

**GEOPTICS LANDSCAPE APPARENCY:  
A DYNAMIC VISUAL RESOURCE INDICATOR AND TOOL  
FOR MULTI-FUNCTIONAL LANDSCAPE PLANNING**

by

**Kenneth Barton Fairhurst**

B.S.F., the University of British Columbia, 1968  
M.Sc., the University of British Columbia, 1980

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## **Abstract**

Forest managers must consider visual quality objectives to meet public expectations for use and enjoyment of forest landscapes. These applications of visual constraints have been criticized for being overly restrictive, and for causing a lack of opportunity for appropriate development. At the same time, inadequate planning and design can cause unnecessary visual impacts in the landscape. Past studies of visual vulnerability, visual magnitude, and angle of visual incidence have attempted to identify relative risk of visual impact, and suggested measures to control that risk, with coarse or partial results. A new approach was sought that might help alleviate those problems, and improve our ability to forecast, model, and manage risks of visual impacts.

Perspectival variability affects how the landscape is seen, and poses complex challenges in the planning and management of visual resources. Therefore, a dynamic and quantitative approach to landscape classification was developed to provide greater understanding and control of visual impact risk from multiple viewpoints. A landscape illumination mapping technique in a three-dimensional terrain model was applied as an analog for viewing from multiple viewpoints. The intensity of illumination, termed cumulative landscape apparency, provided an indicator of relative risk of visual impact for each grid cell in the landscape model.

The model was validated internally through tests and applications and externally through focus group testing. Apparency can provide a new, reliable, geographic information system-based inventory measure that will help guide resource planning, design, and integration. It has been shown to offer a potential enhancement to visual landscape

inventory, and is expected to be useful to land managers without a strong background in visual resource management, by reducing their reliance on experts and increasing their success in meeting visual quality objectives relative to current planning methods.

Apparency was shown to reveal inherent patterns in the landscape that would be useful for differentiating areas requiring greater and lesser attention, improving harvest design outcomes, and partially automating or guiding the design. The knowledge gained in testing apparency for its relation to plan-to-perspective analysis can potentially provide an indicator for refining resource supply questions. GEOptics is expected to be applicable to a wide array of visual resource management and resource planning mechanisms in BC and other jurisdictions.

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## **Dedication**

To Mabel Fairhurst and Brydon Coby – the best, always!

# 1 Introduction

People can travel through and observe the landscape from a variety of elevations along the ground, upon the water, and from the air. Some views are stationary, from one or more viewpoints; others are experienced cumulatively, while on-the-move. The lay of the land changes with each new perspective. Perspectival variability, the changing views of the landscape, was identified very early on in visual landscape assessment and planning, commencing, perhaps, with simply viewing distance and observer position (Litton 1968).

Perspectival variability produces a range of viewing angles towards any single visible land plane. Identifying and accounting for this variability poses real challenges to planners who wish to integrate visual landscape indicators into planning, design, and management of land-uses for multiple values, including aesthetics. With uncertainty of outcomes, and their costs, how then, can the visual landscape be reliably included? To do so requires a dynamic and quantitative approach to landscape classification that, I argue, goes beyond conventional visual resource management (VRM) systems now in use in many jurisdictions, such as Tasmania (Forest Practices Authority 2006), Great Britain (Lucas 1997), the United States of America (USDA Forest Service 1995; USDI BLM 2003), and Canada (Alberta. Forest Service. 1988; BCMoF 1981; BCMoF 1995). A dynamic approach has been defined, developed, tested, and applied during the course of this dissertation.

My quest for this process commenced in 2004 with the original dissertation research proposal and a trial project, a commercial application of the procedure in 2005-2006, and

further quantification and applications testing in 2007-2009. Throughout this period, the research process and its applications were collectively called "GEOptics Landscape Apparency". The name "GEOptics" was selected as a distinguishing and focusing name of the approach, derived from "GEO" – "of the earth", and "optics" – "the science of sight and light". Landscape apparency is the measure of that approach. The GEOptics name has been prominent in the many presentations of my research and at the external testing of the process with the focus groups. However, use of the term in this dissertation has been restricted to provide more clarity to, and emphasis on, the central aspect of the research – *landscape apparency*. The terms GEOptics and landscape apparency (defined in Sec. 1.2.1) therefore are closely related, with GEOptics referring to the specific tool/procedures developed here to address the general concept of degree of visibility and visible risk. In this chapter, a brief review is provided of the concepts, rationale, attributes, potential applications, and landscape apparency research approach.

## **1.1 Research Goal, Objectives, Questions an Tasks**

### **1.1.1 Research Goal and Objectives**

The broad goal of the research was to find a modelling approach and procedure incorporating and controlling for perspectival variability that had the potential to contribute to, and improve upon, VRM systems in one or more applications related to visual risk. The principal objective was to seek a 3-dimensional analytical terrain-based landscape apparency approach and tool that could potentially assist and improve the outcomes of three end-product applications of VRM systems, namely the supply of visual

resource allocation and protection across the forest landscape, integrated resource planning, and visual landscape design of interventions in the landscape. The approach would be tested for applicability with a specific VRM system, using the British Columbia Ministry of Forests and Range (BCMoFR)<sup>1</sup> Visual Landscape Management System (VLM) as an example (BC Ministry of Forests 1995). In addition, the approach would also be considered for its applicability to other VRM systems, including those defined in Sec. 2.1.

Specific study objectives of my research were to 1) define the approach and measures, 2) develop and implement methods of modelling and measuring landscape apparency, 3) develop evaluation criteria for success and 4) determine the success of the new approach and measures through tests and applications.

### **1.1.2 Research Questions**

Four linked research questions were to be addressed in the dissertation. Could a new approach to identifying and accounting for visual risk from multiple viewpoints, spatially, quantitatively, and precisely, improve: 1) visual landscape inventory, 2) visual landscape planning, 3) visual landscape design, and 4) integrative modelling? These questions are developed in greater detail in Section 2.1.

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<sup>1</sup> The BC Ministry of Forests and Range (BCMoFR) changed its name from the BC Ministry of Forests (BCMoF) in June, 2005. Many of the documents authored by the Ministry cited herein are from the BCMoF era and are cited with those initials. Current reference to the Ministry in this dissertation uses the initials BCMoFR. They are used interchangeably in many sources.

### **1.1.3 Research Tasks**

To accomplish the objectives and answer the research questions, six primary tasks were envisioned for the research:

**Task 1.** Examine expert visual assessment (EVA) theory and techniques that address and help explain factors related to landscape apparency, particularly visual magnitude and vulnerability/risk testing and evaluation criteria (Chapter 2). EVA is a term applied to large scale, expert-derived, VRM classification and evaluation systems such as the Scenery Management System (USDA Forest Service 1995).

**Task 2.** Develop a refined vulnerability/risk assessment tool (apparency modelling) and the evaluation criteria by which to test it, and select study areas for its application (Chapter 3).

**Task 3.** Refine evaluation criteria and conduct internal pre-testing through implementation of the tool (Chapter 4).

**Task 4.** Evaluate apparency tool results by internal tests (Chapter 4).

**Task 5.** Evaluate apparency tool results by external (focus group) tests (Chapter 5).

**Task 6.** Discuss findings, make conclusions and explore further research and applications, including applicability to other EVA systems. (Chapter 6).

## 1.2 Landscape Apparency Definition and Process Intent

### 1.2.1 Landscape Apparency Definition

The word "landscape", in this application, as defined in the Oxford English Dictionary (OED) means "*a view or prospect of natural inland scenery, such as can be taken in at a glance from one point of view; a piece of country scenery*" and "*a distant prospect: a vista*" (Oxford University Press 2009). Frequently, for clarification, the word "visual" is added when speaking of the landscape that is experienced by viewers. The word also has another meaning that is prominent in forestry – "*a tract of land with its distinguishing characteristics and features, especially considered as a product of modifying or shaping processes and agents (usually natural)*" (Def. 2b). The geomorphologically-defined landscape, together with all of the biophysical attributes of that landscape, are the intrinsic elements and building blocks of the visual landscape.

The entirety of dynamic viewing orientations toward the landscape can produce a variety of visual experiences of each element in those views. Visual magnitude, visual scale, and relative angles of view influence the visual vulnerability, risk, or visual impact potential of each element (see Chapter 2 for detailed definitions of these terms). I sought the means to quantify this dynamic interaction between the viewer and the landscape. I have termed it "landscape apparency" or just "apparency". The OED definition of apparency for use in this application is "*the quality of being apparent to the senses; visibility, apparentness*" (Def. 2). This apparency is considered to have an important influence on how people

value differing parts of the landscape, and consequently, the level of acceptance they have for resource management within the landscape. Apparency goes beyond, and distinguishes itself from, simple visibility to express the degree or levels of visibility or visual exposure. That is, apparency is not just what is visible or not visible – which is a simple Boolean in/out classification and a very blunt instrument – but a continuous, precisely evaluated surface in GIS. Apparency considers where the landscape is seen from, for example, from a particular viewpoint, or a cumulative viewing experience along a viewing corridor. For purposes of this application, therefore, landscape apparency is defined as:

***"a quantified visual impact risk indicator resulting from the dynamic interaction between the viewer and the landscape, as determined from an array of viewpoints, individually or cumulatively, within a digital 3-D terrain environment"***.

Apparency is the key, unifying element throughout the dissertation.

Apparency is directly related to the angle of visual incidence (AVI). AVI is defined herein as *the angle between the sight line and the land plane at the point of incidence*. Where AVI is perpendicular, apparency is greatest; where AVI is more oblique to the land surface, horizontally, vertically, or in combination, apparency is lower; and where AVI is parallel to the surface, or negative to the surface, effectively becoming invisible, apparency is nil (Fig. 1). While this concept is quite well understood in principle, it has never been systematically mapped and applied to landscape planning at an operational level.

## Apparency is Influenced by AVI

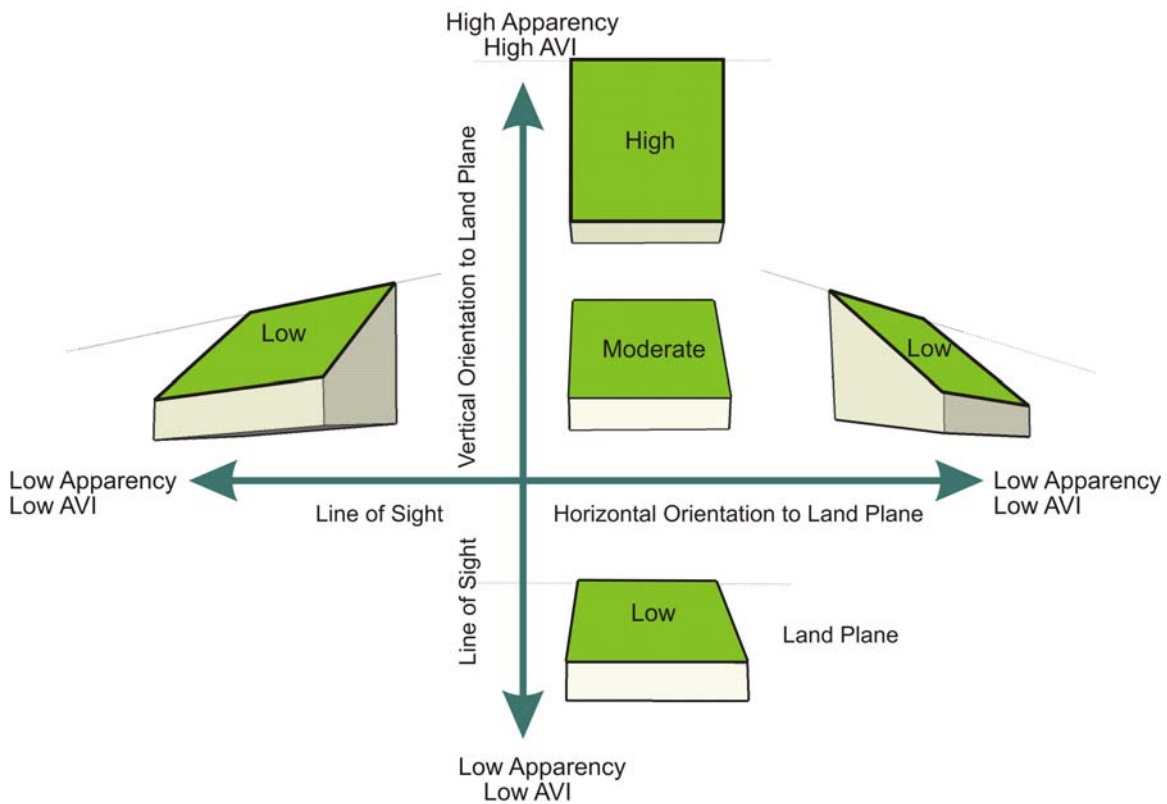


Figure 1 Relationship between landscape apparency and angle of visual incidence.

### 1.2.2 The Cumulative Aspect of Landscape Apparency

What is needed is a method not only to map and model landscape apparency from a single viewpoint, but to harness perspectival variability from an entire array of viewpoints, also called landscape control points (Litton 1973)<sup>2</sup>. GIS programs such as ESRI's ArcGIS 3D Analyst<sup>®</sup> extension have long been capable of projecting individual

<sup>2</sup> The term "landscape control point", or the initials "LCP", introduced by Litton in 1973, is a viewpoint used for analysis. The terms are used interchangeably. When applying the illumination technique in the dissertation, the same point may be alternatively termed a "light point" or the initials "LP".

and cumulative times-seen viewsheds, using the Boolean concept of visibility, but they do not determine "how" they are seen. It is by this distinction, in particular, that apparency modelling differs from ordinary viewshed and times-seen studies. Viewshed mapping determines if a particular cell (land plane) can be seen from a single viewpoint; times-seen mapping counts the number of pre-determined viewpoints able to see a particular cell, producing a cumulative viewshed map – a continuous surface – for those viewpoints, but not providing any information on the visual risk from those viewpoints. Apparency, in contrast with viewshed mapping, is not just what is seen of a landscape segment, or how often it is seen from an array of LCPs, but, more usefully, *how* each land plane within the landscape segment is seen, in totality from the array of LCPs. That is, apparency addresses the extent to which each land plane is observable from each viewpoint - the combined horizontal and vertical angles it makes with the lines of sight from each viewpoint, and the resulting shape and size of each land plane that is observable from the viewpoint(s).

Apparency, by an illumination analog described in Sec. 1.2.3, is determined at each land plane within the visible area, indicating the relative, cumulative apparency of each land plane compared to its neighbours, whether seen once or many times. Each cell or land plane is assigned a measure of relative apparency, thereby providing a much more precise, spatially rich, and discriminating depiction of the landscape. Land planes that are most apparent are more perpendicularly angled to multiple sight lines, in sum, and thus pose higher risk of exhibiting visual impact from land-use operations than land planes that are, generally, more obliquely angled from view. While cumulative apparency is

determined from a set number of LCPs in the following tests, it is potentially applicable to the entire continual viewing opportunity set of LCPs.

### **1.2.3 The Illumination Analog of Landscape Apparency**

The viewers' sighting of the landscape was considered fundamental in the development of the landscape apparency model. To simulate these sightings, standard 3-dimensional software programs project sight lines from the viewpoints, thereby determining, by ray tracing, what areas are seen<sup>3</sup>. These programs may further determine the angles at which the land is seen, and from them, through scalar (dot) product analysis of the viewing vector(s) and surface normal (a vector perpendicular to the terrain surface), provide quantitative measures of vulnerability to reveal areas at risk of visual impact (Bergen et al. 1995). More details of these approaches are provided in Chapter 2.

Computer graphics also use ray tracing as a technique for building 2-dimensional pictures of a 3-dimensional world (Glassner 1989). Although photo-realistic visualizations are commonly used to simulate what the viewer sees from any one viewpoint, and are very effective in that, they are limited, in their analytic potential, to that single viewpoint, or to side-by-side comparisons of the graphics produced from each of the viewpoints. Much as viewshed/times-seen map procedures are capable of providing the combined results of viewing opportunities from a number of viewpoints, a method was sought that would be

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<sup>3</sup> Ray tracing is defined as "An image synthesis technique using geometrical optics and rays to evaluate recursive shading and visibility" in Glassner, Andrew S. 1989. *An introduction to ray tracing*: Academic Press Limited.

capable of adding together the angles of visual incidence as seen from multiple viewpoints, but in a way that is visual in itself (a graphic analog of AVI). Furthermore, the application of the light analog in Visual Nature Studio<sup>®</sup> (VNS) by 3D Nature, LLC., selected for use in this research, required no computer programming.

Terrain illumination is commonly used in GIS analysis (for hillshading in ESRI's 3D Analyst, for example). Hillshade analysis, and other terrain surface illumination procedures such as are available in VNS, produce measurable light reflectance from terrain surfaces, typically simulating illumination from the sun. Recent adaptations of 3D Analyst (Chamberlain 2007) could allow its use in light placement and illumination determination for apparency derivation. However, the availability in VNS of a reasonably user-friendly, fully controllable, illumination tool set, a unique and quick shadow mapping technique, and the ability to directly produce photo-realistic end-product visualizations, lent support to its use in my apparency applications, assisted by ArcGIS for mapping and graphic analysis<sup>4</sup>. More details are provided in Chapter 2 and procedures are provided in Chapter 3.

The visual risk of a land plane seen from one or more viewpoints is determined as an illumination analog for AVI from each LCP to each land plane. The illumination technique is much like providing a bright light for an observer to shine on the landscape.

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<sup>4</sup> ESRI's ArcGIS 9 was made available for my research through the Faculty of Forestry, University of British Columbia. Other GIS programs may offer comparable functions that would likely be fully adequate for GEOptics apparency purposes.

The illuminated landscape corresponds to both what the observer sees, in a bare ground context, and how it is seen, that is, the lay of the land.

Lights are placed in the VNS digital 3-D terrain model at each viewpoint, at a height corresponding to the observer's eye level (2 m, by convention). The elevation may be varied according to the mode of travel. The number of LCPs can be varied as appropriate to the project, such as by the scale and complexity of the landscape. LCPs can be selected where viewing intensity or duration is greatest, if known. There is potential for viewpoint importance to be taken into consideration. LCPs may also be set equidistantly. The topic is further discussed in Sec. 3.2.2.1

### **1.3 Potential Applications, Tests, and Other Influences**

#### **1.3.1 Evaluating Potential Applications in Forest Planning and Design**

In British Columbia, guidance for visual landscape planning and design is available in the form of a training manual: the Visual Landscape Design Training Manual (BCMof 1995), and Visual Impact Assessment Guidebook (BCMof 2001b). Subsequently, guidance was prepared by the BCMofR for comprehensive integrated visual design of entire units (BCMofR 2008a). The design tools provided in those documents increase the likelihood of achieving visually desirable results (see Chapter 2 for more detail), however, there is a considerable skill level required. Whether they are specialists in landscape management, or operational resource management generalists, practitioners

require a substantial amount of experience, ability to think spatially, and understand design aspects (BCMof 1995). They also need to undertake trials to achieve an appropriate resource development design over the short and longer term. Landscape apparency mapping products are intended to be used by resource managers at differing skill levels to improve their likelihood of achieving the desired (or required) visual results with their plans, precisely the complex interface at which the apparency modelling approach is targeted. My research assesses if the modelling approach can provide improved accuracy, validity, and utility over conventional landscape inventory (e.g. USFS, BLM, BCMofR), and viewshed and times-seen studies, such as by Llobera (2003).

Apparency attributes can be directly assigned to polygons proposed for development (cutblocks), thereby providing a dynamic visual resource indicator, meaning it should be responsive and adaptable to any size of landscape, at various scales and levels of complexity, for multiple-objective evaluation (Maness and Farrell 2004). The modelling approach could provide input to hierarchical integrated decision support systems and spatial forest planning models as described by Seely et al. (2004). The GIS layer of quantified apparency has potential to be introduced into the Sustainable Forest Management (SFM) framework to provide advance understanding of visual vulnerability and magnitude considerations. By calibrating the model based on plan-to-perspective "visual magnitude" relationships, it was anticipated that the model would provide an input for the Forest Planning Studio (FPS), also known as the Atlas model, to guide intensity and dispersal of forest development (Nelson 2003). This application was

pursued as a method of "automating" visual landscape design, or at least a method to rapidly improve estimates of what rate, shape, and scale of development will be compatible in the landscape over the short and long term.

By adding design criteria tied to landscape apparency, it is possible that the apparency modelling approach could help guide land management allocation, concentration, and alteration design very early in the planning process, potentially avoiding long-term negative implications on visual quality, and encouraging public support and understanding. Through the development of design criteria, tied to quantified apparency, a modelling approach has the added potential for informing and enhancing long-term visual stewardship outcomes (Sheppard 2001) and forest ecosystem design (Bell 2001; Diaz and Apostol 1992; Diaz and Bell 1999; Kimmins 1999). Highly vulnerable sites (high apparency) could be readily selected, and assigned resource protection measures; while other sites with quantifiably lower risk of visual impact (very low apparency) could receive more intensive land-use alteration while meeting the VQOs already established for the area. Further, by applying apparency to an entire available land-base intended for development, it is postulated that both strategic planning and operational design could be enhanced.

### **1.3.2 Internal and External Tests of Apparency Modelling**

Techniques for the integration of apparency mapping into resource design and decision-making were defined and tested, internally and externally, in relation to conventional

VRM analysis methods, using the criteria of 1) feasibility, 2) validity and defensibility, 3) effectiveness, and 4) usability. Two principle study areas offering distinctive coastal and interior landscapes were used for the research – Howe Sound west side, a southern British Columbia coastal waterway, and Nadina Lake in west-central British Columbia (Fig. 2).



**Figure 2 Map of Study Areas (adapted from iMAPBC<sup>5</sup>).**

Earlier prototypical models were developed, including the original model using the Stella Lake landscape on northern Vancouver Island, to prepare initial procedures, and an imaginary, generic landscape called Dishtin that was built to analyze the procedures

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<sup>5</sup> iMAPBC is a self-serve web-based mapping tool provided by GeoBC, Integrated Land Management Bureau. GeoBC is responsible for managing the provincial geographic information.

systematically. Internal tests examined terrain model construction, illumination/shadow mapping, light placement and light characteristics, apparency classification, and integration of apparency with other resource attributes. Applications examined degree of alteration and plan-to-perspective ratios, integrated visual design, automation potential, and harvest layout. The internal tests and applications, and results, are presented in Chapter 4.

The external tests employed a structured focus group approach with a questionnaire, and written and open discussion. Focus group participants came from government, industry, and academia, with a range of experience and responsibilities for developing and implementing forest landscape plans and design. A pre-test helped shape the presentations to the focus groups. As well, each focus group led to improvements in the clarity of subsequent presentation. Focus groups were held at three venues – Richmond, near Vancouver, the University of British Columbia (UBC) in Vancouver, and in Nanaimo, on Vancouver Island. External tests and results (of the focus groups) are presented, separately from the internal tests, in Chapter 5.

### **1.3.3 Other Influences on Development of the Landscape Apparency process**

Exposure and expert advice contributing to the development of the landscape apparency approach were gained through presentation and discussion of the research at several international conferences and symposia: at the American Society of Landscape Architects

(ASLA) Annual Meeting, San Francisco (Sheppard and Fairhurst 2007); the International Union of Forest Research Organizations (IUFRO) Conference on Simulating Forest Landscape Patterns, Processes, and Consequences of Human Management, Locorotondo, Italy, 2006; the International Symposium on Society and Resource Management in Vancouver, Canada, 2006 (ISSRM 2006); at the International Symposium on Society and Resource Management (ISSRM) in Keystone, Colorado, 2005; and at the "Our Shared Landscape" conference in Ascona, Switzerland, 2005. Additionally, informal presentations were made at the University of Oxford and at the University of East Anglia, Norwich, United Kingdom. The presentations, and the dialogue generated by them, contributed to defining the apperency modelling approach.

The methodology also reflects the author's enduring involvement in the inclusion of visual landscape values in the forest planning process. During my years as the Visual Landscape Specialist for the British Columbia Ministry of Forests Vancouver Forest Region, I was involved from the earliest days (1980) with the building and implementation of the Visual Landscape Management program, during which time the Forest Landscape Handbook was published (BC Ministry of Forests 1981). I supervised research into planimetric to perspective (P2P) relationships (BCMof 1996b; Breslauer 1994a; Breslauer 1994b), and through my consulting company, RDI Resource Design Inc., have, since 1996, conducted further research into P2P relationships within total resource design processes such as the Black Peaks project (Fairhurst 1999). This dissertation is a continuation of that career-long interest, and while there is always more to learn, should provide a marker along the path of knowledge.

Although the apparency approach was developed through independent research, it is very supportive of other research initiatives recently conducted at UBC. The concept of automating visual resource management and the harvest design process was explored and a prototype was developed that would automatically adjust harvest design to be more visually sensitive (Chamberlain 2007; Chamberlain and Meitner, 2009). The approach was limited to analysis and projections from a single viewpoint as compared to the cumulative approach inherent in GEOptics. Earlier work (Meitner et al. 2004) examined the potential to automate variable retention patterns which provided an excellent foundation and understanding of automation potential in my dissertation research.

#### **1.4 Guide to the Dissertation**

Following this introduction (Chapter 1), research questions, tasks, and current approaches to expert visual assessment and visual vulnerability are described more fully in Chapter 2, the methods for landscape apparency modelling are described in Chapter 3, internal tests and applications and their results are presented in Chapter 4, external tests with focus groups and results are presented in Chapter 5, and finally, discussion, conclusions and suggestions for further work are provided in Chapter 6. Additional materials pertaining to the focus groups, apparency classification methods, and copyright approvals are located in the Appendices. The internal and external tests, together with their results, are presented in separate chapters with the intent of organizational efficiency and communication effectiveness.

## 2 Research Questions, Tasks, and Related Concepts and Procedures

The research questions are described in this chapter. The tasks needed to answer the questions are defined and examined in relation to current practices, related concepts, and procedures. Evaluation criteria are described.

### 2.1 Research Questions, Tasks, and Evaluation Criteria

Four research questions were directed at the ability of the new tool to spatially, quantitatively, and precisely, identify and account for visual risk from multiple viewpoints:

1. Does GEOptics apparency modelling improve visual landscape inventory? The tool may improve landscape inventory by basing it on apparency derived from cumulative angle of visual incidence (AVI) rather than just physical slope or other standard predictors of visual risk, such as times-seen or VAC mapping.
2. Does apparency modelling improve strategic level<sup>6</sup> visual landscape planning? The tool may provide a more concrete and objective method for generating visual "constraint and opportunity" ratings to use when setting broad scale planning objectives for visual quality<sup>7</sup>. Apparency may also provide an improved method of

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<sup>6</sup> Strategic level planning is resource allocation at the Timber Supply Area scale and over the long term (300 years) (Boyland 2003).

<sup>7</sup> The plan-to-perspective ratio (P2P) is the extent of alteration in planimetric view expressed as a percent of the landscape in plan view, divided by the extent of alteration in perspective view expressed as a percent of the landscape in that view. See Fig. 8 for more details.

calculating plan-to-perspective ratios over current methods using broad averages and professional decisions. P2P is used in timber supply analysis, a strategic level of planning. As such, apperency could provide supply measures of VRM which may improve the management of a wide variety of resources, including timber, wildlife habitat, and recreation in the landscape.

3. Does apperency modelling improve visual landscape design over the short and longer term? The tool may provide better information to assist land-use design to fit the landscape better, guide the detailed location, intensity, and scale of forest operations, and improve the efficiency of the planning process, by reducing some of the subjective assessments, and need for post-design visualization checks. Having apperency information may help plan for cumulative effects over time, in the integrated visual design / total chance planning process, and to assess the time needed to achieve visually effective green-up.
4. Does apperency improve integrative modelling at the tactical and operational planning<sup>8</sup> level? The tool may provide input into integrated visual design (total chance) planning. Hierarchical, resource development-ecosystem management planning mechanisms such as UBC-FM, developed at the Faculty of Forestry, UBC (Seely et al. 2004), may be capable of including apperency measures. GEOptics may provide guidance relating to visual risk for automated harvest design tools, such as FPS-Atlas.

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<sup>8</sup> Tactical level planning is harvest scheduling and landscape level plans over the mid-term (5-20 years) (and include integrated visual design plans and total resource/total change plans), while operational level planning is how activities will be carried out in a particular harvest unit over the short term (under 5 years) (Boyland 2003).

Six primary tasks were identified in order to address these research questions:

**Task 1.** Examine, by way of a review of the literature, expert visual assessment theory and techniques that address and help explain concepts related to apparency, including visual magnitude and vulnerability/risk testing, and their evaluation criteria. Task 1 is described in this chapter (Chapter 2).

**Task 2.** Develop a refined vulnerability/risk assessment modelling technique and the evaluation criteria by which to test it and select study areas for its application (Chapter 3).

**Task 3.** Refine evaluation criteria and conduct internal pre-testing through implementation of the tool (Chapter 4).

**Task 4.** Evaluate apparency tool results by internal tests (Chapter 4).

**Task 5.** Evaluate apparency tool results by external tests with focus groups (Chapter 5).

**Task 6.** Discuss findings; make conclusions and explore further research and applications including applicability to other EVA systems (Chapter 6).

The same evaluation criteria were applied across the set of research questions and tasks to measure if apparency would provide a useful contribution or improvement to current practices. These were:

- 1) Feasibility – how apparency works, quantifies, integrates;
- 2) Validity and Defensibility – internal and external reliability; precision, accuracy; objectivity;

3) Effectiveness – in comparison to, or contributing to current VRM system(s) and GIS tools; and

4) Usability (by others) – flexibility; ease of use; compatibility with VRM.

## **2.2 Related Concepts and Procedures**

Links are made in this section to related concepts and procedures of expert visual assessment models (Sec. 2.2.1) and in particular, visual vulnerability and visual risk assessment methods (Sec. 2.2.2). Within that section is a discussion of key concepts of visual vulnerability (Sec. 2.2.2.1), angle of visual incidence (Sec. 2.2.2.2), and plan-to-perspective (2.2.2.3), each of which are defined in their respective sections. Following that, the BCMoFR Visual Landscape Management (VLM system, the EVA used to judge the potential contribution of apparency, is described (Sec. 2.3). The relation of the VLI to apparency, and to the research questions is outlined in Sec. 2.4. A summary of the chapter is provided in Sec. 2.5.

### **2.2.1 Expert Visual Assessment**

Large-scale methods of visual landscape quality assessment have been implemented in various parts of the world over the past three decades, in order to produce regional, province/state and country-wide inventories of scenic resources and management prescriptions. As a result, the "visual resource" has found its way into broader, often complex, resource management considerations. These methods conform generally to the

"formal aesthetic" model in that "aesthetic quality resides in the *formal* properties of the landscape... forms, lines, colors, and textures" and "expert judgments of the variety, unity and contrast among the basic landscape elements" (Daniel and Vining 1983, p.49). The formal aesthetic model is also termed an expert visual assessment system (Buhyoff, Miller, Hull, and Schlagel 1995) and scenic aesthetic model (Sheppard 2001). While all of the terms are useful and similar, Buhyoff's descriptor, "expert EVA", best conveys the modeling applications addressed in the GEOptics apparenacy process.

Some major examples of expert EVA are the US Forest Service's Visual Management System (USDA Forest Service 1974) and later, the Scenery Management System (USDA Forest Service 1995), the US Bureau of Land Management's Visual Resource Management Program (USDI BLM 2003), Tasmania's Visual Management System (Forest Practices Authority 2006), and the British Columbia Ministry of Forest's Visual Landscape Management Process (BCMof 1997). The BC system was the EVA system selected for further description and comparison with the GEOptics approach as it is commonly used and broadly applied in the Province, and is used to provide guidance to a major forest planning and operational activities on public forestlands (described in Sec. 2.3).

In addition to these systems adopted by governments, other methods and variants of adopted systems have been developed and applied for forestry and non-forestry purposes, such as the Visual Landscape System developed for the Cumulative Environmental Management Association, Fort McMurray, Alberta by Fairhurst (2003) to provide a

mechanism for planning and managing the cumulative visual impacts of the oil sands and other natural resources.

EVA systems offer the potential advantage of economy as they may often be done in-house by expert staff, and can assess large areas quickly (Daniel and Vining 1983). Such inventories significantly provide, at a minimum, a record of the extent of visual interest in the landscape. The Forestry Commission in the United Kingdom also has a well-established forest design system (Lucas, 1991) that contributed significantly to the BCMoFR visual design process (BCMof, 1995).

Sheppard noted "that the *scenic aesthetic*, as defined by the expert VRM professionals and landscape architects of the US Forest Service, generally fits well with prevailing public perceptions of the landscape" (Sheppard 2001), and that "the various methodologies for landscape assessment are important as possible frameworks for VRM decisions to predict aesthetic values and for modeling of future management outcomes" (Sheppard 2004). He and others mention methodological shortcomings, considerable unreliability, and subjectivity (Buhyoff, Miller, Hull, and Schlagel 1995; Daniel and Vining 1983; Sheppard 2001; Smardon 1986). "The internal and external validity of any visual assessment system is important in its development, including the consistency amongst trained users" (Buhyoff, Miller, Hull, and Schlagel 1995). Major shortcomings include the lack of sensitivity resulting from coarse categorization, the tendency towards selection of midpoints in the range of values (moderate ratings), and the inability to differentiate within and amongst areas of the same rating (Daniel and Vining 1983, p.

