. The General Wildlife Measures later imposed restrictions affecting the trial: **GWM 12** restricted Clumpy Single-tree Selection as described under GWM 10 to Moderate and Low Habitat Stand Structure Classes in Zone 1 until after 2026 so as to provide recovery time for winter ranges having extensive harvest histories; and **GWM 13** constrains the harvest to retain 80% of the pre-harvest basal area. To maintain the integrity of the research design, exemptions for GWM 12 and 13 were requested and granted for the three cut blocks.

***For Future Consideration:*** *The dichotomy between silviculture texts and the GAR Order regarding the relationship of thinning from below to the practice of single tree selection may potentially cause confusion during interpretation of the GWMs. It may be assumed that thinning is inherent to the silvicultural system, however, GWM 9 and 10 are considered discrete activities in the Order and must be addressed as such.*

***For Future Consideration:*** *When combining GWM 9 with GWM 10 in cut blocks with very high numbers of the smallest merchantable diameter classes, considerable effort and focus is required to decide upon the best spatial arrangement for retention. The need to complete thinning to improve vigour in the existing stands during the first couple of cutting cycles can easily dominate the marking process. Managers would benefit from further guidance from government regarding the balance between thinning from below and how to determine the optimal number of small openings per hectare at a given stand.*

***For Future Consideration:*** *While for silvicultural reasons (improved stand vigour) it is valuable to balance out the total basal area in small diameter classes, operationally, these stems are expensive both to mark and to harvest. Prescriptions might favour reducing these classes over the first two cutting cycles to spread the cost of this silvicultural improvement.*

***For Future Consideration:*** *There is a research opportunity in identifying the point at which thinning from within clumps ceases to affect timber quality of retained stems.*

## 4. Marking

Marking seems essential to the operationally viable implementation of the clumpy single-tree selection approach if using a mechanized harvesting system, as was done in this study (see Section 5 below). Comparing the cost of a person on foot to an operator sitting in the seat of a machine, it is likely less expensive to mark by hand beforehand than to employ faller-selection at the time of harvesting. Also, the decision to select individual trees for harvest requires crown analysis. Tree crowns are not clearly visible from the seat of a machine. An excellent resource about marking options and procedures can be found in Section of 5.1 of "Silvicultural Systems Handbook for British Columbia" (British Columbia Ministry of Forests Forest Practices Branch, 2003).

***For Future Consideration:*** *Following harvesting on these cut blocks, the logging contractor strongly supported the conclusion that having pre-marked cut blocks was critical to the harvest operations being viable.*

***For Future Consideration****: Fallers selection might be more viable in simpler prescriptions where the cutting focusses exclusively on thinning from below, when operators have gained experience and clearly understand the prescription objectives.*

### a) Creating Marking Formulas

Marking formulas can be established from the prescription. The quantity of basal area that should be removed from each diameter class can be converted to percent removal by diameter class. For example, if the prescription is to remove 20% of stems in the 35 cm diameter class, you can mark one out of every five on average. Periodic prism sweeps should be performed to confirm retention of minimum basal area targets.

### b) Marking Units and Tallies

The marking process is further facilitated by establishing spatial marking units (Figure 1). Within each marking unit, trees marked to cut are tallied by diameter class (box or dot tally) to help track the progress of prescription implementation on the ground and balance the cut across cut blocks. This is a necessary step because estimations of stand structure based on cruise plots represent average conditions, however, IDF stands are inherently variable and diameter classes may not be uniformly distributed across the cut block. A marking tally provides a more accurate representation of prescribed basal area removal than relying on cruise plot estimates alone because the actual trees being marked to cut are enumerated across the entire cut block areas (Table 5). The sometimes-large differences between the cruise-based prescription values and those of the marking tally exemplify how the cruise sampling technique does not sample sufficient plots to provide averages that truly reflect conditions in these highly variable IDF stands.

By subdividing cut blocks into discrete marking units, those discovered to be lacking in certain diameter classes can be compensated for in other units in which there is surplus (minimum average post-harvest basal areas are based on the net harvested area). In this study, the unmerchantable sections of Block 1/CB 229 and Block 2/CB 222 were not predictable based on the estimated average stand structure generated from cruise plot data. Upon tallying by marking unit, the reality that some portions of those blocks were not worth entering at this harvest entry became apparent.

An additional type of quick tally that provides feedback on prescription and GAR order implementation as cut blocks are marked is to walk transects (in this case, the established mule deer track transect lines) and do prism sweeps every 50 m. Collect data for total pre-harvest basal area as well as for retention trees only at each plot. In doing so, valuable pre-harvest basal area data, additional to the cruise data, can be collected across these variable stands, and a gauge established for how well the prescription is being translated at the stand level.

### c) Marking Criteria

The decision to mark-to-cut in this study was based on the fact there were more trees being retained than removed. Stems were marked using a row of glo-orange paint dots around the bole above eye-height. A row of blue dots was used in instances when particular trees needed to be marked-to-leave. A consistent paint marking colour scheme and symbology is helpful in clearly communicating marking decisions (Day 1998). Trees were marked according to the following criteria.

**Marking Criteria for Thinning From Below:**

In areas that have the merchantable basal area available to remove based on cruise data and diameter distribution targets, mark trees to cut that *:

- Are suppressed / over-topped by adjacent trees
- Have poor stem form / wood quality / susceptible to snow-snap (high slenderness ratio)
- Have damage / scars / disease or decay indicators
- Have poor crown form / growth potential
- Are not expected to survive until next entry period
- Are adjacent to (i.e. touching) a tree that is already marked to cut, making post-harvest beetle infestation likely
- Will not reduce mature clump groupings below 4 stems/clump

*Retain considerable Douglas-fir along ridges, topographic breaks and warm aspects.

For large trees in diameter classes available to be cut or with diameters >D, you may mark to cut if:

- The tree has a small crown / poor snow interception capability
- You are not eliminating the snow interception functionality of the group a tree is a part of
- The tree is isolated and not functioning as part of a clump or providing effective snow interception
- The tree has a live brood of bark beetles expected to emerge
- The tree is recently dead / expected to die before the next entry

## 5. Harvest Methods and Timing

The harvesting contractor, Peter Nilsson (Nilsson Select Contracting Ltd. from Williams Lake), had considerable experience with partial cutting. A harvester (John Deere 1270 D) and forwarder (John Deere 1410 D) were employed (Figure 4). The intention was to harvest during summer 2014, due to dry soil conditions and minimize crown damage during falling. However, due to various delays getting started and slow production, logging went from September through December.

On Block 2/CB222 where BDq calculations indicated there was an over-supply of stems > 65 cm dbh, some stems were hand-felled and grapple-skidded to a landing where they were manually bucked.

***For Future Consideration:*** *Notes from a forest entomologist regarding the 1984 entry recommend logging as long before Douglas-fir beetle flight as possible , i.e. summer to reduce the probability of infestation (L.H. McMullen, pers. comm.).*

*Fall and early winter logging attracted mule deer due to the increased forage the harvest produced (increased mature Douglas-fir foliage and arboreal lichens on the ground), but the deer did not appear to be disturbed by* *the machines. However, as access roads had to be kept open for the duration of operations, the risk of human disturbance was increased.*

*Fall harvesting coincided with hunting season and may have facilitated hunting success due to deer being attracted to the temporarily increased deer forage. There were concerns from neighbours in a residential area adjacent to one of the experimental cut blocks that irresponsible hunters were shooting too close to residences.*


**Figure 4: Harvester and forwarder utilized on AFRF MDWR.**

## 6. Productivity

Logs were processed in the bush and piled along skid trails in small sorts. The forwarder typically did two return passes per skid trail. Products were decked at roadside for loading, including saw logs, veneer logs, and pulp fibre for oriented strand board (Figure 5).

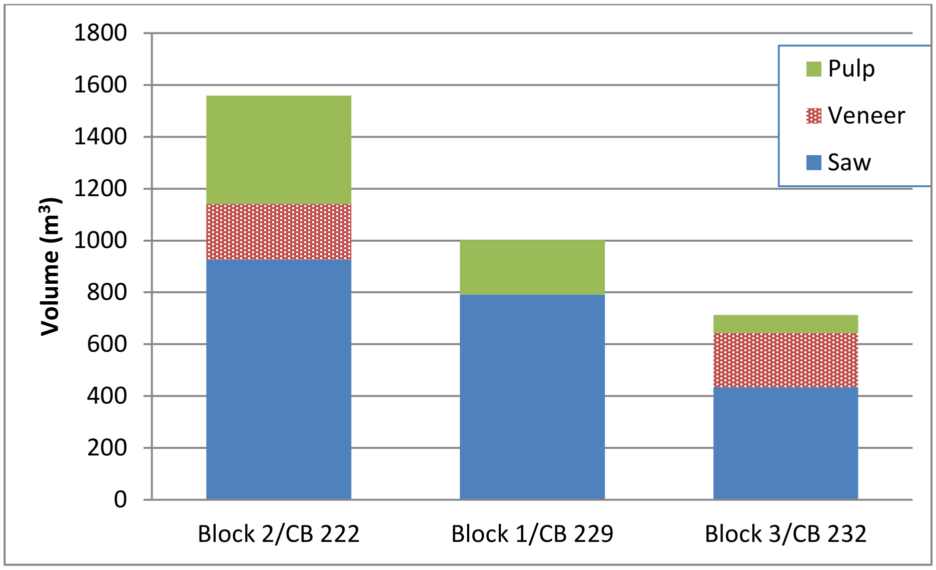


**Figure 5: Product volumes by cut block.**

Revenues covered the cost of marking the stands and production of log products (note $0.25/m$^3$ stumpage) (Figure 6). Phase costs for pre-harvest marking and log production are summarized by cut block in Figure 7 and by mean percentage in Figure 8.

