85 Extension Note

March 2008

The Pothole Creek Study Area: Dry Uneven-aged Douglas-fir Stand Development

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Background

Dry uneven-aged interior Douglas-fir (*Pseudotsuga menziesii* var. *glauca* [Beissn.] Franco) is a highly variable forest type in the southern interior of British Columbia. Interior Douglas-fir stand disturbance history can be complex, resulting in a broad range of stand structures and development pathways. With the mountain pine beetle devastating interior lodgepole pine forests, the importance of understanding the management and potential of other local forest types, such as dry Douglas-fir, is increasing.

The Stand Modelling Group of the British Columbia Ministry of Forests and Range Research Branch started work in a partially cut, multi-cohort dry Douglas-fir stand at Pothole Creek in 1996. The purpose was to study the biology of interior Douglas-fir tree and stand growth, to better understand uneven-aged stand development, and to develop growth and yield models (http://www.for.gov.bc.ca/hre/pothole/). This Extension Note presents stand history, regeneration, and growth and yield information gleaned from 10 years of measurements at the Pothole Creek Study Area. The site is typical of the interior Douglas-fir problem forest type, for which more growth and yield information is needed (Snetsinger 2005).

Site Description

The study site is approximately 25 km southeast of Merritt, B.C., at 1250–1300 m elevation in the Thompson Dry Cool Interior Douglas-fir (IDFdk1) biogeoclimatic subzone variant (Lloyd et. al. 1990), and includes a 5-ha forested area on an upper slope with a southwest exposure. Site series range from 02 (Douglas-fir – Snowberry – Bluebunch wheatgrass) at the highest elevations, through 01 (Douglas-fir – Lodgepole pine – Pinegrass – Feathermoss) at midslope, and 04 (Douglas-fir – Pinegrass – Yarrow) at the lower elevations (Lloyd et. al. 1990). Tree cover is mainly multi-cohort Douglas-fir, with irregularly spaced overstorey trees, and dense patches of advanced regeneration alternating with grassy openings and rocky outcrops (Figure 1). A few lodgepole pine (*Pinus contorta* var. *latifolia*) grow on the mid- to lower slopes and hybrid spruce (*Picea engelmanii* x *glauca*) can be found on the wetter microsites.[1]

[1] D. Lloyd and H. Masata. 1998. Ecosystem mapping for the Pothole Creek Research Site. Unpubl. report.

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(a) (b)

FIGURE 1 *The complex forest at the Pothole Creek Study Area: (a) multi-cohort stand structure; (b) grassy opening (photo (b) by Jeff Stone).*

Glacial till blankets most of the site and fractured bedrock is exposed in localized outcrops. The most common soils are Orthic Eutric Brunisols, with poorly developed, coarse surface horizons on top of colluvial or morainal parent material, and Orthic Melanic Brunisols under areas of grass cover. The slope averages 15% from the top to the bottom of the study area. Drainage is subsurface and partly feeds into a small, south-flowing creek in the southeast corner of the site.[2]

The climate is transitional between the maritime west coast and the southern interior dry belt. A climate station measuring solar radiation, air and soil temperatures, relative humidity, rainfall, and wind speed has been in place in a clearcut about 1 km away from the site since 1998. Over the past 10 years, growing-season precipitation has averaged 210 mm per year, but about 38% of the total annual precipitation occurs as snow from mid-November to mid-April. Average summer air temperature has been 13.2°C with mid-summer extremes reaching 30–35°C. These 10-year values are within historic regional norms, based on interpolation between the data recorded at Merritt and Brenda Mine, the nearest climate stations with longer records.[3] Dry conditions in late summer, due to the southern exposure, low rainfall, and shallow soils, usually create a growing-season moisture deficit for trees and understorey plants (Simpson 2000).

Stand Disturbance History

Past logging has had the greatest influence on recent stand development and current structure. According to British Columbia Forest Service records,[4] this stand was heavily logged in the spring of 1966, using a D6 Cat® with a heel boom and grapple to skid the logs. Several skid trails are still visible, now covered with pinegrass and shrubs. The harvest prescription specified a minimum stump diameter of 38 cm, with 10% retention of seed trees. Post-logging inspections of the subsequent timber sales reported average removals of 100–140 m^3/ha. This intensity of harvest opened the stand severely, giving rise to flourishing pinegrass and semi-open grassland conditions (B. Miller, B.C. For. Serv. technician in 1966, pers. comm., Apr. 1997).

