DO VISUAL QUALITY OBJECTIVES NECESSARILY CONSTRAIN TIMBER HARVEST LEVELS? EXPLORING THE POTENTIAL OF PARTIAL CUTTING

by

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ABSTRACT

The present thesis is an attempt to identify possible win:win solutions to the apparent and widely reported conflict between aesthetics and the practice of timber harvesting in British Columbia (BC). The approach used is to review the literature on silvicultural systems, Visual Resource Management (VRM) as practiced in BC, public perceptions of various harvesting practices, the relationship between aesthetics and timber harvest levels, and on long term timber supply implications of proposed solutions in order to provide for a more complete picture. A series of short-term modelling exercises has been undertaken to assess the potential of using certain visually effective partial cutting techniques (termed dispersed retention cuttings here) as a possible solution to the conflict. This includes a description and comparison of the results obtained with similar independent modelling exercises.

Key findings from the reviews and modelling analysis include the following:

1) Confusion still exists regarding "partial cutting". The term "dispersed retention cutting" is put forward in this thesis to reduce this confusion when discussing more visually acceptable forms of partial cutting.

2) There is a failure to consider the broader landscape-level context in BC, which has significant implications for the management of visual resources.

3) People prefer dispersed retention cutting to clearcutting for a given level of timber removal and some kinds of dispersed retention cutting can virtually eliminate VQOs as a constraint both in the short and long term. The perception that VQOs are a major constraint on timber harvesting appears to be an artefact of the reliance on clearcutting.

4) More research is needed on the feasibility of dispersed retention cutting techniques in different forest types. There is a difference of opinion among practitioners as to the extent to which dispersed retention cutting can be realistically undertaken.

5) Further analysis of the sensitivity of timber supply calculations to the harvesting practices (clearcutting or others) used in visually sensitive areas is needed.

6) More research is needed to find and validate key visual quality thresholds (e.g. at which level of removal is a dispersed retention cut perceived as a clearcut by the public?) and to develop landscape models that can handle dispersed retention cutting techniques over time and over large areas.

Key Words: visual resource management, visual quality, public perceptions, partial cutting, forest, landscape, timber supply, timber availability, visual quality intensity index.
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CHAPTER 1: INTRODUCTION

British Columbia's biggest industry is the forest industry (for the year 2001, based on total value of factory shipments, B.C. Ministry of Management Services [2002]). The forest industry tends to be cyclical, and relies on BC's vast public forests as a source of timber. The forest industry still relies heavily on the use of clearcutting as the main harvesting technique, with over 90% of the area harvested in BC in 1997-1998 being clearcut (BCMoF, 2000a). Tourism is British Columbia's second biggest industry (for the year 2001, based on dollar figures spent by tourists in the province, B.C. Ministry of Management Services [2002]), and is growing steadily. BC is sold worldwide as "Super Natural BC", "Beautiful BC", and so on. BC's spectacular scenery is tourism's biggest asset, its main variable linking it to success (BCMoF, 2002a). Are both these industries currently living happily side-by-side in BC? Not quite as much as one might think. Clearcutting happens to have a negative effect on the visual quality of forested landscapes, and the more visible clearcuts there are, the worse it gets (BCMoF, 1996a).

To blur the picture a bit more, many British Columbians do not like the way clearcutting looks either. So what do we do? Keep clearcutting and tell the unsatisfied public and the tourists that it will grow back? Further constrain the logging industry in favour of a growing tourism sector? Or perhaps a win:win solution exists: maintain visual quality of BC's forested landscape while allowing for some timber harvesting. This is what the current Visual Resource Management (VRM) system in BC is attempting to do for those areas considered to be the most visually sensitive. In essence, the BC VRM system is based on the concept of visual dominance, and uses Visual Quality Objectives (VQOs) as a legislative framework for visual resources. It should be noted that this system does not advocate for less logging in visually sensitive areas but rather for less visible logging (see section 2.2 below for more details).

The prevailing philosophy of the current VRM system in BC has been criticized as safeguarding the front-country at the expense of the environmentally pristine back-country: an out-of-sight, out-of-mind approach (Sheppard, 2000). This is due in part to the fact that most areas managed for visual quality are front-country areas (Marc, pers. comm., 2002), but also because of the historical avoidance of these front-country visually sensitive areas by the forest licensees in many parts of BC (BCMoF, 2000b), presumably due to increased costs and planning requirements. As a result of the Forest Practices Code (FPC) (BCMoF, 1995a), scientific arguments for biodiversity and ecosystem management, lobbying by environmental and eco-tourism groups, and the extensive logging of many back-country areas, the remaining merchantable timber in the less visible parts of the landscape is no longer as available for logging as is the case in the West Kootenays (Sheppard, pers. comm., 2001). In many areas, there is an acute shortage of available timber relative to historic levels (Arrow Forest Licence Group, 2000). This puts pressure back on the more visible slopes, closest to the communities
and highways, with maturing second-growth timber, but where VRM constraints have
typically been highest.

How is this dilemma to be resolved? Current visual landscape design techniques
provide some very useful guidelines for logging in visually sensitive areas, but the forest
industry and the practitioners, still mainly clearcut-oriented, have a longstanding and
widespread belief that visual quality is a major constraint on timber supplies (Nelson
and Wells, 2000). Does it really need to be, or is managing for visual quality only a
constraint because of our reliance on clearcutting? Considering the increasing interest
worldwide in so-called partial cutting practices and continuous-cover forestry, and the
longstanding public rejection of clearcutting in North America, could the use of certain
partial cutting techniques act as a relief to this dilemma between the public’s desire for
jobs and scenic landscape, and between BC’s biggest industries?

In view of this, the thesis will address the following research questions:

a) What is the relationship between visual quality (using VQOs as surrogates)
and timber availability/supply?
b) Are visual quality and timber availability/supply always inversely
proportional?
c) Is this relationship affected by harvesting practices?
d) What type(s) of partial cutting are visually effective?
e) How much gain in timber availability (if any) can one expect from a shift in
harvesting practice from clearcutting to certain types of visually effective
partial cutting techniques (termed here dispersed retention techniques).

This work will focus upon an apparent recent shift in harvesting techniques in BC (such
as the adoption of variable retention and other new/innovative harvesting methods
throughout the province), taking into account visual landscape design principles (from
BCMof, US Forest Service [USFS], United Kingdom [UK], etc.), and recent findings on
public perceptions of various partial cutting approaches (from BC and elsewhere). The
thesis develops a model for predicting timber volumes that could be harvested to meet
VQOs using dispersed retention cutting versus clearcutting, at the landscape scale. The
emphasis will be on short-term availability, but the long term supply situations is also
considered, in order to provide a more complete picture. For the purpose of this thesis,
the expression “dispersed retention cut” will be introduced and used in lieu of the
generic expression “partial cutting”.

The thesis is organized as follows. The relevant literature and key concepts are
reviewed in Chapter 2, followed by a review of the methods used for modelling
purposes in Chapter 3. Chapter 4 presents and analyses the results obtained with a
focus on short-term availability, while discussing the long term implications of the results
and recommendations made throughout the thesis. Conclusions are provided in
Chapter 5. A list of the acronyms and abbreviations used throughout the thesis is
provided as an appendix to facilitate reading.
CHAPTER 2: LITERATURE REVIEW

The literature review includes five key topics. The first two topics covered are necessary to understanding the background context, and key definitions and concepts, while the third and fourth topics covered consist of the literature reviewed pertaining to public perceptions of logging disturbances and pertaining to the relationship between managing for visual quality and timber availability/supply. A fifth topic, focused on long term timber supply implications is included to provide a more thorough review of the topic.

Since the present work deals with visual quality of harvesting operations, it is important to review the forestry terminology that pertains to those treatments. A good understanding of silvicultural systems, and other key forestry concepts and terminology relevant to harvesting approaches is essential in understanding the impact of various forestry activities on the landscape. Such a review of silvicultural systems, and other key forestry concepts and terminology, is presented in section 2.1. Furthermore, since the focus of the thesis is on how alternative approaches (operational and design) to the management of visual resources in British Columbia impact timber availability and supply (and vice-versa), there is a need to review the current management of visual resources (for BC) along with some key concepts relating to Visual Resource Management (VRM). This review is included in section 2.2.

Third, since the present thesis deals with visual quality issues, a review of public perceptions of various timber harvesting disturbances is undertaken in section 2.3. Such a review includes a brief overview of some of the human and landscape factors affecting public perceptions and concludes with an overview of public perceptions of logging disturbances. Fourth, since the thesis addresses the relationship between timber supplies (and availabilities) and visual quality, the available literature on this specific topic needs to be reviewed. Section 2.4 focuses on reviewing the impact of managing for visual quality (of forested landscapes) on timber harvesting (hence timber availability and timber supply impacts). The difference between this section and the previous section stems from the differences between the visual impacts of logging per se (reviewed in section 2.3) and the impacts on timber availability and/or supply of managing for visual quality of forested landscapes (reviewed in section 2.4).

Finally, the long term growth and yield implications need to be reviewed because even if short-term gains in timber availability can be realized with dispersed retention cutting under VQOs, the long term picture may be less promising if it leads to substantial reductions in long term growth and yield. This fifth review includes an assessment over time of the visual performance of the main silvicultural systems, followed by a review of available literature on the estimated long term growth and yield implications of retaining parts of the original overstory.
2.1 SILVICULTURAL SYSTEMS REVIEW

2.1.1 What are silvicultural systems?

For the British Columbia Ministry of Forests (BCMoF), a silvicultural system is a "planned program of silvicultural treatments during the whole life of a stand designed to achieve specific stand structural objectives" (BCMoF, 1998a). Silvicultural treatments include stand regeneration, stand tending, and stand harvesting methods used to obtain benefits from that stand (BCMoF, 1998a). It should be noted that the word "benefit" was used, rather than the word "timber", clearly implying that timber may (or may not) be a derived benefit resulting from a given silvicultural system. Nyland presents a similar definition: "a silvicultural system describes the long term plan for managing an individual stand to sustain a particular set of values of interest" (Nyland, 1996). Again, it is mentioned that any given silvicultural system includes 3 basic components: regeneration, tending, and harvesting (Nyland, 1996).

Besides these definitions, it is important to mention that silvicultural systems are first classified by the resulting age-class structure (whether even-aged or uneven-aged stands are sought), and then by the intent for regeneration (BCMoF, 1998a). While some authors (BCMoF, 1998a) report 5 types of silvicultural systems and several derivatives of those systems, others (e.g. Matthews, 1994) appear to treat the major systems' derivatives as systems of their own and end up with 15 systems. The BCMoF (1998a) structure is used here which results in five main types of silvicultural systems (four even-aged systems and one uneven-aged) which are defined below.

2.1.1.1 Clearcut system

The clearcut system consists of regenerating even-aged stands, whether naturally or artificially, without using any of the overstory trees for regeneration purposes. Therefore, it usually consists of only one harvest per rotation, where the overstory trees are all removed at once. Even-aged stands are usually defined as stands where the trees are less than 20 years apart in age (BCMoF, 2001a) but can include two or three cohorts (e.g. a two-layered stand) in BC (BCMoF, 1998a; Mitchell, pers. comm., 2002). It should be noted that this definition, derived from the forestry discipline, defines clearcutting as the first step of a process (to regenerate an even-aged stand). This view may differ from other non-forestry views, which may see clearcutting as the last step/intervention, or as the end of something (perhaps the end of the forest as an ecosystem for some groups). An example is the clearing of a ski hill. From the forester's perspective, it would not be a clearcut, nor would it be forestry, but simply land clearing since there is not intent to regenerate a future forest on the site (but to develop a ski hill instead). However, for the general public looking at the cleared hillside, it may very well be interpreted as a clearcut. The forestry/silvicultural system's definition is used here rather than the more common definition of the practice of clearcutting as the final intervention. Derivatives of the clearcut as a silvicultural system include:
Clearcut with reserves, where some overstory trees are left on site beyond the harvest to fulfill objectives that are unrelated to stand regeneration (visual management, wildlife trees, etc.). Reserves can be grouped or dispersed throughout the cut block.

Strip clearcutting, where the clearcut areas are rectangular, and take the shape of a strip. Often these strips are removed sequentially (progressive strip clearcutting) or alternately.

Patch cut, where patches at least one hectare in size (BCMoF, 1998a) are clearcut and interspersed with uncut areas or areas harvested during a different entry. The term entry and the number of “entries” refer to the number of times a stand is entered for harvesting purposes. Patches less than one hectare in size would qualify as a group selection system if the whole (larger) area were harvested sequentially to produce an uneven-aged stand. Other definitions of what a clearcut is could also be used to define what constitutes a patch cut. For example, Kimmins defines a clearcut as an area deprived of forest influence (over 50% or more of its area), based on the distance from the closest tree or forest edge (Kimmins, 1992).

The term progressive, often seen and/or associated with clearcutting (e.g. progressive clearcutting, progressive strip clearcutting, etc.), means that the clearcut areas are harvested progressively from point A to point B, with the areas harvested sequentially being adjacent.

2.1.1.2 Shelterwood system

In the shelterwood system, even-aged stands are regenerated using some of the overstory trees (left uncut) to provide shelter of seed. The regeneration can either be planted, natural, or a combination of both (with planted trees complementing the irregular and often “gappy” natural regeneration). The trees left to provide shelter could be dispersed throughout the cutblock or aggregated in strips or groups. The rationale for leaving sheltering trees is that they will reduce growing season frosts underneath the canopy, providing the growing regeneration with a more stable climate than would a clearcut. These sheltering trees will usually be needed until the regeneration is well established. Therefore, it usually consists of at least two harvests per rotation. The first harvest, called establishment cut (where the regeneration is established/planted), consists of removing the majority of the overstory, leaving only a few sheltering trees. The second entry is called the final cut (or regeneration cut) where the sheltering trees are removed to leave the regeneration grow in full light once it is well established. It is important to mention that, in order for this system to be successful in providing shelter to the regeneration, trees left uncut should be healthy, and wind firm (so they can fulfill their sheltering function and not blow down). In some instances, additional entries/cuts will be planned, such as a preparatory cut (equivalent to a thinning from below, to prepare the stand for the regeneration establishment cut and the removal cut once the regeneration cut is established). The BCMoF (1998a) even mentions a salvage cut as being potentially part of a shelterwood system, where dead or blowdown trees-are salvaged/harvested to avoid fibre losses. However, such a cut should be included in all systems (based on the rationale that blowdown could occur under any system) or in
none at all (based on the rationale that a properly designed silvicultural system should aim at minimizing blowdown occurrences). Derivatives include:

**Shelterwood with reserves**, where some (or all) of the sheltering trees are left on site (either initially or once their sheltering function is fulfilled) until the end of the rotation to fulfill objectives that are unrelated to stand regeneration (visual management, wildlife trees, etc.).

**Strip shelterwood**, where the cut areas are rectangular, and take the shape of a strip, and where cut and uncut strips alternate so the uncut strip provides shelter to the regeneration in the cut strip (generally). Cut areas are narrow enough so the centre part can also benefit from the sheltering effect of the adjacent uncut areas.

**Group shelterwood**, which is the same as a strip shelterwood, except that the cut and leave areas do not necessarily have the shape of a strip (groups of trees are cut while other adjacent groups are left to provide shelter for the regeneration in the cut areas). Cut areas are small enough so the centre part can also benefit from the sheltering effect of the adjacent uncut areas. Patches less than one hectare in size would qualify as a group selection system if the whole (larger) area were harvested sequentially to produce an uneven-aged stand.

**Irregular shelterwood** is defined by the BCMoF (1998a) as a variation of the shelterwood system in the sense that the seed bed is kept receptive to regeneration for an extended period of time, still under the shelter of overstory trees. This results in a future forest of irregular tree heights since the regeneration period is so long. However, it is said that despite regeneration periods of up to 50 years, the resulting stand is even-aged and usually has 2-3 distinct age classes. This system is said to be a “catch-all” system (Mitchell, pers. comm., 2002).

### 2.1.1.3 Seed-tree system

The seed-tree system regenerates even-aged stands using some of the overstory trees (left uncut) to provide a seed supply for regeneration purposes. Overstory shelter is not a requirement of this system. The idea behind the seed-tree system is that the trees left uncut will undergo stress due to the removal of their neighbouring trees (sudden increase in sun exposure, etc.) and will produce and release a significant amount of seeds. Trees left as seed-providing trees need to be carefully selected, as they will be reflected in the next forest: species, wind firmness, phenotype (the visual expression of the genes), etc. The regeneration is therefore natural, even though some planting may take place in order to supplement the often “gappy” natural regeneration. The density of the seed-trees left on site will be influenced by the number of seeds estimated to be produced from each tree left, the seed-bed quality, and the seed dispersal capacity (how far from the parent tree can the seeds fall).

Like in the shelterwood system, the seed tree system usually consists of at least two harvests. The first harvest, which could be called the seeding cut (where the cut is intended to provoke the seed fall from retained trees), consists of removing the majority
of the overstory, leaving only a few seed-providing trees. The second entry is called the final cut (or removal cut) where the seed-providing trees are removed to leave the regeneration grow in full light once it is well established. In some instances, additional entries/cuts will be planned, such as a preparatory cut (equivalent to a thinning from below, to prepare the stand for the next cut, which will be the regeneration establishment cut). Derivatives include:

**Seed-tree with reserves**, where some (or all) of the seed-providing trees are left on site (either initially or once their seed-providing function is fulfilled) until the end of the rotation to fulfill objectives that are unrelated to stand regeneration (visual management, wildlife trees, etc.).

**Strip seed-tree**, where the cut areas are rectangular, and take the shape of a strip, and where cut and uncut strips alternate so the uncut strip provides a seed supply for the regeneration in the cut strip (generally). Cut areas are narrow enough so the centre part can receive an adequate seed fall from adjacent uncut areas.

**Group seed-tree**, which is the same as a strip seed-tree, except that the cut and leave areas do not necessarily have the shape of a strip (groups of trees are cut while other adjacent groups are left to provide a seed supply for the regeneration in the cut areas). Again, cut areas are small enough so the centre part can receive an adequate seed fall from adjacent uncut areas. As mentioned earlier, patches less than one hectare in size would qualify as a group selection system if the whole (larger) area is harvested fast enough to produce an even-aged stand, or as a selection system if an uneven-aged stand results.

2.1.1.4 **Coppice system**

The coppice system is also a system which is intended to regenerate an even-aged stand, but via sprouting of the stumps or roots. Sprouting of the stump is when a tree is cut and a new leader/stem germinates directly from the stump and forms a “new” tree, while root suckers are when a root sprouts and forms a “new” tree (BCMoF, 1998a). In this system, all the trees are harvested at the same time, and the stumps are left to sprout. This system requires a species that has the physiology that allows sprouting (usually a deciduous species). A derivative of this system is:

**Coppice with standards**, where a shade-tolerant sprouting species is planted/grown in between the harvests of an overstory species with a longer rotation/life span.

2.1.1.5 **Selection system**

Unlike all other systems seen so far, the selection system maintains an uneven-aged stand structure, and is characterized by several entries/harvests of individual trees or small groups of trees on a regular basis. Since regular entries are occurring, and since a small portion of the entire stand is harvested at each entry, this system has no rotation per se but has instead a cutting cycle. It could be compared to the shelterwood system and the seed-tree system in the sense that the overstory provides seeds and shelter,
but the overstory does so on a constant basis in the selection system as opposed to the other two. Another difference is the intent at the age structure level (uneven-aged sought after in the selection system). Derivatives of this system include:

**Group selection**, where the trees are harvested in groups.

**Individual tree selection**, where the trees are harvested individually.

The BCMoF (1998a) mentions that the term “selection system” should not be confused with “selective logging”, which often refers to high-grading (taking the best trees and leaving the worst trees behind to regenerate, contributing to the degeneration of the stand over time). The concept of high-grading will be addressed in more depth below.

### 2.1.2 Partial cutting: where does it fit?

Partial cutting is not a silvicultural system per se, but rather a generic term used for non-clearcut (and non-coppice) systems. Even though it is widely used (and misused), it does not mean anything more than “some trees are cut, and some are not”, hence the expression partial cut. It does not indicate whether the stand is managed under an even-aged or uneven-aged structure, nor does it provide indications of the regeneration intent for the area. Also, depending on the frame of reference (a small block or an entire hillside), any cut could be considered a partial cut, as long as the reference area is big enough to incorporate both cut and uncut trees. Time also plays a crucial role, since an area may be partially cut temporarily (e.g. a shelterwood or seed tree) and considered a partial cut from a short-term perspective, even though it will result in an even-aged stand in the future. While it may have some use in characterizing non-clearcut systems, or systems that do not remove the entire canopy in one harvest, it is a very delicate term to use and will generally not be used in this thesis with the exception of a few generic examples and when reporting on literature using the term partial cutting (to avoid confusion when relating to the BCMoF partial cutting studies [BCMoF, 1997a] for example).

For the purpose of the present thesis, the expression “dispersed retention cutting” is introduced and will be used (as opposed to the expression partial cutting) to describe a non-clearcut (and non-coppice) harvest where the retained trees are somewhat evenly dispersed (at least in their visual appearance) throughout the cutblock. In other words, the expression “dispersed retention cutting” as used further could refer to a uniform shelterwood, a uniform seed-tree, single-tree or small group selection system, an irregular shelterwood system, a commercial thinning, etc. However, the expression “dispersed retention cut” used further will not refer to the clearcut system, any group/strip/patch cut, or the coppice system. The end result of such a dispersed retention cut will be a forest with a visual appearance of a reduced density, with no visually discernable cleared areas as seen from an oblique aerial angle, at a distance of about one kilometre, simulating a near-middleground cross-valley view (as will be discussed later). It should be noted that this definition is based on the visual appearance of the harvesting operation, rather than on its silvicultural characteristic or intent. Such a visual definition is very important and useful in describing a harvesting operation for visual purposes (rather than for forestry/silviculture purposes), and is
similar to that used by the BCMoF in perception studies (BCMoF, 1997a). It should also be noted that the visual appearance of uniform distribution is used since "perfect" uniform distributions are never achieved (e.g. landings often constitute small cleared areas, etc.), and some non-uniform distribution is tolerable as long as it is not visually discernable as a cleared area or a pattern of removal from any given viewpoint.

2.1.3 Selective logging and high-grading

The concept of high-grading needs to be defined and requires a bit of attention. The BCMoF (1998a) defines selective logging as the old exploitive harvesting approach consisting of removing the best trees, while leaving the low quality trees on site to regenerate the future forest (this approach is also often called "high-grading"). This results in very poor quality forests, and the BCMoF stresses that this approach is different from the selection system and is often referred to as something of the past that is not practiced anymore in BC.

However, while exploitive forestry is to be avoided, it is important to keep in mind that the concept of high-grading requires mostly a timber-oriented perspective. In other words, taking the best trees (from a timber perspective) and leaving the poor trees to regenerate (from a timber perspective) may only be a thing to condemn from a timber perspective. While some loss of species or genetic diversity is a possibility and future timber harvesting options may be limited, the performance of high-grading in regard to non-timber values may not be as negative as it is for timber values. In other words, high-grading one resource (e.g. timber) may not result in high-grading of another resource (e.g. visuals). Consequently, the concept of high-grading may not be a thing to condemn as much in a multi-resource forestry mentality as it should be in a solely timber-oriented mentality. Generally speaking though, it is employed as a catchall term to describe exploitive forestry and should therefore still be condemned and avoided.

2.1.4 Variable retention

In June 1998, under social pressures to change its practices, MacMillan Bloedel Ltd. (MB) announced that it would phase-out clearcutting via the implementation of what it called the "Forest Project" (MB, 1998). The Project was meant to address two issues affecting MB's corporate performance: clearcutting and the logging of old growth

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1 Most of the information provided under this section was taken from MacMillan Bloedel's (now Weyerhaeuser) web page and from speeches given by Tom Stephen (former Chief Executive Officer, MacMillan Bloedel) and Bill Beese (Forest Ecologist, MacMillan Bloedel) attended by the author. Unfortunately, one of the main references for the Forest Project was MB's web site (http://www.mbltd.com), which was taken down and replaced by (re-directed to) Weyerhaeuser's corporate web site literally the day after Weyerhaeuser bought and took over MB. Not only is the reference not there anymore (MB's web site does not exist anymore), but also the Weyerhaeuser web site does not address adequately the Forest Project and the variable retention issue. However, since then, the original documents pertaining to variable retention and the Forest Project were obtained (MB, 1998) and the author is confident they hold the same information (and more), since they are the source documents for the content of the "defunct" web site. This new documentation (MB, 1998) will therefore be used as a reference source for the remainder of the present thesis, replacing the "defunct" web site's reference and printouts.
The backbone of this project was the introduction of a new harvesting approach, variable retention, as an alternative to clearcutting.

According to MB (1998) and Franklin et al. (1997), variable retention is a new silvicultural system designed to leave some trees on each cutblock and in various patterns and quantities to preserve some structural diversity. Trees can either be left in a dispersed manner (dispersed retention) or in aggregates (group retention). The proportion of trees to be left on the cutblock varies depending on the objectives for each stand, and should include snags, large woody debris, live trees, canopy layers, etc. The variable retention system is meant to be a way to regenerate even-aged stands via a single entry (Franklin et al., 1997; MB, 1998). Variable retention does not require one specific regeneration method and, like many other systems (e.g. the clearcut system), can use planting, natural regeneration, or a combination of both. However, variable retention is intended to regenerate even-aged stands, which in itself constitutes a regeneration objective.

The question of whether or not variable retention is a silvicultural system depends on the perspective taken. Mitchell and Beese (2002) argue that it is a harvesting approach and prefer the use of the term “retention system”, while MB (1998) and Franklin et al. (1997) argue that variable retention is a system. It should be noted however, that under current legislation in BC, variable retention had to be recognized as a system by the BCMoF for MB to be allowed to use it (Weetman, pers. comm., 2002). Two points remain to consider however. First, as pointed out by Mitchell and Beese (2002) variable retention as defined by MB (1998) and Franklin et al. (1997) could be achieved at the landscape level with the use of the various classical silvicultural systems in various stands. Second, a clear distinction needs to be made between variable retention and clearcutting with reserves, otherwise it could be argued that it is not a new system but clearcutting with reserves with a fancier, more politically correct name. Several authors (Franklin et al., 1997; MB, 1998; Mitchell and Beese, 2002) raise the “awkward and contradictory” aspects of the clearcut with reserves term, and a clearer distinction between variable retention and clearcut with reserves is needed. Such clarification could be provided by the introduction of a new system, the retention system, which would maintain various levels of permanent structural retention at the landscape level for objectives other than regeneration (as advocated by Mitchell and Beese, 2002).

2.1.5 Commercial thinning

Commercial thinning is a silvicultural treatment, not a system per se, and is often part of a silvicultural system. It basically consists of removing some trees (not all) in a harvest entry, usually to capture mortality, reduce competition, or simply to harvest some volume earlier in the rotation. For example, a very dense stand can be thinned to reduce the inter-tree competition, or to remove the trees that are anticipated to die before the final cut (hence the expression “capturing mortality”). Commercial thinning can also be used to allow fewer selected trees to growth faster (due to the removal of some competing trees in the thinning operation) for a few years before the final harvest. The term commercial indicates that the trees harvested are of commercial value (or size), as opposed to pre-commercial thinning which relates to a thinning where the trees cut are not of commercial value/size (e.g. when a plantation is thinned to reduce
competition). Commercial thinning operations termed “from below” and “from above” relate to the canopy layer(s) in which the thinning is initiated and the direction it is headed in the canopy. For example, a stand containing 1000 m$^3$/ha thinned from above to 600 m$^3$/ha means that 400 m$^3$/ha will be harvested starting from the upper canopy layers (bigger/dominant trees) and will move towards the lower canopy layers (smaller trees) until the 400 m$^3$/ha target is reached. Thinnings from below usually result in less visual impact since the upper canopy is usually maintained or little affected while the thinnings from above may have more pronounced visual impacts.

2.2 OVERVIEW OF THE MANAGEMENT OF VISUAL RESOURCES IN BC

2.2.1 Visual resource management and its origins

Visual resource is defined as the “quality of the environment as perceived through the visual senses only” (BCMof, 1997b). Consequently, Visual Resource Management (VRM) is the discipline that manages those visual resources according to a set of objectives and guidelines. For the purpose of the present thesis, both visual resource and VRM will be considered in the context of forested landscapes.

Visual resource management has its roots in the United Kingdom, where Dame Silvia Crowe introduced visual landscape design concepts, followed by subsequent work from Oliver Lucas and Simon Bell (Sheppard, pers. comm., 2001). In the United States, Litton and others undertook similar work (Sheppard, pers. comm., 2001), which led to the creation of the Visual Management System (VMS) in the 70s (USFS, 1974). This was later updated in 1995 with the Scenery Management System (USFS, 1995). From this work, BC’s own Forest Landscape Handbook was published in the early 1980s (BCMof, 1981), followed by updated material in the 1990s (see for e.g. BCMof, 1995b; BCMof, 1997b; BCMof, 2001b). It must be noted that several documents pre-dating the BC documents already included visual design principles and guidelines and even included recommendations for selected BC landscapes (see for example the work of Sheppard, 1974). Other Canadian provinces with similar VRM systems include Alberta (Alberta Forest Service, 1990), but surprisingly, despite its heavy reliance on the forest industry as an economic driver, Quebec has yet to adopt such a system to manage the visual resources of its forested landscapes (Paquet, pers. comm., 2001). This may be due in part to the presence of more rolling terrain.

2.2.2 The management of visual resources in British Columbia

The BCMof’s objective regarding visual resources is to find a balance between protecting visual resources and minimizing the impact of such protection on timber supply, consistent with the Ministry’s February 1996 report on the impact of the Forest Practices Code on timber supply$^2$ (BCMof, 1996b). This objective clearly states that the BCMof will take into account visual resources in the management of the provincial forests as long as they do not affect timber supply too much (BCMof, 1996b). Exactly how this balance is to be maintained is unclear but it appears that the BCMof has the

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$^2$ See BCMof (1996a) for the complete report reference.
goal of keeping the overall FPC impact on timber supply to no more than 6% (BCMoF, 1996a; BCMoF, 1996b). Until this target figure is reached, visual resources will be managed as summarized in Figure 1. This provides managers with considerable flexibility in how to apply VRM. It is important to note that current forest regulations are in the process of being revised (BCMoF and BC Ministry of Water, Land, and Air protection, 2002) in BC and that this thesis does not consider what those revisions are anticipated to be. However, it appears that VQOs will continue to be managed for in established scenic areas. This section also predates the latest and newly released version of the BCMoF Visual Impact Assessment guidebook released in 2001 (BCMoF, 2001b), and which is broadly similar to pre-existing methods described in this thesis.

The procedure to locate and identify areas that are or could potentially be visually sensitive is known as the Visual Landscape Inventory (BCMoF, 1997b). This procedure mainly consists of inventorying the landscape and subdividing it into Visual Landscape Units (VLUs), based on several key observation viewpoints (KOPs). These are selected based on their relative importance, which includes measures of the duration of view as well as for the number of potential viewers. Once VLUs and KOPs are located and identified, the sensitivity of the unit is determined based on several parameters such as slope, angle of view, Visual Absorption Capacity (VAC), etc. VAC is defined as a component of the visual landscape inventory that rates the relative capacity of a landscape to absorb visual alterations and still maintain its visual integrity (BCMoF, 2001a). A full and more detailed description of the BC Visual Landscape Inventory procedure can be found in the BCMoF's VLI manual (1997b).

