

**Planning for Sustainability of Forests
in British Columbia
Through Land Use Zonation**

Working Paper 96.08

Working Paper



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**Planning for Sustainability of Forests
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Through Land Use Zonation**

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by

Sivaguru Sahajananthan, David Haley and John Nelson

Project Director

**Bill Wilson
Canadian Forest Service
Pacific Forestry Centre
506 West Burnside Road
Victoria, BC V8Z 1M5**

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Authors

Sahajanathan is a Post Doctoral Research Fellow at the Forest Economics and Policy Analysis Research Unit (FEPA), University of British Columbia; Haley is Professor at FEPA; and Nelson is an Associate Professor at the Department of Forest Resources Management, University of British Columbia, Vancouver, BC.

About the report

This report is based on Dr. Sahajanathan's doctoral dissertation (1995, UBC).

About the project

This report was completed as part of a larger project. The other components of the project were a comprehensive examination of research on the economics of silviculture in British Columbia and the development of an examination of zonation in a BC Coastal forest region.

Disclaimer

The views expressed in this report do not necessarily represent those of the Canadian Forest Service of the BC Ministry of Forests.

This report is available from:

Publications
Pacific Forestry Centre
Canadian Forest Service
506 West Burnside Road
Victoria, BC V8Z 1M5

Fax 604 363 0797

ABSTRACT

This study deals with the multiple use management of forests. The main objectives of the study are i) to briefly review the literature on economic theory of multiple use, and ii) to compare current integrated use (Integrated Use system (IU)) forestry practices in British Columbia (B.C.) with an alternative system (Single Use system (SU)) which defines, and incorporates in a unit plan, a zone where timber production dominates. The two systems are compared in terms of timber supply, net timber values and environmental indicators at three timber management intensities (basic, medium and high).

A review of the literature suggests that benefits accruing from multiple use forestry can be measured in terms of rent and the provision of amenity values (non-timber goods and services). Current forest practices in British Columbia (BC) attempt to maintain a constant flow of natural amenity values by retaining certain structural elements in the landscape through a system of resource emphasis rules (RER). These rules residualize timber production. Strict rules lead to lower timber supply.

These theoretical findings were empirically tested by simulation with spatially explicit models, ATLAS and SIMFOR, in a sub-unit of the Revelstoke Timber Supply Area, in British Columbia. At the lowest level of timber management, it was found that a single use system could produce the same annual harvest on 46% of the operable landbase, relative to the integrated use case. The remaining 54% of the landbase would be available for non-timber resources. At the highest level of timber management, only 35% of the operable landbase is needed to produce the equivalent volume. Relative to the multiple use scenarios, the single use system also showed higher economic rent, fewer (65%) active roads, larger patch sizes of old-growth, and less habitat fragmentation. The single use zoning approach is economically efficient and environmentally sound and it could lay the foundation for tenure reforms and help in the creation of both industrial and non-industrial tenure arrangements. The zoning approach appears to be a promising method for achieving sustainability of timber and non-timber resources.

Table of Contents

Abstract.....	iii
Table of Contents	iv
List of Figures	v
List of Tables	vi
1 Introduction	1
1.1 Objective.....	1
1.2 Multiple Use Forest management in British Columbia.....	1
1.3 Organization of Paper	4
2 The Theory and Practise of Multiple Use Forestry	5
2.1 Some Basic Economic Theory.....	5
2.2 Practical Solutions to Complex Multiple Land Use Problems	7
3 The Case Study.....	8
3.1 Location	8
3.2 Methodology.....	10
3.3 Results.....	13
3.3.1 Opportunity Costs of Resource Emphasis Rules.....	13
3.3.2 Transition from Old-Growth to Second-Growth Harvesting.....	16
3.3.3 Timber Supply and Timber Rent Under Intensive Management.....	18
3.3.4 Road Density.....	21
3.3.5 Interior and Edge Habitats	22
4 Conclusions.....	26
Bibliography	29
Appendix A : Resource Emphasis Rules	32
Appendix B : Glossary of Terms	33

List of Figures

<i>Figure 1</i>	<i>Types of production possibilities for two products on a tract of land</i>	<i>6</i>
<i>Figure 2</i>	<i>Map of British Columbia showing the location of the study area Revelstoke 1.....</i>	<i>9</i>
<i>Figure 3</i>	<i>Akolkolex drainage showing the location and area of timber production zone.....</i>	<i>12</i>
<i>Figure 4</i>	<i>Impact of resource emphasis rules on timber supply... ..</i>	<i>14</i>
<i>Figure 5</i>	<i>Impact of adjacency, disturbance and cover constraints of timber emphasis rule on timber supply.....</i>	<i>15</i>
<i>Figure 6</i>	<i>Impact of resource emphasis rules on rent</i>	<i>16</i>
<i>Figure 7</i>	<i>Integrated use system showing composition of harvest area, by old-growth and second-growth, over the 120 year planning horizon.</i>	<i>17</i>
<i>Figure 8</i>	<i>Single use system showing composition of harvest area, by old-growth and second- growth, over the 120 year planning horizon.....</i>	<i>17</i>
<i>Figure 9</i>	<i>Impact of intensive timber management with integrated and single use systems on maximum even-flow volume on a 240 year planning horizon.</i>	<i>19</i>
<i>Figure 10</i>	<i>Impact of intensive timber management with integrated use and single use system on rent</i>	<i>20</i>
<i>Figure 11</i>	<i>Road density under integrated use and single use systems</i>	<i>21</i>
<i>Figure 12</i>	<i>The SU system showing the distribution of patch sizes in very old-growth for high intensity management over a 240 year planning horizon.....</i>	<i>24</i>
<i>Figure 13</i>	<i>The IU system showing the distribution of patch sizes in very old-growth for high intensity management over a 240 year planning horizon.....</i>	<i>24</i>
<i>Figure 14</i>	<i>The Single Use and the Integrated Use systems showing the distribution of edge habitats for high intensity management over a 240 year planning horizon.</i>	<i>25</i>

List of Tables

<i>Table 1 Land use designation system (Resource Management Zones) in the regional and sub-regional land use plans showing their objectives and policies</i>	<i>3</i>
<i>Table 2 Some of the structural features of forests and their means of control through Forest Practices Code</i>	<i>8</i>
<i>Table 3. Summary of resource emphasis rules and their area of application in Revelstoke 1. ..</i>	<i>10</i>
<i>Table 4 Silvicultural treatments constituting the basic, medium and high intensity silvicultural regimes.....</i>	<i>11</i>
<i>Table 5 Comparison of area required for producing 11,200 m³/year of timber on a 240 year planning horizon under the Integrated Use and Single Use Systems with and without intensive timber management.....</i>	<i>19</i>

1 Introduction

1.1 Objective

Forests are physically capable of producing a broad range of goods and services. An important task of public forest managers is to use available land, human and capital resources to produce that mix of forest products which provides society with the highest attainable level of well being or satisfaction. While, theoretically, socially optimum, multiple forest use strategies can be described (see, for example, Bowes and Krutilla 1989), in practise forest managers are faced with formidable problems. The objective of this paper is to compare, empirically, two alternative forest land use strategies for a forest tract in the province of British Columbia (B.C.).

1.2 Multiple Use Forest management in British Columbia

Historically in B.C., except for some areas set aside as parks and ecological reserves, forests were managed mainly for the production of timber. During the post second World War years through to the late 1970s, while non-timber values were recognized, a general philosophy prevailed that if forests were managed for a sustained yield of commercial timber, other values would follow in sufficient amounts. In 1978, with the passage of the *Ministry of Forests Act*¹, multiple use of forest lands became mandatory in B.C. While changes in forest practices were slow to follow, growing demands for non-timber forest values, accelerating timber harvests and the rise of the environmental movement during the 1980s precipitated increasing popular concern for the sustainable development of forests, resulting in a series of regulatory initiatives which have dramatically changed the way in which the public forests of the province are managed. This process was further accelerated by pressures from the international environmental movement which, in the early 1990s, condemned forest practices in Canada, particularly B.C., and campaigned to organize boycotts in Europe and the United States against Canadian forest products.

¹ SBC Chap. 272. 1978.

1.2.1 Forest Management in 1990's

The cornerstones of B.C.'s emerging forest land use policies are the *Protected Areas Strategy* (Government of B.C. 1993) and the *Forest Practices Code of British Columbia Act*² which was proclaimed in April, 1995. Under the *Protected Areas Strategy* a target has been set to increase areas protected from commercial resource exploitation to 12% of the provincial land area by the year 2000. The *Forest Practices Code*, which provides a new legal framework for a whole system of forest management plans from strategic to operational, has as its principle objective the sustainable use of forests including "balancing productive, spiritual, ecological and recreational values" and "preserving biological diversity". Under the *Code*, forest practices at local stand or site levels must be coordinated with higher level land use plans at broader geographic scales. Higher level plans establish land use classification, allocate resources and determine strategic management goals which are delivered through site level plans.

Strategic land use planning in B.C. is still in a developmental stage. In 1992, Commissioner on Resources and Environment Act³ (CORE) was mandated to "develop, implement and monitor regional planning processes". CORE concentrated its attention on four regions: Vancouver Island; Cariboo-Chilcotin; West Kootenay-Boundary; and East Kootenay. Subsequently, Cabinet approved planning frameworks for each of these regions.

This approval has no legal status but simply signals broad government policy directions. Increasingly the focus is now on *Land and Resource Management Plans* (LRMPs). These are on a smaller scale than the regional plans - typically covering one Forest District or a combination of a small number of Forest Districts. They set objectives for all resource uses and broadly consider social and economic issues relevant to forest resource management. Like regional plans, they are subject to approval by Cabinet.

