

UBC Social, Ecological Economic Development Studies (SEEDS) Student Reports

**Malcolm Knapp Research Forest Carbon Neutral Business and Management Plans**

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carbon**neutral**

# Businesss Plan

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## Executive Summary

The purpose of this business plan is to maximize profit from carbon management. The Malcolm Knapp Research Forest located in Maple Ridge, British Columbia, is owned by the University of British Columbia.

Paul Lawson is the forest manager and the dilemma he is facing is the lack of revenue being generated. Carbon Neutral has proposed three scenarios to help sequester carbon which can be sold as carbon offsets to generate profit.

The business plan will focus on the best case scenario and the scenario that is preferred by our client. The best case scenario involves intensive silviculture practices. Fertilization and select seeds will be used to accomplish this scenario. Planting red alder is the scenario that our client would like to know more about.

Each scenario will be explained in detail and cost breakdowns are included. The cost breakdowns include silviculture costs, harvesting costs, and revenue. The best case scenario has potential for further research and refined management strategies.



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## 1.0 Introduction

### 1.1 Key Objectives

A key objective in planting red alder is to maximize profit in the Malcolm Knapp Research Forest. The amount of carbon credit that becomes available from planting can be used to help offset any carbon emission needs for the University of British Columbia by 2012. Based on the Pacific Carbon Trust guidelines, the remaining amount of credits can be sold to provincial buyers who need to offset emissions required by government regulations. The merchantable value of red alder can also produce a product line of furniture and flooring to generate and increase profit.

### 1.2 Business Description

Malcolm Knapp Research Forest was granted to UBC from the Crown and was established in 1949. It consists of 5,157 hectares and is located at the base of the Coast Mountains in the community of Maple Ridge about 60 kilometers east of Vancouver, British Columbia. The forest falls into the Coast Western Hemlock (CWH) biogeoclimatic zone with the lower and upper halves consisting of the dry maritime (dm) subzone and very wet maritime (vm) subzone respectively. Due to the influence of the Pacific Ocean, Malcolm Knapp Research Forest receives the majority of precipitation in the winter from the southern and northern end. We can take advantage of the abundance of precipitation by planting red alder in sites with an index of 7 as a reforestation species in the research forest. Since red alder is known for its high levels of carbon sequestration and fast growing characteristics, its merchantable value can be used to produce a product line of furniture and flooring to generate revenue for the forest. Moreover, the high level of carbon sequestration can offset and fulfill the regulation of being “carbon neutral” at the University of British Columbia by 2012. Any remaining amount of carbon credits can then be sold to the buyers in the market to maximize profit in the future.

### 1.3 Carbon –Pacific Carbon Trust

Carbon Neutral has selected to follow Pacific Carbon Trust (PCT) standards to account for the carbon credits stored in MKRF. UBC wants to become carbon neutral by 2012 and to reduce greenhouse gas (GHG) emissions by 33% below 2007 levels by 2020. PCT standards focus on afforestation, select seed use, and fertilization projects to help reach this goal. PCT standards will address the type of project, the duration of the project, eligible project areas and identify geographic boundaries, identification and measurement of GHG, the level of flexibility, and how real reductions will be achieved. The quantification of project reduction is the result of emission reduction and removal enhancement minus discount. Also, we must take into consideration leakage in carbon emissions. Along with PCT standards, the management plan must include third party assurance.



## 1.4 Scenario description

Due to our client's request, Carbon Neutral will focus on Scenario A: converting desirable landscapes to red alder for this business plan. Also, Carbon Neutral has focused its attention upon Scenario B: applying intensive silviculture to the upper portion of MKRF to satisfy the demand of offsetting carbon credits.

In Scenario A, red alder will be the dominant species composing of 85% mixed with 15% of western red cedar. Red alder will be planted densely at 3000 stems/ha and will be pre-commercially thinned at age 15 to 1500 stems/ha. By doing so, we allow red alder to produce high quality wood with a low knot ratio. By incorporating western red cedar species, Carbon Neutral has addressed the concerns from the Katzie First Nation.

In Scenario B, intensive silviculture will be applied to the upper half of the forest due to its low productivity. Because 30% of the upper half of MKRF has steep slopes and mountainous areas, aerial fertilization will be applied throughout the entire upper portion of the forest as the easier alternative. Not only will fertilization occur, but select seeds, purchased from reliable nurseries, will also be planted in areas where BAU harvesting activities have occurred.

## 2.0 Market Strategy

### 2.1 Timber Market Value Trends

Since 1996, the Canadian lumber industry has experienced many trade and economic challenges causing the Canadian timber market value to plunge (Dufour, 2009). The following are all factors contributing to the current epidemic in the Canadian lumber industry:

- The 1996-2001 Canada-United States Softwood Lumber Agreement
- Increasing energy and raw material prices
- An increase in the Canadian dollar
- Stiffer competition on international markets
- Production overcapacity in the industry
- The American anti-dumping and countervailing duties imposed on lumber exports to the United States from 2002 to 2006
- Decrease in American housing starts

The current condition of the Canadian lumber industry shows brighter prospects (Bater and Lahart, 2010) with the increased U.S. residential construction. However, recovery of the forest industry seems moderate given the constant increase of the Canadian dollar compared to the American dollar. Because "the Canadian lumber industry is largely dependent on its exports to ... the United States (Dufour, 2009)", data from Statistics Canada shows that the Canadian

lumber industry is experiencing “slowdown of Canadian exports to the United States (Dufour, 2009)” as shown in Figure 1 below. Sales of Canadian lumber are negotiated with the Americans in US dollars, but the Canadian lumber industry cannot raise lumber prices to offset the costs of the exchange rate (Dufour, 2009).

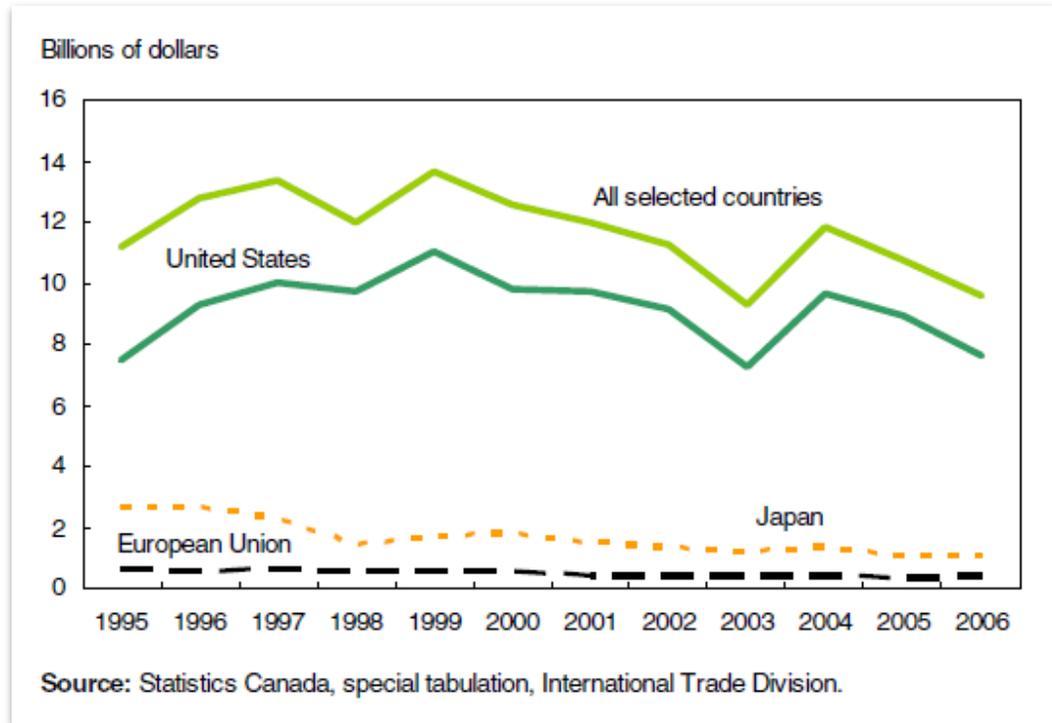


Figure 1: Slowdown of Canadian Exports to the United States (Dufour, 2009)

## 2.2 Current Opportunities

The Malcolm Knapp Research Forest is currently providing a fraction of their timber to the Gallant Enterprises. Gallant Enterprises is a private Canadian company specializing in cutting specialty value added materials (Malcolm Knapp Research Forest, 2010). They manufacture the following:

- Trusses and decorative arches
- Custom specialty products
- Decking and flooring
- Hand peeled poles
- Split rail fencing
- Custom planning
- Custom timbers
- Siding



Special features to their services consist of no minimum orders and arranged delivery (Gallant Enterprises, 2008). In addition, they are also able to source customer orders that are currently not in stock (Gallant Enterprises, 2008).

### **2.3 Competitive Advantage**

The current species composition within MKRF consists of Douglas fir, western red cedar, western hemlock and very little deciduous species such as red alder, black cottonwood and big leaf maple. All the coniferous species are used significantly for structural purposes within residential, light commercial, multi story and industrial construction (Bear Creek Lumber, 2010). Each coniferous species have their relative characteristics, making them advantageous as specialty lumber products. On top of the advantages taken from the Bear Creek Lumber website listed in Table 1 below, the lumber is also sustainably grown (Gallant Enterprises, 2008, para 2).



Table 1: Advantages and uses of tree species in MKRF

Species	Characteristics	General Uses
Douglas fir	<ul style="list-style-type: none"> <li>• Dimensionally stable</li> <li>• Superior strength to weight ratio</li> <li>• High specific gravity – excellent nail and plate-holding ability</li> <li>• Superior performance against natural forces (winds, storms and earthquakes)</li> <li>• Highest modulus of elasticity of North American Softwood Species: ratio amount of a piece of lumber that will deflect in proportion to applied load</li> <li>• High degree of stiffness- important for the design of floors and other systems</li> <li>• High ratings in physical working properties such as bending, tension parallel to grain, horizontal sheer, compression perpendicular to grain and compression parallel to grain</li> <li>• Durability of heartwood</li> <li>• Tight knotted and close grained</li> </ul>	<p>Framing lumber in residential, light commercial, multi story and industrial construction</p>
Western Red Cedar	<ul style="list-style-type: none"> <li>• Fine, even grain flexibility and strength in proportion to weight</li> <li>• High impermeability to liquids</li> <li>• Natural phenol preservatives</li> <li>• High thermal insulation due to cellular composition</li> <li>• Slow growth causing dense fibers, with natural oily extractives →decay resistance</li> <li>• Rich coloring</li> </ul>	<p>Suited for exterior and interior use with high humidity</p>



<p style="text-align: center;">Hemlock</p>	<ul style="list-style-type: none"> <li>• Excellent in form and function</li> <li>• Air-dried wood is stable- little tendency to cup, check or twist</li> <li>• Uniform coloring</li> <li>• Excellent gluing properties make it ideally suited to finger jointing, edge veneering and laminating</li> <li>• Light in weight and moderate in strength, moderate in hardness, stiffness, and shock resistance</li> <li>• Tendency to split when nailed</li> <li>• Fine straight grain with little difference between heartwood and sapwood</li> <li>• Satisfactory with respect to being glued and in taking stains, polish, varnish and paint</li> </ul>	<p>Used as doors, windows, staircases, louvered cabinets, moldings, spindles and paneling</p>
<p style="text-align: center;">Red Alder</p>	<ul style="list-style-type: none"> <li>• Fast growing species</li> <li>• Fine grained</li> <li>• Shorter harvest rotations (Hibbs, 2005)</li> <li>• wood pore size does not vary (Harrington, 1984, page 4)</li> <li>• moderately light and soft (Harrington, 1984, page 1)</li> <li>• excellent turning and polishing characteristics (Harrington, 1984, page 1)</li> <li>• works well with glue, paint (Harrington, 1984, page 1)</li> <li>• stain well (Harrington, 1984, page 1)</li> </ul>	<p>modern - furniture, flooring, firewood (Interactive Broadcasting Corporation, 2010, Uses Section, para 1)</p> <p>traditional - bark: dying basket material, fish nets, wood, wool, feathers as well as human hair and skin (colours ranged from black and brown to orangey-red; inner bark sometimes used for food; wood: carving bowls, spoons and platters, smoking meat, firewood (Interactive Broadcasting Corporation, 2010, Uses Section, para 1)</p>



## 2.4 Target Market

### 2.4.1 Scenario A: Alder

For this scenario, Carbon Neutral has focused on value added products such as furniture that will be produced in MKRF mill. The desirable target market for this product line is for homeowners and higher end consumers. In addition, about 20% of the lumber that is incapable of furniture manufacturing can be exported for pulp and paper markets.

### 2.4.2 Scenario B: Intensive silviculture

In this scenario, Carbon Neutral will propose the business-as-usual approach. Since the timber is currently distributed to companies with growing markets, this business plan will not take into account the lumber breakdown. Given that this scenario generated the greatest additionality as described in the management plan, potential target markets could include big manufacturing companies or simply any companies that are emitting high carbon emissions.

## 3.0 Financials

### 3.1 Scenario A: Alder Plantation Cash Flow Analysis

Table 2 below, shows clearly that although Scenario A is generating a positive net cash flow at the end of each year, the amount that is retained each year is decreasing linearly as shown in Graph 1. There were several assumptions made throughout the course of creating this summary table below, most of which will be found within the relative breakdown of each component of this summary in Appendix A.