This VLI has been undertaken for major areas of BC with nearly 16 million ha being inventoried (out of approximately 95 million ha in total in BC) for visual values (as of November 13th, 2001 [Marc, pers. comm., 2002]). Out of these inventoried areas, about half (8 million ha) are included in known scenic areas and approximately 1 million ha are managed under VQOs (the majority of which is under a Partial Retention VQO). These inventoried areas constitute most of BC's front-country, i.e. much of what is visible from a major highway/travel corridor, from a community, a major lake, etc.
In BC, a potentially important factor influencing the effect of VRM on timber supplies and availability is the role of the District Manager. Unless otherwise stated in a Higher Level Plan (HLP), the District Manager is provided with considerable discretion in terms of managing (or not managing) visual resources (BCMoF, 1998c). The District Manager has the latitude to determine the intensity and extent to which VRM will be conducted, including deciding whether or not to establish VQOs based on the initial Visual Landscape Inventory. He/she also has the latitude to modify the management of visual resources if the impact on timber supplies is judged to be too great. The District Manager can vary VQOs by "relaxing" or tightening them\(^3\) by moving to a lower or higher Visual Quality Class (BCMoF, 1997c; BCMoF, 1997d; BCMoF, 1998c). However, once the decision to manage for visual resources is made (especially once VQOs have been established), it is unclear to what extent established VQOs could be dismissed. No documentation was found stating that established VQOs could be cancelled; on the other hand, no limitation is set on the "relaxation" of established VQOs. BCMoF documents also state: "given the sensitivity around this issue, it is important that this process ("relaxing" VQOs) be carried out in a prudent and rational manner" (BCMoF, 1998d, p. 20). No further guidance is given on the meaning or interpretation to be made of "prudent and rational".

While the legislation and policy seems to permit considerable flexibility and variation in the District Manager's stance on VRM, the theoretical goal of watering-down VQOs might not be politically attainable in practice since the procedure to "relax" established VQOs encourages external input and consultation (BCMoF, 1997d; BCMoF, 1998d). In this procedure, the BCMoF recommends that the District Manager consult and review the proposed VQO "relaxation" with the public (BCMoF, 1997d) and the stakeholders such as the Ministry of Small Business, Tourism and Culture (BCMoF, 1998d). The first step is to prioritize the scenic areas in terms of their visual sensitivity and the potential timber supply or availability gain and then to evaluate each visual sensitivity unit within the scenic areas for its potential to increase timber supplies by relaxing the VQOs (BCMoF, 1998d). From the licensee's point of view, visual resources need to be protected to the satisfaction of the District Manager. This issue raises the question of how to manage for visual quality in areas where timber extraction is desired. VQOs could be maintained, along with the use of visual landscape design techniques and Visual Impacts Assessments (VIAs), but this option is considered a major constraint on timber harvests (Nelson and Wells, 2000). VQOs could be altered to allow for timber extraction using conventional clearcutting, or alternative harvesting practices could be used to meet current VQOs while allowing for some timber extraction. This latter aspect of the question is the focus of this thesis.

2.2.3 BC's Visual Quality Objectives (VQOs)

Once the decision has been made to manage an area for scenic quality, and once the decision has been made to establish a VQO for an area, the current VRM system in BC offers the manager a choice of five objectives (VQOs) (from BCMoF, 1997a):

\(^3\) Unless the management of visual resources or VQOs have been established/determined through a HLP.
1) **Preservation VQO**: no visible alterations.
2) **Retention VQO**: Human-caused alterations are visible but not evident. Alterations are visible if one looks carefully, but they are not visually evident to the untrained eye or at a first glance.
3) **Partial Retention VQO**: Human-caused alterations are visually evident but subordinate in the landscape and do not dominate. Alterations are easily noticeable but they are small enough that they do not constitute a major feature in the landscape and they remain visually subordinate in relation to other visible landscape features.
4) **Modification VQO**: Human-caused alterations are dominant but have natural appearing characteristics. Alterations are visually dominant in the landscape relative to other visible landscape features but they have a natural appearance (e.g. organic shapes), which makes them fit a little better in the landscape.
5) **Maximum Modification VQO**: Human-caused alterations are dominant and out of scale. Alterations are visually dominant in the landscape, they do not have a natural appearance and look out of scale in the landscape relative to other landscape features.

Those definitions are centred on the concepts of visual dominance, scale, contrast, and “fit” into the landscape of a given proposed disturbance. These concepts, which draw directly from the disciplines of landscape design and landscape architecture, are key to the above definitions of VQOs, and are at the essence of dispersed retention cutting being perceived as less visually intrusive into the landscape than clearcutting. In other words, dispersed retention cuts can be visually less contrasting with their surrounding which in turn may result in less visual dominance in the landscape and increased fit.

### 2.2.4 Percent alteration

It is important to note that while the word definition of each VQO is provided here, there are also numerical VQO definitions which are used both as field guidelines (to assess whether a VQO is likely to be met) and for modelling purposes (e.g. to model VQO impact in timber supply analyses and reviews). These numerical VQO definitions are referred to as the “percent alteration” figure when clearcutting is used. Percent alteration is defined as the scale of any type of disturbance to a landscape caused by human activity, including cutblocks, expressed as a percentage of a landscape or the total scene seen in perspective (BCMoF, 1997a). In other words, it is the percent of a Visual Sensitivity Unit (VSU) that can be altered (e.g. clearcut) from a perspective view, in order to meet a given VQO. A VSU is a distinct topographical unit as viewed from one or more viewpoints, delineated based on the homogeneity of the landform and of biophysical elements comprised in a scene (BCMoF, 1997b). Figure 2 provides an example for a given Visual Sensitivity Unit (VSU).
When dispersed retention cutting is used, the percent alteration concept is replaced by a uniformly applied percent removal concept, which is expressed in terms of a "percent basal area removal" (BCMoF 1998c), percent of the stems removed, or in terms of a combination of percent of the stems removed and height of the dominant trees (BCMoF 1997a). The notion of percent basal area removed will be used in this thesis for the sake of simplicity. The "percent basal area (or volume) removal" figure refers to the percent of the basal area (or volume) of a Visual Sensitivity Unit (VSU) that can be harvested (using dispersed retention cutting), as seen from a perspective view, in order to meet a given VQO. The extent to which dispersed retention cutting can be applied to a full VSU (or an entire hillside) while still meeting a given VQO is still under investigation but preliminary results show that it appears possible (e.g. see Sheppard and Picard, 2000), especially for the Retention and Partial Retention VQOs. The BCMoF appear to acknowledge this, since recent publications (e.g. BCMoF, 2001b) clearly indicate that these percent removal figures for dispersed retention cuttings are not limited by any maximum block sizes, as long as the VQO is met. Such clarification was not evident in previous BCMoF publications. Figure 3 provides an example of how a basal area removal (in percent) could be applied to the entire green-operable area (defined below in section 2.2.7) of a VSU.
2.2.5 Visually Effective Green-up (VEG)

A crucial point in assessing the impact of VRM on timber availability is the determination of how long it would take for harvested stands to be considered as "visually healed". This process of restoring a "natural" visual appearance directly affects the time lag before more logging activities are allowed in the vicinity. In BC, the concept used to make such a determination is called Visually Effective Green-up (VEG): "the stage at which regeneration is perceived by the public as newly established forest" (BCMoF, 1994a; BCMoF, 1998c). However, the US Forest Service has used the notion of Effective Alteration (EFFALT), which they define as: "percent of noticeably altered lands at any one time" (US Forest Service, 1981). The US Forest Service defines "noticeably altered" as extending through post-harvest regenerated stands that are noticeable as visual contrasts. This presumably means that the US system has a more severe effect on timber availability, due to longer delays in achieving visually acceptable "green-up". Since VEG determines the point in time at which a given stand ceases to contribute negatively to visual quality, this VEG concept could cause major variations in VRM impacts on timber availability and timber supply.

In general, the sooner VEG is reached, the lower the impact of VRM on timber availability for any level of VQO. VEG is also usually expressed in meters (minimum tree height needed for the stand to be considered visually greened-up) and varies depending on slope, distance, stand attributes, etc. As an example, a VEG of 5 meters was modelled in TSR 1 for the Arrow Forest District (BCMoF, 1994b). It is also important to note that a harvested block where at least 40% of the initial forest was retained in a uniform distribution is not subject to VEG or to the adjacency constraints (BCMoF, 2001c).
2.2.6 Plan to Perspective (P2P) concept

The notion of human-caused alterations used in defining adherence to VQOs in BC is expressed in terms of percent (%) “visible alteration” as measured in perspective from ground views (e.g. 5% to 15% to meet a Modification VQO). However, in assessing the impact of VRM on timber supply, “percent denudation” (as measured in plan) is applied (BCMoF, 1998c). Percent denudation is one of the current measures used by the BCMoF to quantify how much visible landscape alteration is permitted in a visual landscape unit at any one time, in order to meet a given VQO. Percent denudation is expressed as a range of percent (%) area cleared (seen in plan), using clearcutting, that is allowed in any given Visual Quality Class (or VQC). These percent denudation ranges are to be applied planimetrically (in plan) to the total “green” area (forested area, whether operable or not) and were derived for the purposes of modelling clearcutting operations in Timber Supply Reviews (TSRs) (BCMoF, 1998c).

The conversion between percent alteration in perspective and the percent denudation in plan is what is called the “plan to perspective” (P2P) ratio. This ratio mainly depends on the slope, tree height, viewing angle, and viewing distance (Marc, pers. comm., 1999). Whenever possible, this conversion should be calculated on a case-by-case basis for greater accuracy, since it may affect significantly the management of visual resources as well as the available timber under a given VQO. BCMoF (1998c) recommends the middle value of the percent denudation range, using clearcutting, to be modelled when a full visual landscape inventory and analysis are lacking. However, where visual landscape design is actively practiced, a greater percent denudation value (the upper end of the range allowed) for clearcutting in each Visual Quality Class (VQC) may be used (BCMoF, 1998c). Higher Visual Absorption Capability (VAC) will also allow for greater percent denudation values for clearcutting in each VQC (BCMoF, 1998c). In practice, it is estimated that the percent alteration ratio between plan and perspective is about 2:1 on average in BC (Marc, pers. comm., 1999).

2.2.7 Green-operable/green-inoperable ratio

The concept of a green-operable/green-inoperable ratio stems from the fact that parts of a Visual Sensitivity Unit (VSU) often include parcels of non-operable timber, or parcels of private (or otherwise unavailable) land. Consequently, the actual percent denudation suggested to meet a particular VQO with clearcutting, is a higher percentage of the “green-operable” area. A comparison of Figure 2 and Figure 4 shows the increased allowed alteration for a VSU based on this concept of green-operable/green-inoperable ratio. This ratio of green-operable to green-inoperable is generally estimated as 2:1 on average across BC (Marc, pers. comm., 1999) and could allow for one and a half times as much denudation of available stands (when clearcutting is used).
2.2.8 Timber availability and timber supply: what are they?

For the purposes of this thesis, the expression “timber availability” is used to represent timber that could be harvested in the current or near-term timber availability. Availability incorporates both the biophysical and the legislative availability of timber. Availability does not necessarily take into account forest growth rates, which should be included if longer-term timber supply were being considered. It should be noted that in the absence of legislative framework (or other requirements), the timber availability would correspond to the merchantable mature growing stock contained within the timber harvesting landbase. At the other end of the spectrum, where a legislative framework forbids logging, the timber availability would be zero. It should also be noted that timber availability depends on the size and extent of the economically harvestable forests, and due to the market fluctuations (or softwood lumber duties), the timber availability figures for an area can be quite volatile and depend on the frame of reference taken. For the purposes of simplifying the modelling exercises, the legislative framework will be simplified in the present thesis and it will be assumed on at least one occasion (e.g. section 4.2) that timber availability corresponds to the total mature growing stock.

Timber supply is the available timber categorised by species, end-use, and relative value (BCMoF, 2001a). This definition may not be the most informative so another definition will be used for the purpose of this thesis. The expression “timber supply” will be used as an estimate of future sustainable timber supplies (modelled forecast of what could be harvested over time under a given set of rules) over long planning horizons (more than 200 years).
2.2.9 Timber supply reviews and VQOs

Timber Supply Reviews (TSRs) are complex calculations aimed at identifying the maximum and most sustainable level of harvest for an area. Usually undertaken for a period of five years, they are then forwarded to assist the Chief Forester of the province in setting what is called the Annual Allowable Cut. The Chief Forester is responsible for determining how much timber can be harvested per year in any given area in BC (except private land), and this determination is made upon information provided to him, which includes the TSRs. Usually, VQOs are factored into TSRs by converting alteration levels (seen in perspective and derived from public perception studies) allowed under each VQO into planimetric (in plan) equivalents (hence the concept of P2P seen earlier). Assumptions generally made (at least in the case of the Arrow TSA) include high VAC (as opposed to a medium value or a true/measured averaged value) and the active use of visual landscape design (which results in the upper extreme of the percent denudation allowed under each VQO to be used for the TSR calculations). This latter point constitutes a weakness of the TSR calculations in the authors’ opinion since VAC is not always high and the benefit of actively using visual landscape design depends on its successful application. It should also be noted that, despite extensive BCMoF research on public perceptions of timber harvesting in BC (see for example BCMoF [1994a; 1996c; 1997a] and Marc [2001]), any genuine inclusion of dispersed retention cutting into TSR calculations for areas such as the Arrow Forest District in the Kootenays remains to be seen.

2.3 VISUAL QUALITY OF FORESTED LANDSCAPES AND PUBLIC PERCEPTIONS OF VARIOUS DISTURBANCE TYPES

In assessing visual quality of a landscape, or the visual impact of a given specific disturbance, there are two basic sets of factors to consider:

*Human factors* (inside the observer’s head), that influence the aesthetic response an observer obtains from a landscape (e.g. cultural values, personal expectations for the landscape, education, etc.). These factors fathered the psychophysical method of landscape evaluation (see for example Daniel and Boster [1976]), which stems from environmental psychology.

*Biophysical (landscape) factors* inherent to the landscape, which determine the visual characteristics that an observer sees (e.g. colours, textures, and forms). These led to the more formal method of describing visual characteristics in the landscape. This second method stems from the discipline of landscape architecture and usually involves “Visual Landscape Inventories” (e.g. BCMoF, 1997b) being completed by trained landscape professionals, and following general rules and theories of visual quality (e.g. see BCMoF, 1981; BCMoF, 1995b; Litton, 1968; Litton, 1973; USFS 1974; USFS, 1995).
2.3.1 Human factors

In any attempt to assess and model visual quality over time, it is very important to define the visual quality or aesthetic impact attributes under consideration. This point is stressed by several authors (e.g. Hull, 1988; Meitner and Daniel, 1997): will the model or prediction be targeted at meeting given Visual Quality Objectives (VQOs), attempting to model future social acceptability, or predicting future scenic beauty estimates (as introduced by Daniel and Boster, 1976).

For the purposes of the present thesis, the focus will be on meeting VQOs (as defined earlier), since we are interested in assessing the impact of BC's management of visual resources on timber availability and supply. However, it should be noted that VQOs have been shown to be good predictors of the public's visual preferences (Berris and Becker, 1989; McCool et al., 1986). This allows some extension of the conclusions from meeting VQOs to meeting the public's visual quality expectations and preferences. However, caution must be used when such extensions are made since meeting VQOs may not always correspond to meeting the public's visual quality preferences in terms of scenic beauty and in terms of visual acceptability.

While not at the heart of the modelling exercise, these human factors are still deemed important to address because they affect the results obtained in the public perception studies on which the model developed in this thesis is based. For example, if it is found that different publics have different visual preferences (e.g. locals versus tourists), then any attempt at modelling visual quality will be affected by the public surveyed for perception preference. This issue was avoided in the present thesis by using VQOs as a surrogate for visual quality, but questions pertaining to public factors still deserve attention.

2.3.1.1 The public in question needs to be defined

Indicators of visual sensitivity can vary with the type of public concerned and several authors (e.g. Hull, 1988) identify the question of which public is the focus of interest. Will it be the local public only or will it also address tourist/visitor concerns? Will those in favour of resource use be given equal weight to those that are in favour of more non-consumptive resource uses? Will the model assume that the public is informed or uninformed?

Dearden (1984) investigates factors that could influence landscape preferences (professional training, environmental interest and awareness, familiarity, and various socio-economic criteria). Familiarity (as represented by housing density at the place of residence, size of the city occupied, and wilderness contact time) is reported as having a positive effect (more familiarity leads to increased preference) on landscape preferences (Dearden, 1984). However, these results may need to be taken cautiously, due to the possible circular referencing in the testing of the influence of familiarity on landscape preferences. Respondents occupying lower-density housing prefer less developed landscapes; hence the conclusion that familiarity has a positive impact on
landscape preference (Dearden, 1984). Another interpretation of such results is that respondents who had a preference (in the first place) for less developed landscapes chose to live in those lower-density housing areas. The implication of the latter interpretation would be that there is no familiarity effects but only a reflection of consistency in the respondents’ preferences (low density housing – less developed areas).

Magill (1994) addresses what people see in managed and natural landscapes in which people were asked to assess landscapes (like – dislike) and to identify landscape features that affect their responses. The great majority of people were reporting natural landscape features rather than evidence of management such as roads and clearcuts. People tend to focus their attention on things of greatest interest to them, while seeing less important things only peripherally (Vernon, 1968). This implies that the great majority of Magill’s respondents (nearly 80%) had more actual interest in landscape features than in man-made features (Magill, 1994). In the case of timber harvesting scenes, forest stands, mountain ranges, dome peaks, meadows, and hills were reported respectively in 14.5%, 8%, 7.1%, 5.3%, and 4.4% of the cases as attracting respondents’ attention and were all liked. On the other hand, bare areas (denuded from vegetation but not necessarily from a disturbance), roads, and clearcuts were reported respectively in 4%, 3.5%, and 3.4% of the cases as attracting respondents’ attention and were disliked (Magill, 1994). Even when combined, all seven harvesting types (ranging from clearcutting to shelterwood cuts) only accounted for 6% of all objects reported as attracting respondents’ attention on the managed (for timber) scenes. These findings bring the very interesting issue that while foresters and environmentalists may more easily pick up management activities and react strongly to them (though possibly in opposite directions) due to their interest in the matter, the general public may not pick up on those same landscape features, even though they may not like them when they notice them. Another very interesting implication of such findings is that by specifically putting the emphasis on various levels of disturbance, public perception studies as well as the current debate on public perceptions of logging, may overemphasize the importance of those disturbances to the landscape by artificially attracting people’s attention to those disturbances. Once their attention is on those disturbances, people tend not to like them. This is reported pretty much across the board in the available literature (e.g. BCMoF, 1996c; BCMoF, 1997a; Paquet and Belanger, 1997), as well as by Magill (1994).

It is not clear to what extent people actually detected forest management disturbances in the Magill (1994) study in the sense that the respondents were all asked to point out the 2 objects attracting their attention the most, and were not asked (or at least it is not reported) whether or not they were detecting logging activities of any type in the landscape scenes shown. This latter question, once answered for each respondent and then compared to the ratio of scenes comprising logging activities would have provided a very helpful figure as to how much respondents actually detected logging activities. In other words, it could be hypothesized that the great majority of people did not detect harvesting activities and therefore could not report them as attracting their attention. This appears to be reinforced by one of Magill’s findings in which respondents reported clearcuts as attracting their attention in scenes containing no such clearcuts. For example, if scenes equivalent to a Retention VQO (where logging is visually not
evident) were to be shown to a set of respondents, one could expect natural landscape features to be reported overwhelmingly as attracting the respondents’ attention while logging activities (which are visually not evident in a Retention VQO) would not be expected to be reported frequently as attracting attention. While these findings could be used to advocate landscape disturbances that are visually not evident (so people don’t detect them) in order to keep the risk of visual damage to minimum levels, further research is required as to how much of the logging contained in the landscape people actually detect.

McCool et al. (1986) tested public perceptions of logging activities for visual quality by showing different interest groups (representing different publics) five middleground scenes for each of the five Visual Quality Objectives of the U.S. Forest Service (VQOs used in BC are derived from the US-Forest Service VQOs, and the two sets of VQOs are essentially identical). While nearly all groups ranked the images similarly (same order), the absolute values given for visual quality differed. This result appears to be consistent with Berris and Bekker (1989), which also found that the five VQOs were good predictors of public perceptions. However, a finding that may have significant implications for a VRM system relying on five VQOs is that for the majority of interest groups, respondents of those groups could generally not visually differentiate the scenes representing the Preservation VQOs from those representing the Retention VQOs or from those representing the Partial Retention VQOs McCool et al. (1986). However, a significant break (statistically significant) was noticed between the rating of scenes representing the Partial Retention VQOs and the Modification VQOs and between the scenes representing the Modification VQOs and the Maximum Modification VQOs McCool et al. (1986). This break between Partial Retention VQO and the Modification VQO may represent a shift in acceptability (from visually acceptable to visually not acceptable), and would be consistent with the other literature which shows that the acceptability threshold sits somewhere between a Partial Retention VQO and a Modification VQO (BCMoF, 1996c; Paquet and Belanger, 1997). This raises the issue of whether five VQOs are needed, if the general public can only visually differentiate three classes. Interestingly enough, the BCMoF currently manages only for Retention VQOs and for Partial Retention VQOs, which suggests that it is known that all five classes may not be worth managing for. After all, there seems to be little value in managing for (and aiming to meet) a Maximum Modification VQO if that VQO is visually unacceptable to the public concerned (as shown by BCMoF, 1996c; Paquet and Belanger, 1997).

2.3.1.2 Implied human influence and other information: does it affect visual quality?

Anderson (1981) found that scenic judgments were sensitive to the scene shown, but of greater interest to this research project, labels associated with each scenes significantly affected judgments of scenic quality. More specifically it was found that scenes labelled as “wilderness areas” and “national parks” consistently received higher scenic quality ratings, while the labels “commercial timber stand” and “leased grazing range” consistently reduced the scenic quality ratings (Anderson, 1981). It is also important to

4 Berris and Bekker (1989) is reviewed in greater depth below.
note that while labelling had an impact on scenic judgments, it appeared the scenic quality of the scene had a greater influence on scenic quality judgments than the labelling itself. One explanation suggested by Anderson (1981) is that respondents had different expectations and used different visual quality standards based on the labelling. This would be in accordance with Daniel and Boster (1976), who suggested that different respondents would have different standards of visual quality from which to judge scenes, which is a foundation of their Scenic Beauty Estimation method. On the other hand, the labelling of unattractive areas as “wilderness areas” or “parks” (possibly as an attempt to increase their scenic beauty) is not likely to result in the public finding those areas visually attractive, and would most certainly not be an appropriate measure to use in replacement of visual rehabilitation or visual resource management.

Hodgson and Thayer (1980) also found that implied human influence reduced scenic quality of a given scene. In this case, it was found that an image labelled as a lake would get higher scenic quality ratings than the same image labelled as a reservoir (Hodgson and Thayer 1980). Similarly, a forest scene labelled as a growing forest would get significantly higher scenic quality ratings than the exact same image would when labelled as a tree farm (Hodgson and Thayer, 1980). Carls (1974) also reports that signs of human presence in a forest tend to decrease scenic beauty ratings. In a very similar study, Yeiser and Shilling (1978) also found that some terms resulted in different responses from students, depending on whether or not they were familiar with the technical meaning of the word (e.g. cull tree). The word clearcutting was also tested, and all respondents agreed on it (similar responses), however, the article does not provide the reader with the orientation (positive or negative) of that response.

Jensen (2000) showed that information given to people in Denmark, explaining the reason why a given forest management practice is done, can make them more accepting of that practice. More specifically, it was found that the more information given, the more accepting people would be (Jensen, 2000). However, Jensen (2000) probably did not test with high enough levels of information because other literature (e.g. Taylor and Daniel, 1984) suggests that there is an information saturation point beyond which an “information overload” occurs and negatively affects people’s responses. Jensen (2000) also found that the caption “natural forest” would improve people’s perceptions of this image, which is consistent with both Anderson’s findings (1981) and Hodgson and Thayer’s findings (1980), which found that implied naturalness resulted in higher preference. The data appears to be robust over time, as the two surveys from which the data comes were collected 20 years apart (1973-4 and 1993-4).

Jones (1995) reports that one of the most important factors in the success of a visually sensitive harvest operation is the attitude of the loggers themselves, their involvement in the planning stages, whether they are willing to do a high quality job, and whether they believe in managing the forests for their aesthetic values. This finding is also reported by several authors (Bordin, 2001; Clay, 1998; Eason et al., 2002; Mitchell, 2000) and was heard on numerous occasions in the field by the authors of the present report (Preus, pers. comm., 2000) and appears to be the key to any successful innovative cutting operation, at least recently in BC.
The above studies show that information has an effect on people’s responses. Considering that it is not always feasible to have signs or people standing next to the landscape and explaining to the public the logging that occurred, the concept of “visible stewardship” as advanced by Sheppard (2000) and that of “making the cutblocks speak for themselves” may prove key. These concepts consist of using design in the harvesting undertaken to clearly (visually recognisable by the public) show signs of care for the land. In other words, considering that humans are a visual species and that they derive information from the landscapes and logging anyway, it is important to take the time to sit back and ask oneself what messages the public would be getting from a proposed cutblock. Would they be getting the message that the land was exploited and then abandoned, that the land was left untouched, or would they be getting the message that some trees were harvested, but that clearly, within the area treated (harvested), some trees were also left? In other words, would the proposed logging plan show signs of care for the land or would it not. It is important however to segregate between simply “good looking” and “showing signs of care”. The author (along with Sheppard, 2000) advocate that showing signs of care in combination with ecological soundness are important and crucial to the success of a harvesting operation in visually sensitive areas, which is different from simply advocating for nice looking harvests no matter how sound they are ecologically.

This brings us to the question of what happens in the absence of information. If it looks bad, is it perceived as being bad? Jones (1995) reports on this idea by stating that since sight is one of the most powerful human senses, if a cut block looks bad, it will be bad in the mind of the public and that no theories in the world will change that. Such statements have major implications in the sense that they imply very clearly that logging that looks bad reflects poor forestry practices in the public eye, while logging that looks good must reflect good forestry practices. Despite this (what looks good is good and vice versa) being a very popular belief, there are countless examples that show that this is far from true (Sheppard, 2000) and this needs to be brought forward to the public’s attention. It is also very important to keep in mind that most visual impacts resulting from logging are not permanent and tend to recover over time. The above discussion may hold part of the reason why certain dispersed retention cutting techniques are generally preferred over clearcutting practices (for a given volume harvested); their natural-looking state may lead the untrained observer to believe that since they look natural, light touch, and environmentally friendly, they must be good for the environment. It must be stressed, though, that ecological appropriateness and high scenic beauty do not necessarily always go hand in hand, and that the ecological appropriateness is not always reflected in the appearance of a cut block.

Human factors are critical in determining the underlying assumptions for any predictive model, especially when characterizing the public at stake. One possible simplification would be to consider local communities as being part of the more informed public, while tourists and visitors could be considered the uninformed public. Also, when identifying the public for which scenic quality will be modelled, it is important to determine whether the model will address concerns of the loud minority or also those of the silent majority (Gregory, 1972). In cases where satisfying (visually or otherwise) the silent majority is the objective, it may prove hard to identify their preferences (i.e. it may prove hard to manage for the “non-squeaky” wheels, if no feedback is obtained from them).
Fortunately, some very valid perception studies have been undertaken in BC (BCMoF, 1994a; BCMoF, 1996c; BCMoF, 1997a; Bekker, 1987; Berris and Bekker, 1989; Marc, 2001), allowing some light to be shed on the preferences of the BC public.

For the purpose of the present thesis, the public considered will mainly be the BC public, with some consideration for other publics (from outside BC). For example, the public considered and used as a basis for the short-term modelling (see sections 3.1 and 4.1) is the same public as the one surveyed in the BCMoF perception studies on which this modelling is based. However, since a component of the modelling involves a re-assessment of the VLI for a case study area (see section 3.2 and 4.2 pertaining to the Lemon Landscape Unit), and since this re-assessment is based on the literature reviewed (which extends beyond BC and therefore includes a broader public than that of BC), it must be kept in mind that a broader public is also considered to some extent.

2.3.2 Landscape factors affecting visual sensitivity to disturbance

Landscape factors are included here because they represent key influences of visual sensitivity, which are independent of the viewer and the harvesting design. Three of the main landscape factors affecting scenic impact of forest management actions (and natural disturbances) are summarized by Hull (1988) as follows: the effect of distance, the effect of topography, and the effect of time. A fourth landscape factor is season, which is particularly important for BC even though it is not managed for under the current VRM system. While several other landscape factors exist (see for example Litton, 1968; Litton, 1973), only selected landscape features are reviewed here, as they are judged to be the most relevant to the present thesis and to BC.

2.3.2.1 Distance

Distance generally affects scenic beauty ratings by reducing the negative visual impact of a given disturbance as distance increases (e.g. Hull and Buhyoff, 1983), and is usually divided in three categories: foreground, middle-ground, and back ground distances. The middle ground is said to usually range from 1 km and up to 5 to 8 km away from the observer (Paquet, 1993). However, Paquet (1993) rather use a range of 0.5 km to 3 km from the observer as the middle ground distance. Similarly, McCool et al (1986) defines middle ground viewing distances as ranging from 0.4 km to 4.8 km from the observer. For the purpose of the present thesis, the foreground distance will range from 0 to 500 meters from the observer, the middle-ground distance will range from 500 meters to 4 km away from the observer, and the background distance will range from 4 km away from the observer and beyond.

Hull and Buhyoff (1983) looked at the effect of distance on scenic beauty and obtained a quadratic function (parabola, or "U" shaped curve), with higher scenic beauty ratings both at shorter distances and at greater distances, while the worst visual impact (lowest scenic beauty ratings) were found in the middle (1 km from the observer). Hull and Buhyoff (1983) consider this to be part of the foreground viewing distance since they define foreground situations as less than 2 km, the greatest distance considered in their
study. However, based on the middle ground distance ranges reported by McCool et al. (1986) Paquet (1993), the Hull and Buhyoff (1983) results would confirm that the worst scenic impact occurs within middle ground viewing distances. It should be kept in mind however that a 1 km distance might be the most vulnerable distance (rather than the middleground classification) but that distance is still part of the middleground viewing distance as defined for the purpose of this thesis. Miller (1984) who looked at middleground public perceptions on the Inside Passage of BC’s coast, also looked at the effect of distance on scenic beauty ratings. Results show that for natural scenes, smaller distances increased scenic beauty ratings, while for disturbed scenes (clearcut, developed, etc.) the further away the respondents were, the higher the scenic ratings (Miller, 1984). However, positive effect of increased distance on scenic beauty ratings of clearcut scenes was only felt at great distances (Miller, 1984), hinting that the middleground viewing distance may not be far enough to offset negative scenic ratings. Miller (1984) also points out the importance of the overall magnitude (size relative to other landscape features) of the man-made disturbances (e.g. clearcuts), which can be best assessed from middle ground distances.

These findings appear to be in agreement with Litton who says that middleground is the most critical distance in the management of landscapes for visual resources because it is the distance at which it is the hardest to achieve harmonization among the different cuts (or disturbances) affecting the landscape (Litton, 1979). Similarly McCool et al. (1986) reports that the middle ground viewing distance is the most crucial viewing distance for VRM systems such as the VMS (USFS, 1974), on which the BCMoF VRM system is based, because the emphasis is on texture, form, and line compatibility of a disturbance within the adjacent natural appearing landscape rather than on stumps and slash features within that disturbance. Two major BCMoF public perception studies (BCMoF, 1996c; BCMoF, 1997a), on which the modelling exercises undertaken in this thesis are based, are also using photographs representing middle ground situations. Consequently, the middleground distance is deemed most appropriate for the present thesis and public perceptions of landscapes at this distance will be the focus of our attention in the present document.