In general, these regional and sub-regional plans recognize four resource management zones (See **Table 1**). They are: Protected Areas for resource conservation

² SBC Chap. 41. Vol. 2. Bill 40. 1990

³ SBC Chap. 34. 1992

where no industrial resource extraction is permitted; Special Management Zones where management emphasizes conservation of special values through specific management regulations; General Management zones in which commercial timber extraction is closely integrated with other resource values which are deemed to be of major importance; and Enhanced Management Zones which emphasize resource use and development while ensuring basic environmental quality. It is in the latter two zones that one would expect commercial timber harvesting to be concentrated.

Table 1 Land use designation system (Resource Management Zones in the proposed regional land use plans showing their objectives and policies

	Resource Management Zone	Objective	Policy
1	Protected Areas	Resource conservation	No resource extraction permitted.
2	Special Management Zones	Conserve special values	Compatible human use and development; resource extraction permitted.
3	General Management Zones	Maintain broad landscape and stand level bio-diversity	Integrated use; balanced development of environmental, social and economic resource values.
4	Enhanced Management Zones	Enhance timber supply and forest employment	Intensive timber management while maintaining basic environmental quality.

While the planning process would seem to make provision for intensive timber management zones, developments to date in setting zonal objectives and practices would suggest that, in fact, all zones, other than Protected Areas are being managed to produce a broad spectrum of forest values simultaneously. Under the provisions of the Forest Practices Code, this is accomplished by using resource emphasis rules comprising complex harvesting constraints, designed to retain certain landscape elements to ensure the maintenance of biological diversity and a sustained flow of non-timber values while

commercial timber production is residualized. These strategies are having a serious impact on B.C.'s timber products industry which remains the province's major engine of economic development and prosperity. Major social upheavals are threatened in forest dependent communities and the provincial economy is being weakened. Timber harvesting costs have risen by as at least \$8-10 per cubic metre and continue to escalate (Haley 1996); reductions in allowable annual timber harvests as a result of the *Code* are conservatively set by the Ministry of Forests (MOF) at 6% (Ministry of Forests 1996), which translates into near-term losses in provincial GDP of \$1.4 billion annually and job losses of 22,000 (Haley 1996).

Can this situation be ameliorated? Both theory and practical experience suggest that, under certain conditions, it is economically inefficient to produce forest products jointly from exactly the same land area. Rather, it is better to separate uses by zoning. Under such a strategy, the desired mix of products from the planning unit as a whole is achieved but benefits are enhanced and, by avoiding diseconomies of joint production, total production costs are reduced.

1.3 Organization of Paper

This paper is organized in to three main sections. The first discusses multiple use management in British Columbia. The second section reviews basic economic theory and practical solutions to multiple land use problems. The third reports on a case study which compares current integrated use forestry practices in B.C. with an alternative system which defines, and incorporates in a unit plan, zones where timber production dominates. The two systems are compared in terms of timber supply, net timber values and environmental indicators. The final section draws some conclusions from the study for forest management planning in British Columbia.

2 The Theory and Practise of Multiple Use Forestry

2.1 Some Basic Economic Theory

The economic theory of multiple use is based on the theory of the multi-product firm and on capital theory. The theory of the firm is important because it is concerned with combining fixed and variable inputs - land labour and capital - to produce a mix of outputs which maximizes net revenues or benefits. Capital theory is important as output decisions are concerned with the use of resources and the production of benefits over time.

Gregory (1955) was the first to adapt the analytical theory of the multi-product firm to the multiple forest use problem. This work was elaborated by Pearse (1969) and was further developed in a rigorous and comprehensive manner by Bowes and Krutilla (1989). An important contribution of this work is to describe those conditions under which joint production (integrated use) is optimal or when it better to produce products within separate, dedicated zones (single use). An optimal management plan for a land unit, that is one that maximizes economic rent or net returns to the fixed factor - land, may well be one which incorporates a mosaic of integrated and single use zones.

Interactions between goods and services produced from the same site can be defined in terms of cost relationships. If, at certain output level, an increase in the production of a good causes the marginal, or incremental, cost of producing a second good to fall, then this pair of goods can be said to be local complements. For example, timber and some wildlife species (**Figure 1(a)**). If, on the other hand, an increase in the production of one good causes the marginal cost of producing a second good to rise, then production of these goods is said to display diseconomies of jointness and they are known as local substitutes or competitive products. For example, timber and certain aesthetic values (**Figure 1(b)**). Finally, if an increase in the production of one good does not affect the marginal cost of producing a second good, then these products are said to be locally independent. For example, watershed quality and wilderness (**Figure 1(c)**). A pair of goods may exhibit

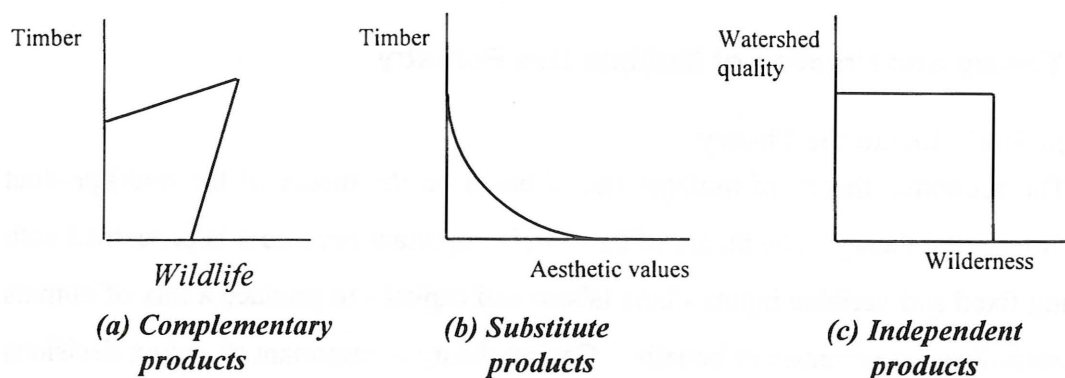


Figure 1 Types of production possibilities for two products on a tract of land. (Source: Pearse (1990))

complementarity, substitutability and independence for the same area of land at different relative levels of output. If the cost relationship between a pair of goods is independent of the level of output they are said to be global complements, or substitutes, or globally independent.

Single, or specialized, use is always indicated where products are mutually exclusive (for example timber production and wilderness) or highly competitive (for example certain types of extensive recreation and timber production). Where products compete for resources on the same sites but are not highly competitive, for example timber production and certain species of wildlife, joint production is sometimes, but not always, optimal. Optimum product mixes will depend upon the relative productivities of the sites for the products in question. Thus, some sites will favour the production of a higher proportion of one output while other sites favour the production of a higher proportion of a different output. Spatial separation of moderately competitive products will be optimum when diseconomies of jointness, including the transactions⁴ costs associated with

⁴ For owner-managed land, transactions costs are those associated with the coordinated management of two, or more, products including the costs of obtaining additional information. In the case of public land managed under license by the private sector - the situation in B.C. - transaction costs of multiple use also include the incremental public costs of administering, monitoring and enforcing contractual arrangements. In B.C., these costs have been conservatively estimated at \$50 million per annum (Haley 1996).

coordinating multiple product management, exceed the related economies of joint production, including economies of scale. Finally, Vincent and Binkley (1993) have proposed that where products differ in their responsiveness to increasingly intensive management it may be more efficient to favour specialization in that product which responds the most to management effort.

The analytical framework described above depicts a static environment. However, forests are dynamic thus adding a temporal dimension to the, already, complex multiple use problem. In a dynamic world, the ability of a certain forest area to produce a mix of products will depend upon the changing composition and age structure of the forest over time. Add to this the fact that the values humans place on forest products also change, often rapidly, with the passage of time and the planning problems faced by forest managers become overwhelmingly complex.

2.2 Practical Solutions to Complex Multiple Land Use Problems

In the face of extreme uncertainty and enormous data gaps - including the problems associated with evaluating non-marketed services, many of them public goods - forest managers have sought tractable, practical solutions to land use problems.

Forest products can be broadly categorized into timber and amenity. Amenity refers to naturalness and the non-commercial goods and services which are associated with naturalness. The major commercial component of forests is timber and the economic rent, or net value, generated through timber production is, generally, the main financial and readily measured return to forest management. Therefore, timber rent and a measure of the amenity values produced by a tract of forest land could be considered as forestry's contribution to human welfare. Thus, foresters have circumvented the complexities associated with optimal, sustainable, multiple use management by managing for maximum, sustainable timber harvests, or values, while maintaining certain structural features of the timber growing stock that are thought likely to ensure a continuous flow of desired non-timber values through time.

In British Columbia, under the Forest Practices Code, managers are required to maintain certain structural features of the forest (For example: species composition, age or height of trees, basal area distribution, recruitment of snags, ground vegetation) by means of forest cover constraints and harvest cut block constraints (See **Table 2**) These constraints control the structure of the forest by: imposing minimum harvest ages, specifying allowable harvesting rates, controlling ground vegetation and recruitment of snags, ensuring that at any point in time a minimum percentage of forest cover is in various seral stages, limiting the sizes and controlling the spatial and temporal distribution of harvest cutblocks, and by imposing adjacency and green-up requirements.