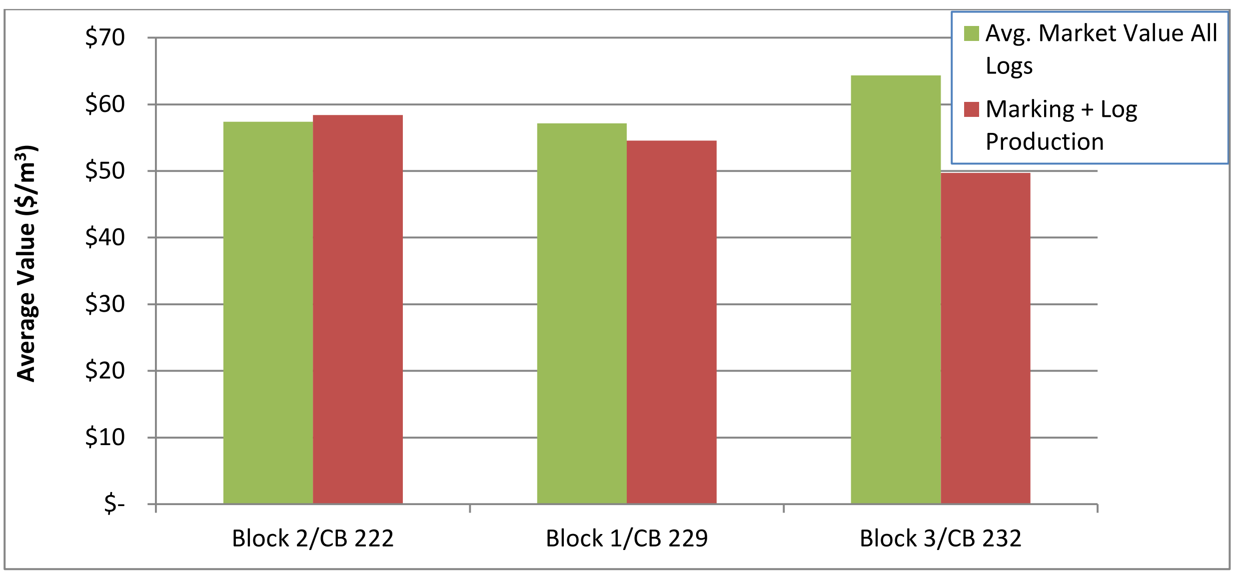


**Figure 6: Average market log value by volume compared to marking and log production cost by volume, by cut block.**

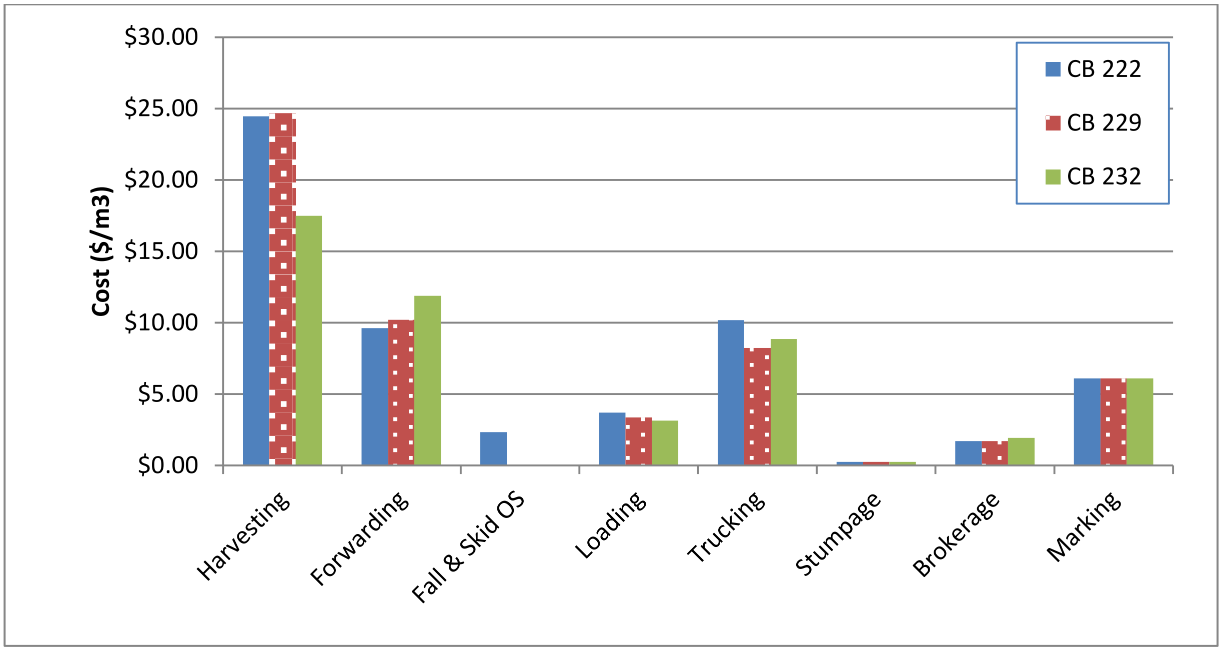


**Figure 7: Phase costs per cubic metre for marking and log production by cut block. OS=oversized (dbh>65 cm).**

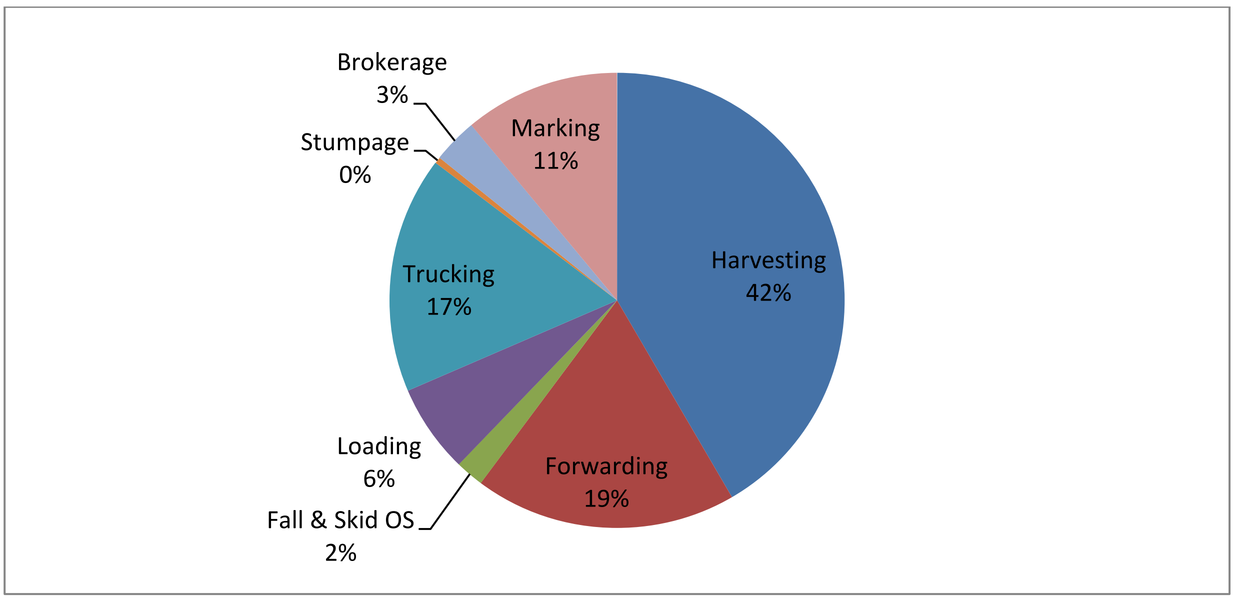


**Figure 8: Mean percentage costs for marking and log production phases. OS=oversized (dbh>65 cm).**

***For Future Consideration:*** *The harvester and forwarder combination was very successful at maintaining narrow skid trails, thinning in between skid trails, and keeping stem damage in the retained matrix to a minimum. Skilled operators are imperative.*

*While revenues did cover the costs of marking as well as log production, they did not cover planning, layout and supervision costs. Marking costs can be expected to go down with subsequent entries as a more balanced* *uneven-aged diameter distribution is attained. Also, production costs should fall as fewer small diameter stems require handling. To spread out the cost of handling small stems, consider setting the prescription to reduce the smallest diameter classes to optimal target basal areas over two cutting cycles rather than aiming to complete most of it during the first. Though marking and harvesting these small stems is relatively expensive, the resultant release of growing space and resources to the retained matrix benefits both timber and mule deer winter range values.*

*Costs are expected to be lower in moderate and low habitat stand structure classes than those encountered in stands being managed towards high stand structure objectives such as these, if stand structure and density are comparable.*

## Conclusion

Clumpy single-tree selection including thinning from below in the three cut blocks being managed towards High Habitat Stand Structure objectives in this study proved to be operationally feasible, but financially marginal, in terms of both applying the GAR order (with some exceptions for conditions created prior to its establishment) and from a harvesting standpoint. Considerable improvements to growth and yield, as well as mule deer winter range conditions are expected as a result of ongoing implementation of this silvicultural system.