2.3.2.2 Topography

Topography is another general factor affecting scenic quality ratings (Hull, 1988) and influences the amount of disturbance that is actually visible. Generally speaking, the flatter the topography (as is the case in the plateau of BC’s interior), the lower the visual risk associated with disturbances, and the more effective any visual buffers or green-tree retention levels. The observer’s position in relation to the disturbance also has an impact on scenic quality ratings. Usually, the lower an observer is compared to a disturbance, the lower its negative impact (Hull, 1988). Some very interesting work related to this topic is the plan-to-perspective (P2P) ratio concept used by the BCMoF, as an indicator of how much visible disturbed area would be expected to be seen from its area in plan view. This concept is particularly of interest for planning and modelling purposes and is commonly used in Timber Supply Reviews (TSRs) performed by the BCMoF (e.g. BCMoF 1998c).
2.3.2.3 Time

As one would expect, time has a significant impact on scenic beauty ratings in the sense that most ratings are worse initially after the disturbances (whether natural or man-made) and recover as time elapses (e.g. Hull, 1988, Ribe, 1991). This may prove different for pests and diseases (e.g. beetle), which may spread over time before the infestation/disease eventually dies off and the visual impact recovery process is initiated. However, for the purpose of the present thesis, logging disturbances will be the focus of our attention, and it will be assumed that the worst visual impact occurs immediately after a given entry (whether total removal or partial removal of trees occurred), and that time since disturbance has a beneficial effect on visual quality. Along with perception studies (e.g. BCMoF, 1994a), these assumptions are behind the concept of Visually Effective Green-up (VEG).

2.3.2.4 Season

Season has an impact on landscape perceptions (Hull, 1988; Jensen, 2000; Palmer, 1990), not only in terms of how it affects the landscape but also in terms of the season during which people are tested as compared to the season represented on the images to be evaluated for visual quality (Palmer, 1990). This leads Palmer (1990) to suggest that it should become standard practice to evaluate landscape scenes during the same season as the one represented on the scenes. These findings have implications for visual quality assessments in BC in the sense that winter scenes could be included in the visual quality models, on the basis that they are present for 25% or more of the year and on the basis that there is a lot of winter tourism to ski resorts. However, for the sake of simplicity, and since winter scenes are not accounted for in the current BC VRM system, only summer scenes will be considered in the present thesis. The season in which the respondents were surveyed in the studies reviewed from the literature was also not considered, again for the sake of simplicity.

2.3.3 Visual impact of perceived responses of timber harvesting disturbances

The following section will review some of the visual impacts of various logging disturbances. It is important to mention that the emphasis of the present section will be on landscape factors, especially the harvesting practices and patterns. Findings on human factors will be included (to a lesser extent) as contextual information since human factors are not the key drivers of the model presented in Chapter 3. The focus is also on research findings on people’s aesthetic responses to harvested landscapes, rather than descriptive guides or other professional studies.

An important note of caution before we jump into the heart of this section’s topic: throughout the reviewed literature, many of the so-called different harvesting patterns tested may actually be different visual intensities of the same treatment. For example, a
patch cut treatment could be considered a visual variation of a clearcut treatment; only the clearcut is divided into several smaller units. The same could apply to a group selection treatment (a group of trees is selected and clearcut). The visual difference is assumed to be that the group selection leaves most of the initial stand, while the patch cut leaves little of the initial stand and the clearcut leave none of the initial stand. We are then left with one treatment: a clearcut treatment with three intensity levels (high: clearcut, medium: patch cut, and low: group selection). These differences stress the importance of properly defining the terms used, and whether we are talking about "visual" harvesting systems (systems that differ visually) or silvicultural systems per se (systems that differ from a silvicultural perspective). For the purpose of the present review, the terms used in the literature will be reported here for simplicity, but the above point should nevertheless be kept in mind.

2.3.3.1 Public perception studies using non-systematically modified logging scenes

Non-systematically modified logging scenes are defined for the purpose of the present thesis as scenes where different harvesting scenes are being shown without any attempt to hold constant all the non-logging related variables. The studies reviewed include an array of logging practices, and an attempt was made to rank them in increasing order of tree retention (i.e. from those looking at clearcut scenes to those looking at dispersed retention cut scenes).

Daniel and Orland (1994) evaluated remote tourists' experiences in Northern Ontario, as affected by logging and found that regeneration treatment (e.g. planting) and slash treatments were the most important predictors of suitability for remote tourism while the pattern of cutting was only marginally significant. This was to be expected and is consistent with other literature relating to acceptability and aesthetics (see below). As well, a significant negative correlation was found between the size of the cut and remote tourism suitability (which were inversely proportional), and preferred scenes were those representing cutblocks that had substantially grown back and scenes in which the blocks were generally further away (no pristine scenes were shown) (Daniel and Orland, 1994). However, an interesting finding is that the quality of the wilderness setting (access to pristine environment, remoteness, solitude, etc.) ranked as high, or even higher than fishing success, in determining preferences. The authors conclude that visual evidence of extensive recent harvesting activities negatively impact the remote tourism experience not only because of their unattractive visual quality but also because the respondents perceive from the logging activities that the remoteness and the wilderness setting quality are significantly reduced. In other words, the presence of logging cut blocks and roads is perceived as an intrusion into the wilderness setting that the remote tourists are pursuing, and reduces the remote setting's quality. These findings are consistent with Anderson's (1981) and Hodgson and Thayer (1980) findings on implied human influence. Finally, the Daniel and Orland (1994) study is the only study found so far which addresses visual quality from the air (as seen from a plane).

Paquet and Belanger (1997, see also Paquet, 1993 and Paquet, 2001) worked with sensitive recreational landscapes in Quebec's boreal balsam fir (Abies balsamea) forest type, and found that people tested in perception studies reacted adversely to even very
low levels of clearcut activity. However, most felt that a certain level of clearcut was acceptable (up to approximately 25% of the visible landscape in a photographic slide, as measured in perspective), when seen in a single cutblock situation in middle-ground views with rolling terrain. Harvesting activity that occupied 50% or more of the visible landscape (as if the clearcut patch represented in Figure 2 represented 50% of the VSU or hillside) was considered unacceptable by most people (Paquet and Belanger, 1997). When the cutblocks were distributed as smaller patches over the visible landscape (rather than one big clearcut), acceptability thresholds were somewhat higher, and closer to 50% with the majority of tested groups. Above the 50% harvest level, the level of unacceptability did not increase substantially and there was a stabilization of the visual unacceptability levels between 50% and 90% clearcutting of the visible landscape, which indicates that once a landscape is beyond the visual acceptability threshold, any increase in alteration may not affect visual quality much further (Paquet, 1993). In other words, once the scenes had passed a visual unacceptability threshold, scenic beauty ratings slowed their decrease as logging amount kept increasing and any increase in cut level did not result in any further decrease in visual quality. Buhyoff and Leuschner (1978) found similar results concerning the leveling-off of people’s perceptions of beetle damage once it reached beyond 10%.

In a large public perception study of BC residents, the BCMoF (1996c) found that the visual acceptability of forest scenery in middle-ground landscape views of clearcuts varied substantially with the scale of alteration and the Existing Visual Condition (EVC refers to the same definition of level of visual alteration as the VQOs, but reflects actual rather than desired conditions). People consistently showed high levels of acceptability to more natural-appearing conditions (e.g. EVC classes of Preservation and Retention, with percent alteration of approximately 0-1.5% of dominant landforms seen in perspective), and high levels of unacceptability to landscapes with EVC of Maximum Modification (approximately 5-30% alteration) (BCMoF, 1996c). More specifically, alterations greater than 6% (of a Visual Landscape Unit as seen in perspective) were rated as neutral to unacceptable (BCMoF, 1996c, p. 14). These results appear to indicate that BC conditions (more mountainous, with steeper slopes, and possibly other cultural, biophysical, and visual factors) result in what appears to be much lower thresholds of percent alteration than the 25% and 50% figures obtained in the Quebec study (Paquet and Belanger, 1997). Also, the BCMoF study (1996c) used percent alteration of the dominant landform (within the total photo area) while the Quebec study (Paquet and Belanger, 1997) used percent alteration of the total photo area. The alteration figures obtained in the Quebec study would represent an even greater percent alteration if applied to the dominant landform instead of the entire photo area.

In his Ph.D. thesis, Miller (1984) looked at public (ferry users) perceptions of BC’s coast, and discussed possible implications for the management of BC’s coastal forests. The study looked at middleground scenes of the Inside Passage, using respondents from the Vancouver-Victoria ferry route (Miller, 1984). Despite the use of fairly small screens to display the slides (9 inches square screens, of approx. 23cm by 23cm), some very interesting results are reported (Miller, 1984), one of which is that as the intensity (visible amount) of man-made disturbances increases in the landscape, scenic beauty ratings decrease, and that people react negatively to clearcuts, regardless of their shape. Clearcut scenes (only 8 of them) had the widest scenic beauty rating range
(indicating a potential split of the respondents over this issue), and showed that how a clearcut “fits” in the surrounding landscape (whether it is designed or not, dominant or not in the landscape, etc.) was of significant importance in scenic beauty ratings observed (consistent with landscape design principles). In other words, not only was the natural appearance of the clearcuts important (for scenic beauty ratings), but also even more important was the natural appearance of the entire landscape, causing Miller to suggest that some areas should be preserved from logging altogether (Miller, 1984). These findings also stress the importance of using visual design principles when planning a harvest, in order to mitigate (but not completely remove) the negative visual impact. Other findings show that planners and trained forestry professionals were able to predict the extremes of the respondents’ preferences but not between those extremes, and that older people were more tolerant to man-disturbed (developed) landscapes. Miller (1984) also found that people from outside BC were more tolerant towards clearcutting than BC residents, which brings Miller to point that managing for aesthetics only in areas with high tourism value may not meet the visual expectations of local residents, and that equal value should be given to the concerns of local residents and tourists in terms of managing the landscape for visual quality (Miller, 1984). A final recommendation made by Miller (1984) is that visual resource management should not be confined to highway corridors and front-country locations, but should be applied to all areas where people go and experience the landscape.

McDonald and Stokes (1997) tested the use of visualization tools to design clearcuts in order to reduce their visual impact. Results show that the use of strip clearcutting could reduce the potential for negative public reaction towards logging (McDonald and Stokes, 1997). These results are in accordance with several other authors that also found that visual buffers were effective in reducing visual impact of logging activities (Karjalainen and Komulainen, 1999, etc.). However, as reported by Hull (2000), this design approach may deceive the public in regard to forest management and a backlash effect may be observed.

Bekker (1987) looked at the public perceptions of various landscape scenes in the East Kootenays of British Columbia, including some logging scenes, but also some non-logging man-made disturbances (gravel pits, electric power lines, etc.). Results show that most of the unattractive views tended to include man-made disturbances visible and located less than three kilometres away (which could include foreground scenes) (Bekker, 1987). This stresses again the importance of the middleground viewing distance, which allows for significantly more scenery to be visible than in foreground conditions, while allowing better viewing conditions than in background scenes which tend to be too far to have a strong negative impact on scenic beauty. Other findings include the fact that certain types of logging are acceptable, which is consistent with several other authors (e.g. BCMoF, 1996c; BCMoF, 1997a; Paquet, 1993). Recommendations are made for the management of visual resources in the area (in order to meet public acceptability) and suggest that foreground and near middleground views be managed for a Retention VQO, while far-middleground and background views be managed for a Partial Retention VQO, or for a Modification VQO if visual design (feathering of the edges, organic shapes, etc.) is used (Bekker, 1987). These results are in accordance with Paquet and Belanger (1997) but appear more permissive than the acceptability threshold obtained by the BCMoF for clearcutting (BCMoF, 1996c).
Bekker (1987) also found that gravel pits were being more criticized than clearcuts (2nd) in terms of their impact on scenic beauty, while dispersed retention cuts, well designed small clearcuts, and well designed/located power lines were not identified as being unattractive. Still in BC, Berris and Bekker (1989) also explored public preferences for forested landscapes with varying levels of landscape alteration. Results indicated that preferences are most affected by the presence or absence of highly visible alteration, and second by the drama of the landscape (Berris and Bekker, 1989). A high degree of correlation was found between public preferences and the BCMoF VQOs (Berris and Bekker, 1989).

Brunson and Reiter (1996) looked at the effect of providing ecological information on scenic beauty ratings of various harvesting techniques. While the authors did not find that the information given had a significant effect on their ratings of scenic beauty, some very interesting results were obtained on the acceptability scores of various so-called “ecosystem management” harvesting techniques. Among the treatments considered (Brunson and Reiter, 1996), were an old growth control stand, some group selection harvests (both on flat and steep ground), thinning operations, two-storied stands partially cut (in order to convert them to uneven-aged management), and clearcut harvest scenes (some with snags and some without). Results show that the unharvested old-growth control stand was rated highest for visual acceptability, that the group selection stands and the thinning stand obtained neutral scores (neither visually acceptable nor unacceptable), and that both types of clearcut harvest were given visually unacceptable scenic ratings. It is not clear whether the Brunson and Reiter (1996) study was done at the foreground, middleground, or background distances, but the terminology employed (e.g. the visibility of stumps; a foreground feature) suggests that the study might have been considering foreground situations (Brunson and Reiter, 1996). Also, there appears to be a great deal of variability in the various harvesting treatments compared. For example, the clearcut area is 20 hectares, the commercial thinning area is 3.5 hectares in size, and the two-storied stand is only 9 hectares (the group selection cut contains 0.2 hectare patches being cut but the area to which this treatment is applied is not provided). This may mean that the harvesting patterns tested are not only different in terms of different harvesting patterns, but also in terms of size, and intensity, all of which can have a significant impact on scenic beauty ratings, as suggested by several authors (e.g. Palmer et al., 1994, Ribe, 1999). However, in a foreground situation, none of the above concerns pertaining to treatment sizes would hold.

In BC, anecdotal evidence from the Malcolm Knapp Research Forest (MKRF) provides insight as to where the threshold at which point retained trees have a positive effect on visual quality may lay (Lawson, pers. comm., 2002). Wanting to preserve a certain level of visual quality (no VQOs currently apply to the MKRF land) for the visitors of an adjacent regional park, the research forest has been testing two levels of retention for a positive impact on visual quality: three trees/ha and 20 trees/ha left after harvest. Staff at the MKRF found that in order to obtain a positive visual effect of any value, it was necessary to leave 20 trees/ha, since the three trees/ha option clearly did not have a significant positive impact on the visual quality (Lawson, pers. comm., 2002). The measure used to assess the visual gain of retaining a certain number of trees per ha is unknown but it is assumed the MKRF staff's own visual assessment was used as a
measuring stick. While anecdotal, this preliminary information sheds some light as to where the visual threshold for improved visual quality resulting from dispersed retention cutting may lay.

In another major public perception study, one of the few which has attempted to look specifically at public perceptions of dispersed retention cutting (termed partial cutting in the study), the BCMoF (1997a; see also Marc [2001] which reports on BCMoF, 1997a) found that higher levels of overstory removal were associated with lower levels of visual quality. Certain stand variables were correlated with professional evaluations of the post-harvest EVC. The study indicates that when available, "percent basal area removed" was the best predictor of the Retention, Partial Retention and Modification EVCs (equivalent to the same VQO classes). However, when the "percent basal area removed" information was not available, a combination of "percent volume removed", "percent stems removed", and "tree height" were also shown to be useful predictors. Probability tables are also provided for the most likely achieved EVC with various "percent basal area removals" or for a combination of percent volume/stems removed and tree height. The study also found a correlation between EVC classifications used by visual landscape specialists and public perceptions of scenic quality (BCMoF, 1997a; Marc, 2001). When compared to the clearcutting perception study (BCMoF, 1996c), results clearly suggest that using dispersed retention cut techniques, even with severe visual constraints, permits much higher timber volumes to be harvested under the more restrictive VQOs than would ever be possible with clearcutting (Sheppard, 1999). For example, with trees 25 meters high, and 60% volume removal, there is a 90% chance (or greater) of meeting a VQO of Partial Retention (BCMoF, 1997a; see also Marc, 2001).

The above BCMoF study is a crucial study for the present thesis, which makes use of the "percent basal area removed" as a main predictor when dispersed retention cutting is used. This decision was taken based on three considerations. Firstly, the only document published to date specifically addressing procedures to factor visual resources into timber supply analyses recommends using percent basal area removed when dispersed retention cutting is used (BCMoF, 1998c). Secondly, "percent basal area removed" (when available) was identified as the best statistical predictor of EVC for the three the major classes (Retention, Partial Retention, and Modification) (BCMoF, 1997a). Thirdly, "percent basal area removal" was used for increased simplicity (one variable instead of two) in the modelling exercises.

2.3.3.2 Public perception studies using systematically modified logging scenes

This section reviews studies that attempted to use images or scenes of systematically modified logging scenes. As mentioned earlier, systematically modified scenes are scenes where only the harvesting (pattern, intensity or both) is modified, while an attempt is made to hold all other variables constant.

Palmer et al. (1994, 1995) looked at the long term visual effects of various clearcutting intensities, sizes, and patterns (up to 24 years into the future). The various harvesting treatments used varied in terms of intensity (percent of the viewshed cut [in perspective]
at each entry, ranging from 0% to 5% of the visible area), in terms of pattern of cutting used (concentrating the clearcuts versus dispersing them into the viewshed), and in terms of size of each clearcut (2 hectares, 5 hectares, or 10 hectares). The methodology used (photo-editing) allowed for the testing of cumulative effects of clearcutting over time (seldom tested) and provides some very interesting insights, in addition to taking place at the middleground viewing distance. However, only low levels of cutting intensity were tested (5% of the viewshed or less), which allows little comparison with other studies and little information for higher cutting intensity levels. Results show that scattering the cutting units across the landscape produces higher scenic beauty ratings, which is consistent with most landscape design principles (BCMoF, 1995b; Bell, 1993; Lucas, 1991), and with Paquet’s findings (Paquet, 1993; Paquet, 2001; Paquet and Belanger, 1997). Other results show that moderately sized units (approx. five hectares in size each) were preferred (for scenic beauty) over larger of even smaller units (Palmer et al., 1994). In this regard, the author of the present thesis along with other researchers at UBC and involved in the Wells and Nelson (2002) study described in section 3.3 and 4.3, found that applying scattered 1 hectares patch cuts over entire hillsides resulted in what appears to be less scenic beauty than a fewer bigger clearcuts or than some types of dispersed retention cutting over the same area. Palmer et al, (1994) also found that there was a constant decline in scenic beauty as the percent of the viewshed was increasingly clearcut, that scenic impact decreased as the clearcuts were further away from the observer, and that visible young regeneration had a positive impact on scenic beauty. These findings are also consistent with other literature (e.g. BCMoF, 1994a). It is important to point out that while many other authors obtained similar results, very few were testing the middleground viewing distance as Palmer et al. (1994) did. Finally, one of the most interesting things about Palmer’s (1994) article is that it appears that the intensity of harvesting (percent clearcutting visible) is more important than both cut size (individual sizes of each unit) and cutting pattern (concentrated versus aggregated). This finding supports the concept of percent alteration when clearcutting is used.

More recently, Ribe (1999) looked at public acceptability and aesthetic ratings of various types of green-tree retention harvest. In essence, Ribe (1999) tested uncut scenes, 15% dispersed green-tree retention, 15% aggregated green-tree retention, and 0% green-tree retention (clearcut scenes), using existing photographs and simulations (using a photo-editing software) to depict the various scenarios. These scenarios were tested for both public acceptability and scenic quality, informing half the respondents that they were about to see/judge ecosystem management, while the other half was kept uninformed of the management to be judged, thus also testing the effect of information. The research is preparatory to a larger public perception testing experiment that will stem from a broader research project looking at the various impacts of ecosystem management alternatives and entitled Demonstration of Ecosystem Management Options (DEMO)². Results show that 15% green-tree retention may not be enough to trigger a different acceptability response from a clearcut scene, and that public education is needed to improve acceptability ratings of 15% green-tree retention harvests. In other words, information was found to have a significant positive impact on

² More detailed information on the DEMO research project can be found in Northwest Science, which published a full and dedicated issue on the topic in 1999: Northwest Science, vol. 73 (Special Issue).
acceptability ratings, but only a minor one (if any impact at all) on scenic beauty ratings. When information was given, both retention patterns were equally acceptable. This suggests that information may make unacceptable scenes become more acceptable, at least within the context of the present study (Ribe, 1999). The finding that 15% retention (whether dispersed or aggregated and without information) is not enough for a scene to be judged acceptable is consistent with other literature (e.g. BCMoF, 1997a; Marc, 2001). It was also found that aggregated green-tree retention at this level produced higher ratings than did dispersed green-tree retention.

However, several methodological issues raise some serious concerns over the validity of such results. First, two sets of images were used to test the retention patterns (dispersed versus aggregated retention), instead of one stand image, i.e. a dispersed retention photograph was digitally altered to produce an uncut image and a clearcut image of the same scenes (1st set of 3 images), while a second scene, representing an aggregated retention image was digitally altered to produce an uncut image and a clearcut image of that same scene (2nd set of 3 images). These were then used for the acceptability and scenic beauty ratings. Issues arise when considering the differences between the two sets of images, as noted by Ribe (1999). In essence, the scene sets differed in terms of regeneration stages, scenic context, and presence/absence of other harvests. More specifically, as Ribe (1999) puts it, the aggregated retention scene showed an overall smaller harvest area, visually evident early forest regeneration, and no other harvested areas were contained in the scene. On the other hand, the dispersed retention scene showed a bigger overall harvested area, no visible regeneration, and two other harvested areas visible within the same scene. Considering that other literature overwhelmingly shows the significant importance of visually discernable regeneration (BCMoF, 1994a; Paquet, 1993; Paquet, 2001; Paquet and Belanger, 1997), the importance of other harvests in the scene (harvest intensity) (Palmer et al., 1994; Paquet, 1993; Paquet, 2001; Paquet and Belanger, 1997), and the importance of the size of the harvested area (BCMoF, 1996c; Palmer et al., 1994; Paquet, 1993; Paquet, 2001; Paquet and Belanger, 1997) on people's ratings of landscape scenes, it is not surprising that Ribe (1999) obtained better ratings for the aggregated retention scene. Ribe (1999) appears to be aware of this situation and mentions that his results were most likely affected by the methods employed as stated above, and therefore that they are problematic and should be used tentatively. Other potential methodological issues and uncertainties for which Ribe (1999) does not provide clarification include whether or not an uncut scene was used in both slide trays (or whether the 2nd slide tray contained no uncut scene), and whether the same procedure was used to present the scenes to the informed versus the un-informed group (or was a different scene presentation procedure used)? Also, it should be noted that the effect of information on scenic beauty ratings and on scenic acceptability ratings is still the focus of some debate and warrants further testing (Meitner, pers. comm., 2002). Based on the literature reviewed, implied human influence has been shown to reduce scenic quality of natural landscapes (Anderson, 1981; Hodgson and Thayer, 1980) while information has been shown to increase acceptability of a given practice (Jensen, 2000; Ribe, 1999), up to a saturation point (Taylor and Daniel, 1984), but not necessarily increasing scenic beauty ratings (Ribe, 1999).
Bradley et al. (1998) reports on an ongoing research project looking at public acceptability of various harvesting patterns in Washington State. Six different treatments (clearcutting, patch clearcutting, group selection, two-aged [shelterwood], and heavy thinning) and a control were used and tested for acceptability. Bradley et al. (1998) found that from three tested groups, forestry professionals had different ratings than students or mountaineers did, hinting that trained professionals may see some scenes differently. However, these group differences did not occur for all scenes tested (Bradley et al., 1998). No group differences were found for either the natural scenes or the clearcut scenes (all three groups agreed on their ratings), while the groups disagreed for those scenes where some trees were evidently removed while some were left uncut (Bradley et al., 1998). This suggests that some respondents with increased forestry knowledge may recognize more logging variance than non-trained groups (as suggested by Magill, 1994) and may come to rating logging scenes differently than the rest of the public. It also suggests that providing non-trained respondents with adequate information may remove those group differences for scenic beauty ratings. It also appears that the study is based on foreground views, but aerial oblique photographs were also taken (to simulate cross-valley viewing conditions).

In a perception study in Finland, Karjalainen and Komulainen (1999) tested various logging alternatives for scenic beauty as seen from two villages, from what appears to be middleground views. More specifically, Karjalainen and Komulainen (1999) tested five different logging variables, each with various options/alternatives: cut block position on the hillside (high, mid-slope, bottom), cut shape (irregular, geometric horizontal, geometric vertical), skyline cuts (unbroken skyline, partially cut skyline, clearcut skyline), visual buffer along a lake (full buffer, heavily thinned buffer, no buffers), group retention (groups in the middle of the cutblock, groups on the edge of the cut block, no retention), individual tree retention (live trees left on the block edge, live trees left scattered in the middle, live trees left grouped in the middle, dead trees left scattered in the middle, no trees left). As for the methodology employed, a photo-editing software was used to create the various options from scanned photographs (Karjalainen and Komulainen, 1999). A 100-millimetre scale was used by respondents to rate each scene, and their marks were then measured (in distance) from the beginning of the scale and the distance (between 0 and 100 millimetres) was then converted to a scenic beauty score ranging from 0 to 100 (Karjalainen and Komulainen, 1999). It is not explained why respondents were not directly asked to rate the scenes on a numeric scale from 0 to 100.

Results obtained confirmed several observations reported in other literature: logging negatively affects the scenic beauty of forested scenes; clearcutting the skyline negatively affects scenic beauty; seed trees left in the scenes enhanced visual quality, but very few scattered individual trees did not enhance visual quality (consistent with BCMoF, 1997a, and with Ribe, 1999); scenic beauty is less affected by blocks situated lower on the hillside than further up towards the skyline; visual buffers along shorelines are effective in increasing scenic beauty; irregularly shaped cut blocks are preferred over geometrically shaped ones; and that horizontally oriented blocks are preferred over

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[6] For example, trained professionals may be able to detect the full spectrum of harvesting treatments being tested while untrained respondents may only recognize the extremes.
vertically oriented blocks (Karjalainen and Komulainen, 1999). Also, consistent with Bradley et al. (1998), it was found that forestry professionals distinguished various alternatives more effectively than non-trained respondents (Karjalainen and Komulainen, 1999).

However, a closer look at the results provided raises some questions regarding the conclusions. For example, it is said that when testing for logging of the skyline the seed tree and the uncut skyline options were preferred (for both locations/villages tested) and statistically did not differ in ratings (Karjalainen and Komulainen, 1999). However, it is reported that clearcutting of the skyline for one location (out of only two locations/villages used) did not significantly differ from the seed tree option on the skyline. It is therefore somewhat surprising to see the conclusion being made that clearcutting the skyline reduces scenic beauty (Karjalainen and Komulainen, 1999) when it appears that the results are not so clear. Another issue is with regard to the shape of the harvested area (irregularly shaped cut blocks are preferred over geometrically shaped ones). Results reported show that the irregular-shaped block was preferred again in only one out of two locations (the geometrically horizontal block was preferred in the other one) (Karjalainen and Komulainen, 1999). The authors dismiss these results on the basis that the geometrically horizontal block which was preferred in one of the two locations appeared smaller and that otherwise it would not have been preferred (Karjalainen and Komulainen, 1999). While a very valid and acceptable point, this raises the other issue that it appears the tested harvesting units were not visually similar in size. Karjalainen and Komulainen (1999) did mention however that the size of each felling area was constant in each option. This raises the issue of whether the felling area was indeed constant in each option, but also whether the logging area size was held constant in plan or in perspective, which may impact the perceived size (which should be held constant if other variables such as cutblock shape are being tested).

Results for the scenically preferred location of a cutblock on a hillside (scenic beauty is less affected by blocks situated lower on the hillside than further up towards the skyline) also raise some doubt. The authors state that the cutblock situated lower on the hillside was a cutblock along a lake (without any visual buffers), and that it might have looked smaller than the others (Karjalainen and Komulainen, 1999). Again, the perceived size should be held constant if other variables such as the scenic importance of cutblock location on a hillside are being tested. As for the impact of residual trees, and trying to compare dispersed retention versus aggregated retention, they were again (as done by Ribe, 1999) each tested on two different locations (instead of being tested either at the same location or at both locations), which raises some doubts on the validity of the results. As for individual green-tree retention, it was found that most options (in the middle, close to the edge, etc.) had no significant visual impact (Karjalainen and Komulainen, 1999). One exception to this was when the individual trees were left in the middle of the cutblock (scenically preferred over no trees being left). Looking more closely at the figures provided, it appears only three trees per hectare were left/used to test the effectiveness of leaving individual residual trees. BCMoF (1997a) and Lawson (Lawson, pers. comm., 2002) state that a minimum threshold amount of individual trees must be left on the cutblock in order to get any scenic gain. This threshold is currently estimated at 20 trees per hectare (Lawson, pers. comm., 2002), which is significantly more than the three trees left/tested by Karjalainen and Komulainen (1999). However,
the authors appear to be aware of the above, and suggest that more trees need to be left in order to achieve a scenic benefit, and that the greener the scene, the higher scenic beauty ratings it gets (Karjalainen and Komulainen, 1999). Another very interesting finding of Karjalainen and Komulainen (1999) is that local residents made more distinctions among the various logging options than did tourists, which is consistent with preliminary Multi-Criteria Analysis results obtained in the Arrow Innovative Forestry Practices Agreement (Arrow IFPA) research project. Local residents can be very knowledgeable of their environment/landscapes and may pick up some very subtle nuances that tourists/non-local people may not see (Sheppard, pers. comm., 2001). This point should be kept in mind for forest managers in need of maintaining visual quality of a given area if the local public is to satisfy, in the sense that they may actually pick up many more logging disturbances than they could be expected to see.

Finally, despite some very interesting results and an even more interesting study layout, Karjalainen and Komulainen (1999) state that some scenes might have appeared smaller as an explanation of the results obtained. As Palmer's (Palmer et al., 1994), Miller's (1984) and Berris and Bekker's (1989) results appeared to show, the concept of percent alteration and the amount of clearcutting/disturbance seen in a scene is of paramount importance for scenic beauty, and since this is what Karjalainen and Komulainen attempted to measure, this raises some doubts on Karjalainen and Komulainen's results (1999). Also, Karjalainen and Komulainen (1999) assume that most forestry professionals have received visual design training. However, such training is far from guaranteed in North America at least in Canada, where it is not known to be required in two of the country's biggest forestry faculties (Laval University and University of British Columbia).

