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Grant Creek Spacing Trial: 15-Year Remeasurement



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Cover page photo is control area treatment unit (TU 6) in the south east portion of the trial. Photo taken by Jim Thrower, October 2014.

Executive Summary

In 1999, Weyerhaeuser Company Ltd. (Weyco) installed a juvenile spacing trial near Princeton, BC. The primary objective was to study the long-term growth and yield impacts of juvenile spacing lodgepole pine (Pl) regenerating naturally after harvest to high stand density. The area was logged in 1988-89 and immediately regenerated to almost pure Pl with densities about 60,000 - 120,000/ha. The trial is in the MSxk Biogeoclimatic subzone at 1,430 - 1,530 m elevation.

The trial included three replicates of three treatments and a control. The three treatments were: 1) spacing to a residual density of 2,400 trees/ha leaving trees less than 50% of median crop tree height; 2) spacing to 2,400/ha leaving trees less than 20% of median crop tree height; and 3) spacing to a residual density of 3,500 trees/ha leaving trees less than 20% of median crop tree height. The trees less than the relative *cut-off* heights did not contribute to the residual density estimate, thus the post-spacing stands were two layered with different understories.

Each treatment unit was approximately 100 x 100 m (1.0 ha) subsampled with nine 20 m² circular plots. Measurements were taken immediately before and after treatment (1999), after five years growth (2004), and after 15 years growth (2014).

The 15-year results show no meaningful difference in site index between spaced areas (17 m) and unspaced control areas (18 m). These relatively high values for this Biogeoclimatic zone and site, and the small difference between the two areas, suggests the stand was not of high enough initial density to induce height-growth repression. This is contrary to observations in fire-origin stands where repression has been observed in areas regenerating to as little as 50,000/ha. This result is consistent with the theory that stands regenerating after harvest are sufficiently different in temporal and spatial distribution from fire-origin stands that height growth repression does not occur – or at least not until densities are extremely high.

The 15-year results are showing early impacts of spacing on branch size and crown lift. Measurements taken on the largest branch in the first whorl below 2.0 m on the tallest 2,000 trees/ha in each treatment unit show that about 65% were dead in unspaced areas and only 13% in spaced areas. Measured branches were on average about 10% larger in spaced areas, and although not of concern at this stage of stand development, may become a problem in the future as the live branches in spaced areas continue to grow. These differences are also reflected in live crown ratios that were on average 70% in spaced areas and 58% in unspaced areas.

The distribution of diameters (measured from the tallest 2,000 trees/ha) showed the typical trend where spaced areas had more trees of larger size than unspaced area, but where unspaced areas had more small trees. These differences are not practically meaningful at this early stage of stand development, but will become more significant as these trees grow over time and approach merchantable size.

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1. INTRODUCTION

In 1999, Weyerhaeuser Company Ltd. (Weyco) installed a juvenile spacing trial in the Grant Creek area near Princeton, BC. The objectives were to study the long-term growth and yield impacts of juvenile spacing lodgepole pine (Pl) that had regenerated naturally after harvest to relatively high stand density, and to test some new ideas on how silviculture surveys could be done in high density stands.

The trial is located in CP 583-1 (FL A18698) approximately 30 km northeast of Princeton (Figure 1). The site is in the MSxk Biogeoclimatic subzone at 1,430-1,530 m elevation. Weyco silviculture records show the area as 100% BEC site series 05 (Appendix 1). The 46 ha area was logged in winter 1988-89. The area regenerated immediately to almost pure Pl with stand density about 60,000 to 120,000/ha.

The trial idea was conceived by Weyco staff and designed by J.S. Thrower and Associates Ltd. W.J. Nash & Associates Ltd.

(Merritt, BC) installed the trial, completed pre- and post-treatment measurements, and supervised the operational spacing of the trial and surrounding area (Oct. 1999).

They also completed the five-year remeasurement in the fall of 2004. The 15-year remeasurement was completed in the fall of 2014 (Oct. 19 - Nov. 3) by Steve Jones, RPF and his crew (Southern Interior ForestCraft Ltd., Penticton, BC).

This report describes the 15-year remeasurement of the trial. Previous documentation includes an establishment report¹ and a five-year remeasurement report.²

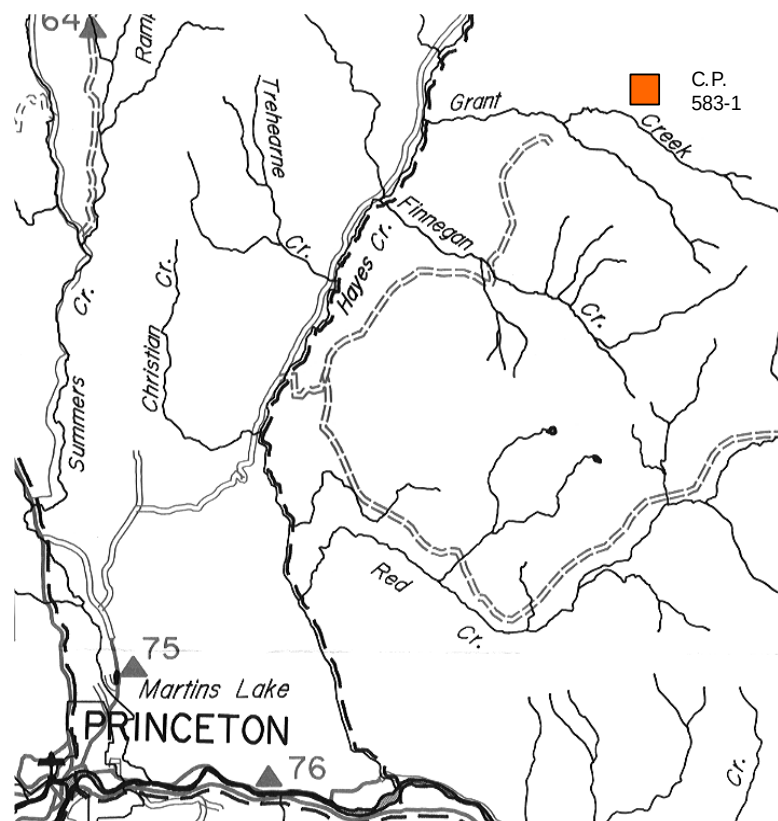


Figure 1. Location of the Grant Creek spacing trial.