Insect defoliators have periodically affected tree crown and height development at the site. An outbreak of the western spruce budworm (*Choristoneura occidentalis*) is currently under way, and is causing repeated defoliation of Douglas-fir apical and upper branch shoots, most noticeably on the understorey trees. Douglas-fir beetle (*Dendroctonus pseudotsugae*) is endemic in the area and visible on some of the large mature trees.

Fire is typical of the dry Douglas-fir forest, but this site has not burned for 40 years. Fire scar analysis indicated that the mean fire return interval is 13 years, but the most recent moderate-intensity fire was in 1967, 1 year after harvest and perhaps the result of post-harvest clearing operations (Gray and Riccius 1999).

The forest in which the study site is located has been part of an active range tenure since the nineteenth century. Cattle graze this pasture from about October 1 to October 15 each year.[5]

[2] C. Braybrook. 1997. Soil assessment of the Pothole Creek research forest. Univ. Victoria, Dep. Geog., Work Term Report.

[3] Lloyd and Masata, 1998.

[4] Cascades Forest District history record file for Opening #92H098-011.

[5] Grazing Licence RAN074349, Range Use Plan. 2000. 900 cow/calf pairs and 45 bulls. Douglas Lake Cattle Co. Ltd.

Study Methods

The focus of the Pothole Creek installation is a 1-ha permanent growth and yield sample plot (approximately 100 × 100 m) located midslope within the stand. This plot was intensively measured and stem-mapped in 1996. All live trees at least 6 cm diameter at breast height (dbh) were tagged and measured for height, diameter, and crown length. Increment cores were removed from the base of as many live trees as possible to determine tree ages. Stumps from the most recent harvest were also tagged and measured for height and diameter. Three smaller, nested subplots (one 900 m² and two 400 m²), in which all trees 10 cm high and up to 5.9 cm dbh were similarly tagged, mapped, and measured, were established for the study of natural ingress and understorey tree development. To reconstruct past growth patterns, 349 sample trees growing outside the permanent plot and drawn from all age groups and canopy layers were cut apart. Seedfall data have been collected annually since 1999 via thirty 0.54 m² seed traps placed at random locations within the main plot.

The main plot and subplots are now remeasured periodically to build a long-term data set for spatial growth and yield model testing. The most recent remeasurement was completed in October 2006, 10 years after establishment. For this report, the establishment and 10-year tree measurements were compiled to produce stand and stock information for each assessment and to estimate growth, mortality, and ingress over the period. Tree volumes were estimated by predicting inside bark diameters via integration of taper equations developed for provincial species (Kozak 1988), and then summing stem volume segments using Smalian's and Newton's formulae (Husch et al. 1972).

Results

Current stand structure reflects past disturbance

Although the pre-harvest stocking is unknown, the 1966 entry likely removed a large portion of the growing stock, given the modest carrying capacity of these dry sites. From the plot stump measurements and locally developed lower bole taper (after Alemdag and Honer 1977) and tree height prediction equations, the total volume and basal area of trees removed from the main permanent sample plot were estimated to be 193 m³/ha and 29.2 m²/ha, respectively. This greatly increased the soil moisture and light available for the remaining trees and new vegetation. Figure 2 shows the