2.3.3.3 Long term visual quality modelling based on different harvesting systems

Ribe (1991) looked at the scenic impact of the forest attributes and at some long term management alternatives for hardwood forests. While his study is about foreground scenes, it contains some interesting results and discussion on future modelling of visual quality. In fact, the author attempts to answer the question of whether even-aged management might actually yield more total scenic beauty than would uneven-aged management (Ribe, 1991). This latter question, even though addressed at the foreground view in Ribe (1991) is of crucial importance to attempts to model visual quality over time in relation to the forest management regime in place. The results presented here need to be taken cautiously because not only are they based on a very limited sample of photographs (it appears that less than ten slides were used) but the sampled photographs represent different stands at different time periods throughout their respective rotations rather than representing the same stand throughout different time periods. In other words, no one stand was followed and photographed over an entire rotation to provide the reported findings, but rather several stands were photographed at different stages of their life and used as surrogates to represent the life stages of a given representative stand (from a visual perspective). However, despite those methodological uncertainties, the results appear to be very promising. They show that, both under a clearcut system and a shelterwood system, the visual quality follows a similar trend over time in the sense that an abrupt initial loss in visual quality at the
time of harvest occurs, followed by a gradual recovery in visual quality as time since disturbance increases. The only difference is that the initial loss of visual quality is more pronounced under a clearcut system than under a shelterwood system (in which the regeneration cut would leave some residual trees) (Ribe, 1991). However, one would expect the shelterwood harvest to have a second reduction in visual quality (due to the final cut) but this is not apparent in Ribe (1991). This may be due to the fact that the study deals mainly with deciduous forests in which the understory regeneration may be high enough to offset any negative visual impact of the final cut. It also appears that the reason why the clearcut system starts off with lower scenic quality is because it implies (based on the parameters of the Ribe study [1991]) shorter rotations (40 year rotation) and the stands are not allowed to reach older ages which are associated with higher scenic beauty levels, while these same stands are allowed to grow older under a shelterwood system (110 year rotation) (Ribe, 1991). Also, it appears that the shelterwood recovery rate is initially about twice as fast as a clearcut rate (3 years vs. 7 years to reach neutral scenic quality) but three-quarters of the initially lost scenic beauty is regained two years faster under a clearcut system than it would under a shelterwood system (11 years vs. 9 years). These findings suggest clearcutting has an initial visual impact worse than shelterwood (immediately after the initial harvest) due to the removal of all the trees. However, the regeneration will grow faster under a clearcut than it would under a shelterwood system meaning that Visually Effective Greenup may be reached sooner and therefore the visual quality may be recovered faster over a 10 to 20 year period.

Another very interesting finding is the fact that it appears longer rotations reach higher levels of visual quality that shorter rotations are not allowed to reach, which appears to give an overall visual quality advantage to longer rotations and a shelterwood system over a clearcut system (Ribe, 1991). In regards to uneven-aged management systems, it was found that a slight reduction in scenic quality resulted from thinning operations and that full scenic quality recovery was achieved 40 years after the thinning (Ribe, 1991). This latter result needs to be taken cautiously because it reflects within stand conditions and may not be applicable to middleground conditions since thinning may not be visually discernible.

Ribe (1991) also looks at the long term scenic impact of allowing a stand to reach old-growth conditions. Interestingly, the maximum visual quality achieved (still in foreground views) does not appear to be significantly higher than with the even-aged shelterwood system or with the unmanaged forest. Even more interestingly, the scenic quality of the old-growth forest is not steadily high but rather fluctuates. This could represent cyclic higher scenic quality values associated with snags/dead trees, which are typical of old-growth forest dynamics. This would be consistent with the literature, which states that even low levels of dead trees (often represented as beetle damage in the literature) induce lower visual quality ratings (Buhyoff and Leuschner, 1978; Buhyoff et al., 1982). Overall, Ribe (1991) finds that uneven-aged management yields higher long term average scenic beauty values than even-age management (both clearcut and shelterwood), that old-growth conditions in hardwood forests yield the highest average scenic beauty values, and that under even-age management, systems using longer rotations (such as a shelterwood system) yield greater average scenic beauty values than systems using shorter rotations (such as a clearcut system). While very interesting
and potentially of crucial importance to modelling visual quality in relation to the harvesting regime used, the above results need to be taken cautiously due to the very small sample used and also because they were derived from foreground conditions (as opposed to middleground views).

2.3.3.4 Summary of the visual effects of harvesting treatment on user perceptions

Hull (1988), in reviewing the literature concerning the visual impact of various forest management activities, addresses the visual impact of even-aged versus uneven aged management, rotation length, harvest method, regeneration (planting) techniques, thinning operations, slash treatments, implied human influence, roads, and land use designation. In regard to even-aged management versus uneven-aged management, Hull (1988) reports that the visual impact of any given management action in an uneven-aged management regime is lower due to the increased diversity inherent to uneven-aged management regimes in comparison to even-aged management regimes. Clearcutting (single large clearcuts being worse than many smaller ones, and geometrically shaped ones being worse than organically shaped ones) as a harvesting technique has the biggest negative scenic impact (BCMoF, 1996c; BCMoF, 1997a; Hull, 1988; Marc, 2001; Palmer, 1990; Paquet and Belanger, 1997; Ribe, 1999). Shelterwood cuts (or dispersed retention cuts) generally have a lesser negative scenic impact (BCMoF, 1996c; BCMoF, 1997a; Hull, 1988; Karjalainen and Komulainen, 1999; Marc, 2001; Ribe, 1991). Hull (1988) also reports some key design principles in order to minimize the negative visual impact of clearcutting such as using organically shaped blocks, screening skidding trails and landings, and feathering of the cut block edges in order to reduce visual contrast and negative edge effect. Similar landscape design principles can also be found in BCMoF (1995b), Bell (1993), Lucas (1991), and very interesting findings/comments on cutblock shape and feathering of edges can be found in McQuillan (1995, 2001), which recommends using principles of fractal geometry in the design of harvesting operations in order to increase public acceptance. Interestingly, Hull (1988) mentions a U.S. practice called “aesthetic shelterwood” which is a shelterwood cut in which one more entry is added in order to increase scenic quality (by deferring or staging the timber removal). Unfortunately, no further detail is provided on this system.

Results reported regarding thinning and slash mostly relate to foreground views and tend to show that thinning increases scenic beauty while slash reduces scenic beauty. As for rotation length, it appears that longer rotations increase overall scenic beauty, as reported by Hull (1988) and Ribe (1991). This latter finding may be negated if the longer rotation increases susceptibility to insects, diseases, and fire, all of which were shown to have strong negative scenic impact (see above discussion). Finally, another interesting finding brought forward by Hull (1988) relates to the scenic impact of logging roads and reports that newly constructed logging roads may have a strong negative visual impact on scenic beauty for the same reasons as clearcutting (loss of vegetative cover, contrast, high visibility, etc.) or due to bad visual design if they do not fit properly into the landscape.
2.4 REVIEW OF SELECTED NORTH AMERICAN CASE STUDIES ON THE RELATIONSHIP BETWEEN AESTHETICS AND TIMBER AVAILABILITY AND SUPPLY

This section is divided between more generic studies looking at the impact of managing for visual quality on timber harvesting and some very specific studies undertaken in BC looking at that same topic. The rationale for addressing those later specific studies in a separate section is that they are very critical to the topic of the present thesis. This is due to the fact that they attempt to answer similar questions as those addressed in this thesis, they are from BC, and they are very recent studies (less than 5 years). Consequently, they are reviewed in much greater depth and will also be included in further discussions in Chapter 4.

2.4.1 Generic studies looking at the impact of managing for visual quality on timber harvesting

Fight and Randall (1980) attempted to assess the cost ($/acre) of enhancing visual quality of forest lands (to meet a Partial Retention VQO from middle-ground) in the Mt. Hood National Forest, OR, USA. The same silvicultural treatments (planting, precommercial thinning, commercial thinning and a final cut) were undertaken on pairs of similar areas and the same volume was harvested but using different approaches (one using conventional practices, and one using practices designed for visually sensitive areas). Visual sensitivity was addressed through a combination of large planting stock, thorough slash cleanup, staged timber removals, long rotations and shaped harvest blocks in small units. Consequently, there was an increased cost at roadside of about 14%. No impact of VRM on the timber availability (in terms of m$^3$ available) was found.

Stier and Martin (1997) looked into the financial impact of visual and forest cover constraints for private forest land owners along a river-way valued for recreation (WI, USA). In this case, three visual zones were established:

- **River Edge Zone**: 25 meters on each side of the river with a “no touch” rule.
- **Bluff Zone**: 30 meters on each side of the skyline as seen from the river, where only selective logging (removing 30% on average of the basal area) was allowed.
- **River View Zone**: All land occurring between the two previous zones. No clearcuts over 2.5 ha in size were allowed and no more than 1/3 of the land could be clearcut per 10-year period. Adjacency constraints were applied and when dispersed retention cutting was used, up to 50% of the basal area was allowed for removal.

The projected impact was modelled over a 15-20 year period for five management scenarios (control, unregulated selected thinning, unregulated diameter-limit cut, basal area regulated thinning and regulated patch clearcut). Reductions in present value of forest lands ranged from 0% up to 18% due to visual and forest cover constraints. However, the magnitude and direction of the impact on timber supply could not be estimated from current stand conditions alone (Stier and Martin, 1997). For example,
"high-grading" harvests undertaken to meet visual quality constraints, while allowing some flow of timber, may reduce the short-term financial impact of visual constraints but may jeopardize future harvests and worsen the long term impact. Also, the impact of VRM on timber supply critically depends upon what is believed the owner would do if there were no such visual restrictions (Stier and Martin, 1997). In other words, VRM may not have much of an impact if the land is not to be logged for other reasons (other regulations, poor market conditions, water quality, soil stability, etc.). The critical measure is not percent of merchantable timber, but percent of otherwise available timber. This finding emphasizes the importance of the assumption that licensees would harvest more wood in visual zones in the absence of visual management.

In a third study conducted for a road corridor in California, it was found that VRM increased timber availability (relative to previous level without landscape design being used) as well as improving the scenery by opening up views (Litton, 2001; McDonald and Litton, 1998). The harvest method used was a combination of commercial thinning, non-commercial thinning and brush removal. Thinnings were based on a cross-section of the initial stand, respecting initial ratios of species composition and diameter classes (per species). 27% of the Basal Area (and 53% of the trees) was removed along a roadside, enhancing the view and meeting the equivalent of a Partial Retention VQO as defined in BC (Litton, 2001; McDonald and Litton, 1998). These results highlight the importance of linking landscape architecture and silviculture as a way to preserve visual quality and recreational experiences while allowing some harvesting.

In BC, Clay (1998) successfully achieved a Retention VQO in phase one of a harvesting approach using irregular strip shelterwood in the Nelson Forest Region. The management scenario included a rotation of 90 years with entries every 30 years (three entries total), removing approximately 180 m$^3$ per ha at each entry. Cleared strips, sandwiched between dispersed retention strips (termed “partial cut” strips in the study) and then reserve strips, were harvested in the first entry. At the second entry, the reserve strips will be partially cut and the initial dispersed retention strips will be cleared. In the third and last entry, the initial reserve strips (partially cut in the second entry) will be cleared and the cycle will start again. Volumes harvested through this staged removal are not compared with those that could be harvested with clearcutting on a 60-year rotation, but costs are estimated to be 20% higher than clearcutting. In other words, the impact of managing for the visual resource in this case is potentially a longer rotation (90 years over 60 years) and a 20% increased harvesting cost. However, cost increases are expected to decline with increased experience (Clay, 1998). Key points in this successful operation included the involvement of highly motivated loggers in all aspects of layout and harvesting.

In the Nelson Forest Region, Crampton (1995) located areas subject to VQOs that could benefit from visual rehabilitation and therefore have an impact on short and long term timber supplies. The rehabilitation of existing clearcuts in visually sensitive areas was the main focus of this study for short-term wood opportunities. Applying this approach in the Arrow Forest District led to increased acceptable percent denudation figures from 15% to 25% for a Partial Retention VQO (allowing 10% increase for example) and from 30% to 40% for a Modification VQO (also allowing a 10% increase). These increases yield a short-term volume of 17,875 m$^3$ over an area of 55 ha (at 325
m³/ha) throughout the Arrow Forest District. However, the rationale for such percent denudation increases is not clear. It is assumed that these increases are the result of active visual landscape design and visual rehabilitation of specific cases. Also, the study does not consider the use of dispersed retention cutting as a means to increase timber availability within those areas constrained by VQOs.

For the purpose of timber supply modelling, Region 5 of the US Forest Service (1981), using the EFFALT system (EFFective ALTeration system), attempted to equate VQOs with maximum percentages of land that can be in an altered (logged or cleared) state at any one time. These percentages (assumed to be applied in plan) range as follows:

- Retention VQO: 0 to 30% alteration (15% avg.)
- Partial Retention VQO: 4 to 40% alteration (22% avg.)
- Modification VQO: 10 to 50% alteration (30% avg.)
- Maximum Modification VQO: 30 to 60% alteration (45% avg.)

It is interesting to compare the BC figures (BCMoF, 1996c) with those generated by the EFFALT method used by Region 5 (California) of the US Forest Service. It should be noted that the US percent averages of land that could be altered under VQOs using these calculations are considerably higher than in BC, even when taking into account the fact that the BC figures reflect percent alteration in perspective view while the US Forest Service figures reflect percent alteration in plan view. Also, the range of overlap across VQOs is substantially greater, indicating more flexibility in the use of this approach in the US. All of these factors suggest that the BC system of percent alteration may be significantly more restrictive than in the US. However, this may be compensated for by the shorter time required for green-up (VEG) in BC (as discussed above).

2.4.2 Critical studies for the present thesis

In the Robson Timber Supply Area (TSA) of BC, the use of clearcutting in conjunction with dispersed retention cutting (termed partial cutting in the study) within scenic areas was analyzed in relation to its impact on timber supplies and availability (Industrial Forestry Services Ltd. and BCMoF, 1998). The results of this analysis show that both short-term timber availability and long term timber supply will increase when dispersed retention cutting is used in combination with clearcutting in the more visually constrained areas. More specifically, dispersed retention cutting applied to 22% of the stands within scenic areas could increase timber availability by as much as 58% and timber supply by 36% (Industrial Forestry Services Ltd. and BCMoF, 1998). It is important to note that these increases result from using a combination of clearcutting and dispersed retention cutting (dispersed retention cutting is applied to 22% of the visually sensitive areas) and that the increased figures (58% availability and 36% supply) are for the areas subject to VQOs, not for the whole TSA. These results may be underestimated since it was assumed in this study (and in this thesis) that there was no current denudation (no visible alterations) in Visual Landscape Units. Also, the maximum percent alteration figures for clearcutting (as opposed to averages) were used for comparison, and all stands requiring a cable harvest system were clearcut. However, available evidence from the Coast (Sheppard and Picard, 2000) and preliminary evidence from the Slocan Valley show that cable systems can be used in
dispersed retention cuts. The figures of allowed timber removal for the dispersed retention cut operations used were the percent volume removed/tree height combination provided by the BCMoF (1997a). Another interesting point brought up in this study is that silviculture foresters, intimately familiar with dispersed retention cutting, were of the opinion that any stand can be partially cut, while licensees, also experienced with dispersed retention cutting, believed the opposite (Industrial Forestry Services Ltd. and BCMoF, 1998). Clearly, more research into the economic viability and benefits of dispersed retention cutting approaches is needed.

In coastal BC, a similar study was conducted in the Strathcona TSA, which evaluated timber availability using dispersed retention cutting versus clearcutting in scenic areas subject to VQOs (Timberline Forest Inventory Consultants Ltd. and Rowe, 1999). This study concluded that wood availability in scenic areas is increased considerably (36% to 46%, depending on the scenario considered) with the use of dispersed retention cutting and that most of this increase comes from the areas under a Partial Retention VQO. These gains are achieved despite the relatively small proportion of areas considered suitable for dispersed retention cutting (14-25%) (Timberline Forest Inventory Consultants Ltd. and Rowe, 1999). It was found in this study that dispersed retention cutting could be carried out in most stands in the Strathcona TSA, but that increased costs were a limiting factor. The study noted that without dispersed retention cutting, much of the timber is otherwise unavailable (Timberline Forest Inventory Consultants Ltd. and Rowe, 1999).

Another study on the effects of dispersed retention cutting on the timber supply of the Arrow, Cranbrook and Golden TSAs (Wang and Pollack, 1998) found that a gain in annual harvest of 2-3% could be achieved in the first decade as a result of dispersed retention cutting in areas subject to VQOs in the Arrow TSA. It is important to note that these results are TSA-wide increases achieved from dispersed retention cutting only portions of the TSA (i.e. areas under VQOs), which means that the local increase or benefit from dispersed retention cutting may be significantly higher in specific and highly constrained areas (e.g. Slocan Valley). The areas considered suitable for dispersed retention cutting are significantly less than those considered suitable for clearcutting and represented only about 23% of the stands in VQO areas for the Arrow TSA (Wang and Pollack, 1998). This 23% figure was based on site index (only good and medium sites were considered for dispersed retention cutting), slope (slopes above 40% were excluded from dispersed retention cutting), and minimum economically harvestable volumes (Wang and Pollack, 1998). In addition, not all stands suitable for dispersed retention cutting were actually partially cut in the scenario used by Wang and Pollack (1998) on the basis that it may not be realistic to undertake a dispersed retention cut in every stand that is suitable for it. Rather, only 60% of the stands deemed suitable were actually modeled under a dispersed retention approach. Consequently, the results reported (2-3% increase) represent TSA-wide increases from using dispersed retention cutting approaches in only about 14% of the stands in VQO areas. It should also be noted that these increases result from using dispersed retention cutting techniques that remove only 30 to 35% of the initial volume in the 1st pass. Considering that significantly more volume than 30-35% can be partially cut in order to meet any given VQOs, and that possibly more than 14% of the stands can be partially cut (e.g. dispersed retention cutting on slopes higher than 40% as is done on the coast [see Sheppard and Picard,
2000), the 2-3% increase obtained by Wang and Pollack may be underestimated. The potential impact of such underestimation is reflected in sensitivity analyses undertaken by Wang and Pollack (1998), one of which shows that removing 50% of the initial volume (instead of 30-35%) would double the timber availability gains for the first decade (6% increase instead of 3%). However, the study reports that the Arrow TSA already uses dispersed retention cutting on 25% of the area harvested and on 35% in areas subject to VQOs, and concludes that the dispersed retention cutting potential gain is already being utilized in the Arrow TSA (Wang and Pollack, 1998). This appears to contradict other publications indicating that approximately 90% of the harvesting in the Arrow is carried out under an even-aged management regime (BCMoF, 1999a). This difference may be due to the definition given to “partial cutting”. Wang and Pollack (1998), define partial cutting as a two-stage treatment in which all of the volume is removed in 2 passes, while the BCMoF document (1999a) defines partial cutting as harvesting that falls under uneven-aged management regimes. Considering anecdotal evidence showing a general avoidance of VQO areas by licensees (in the Arrow and elsewhere in BC), it is believed that the gains obtained by Wang and Pollack (1998) could be achieved in the Arrow TSA. Wang and Pollack (1998) also found that the annual harvest increase (or decrease) that could be achieved through the use of dispersed retention cutting was very sensitive to the determination of minimum economic volumes (for dispersed retention cutting). This last finding stresses once again the importance of economic viability in the success of any dispersed retention cutting operation and in determining the full potential of dispersed retention cutting in VQO areas as a mean to alleviate constraints on timber flows.

2.5 LONG TERM IMPLICATIONS: GROWTH AND YIELD IMPACTS OF SELECTED NON-CLEARCUT SILVICULTURAL SYSTEMS

This section is intended to shed some light on the long term growth and yield implications of retaining parts of the original overstory. It is important because even if short-term gains in timber availability can be realized with dispersed retention cutting under VQOs, the long term picture may be less promising if dispersed retention cutting leads to substantial reductions in long term growth and yield. While the focus of the thesis is mainly on short-term availability gains, long term implications need to be considered and discussed in order to provide a more complete picture, even though long term implications will not be reviewed with the same depth that is applied to short-term implications.

The focus will be on a few selected silvicultural systems, most relevant to the approaches discussed in this thesis. Consequently, only those silvicultural systems believed to meet visual quality objectives both in the short and long term (at the landscape level) will be considered for timber supply and growth and yield implications. The selection is based on an assessment of each system’s impact on visual quality (both in the short and long term). Negative extremes in visual quality will be the focus of attention here, because they are the ones that are most likely to reduce visual quality to the point of triggering public outcry. Dramatic and sharp decreases in visual quality will be the focus rather than smaller sustained change over time. For example, cases where visual quality would drop sharply towards visual unacceptability and very low scenic
beauty following a given intervention/harvest entry, whether or not it is a clearcut. Section 2.5.1 will identify systems (or approaches) that appear promising for meeting both short-term and long term visual quality requirements. The following sections include reviews of available literature on the timber supply (and growth and yield) implications of those systems identified (in section 2.5.1) as promising for visuals. This review of literature initially looked at several BC alternative silvicultural systems trials and research sites in the hope that they would shed light on the specific long term growth and yield impact of applying those alternative silvicultural systems in BC. However, due to an apparent lack of solid long term published scientific research from BC on this specific topic, the search was expanded beyond BC's network of alternative silvicultural systems trials and research sites to include other BC and Pacific Northwest (PNW) studies. Results from this expanded review of literature are presented in section 2.5.2 in the case of retrospective studies (attempting to measure the growth and yield impact of past examples of overstory retention), and in section 2.5.3 in the case of modelling studies (attempting to forecast the growth and yield impact of present/hypothetical examples of overstory retention). It should be noted that the literature review (sections 2.5.2 and 2.5.3) included some very strict search parameters, which may explain why the results appear somewhat limited. The list of potentially growth-limiting factors is extensive (Oliver and Larson, 1996) and while it is recognized by the present author that all of these factor have a crucial role to play in the growth and yield of a stand and that extensive research has been done and published on the growth and yield impacts (both short and long term) of each one of those factors, the objective here is to shed light on the overall growth and yield impact of retaining various levels of live overstory trees for a rotation. Unfortunately, very little was found on the overall growth and yield impact of retaining various levels of live overstory trees for a rotation.

2.5.1 Silvicultural system's performance from a visual quality perspective

From a long term middleground visual quality perspective, the ideal silvicultural system will avoid, at any given time, dramatic negative visual impact (visual unacceptability), and rather will aim for a more consistent (and visually acceptable) visual quality over the entire rotation.

Consequently, based on a review of silvicultural systems and of public perceptions of harvesting activities, the following visual impacts are anticipated for each silvicultural system:

Clearcut, patch cut, group selection, strip shelterwood, group shelterwood): Because they result in visually distinguishable denuded areas, these systems are believed to be the systems that have the highest risk of short-term and periodic impact on visual quality of the landscape, but also those systems (variants) with the greatest recovery potential (because the regenerating trees grow in full sunlight with no overstory shading/competition). This impact is due to the strong visual contrast (colour and texture contrasts) of bare ground resulting from harvest versus the adjacent forest, the presence of sharp edges (line contrast), often geometric shapes (form contrast) largely or fully revealed abruptly. Design techniques (e.g. smaller patch cuts, dispersal of cut areas over the landscape, organic shapes, feathered edges, etc.) can reduce the initial
impact of the harvesting, but inherently, the negative impact results from increased dominance of the denudation process itself. Long term visual impact depends on the rate of regrowth, and the time until Visually Effective Green-up (VEG) is reached. The average visual quality over time of these systems may be generally positive, but because it is a system with one final cut per rotation (versus a system with multiple entries per rotation), the visual impact of these cuts tends to be strongly negative. Luymes (2000) provides a more in-depth discussion of the emotional response over time to a clearcut system.

Uniform shelterwood, uniform seed tree systems, retention system (including variable retention), irregular shelterwood, and clearcut with reserves: these systems may have both strong visual quality performance and considerable timber supply potential under VQOs, depending on the amount of initial overstory retained, the pattern of retention, and on the timber supply impacts of retaining part of the overstory. If not enough of the initial overstory is retained (or if the retention is aggregated instead of being dispersed), the visual impact may be as negative (or worse) than that of a clearcut (BCMoF, 1997a). However, if enough of the initial overstory is retained to provide the visual impression of a dispersed retention cut with more continuous cover (versus a clearcut), then the initial visual quality should not be negatively affected by the cut. Over the long term, visual quality is expected to be significantly negatively affected by the final cut, when the shelter-providing trees are removed. However, this negative visual impact would only result if it were assumed the regeneration (at the time of the final cut) would not have reached VEG. If the final cut is delayed until VEG is reached, then these systems would have no long term negative visual impacts either (in theory). In the specific case where the retained trees constitute permanent retention (e.g. variable retention), the long term visual quality is anticipated to increase over time as the area is regenerated, since no future entries are planned within the rotation. It should be noted that since the BCMoF (1998a) itself is unclear as to how many harvests are planned in an irregular shelterwood system, the visual impact of future entries is uncertain but only a few entries per rotation [e.g. early and mid-rotation entries] are assumed to occur which suggests that the visual impact of future entries would be kept to a minimum under such a system. Since irregular shelterwood systems are usually carried out in multi-layered stands (trees of all ages and sizes), the visual impact of the initial entry is not expected to result in a significant negative visual impact.

Coppice: like the clearcut system, the coppice system is believed to be a system that has fairly high short-term impact on visual quality of the landscape, but has the greatest recovery potential, since the regeneration grows in full sunlight. However, the coppice with standard variant of this system may have both strong visual quality performance and considerable timber supply potential, because an understory (e.g. a sprouting species) is present at the time of overstory harvest, and vice-versa when the sprouting species is harvested, which will avoid strong negative visual impact linked to visual contrasts of bare logged areas.

Selection system: this system is probably the system that has the highest guarantee of maintaining high visual quality on the landscape at any given point in time, since it maintains a continuous forest cover. This results in very low visual dominance of the harvest, which remains subordinate in the landscape or even visually undetectable.
From this review of the anticipated visual impact of the various silvicultural systems and their variants, a selection of the systems deemed most appropriate to meet both visual quality objectives and timber supply objectives is possible. The clearcut system (considered to be the baseline or status quo to which an alternative is sought) is not generally well suited to meeting visual quality objectives over the long term, because of its significant negative visual impact at time of harvest, even with landscape design techniques. At the very least, a clearcut system approach in visually sensitive areas is highly risky (high risk of failure to maintain visual quality). As for the selection system, it will not be looked at as a generally viable alternative to current practices (i.e. clearcutting), because its negative timber supply implications and high economic consequences are deemed too significant since it maintains a continuous forest cover, and requires multiple regular entries. The coppice with standard system (or variant) will also not be considered further as an option, because it is not used in BC, based on the information available to date.

Regarding the practices of shelterwood (uniform and irregular), uniform seed-tree, variable retention, and clearcut with reserves\(^7\), they may if enough initial overstory is maintained on site in a dispersed fashion meet certain VQOs, both in the short and long term. Most importantly, they can do so from any given viewpoint or angle of view, which may give them a competitive edge over conventional landscape design approaches (which use a limited number of viewpoints). These systems (or variants) are more likely to meet short and long term visual quality requirements, as long as enough initial dispersed overstory is maintained on site. This minimum overstory retention threshold for maintaining visual acceptability is still unknown, but is estimated at about 20% retention by the author of the present report, based on the literature reviewed, visual landscape design training, and several field assessments.

Since the shelterwood (uniform and irregular) and uniform seed-tree are designed for the removal of the retained trees as soon as the regeneration is established (later in the case of irregular shelterwood), particular attention needs to be paid after the removal of those trees (for the overall impact on the visual quality). In other words, the long term visual impact of these systems will depend on the height of the regeneration or understory at the time of the second and final entries. A negative visual impact will occur if the regeneration has not reached VEG yet, but in cases where regeneration has reached VEG, such systems could have no negative visual impacts in the long term either (at least in theory). This still needs to be tested and validated for large scale operations as mentioned under the visual prescription #2 (see section 4.2 and Figure 21).

The variable retention and clearcut with reserves approaches, assuming they maintain enough initial overstory to meet short-term visual quality needs, will also guarantee meeting long term visual quality objectives (assuming no windthrow, etc.) since the retained trees are reserved for the entire rotation.

\(^7\) Again, assuming the reserves are in sufficient quantity and dispersed throughout the cut area.
This leaves us with a clearer idea of the "ideal" visual prescription: a system/approach that will leave on site (evenly distributed across the cut area and depending on site-specific conditions) approximately 20% (for a partial retention VQO) to 40% (for a retention VQO) of the initial overstory at the time of the initial entry, and will maintain this level of retention either throughout the entire rotation or until the regeneration is high enough. In other words, dispersed retention cutting as defined and used in this thesis. It should be noted that VEG is not believed to be enough for meeting visual quality objectives in cases of large scale shelterwoods or seed tree cuts, and higher regeneration (e.g. 12 to 14 meters in height) may be required before the final cutting can take place, in order to maintain visual quality.

Bearing in mind the timber supply/growth and yield implications of a system that retains 20-40% of the initial stand on site, a review of available literature and current research was undertaken.

2.5.2 Retrospective studies

The focus of this section is to report on findings from the literature pertaining to studies or review of literature concerned with past data (as opposed to modelling studies which are presented in section 2.5.3). An example of such a retrospective study is Rose and Muir (1997) which attempted to assess the growth and yield impact of retaining live overstory trees on regeneration by measuring growth rates of the understory in stands that were burned (or partially cut) several decades ago and in which remnant trees were left unburned (or uncut). On the other hand, modelling studies (presented in section 2.5.3) address those studies that base their estimate of the growth and yield impact of retaining live overstory trees on regeneration on growth models (such as PROGNOSIS). It should be noted that very little information was found on the specific topic of the growth and yield impact of retaining live overstory trees on regeneration. Results on retrospective studies are presented below.

Rose and Muir (1997), in a retrospective study attempting to assess the growth and yield impact of retaining overstory trees throughout the next rotation, looked at 132 sites from the Pacific Northwest. The sites selected held coniferous stands aged between 70 and 110 years and either had no overstory ("clearcut" sites) or had overstory remnant trees from the previous rotation (aged 200 to 300 years old, simulating the "green-tree retention" sites) (Rose and Muir, 1997). While these stands were most likely initiated by natural fires (which retained some live trees), Rose and Muir (1997) assumed that the impact would be similar to that of harvesting with green-tree retention. Understory growth was compared with nearby clearcut stands while the amount of overstory remnants was assessed compared to nearby fully stocked old growth stands (to estimate the percent of the original stand that was left on site after the fire). Rose and Muir (1997) found that there was no impact in cases where 15 remnant trees/ha or less were left. For cases where 15 to 45 remnant trees/ha were left, results obtained show that retaining overstory trees had a negative impact on understory growth. Unfortunately, estimated figures of the percent growth reduction for each percent overstory retained are not provided (the authors seem to focus on the cause of growth...
reduction and the potential understory species composition change due to retaining part of the overstory). However, Rose and Muir (1997) are concerned with assessing the impact of new management guidelines (15% green-tree retention) and consequently focus their attention on the impact of 0 to 45 remnant trees per hectare. This parallel would lead one to believe that the 15 remnant trees/ha threshold (to observe a growth impact) would sit at about 5% overstory retention. However, Rose and Muir (1997) also estimate fully stocked old growth stands to contain 144 trees/ha, which would indicate that the impact threshold would rather sit at 10% retention (15 remnant trees/ha over 144 trees/ha).

An apparent excellent source of information for timber supply implications of non-clearcut silvicultural systems was MacMillan Bloedel's (MB) Forest Project background studies, especially those of Smith (1998a; 1998b). In a first report (Smith, 1998a), Smith reviews available literature, including one of MB's own studies (Smith, 1998b) and concludes that 1% growth reduction can be anticipated for each 1% of green-tree retention level, and that an extra 10% in growth reduction can be anticipated when dispersed retention (as opposed to aggregated retention) is used. However, the link between the literature reviewed by Smith and the conclusions reached is not always clear, and the use in Smith's conclusion section of a “notional effect” graph to illustrate the findings raises concerns as to where the data for those conclusions came from. The term “notional” hints to a theoretical and hypothetical basis, which could be acceptable if it appeared to be supported by the literature reviewed but without this clear link back to the reviewed literature, it is hard to accept as solid evidence for the growth and yield impact of retaining overstory trees advanced by Smith. However, it must be said that the Smith reviews (1998a, 1998b) constitute some of the most comprehensive work done to date on the topic, and since it was undertaken specifically for a BC context (MB’s Forest Project), these results are considered highly valuable to the present thesis.