53). The authors stressed that an assessment method must be sensitive and reliable, or it can't achieve an acceptable level of validity, and further asked if the formal elements truly identified all of the scenically relevant characteristics of the landscape (p. 53).

The visual landscape inventory and management system must be capable of covering large areas efficiently and capably while providing useful guidance to management of the visual resource. The generality and inconsistency inherent in large-scale system ratings can lead to misappropriation of visual resources, resulting in management regimes that are either overly and needlessly restrictive, or lacking in necessary resolution to provide sufficient control over scenic values. This generalization can also provide too much latitude for interpretation and, with the possibility of manipulation of operational outcomes, can lead to inappropriate diminishment of scenery and other values, or overly strict assumptions for visual protection.

Descriptive inventory methods have proved quite valid for their purpose – that of representing and evaluating the seen (and scenic) landscape – its shapes, prominence, vegetation patterns, as it unfolds and presents itself as a cumulative viewing experience along a highway or waterway. The word cumulative is significant to the process: experiences and values are identified while travelling through the landscape, i.e., "the view from the road" (Appleyard 1964); areas of containment and identity (Preece 1991). The inventory approach "requires that a set of landscape features or components thought to be relevant to scenic beauty, be selected, and to some extent, defined." (Daniel and Boster 1976). The authors contended: "...the effectiveness of inventory techniques

depends to a great extent on the expertise and judgment of the user and on the relevance of the descriptive features selected" (p.7). They cautioned that a weakness in this approach "has been the failure to relate the features in the inventory to validated measures of scenic beauty" (p. 7).

Much has been written recently on the transition from the multiple-use paradigms that helped to generate the need for expert EVA systems to ecosystem management paradigms that seek to explain the affinity of the public with ecological values in scenic beauty perceptions (Daniel and Vining 1983; Daniel 2004; Gobster 1999) and visible stewardship (Sheppard 2001). Daniel and Vining (1993) selected five conceptual landscape assessment models in their analysis of methodological issues. These were the 1) the ecological model, whose assumption is "that landscape quality is directly related to naturalness or ecosystem integrity" (p. 47); 2) the EVA or formal aesthetic model, whose "basic tenet is that aesthetic value is inherent in the abstract features of the landscape" (p. 49); 3) the psychophysical model, whose "central assumption ...is that the aesthetic judgments of public panels provide an appropriate measure of landscape quality" (p. 63); 4) the psychological model, which "refers to the feelings and perceptions of people who inhabit, visit, or view the landscape" (p. 65); and 5) the phenomenological model, concerned with "individual subjective feelings, expectations and interpretations" (p. 72). While each has a role, continuance of a broad-scale EVA (VRM) approach in large landbases seems to be a practical necessity, though opportunities to link with more public perception-based methods exist. As such, the other paradigms were not further investigated.

There are a number of typical components of visual assessments, as clearly set out in the Visual Analysis chapter of the Encyclopedia of Forest Sciences (Sheppard 2004). The first stage is usually visual landscape description and inventory, which defines visual units, and addresses visibility, visual absorption capability (VAC), viewer sensitivity, visual quality, and possibly landscape meanings to the observer, which may go beyond aesthetics to include cultural, spiritual and use values. Visual quality may be defined and measured in various ways. Sheppard described visual quality: "It is sometimes referred to as scenic beauty, aesthetic value, or a measure of visual preference, factors that approach the landscape as a source of aesthetic enjoyment" (p. 444). Daniel and Vining (1983) defined landscape quality by characteristic elements and attributes, such as biophysical factors, and the "degree of excellence" of the feature, variously termed scenic quality, visual attractiveness, visual quality, aesthetic quality, and scenic beauty (p. 42).

The second stage is visual impact assessment, which has the purpose of supporting project level decisions and design activity, often accompanied by visual simulation. VIA applies a set of measurement criteria and a rating system which considers elements of good design. Design procedures were suggested by Bradley (1996). Design criteria can include consideration of VAC, viewer sensitivity, etc., to ensure the level of expected visual quality is achieved such as in the BCMoFR VIA guidebook (2001). VAC is defined as "the relative ability of a landscape to accept management manipulations without significantly affecting its visual character" (BC Ministry of Forests 1981). VAC is a concept that is related to visual vulnerability (Litton 1984), as both terms are used to describe the risk or likelihood of visible change occurring in the landscape, though the

measures of each are opposite to each other (the higher the VAC, the lower the vulnerability). Their identification and evaluation can be objectively determined while visual quality, though tied to landscape factors, is considered by many to be more subjective. This dissertation primarily focused on VAC and visual vulnerability, rather than on visual quality, and are further described in Sec. 2.2.2 and its subsections. The concept of landscape apparency, as developed in this dissertation, is tied directly to visual vulnerability and VAC.

## **2.2.2 Visual Vulnerability and Risk Assessment**

Concepts of visual risk and systems for its identification and control have been a prominent part of EVA systems in North America and elsewhere. In his objective of providing a mapping system of visual risk, Litton (1973) established a network of landscape control points (LCPs) to obtain a continuous view of scenically significant areas and segments that are vulnerable to use impacts. An individual LCP is described by Litton as "a fixed station from which a broad, intermediately distant view may be seen" (p.1). Litton also suggested methods to analyze cumulative views both by direct observation and by computer plots. Several terms have been used to express visual vulnerability and ways of assessing potential visual impact, and are discussed below.

### **2.2.2.1 Visual Vulnerability, Absorption, Impact Prediction, and Magnitude**

Modelling procedures have been developed that provide a classification process for a landbase by determining degrees of visual risk, or visual vulnerability by Litton (1984)

("some landscapes... are more sensitive to change than others" (Litton 1973, p. 21)), recognizing that the concept has been implemented in resource analyses for some time (Tetlow and Sheppard 1979). Litton defined visual vulnerability as follows: "the degree to which man-made changes might be seen in the landscape and their potential for degradation---in essence, the landscape's resistance or susceptibility to visual changes" (Litton 1974). Sylvia Crowe used the term vulnerability in her 1969 report to the International Union for the Conservation of Nature (IUCN and Crowe 1969): "The landscape planner's contribution to the planning team is an understanding of the landscape; why it looks as it does; the interdependence of its components; its potentiality and its vulnerability (p. 14).

Recognizing mobility of the observer, Hadrian et al. (1988) examined the influence of factors contributing to visual vulnerability. Their visual impact model sought to incorporate the interaction between the viewer and the landscape. Conventional landscape inventory procedures identify factors in the landscape that contribute to visual vulnerability, or VAC (Lucas 1991; USDA Forest Service 1995; USDI BLM 2003). VAC is defined as "a classification system used to denote the relative ability of a landscape to accept human alterations without loss of character of scenic quality" (USDA Forest Service 1995, Glossary p.7). Components of VAC in the US Forest Service system are: topographic slope (which is stated as "often the most important factor" (p. C-5)); vegetative cover pattern diversity and screening capacity ("most important on gently rolling slopes" (p. C-5)); and soils and geology, which create colour contrast, openings, stability and erosion considerations, and regeneration capacity. Similarities exist in terminology and approaches to VAC across VLM systems, particularly as precursors to

the present BCMoFR VLM process; BC's Forest Landscape Management program and handbook (BCMoF 1981) were strongly influenced by the USDA Forest Service's National Forest Landscape Management program (USDA Forest Service 1974). The BCMoFR's use of VAC is further discussed in Sec. 2.3.1.1.

Hadrian et al. (1988) and Bishop and Hulse (1994) sought sets of predictor variables for visual impact prediction and visual quality within a GIS. Hadrian et al examined the scale and distance of structures (utility lines) and land use relative to the viewer (viewer position; distance, view angle); the latter examined an array of mapped features of land use, water, vegetation as predictor variables, keyed to a grid within the area of coverage, accounting for the effect of distance and slope steepness (and indirectly, for angle of visual incidence).

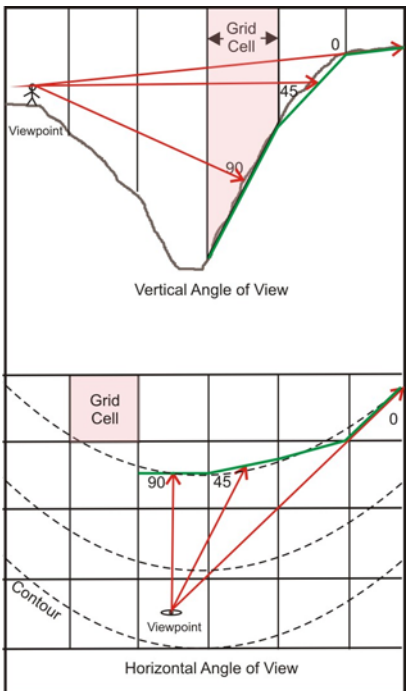
Visual magnitude is the apparent scale of an object or intervention in the landscape (Iverson 1985). This measure was tested for its influence on visual thresholds affecting the detection and recognition of visual impacts in landscape settings (Bishop 2003; Shang and Bishop 2000). Though many would consider it impossible to model scenic beauty, Germino et al. (2001) considered the ability (and potential) to quantitatively model scenic beauty through GIS viewshed analysis, together with parameters of depth, relief, edge, and diversity. This ability would potentially enhance the incorporation of visual analysis into land management (p.82). A distinction of purpose for GIS was made by Brabyn "to classify landscape character rather than make quality judgements" (2005). Ervin and Steinitz (2003) contended that landscape visibility was only "a reassuring surrogate" for "what is 'seen' (and so remembered, preferred, protected, etc)" (p. 758), and suggested that "the best descriptions of a 'view from the road' may not just be the aggregate sum of

individual viewsheds...but may call for an entirely different representation, as yet undeveloped" (p. 764).

Studies of visual vulnerability and VAC, visual impact predictor variables, visual magnitude, and visual thresholds, and the call for new representation, tie closely to apparency as developed in this dissertation. Models of scenic beauty, though definitely related, are not directly applicable to apparency.

#### **2.2.2.2 Angle of Visual Incidence**

Iverson (1975) quantified the landscape by measuring the viewed angle of each grid cell of a topographic model, taking vertical (slope) and horizontal (aspect) angles of view as relevant factors (Fig. 3) for determining the apparent scale of an intervention and, in a later landscape assessment model, the visual magnitude (Iverson 1985).

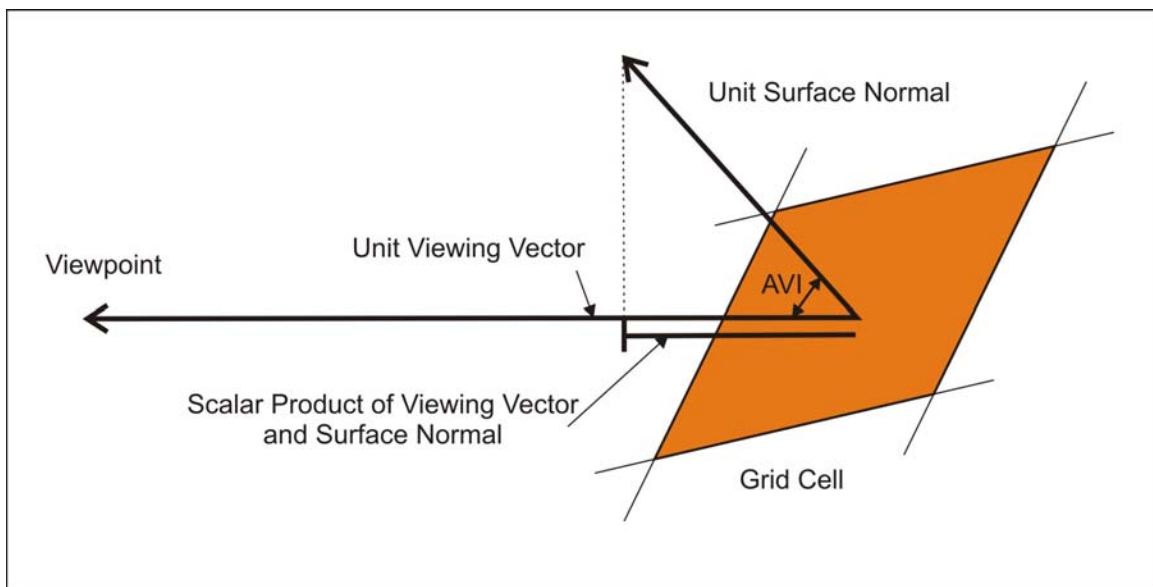


**Figure 3 Angle of viewed land plane, vertically and horizontally (adapted from Iverson 1975).**

Similar to Iverson's 1975 work, other studies have investigated the use of angle of visual incidence (AVI) (Alonso, Auido, and Ramos 1986; Bergen 1993; Bergen et al. 1995) and light incidence (Horn 1975). The AVI in those assessments was determined by the conventional method of calculation by computer ray-tracing techniques, using the angle between the sight line and the surface normal (a line projected perpendicularly away from the surface at the point of incidence). The identification and use of AVI was described by Bergen et al. (2001): "The slope and aspect of a cell are used to calculate the unit surface normal of a grid cell. The 3-dimensional coordinates of the DTM cell and the viewpoint are used to derive a unit viewing vector pointing from the cell to the viewpoint. The scalar product of the two vectors provides a measure of the angle of visual incidence on a zero to one scale" (P.17). In his description of scalar product in his Master's thesis (1993), Bergen described the output values of 0 when the cell is parallel to the viewing

vector and 1 when the cell is perpendicular, and the inverse cosine of the scalar product would give the actual angle of incidence on a 0° to 90° scale.

The following diagram from Bergen (1993) defines the AVI as the angle between the viewer's sight line where it meets the grid cell (land plane) and the surface normal, which, by convention for the properties of light and reflection, is a line projected perpendicularly out from the surface (Fig. 4).

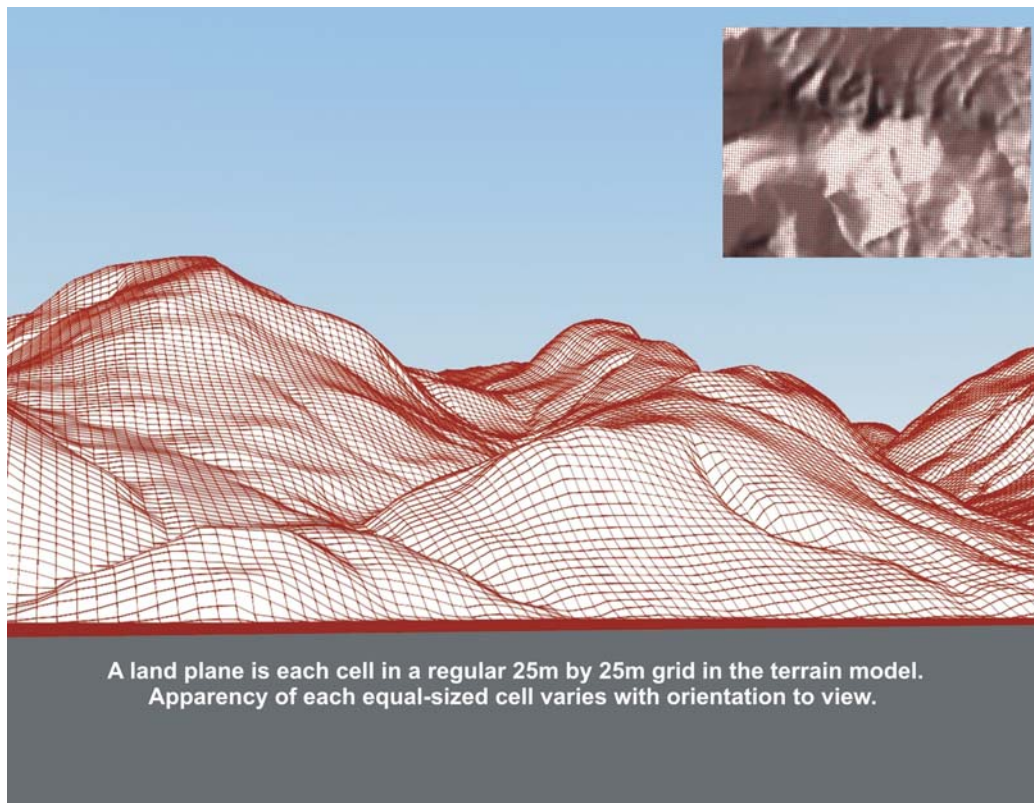


**Figure 4** Angle of visual incidence schematic, showing viewing vector, surface normal vector and resultant scalar product (adapted from Bergen 1993).

In this dissertation, the AVI is the angle formed between the sight line and the land angle at the point of contact along the sight line (as opposed to the surface normal). AVI represents the "seen" angle of the land plane rather than the topographic slope. Bergen noted that his analysis was independent of whether a cell is blocked from view by other areas of the landscape (i.e., not visible) – a limitation of that approach, and corrected by

defining the individual viewshed boundary separately. Bergen suggested the model was capable of adding a rating based on distance from viewpoint to visible areas.

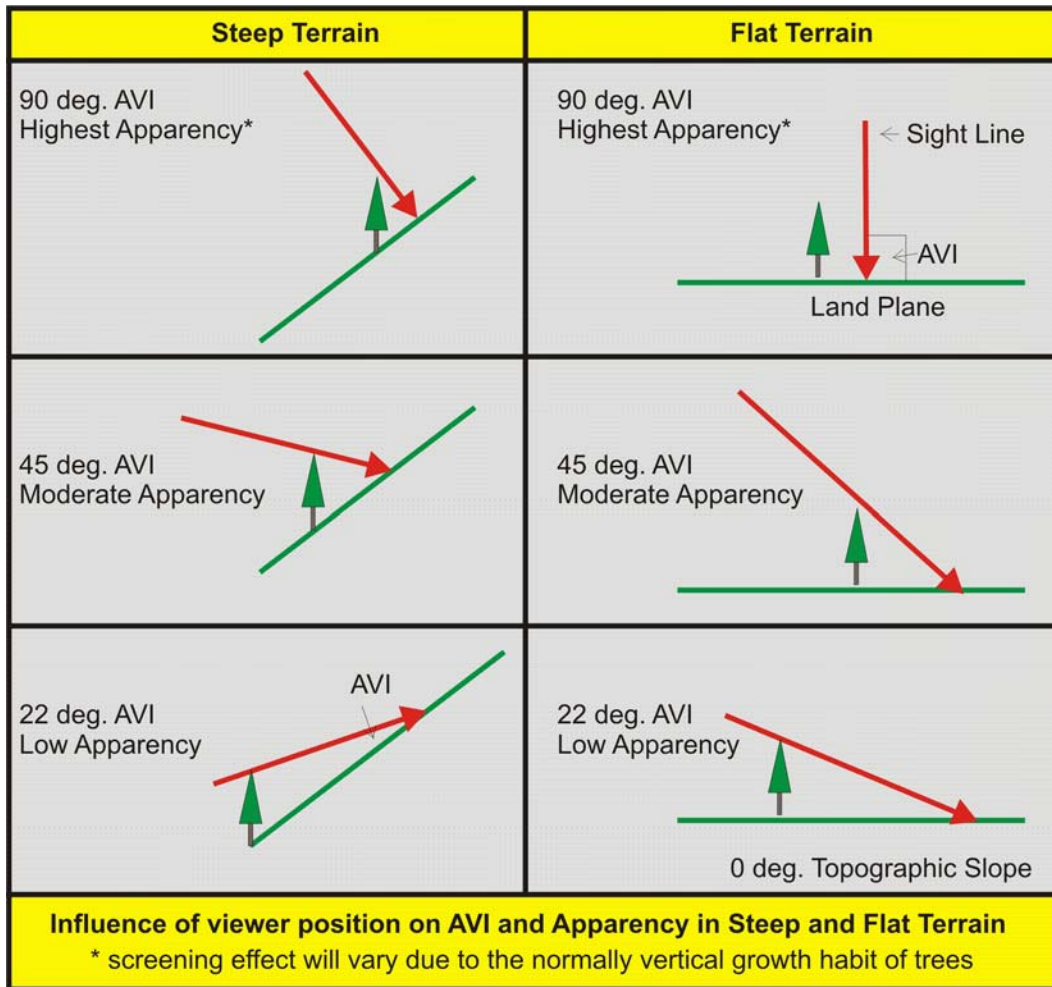
AVI incorporates both the horizontal (planimetric) and vertical (cross-section) angles of view, to make what Iverson termed the "angle of viewed land plane" (Iverson 1975), previously shown in his diagram (Fig. 3). The variation in visual magnitude of equal sized grid cells, imposed on the terrain model in plan view, due to this effect, is evident in Figure 5.



**Figure 5** Angle of visual incidence and apparency affect the scale and shape of individual land planes relative to the viewpoint. Inset shows planimetric pattern of grid cells.

Land planes that enter the field of vision are differentiated by two primary influences: 1) the angle of interception that the sight line makes with the viewed land plane (AVI), and 2) the distance between the viewer and the land plane (viewing distance). AVI ranges from  $90^\circ$ , being face-on and fully perpendicular, to  $0^\circ$  being no contact and non-visible, or reverse angle (i.e., hidden) from view.

Viewpoint-to-terrain interactions allow topographic slope to be experienced in its fullest magnitude only if the viewpoint is directly in front of, and perpendicular to, the slope's downhill fall-line (i.e., straight down the slope). If the line of sight crosses the terrain laterally or diagonally, or is close to it while looking up or down upon it, the "seen" terrain angle will vary greatly from the topographic slope. Views may be very close to paralleling the terrain even if it is topographically steep, rendering it nearly "flat" to the view. A reduction in the angle of incidence across the seen terrain drastically decreases its visual vulnerability and therefore lowers the risk of change being seen or impacting very strongly on the landscape. Higher elevation or aerial views to a flat terrain may appear as a steep gradient which raises the visual vulnerability. Figure 6 expresses the AVI of the sight line contacting the terrain from any potential direction and elevation, and its relationship to apparency. Depending on the position of the viewer, both steep and flat terrain may have similar AVI and apparency.



**Figure 6 Influence of viewer position on AVI and apparency in steep and flat terrain.**

The distinction between the angle of terrain as seen from the viewpoint and slope is critical. For example, the observed angle of the land plane may be very low if the sight line crosses the slope at near a right angle to the slope, regardless of actual steepness. The observed angle of the AVI in elevated or aerial views towards flatter terrain may be quite high, while sight lines towards steep slopes parallel to, but angled away from view, may have low AVI. The principles of AVI are expressed in the photograph of the Frederick Arm landscape where steep slopes of the side valleys, angled away from the viewer, have

a lower overall AVI and apparency than the gentler front slopes facing the viewer (Fig. 7).



**Figure 7** Angle of visual incidence expressed in the variety of terrain angles relative to the viewpoint in the photograph of timber harvesting activity, Frederick Arm, BC (photo by K. Fairhurst, 2005).

Variations in AVI will affect various components of visual perception, and in particular, will provide an indication of the perceived magnitude (Iverson 1985) of each land plane. That magnitude could also indicate the landscape's visual vulnerability. AVI also affects visual orientation, and the perceived pattern of interventions and features. As such, low AVI/apparency may increase the perceived fit in relation to its context. The AVI determines the perceived relative scale of the land planes of similar distance from the viewer, with direct-on, perpendicular intercepts being the largest possible in perceived scale, and with parallel or near-parallel intercepts with the land planes being the smallest, if evident at all. Other characteristics of the land plane and of intervening land planes, such as height of vegetation and viewing distance, will change perceptions. While not intending to diminish the importance of these characteristics in the visual landscape, it is

expected that by controlling these influences, AVI (i.e., apparency) will be shown to account for much of the variation in the perception of each land plane as illustrated in Figure 6.

AVI also has a strong influence on other variables. For example, a tree with dense foliage seen with a high AVI forms a shallow shadow zone (screening a short distance), while the same tree seen with a low AVI would have a deep shadow zone, screening a great distance behind it. This influence is an essential factor in landscape design. Where the AVI is parallel ( $0^\circ$ ), the screening distance will be infinite.

Viewing distance influences the relative scale of the land planes, obviously with up-front ones being seen as the largest and distant ones as the smallest, or non-evident. According to Iverson (1975), a 1 minute angle of vision might be considered as a basic measure of visual magnitude (28 cm at 1 km, or 2.8 m at 10 km) as it is the smallest discernable area or object to a person with 20-20 vision. Backlit skyline features, such as trees on ridges, are often more distinguishable than features within the landscape. Besides influencing the relative scale of the perceived land plane, distance also influences visual perception by introducing other factors such as atmospheric haze, which may obscure land planes that would be visible in clear conditions. By controlling or weighting visual magnitude by viewing distance, the AVI values for each zone could be used to guide land-use decisions.

### 2.2.2.3 Plan-to-Perspective Ratio

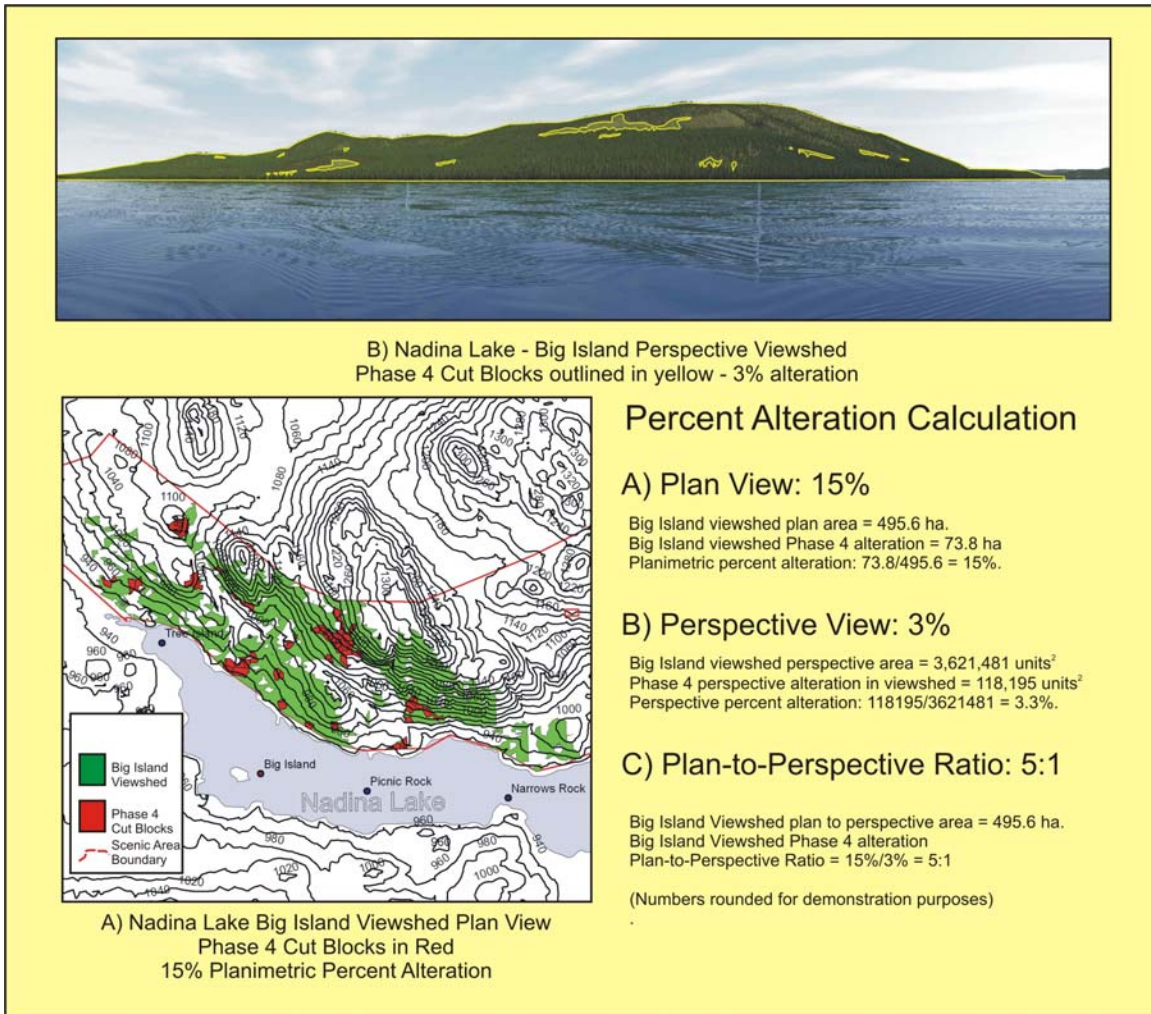
Visual magnitude is an indicator of how much planimetric area a visible element, such as a cutblock<sup>9</sup>, has in the visible landscape, and how much the given element is revealed in perspective views. The planimetric (map) area of any element in the visible landscape can be measured in terms of its actual area and as a percentage of the visible unit containing the element (e.g. a viewshed, or that portion of a Visual Sensitivity Unit (VSU) as outlined in the Visual Landscape Inventory (VLI) (BCMof 1995) that is visible from the viewpoint). The same element seen in perspective (picture) view can also be measured in area as a proportion or percentage of a VSU as it is seen in that particular view (i.e. in a photograph or computer rendering). The planimetric and perspective percentages for a visible element in the landscape can be considered together, as a ratio, known as the plan-to-perspective (P2P) ratio, as shown (C) in Fig. 8. As applied by the BCMofR, P2P is a "multiplicative factor that is used in a timber supply analysis to convert the percent alteration of a cutblock in perspective view to the equivalent percent alteration in plan view" (Nemec 2002), and is expressed by the following formula where "plan" means "planimetric":

$$P2P = \frac{\text{Block area (plan)}/\text{Total area (plan)}}{\text{Block area (perspective)}/\text{Total area (perspective)}}$$

Typically (as in Fig. 8), perspective percent alteration is lower than planimetric due to the screening effect of remaining trees.

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<sup>9</sup> "A specific area, with defined boundaries, authorized for harvest", as defined in the Glossary of Forestry Terms in British Columbia; (<http://www.for.gov.bc.ca/hfd/library/documents/glossary/Glossary.pdf>) (MoFR 2008c).



**Figure 8 Percent alteration calculation method in plan view (A) and perspective view with tree screening (B), with plan-to-perspective (P2P) ratio derived from the two measures (C), Nadina Lake Integrated Visual Design Plan Phase 4 example, with visible unit determined by the viewshed shown as the green area on the key map, and Phase 4 alteration shown as red, and the same alteration shown in perspective view as tan coloured cutblocks.**

Plan-to-perspective relationships were determined in research conducted for the BC Ministry of Forests (Olivotto 2001) based on photos and maps of existing operational cutblocks, measuring percent alteration of each cutblock as a percentage of the VSU to derive P2P ratios. The photos were taken from best viewing locations, in middle ground,

and directly in front of the cutblock where possible. Vertical AVI was measured in the field. That research provided the data for further analysis and development of predictive P2P models (Nemec 2002). Consideration of AVI was limited by the choice of single analysis viewpoints. Measurement factors included slope, cutblock design, cutblock size, and landscape area. The analysis found these factors to be "significant predictors of P2P". P2P ratios were expected to decrease by 20-24%, regardless of design quality, with each 10% increase in slope; medium design increases P2P by factors of 1.6 and good design increases P2P by a 3.6 factor. The results subsequently were used to adjust the P2Ps used in timber supply review (BCMof 2003). The findings indicated P2P could rise to as high as 14:1 for good design at 0% slope. It is important to note that the BCMofR determined that vertical slope was the most important variable yet affecting P2P. It is my understanding that, although vertical AVI has been determined by field measures in the above analyses, the agency has not fully tested the combined horizontal/vertical angle of visual incidence, in a controlled sense, nor used the findings to determine the influence of AVI on P2P, as does this dissertation research. The BCMofR procedure has the effect of maximizing horizontal and vertical AVI and therefore reduces the greater likely diversity of P2P measures (i.e., higher ratios). Higher ratios allow more planimetric alteration contribution in timber supply for a given (controlling) percent alteration in perspective view, whereas lower ratios reduce that potential allowance.

The Nemec predictive modelling analysis study (Nemec 2002) led to a revision of BCMofR modelling procedures for visual constraints in timber supply analysis, with the following predictive P2P ratios applied by slope classes in each landbase (BCMofR 2003) (Table 1).

**Table 1 Predicted P2P ratios for slopes 0% - 70% for all visual designs (BCMof 2003, Table 4).**

Slope	0%	10%	20%	30%	40%	50%	60%	70%+
P2P	4.68	3.77	3.04	2.45	1.98	1.60	1.29	1.04

While the BCMoFR does apply topographic slope to moderate P2P ratios, based on these broad slope classes, my dissertation was aimed at furthering the understanding of P2P by examining the contribution of AVI and its derivative, the new measure of landscape apparency, fully considering the combined horizontal and vertical AVI in strategic, tactical and operational plans. An earlier study "Black Peaks total resource plan and plan-to-perspective analysis" conducted for the BCMoFR provided understanding of the advantages of applying the concept of AVI-P2P relationships in a predictive model for timber supply (Fairhurst 1999). The study utilized ESRI ArcInfo software to build a terrain model of a coastal landscape, with forest cover stand height adjustments. A total chance harvest plan was designed to access all available timber over 5 passes with re-growth included. Visual landscape design techniques were employed to maximize harvest volumes while meeting the design VQO of Partial Retention<sup>10</sup>. The P2Ps of harvest areas were determined with a 100:1 weighting assigned to fully screened areas, as determined in perspective view. The overall P2P was 3:1, indicating that less constraint for visuals was warranted in planimetric calculations of timber supply than is routinely imposed by

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<sup>10</sup> A measure of visual quality, described in Sec. 2.3.2 and Table 5.

the BCMoFR. This dissertation was aimed to extend understanding about plan-to-perspective relationships beyond these BCMoFR initiatives.

