Nelson Forest Region

Using Prognosis^{BC} to Analyze Partial-Cutting Options over a Rotation.

by

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Extension Note 059

INTRODUCTION

- ***Stand level models can be an invaluable tool when planning for Sustained Forest Management over the long term.***
- ***Models have limitations and output must be carefully scrutinized. Professional judgement is key.***

Using alternative silvicultural methods that create more "naturalness" at the stand level is an ongoing international trend (O'Hara 2001). This desire for naturalness has been emphasized by the increased interest in certification of forest practices to promote sustainability (O'Hara 2001). Efforts to achieve sustainable forest management will likely lead to more partial-cutting stand treatments in many forest types in southeastern British Columbia. Many stands in the Interior Cedar-Hemlock (ICH) biogeoclimatic zone lend themselves to a range of partial-cutting options. Choosing an option for a particular stand may also be driven by immediate operational concerns associated with the current harvesting entry, such as forest health and harvesting costs. Yet, designing an effective long-term silvicultural systems strategy to meet several targets, including those for timber, is a challenge. Mitchell and Beese (2001) suggest that partial cutting applications need to address the following questions to fully meet the intent of a silvicultural system as defined by Mathews (1989) and Smith (1997):

- Have the effects of the partial harvesting on the growth, yield and health of overstorey trees been evaluated?
- Have yield expectations and target stand projections been adjusted for the expected health and vigour of the future stand?

To assist with long-term planning, it is helpful to model stand development to ensure that expectations for sustainability of identified criteria, such as biodiversity targets and timber yield targets, can be met over time. Stand-level computer models such as Prognosis^{BC} can help narrow the range of management options and provide feedback for planning. Prognosis ^{BC} is the result of efforts to calibrate the North Idaho Forest Vegetation Simulator (FVS) for British Columbia. Calibration of Prognosis ^{BC} continues as each underlying growth and mortality relationship in the model is revisited and the size and shape of each relationship is reestimated. Calibration of a growth model is an iterative process and will be refined as more data become available. The current version of the model is intended for foresters who develop prescriptions in the Interior Douglas-fir (IDF), ICH, Montane Spruce (MS), and Engelmann Spruce-Subalpine Fir (ESSF) biogeoclimatic zones in the southern Interior of British Columbia. Prognosis ^{BC} can be downloaded at https://www.for.gov.bc.ca/research/gymodels/progbc. The site also includes a self-guided tutorial and directions to the online help service. The tutorial usually takes 3-5 hours to complete. Using Prognosis ^{BC} with the Stand Visualization System (SVS) (McGaughey 1997) graphically depicts the stands that the user is manipulating over time. This allows the user to actually see the choices that Prognosis ^{BC} is making using the inputs provided and the assumptions and constraints built into the model.

The objective of this extension note is to familiarize the reader with the stand-level model Prognosis^{BC} and demonstrate and evaluate the model output using real stand examples. Stand development pathways are described using the model (version 2.0; B.C. Ministry of Forests 2000) for five silvicultural systems options in one stand type in the ICH dry warm biogeoclimatic subzone (ICHdw) in the West Arm Demonstration Forest.

SITE AND STAND DESCRIPTION

Starting in 1990, five blocks in the Kokanee Creek drainage of the West Arm Demonstration Forest were harvested to demonstrate a variety of partial cuts (Figure 1). Tree data from each of these blocks was used for the Prognosis ^{BC} runs of future harvesting options.

Site characteristics		**Preharvest stand characteristics (1999)**	
Ecological classification:	ICHdw - 01 (02)	Species composition:	Fd-60% Py-15%
Slope:	Predominantly 20 to 55%		(Cw, Bg, Pl, Lw)-25%
Elevation:	720 to 870 m	Volume:	280 to -430 m^3 /ha
Aspect:	S to SW	Basal area:	30 to 47 m^2 /ha
Soil:	Mor (Moder)/sandy loam, some shallow to bedrock	Age:	90 years

Figure 1. Overview of the five blocks in the West Arm Demonstration Forest.

STAND LEVEL TARGETS

To evaluate the relative success of each of the blocks in meeting required targets over time, targets must be measurable. For this extension note, the following hypothetical stand-level targets are described and used for comparison.

Biodiversity Targets

Historically, natural disturbances in dry south-facing slopes of the ICHdw created a natural mix of age classes, with veteran trees in both young and older stands (Quesnel and Pinnell 2000). These biological legacies are therefore desired after harvesting in all stands of all ages across the landscape.