However, an apparent discrepancy between Smith’s conclusions (1998a) and other authors (especially Rose and Muir, 1997) pertains to the growth and yield impact on regeneration at retention levels of 5% or less. Rose and Muir conclude no impact, while Smith concludes 5% impact (with aggregated retention) or 15% impact (with dispersed retention). An explanation to such a discrepancy may be a question of interpretation of the results. Smith (1998a), reviewing Rose and Muir (1997, in Smith, 1998a) reports: “below 15 remnant trees/ha there was too much variability to discern any trends” (Smith, 1998a reporting on Rose and Muir, 1997). A close look at Rose and Muir (1997) shows that they report “no significant decline in regeneration growth until remnant densities were greater than about 15 trees/ha” (Rose and Muir, 1997, p.213). It is important to note that too much variability to discern any trends (as reported by Smith, 1998a) is different from no significant impact (as reported by Rose and Muir, 1997). Rose and Muir indicate that there is no impact below 15 remnant trees per hectare, while Smith re-interprets Rose and Muir’s finding and reports it as there is an impact below 15 remnant trees per hectare but Rose and Muir did not find it because of excess variability in their data. Clearly this issue is still in need of clarification, and further research at those low levels of removal is needed. Interestingly enough, it is at those same levels of...

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9 Rose and Muir (1997) indicate that 15% retention is approximately 45 trees/ha, so it is assumed here that 15 trees/ha would be 5% retention.
retention (5% retention or 95% removal) that dispersed retention cutting techniques need to be tested for visual quality as mentioned in section 4.4.

Besides reviewing the literature on the topic (Smith, 1998a), Smith undertook a growth and yield analysis (for impact on regeneration) of several partially cut sites from MB’s database (Smith, 1998b). In this second Smith study (1998b), 57 sites/pairs from Coastal BC (including data for a wide variety of commercial coastal species) were identified and the growth and yield impact of each one of those sites was plotted against the percent (%) retention left on site. These plotted results are among those used by Smith to conclude that 1% growth reduction can be anticipated for each 1% of green-tree retention level, and that an extra 10% in growth reduction can be anticipated when dispersed retention (as opposed to aggregated retention) is used. However, a closer look at the data provided shows that out of the 57 comparisons used, 72% (41 out of 57) related to retention levels below 5%, leaving very little data for retention levels above 5%. And while the 12 comparisons where retention levels ranged from 10% to 40% (25% retention average) resulted in an average growth reduction of 23% (almost 1:1 ratio as advanced by Smith), the growth reduction averaged only 19% for the 9 comparisons comprised of between 20% and 40% retention, when an average growth reduction of 30% on average would be expected based on Smith’s conclusions (1:1 ratio). This gap between 19% obtained and 30% expected growth reduction for retention levels ranging from 20% to 40% retention is not explained in the Smith analysis (1998a, 1998b). Based on the data provided by Smith (1998b), it seems that the data is all over the map especially below the 5% retention levels. Above the 5% retention levels, a negative correlation is apparent between overstory retention and understory growth but great variability in the data remains (there is a 100 % growth variation [+35% to − 65%] for retention levels of 20% to 40% in Smith’s [1998b] data). All these uncertainties relating to Smith’s findings (1% growth reduction for each 1% green-tree retention level, and an extra 10% growth reduction when dispersed retention [as opposed to aggregated retention] is used) raise doubts as to their validity, but they nevertheless are the results of very comprehensive analyses, in addition to being Coastal BC data. They may therefore represent some of the best available information for the purpose of the analysis undertaken in this section.

2.5.3 Modelling studies

Having apparently very few research sites from which to actually measure growth and yield impacts of alternative silvicultural systems in BC and North America, and very few studies on the growth and yield impact of green-tree retention world-wide, several authors have attempted to model such impacts. Their findings are presented below.

Zielke et al. (2002), using PrognosisBC to model dispersed retention cutting options over a rotation reports interesting results (it should be noted that the figures for options 3 to 6 are not provided by Zielke et al. [2002] and were estimated by the author of the present report based on other data provided by Zielke et al.). Six options were looked at and are described here:

Option 1: 20% removal every 20 years with an estimated 24% volume yield reduction (compared to clearcutting).
Option 2: 50% initial removal with 40% removed 60 years later with an estimated 24% volume yield reduction (compared to clearcutting).

Option 3: 60% initial removal with 40% removed 60 years later with an estimated 24% volume yield reduction (compared to clearcutting).

Option 4: 45% initial removal with 40% removed 60 years later with an estimated 44% volume yield reduction (compared to clearcutting).

Option 5: 70% initial removal with no future entries resulting in an estimated 27% volume yield reduction (compared to clearcutting).

Option 6: 90% initial removal with no future entries resulting in an estimated 15% volume yield reduction (compared to clearcutting).

From these results, particular attention will be given to those of options 5 and 6 since no future harvests are planned, which potentially allows for comparisons to be made with other studies reviewed in the literature. In the case of Zielke's options 5 and 6 (Zielke et al., 2002), ratios of percent initially retained on site versus the reduction in growth and yield are respectively 1:1 (option 5) and 1:1.5 (option 6, showing more growth reduction than what is retained). These figures appear in accordance with Smith (1998a, 1998b), which found ratios of 1:1 or greater (more growth reduction than what is retained).

Birch and Johnson (1992), in a modelling exercise also looked at this issue of overstory retention impact on understory growth. The modelling exercise used Oregon-calibrated models (ORGANON and SPS) in well-stocked medium site Douglas-fir stands. Interestingly, they found that after two rotations of 60 years, the average impact was about 1:3 (1% volume retained for 3 percent growth impact) for retained volumes of up to about 10%, beyond which the marginal impact was decreasing. This results in ratios of 1:2 (1% volume retained for 2 percent growth impact) when 15% volume is retained and in ratios of 1:1 (1% volume retained for 2 percent growth impact) when 20% of the volume is retained (Birch and Johnson, 1992). These results led Birch and Johnson (1992) to point out that the impact of retaining small amounts of trees could be underestimated while the impact of leaving larger amounts of trees could very well be overestimated (Birch and Johnson, 1992). These results appear to contradict previous results (e.g. Rose and Muir, 1997; Smith, 1998a; Smith, 1998b), which would support the need for further research on the topic.

Long and Roberts (1992) used the PROGNOSIS model to compare two scenarios, a conventional scenario (initial cut, precommercial thinning, commercial thinning, and final cut) and an identical scenario (initial cut, precommercial thinning, commercial thinning, and final cut) but in which trees are retained in the initial overstory. Results showed that retaining 24% of the initial basal area for the 100 year rotation resulted in a 20% long term growth reduction. These figures result in a ratio of 1:0.8, which is slightly lower than other results obtained in the literature (e.g. Smith, 1998b), which would be in accordance with Smith (1998a), which reports Prognosis as being somewhat optimistic. Nevertheless, Long and Roberts's (1992) results are within the range of other results found in the literature.

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It is assumed Smith (Smith, 1998b) also used single entry cases where part of the initial overstory was retained for the entire rotation length.
It should be noted that most studies reviewed above concluded that the net growth of the overstory retained was nil. This is due to the balancing-off of any growth by anticipated losses resulting from yarding damage, windthrow, mortality (especially in old growth stands), etc. In other words, while it is recognized that the retained overstory trees will continue to grow (and therefore should be accounted for in any attempt to quantify the overall growth and yield impact of retaining them), the anticipated losses of volume within those trees are expected to completely offset this growth (hence a net overstory growth of zero).

In summary, despite having found some results, it appears that there is a strong need for research on the long term growth and yield impacts of retaining part of the overstory on regeneration. It appears that there is a lack of silvicultural system research in BC and in the western US, that retrospective studies are limited by the amount of available/suitable sites, and there are very few models that can handle dispersed retention cutting to date. PROGNOSIS BC (BCMoF, 2002b) is probably one of the best for BC to date, and has been calibrated for the south eastern portion of the province, but it requires substantial data that may not be easily obtained, which may limit its use. Other models currently being developed at the University of British Columbia, which tie together stand growth models, harvest scheduling models, and visualization software, are promising and should prove to be very useful modelling tools (as shown by the Wells and Nelson [2002] study) once they are fully calibrated.

2.6 DISCUSSION OF THE LITERATURE REVIEWED

2.6.1 Silvicultural systems

Confusion still exists around silviculture system terminology and the widespread use and misuse of generic terms such as partial cutting contribute to this confusion. Improvements include the introduction of a new retention system (as advocated by Mitchell and Beese, 2002), and the introduction of a dispersed retention cutting terminology as advocated in this thesis. Also, the apparent reliance of the present silviculture terminology on intent may have huge social implications, both for the forestry profession and for silviculture. Intent is very hard even for other foresters to detect, let alone the public, unless they are told, which leaves the public in a position were they have to trust the professional foresters about what is happening in the forest. This opens the door and facilitates the job for any third party interested in discrediting or criticizing foresters, and puts the foresters in a trusted position that is very delicate and hard to maintain.

As for variable retention and the recent worldwide push towards non-clearcut approaches, a potential drawback is that they may not be compatible with actual growth models and yield estimates will be very hard to forecast. It will be harder to keep track of stand composition, stand types, stand structure, stand growth and all other stand attributes with various levels of retention left on various blocks. Our knowledge of the stands treated with dispersed retention cutting or variable retention may therefore diminish over time as these techniques are increasingly undertaken from rotation to
rotation, unless greater investments (time and effort) are made to keep track of all the stand attributes and to develop adequate growth models.

2.6.2 Options for VRM in BC

As for VRM in BC, the review undertaken sheds light on three possible options. The first option involves maintaining the visual constraints as they have been managed in the past, and accepting the continuing reduction in timber availability as the less visible areas are used up or become unavailable. This situation is likely to continue in areas where VQOs have already been established, and conventional cutting practices are maintained.

Figure 5: Advertisement that ran in the Vancouver Sun (Vancouver Sun, Friday October 20th, 2000 p. A5), condemning the Chief Forester’s statement asking licensees to harvest in the Inside Passage or risk losing their rights to the timber.

A second option is to relax the visual constraints and permit expanded conventional harvesting in the front-country. This is an avenue now open to District Managers in deciding whether to impose or relax VQOs, whereby the Ministry of Forests (BCMoF, 1998d) hopes to offset FPC constraints on timber availability through a more flexible approach to VRM. With this approach, there is a risk that visual objectives will be compromised and public outcry will arise from affected communities, tourism providers and visitors. This seems likely to arise in the Inside Passage of BC, North Coast TSA, where recommended VQOs were relaxed in 1998 to reduce their impact on timber supply (BCMoF, 2000b). Despite this relaxation, visually sensitive areas are still being
avoided by the licensees, putting increased harvesting pressure on the remaining timber harvesting landbase. In response to this situation, the Chief Forester recently threatened an AAC reduction in the North Coast TSA, unless more harvesting takes place in the visually sensitive areas of the Inside Passage (BCMoF, 2000b): a “cut it or lose it” type of approach. This announcement triggered strong and immediate reaction, and within a week, an advertisement condemning the situation was running in the Vancouver Sun (see Figure 5), paid for by the David Suzuki Foundation.

The third and last option is to explore alternative planning procedures and timber harvesting practices, such as dispersed retention cutting, which may meet visual objectives in the front-country and are more acceptable to local communities, but may permit timber extraction at levels substantially higher than is possible with clearcutting under VRM procedures and the FPC.

However, it is important to stay focused on dispersed retention cutting as advocated and defined in this thesis rather than simply promote the use of “partial cutting” in areas subject to VQOs since not all so-called “partial cuts” are visually effective. Figures 6 to 8 illustrate very different appearances than would be expected from a dispersed retention cut, where residual trees are evenly distributed throughout the harvested area (as shown in Figure 9), for a given timber removal. There is a wide range of non-clearcut harvesting techniques, ranging from low-intensity thinnings, which are almost imperceptible in the landscape to seed tree, and wildlife patch techniques that may look like clearcutting to most people. The notion of perceptible thresholds on the effect of timber harvesting on the visual integrity of the forest may have major implications for the public acceptability of the practice of variable retention (for example) as an alternative to clearcutting, as espoused by (originally MacMillan Bloedel Ltd.) Weyerhaeuser Company (MB, 1998).
Figure 6: Example of partial cutting approach using a strip pattern of removal.

Figure 7: Example of partial cutting approach using a checkerboard pattern of removal.
Figure 8: Example of a partial cutting approach using organically shaped patch cuts.

Figure 9: Example of a dispersed retention cutting approach.
2.6.3 Public perceptions of logging disturbances

Public perceptions can best be summarized by a short list of “quick facts” obtained from the literature. The main ones go as follows:

- Increased landscape familiarity leads to increased preference (Dearden, 1984).
- The general public may not always assess natural landscapes based on the man-made disturbances contained in them, but when their attention is brought to those man-made disturbances, they tend not to like them (Magill, 1994).
- People tend to visually differentiate only three VQOs suggesting not all five VQOs may be worth managing for (McCool et al., 1986).
- Logger’s attitude towards VRM and involvement in the early stages of planning is key to the success of a visually sensitive harvest operation (Bordin, 2001; Clay, 1998; Eason et al., 2002; Jones, 1995; Mitchell, 2000).
- Middleground is the most critical distance for scenic landscape assessments (Litton, 1979; McCool et al., 1986; Paquet, 1993).
- People react negatively to even very low levels of visible clearcutting (BCMoF, 1996c; Paquet, 1993).
- Size (scale) of visible clearcutting is paramount to landscape scenic quality (Daniel and Orland, 1994; Miller, 1984; Palmer et al., 1994) and as it increases, scenic quality decreases (BCMoF, 1996a; Daniel and Orland, 1994; Miller, 1984; Palmer et al., 1994; Paquet, 1993). This supports the concept of percent alteration when clearcutting is used. Of lesser but still significant importance, organic shapes, subdividing the clearcut area into several smaller patch cuts, and increased “fit” of a clearcut in the landscape have a positive influence on scenic beauty (Miller, 1984; Palmer et al., 1994; Paquet, 1993). This supports the active practice of landscape design.
- Certain types of logging are visually acceptable (Bekker, 1987; BCMoF, 1996c; BCMoF, 1997a; Paquet, 1993).
- When available, “percent basal area removed” was found to be the best predictor of the Retention, Partial Retention and Modification EVCs (equivalent to the same VQO classes) (BCMoF, 1997a).
- Using dispersed retention cut techniques, even with severe visual constraints, permits much higher timber volumes to be harvested under the more restrictive VQOs than would ever be possible with clearcutting (BCMoF, 1996c; BCMoF, 1997a; BCMoF, 1998c; Sheppard, 1999).
- When dispersed retention cuts are used, very low levels of retention may result in as low visual quality as if the area had been clearcut (Ribe, 1999), if not even lower visual quality (BCMoF, 1997a).
Available evidence suggests that with a set of restrictive VQOs in place on a given landscape (or on a given visible slope if considered in perspective), the greatest timber availability should occur when dispersed retention cutting is used. Similarly, for potentially any given level of timber availability, highest visual quality should be achieved when using dispersed retention cutting. In addition, as pointed out by McDonald and Litton (1998) and Litton (2001), linking landscape design with silviculture may increase both timber yields and visual scenery, or, at least, it may help mitigate the impact of VRM on timber supplies and vice-versa. Finally, evidence from the literature reviewed clearly shows a potential for gains in timber harvests, both in the short and long term, from using certain types of dispersed retention cutting techniques in visually sensitive areas. Despite some very relevant studies on the topic originating from BC, there is still no clear landscape level measurement tool for assessing the intensity with which VRM is being managed in a given area. There is also a need for exploring at the landscape level whether tailored harvesting prescriptions, combined with enhanced visual landscape inventories could provide timber availability and timber supply gains.

In summary of the impact of aesthetics on timber availability and supply, traditional VRM approaches using VQOs have assumed that increased visual sensitivity constrains timber supply (BCMoF, 1998c). The most common impacts of VRM on the timber resource found in the literature include higher harvesting costs (Clay, 1998; Fight and Randall, 1980; Stier and Martin, 1997) and some reduction in timber availability when conventional harvesting is used (Industrial Forestry Services and BCMoF, 1998; Timberline Forest Inventory Consultants and Rowe, 1999; Wang and Pollack, 1998). However, under current BC applications of VRM, not all VQOs have an impact on timber availability and supply. Modification and Maximum Modification VQOs may place less spatial constraints on clearcutting than do other legislative requirements such as adjacency. The use of alternative cutting practices, as opposed to conventional clearcutting, appears to offer gains in timber availability and supply in visually constrained areas, based on reviewed literature, which suggests the key factor is the lower visual dominance of dispersed retention cutting. Also, increased volume harvest does not necessarily correlate with reduced visual quality. The opposite has been shown to occur and various dispersed retention harvesting practices have proven successful in meeting VQOs in visually sensitive areas (BCMoF, 1997a; Clay, 1998; Fight and Randall, 1980), and even in increasing both timber availability and aesthetic quality (Litton, 2001; McDonald and Litton, 1998).

Finally, determining the true impact of VRM on timber availability and supply requires careful analysis and depends on:

1) The extent of overlapping constraints from other non-timber resource values and policies (which limit the impact of VRM on timber supply, as pointed out by Stier and Martin [1997]).

2) The forest practices used (e.g. clearcutting or dispersed retention cutting).
3) The extent of VQO coverage and the class of VQOs (i.e. more restrictive Preservation, Retention and Partial Retention VQOs versus less or not restrictive Modification or Maximum Modification).

4) VEG tree height requirements of the particular area, since it may directly affect timber availability if different from the typical 3-meter free-to-grow requirement (for BC).

5) The distance considered. Middleground distance, which is considered in this thesis, is the most crucial distance (Litton, 1979) since it is at this distance that the disturbance is seen in its greater landscape context and "fit", only then can a disturbance be assessed in its broader landscape context. The cumulative picture can only be seen at this landscape scale, and the complexity and importance of working-out these variables and overlaps at the landscape scale is crucial in determining the impact of VRM on timber availability and supply.

6) The District Manager. It is possible that the impact of VRM on timber supply also depends upon the policies and decision-making styles of managers, as discussed earlier. However, this latter point needs further testing and validation.

2.6.5 Long term growth and yield and timber supply impacts of retaining part of the overstory (as in dispersed retention cutting)

In trying to summarize the growth and yield impact, it should be noted that these impacts are reported in various ways and that comparison between studies is not always easy. At least five different measures were used in the literature: percent of the initial volume left, percent of the initial basal area left, percent of the initial stems left, net basal area per hectare (or acre) left, and in terms of the number of trees left. And while some transformations from one measure to another may be possible in some cases and were done here occasionally to allow for comparisons to be made, great caution should be used.

Nevertheless, from this review of literature it appears that the retention of each 1% of the overstory results in a growth and yield reduction of a corresponding 1 to 2% in the understory. In other words, leaving 20% of the initial stand as green-tree retention will result in a 20% long term yield reduction in an optimistic case, and a 40% long term yield reduction will ensue in a pessimistic scenario. It should also be noted that a shift in species may occur, and that special attention (e.g. planting desired species) will need to be given to this matter.

In addition, it is important to keep in mind that the literature review results pertaining to the long-term growth and yield implications of retaining part of the overstory need to be taken cautiously since very little data was found, and that most data found pertaining to BC (e.g. Smith, 1998a; Smith, 1998b; Zielke et al., 2002) can not be considered as scientific information since it is not peer-reviewed and constitute corporate (private) reports in the case of the Smith reports (1998a, 1998b). Further research is needed on this topic in BC.
CHAPTER 3: METHODS: SHORT-TERM MODELLING AND LONG TERM IMPACT ASSESSMENT OF VRM ON TIMBER

This chapter will build upon the literature reviewed and present modelling procedures and analyses. Results and discussion are presented in Chapter 4, which include a discussion on long-term implications. It should be kept in mind that the focus of the present thesis is mainly on short-term timber availability and that long term timber supply implications are not presented with the same depth of analysis and are only meant to provide a more complete picture. Long term modelling should be the focus of further research.

More specifically, section 3.1 will address the methodology used for the development and foundation of a short-term model attempting to shed light on the relationship between timber availability and the level of VRM (expressed in terms of VQOs) applied to a given landscape. This general landscape unit level model will then be applied to the Arrow TSA as a case study. Section 3.2 is a refined application of the model developed in the previous section and is applied to a specific landscape unit within the Arrow TSA (the Lemon Landscape Unit). This refined analysis will include a re-assessment of the current VLI (while maintaining the VQOs) combined with specially designed site-specific harvesting plans. These tailored harvesting plans result in a new set of percent removal figures, which differ from the generic BCMoF figures. Section 3.3 will describe a modelling exercise undertaken as part of the Arrow IFPA project, which used a shelterwood system in visually sensitive areas for the Lemon Landscape Unit (Wells and Nelson, 2002).

Before heading into the core discussion of the modelling methods undertaken, some distinctions need to be made as to what information and methodologies exist already and what is still needed.

Already available are:

- perception studies (from BCMoF and others) on clearcutting and dispersed retention cutting (for visual quality and acceptability) (BCMoF, 1996c; BCMoF, 1997a).
- correlations of actual perceptions with timber volume removals (e.g. Paquet and Belanger, 1997).
- proposed relationships between the percent of volume removed combined with tree heights and VQO compliance at the stand level and possibly at the visual sensitivity level (BCMoF, 1997a).
- TSR analysis of VQOs at the TSA level, assuming visual landscape design and largely the use of clearcutting in the Arrow TSA, and basal area removal figures being proposed for those analyses (e.g. BCMoF, 1994b; BCMoF, 1998c).
• specific studies specifically looking at the potential effect of using dispersed retention cutting in visually sensitive areas on timber availability and supply in BC (Industrial Forestry Services Ltd. and BCMoF, 1998; Timberline Forest Inventory Consultants Ltd. and Rowe, 1999; Wang and Pollack, 1998).

New from this thesis:
• an explicit comparison of clearcutting and dispersed retention cutting figures recommended for inclusion in TSR by the BCMoF (1998a).
• a VQO Intensity Index to provide a numerical value representing cumulative effect of multiple VQOs at the landscape level to allow comparisons between the intensity of VQOs between landscape units.
• theoretical cumulative relationship between timber availability and VQOs at the landscape level for dispersed retention cutting and clearcutting in order to shed light on this relationship.
• interpretation and application of these relationships to a specific landscape unit and to the TSA level in the Arrow with different assumptions than those used in other studies.

3.1 THE FOUNDATION FOR THE SHORT-TERM MODEL: THEORETICAL RELATIONSHIPS BETWEEN TIMBER AVAILABILITY AND VQOS

The policy and procedures relevant to VRM in BC, as described in the previous sections, can be used as the framework for a theoretical quantification of effects of VQOs on timber availability, taking into account the results of perceptual research on different timber harvesting methods. It should be noted that the procedures used by the BCMoF for timber supply analysis typically presume the use of clearcutting as the dominant harvesting practice in visually sensitive areas. However, recent research on public perceptions of dispersed retention cutting relative to the extent of timber removal at the stand level (BCMoF, 1997a) enables quantitative comparisons of the effects of alternative timber harvesting practices on overall timber availability under VQOs.

Theoretical relationships between timber availability and visual quality have been derived primarily from BCMoF figures (BCMoF, 1998c), which in turn are based on public perception studies (BCMoF, 1996c; BCMoF, 1997a). In these studies, representatives of the public ranked photographs showing different levels of landscape alteration/denudation from timber harvesting (clearcuts and dispersed retention cuts), based on their visual quality. Scenes used represented a range of stand types, slope/landform conditions, and harvesting designs. The dispersed retention cutting examples were selected to represent "uniform distribution of residual trees" (BCMoF, 1997a, p.2): in other words, dispersed retention cutting with no discernible pattern (such as strip cuts or patch cuts) as defined earlier in this thesis. It is important to keep in mind the fact that the model rely on those studies because they represent the most detailed, most recent, and most advanced BCMoF studies on this topic in BC. It is also important to note that they are largely in accordance with other literature reviewed. It should be noted that the number of examples shown to participants with either very low or very high volume removals (Preservation and Maximum Modification VQOs) in the 1997 study (BCMoF, 1997a) was small, which casts some doubt on the reliability of
these results at these extreme levels of basal area removal. Further testing of perceptual responses in this range is required.

The reason for the apparent timber volume advantage of dispersed retention cutting when attempting to meet VQOs seems to be the substantial reduction in visual dominance of harvesting due primarily to the screening effect of residual trees. Except with the steeper slopes and highest viewing angles, a relatively small number of residual trees is able to filter and block open views of disturbed ground, as well as softening or eliminating abrupt cut block edges (Figure 10), and maintaining the appearance of a continuing forest canopy. This makes the amount of landscape alteration hard to detect or measure. Dispersed retention cutting, as defined in this thesis, is simply much less noticeable to the public, and also less distinguishable from natural vegetation patterns since it avoids discernable clearcut areas or patterns.

![Figure 10: Examples of a dispersed retention cut (left) and a typical square clearcut (right) as seen with snow on the ground (winter conditions).](image)

By extension, then, the reduced visual dominance of the “cut block” potentially frees dispersed retention cutting from the limitations of “percent alteration” and adjacency (depending on the amount and pattern of retention), at least where visual impact is the primary rationale for adjacency restrictions. The majority of a hillside or visual landscape unit could in theory be harvested by dispersed retention cutting at some level without necessarily reducing the level of visual quality.

The percent denudation allowable when clearcutting is used, as well as percent basal area allowable for dispersed retention cutting to meet given VQOs, are presented in Table 1 based on the figures suggested by the BCMoF (1998c). It should be noted that while the clearcutting and dispersed retention cutting presented in Table 1 originate from the BCMoF, they have not been presented side-by-side to date as is shown in Table 1. Timber available is defined as what could be harvested at any one time while meeting a given VQO, taking into account previously harvested areas that have not yet achieved Visually Effective Green-up (VEG) (BCMoF, 1994a). These figures (percent alteration and percent basal area) are assumed to be roughly equivalent for comparison purposes. More specifically, figures provided by the BCMoF (1998c) used percent (%)
planimetric denudation allowed for clearcutting under any given VQO and were converted to percent (%) basal area available in a ratio of 1 to 1 for the purpose of this thesis. This assumption was made to compare available basal area under both dispersed retention cutting and clearcutting. As discussed below, it is understood that this ratio is likely to vary substantially within a landscape due to variations in stand density, growth rate, age class, site index, etc. Further research is underway to find avenues that would allow better comparison between timber supplies available under clearcutting versus dispersed retention cutting for any given VQO.

The figures contained in Table 1 will form the basis of the model development and exercise (for which results are provided in section 4.1) focused on potential short-term availability gains that may result from a shift in harvesting practices (shifting from clearcutting to dispersed retention cutting) in areas subject to VQOs. Figures using a 2:1 green-operable/green-inoperable ratio have also been included in Table 1 for comparison purposes. It should be noted that the BCMoF figures (1998c) provided in Table 1 were often expressed as ranges rather than discrete values and that in these cases, the average value of these ranges was computed and used in the model developed in the present thesis.

Table 1: VQOs associated with different levels of timber removal under clearcutting and dispersed retention cutting. Derived from BCMoF (1998c).

<table>
<thead>
<tr>
<th>VQOs</th>
<th>Clearcutting % denudation (assumed to be roughly equivalent to % Basal Area available) for clearcutting (BCMoF, 1998c)</th>
<th>Dispersed retention cutting % denudation for clearcutting with a 2:1 green-operable/green non-operable ratio</th>
<th>% Basal Area available for Dispersed retention cutting (BCMoF, 1998c) with a 70% or higher probability of achieving the VQO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preservation</td>
<td>0-1</td>
<td>0-1.5</td>
<td>N/A</td>
</tr>
<tr>
<td>Retention</td>
<td>1.1-5</td>
<td>1.6-7.5</td>
<td>5-45</td>
</tr>
<tr>
<td>Partial Retention</td>
<td>5.1-15</td>
<td>7.6-22.5</td>
<td>65-70</td>
</tr>
<tr>
<td>Modification</td>
<td>15.1-25</td>
<td>22.6-37.5</td>
<td>95</td>
</tr>
<tr>
<td>Maximum</td>
<td>25.1-40</td>
<td>37.6-60</td>
<td>N/A</td>
</tr>
<tr>
<td>No VQO</td>
<td>100 (if no constraint other than visual quality is considered)</td>
<td>100</td>
<td>100 (if no constraint other than visual quality is considered)</td>
</tr>
</tbody>
</table>

The Arrow Forest District covers approximately 1,388,000 ha within the Nelson Forest Region in the West Kootenays of BC, of which 754,000 ha compose the Arrow TSA (BCMoF, 1999b). It consists of several major valleys occupied by the Arrow Lakes, Slocan Lake, and the Slocan, Kootenay, Salmo, and Columbia rivers. The area is characterized by several biogeoclimatic zones (BCMoF, 1998e), and contains a rich diversity of forest types. While there has been a history of logging in both the front-country and in the back-country, the most visible areas seen from major highways and communities within the Slocan Valley and parts of the Columbia River Valley appear to be relatively natural and undisturbed by logging. Forest licensees in the District have
expressed concerns over the dwindling availability of merchantable timber (Arrow Forest License Group, 1999) as many of the less visible back-country areas have been logged and are now constrained by FPC limitations. In the case of the Arrow TSA, the current available timber practically equals the Allowable Annual Cut (AAC), leaving licensees with very little or no manoeuvrability (Arrow Forest License Group, 2000). Some of the local communities have also strongly voiced their opposition to logging. The District is therefore a classic example of the situation addressed in this thesis, both in terms of the problems faced and potential solutions available.

3.2 SHORT-TERM MODELLING APPLIED AT THE LANDSCAPE UNIT LEVEL FOR THE LEMON LANDSCAPE UNIT

A study applied to the Lemon Landscape Unit within the Arrow TSA was conducted to assess whether the generic and province-wide BCMoF figures for percent alteration and percent basal area removal could be refined on a site-specific basis in order to yield different results than those obtained using the generic province-wide figures. This site-specific refinement involved reviewing and changing the current Visual Landscape Inventory (BCMoF, 1997b) and VQOs for possible errors, as well as a customisation of the harvesting practices (focusing on the 1st pass but with future passes in mind as well) rather than a simple application of the BCMoF numbers to the area. The overall goal of this exercise was to maximize short-term timber harvests (timber availability) while meeting the given VQO for the Lemon Landscape Unit, and to allow for comparisons to be made with the BCMoF figures in order to assess the difference between what could be immediately available for harvest under the generic BCMoF figures versus what could be available under a site-specific visual landscape design prescription using certain dispersed retention cutting techniques in visually sensitive areas and clearcutting elsewhere. It should be noted that the recommended VQOs for the Lemon Landscape Unit were not changed per se, but areas under the VQOs (e.g. visible areas) were refined and alternative harvesting prescriptions were considered that would allow potentially more timber to be harvested while meeting the Lemon Landscape Unit recommended VQOs.

The Lemon Landscape Unit covers approximately 40,900 ha and is located between Valhalla and Kokanee Glacier Provincial Parks, and sits immediately to the East of Slocan city. The Lemon Landscape Unit contains 7,720 ha under VQOs, the majority of which are under some of the most restrictive VQOs (Retention VQO and Partial Retention VQO). This unit was selected based on data availability, and based on its overall ability to represent the Arrow TSA, as identified by the Arrow IFPA team (Sheppard et al., 2002).

This site-specific visual landscape design prescription for the Lemon Landscape Unit, is based on public perception results from the literature, Visual Landscape Design training of the author of the present thesis, on several field visits of various innovative logging trials, and on several site visits in the Lemon Landscape Unit.