## Acknowledgements

The authors of this report wish to express appreciation for the input and constructive recommendations contributed throughout the development of this report by Mule Deer Winter Range Committee members, Michaela Waterhouse, Rick Dawson, and Becky Bings. Our thanks are also extended to the technicians who collected data in the field.

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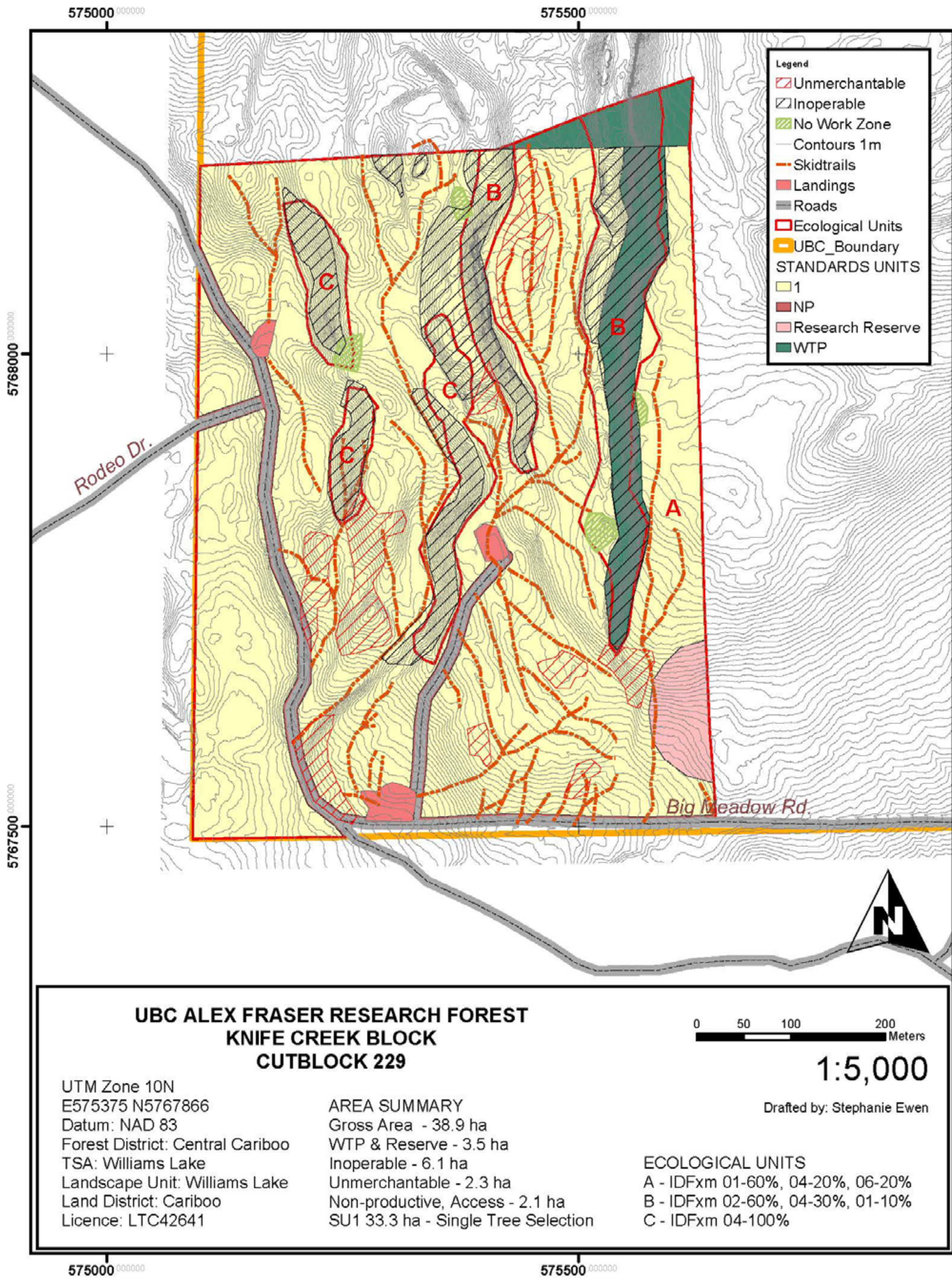
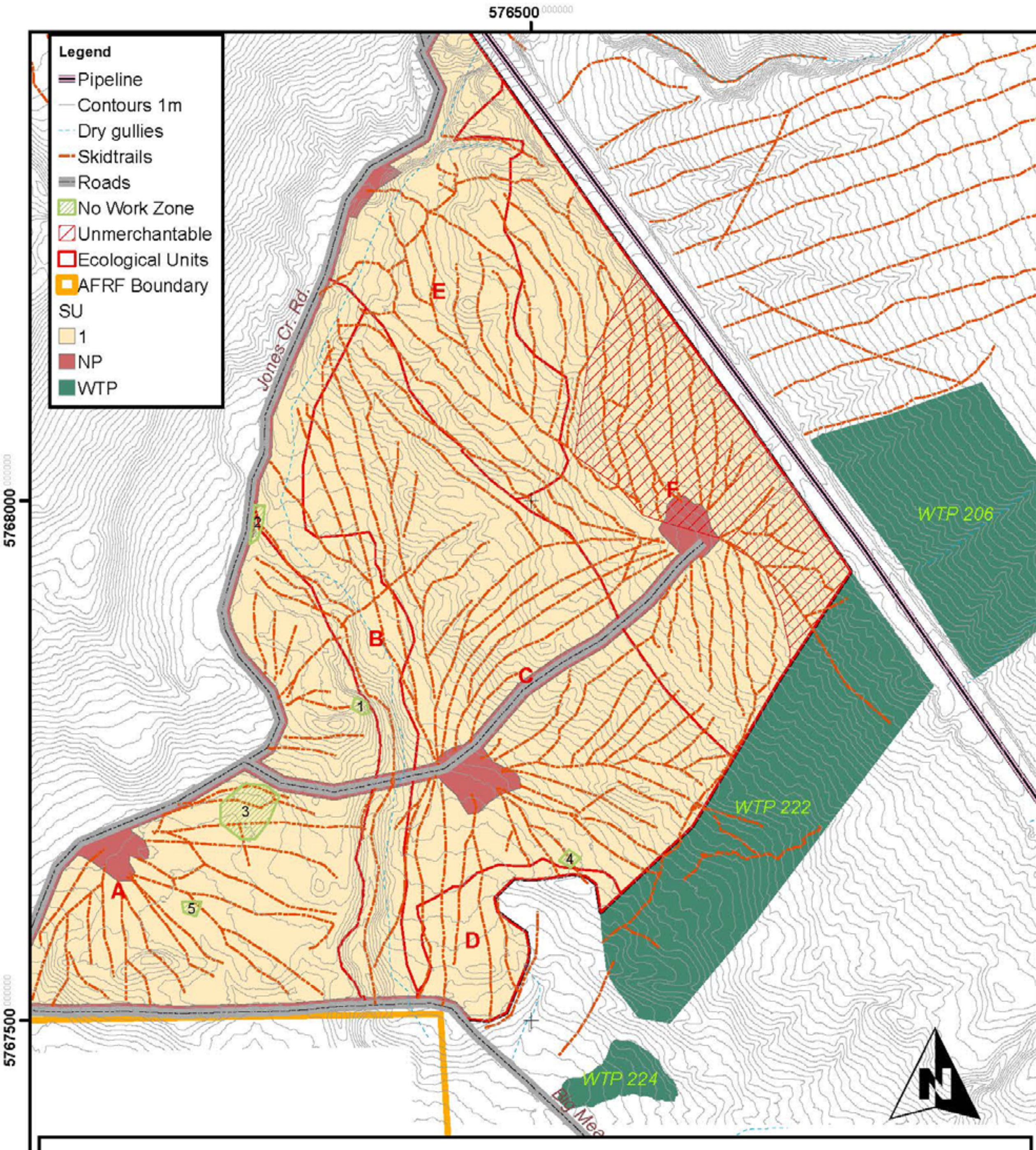
# Appendix 1: Maps



575000
575500
5768000
5767500
Legend
Unmerchantable
Inoperable
No Work Zone
Contours 1m
Skidtrails
Landings
Roads
Ecological Units
UBC_Boundary
STANDARDS UNITS
1
NP
Research Reserve
WTP
A
B
C
Rodeo Dr.
Big Meadow Rd.
N
UBC ALEX FRASER RESEARCH FOREST
KNIFE CREEK BLOCK
CUTBLOCK 229
0 50 100 200 Meters
1:5,000
UTM Zone 10N
E575375 N5767866
Datum: NAD 83
Forest District: Central Cariboo
TSA: Williams Lake
Landscape Unit: Williams Lake
Land District: Cariboo
Licence: LTC42641
AREA SUMMARY
Gross Area - 38.9 ha
WTP & Reserve - 3.5 ha
Inoperable - 6.1 ha
Unmerchantable - 2.3 ha
Non-productive, Access - 2.1 ha
SU1 33.3 ha - Single Tree Selection
Drafted by: Stephanie Ewen
ECOLOGICAL UNITS
A - IDFxm 01-60%, 04-20%, 06-20%
B - IDFxm 02-60%, 04-30%, 01-10%
C - IDFxm 04-100%