- Harvesting should leave approximately 27 stems/ha, or 5.2 m ^{2} /ha of basal area, of wildlife trees (Class 2 or higher, with defect or evidence of decay and diameter at breast height [dbh] > 40 cm). Where such trees do not exist, the target will be to develop them by the last third of the rotation.

Visual Targets

Harvesting should maintain or enhance natural forested views along the road, which is the main access route to Kokanee Glacier

Provincial Park.[1]

- Harvesting disturbance may be noticeable, but only minor within the stand. Vertical structural diversity, species diversity, and small, irregular openings are desired to allow the effects of harvesting to appear more natural.

Old-growth Targets

Due to the lack of old growth in the ICHdw, a third target is to recruit future old-growth stands. Based on Holt et al. (1999), the following targets were set over the rotation to recruit old growth:

- A normal distribution of trees from 50 to 75 cm dbh.
- A residual basal area of 19 to 20 m^2 /ha.
- A minimum of 64 stems/ha at 50 cm dbh (including snags).
- The largest tree will be 70 cm dbh (including snags).
- A minimum of 69 stems/ha of snags (Class 3 or higher) at 25 cm dbh.

Timber Targets

Over the rotation, partial-cutting options are anticipated to provide less volume than from clearcutting. This reduction is acceptable due to sustainability targets. Yet it is important to consider that no volume may be available if the only options were either clearcutting or no harvesting.


Figure 2. View of Block 2.

Harvested volume cannot be reduced by more than 20% over the rotation (100 years) relative to a clearcut prescription, while still meeting sustainability targets. Further reductions in volume will be acceptable if they are offset by increases in timber values.

Partial-cutting Options

Six different partial-cutting options were analyzed using the five stands. A clearcut system was used as the bench mark for comparison of volume and value outputs over time. The current stands are used as the starting point for developing future harvesting options, each of which has been recently partially harvested (Table 1).

A number of future harvesting options were used as model runs (Table 2). For Prognosis^{BC} to analyze these options, they needed to be non-spatial uniform treatments, rather than treatments that harvested or retained trees in groups or strips.[2] Where multiple entries were used, future entries were timed to try to take advantage of peaks in the production of mean annual increment. Stand tables (species by diameter classes) projected by Prognosis^{BC} at 10-year intervals were used to determine future harvesting levels, target species, and diameter classes for the analyzed harvesting options.[3] Reasonable reductions for harvesting damage mortality were also included.

Table 1. *Block descriptions and model run choices.*

Harvesting Options	Block History	Description of future entries
Option 1 (using Block 1) Single tree selection with	- Harvested in 1998 reducing basal area by 50% to **24 m^2 /ha** . - Marking preference was for Py, Fd, and Lw with all Pl removed.	- **Harvest entry every 20 years (volume cut 1st entry - 130 m^3/ha; 2nd entry - 56 m^3/ha; 3rd entry - 80 m^3/ha; 4th entry - 74 m^3/ha).** - **Residual basal area goal = 18-20 m^2/ha (q-distribution factor = 1.2).**

entries every 20 years.		• Maximum diameter target = 67.5 cm dbh (with some holdover volume). • Objective - promote new regeneration, as well as growth of all size classes in every entry.
Option 2 (using Block 1 Heavy shelterwood with future crown thinnings.	• Harvested in 1998 reducing basal area by 50% to **24 m^2/ha**. • Marking preference was for Py, Fd, and Lw with all Pl removed.	• **Crown thinning in 2059 (volume cut - 207 m^3/ha).** • **Residual basal area = 27 m^2/ha (60% of basal area in 2059).** • Objective - reduce competition between main canopy trees (dominants and codominants). Lower canopy trees are not cut, and may be released.
Option 3 (using Block 2) Shelterwood favouring cedar and grand fir.	• Harvested in 1990, thinned "from below" to **24 m^2/ha** , leaving all stems >30 cm and removing all remaining Py, Pl, and Hw	• **Regeneration cut in 2029 (volume cut).** • **Residual basal area = 19 m^2/ha (60% of basal area in 2059).** • Objective - reduce competition between main canopy trees and open up stand to allow for regeneration and subsequent growth of the next cohort.
Option 4 (using Block 3) Heavy shelterwood with future low thinnings.	• Harvested in 1998 leaving **22 m^2/ha** of mostly Fd and Py.	• **Low thinning in 2049 (volume cut - 35 m^3/ha).** • **Residual basal area = 27 m^2/ha (60% of basal area in 2059).** • Objective - reduce competition by removing all less vigorous lower and mid-canopy trees (in this case, all trees < 40 cm dbh).
Option 5 (using Block 4) Light shelterwood with no future entries.	• Harvested in 1998 leaving **15 m^2/ha** of mostly Fd and Py.	• **Clearcut 2099.** • Objective - leave overstorey stocking until end of rotation to meet non-timber management objectives.
Option 6 (using Block 5) Clearcut with reserves with no future entries.	• Harvested in 1996, retaining **5 m^2/ha** mostly in Py.	• **No future entries until 2099.** • Objective - leave overstorey stocking until end of rotation to meet non-timber management objectives.