¹ J.S. Thrower and Associates Ltd. 2000. Grant Creek Pl spacing trial: establishment report. Contract report to Weyco, Merritt, BC. JST project WCK-058. 9 pp.

² J.S. Thrower and Associates Ltd. 2005. Grant Creek juvenile spacing trial: Five-year remeasurement. Contract report to Weyco, Princeton, BC. JST project WCM-023. 15 pp.

2. TRIAL DESIGN

2.1 EXPERIMENTAL DESIGN

The trial is a randomized complete block design with three treatments and a control. Each of the 12 treatment units (TUs) are approximately 100 x 100 m (1.0 ha). The 12 TUs were grouped into three experimental blocks reflecting differences in initial stand density (high, medium, and low) (Table 1, Figure 2). The three treatments and a control were randomly assigned to the four experimental/treatment units (TUs) in each block.

2.2 TREATMENTS

The three treatments included two post-spacing densities. The 2,400/ha density was recently approved by the Ministry of Forests (MOF) at that time for use by Weyco in operational application. The MOF standard at the time was 1,600/ha.

The other post-spacing density was 3,500/ha. This was included because Weyco wanted to compare the difference in tree, log, and wood quality in later stages of stand development with the 2,400/ha treatment.

The two cut-off heights were 20% (the MOF standard) and 50% (Table 1). Weyco included 50% to compare the impact of leaving more trees in the understory at time of spacing on growth and yield in later stand development.

Table 1. Treatment units.

Initial Density Experimental Block	Pre-Spacing Stand Density (no/ha)	Treatment Unit (residual density & countable height)		Average 1999 Sample Tree Height (m)
Low Initial Density	66,556	1	Control	1.6
	72,111	8	3,500 - 50%	1.9
	62,167	9	2,400 - 50%	2.0
	73,722	12	2,400 - 20%	1.5
Medium Initial Density.	91,944	2	Control	1.8
	69,778	10	3,500 - 50%	1.9
	81,944	4	2,400 - 50%	1.8
	78,833	7	2,400 - 20%	1.8
High Initial Density	109,500	6	Control	2.0
	103,111	3	3,500 - 50%	2.0
	109,167	5	2,400 - 50%	1.5
	121,833	11	2,400 - 20%	1.3

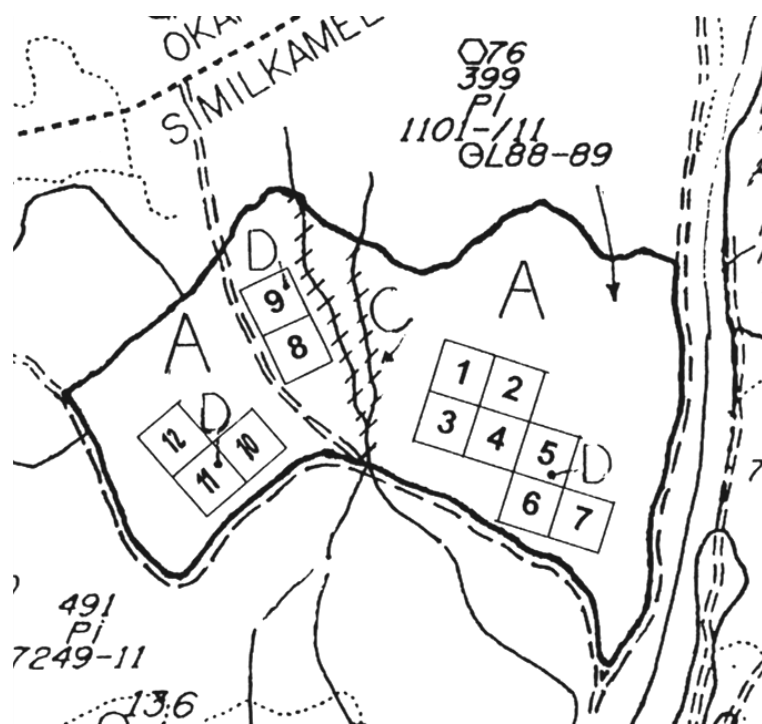


Figure 2. Location of TUs in the spacing trial.

2.3 SPACING APPLICATION

The trial area and the surrounding block were spaced by the same crew. This was done by Weyco with the intent of applying the treatments under *operational* conditions. The idea was that the treatment application, and resulting impacts on tree growth and yield in the trial, would reflect what would be done if the treatments were applied elsewhere in a fully operational environment. The TUs were spaced to the prescriptions under the trial design and the surrounding area was spaced to 3,500/ha estimated using a 20% cut-off height. This higher density for the surrounding area was approved by the MOF as an exemption to the 2,400/ha standard for Weyco at the time.

The spacing crew was given instructions on the number and type of trees to leave and remove in the treatment. The target post-spacing density was based on the MOF free-growing survey definition. This included criteria for minimum inter-tree distance and forest health criteria. Examination of the data collected immediately after the treatment (1999) would show more than the target number of trees, because some would be within the minimum inter-tree distance and thus would not be considered as *well-spaced crop trees* in the MOF definition.