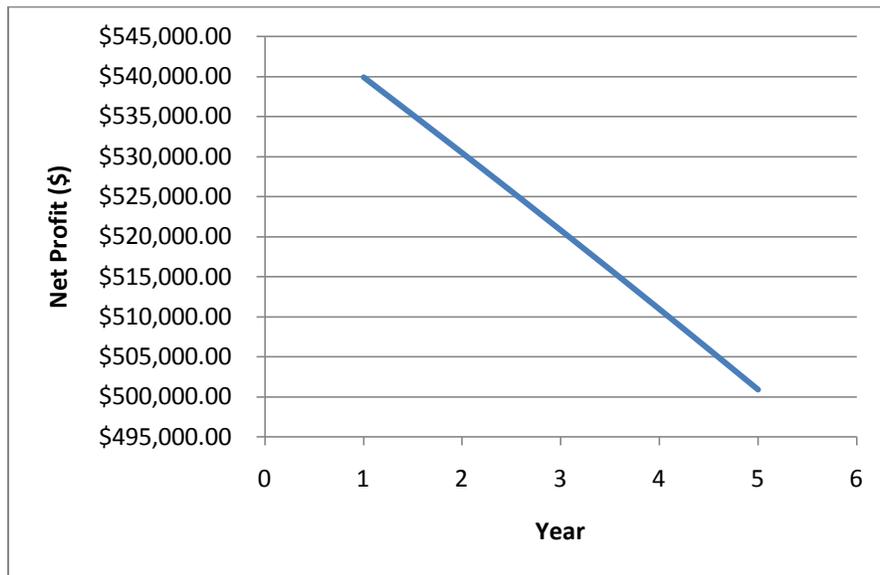
A few assumptions are worth mentioning immediately. Silvicultural costs will not be increasing throughout the 5 year period. Harvesting costs are estimated to escalate at a rate of 2% annually. Profit and risk is set at 10% of the sum of all cost, which includes total silvicultural costs and total harvesting costs. The amount set aside for profit and risk will ideally be able to cover for the fluctuations in total costs and the timber market value of the logs being removed.

One of the main components that have affected the financial results of this scenario is likely due to the negative revenue generated from carbon sequestration. As a reminder, based on the modeling performed in the management plan, Scenario A- Alder Plantation generated the least amount of additionality compared to the other 2 scenarios including the base case. Simply put, because this scenario is not generating any carbon sequestration and may possibly be adding to the carbon emissions, the purchase of carbon credits may be necessary. Therefore, instead of generating revenue, the carbon credits have become a potential cost.



	Year 1	Year 2	Year 3	Year 4	Year 5
Total Silvicultural Costs	\$ 224,443.27	\$ 224,443.27	\$ 224,443.27	\$ 224,443.27	\$ 224,443.27
Total Harvesting Costs	\$ 430,124.93	\$ 438,727.43	\$ 447,501.98	\$ 456,452.02	\$ 465,581.06
Grand Total (Cost)	\$ 654,568.20	\$ 663,170.70	\$ 671,945.25	\$ 680,895.29	\$ 690,024.33
Profit and Risk at 10%	\$ 65,456.82	\$ 66,317.07	\$ 67,194.52	\$ 68,089.53	\$ 69,002.43
Sum of All Costs	\$ 720,025.02	\$ 729,487.77	\$ 739,139.77	\$ 748,984.82	\$ 759,026.76
Potential Income	\$ 1,259,949.71	\$ 1,259,949.71	\$ 1,259,949.71	\$ 1,259,949.71	\$ 1,259,949.71
Net Loss or Net Profit	\$ 539,924.69	\$ 530,461.94	\$ 520,809.94	\$ 510,964.90	\$ 500,922.95

Table 2. Summary of the Cash Flow (Alder Plantation Scenario)



Graph 1. Cash Flow Over a Period of 5 Years: Conversion to Alder Plantations

### 3.2 Scenario B: Intensive Silviculture Cash Flow Analysis

Unlike the previous scenario, Table 3 demonstrates that Scenario B – Intensive Silviculture is generating a constant net cash flow (Graph 2). Again, there are many assumptions made throughout the course of generating this summary table, most of which can be found in Appendix B.

One factor worth noticing is that within the cost component of the summary, Scenario B only incorporates the total silviculture costs as the expenses required to implement the scenario. Because of the assumption that there is no additional harvesting performed besides from the business as usual harvesting activities, there will be no harvesting costs involved. Again, business as usual for MKRF refers to the break-even situation where the total costs and total revenues

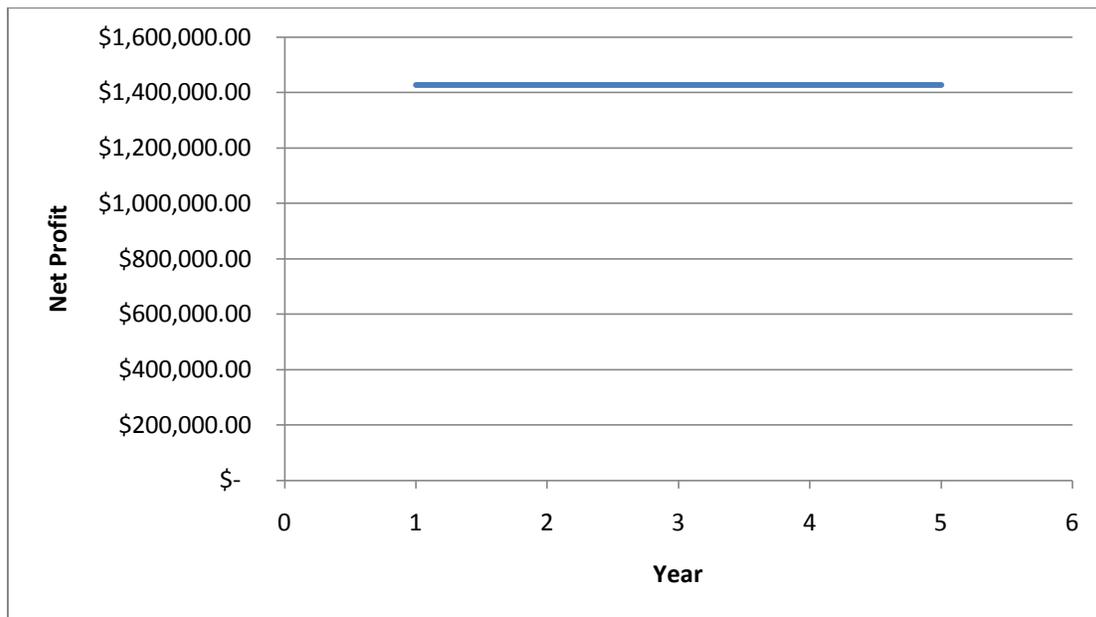


are balanced. With the assumption that there will not be any fluctuations in silvicultural costs and that the break-even situation continues throughout the course of the 5 years, these results are valid. Profit and risk is set at 10% of the total costs. The cost accounted for profit and risk will ideally be able to cushion any fluctuations in costs if it does occur.

One major component allowing Scenario B – Intensive Silviculture to exceed the net profit generated from Scenario A – Alder Plantation is the carbon revenue. From the modeling performed within the management plan, this scenario is able to sequester a massive amount of carbon. Unlike Scenario A, additionality is created. Instead of generating a net cost, carbon sequestration is generating a net profit for this scenario.

	Year 1	Year 2	Year 3	Year 4	Year 5
Total Silvicultural Costs	\$ 105,276.60	\$ 105,276.60	\$ 105,276.60	\$ 105,276.60	\$ 105,276.60
Profit and Risk at 10%	\$ 10,527.66	\$ 10,527.66	\$ 10,527.66	\$ 10,527.66	\$ 10,527.66
Sum of All Costs	\$ 115,804.26	\$ 115,804.26	\$ 115,804.26	\$ 115,804.26	\$ 115,804.26
Potential income	\$ 1,543,580.00	\$ 1,543,580.00	\$ 1,543,580.00	\$ 1,543,580.00	\$ 1,543,580.00
Net Loss or Net Profit	\$ 1,427,775.74	\$ 1,427,775.74	\$ 1,427,775.74	\$ 1,427,775.74	\$ 1,427,775.74

Table 3. Summary of Cash Flow (Intensive Silviculture Scenario)



Graph 2. Cash Flow Over a 5 Year Period: Intensive Silviculture



## 4.0 Scenario Analysis

### 4.1 Scenario A: Alder

Once a tree has been harvested, the tree can no longer store additional carbon and slowly releases carbon back into the environment as the wood decays. To promote continued carbon sequestration after harvesting, a proposed sequestration method consists of transferring harvested timber into solid wood products for use as furniture. As such, planting red alder from the bottom of the Malcolm Knapp Research Forest has been determined to be the main source of carbon sequestration for Scenario A. Since timber is well preserved especially in furniture applications, the wood product can function as a carbon reservoir and help mitigate problems of future climate change. Sequestered carbon stored in furniture is held for the duration of the product's lifetime and is prevented from being released into the atmosphere through decay. Furthermore, timber can be recycled for other uses such as paper products or stored in landfills to store carbon in a longer period of time.(Planet Friendly Canada, 2009). As long as timber is not combusted or decay naturally, the end goal of storing carbon using various wood products such as furniture can be achieved. To help visualize the scale and importance of furniture wood products, roughly 25 to 40 percent of carbon harvested in BC is stored for long periods of time in wood products for domestic use only (Government of B.C., 2009).

### 4.2 Scenario B: Intensive Silviculture

The following intensive silviculture treatment scenario produces the highest carbon storage. Analyzing areas within Malcolm Knapp Research Forest, the upper portion of the forest in the vm subzone is less productive and requires fertilization to promote faster and better growth. Accelerated tree growth resulting from increased fertilization will allow trees to sequester additional carbon in shorter time periods while creating the potential to generate added revenue. After the business as usual harvesting activities are performed, selected seeds will be planted to further sustain and facilitate accelerated growth. Overall, the prescribed silviculture treatments are an effective solution to promote accelerated tree growth within non-productive areas and sequester additional carbon within a shorter time frame.

## 5.0 Recommendations

Between the two scenarios that Carbon Neutral has proposed for this business plan, Carbon Neutral is strongly suggesting the intensive silviculture approach to satisfy our objective. Because Scenario B offers business as usual level of harvesting, the amount of revenue that is currently generated from harvesting will not be diminished. Also, this scenario is able to offer the greatest amount of carbon additionality which will generate revenue from the carbon



markets. Applying intensive silviculture to harvested land base allows more carbon sequestration and generates more revenue for MKRF.



## Appendix A. Financial Breakdown of Scenario A – Alder Plantation

### Detailed Summary of the Financial Costs Required

Table 4. Breakdown of the Silvicultural Costs

	Seedling Cost (\$/seed)	Planting Cost (\$/seed)	Total Cost (\$/seed)	Density (seed/ha)	Cost/ha	Total Cost for Year 1
Stock Type - PSB 415D 1+0	\$ 0.38	\$ 0.50	\$ 0.88	3000	\$ 2,640.00	\$ 75,504.00
Site Prep - excavator (slash rake)					\$ 4,666.67	\$ 133,466.67
brushing - manual					\$ 541.00	\$ 15,472.60
Total Silvicultural Costs						\$ 224,443.27

#### Assumptions:

- The stock type – PSB 415D 1 + 0 will be purchased from nurseries.
- The elevation of MKRF is relatively flat in the lower half of the forest which will facilitate the usage of an excavator to remove excessive slash present on the surface.
- There is excessive slash present after the harvesting process that an excavator is required.
- The excavator will induce the minimal amount of soil disturbance.
- Because of the alder are being replanted in high densities, there will be little opportunity for shrubs to out compete the alder plantation.
- Little competition for shade and the assumption that small areas will be converted at a time will make manual brushing an ideal method to remove competition if necessary.
- Manual brushing cost is retrieved from an Abstract of the Book *Manual Brushing for Forest Vegetation Management in British Columbia : A Review of Current Knowledge and Information Needs*.
- Manual brushing cost is up to date
- All other costs are obtained from the forestry 305 course website.



*Table 5. Breakdown of the Harvesting Costs*

	Productivity (m <sup>3</sup> /day)	Pay Rate (\$/hour)	Daily Pay (\$/day)	Number of Days	Total
Falling (including powersaw costs)	120	\$ 45.09	\$ 360.72	238	\$ 85,971.60
Supported Grapple Skidder*	300	\$ 120.00	\$ 960.00	95	\$ 91,520.00
Hoe Chucking**	300	\$ 175.00	\$ 1,400.00	95	\$ 133,466.67
Logging Trucks	240	\$ 125.00	\$ 1,000.00	119	\$ 119,166.67
Stumpage (\$/m <sup>3</sup> )		\$ -			\$ -
<b>Total Harvesting Costs</b>					<b>\$ 430,124.93</b>

**Assumptions:**

- No old growth trees, due to forest fires, will be within the areas of harvest
- Productivity rates is based on secondary growth forests.
- Falling productivity rates and pay rates are obtained from the Coastal Appraisal Manual and the costal union rates of the BC Ministry of Forest.
- Productivity rates and pay rates for supported grapple skidder, hoe chucking and logging trucks are all obtained through the current rates that MKRF are provided.
- Everyone will be working 8 hour shifts excluding machine downtime.
- No stumpage because MKRF is crown land.
- Road densities are ideal for supported grapple skidders
- Hoe chucking and supported grapple skidder combination will increase productivity rate
- Hauling trucks are assumed to be able to haul 48 cubic metres per load at 4 -6 loads per day giving an average of 5 loads per day



## Detailed Summary of the Revenue Generated

*Table 6. Breakdown of Average Log Prices*

Species	Marketable Grades															Average Log Price (\$)
	B	C	D	E	F	G	H	I	J	K	L	M	U	X	Y	
Cw			\$247.13		\$201.97		\$153.34	\$103.07	\$121.35	\$149.91	\$110.42	\$ 72.95	\$ 49.44	\$ 37.52	\$ 4.18	\$ 113.75
Fd	\$ 184.81	\$125.33	\$371.33		\$256.57		\$115.96	\$ 70.77	\$ 55.01				\$ 41.65	\$ 29.59	\$ 29.87	\$ 128.09
Hemba			\$122.72		\$104.68		\$ 63.40	\$ 45.88	\$ 43.84				\$ 41.09	\$ 42.14	\$ 39.60	\$ 62.92

### Assumptions

- The distribution of the different grades obtained from the harvested timber is relatively even therefore an average of the log prices was taken
- Information of the grade values are obtained off the Log Market Reports for Coastal timber of the BC government website
- There is no balsam in the area of interest therefore the grade values shown above for hemba are solely for Western hemlock.