### **2.3 BCMoFR Visual Landscape Management Process**

The Visual Landscape Management (VLM) Process in British Columbia provides the principle means for managing the visual landscape in the Province, particularly the forest landscape. The VLM is a significant EVA process, and amongst the most sophisticated, detailed and most quantitative of all VRM (EVA) systems, and was therefore selected in this dissertation to examine for potential contribution of landscape apparency towards its worth. It was expected that if good results were achieved with the VLM, then even better results would be expected for its contribution to more generic systems such as the BLM, USFS, and US State systems, other Provincial systems in Canada, and further afield such as in the UK and Australia. That is, if GEOptics works with, or in relation to, the VLM (the toughest comparison), then it could be even more useful to other systems.

The VLM has six phases, which are summarized in Table 2 and described in detail following that table.

**Table 2 The BCMoFR Visual Landscape Management Process (adapted from BCMoF 1997, Fig. 3).**

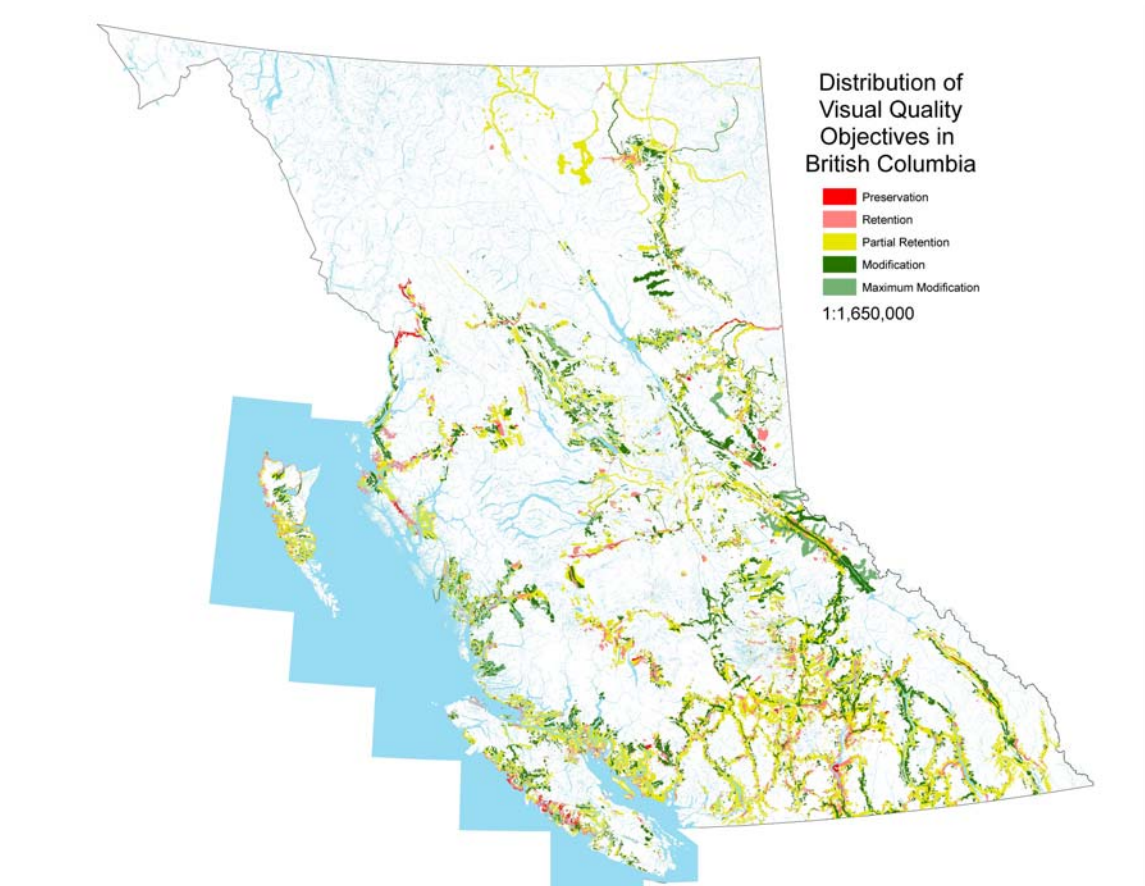
<b>BCMoFR Visual Landscape Management Process</b>		
PHASE 1	Visual Landscape Inventory	Identified visual values
		Delineation and classification of the provincial landbase into visually sensitive/not visually sensitive areas
		Delineation of visually sensitive areas into visual sensitivity units (VSUs) and their classification into visual sensitivity classes (VSCs)
PHASE 2	Visual Landscape Analysis	Recommended Visual Quality Classes (VQCs)
		Assessment of implications and options
		Modeling of current management practices for timber supply reviews
		Identification of scenic areas
PHASE 3	Setting of objectives, priorities and guidelines	Establishment of Visual Quality Objectives (VQOs)
		Approval of operational plans
		Visual simulations and design solutions
PHASE 4	Visual Landscape Design	Visual simulations
		Visual impact assessments
		Visual landscape design solutions
PHASE 5	Implementation	Timber harvesting and other resource management interventions; Achieved visual conditions;
PHASE 6	Monitoring	Program audits, Monitoring/inspections

The key features of the VLM phases are described in four sub-sections (Sections 2.3.1-2.3.4).

### **2.3.1 VLM Phase 1: Visual Landscape Inventory**

The British Columbia Ministry of Forests and Range Visual Landscape Inventory (BCMof VLI) process has been in existence since 1980, and has developed in complexity over the years (BCMof 1981; BCMof 1990; BCMof 1997). The procedure is intended to be broad in application, and is coarse in the level of detail. The landbase

covered by existing BCMoF VLI is large. There are currently 14.6 million hectares of mapped visually sensitive public lands, 72% of which are managed with visual quality objectives (VQOs<sup>11</sup>) as indicated by the Scenic Areas map in Fig. 9 (Jacques Marc 2010).



**Figure 9 VLI Scenic Areas with VQOs in British Columbia in 2009 (BCMofR, 2010).**

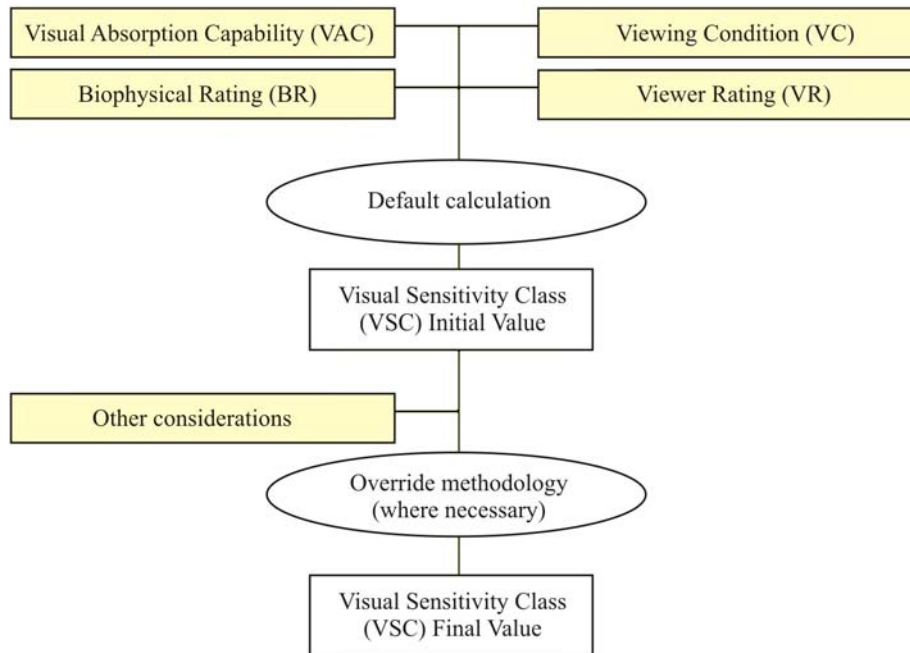
The BCMoFR VLI records the visual experience while moving along travel corridors. Topographical units, called a Visual Sensitivity Units (VSUs), are "delineated based on the homogeneity of the landform and of biophysical elements comprised in a scene" (BCMof 1997). Each VSU may extend for several kilometers and may be seen quite

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<sup>11</sup> The basic terminology and percent alteration limits of VQOs are defined and further discussed in Sec. 2.3.2 (Table 4).

differently from the array of viewpoints along the way, with different viewing distances, viewing angles, and characteristics of the same unit coming into and out of view. Factors within the VSU, such as the visual magnitude of an object or an alteration, and the screening capacity of tree cover, can vary considerably within the VSU and along the sight paths looking towards a particular VSU.

The VLI provides ratings of Visual Sensitivity Class (VSC), an overall measure of the sensitivity of the VSU to visual alteration, and an assessment of the likelihood that carrying out forest practices or other resource development activities in the VSU could give rise to some degree or kind of public criticism or concern. The VSC is a derivative of four factors 1) Biophysical Rating (BR) - a measure of the degree to which the biophysical characteristics of the VSU creates visual interest and draws peoples attention; 2) Viewing Condition (VC) - a measure of the condition under which the VSU is most commonly viewed; 3) Viewer Rating (VR) - a measure of the number of people likely to view the VSU and their anticipated level of concern about visual quality in the VSU; and 4) Visual Absorption Capability (VAC). These components are indicated in Fig. 10 (BCMof 1997). The VLI is consistent with visual vulnerability approaches discussed in Sec. 2.2.2, but represents a somewhat broader definition and measure of visual risk than the concept identified with landscape apparency in this dissertation.



**Figure 10 The BC Ministry of Forests and Range Visual Landscape Inventory System**

**(BCMoF 1997, Fig. 13).**

All four components of VSC are relevant to apperency, as they consider, in total, the inter-relationships between the landscape and the viewer. VAC is of particular interest in this examination of the BCMoF VLI as it relates directly to visual vulnerability. The VLI procedure considers four factors in the determination of a single VAC category (rated high, medium, or low) for each VSU: 1) average land slope, 2) surface variation – a descriptive measure of slope on a finer scale; bumps and hollows, or lack of them - a measure of relative roughness, 3) rock/soil/vegetative variety – factors often influenced by the previous two slope factors, including the effects of tree screening, and 4) aspect – the directional orientation of the landscape, which is a measure of lighting and shading of the landscape, which is, in turn, influenced by slope factors. Slope and surface variation often dominate the evaluation of VAC, particularly where the other values are weak. A

single slope class is assigned to each VSU (high - greater than 60%; moderate - 30-60%; low - under 30%). As the slope measure of VAC is applied singly across the entire VSU, it is incapable of responding to either major slope changes within the VSU, or to the detailed bumps and hollows that are missed at its scale of observation. While it may be consistent with the intended scale and application of the VLI, topographic slope as a single, generalized record across each VSU, offers little guidance to the land-use planner, designer or manager. Finer descriptive detail of Surface Variation is also evaluated into 3-classes as contributing to VAC. These two measures are tabulated along with 3-class ratings of aspect and rock/soil/vegetative variety and summed to fit in an overall 3-class rating of VAC as shown in Table 3 (BCMof 1997). The categorical system of generalized factors leads to the inability to differentiate within and amongst VSUs, a problem inherent in EVA systems raised by Daniel and Vining (1983).

**Table 3 Visual Absorption Capability rating system (BCMof 1997, App. 2, excerpt).**

Slope	H (3)	M (2)	L (1)
Aspect	H (3)	M (2)	L (1)
Surface Variation	H (3)	M (2)	L (1)
Rock/Soil/Vegetative Variety	H (3)	M (2)	L (1)
<b>VAC Initial Value</b>	H (10-12)	M (7-9)	L (4-6)
<b>VAC Final Value</b>	<b>H</b>	<b>M</b>	<b>L</b>

VAC is an important consideration when designing land-use to fit the landscape (VLM Phase 4). Human-made alterations that fit the level of pattern and detail already present in the landscape have a greater opportunity for maintaining visual integrity. Alterations that overwhelm the present variety and texture, in even high VAC areas, can nullify the potential benefits offered by the VAC for accepting human-caused alterations without impacting the visual integrity. If the procedures that are used to derive VAC are too broad in scale, the VAC may prove meaningless when it comes to actual design considerations. Similarly, such broadly-derived VAC, or one of its components – topographic slope, when factored into timber supply as it is in British Columbia (BCMof 1998; BCMof 2003), may influence the approved rate of harvest and therefore the economics of resource management.

VAC was applied by the BCMof from 1998 to 2003, as an adjustment factor for planimetric percent alteration limits for visual quality classes (VQCs) and visual quality objectives (VQOs) and applied in timber supply analysis (BCMof 1998). The weighting mechanism gave higher P2Ps to areas with higher VAC, summarized across the landbase. In 2003, VAC was replaced with topographic slope as an adjustment factor (BCMof 2003). The change from VAC to slope provided for greater resolution and detail within the VSUs, by categorizing the landbase in 10% slope classes using on GIS analysis. The slope factor recognized diminishing P2Ps as slope increased, until close to a 1:1 ratio was realized at 70% and greater. However, slope is broadly summarized across entire landbases, and is only optionally applied as a modifier of planimetric to perspective (P2P) ratios (previously discussed in Sec. 2.2.2.3) which are used in timber supply calculations

(Nemec, 2002). The BCMoFR's procedures for integrated visual design planning, visual impact assessment, and operational planning (VLM Phase 4) does provide the opportunity for greater consideration and precision of slope factors at those stages, however, once VQOs are legally established, operational plans must not exceed them. The basic terminology and percent alteration limits of VQCs/VQOs are defined and further discussed in Sec. 2.3.2 (Table 4).

Although intended to be cumulative in concept, the procedure for VLI is to select a single viewpoint or viewing location that offers the best possible view of the unit, otherwise known as the VSU Rating Point (BCMof 1997). In contrast to the apparency approach, the VLI's single point analysis and use of topographic slope does not address how the landscape is seen except from a narrow range of optimum viewing conditions. The BCMoFR method assumes all land planes within the visual unit are seen equally with the same perspective angle of view from the viewer to each land plane, presumably having accounted for any and all LCPs. No information is collected as to the perspective angles of visual incidence (AVI). Depending on the position of the viewer, both steep and flat terrain may have similar AVI and apparency. Using only topographic slope could result in an under-estimate of VAC if a steep slope is seen only laterally across the terrain, such as when looking up a side valley that is not accessible as a travel route. Conversely, topographic slope could result in an overestimate of VAC if slopes are gentle but viewing locations are high above them, such as from alpine ski runs or airplanes.

The consideration of how the landscape is seen is only coarsely evaluated as one element (viewing angle) of the four measures of Viewing Condition contributing to Visual Sensitivity Class. Viewing Angle is measured as one of a 3-class descriptor, either focal, tangential, or peripheral view, and is only considered in the horizontal, not vertical interface with the landform. Also, viewing angle is considered relative to the major travel direction, and not necessarily to the angle of the landform being viewed. Use of topographic slope as an indicator of VAC and as a moderator of P2P in timber supply analysis does not consider changing views of the same landscape from an often large number of viewpoints or view sources along a travel corridor. However, visual impact potential is considered from multiple viewpoints (although still limited in number) in the Design phase (VLM Phase 4).

### **2.3.2 VLM Phases 2 and 3: Visual Landscape Analysis and Objectives**

Visual quality is one of the 11 recognized values under the Forest and Range Practices Act of British Columbia (FRPA)<sup>12</sup>:

1. Soils
2. Timber including Forest Health
3. Wildlife
4. Fish
5. Water
6. Biodiversity
7. Cultural Heritage Resources
8. Resource Features

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<sup>12</sup> The Forest and Range Practices Act and its regulations govern the activities of forest and range licencees in B.C. The statute sets the requirements for planning, road building, logging, reforestation, and grazing. The link to FRPA is: <http://www.for.gov.bc.ca/code/>.

9. Recreation Resources
10. Visual Quality
11. Forage and Associated Plant Communities

Following from the VLI, recommendations for visual quality (VLM Phase 2) and legally established objectives (VLM Phase 3), are set by government regulation or from a higher level planning process, and are implemented in Forest Stewardship Plans. The Forest Stewardship Plan<sup>13</sup> (FSP) is a landscape level plan, which is focused on establishing strategies and results for conserving and protecting timber and non-timber resource values for forest management activities, including visual quality.

The descriptions and measures of visual quality classes and objectives are provided in Table 4. During the analysis process, initial ratings are called recommended visual quality classes (VQCs) with the same definitions as the VQOs. The percent denudation limit is the same measure as percent alteration. The terms are used interchangeably, though percent alteration is most commonly used.

In order to provide guidance in timber supply calculations, VQOs are assigned a quantification measure by way of percent denudation of the VSU (Table 4, Column 4). The measures assume clearcutting operations are the type of practice being measured. Other measures are applied to variable retention alterations (BCMoF 1998). The perspective denudation percentages (Column 5) were derived from public acceptance research<sup>14</sup> conducted by the BCMoFR (BCMoF 1996a) which helped derive the

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<sup>13</sup> An example of a Forest Stewardship Plan by Kalesnikoff Lumber Co. Ltd. can be viewed on-line at <http://www.kalesnikoff.com/pdf/Amendment1.pdf>.

<sup>14</sup> Reactions to forest management activity were tested with photographic slides (perspective views).

planimetric percentages. Planimetric denudation and related perspective limits together provide the initial plan-to-perspective ratio (P2P). Where VLI and full analysis is lacking, the BCMoF 1998 report provides further guidance: "it is recommended that the mid-point of each visual quality class be used. Where visual landscape design is actively practiced, a greater percent denudation value for clearcutting in each visual quality class may be used" (p. 6).

**Table 4 Visual quality objective/class definitions and related VLI visual sensitivity classes used for default VQC/VQO selection in visually sensitive areas without established VQOs (adapted from BCMoF, 1998).**

<b>Column 1</b>	<b>Column 2</b>	<b>Column 3</b>	<b>Column 4</b>	<b>Column 5</b>
VQC/VQO	VQC/VQO Letter Code	VQC/VQO Definition	Planimetric Percent Denudation Limits (Timber Supply Analysis Only)	Perspective Percent Denudation Limits for Operational Planning and VQO Achievement
<b>Preservation</b>	P	No visible man-made alteration	0-1	0
<b>Retention</b>	R	Alterations not visually evident	1.1-5	0.1-1.5
<b>Partial Retention</b>	PR	Alterations visually evident but subordinate	5.1-15	1.6-7.0
<b>Modification</b>	M	Alterations visually dominant but have natural characteristics	15.1-25	7.1-18.0
<b>Maximum Modification</b>	MM	Alterations visually dominant and out of scale	25.1-40	18.1-30.0

Areas of previous denudation (i.e., clearcut logging) are deleted from the percent alteration measure once they have achieved visually effective green-up (VEG)<sup>15</sup>. "VEG is the stage at which regeneration is perceived by the public as newly established forest. When VEG is achieved, renewed forest cover generally blocks views of site disturbances such as stumps, slash, road cuts, exposed rock and soils" (p. 8). VEG heights might range from 3m on flatter terrain to more than 8 m on steep terrain. VEG values were also derived from public perception research (BCMof 1994).

As discussed in Sec. 2.2.2., P2Ps are used by the BCMofR to determine and verify visual constraint relationships for visual quality objectives. Planimetric values are applied to visual quality objectives (VQOs) in timber supply analysis while perspective values are applied in harvest planning and layout to meet VQOs. Verification procedures examine the visual results of actual timber harvesting (perspective view) relative to the planimetric area involved. The Nemec study, discussed in that section, led to a revision of BCMofR modelling procedures for visuals constraints in timber supply analysis.(BCMof 2003).

New definitions of visually altered forest under the Forest and Range Practices Act (BCMofR 2008b) are more descriptive and speak to design quality rather than percent alteration limits (Table 5). The definitions are intended to be used when assessing how well an alteration achieves the VQO (VLM Phases 5 and 6), but are also used to guide the VLM design phase (Phase 4).

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<sup>15</sup> "VEG is the stage at which regeneration is perceived by the public as newly established forest. When VEG is achieved, renewed forest cover generally blocks views of site disturbances such as stumps, slash, road cuts, exposed rock and soils". VEG heights might range from 3m on flatter terrain to more than 8 m on steep terrain. VEG values were also derived from public perception research (BCMof. 1994. "A first look at visually effective green-up in British Columbia: a public perception study." Recreation Branch, Victoria, B.C., p. 8).

**Table 5 Definitions of visually altered forest under FRPA (BCMofR 2008b, Table 1, p.10).**

**Categories of visually altered forest landscape**

The following categories are prescribed, each according to the extent of alteration resulting from the size, shape and location of cutblocks and roads:

- (a) **preservation**: consisting of an altered forest landscape in which the alteration, when assessed from a significant public viewpoint, is
  - (i) very small in scale, and
  - (ii) not easily distinguishable from the pre-harvest landscape;
- (b) **retention**: consisting of an altered forest landscape in which the alteration, when assessed from a significant public viewpoint, is
  - (i) difficult to see,
  - (ii) small in scale, and
  - (iii) natural in appearance;
- (c) **partial retention**: consisting of an altered forest landscape in which the alteration, when assessed from a significant viewpoint, is
  - (i) easy to see,
  - (ii) small to medium in scale, and
  - (iii) natural and not rectilinear or geometric in shape;
- (d) **modification**: consisting of an altered forest landscape in which the alteration, when assessed from a significant public viewpoint,
  - (i) is very easy to see, and
  - (ii) is
    - (A) large in scale and natural in its appearance, or
    - (B) small to medium in scale but with some angular characteristics;
- (e) **maximum modification**: consisting of an altered forest landscape in which the alteration, when assessed from a significant public viewpoint,
  - (i) is very easy to see, and
  - (ii) is
    - (A) very large in scale,
    - (B) rectilinear and geometric in shape, or
    - (C) both.

### **2.3.3 VLM Phase 4: Visual Landscape Design and Visual Impact**

#### **Assessment**

Visual landscape design procedures are used to 1) evaluate whether or not measures specified to protect the scenic resource can achieve expected visual results necessary to meet VQOs, and 2) conduct visual impact assessment (VIA) at the operational scale in

British Columbia. An evaluation protocol was developed by the BCMoFR<sup>16</sup>, together with a field form<sup>17</sup>. Design guidelines are provided in the BCMoFR Visual Landscape Design Manual (BCMof 1995), which is also available as an on-line document<sup>18</sup>. Several example VIAs can also be found on the Forestry 491 Visualization and Forest Design web site, used as case studies<sup>19</sup>.

Details are collected at this stage about terrain features and viewing opportunities.

Usually a planned intervention is assessed from one to three viewpoints, particularly from the "worst case" viewpoint. VIA procedures are followed to identify the ability of the intervention to meet the VQOs by verbal definition, scale of the operation (measured as the percent alteration in perspective view as derived from 3D visualization with tree cover, (as in the example in Fig. 8), and design quality.

The effects of perspective foreshortening, tree-screening, and other influences useful to land-use design can be determined during the VIA process. While these are affected by slope, how the terrain is actually seen will have more influence, and therefore validity and utility for planning and design than topographic slope alone. The effect of tree screening with respect to AVI was demonstrated in Fig. 6. The screening effects of vegetation will diminish in both the steep and flat terrain as viewer position becomes perpendicular to the land plane, regardless of topographic slope.

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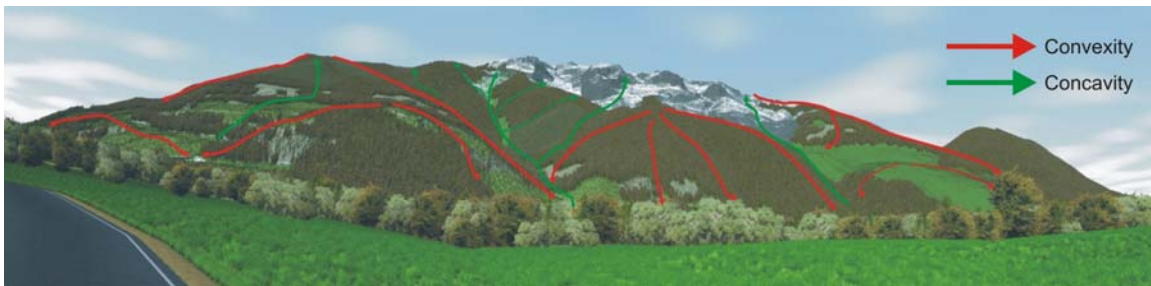
<sup>16</sup> BCMoFR Protocol for Visual Quality Effectiveness Evaluation Procedures and Standards - Nov, 2008 produced under the Forest Resources Evaluation Program (FREP) (<http://www.for.gov.bc.ca/ftp/hfp/external!/publish/frep/indicators/Indicators-VisualQuality-Protocol-Nov2008.pdf>),

<sup>17</sup> BCMoFR Visual Quality Effectiveness Evaluation form (<http://www.for.gov.bc.ca/ftp/hfp/external!/publish/frep/indicators/FS-1252-VQEE-Nov2008.pdf>).

<sup>18</sup> Available on-line at <http://www.for.gov.bc.ca/hfd/pubs/Docs/Mr/Rec023.htm>.

<sup>19</sup> [http://faculty.forestry.ubc.ca/sheppard/FRST491/FRST491\\_2008.htm](http://faculty.forestry.ubc.ca/sheppard/FRST491/FRST491_2008.htm).

One key design consideration worthy of mention is visual force, a concept adapted by the BCMoFR from the UK Forestry Commission (Bell 2004; Lucas 1991). The analysis method is provided in the Visual Landscape Design Training Manual (BCMof 1995). An example of a visual force line application within a VIA simulation is provided in Figure 11. Visual force is important as it considers firstly how the eyes access the landscape: up hollows and down ridges. The analysis also helps define the structure of the landscape, (i.e., the hollows and ridges). The analysis supports the design criteria specified in the training manual, such as not crossing a force line at right angles; merge upwards in hollows, downwards down ridges, etc.



**Figure 11 Visual force lines applied to a visual simulation of proposed timber harvesting; Pemberton, BC (source: RDI Resource Design Inc, 2005).**

The same training manual (BCMof 1995) provided first guidance for preparing comprehensive, long-term planning approach called integrated visual design (IVD). The approach was promoted and clarified in later study (BCMof 2001a) and procedures documents (BCMof 2002; BCMofR 2008a). The intent of IVD was to "provide long-term direction for the development of timber resources for an area of 5000 hectares or less in a manner consistent with higher-level planning objectives and respectful of other resource values....simultaneously in an integrated fashion" (p. 1). The design procedures

follow a structured set of analyses, which include: 1) defining the visual unit; 2) establishing management objectives; 3) assembly of resource inventory information, typically including VQOs, timber flow , recreation, tourism, water quality, biodiversity fish and wildlife cultural heritage, soils and terrain hazard and forest health; 4) conducting a resource analysis, including visual force and land features analysis; 5) developing a concept design; 6) develop a detailed design, and testing through visual simulations. An example of an IVD, the Nadina Lake IVD is presented in Chapter 4 as a commercial application of apperency. Results were presented to the focus groups (Chapter 5).

### **2.3.4 VLM Phases 5 and 6: Implementation and Monitoring**

Stages 5 and 6 are the implementation of plans and the monitoring of their success. The VQOs, derived from VLI, having influenced timber supply, then influence harvest operations. On-the-ground practices then are intended to achieve the VQOs. The monitoring process is intended to track that achievement through effectiveness evaluation (BCMofR 2008b), and through compliance and enforcement. The Compliance and Enforcement Program is responsible to protect the public's interest in the management of B.C.'s forests and the generation of revenue<sup>20</sup>.

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<sup>20</sup> For more information, the BCMofR's Compliance and Enforcement Program website is <http://www.for.gov.bc.ca/hen/program/role.htm>.

## **2.4 GEOptics Apparency and VRM**

The potential applications and contributions of GEOptics apparency approach and tool to VRM systems (using the BCMoFR VLM process as an example) are shown in Table 6. The stages of GEOptics, which are mentioned in the table, are discussed in Chapter 3 (Table 7). The research questions and evaluation criteria (from Sec. 2.1) by which to determine the success in answering the questions through internal and external tests are also provided in the table.

**Table 6 Potential contribution of GEOptics apparency to Visual Resource Management Processes**  
(using the BCMoFR VLM as an example).

	<b>General VRM Category (Phase/Stage)</b>		
	<b>Inventory</b>	<b>Analysis</b>	<b>Design</b>
<b>EVA/VRM systems (general)</b>	Visual vulnerability, visual magnitude, visual thresholds; angle of visual incidence (AVI); VAC; Visual contrast rating.	Studies provide tests and measures;  VRM systems set classes and objectives for VRM; usually with descriptive but not numerical constraints.	Provide design considerations and examples.
<b>Current VLM (BCMoFR)</b>	Visual vulnerability factors (VAC) VLM Phase 1: VLI.	VQOs: verbal/numerical constraints for visual quality (P2P weighting by slope class factor over landbase (VLM Phases 2-3).	VQOs guide planning, design, and operations. Numerical con; new information acquired at this stage from additional viewpoints, visual simulation, visual impact assessment, integrated visual design (VLM Phase 4); leading to implementation (Phase 5) and effectiveness monitoring (Phase 6).
<b>Potential Applications of GEOptics Apparency</b>	Apparency rating as a potential visual vulnerability/risk/AVI factor derived from cumulative viewpoint analysis (GEOptics Stages 1-4, see Table 7)	Potential VQO Apparency Class as a numerical P2P weighting factor for each landbase as completed; potentially-entered in TSR (GEOptics Stage 5).	Apparency values potentially applied to guide design and operations; visual simulation and visual impact assessment; hierarchical integrated planning (GEOptics Stage 6).
<b>GEOptics Research Questions</b>	Research Question 1: Is apparency applicable to VLI/VLM?	Research Question 2: Can apparency improve planning?	Research Question 3: Can apparency improve design? Research Question 4: Can apparency improve integrative modelling?
<b>Apparency Evaluation Criteria</b>	<ol style="list-style-type: none"> <li>1) Feasibility – how apparency works, quantifies, integrates;</li> <li>2) Validity and Defensibility – internal and external reliability; precision, accuracy; objectivity;</li> <li>3) Effectiveness – in comparison to, or contributing to current VRM system(s) and GIS tools; and,</li> <li>4) Usability (by others).</li> </ol>		

The next section (Sec. 2.5) relates the concepts and considerations raised in this chapter to each other and to GEOptics apparency, as a summary of this chapter, and in preparation for the full discussion of GEOptics development, testing, applications, results and conclusions which are presented in the subsequent chapters (Chapters 3-6).

## **2.5 Chapter Summary**

I began this chapter by stating the research questions, tasks, and evaluation criteria for my dissertation (Sec. 2.1). I next presented key related concepts and procedures that provide some understanding and relevance to the research questions, namely expert visual assessment systems, key concepts, and the limitations of current approaches (Sec. 2.2). These are commonly known as visual resource management (VRM) systems employed by several major resource management agencies to address visual quality and vulnerability in the inventory phase, set management objectives in the analysis phase, and encourage/require management procedures to meet those objectives in the design stage. I looked specifically at visual vulnerability or risk assessment, and related concepts of visual magnitude and visual thresholds in past studies and current VRM procedures, examining the BCMoFR as one important example. Studies related to the concept of angle of visual incidence (AVI) were briefly discussed. AVI was very central to the development of apparency, and to my identification of the perceived need for such a tool as a potential component of VRM processes. The use of plan-to-perspective (P2P) ratios by the BCMoFR and topographic slope as a modifier of the ratios, for consideration in timber supply analyses, was also examined, raising the shortcoming of that approach in

its inability to respond, in any level of detail, to AVI and viewer mobility (multiple viewpoints). I proposed that the finer level of detail in the GEOptics approach compared to current VRM systems (such as the BCMoFR VLM) for addressing visual vulnerability/risk may provide a useful and effective contribution to these EVA-type systems. Constructed for smaller management units and then amalgamated spatially, for entire corridors and entire landbases, apparency might be used as a weighting factor for VQOs and as a potential influence in Timber Supply Reviews. The same level of detail can be directly applied to design and integrated planning. These potentials are developed in Chapter 3 and tested internally in Chapter 4, and externally with the focus groups in Chapter 5.

### 3 Methods

I have developed a systematic technique called landscape apparency (an illumination analog for the angle of visual incidence ) to quantify the cumulative visual risk of each land plane relative to its neighbours, from a set of viewpoints, or landscape control points (LCPs). The following sections describe how the new landscape apparency tool was developed, how it works, how it relates to, and builds on, the key concepts described in Chapter 2, and the procedures for its use. The methods for the internal testing of the apparency tool, and those results, are presented in Chapter 4, and methods for the external evaluation of the tool with focus groups, and those results, are described in Chapter 5.