The cut-off height was either 20% or 50% of median crop tree height. This was implemented as instructions to leave trees below the specific cut-off height prescribed for each TU. How this was applied would vary among crew members as either a constant height below which trees were left, or a height that varied from place to place in the stand as *crop tree* height varied. The area was spaced with brush saws, thus some of the trees below the cut-off height would have been removed while cutting larger trees.

The impact of the spacing prescriptions was to create two layered stands. The upper layer was similar in height (of the tallest trees) for all TUs but with different densities (i.e., 2,400/ha or 3,500/ha) (considering only trees above the cut-off height). The lower layer would be different in height (of the tallest trees) from 20% of the median crop tree height in some TUs and 50% in others (Table 1). This difference in stand structure is important to consider when interpreting these 15-year results and future measurements.

3. MEASUREMENTS

3.1 ESTABLISHMENT MEASUREMENT (1999)

Each 100 x 100 m TU area was subsampled with nine 20 m² (2.52 m radius) plots located on a 25 m grid centered in each TU. Plot centers were located prior to spacing and marked with 4' metal rebar stakes (see photo on cover page). Pre-treatment measurements were taken for:

1. Sample trees. Height was measured on the four tallest trees in each plot. Total age and breast height (BH) age were measured on the largest diameter sample tree. Inter-tree competition measures were taken for the sample trees (described in the establishment report). Sample trees were tagged with rectangular aluminum tags stapled to the tree or wired to a branch.
2. Plot trees. The total number of trees in each plot was tallied by height class (<20%, 21-50%, >50% of average sample tree height in each plot). These trees were not tagged. These height classes were used to provide Weyco with information to help evaluate new ideas for how to implement silviculture surveys and to relate to the spacing treatment prescriptions.

Measurements were also taken in each plot for the MOF definition of *well-spaced* trees (not included in this analysis). Site index was not estimated in 1999 as the trees were too young.

All measurements were repeated after the spacing treatment. Some sample trees were cut in the spacing and new ones selected as replacements. Approximately 25% of the sample trees selected before spacing were cut in the spacing. This reduced plot average height and likely the site index potential of the stand. This is described in more detail in the establishment report.

3.2 FIVE-YEAR MEASUREMENT (2004)

The five-year remeasurement was done using the same procedures, plots, and sample points as in 1999. The measurements of interest for this report include:

1. Sample trees. The four tallest trees in each plot were again measured. Most were the same trees selected in 1999, but new ones were selected (and tagged) in plots where relative heights had changed. All 1999 sample trees were also measured, thus some plots have heights for more than four trees.
2. Plot trees. Trees were tallied using the same procedures as 1999, with the additional of a new height class (<20%, 21-50%, 51-80%, and >80%). The relative height classes were recalculated using the current (2004) average sample tree height in each plot.
3. Site index. Trees were old enough in 2004 to get an early estimate of site index. One Pl site tree was selected from a 100 m² plot at each sample point. The site trees were

selected as the largest diameter, undamaged, suitable tree. The site trees were not tagged and thus could not be relocated in 2014. Age was estimated from an increment core taken at breast height (BH) (1.3 m above ground) and counted in the lab. Site index was estimated in the 2004 report using a PI growth intercept (GI) equation and height-age curves in the MOF Site Tools program (Version 3.2). Radial increment was measured from the core. These measurements and results are described in the 2004 report.

3.3 FIFTEEN-YEAR MEASUREMENT (2014)

3.3.1 *Trial & Plot Maintenance*

The plots had not been revisited for 10 years and thus considerable maintenance was required. This mostly included re-tagging and marking sample trees and re-flagging TU boundaries (Appendix 2).

3.3.2 *Sample Tree Measurements*

Sample trees were selected and measured in the same manner as previous measurements. The four tallest trees in each 20 m² plot were identified, tagged, and measured for height and diameter (all were PI). Height was measured using a height pole and diameter with a plastic ruler for small trees and diameter tape for larger trees. Notes on forest health were taken.

Branch and crown measurements were taken for the first time. The branch measurements included the diameter and status (live/ dead) of the largest branch in the first primary whorl below 2.0 m on each sample tree. The base of the live crown was identified on each sample tree as the lowest point where three-quarters of the circumference of crown was alive. The height to live crown base was measured to calculate live crown length and live crown ratio.

3.3.3 *Plot Tree Measurements*

All trees in each plot were measured for diameter, species, and status (live/ dead). This was a change in methods compared to previous measurements where trees were tallied by relative height class. Forest health notes were not taken for each tree but are described generally in Appendix 2.

3.3.4 *Site Tree Measurements*

One PI site tree was selected at each sample point using the same procedures as 2004. These trees were selected from a 100 m² (5.64 m radius) plot at each sample point as the largest diameter, undamaged, free-growing tree. Tree height was measured using a height pole and age from an increment core taken at BH. Rings were counted in the field. Where the site index tree was also a sample tree, BH age was taken by counting branch whorls.

3.4 COMPILATION & ANALYSIS

3.4.1 *General Procedures*

The analyses were simple summaries and comparisons of plot averages by TU, spacing treatment, initial density block, and other categories. Individual tree analyses were not done but should be considered in future measurements and analyses.

Statistical comparisons were not done in this analysis as none of the differences in averages were of practical significance at this early stage of stand development. Statistical comparisons will be warranted in later stages of stand development if differences are sufficiently large to be of practical concern.

3.4.2 *Site Index*

For this analysis, site index was estimated for the 2004 and 2014 measurements using a program written in VBA (executed in MS Excel and Access) to implement the *iteration technique* with the MOF recommended³ PI height-age curves. Site index in the 2004 analysis and report was estimated using different methods, thus the consistent method used in this analysis allows a more direct comparison between the two measurements.