**UBC ALEX FRASER RESEARCH FOREST**
**KNIFE CREEK BLOCK**
**CUTBLOCK 222**

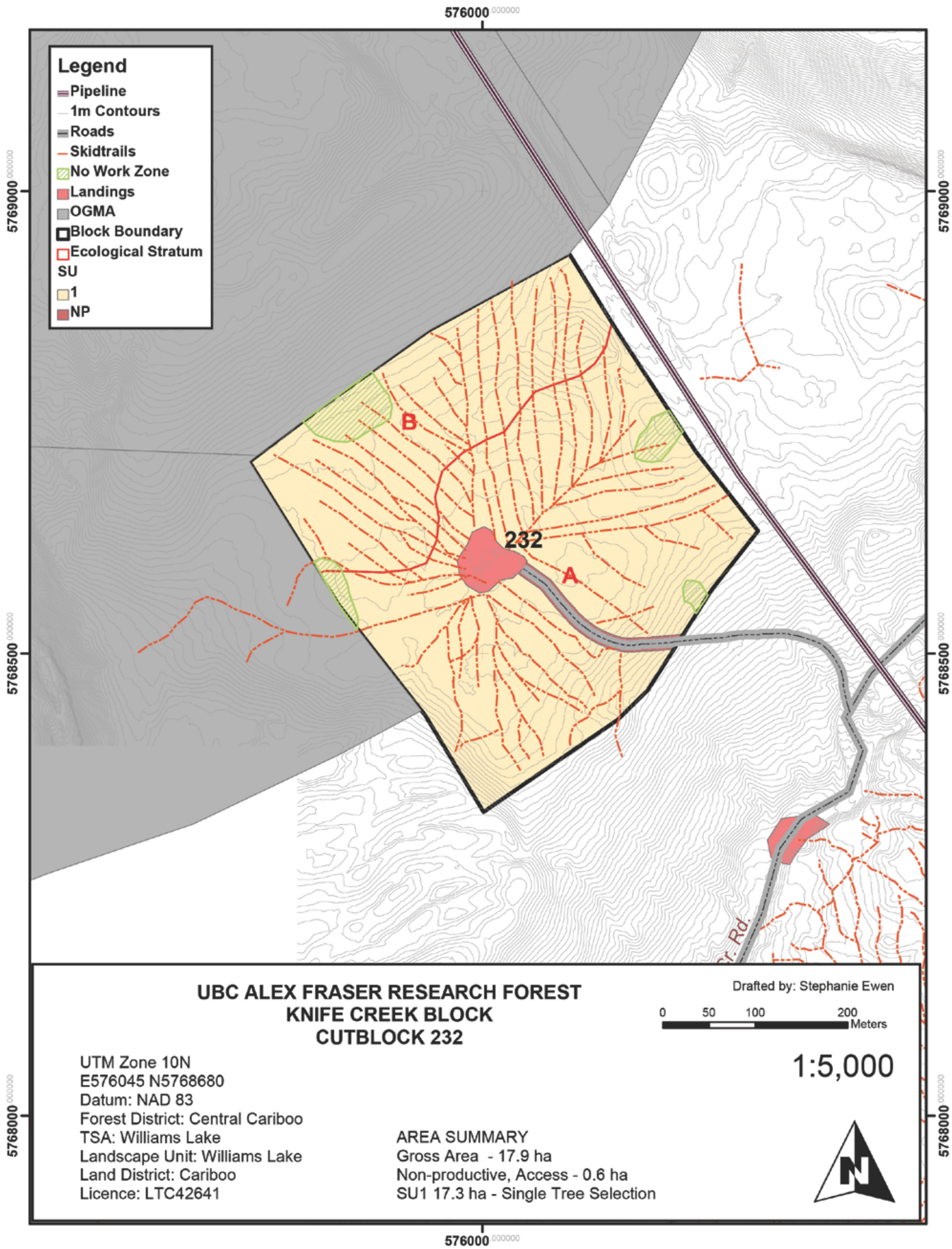
1:5,000

UTM Zone 10N
E576452 N5767956
Datum: NAD 83
Forest District: Central Cariboo
TSA: Williams Lake
Landscape Unit: Williams Lake
Land District: Cariboo
Licence: LTC42641

AREA SUMMARY
Gross Area - 43.4 ha
WTP 5.0 ha
Unmerchantable 3.8 ha
Non-productive, Access - 2.7 ha
SU1 35.7 ha - Single Tree Selection

ECOLOGICAL UNIT
A - IDFxm 07-60%, 01-40%
B - IDFxm 07-100%
C - IDFxm 01-80%, 07-20%
D - IDFxm 08-60%, 07-20%, 01-20%
E - IDFxm TRANZ 07-100%
F - IDFxm TRANZ 01-90%, 07-10%

576500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5768500
5768000
Legend
Pipeline
1m Contours
Roads
Skidtrails
No Work Zone
Landings
OGMA
Block Boundary
Ecological Stratum
SU
1
NP
B
232
A
UBC ALEX FRASER RESEARCH FOREST
KNIFE CREEK BLOCK
CUTBLOCK 232
Drafted by: Stephanie Ewen
0 50 100 200 Meters
1:5,000
UTM Zone 10N
E576045 N5768680
Datum: NAD 83
Forest District: Central Cariboo
TSA: Williams Lake
Landscape Unit: Williams Lake
Land District: Cariboo
Licence: LTC42641
AREA SUMMARY
Gross Area - 17.9 ha
Non-productive, Access - 0.6 ha
SU1 17.3 ha - Single Tree Selection
N

## Appendix 2: Stand Structure Tables and Charts

## Pre- and Post-Harvest Stand Tables Block 1/CB 229 for 2014 from Cruise Data

**Post-Harvest Cruise Results - Summary Table**

Knife Creek 229

| | B | D | q |
|---|---|---|---|
| Prescribed Stand | 27.0 | | |
| Long Term Target Stand | 27 | 65 | 1.25 |

**SUMMARY**

| Diameter | SPH | | | | BA | | | | Volume | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Initial Stand | Long Term Target | Prescribed Stand | Final Stand Estimate | Initial Stand | Long Term Target | Prescribed Stand | Final Stand | Initial Stand | Final Stand |
| AR | 843 | 136 | 200 | 59 | | 0.0 | | 0.0 | | 0.0 |
| 5 | 2686 | 109 | 180 | 188 | | 0.0 | | 0.0 | | 0.0 |
| 10 | 429 | 87 | 130 | 30 | 3.4 | 0.7 | 1.0 | 0.2 | 7.3 | 0.5 |
| 15 | 259 | 70 | 86 | 178 | 4.6 | 1.2 | 1.5 | 3.1 | 13.2 | 9.1 |
| 20 | 173 | 56 | 68 | 127 | 5.4 | 1.8 | 2.1 | 4.0 | 29.6 | 21.8 |
| 25 | 93 | 45 | 62 | 76 | 4.6 | 2.2 | 3.0 | 3.7 | 27.7 | 22.5 |
| 30 | 77 | 36 | 48 | 68 | 5.4 | 2.5 | 3.4 | 4.8 | 34.3 | 30.7 |
| 35 | 48 | 29 | 40 | 48 | 4.6 | 2.8 | 3.8 | 4.6 | 30.5 | 30.5 |
| 40 | 9 | 23 | 15 | 9 | 1.1 | 2.9 | 1.9 | 1.1 | 8.0 | 8.0 |
| 45 | 5 | 18 | 7 | 5 | 0.9 | 2.9 | 1.1 | 0.9 | 6.3 | 6.3 |
| 50 | 3 | 15 | 3 | 3 | 0.6 | 2.9 | 0.5 | 0.6 | 4.4 | 4.4 |
| 55 | 6 | 12 | 6 | 5 | 1.4 | 2.9 | 1.3 | 1.1 | 11.0 | 8.8 |
| 60 | 4 | 9 | 4 | 4 | 1.1 | 2.5 | 1.1 | 1.1 | 9.0 | 9.0 |
| 65 | 9 | 7 | 8 | 9 | 2.8 | 2.3 | 2.7 | 2.8 | 16.6 | 16.6 |
| 70 | 5 | 0 | 5 | 5 | 2.0 | | 1.9 | 2.0 | 17.3 | 17.3 |
| 75 | 3 | 0 | 2 | 3 | 1.2 | | 1.1 | 1.2 | 10.5 | 10.5 |
| 80 | 1 | 0 | 1 | 1 | 0.6 | | 0.5 | 0.6 | 5.4 | 5.4 |
| 85 | 1 | 0 | 1 | 1 | 0.6 | | 0.5 | 0.6 | 5.5 | 5.5 |
| 90 | 1 | 0 | 1 | 1 | 0.6 | | 0.5 | 0.6 | 5.6 | 5.6 |
| 95 | 0 | 0 | 0 | 0 | 0.0 | | 0.0 | 0.0 | 0.0 | |
| 100 | 0 | 0 | 0 | 0 | 0.0 | | 0.0 | 0.0 | 0.0 | |
| TOTAL | 696 | 320 | 356 | 543 | 37.4 | 27.0 | 27.0 | 32.9 | 235.0 | 212.1 |
| % | | 46 | 51 | 78 | | 72 | 72 | 88 | | 90 |