#### 3.1 Developing the Apparency Tool

The apparency illumination analog is produced in Visual Nature Studio<sup>®</sup> (VNS), a commercial visualization software program produced by 3D Nature, LLC. VNS was selected because it enables illumination modelling and for its current familiarity and availability, both to myself and to forestry practitioners. VNS is principally a 3D visualization tool with capabilities not available, or not easily available, in GIS programs such as ESRI's ArcGIS<sup>®</sup>. While ArcGIS provides a hillshading capability, and the "sun" can be set at a single location by advanced controls, those controls are not available "out-of-the-box". In contrast, VNS provides an illumination/shadow mapping procedure<sup>21</sup> that

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<sup>21</sup> VNS processes the shadows while it is rendering the illumination map as a single entity (GEOTIFF). As such, the output GEOTIFF has been called, alternatively, an illumination/shadow map or just an illumination map in this dissertation.

readily provides for cumulative illumination from specific, multiple viewpoints. With no requirement for programming knowledge, light sources can be set accurately at any number of viewpoints and at accurate viewpoint elevations. VNS also offers 3-D visualization capability with full forest cover portrayal that can provide photorealistic visual interpretation and used for measuring plan-to-perspective (P2P) relationships<sup>22</sup>.

VNS is used in two principle applications of GEOptics: for illumination map (shadow map) production – the basis of apparency; and for perspective visualization production. It was considered an advantage to be able to employ VNS for multiple operations in GEOptics. It was also advantageous that VNS is compatible with ESRI's ArcMAP which is also in common usage, and which I used in my dissertation research to prepare data for VNS, validate certain aspects of VNS use, and also to classify illumination map output images from VNS. The applications are discussed in later sections of this chapter.

The GEOptics procedure was designed for users with moderate, but general, GIS skills and familiarity with the use of Visual Nature Studio software, which requires some advanced skills or training, but no programming (i.e., a skill level of a typical GIS technician). An organization's GIS department or the consulting community would likely prepare apparency maps and analyses while actual use of the maps for analysis, planning, harvest design, and decision-making would be made by planning and operations personnel.

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<sup>22</sup> As a disclaimer, it should be noted that, through my company, RDI Resource Design Inc., I am a vendor of VNS software, and predominantly use the software in my commercial visualization projects.

Although it was not an objective in my dissertation to further compare VNS with other software applications, commercially-available 3-D visualization software programs might be found which provide similar capabilities as VNS for the purposes used in apparency (illumination) mapping and visualization. Many types were reviewed for their use in forest planning (Mendoza, Song, and Mladenoff 2006) and landscape planning (Paar 2006).

Apparency was tested in three principal trial landscapes in BC: 1) Stella Lake on northern Vancouver Island, 2) Howe Sound in southwest BC near Vancouver, and 3) Nadina Lake in northwest BC as located in Fig. 2. All three sites were representative of mountainous BC landscapes, and all three study areas provided water-based viewing opportunities and typical high sensitivity viewing conditions.

Preliminary development and testing of the landscape apparency procedure commenced with the Stella Lake project in 2004, followed by early testing in the Howe Sound project that same year. Based on the Stella Lake project, it was determined that an illumination technique could be constructed from multiple viewpoints, and the resulting illumination (reflectance) values could be used to differentiate AVI (and therefore visual risk) collectively from those viewpoints. The Stella project is discussed further in Chapter 4.

Subsequently, the approach was further tested in a commercially-oriented project – the Nadina Lake Integrated Visual Design (Fairhurst, 2006). Apparency values were used in the timber harvest scheduling process of all operable forest over a full rotation (forest growth cycle of about 80 to 100 years). That project is also discussed in Chapter 4.

Following that project, more development and testing took place to validate the

illumination/reflectance and shadow mapping techniques with the Dishtin imaginary landscape. The Howe Sound project was again used to test the quantification of apparency and its visual and numerical results, including percent alteration in perspective view, plan-to-perspective ratios, and its implications for timber supply planning. Comparisons were developed in that project between apparency and slope, viewshed, and times-seen analyses. The use of apparency for harvest design was also examined in the Howe Sound model. Finally, the Nadina project was revisited to test long term automated design using the Atlas/Forest Planning Studio scheduling program. The tests and results are presented in Chapter 4.

### **3.2 How the GEOptics Procedure Works**

The GEOptics procedure involves six stages which fit, conceptually, into the three general categories of VLM discussed in Chapter 2 (Table 6). The first four stages (Stages 1-4) fit into the "Inventory" category, Stage 5 is in the "Analysis" category, and Stage 6 is in the "Design" category (Table 6). The basic, stand-alone, apparency "inventory" maps are produced in Stages 1-4, providing the means for their classification, validation, and further use. Stage 1 is data assembly; Stage 2 is the essential, key procedure in the entire process – the production of cumulative illumination / shadow maps in Visual Nature Studio; Stage 3 is the classification of apparency maps for analysis; and Stage 4 is conversion to vector polygons and the further integration of GEOptics apparency with other resource values through GIS analysis. The remaining two stages are interpretive applications that provide an examination of plan-to-perspective relationships of apparency, and cover three levels of integrated resource planning: 1) the strategic level –

resource allocation at the broad scale and over the long term; 2) the tactical level – harvest scheduling and landscape level plans over the mid-term , and 3) the operational level over the short term. Potential timber supply analysis considerations and visual constraint influences at the strategic level are considered in Stage 5; and applications in tactical and operational forest planning at the design scale are considered in Stage 6. The stages, together with the related tests and applications, are summarized in Table 7.

**Table 7 GEOptics procedures, products and applications, by Stage and Research Question.**

<b>GEOptics Landscape Apparency</b>						
<b>Procedures, Products and Applications</b>	<b>Inventory</b>				<b>Analysis</b>	<b>Design</b>
	<b>Stage 1</b>	<b>Stage 2</b>	<b>Stage 3</b>	<b>Stage 4</b>	<b>Stage 5</b>	<b>Stage 6</b>
	<b>Terrain</b>	<b>Illumination</b>	<b>Classification</b>	<b>Integration</b>	<b>Analysis</b>	<b>Planning</b>
	Construct terrain DEMs.	Produce cumulative illumination / shadow maps as basis for apparency mapping.	Classify apparency map by RGB values, single light, cumulative lights; compare with raster viewshed, times-seen, and slope mapping.	Integrate apparency map with other resource databases, leading to further applications.	Percent alteration and plan-to-perspective calculations for apparency classes, for strategic planning applications.	Tactical and operational planning applications of apparency mapping.
<b>Projects</b>	Howe Sound project; Nadina IVDP.	Pre-tests: Stella Lake; Dishtin.	Howe Sound project; Nadina IVDP.	Howe Sound; Nadina IVDP.	Howe Sound; Nadina.	Nadina IVDP; Atlas-Nadina; Howe Sound.
<b>Research Question</b>	1. Does apparency improve Inventory?				2. Does apparency improve strategic planning?	3. Does apparency improve design? 4. Does Apparency improve tactical / operational planning?

The procedure for building the apparency maps can be completed with VNS, independently of a GIS, but ArcGIS, or another comparable GIS software program, is required for conversion of raster apparency map images to vectors and for further analysis.

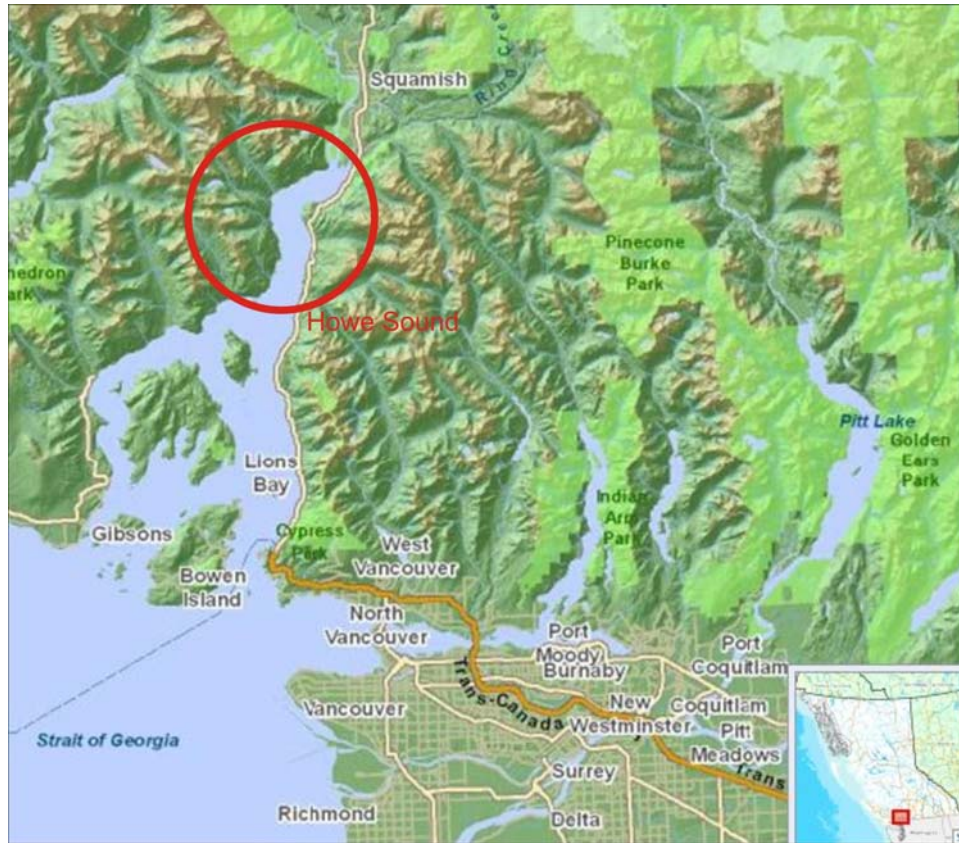
### **3.2.1 Stage 1: Terrain Model Assembly**

In Stage 1, ArcMap is used to prepare the digital elevation model (DEM) terrain and to locate and digitize the analysis viewpoints (LCPs). 3D Analyst, an extension within ArcGIS 9, is used to prepare the terrain model for Visual Nature Studio. Alternatively, the terrain model can be built, and viewpoints located, directly in Visual Nature Studio. While there is a range of terrain products with various resolutions and contour intervals, conventional British Columbia Ministry of Environment, Lands, and Parks (BCMōELP) Terrain Resource Information Management program (TRIM)<sup>23</sup> was selected as it is a standard for use in British Columbia (BCMōELP, 1992). A typical TRIM mapsheet contains the following data: principally, it contains a digital elevation model (DEM) in elevation point form<sup>24</sup>, and also contains 20 metre contours, and other features such as cultural, land cover, transportation and water features. The west side of Howe Sound was selected as a test area. Howe Sound is close to Vancouver and leads to Squamish, a town on Highway 99 to Whistler (Fig. 12).

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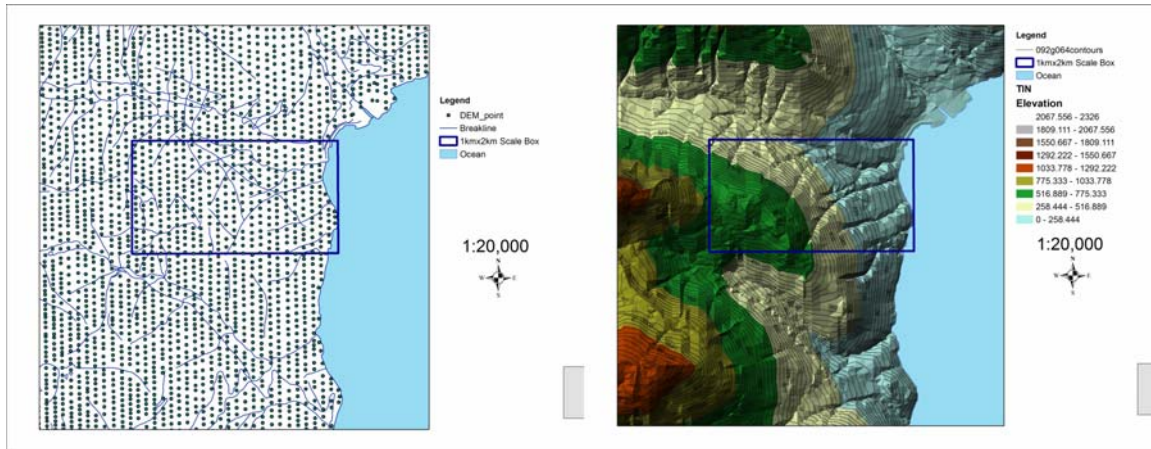
<sup>23</sup> The TRIM program produces digital maps covering the province of British Columbia at a scale of 1:20 000. The cartographic framework for this mapping is the Universal Transverse Mercator coordinate system, based on NAD83 (1983 North American Datum). Each mapsheet is precisely 12 minutes of longitude wide by 6 minutes of latitude high. More information can be found at: <http://www.ilmb.gov.bc.ca/crgb/pba/trim/>.

<sup>24</sup> A DEM is a series of mass points and break lines defining the earth's surface shape with elevation and position values.



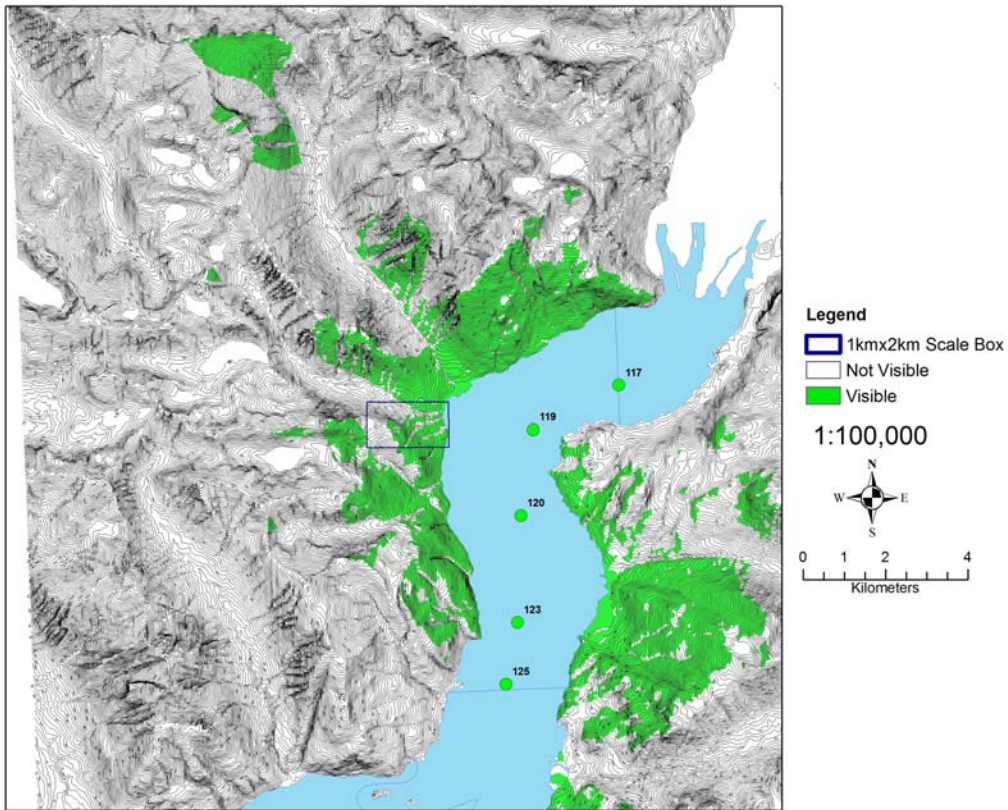
**Figure 12** Location map of the Howe Sound west side model test area (adapted from iMAPBC).

Figure 13 shows a portion of the terrain model used in the Howe Sound project. The model was built as a triangulated irregular network (TIN) in the ArcGIS 3D Analyst<sup>®</sup> extension (right image) from digital elevation model (DEM) points and breaklines (left image). DEM points are gridded with 75 m spacing where slope is less than 25°, and 50 m spacing where slope is greater than 25° (BC Ministry of Environment 1992). A 1 km by 2 km scale box is outlined in blue in each map for reference. The same scale box is present in most Howe Sound maps presented in the dissertation. North is at the top of the each map.



**Figure 13 Stage 1: preparation of base terrain data in ArcMap, including building the TIN (right map) from TRIM DEM points and breaklines (left map).**

The TIN is then converted to a raster grid or Ascii file in ArcGIS using the 3D Analyst<sup>®</sup> extension. The resolution for the grid DEM was set at the time of DEM creation (25 m in the Howe sound project; 10 m in the Nadina project). While in ArcGIS, conventional visual landscape analysis products can be prepared to assist further analysis. Products from the 3D Analyst<sup>®</sup> extension, such as viewshed maps, times-seen maps, slope maps, hillshades, and other tests of DEMs, were prepared in order to provide some understanding about the accuracy and limitations inherent in terrain data, and also for apparency modelling tests, as presented in Chapter 4. The following example is a single viewpoint viewshed produced in the Howe Sound project from LCP 120 (Fig. 14).



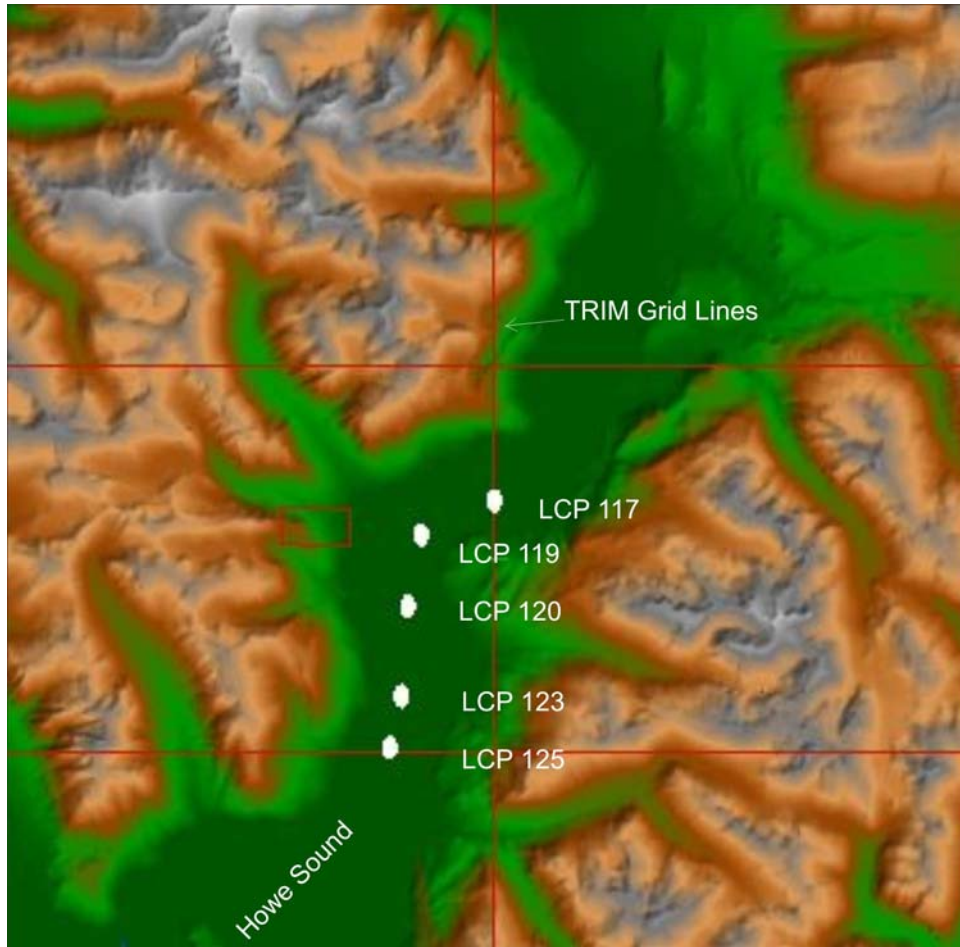
**Figure 14 Basic terrain and viewshed in ArcMap with (green) viewshed produced in 3D Analyst from a single viewpoint (LCP 120).**

It is also appropriate at this stage to assemble conventional GIS layers that will be used for forest development planning, environmental constraints and opportunities analyses, economic analysis, integrated visual design planning (BCMofR, 2002), and long term planning (Boyland 2003) (Stages 5 and 6).

## **3.2.2 Stage 2: Illumination/Shadow Map Production**

### **3.2.2.1 Creating the VNS Illumination Model**

The ArcMap terrain DEMs and viewpoints (LCPs) prepared in Stage 1 are imported in VNS in order to produce the illumination/shadow maps - the principal element of appearance mapping. VNS grids the input DEMs in its own standard manner and file extension to create VNS DEMs at the desired resolution. Light sources are assigned to the LCPs. The number of lights set at viewpoints to produce the illumination maps, and their locations, are variable. In the Howe Sound model, lights were set at each of 5 LCPs (established viewpoints in the Sea-to-Sky VLI) (Fig. 15).



**Figure 15** Lights are set at LCPs in the VNS DEM to produce the illumination maps. The terrain is assigned a default colouration based on elevation. The 1kmx2km scale box is outlined in red to the left of LCP 119.

The lights at each LCP are positioned at eye level in the VNS model (a standard 2 m above ground or water level at the viewpoints). The elevation may be varied according to the mode of travel (the eye of a viewer in an automobile may be 1.5m above the surface, in a kayak may be 0.5 m above surface, in a cruise ship passenger may be 20 m above the surface).

The number of LCPs can vary as appropriate for the project, depending on the scale of the landscape being assessed, the complexity of the landscape, known viewpoints, or by intent of the application. LCPs can be selected where viewing intensity or duration is greatest, such as from towns, resorts, ski hills, parks, or public beaches. If there is no particular, or known, distinction of viewpoint significance along a travel corridor, LCPs may be set equidistantly, such as every kilometer or much closer, as preferred or needed, along the viewing-path within the 3-D terrain model.

Lights are intended to be sufficient in number and location to capture the major distinctions in landforms as seen from the view corridor, including side faces and back-end faces. As with viewshed mapping, the greater the number of viewpoints, the less the uncertainty of missing areas in complex landforms, though more viewpoints will require increased illumination map production time. For example, in the Howe Sound model, the five points were selected from actual VLI rating points identified in the Sea-to-Sky Frontcountry VLI (BCMofR 2006), at approximately 2000 m intervals, and spanning 8500 m between the first and last points (Fig. 15).

Placement and number of LCPs/lights is a sensitivity factor, addressed in Chapter 4. All viewpoints were water-based in the Howe Sound project as a selection preference for the analysis, though they could also have included land-based (highway views). The other two test locations, Stella Lake and Nadina Lake (location map, Fig. 2), also had water-based viewpoints that represented the greatest viewing opportunity and viewing intensity.

The water-based viewpoints afforded broadly open and clearly sensitive viewing opportunities while opportunities from land-based viewpoints are frequently narrowed or

screened by intervening terrain, vegetation, or structures. Highway viewpoints, and other land-based viewpoints, such as at recreation use areas, will frequently have vegetative screening obscuring potentially visible areas. Specific viewpoint knowledge, such as tree screening, can be applied to set individual view cones (width of view) if required.

Detailed roadside screening information is generally lacking in the VLI, given its broad scale, and the limited capability for updating the inventory. Detailed knowledge about screening is not usually gained until operational level planning is carried out and the best viewing opportunities ("worst case" viewpoints) are selected and analyzed.

While generalized vegetation heights could be added to the model based on forest cover heights as provided in the BCMoFR Vegetation Resources Inventory (VRI)<sup>25</sup>, I decided that bare ground would be the best way to generate and portray initial apparency, as the terrain is effectively constant, while vegetation cover will undergo continual change, and at the VSU or landscape level is relatively a minor influence on overall apparency.

Vegetation data from VRI was added to the VNS model at a later stage (Stage 5).

### **3.2.2.2 Light Source and Surface Reflectance Attributes**

Visual Nature Studio is used to illuminate terrain models with lights set at specific locations that equate to observation points (viewpoints; landscape control points). Each light is omni-directional, illuminating a full 360° arc, projecting equally in all directions, vertically and horizontally. Each light has a red-green-blue (RGB) primary colour with a

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<sup>25</sup> The digital inventory of vegetation resources in British Columbia:  
<http://www.for.gov.bc.ca/hts/vri/intro/index.html>.

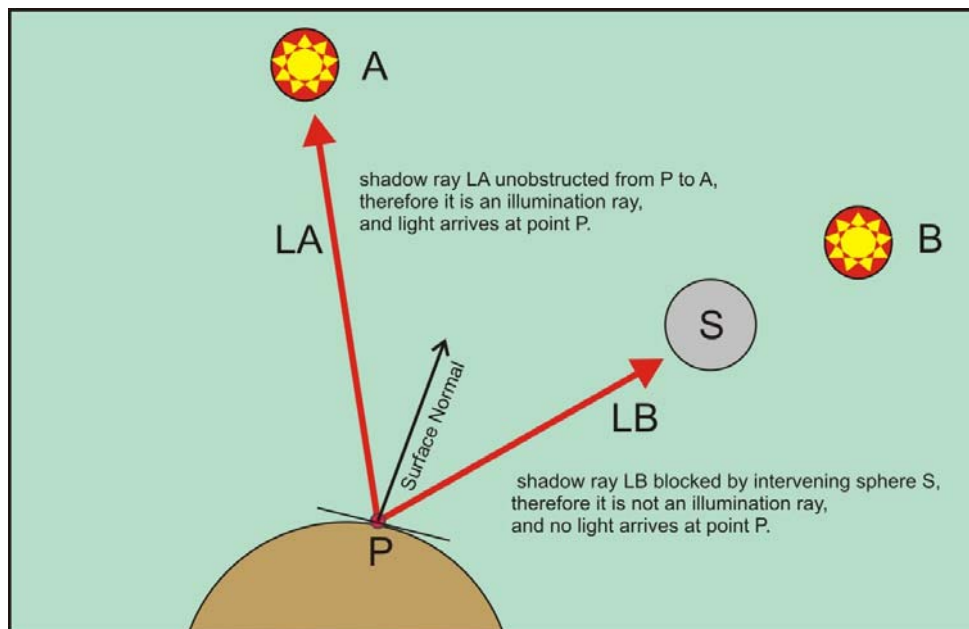
colour value of 255 for each, creating a white light with value (intensity) of 100 (100% at 255-255-255). The RGB color model is an additive color model in which red, green, and blue light are added together to produce a broad array of colors. The lights illuminate the terrain surfaces with varying intensity according to the angle of incidence of light rays as they hit each surface plane (i.e. the same amount of incoming light is spread over a larger area of land at lower AVI, and therefore the reflected intensity per unit of land is less).

The terrain model displays a bare, grey "ground" surface, devoid of vegetation. Greater reflected illumination indicates land cells with greater angle of visual incidence and therefore visual vulnerability (risk). The illumination response from each light could be measured individually in perspective view simulations at each light location. However, to determine the cumulative illumination across the landscape for use in GIS analysis and planning requires that it be determined in planimetric view. A shadow mapping technique is applied within VNS to eliminate all unseen areas, as discussed in Sec. 3.2.2.3. The illumination/shadow map is rendered and saved as a geo-referenced raster illumination image (GEOTIFF), discussed in Sec. 3.2.3. The GEOTIFF is then imported as a layer in the ArcMap model of the same terrain for use in planimetric (map) planning procedures.

When producing shading in computer graphics, with backward ray tracing, it is "the ray that carries the light away from the surface, and eventually back to our eye" that is called the incident ray (Glassner 1989). In his overview of ray tracing, Glassner, in Chapter 1, defines four types of light rays: 1) pixel rays or eye rays which carry the light directly to the eye through a pixel on the screen; 2) illumination rays or shadow rays which carry light from a light source directly to an object surface; 3) reflection rays which carry the light reflected by an object back to the eye; and 4) transparency rays which carry light

through an object. The pixel rays carry the photons which end at the eye after passing through the screen, or pass from the eye through the screen in backwards ray tracing (more efficient process for computation). By knowing the illumination and surface physics at a point on a surface, the properties of the light leaving that surface can be determined. In the case of apperency, we are interested in reflected light, and specifically, diffusely reflected light.

Glassner calls the shadow ray a "feeler" ray. If a shadow ray reaches a light source without interruption from an opaque surface, the ray is turned around (in our thinking) and is thought of as an illumination ray which carries light to the eye from the light source (Fig. 16).

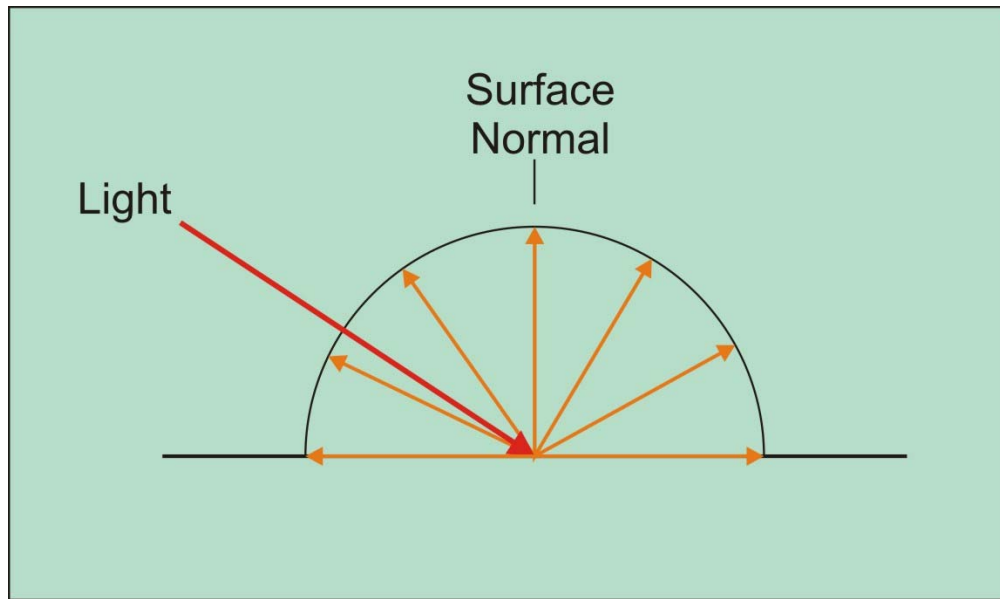


**Figure 16 Diagram of two shadow rays, with only the unobstructed one (LA) becoming an illumination ray (as adapted from Glassner, 1989, p.11).**

The VNS software program offers two types of surface reflectance – spectral reflectance (sunlight on water), and diffuse "Lambertian" reflectance<sup>26</sup> (Glassner, p. 315), which bounces rays in all directions from the terrain as from a matte surface. If the surface receiving the light was fully reflective and light bounced off the surface at the same angle of incidence, as would sunlight glancing of a water surface, then reflectance would greatly vary with the position of the observer. If so, planimetric illumination maps would be useless. With diffuse reflectance, the only importance is how much of the surface is visible to the light source. Diffusely reflected light is reflected in all directions with equal amplitude, and that amplitude is directly proportional to the cosine of the angle between the incident light and the normal (Glassner, p. 134). The (surface) normal is the perpendicular to the surface (Fig. 16). This means that a plan view of an illumination map is as accurate a record of AVI from a light source to the terrain model as is the perspective view from the light source. The following figure from the University of Waterloo's Computer Graphics Lab (Waterloo 2009) illustrates diffuse reflectance (Fig. 17) with light bouncing equally in all directions.

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<sup>26</sup> Lambert's Law is the fundamental description of diffuse light transport. It states that diffusely reflected and transmitted light is scattered in all radiated directions with equal intensity, and that this intensity is proportional to the intensity of the incident light, the reflectance of the surface, and the cosine of the angle between the incident light and the surface normal (Glassner, p. 315).



**Figure 17 Lambertian diffuse reflectance (Waterloo 2009).**

With spectral reflectance disabled, and in the absence of ambient light, VNS produces only diffuse reflectance, meaning that observed reflectance intensity (illumination) from a given land cell will be the same regardless of observer position, provided the particular surface cell in question is visible at all from that position. Basically, the amount of light diffused by Lambertian reflection is proportional to the AVI at the cell.

The Lambertian property is key to the apparency mapping technique. As relative illumination intensifies for a given light source, it remains the same regardless of the position of the observer, it therefore permits measurement from overhead, and the production of the resultant planimetric illumination map.

When preparing the illumination maps for apparency, specular reflectance is disabled and diffuse reflectance is enabled in the VNS model. Further discussion of the illumination properties is provided in Chapter 4.