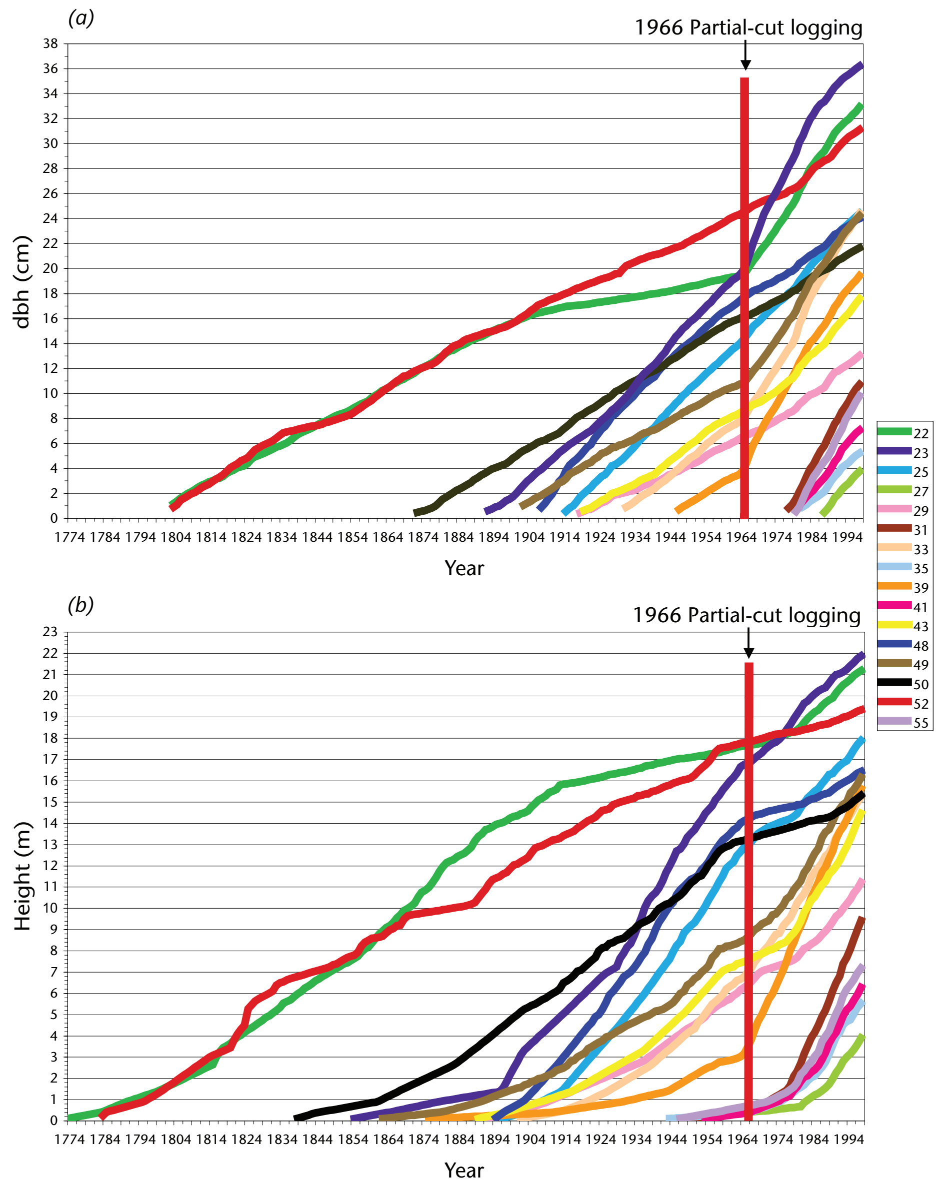

FIGURE 2 *Growth over time of selected Douglas-fir stem analysis sample trees from Pothole Creek, representing the range of tree age and size found on site. Each line represents: (a) the breast height diameter growth; and (b) the height growth of one sample tree over time since establishment. In the case of height growth (b), the year at which the line meets the x-axis is the year of establishment. Diameter growth (a) is not recorded until the tree reaches 1.3 m in height.*

diameter and height development of a selection of stem analysis sample trees, chosen to represent the range of tree age and size found at the Pothole site. Not all of the trees showed a diameter growth increase after the partial-cut logging, but the response was immediate in those that did. In contrast, height growth rates did not increase until 5–15 years later. In fact, height growth appeared to slow for some trees, perhaps because growth was primarily allocated to root and diameter increment in adjustment to the more open conditions.