*Table 7. Breakdown of the Revenue Generated from Removing the Existing Timber*

Tree Species	Average Market Value (\$/m <sup>3</sup> )	Composition Percentage	Volume (m <sup>3</sup> )	Total Revenue (\$)
Cw	\$ 113.75	29%	8294	\$ 943,465.12
Fd	\$ 128.09	26%	7436	\$ 952,469.80
Hemlock	\$ 62.92	43%	12298	\$ 773,774.79
Alder		2%	572	\$ -
Grand Total			28600	\$ 2,669,709.71



*Table 8. Summary of the Revenue Generated from the Carbon Sequestration*

Potential revenue for carbon		
Carbon Cost (\$/tonnes)	Tonne of CO <sub>2</sub> e	Total Revenue (\$)
\$ 10.00	-140976	-\$ 1,409,760.00

**Assumptions**

- Carbon can be sold at \$10.00 per tonne



## Appendix B. Financial Breakdown of Scenario B – Intensive Silviculture

Table 9. Breakdown of the Silvicultural Costs

	Seedling Cost (\$/seed)	Planting Cost (\$/seed)	Total Cost (\$/seed)	Density (seed/ha)	Cost/ha (\$/ha)	Total (\$)
Stock Type - PSB 415D 1+0	\$ 0.38	\$ 0.50	\$ 0.88	3000	\$ 2,640.00	\$ 75,504.00
fertilization					\$ 500.00	\$ 14,300.00
brushing - manual					\$ 541.00	\$ 15,472.60
Total						\$ 105,276.60

### Assumptions:

- The stock type – PSB 415D 1 + 0 will be purchased from nurseries.
- Business as usual, therefore costs are only referring to the select seed replantation, fertilization and monitoring components.
- Fertilization costs includes the cost of fertilizer and labour costs.
- Replanting at high densities, there will be little opportunity for shrubs to out compete the alder plantation.
- Little competition for shade and the assumption that small areas will be converted at a time will make manual brushing an ideal method to remove competition if necessary.
- Manual brushing cost is retrieved from an Abstract of the Book *Manual Brushing for Forest Vegetation Management in British Columbia : A Review of Current Knowledge and Information Needs*.
- *Manual brushing cost is up to date.*
- All other costs are obtained from the forestry 305 course website.

Table 10. Summary of the Revenue Generated from the Carbon Sequestration

Potential revenue for carbon		
Carbon Cost (\$/tonnes)	Tonne of CO <sub>2</sub> e	Total Revenue (\$)
\$ 10.00	154358	\$ 1,543,580.00

### Assumptions

- Carbon can be sold at \$10.00 per tonne



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carbonneutral

# Malcolm Knapp Research Forest Management Plan

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## Executive Summary

The main focus of this management plan is for Malcolm Knapp Research Forest, where Paul Lawson is the forest manager. Currently, there is a lack of revenue in the forest due to the low prices of timber. Carbon is an alternative that will be explored as a new source of revenue. Carbon Neutral has set out to neutralize University of British Columbia's carbon emissions. We analyzed the different values that include social, economic, and environmental and applied these to several scenarios. Two of the three scenarios are focused upon adjusting what is currently available, and shows potential carbon storage. The third scenario converts a large portion of the area into alder which will increase carbon sequestration due to its fast growing nature. The framework described in each scenario will allow Malcolm Knapp Research Forest and the University of British Columbia to sustain forests while reducing carbon emissions.



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## 1.0 Introduction

### 1.1 The Historic and Cultural Overview of Malcolm Knapp Research Forest

Nestled at the base of the Coast Mountains, Malcolm Knapp Research Forest (MKRF) lies in the heart of Maple Ridge, British Columbia (B.C.). The biogeoclimatic zone that the research forest falls into is the Coast Western Hemlock zone. The upper half of the forest falls under the dry maritime subzone category and the lower half of the forest falls under the wet maritime subzone category (Malcolm Knapp Research Forest, n.d.). The research forest was named after Professor Malcolm Knapp who taught in the Department of Forestry from 1922-1963 at the University of British Columbia (UBC). Professor Knapp played a large role in acquiring the forest for the university which, at the time, only consist of the Campus Forest which was a small second growth area on the university grounds (Malcolm Knapp Research Forest, n.d.). Knapp's negotiations with the provincial government initially started with a lease agreement between UBC and the Crown but later resulted with the forest being gifted to UBC with the condition that the main purposes of the forest are for research, education and demonstration. To this day, there have been over 800 research projects established within the forest (P. Lawson, personal communication, January 15, 2010).

Prior to the university's ownership of the forest, two major regimes shaped the landscape: logging and fire. One of the earliest large scale fires took place in 1868 (Malcolm Knapp Research Forest, n.d.). This fire burned almost everything in the area. Between 1920 and 1931, logging activity in the area increased. Approximately 2800 hectares were harvested by railway logging and steam donkeys over the 11 years (Malcolm Knapp Research Forest, n.d.). A second fire took place in 1931. A spark from a piece of logging equipment ignited the forest which resulted in a fire that burned for over a month. Logging stopped after the fire and the forest was left to naturally regenerate. Currently the research forest is made up of two major age classes: 120 year old Douglas-fir (*Pseudotsuga menziesii*), western red cedar (*Thuja plicata*),

and western hemlock (*Tsuga heterophylla*), and 60-70 year old western red cedar and hemlock (Malcolm Knapp Research Forest, n.d.).

The area surrounding MKRF has changed significantly since its early beginnings. As seen on the map (Figure 1), MKRF is bordered by the municipalities of Maple Ridge, Coquitlam and Pitt Meadows. Urban development is quickly growing along the southern boundary of the research forest. Golden Ears Provincial Park, a protected area, also shares a boundary with the forest. Lastly, MKRF sits on traditional Katzie First Nation land (P. Lawson, personal communication, January 15, 2010). All these factors are important when dealing with values and constraints of the research forest.

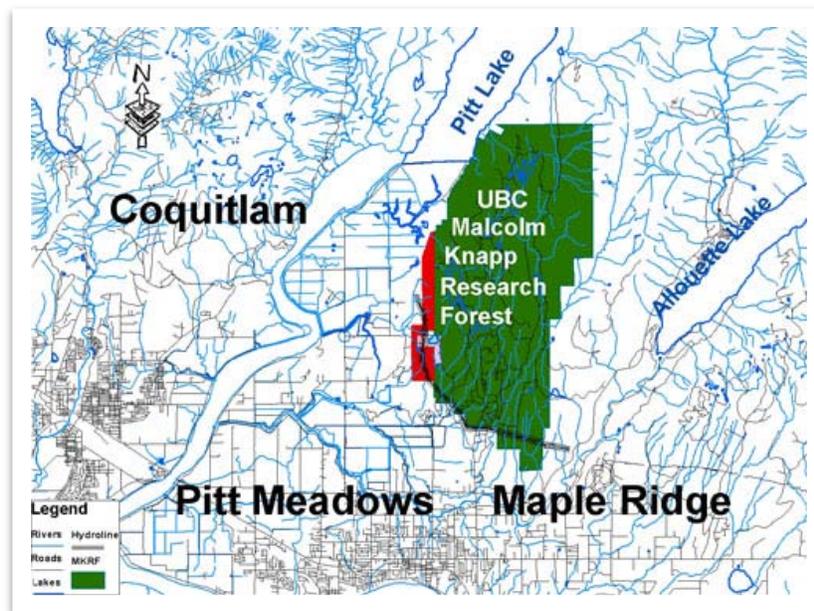


Figure 1: Location of MKRF (Malcolm Knapp Research Forest, n.d.)

## 1.2 The Forest and its Health Risks

MKRF is composed of 43% western hemlock, 29% western red cedar, 26% Douglas fir, and 2% broadleaf species. The forest is made up of two subzones: dry maritime (dm) and very wet maritime (vm). The dry maritime subzone covers the southern half of the forest where it is

most productive due to longer growing seasons, shown in the green area in Figure 2. Again referring to Figure 2, the very wet maritime subzone is split into two, the submontane vm1 as the blue area, and the montane vm2 as the pink area. The submontane vm1 subzone is located in the central to northern portion of the forest where growing seasons are long and precipitation is high. The montane vm2 subzone is in the northern upper corners of the forest where there is high precipitation in the form of snowfall and shorter growing seasons.

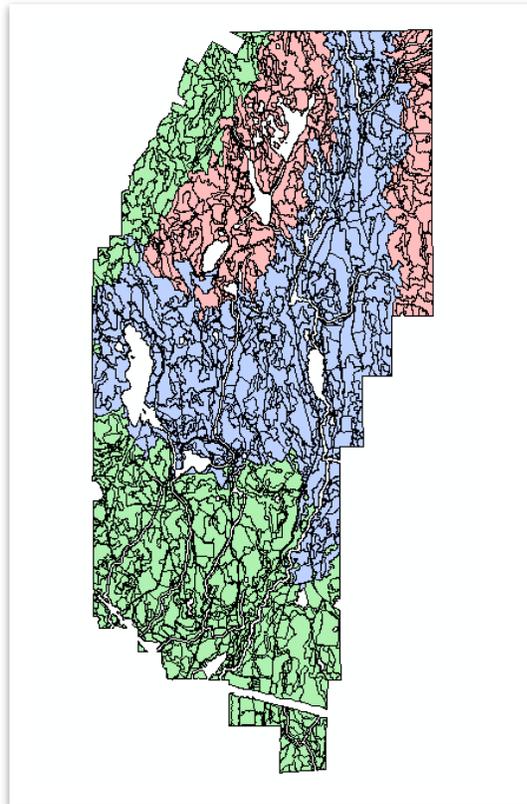


Figure 2: Subzones of MKRF

Within MKRF, the main forest health risks are fire and western hemlock looper (*Lambdina fiscellaria lugubrosa* (Hulst)) (C. Powers, personal communication, January 15, 2010). Since the research forest is heavily used by researchers, workers, and visitors, the chances of wildfires occurring is high. This is especially critical during dry, hot summers. Frequent visitor activities (e.g. campfires) in isolated areas around Loon Lake can increase the potential of a fire



spreading from either the forest into the community or vice versa (P. Lawson, personal communication, January 15, 2010). Therefore, fire suppression and fuel maintenance are critical roles for the resident foresters. The other predominant forest health risk is the western hemlock looper which occurs periodically in MKRF (P. Lawson, personal communication, January 15, 2010). Other possible health risks include root rot (P. Lawson, personal communication, January 15, 2010). Observations of the current stand indicate relatively low risks of root rot because the forest is young and diversified. As the stands age, the risks of root rot will increase.

### 1.3 General Key Values

MKRF emphasizes three main areas of focus: aesthetics, the economy, and education and research. Containing more than 5, 157 hectares of forest land, MKRF provides a beautiful sanctuary ideal for recreation and nature lovers (Malcolm Knapp Research Forest). Local communities around MKRF can enjoy many activities including hiking to undisturbed forest areas and camp users can go canoeing along Loon Lake (Malcolm Knapp Research Forest). Fish and local wildlife thrive in MKRF and a biologically diverse forest of coniferous trees. As such, many silvicultural programs are enforced within MKRF to protect wildlife including deer, black bear, snowshoe hare, beaver, coyote, and grouse (UBC Department of Zoology).

MKRF appeals to recreationists and environmentalists alike for its inherent beauty and silvicultural practices, but MKRF also contributes economically to the community. From general public uses to the sawmill production facility, income is generated for many workers, and surveyors employed within MKRF. There are many job opportunities that are derived from MKRF. Students from UBC take advantage of MKRF summer job openings as well as other activities ranging from logging equipment operators to silviculturalists to forest management level positions (Malcolm Knapp Research Forest). For example, in 2004, MKRF created a joint partnership with Gallant Enterprise to start a sawmill within the research forest (Gallant Enterprise). This sawmill specializes in cutting speciality and value added products. It is treated separately from the rest of the forest. In 2005, log home buildings were set up adjacent to the

sawmill. This project involved UBC and Artisan Log Construction of Mission BC (Malcolm Knapp Research Forest).



Figure 3: Sawmill located in MKRF

Education is the primary focus of MKRF. This research forest is used by UBC faculties, Simon Fraser University, B.C.'s provincial government and the Canadian federal government (Malcolm Knapp Research Forest). In the Faculty of Forestry, every third and fourth year student will be able to take advantage of the opportunity to attend field camps (Malcolm Knapp Research Forest). There are 800 projects held in this forest and 100 of them are ongoing (Malcolm Knapp Research Forest). Most of the forestry projects look at maximizing growth and yield in managed forests and measuring the impacts of different forestry practices (Malcolm Knapp Research Forest). Also, many school groups contribute to collecting data for the Ecological Monitoring and Assessment Network (EMAN) in the research forest (Malcolm Knapp Research Forest). Moreover, there are extensive research projects that are being carried out by UBC's Faculty of Land and Food Systems. Other departments such as astronomy and forensic entomology also have projects held in this forest (Malcolm Knapp Research Forest).

Currently, MKRF and UBC maintain road systems throughout the forest that allow for easier access to remote areas for research purposes. In an era dominated by fears of global



warming and climate change, sustainable development and alternatives are constantly evaluated to help offset and prevent further problems of greenhouse gas emissions. As such, MKRF provides an excellent location for research involving biological methods for carbon sequestration. Motivated by economic incentives and public awareness, MKRF's current 5, 157 hectares forest is perfect for modeling, testing, and demonstrating the feasibility of tree-related carbon sequestration.

## 1.4 Carbon

In 1997, the Kyoto Protocol was created in response to climate change and the amount of greenhouse gases (GHG) being released into the atmosphere. This protocol was signed by many countries and stated that GHG emissions would need to be reduced by an average of 5%, compared to the year 1990, over five years. Canada signed the agreement in 2002 and committed to a 6% reduction over five years in comparison to the year 1990 (United Nations Framework Convention on Climate Change, 2010).

In 2007, UBC signed the Climate Action Plan (The University of British Columbia). UBC committed to a reduction in their overall greenhouse gas emissions. MKRF is an area that can be a positive contributor to the emission issues at UBC. MKRF is a relatively young forest and younger trees have a greater ability to sequester more carbon for longer periods of time. Combined with a large forest area, MKRF has excellent carbon sequestration capabilities. By utilizing MKRF to biologically capture carbon, UBC can promote sustainable development while generating several forms of income. For instance, resulting forest development can improve local air quality and provide more habitat and increase wildlife biodiversity. MKRF can also generate additional revenue from higher volumes of timber sold for exportation or to local markets (e.g. furniture).

### 1.4.1 Pacific Carbon Trust

A standard or set of rules is required in order for carbon sequestration to be applicable or valid. Since MKRF is crown land that was given to UBC by the government, the standards that



the Pacific Carbon Trust set were chosen to be used. This standard addresses three different project types, afforestation, fertilization, and selects seed use which complement our scenarios. The Pacific Carbon Trust is a government run corporation that manages carbon offsets (Pacific Carbon Trust, 2010). Pacific Carbon Trust standards also require the assurance of a third party. A management plan has to be validated and verified by a third party every 5 years based on the Pacific Carbon Trust standard in order to make sure that criteria is being met and that GHG emissions are being evaluated.