### 3.2.2.3 Illumination Mapping Procedures

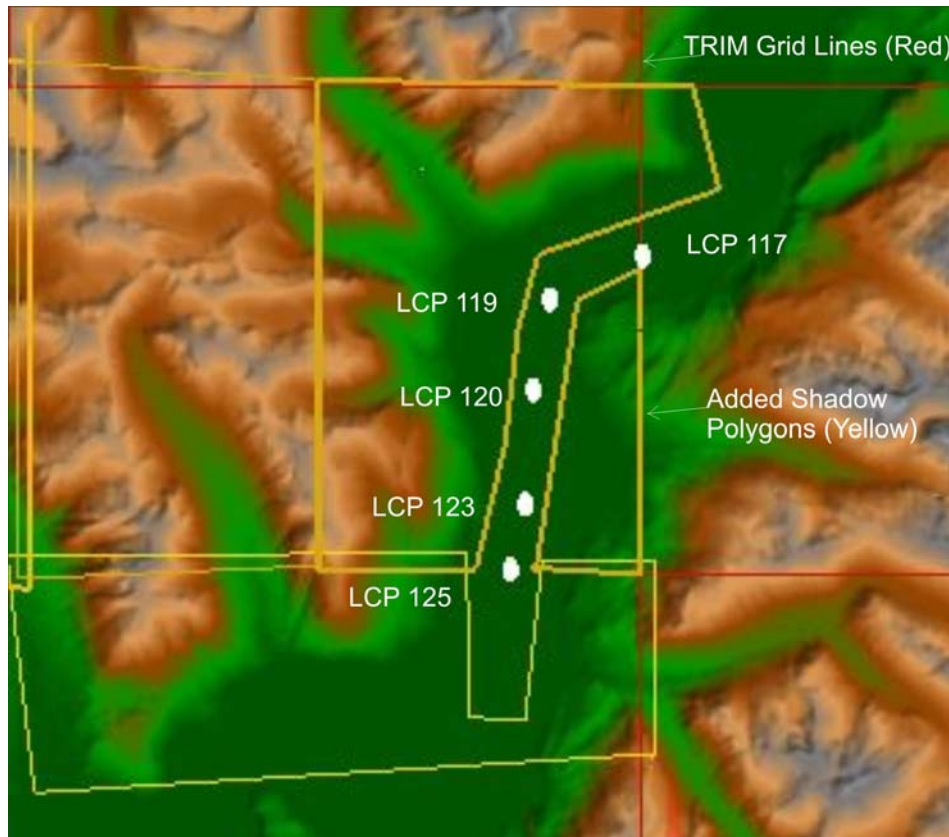
Illumination map production is the principle procedure unique to the GEOptics approach leading to apparency classification and applications. The illumination map production required a simultaneous VNS procedure, called shadow mapping, "the method that considers light blocking" (Hanson 2009a), to be activated in order to render the illumination maps with completely shaded terrain where the light, set at the viewpoint, cannot reach due to intervening terrain. To produce the illumination maps in VNS, a "shadow" is cast on all terrain surfaces where the light doesn't shine, (representing non-visible areas from the viewpoints,). There is no ambient light in the model so there is no effect of light reflecting off the ground or sky.

Shadows must be attached to vector polygons so that they can be rendered. To create shadows, the VNS "shadow" must be attached to one or more shadow vectors (polygons) covering the land surface of interest in an apparency project. As a starting point for shadow vector polygon coverage, the standard neatline polygons outlining the TRIM mapsheets<sup>27</sup> can be imported into VNS and assigned as the shadow map vectors (the red rectangles lines in Fig. 18). However, the shadows will not be created for a particular a shadow polygon if the light source is located within that shadow polygon. Additional shadow vectors may be required to complete the illumination/shadow map correctly as shadow vectors cannot cover light points (the white dots in Fig. 18). The additional shadow vector polygons can be any shape, such as following each side of a roadway or each side of a waterway route on which the LCPs are located. They can be quickly

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<sup>27</sup> The 1:20,000 scale polygon grid for British Columbia is freely available from GEOBC (<http://ilmbwww.gov.bc.ca/crgb/products/free.htm>).

digitized in VNS, or polygons can be drawn in ArcMap and imported into VNS. The figure shows yellow shadow polygons that were added in VNS to avoid the light points. VNS processes each shadow vector for each light separately, therefore processing time increases with the number of lights and the number of shadow vectors.



**Figure 18 Shadow map vector-setting procedure in VNS is applied to TRIM neatlines (red) covering the study area, with added vectors (yellow) to avoid light positions (white).**

Without shadow mapping, an illumination map will erroneously light all terrain faces facing the light source, even those hidden from view, but will have shading on back faces (Fig. 19(A), the same behaviour as with the ArcGIS hillshade function. A correct illumination map with only the visible front faces illuminated (produced from LCP 117 in the Howe Sound project) is shown in Fig 19(B).



**Figure 19 Comparison of terrain illumination in VNS: A) without shadow mapping (an erroneous illumination map); B) with shadow mapping (a correct illumination map).**

Examples of a single light illumination map and a multiple light map are presented for the Howe Sound project in Figure 20. The image for the single light source (left image) is quite dark in appearance, while the multiple light image (right image) is much brighter, revealing the cumulative illumination (apparent) of five light sources. Face-on perpendicular land planes have 100% light intensity (bright white; RGB values 255, 255, 255); fully parallel planes and planes turned away from the sight line (i.e., no contact) have 0% intensity (black; RGB values 0, 0, 0); with gray-scales in between that represent

intermediate light intensities. There is, by necessity, no ambient light, nor is there any spectral reflectance, just diffuse reflectance. The capability of adding lights together to derive the cumulative effect, and to consider the viewpoint importance by changing light intensity, were tested for validity, accuracy and replicability in Chapter 4.



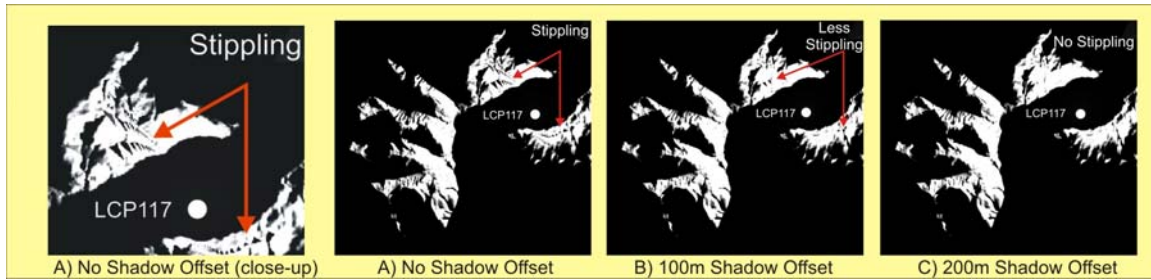
**Figure 20** Examples of single light at LCP 120 (left image) and multiple light (right image) cumulative illumination maps (Howe Sound project); Lights are set at the LCPs shown in Fig. 18.

A multiple light, cumulative illumination map can be prepared with all lights on simultaneously in the VNS model for the Howe Sound project as illustrated above (Fig. 20, right image). The landform is brighter with the five lights, but not much can be inferred quantitatively at this point. This cumulative illumination map is essentially the cumulative apparency map, prior to classification (Stage 3). The apparency (illumination)

map is importable as a geo-referenced TIFF (GEOTIFF) image into ArcGIS and easily registered with the existing GIS layers for further analysis (Stage 3).

A successful illumination map will have illumination correctly restricted to the viewshed area, and can be compared with viewsheds produced from the same viewpoint(s) for validation of accuracy (see Ch. 4, Fig. 39 and related testing presented in that chapter).

Shadow maps consume large amounts of memory, and steps are taken in the VNS program to reduce their memory footprint. The downside of this is that shadow maps sometimes are "fuzzy" about whether a surface is behind a shadow-casting surface or not. Sometimes the shadow system confusedly believes that a surface is behind a shadow-caster when in fact it is itself the shadow caster, and can't possibly be behind it (Hanson 2007). The result is "stippling" that can be seen in the left image (A) of Figure 21. VNS shadow mapping uses a compensation factor called "Shadow Offset". This appears as the "Shadow Offset from Terrain" control in the Cast Shadows tab of the Shadow component editor. The procedure for adjustment is discussed in Chapter 4. Adjusting this higher will reduce (B) or prevent the stippling (C) as shown in Figure 21.



**Figure 21 VNS Shadow map with stippling artifacts evident with no shadow offset (A); partially controlled by applying 100 m shadow offset (B); and fully controlled with a 200 m offset (C); in single light (LCP 117) illumination map, Howe Sound model.**

Setting the offset value too high will result in shadows that no longer appear to "attach" to the base of the item casting the shadow. Sometimes it may be necessary to use a large-area shadow with one setting, and one or more small-area shadows with a different setting to properly capture features of this type. Additional illumination tests are presented in Chapter 4.

### **3.2.3 Stage 3: Apparency Classification**

In Stage 3, the procedure returns to ArcMap in order to examine the apparency values within the GEOTIFF raster apparency maps produced in VNS. The geo-referencing of the raster image in VNS is beneficial to its further use as it can be added directly to the existing ArcMap project that contains the original terrain, viewpoints, and additional data such as forest cover.

Individual raster illumination maps can also be used to produce a cumulative apparency map for an entire array of LCPs by using the raster math "add" function in ArcMap. This approach may be useful for producing apparency maps over a long corridor, allowing

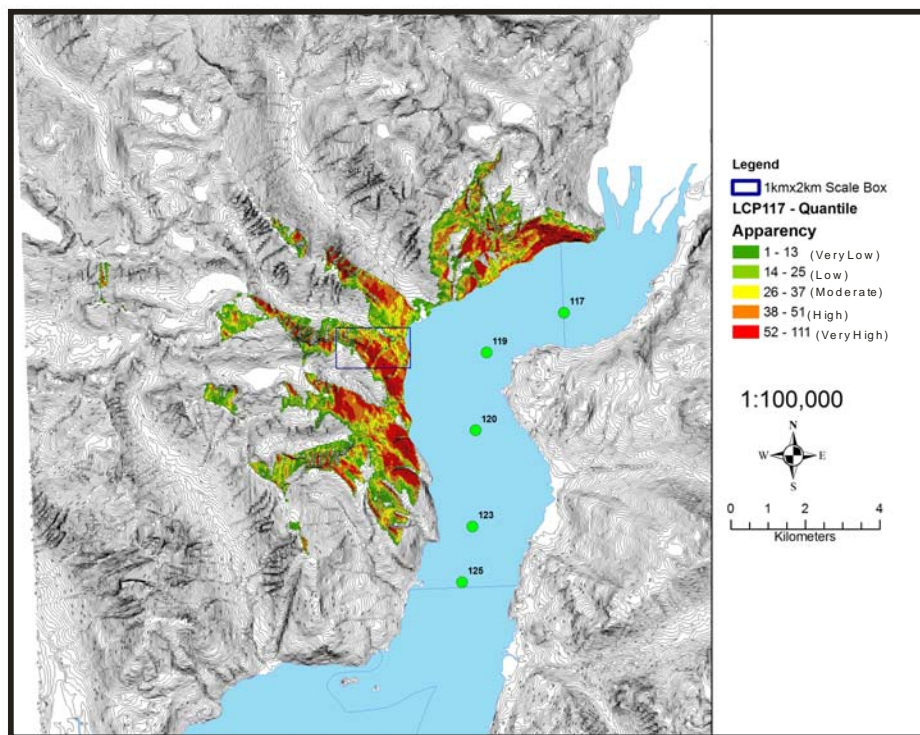
lights set a greater distances to be eliminated from the apparency model as one of several techniques for applying a distance fall-off or restriction in the model (when examining a particular stretch of a corridor landscape). The Howe Sound and Nadina projects simply assigned a distance limit – that being the scenic area boundary established by the extent of the existing visual sensitivity units or viewsheds that were to be addressed in the projects. Fall-off mechanisms available for the lights used in VNS were tested and assessed in Chapter 4.

For apparency classification of individual and cumulative viewpoint mapping, the original RGB illumination image needs to be converted to a single band image to allow classification. This is easily accomplished using the "times" raster math function and multiplying by a factor of 1.

For differentiation, apparency can be classified into a number of classes by an ArcGIS classification method (e.g. equal interval, natural breaks (Jenks), quantile, or standard deviation) that brings out the distinctions fairly and clearly. Quantile classification was selected as the preferred method for testing since it provides an equal number of cells in each group, and nearly equal total area of each group, with variations based on the classification process itself. This provided the means to compare across quantiles (similar proportions of the landbase) and conduct further analysis, such as P2P calculation. For the Howe Sound model, a 5-class system was prepared to facilitate comparison with a 5 viewpoint times-seen map and 5-class topographic slope map produced in ArcGIS (Chapter 4). A six class system for Howe Sound was also tested for a demonstration of one class finer classification, and the Nadina project (Stage 6) was assigned a 10 quantile

class approach. Greater classifications would break up the surface patterns into increasing fragmentation; fewer classes would generate broadly consolidated areas of apparency.

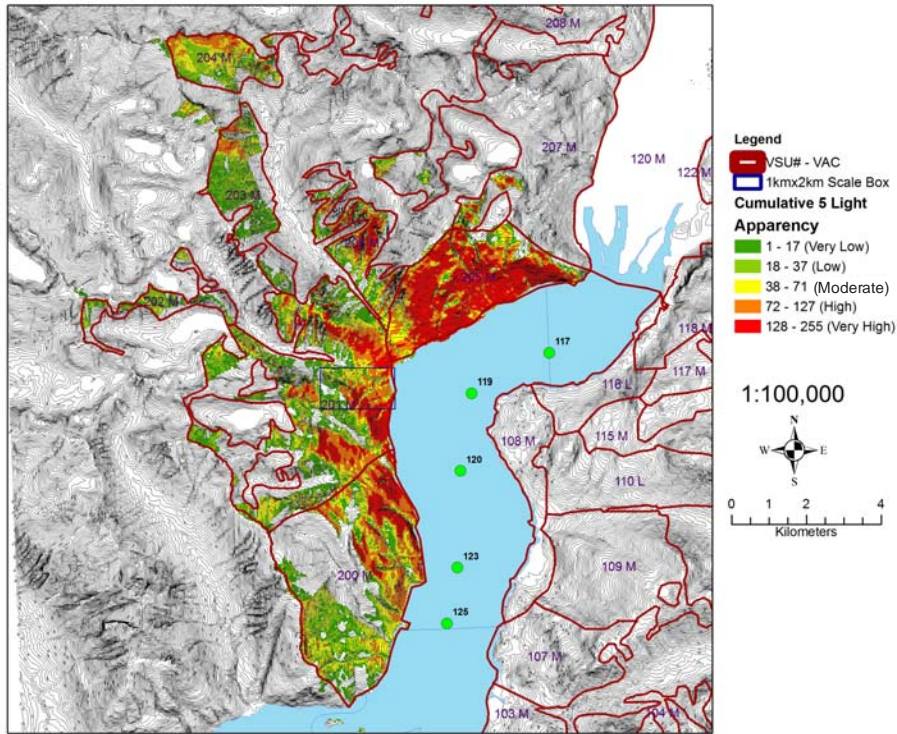
With a 5-class classification, the image illumination values are colour-classified from green to red in 5 steps in ArcMap. As an example, Fig. 22 reveals the apparency (visual risk) as would be experienced from LCP 117 with a single light source. The green zones represent the least apparency and therefore the least visual risk in terms of visual landscape alteration. The red zones, ranging in RGB values of 52-111, represent the highest apparency and therefore the greatest visual risk.



**Figure 22 Single LCP (single light) apparency map, showing apparency classified by RGB values, from a single light source at LCP 117.**

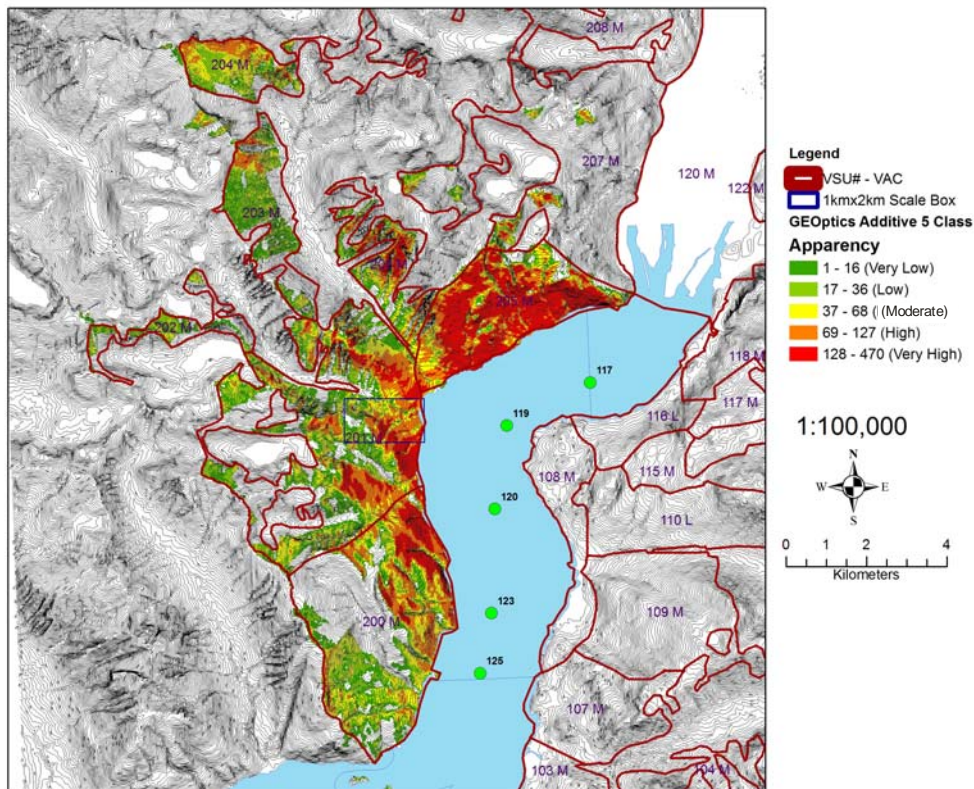
In the single apparency map, areas of greater and lesser need for consideration of visual impact issues in tactical and operational planning are revealed, but the overall visual risk from all viewpoints along the travel route is not yet determined. A single LCP apparency map can be compared to another LCP map to determine relative risk levels in each view, or between landscapes in different areas, using the apparency ratings for comparison, and perhaps for constructing a quantification guide, such as by grouping LCPs arbitrarily by high apparency range (e.g. >100 maximum pixel value), medium apparency range (e.g. 50-100 maximum pixel value), and low apparency range (e.g. < 50 maximum pixel value). As different viewpoints will have different intensity ranges, actual value ranges would have to be determined from each apparency map before preparing a classification table. In the Howe Sound west side model, which contained steep terrain reaching to 1600 m elevation, the five individual LCPs ranged in illumination intensity of reflected light from maximum values of 98 RGB value in LCP 119 to 111 in LCP 117, and averaged 106 RGB value overall (of a theoretical maximum of 255).

The cumulative illumination raster GEOTIFF map produced in VNS with all lights turned on can be imported into ArcMap and classified using the same quantile approach. The cumulative pixel values are limited to a maximum of 255. The RGB 255-255-255 maximum illumination value for each pixel is a limitation of the cumulative all-at-once illumination technique in VNS. Steep terrain and multiple light points can potentially push values to maximum without the ability to differentiate quite large parts of the critical landscape (Fig. 23). Existing VLI Visual Sensitivity Units are outlined in red for reference



**Figure 23 Howe Sound westside five quantile class cumulative apperency raster map from a single VNS illumination map GEOTIFF with lights at all 5 viewpoints turned on simultaneously; VLI Visual Sensitivity Units added for reference.**

To provide greater latitude with respect to illumination intensity, ArcMap's raster math function can be utilized to add the individual LCP illumination maps (one for each viewpoint) to produce a single additive cumulative apperency map with a pixel value (illumination) range that is not arbitrarily limited in its upper range value (Fig. 24)



**Figure 24 Howe Sound five quantile class additive cumulative apperency raster map produced from the addition of 5 individual illumination maps (additive method) from each viewpoint; VLI Visual Sensitivity Units added for reference.**

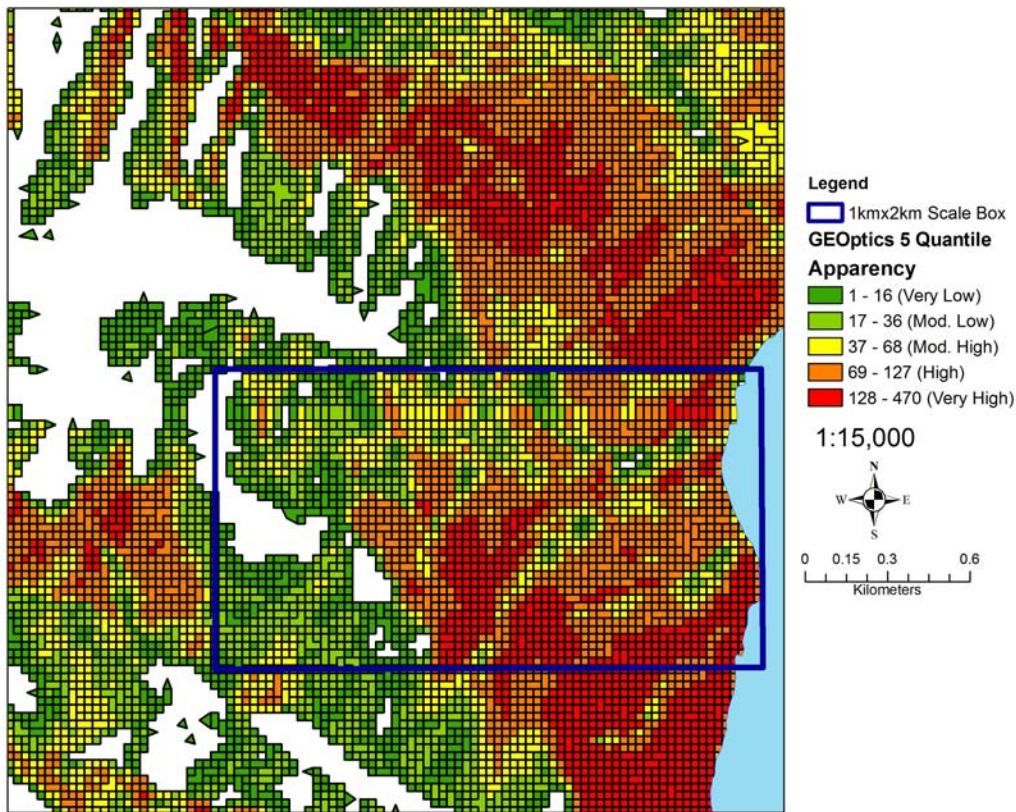
The approach is further discussed in Chapter 4, together with detailed comparison of apperency with slope analysis and times-seen analysis (Chapter 4).

The apperency values and patterns, together with slope maps, topography and forest cover data, could be used as a guide when locating areas of greater and lesser visual risk when considered for development, and potentially inform the type, scale, and design of that development, including integrated visual design planning. The cumulative apperency map serves as a GIS layer, complete in itself. However, greater utility and analysis capability may be realized from the apperency map when linked to the attributes of other

GIS layers (Stage 4). Internal tests and results of the apparency mapping approach are presented in Chapter 4.

### **3.2.4 Stage 4: Apparency Integration**

In Stage 4, the GEOptics individual and cumulative apparency GEOTIFFs are converted from raster pixels to polygons to enable further GIS analysis. Polygonization allows attachment of attributes from other GIS layers such as forest inventory data and environmental considerations. The polygons will have the identical illumination value of each pixel, but as an attribute. There is no known loss of accuracy in the conversion process, and the vector map will be virtually identical to the raster image map, except that some simplification occurs automatically in the process as ArcMap merges neighbouring pixels with identical values (Fig. 25).



**Figure 25 Polygonized apparency map derived by converting a raster GEOTIFF apparency map, with apparency values attached as attributes, classified by quantiles as with the GEOTIFFs.**

**Automatic simplification of polygons (polygon merging) is evident within the scale box.**

Attributes such as forest cover heights and volumes can be attached to each polygon in a shapefile format and assessed to determine the operable forest area in the apparency dataset. The GEOptics apparency polygonal layer with its forest and environmental attributes can then be imported into VNS to derive plan-to-perspective relationships for potential consideration in strategic level planning (Stage 5) and to help develop tactical total resource / integrated visual design planning scenarios and operational plans (Stage 6). The procedure for considering all constraints together with apparency was applied in the Nadina Lake Integrated Visual Design Plan, discussed in Stage 6.

### **3.2.5 Stage 5: Strategic Level Analysis Applications**

At the strategic planning level (Boyland 2003), the BCMoFR uses plan-to-perspective (P2P) ratios to check and refine the planimetric percent alteration limits for each visual quality objective, with the numbers providing a component of timber supply calculations. As briefly described in Sec. 2.2.2.3, and in detail in Sec. 4.5, the P2P ratio is the visible area of timber harvesting alteration in plan view, as a percentage of the total area visible in plan view (ArcMap or VNS planimetric map), divided by the amount of visible area of the same elements in perspective view as a percentage of the amount of visible area in total in perspective view (VNS simulation with tree screening) as presented in Chapter 2 (Fig. 8). Total area is generally restricted to a defined viewshed, landform or visual sensitivity unit as identified in visual landscape inventory (BCMoF 1997).

While an operational design would have tree heights assigned based on actual forest cover data, the apparency test approach used generic 25m-30m tree height and 300 trees per hectare in the VNS simulation model to provide for a controlled approximation of the screening capacity of the forested terrain. For the purpose of testing, the vegetation effect was evenly placed throughout the model to enable the examination of apparency without variances due to land-use that might be present on typical forested terrain.

Two apparency analyses were prepared using the Howe Sound model: 1) bare land, and 2) with tree screening. The bare land visualizations provided a clear understanding of the extent and patterns of the various apparency classes from each viewpoint. An example of bare land apparency visualization is presented in Fig. 52. An example of tree-screened visualization is presented in Fig. 53. The complete array of apparency by each viewpoint

in the Howe Sound model and the P2P ratios of each class is presented in Chapter 4, followed by a discussion of the results. The aggregated apparency approach (the visual result of aggregation by stepwise addition of apparency classes) and the P2P ratios of the aggregations is shown in Chapter 4 (Sec. 4.5) and provided documentation and discussion of those ratios.

The apparency quantile and aggregated apparency quantile approach were also used to test the visual design influences of apparency in the landscape as shown in Sec. 4.5. They were not intended as timber harvest plans in themselves as there was no consideration of forest cover attributes or environmental, economic, and operational constraints. Actual design and applications using apparency are presented in Stage 6 (Planning) (Secs. 3.2.6 and 4.6).

Key factors in assessing the implications of the visual design influences are: 1) visibility distinctions amongst apparency classes; 2) "fit" in the landscape in regards to shape and pattern, lay of the land; lines of force; 3) landform composition, such as breaks, ridges and hollows; 4) percent alteration in perspective view; and 5) P2P ratios.

Both approaches indicate the contribution of apparency to visible change in the landscape, a measure of that change that can be compared with existing limits of change (BCMof 1995) and the potential for apparency to help guide landscape design and automation, discussed in the results in Chapter 4 and in the conclusions (Chapter 6).

### **3.2.6 Stage 6: Tactical and Operational Planning Applications**

Stage 6 is the application of GEOptics apparency in at the tactical and operational levels of forest planning (Boyland 2003). Four applications are provided to address a range of forest management issues within typical visually sensitive landscapes in BC: 1) the first commercial application of GEOptics apparency in the Nadina Integrated Visual Design Plan (IVDP); 2) an extension of the apparency data from that plan to guide an automated design using Forest Planning Studio (Atlas); 3) preparation of a simple cutblock plan guided by apparency mapping generated in the Howe Sound project; and 4) application of Howe Sound apparency mapping with actual forest cover data as provided in the BCMoFR vegetation resource inventory (VRI)<sup>28</sup>. The methods and results for Stage 6 are presented in Chapter 4 (Sec. 4.6).

### **3.3 Chapter Summary**

In this chapter, I described the development of the apparency tool, and how it works. The 6 stages of apparency, fitting as they do into 3 general categories - inventory, analysis and design, were described with their constituent parts. Commencing with the base terrain model and viewpoint selection (Stage 1), the apparency process was defined and tracked from initial apparency derivation as illumination maps (Stage 2) with the provision of some understanding of light characteristics and shadow mapping, through

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<sup>28</sup>More information about the VRI can be found at: <http://www.for.gov.bc.ca/hts/vri/intro/index.html>.

classification techniques (Stage 3) and conversion to vector polygons for further analysis and integration with other resource management data (Stage 4), strategic planning applications (Stage 5) and tactical/operational planning applications (Stage 6). Agency tests and results follow these preliminary descriptions in the internal tests, applications and results chapter which follows (Chapter 4).

## 4 Internal Tests, Applications, and Results

Derivation of landscape apparency required several stages, each with decision factors that could affect the internal validity, sensitivity, and reliability of the GEOptics model, and, ultimately, its external validity and utility for users of the model. A number of post-development tests were conducted. The individual factors examined, and the relation of the internal and external tests are summarized in Table 8.

**Table 8 Internal tests, trials, and applications of GEOptics apparency modelling.**

<b>Internal Tests and Applications</b>					
<b>Stage 1 Terrain Modelling</b>	<b>Stage 2 Illumination</b>	<b>Stage 3 Classification</b>	<b>Stage 4 Integration</b>	<b>Stage 5 Analysis</b>	<b>Stage 6 Planning</b>
Terrain model validation.	Illumination/ shadow map production / evaluation.	Apparency classification; comparison with viewshed, timeseen, and slope mapping.	Integration and further applications.	Strategic analysis applications.	Tactical and operational planning applications.
<----- Research Question 1 -----> Can GEOptics improve inventory?				Research Question 2: Can GEOptics improve planning?	Research Question 3: Can GEOptics improve design? Research Question 4: Can GEOptics improve operational planning?
Evaluation Criteria 1. Feasibility 2. Validity 3. Effectiveness 4. Usability					

Each stage of GEOptics apparency required tests and trial applications to validate the model based on the research questions and the evaluation criteria. These tests of model functions and applications addressed components within each of the 6 stages of GEOptics shown in the table. There was no capacity for direct cross-comparison of apparency with

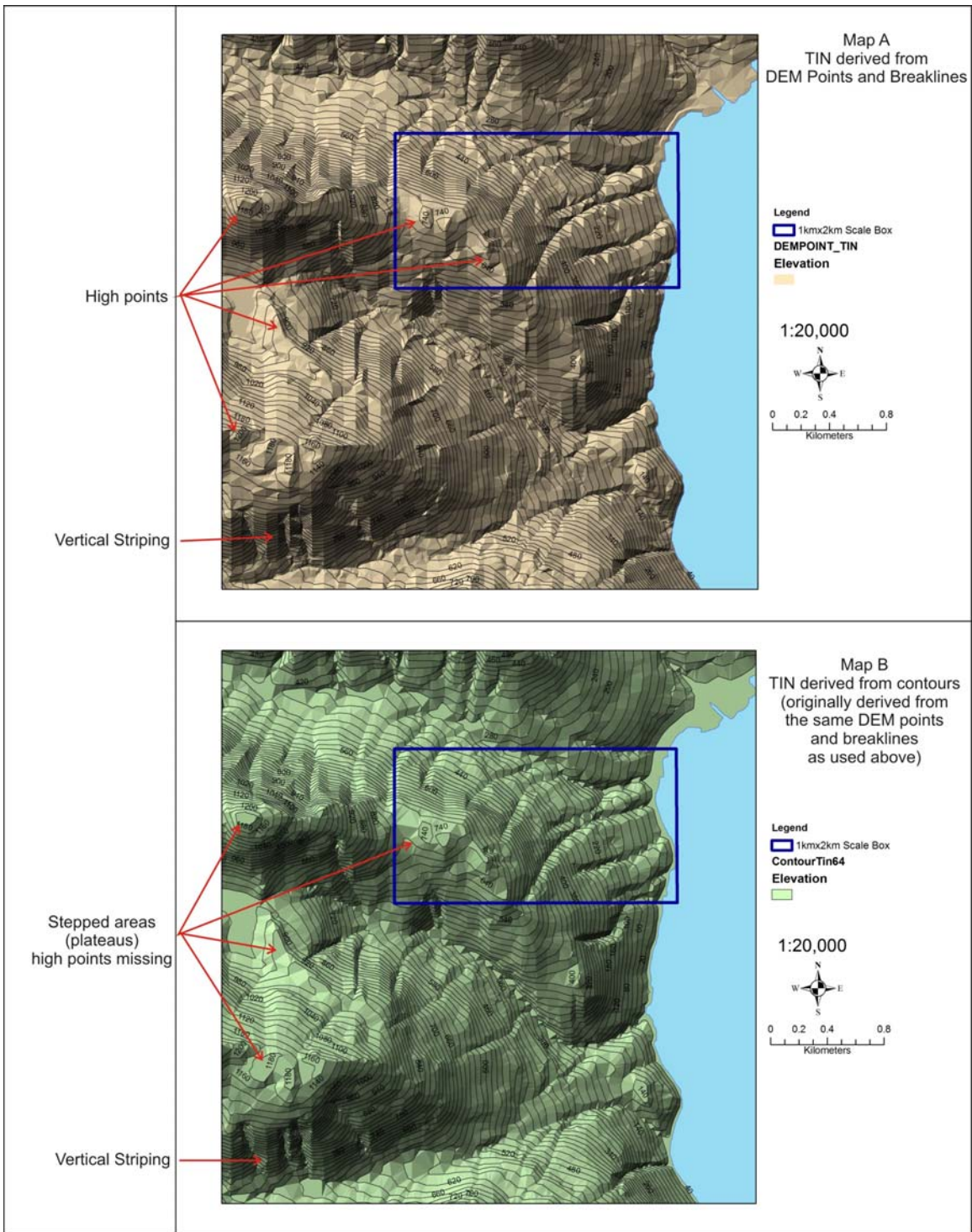
existing similar studies as the apperency mapping process and product is unique, though some elements are identical to other 3-D terrain analysis procedures (e.g. viewshed mapping, times-seen analysis). The rule-based objective output was considered to be reliable in itself as the results would be the same each time the model was ran with the same parameters, though parameters could change with the user (external validity question). Internal tests, trials, and applications conducted, by stage of the GEOptics approach, were as listed in Table 8. Results of each test and application are provided immediately after the description of each test application.