Table 2 *Some of the structural features of forests and the means of controlling them through the B.C. Forest Practices Code*

Structural Feature	Constraints	Mode of Control
Species composition	Forest cover	<ul style="list-style-type: none"> • Minimum harvest ages • Allowable rate of harvest • Ground vegetation control
Age or height of trees		<ul style="list-style-type: none"> • Temporal and spatial control of seral stages
Basal area distribution	Harvest cut-blocks	<ul style="list-style-type: none"> • Maximum area of disturbance • Size of cutblock
Snags		<ul style="list-style-type: none"> • Spatial and temporal distribution of cut-block
Ground vegetation		<ul style="list-style-type: none"> • Adjacency and green-up requirement

3 The Case Study

3.1 Location

In order to explore the implications of alternative multiple use strategies for British Columbia, a study was undertaken in the Akolkolex drainage, a sub-unit of the Revelstoke Timber Supply Area (TSA) (**Figure 2**). This TSA has severe resource use conflicts

involving, in particular, timber production, wildlife management and the preservation of visual landscape values. The Revelstoke Forest District has developed a set of management and harvesting constraints, or Resource Emphasis Rules, to address these problems (Ministry of Forests 1993; Price and Blake 1993), the objective being to maintain a continuous flow of timber, wildlife habitat and visual quality throughout the planning period. The Resource Emphasis Rules, 14 in number, are described in Appendix I. A summary of Resource Emphasis Rules and their area of application in Akolkolex drainage is given in **Table 3**.

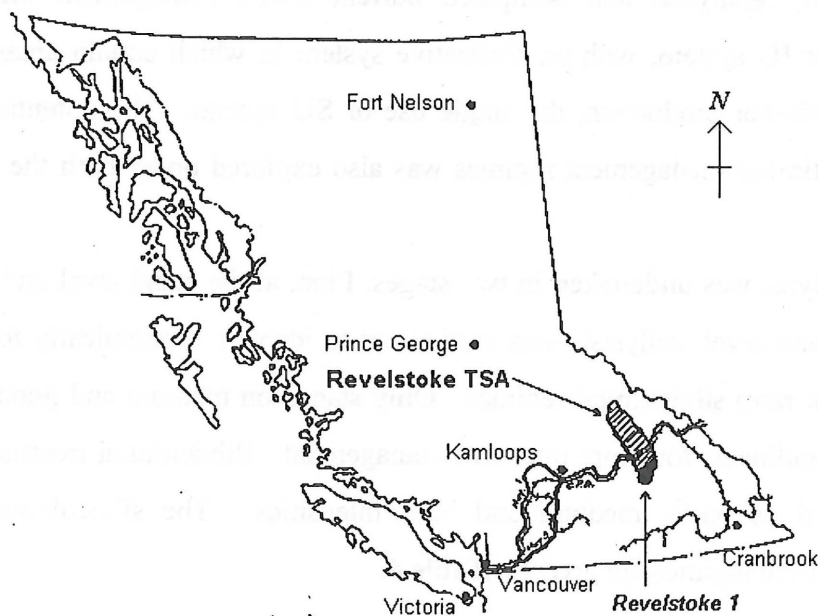


Figure 2. Map of British Columbia showing the location of the study area Revelstoke 1 (Akolkolex drainage in the Revelstoke Timber Supply Area)

Table 3. Summary of resource emphasis rules and their area of application in Revelstoke 1.

Rule No.	Description	Code	Area (ha)	%
4	Wildlife (low)	Wlife(l)	1324	7.5
5	Wildlife (medium)	Wlife(m)	6601	37.6
11	Visual quality partial retention and wildlife (high)	VPR_Wlife(h)	4550	25.9
13	Visual quality partial retention and wildlife (medium)	VPR_Wlife(m)	5100	29.0
		Total	17575	100

3.2 Methodology

The study analyzed and compared current forest management practices, the integrated use or IU system, with an alternative system in which certain areas are zoned exclusively for timber production, the single use or SU system. The potential for using more intensive timber management regimes was also explored under both the IU and SU scenarios.

The analysis was undertaken in two stages. First, at the stand level and then at the forest level. Stand level analysis⁵ was carried out to identify economically feasible (at a 3% p.a. discount rate) silvicultural regimes. Only stands on medium and good sites were considered as candidates for more intensive management. Silvicultural treatment regimes were categorized as basic, medium and high intensities. The silvicultural treatment components of these regimes are given in **Table 4**.

⁵ Growth and yield under intensive management was simulated using the MOF's *Tree And Stand Simulator* (TASS) model. At the forest level, simulations of forest harvesting practices were performed using the *ATLAS* (Nelson et al. 1993) and *SIMFOR* (Daust, 1994) models. *ATLAS* (*A Tactical Land Analysis System*) is a forest harvesting simulation model which generates feasible harvest schedules within the confines of various spatial constraints such as adjacency, forest cover and green-up. *SIMFOR* (*SIMulator of FORests*) uses *ATLAS* output to quantify landscape pattern responses in the form of selected landscape statistics such as patch sizes and the length of forest edges.

For the forest level analysis, it was assumed that all existing, naturally regenerated, second-growth is of similar species composition to the original old-growth stands and that in the future all areas harvested will be planted with Douglas-fir, Engelmann spruce and western red cedar. Timber volumes for old-growth (over 120 years of age) and naturally regenerated second-growth stands were derived from the MOF's Variable Density Yield Prediction (VDYP) model (Ministry of Forests 1993).

Table 4 *Silvicultural treatments constituting the basic, medium and high intensity silvicultural regimes*

Silviculture Treatment	Basic Intensity Regime	Medium Intensity Regime	High Intensity Regime
Planting	yes	yes	yes
Fertilization	no	no	yes
Pre-commercial thinning	no	yes	no
Commercial thinning	no	no	yes
Pruning	no	no	yes

Selection of a timber zone is a complex problem. In this study it was selected iteratively as the minimum area necessary to produce a sustainable even-flow volume of timber, under unconstrained conditions, equivalent to the maximum even-flow volume achievable under current management practices from the study area as a whole. The timber zone, shown in **Figure 3**, is not optimal but is one example of many alternatives. It contains a range of growing sites and terrains requiring a variety of harvesting systems. Major riparian buffers and other sensitive sites within the zone were reserved from harvesting.

The gross land base of the Akolkolex drainage is approximately 17,600 ha and the operable land base 11,600 ha., or 66%. Under the IU system, the whole of the operable land base is required to provide a sustainable harvest of 14,500 m³ per annum, while under

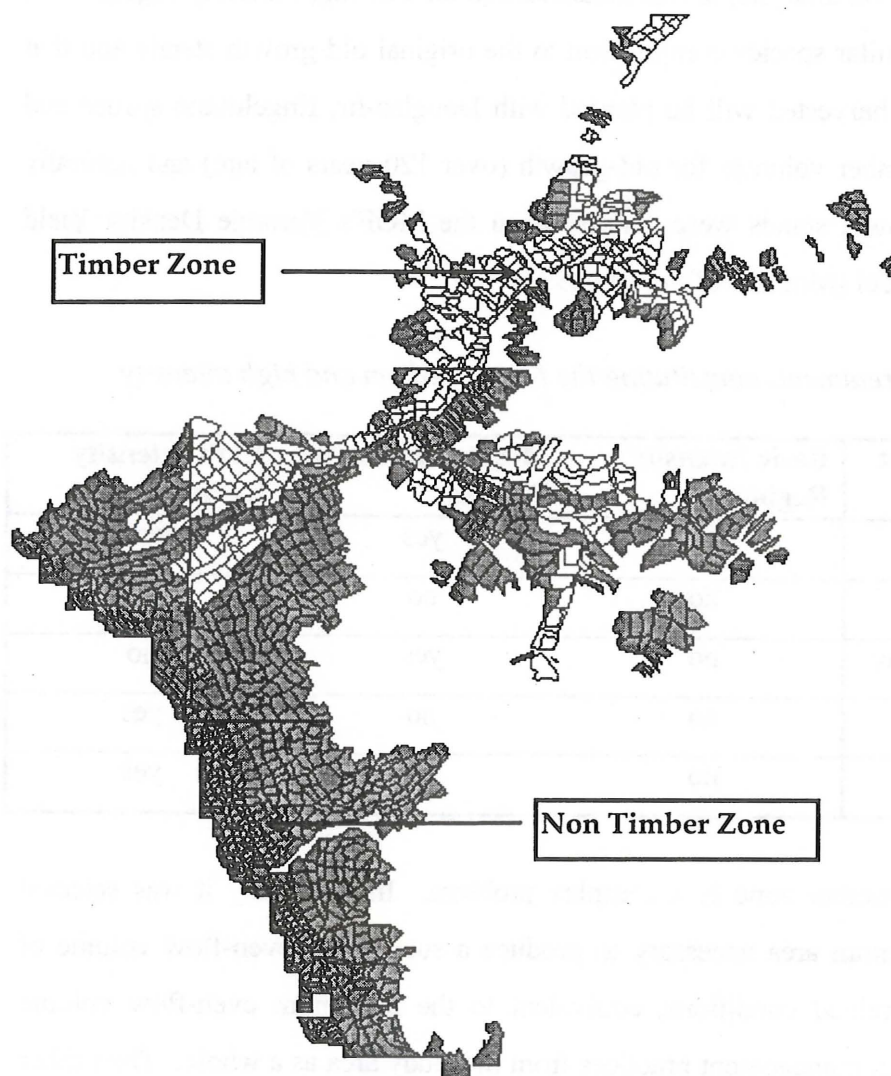


Figure 3 Akolkolex drainage showing the location and area of the timber production zone (31% of gross area, shown in white colour) in the Single Use system used in this analysis. The balance of the area (69% of the gross area, shown in dark colour) was excluded from timber production. In the Integrated Use system the whole operable area, that is 66% of the gross area including the timber zone, was used for timber production. 34% of the gross area is considered to be either protected or non operable under both Single Use and Integrated Use systems for environmental and or economic reasons

the SU system, the same sustainable harvest is produced from 5,400 ha, or approximately 46% of the operable area.