**Note**: BA and Volume totals and percentages do not include the 5 cm and 10 cm diameter classes.

Wildlife trees

Layer Summary (sph)

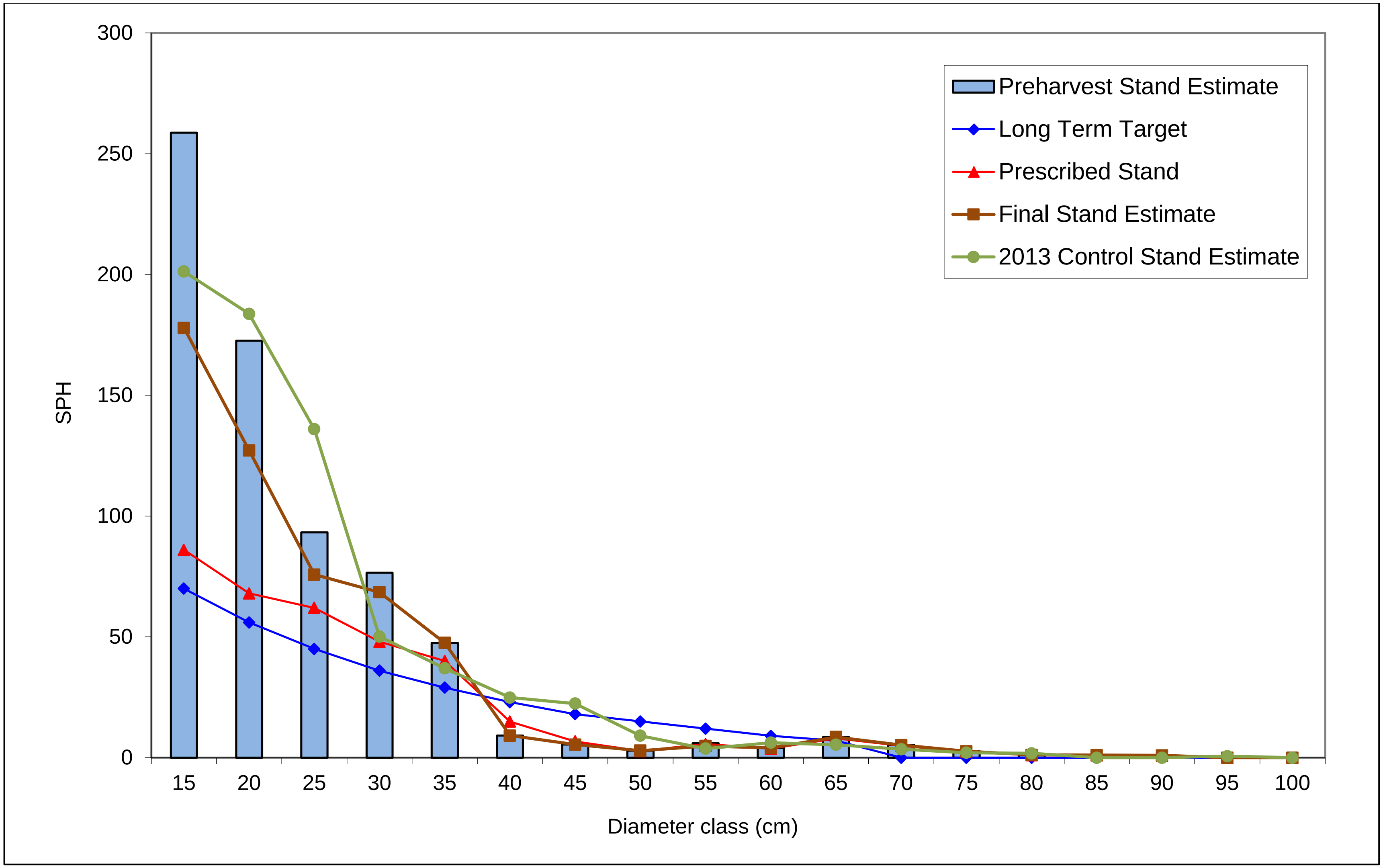
| Layer | Initial | Target | Prescribed | Final |
|---|---|---|---|---|
| 4 | 843 | 136 | 200 | 59 |
| 3 | 2686 | 109 | 180 | 188 |
| 2 | 429 | 87 | 130 | 30 |
| 1a | 259 | 70 | 86 | 178 |
| 1b | 437 | 250 | 270 | 365 |
| TOTAL | 4653 | 652 | 840 | 820 |

Regeneration Assessment Summary (sph)

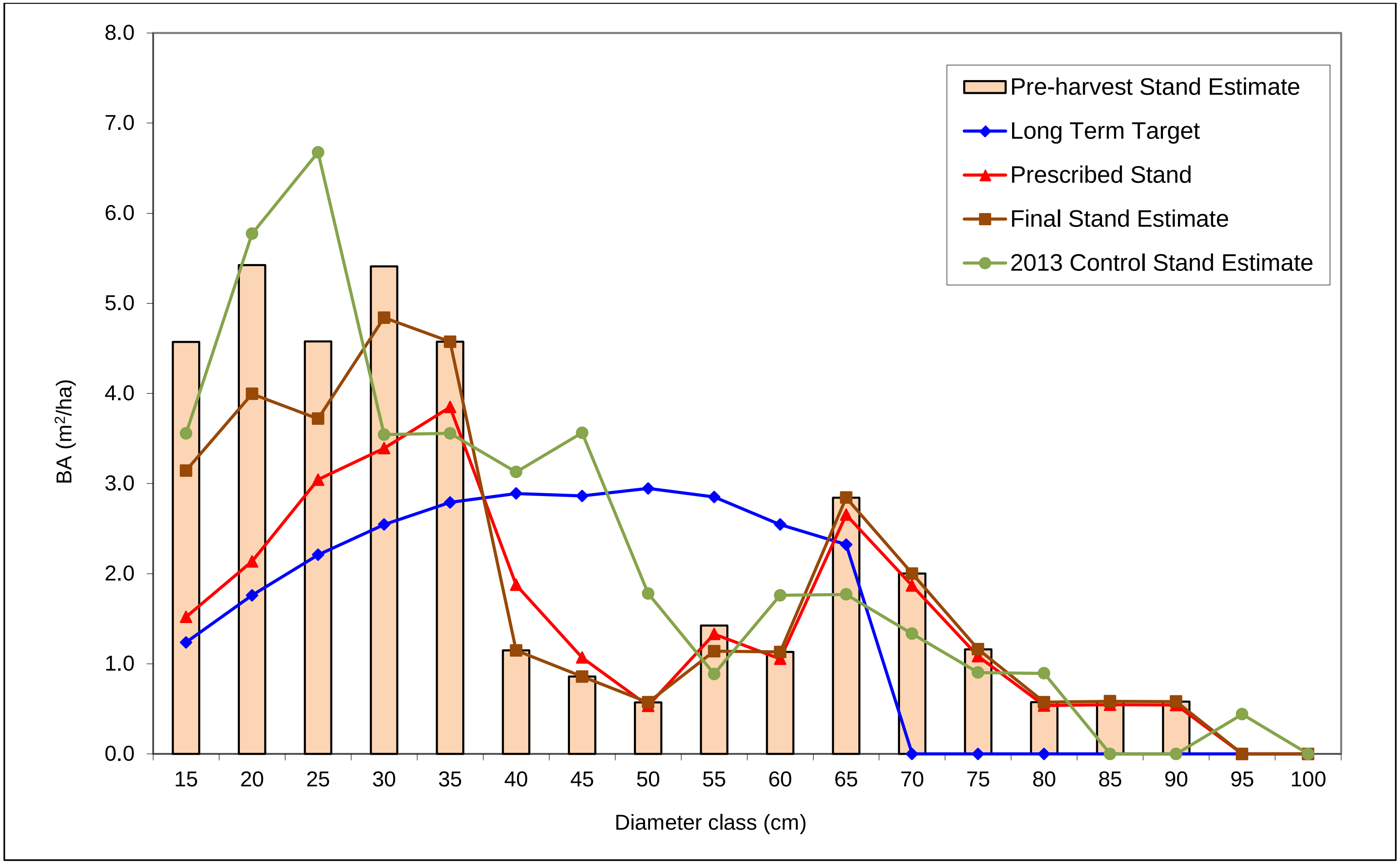
| Layer | Initial | Target | Prescribed | Final |
|---|---|---|---|---|
| 1 | 696 | 320 | 356 | 543 |
| 1+2 | 1124 | 407 | 486 | 573 |
| 1+2+3 | 3810 | 516 | 666 | 761 |
| 1+2+3+4 | 4653 | 652 | 866 | 820 |