RESULTS

Success with Targets

Most options met the targets if developed over the entire rotation with growth functions and mortality assumptions built into Prognosis^{BC}. The model showed mortality for both competition and age at what appeared to be acceptable rates.

Option 6 (clearcut with reserves; Table 3) has the greatest difficulty in meeting visual goals, but meets the habitat and old-growth goals fairly well considering the relatively few biological legacies held over into the next rotation. Option 2 (shelterwood with future crown thinning; Table 3) appears to miss the target for old-growth after the crown thinning. However, this is related to the inability to select specific leave trees with Prognosis ^{BC} beyond diameter and species[5].

A major limitation to meeting the biodiversity and old growth targets with Prognosis^{BC} is the uniform manner in which treatments are applied. Targets for old growth and biodiversity can generally be met if intact clumps or groups are retained within the stand to augment the recruitment of large trees and snags through the rotation.

Meeting Timber Targets

Because a number of partial-cutting options appear to meet the non-timber targets in this example, the timber target becomes useful in narrowing potential options. Prognosis^{BC} projections were used to help assess success in meeting the timber target. Total harvested volume and values from these projections were compared with a standard clearcut projection for the same stand (Table 2). Timber values were assessed according to the following rough assumptions:

1. All blocks had the same starting volume before being harvested.
2. Larger sawlogs will have a higher net value than smaller sawlogs. [4] A 20% increase in value will be assigned for timber > 40 cm dbh relative to timber < 40 cm dbh.
3. Western redcedar and white pine sawlogs will command values 20% higher than Douglas-fir, western larch, and yellow pine, while grand fir and western hemlock will command values 15% lower.
4. 50% of western redcedar in the 40-70 cm dbh class will be suitable as poles, commanding values 70% higher than Douglas-fir/western larch/yellow pine sawlogs.

Table 2. Total volume and relative value of total volume for the five partial-cutting options compared with clearcutting.

Harvesting options [a]	Total merch. volume (m^3/ha)[b]	% of clearcut volume 1999-2099	% of clearcut relative value, for 2099 + 1999 volume	Meets timber target
Clearcut for comparison	931	100	100	
1	710	76	91	Yes
2	705	76	92	Yes
3	568	61	75	No
4	526	56	66	No
5	683	73	72	No
6	793	85	83	Yes

a See Table 1 for descriptions of the harvesting options.

b Total merchantable (> 17.5 cm dbh, after decay, waste, and breakage) volume production over one rotation (100 years) is the sum of: the actual volume harvested in the first entry plus volume harvested in the modelled intermediate cuts between 1999 and 2099, and final standing volume in 2099 as projected by Prognosis^{BC} .

INTERPRETING OUTPUT

Table 3. *Ability of harvesting options to meet non-timber targets over a 100-year time frame, as simulated by Prognosis^{BC}.*

	Ratings to meet non-timber targets (see definitions below)		
Harvesting Options	**Biodiversity - high priority**	**Visuals - high priority**	**Old growth - secondary priority[5]**
Option 1 **(using Block 1)**	Can save wildlife trees assessed as safe. However, with the frequency of entries it is likely	Provides diversity and natural appearance.	Meets basal area goals and has a diverse structure, but there are too few larger trees and snags if