Forest level analysis was first used to estimate the impacts of current constraints, or Resource Emphasis Rules, on timber supply and the economic rent generated under the IU system over a period of 120 years, or about one rotation. The IU system and SU system were then compared in terms of: (i) the composition of the harvest (old-growth and second-growth) to a 120 year time horizon; (ii) timber supply and the economic rent generated to a 240 year time horizon⁶ under basic, medium and high management intensities; (iii) road density measured in terms of the average length of roads maintained during each 20 year planning period and the total length of road opened over the 240 year planning horizon; and (iv) the fragmentation of the forest as indicated by the relative patch⁷ sizes of interior forests and the area, in percent, of edge habitats⁸ over a 240 year planning horizon.

3.3 Results

3.3.1 Opportunity Costs of Resource Emphasis Rules

Resource Emphasis Rules designed to provide for the production of timber, wildlife habitat and visual quality on a sustained basis affect timber supply and timber rents to differing degrees according to the adjacency, cover constraints and allowed maximum disturbance rates they impose (see Appendix I for a description of the constraints imposed by Resource Emphasis Rules in the Revelstoke TSA). Impacts were determined by first determining the ability of the Akolkolex drainage to produce a sustained supply of timber

⁶ A 240 year, rather than a 120 year, time horizon, was used to compare the impacts of more intensive management regimes since the total effects of silvicultural operations are not realized until the second growth stands enter the harvesting schedule in substantial proportions.

⁷ Patch is a fundamental structural element of the landscape. In this study, it refers to a forest that is homogenous with respect to a specific seral stage such as old-growth. For purposes of this analysis, the patch sizes have been grouped into four classes viz.: small (0 - 100 ha), medium (101 - 500 ha), large (501 - 1000 ha), and very large (> 1000 ha).

⁸ Edge habitat refers to a band on the periphery of a patch that differs abiotically and biotically from the interior and exterior of the patch. In this study, the width of this band is assumed to be 100 metres for contrasting patches of regeneration seral stage and old-growth seral stage (>120 years), and 50 metres for contrasting patches of pole seral stage and old-growth seral stage (>120 years).

assuming no harvesting constraints. The Resource Emphasis Rules were then introduced in turn and their impact on timber supply and net timber values, or rents, estimated. The results are summarized in **Figures 4 through 6**. As expected, the introduction of increased management rules or regulations, designed to protect or enhance other resource values, causes a decrease in timber volume and in rent.

Reductions in timber supply range from 32% below unconstrained potential for the basic Timber Emphasis Rule to 93% below unconstrained potential for Visual Quality Rules with Partial Retention. Current management practices (that is the application of all prescribed Resource Emphasis Rules for the Akolkolex drainage, given in Table 3) under the IU system reduce the timber supply to about 40% of its full potential. (**Figure 4**).

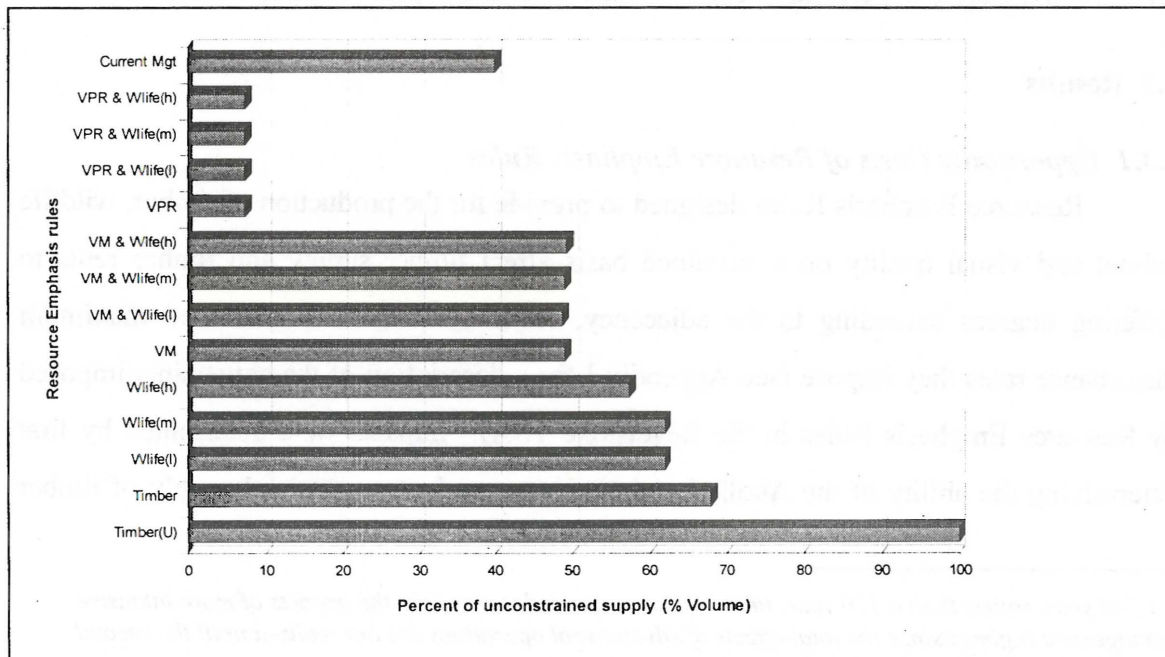


Figure 4 Impact of resource emphasis rules on timber supply. (Current Mgt - current management where all applicable rules are applied; VPR - Visual quality with partial retention; VM - Visual quality with modification; Wlfe (h) - Wildlife (high); Wlfe (m) - Wildlife (medium); Wlfe (l) - Wildlife (low); Timber - Timber Emphasis; Timber (U) - Timber (unconstrained)..

Timber Emphasis Rule (Rule 2 in Appendix A) emphasizes the production of timber, with a minimum flow of other values for wildlife habitat and visual quality, or in other words, with the least amount of constraints on timber production. This is achieved through adjacency (with 20 year green up) and other constraints relating to cover (30% in the 40 year or older age class) and maximum disturbance rates (40% of the area). When each of the constraints (adjacency, cover constraints and disturbance rates) that are built into the timber emphasis rule were examined independently, it was found that it is the adjacency constraint that restricts the timber supply to 68% of its full potential (**Figure 5**).

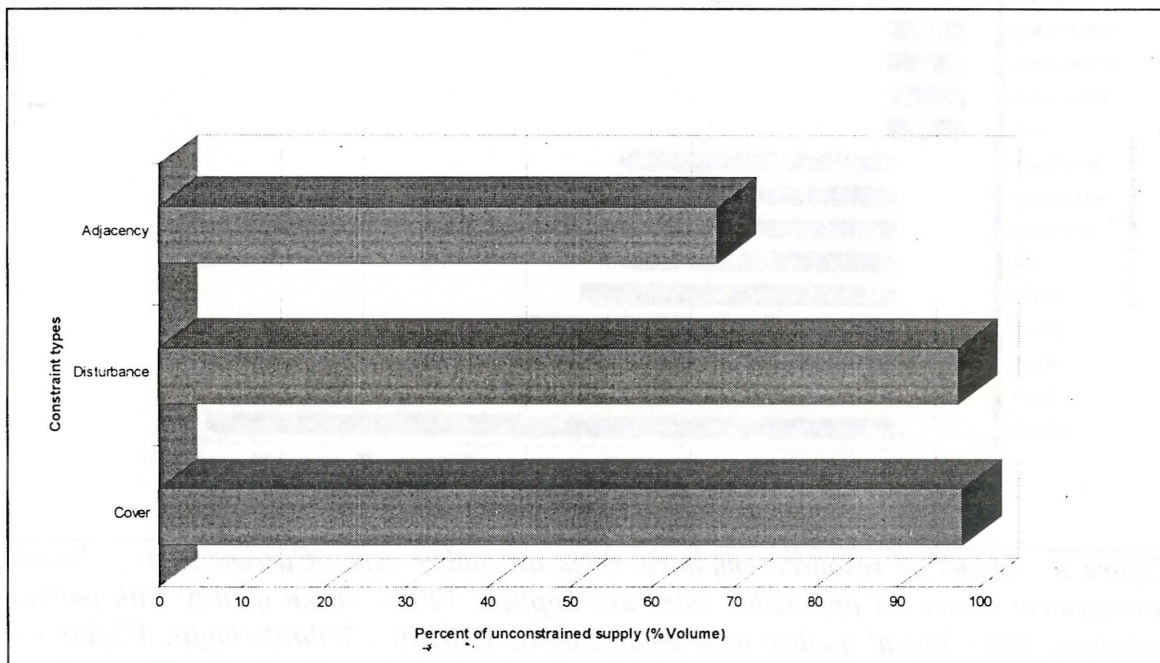


Figure 5 *Impact of adjacency, disturbance and cover constraints of timber emphasis rule on timber supply.*

Impact of adjacency on the flow of harvest volume is due to a combination of factors. These include the size of harvest cutblock in relation to the operable area of the management unit, length of required green-up period in adjacency, and the rate of harvest. Higher rates of harvest with large cutblocks and a long green-up periods lock up

much of the harvestable timber under the adjacency constraint. This effect is more pronounced in management units with a high proportion of old-growth.

Losses in timber rent, at a discount rate of 2%, due to the imposition of the various resource emphasis rules range from about \$25 million for the basic Timber emphasis rule to about \$70 million for the Visual Quality Partial Retention rule (**Figure 6**). Each visual quality rule with partial retention generates negative rent (i.e., costs exceed revenues) of about 6.5 million dollars.