The heavy equipment used in the operations created a mix of seedbed substrate conditions. Some areas were severely compacted and are still visible as relatively treeless, grass-covered trails. Other areas were disturbed sufficiently to tear up the dense grass root mats and expose mineral soil. With the presence of seed trees and some ground disturbance, stand-reinitiating ingress was abundant, though patchy. The 1966 partial harvest seems to have fortuitously coincided with a period of good seed production and seedling survival conditions because the age distribution of live trees in the permanent plot (Figure 3) shows an establishment episode that peaked 1–2 years post-harvest as might be expected, but which actually began at least 2 years before the harvest entry. Twenty percent of the trees in the 30-year age class were 31–32 years old in 1996. New trees were probably suppressed by the resurging residual tree growth, but by 1973 the opening was declared sufficiently restocked[6]; however, the regeneration remains clumpy due to uneven soil depth and grass competition.

The age frequency distribution for trees older than 30 years in the plot (Figure 3) reflects that of the residual trees on the site. The oldest may have been left as either unmerchantable veterans or good seed trees; the small concentration at ages of 100–120 years may be a remnant of a previously significant age cohort. Each of these age cohorts represents a very wide range of tree sizes (see age ranges by size class in Table 1). The pattern by height classes is similar, an indication not only of previous growth suppression but also of eventual growth release, of which most trees have been capable regardless of age. Most of the trees on the site, from the largest overstorey trees to those in the understorey, have

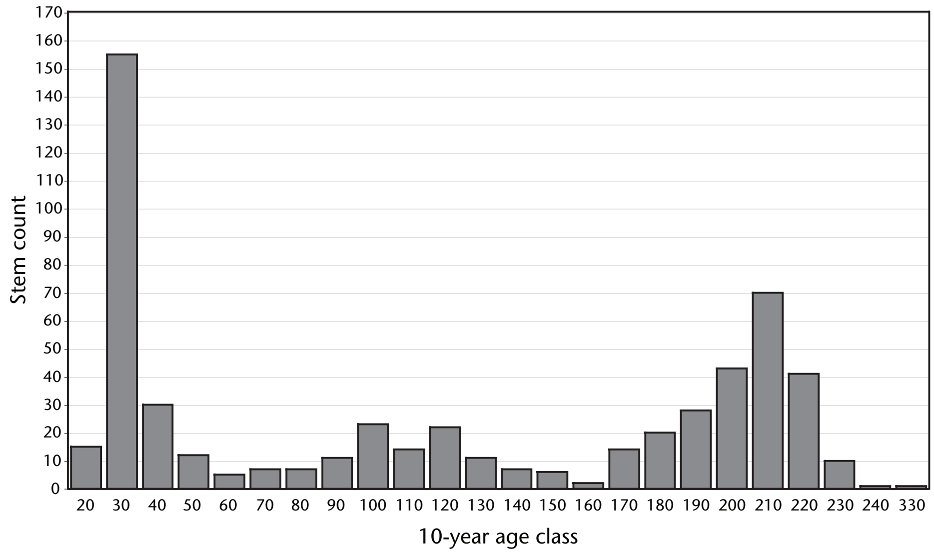

FIGURE 3 *Approximate age frequency distribution of Pothole Creek permanent sample plot trees in 1996, based on basal increment core ring counts on all stems 6 cm dbh and larger that were sufficiently sound to core. Ages are adjusted for the height of coring on the stem.*

TABLE 1 *1996 age statistics for plot trees 6.0 cm dbh and larger, by 5-cm diameter classes*

Diameter class midpoint (cm)	*N*	Minimum age	Maximum age	Mean age	Median age
7.5	198	21	207	48.4	30
12.5	93	19	217	78.5	55
17.5	49	26	327	149.9	120
22.5	62	43	228	173.4	192
27.5	70	70	235	199.1	209
32.5	56	121	231	203.9	210
37.5	21	115	225	182.6	192
42.5	5	181	218	199.0	200
47.5	1	203	203	203.0	203

[6]Refer to footnote 4.

endured a prolonged period of slow growth after establishment.