Stand Structure Summary

| Parameter | Initial | Target | Prescribed | Final |
|---|---|---|---|---|
| B (m2/ha) | 37.4 | 27.0 | 27.0 | 32.9 |
| D (cm) | | 65.0 | | |
| q | | 1.25 | | |
| vol. (m3/ha) | 235 | | 198 | 212 |
| Total BA | 37.4 | 27.0 | 27.0 | 32.9 |
| BA>37.5 | 12.9 | 15.0 | 13.1 | 12.6 |
| BA>D | 4.9 | 0.0 | 4.6 | 4.9 |




**Pre-harvest, Long Term Target, Prescribed and Final Stand Structure Estimates (Stems Per Hectare) from Cruise Data as compared to Control, Block 1/CB 229, 2014**




**Pre-harvest, Long Term Target, Prescribed and Final Stand Structure Estimates (Basal Area) from Cruise Data as compared to Control, Block 1/CB 229, 2014**

## Pre- and Post-Harvest Stand Tables Block 2/CB 222 for 2014 from Cruise Data

**Pre- and Post-Cruise Results - Summary Table**

Knife Creek 222

| | B | D | q |
|---|---|---|---|
| Prescribed Stand | 27.0 | | |
| Long Term Target Stand | 27 | 65 | 1.25 |

**SUMMARY**

| Diameter | SPH | | | | BA | | | | Volume | |
|---|---|---|---|---|---|---|---|---|---|---|
| Class | Initial Stand | Long Term Target | Prescribed Stand | Final Stand Estimate | Initial Stand | Long Term Target | Prescribed Stand | Final Stand | Initial Stand | Final Stand |
| AR | 300 | 136 | 200 | 300 | | 0.0 | | 0.0 | | 0.0 |
| 5 | 1144 | 109 | 180 | 1144 | 2.2 | 0.0 | | 0.0 | | 0.0 |
| 10 | 233 | 87 | 130 | 233 | 1.8 | 0.7 | 1.0 | 1.8 | 4.0 | |
| 15 | 214 | 70 | 70 | 101 | 3.8 | 1.2 | 1.2 | 1.8 | 20.2 | 6.0 |
| 20 | 113 | 56 | 60 | 49 | 3.6 | 1.8 | 1.9 | 1.6 | 19.1 | 7.8 |
| 25 | 95 | 45 | 52 | 73 | 4.7 | 2.2 | 2.6 | 3.6 | 25.2 | 20.2 |
| 30 | 69 | 36 | 40 | 56 | 4.9 | 2.5 | 2.8 | 4.0 | 31.5 | 27.1 |
| 35 | 42 | 29 | 35 | 35 | 4.0 | 2.8 | 3.4 | 3.3 | 25.3 | 26.3 |
| 40 | 25 | 23 | 25 | 21 | 3.1 | 2.9 | 3.1 | 2.7 | 21.9 | 20.4 |
| 45 | 11 | 18 | 11 | 11 | 1.8 | 2.9 | 1.7 | 1.8 | 13.5 | 14.2 |
| 50 | 14 | 15 | 13 | 12 | 2.7 | 2.9 | 2.6 | 2.4 | 23.1 | 20.9 |
| 55 | 13 | 12 | 12 | 10 | 3.1 | 2.9 | 2.9 | 2.4 | 30.0 | 21.0 |
| 60 | 5 | 9 | 4 | 5 | 1.3 | 2.5 | 1.1 | 1.3 | 13.4 | 12.7 |
| 65 | 3 | 7 | 2 | 3 | 0.9 | 2.3 | 0.7 | 0.9 | 9.4 | 8.1 |
| 70 | 3 | 0 | 2 | 3 | 1.3 | | 0.8 | 1.3 | 14.7 | 12.1 |
| 75 | 3 | 0 | 2 | 3 | 1.1 | | 0.9 | 1.4 | 13.2 | 14.0 |
| 80 | 1 | 0 | 1 | 1 | 0.7 | | 0.5 | 0.4 | 8.0 | 4.7 |
| 85 | 0 | 0 | 0 | 0 | 0.2 | | 0.0 | 0.2 | 2.7 | 2.5 |
| 90 | 1 | 0 | 1 | 1 | 0.5 | | 0.4 | 0.5 | 5.5 | 4.9 |
| 95 | 0 | 0 | 0 | 0 | 0.0 | | 0.0 | 0.0 | 0.0 | |
| 100 | 1 | 0 | 1 | 1 | 0.5 | | 0.4 | 0.5 | 5.6 | 4.9 |
| TOTAL | 612 | 320 | 330 | 385 | 38.0 | 27.0 | 27.0 | 30.0 | 282.2 | 227.8 |
| % | | 52 | 54 | 63 | | 71 | 71 | 79 | | 81 |

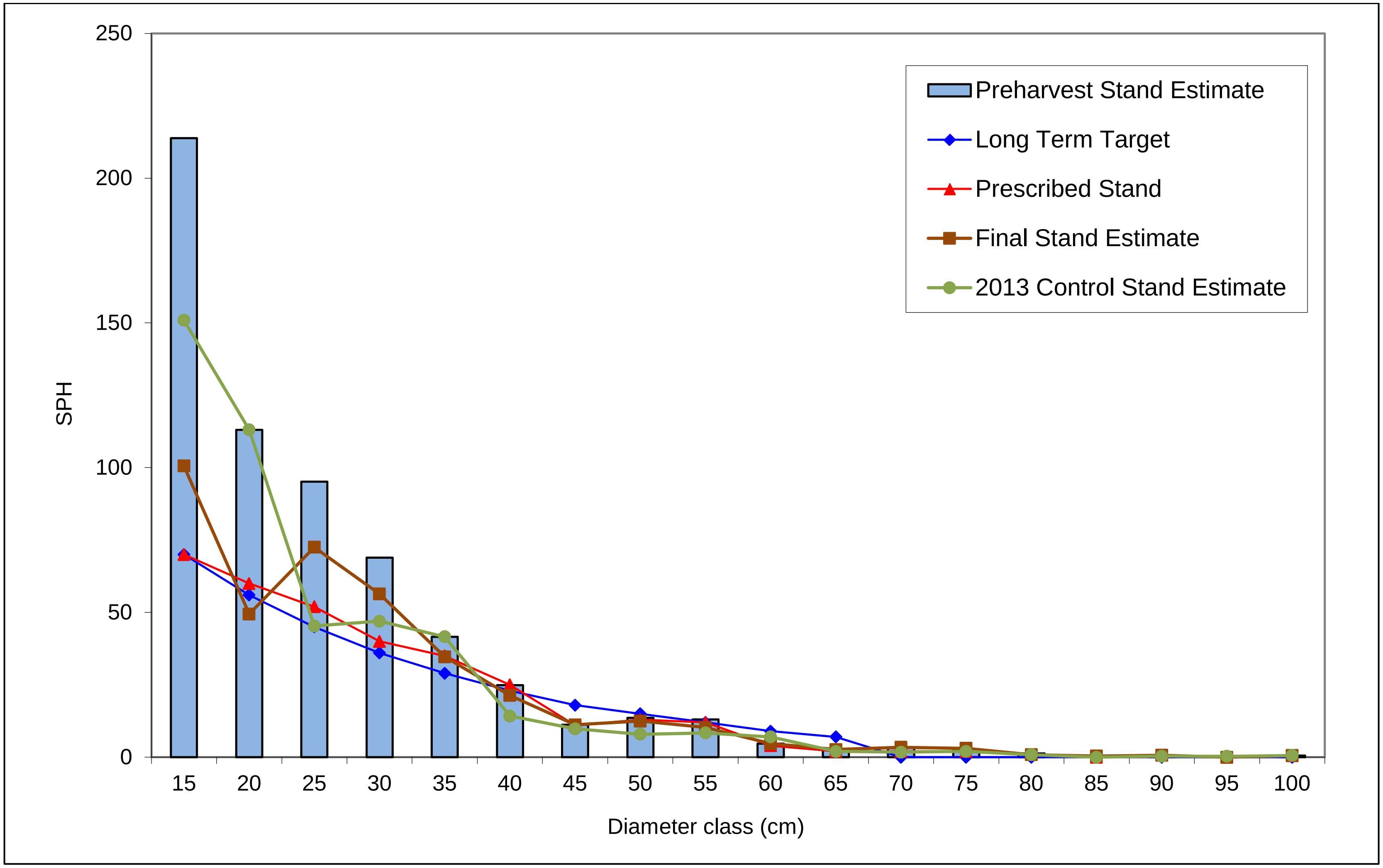
**Note**: BA and Volume totals and percentages do not include the 5 cm and 10 cm diameter classes.