## 1.5 Purpose of the Management Plan

The purpose of this project is to sequester carbon at MKRF in order to reach carbon neutrality and ultimately generate carbon credits for revenue. This goal includes having the amount of carbon emitted on the UBC campus equal to the amount of carbon sequestered at MKRF. Our objectives include:

- Making assumptions that takes into the account of measuring carbon
- Running forest growth through carbon models such as the amount of carbon stored in the forest currently and projected
- Develop possible scenarios to achieve net gain from carbon sequestration

## 1.6 Legal issues and constraints

As mentioned previously, MKRF is crown land that is granted to UBC by the government. Therefore this area is operated as if it was private land and there are many more opportunities to create projects and for more research compared to areas of public land (P. Lawson, personal communication, January 15, 2010). When the government granted the land to UBC some restrictions were also put in place in terms of how the land was going to be put to use. The land must be used for education, research and demonstration (P. Lawson, personal communication, January 15, 2010); it also cannot be used for any other type of land use such as housing developments. As for other legal issues, there are some concerning this area. Tenure



responsibilities are not applicable to this area (P. Lawson, personal communication, January 15, 2010). Within the forested land area there is a woodlot license that allows MKRF to process lumber. This license is cared for separately and will not be included in the report. There is also another piece of land about 40 to 50 hectares called the Knapp Reserve that cannot be affected by harvesting activities (C. Powers, personal communication, January 15, 2010). MKRF is also responsible for protecting the environment, the abundant wildlife, and the quality of water. In the case of water quality, Forests and Range Practices Act (FRPA) guidelines are used as default (P. Lawson, personal communication, January 15, 2010).

Some constraints over this area are the many ongoing research projects that occur throughout the year. There are also wildlife management areas that are located in the western corner of the land. The southern border creates a constraint due to the rapid increase of urbanization. On the eastern end of the forest is Golden Ears Provincial Park. This park is one of the largest and most frequently used in BC therefore it also creates a constraint for MKRF (C. Powers, personal communication, January 15, 2010).

## 1.6 Introduction of scenarios

Since the objective to sequester carbon, there are three different scenarios that can be considered. The first scenario (Scenario A) involves converting the lower half of the forest from coniferous trees to red alder (*Alnus rubra*). Scenario B uses the application of fertilization and select seed use to areas of the forest under the very wet maritime subzone. Lastly, Scenario C deals with reducing timber harvesting land base.

## 2.0 Criteria and Indicators

### 2.1 Framework

The three scenarios along with the base case scenario mentioned previously are measured by a framework of criteria, indicators, and targets. A summary of the purpose for each component of the framework is provided below in Table 1.



**Table 1: A descriptive summary of each component forming the framework**

Criteria	Indicators	Target
<b>Values regarding the forest that people want to enhance or sustain.</b>	Quantitative or descriptive factors that can be assessed to determine the current state of the forest and to measure its progress over time.	A quantitative or descriptive statement of the ideal state of the indicator.

Based on the description in Table 1 above, values that are significant to MKRF are criteria regarded as relevant to this management plan. Indicators were chosen based on its capacity to determine the state of the forests and to measure the progress over time. From the Canadian Council of Forest Minister (CCFM) criteria and indicators framework, only those relevant to this management plan were chosen. Relevance of the criteria and indicators are determined based on their capacity to relate to all three scenarios.

Similar to the CCFM criteria and indicators framework, the framework used for this management plan recognizes that the forest provides three broad categories of benefits: environmental, economic, and social. A brief summary of the relevant criteria and indicators used are shown in the framework below (Table 2). The framework is separated into the three categories resembling those that were mentioned earlier: ecological, economic, and social values.

Table 2: Criteria and indicators

Ecological Values		
Criteria	Indicators	Target
1. Conservation of Biological diversity	1a. Age class distribution (% across land-base)	Maintain the current biodiversity of the forest
	1b. Number of forest cover types (diversify for natural disturbance)	
2. Maintenance of Productive capacity of forest ecosystem	2a. Change in growth and yield (harvest and growing stock)	Maintain forest’s soil nutrients and moisture content
3. Conservation of soil and water	3a. Amount of area harvested	Avoid soil erosion, minimal soil disturbance
Economic Values		
Criteria	Indicators	Target
4. Provide sustainable economic benefits	4a. Cash Flow (including income from non timber and timber products)	Provide a positive net cash flow or provide a break-even situation
	4b. Replacement of Capital	
5. Maintenance of forest contributions to global carbon cycles	5a. Carbon Storage	Provide additionality compared to the base case scenario to offset UBC carbon emissions
Social Values		
Criteria	Indicators	Target
6. Respect for aboriginal forest values, knowledge and uses- non timber products	6a. First nation acceptance	Maintain friendly relationship with First Nations; Provide opportunities for First Nation Cultural practices and forest values
7. Education and research opportunities	7a. Number of research projects per year	Continue to provide education and research opportunities; Maximum decrease in education and research opportunities of 20%
8. Maple Ridge Community (Aesthetic Values)	8a. Number of Complaints	Maintain friendly relationship with Maple Ridge Community



## 2.1 Criteria and Indicators for the Malcolm Knapp Research Forest

### 2.2.1 Ecological Values

#### *Conservation of Biological Diversity*

Biological diversity is the interaction between different types of ecosystems that are important for wildlife living conditions (Nature conservation and biological diversity, 2004). For example, there is an old growth tree patch in the eastern part of the forest. This tree patch has survived through the wildfire that occurred in 1868, it consists mainly of old growth western red cedar and Douglas fir. MKRF is a desirable habitat for species such as deer, black bears, snowshoe hares, beavers, coyotes, and grouse (Malcolm Knapp Research Forest) because of the existence of old growth forests. In other low-nutrient streams, ponds, lakes, and bogs are supporting trout and salmon as the dominant species as well as other fishes (Malcolm Knapp Research Forest). Diversity also decreases forest health risks such as insect infestation and pathogenic diseases.

Two indicators were chosen, age class distribution and the number of forest cover types. Age class distribution was chosen as an indicator because different tree species depend on different seral stages for habitat and protection. For example, although taller trees are more susceptible to wind and insect damage, many birds of prey are dependent on these trees. Shorter trees exist as well due to periodic trimming where the power lines are in the south part of the forest. Maintaining different forest cover types refers to the matter of tree species composition of the stand as well as different compositions in each forest polygon. With different tree species composition there is a strong correlation between wildlife species abundance.

#### *Maintenance of Productive Capacity of the Forest Ecosystem*

The productive capacity of the forest ecosystem was chosen because of the importance of keeping the forest productive for education and research. Education and research, as stated previously, is the main purpose of this forest. Maintaining a productive forest is also important



for the forest's cash flow. With a low productive forest, the growth rate of trees will be minimal and will not be able to produce a constant supply of timber. The ability to harvest and sell the logs from the forest is one of the main sources of revenue.

In order to measure this indicator, analysis on the outputs obtained through ATLAS will be performed. This indicator will allow us to see how well the forest is doing and if any of our scenarios is doing particularly well in addition to measuring the feasibility of each scenario.

### *Conservation of Soil and Water*

Within MKRF, many small streams (including Blaney Creek, U. Spring, East Creek, Loon Creek, Mackenzie Creek, Cranberry Creek, Goose Creek, and U. Donedani) connect and deposit into a total of 18 possible lakes. In most cases, small streams are more vulnerable to forest harvesting than larger streams because they are linked to their surroundings through shading, leaf litter, wood inputs, water quality, bank stability, sediment transport, and nutrient dynamics. In order to sustain clean and safe drinking water, the community watershed must be conserved and free of any small stream related contamination as mentioned above. Also, soil conservation is critical to prevent soil erosion which can cause many problems such as soil loss and ecosystem damage.

Many forest harvesting activities like logging can cause an increase in the rate of soil erosion due to soil compaction and exposure of mineral soil. If the litter layer is removed or compacted, the soil becomes more susceptible to soil erosion. Therefore, soil disturbances must be minimized to mitigate these problems. Since soil disturbances can be directly related to the area harvested, one method to measure such an indicator is to use ATLAS to determine the area harvested.



## 2.2.2 Economic Values

### *Sustainable Economic Benefits*

On top of promoting carbon sequestration to create carbon neutrality with UBC's carbon emissions, the scenarios should be financially feasible to perform. To accomplish the additional request of either maintaining the current financial break-even situation or to generate a positive net cash flow (revenue), the ideal scenario must be able to produce the greatest amount of revenue with the least amount of expenditure.

The scenario must generate a positive net cash flow, in order to satisfy this criterion. If the scenario generates a negative net cash flow, this may cause complications in performing the scenario altogether. A situation where a break-even cash flow may occur will demonstrate that the scenario is feasible, but it will not mean the scenario will be ideal.

This indicator is referring to the amount of money required to maintain roads and bridges. This is an important factor because some scenarios may be preferred over others due to the amount of disturbance required to maintain access to stands of interest. For example, for the scenario with the objective of converting ideal stands into alder plantations, this scenario may not be preferred in the sense that it will require high costs in road and bridge maintenance. In addition, it may also cause aesthetical conflicts with the public.

### *Maintenance of Forest Contributions to Global Carbon Cycles*

The maintenance of the forest's contribution to global carbon cycles is an important criterion to address because of the increasing interest towards climate change. Every year more carbon and other greenhouse gases are being emitted into the atmosphere. The forest is an example of one type of ecosystem that is contributing to these emissions. Therefore it is important to maintain the amount of GHG released. Since our project is mainly revolved around the subject of carbon, it is logical for our group to address this criterion.



Carbon storage is an ideal indicator of forest contributions to global carbon cycles. The amount of carbon that is stored will let us know how productive the forest is being and also how young or old the forest is. A way to measure this indicator is to use the output projections through carbon based modeling (CBM).

### 2.2.3 Social Values

#### *Respect for Aboriginal forest values, knowledge and uses*

Malcolm Knapp Research Forest lies on traditional Katzie First Nation territory. Though the land is privately owned, the research forest maintains a relationship with the local Katzie First Nation which we believe is an important element to preserve. Some scenarios may affect their traditional practices (i.e. western red cedar bark stripping); therefore this is an important aspect to analyze when ranking scenarios.

Because computer models will not allow an input such as this, we will use our best judgment to determine whether First Nation values are preserved. An example would be the amount of western red cedar trees retained after the conversion period.

#### *Education and research opportunities*

The sole purpose of the MKRF is to provide education and research opportunities. Any impact to the ability of the forest to do so would be an important issue to address and analyze.

Since the computer models will not allow us to directly measure an indicator like this one, we will monitor the changes to the current research areas and rank the scenario based on any effect to the area available for research. As for education opportunities, we will monitor the known areas that are currently used for education (i.e. Loon Lake) and observe whether a scenario will enhance or diminish the area.



### *Maple Ridge Community (Aesthetic Values)*

The Maple Ridge community is fortunate enough to experience the aesthetic beauty provided by MKRF. The aesthetics created by MKRF are incorporated into the community's scenery to create inspiration, harmony, and a sense of security for the many citizens of Maple Ridge. Therefore, it is important to ensure the ecosystem and biodiversity within MKRF is healthy, and members of MKRF show courtesy towards the local residents of Maple Ridge.

The satisfaction of the residents of Maple Ridge should be an excellent indicator. The number of complaints filed within a given time period can be a good representation of the number of people affected by operations within MKRF. To local residents, MKRF provides a beautiful aesthetic value; however, the aesthetic beauty of MKRF comes with a price including noise, pollution and other disturbances created by forest harvesting activities. Thus, members and operations of MKRF should strive to minimize the number of complaints as much as possible. The number of complaints cannot be measured with computer models. However, we can draw conclusions qualitatively.

## **3.0 Scenario Modeling**

In order to develop a management plan that can be sustainable and acceptable for MKRF, three scenarios along with the base case were modeled. Modeling the various scenarios will be able to show how well each alternative will stand against business as usual. Scenario modeling focuses on carbon sequestration and its influence on social, economic, and environmental values.

### **3.1 CBM-CFS3 – Carbon Budget Model**

The Carbon Budget Model (CBM) or CBM-CFS3 is a program that was developed by the Canadian Forest Service. This program helps forest managers understand how their decisions



and actions affect the carbon balance in their forests (Natural Resources Canada). CBM was used to determine the amount of carbon sequestration occurring in MKRF for each scenario along with the base case. Carbon curves were first created for each stand type in CBM. The data was then imported into FPS-ATLAS. From FPS-ATLAS landscape-level carbon curves were created according to each scenario and projected for 250 years.

### 3.2 FPS-ATLAS

The program “FPS-ATLAS is a forest-level harvest simulation model” (Nelson). It is a program that was created to scheduled harvest flows according to different objectives and constraints. The software was used for the project to model the three different scenarios according to what each scenario required. Assumptions and constraints were applied to each scenario run in order to project an outcome.

### 3.3 Assumptions and Constraints

- Scenario A
  - Red alder and western red cedar will be planted at 75% and 25% respectively
  - Only the southern portion of the forest would be affected
  - Standgroup 999 was created in order to model successfully
- Scenario B
  - Harvest levels stay the same as BAU
  - Modeled in excel since data in ATLAS conflicted with the requirements of our scenario
  - Assumed a 10% increase in growth when scenario was applied
- Scenario C
  - The current harvesting level considers the entire land base
  - Zone 5 was created and no harvest was applied as a constraint



### 3.4 Forest Management Scenarios

Below is a description of three scenarios. These scenarios were created based on PCT standards, the collaboration of the team and the knowledge of our clients and professors.

Table 3: Scenario Descriptions

Scenario	Description
Base Case	Business as usual
Scenario A	Converting the lower half of the forest to red alder
Scenario B	Use intensive silviculture (select seed use and fertilization)
Scenario C	Reduce the current timber harvest land base

#### 3.4.1 Scenario A: Red alder

Scenario A (Appendix 2) considers converting the lower half of MKRF from coniferous species to a deciduous species red alder. Red alder was chosen because of its ability to grow quickly with a rotation age of about 50 years. Because of the high growth rate, it will be able to sequester more carbon at a faster rate. The lower half will be converted because of its higher productivity rate compared to that of the upper half of the forest. The purpose of this scenario is to demonstrate whether red alder is able to sequester carbon quickly and in large amounts. This scenario requires planting red alder at 3000 stems/ha. After 15 years pre-commercial thinning will occur resulting to 1500 stems/ha. These patches will have a composition of 75% red alder and 25% western red cedar.