3.4.3 *Tree & Stand Attributes*

All sample tree and stand attributes were computed as simple averages within plots and averaged to TUs, spacing treatments, and density blocks. All plots and TUs were of equal statistical weight.

³ J.S. Thrower and Associates Ltd. 1994. Revised height-age curves for lodgepole pine and interior spruce in British Columbia. Contract report to the BC MOF, Res. Br., Victoria, BC. JST Project 94-02-JG. 27 pp.

4. RESULTS

4.1 SAMPLE TREE HEIGHT

The 2014 measurement showed similar average sample tree (tallest 2,000/ha) heights of 6.2 - 6.4 m among spaced and control areas, except the low site area (2400-20 treatment) at 5.2 m (Table 2). The TU averages did not show a consistent relationship among experimental blocks, suggesting that initial stand density conditions have not affected sample tree height. Similar trends were shown in the 1999 and 2004 measurements.

Average height increment over the last 10 years was highest (3.6 m) in the 2400-50 treatment and lowest (2.9 m) in the 2400-20 treatment (Table 2). The highest increment (4.1 m) was in TU 7 (medium density spaced to 2400-20), which also had the tallest height and highest site index in the trial (Table 3).

There is suggestion of a trend of lower height increment over the last 10 years with increasing density – which was not shown in the first five years after treatment. The differences are small and not of practical importance; however, they can be reevaluated in future measurements, and if practically important, tested for statistical significance.

Table 2. Average sample tree height and height increment.

	Spacing Treatment			
	2400-20	2400-50	3500-50	Control
Height (m)				
1999	1.4	1.7	1.9	1.8
Low Density	1.4	2.0	1.8	1.6
Medium Density	1.6	1.7	1.8	1.8
High Density	1.2	1.4	2.0	2.0
2004	2.3	2.8	2.9	3.0
Low Density	2.3	3.2	2.9	3.0
Medium Density	3.0	2.7	2.8	3.0
High Density	1.8	2.5	3.1	3.2
2014	5.2	6.4	6.3	6.2
Low Density	4.8	6.9	6.1	6.7
Medium Density	7.1	6.1	5.8	5.8
High Density	3.8	6.2	7.0	6.2
Height Increment (m)				
1999-2004	0.9	1.1	1.1	1.2
Low Density	0.8	1.2	1.1	1.3
Medium Density	1.4	1.0	1.0	1.2
High Density	0.6	1.1	1.2	1.3
2004-2014	2.9	3.6	3.3	3.2
Low Density	2.6	3.7	3.2	3.7
Medium Density	4.1	3.4	3.0	2.8
High Density	2.0	3.6	3.9	2.9

4.2 SITE INDEX

The average site index estimated using 2014 measurements was 17-18 m for the spaced and control areas (Table 3). Site indexes for individual TUs varied from 14-19 m. The exception to the trend of similar site index is the three TUs (10, 11, and 12) in the south-west portion of the trial (Figure 2). In 2004 and 2014, those TUs had the lowest site index estimates (TU 11 at 13-14 m). Two of those three TUs are in the 2400-20 spacing treatment, and although this difference in site quality reduces the scope of inference for that treatment, it largely limits the impact of the difference to that treatment. However, the 2400-20 treatment also includes TU 7 which has the highest site index (19 m in 2014).

The results for height and BH age of the site trees are the same as site index where there was no meaningful difference among spacing treatments, density blocks, or measurements (Table 3). However, again the exception is the three TUs in the lower site area that showed somewhat lower heights and ages.

Table 3. Site index, height, and breast-height age of site trees. Shown are averages for the nine plots in each TU by spacing treatment and initial stand density experimental block.

	Spacing Treatment			
	2400-20	2400-50	3500-50	Control
Site Index (m)				
2004 (all blocks)	15	17	17	18
Low Density Block	15	19	16	18
Medium Density Block	18	16	17	17
High Density Block	13	17	17	17
2014 (all blocks)	17	18	17	18
Low Density Block	16	18	17	18
Medium Density Block	19	17	16	17
High Density Block	14	19	18	18
Height (m)				
2004 (all blocks)	3	4	4	4
Low Density Block	3	4	4	4
Medium Density Block	4	4	4	4
High Density Block	3	4	4	4
2014 (all blocks)	7	8	7	7
Low Density Block	7	8	7	8
Medium Density Block	9	8	7	7
High Density Block	5	8	8	7
BH Age (yrs)				
2004 (all blocks)	8	8	8	8
Low Density Block	8	8	9	8
Medium Density Block	8	8	8	8
High Density Block	7	8	8	8
2014 (all blocks)	16	18	17	16
Low Density Block	17	18	17	17
Medium Density Block	17	18	17	16
High Density Block	15	17	18	16

Site index in the control areas was the highest (18 m) using 2004 measurements and tied for highest (18 m) using 2014 measurements (Table 3). These are higher values than the average of 15-16 m given in the 2013 MOF SIBEC tables for MSxk mesic and circum-mesic sites. This suggests that, at least to this point in stand development, the spacing treatment has had little or no impact on site index. The slightly higher site index in the control areas could be the result of removing some of the tallest trees in the spacing treatment. Those trees would have higher site indexes, on average, and thus removing some of those trees in the spacing has the effect of reducing site index of the remaining stand.

This small difference in site index also suggests the density levels regenerating in this block (60,000 – 120,000/ha) were not sufficiently high to induce height-growth repression. This small difference could also result if all areas were in repression and the spacing treatment has done nothing to mitigate the effect. However, that result would likely show site indexes much lower than the 17-18 m observed in this stand. This lack of repression at these establishment densities is contrary to observations in fire-origin stands where repression has been observed at lower densities (e.g., 50,000/ha). However, regeneration after harvest has a different temporal and spatial distribution^{4,5} than fire-origin stands, which could result in this apparent difference in densities at which repression occurs.