The specific procedure and method employed consisted of two main steps, which are described as follows:
a) Review the VQOs and visible areas based on the same Key Observer Points (KOPs) as those used in the VLI (BCMoF, 1991) which included Slocan Lake and Slocan city as key viewpoints and Highway #6 as a continuous line of viewpoints to assess the VQO areas (Fitchett, pers. comm., 1999). In other words, almost everything visible from these three viewing areas was recommended for inclusion in an area subject to VQOs. These same viewing areas (Slocan Lake, Slocan city and Highway #6) were the viewpoints used in re-assessing the visual landscape inventory and the VQO polygons for the purposes of the present thesis. A review of operable/inoperable areas within VQO polygons was also undertaken, and sub-polygons (within the VQO polygons) that have different visual characteristics were mapped/identified. For example, areas that are screened by vegetation, viewed at very low viewing angles, or hidden areas at the bottom of creek gullies were removed from the VQO requirements, etc. This analysis included ArcView/GIS analysis (both in 2D and in 3D), visual analysis of site photography, and several site visits (winter and summer visits, using both ground (car) and aerial (helicopter) perspectives. Figure 11 shows the viewpoints considered in this analysis.

b) Assign harvesting prescriptions to those revised polygons that would still meet the original VQOs for that area. It should be noted that all prescribed blocks are within 1 km or less of an existing or proposed road, that landings are located for each block for which a prescription was made, and that 2\textsuperscript{nd} and/or 3\textsuperscript{rd} passes will not necessarily involve yarding over regenerating areas, depending on the yarding pattern used. The 1 km maximum yarding distance threshold was determined based on a proposed block by Slocan Forest Products (the historical licensee for the Lemon Landscape Unit) in which yarding corridors 1 km in length were proposed for a Retention VQO polygon within the Lemon Landscape Unit. As for the yarding pattern suggested, a radiating strip pattern of removal can be used and yarding corridors can be shifted from one harvest pass to another in such a fashion that yarding mostly occurs over mature areas (see Sheppard and Picard [2000] for more details on the radiating strip pattern of removal). Finally, it should be noted that the minimum economic harvest levels (in m\textsuperscript{3}) resulting from these prescriptions are equal to or above the levels used in other literature for the area (e.g. Wang and Pollack, 1998).
Figure 11: Viewpoints used for a re-assessment of the VLI for the Lemon Landscape Unit.
Results of this detailed modelling exercise are compared with the BCMoF figures (the same figures as those used in the first modelling exercise from section 3.1) and presented in section 4.2.

3.3 AN INTERDISCIPLINARY MODELLING EXERCISE USING VARIOUS HARVESTING PRACTICES IN VISUALLY SENSITIVE AREAS

This section describes an interdisciplinary modelling exercise undertaken at the University of British Columbia on the Lemon Landscape Unit. This modelling exercise, which is part of the Arrow IFPA Research Project, modelled over time the impact of various management scenarios (see Wells and Nelson [2002] for more details). The models used in this exercise include the FORECAST stand growth model, which was fed into the ATLAS harvest scheduling model in order to provide both short-term and long term spatially explicit harvest schedules and timber volumes that could be harvested. The three scenarios modelled include the Forest Practices Code Scenario (base-case, using clearcutting as a main practice, and following current FPC regulations for BC), a patch-cut scenario where 1-hectare patches were used in visually sensitive areas, and a third scenario which consisted of using shelterwood harvests in visually sensitive areas, combined with expanded visually sensitive areas (and extra VQO polygons). These increased areas, called Visual Priority Areas in the Wells and Nelson (2002) modelling exercise, effectively increased the areas under VRM in the area concerned (the Lemon Landscape Unit in the Arrow TSA) from about 19% of the landscape unit under VQOs to about 33% of the unit under some sort of visual management.

All three scenarios were then compared for their respective impact on timber supplies, over approximately 300 years, and it is these comparisons that will be the focus of interest here, since they have great potential to shed light on the short and long term VRM-timber availability/supply relationship sought after in the present thesis. The author of the present thesis provided guidance for VRM (and how to manage/model for the visual resource) in the Wells and Nelson (2002) modelling exercises in order to obtain another set of results as part of the research design. Outputs from the ATLAS model were then fed into an advanced realistic visualization software in order to produce realistic visualizations to assess the visual performance of each of the three scenario considered.

11 Several other values were accounted for other than visuals, but the focus will be kept on VRM for the purpose of the present thesis (see Nelson, 2002 for more details).
CHAPTER 4: MODELLING RESULTS AND DISCUSSION

This chapter will present and discuss the results obtained and is organized as follow. Section 4.1 addresses the short-term model attempting to shed light on the relationship between timber availability and the level of VRM (expressed in terms of VQOs) and is then applied to the Arrow TSA as a general example. Section 4.2 presents the results of the refined application of the model developed in the previous section and is applied to a specific landscape unit within the Arrow TSA (the Lemon Landscape Unit). Section 4.3 presents and compares the results of an interdisciplinary modelling exercise undertaken as part of the Arrow IFPA project, which are then compared with the modelling results from previous sections. Discussions are provided in section 4.4 while section 4.5 briefly addresses long-term implications on timber supply of retaining part of the overstory.

4.1 MODELLING TIMBER AVAILABILITY UNDER VQOS AT THE LANDSCAPE UNIT LEVEL BASED ON THE BCMOF DATA

4.1.1 The short-term model

While the discussion in the present section pertaining to VQO Intensity Index calculations and Timber Availability Score calculations may appear to be part of the method used to create the short-term model, they constitute newly created approaches to computing the cumulative impact of various VQOs (and cumulative relative estimates of timber availability) at the landscape level and therefore were deemed to constitute key results/outcomes of the present thesis. This is why these discussions and calculation descriptions are included here rather than in the methods section.

The figures presented in Table 1 can be used to quantify, in an area subject to a given VQO, potential differences in timber availability that could result from a shift in harvesting techniques. However, based on review of the available literature, there appears to be no commonly used measure to express the cumulative intensity of the VQOs at the landscape unit level. Thus, it is difficult to compare the effect of different VQO combinations on timber availability between landscape units, and to gauge the potential timber gains to be realized with dispersed retention cutting under VQOs in real-world situations at the landscape unit scale. This thesis advances the concept of a VQO Intensity Index, as a scale of the severity of the visual concerns or constraints.

For the purpose of the present work, a value from 0 to 1, expressing the intensity or restrictive ness of VQOs, is assigned to each VQO (0 for no VQO and 1 for a Preservation VQO), as shown in column 3 of Table 2. These values were selected based on the definition of the VQOs, with the most restrictive VQO (Preservation) being assigned the maximum possible VRM intensity value since no man-made alterations
can be visible under this VQO. At the other end of the spectrum, "No VQO" was assigned the lowest possible VRM intensity value. The values between those extremes were then divided equally between the remaining VQOs. The linearity of the scale of this index was also selected for simplicity.

For a particular landscape unit, this VQO Intensity value is multiplied by the area under each given VQO (percent of total area as seen in plan). The result is used as a measure of the individual contribution of the VQO polygon towards the total VQO intensity applied to the landscape unit. The sum of these "VQO by Area" multiplications for a given landscape unit provides an overall "VQO Intensity Index", which expresses the restrictiveness of the VQOs over an area composed of many visual sensitivity units with different VQOs. The VQO Intensity Index then allows for the ranking of all possible combinations of VQOs (or "No VQOs") that could be applied to a landscape, from 0 to 100 (where 100 represents 100% of the area under a Preservation VQO, and 0 represents 100% of the area without VQOs).

Table 2: Example of VQO Intensity Index and associated timber availability "scores" under a clearcut system in a hypothetical landscape unit with a particular combination of VQOs.

<table>
<thead>
<tr>
<th>VQOs</th>
<th>% of area under each VQO</th>
<th>VQO Intensity value</th>
<th>VQO Intensity Index contributions in % (col. 2 by col. 3)</th>
<th>Average % of basal area available for harvest (in theory)</th>
<th>Timber Availability Score (TAS) (col. 2 by col. 5)</th>
<th>Timber Availability Score (TAS) with a 2:1 green-operable/green-inoperable ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preservation</td>
<td>1.0</td>
<td>0</td>
<td>0.0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retention</td>
<td>25</td>
<td>0.8</td>
<td>20</td>
<td>3.0</td>
<td>0.8</td>
<td>1.2</td>
</tr>
<tr>
<td>Partial</td>
<td>10</td>
<td>0.6</td>
<td>6</td>
<td>10.0</td>
<td>1</td>
<td>1.5</td>
</tr>
<tr>
<td>Retention</td>
<td>Modification</td>
<td>2</td>
<td>0.4</td>
<td>0.8</td>
<td>20.0</td>
<td>0.4</td>
</tr>
<tr>
<td>Maximum</td>
<td>Modification</td>
<td>2</td>
<td>0.2</td>
<td>0</td>
<td>32.5</td>
<td>0</td>
</tr>
<tr>
<td>No VQO</td>
<td>63</td>
<td>0</td>
<td>0</td>
<td>100.0</td>
<td>63</td>
<td>63</td>
</tr>
</tbody>
</table>

As with the VQO Intensity Index, an associated indicator of the level of available timber can be derived at the landscape unit level. Percent denudation or percent basal area allowed for removal under the harvesting system used (clearcut or dispersed retention cut), is multiplied by the area (in percent of the total area) under each VQO. Similar to the VQO Intensity Index, a resulting "Timber Availability Score" (TAS) (using a similar scale from 0 to 100%, 0 being the lowest once again) can be summed from the individual available timber levels from each VQO (for a given harvest system). The TAS represents the percent of available standing timber in the landscape unit, assuming it is all operable and mature and that VQOs are the only limiting factor. The TAS represents
only the timber theoretically available (under a given harvesting practice) at the time of the first pass through attainment of VEG.

Examples of VQO Intensity Index and Timber Availability Score are presented in Figures 12 to 14, where Figure 12 and 13 provide two extreme examples with one VQO per landscape unit (considering "No VQO" as a visual prescription), while Figure 14 provides an example where multiple VQOs are found in a landscape unit (as is usually the case in the real world). These examples, in conjunction with the calculations provided in Table 2, illustrate the method used for computing the VQO Intensity Index and the Timber Availability Scores presented in this thesis. Values used for the available timber for clearcut and dispersed retention cut are the averages of the BCMoF (1998c) values presented in Table 1.

Table 3: Example of VQO Intensity Index and associated timber availability “scores” using a dispersed retention cut approach in the same hypothetical landscape unit as Table 2.

<table>
<thead>
<tr>
<th>VQOs</th>
<th>% of the area under each VQO</th>
<th>VQO intensity value</th>
<th>VQO Intensity Index contributions in % (col. 2 by col. 3)</th>
<th>Average % of basal area available for harvest (in theory)</th>
<th>Timber Availability Score (TAS) (col. 2 by col. 5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preservation</td>
<td>1.0</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retention</td>
<td>25</td>
<td>0.8</td>
<td>20</td>
<td>25.0</td>
<td>6.25</td>
</tr>
<tr>
<td>Partial</td>
<td>10</td>
<td>0.6</td>
<td>6</td>
<td>67.5</td>
<td>6.75</td>
</tr>
<tr>
<td>Retention</td>
<td>2</td>
<td>0.4</td>
<td>0.8</td>
<td>95.0</td>
<td>1.9</td>
</tr>
<tr>
<td>Modification</td>
<td>0.2</td>
<td>0</td>
<td>N/A</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>No VQO</td>
<td>63</td>
<td>0</td>
<td>100.0</td>
<td>63</td>
</tr>
<tr>
<td>Modification</td>
<td>Total</td>
<td>100%</td>
<td>26.8%</td>
<td>-</td>
<td>77.9%</td>
</tr>
</tbody>
</table>

Table 3: Example of VQO Intensity Index and associated timber availability “scores” using a dispersed retention cut approach in the same hypothetical landscape unit as Table 2.
"No VQO" (entire landscape unit):

100% of area @ 0 VQO Intensity value = 0% VQO Intensity Index.

100% of area @ 100% Timber Availability Score (TAS) = 100% Timber Availability Index.

Figure 12: Example of calculations for a hypothetical landscape unit with one visual prescription. VQO Intensity Index = 0%, Timber Availability Index = 100%.

Once the VQO Intensity Index and Timber Availability Scores have been calculated, one can compare available timber under a constant VQO Intensity Index (but using different harvesting approaches) or compare the combinations of visual prescriptions (VQOs) that could be achieved with a given Timber Availability Score. Two hypothetical examples are provided in Tables 2 and 3, one using clearcutting and the other using dispersed retention cutting (based on the example area shown in Figure 14). A comparison of the Tables reveals the difference in timber availability due to harvesting practice for an identical set of VQOs. In this situation, theoretical available timber increases by 12.7% (from 65.2% to 77.9%) by using a dispersed retention cut approach instead of a clearcut system. When a green-operable/green-inoperable ratio of 2:1 is taken into consideration, the dispersed retention cutting option still yields a timber availability increase of 11.6% (from 66.3% to 77.9%) in this scenario.

The theoretical relationship between VQO Intensity and short-term timber availability, based on the figures provided by the BCMoF (1998c), can be visualized by plotting VQO Intensity against timber availability. Figure 15 illustrates the theoretical relationship, which would occur in the simple situation of one VQO covering an entire landscape unit (as in Figure 12 and 13). For a given VQO, significant availability increases are observed with a shift towards dispersed retention cutting.
"Preservation VQO" (entire landscape unit):

100% of area @ 100 VQO Intensity value = 100% VQO Intensity Index.

100% of area @ 0% Timber Availability Score (TAS) = 0% Timber Availability Index.

Figure 13: Example of calculations for a hypothetical (square) landscape unit with one visual prescription. VQO Intensity Index = 100% and Timber Availability Index = 0%.

R: 25% of area @ 0.8 VQO Intensity value: 20.0%
PR: 10% of area @ 0.6 VQO Intensity value: 6.0%
M: 2% of area @ 0.4 VQO Intensity value: 0.8%
No VQO: 63% of area @ 0 VQO Intensity value: 0%

Total VQO Intensity Index for the unit: 26.8%

R: 25% of area @ 3% TAS: 0.8%
PR: 10% of area @ 10% TAS: 1.0%
M: 2% of area @ 20% TAS: 0.4%
No VQO: 63% of area @ 100% TAS: 63.0%

Total Timber Availability Index (with clearcutting) for the unit: 65.2%

Figure 14: Example of calculations for a hypothetical (square) landscape unit with multiple VQOs. VQO Intensity Index = 26.8% and Timber Availability Index = 65.2% (when clearcutting is used).
Towards dispersed retention cutting (source: derived from BCWOF 1998), and dispersed retention cutting regimes. For a given VQO, significant availability increases are observed with a shift and dispersed retention cutting regimes. For a given VQO, significant availability increases are observed with a shift towards dispersed retention cutting (source: derived from BCWOF 1998).

**Figure 15:** Theoretical short-term timber availabilities for landscape units with a single VQO, under both clear-cutting and a dispersed retention cut approach (CRC)
Figure 16: Theoretical short-term VQO-timber availability relationships for both clearcutting and dispersed retention cutting based on the full range of possible combinations of VQOs at the landscape unit level.
Building from Figure 15, the rationale is extended to establish theoretical relationships between timber availability and different VQO combinations in order to determine the timber available (until VEG is reached) for any given combination of VQOs in a given area. Using this simple model, the full range of VQO Intensity indices and associated timber availability scores for different combinations of VQOs have been computed and plotted (Figure 16). In other words, Figure 16 is generated by computing timber availability and VQO scores for any given combination of VQOs and on any given proportion of the landbase (by varying the area under each VQO in column 2 of Tables 2 and 3). Figure 16 attempts to show the hypothetical relationship between timber availability and VQOs for both clearcutting and dispersed retention cutting: it demonstrates the difference in timber availability due to the harvesting system used. For example: 1) in areas with a VQO Intensity of 80% (equivalent to the entire area being under a Retention VQO), timber availability can vary from 3% (with clearcutting) to 33.75% (with dispersed retention cutting): an 1,125% increase; 2) in areas with a VQO Intensity of 60% (equivalent to the entire area being under a Partial Retention VQO), timber availability can vary from 10% (with clearcutting) to 67.5% (with dispersed retention cutting): a 675% increase; 3) in areas with a VQO Intensity of 40% (equivalent to the entire area being under a Modification VQO), timber availability can vary from 20% (with clearcutting) to 95% (with dispersed retention cutting): a 475% increase. For a given VQO intensity, the resulting timber availability can vary significantly according to the particular combination of VQOs, and great variance is observed in VQO intensity for a given timber availability.

It is important to note that the reason why there is no overlap (or very little of it) between the clearcutting and the dispersed retention cutting values shown in Figure 16 is because no such overlap in the timber removal figures existed in the first place in the BCMoF figures (see Table 1). And since the model presented here is based on those Figures, the lack of overlap is carried over.

Under these theoretical circumstances, for any given set of VQOs, the greatest short-term timber availability occurs when dispersed retention cuts are considered. Similarly, for any given timber availability, highest visual quality is achieved when using dispersed retention cutting. This is due to the assumed avoidance of percent alteration/denudation limits (i.e. cut block limitations) with dispersed retention cutting (up to a certain removal level, beyond which it starts to be perceived as a clearcut). These findings, even though theoretical, stress the potential importance of dispersed retention cutting in visually sensitive areas, and the potential to increase either the available timber or the visual quality of given landscapes by applying a shift in harvesting techniques. This is to be expected given the relatively low percent denudation available for harvest under VQOs with clearcutting and the high percentages of basal area apparently available with dispersed retention cutting as suggested by the BCMoF (1998c) data.

It should be noted that the active use of visual landscape design (when clearcutting is used) would effectively reduce the gap between clearcutting and dispersed retention cutting and reduce the apparent dispersed retention cutting timber availability gain. In this regard, the use of feathered edges and organically-shaped clearcuts would reduce the dispersed retention cutting advantage and using dispersed retention cutting at very
high removal levels will necessitate the use of visual landscape design techniques (e.g. feathered edges and organic shape) to mitigate the negative visual impacts.

4.1.2 Discussion of potential uncertainties

Clearly there are a number of major caveats that need to be considered before attempting to apply these hypothetical findings to the real world of forest management. Principal among these are the following:

Insufficiently tested percent removal numbers at the high percentages of removal (the extremes) when dispersed retention cutting is considered. Ongoing research within the BCMoF and at the University of BC should shed some light on this issue.

Inaccuracies in assigning the same percentage of basal area in clearcutting to percent denudation. One of the assumptions made in this thesis is that the recommended percent denudation values provided by BCMoF (1998c) are equivalent to percent basal area available (i.e. a ratio of approximately 1:1). In other words, we assumed that to clearcut “X” percent of a landscape would result in “X” percent of basal area removal for that same landscape. This assumption is only true if the basal area is constant over the landscape or if the timber clearcut represents the average basal area, which would not necessarily be the case in a "real world" situation. Basal area is a stand level attribute, while percent denudation is a landscape-level attribute. However, despite this weakness, the theoretical approach presented in this thesis can still reveal trends in the VRM-timber availability relationship.

Assuming that basal area is not evenly distributed (as is likely in most situations), and that the areas harvested correspond to those with higher basal area concentration, clearcutting the allowed percent denudation would result in higher basal area removal (for any given VQO) than those assumed in Table 1. This would result in a reduction of the timber availability gap between clearcutting and dispersed retention cutting under VQOs. On the other hand, if the percent denudation allowed under clearcutting is applied over the areas of the landscape with lower than average basal area (harvesting of the stands with low basal area), then the timber availability difference between clearcutting and dispersed retention cutting would be increased, since a given percent landscape denudation would yield lower basal area removal. This could be the case if, for example, clearcutting is focused in areas of lower basal area and dispersed retention cuts are concentrated in areas of higher basal area. However, the first scenario (reduction of the gap between clearcutting and dispersed retention cutting) is likely to be more common since the general harvesting strategy consists of cutting the oldest stands first (and therefore those stands with higher basal area).

Cutblock size and extent of dispersed retention cutting may exert an influence on the potential dispersed retention cut advantage. The theoretical relationships developed above do not take into account any practical limit on the extent of dispersed retention harvesting operations. While extensive dispersed retention cutting over an entire landscape, unlike clearcutting, may theoretically meet VQOs, there is inevitably a physical limit to individual harvesting blocks and the rate at which a finite pool of labour and equipment can harvest the entire forest landscape. It has not yet been established
that dispersed retention cutting over entire landscapes in BC would meet VQOs, since the limited samples used in perception testing did not contain such large scale harvesting blocks. However, preliminary analysis of certain case studies using innovative dispersed retention cutting techniques over entire hillsides (e.g. Timfor’s operation at Knight Inlet) show that visual quality may be maintained while allowing significantly more timber to be removed (Sheppard and Picard, 2000). In the latter case study, the extensive use of dispersed retention cutting, landscape design, and alternative management approaches resulted in Forest Stewardship Council (FSC) certification being provisionally granted, in addition to yielding increased timber availability.

Under dispersed retention cutting, rotation length, growth rates in partially shaded conditions, species regenerated, and the sustainable rate of cutting may also reduce the initial volume advantage of dispersed retention cutting over clearcutting in the long run.

Adjacency, which does not apply to dispersed retention cutting under the FPC when 60% (or less) of the timber is removed (BCMoF, 2001c), could yield even higher differences in timber availability when a shift towards dispersed retention cutting is undertaken. In the case of our model, no adjacency was factored in for either clearcutting or dispersed retention cutting. Factoring in adjacency would result in the data shown in Figure 16 shifting to the left (less timber availability for a given VQO Intensity), but this shift would be less pronounced in the cases where dispersed retention cutting is used (shown in red on Figure 16) versus when clearcutting is used since a proportion of the dispersed retention cutting (which removes 60% or less of the timber) would not be subject to adjacency under current FPC regulations.

Also, if the rule-of-thumb ratio of percent alteration to percent denudation (1:2 as seen earlier) is inaccurate at any given location, volumes available for harvest within the percent denudation range with clearcutting may greatly exceed or underestimate the level of cut recommended to meet the given VQO, depending on actual landscape conditions.

In an attempt to obtain a more accurate figure regarding the potential “boosting” effect of green-operable/green-inoperable ratios for clearcutting, we can apply such a ratio (2:1) to the example shown in Figure 14. Surprisingly, it emerges that the green-operable/green-inoperable ratio has no significant result in this case. This is because in areas with no VQOs, the timber availability is already considered to be 100%, while in areas subjected to VQOs, the volumes allowed (under clearcutting) are so constrained that the gains are very modest. In fact, multiplying the available timber under a clearcut system by a factor of 1.5 (to account for a green-operable/green-inoperable ratios of 2:1 as seen above) only increases the clearcut availability by 1.1% (up to 66.3%) in the case of the Arrow TSA (see Table 2 for detailed calculations).

The linear scale used in the VQO Intensity Index may influence the relationship between visual quality and timber availability, as opposed to a non-linear scale. In this regard, McCool et al. (1986) found that people detected only three VQOs (instead of 5), which effectively mean that the Index could have been skewed in such a way as to represent this finding. For example, alternate intensity values for each of the five VQOs
could have been 1.0, 0.9, 0.8, 0.5, 0.2, and 0.0 (for each of the five VQOs from Preservation to Maximum Modification including "No VQO") as opposed to the regular (linear) scale used in the present thesis. Such a scale could have better represented the McCool et al. (1986) results in the sense that the three most restrictive VQOs would be assigned high intensity values (1.0 to 0.8), with a significant break around the Modification VQO (value of 0.5), and another break for the Maximum Modification VQO and ‘No VQO’ appellation (values of 0.2 and 0.0). However, several reasons are in favour of the linear model used here rather than a non-linear one. First, the McCool study is from the US and used only 25 slides in total (for 5 VQO classes). Second and most important, the focus of the present thesis is to assess the relationship between timber availability and supply and visual quality as represented by the current BC VQOs. Using a non-linear scale, as suggested by McCool et al. (1986) would have been similar to considering only three VQOs instead of five which is not in line with the current VRM system in BC which uses all five VQOs. Third, since we are concerned with comparing clearcutting and dispersed retention cutting practices, the linearity or non-linearity of the scale used would have changed the shape of Figure 16 but not the relationship between the two harvesting systems. In other words, whether a linear scale is used or not, dispersed retention cuttings would have still yield either higher visual quality or higher timber availability (or both) for any given VQO combination on the landscape. For these reasons, the linear scale was deemed appropriate for the present modelling exercise. Nevertheless, the non-linear scale should be the focus of future research efforts and testing should be undertaken to assess in greater depth the impact (if any) of using a linear versus a non-linear scale in the present modelling exercise.

Other overlapping constraints: as discussed earlier, other resource values and policies (e.g. water quality, biodiversity requirements) may limit the areas available for harvesting, and the resultant available timber. Assuming that dispersed retention cutting is subject to the same restrictions from other resource values as clearcutting, this would further reduce the apparent "dispersed retention cutting gain" over clearcutting under VQOs, particularly in visual landscape units with higher VQO Intensities where clearcutting is the most tightly constrained.

The spatial extent of the visual sensitivity units within which the percent alteration or percent denudation is calculated can be critical. Five percent of a large hillside or valley can permit large openings whereas 10% of a small unit may restrict harvests to patch cuts with a different set of cost/volume ratios. This would not affect the model as long as the same size/extent of visual sensitivity units are applied equally for both dispersed retention cutting and clearcutting. However, increasing the size of the visual sensitivity unit will increase the risk of not meeting the VQO for this unit, especially when clearcutting is used because the net size of the visible disturbance will increase and therefore increase the risk of it being visually evident or visually dominant in the landscape.

Other less obvious factors may reduce the dispersed retention cutting potential gain over clearcutting under VQOs. Planning and permitting procedures, which are geared for clearcutting, combined with the relative lack of experience with dispersed retention cutting in industry and government, may add to the "red tape", complexities, and delays in approving dispersed retention cutting operations. Also, the apparent relative losses in
volume with clearcutting under VQOs may be reduced in practice by application of the maximum percent denudation levels recommended in the BCMoF (1998c) procedures, rather than using the average levels (as used in Table 1 and applied to generate Figures 15 and 16). The application of skilful forest design, as advocated in the training manuals for the BCMoF (1995b), may also allow higher volumes to be removed with clearcutting or mixed harvesting systems while still attaining VQOs. As indicated earlier, the relationships shown in Figure 16 may also exaggerate the advantages of dispersed retention cutting at higher volume removals, since we have very little information on public judgments of visual quality at these levels. If growth rates under dispersed retention cutting are lower, this may lead to reduced Annual Allowable Cut allocations.

However, where alternative harvesting techniques with at least some kinds of dispersed retention cutting can be shown to be feasible, and within the range of low to moderately high basal area removals, there appears to be a strong possibility that VQOs may cease to act as major constraints on timber availability and supply relative to other resource constraints.

4.1.3 Tying the model to the real world: applications to the Arrow Timber Supply Area (TSA) and short-term availability impacts

As an example of the implications of these approaches to VRM and timber availability, the status quo and potential options for VRM in the Arrow Forest District was analyzed. Considering the importance of visual resources and public perceptions in the District (BCMoF, 1994b; BCMoF, 1994c), it is surprising that no VQOs have been established, but only Known Scenic Areas and recommended visual quality classes (Fitchett, pers. comm., 1999), up until January, 2001. It appears that the explanation for this situation may be that the District Manager made known the scenic areas and asked the Licensees to manage the visual resource according to the recommended VQOs without actually establishing them (VQOs are legally binding once established). In other words, there were technically no established VQOs in the Arrow up until 2001, only recommended ones, but the Licensees and the TSR calculations managed and accounted for those recommended VQOs as if they were established and legally binding. This may result in low VQO intensities “on the books”, but higher levels of visual resource management on the ground. However, if public pressures are more constraining than the established (or recommended) VQOs themselves, the impact of VRM on timber availability is effectively eliminated since the most restrictive constraint determines what management will prevail. It is also possible that differences in the degree of visual constraint between different districts may become more marked, reflecting the priorities of the district and the inclinations of the individual District Manager.

As pointed out earlier (Stier and Martin, 1997), the impact of any VQO depends on the assumption that more timber would be harvested in the absence of such visual

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12 The Kootenay/Boundary Land Use Plan (KBLUP) came into effect at the end of January 2001 and establishes three classes of landscape management for scenic areas, which translate into Retention, Partial Retention and Modification VQOs, for areas that are visible from major highways, towns, and lakes (LUCO, 2000).
management regimes. This is far from being clear in the Arrow TSA where harvesting has been avoided in many of the areas subject to more restrictive VQOs, due to public pressures (such as those leading to the logging moratorium in Hasty Creek), and higher operating costs associated with VQOs (BCMoF, 1994b; BCMoF, 1994c). There are also other FPC regulations and biodiversity/forest cover constraints for community watersheds, etc. that could significantly reduce the effective impact of VQOs on timber supply and availability (BCMoF, 1995a; BCMoF, 1995c) or even eliminate the impact of VQOs if these other values were more constraining on the cut.

Nevertheless, in order to apply these theoretical relationships and findings on VRM in relation to timber availability in the Arrow TSA, the Timber Supply Review 1 (TSR 1) for the TSA has been used as a data source (see BCMoF, 1994b). Although recently revised, it can still provide an instructive illustration of the VQO-timber availability relationship in the Arrow Forest District. In addition, an initial review of TSR 2 (BCMoF, 2000c) suggests that the results obtained would remain similar. It is important to note that the Arrow Forest District has no established VQOs but only Known Scenic Areas with recommended Visual Quality Classes (VQCs) (Fitchett, pers. comm., 1999). However, VQOs of Retention and Partial Retention were modelled in TSR 1 (BCMoF, 1994b) based on the recommended visual quality classes from the VLI (BCMoF, 1991). These modelled VQOs are used here to illustrate the VRM-timber availability relationship in the Arrow TSA.

BCMoF has divided the harvesting landbase in the TSR 1 into five management zones to account for various resource constraints and management emphasis based on wildlife habitat, water quality and quantity, and landscape aesthetics (BCMoF, 1994b).

<table>
<thead>
<tr>
<th>Management Zone</th>
<th>Percentage</th>
<th>Land Area</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention VQO</td>
<td>1.5%</td>
<td>3,156 ha</td>
</tr>
<tr>
<td>Partial Retention VQO</td>
<td>17.3%</td>
<td>37,439 ha</td>
</tr>
<tr>
<td>Class 1 &amp; 2 Watersheds</td>
<td>14.0%</td>
<td>30,384 ha</td>
</tr>
<tr>
<td>Timber</td>
<td>59.0%</td>
<td>125,618 ha</td>
</tr>
<tr>
<td>Wildlife</td>
<td>9.3%</td>
<td>20,162 ha</td>
</tr>
</tbody>
</table>

**Figure 17:** Management Zones defined for the timber harvesting landbase, Arrow TSA (BCMoF, 1994b).
Visual Quality Objectives:
- Preservation
- Retention
- Partial Retention
- Modification
- Maximum Modification
- Streams
- Lakes
- District Boundary

Figure 18: Arrow Forest District VQO map (recommended) (BCMof, 1991).
Figure 17 illustrates the distribution of the management zones over the Timber Harvesting Land Base (THLB). A total of 18.8% of the THLB is managed under restrictive VQOs: 1.5% is managed for a Retention VQO and 17.3% is managed to meet a Partial Retention VQO. It should be noted that more than 18.8% of the timber harvesting land base is managed for visual quality in the Arrow but the Retention and Partial Retention VQOs are the most binding constraints on 18.8% of the timber harvesting land base, which is why this figure was used in the TSR calculations and in our analysis. The VQO map for the Arrow Forest District (Figure 18) shows that the most restrictive VQOs are contained on the valley-sides surrounding the Arrow Lakes, Slocan Lake, Trout Lake, and their smaller tributary watersheds closest to the main highways and communities.