#### 3.4.2 Scenario B: Intensive silviculture

For the prescribed enhanced silviculture scenario (Appendix 3), the upper half of MKRF will be used. Since the upper half of MKRF is less productive and contains vm1 and vm2 subzones, western hemlock and western red cedar are expected to dominate the area. To promote both the growth of western hemlock and western red cedar, only regions containing vm1 subzones will be fertilized. Depending on the desired growth rate, more money may be



invested in fertilization to allow faster tree growth and greater carbon sequestration in the short run. However, heavily investing in fertilization will not be feasible in the long run because fertilization costs are projected to increase annually. To help mitigate the problems of a fertilizer dependent prescription, an additional plan will consist of using the select seed method to choose high quality seeds. Having been stored well in a sound environment, high quality seeds have the ability to produce healthy seedlings that can adapt well to any reforestation site. Therefore, high quality seeds will be used in conjunction with increased fertilization in hopes of accelerating tree growth and greater carbon sequestration.

### ***3.4.3 Scenario C: Reduced Timber Harvest Land Base***

This scenario is suggesting a decrease in the timber harvesting land base within MKRF (Appendix 4). By decreasing the timber harvesting land base, more trees will be sequestering more carbon. Moreover, because the harvesting land base is not as widely spread, the emissions from logging machines will be reduced. The reduction in emissions by machines is due to the result of shorter traveling distances and shorter operating periods for machines. The chosen reduced area consists of: steep slopes, mountainous areas, and the riparian area surrounding Loon Lake. These areas are based on the efficiency of machine operability. In addition, the riparian area around Loon Lake is reserved for education and recreational uses.

## **3.5 Results of scenarios**

Explanations below describe the results of each scenario when run through FPS-ATLAS. Analysis of each scenario includes results of harvest volume, carbon inventory, and growing stock.

### ***3.4.1 Scenario A: Alder***

The graphs below (Figure 4, 5) show the comparison between the base case and the red alder scenario. The red alder scenario shows a larger decline in growing stock as the forest is continually going through the conversion period where the current stand is harvested and replaced with red alder. If this scenario were to be modeled for a longer period of time, the

growing stock would level out and become constant. Reserve and no harvest levels will remain the same as this scenario does not affect these areas.

Figure 6 shows the CO2 Equivalent changes between the base case and the red alder scenario. Again, the red alder scenario is at a lower level due to the continual harvest during the conversion period. As the red alder matures and begins to sequester more carbon, we expect the curve to begin to rise.



Figure 4: Growing stock of the base case

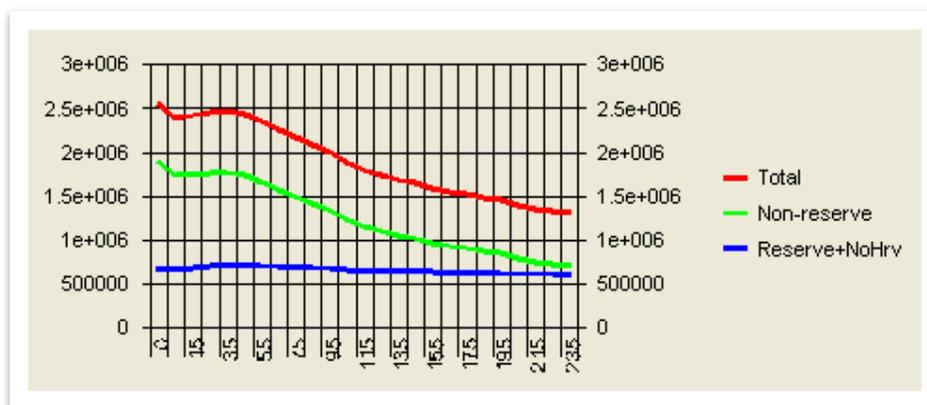


Figure 5: Growing stock of the Alder scenario

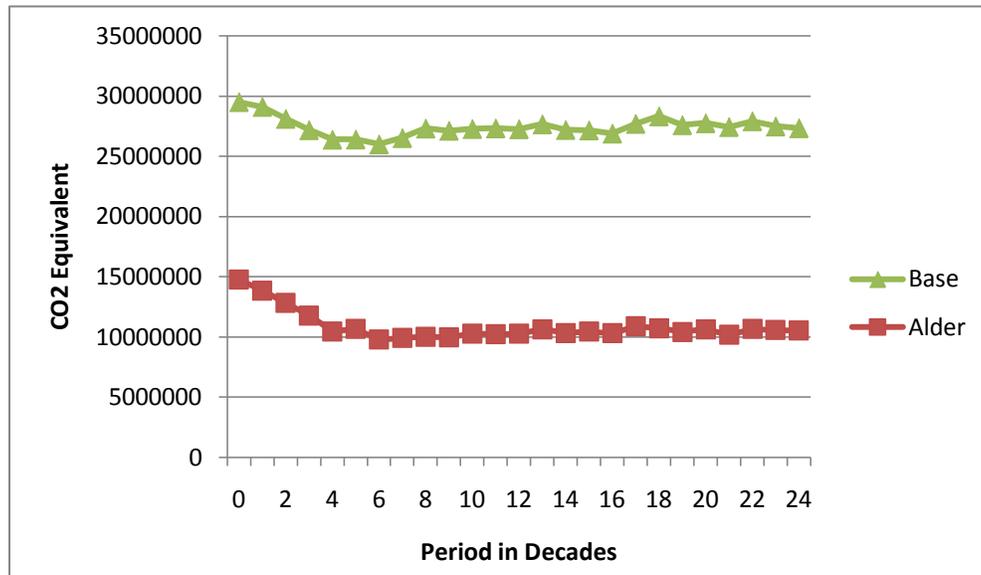


Figure 6: Graph comparing CO2E changes between base case and alder scenario

The harvest flow and levels between the two scenarios are shown in Figure 7. Once again, higher harvest flows are seen in the base case. This is due to the designated area for red alder which is slowly converted over time. This limits the amount of available area for harvest which is seen in the reduced harvest flows in the red alder scenario.

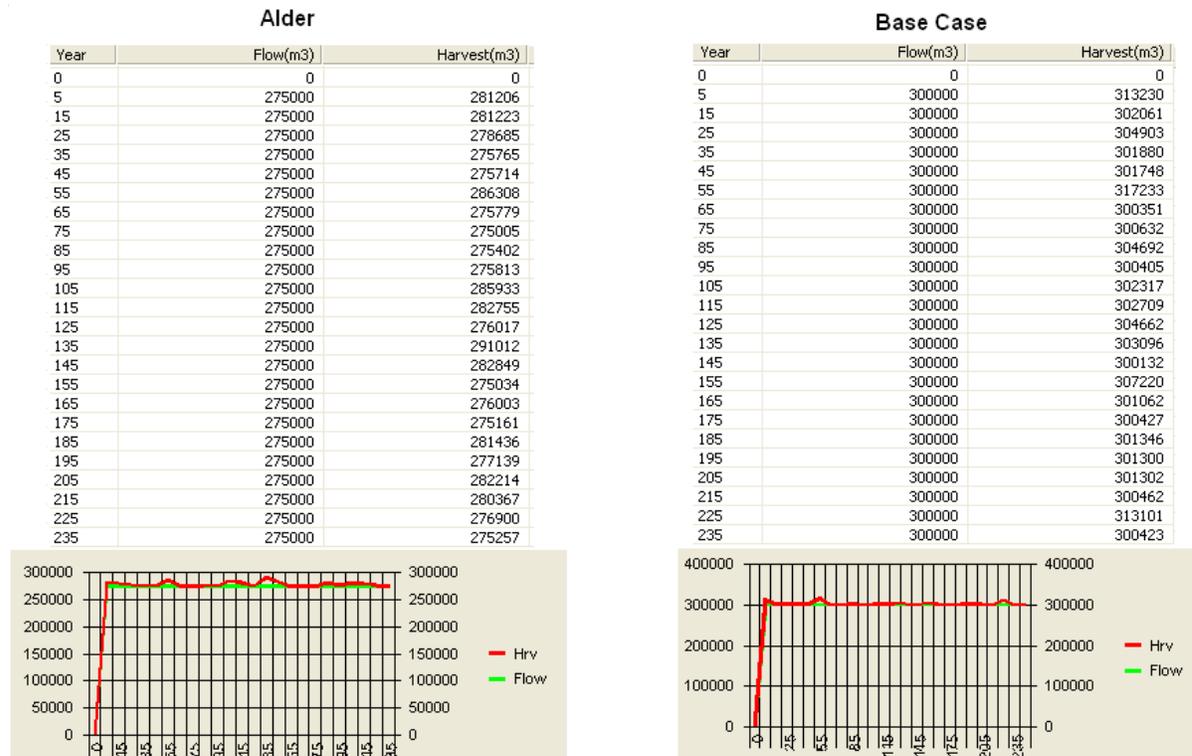


Figure 7: Harvest flow and level comparisons between the base case and alder scenario

### 3.4.2 Scenario B: Intensive silviculture

The intensive silviculture scenario was done outside of FPS-ATLAS so there are no graphs to show harvest patterns and growing stock. The scenario proposed an area of the forest where silviculture treatments such as select seed and fertilization be carried out. While trying to model this scenario, we realized that there would be an overlap in polygons that we selected. For example, there would be two polygons (one inside the selected area and one outside) that share the same growth data. If we were to alter one of the polygons, they both would be changed as they share the same data. As a result, we had to run the model and then change the outputs in Microsoft Excel. We assumed a 10% increase in the results. This was the best way to carry out this scenario due to our time constraints.

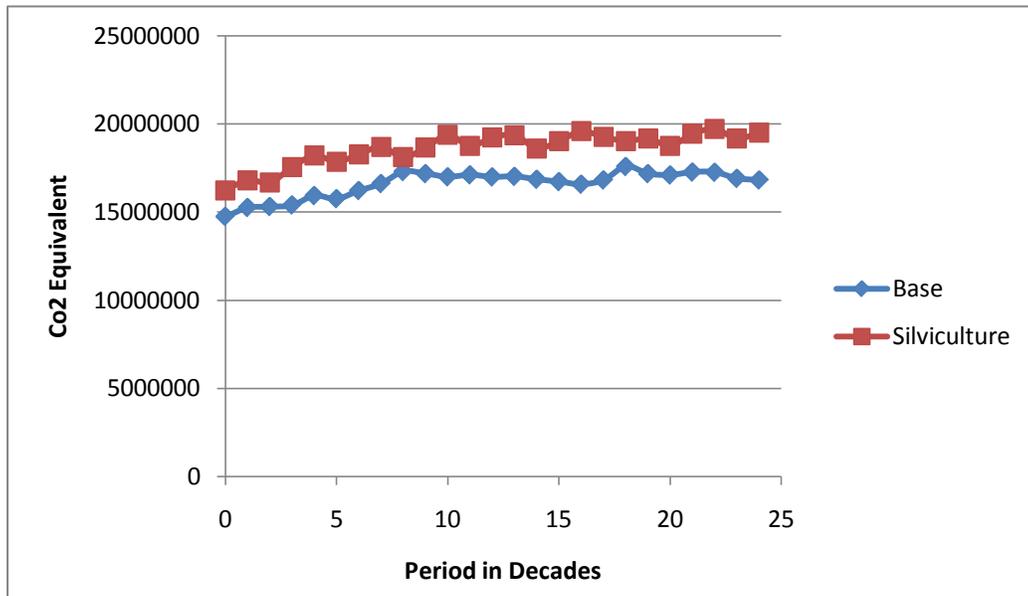


Figure 8: Graph of CO2 E changes between the Base Case and Silviculture scenario

Figure 8 shows the changes in CO2 equivalent between the base case and silviculture scenario. Due to the increase growth of the scenario, the forest is able to sequester more carbon in the given time period. This is evident in the higher curve seen in the graph above.

This scenario is the most hypothetical of all our scenarios. By manipulating the numbers in the outputs, we may have overlooked other factors in the model; however, due to our time constraint we believe this was the best way to approach the problem.

### 3.4.3 Scenario C: Reduced THLB

As seen in Figures 9 and 10, the growing stock varies quite a bit from the two scenarios. In Figure 9, the total growing stock is seen to decrease as the forest proceeds with “business as usual”. Reserve and no harvest stock remains a consistent value as there is no change over time. On the other hand, we see a more stable decline in the total growing stock in the reduced timber harvesting land base scenario (Figure 10). The reserve and no harvest levels increase over time as the increased no harvest zone is put in place.

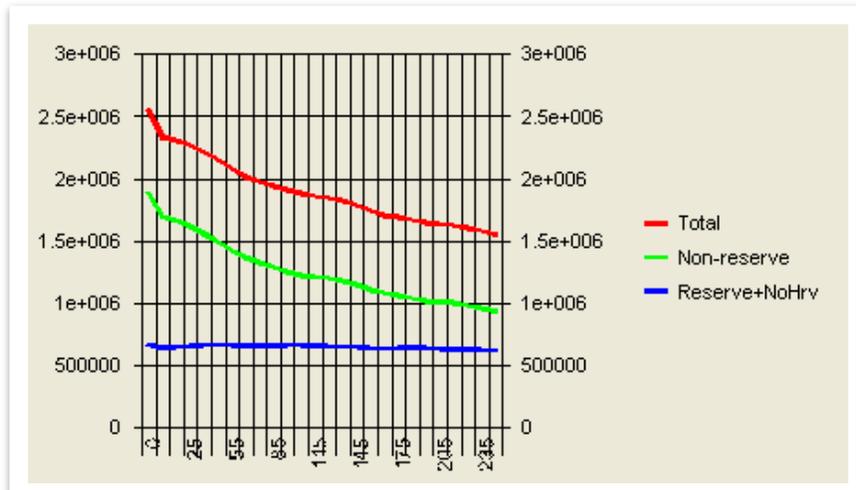


Figure 9: Growing stock chart of the base case

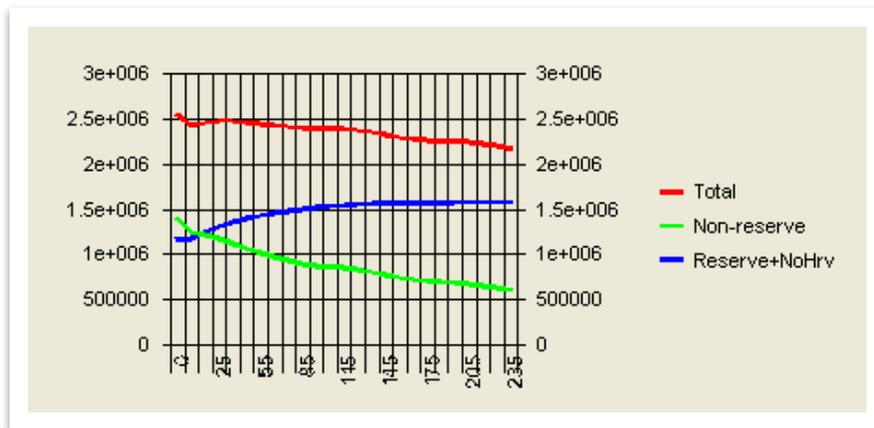


Figure 10: Growing stock chart of the reduced Timber Harvest Land Base

Figure 11 shows the changes in CO2 Equivalent between the two scenarios. The results were surprising as the two scenarios yielded similar results. A reason may have been the small changes in harvest based on the area that was added to the no harvest zones. In our scenario, we added steep, low operable areas to the no harvest zones in the reduced THLB scenario. Prior harvesting in these areas was most likely quite low. This meant that by designating them as no harvest zones, they would not have affected the overall carbon storage levels.