Stand dynamics

Stem numbers

The tree size distribution is changing as some trees are recruited into larger size classes and others die (Figure 4). Compared to 1996, there are now more large trees, fewer small trees, and total stem numbers have dropped by about 2400 per hectare. The change is most marked in the smaller understorey trees (Figure 5 and Table 2) where net losses of 2338 and 170 trees per hectare occurred in layers 4 and 3, respectively. Assessment data from 1996 and intermediate survival checks indicated that wildlife browsing, drought, and spruce budworm defoliation were responsible for most of this mortality. In contrast, the mid- and upper canopy layers (layers 1 and 2) had net recruitment of 127 trees per hectare. The mean diameter of the largest 200 trees per hectare (prime trees) had increased by 2.4 cm.

Regeneration

Regeneration has been sporadic and the rate of ingress has declined over the 10-year assessment period. Seedfall on the site built up to a peak of about 400 000 filled seeds per hectare in 2003, but has dropped off sharply since, in part because of increasing spruce budworm defoliation (Figure 6). According to a previous broad survey of seedling development, a cohort of regeneration might have been initiated in 2003, but it will take at least 5 years for these trees to reach the 10 cm height threshold for tallying in the sample subplots.[7] Given the lack of recent forest floor disturbance and the sporadic synchrony between good seed crops and favourable spring germination conditions, it is likely that major regeneration events at the site will continue to be episodic and

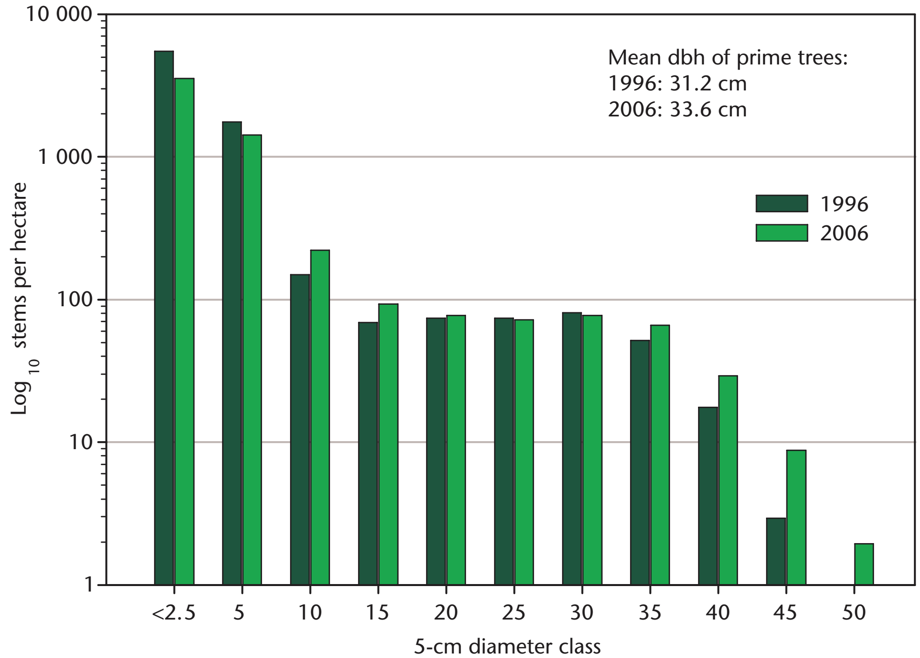

FIGURE 4 *Change in permanent plot stem diameter frequency distribution over 10 years. Prime trees are the 200 largest per hectare by diameter, representing the most dominant trees in the stand.*