The site index estimates using 2004 and 2014 measurements differed by only about 1.0 m. Assuming that the 2014 estimates are more reliable, this suggests that (at least for this stand) the MOF height-age curves provided reasonably accurate estimates in 2004 when the trees were only 7-8 years BH age.

4.3 STAND DENSITY

The 2014 estimates of average stand density (live trees above BH) were 9,500 – 16,100/ha in spaced areas and 41,000/ha in control areas (Table 4). The change in density over the last 10 years indicates relatively little mortality in the spaced or control areas (Figure 3). This was expected in the spaced areas but not in controls. However, some of the indicated trends may be the result of using different techniques to estimate stand density in the 1999 and 2004 (tree counts by height class) compared to 2014 (measurement of all trees above BH).

In the first five year after treatment (1999-2004), stand density fell dramatically in the control areas but increased in the spaced area (Figure 3). Mortality in the controls was expected but the increase (in total trees) in the spaced areas was not. This apparent anomaly can be explained by

⁴ J.S. Thrower and Associates Ltd. 2001. Lodgepole pine ingress on TFL 15 & TL 35 pilot project. Contract report to Weyco, Kamloops. JST project WCK-068. 13 pp.

⁵ J.S. Thrower and Associates Ltd. 2002. Sampling lodgepole pine ingress in the Merritt TSA& TFL 15. Contract report to Weyco, Merritt. JST project WCM-020. 23 pp.

continued natural ingress in the spaced areas after the 1999 measurements. Previous studies by Weyco indicate that natural ingress occurs in these stand types for 12-13 years after harvest, thus ingress likely continued after the 1999 spacing was completed. The increased density may also be the result of live limbs from cut trees continuing to grow in height.

Table 4. Average stand density (no/ha) by measurement year and tree class (height class in 1999 and 2004 and initial density block in 2014). Density in 1999 and 2004 includes all trees and in 2014 is live trees taller than BH only.

	Spacing Treatment							
	2400-20		2400-50		3500-50		Control	
1999 (all trees)	9,444		21,907		25,907		89,333	
Trees < 50% of avg ht	6,759	72%	18,667	85%	21,852	84%	62,241	70%
Trees > 50% % of avg ht	2,685	28%	3,241	15%	4,056	16%	27,093	30%
2004 (all trees)	35,019		27,352		30,537		42,926	
Trees < 50% of avg ht	32,093	92%	23,722	87%	26,278	86%	18,963	44%
Trees > 50% % of avg ht	2,926	8%	3,630	13%	4,259	14%	23,963	56%
2014 (trees above BH)	9,481		15,315		16,093		41,037	
Low Density	9,111		12,389		16,556		30,889	
Medium Density	11,556		14,056		16,778		36,889	
High Density	5,556		15,111		13,000		41,278	

Table 5. Number (no/ha) of live and dead trees in 2014 by diameter class and spacing treatment.

Tree Status & DBH Class (cm)	Spacing Treatment							
	2400-20		2400-50		3500-50		Control	
Dead Trees	741		1,463		648		4,685	
0 cm class	722	97%	1,370	94%	611	94%	4,556	97%
5 cm class	19	3%	93	7%	37	6%	130	3%
Live Trees	8,741		13,852		15,444		36,352	
0 cm class	5,259	60%	9,148	66%	10,630	69%	21,444	59%
5 cm class	2,630	30%	3,574	26%	3,611	23%	14,519	40%
10 cm class	815	9%	1,130	8%	1,204	8%	389	1%
15 cm class	37	<1%	0	0%	0	0%	0	0%
< 7.5 cm	7,889	90%	12,722	92%	14,241	92%	35,963	99%
> 7.5 cm	852	10%	1,130	8%	1,204	8%	389	1%
All Live & Dead Trees	9,481		15,315		16,093		41,037	



Figure 3. Change in stand density in the three spacing treatments and controls. Density is all live trees for the 1999 and 2004 measurements, and in 2014 is all live trees taller than breast height (1.3 m).

The 2014 estimated stand density in the spaced areas is considerably higher than targeted in the 1999 spacing treatment. The reason for this apparent discrepancy is how trees have been measured and reported for density. In 1999, the target density for the spacing treatment was based on trees above the *countable (cut-off) height* (20% or 50% of median *crop tree* height in each plot). For most of these areas, there was a large number of trees shorter than the countable height. For example, in 1999 the 2400-50 treatment had 21,907 trees/ha, of which 18,667 (85%) were below the 50% cut-off height (Figure 4). With growth over time, many are now taller than BH and were included in the 2014 estimate of stand density.

In 2014, about 11% of trees in the controls were dead, and 97% of those were less than 2.5 cm DBH (Table 5). Currently about 52% of live trees in the controls are less than 2.5 cm DBH. If 97% of those die by the next measurement, that will reduce stand density by about 50%. That would be a dramatic reduction compared to previous trends, which would give the appearance of what is often referred to as a *wave of mortality*.

4.4 STAND DIAMETER

The diameter distribution at this early stage of stand development is not meaningful in the context of merchantable sized trees; however, it does show the typical trend where spaced areas have more large trees but fewer small trees than unspaced areas (Table 5, Figure 4). For example, in 2014 the spaced areas had about 850 - 1,200 live trees/ha (8-10%) larger than 7.5 cm DBH, and controls had only 390/ha (1%) (Table 5). For trees less than 7.5 cm DBH, unspaced areas had about 36,000/ha compared to 8,000 - 14,000/ha in spaced areas.