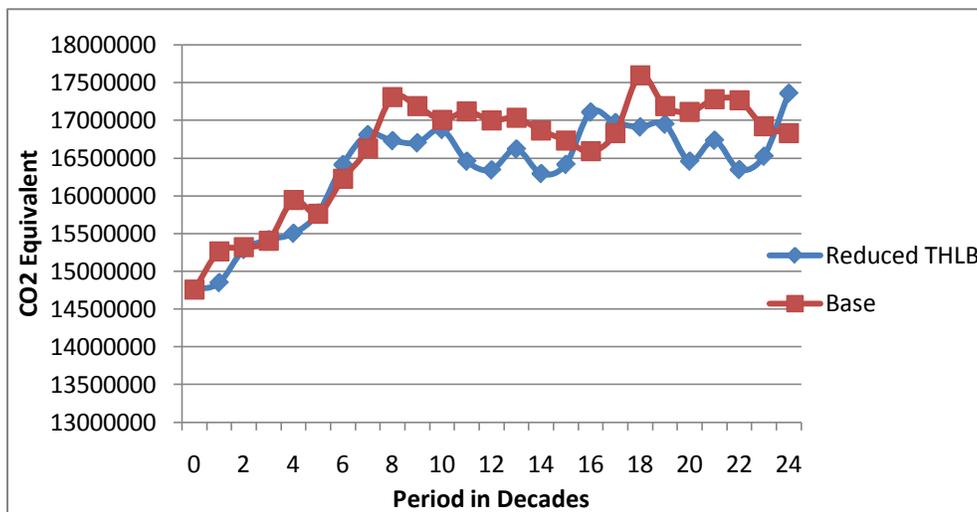


Figure 11: Graph comparing CO2E changes between the base case and reduced THLB scenario

The graph below (Figure 12) shows the harvest flow comparison between the two scenarios, base case and reduced timber harvest land base. We can see reduced harvest levels in the reduced timber harvest land base due to the increased no harvest zones.

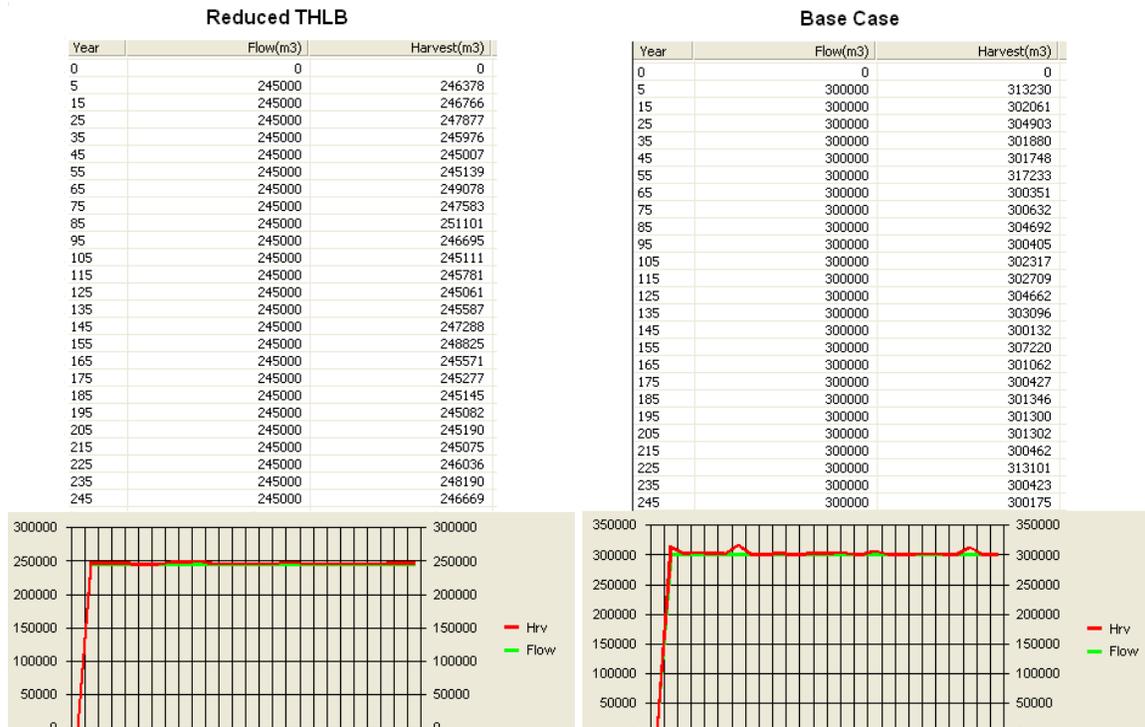


Figure 12: Harvest flow comparisons of the Base Case and reduced THLB scenario

### 3.5 Summary of Results

When comparing the amount of carbon storage of the base case and the three scenarios (Figure 13), Scenario B intensive silviculture was above the rest. Due to the increased growth rates of the trees, Scenario B is able to sequester the most carbon. Scenario A alder plantation has the lowest amount the carbon storage while Scenario C the reduced timber harvesting areas and the base case were in the middle with quite similar results. We think that the red alder scenario is losing a lot of storage capacity due to the short spacing of harvest rotations. Perhaps if the harvesting time was increased there would be a higher level of carbon storage. The base case and Scenario C, reduced THLB, were very similar in carbon storage because of the already low levels of harvesting occurring in the high mountainous area in the base case.

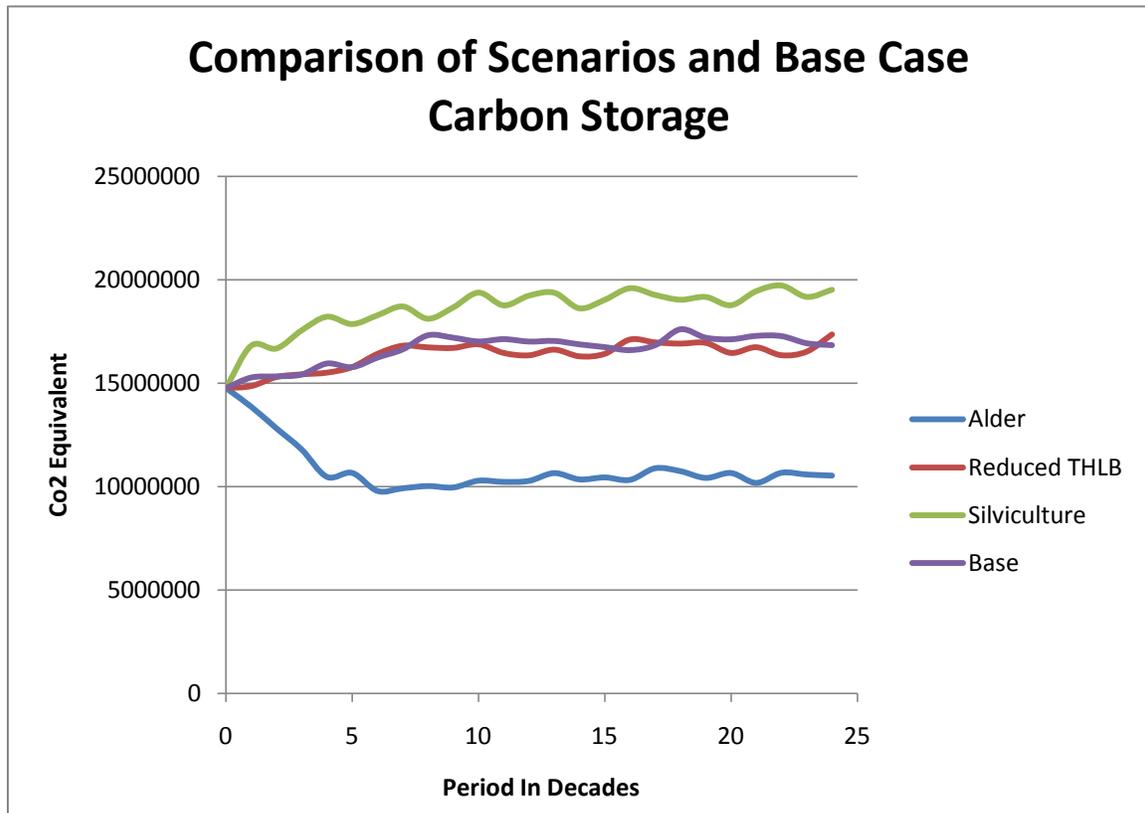


Figure 13: Comparison of Scenarios and Base Case Carbon Storage

The additionality graph (Figure 14) shows the amount of carbon that each scenario stores compared to the base case; the base case being a flat horizontal line. Again, it clearly shows Scenario B as the best situation in terms of carbon sequestration and Scenario A as the worst case.

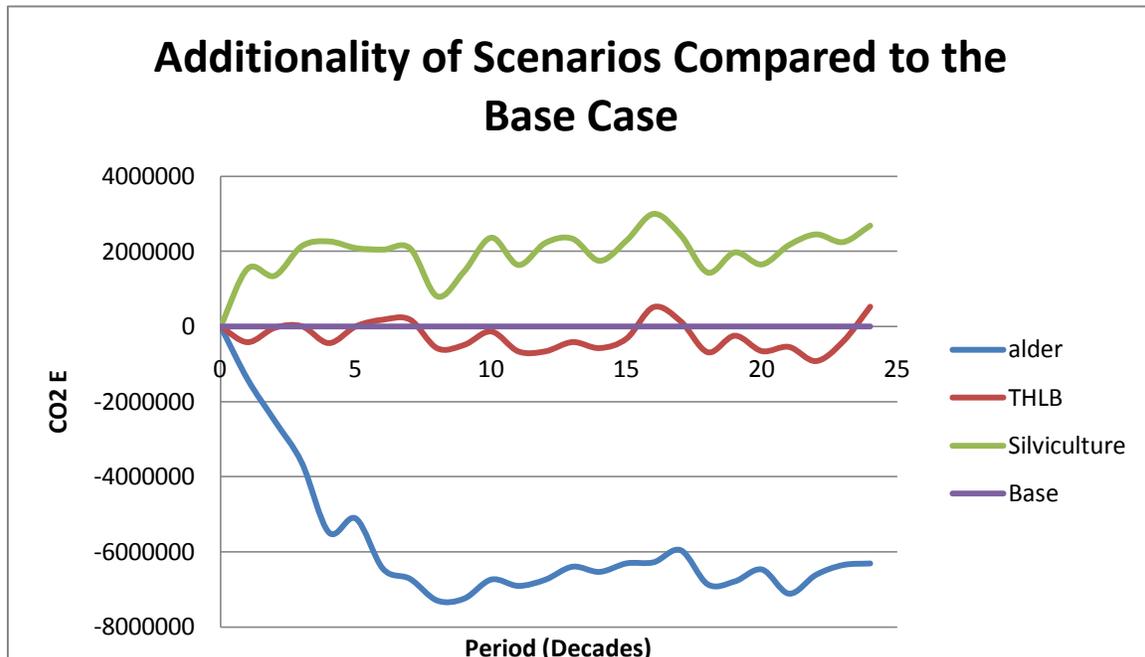


Figure 14: Additionality of scenarios compared to Base Case

The non reserve growing stock (Figure 15) shows the amount of timber that is available for harvesting. Based on a 250 year period, it is seen that all the scenarios including the base case will decrease in the amount of timber available. However, the base case results in the highest amount of timber available after the 250 years while Scenario B has the lowest amount of timber available. Scenario A does increase in available timber until about 50 years when it will be harvested. Overall, the total growing stock (Figure 16) shows that the reduction in THLB scenario has the highest amount of growing stock available. This is due to an increase in the no harvest/reserve areas. The silviculture scenario has the lowest growing stock because the harvest levels stay as BAU and the amount of reserve areas will decrease.