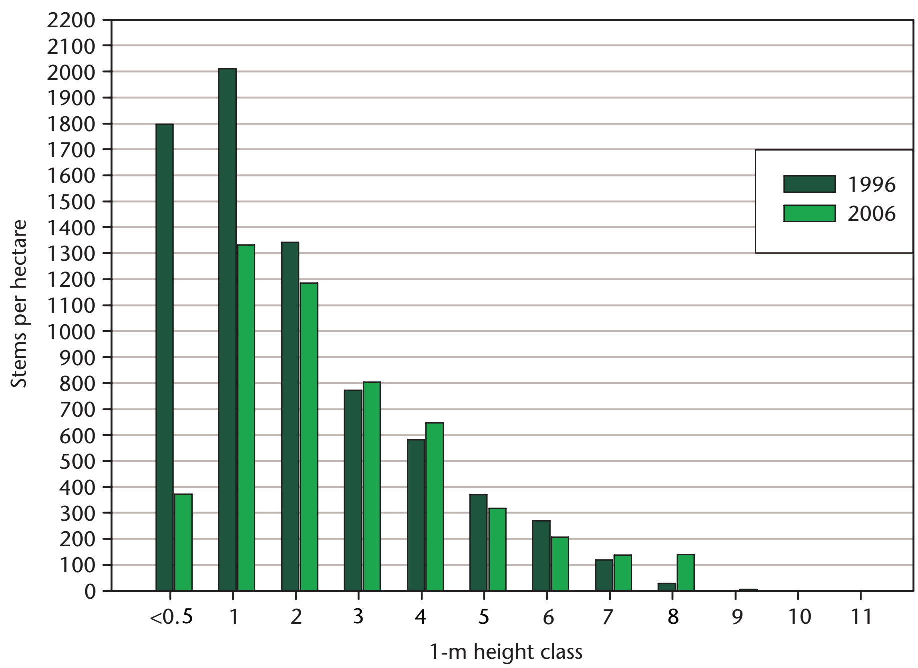

FIGURE 5 *Understorey tree height frequency distribution 1996–2006. Data include all trees 7.5 cm dbh or smaller.*

[7] J. Stone. 1996. Seedling and coarse woody debris distribution on the Pothole Creek site. Unpubl. file report.

TABLE 2 *Net change in live tree numbers by stand layers over the 10-year assessment period in the permanent sample plot. Layers 1–4 are the standard size classes used for measurement of stocking in uneven-aged drybelt Douglas-fir in British Columbia (Silviculture Interpretations Working Group 1992).*

Stem count (per hectare)

Year	Layer 4 (0.10–1.29 m height)	Layer 3 (1.3 m height; 7.49 cm dbh)	Layer 2 (7.5–12.49 cm dbh)	Layer 1 (≥ 12.5 cm dbh)	Total
1996	3791	3425	150	370	7736
2006	1453	3255	222	425	5355

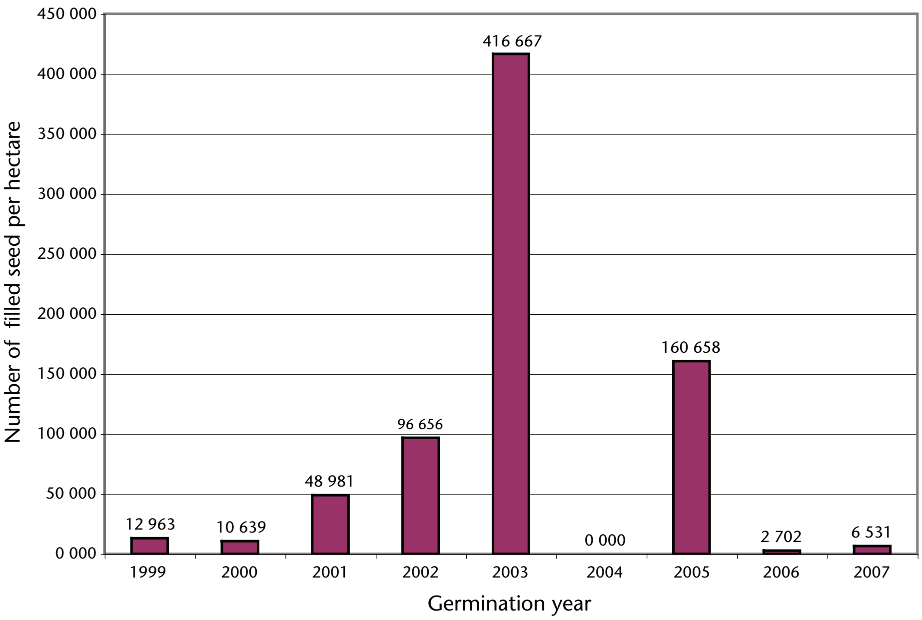

FIGURE 6 *Seedfall rates as estimated from spring monitoring of 30 seed traps in the permanent plot.*

infrequent. Cattle management during the grazing period may also be influencing the number and spatial distribution of recruits, but the nature and degree of effect is unknown and requires further research.