This relative distribution of tree diameters between the spaced and unspaced areas should remain similar as these stands develop. Thus spaced areas should be first to show potential merchantability volume as they have more large diameter trees. However, the unspaced areas, with many more small trees, may show more merchantable volume when a larger number of

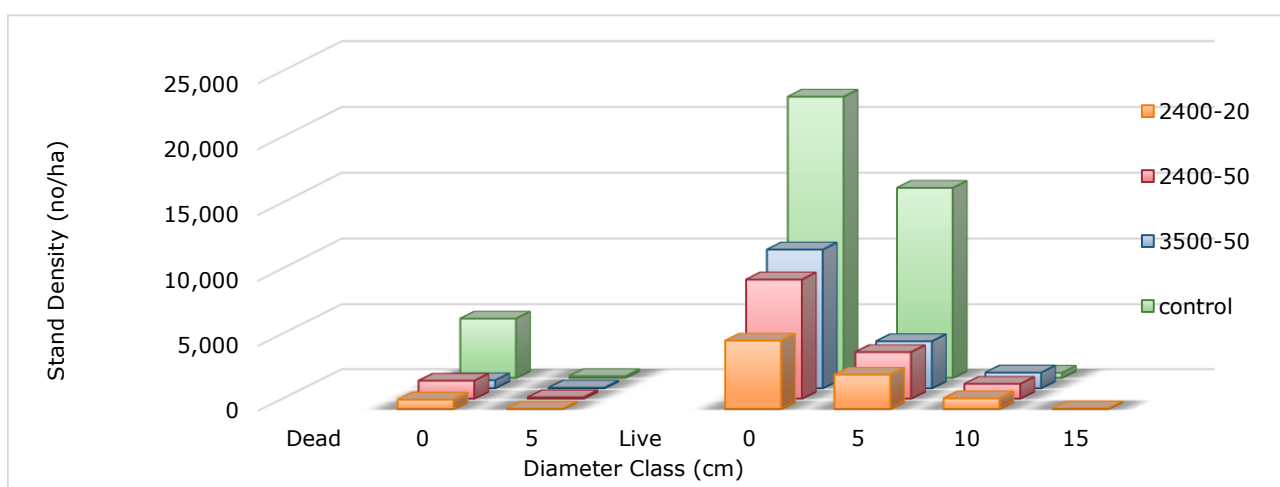


Figure 4. Distribution (no/ha) of live and dead trees by diameter class and spacing treatment.

those pass the merchantable size limit. An additional consideration in future analyses and comparisons of *merchantable* volume is the ability of modern harvesting equipment to economically harvest very small trees for biomass and pulp chips - of which there are many more in unspaced areas than in spaced areas. This changes the definition of a *merchantable* tree and may change how stands with many small trees are considered in the context of timber management.

4.5 BRANCHES

Branch size and status (live/dead) are showing the impact of spacing (i.e., stand density) at this early stage of stand development. In this measurement, about 65% of measured branches (largest branch in first main whorl below 2.0 m) in the control areas were dead where only 13% were dead in spaced areas (Table 6).

The average size of dead branches was about the same in the control and spaced areas (0.72 – 0.78 cm). The average size of live branches in spaced areas (1.02-1.04 cm) was larger by about 0.13 cm (14%) than the control areas. This small difference is not meaningful at this early stage of stand development; however, the live branches will continue to grow over time. The growth increase will be larger in spaced areas. And given that spaced areas have substantially more live branches, branch size could become a problem in later stages of stand development if a significant number exceed 2.5 cm in diameter. The average size of the largest branches already exceeds the critical size of about 2.5 cm in two of the three spacing treatment areas.

An additional consideration when interpreting these branch measurements is that branch size and status at or near BH (in this case about 2.0 m above ground) is only an index that is related to overall branch condition and size for the entire stem. Branch size and status varies over time and vertically along the stem as influenced by crown lift. In later stages of stand development, branches at points higher up the stem will be much larger than those measured at BH or 2.0 m.

Branches should always be larger in the spaced area compared to unspaced areas; however, the post-spacing densities in this trial may be sufficiently high to avoid major branch problems. This can be assessed in future measurements, and was one of the thoughts in designing this

Table 6. Attributes of the largest branch on sample trees measured from the first main whorl below 2.0 m in height.

	Spacing Treatments							
	2400-20		2400-50		3500-50		Control	
Trees Measured	108		108		108		108	
Dead	9	8%	12	11%	20	19%	70	65%
Live	99	92%	96	89%	88	81%	38	35%
Avg Diameter (cm)	0.99		1.01		0.99		0.82	
Dead	0.72		0.78		0.74	71%	0.77	85%
Live	1.02	141%	1.04	135%	1.04	141%	0.91	117%
Largest Diameter (cm)	3.1		2.2		2.5		1.7	
Dead	1.3		1.2		1.5		1.6	
Live	3.1	238%	2.2	183%	2.5	167%	1.7	106%

trial. This is not the case in PHR stands growing at lower densities where a high proportion of trees have branches in the lower and mid bole sections that exceed 2.5 cm.⁶

4.6 HEIGHT TO LIVE CROWN

The height to live crown (HLC) and live crown ratio (LCR) are also showing the impacts of spacing. The HLC was about 1.5 - 2.0 m in the spaced areas and 2.6 m in the controls (Table 7). Expressed as LCR, the measurements show that sample trees in spaced areas have about 68 - 71% live crown and only 58% in control areas. As with branch size, these differences are not practically meaningful at this early stage of stand development, but should become more pronounced as trees grow taller and the live crowns continue to lift accordingly.

There appears to be no impact of initial stand density conditions (as reflected in the experimental design blocks) on HLC and LCR. This suggests that pre-spacing conditions affecting these attributes have not carried through to this stage of stand development.

Table 7. Height to live crown and live crown ratio for sample trees in each TU.