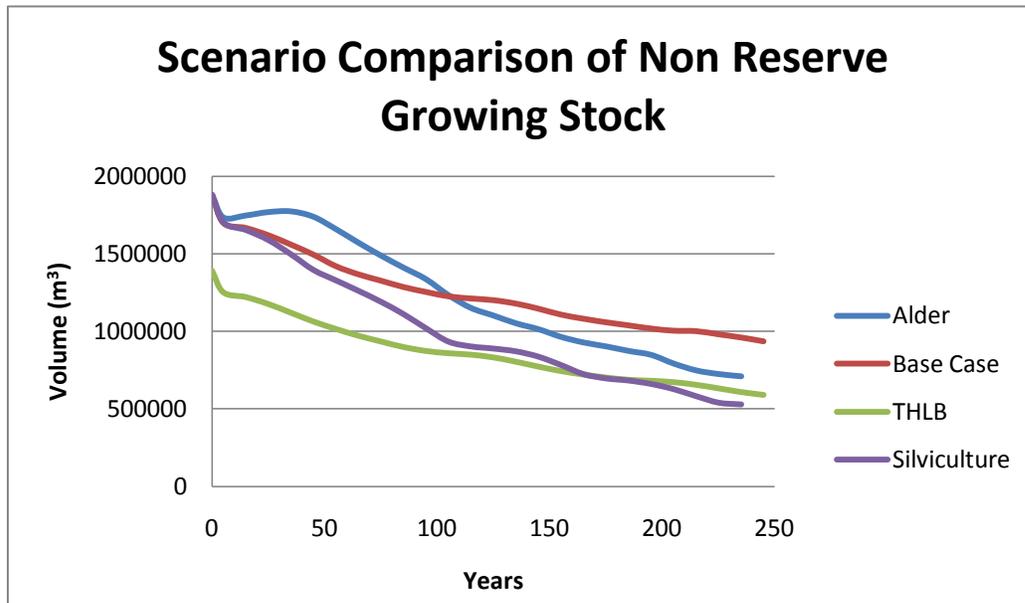


Figure 15: Scenario Comparison of Non Reserve Growing Stock

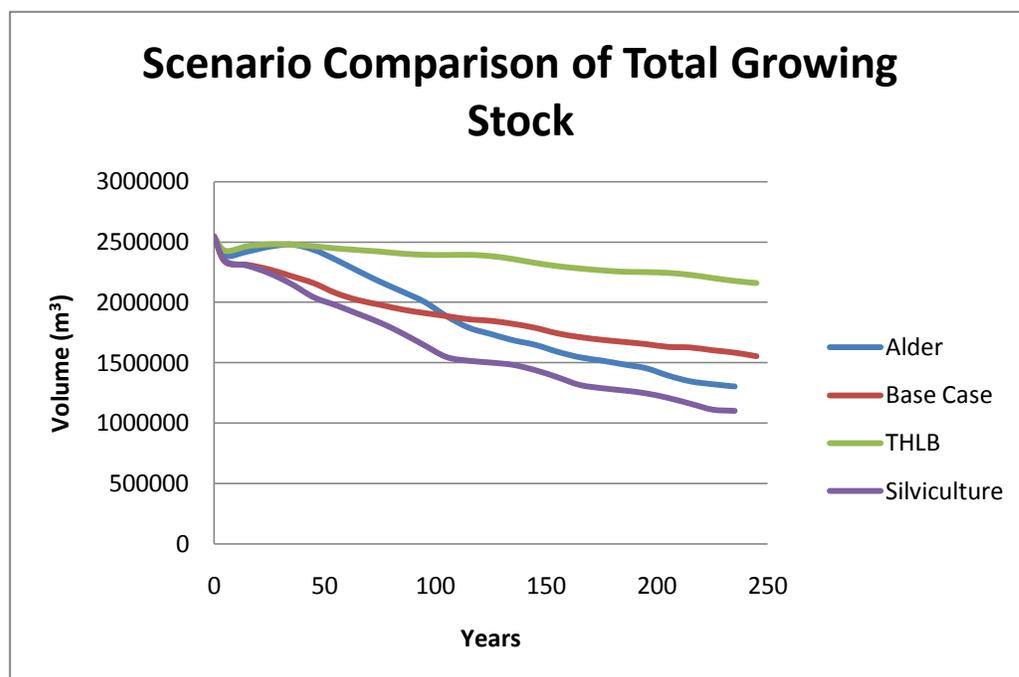


Figure 16: Scenario Comparison of Total Growing Stock



## 4.0 Analysis of Scenarios

Each of the three scenarios and the Base Case was ranked by the ordinal and multi criteria ranking method. The results can be analyzed and used to make decisions for any future events.

### 4.1 Ordinal Ranking

Ordinal ranking was used to compare each scenario to criteria. The criteria were generated by three main values, economic, environmental, and social.

The ranking was done on a scale of one to four. One is considered to be the best while four is the worst. All these scenarios were compared to criteria with the following factors:

- The ability to meet target goals
- Projections from scenario modeling
- Quantitative measures



Table 4: Key for ranking

	<b>Best</b>			<b>Worst</b>
<b>Key</b>	1	2	3	4

Table 5: Ordinal Ranking

	<b>Criteria</b>	<b>Base case</b>	<b>Scenario A - alder</b>	<b>Scenario B – silviculture</b>	<b>Scenario C – reduced THLB</b>
<b>Resource Value</b>	Conservation of biological diversity	2	3	2	1
	Productive capacity of forest ecosystem	2	4	1	2
	Conservation of soil and water	1	4	2	2
	Economic benefits (timber and carbon)	3	2	2	3
	Carbon storage	2	4	1	2
	Respect for aboriginal forest values	1	3	1	1
	Education and research opportunities	1	3	1	4
	Maple Ridge community (aesthetic values)	1	3	1	1
	<b>Total</b>		<b>13</b>	<b>26</b>	<b>11</b>



#### **4.1.1 Conservation of biological diversity**

Scenario C reduces the total area that will be harvested, therefore it is ranked as best when conserving biological diversity. The Base Case and Scenario B are ranked similarly due to the nature in which there will still be harvesting. The only difference is that with Scenario B growth of trees will be enhanced. The red alder scenario is ranked 3<sup>rd</sup> because the lower half of the forest is being converted to alder. This would negatively affect animal habitat because of the lack of larger coniferous trees in productive areas of the forest.

#### **4.1.2 Productive capacity of forest ecosystem**

The productive capacity of the forest ecosystem is best in Scenario B, intensive silviculture. Intensive silviculture promotes growth rate which in turn increases the production of the forest. The Base Case and Scenario C are ranked similarly as second. The Base Case is considered as business-as-usual (BAU), and currently MKRF is performing well in maintaining its productive capacity. Scenario C is ranked second because the overall area of the forest that will be harvested is being reduced. There will be a reduction in area harvested; however there will still be enough harvesting to keep MKRF productive. Scenario A is ranked lowest for this criteria because of the fact that the lower half of the forest is being converted into red alder.

#### **4.1.3 Conservation of soil and water**

The Base Case has the best outcome and is ranked first since what is being done now, BAU, is working well for soil and water quality. Scenario B and C are ranked equally because they both require a lower amount of machinery compared to the red alder scenario which is ranked last. Scenario A is ranked last because of the constant amount of harvesting.

#### **4.1.4 Economic benefits (timber and carbon)**

Both Scenario A and B are ranked 2<sup>nd</sup>. The alder scenario is ranked 2<sup>nd</sup> because we are able to keep a constant flow of harvest and a consistent growing stock level to create value added products (Figure 5, 7). Intensive silviculture is also ranked 2<sup>nd</sup> because fertilization and select seed use will result in larger volumes of timber being harvested which will then bring in



more revenue. The Base Case and reduced THLB is ranked 3<sup>rd</sup>. Due to the reduction in harvestable area, Scenario C will not be able to generate as much revenue compared to Scenario A or B. The Base Case is also currently not generating enough revenue to make a profit.

#### **4.1.5 Carbon storage**

All the scenarios except for Scenario A were able to sequester carbon and create additionality (Figure 14). Total carbon storage was used to determine the rank for each scenario. Since Scenario A did not store more carbon than what was business-as-usual, it was given a rank of 4. Scenario B performed the greatest; therefore it was given a rank of 1. Scenario C and the base case were very similar and both were able to store large amounts of carbon so a rank of 2 was given.

#### **4.1.6 Respect for aboriginal values**

Overall, aboriginal values are well respected in Scenario B, C and the Base Case. Therefore we have decided to rank these three cases as 1. The Base Case reflects the current well established relationship between the Katzie First Nation and MKRF. Scenario B will generate larger and faster growing trees for the First Nation to use. Scenario C which is the reduction in the THLB will be in favour of the Katzie First Nation as it will preserve more non timber products that are significant to the tribe. Scenario A is ranked 3<sup>rd</sup> because changing the lower half of the forest into red alder will reduce the amount of red cedar trees and non timber products the Katzie First Nation needs for traditional practices.

#### **4.1.7 Education and research opportunities**

Both the Base Case and Scenario B were ranked 1<sup>st</sup>. The Base Case is doing well as it is BAU and education and research is priority. The silviculture scenario is also ranked first as it allows the same amount of education and research opportunities. Scenario A is ranked 3<sup>rd</sup> because it limits the amount of research. Only those research related to red alder will have the opportunity to be launched. The reduced THLB scenario is ranked last because we are reducing the area that is permitted for access.



#### **4.1.8 Maple Ridge community (aesthetic values)**

Aesthetic values are most respected in the base case, Scenario B and Scenario C. These three cases do not require the need for the removal of large areas; therefore there will not be many complaints. Scenario A however, requires the lower half of the forest to be converted into red alder. This can create patches that would not be pleasing for the eyes resulting to more complaints from the community.

#### **4.2 Ordinal Ranking with Weighted Criteria**

The previous method of ordinal ranking considers each criterion equally. Since each criterion is not weighted equally in reality, we have decided to place a weight on each of them. They are ranked from one to four, one being the most important and four being the least important. Table 7 below is a summary of the results of the scenario when measured against each of the criteria with its relative weights towards those criteria that seemed more significant to our client’s objectives. An additional column “Weight” was added to demonstrate the different weights assigned to each of the criteria. The weights are then carried out through each scenario. Explanations of each criterion and why it was given its weight are also provided in the following subsections.

Table 6: Key for Weighted Criteria

	<b>Most Important</b>			<b>Least Important</b>
<b>Key</b>	1	2	3	4

Table 7: Ordinal Ranking with Weighted Criteria

	<b>Criteria</b>	<b>Weight</b>	<b>Base case</b>	<b>Scenario A - alder</b>	<b>Scenario B – silviculture</b>	<b>Scenario C – reduced THLB</b>
<b>Resource Value</b>	Conservation of biological diversity	3	6	9	6	3
	Productive capacity of forest ecosystem	3	6	12	3	6
	Conservation of soil and water	3	3	12	6	6
	Economic benefits (timber and carbon)	1	3	2	2	3
	Carbon storage	1	2	4	1	2
	Respect for aboriginal forest values	2	2	6	2	2
	Education and research opportunities	1	1	3	1	4
	Maple Ridge community (aesthetic values)	4	4	12	4	4
	<b>Total</b>		<b>27</b>	<b>60</b>	<b>25</b>	<b>20</b>



#### **4.2.1 Conservation of biological diversity**

This criterion has a relatively important weight because the diversity of the forest is necessary. Diversity is an advantage for the forest as it is the concerning factor when insect epidemics and other natural disasters occur. A forest with a greater diversity will also facilitate a diverse range of research.

#### **4.2.2 Productive capacity of forest ecosystem**

Productivity of the ecosystem is important since it considers how well trees will grow in the forest. However, it is only weighted with a 3 because compared to other criteria, such as carbon storage, economic benefits, and education and research, it is of minimal importance.

#### **4.2.3 Conservation of soil and water**

This criterion is weighted as minimal important because although proper soil and enough water are necessary for vegetation growth, it is not included as one of the main priorities of this management plan.

#### **4.2.4 Economic benefits (timber and carbon)**

Economic benefit is weighted as one of the most important criterion. In terms of revenue, MKRF is currently breaking-even. Since our client has requested for a solution the current break-even situation, it is logical that we make this our priority.

#### **4.2.5 Carbon storage**

Carbon storage is weighted as most important because it is the purpose of this management plan. The goal is to sequester carbon in the forest to offset UBC's emissions and to generate revenue from selling carbon offsets.

#### **4.2.6 Respect for aboriginal values**

Because MKRF is within traditional Katzie First Nation territory, we must maintain a healthy relationship with them. Therefore, it was weighted to be an important factor. It was not



weighted as the most important factor because it is not our main priority. MKRF’s current relationship is friendly and we want to sustain that kind of relationship.

#### 4.2.7 Education and research opportunities

Education and research opportunities are weighted as one of the most important criteria because UBC was granted MKRF for this very purpose. Therefore it is important to maintain the forest as working and accessible for research.

#### 4.2.8 Maple Ridge community (aesthetic values)

Carbon Neutral has weighted the aesthetic values for the Maple Ridge community as the least important because when we compare it to other criterion, it does not offer any monetary gain or ecosystem protection.

### 4.3 Multi Criteria Analysis

Based on the results from the ordinal ranking with weighted criteria, each scenario was then evaluated against each other. The tables below show which rank each scenario is placed

Table 8: Multi criteria analysis 1

	Base Case	Scenario A – alder	Scenario B – silviculture	Scenario C – reduce THLB	Best minimum
Base Case	X	7	1	2	1
A	1	X	0	2	0
B	3	7	X	4	3
C	1	6	1	X	1

From this first table, the best minimum, referring to the largest number in the best minimum column, is Scenario B. Therefore it is ranked first.

**Table 9: Multi criteria analysis 2**

	Base Case	Scenario A – alder	Scenario C – reduce THLB	Best minimum
Base Case	X	7	2	2
A	1	X	2	1
C	1	6	X	1

Now that Scenario B is ranked, it can be eliminated from the table. Using the same techniques as before, the Base Case was found to be the next best minimum. The Base Case will be ranked second.

**Table 10: Multi criteria analysis 3**

	Scenario A – alder	Scenario C – reduce THLB	Best minimum
A	X	2	2
C	6	X	6

Scenario B can be eliminated from the table. The best minimum here is Scenario C. Scenario C will be ranked third. The remaining scenario, Scenario A, will be ranked fourth.

**Table 11: Summary of ranking**

Rank	1	2	3	4
Scenario	B	Base case	C	A

Based on the results of the multi criteria analysis, Scenario B is ranked the best out of all the scenarios. Scenario B ranks highest in several criteria when using the ordinal ranking method. It has also been ranked first in the multi criteria analysis.



## 5.0 Recommendation

With the results obtained from the modules, Scenario B intensive silviculture is the best choice in terms of carbon management. It ranks the highest when compared to several criteria and it sequesters the most carbon with the greatest additionality compared to other scenarios. Having said the later, this scenario currently only satisfies the objective of producing an additionality to offset UBC's carbon emissions. Further cost analysis will be performed within the business plan to determine whether Scenario B will satisfy the objective of producing the highest net profit.