Stocking and volume increment
Over the 10-year assessment period, stocking in the permanent plot has increased by 29 m³/ha in total volume (23 m³/ha in merchantable volume) and 4.4 m²/ha in total basal area (Table 3). Volume lost to mortality in trees over 2.5 cm dbh is 2.9 m³/ha, or 10% of net total volume growth. The volume in larger trees has increased, while that in the smaller trees is holding fairly steady, by virtue of greater stem numbers (Figure 7). Indeed, the proportion of total volume increment attributable to the smaller trees is greater than the proportion of total stocking they represent (Figure 8). Despite this, a full 79% of the total 10-year volume growth was still gained by trees over merchantable size (17.5 cm dbh) and the 21% of annual increment accumulated on smaller trees indicates that development of future crop trees continues to be vigorous.

Implications for Management

The stand at the Pothole Creek Study Area has been growing at a rate of over 2 m³/ha per year for the last 10 years, 30–40 years after the last harvest entry. More intensive retrospective work will be required to determine the length of time that this rate of growth has been sustained. To the extent that this study site represents the broader landscape around it, the forest could support another partial-cut entry or be profitably left to accumulate more volume. The dense understorey clumps of advanced regeneration appear to be self-thinning and differentiating in height; however, the spatial distribution is very clumpy and the declining ingress is not filling in the open areas. Another harvest entry would certainly damage some of the understorey, but would also initiate recruitment by breaking up the dense grass patches and releasing growing space for new trees. If harvesting is delayed, then site preparation and planting of the bigger openings might be explored, assuming that increased site occupancy is desired. The local risk of loss to browsing and drought has been shown to be high.[8] More research is recommended on underplanting methods that reduce losses to browsing and drought, and the effects of cattle behaviour and management on recruitment patterns in dry Douglas-fir stands.

[8]See http://www.for.gov.bc.ca/hre/pothole/demo.htm for a description of underplanting demonstrations in the Pothole Creek Demonstration Area that surrounds the Pothole Creek Study Area.

TABLE 3 *Stocking changes in the permanent plot over the 10-year assessment period*

	1996	2006	Periodic annual increment (ha/year)
Total volume (m^3/ha, 2.5+ cm dbh, net mortality)	134.6	163.1	2.9 m^3
Mortality (m^3/ha, 2.5+ cm dbh)		(2.9)	(0.29) m^3
Merchantable volume (m^3/ha, 17.5+ cm dbh)	114.2	137.4	2.32 m^3
Basal area (m^3/ha, 2.5+ cm dbh)	21.9	26.3	0.44 m^2