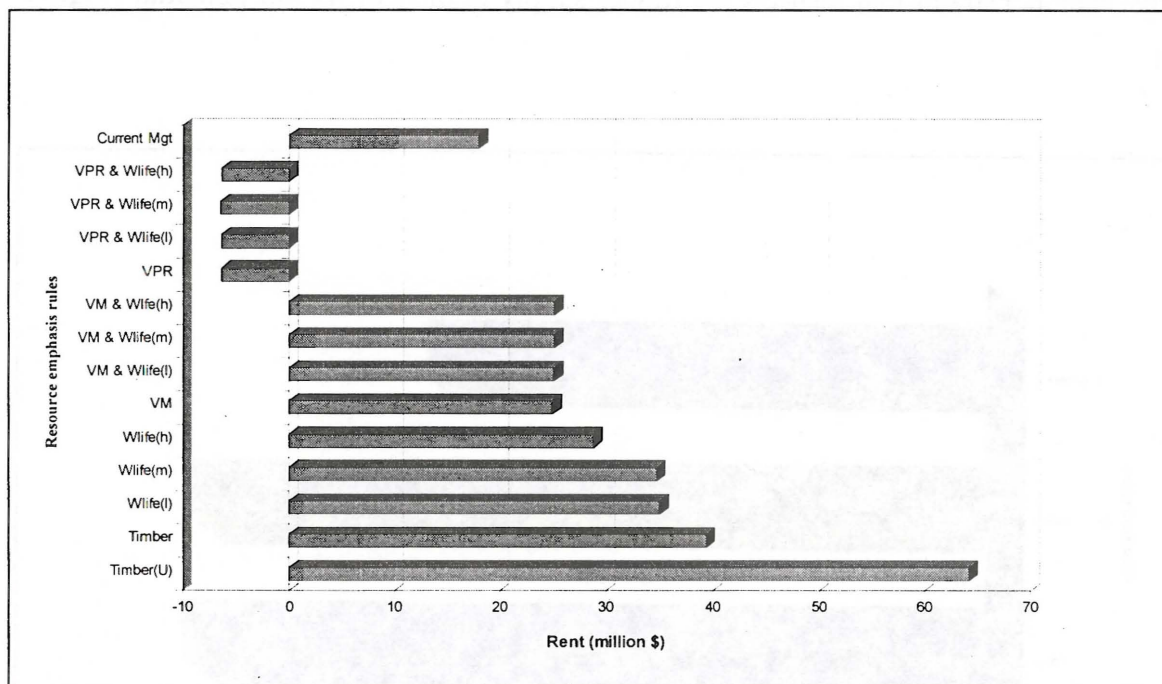


Figure 6 Impact of resource emphasis rules on timber rent. (Current Mgt - current management where all applicable rules are applied; VPR - Visual quality with partial retention; VM - Visual quality with modification; Wlife(h) - Wildlife(high); Wlife(m) - Wildlife(medium); Wlife(l) - Wildlife(low); Timber - Timber Emphasis; Timber(U) - Timber(unconstrained).

3.3.2 Transition from Old-Growth to Second-Growth Harvesting

Forest harvesting leads to the eventual transition from unmanaged old-growth (low timber productivity) to managed second-growth (higher timber productivity). The faster the transition, the easier it is to manage the forest towards achieving desired goals. The rate and

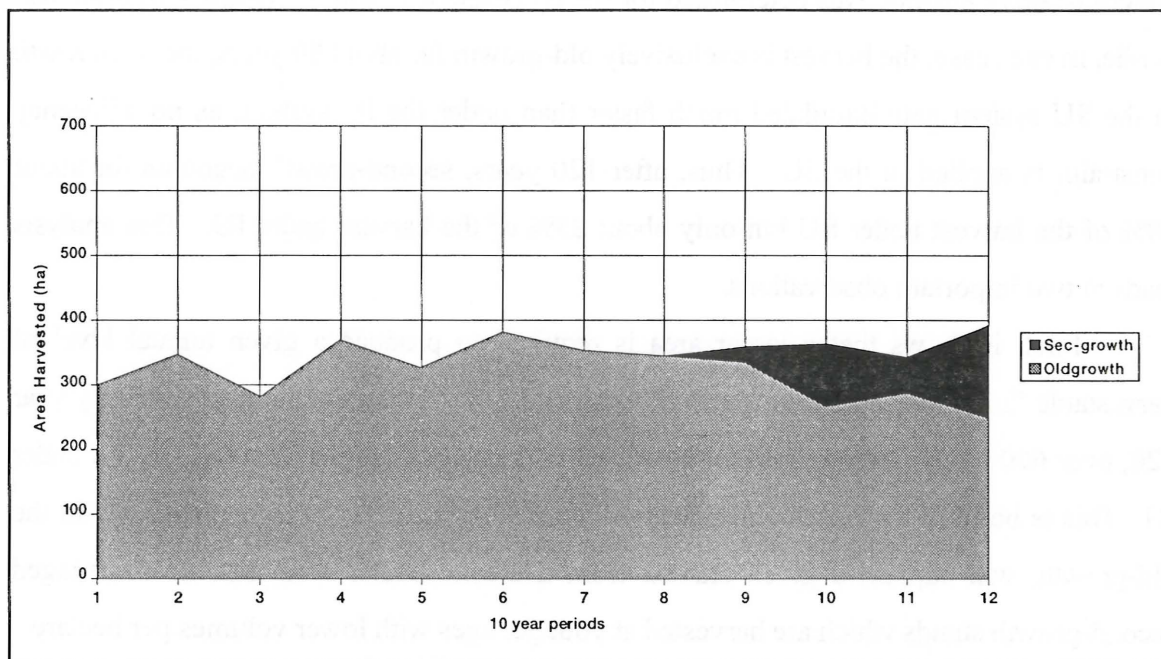


Figure 7 Integrated use system showing composition of harvest area, by old-growth and second-growth, over the 120 year planning horizon.

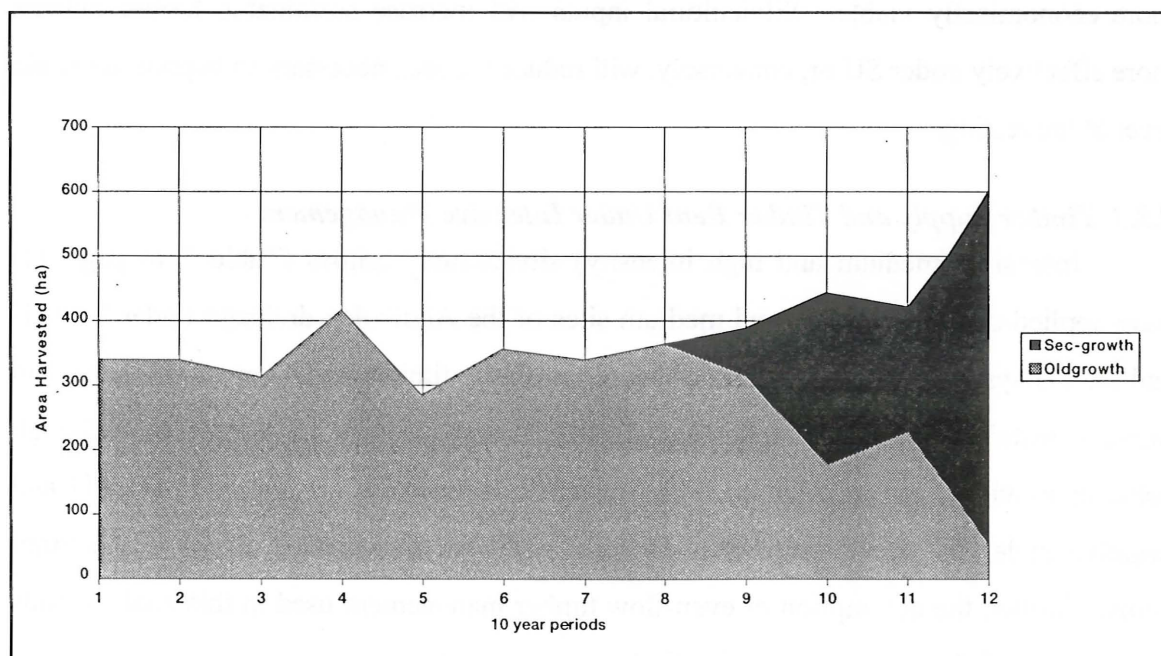


Figure 8 Single use system showing composition of harvest area, by old-growth and second-growth, over the 120 year planning horizon.

pattern of this transition was determined for the IU (**Figure 7**) and SU (**Figure 8**) systems. While, in each case, the harvest is exclusively old-growth for about 80 years, the old-growth in the SU system gets liquidated much faster than under the IU system, as no adjacency constraint is applied in the SU. Thus, after 120 years, second-growth accounts for about 90% of the harvest under SU but only about 25% of the harvest under IU. This analysis leads to two important observations.

First, it shows that a larger area is required to produce a given annual level of harvestable timber volume from unmanaged second-growth than from old-growth. By year 120, over 600 ha. per annum will be harvested under SU compared to about 400 ha under IU. This is because the accumulated volume over many decades, or even centuries, in the old-growth, will support a given harvest from a much smaller area than in unmanaged second-growth stands which are harvested at younger ages with lower volumes per hectare.

Second, under the SU system the old-growth is liquidated more rapidly. This means that silvicultural investments will show earlier returns under SU than under IU and will be more economically viable. Silvicultural inputs will increase sustainable timber outputs more effectively under SU or, conversely, will reduce the area necessary to support a certain level of harvesting.

3.3.3 Timber Supply and Timber Rent Under Intensive Management

Intensive (medium and high intensity) silviculture regimes (Table 2 in page 11) were applied only to the good and medium sites of the Akolkolex drainage under both IU and the SU systems. Application of the more intensive timber management was shown to increase sustainable timber supplies in both the IU and SU systems (**Figure 9**), although gains in moving from medium to high management intensity are minor under SU and negative under IU where harvesting constraints prevent the capture of full silvicultural gains. Further, the assumption of even-flow timber management used in this analysis fails to capture the full benefits of intensive timber management.