Wildlife trees

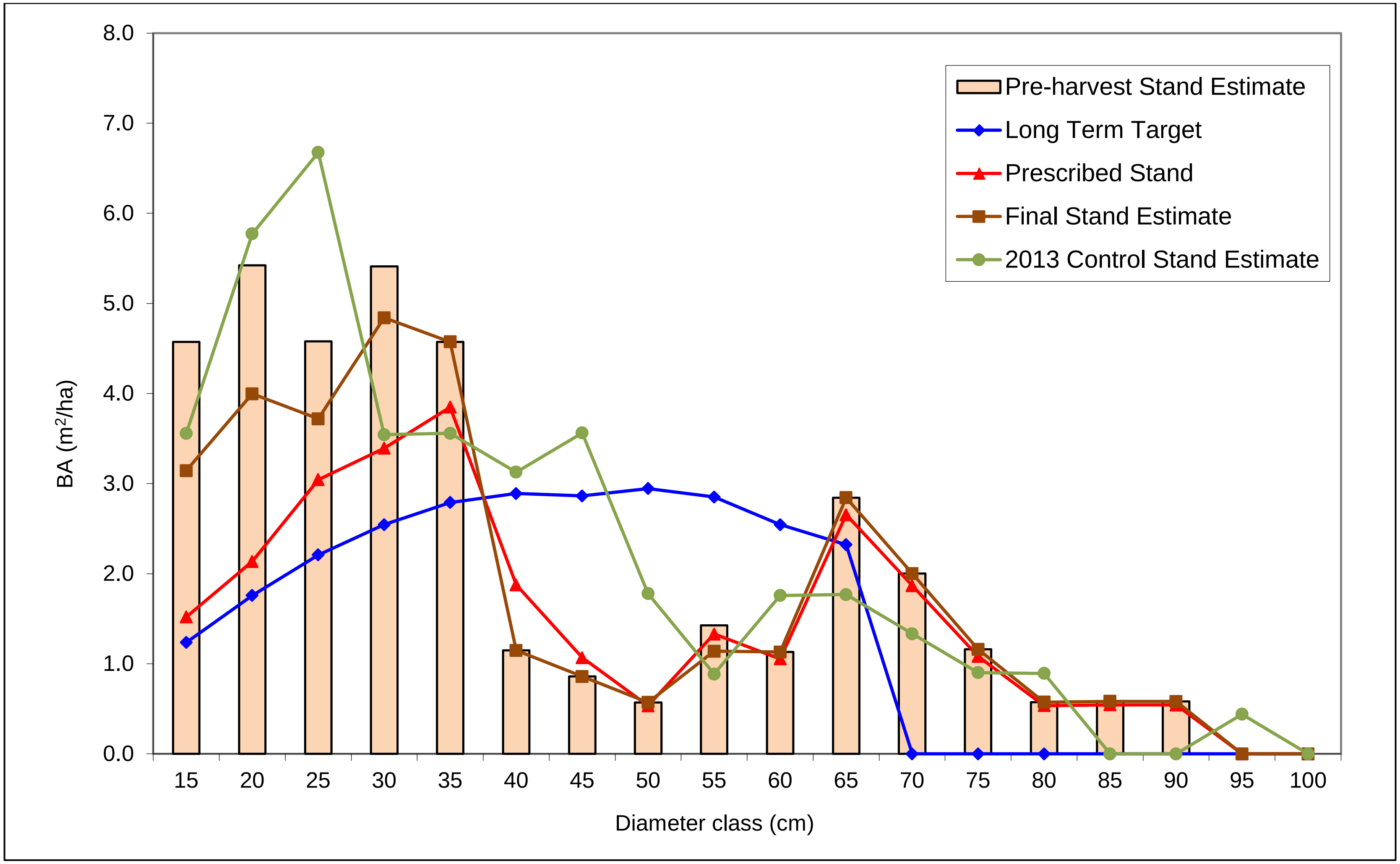
| Layer Summary (sph) | | | | |
|---|---|---|---|---|
| Layer | Initial | Target | Prescribed | Final |
| 4 | 300 | 136 | 200 | 300 |
| 3 | 1144 | 109 | 180 | 1144 |
| 2 | 233 | 87 | 130 | 233 |
| 1a | 214 | 70 | 70 | 101 |
| 1b | 398 | 250 | 260 | 285 |
| TOTAL | 2290 | 652 | 840 | 2062 |

| Regeneration Assessment Summary (sph) | | | | |
|---|---|---|---|---|
| Layer | Initial | Target | Prescribed | Final |
| 1 | 612 | 320 | 330 | 385 |
| 1+2 | 845 | 407 | 460 | 618 |
| 1+2+3 | 1990 | 516 | 640 | 1762 |
| 1+2+3+4 | 2290 | 652 | 840 | 2062 |

| Stand Structure Summary | | | | |
|---|---|---|---|---|
| Parameter | Initial | Target | Prescribed | Final |
| B (m2/ha) | 38.0 | 27.0 | 27.0 | 30.0 |
| D (cm) | | 65.0 | | |
| q | | 1.25 | | |
| vol. (m3/ha) | 282 | | 198 | 228 |
| Total BA | 38.0 | 27.0 | 27.0 | 30.0 |
| BA>37.5 | 17.2 | 15.0 | 15.1 | 15.8 |
| BA>D | 4.3 | 0.0 | 3.0 | 4.3 |




**Pre-harvest, Long Term Target, Prescribed and Final Stand Structure Estimates (Stems per Hectare) from Cruise Data as Compared to Control, Block 2/CB 222, 2014**




**Pre-harvest, Long Term Target, Prescribed and Final Stand Structure Estimates (Basal Area) from Cruise Data as Compared to Control, Block 2/CB 222, 2014**

## Pre- and Post-Harvest Stand Tables Block 3/CB 232 for 2014 from Cruise Data

**Pre- and Post-Harvest Cruise Results - Summary Table**

Knife Creek Block 3/CB 232 Treatment

| | B | D | q |
|---|---|---|---|
| Prescribed Stand | 29.0 | | |
| Long Term Target Stand | 29 | 70 | 1.25 |

| SUMMARY | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Diameter | SPH | | | | BA | | | | Volume | |
| Class | Pre-harvest Stand Estimate | Long Term Target | Prescribed Stand | Final Stand Estimate | Pre-harvest Stand Estimate | Long Term Target | Prescribed Stand | Final Stand Estimate | Pre-harvest Stand Estimate | Final Stand Estimate |
| AR | 350 | 135 | 200 | 280 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 5 | 2075 | 108 | 180 | 1660 | | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10 | 150 | 86 | 120 | 120 | 1.2 | 0.7 | 0.9 | 0.9 | 2.6 | |
| 15 | 0 | 69 | 0 | 0 | | 1.2 | 0.0 | 0.0 | | |
| 20 | 32 | 55 | 38 | 16 | 1.0 | 1.7 | 1.2 | 0.5 | 5.7 | 2.3 |
| 25 | 61 | 44 | 48 | 20 | 3.0 | 2.2 | 2.4 | 1.0 | 18.0 | 4.9 |
| 30 | 63 | 35 | 41 | 14 | 4.5 | 2.5 | 2.9 | 1.0 | 28.4 | 5.5 |
| 35 | 83 | 28 | 38 | 52 | 8.0 | 2.8 | 3.7 | 5.0 | 53.2 | 35.9 |
| 40 | 20 | 23 | 30 | 20 | 2.5 | 2.9 | 3.8 | 2.5 | 17.6 | 18.7 |
| 45 | 60 | 18 | 25 | 50 | 9.5 | 3.0 | 4.0 | 8.0 | 72.3 | 56.5 |
| 50 | 18 | 14 | 15 | 18 | 3.5 | 2.7 | 2.9 | 3.5 | 28.0 | 26.9 |
| 55 | 6 | 12 | 11 | 4 | 1.5 | 2.9 | 2.6 | 1.0 | 12.5 | 7.7 |
| 60 | 7 | 9 | 7 | 5 | 2.0 | 2.5 | 2.0 | 1.5 | 17.2 | 11.6 |
| 65 | 6 | 7 | 5 | 6 | 2.0 | 2.3 | 1.6 | 2.0 | 17.9 | 18.2 |
| 70 | 1 | 6 | 1 | 1 | 0.5 | 2.3 | 0.4 | 0.5 | 4.7 | 3.8 |
| 75 | 2 | 0 | 2 | 2 | 1.0 | | 0.8 | 1.0 | 9.6 | 7.9 |
| 80 | 0 | 0 | 1 | 0 | | | 0.4 | 0.0 | | |
| 85 | 0 | 0 | 0 | 0 | | | 0.0 | 0.0 | | |
| 90 | 1 | 0 | 1 | 1 | 0.5 | | 0.4 | 0.5 | 4.9 | 4.9 |
| 95 | 0 | 0 | 0 | 0 | | | 0.0 | 0.0 | | |
| 100 | 0 | 0 | 0 | 0 | | | 0.0 | 0.0 | | |
| TOTAL | 361 | 1298 | 762 | 211 | 39.5 | 29.0 | 29.0 | 28.0 | 289.8 | 204.9 |
| % | | 360 | 211 | 58 | | 73 | 73 | 71 | | 71 |