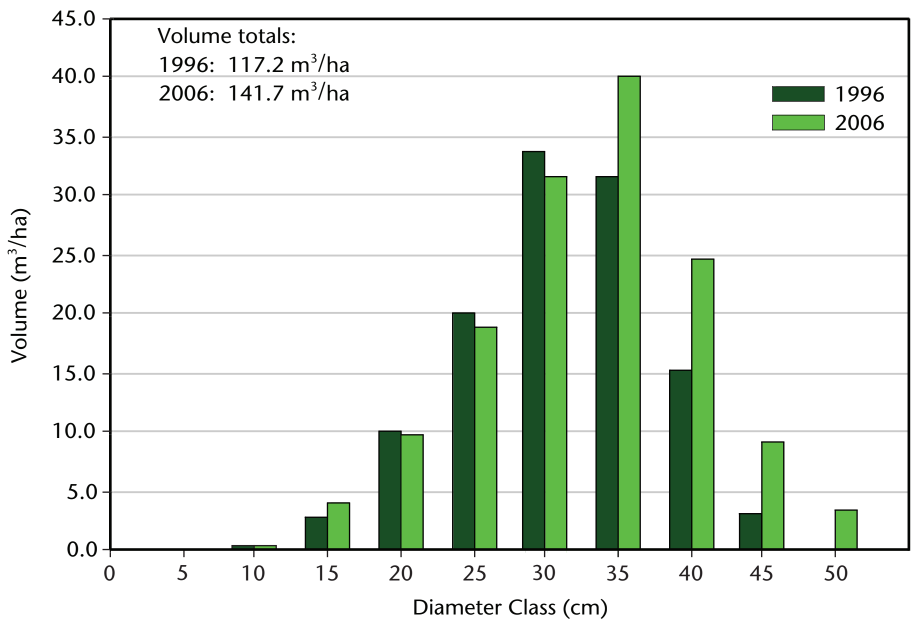

FIGURE 7 *Volume frequency distribution changes over 10 years in the Pothole Creek permanent sample plot. Volumes include all live trees 7.5 cm dbh and larger, less a 10 cm diameter top and 30 cm tall stump.*

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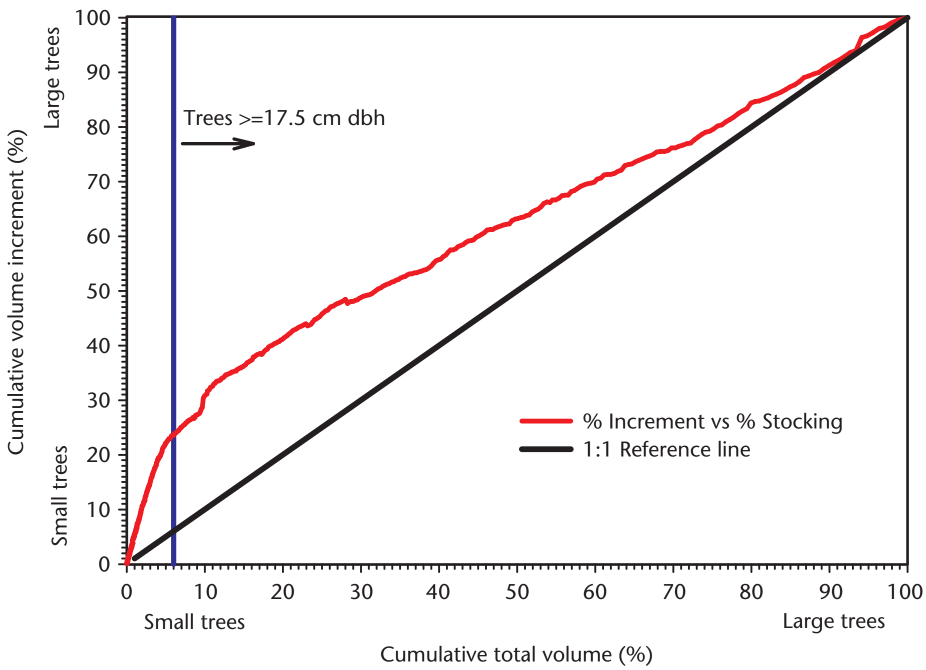

FIGURE 8 *The relative contribution of different-sized trees to total volume increment for the stand over the 10-year observation period, based on all live stems that were 7.5 cm dbh or larger at the beginning of the assessment period (1996). The red line shows the percentage of total volume increment attributable to the percentage of total standing volume enumerated on the x-axis, cumulative by increasing tree size. The blue reference line shows the approximate cumulative total volume percentage above which all trees are 17.5 cm dbh or larger.*

Acknowledgements

The B.C. Ministry of Forests and Range Research Branch, Forest Renewal BC, and the FIA–Forest Science Program have provided funding for this project. I thank Ken Mitchell, Jeff Stone, Dennis Lloyd, and David Simpson for their important research contributions; Rich Hodson for logistical support; Bob Miller and Bill Nash for site and history information; and Jorge Schwarz, Christine Halenda, Carla Davidson, and Chris Braybrook for their conscientious fieldwork.

Citation

Bealle Statland, C. 2008. The Pothole Creek study area: dry uneven-aged Douglas-fir stand development. B.C. Min. For. Range, Res. Br., Victoria, B.C. Exten. Note 85. http://www.for.gov.bc.ca/hfd/pubs/Docs/En/En85.htm