Linking the land allocation figures for VQOs shown in Figure 17 to the available timber values provided by the BCMoF (1998c) and shown earlier in Table 1, yields the theoretical values shown in Table 4. As seen earlier in Table 1, on average 25% and 67.5% of the basal area could be available for harvest under Retention and Partial Retention VQOs respectively (using dispersed retention cutting). Conversely, using clearcutting, an average 3% and 10% of the visual sensitivity unit (and, by extension, of the potential basal area) could be available for harvest under Retention and Partial Retention VQOs respectively. Using the same rationale as above (see Figure 12 to 14 calculations earlier in this chapter), we obtain values of potential timber availability for both the Retention VQO and Partial Retention VQO, and for clearcut and dispersed retention cut as shown in columns 3 and 5 of Table 4. These values are approximations of hypothetical figures of the impact of such VQOs on timber availability for both clearcutting and dispersed retention cutting (see columns 5 and 6 in Table 4) in the Arrow TSA.

Table 4: Theoretical differences in timber availability between clearcut and dispersed retention cut harvesting approaches for the Arrow TSA. Adapted from BCMoF (1994a; 1998a).

<table>
<thead>
<tr>
<th>VQO Applied for the management zones 1 and 2 for the Arrow District</th>
<th>Proportion of Arrow TSA timber harvesting landbase (%)</th>
<th>Timber Availability Scores based on the average % of basal area available for harvest as shown in Tables 2 and 3</th>
<th>Using Clearcutting</th>
<th>Using Clearcutting and a green-operable/green-inoperable 2:1 ratio</th>
<th>Using Dispersed retention cutting</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention</td>
<td>1.5</td>
<td>0.045%</td>
<td>0.068%</td>
<td>0.375%</td>
<td></td>
</tr>
<tr>
<td>Partial Retention</td>
<td>17.3</td>
<td>1.730%</td>
<td>2.595%</td>
<td>11.678%</td>
<td></td>
</tr>
<tr>
<td>Total: 18.80% of the TSA under VQOs</td>
<td>1.78% of the area under VQOs is available at any one time</td>
<td>2.66% of the area under VQOs is available at any one time</td>
<td>12.05% of the area under VQOs is available at any one time</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

It appears from these broad, hypothetical calculations that the impact of VQOs on overall timber availability in the Arrow TSA could theoretically be reduced by as much
as 10.27% (from 1.78% to 12.05% availability), by shifting from clearcutting to dispersed retention cutting. In other words, if we accept for the moment the arbitrary assumptions on basal area and theoretical relationships between aesthetics and cut volumes described above, currently available timber supplies in the Arrow TSA would appear to increase potentially by up to 10% while still meeting existing VQOs, based on a switch to dispersed retention cutting in visually sensitive areas. This represents around 55,000 m$^3$ (or about 1200 truckloads assuming 45 m$^3$/highway truckload) of timber based on current constrained (under the FPC regulations) timber availability figures for the Arrow (Arrow Forest Licence Group, 2000). This figure represents what could theoretically be made available immediately by a shift in harvesting practices. It is important to note that the hypothetical 10% increase obtained above, expressed at the TSA level, comes from the use of dispersed retention cutting only in areas subject to VQOs. At the landscape unit level, availability increases obtained could be significantly higher (as seen in Figure 16). Clearly, there are many caveats which need to be applied before any realistic numbers can be accepted; research is already underway in the Arrow TSA to quantify the actual predicted impact of such a shift in harvesting practices. Nevertheless, the potential scale of the difference in timber supply and availability suggests the topic is worthy of serious attention.

In addition to harvesting technique, the “active practice” of visual landscape design could potentially allow more harvesting when clearcutting is used (estimated by the BCMoF [1998c] at up to 5% denudation for Retention and up to 15% denudation for Partial Retention). Since the present calculations used three percent denudation for the Retention VQO, a potential two percent gain (up to five percent) from the practice of visual landscape design (BCMoF, 1995b) is possible. For Partial Retention VQO, five percent denudation was used for slopes below 50%, and 15% denudation was used for slopes above 50% (for an average of 10% denudation), which also leaves room for a five percent potential increase through the use of visual landscape design (BCMoF, 1995b). In the Arrow Forest District, these increases based on the practice of visual landscape design could translate hypothetically to a 0.9% potential increase in total timber availability. For comparison purposes, a green-operable/green-inoperable ratio of 2:1 was considered (see Table 4 for detailed calculations) and timber availability (when clearcutting is used) is still only 2.66% (compared to 12.05% when dispersed retention cutting is used). Even when the maximum figures for the percent denudation ranges are used (for clearcutting only), and a green-operable/green-inoperable ratio of 2:1 is considered, timber availability is still three times more with dispersed retention cutting than with clearcutting (4% versus 12%). These results are particularly relevant to the Arrow Forest District since the difference between the AAC and the timber availability level is often quite small (Arrow Forest License Group, 1999; BCMoF, 1999a), leading to licensees having problems in actually "finding" the timber on the ground in order to meet their AAC requirements. However, more research and detailed estimations are required before such figures can be considered accurate for the Arrow TSA.
4.2 MODELLING SHORT-TERM AVAILABILITY BASED ON A RE-ASSESSMENT OF THE VLI AND THE VQO POLYGONS FOR THE LEMON LANDSCAPE UNIT

Once one has a general idea (based on the application of the province-wide BCMoF figures presented in Table 1 to VQO prescriptions at the TSA level) of the potential timber availability gain possible from a shift in harvesting practices in visually sensitive areas, the question that arises is whether such an availability increase is borne out of a specific local area of interest, based on the site-specific conditions. In an attempt to answer such a question, the Lemon Landscape Unit was chosen in the Arrow TSA as a case study area (Figure 19). Table 5 contains detailed area figures for the Lemon Landscape Unit, from which important findings are derived and reported here.

Table 5: Lemon Landscape Unit timber harvesting landbase (THLB) areas (in ha) under various VQOs.

<table>
<thead>
<tr>
<th></th>
<th>Total Area</th>
<th>Total Area Under VQOs</th>
<th>Area in Retention VQO</th>
<th>Area in Partial Retention VQO</th>
<th>Area in Modification VQO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lemon Landscape Unit Timber Harvesting Landbase (THLB)</td>
<td>40,970</td>
<td>7,723</td>
<td>1,974</td>
<td>5,587</td>
<td>162</td>
</tr>
<tr>
<td>Mature stands in the THLB</td>
<td>12,980</td>
<td>4,453</td>
<td>1,320</td>
<td>2,278</td>
<td>19</td>
</tr>
<tr>
<td>Immature but VEG stands in the THLB</td>
<td>8,860</td>
<td>3,324</td>
<td>1,167</td>
<td>2,145</td>
<td>12</td>
</tr>
<tr>
<td>Non VEG stands in the THLB</td>
<td>994</td>
<td>742</td>
<td>50</td>
<td>45</td>
<td>-</td>
</tr>
</tbody>
</table>

The total area under VQOs represents approximately 18.8% of the Lemon Landscape Unit (see Table 5 for the detailed figures), most of which is under a Partial Retention VQO. However, when the 12,980 ha THLB\(^\text{13}\) is taken into account (as opposed to the entire unit), the total area subject to VQOs represents 34.3% of the THLB in the unit (see Figure 20). Even more worrisome for forest managers facing a short supply of timber is that when the mature forest stands within the operable THLB are looked at, it appears that 13.2% of all mature stands in the Lemon Landscape Unit are under Retention VQOs and 24.2% are under Partial Retention VQOs (virtually none is under Modification VQOs). This results in a total of 37.5% of all mature forest stands within the THLB of the entire landscape unit being under some of the most restrictive VQOs (Retention and Partial Retention VQOs). In other words, 74.6% of the area in the VQOs and within the THLB is considered mature, which may be a reflection of the historical

\(^{13}\) The size of the THLB presented here was obtained following the BCMoF net down procedure for the TSR analysis (BCMoF, 1999c) but is to be taken as an estimate only, since it is spatially explicit (the TSR THLB is not) and some non-spatially explicit attributes had to be estimated or omitted.
avoidance of visually sensitive areas by forest managers. When turned into volume figures, this mature timber under VQOs represents a total of 952,455 $\text{m}^3$. This is 1.7 times the AAC for the entire TSA, or almost two years worth of timber for the entire TSA based on the new AAC of 550,000 $\text{m}^3$/year (BCMoF, 2001, or five years' worth of timber supply for Slocan Forest Products.

When the BCMoF figures are considered using the theoretical approach developed in this thesis, the VQO Intensity Index (using the method discussed in section 4.1.1) for the Lemon Landscape Unit is 12.2%, the TAS is 82.7% for clearcutting, 83.9% for clearcutting with a 1.36:1 green-operable/green-inoperable ratio, and 91.9% for dispersed retention cutting (see Table 6 for detailed figures). The 1.36:1 green-operable/green-inoperable ratio was specifically calculated for the Lemon Landscape Unit based on the area under VQO that is in the THLB (4,453 ha) versus the area under VQOs not in the THLB (3,270 ha) and effectively multiplies the TAS under a clearcut system by a factor of 1.72. The figures show that a net 8% to 9.2% (depending on whether a green-operable/green-inoperable ratio is considered) immediate increase results from a shift in practices (in theory and based on the BCMoF figures). That percentage multiplied by the total volume contained under those VQOs (952,455 $\text{m}^3$) represents a potential increase in timber availability of at least 76,176 $\text{m}^3$ (when a green-operable/green-inoperable ratio is used) simply from applying a shift in practices. These figures, while theoretical, suggest significant potential volume gains resulting from stepping away from clearcutting in visually sensitive areas (the Lemon Landscape Unit is only one landscape unit among 32 in the Arrow TSA).

Table 6: Example of VQO Intensity Index and associated timber availability "scores" under various harvesting techniques for the Lemon Landscape Unit VQOs, using the same calculation approach as earlier, and based on the BCMoF (1998a) figures.

<table>
<thead>
<tr>
<th>VQOs</th>
<th>Lemon Landscape Unit under each VQO (in %)</th>
<th>VQO Landscape Intensity Index (in %)</th>
<th>Timber Availability Score (TAS) under a clearcut system</th>
<th>Timber Availability Score (TAS) with a 1.36:1 green-operable/green-inoperable ratio.</th>
<th>Timber Availability Score (TAS) under a dispersed retention cut approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preservation</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retention</td>
<td>4.8</td>
<td>3.9</td>
<td>0.144</td>
<td>0.248</td>
<td>1.205</td>
</tr>
<tr>
<td>Partial</td>
<td>13.6</td>
<td>8.2</td>
<td>1.364</td>
<td>2.352</td>
<td>9.205</td>
</tr>
<tr>
<td>Retention Modification</td>
<td>0.4</td>
<td>0.2</td>
<td>0.079</td>
<td>0.136</td>
<td>0.376</td>
</tr>
<tr>
<td>Maximum</td>
<td>-</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Modification</td>
<td>81.1</td>
<td>0</td>
<td>81.149</td>
<td>81.149</td>
<td>81.149</td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>12.3%</td>
<td>82.74%</td>
<td>83.89%</td>
<td>91.94%</td>
</tr>
</tbody>
</table>

Slocan Forest Products, which has been the licensee historically harvesting in the Slocan valley (and based out of Slocan city), has an AAC of 200,000 $\text{m}^3$ for the area (BCMoF, 2000c).
Figure 19: Lemon Landscape Unit with VQOs.
Figure 20: Timber Harvesting Landbase (THLB) for the Lemon Landscape Unit.
While the above figures are very promising, they remain theoretical and based on generic application of province-wide figures. They also do not provide potential site-specific timber availability increases that may result from applying a combination of landscape design and dispersed retention cutting approaches specifically designed for the VQO areas in the Lemon Landscape Unit. Consequently, such a site-specific exercise was undertaken for the Lemon Landscape Unit (as described in section 3.2), which included re-visiting and refining the current visual landscape inventory, and exploring whether prescribing site-specific harvesting prescriptions could yield increased timber availability while meeting the VQOs, taking into account vegetation and screening.

A review of the current VLI and a close landscape analysis reveals that not only are significant portions of these VQO polygons not visible from the viewpoints considered in the landscape inventory, but large areas are only visible at such a low angle of view that significantly more timber could be harvested than that recommended by the BCMoF while still meeting the given VQO. One of the major differences between the Arrow VLI (BCMoF, 1991) and the current re-assessment lies in the fact that vegetation screening was considered and accounted for in this thesis. Preliminary analysis (Ma, 1999), showing a high degree of correlation between an ArcView/GIS viewshed mapping (which does not account for vegetation) and the BCMoF (1991) VLI, suggests that vegetation screening was not considered. Such findings (low angle of view and areas not visible) allow for site-specific visual prescriptions for assessing how much timber could be harvested in a first pass harvesting entry while meeting all applicable VQOs. Figure 21 presents those six visual prescriptions applied to the visually sensitive areas for the Lemon Landscape Unit within the THLB. The overall rationale behind those prescriptions was to allow for a maximum volume removal (in the 1st pass) while still meeting the given VQO taking into account slope, vegetation screening, viewing angle, natural openings, etc. These visual prescriptions essentially consist of the following:

a) **Prescription #1**: Irregular shelterwood, with a maximum removal of 50% of the stand to leave a visual impression of a fairly dense canopy. This particular stand is between slides, in the middle of a retention patch, on a ridge (coming down slope between the slides), and contains some of the highest growing stocks in the entire TSA (440 m³/ha). It is a pure (100%) Douglas fir (*Pseudotsuga menzeisii* var. *glauca*) aged 130 years, average Diameter at Breast Height (DBH) of 40 cm, and with a Site Index (SI) of 22 meters. For these reasons, it is believed standing stem harvesting, a type of Heli-logging described by Kirby (2000), is deemed most appropriate to minimize the visual impact (no roads or yarding corridors). The 50% removal figure was selected following consultation with local BCMoF experts in silvicultural research which indicated that at least 50% of a stand had to be harvested in general in the Arrow TSA in order to have any hope of triggering regeneration establishment (Delong, pers. comm., 2002). The long term goal for this stand should be to grow high quality stems

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15 The term visual prescription will be used rather than silvicultural prescription because the intent of those prescriptions is to yield timber while meeting VQOs, and have little to do with regeneration.
(eventually converting it to a selection system) if economically feasible to heli-log each pass.

b) **Prescription #2:** 50% shelterwood removal in the 1st pass, with the remaining stems harvested in 50 years. Particular attention will need to be paid for regeneration under such a dense canopy (it may be necessary to harvest 60% on a smaller area, instead of the entire VQO polygon at once). The second pass will also need special attention since the harvest may become evident (even if the regeneration has reached VEG). This prescription needs further testing/field validation especially in regard to the visual impact of future passes and to assess the required understory height to meet the VQO for the area.

c) **Prescription #3:** Shelterwood system with 75% removal in the 1st pass, the remaining being harvested in a second pass in 50 years. The 50-year delay period is to ensure more than adequate VEG is on site before the final harvest (12 to 14 meters VEG should be aimed at for the second pass to take place in order to minimize visual impact). Denser buffers should also be left along the highway, along Slocan Lake, and along the skyline where applicable.

d) **Prescription #4:** Retention system (variable retention) with 75% removal (25% dispersed green-tree retention for the rest of the rotation). This prescription applies to areas viewed at a very low viewing angle (e.g. south of the unit). While prescription #3 could also be applied here (shelterwood), the small size of the areas concerned probably will not allow for an economically viable second entry. The small area will also result in relatively small long term growth losses (overall) due to the retained trees.

e) **Prescription #5:** Retention system (variable retention) with 85% removal (15% dispersed green-tree retention for the rest of the rotation). This prescription applies to areas viewed at a very low viewing angle (e.g. the bottom [Western most] part of the Retention VQO patch east of Slocan). While prescription #3 could also be applied here (shelterwood), the small size of the areas concerned probably will not allow for an economically viable second entry. The small area will also result in relatively small long term growth losses (overall) due to the retained trees.

f) **Prescription #6:** Standard Forest Practices Code practices (with adjacency and green-up requirements). This prescription represents areas that could generally be removed from the VQO polygons since it is estimated that these areas are not visible (based on the viewpoints considered), or visible at such low angle of view that the standard FPC requirements for adjacency and block size limit will be sufficient in meeting any visual concern. Effectively, this represents a reduction in area under VQOs of 1,081 ha (14% of the current VQO area). However, the extent to which this will benefit licensees is unclear, since several field visits and aerial imagery reveal that logging in VQOs has been concentrated in those areas that are deemed not visible (e.g. the eastern portion of the Retention patch just east of Slocan city).
Visual Prescriptions

- Prescription 1: Irregular shelterwood with 50% removal per 100 years (heli-log crack'n'fly)
- Prescription 2: 50% shelterwood removal in 1st pass, rest in 2nd pass in 50 years.
- Prescription 3: Shelterwood with 75% removal in 1st pass, rest in 2nd pass in 50 years.
- Prescription 4: Variable Retention with 75% removal (25% permanent dispersed retention).
- Prescription 5: Variable Retention with 85% removal (15% permanent dispersed retention).
- Prescription 6: Standard Forest Practices Code (with adjacency and VEG requirements).

Figure 21: Lemon Landscape Unit visual prescriptions.
As for the impact on short-term timber availability, Table 7 and Table 8 show that 719,698 m$^3$ could be immediately harvested without violating current VQO requirements for the Lemon Landscape Unit, while using site-specific landscape design techniques combined with an array of silvicultural systems. This represents a net availability increase of 595,506 m$^3$, or 5.8 times the volume estimated to be available under the generic application of BCMoF figures (124,192 m$^3$ as shown in Table 8) for the exact same areas. This increase, which represents 13,233 truckloads also equates to 75.5% of the entire growing stock under VQOs. This effectively demonstrates that VQOs fall off the scale as a constraint when practices other than clearcutting (e.g. landscape design and certain dispersed retention cutting techniques) are considered, since the current FPC is routinely considered either a 4-pass system or a 3-pass system (Marc, pers. comm., 1999) which effectively limits the maximum timber availability to either 25% or 33% of the total standing volume.

It should also be noted that figures in the left-most column of Table 8 include a green-operable/green-inoperable ratio of 1.36:1, as calculated earlier, for increased accuracy in the comparisons. These figures are also using average denudation ranges from Table 1, and assuming 10% denudation equates 10% volume harvested. This assumption is made because while the area with the highest volume could be harvested initially and yield higher volume, areas of lower volume (within the THLB) will have to be harvested eventually (or suffer a reduction in THLB) which will balance out. For example, if a VQO allows a harvest of 10% per decade, all areas (high and low standing volume) within the mature THLB will have been harvested after 100 years, yielding an average harvest corresponding to the average standing volume (if growth is not considered, for simplicity sake).

These increases come mainly from three sources:

a) Refining as finely as possible the areas under VQOs. In the case of the Lemon Landscape Unit, this resulted in subtracting 1,081 ha (299,850 m$^3$ of mature growing stock) from some of the most restrictive VQO areas (Retention VQO and Partial Retention VQO), which resulted in an immediate availability increase of 256,598 m$^3$ (assuming no other constraints and that 43,252 m$^3$ was previously available under clearcutting).

b) Use of high retention harvests in areas subject to a Retention VQO. The use of a 50% removal shelterwood approach in only one single Retention VQO polygon (the one East of Slocan) resulted in an immediate availability increase of 105,408 m$^3$ over 770 ha (assuming that 12,162 m$^3$ was previously available under clearcutting).

c) Use of medium to low retention harvests in areas subject to a Partial Retention VQO. The use of 75% removal shelterwood approach, along with 75 to 85% removal variable retention in Partial Retention areas resulted in an immediate availability increase of 200,801 m$^3$ over 1,094 ha (assuming that 59,465 m$^3$ was previously available under clearcutting).
Table 7: Growing stock (standing timber volume) for mature stands only, along with the respective areas affected, for each visual prescription and for each VQO.

<table>
<thead>
<tr>
<th>VQOs</th>
<th>Visual Prescriptions</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th>Total per VQO</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td># 1</td>
<td># 2</td>
<td># 3</td>
<td># 4</td>
<td># 5</td>
<td># 6</td>
</tr>
<tr>
<td>Retention VQO</td>
<td>Area affected (in ha)</td>
<td>28</td>
<td>770</td>
<td>23</td>
<td>-</td>
<td>59</td>
<td>257</td>
</tr>
<tr>
<td></td>
<td>Growing stock (m³)</td>
<td>9,369</td>
<td>235,139</td>
<td>6,709</td>
<td>-</td>
<td>10,426</td>
<td>73,370</td>
</tr>
<tr>
<td>Partial Retention VQO</td>
<td>Area affected (in ha)</td>
<td>5</td>
<td>143</td>
<td>999</td>
<td>19</td>
<td>76</td>
<td>813</td>
</tr>
<tr>
<td></td>
<td>Growing stock (m³)</td>
<td>815</td>
<td>45,250</td>
<td>321,956</td>
<td>3,012</td>
<td>19,929</td>
<td>224,112</td>
</tr>
<tr>
<td>Modification VQO</td>
<td>Area affected (in ha)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Growing stock (m³)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>2,368</td>
</tr>
<tr>
<td>Total area and growing stock</td>
<td>Area affected (in ha)</td>
<td>33</td>
<td>913</td>
<td>1,022</td>
<td>19</td>
<td>135</td>
<td>1,081</td>
</tr>
<tr>
<td></td>
<td>Growing stock (m³)</td>
<td>10,182</td>
<td>280,389</td>
<td>328,665</td>
<td>3,012</td>
<td>30,355</td>
<td>299,850</td>
</tr>
</tbody>
</table>
Table 8: Timber availabilities from the 1st pass (based on the possible percent removal) of each visual prescription and what could be expected with an average of the BCMoF figures.

<table>
<thead>
<tr>
<th>Visual Prescriptions, volume available from 1st pass removals (in m$^3$)</th>
<th>Total standing volume available based on the BCMoF (1998a) figures (in m$^3$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retention VQO</td>
<td>4,685</td>
</tr>
<tr>
<td>Partial Retention VQO</td>
<td>408</td>
</tr>
<tr>
<td>VQO Modification</td>
<td>-</td>
</tr>
<tr>
<td>Total</td>
<td>5,093</td>
</tr>
</tbody>
</table>

4.3 COMPARISON WITH AN INTERDISCIPLINARY MODELLING EXERCISE USING VARIOUS HARVESTING PRACTICES IN VISUALLY SENSITIVE AREAS FOR THE LEMON LANDSCAPE UNIT

The UBC interdisciplinary modelling exercise undertaken for the Lemon Landscape Unit in the Arrow TSA (see Wells and Nelson, 2002) will be presented here, in order to see what results can be expected from a more comprehensive modelling exercise.

Essentially, the three scenarios considered for this modelling exercise (Nelson and Wells, 2000; Wells and Nelson, 2002) can be summarized as follows:

a) Forest practices code (FPC) scenario: the essence of this scenario was to model as closely as possible the current rule-based management practices (Forest Practices Code in BC). This was the base-case scenario. Key characteristics of this scenario include a 15,728 ha THLB, 7,442 ha under some sort of VRM, 8,313 ha excluded from harvesting for old growth management, etc.

b) Patch cut/zoning scenario: the essence of this scenario was to apply a zoning approach to the landbase, distinguishing between areas focused on timber production (with higher growth potential, lower costs, and less regulatory constraints) and expanded areas outside the timber harvesting landbase (THLB) focused on non-timber objectives. This scenario employed

$^{16}$ As an example, this figure comes from 3% (BCMoF availability average figure for a Retention VQO) of the growing stock in the Retention VQO (335,013 m$^3$), multiplied by the 1.72 factor to account for the green-operable/green-inoperable ratio.
1-hectare patches in areas subject to VQOs: this was based on a 4-pass approach, 25% of the VQO areas being harvested via 1-hectare patches until VEG is reached before allowing the next pass. Key characteristics of this scenario include a smaller THLB than the Clearcut scenario, the same area (7,742 ha) under some sort of VRM, etc.

c) Tactical plan (criteria and indicator-based plan): the essence of this scenario was to shift the focus away from the timber resource even more than in the first two scenarios, driven by criteria and indicators developed for Sustainable Forest Management. This resulted in the application of several constraints, differing from current FPC regulatory requirements (used in scenario 1), to the landbase (e.g. modified old growth management areas, increased areas under VRM, areas set aside and/or managed specifically for recreation, etc.). This scenario employed various shelterwood and aggregated retention (as defined below) approaches (developed primarily by the present author) in areas subject to VRM. These harvesting approaches were allocated to the visually sensitive areas as follows: i) Retention VQO areas were managed under a 3-pass irregular shelterwood system, which retained 60% of the initial stands after the 1st pass; 40% thinning (preparatory cut) as 1st pass, then a 50% thinning (establishment cut) 40 years later, and a final cut (regeneration cut) after another 40 years (80 years from the initial entry). ii) Partial Retention VQO areas were generally (not in all cases) managed under a 2-pass irregular shelterwood system, where the 1st pass removes 60% of the initial stands (establishment cut), followed by a final cut (regeneration cut) 40 years later. iii) Newly added areas (called Visual Priority Areas) under VRM were managed under an aggregated retention approach (e.g. variable retention or clearcut with reserves) leaving permanently 20% of the initial stands on site. Key characteristics of this scenario include a 14,432 ha THLB, 13,042 ha under some sort of VRM, 9,764 ha managed for recreation objectives, 8,076 ha excluded from harvesting for old growth management, etc. In terms of the extent of management for visual resources, the area described above is divided into three management levels for which the respective areas are: 929 ha under the 3-pass system, 2,751 ha under the 2-pass system, and 9,362 ha under the 20% permanent aggregated retention approach for visual requirements.

Results show that both the zoning approach (scenario 2) and the criteria and indicator-based approach (scenario 3) resulted in significantly higher timber availability than the standard clearcut approach (scenario 1). In addition to these very interesting results, the shelterwood approach was so successful at providing increased timber availability that even when the future shelterwood yield was cut in half (50% reduction to account for any unquantifiable worst-case circumstance such as root rot, etc.), scenario 3 still yielded either as much timber as, or more timber than, the base-case clearcut scenario (Wells and Nelson, 2002).

In fact, the FPC scenario had a long term timber supply of about 27,000 m³, while the scenario 3 (criteria and indicator-based) had a long term supply of 31,500 m³, despite using stringent visual resource management on an area almost twice as big (13,042 ha
was under some sort of VRM for the 3rd scenario compared to 7,442 ha under VQOs in the Lemon Landscape Unit for the 1st scenario). These results are key to the present thesis in the sense that they show that using certain types of visually effective dispersed retention cutting techniques in areas subject to VQOs yields significantly more long term timber supplies (117% higher) than would an approach using clearcutting as the main practice in areas subject to VQOs. Even more significant are the short-term timber increases that could be achievable with the Criteria and indicator scenario, which translate into a 200% increase (from about 17,000 m³ to about 34,000 m³). Figure 22 provides a graphic representation of the Wells and Nelson results (adapted from Wells and Nelson, 2002).

![Figure 22](image)

**Figure 22:** Graphic representation of the Wells and Nelson (2002) results showing the various harvest forecasts for the Lemon Landscape Unit under three management scenarios. Figure adapted from Wells and Nelson (2002).

In terms of results from a visual basis, a visual analysis was undertaken of each one of the three scenario considered, and the "visual performance" of each scenario was assessed and can be summarized as follows:

- **Clearcut scenario:** This scenario may or may not meet any VQOs for any or all time steps, depending on several site-specific factors. These include the P2P (Plan to Perspective) ratio, which will affect how much clearcutting is visible in perspective view based on the 5% plan denudation assumed for the Retention VQOs and the 15% assumed for the Partial Retention VQOs. The successful use of landscape design (not considered in the modelling exercise), and site-specific VAC will also affect greatly the visual performance of this scenario. It is therefore anticipated that this scenario’s capacity in meeting the VQOs for the Lemon Landscape Unit will be marginal, and that this marginal ability to meet the VQOs will remain so in the future.
(after subsequent passes). Figure 23 shows an actual photograph (without any of the proposed logging activity by Wells and Nelson [2002]) of the Retention VQO polygon east of Slocan city in the Lemon Landscape Unit. Figure 24 provides an example (using realistic computer visualizations) of that scenario after a given entry (simulation credit for Figures 23 and 24: Jon Salter).

- **Zoning scenario:** This scenario (1 hectare patch cuts in the VQO areas) will not meet a Retention VQO after the 1\(^{st}\) pass and may not meet a Partial Retention VQO. The failure to meet the Retention VQO is caused by the visual evidence of the patches, and the overall cumulative effect of the patches creates a visual dominance in the landscape that most likely will not be compatible with meeting a Partial Retention VQO. The long term ability of the Zoning scenario to meet the VQOs for the Lemon Landscape Unit (after the 2\(^{nd}\) and 3\(^{rd}\) passes) is not anticipated to be different from its short-term visual performances, and will depend once again on specific P2P ratios, and on the height of the regeneration in the patches in previous passes (passes are scheduled every 25 years). It should be noted that while the visual performance of the Zoning scenario may be worse than that of the Clearcut scenario, it does not depend on the successful use of visual landscape design, and the visual impact is anticipated to remain constant from any given point of view. In others words, while the visual performance is somewhat less successful, less uncertainty is attached to it, which is not the case with the visual performance of the Clearcut scenario. Figure 25 provides an example (using realistic computer visualizations) of that scenario after a given entry (simulation credit: Jon Salter).

- **Criteria and indicator scenario:** This scenario (irregular shelterwood approaches) should meet a Retention VQO after the 1\(^{st}\) pass and will meet a Partial Retention VQO. The ability to meet the Retention VQO will depend on the visibility of roads, and possibly on the screening capacity of the crowns of the trees left on site. Future passes are anticipated to meet the VQOs but this remains to be tested, especially in regard to the height of the regeneration at the time of the 2\(^{nd}\) and 3\(^{rd}\) passes, and on the ability to protect this regeneration during the future harvesting operations. As for the Zoning scenario, the visual performance of the criteria and indicator scenario does not depend on the successful use of visual landscape design, and the visual impact is anticipated to remain constant from any given point of view. The Criteria and indicator scenario is the scenario with the most successful visual performance of all three scenarios considered, both in the short and in the long term. Figure 26 provides an example (using realistic computer visualizations) of that scenario after a given entry (simulation credit: Jon Salter).
**Figure 23:** Actual photograph (without recent logging activity) of the Retention VQO polygon east of Slocan city in the Lemon Landscape Unit. Photo-editing credit: Jon Salter.

**Figure 24:** Example (using realistic computer visualizations) of what the Clearcut scenario could look like after a given entry on the Retention VQO polygon east of Slocan city in the Lemon Landscape Unit. Computer visualization credit: Jon Salter.
Figure 25: Example (using realistic computer visualizations) of what the Zoning scenario could look like after a given entry on the Retention VQO polygon east of Slocan city in the Lemon Landscape Unit. Computer visualization credit: Jon Salter.