	Spacing Treatment			
	2400-20	2400-50	3500-50	Control
Height (m) to Live Crown (HLC)	1.5	1.8	2.0	2.6
Low Density	1.3	1.9	1.7	2.7
Medium Density	2.1	1.7	2.0	2.3
High Density	1.2	1.8	2.3	2.9
Live Crown Ratio (%) (LCR)	70%	71%	68%	58%
Low Density	73%	72%	71%	60%
Medium Density	71%	71%	66%	61%
High Density	68%	71%	66%	53%

⁶ J.S. Thrower and Associates Ltd. 1999. A pilot study of branch size in post-harvest regenerated lodgepole pine stands in the Merritt and Kamloops areas. Contract report to Weyco, Kamloops. JST project WCK-048. 17 pp.

5. CONCLUSIONS

This stand is in early stages of development and the impacts of spacing are not fully expressed. Thus the following conclusions are limited to only a few attributes where trends are appearing - which could change with subsequent measurements at later stages of stand development.

1. Site index and height growth – has not been impacted by the spacing treatments. This suggests that the density levels regenerating in this stand after harvest (60,000-120,000/ha) were not sufficiently high to induce height-growth repression.
2. Branch size and crown lift. Spacing has resulted in branches in the lower bole remaining alive longer than in unspaced areas, as reflected through higher LCRs. The log and wood quality, and value impacts of this can be estimated in later stages of stand development when trees approach merchantable size.

6. RECOMMENDATIONS

The recommendations from this measurement are:

1. Find a champion and custodian for this trial. This trial was initiated in 1999 by Weyco staff, most of whom have left Weyco or have or will soon retire. Thus there is a high likelihood that this trial will be lost and forgotten if a new custodian is not found. This would be a waste of the substantial investment to date, and the valuable information that will result from this trial in 10 - 15 years from now.
2. Remeasure the trial in the fall of 2019 (five years from now) using the 2014 procedures. In five years, some trees in this stand will be approaching merchantable size. Although the interpretation of that measurement will still be limited by lack of sufficient tree size, the data will be a very important link to the following measurement (10 years from now) when results can be related to a merchantable crop.
3. Future analyses. The next measurement may warrant statistical analysis of differences in some tree and stand attributes – if observed differences are of a magnitude that could be practically important to decisions related to applying spacing treatments, or to merchantable yields. Also, there are myriad of detailed individual tree analyses that can be done with those data that will greatly improve the inference and interpretation of the growth and yield impacts of spacing in this stand.

APPENDIX 1 - SILVICULTURE RECORDS

Weyerhaeuser
Princeton Division

Silviculture Database Catalog Listing

Page 1 of 2
2014/10/29

Licence: A18698

Permit: 583

Block: 583-1

Opening Number: 92H069-76

Block Description

Operating Area: FIN BCGS Map Sheet: TSA: 18
 Timbermark: EU7583 Latitude: 49 38 42 Forest District: Cascades Forest District
 Funding Source: FS Longitude: 120 15 35 Forest Region: RSI
 Earliest Regen Delay: 7 yrs Nearest Community: Supply Block: 07
 Earliest Free to Grow: 12 yrs to 20 yrs Opening: 92H069-76 Trapper:
 Gross Area: 50.8 ha NAR: 46.3 ha Guide:
 Internal Comments: Location: FINNEGAN/GRANT CREEK
 Cut Block Comments: This file is an amalgamation of CP 583 Blk 1 & CP583 Blk 1A - May 29, 1998

Management Activities

Planned Date	Completion Date	Status	Activity	Area (Ha)	Cost	Contractor
		Planned	Ecology Units		\$0.00	
		Planned	SP		\$0.00	
1988/11/01	1989/02/01	Done	Harvesting	50.8	\$0.00	
1992/08/01	1992/08/01	Done	SU - RD - Single Plant	43.9	\$485.10	TRANSITION FORESTRY
1996/09/03	1996/09/03	Done	SU - RD - Single Plant	1.3	\$23.40	WJ NASH & ASSOC
1997/09/01	1997/09/01	Done	Assessment - Performance	43.9	\$0.00	WEYERHAEUSER STAFF
Comments: Survey Comments: by Cya and Norm						
1999/10/25	1999/10/29	Done	JS - Power Saws	11.6	\$9,600.00	KLO-WELL SILVICULTURE LTD.
Comments: Tending Comments: This area is made up of 12 individual Treatment units. Area has permanent research plots established. 3 treatment regimes were used.						
1999/11/01	1999/11/06	Done	JS - Power Saws	33.6	\$21,237.70	KLO-WELL SILVICULTURE LTD.
Comments: Tending Comments: This stratum is portion of opening that was not included in research project.						
1999/11/10	1999/11/10	Done	SU - FG - Single	45.2	\$800.00	WJ NASH & ASSOC
Comments: Survey Comments: Strata B consists of 12 individual treatment Units. This stratum is a research area. Future treatments in this stratum will be at the discretion of Weyerhaeuser and Research contractor. See attached spacing trial summary.						
2001/10/16	2001/10/19	Done	JS - Power Saws	1.8	\$1,257.46	KLO-WELL SILVICULTURE LTD.
2001/10/16	2001/10/19	Done	SU - FG - Single	1.8	\$35.01	WJ NASH & ASSOC
Comments: Brush Species 1: Silka Alder Cover: 1% Height: 1.9						

Ecological Classification

Standard Unit	Eco Unit	Biogeo Classification	Total Area (Ha.)
A	A	MSxk 05/100	46.3
			46.3

Current Status -- Area

FG (ha)	IMM (ha)	Reserve (ha)	NPUNN (ha)	NPNATT (ha)	NSR (ha)	Total (ha)
46.3	0.0	0.0	0.0	0.0	0.0	46.3

Current Status -- Survey

<u>Stratum</u>	<u>Area</u>	<u>Date</u>	<u>Survey Code</u>	<u>MLSIS Code</u>										
A	32.9													
<u>Layer</u>	<u>Rank</u>	<u>Status</u>	<u>Type</u>	<u>Species</u>	<u>Age</u>	<u>Age P/I</u>	<u>Ht</u>	<u>Cr Clos</u>	<u>Ref Yr</u>	<u>Density</u>	<u>Well Spaced</u>	<u>FG Stems</u>	<u>Site Class</u>	<u>Site Index</u>
I	IMM	NAT	Pli-100		9		1.5	30.0	1999	10719			M	16

APPENDIX 2 – NOTES FROM STEVE JONES

Crew Size

A crew of two or three persons was used to re-measure the 2.52 m radius plots. The senior field person was dedicated to recording measurements.