Single tree selection with entries every 20 years.	that few will stay beyond Class 4 unless a suitable no-work zone surrounds them.		the treatments were uniformly applied. This issue could be addressed by strategically leaving some clumps or groups intact.
Option 2 **(using Block 1)** Heavy shelterwood with future crown thinnings.	Can save wildlife trees assessed as safe. A well executed crown thinning [6] (difficult with Prognosis^{BC}) will focus on leaving vigorous overstorey trees, which could reduce snags. Marking can favour some large old trees, which may provide up to 50% of target requirements between 2079 and 2099. Strategic placement of several intact clumps or groups would meet targets for both large trees and snags.	Though considerably opened up in the overstorey in 2059, understorey layers assist aesthetic appearance.	Appears not to have enough larger trees after 2059, but this is a problem with Prognosis^{BC}. May get enough dead trees from competitive exclusion in the 25-45 cm dbh classes (2059-2099). Strategic placement of several intact clumps or groups would meet targets for both large trees and snags.
Option 3 **(using Block 2)** Shelterwood favouring cedar and grand fir.	Can save wildlife trees in 2029 assessed as safe. There is enough time to 2099 to develop wildlife trees, especially in the Douglas-fir and grand fir components. Could come close to target by 2069-2079. Prognosis^{BC} actually shows significant mortality between 2079 and 2099.	Though opened considerably in 2029, the deep crowns of the tolerant cedar and grand fir are very effective at modifying visuals.	Meets basal area goal. Likely enough larger trees. Prognosis^{BC} indicates significant mortality between 2079 and 2099 will probably produce enough snags.
Option 4 **(using Block 3)** Heavy shelterwood with future low thinnings.	Can save wildlife trees in 2049 assessed as safe. Since the emphasis is on retaining all trees over 40 cm, there is an abundance of large trees with potential to develop into wildlife trees, perhaps coming close to target by 2079.	The low thinning significantly opens the understorey, but the stand as a whole is not opened much more than in 1999.	Meets basal area goal. Comes close with the larger trees, but likely not enough of them would become snags if the treatment were applied uniformly across the stand. This issue could easily be addressed by strategically leaving some intact clumps or groups.
Option 5 **(using Block 4)** Light shelterwood with no future entries.	This approach can target enough safe wildlife trees in the first entry to suitably develop over time (as Prognosis^{BC} indicates with its mortality function).	The block will be quite open, but there is enough residual basal area to make it look quite natural.	Meets basal area goal. Likely there are enough snags, although this option provides only 50% of the target for large trees. This issue could be addressed by strategically leaving some intact clumps or groups.
Option 6 **(using Block 5)** Clearcut with reserves with no future entries.	Although barely enough basal area is left if proper wildlife trees are chosen, the target could be met by 2059.	The most open block (in 1999). Visuals will depend greatly on the block shape and the distribution and characteristics of leave trees. Larger cleared openings within the block must be made to look natural.	Meets basal area goal and has enough large trees (though most are at the margin of 50-60 cm dbh). Meets snag target but mostly in the smaller less valuable classes (25-40 cm dbh) through competitive exclusion. Overall structure not as diverse as others. Again, structural targets could be improved by

strategically leaving some
clumps or groups.

The following key points emerged from the modelling exercise:

1. For all acceptable harvesting options at least 64% of the timber volume occurred in stems > 40 cm dbh.

Options 1 and 2 had 68-69% of volume in stems > 40 cm dbh, while Option 6 had only 64% (but also had significantly higher volumes than Options 1 and 2). Option 3 had a higher proportion of volume in larger sawlog sizes (76%), but not enough total volume to become an acceptable option. Options 4 and 5 were significantly lower in their proportion of volume in larger sawlog sizes (Option 5 had only 17%).

2. The initial entry into a stand sets the stage for the future. Option 2 was much more successful than Option 4.

Higher levels of basal area left after the first entry allow for more harvesting options later. However, when a relatively high level of overstorey stocking is left, it will have a significant impact on growth of understorey stems and overall yield unless growth of the overstorey trees can compensate for this loss throughout the rotation. Old-growth trees in an overstorey canopy may not compensate well. A significant reduction in overstorey density may be required at some point in the rotation to stimulate growth and provide acceptable volume and value returns. Low thinning that removes understorey and intermediate canopy stems alone may not be sufficient.

3. Increased future timber value may compensate for volume reductions when comparing partial cutting options.

Only Option 6, the clearcut with reserves, achieved the timber targets based on volume alone with a 15% reduction in volume relative to clearcutting. Options 1 and 2 both produce uneven-aged to irregular stand structures at the end of the rotation. These options had a 24% reduction in volume but only a 9% reduction in value when compared with the clearcut option. Both of these options performed better than Option 6 (clearcut with reserves) for non-timber targets. However, Option 6 was still an acceptable option for nontimber targets and it would likely have lower harvesting costs when considered over all entries.

4. The value of the harvestable volume may have been underestimated due to potentially random selection of leave trees by Prognosis^{BC} .

One of the limitations of Prognosis^{BC} is that it harvests the stand based on dbh class and species, not based on quality.