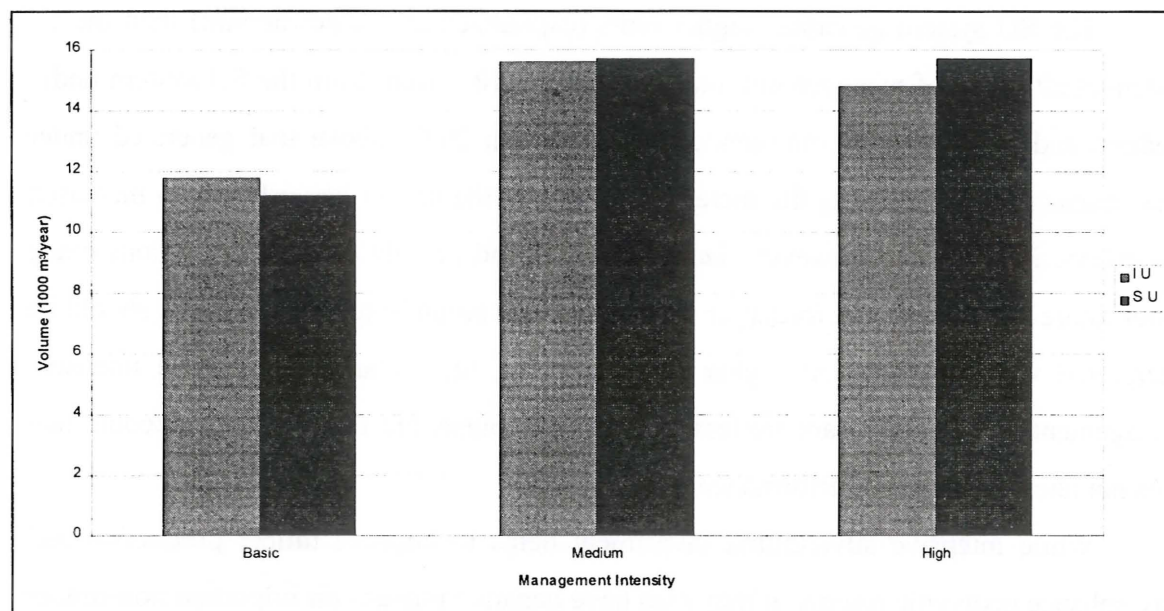


Figure 9 Impact of intensive timber management under integrated (IU) and single use (SU) systems on maximum even-flow volume on a 240 year planning horizon.

Conversely, the increase in timber supply due to intensive timber management could be used to reduce the area dedicated to produce a given volume of timber under the SU system. It can be inferred from this analysis for a 240 year planning horizon, that the area required for dedicated timber production under the SU system can be reduced from 46% to 33% with intensive management, to produce timber volumes equivalent to current harvests under the IU system with no intensive management (**Table 5**).

Table 5 Comparison of area required to produce 11,200 m³/year of timber on a 240 year planning horizon under the Integrated Use and Single Use Systems with and without intensive timber management.

Systems of Management	Percent of Operable Area required without Intensive Management	Percent of Operable Area required with Intensive Management
Integrated Use System	100	100
Single Use System	46	33

The SU system generates higher rents (capitalized at 2% per annum) than the IU system at all levels of management intensity (**Figure 10**). Rent from the SU system under medium and high intensity management is more than 200% above that generated under basic management, reflecting the increased quality of the timber harvested from increased silviculture investment. However, these results depend heavily on the assumptions made about future price premiums for larger sized trees from second-growth stands and should be interpreted with caution. At higher discount rates, the advantages of more intensive management in the early years are less apparent, of course, but the choice of discount rate does not alter the superior performance of SU over IU.

While intensive silvicultural investment helps to improve timber production and may enhance economic returns, it may also have negative impacts on important non-timber resource values such as interior forest habitats and visual quality. This is clearly demonstrated in the results of this research (see sections 3.3.4 and 3.3.5).

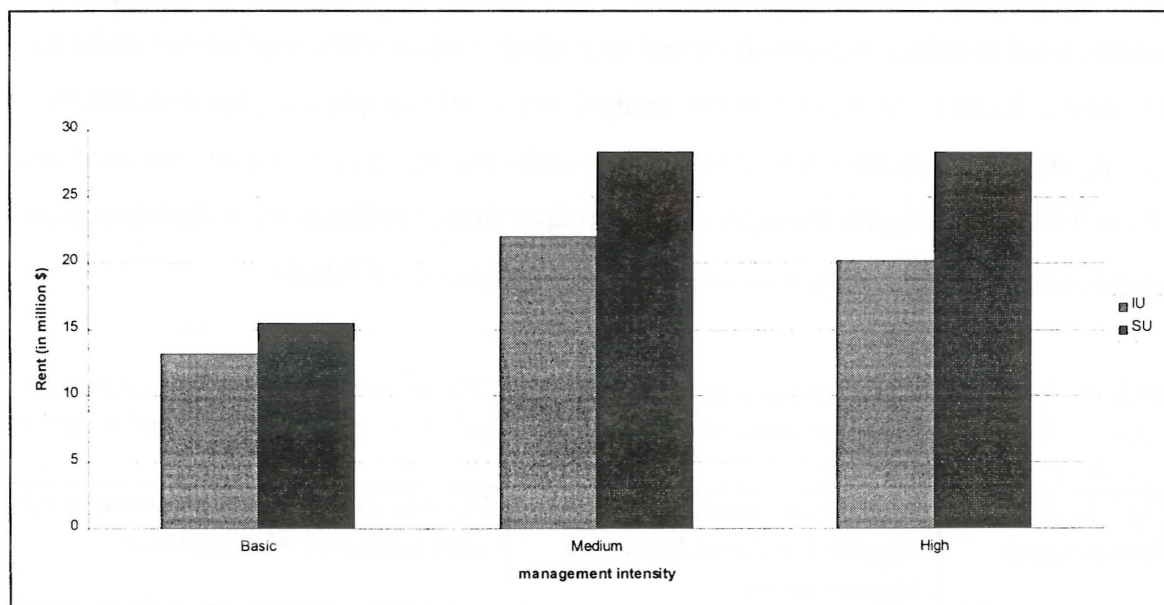


Figure 10 Impact on rent of intensive timber management under integrated use (IU) and single use (SU) systems (2% discount rate on a 240 year planning horizon).

3.3.4 Road Density

Roads are considered to be one of the key factors contributing to environmental damage through slope failure, erosion, and siltation of water courses. By increasing accessibility they also make it more difficult to control human pressures on wildlife populations.

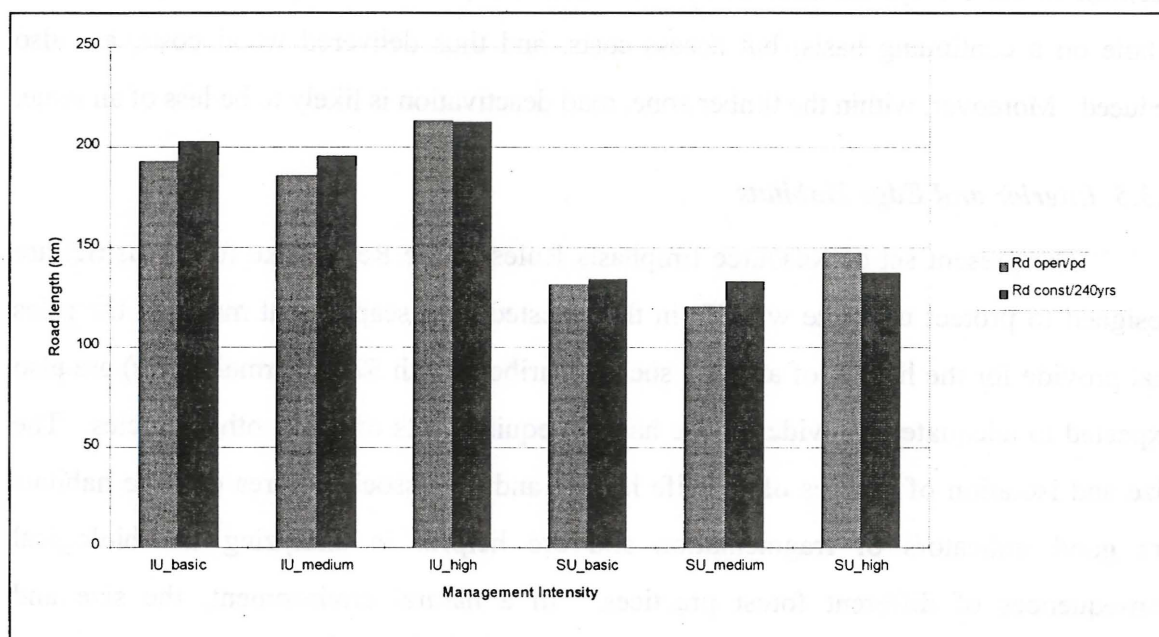


Figure 11 Road density under integrated use (IU) and single use (SU) systems at basic, medium and high management intensities showing average length of roads maintained per period, and constructed during the planning horizon.

The density of roads in the SU and IU systems was estimated in terms of the average length of roads maintained during a planning period and on the total length of roads constructed to the planning horizon. Results (**Figure 11**) show that at all three levels of intensity, the length of roads maintained and constructed in single use is about 35% less than that of integrated use. The length of roads constructed and maintained is higher at high intensity levels because of the thinnings. At medium intensity levels, fewer roads are required than at basic levels because a higher volume per hectare is

harvested. This is mostly due to even-flow policy, otherwise it is likely that the road densities would be the same across all SU systems. Furthermore, under the IU system all forests, other than protected areas, will be crisscrossed by a network of active and deactivated roads and ecosystem functions are compromised everywhere.