TU & Plot Marking

1. All 12 TU boundaries were located and re-flagged with winter weight orange ribbon.
2. The large steel stakes at TU corners were spray painted orange and flagged in orange winter weight ribbon.
3. All 9 plots in each TU were located and re-tagged.
4. The 4' rebar plot center stake was spray painted orange and flagged in orange ribbon.
5. An orange and blue ribbon was hung at or near plot center at eye level.
6. GPS coordinates were recorded for all plot centers and TU corner stakes.

Field Cards

Three field cards were used to record data: mensuration data card, sample tree data card, and site index tree data card.

1. **Mensuration data card.** Included Sample tree number species, status (live/ dead), and DBH. Clear plastic rulers were used to measure DBH and sample trees were measured with a steel diameter tape. Forest health data were not recorded. Plot radius was 2.52 m.
2. **Sample tree data card.** Included sample tree number, species, status (live/ dead), DBH, total tree height, height to live crown, branch diameter at the nearest main whorl below 2 m, and branch status (live/ dead). Height poles were used to measure total tree height and height to live crown. A steel diameter tape was used to measure diameters of sample trees. Branch diameters were measured with clear plastic rulers. A new aluminum tag was attached to sample trees where the old one was not clearly legible or of incorrect kind.
3. **Site index tree data.** Plot size was 5.64 m radius. The tallest PI tree of acceptable form and vigour was selected and measured for total height and age at DBH. Site index trees were flagged with a blue or orange ribbon at eye level and marked "SI50tree". If the site index tree was also a sample tree, this was recorded and the age at DBH was estimated by counting the whorls from the top of the tree to breast height.

Field Card Issues & Resolutions

The format of field cards was somewhat problematic. Field cards were on 8.5 x 11 letter sized paper. This paper size necessitated keeping the paper on a flip style clip board. Though waterproof, the paper tended to tear when it was flipped too many times; this worsened in wet conditions. To avoid losing or tearing sheets and to remain efficient in the field, numerous

liberties were taken with the field cards and how data were recorded. This resulted in the need to re-write some of the forms later.

The final field notes were scanned and distributed to Ed Collen (Weyco), Bernie Peschke (MOF), and Jim Thrower. Ed Collen has retained all original field cards (plus re-writes) on file at the Okanagan Falls Weyerhaeuser office (250) 497-1265. Steve Jones retains digital copies of all project related information (250) 488-4930.

Sample Tree Tallying Conventions

The goal of data gathering was to identify the four tallest trees in each plot across all 12 TU's. Since annual height growth varies both within a single tree and among trees, the tallest four trees in a plot may change over time. It was common to have to identify, tag and record new sample trees. New sample trees entering the 'tallest four' cohort were assigned new numbers based on this convention: 101, 102, 103 and 104.

If a plot had one or more new sample trees, the data from all new and all identifiable old sample trees was collected. This resulted in some plots having more than 4 sample trees measured. These trees are noted in the data as "too short". It was important to continue gathering data on as many old sample trees as possible because sample trees with missing tags are lost from the data forever, i.e. temporal continuity is lost even though the tree is probably still alive. Thus we managed to retain temporal continuity in a subset of sample trees.

Tree Tagging Issues & Resolution

It was common for tree tags to be missing or found on the ground. The last re-measurement crew often used thin gauge aluminum sheets as tags and stapled the tags directly to the bole of the tree. If the tag had been loosely stapled, the tags were eventually torn off by wind, snow and/or ice. If tightly stapled, the tag was torn or pushed off by the growing bole of the tree which also left the staples embedded in the tree. Where better quality tags were used, it was common to find them improperly wired to the main stem or wired on a branch but too close to the tree bole. Some of these tags also had to be abandoned. As too many assumptions were required to match tags found on the ground with the proper sample trees, all loose or unidentifiable tags were removed from the plot as operational waste. No further attempt was made to identify old sample trees. Illegible, loose, damaged or embedded tags were also removed.

Identifiable sample trees with tags improperly affixed, chewed, or mangled were retagged with 7/8" x 3" aluminum tags having the sample tree number on it. All tags were wired to branches in such a way that branch or stem diameter growth would not dislodge the tag. It is anticipated that even some of these tags will go missing over time as animals appear to chew them and pull them off. New tags were also required at some plot centers when they were illegible or missing entirely (control TU's 1, 2, and 6).

Forest Health Agents

In terms of forest health, the largest issue noted was rabbit feeding damage on suppressed or intermediate trees. Numerous small trees were clipped off completely and the damage was ubiquitous on all TUs and plots - rabbits were still on site during re-measurement activities. Other forest health agents noted were gall rust, stalactiform rust, and commandra rust. Gall rust was most prevalent and was ubiquitous but at relatively low incidence. Only several occurrences of stalactiform and commandra were noted. Leader weevil was also noted and only affected two or three sample trees. The prevalence and incidence of the rusts and weevil is at endemic levels and are not cause for concern.