Figure 26: Example (using realistic computer visualizations) of what the Criteria and indicator scenario could look like after a given entry on the Retention VQO polygon east of Slocan city in the Lemon Landscape Unit. Computer visualization credit: Jon Salter.
Clearly these very interesting results have major implications for the future of VRM in BC, along with major implications for the use of non-clearcut approaches in areas subject to VQOs, as is advocated in the present thesis. Limitations of this modelling exercise include the apparent lack of background literature research. While the authors of this modelling exercise have extensive knowledge of the topics covered, very few references can be found in the reports obtained. It is also very important to keep in mind that these results are yet to be validated in that they are the first run of results from a combination of several models that were not used together before. Several potential problems need to be identified and solved.

4.4 DISCUSSION OF THE MODELLING EXERCISES

4.4.1 Generic results and implications for the Arrow TSA

Caution should be used in applying these preliminary hypothetical relationships to actual forest management scenarios. These figures are based primarily on two studies (BCMoF 1996c and 1997a), though generally supported by other broader perceptual research findings (e.g. Berris and Bekker, 1989; Bradley, 1996; Clay, 1998; Paquet and Belanger, 1997), as well as considerable practical experience within the BCMoF. Assumptions used and calculations made here need to be tested and validated but, clearly, the subject is worthy of considerable further research to replicate, corroborate, and perhaps expand the BCMoF results. Further work, needs to be done to apply such findings quantitatively to the complexities of real world situations.

In particular, the questions of which dispersed retention cut techniques conform to these relationships needs to be examined in depth. While the BCMoF perception studies used a range of dispersed retention cut and clearcut techniques, there would appear to be different visual effects with different harvesting techniques for a given volume removal. If not enough of the initial overstory is retained, or if the retention is aggregated instead of being dispersed, the visual impact may be as negative (or worse) than that of a clearcut (BCMoF, 1997a). In addition, it was assumed in the present thesis that dispersed retention cutting could be undertaken virtually everywhere and while it may not be feasible everywhere, it should not be discounted on the assumption that it is infeasible without examination of local stand dynamics and operational constraints.

As mentioned earlier, there are FPC regulations and biodiversity/forest cover constraints for community watersheds, etc., that could significantly reduce the effective impact of VQOs on timber supply and availability (BCMoF, 1995a; BCMoF, 1995c), or even eliminate the impact of VQOs if these other values were more constraining on the cut. Unless the different constraints occur in different areas, overlapping in forest cover constraints (for managing water quality, wildlife habitat, etc.) may reduce the impact of VRM on timber availability. An example is the maximum Equivalent Clearcut Area (ECA) value allowed for each of the six watershed classes in the Arrow TSA (BCMoF, 1994b). The ECA allowed varies from 15% (for class 1 and 2) to 40% (class 6) and cutoffs for ECA contribution (when a stand reaches hydrological green-up) have been established at seven meters (stand height) for watersheds classed 1 and 2 and at nine meters for all other classes (BCMoF, 1994b) in TSR 1. Since the VEG height used for
the Arrow TSA in TSR 1 is five meters (BCMoF, 1994b), this means that the ECA requirement for class 1 and 2 watersheds would most likely meet a VQO of Partial Retention, at least within these watersheds. Similarly, watersheds classed 3 to 6 have an ECA of 25% (class 3), 30% (class 4 and 5), and 40% (class 6). This means that these classes could potentially meet a VQO of Maximum Modification (according to BCMoF figures [1998c]) within their respective watersheds where clearcutting is used (and depending on the ECA contribution of dispersed retention cut approaches, even more restrictive VQOs may be met for a given ECA). Class 3 watersheds may even meet a Modification VQO. Therefore, through forest cover constraints, watershed management may contribute to additional visual resource management. At the landscape level, this means that the overall or net impact of VQOs on timber availability will have to take into account the forest cover constraint “contributions” from managing other non-timber resources and the degree of spatial overlap. It is not clear, however, to what extent dispersed retention cutting practices would reduce the risks of, and therefore limitations on, logging in sensitive watersheds.

In further studies at the landscape level and higher, simple techniques such as the VQO Intensity Index described above should be tested further to substantiate the assumptions used and applied, to allow comparison between landscape units and to aggregate relative levels of VQO constraint. This could be of value in strategic planning and in spatially explicit allocations of AAC.

4.4.2 Comparison of results at the TSA and Landscape Unit scale

Table 9 presents the results obtained so far from the modelling exercise undertaken, along with those of other studies for comparison purposes. It should be noted that the figures for the timber availability and timber supply impacts for the Robson TSA and the Strathcona TSA were estimated at the TSA level based on the area under VQOs relative to the whole area of the TSA.

A close look at Table 9 provides much valuable information but also identifies areas where improvements could be made. First, not all study provide the same variables, and several values had to be estimated based on other sources (e.g. Wand and Pollack [1998] did not provide the areas under each VQO considered in their study so it was assumed that they used the same VQOs as those modelled in TSR 1 for the Arrow TSA). It should also be noted that several studies undertook what is termed “harvest flow constraints” which effectively artificially reduce maximum harvest levels (to increase the minimum levels) in order to provide a more constant flow of timber. While very adequate for identifying sustainable long term timber harvest levels, it prevents the identification of the value sought for comparison: the full extent of the impact (positive or negative) of shifting from clearcutting to dispersed retention cutting on timber availability. Also, it should be noted that no flow constraints were applied in the modelling exercises undertaken in the present thesis and the availability was considered equal to the merchantable mature growing stock in the Lemon Landscape Unit which explains in part the apparent very high timber availability increase (580% increase) relative to that obtained in other studies. In this regard, it appears that applying any percentage increase to the current AAC as was done for the generic Arrow
TSA modelling may provide figures closer to those reported by other authors. This may reflect a trend to compare any increase (or decrease) to current (constrained) availability levels rather than to merchantable mature growing stocks.

Table 9: Comparison of timber availability and timber supply figures for the modelling exercises included in this thesis (for both new modelling exercise results and results from reviewed literature). It should be noted that the Wells and Nelson (2002) figures for scenarios 2 and 3 are based on the scenario 1 base case. Source: Timberline Forest Inventory Consultants Ltd. and Rowe (1999); Wang and Pollack (1998); Wells and Nelson (2002).

<table>
<thead>
<tr>
<th>Analysis and scenario considered:</th>
<th>% area under VQOs</th>
<th>VQO Index value</th>
<th>Timber availability impact (in %)</th>
<th>Timber availability impact (in m$^3$)</th>
<th>Timber supply impact (in %)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ROBSON TSA, Industrial Forestry Services Ltd. and BCMoF, 1998</td>
<td>44%</td>
<td>N/A</td>
<td>26% increase</td>
<td>N/A</td>
<td>16% increase</td>
</tr>
<tr>
<td>STRATHCONA TSA, Timberline Forest Inventory Consultants Ltd. and Rowe, 1999</td>
<td>32.5%</td>
<td>N/A</td>
<td>13% increase</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>ARROW TSA, Wand and Pollack (1998)</td>
<td>18.8%</td>
<td>11.6</td>
<td>Up to 30% increase</td>
<td>N/A</td>
<td>2-3% increase</td>
</tr>
<tr>
<td>Lemon Landscape unit, Wells and Nelson (2000)</td>
<td>Scenario 1</td>
<td>18.9%</td>
<td>12.2</td>
<td>Base case</td>
<td>Base case</td>
</tr>
<tr>
<td></td>
<td>Scenario 2</td>
<td>18.9%</td>
<td>12.2</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Scenario 3</td>
<td>33%</td>
<td>18.2$^{17}$</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Arrow TSA, Picard</td>
<td>18.8%</td>
<td>11.6</td>
<td>10% increase</td>
<td>55,000 m$^3$ increase</td>
<td>N/A</td>
</tr>
<tr>
<td>Lemon Landscape Unit, Picard</td>
<td>18.9%</td>
<td>12.3</td>
<td>580%</td>
<td>595,506 m$^3$ increase</td>
<td>N/A</td>
</tr>
</tbody>
</table>

17 This figure had to be estimated since the scenario 3 Visual Priority Areas did not necessarily follow the BCMoF VQO definitions. Consequently, the VQO Intensity score for the scenario 3 was calculated based on the 12.2 initial score for the VQOs areas plus 6 (for a total of 18.2) to account for the 15% of the Lemon Landscape Unit managed for an equivalent of a Modification VQO.
It should be noted that the 580% increase obtained for the Lemon Landscape Unit actually represents the increase achievable from the areas subject to VQOs only, rather than from the entire landscape unit, which is why this value is significantly higher than those reported by other authors. When applied at the entire Lemon Landscape Unit level, the 585,506 m³ increase (from which the 580% figure is derived) yields an increase closer to what other authors report is obtained (217.5%). This 217.5% increase at the Lemon Landscape Unit level is derived from the 580% increase over 37.5% (the extent of the VQO areas) of the Lemon Landscape Unit.

The results obtained and presented above mainly apply to British Columbia, with the exception of the Lemon Landscape Unit work described in this thesis, since they are based on BCMoF public perception studies (1996c; 1997a) that used a sample of the BC population. Any generalization beyond BC in the case of those results should be made with extreme caution. However, the results pertaining to the Lemon Landscape Unit work described above can be extended beyond BC. While still mostly applicable to BC, since they also rely on results from the BCMoF public perception studies (1996c; 1997a), the Lemon Landscape Unit results can be applied, to a certain extent, beyond BC since they are a refining (for a local area) of the BCMoF figures which is driven by the review of literature which incorporates results from around the world. For these reasons, some careful extrapolating outside of BC is possible.

4.4.3 Limitations and caveats at the Landscape Unit scale

Some uncertainty and limitations need to be addressed in regard to the modelling undertaken for the Lemon Landscape Unit. These uncertainties and caveats are as follows:

- Uncertainty surrounding the THLB. While the procedure followed in the net-down procedure to identify the THLB is essentially the same as the one used in TSR 1 for the Arrow, omissions and estimations had to be made for several non-spatial parameters. An example is the riparian zones, which were not removed from the THLB used in this thesis.
- Uncertainty about the visual prescriptions for regeneration purposes. While the visual prescriptions are visually adequate for the first pass, they hold a fair amount of uncertainty around their operational feasibility which remains to be tested and validated, as well as uncertainty regarding the ability of the visual prescription to trigger regeneration establishment and survival until the second pass is harvested. This latter issue may prove crucial in the sense that the second pass relies on an adequate regeneration in order to take place and still meet the VQOs. In the eventuality where regeneration failure occurs (or regeneration is not triggered), the physical extent of the prescription may have to be reduced in order to allow for greater timber removal. This would effectively result in the staging of the visual prescription in order to allow for more timber to be removed on a smaller area in order to meet the regeneration requirements while still meeting the VQOs.
- Uncertainty about the visual prescriptions for meeting VQOs in future passes. The ability of meeting the VQOs in the future passes inherent to some visual prescriptions has not been fully tested yet and further validation is needed in order to
assess this issue. Again, the physical extent of the prescription may have to be reduced in order to guarantee meeting the VQOs in future passes. This would effectively result in the staging of the visual prescription in order to allow for a more gradual removal of the timber in the VSU in order to maintain the desired visual quality for the area.

Finally, more testing is needed to assess the impact of the linearity of the VQO Intensity Index used and to determine whether a non-linear index may prove more appropriate as mentioned earlier. It is also quite surprising to obtain a VQO Intensity Index of only 12.3 for the Lemon Landscape Unit, which is situated in a highly contentious and highly visually sensitive area. An exponential or logarithmic scale, providing much higher VRM intensity values for the more restrictive VQOs may in this regard provide more realistic VQO Intensity values for areas such as the Lemon Landscape Unit (for example, a VRM Intensity Index showing the VRM intensity at 80% would probably receive greater credibility from local managers). Further testing and validating on this issue is needed.

4.4.4 Implications for the case study areas

Given the community interest in alternative harvesting practices and the availability of BCMoF data favouring dispersed retention cutting in visually sensitive areas (as described above), it is perhaps surprising that the draft document for TSR 2 (BCMoF, 1999c) assumes an increased use of clearcutting from 53.1% of the total harvested to 64.7% of total harvested in the Arrow TSA.

In summary, considering that resource managers are concerned with accessing a limited timber supply while maintaining visual quality in the front-country, available strategies in regions like the Arrow Forest District would include the following:

a) Relax VQOs and use a public education program, alternative planning processes, and perhaps an ecological aesthetics movement, as advanced by Gobster (1995), to convince the public that certain practices which are currently unpopular may be ecologically desirable, particularly when traded off against back-country or old growth preservation. The success of this latter strategy may depend upon increased community involvement and ownership of the design and decision-making process, but it seems unlikely to be successful in the foreseeable future.

b) Maintain recommended VQOs as they are now, but remove percent denudation as the effective performance standard, and use better landscape design to allow greater flexibility, e.g. through larger irregular openings, feathering, etc. To be effective, this would require much more training than is given now, as well as many more landscape architects and landscape foresters than are currently available. However, this option is unlikely to liberate substantially increased amounts of timber while still meeting VQOs.

c) Maintain recommended VQOs in Known Scenic Areas as is currently done, along with the current procedures for percent alteration limits for clearcutting, but whenever possible use certain dispersed retention cutting approaches to maintain visual quality and increase timber flow. This
appears to be the most likely to be effective, but is dependent on operational and silvicultural feasibility of those dispersed retention cutting approaches.

The need for such strategies would be further increased if visual qualities in the back-country (as modelled in the Criteria and indicator scenario in Wells and Nelson [2002]) were more proactively managed in recognition of tourism opportunities and public pressure, while limiting impacts on timber availability. Allowing some timber flow from the front-country, via visually acceptable harvesting techniques and landscape design, may provide an effective trade-off and allow such recognition of visual quality in the back-country. Front-country areas, often harvested at the turn of the century, may offer more volume, higher site index, and shorter hauls, while the back-country/higher elevation areas may in some cases have less volume, lower site index, and longer hauls. Such a shift in location of timber harvesting to more visible areas, rather than less visible areas, will require a major effort on the part of industry to exhibit visual care for the land or “visible stewardship” of these much-loved front-country places as advanced by Sheppard (2000).

4.5 LONG TERM GROWTH AND YIELD AND TIMBER SUPPLY IMPACTS OF DISPERSED RETENTION CUTTING: HOW CAN WE APPLY THIS TO THE LANDSCAPE LEVEL AND TO VISUALLY SENSITIVE AREAS?

Based on the literature reviewed in Chapter 2 (with the exception of Birch and Johnson [1992] which appear to have obtained different results than most authors) and the results presented above (and comments from Delong [Delong, pers. comm., 2002]), an impact of retaining part of the overstory on regeneration growth can be put forward by retention classes for the Arrow Forest District and the Lemon Landscape Unit. From 0 to 5% retention, the data appears to be inconclusive; from 5% to approximately 20% retention, the impact appears to be 1% long term growth and yield impact for each percent retention; for 25% to 50% retention, the impact appears to be closer to 2% growth and yield impact for each percent of trees retained on site; and for retention levels of 50% or more, the impact appears to be 100% in the sense that it may not be feasible in the Arrow TSA and the Lemon Landscape Unit to establish a regeneration at these retention levels (Delong, pers. comm., 2002). It should be noted also that as the tree retention level increases, the importance of shade tolerance in the species to be regenerated increases.

From a stand level perspective, or from a block level perspective, it is generally a fair assumption that trees growing free of overstory competition will grow better and are most likely to offer the full (100%) growing potential from the site (except where shelter is required, in which case a shelterwood system will yield equivalent or better growth). However, if one fails to look beyond the stand level, and into the forest level (landscape level), the retention of overstory trees will be erroneously dismissed as a poor option,

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18 It is important to keep in mind that these figures will also depend on site factors such as aspect, moisture regime, slope, shade tolerance of the regenerating species, etc. and that they still need to be tested and validated for the Arrow.
when in fact it may not be. Indeed, when the growth comparison is taken to the landscape level over the long term, one realizes that the very attractive option at the block level (the clearcut option) quickly loses ground when one considers how much clearcutting is constrained at the landscape level. In fact, the assumption on which all of those growth and yield comparison studies are based (that clearcutting yields 100%) is only true at the block level. This assumption could not be further from the truth at the landscape level, given all the forest cover requirements currently in place in BC. Yet, this key distinction between the block level and the stand level is often not made, as is the case in Smith's review (1998a).

The consequences of failing to consider the landscape level are demonstrated in the case of the management of visual resources. For example, a Partial Retention VQO is typically interpreted to permit a maximum of 15% of the VQO polygon to be clearcut at any given time (see Table 1). Considering a Visually Effective Green-up (VEG) period of 25 years, this means that clearcutting in this VQO polygon over a 100-year rotation will only yield 60% of the maximum possible yield (100% if no VQO is applied). On the other hand, a green-tree retention harvest, retaining 20% of the initial overstory (even with estimated negative impacts to growth of 20% to 40% based on 1:1 and 1:2 ratios), suddenly becomes an option that may yield more timber. In the case of a 1:1 ratio (1% volume retained for 1% growth impact), the green-tree option results in a net 20% greater yield at the landscape level than the clearcut option (80% yield versus 60% yield for clearcutting). Only when the worst case scenario (1:2 ratio) is considered does the clearcutting option yield equivalent figures (60% in both cases).

However, one also needs to consider the fact that the overstory trees initially retained do not need to be carried through the entire rotation. In fact, with visual constraints, they can be removed as soon as the understory reaches VEG height (in theory). More realistically, assuming higher VEG heights might be more appropriate (e.g. 12 to 14 meters instead of 7 meters for the Arrow TSA). Assuming that the negative impact of the overstory trees on the understory growth is constant through the rotation, removing those trees after a quarter of the rotation will reduce the impact accordingly (a quarter of the growth impact would be expected since the trees are only retained for a quarter of the rotation). Consequently, following the previous example (partial retention VQO, and 25 years VEG period), and based on the above assumption, one could remove the 20% initially retained trees after 25 years (having reached VEG) and therefore forego the negative impact of those trees on the understory for the rest of the rotation (75 years). This results in a net impact of the overstory trees of only 5% to 10% (a quarter of the full rotation impacts of 20% to 40% growth based on ratios of 1:1 and 1:2 respectively). The above example stresses the importance of looking not only at the block level, but also at the landscape level. As shown above, the impact at the stand level of retaining 20% of the initial stand, estimated at 20% to 40% growth reduction in the literature, could be reduced to a 5% to 10% impact when the trees are removed after a quarter of the rotation. Moreover, this negative growth impact becomes a major gain when compared to constrained landscape level clearcutting (yielding 60% of the growth potential of unconstrained clearcutting) rather than comparing it to block level unconstrained clearcutting (assumed to yield 100% growth). In fact, a 5% to 10% impact indicates that effectively 90% to 95% (100 less 5 and 10) is effectively yielded compared to only 60% with the landscape level constrained clearcutting.
While conceptual, the above example is in accordance with several other authors reviewed earlier (Industrial Forestry Services Ltd. and BCMoF, 1998; Timberline Forest Inventory Consultants Ltd. and Rowe, 1999) which also attempted to compare the use of clearcutting and that of dispersed retention cutting (non-clearcut approaches that retain part of the initial overstory for various periods of time). All found non-clearcut approaches to be more beneficial in terms of timber supply impact than conventional clearcutting when applied at the landscape scale with constrained areas such as visually sensitive areas.

Further research is needed, and more importantly, the research done at the block level, where clearcutting is assumed to yield 100% of the potential growth of a site, needs to be brought up at the landscape level before any growth and yield conclusions are made. Unfortunately, this does not appear to be the common practice at present, and it is unclear whether or not spatially explicit Timber Supply Reviews would include such landscape level considerations.
CHAPTER 5: CONCLUSIONS

A review of silvicultural systems shows that such widely used concepts as partial cutting need to be clarified and the term dispersed retention cutting was rather used in the context of the present thesis. While other concepts and definitions could also use some clarification, the introduction of new systems such as the retention system could lead to less confusion especially among the public.

When clearcutting is used, visual landscape design techniques and percent alteration measures can be effective tools and guidelines in the management of visual resources. However, for a given timber volume removed, people tend to prefer dispersed retention cutting to clearcutting. In terms of visual performance, it appears that systems with partial initial removal of the overstory (and either delayed removal of the remaining trees or their retention for the full rotation) deliver best results from a visual perspective while maintaining high timber flows (e.g. green-tree retention, seed-tree systems with delayed final cut, shelterwood systems with delayed final cut, selection system, irregular shelterwood, etc.). While clearcutting with landscape design can, in certain circumstances (e.g. particular landscape types and certain viewpoints), deliver equally good results or occasionally even better visual results, much lower volumes can be harvested and there is a significant risk that it will not look good from other viewpoints (e.g. a green-tree harvest looks the same from any given angle, while a designed clearcut may be acceptable from one perspective and unacceptable from another).

As for the long term growth and yield impact of retaining overstory trees in dispersed retention, it appears to be ranging between one and two percent long term growth and yield reduction for each percent of the initial overstory retained for the full rotation. However, this impact is only valid at the block level and yield achieved within a clearcut block do not constitute a valid reference against which to contrast non-clearcut growth rates at the landscape level when forest cover requirements (e.g. percent denudation limits to meet VQOs) are considered. Retaining trees for a fraction of the rotation length would reduce their negative growth impact on the understory accordingly (a tree retained for half the rotation will have half the growth impact on the understory than if the same tree were to be retained for the full rotation) assuming regeneration is triggered.

Results from modelling exercises reported in this thesis show that substantial gains could be made in terms of timber availability and timber supply by applying certain types of dispersed retention cutting over clearcutting in areas subject to VQOs. This is in accordance with several other modelling exercises reviewed, though not with all of them. It appears that the assumptions made regarding the extent to which dispersed retention cutting is feasible is at the centre of those differences. Timber availability increases could range from 10% to 30% at the TSA level and could reach up to 580%
availability increases in some specific local cases. Timber supply increases could range from 2% to 117% long term increases. The results obtained strongly support the incorporation of dispersed retention cutting techniques in the BCMoF TSR modelling process, at least for visually sensitive areas for which VQOs apply. Unfortunately, and despite an extensive amount of research from the BCMoF and elsewhere, dispersed retention cutting techniques have yet to be incorporated into the BCMoF TSR process in any meaningful manner in areas such as the Arrow Forest District.

In summary, key findings from the present thesis include numerous interpretations based on the literature reviewed and key findings from the thesis per se. Interpretations include the following:

1) There exists initial evidence (both in theory and in practice) that people prefer dispersed retention cutting to clearcutting for certain levels of removal, and that some kinds of dispersed retention cutting can virtually eliminate Visual Quality Objectives as a constraint at least at the VSU level.

2) With the exception of the Preservation VQO, the more stringent the VQO, the bigger the potential timber gain from using visually effective dispersed retention cutting techniques over clearcutting.

3) There is a difference of opinion among the practitioners and managers as to the extent to which dispersed retention cutting can be operationally and realistically undertaken. More research is needed on the costs, operational feasibility, actual growth effects, safety/training, etc. for dispersed retention cutting techniques.

Key findings directly resulting from the work undertaken in this thesis, along with recommendations for future research endeavours, include the following:

1) There is still confusion even among foresters on the partial cutting terminology and in regard to the intent of silvicultural systems, let alone confusion among the general public. The present thesis puts forward the concept of dispersed retention cutting, a visual definition of partial cutting, as an attempt to reduce this confusion. Such a visual definition would allow for potentially increased public understanding of the issues at stake and allow for more effective public participation in the current debate over the use of dispersed retention cutting versus clearcutting.

2) There is surprising ignorance and lack of long term research of dispersed retention cutting techniques in BC (and elsewhere), especially in regard to long term silvicultural systems trials. Very few models available can handle dispersed retention cutting and it is not consistently factored into Timber Supply Reviews throughout BC. However, it appears there is little basis for rejecting dispersed retention cutting as a viable alternative in some cases (especially in visually sensitive areas).

3) There is a widespread misunderstanding of the impact of visual constraints on timber availability and supply. There is also a failure to consider the broader landscape level context. As was shown in this thesis, the management of visual resources does not necessarily constrain timber harvests.
4) It appears that the perception of Visual Quality Objectives being a major constraint on timber may in fact be an artefact of the present reliance on clearcutting as the main harvesting approach.

5) Substantial timber availability gains are possible in areas subject to Visual Quality Objectives without sacrificing visual quality, both in the short and long term. A win: win solution is possible, as was shown for the Arrow Forest District and the Lemon Landscape Unit.

6) More focused Visual Resource Management studies (e.g. combining refined Visual Landscape Inventories with site-specific visual prescriptions) can help in identifying better forest development plans and yield more timber (corroborated in the literature).

7) More research is needed to deepen current understanding of visual quality – timber supply relationships, and to shed light on in-depth long term responses.

8) The landscape level VQO Intensity Index developed in this thesis will facilitate future modelling needs, by allowing to compute the cumulative effect of various VQO combinations and to compare different VQO intensities, as was shown in this thesis. Such an index should be further tested and validated in order to allow further comparisons on the intensity of the management of visual resources between different landscape units or Forest Districts.

9) Current Timber Supply Reviews should account for recent BCMoF research findings on public perceptions of dispersed retention cutting and should incorporate into their calculations the removal figures advanced by the BCMoF in regard to what could be harvested under each Visual Quality Objective. Sensitivity analyses could then be produced which would show the sensitivity of timber supplies to the harvesting practice (clearcutting or dispersed retention cutting) used in visually sensitive areas.

10) More research is needed to find and validate the visual quality thresholds. Forest companies considering/applying variable retention or any other type of dispersed retention cutting as an attempt to gain a social license or to meet given Visual Quality Objectives need to pin-point the public's visual acceptability thresholds, and determine what minimum retention level is required to avoid triggering a strong negative visual response. If this visual threshold is exceeded (if too much is harvested), visual quality may end up worse than if clearcutting had been used. This last point is key and cannot be stressed enough.

11) Other needs for future research include the modelling (and visualizing) over time of specific visual prescriptions, such as those presented in this thesis, in order to validate the current belief that they would meet visual quality requirements when future and subsequent passes are undertaken. Specific calculations as to the required VEG height needed to maintain VQOs at the time of those future passes is also needed since preliminary information tends to show that current VEG height requirements (meant for clearcutting) may not be sufficient for potentially large scale dispersed retention cutting operations.

12) There is also a need for models that can handle dispersed retention cutting techniques over time and over large areas (at the landscape level). One of the best models so far tends to focus at the stand level and requires significant data input, data that is often lacking (e.g. tree lists), especially when the landscape scale is considered. Other recent models developed at the University of British Columbia are promising but still need to be validated. Landscape level models
able to handle dispersed retention cutting are also a key component to incorporating dispersed retention cutting in the BCMoF TSR process.

13) There is a need for a spatially explicit TSR process in BC, in order to shed light on the actual ground feasibility of large scale dispersed retention cutting experiments and to visually identify areas that would be suitably large enough for such experiments.

14) Finally, so-called "back-country" VQOs for key recreation destinations need to be considered. Also, the public in question, for which visual resources in BC are managed, could use some clarification.

In regard to the five key objectives set out at the beginning of this thesis, results obtained shed light on those initial questions and the following has been found:

a) What is the relationship between visual quality (using VQOs as surrogates) and timber availability/supply? It appears the relationship is inversely proportional, yet highly variable depending on the harvesting practice used and use of landscape design techniques.

b) Are visual quality and timber availability/supply always inversely proportional? The present thesis demonstrated that in some cases, it is possible to increase both landscape visual quality and short-term timber availabilities, or at least increase one of the two significantly without negatively affecting the other variable.

c) Is this relationship affected by harvesting practices? Yes, as clearly shown in this thesis and by Figure 16 (for example).

d) What types of "partial cutting" are visually effective? Dispersed retentions cuts, as defined and introduced in this thesis, where no opening or pattern of removal is visually discernable are the most effective from a visual standpoint. More specifically, the technique known as a radiating strip pattern of removal appears to be very promising for large-scale operations and from any given viewpoint.

e) How much gain in timber availability (if any) can one expect from a shift in harvesting practice from clearcutting to certain types of visually effective partial cutting techniques (termed here dispersed retention techniques)? It appears that significant gains can be achieved from a shift in harvesting practices from clearcutting to dispersed retention cutting. As mentioned earlier, these gains have been found in the present thesis to range from 10% to 30% at the TSA level for timber availabilities and could reach up to 580% in some specific local cases. Timber supply increases could range from 2% to 117% long term increases.

In the end, BC's two biggest industries do not necessarily need a separate landbase on which to operate. Evidence brought to light in this thesis clearly shows that it is possible on certain occasions to provide a win:win solution. That is, to maintain high levels of scenic quality while maintaining or increasing current timber harvests and to maintain
high levels of timber harvests while maintaining or increasing current visual quality of BC's spectacular landscapes. This is possible through a combination of visually effective dispersed retention cutting techniques tailored to site-specific conditions, combined with visual landscape design techniques, thorough landscape assessments, and combined with clearcutting where visually appropriate.
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APPENDIX
## APPENDIX 1: LIST OF ACRONYMS USED

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>AAC</td>
<td>Annual Allowable Cut</td>
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<tr>
<td>BC</td>
<td>British Columbia</td>
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<tr>
<td>BCMoF</td>
<td>British Columbia Ministry of Forests</td>
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<tr>
<td>CC</td>
<td>Clearcut/clearcutting</td>
</tr>
<tr>
<td>DBH</td>
<td>Diameter at Breast Height</td>
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<tr>
<td>DEMO</td>
<td>Demonstration of Ecosystem Management Options</td>
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<tr>
<td>DR</td>
<td>Dispersed Retention cut/cutting</td>
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<tr>
<td>ECA</td>
<td>Equivalent Clearcut Area</td>
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<tr>
<td>EFFALT</td>
<td>Effective Alteration</td>
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<tr>
<td>EVC</td>
<td>Existing Visual Condition</td>
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<tr>
<td>FPC</td>
<td>Forest Practices Code</td>
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<td>FSC</td>
<td>Forest Stewardship Council</td>
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<tr>
<td>GIS</td>
<td>Geographic Information System</td>
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<tr>
<td>HLP</td>
<td>Higher Level Plan</td>
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<tr>
<td>IFPA</td>
<td>Innovative Forestry Practices Agreement</td>
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<tr>
<td>KBLUP</td>
<td>Kootenay-Boundary Land Use Plan</td>
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<tr>
<td>KOP</td>
<td>Key Observation Point</td>
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<tr>
<td>MB</td>
<td>MacMillan Bloedel (now Weyerhaeuser)</td>
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<tr>
<td>MKRF</td>
<td>Malcom Knapp Research Forest</td>
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<tr>
<td>P2P</td>
<td>Plan to Perspective</td>
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<tr>
<td>PC</td>
<td>Partial Cutting</td>
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<tr>
<td>PNW</td>
<td>Pacific Northwest</td>
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<tr>
<td>SI</td>
<td>Site Index</td>
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<tr>
<td>TAS</td>
<td>Timber Availability Score</td>
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<td>THLB</td>
<td>Timber Harvesting Landbase</td>
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<td>TS</td>
<td>Timber Supply</td>
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<td>Timber Supply Area (s)</td>
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<tr>
<td>TSR</td>
<td>Timber Supply Review</td>
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<td>UBC</td>
<td>University of British Columbia</td>
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<tr>
<td>USFS</td>
<td>United States Forest Service</td>
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<tr>
<td>VAC</td>
<td>Visual Absorption Capacity</td>
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<td>VEG</td>
<td>Visually Effective Green-up</td>
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<td>VIA</td>
<td>Visual Impact Assessment</td>
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<td>Visual Landscape Inventory</td>
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<td>Visual Landscape Unit</td>
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<td>Visual Management System</td>
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<td>Visual Sensitivity Unit</td>
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<td>Visual Quality Class</td>
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<td>VQC (s)</td>
<td>Visual Quality Objective (s)</td>
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