Not only does a smaller, more concentrated and permanent high quality road network in the SU system offer better environmental protection for the SU system as a whole on a continuing basis, but access costs, and thus delivered wood costs, are also reduced. Moreover, within the timber zone, road deactivation is likely to be less of an issue.

3.3.5 Interior and Edge Habitats

The present set of Resource Emphasis Rules in the Revelstoke forest district are designed to protect ungulate wildlife in the forested landscape. But many of the rules that provide for the habitat of animals such as caribou (with 52% thermal cover) are also expected to adequately provide for the habitat requirements of many other species. The size and isolation of patches of wildlife habitat and the associated area of edge habitats are good indicators of fragmentation and are helpful in analyzing the biological consequences of different forest practices. In a natural environment, the size and isolation of forest patches are generally correlated with groups of environmental variables such as soil type, drainage, slope and disturbance regime (Sharpe et al. 1987). But under commercial forestry, these are dictated by the harvesting pattern and the extent of protection and fire management practiced in the area.

Presently, a major concern of the public is the fast rate at which interior natural habitats are disappearing, particularly those associated with natural old-growth areas. Large patches are likely to accommodate a mosaic of habitats. The higher the level of fragmentation, the lower the availability of various critical habitats. These are particularly important for certain species that require a minimum size or specific arrangement of patches, such as the spotted owl in the Pacific Northwest (Gutierrez et al. 1985). The current issue, therefore, is the identification of suitable patches that will have

practical conservation values and how to manage them to retain these values (Saunders 1987).

The analysis of the SU and the IU systems for relative patch sizes shows that, relative to the IU system, there are less small patches of interior forest and more large patches under the SU system (**Figures 12 and 13**). Furthermore, and perhaps more critical, under the IU system the relative proportion of largest patches declines and they completely disappear for considerable periods of time with potential disastrous effects on some species requiring interior habitats. A comparison of the distribution of patch sizes at the three levels of intensive timber management (basic, medium and high) showed that the large patches get increasingly fragmented as management intensity increases. This suggests that high intensity timber management may not be compatible with maintaining large patch sizes either within the landscape of the IU system as a whole or within the timber zone of the SU system.

Similarly, the analysis of the temporal distribution of edge habitat shows that the proportional area of edge habitat (i.e. edge habitat as a percentage of old growth area) in the IU system is more than double that in the SU system. Further, it increases during the first 40 years of the planning period as the proportional area of edge habitat in the SU system rapidly declines (**Figure 14**).

There is an important difference between patches found in the SU and IU systems. In the SU system, most of the large patches will be maintained permanently in non-timber zones. A likely management strategy might be to select a network of ideal patch sizes of endemic vegetation, possibly representing each ecosystem subzone. In the case of the IU system, the patches would show a stereotypical temporal variation in their size, distribution and composition as dictated by the harvesting pattern. A “large” patch (501 - 1000 ha) in a particular period may either aggregate with other patches and grow into a “very large” patch (>1000 ha), or it may get further fragmented into a “small” patch (0 -

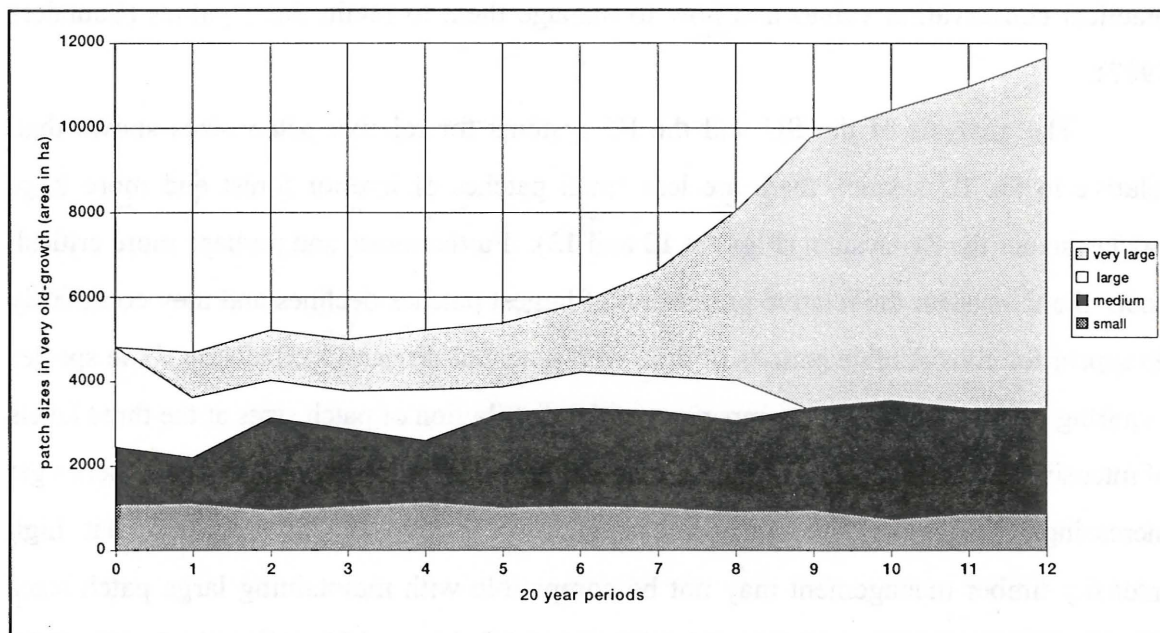


Figure 12 The IU system showing the distribution of patch sizes (as area in ha) in very old-growth (>240 years) for high intensity management over a 240 year planning horizon. (small: 0-100 ha; medium: 101-500 ha; large: 501-1000 ha; very large: >1000 ha)

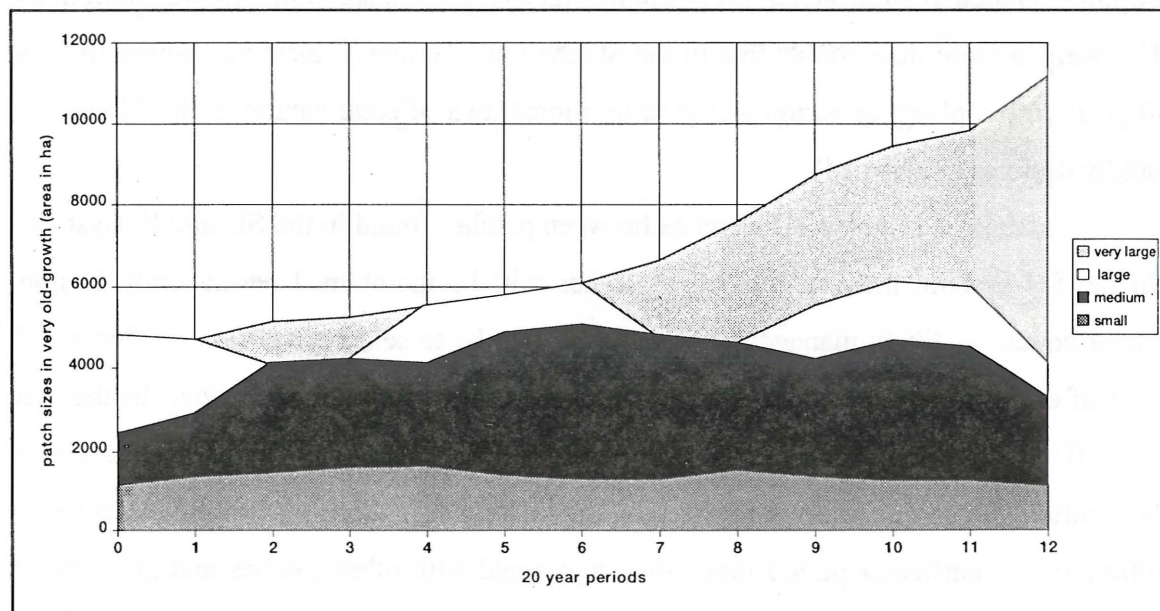


Figure 13 The IU system showing the distribution of patch sizes (as area in ha) in very old-growth (>240 years) for high intensity management over a 240 year planning horizon. (small: 0-100 ha; medium: 101-500 ha; large: 501-1000 ha; very large: >1000 ha)

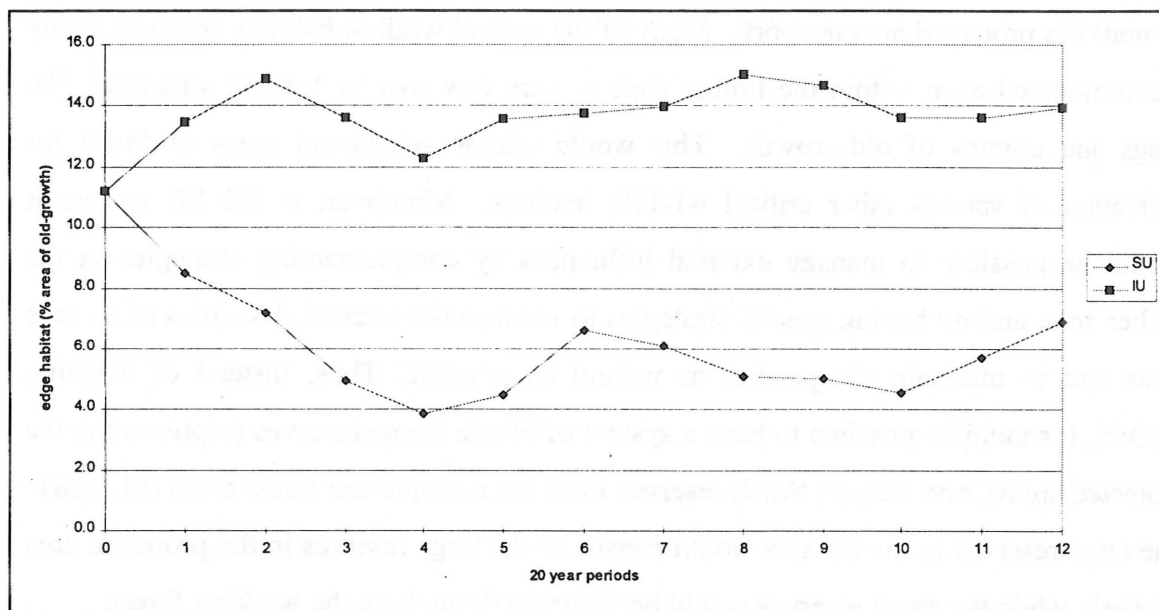


Figure 14 The Single Use (SU) and the Integrated Use (IU) systems showing the distribution of edge habitats (as percent area of old-growth (>120 years)) for high intensity management over a 240 year planning horizon.