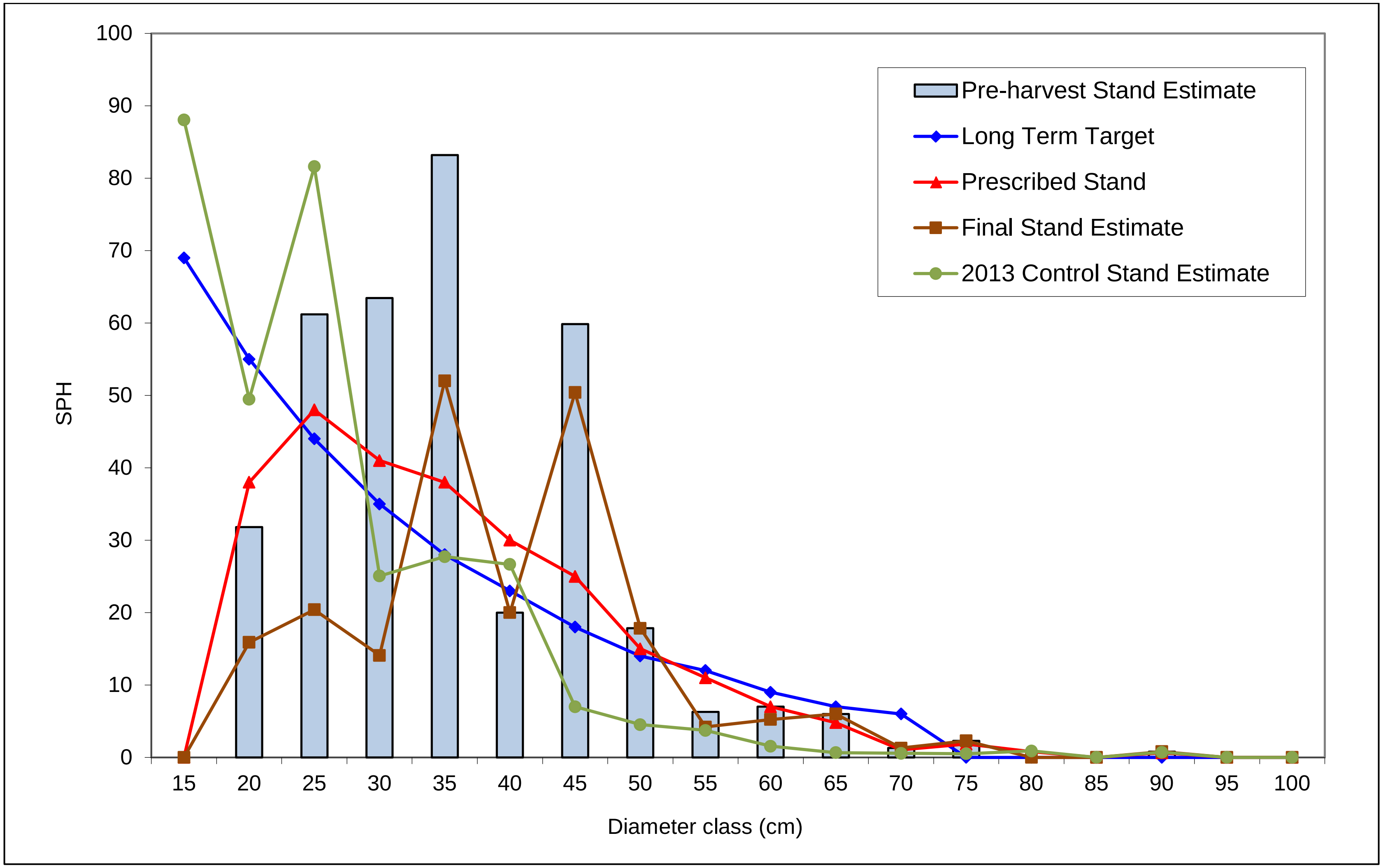
**Note**: BA and Volume totals and percentages do not include 5 cm and 10 cm diameter classes.

Wildlife trees (rows 75–100 shaded)

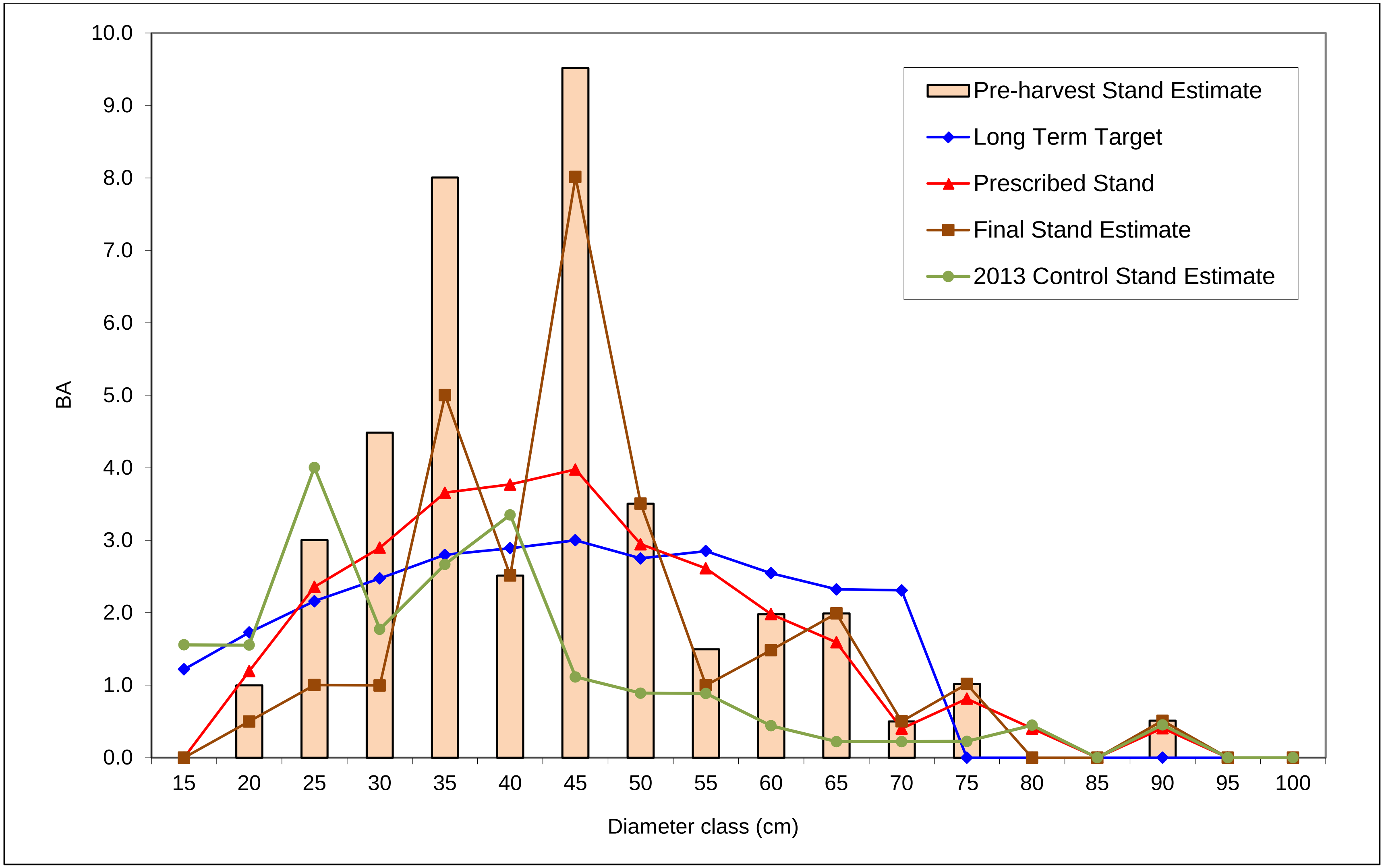
| Layer Summary (sph) | | | | |
|---|---|---|---|---|
| Layer | Initial | Target | Prescribed | Final |
| 4 | 350 | 135 | 200 | 280 |
| 3 | 2075 | 108 | 180 | 1660 |
| 2 | 150 | 86 | 120 | 120 |
| 1a | 0 | 69 | 0 | 0 |
| 1b | 361 | 251 | 262 | 211 |
| **TOTAL** | **2936** | **649** | **840** | **2271** |

| Regeneration Assessment Summary (sph) | | | | |
|---|---|---|---|---|
| Layer | Initial | Target | Prescribed | Final |
| 1 | 361 | 320 | 262 | 211 |
| 1+2 | 511 | 406 | 382 | 331 |
| 1+2+3 | 2586 | 514 | 562 | 1991 |
| 1+2+3+4 | 2936 | 649 | 762 | 2271 |

| Stand Structure Summary | | | | |
|---|---|---|---|---|
| Parameter | Initial | Target | Prescribed | Final |
| B (m2/ha) | 39.5 | 29.0 | 29.0 | 28.0 |
| D (cm) | | 70.0 | | |
| q | | 1.25 | | |
| vol. (m3/ha) | 290 | | 204 | 205 |
| Total BA | 39.5 | 29.0 | 29.0 | 28.0 |
| BA>37.5 | 23.0 | 16.0 | 18.9 | 20.5 |
| BA>D | 2.0 | 0.0 | 2.0 | 2.0 |




**Pre-harvest, Long Term Target, Prescribed and Final Stand Structure Estimates (Stems Per Hectare) from Cruise Data as compared to Control, Block 3/CB 232, 2014**




**Pre-harvest, Long Term Target, Prescribed and Final Stand Structure Estimates (Basal Area) from Cruise Data as compared to Control, Block 3/CB 232, 2014**