#### **4.1 Stage 1: Terrain Modelling Construction**

Terrain modelling is a component of landscape inventory and therefore addresses, in part, the first research question (Table 8). Terrain models are representations of the real world. The required accuracy for British Columbia's TRIM coverage is that 90% of all well-defined features be coordinated to within 10 metres of their true position, and that spot elevations and DEM points be accurate to within 5 m of their true elevations (BC Ministry of Environment 1992). Given the established quality control procedures, availability, and general acceptance, including for purposes of landscape visualization in BC, TRIM maps were already deemed to meet "acceptable" evaluation criteria for validity and utility. Beyond production standards of accuracy, which components are selected for terrain surface creation, the order of processing, and final gridding resolution each influence the resulting DEM.

Production artifacts can also affect the DEM. Digital terrain surfaces are normally created from DEM points and breaklines (shown in Fig. 13). An example of the resulting terrain model for the Howe Sound project area is shown in Fig. 26, Map A. When contours derived from DEM points are used to create terrain models, steps or plateaus can occur on the created surface (Fig. 26, Map B). Use of contours should be avoided for these purposes; no further testing of the contour approach was conducted.

Another effect was examined for presence in the models: a striping effect resulting from photogrammetric line scanning procedures. The striping effect with a north-south orientation was noticed in the Howe Sound terrain model. Low-angled illumination emphasizes the striping in a DEM gridded from DEM points using ESRI ArcMap 3D Analyst (Fig. 26).



**Figure 26** Map A: TIN produced from TRIM DEM points and breaklines; Map B: TIN produced from TRIM contours; using ArcGIS 3D Analyst revealing vertical striping effect in both and stepping error in contour-derived Map B. (Howe Sound west side).

As the stripes represent somewhat raised ridges, slope and aspect could be affected, and therefore appearance outcomes could be influenced. The extent of this effect, and actual influence on appearance, was not measured. A Ph.D. dissertation by Marco Albani (2001) applied an algorithm for the mitigation of these artifacts. Findings were discussed in a paper by Albani and Klinkenberg (Albani and Klinkenberg 2003). Elongated production artifacts are created along the collection lines from the photogrammetric procedure used to create the DEM. The result is biased estimates of slope and aspect, which then could result in errors when determining landscape appearance. Albani's algorithm mitigated the artifacts by applying a sequence of spatial filters to the elevation and a probability function to constrain elevation changes to an acceptable range. While the approach was not applied in the current research as the effects on appearance were regarded as minor, it might be considered for future research, or where greater uncertainty exists in key areas of the terrain.

In conclusion, the broad and standard usage of TRIM suggests a satisfactory confidence in the mapping. The application of TRIM in appearance mapping therefore accepted it as the norm, with satisfactory results, thus meeting the evaluation criteria of feasibility, validity, effectiveness, and usability.

## **4.2 Stage 2: Illumination/Shadow Map Production**

The illumination procedure is a fundamental element of GEOptics, a key approach required for conducting appearance "inventory" procedures, and therefore addresses, in part, the first research question (Table 8). Six technical topics framed the developmental

tests and applications which were conducted for the illumination procedure, commencing in 2004 with 1) the initial envisionment of GEOptics (Stella Lake) (Sec. 4.2.1), 2) illumination / shadow map production; intensity and fall-off properties (Sec. 4.2.2), 3) diffuse reflectance (Sec. 4.2.3), 4) cumulative and additive properties of illumination / comparison with VLI (Sec. 4.2.4), 5) comparison with hillshading techniques (Sec. 4.2.5), and 6) viewshed-illumination map comparison (Sec. 4.2.6).

#### **4.2.1 Initial Apparency Modelling Trial – Stella Lake Project**

Envisioning and testing of the preliminary cumulative illumination approach commenced with the Stella Lake model. From Stella, it was determined that an illumination technique could be constructed from multiple viewpoints, and the resulting illumination (reflectance) values could be used to differentiate visual risk collectively from those viewpoints. At that time, landscape apparency was termed landscape vulnerability quotient (LVQ) as shown in a poster prepared at that time (Fig. 27).

# GEOptics LVQ Modelling

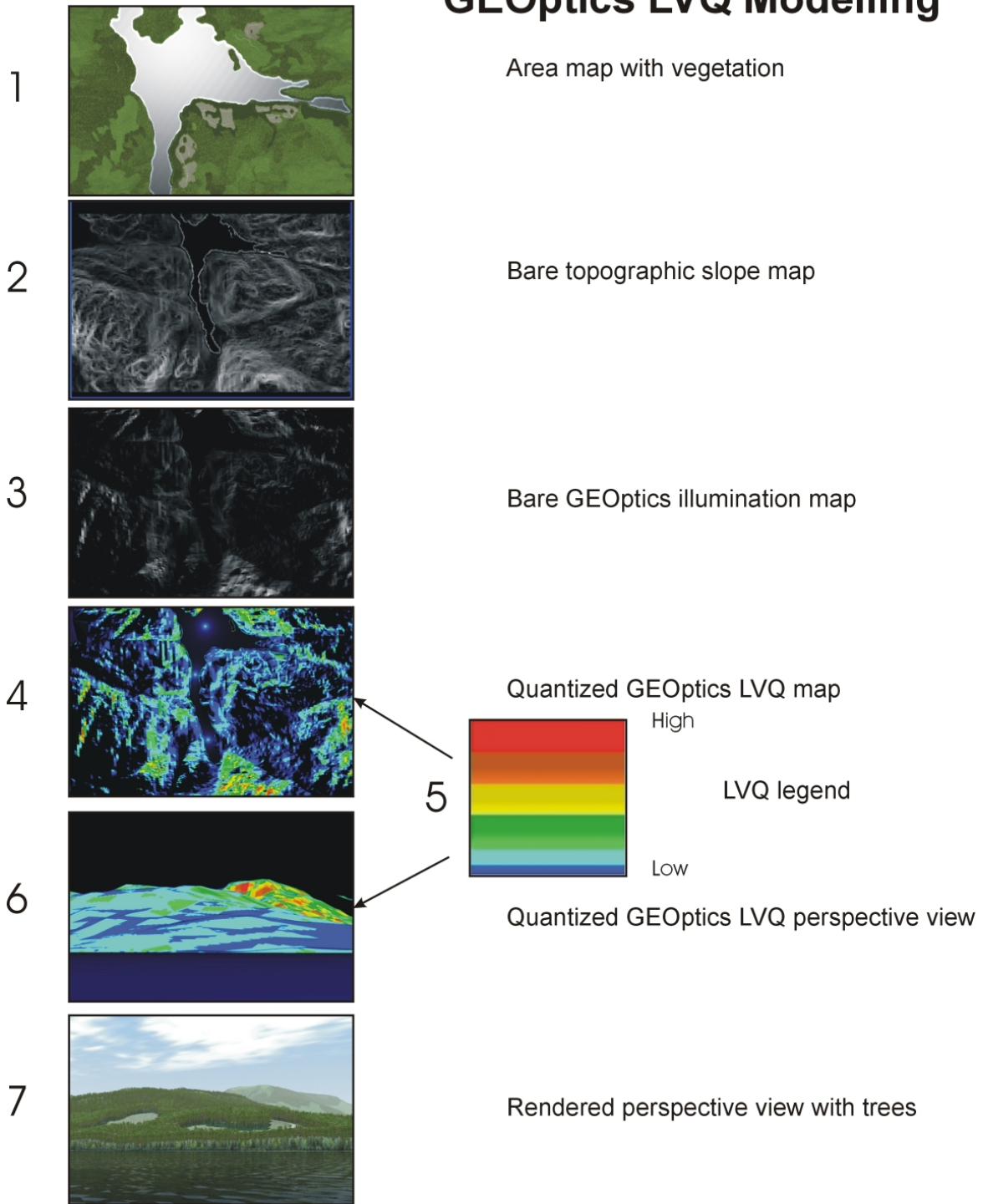


Figure 27 2005 poster of the GEOptics process, using the term "landscape vulnerability quotient" prior to the adoption of the term "landscape apparency".

## 4.2.2 Illumination / Apparency Effects

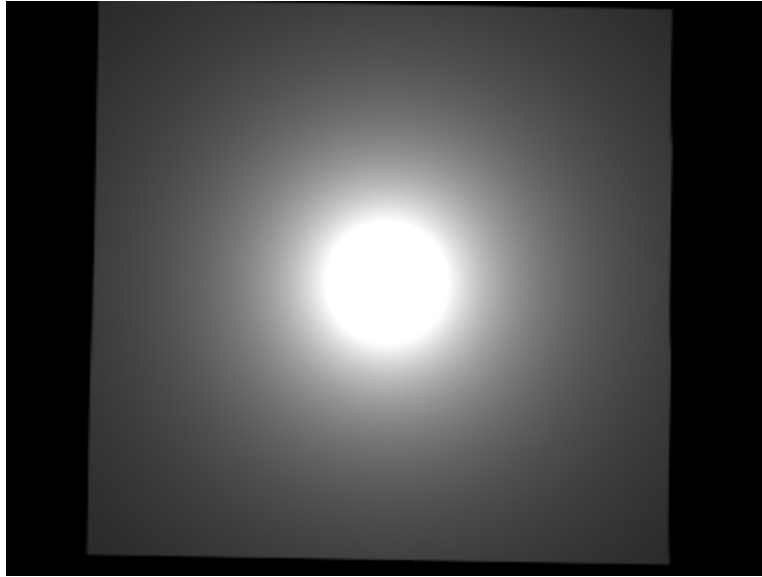
The VNS shadow mapping procedure provided the illumination maps with completely shaded terrain representing non-visible terrain from each viewpoint. Shadows have to be "attached" to vector polygons so they could be rendered (as shown previously in Fig. 18). The shadow component and shadow receiving vector polygons were set up in a few minutes in the Howe Sound project, including additional polygons digitized in VNS to avoid the light positions. Shadow mapping was automatically carried out as part of the rendering process for the illumination map. Illumination map rendering time with shadow production was dependant on the number of lights and the number of shadows.

Shadow map polygon size was a consideration for the shadow to successfully take effect – a computer issue, a scale issue, or both. The need to ensure that shadow map polygons avoid the light points requires digitizing additional polygons in VNS. While quick, the shadow map polygons could have been drawn in ArcMap for greater (but perhaps not necessary) accuracy, following road edges, etc., and imported into VNS.

Shadow stippling effects, or small triangles of shadow error, were noticed in single light source illumination maps (indicated in Fig. 39, Map B). Stippling is caused by the "shadow system believing that a surface is behind a shadow-caster when in fact it is itself the shadow caster" (Hanson 2007). While few in number in the Howe Sound model, they posed a credibility and accuracy issue, in that small surfaces that should have been illuminated were not. VNS provides a shadow offset mechanism, allowing the shadow to

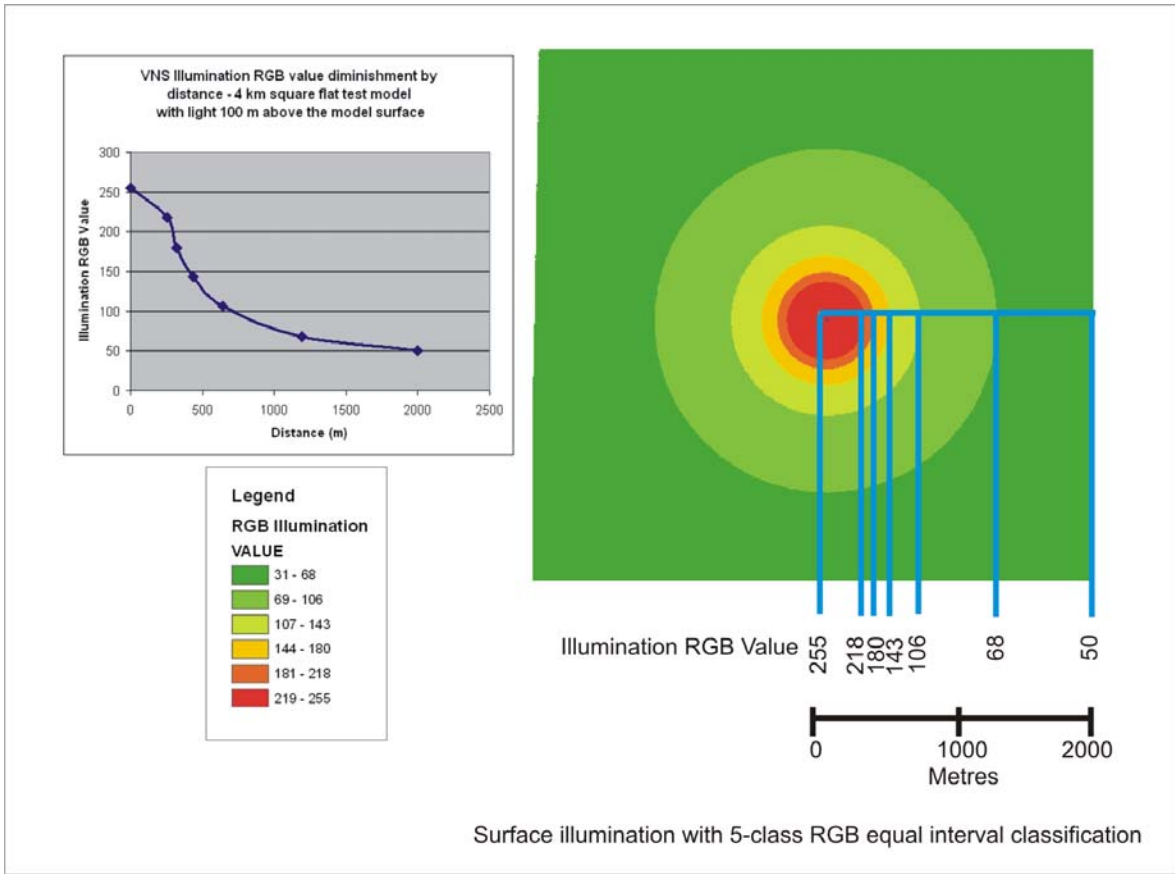
be raised. Stepwise tests of 50 m increments determined that a 200 m offset provided the correction, thereby eliminating the stippling error. The stippling was not noticed in the earlier models (Stella and Nadina) and was therefore not a major concern. In these models, multiple lights were set to produce cumulative illumination maps and likely obscured any stippling created from individual light sources.

To verify the supposed omni-directional qualities of VNS lights, a test light was set at an altitude of 100m above an imaginary flat terrain model surface 4000m by 4000m (16km<sup>2</sup>), created in ArcMap and imported into VNS as a raster grid. The illumination intensity was set at 500% for ease of detection, with a range of 0-255 RGB value. The light radiates evenly outwards in all directions, diminishing in intensity as distance increases from the light source (Figure 28). The effect is likely indicative of the change in the angle of incidence of the light with the flat surface as distance increased.



**Figure 28 VNS light source used for illumination mapping is omni-directional, casting light in all directions, vertically and horizontally across a flat terrain model surface, diminishing as distance increased; seen in plan view.**

The illumination characteristics were further checked in the flat test model for the apparent diminishment of illumination intensity over distance. Figure 29 shows a 6-step equal interval classified image of illumination intensity, diminishing in RGB value from full intensity (RGB 255) in the centre to a value of RGB 50, 2000 m away from the centre at the edge of the 4 km<sup>2</sup> model. The accompanying graph in Fig. 38 tracks the diminishing illumination.



**Figure 29** Six class RGB equal interval classified image of VNS and graph of illumination of a 4 km<sup>2</sup> flat terrain model from a light at 100 m elevation showing illumination RGB value diminishing as distance from the light increases and AVI decreases.

The graph indicates a somewhat rapid diminishment of illumination intensity over distance, with half the loss occurring in the first 500 m. The outer edges of the model were still illuminated, but the downward tracking line with a slowing rate of decline, suggests the illumination will continue to decrease, at a slowing rate, with greater distance. The diminishment indicates a response of illumination to changes in apparency due to the diminishing angle of incidence between the light at 100 m elevation and the ground – the further away, the smaller the angle of incidence. This finding supports the

premise of apparency and its use as an analog to viewing, including the diminishing importance or risk potential of low-lying land in view as distance increases and AVI decreases. The outer limit of illumination was not determined in this test.

It is not clear why the fall-off is not a simple logarithmic curve. The drastic reduction in illumination over fairly short distances appears to conflict with apparency mapping results in which landforms are illuminated over much greater distances as, for example, in the Howe Sound model (Fig. 20), where the apparency reaches upwards of 12 km, and was only limited by intervening topography blocking more distant landforms. A possible explanation is that the flat model illumination does diminish rapidly due to very low angles of incidence, while steep terrain, being more perpendicular to the light source, maintains large angles of incidence over large distances. In other words, it is not a true distance fall-off, it is a combination of RGB capping off at high intensities and the expected logarithmic curve for diminishing AVI.

In further consideration of illumination diminishment over distance, a fall-off effect that could be applied to the light itself was sought, as it was considered to be able to potentially represent the effect of distance on actual human viewing, establishing distance zone limits where detail and some colour effects are lost. Both the Howe Sound and Nadina models employed pre-assigned limits of view based on recorded visual sensitivity units within existing visual landscape inventory.

Additional tests of fall-off effect were conducted using an optional VNS fall-off exponent ranging from 0-5 for each light. The software manufacturer claimed that a VNS fall-off exponent of 2 which is equivalent to normal light fall-off over distance, stating:

"Basically, real lights always obey an inverse-square fall-off law<sup>29</sup> (Hanson 2009a). VNS provides a fall-off exponent selection box in the light editor, following Lambert's inverse square law for light intensity which is: the intensity of illumination is proportional to the inverse square of the distance from the light source ( $I \sim 1/r^2$ ), where r is the radial distance from the light source (Glassner 1989). The factor of 2 was found to be too drastic (i.e., darkness in the model) so tests with factors of 0.0 (no fall-off) through 0.5 (reduced fall-off) were performed.

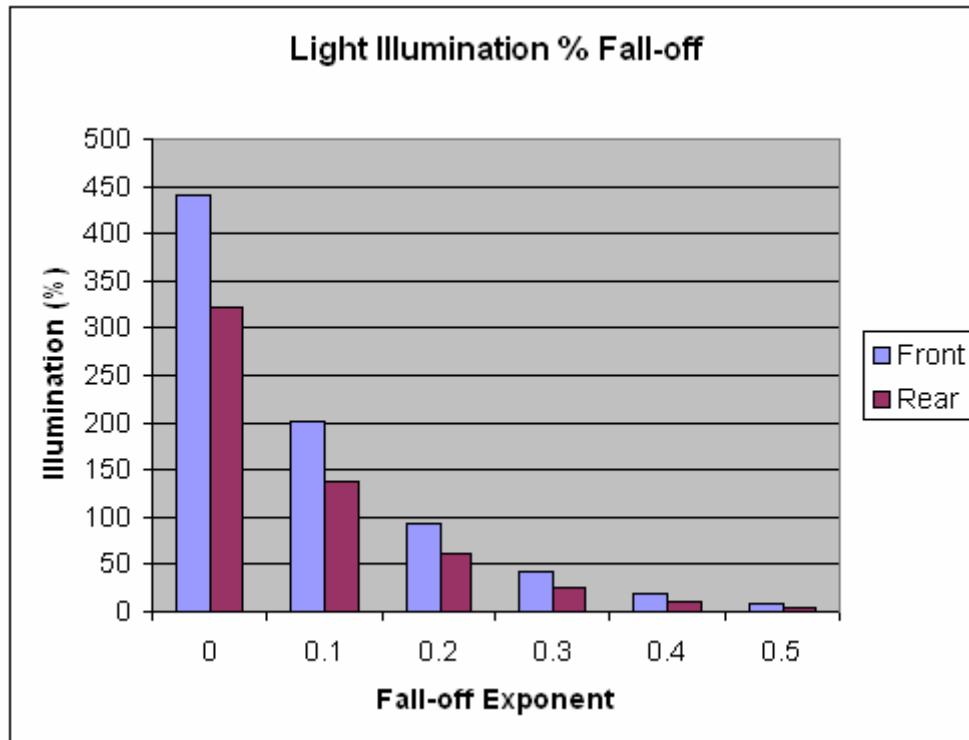
Figure 30 reveals that illumination intensity has an initial steep rate of decline as fall-off exponent increases, leveling out as it approaches zero illumination with a fall-off exponent of 0.5. A fall-off exponent of 0.1 would cause an approximate 50% drop in each intensity rating while a factor of 0.2 would cause all illumination intensities to drop by 80% approx. The factor appeared not to be responsive to distance, that is, the rate of fall-off was even across the terrain, though back areas received less overall intensity, presumably due to the apparency/AVI effect. The earlier test of illumination diminishment in the flat test model was conducted with the fall-off exponent disabled. All subsequent applications in this research also had the fall-off exponent disabled. It is possible that there is an inherent fall-off effect with the VNS lights that has not been realized by 3D Nature when developing the fall-off exponent tool. Whether the

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<sup>29</sup> citing: [http://www.portraitlighting.net/inversesquare\\_law.htm](http://www.portraitlighting.net/inversesquare_law.htm) Hanson, Chris. 2009a. "Re: Light fall-off in VNS." Pers. comm; e-mail, 3D Nature, LLC.

diminishment is attributed to fall-off or apparency or both will require further study.

However, the general similarity of the curve in Fig. 29 to the expected distance effect due to AVI (with no fall-off exponent) supports the overall validity of the illumination effects observed.



**Figure 30 Single light VNS fall-off exponent application, showing higher foreground illumination percent intensity than background intensity of single selected foreground and background pixels throughout the test, but an equal rate of decay of illumination with each increase of fall-off exponent;**

**Howe Sound model.**

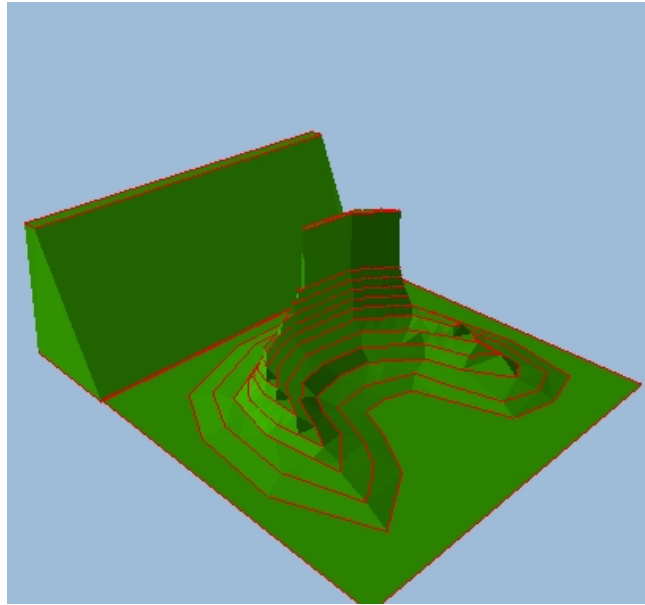
### 4.2.3 Diffuse Reflectance – Dishtin Imaginary Test Model

The initial application of Visual Nature Studio to illuminate terrain models, with lights set at specific locations which equate to observation points, raised questions of the exact nature of the illumination modelling and measurement. Surface illumination intensity from the lights is considered, in this approach, to be the analog to the line-of-sight view angles across the landscape, thus representing cumulative viewing intensity. Greater illumination intensity indicates land cells with greater visual vulnerability. The illumination response from each light would be properly measured individually in perspective view at each light location. However, cumulative illumination, representing cumulative viewing intensity, can only be determined in planimetric view. The resulting geo-referenced illumination image needs to be imported as a layer in the ArcMap model of the same terrain for use in planimetric planning procedures. The illumination in the resulting planimetric imagery needed to be tested for correspondence with individual and collective perspective illumination from the light points.

The non-spectral, diffuse reflectance property of the VNS terrain surface provides the illumination values applied in GEOptics was described in Ch. 3 (Fig. 17). Henceforth in this dissertation use of the word "illumination", and the values determined for it by the lighting technique, means the intensity of diffuse reflectance.

A test to verify this diffuse reflectance property was conducted in a synthesized model called "Dishtin" for the shape of the modelled terrain – a dished or bowl-shaped terrain (TIN) which is flat on the bottom ( $0^\circ$  slope) and has sides ranging upwards to nearly

vertical at the upper reaches (Fig. 31), in order to permit testing of the full range of AVI conditions likely to be found in the landscape, from flat valley floors to enclosing cliffs.



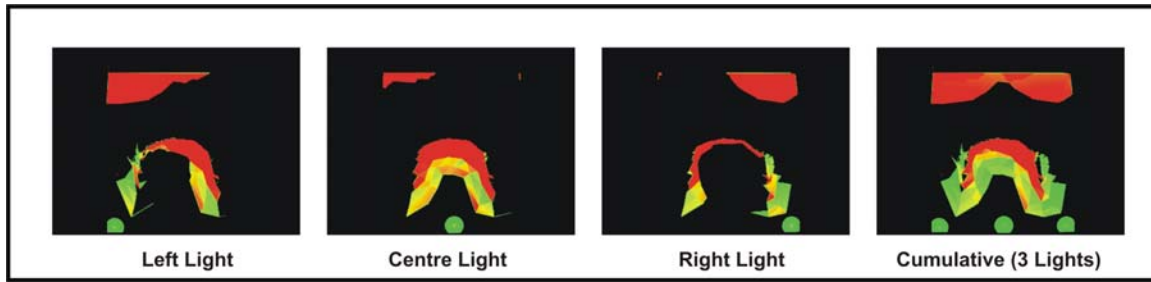
**Figure 31 The Dishtin purpose-built model used for illumination tests.**

The Dishtin terrain model was created in ArcMap, 18 km<sup>2</sup> in extent, and with an elevation range of 1500 m. From a surrounding ground of 0 m elevation, a dished terrain was built with 100 m interval contours to a height of 1500 m. An additional 50 m contour was added at the base to provide a more gentle slope integration with the surrounding elevation. Slopes ranged from 0° to 88°. The verticality of the model was purposefully exaggerated in the upper portion to display nearly vertical ground (88° slope). A sloping backdrop was added to the north end of the model to act as a shadow receptor, primarily to check shadow performance. The purpose was to determine if all views of a lit model displayed similar illumination. As VNS applies diffuse surface reflectance, all views of

the same cells were expected to have the same illumination value with a given light or combination of lights.

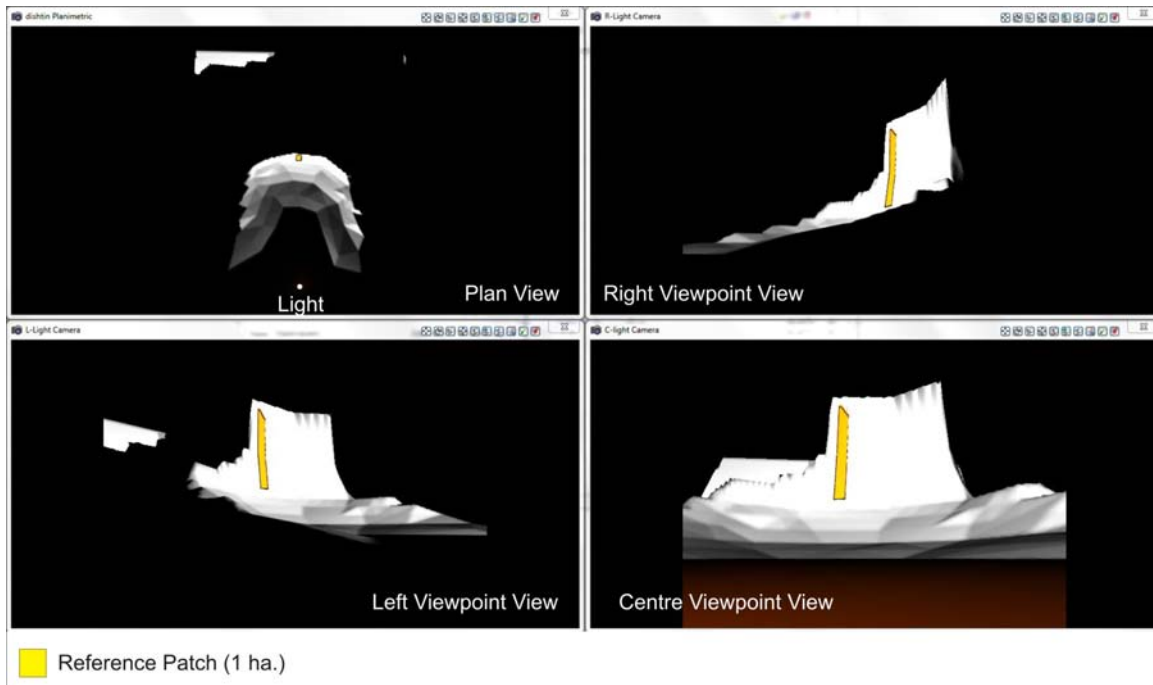
VNS has three types of aerial view projection cameras – the "regular" camera can be positioned at any location, vertically or horizontally, and is normally set at viewpoints or positioned to provide an aerial oblique view. The second is an "overhead" camera, positioned at some elevation above the terrain, and pointing straight down to the earth's centre. The overhead camera will produce distortion at the outer edges of the image/model. The third camera type is the "planimetric" camera. With the planimetric camera, projection is flat, and the longitude of all coordinates is compressed based on the latitude of the camera (i.e., a cartographic projection). Only the planimetric camera is used to create the illumination maps in GEOptics as they must be undistorted to provide a geo-referenced image.

The Dishtin model was first used to prepare a set of illumination/shadow maps with lights set at 3 ground viewpoints. An illumination/shadow map was prepared for each light, singly (left, centre, and right) and then a single cumulative illumination map was prepared with all lights on at the same time (Fig. 32).



**Figure 32** Planimetric illumination/shadow maps in the Dishtin model with single light points and cumulative (three) lights at once; with colour ramping from lowest illumination (green) to highest (red).

The images in Fig. 32 were assigned colours based on a colour ramp; absence of illumination was assigned a black colour. The results show differences amongst (and sensitivity to) light positions, having 1700 m separation between nearest neighbours, and between individual and the cumulative, 3-light results. A further variable (also a sensitivity factor), that of vertical position (elevation), was controlled in this exercise, with each light position assigned the same elevation. Perspective views from the same viewpoints were then rendered, plus a planimetric image for orientation (Fig. 33).

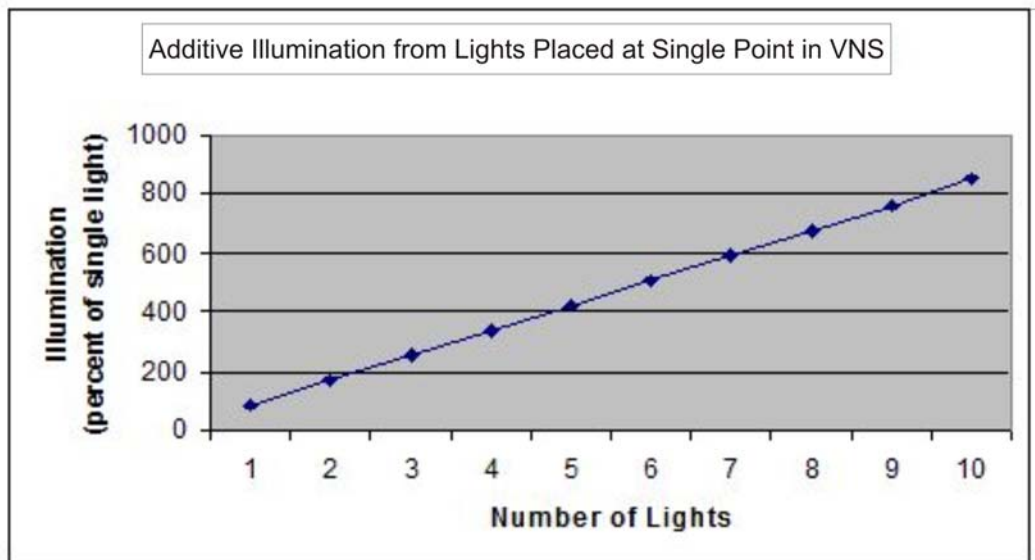


**Figure 33 Illumination shadow map of Dishtin model terrain tested with a single light source revealed light intensities to be identical across all views, including the planimetric view with white representing greatest illumination. Reference patch of 1 ha area tested with identical illumination results.**

Tests of illumination values within the reference patch confirmed that there was consistency of illumination across viewing directions, for cells present in each view, for a given light source, regardless of the angle of view or slope angle (other than absolute vertical where the cell would not be visible to the planimetric camera). Steep slopes had identical (white) tones and high intensities from all viewpoints, while gentle slopes had identical greyer tones and low intensities across all viewpoints.