100 ha) or a “medium” patch (101-500 ha). This “floating patch” behavior, where there is systematic movement of patches across the landscape, is likely bring in new species (included many exotics to the region) forming a synthetic community, which is constantly adapting to the changing balance of interior and edge habitat. The species that are considered to be endangered through loss of old-growth forests will likely disappear at a much faster rate under the IU system of management.

For some time there has been debate as to whether the most appropriate strategy for bio-diversity conservation should be to protect a Single Large reserve Or Several Small reserves (the so-called SLOSS debate) (Simberloff and Abele 1984; Gilpin and Diamond 1980; Higgs and Usher 1980; Simberloff 1986). The IU system will not provide either of these, as it can only have small patches that support a synthetic biotic community with high mobility. It will be difficult to control both the external and internal influences on the patch. On the other hand, the SU system will help to create a network (or a satellite) of fairly large patches of remnants that can be linked to (or

around) the protected area network. Many of the critical wildlife habitats could be easily accommodated even within the timber zone at very low cost by leaving structures like snags and clumps of old-growth. This would release substantial areas of forest for protection of various other critical wildlife habitats. Moreover, in the SU system it should be possible to manage external influences by complementing strategies in the timber zone and by having special strategies to manage the internal dynamics of reserve areas and to maintain the patches as natural as possible. Thus, instead of debating SLOSS, it should be possible to have a system of Single Large reserves (representing the protected areas) And Several Small reserves from the multiple use forest areas (SLASS). The large reserves in the SLASS would consist of the large reserves in the protected area network, while the small reserves would be scattered throughout the working forest.

The regeneration of early seral, light demanding species may also be seriously affected by microclimatic conditions created in small cut blocks surrounded by old-growth stands (Bradshaw 1992; Chen et al. 1992; Hansen et al. 1993). For the IU system, at various intensities of management, the affected area ranges from 42% to 45% of total cut block area, while for the SU system it is as low as 10% to 14%. Implications for stand growth and yield are unknown and these impacts are not incorporated in this study.

4 Conclusions

Managing every hectare of forest for multiple products is economically inefficient particularly while actively producing mutually exclusive or highly competitive products or when the economies of joint production are outweighed by the diseconomies. This has been demonstrated to be true empirically for the selected economic and environmental indicators examined. This study suggests that the spatial separation of commercial timber activities from the production of non-timber values can generate higher timber rents and enhance timber supplies while affording better protection for the environment including critical wildlife habitats.

These results have serious implications for zoning. It has been shown that zoning for timber production appears economically efficient and environmentally sound. With basic silviculture and environmental protection within the timber zone, including riparian strips and the reservation of environmental sensitive areas, the area required to maintain timber production at current long run, sustainable levels, can be reduced to less than 50% of the total. With more intensive management, this may be reduced further. This means that in 50%, or more, of the management unit outside the timber zone, complementary non-timber values can be produced with low levels of management.

Zoning provides for the intensive management of timber while enhancing the flow of other resource values from the unit as a whole. With careful zoning, areas where visual quality, wildlife, water or other values are particularly sensitive can be avoided. This may not be possible under the current IU system which permits every hectare to be managed for multiple values.

This raises some interesting questions about how the non-timber areas should be managed, especially in terms of forest protection. Should they be protected from natural disturbances such as wildfire and insects, or should nature be allowed to take its course? What are the implications of each strategy for neighbouring timber zones? These and related questions require further thought and research.

Establishing timber zones has implications for short-term timber harvests. Since above average sites carrying high volumes of valuable old-growth timber, hitherto locked up by adjacency constraints, may be released, immediate declines in allowable annual harvests could be ameliorated or even avoided.

Zoning could also help lay the foundation for much needed tenure reforms as old-growth forests diminish and public demands on forest resources increase and become more diverse. It would allow policy makers to more clearly separate public and private responsibilities on Crown forest lands and facilitate the creation of both industrial and non-industrial tenure arrangements where efficient, but environmentally sensitive, management

of timber values would dominate and uncertainty would be reduced thus providing a more agreeable environment, than at present, for private sector timber investments (Haley and Luckert, 1995).

This study demonstrates the high potential for forest land use zoning as a strategy to balance economic and environmental values from British Columbia's forests and offers an innovative method for achieving simultaneous sustainability of timber and non-timber values. Results are based on a narrowly focused case study and it would be unwise to extrapolate the results to other regions where forest ecosystems and management imperatives differ. Nevertheless, the results are very positive and suggest a need to study the concepts introduced in more depth in other parts of the Province.

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Appendix A: Resource Emphasis Rules for Revelstoke TSA.

Rule No.	Resource Emphasis	Description
1	Timber: Unconstrained U	no constraints
2	Basic Timber T	adjacency and 20 year greenup, maximum disturbance rate of 40% of area, disturbance age of 20 yrs, retain 30% of area in height class 2 (40 years or older)
Note: All subsequent Resource Emphasis Rules are incremental to the Basic Timber rule		
3	Wildlife(h) Wlife (h)	retain 60% of area in height class 3 (stands 80 years or older)
4	Wildlife(l) Wlife (l)	retain 40% of area in height class 3
5	Wildlife(m) Wlife (m)	retain 52% of area in height class 3
6	VQ(modification) VM	maximum disturbance rate of 25%; Green-up age 40 years
7	VQ(modification) & Wildlife(h) VM-WC1	maximum disturbance rate of 25%; green-up of 40 years and retain 60% of area in height class 3
8	VQ(modification) & Wildlife(l) VM-Wlife (l)	maximum disturbance rate of 25%; green-up of 40 years and retain 40% in height class 3
9	VQ(modification) & Wildlife(m) VM-Wlife (m)	maximum disturbance rate of 25%, green-up of 40 years and retain 52% of area in height class 3
10	VQ(Partial Retention) VPR	maximum disturbance rate of 10%, green-up of 40 years
11	VQ(PR) & Wildlife(h) VPR- Wlife (h)	maximum disturbance rate of 10%, green-up of 40 years and retain 60% of area in height class 3
12	VQ(PR) & Wildlife(l) VPR- WC2	maximum disturbance rate of 10%, green-up of 40 years, and retain 40% of area in height class 3
13	VQ(PR) & Wildlife(m) VPR- Wlife (m)	maximum disturbance rate of 10%, green-up of 40 years, and retain 52 % of area in height class 3
14	Total Retention - No cut TR	No logging

Appendix B: Glossary of Terms

Adjacency: an integrated management guideline that specifies that adjoining areas surrounding an harvest cutblock should not be harvested until the regeneration in the harvest cutblock reaches specified height or age.

Biological diversity: the diversity seen in living organisms in all its life forms at all levels of organization. It may range from diversity in genetic alleles to diversity in ecosystems.

Edge: it is a band on the periphery of a patch of forest that differs abiotically and biotically from the interior and the exterior.

Forest cover requirements (in British Columbia management context): Specify desired distribution of areas by age or size class groupings in a management unit. They reflect desired conditions for wildlife, watershed protection, visual quality and other integrated resource management objectives.

Forest Practices Code (FPC): legislation, standards and field guides that govern forest practices in British Columbia.

Forest Renewal Plan (FRP): a major long-term plan, supported by legislation, to renew British Columbia's forests by improving reforestation, silviculture, cleaning up environmental damage and enhancing community stability and employment within the forest sector.

Green-up period: the time needed for a stand of trees to reach a desired condition (e.g. height) to ensure maintenance of water quality, wildlife habitat, soil stability or aesthetics.

Height class: an interval into which the range of tree or stand heights is divided for classification and use. Also, the trees or stands falling into such intervals.

Patch: an area of forest that is homogeneous with respect to some attribute, for example, a seral stage. It is a fundamental structural element of the landscape.

Protected Areas Strategy (PAS): a process to coordinate all of British Columbia's protected areas programs and objectives.

Protected areas: areas such as federal parks, provincial parks, wilderness areas, ecological reserves and recreation areas that have protected designations according to federal and provincial statutes.

Seral stage: stage in a sequence of biotic communities (the sere) that successively occupy and replace each other in a particular environment over time.

Sustained yield: a method of forest management that calls for an approximate balance between net growth and amount harvested.

Tenure: an interest or right held in Crown land or resource granted by statute (e.g., Forest Act).

Timber Supply Area (TSA): an integrated management unit established in accordance with Section 6 of the Forest Act.

Visual Quality Objective (VQO): defines a level of acceptable landscape alteration resulting from timber harvesting and other activities. A number of visual quality classes have been defined on the basis of the maximum amount of alteration permitted.

Visual Quality Objective - Modification (VQM): alterations may dominate the landscape in this VQO class.

Visual Quality Objective - Partial Retention (VPR): alterations are visible but not conspicuous.