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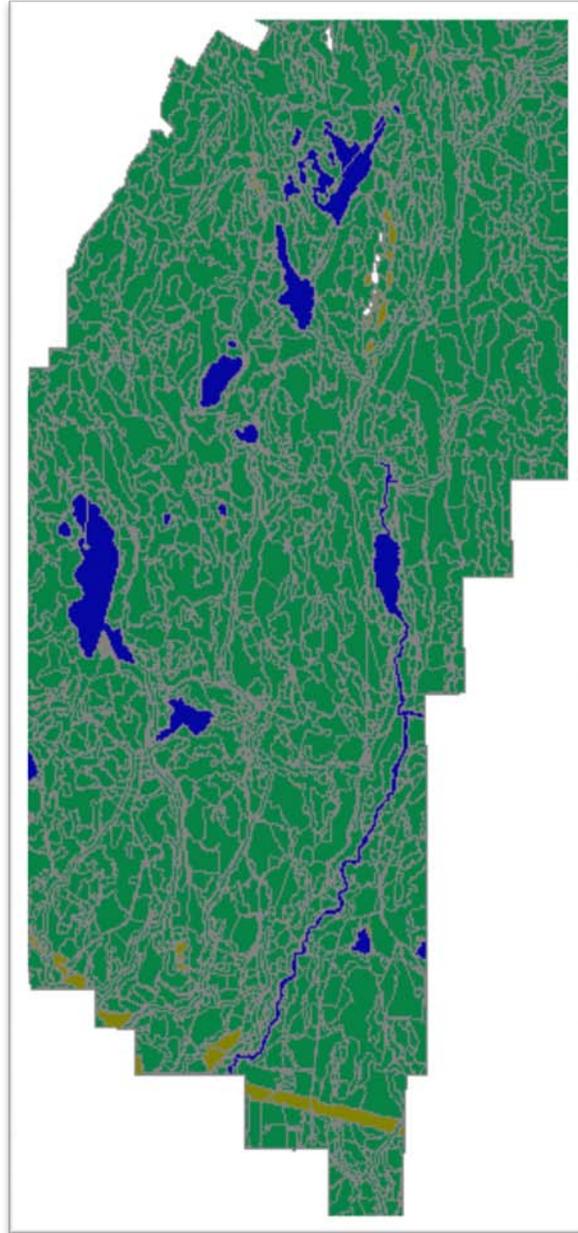


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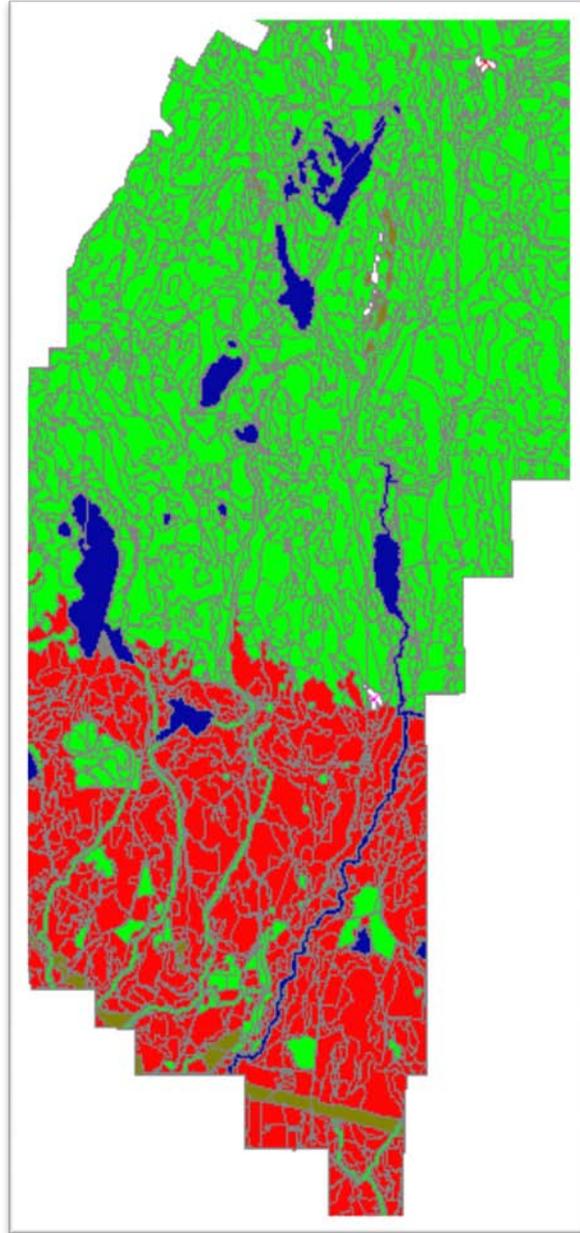
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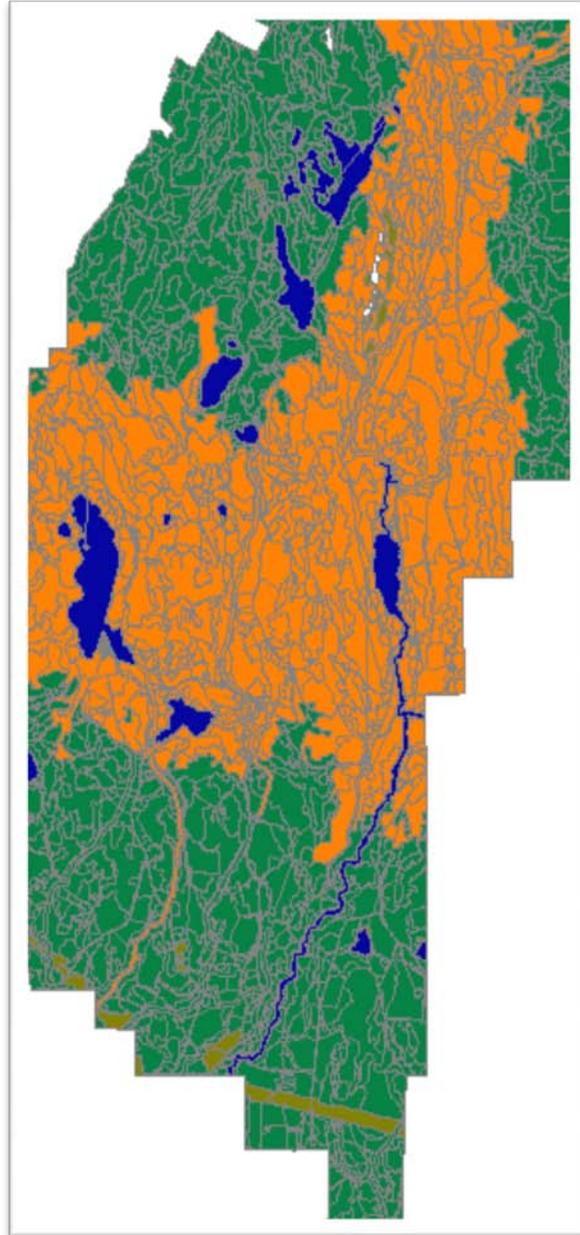
## Appendix 1: Base Case



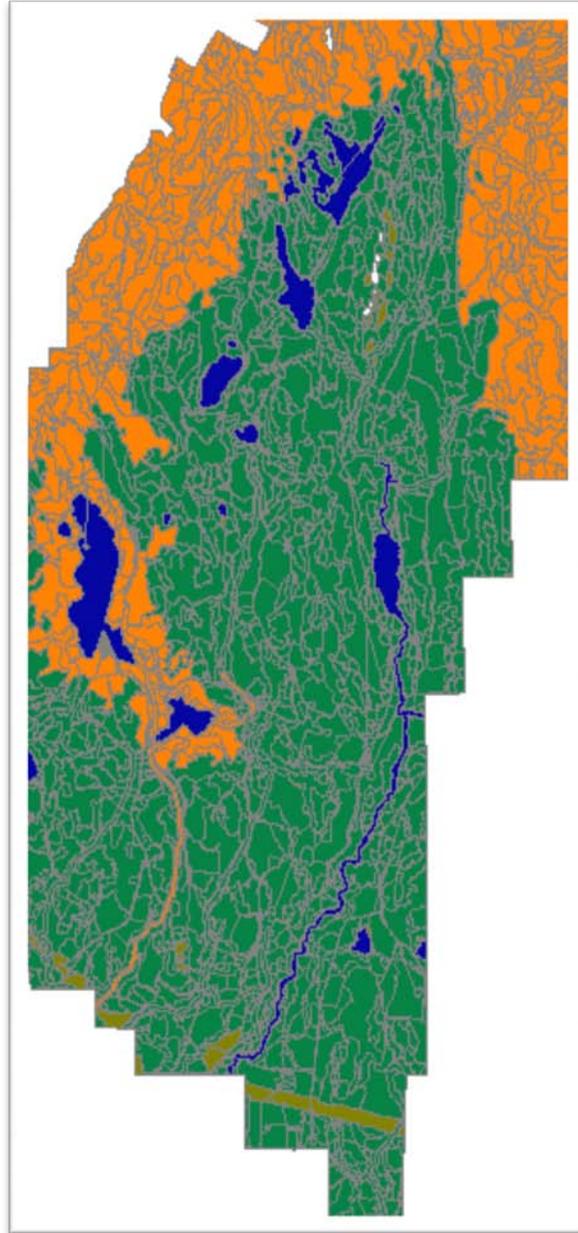
## Appendix 2: Scenario A - Red Alder



## Appendix 3: Scenario B - Intensive Silviculture



## Appendix 4: Scenario C – Reduced Timber Harvest Land Base



## Appendix 5: 2009 Timber Supply Analysis

Classification	Area (ha)	Volume Harvested (m <sup>3</sup> )	Number of Trees	Percent of total TSA area (%)
<b>Total TSA area</b>	<b>5 157</b>			-
Operable	3 570.23			69.2
Low operability	626.61			12.2
Reserve	426.31			8.3
<b>Silviculture System (Operations)</b>				
Clearcut	20.9	13 171		0.41
Clearcut with reserves	8.7	6 630		0.17
Variable Retention	0.3	117		0.006
Patch Cut	4.4	2 743		0.09
Salvage	0.3	158		0.006
Commercial Thinning	11.9	3 391		0.23
Roads/Utilities	4.2	2 724		0.081
<b>Total</b>	<b>50.7</b>	<b>29 033</b>		<b>0.98</b>
<b>Silviculture Activity</b>				
Planting	44.7		65 235	0.87
Brushing	13.1		-	0.25
Deer Protection	3		-	0.06
Juvenile spacing	-		-	-
Surveys	153.8		-	2.98
<b>Total</b>	<b>214.6</b>			<b>4.16</b>



## Appendix 6: Glossary

**Additionality (or incrementality)** – to create carbon credits to show that carbon has been reduced, above and beyond what would have occurred if no management plan was carried out (i.e. above the baseline scenario)

**Afforestation** – converting non-forest land into forest via natural seed source, reforestation, etc. This only applies if the land was not a forest post December 31, 1989. Note: international definition of afforestation and reforestation definitions have been combined as “afforestation” in BC to avoid confusion with conventional use of “reforestation” in BC

**Baseline emissions** – estimate of GHG emissions within project area if a management strategy for carbon was not carried out (can be thought of as the “control” in the experiment)

**Baseline removals** – estimate of removals via sinks and reservoirs within project area assuming no management strategy for carbon was carried out

**Baseline scenario** – scenario made on the assumption that no project is carried out; describes activities that will effect GHG emissions and/or removals; allows estimates of baseline emissions and removals to be made

**Broadcast Burning** – a controlled burn that is ignited to reduce fuel hazard after logging or for site preparation

**Carbon dioxide equivalent (CO<sub>2</sub>e)** - a common unit of measure for the 6 main greenhouse gases (carbon dioxide, water vapour, methane, nitrous oxide, and ozone); refers to the mass of each greenhouse gas emitted. The main greenhouse gas emitter focused for the purpose of



this report is carbon dioxide (1 tonne carbon = 3.667 tonnes of CO<sub>2</sub>e).

**Carbon Emitter** – any activity that emits GHG on an area land base and is accounted as a whole

**Carbon Neutral** – reaching net zero carbon emissions by balancing the amount of carbon released with an equivalent amount sequestered or offset

**Carbon sequestration** – a technique used for long term storage of carbon

**Carbon stock** - the amount of stored carbon at a specified time

**Emission offset** - to reduce greenhouse gas emissions and or to reduce atmospheric greenhouse gas concentrations through storage, sequestration or other means (approved or recognized under the *Emission Offsets Regulation*)

**Emission reduction** - the result from baseline emissions minus project emissions

**Fertilization** - the addition of nutrients on sites with insufficient amount in one or more soil nutrients to increase tree growth

**Forest land** – land with woody vegetation and must satisfy:

- a) Minimum 1 ha in area
- b) Minimum 25% tree crown cover at maturity
- c) Minimum tree height is 5 meters at maturity
- d) Minimum 20 meter of distance between trunks

**Forest Practices** – an activity relating to the growing, protecting, harvesting, or processing of forest tree species on forest land and other aspects such as wildlife, recreation, etc



**Greenhouse gas** – any or a combination of carbon dioxide, methane, nitrous oxide, hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride that is prescribed by *Greenhouse Gas Reduction Target Act*

**Greenhouse Gas (GHG) protocol** – standards for reporting emissions that is developed by World Resources Institute and the World Business Council for Sustainable Development (2005)

**Greenhouse gas reduction** – reducing GHG emissions or enhancing GHG removals

**Leakage (or land use leakage)** – taking the carbon sequestered in a certain area at a certain time and take into account of it in another place or time

**Monitoring** - measuring the amount of green house gases (GHG) emitted or removed from the atmosphere at regular intervals.

**Opportunity Cost** – benefits in return when choosing between two different alternatives.

**Permanence** - feasibility, expected operational lifetime, and stability of a proposed carbon pool resulting from a proposed management plan for the environment.

**Project** – a plan and corresponding development aimed at reducing GHG emissions.

**Project Emissions** - an approximation of the net GHG emissions from all the available sources of and possible reservoirs for GHG emissions.

**Project Reduction** - the expected total reduction in GHG emissions plus improvements to the removal efficiency of GHG emissions; project reduction excludes any discounts applied as a result of contingency plans or risk mitigation.

**Protocol** – formal procedures and regulations that are listed and are followed in order to produce an acceptable procedure



**Reforestation** – replanting trees on bare forest land naturally or artificially

**Select seed use**– planting seedlings that have come from provenances, orchards, or other seed sources so that the trees will grow faster and be more resistant to disturbances

**Sink** – any kind of process that removes GHG from the atmosphere

**Source** – any kind of process that releases GHG into the atmosphere

**Standards** – an approved model that is considered by an authority as a basis of comparison

**Verification** – a process in which GHG emissions and reductions are analyzed against criteria which then determine whether approval will be given or not