#### 4.2.4 Cumulative and Additive Properties of Illumination Maps

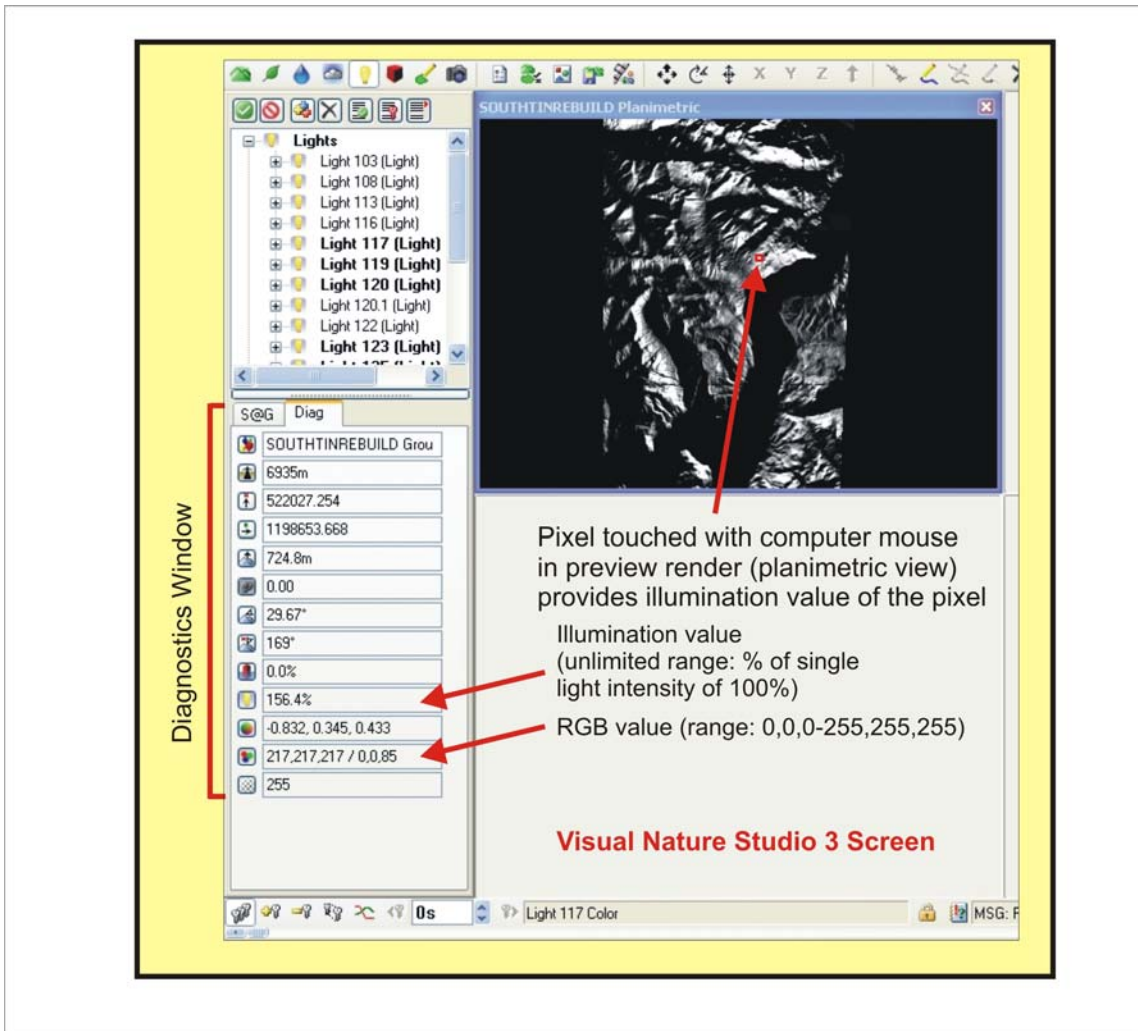
To test the additive capability of illumination, a series from 1 to 10 lights was generated from a single position that was placed centrally in the Dishtin model, 2 m above ground. VNS provides illumination intensity in percent of a single full light intensity of 100%. A linear relationship was determined when lights were added in the same location, one at a time, and images rendered "in preview" for each number of lights (Fig. 34).



**Figure 34 Linear relationship of single point light illumination intensity (percent) and number of lights at one position; Dishtin test model.**

The illumination value, in percent, is identified for cumulative illumination without an upper limit. The single point trial was at a single selected pixel in the Dishtin model with 85% illumination, not one with maximum illumination value. Successive light additions produced multiples of 85% (eg. 10 lights produced 850% illumination). The illumination values were recorded manually at the touch of the computer mouse on the chosen pixel in

the preview rendering, which has a "live" surface, and shown in the illumination channel of the diagnostics window on screen in VNS at the same pixel (Fig. 35). The 13 diagnostic information types for each point in the diagnostics window include geographic position, elevation, slope, aspect, reflection, illumination value, and RGB value. An interactive reference manual, provided with VNS, offers detailed explanations of the diagnostics window information and all other aspects of VNS (Huber, Hanson, and Weed II 2003).



**Figure 35 VNS determines the illumination value of each pixel in an unlimited range of percent (of a single light intensity of 100%) and RGB values in the limited range of 0-255 each, revealed in the diagnostics window at the left of the "screen-grab" of the VNS screen; Howe Sound example.**

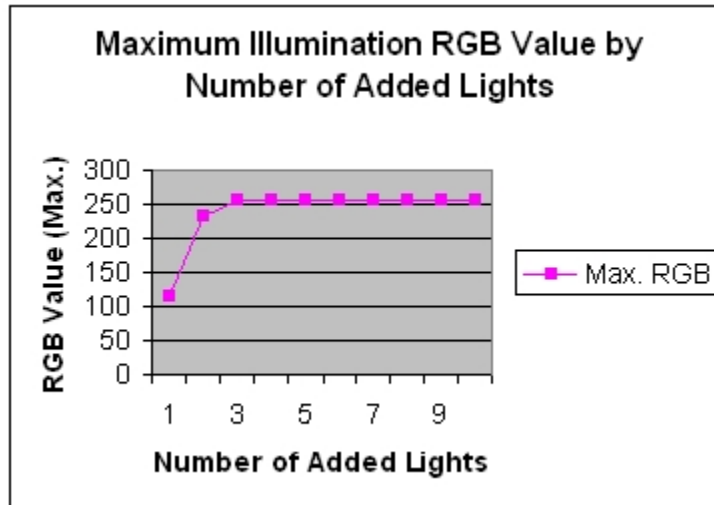
The illumination intensity in this approach is different from the final rendered images with RGB values used in apparency classification and mapping. Constrained RGB values are determined simultaneously with the unconstrained percentage illumination values in the diagnostics window and are accessed in the rendered GEOTIFF image. The unlimited

percent illumination measure provided in the diagnostics window of VNS is fully linear with each added light.

A procedure for saving the values of percent illumination was suggested by 3D Nature, LLC, makers of VNS (Hanson 2009b)<sup>30</sup>. The illumination export procedure was not successful in limited attempts, but is available for future consideration. Instead, the RGB channels were selected as the chosen output format, as a geo-referenced "GEOTIFF" would be immediately importable and registered in ArcMap with other terrain and resource data. The RGB approach does have a built-in limitation – that of fitting high intensity illumination of multiple lights within the RGB value limits of 0-255 for each pixel. The 255 limitation meant that there would be a topping out of the maximum output values as the number of lights increased for some cumulative light sources. A test of this response was conducted and verified by adding 10 lights, one at a time, at the same point as before, but rendering the cumulative illumination maps in VNS. The maximum illumination value was determined when the raster image was processed in ArcMap. The maximum was reached with the addition of the third light. (Fig. 36).

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<sup>30</sup> "Add a RAW saver to the Image Output Events, and choose the Illumination channel and the Full Precision Channel option to get a dump of the raw data. If you add a RAW saver to your Image Output Events, and choose the Illumination channel and the Full Channel Precision option, you should get a dump of the raw data. I think that it will be an IEEE single-precision floating point value (4 bytes) for each pixel in the image, scanning in image-order from top-left moving right, then down. Photoshop won't be able to load a float, but ArcGIS might be able to (as some sort of Floating-point BIL, perhaps). If you generate a GEOTIFF image with world file at the same time, you might be able to recycle the world file to go with the faux-BIL file" (Hanson 2009b, p.1).



**Figure 36** Cumulative (additive) illumination test using the Dishtin model, within the RGB range of 0-255, demonstrating a topping-out at the upper end of the RGB scale.

A procedure for overcoming the RGB cap (255) was sought, while still using the RGB format. Individual raster images can be manipulated using Raster Math in ArcMap. The addition of individual illumination maps to produce the cumulative illumination in ArcMap overcame the RGB 255 topping-out experienced when adding lights consecutively in VNS to produce the cumulative illumination maps.

#### **4.2.5 Comparison with Conventional 3-D Hillshade in ArcGIS**

In conventional three-dimensional hillshade programs such as ESRI's ArcMap 3D Analyst and Spatial Analyst extensions, sun illumination is set by azimuth and elevation angle. A test was produced to examine hillshade using the Dishtin model in 3D Analyst, and compare the results with VNS. The hillshade model applied a distant light (the sun)

located directly south of the model (180°), at an unspecified and unadjustable distance from the model, and at an elevation of 0° (Fig. 37).

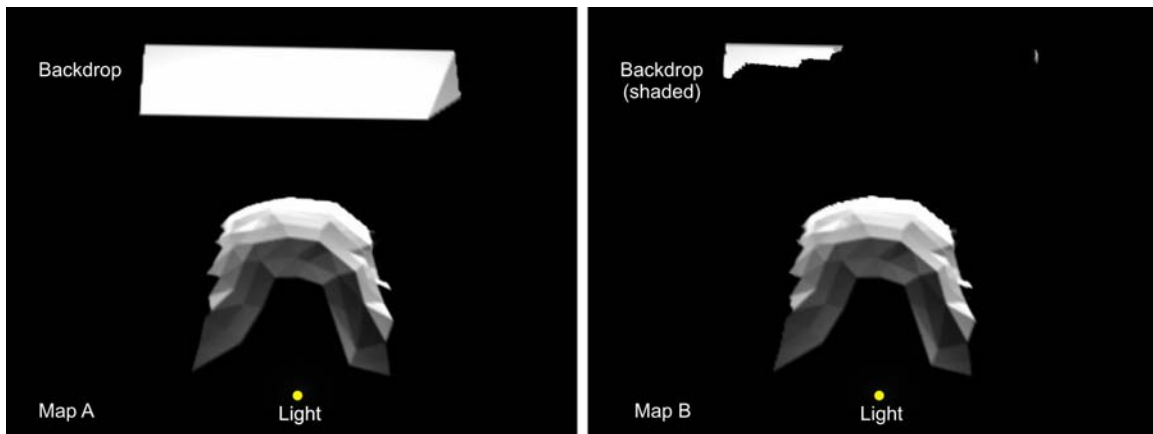
Light placement in 3D Analyst is limited to azimuth and direction, adjusted graphically. Advanced techniques are required to place the sun at a particular position in a model (Chamberlain 2009; Chamberlain and Meitner 2009). As well, multiple light placement also requires advanced techniques in 3D Analyst.



**Figure 37** Dishtin model hillshade produced in 3D Analyst with a distant light (sun) at an azimuth of 180° and elevation of 0°, revealing the illumination of terrain behind the obscuring front terrain.

The result indicated that 3D Analyst allows some illumination on the surfaces facing away from the light, and failed to shade any of the backdrop, therefore it cannot be used to generate accurate shadow maps or illumination mapping.

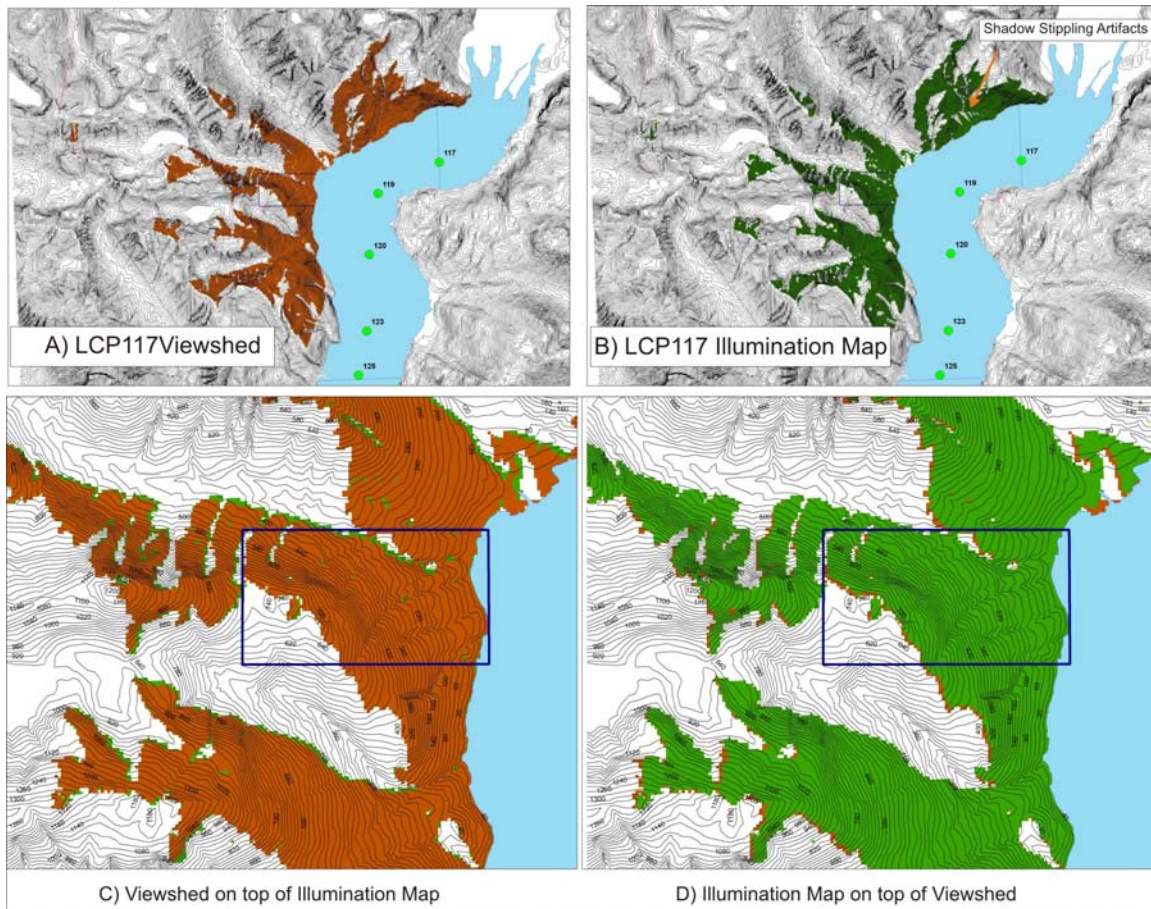
The same backdrop illumination effect was obtained in VNS when the illumination model was produced without a shadow map (Fig. 38, Map A). This incorrect illumination map can be compared with the correct illumination map that was produced with a shadow map in effect, and with the backdrop correctly in the shadow of the foreground terrain (Fig. 38, Map B).



**Figure 38 VNS illumination map from single viewpoint, no shadow map (Map A) and with shadow map (Map B).**

#### 4.2.6 Viewshed and Illumination Map Comparison

The Howe Sound viewshed map, produced in ArcGIS 3D Analyst from LCP 117 shown in Fig. 39 (A) was compared with the illumination map (B) produced in VNS for the same viewpoint in the Howe Sound model. Both the VNS terrain model and the ArcMap terrain model were derived from the same TRIM source. Both maps were clipped to show the results for the west side of Howe Sound only. The two approaches were found to be identical with the exception of small proportions of fringe pixels of the both the illumination map (green), observable in close-up view (C) and of the viewshed (orange), observable in the close-up view (D). The difference was estimated, visually, to be in the order of 1%, with both the viewshed and illumination in variance along separate portions of visible terrain edges. The differences are presumed to be due to minor differences in how the terrain models are interpreted in the two systems, and approximately cancel out each other in total extent. The edges defined by these differences can be advantageous as they are frequently observed ridges in the model, as seen from the viewpoints, where additional attention can be drawn, particularly if sky-lighted, and additional consideration may be required in their management to avoid enduring visual impacts.



**Figure 39** Single LCP ArcGIS Howe Sound west side viewshed map (A) comparison with a VNS illumination map (B); composite of the two maps with additional pixels of illumination map (in green) showing around the viewshed (C) and additional pixels of the viewshed (in orange) showing around the illumination map (D); 1kmx2km scale box is outlined in blue; shadow stippling artifact is indicated in map B.

### 4.3 Stage 3: Apparency Classification Methods and Comparison with VLI

In Stage 3, the illumination maps produced in VNS were added as geo-referenced images (GEOTIFFS) directly to the existing Howe Sound ArcMap project that contains the original terrain and viewpoints. By classifying the illumination maps, they become much more informative and could be compared with the existing Visual Sensitivity Units

(VSUs) from the VLI (as shown in Figs 42 and 43), a 5-class topographic slope map produced in ArcGIS (Sec. 4.3.2) and a 5-viewpoint times-seen map (Sec. 4.3.3). As well, with classification, they become the landscape apparency maps that will be used for the remainder of the GEOptics stages. The existing BCMoFR Visual Landscape Inventory, prepared by my company in 2006 following VLI procedures (BCMof, 1997) was added as a map layer to facilitate comparison of apparency with the Visual Sensitivity Units (VSUs) derived in the VLI. The VLI is discussed in Sec. 4.3.1.2 (Cumulative Apparency Mapping), and is shown in Fig. 42.

#### **4.3.1 Apparency Map Classification**

Quantile classification provides an equal number of cells in each group (and nearly equal total area each group). The classification procedure provided the opportunity to test and compare visual results of differing levels of apparency but with similar spatial extent. The spatial extent equivalency was required to determine the plan-to-perspective relationships of each class (Sections 4.5.1; 4.5.2). A 5-class apparency rating system was prepared in the Howe Sound project and applied to produce three types of apparency mapping: 1) individual (light sources on one at a time; separate illumination maps), 2) cumulative (all light sources on at the same time; single illumination map), and 3) additive cumulative (individual illumination maps added together to make a single illumination map using raster math). These are presented separately in the following 3 sections (4.3.1.1 to 4.3.1.3). Another classification method, "equal-interval" (EI), was explored for comparative purposes. The method classified visible cells across equal ranges of RGB

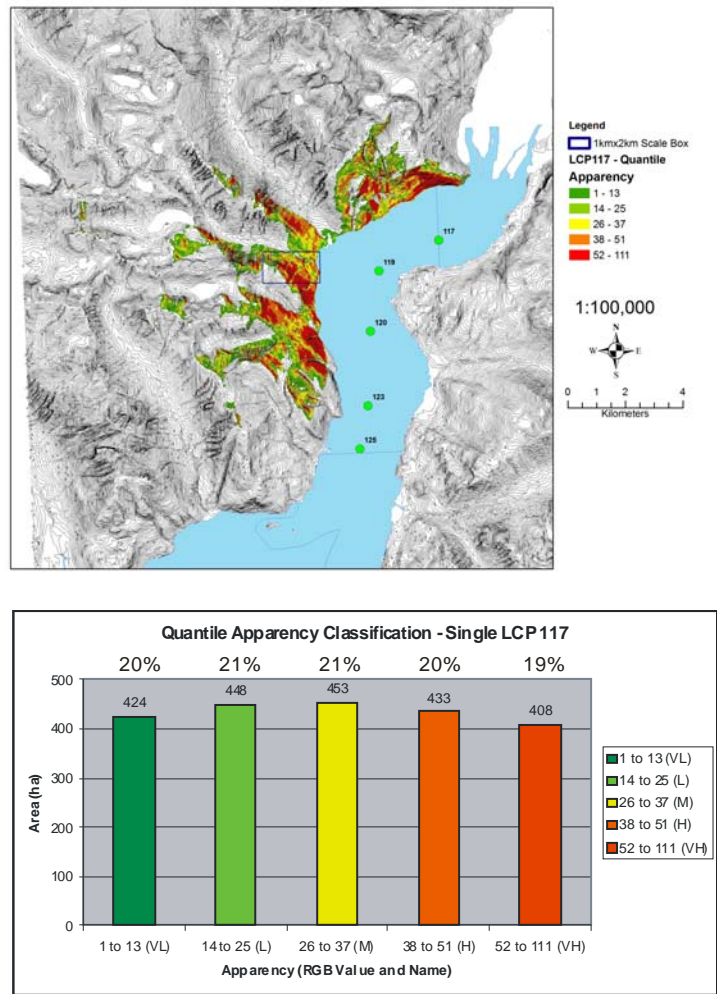
values. The results are presented graphically in Appendix 11, and discussed in Sec. 6.1.2 (in Stage 3 under the Apparency Classification heading).

#### **4.3.1.1 Individual LCP Apparency Mapping**

An individual illumination map was produced in VNS for the Howe Sound westside area for each of the 5 LCPs in VNS, with lights turned on one at a time. The resulting GEOTIFFs were imported into ArcMAP and classified in 5 steps by their illumination values into equal numbers of cells called quantiles and assigned colours from green (very low apparency) to red (very high apparency). The resulting map for LCP 117 is presented in Fig. 40. Individual apparency maps for all of the 5 LCPs are presented in Fig. 41.

The quantile classification procedure assigned an equal number of cells (approximately equal areas) in each class. Having equal areas in each class provided the opportunity to compare the visual results of each class, and allow further analysis (such as deriving P2Ps). The colour-classified 5-class groupings were equated to named classes of apparency (visual risk) ranging from very low (VL), to low (L), moderate (M), high (H), and very high (VH). The names provided easier recognition and relations amongst the classes of RGB values. The verbal definitions were dictated by area, not by RGB values in the landscape, and span the anticipated levels of visual risk when portrayed in perspective view (as if cleared). The quantile approach provided most differentiation (4 classes) for cells with RBG values in the lower half of the spectrum (RGB 1-51), and lumped together, in a single class, cells with RGB values in the upper half of the spectrum (RGB 52-111), having much fewer cells (less area) than the bottom half.

The following map (Fig. 40) reveals the quantile classified apperency as experienced from a single viewpoint, LCP 117. The RGB values extend only to 111, well within the maximum of RGB 255. The chart in Figure 40 shows the areal extent (in hectares) within each group (approx. 400-450 ha in each class as determined by the ArcMap quantile classification procedure<sup>31</sup>).



**Figure 40** Single light apperency map and histogram for LCP 117, Howe Sound; classified in five "equal area" quantiles from very low to very high apperency.

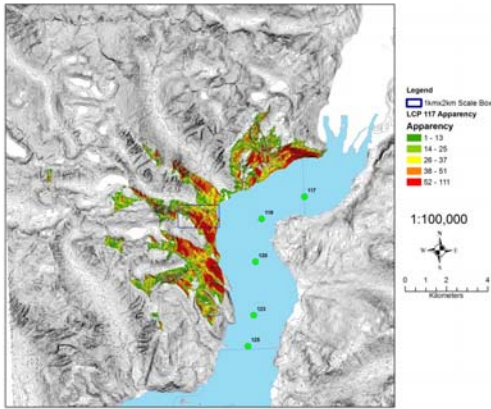
The histogram of values and quantile classification chart for LCP 117 is provided in Appendix 11 (Fig. A1). Another classification technique, equal-interval (EI), was explored for comparison with the quantile method. The ArcGIS EI technique separated the apparency map cells into 5 equal ranges of RGB values. The classified map, histogram and chart of values are presented in Appendix 11 (Fig. A2). The results showed nearly three-quarters of the cells (74%) were lumped together in the lowest two apparency classes, with the remaining quarter (26%) in the other 3 classes. Having such a large component of the apparency map in the lower visual risk classes would reduce flexibility in design options, and could defeat the intended purpose of apparency classification - differentiating visual risk over large areas. While EI classification would enable cross-landscape comparisons of landscapes with the same RGB range (particularly those having the full RGB 1-255 spectrum)<sup>32</sup>, and appears to be more sensitive in the upper range categories, its use was not pursued further in this dissertation in favour of the quantile technique. Quantiles were more amenable to the multiple applications intended for apparency mapping (strategic and operational combined). Distinctions between the 2 approaches are discussed in Sec. 6.1.2 (Stage 3, part 1). However, regardless of classification technique, the source RGB values remain unchanged and could be assessed by any or all types of analysis in practice, as need arises.

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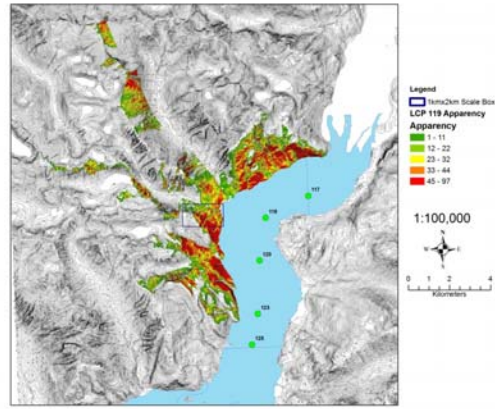
<sup>32</sup> ArcGIS quantile classification groups cells by equal numbers based on apparency value, with area in each class roughly equivalent. Numbers of cells having a particular value can result in variance of areas in each class. Greater refinement will be achieved as the number of quantile classes are increased.

The locations and elevations of light sources at the viewpoints are sensitivity considerations. While all 5 viewpoints (LCPs) were located on Howe Sound at 2 m above sea level, lights could also have been set along the highway, on the opposite side of Howe Sound from the study area, at higher elevations, or at additional viewpoints on Howe Sound. The viewpoints were selected from existing visual landscape inventory using standard procedures as representative of typical worst case viewing conditions from the water within the general viewshed of the study area. The sensitivity of apparency to light placement at the 5 different viewpoints is evident when progressing sequentially along Howe Sound from LCP 117 in the north to LCP 125 in the south (Fig. 41). While there are obvious differences in the distribution of high and low apparency areas by viewpoint as horizontal viewing angles change along Howe Sound, there is also considerable similarity in the highest risk areas between all viewpoints within the general viewshed. The most southerly viewpoint where Howe Sound bends to the west shows the biggest differences from the others, suggesting that viewpoint placement near the edges of the general viewshed/study area, where terrain conditions may be shifting, should be treated with particular care.

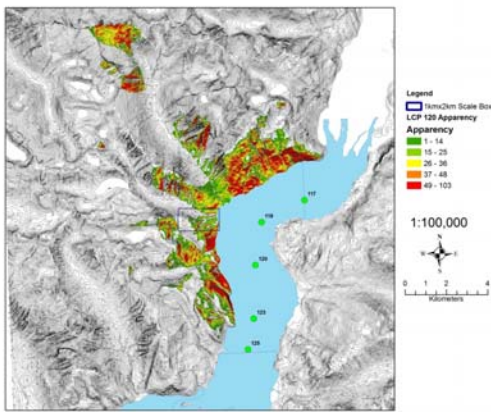
Individual apparency maps also provide a good utility in that they can be added together, such as for a sequence of viewpoints, for changing sequences progressing along a corridor, and for emphasis of viewpoint importance. The additive approach is explored following the cumulative approach presented in the next section (Sec. 4.3.1.2).



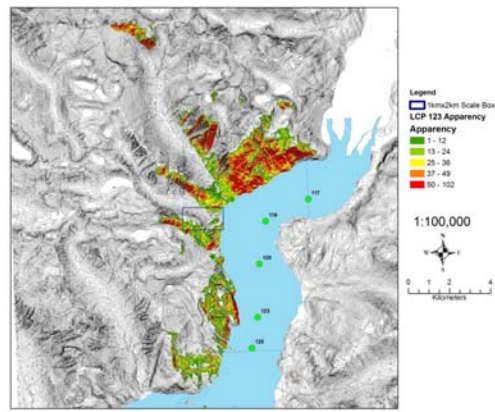
Map A - LCP 117 - 5 Quantile Apparency (single light)



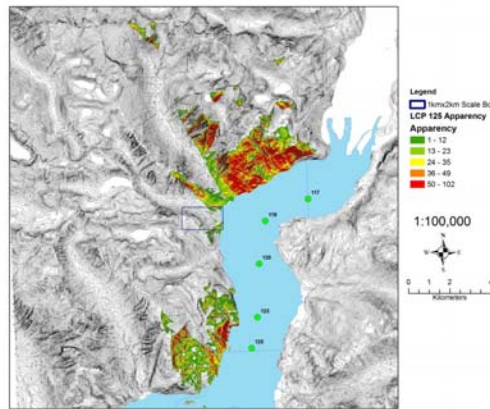
Map B - LCP 119 - 5 Quantile Apparency (single light)



Map A - LCP 120 - 5 Quantile Apparency (single light)



Map A - LCP 123 - 5 Quantile Apparency (single light)



Map A - LCP 125 - 5 Quantile Apparency (single light)

**Figure 41 Individual apparency maps from each viewpoint, indicating sensitivity to light placement.**

#### 4.3.1.2 Cumulative Apparency Mapping

Following the production of the individual viewpoint apparency maps, a cumulative apparency map for the Howe Sound project's 5 LCPs was derived from the cumulative illumination GEOTIFF with all 5 lights turned on at once (Figure 42). Pixel illumination RGB values were limited to 255-255-255 in the GEOTIFF images. In all, the cumulative apparency map consisted of 51612 cells with a total area of 4625 ha. The cumulative approach resulted in 99 ha (2.1%) of the total area reaching RGB 255-255-255, indicating a slight topping-out at the upper end of the scale<sup>33</sup>. The cumulative apparency map was classified using 5 quantiles as for the single viewpoint.

When the quantile cumulative apparency mapping (Fig. 42) is compared with mapping from individual viewpoints (Figs. 40, 41), it can be seen that there is considerable similarity in identifying the higher risk areas (as defined by quantiles) between the cumulative and the individual viewpoints, especially for the nearer viewing distances (major Howe Sound side-slopes). The cumulative apparency mapping covers a larger extent as would be expected for the aggregate of 5 somewhat different individual viewsheds. It is recognized that the precise extent of the cumulative apparency mapping depends on the number and placement of viewpoints (lights) within the general viewshed, especially the placement of viewpoints near the edges of the study area that could be somewhat under-represented in a cumulative mapping exercise aggregating many viewpoints. This is why the individual apparency maps by viewpoint remain important in

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<sup>33</sup> The RGB topping-out response would be expected to increase as the number of lights and illumination intensity increase.

more detailed area planning, and provide the basis for the additive cumulative approach discussed in Sec. 4.3.1.3.

The apparency approach was shown to provide visual risk information for each land-plane, whereas the VLI provides only generalized information, such as VAC, for land-form sized VSUs, as evident in Fig. 42 (VSUs outlined in red). The Howe Sound apparency project area incorporated 8 VSUs from the VLI covering nearly 8100 hectares (determined as total visible area seen from the viewpoints along the Sea-to-Sky Corridor and Howe Sound), or roughly 1000 ha per VSU. The VAC was recorded as identical (moderate, in a 3-class rating system of high, moderate, or low) in all of the 8 VSUs, and is not broken down within VSUs. In this landscape type, the existing VAC mapping appears to average out large areas as moderate VAC, potentially under-representing the large areas of high or very high visual risk and over-representing large areas of low visual risk. By comparison, the cumulative apparency approach, generated from 5 specific viewpoints in Howe Sound (for purposes of this study), contained nearly 52,000 land-plane polygons (when converted from raster) in nearly 5,000 ha, averaging 0.1 ha per polygon (cell), each with its own trackable visual risk (RGB) number (ranging from 1-255). The cells were classified into 5 groups with "equal" areas in each class. A chart of the apparency classes is provided in Fig. 43. The number of classes can be easily made lesser or greater, depending on the need. The apparency-classified cells occurred mainly in just 3 VSUs (201, 201, and 205), providing a much finer resolution and more flexible analysis potential for visual risk mapping within critical VSUs than the uniform VAC mapped in the VLI.

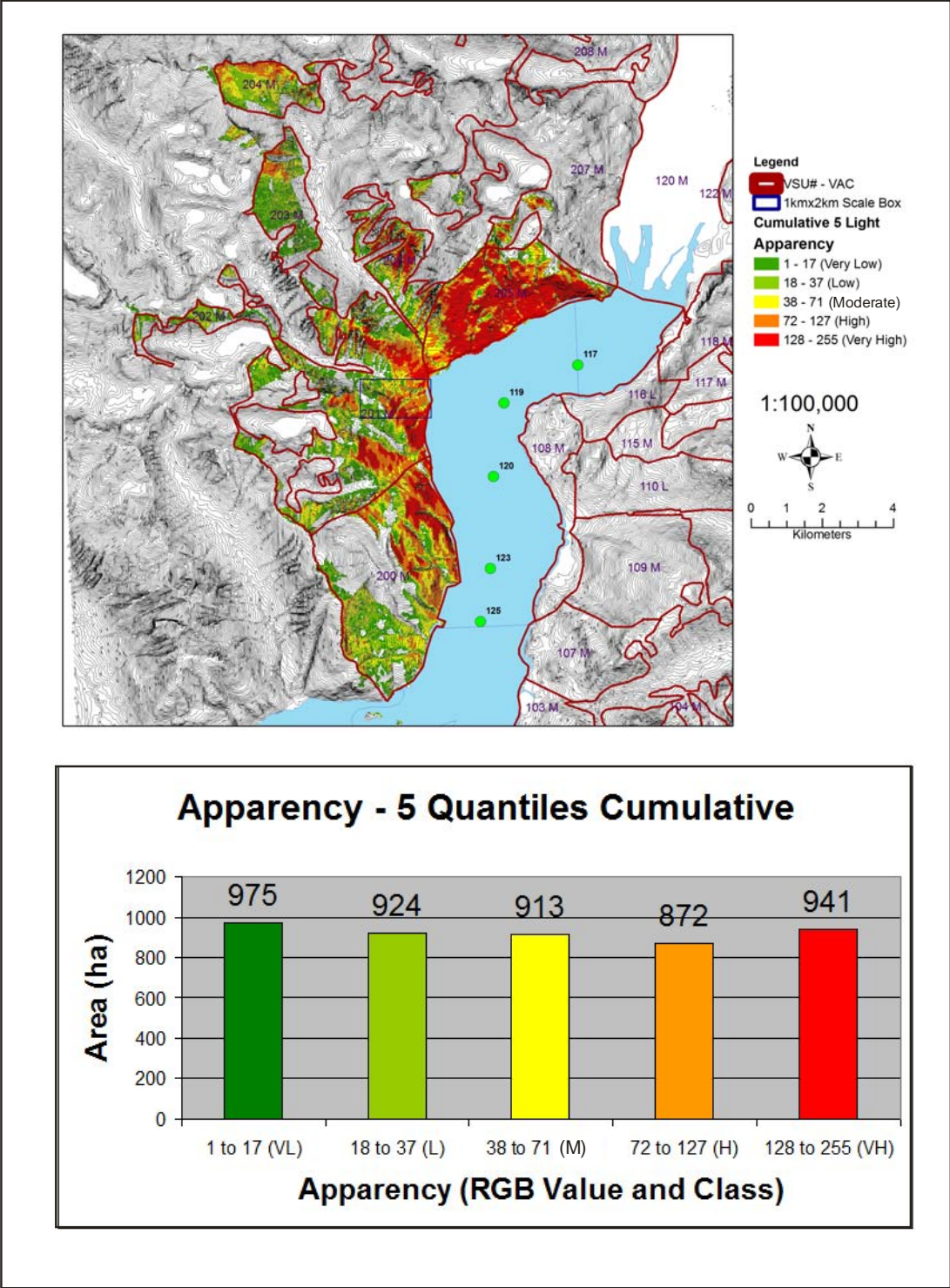


Figure 42 Five quantile cumulative apparency map and histogram of area in each quantile, with VSUs outlined in red.