Crown thinning removes trees of lower vigour that are competing with selected crop trees. Since it was not possible for Prognosis^{BC} to harvest trees based on percentage live crown and proximity to the best trees, Prognosis^{BC} often harvested more vigorous trees, or noncompetitors, based only on diameter. If more vigorous stems could have been favoured, the thinning response and subsequent value and perhaps total available volume may have been greater.

While no broad consensus exists regarding timber productivity losses due to partial cutting, some suggest that it may not be significant. Zingg (1997), based on 90 years of data collected in Switzerland, concluded similar volume and superior value production can be achieved in selection forests compared with even-aged forests. Kerr and O'Hara (2000) found little significant difference in the timber productivity of partial-cutting and clearcutting systems if the average leaf area index is comparable over a cutting cycle. Forty year data from Aleza Lake in northcentral British Columbia suggest similar results.[7]

5. Values in partially cut stands may have generally been underestimated due to the mechanics of Prognosis^{BC} .

Because of the non-spatial nature of Prognosis^{BC} , favouring a species like western redcedar over the rotation (to produce more poles) was difficult with single-tree selection and other options. Actual application of single-tree selection on the ground may favour clumps of western redcedar, which could develop into poles, thus further increasing the relative value further.

6. Harvestable volume and value in Option 3 may be acceptable, given the underestimations by Prognosis^{BC} due to assumptions for redcedar.

The assumptions for decay, waste, and breakage came from those generally used for this forest inventory zone. These assumptions, which are mostly based on old-growth stands, not stands manipulated to be more vigorous, may overestimate volume and value losses, especially for redcedar. Option 3, which had volume that was almost 40% less than a clearcut, only needed a slight increase in value to be an acceptable option. This option produced the highest proportion of volume > 40 cm dbh (76%), the greatest proportion of redcedar (46% of volume), and the greatest proportion of redcedar poles (19% of volume).

7. Some of the unacceptable options may become acceptable using approaches to marking and layout that Prognosis^{BC} cannot model.

Option 5 would have been acceptable had either volume or value been increased by 7-8%. This prescription could easily have been altered to clump the retention. This clumping would allow more light into the stand for prolonged periods to increase both volume and value in the understorey. This is also true for Option 3, which gradually transformed the stand from a typical mixed ICH type to one dominated by red cedar and grand fir and was opened up by a regeneration cut in 2029. Option 3 only needed a 5% increase in value to make it an acceptable option for the timber objectives. This increase could easily have been achieved with a slightly higher volume in redcedar poles or larger sawlogs. Unfortunately, being a non-spatial model, Prognosis ^{BC} cannot be adjusted to model strategically clumped retention.

8. Projected volumes and values did not consider potential losses to forest health agents like Armillaria root disease.

Because the Armillaria component of the model is still being developed, it was not used for this exercise. For this extension note, we assumed that the losses due to Armillaria would be proportionally equal across all treatments.

CONCLUSIONS

It appears that several partial-cutting options can be used to meet the targets of sustainability set in this exercise. While this analysis indicates that only three of the six options modelled can meet the timber targets, minor alterations to the prescription, some of which Prognosis ^{BC} cannot model, could make them acceptable. This exercise also points out the danger of trying to meet all targets in each stand. Each of the options modelled here has its own advantages under site-specific conditions. None of them met all targets optimally. Therefore, final stand-level decisions cannot be made without considering the landscape-level context, and the changes in that context over time.

Prognosis^{BC} can be useful in assisting foresters to develop complex prescriptions by projecting stand development over time and identifying possible tradeoffs between treatments. However, models do not supply ready-made solutions to complex management problems. The limitations of the model should be remembered, and output must be carefully scrutinized. Professional judgement is key.

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ENDNOTES

1 Kokenee Glacier Provincial Park is located along the north boundary of WADF.

2 Since Prognosis^{BC} is not able to model spatially explicit harvesting patterns, group or strip systems were not modelled, but may be equally valid.

3 Increment data were used to localize projections specifically to these stands and a customized conceptual regeneration model was built and implemented for this modelling exercise.

4 While it is unclear if the current price premium for large logs will continue given the trend towards using engineered wood products, it is assumed that small sawlogs will continue to carry significantly higher costs.

5 The old-growth target is mostly a landscape concern, becoming a secondary priority at the stand level next to the other targets, including timber. Therefore, it is important to identify and use some options that meet the old-growth objective in some portions of the landscape.

[6] A well-executed crown thinning can be difficult to depict properly with Prognosis^{BC}. The model cannot be instructed to cut better formed trees. It will cut trees randomly.

[7] Mike Jull, Silviculture Systems Ecologist, University of Northern B.C., Prince George., personal communication, spring 2000.

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