The quantiled cumulative apparency map is again presented, along with the histogram of values, and classification chart, in Appendix 11 (Fig. A3). An equal-interval classification was also produced for cumulative apparency, as it was for single LCP apparency, and is presented in Fig. A4 for comparison with the quantile approach, and distinctions discussed in Sec. 6.1.2 (Stage 3, part 1).

#### **4.3.1.3 Additive Cumulative Apparency Mapping**

To provide greater latitude with respect to illumination intensity and to overcome the potential problem of "topping-out" at RGB 255, ArcMap's raster math function was utilized to add the RGB values of the five individual LCP illumination maps (one for each viewpoint, lights turned on one at a time) in the Howe Sound project (Fig. 43). This addition-method cumulative apparency map was thereby unlimited in its upper range RGB value. Actual additive RGB values obtained extended to 470, classified into 5 quantiles for comparison with the cumulative method shown in Fig. 42, and are shown together in close-up view for detailed comparison (Fig. 44).

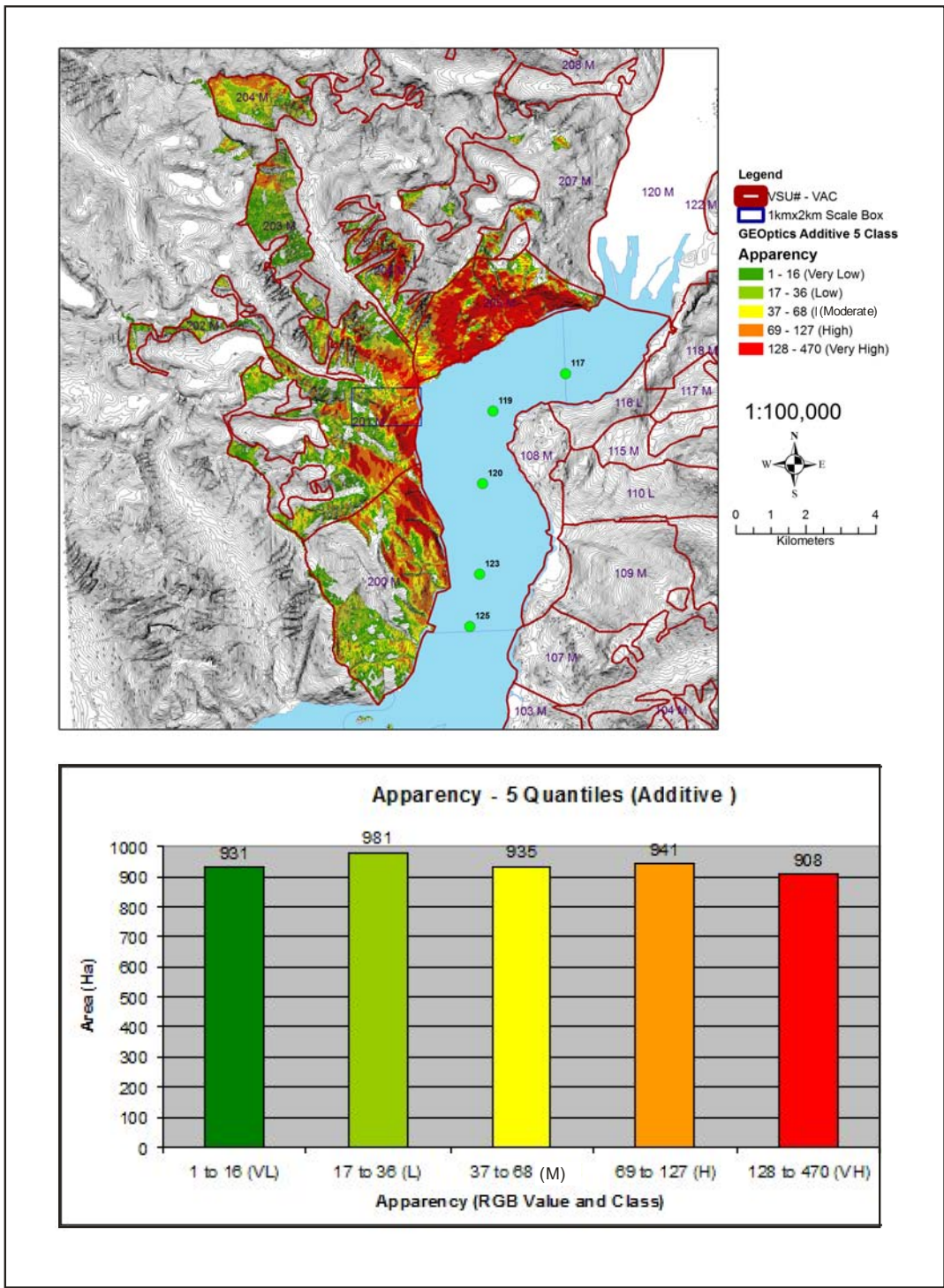
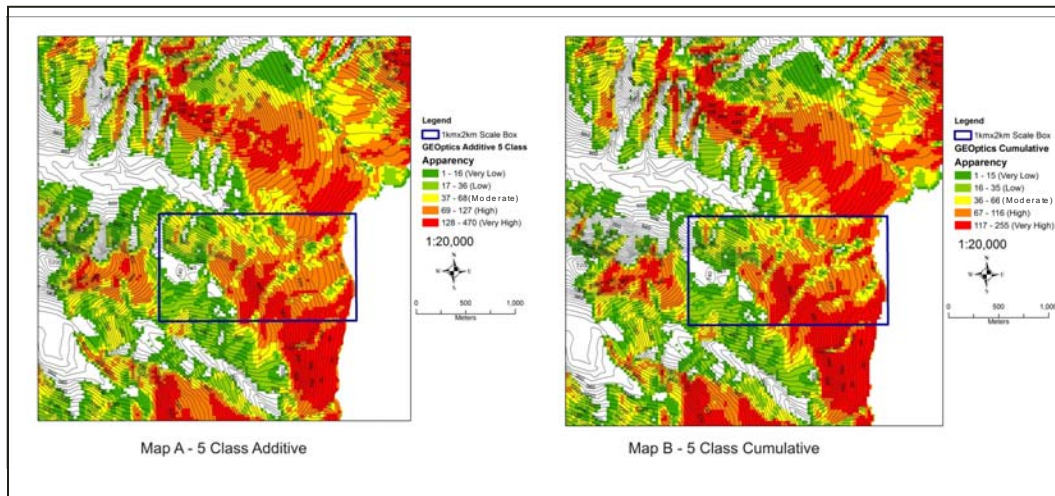


Figure 43 Additive cumulative approach adding 5 separate illumination maps together using raster math, with lights turned on one at a time; using a 5-quantile classification, with VSUs outlined in red.

The additive cumulative method (Map A) and the cumulative method (Map B) shown in Fig. 44 are, for the most part, visually very similar, despite the capping off of RGB values in 2% of the area in the cumulative approach. The similarity suggests that the cumulative approach is valid for these kinds of landscapes with similar small numbers of viewpoints, and a small number of high apparency cells.

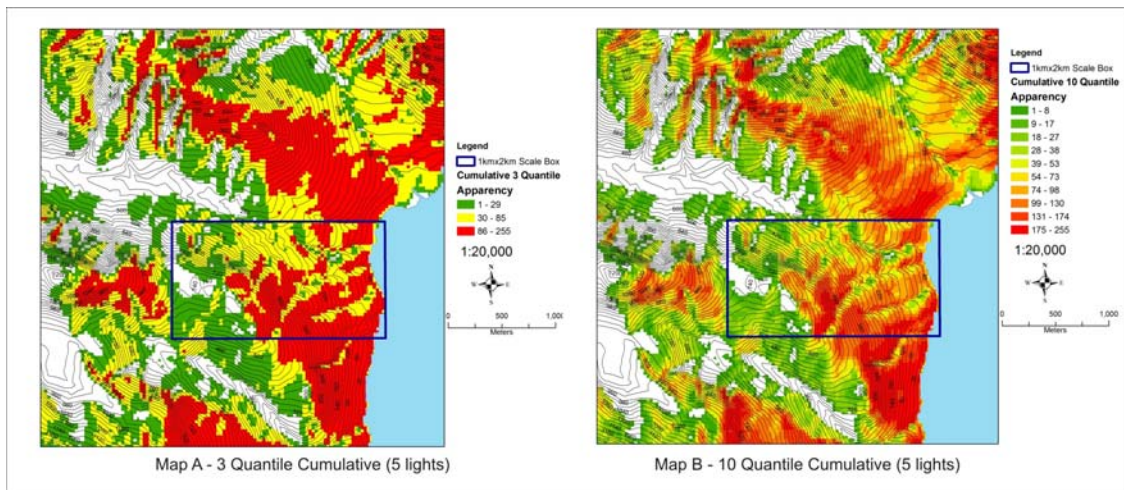


**Figure 44 Comparison of cumulative apparency (Map A) with the additive cumulative approach (Map B) showing closeness of results.**

The additive approach also provides the option of having individual apparency maps to work with, providing flexibility to select a set of maps for a part of a corridor of interest, and the grouping of maps to cover different management objectives, such as undertaking a detailed assessment for integrated visual design planning. As well, the individual maps may be used on their own to classify and compare visible landscapes, (i.e, a landscape with an average apparency value of 50 will be less visually sensitive than a landscape

with an average of 100). Further work will be required to construct that classification system and its implications to visual landscape management.

Classification can be varied to achieve either greater refinement or simplification. As a sensitivity test, 3-quantile and 10-quantile classifications of cumulative apperancy are compared in Fig. 45, showing broadly similar patterns at a coarse scale, but significant areas with intermediate apperancy levels in the 10-quantile version. This suggests that a more precise classification than the 3-quantile could be important in guiding visual design, but an intermediate classification (e.g. 5-6 classes) may balance precision with simplicity of use.



**Figure 45 Comparison of 3-quantile, 5-light cumulative apperancy (Map A) and 10-quantile, 5-light cumulative apperancy (Map B).**

### 4.3.2 Comparison of Apperency Map with Slope Map

Topographic slope is a prominent consideration in VAC determination. While slope indicates physical terrain steepness, an important management consideration when planning forest development initiatives, for example, it does not necessarily correspond to how the terrain is seen, based on AVI, as does apperency, particularly cumulative apperency. The two approaches are compared in Figures 46 and 47.

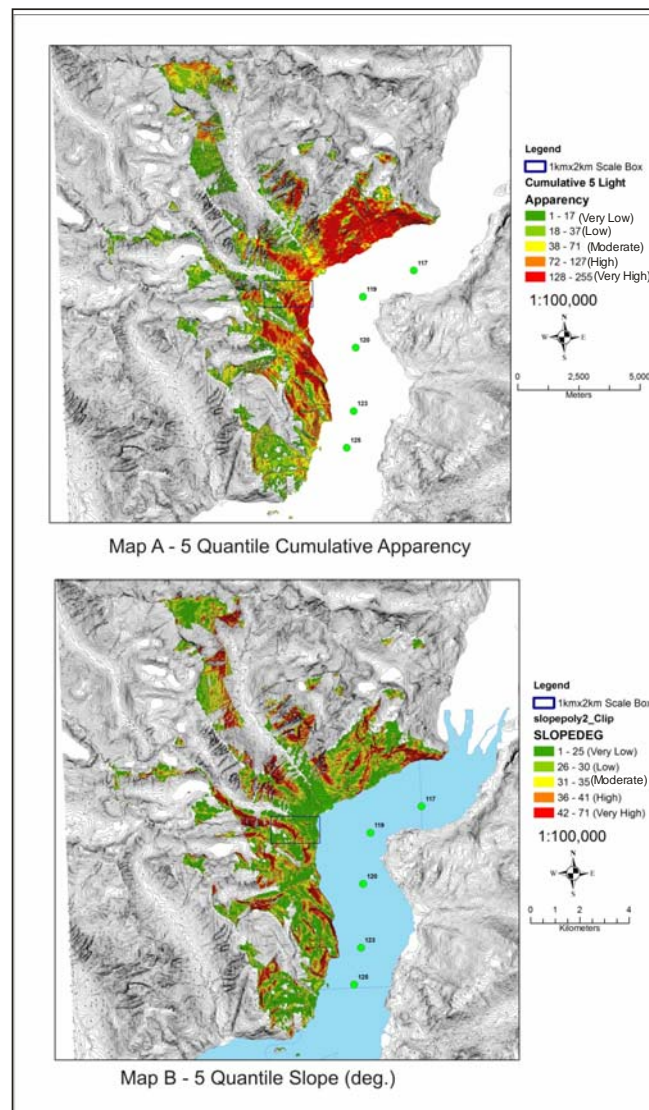
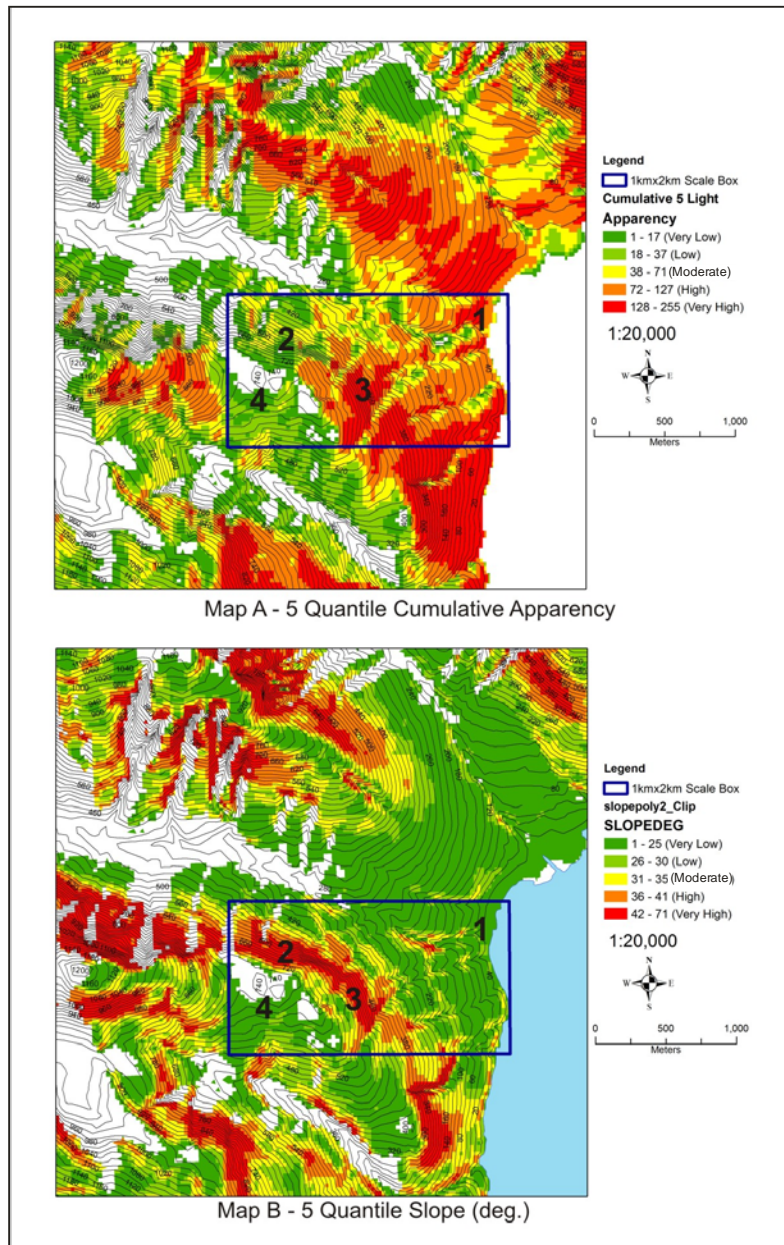


Figure 46 Comparison of 5 quantile cumulative apperency (Map A) and 5 quantile topographic slope (Map B); Howe Sound model.



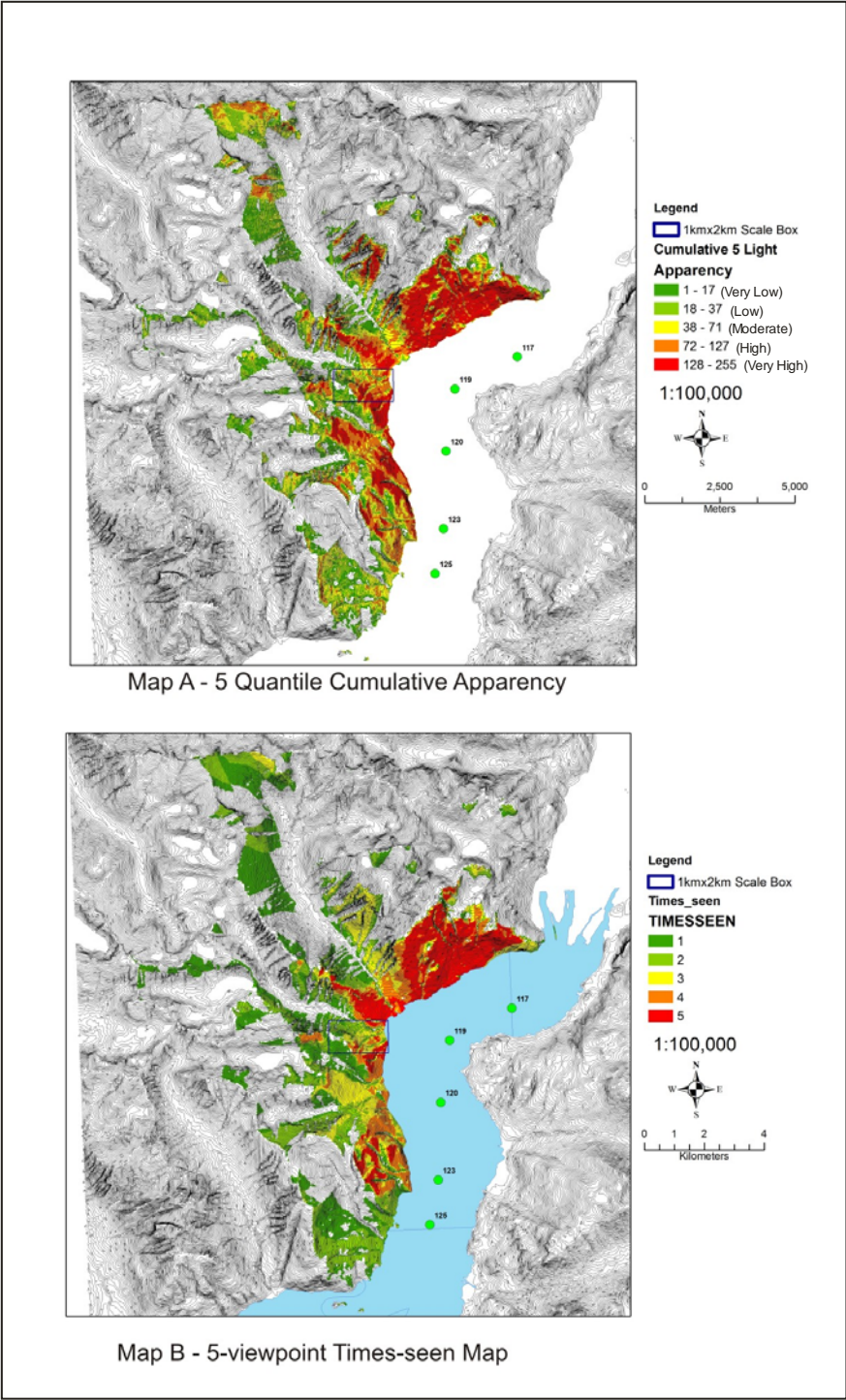
**Figure 47 Comparison of 5 quantile cumulative apparency (Map A) and 5 quantile topographic slope (Map B); Howe Sound model close-up.**

The number "1" in the scale box of each map indicates an area with very high apparency and very low slope. Such areas may have greater visual risk than would be indicated by the slope, suggesting such areas will have a lower tolerance to the amount of land use alteration per degree of visual impact than would be predicted by slope alone. A large

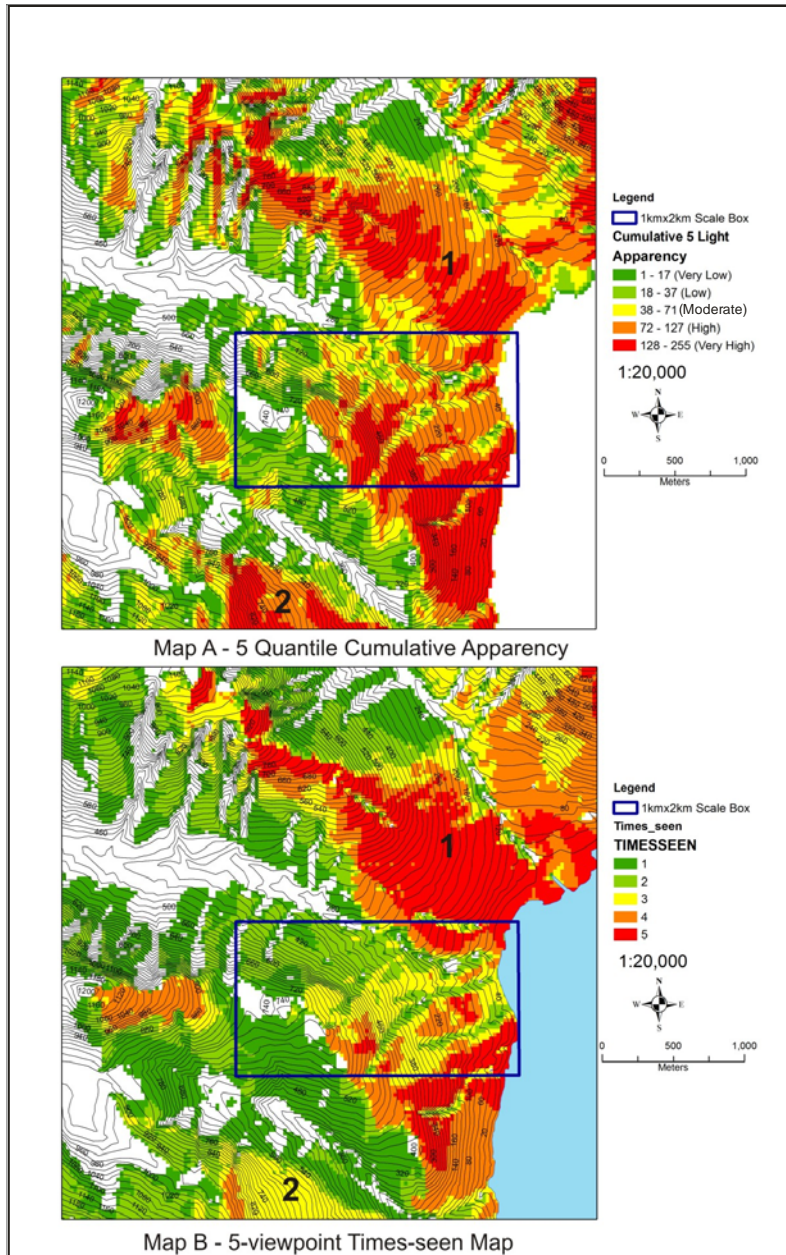
proportion of the land-base is type "1", especially in the more widely visible front country, closer to viewpoints, suggesting visual risk may be significantly underestimated by use of slope alone as a predictor. The number "2" in the scale box of each map indicates an area with very low apparency and very high slope. Steep slopes with low apparency may have lower visual risk than indicated by the slope. In the "2" type areas, such as steeper, more distant, side valley walls that are only obliquely seen from the viewpoints, slope may be over-estimating visual impact risk, and may have a higher tolerance to the amount of land use alteration per degree of visual impact than would be predicted by slope alone. The number "3" indicates an area where both apparency and slope are high and the number "4" indicates an area where both are low. Both the "3" and "4" type areas would have similar risk assessments based on the two approaches. These findings suggest apparency and slope could easily be used together to provide more detailed guidance for forest management planning and operations.

### **4.3.3 Comparison of Times-seen Map with Apparency Map**

Times-seen is a composite of individual viewsheds, indicating how many times a particular grid cell is counted as "seen" from multiple viewpoints. It is commonly used to represent cumulative visual sensitivity in VLM planning. A five viewpoint times-seen map was generated for the Howe Sound project in ArcGIS 3D Analyst. Visual comparisons of five class apparency mapping and five-viewpoint times-seen mapping are presented in the next 2 figures (Figures 48 and 49).



**Figure 48 Comparison of Howe Sound project cumulative apperency (Map A) and times-seen (Map B), indicating the finer differentiation of apperency mapping, classified into quantiles, with the same number of classes as times-seen from the same viewpoints, and numerous differences in classification of at least 1-2 levels between sizeable areas of the two maps.**



**Figure 49 Close-up comparison of Howe Sound project cumulative apparency (Map A) and times-seen (Map B), indicating the finer differentiation of apparency mapping, classified into quantiles, with the same number of classes as times-seen from the same viewpoints.**

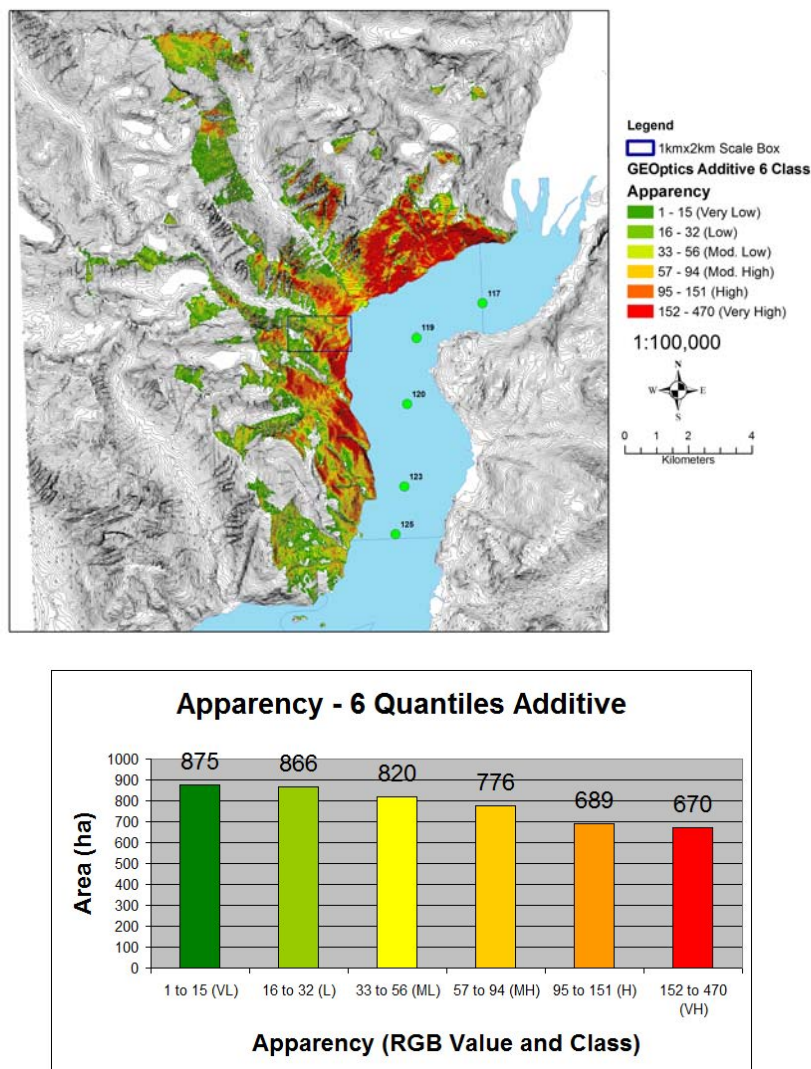
While overall patterns were somewhat similar, times-seen was considerably less refined in level of detail than apparency. For example, the "1" area on the times-seen map (Fig. 49, Map B) was a largely homogeneous area (rated as 5 times seen) while the same area

in the 5-class apparency map (Map A) indicates an area with a more precise range of apparency from moderate to very high which could be used to assist the visual landscape design of timber harvesting. The "2" area shows a large, undifferentiated area seen 3 times, but still with greater apparency worthy of more attention and visual design considerations. Times-seen maps indicate just the number of times a particular cell is seen from the viewpoints, while apparency also indicates how, or how much, each is seen. Times-seen is also limited in classification capability to the number of viewpoints, whereas apparency can be classified to any number of levels for either greater refinement or simplification.

Apparency and times-seen are more closely related, in pattern, than apparency and slope, being derived by similar ray-tracing processes from the same viewpoints. However, there are significant and substantial differences in findings from the two analyses, even with the identical viewpoints, suggesting the possibility of significant bias in decision-making depending on which system is used. Again, there are several areas of higher apparency but with low or moderate cumulative visibility over the southern two thirds of the study area shown in Fig. 49. The mapping reveals numerous significant differences in classification of at least 1-2 levels between sizeable areas in the two maps, and in some cases (eg. within Box 1) discrepancies of 4 levels can be found (eg. high cumulative apparency while times seen is only 1, i.e, seen from only 1 viewpoint). In general, there are more areas of higher apparency than of high visibility (times-seen), raising the possibility that times-seen mapping underestimates vulnerability to visual impacts.

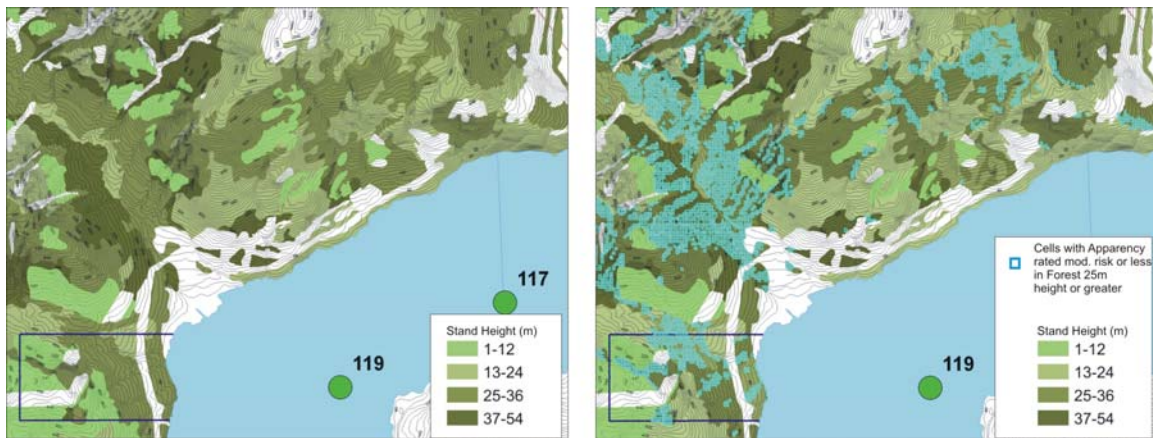
#### 4.4 Stage 4: Integration

Continuing into Stage 4, the integration stage is still a component of the first research question with regards to inventory, and addresses the usability evaluation criterion (Table 8). One further enhancement was made with classification, by changing the number of quantile classes to 6 in order to obtain a slightly finer differentiation compared to the 5-classes used earlier in this chapter (Fig. 50).



**Figure 50** Polygonized, 6-quantile additive apparency map and quantile area histogram; Howe Sound.

Conversion of the Howe Sound additive 5-light GEOTIFF with a 25m grid resolution to polygons with the same resolution provided the opportunity to select specific grid cells by a range of attributes. By first assigning forest cover attributes to each cell, all cells with forest heights of 25m or greater and apparency of moderately low or lower (1-56 RGB apparency value) were selected – thereby indicating all cells of likely higher economic value and lower visual risk if harvested (other constraints considered) (Fig. 51).



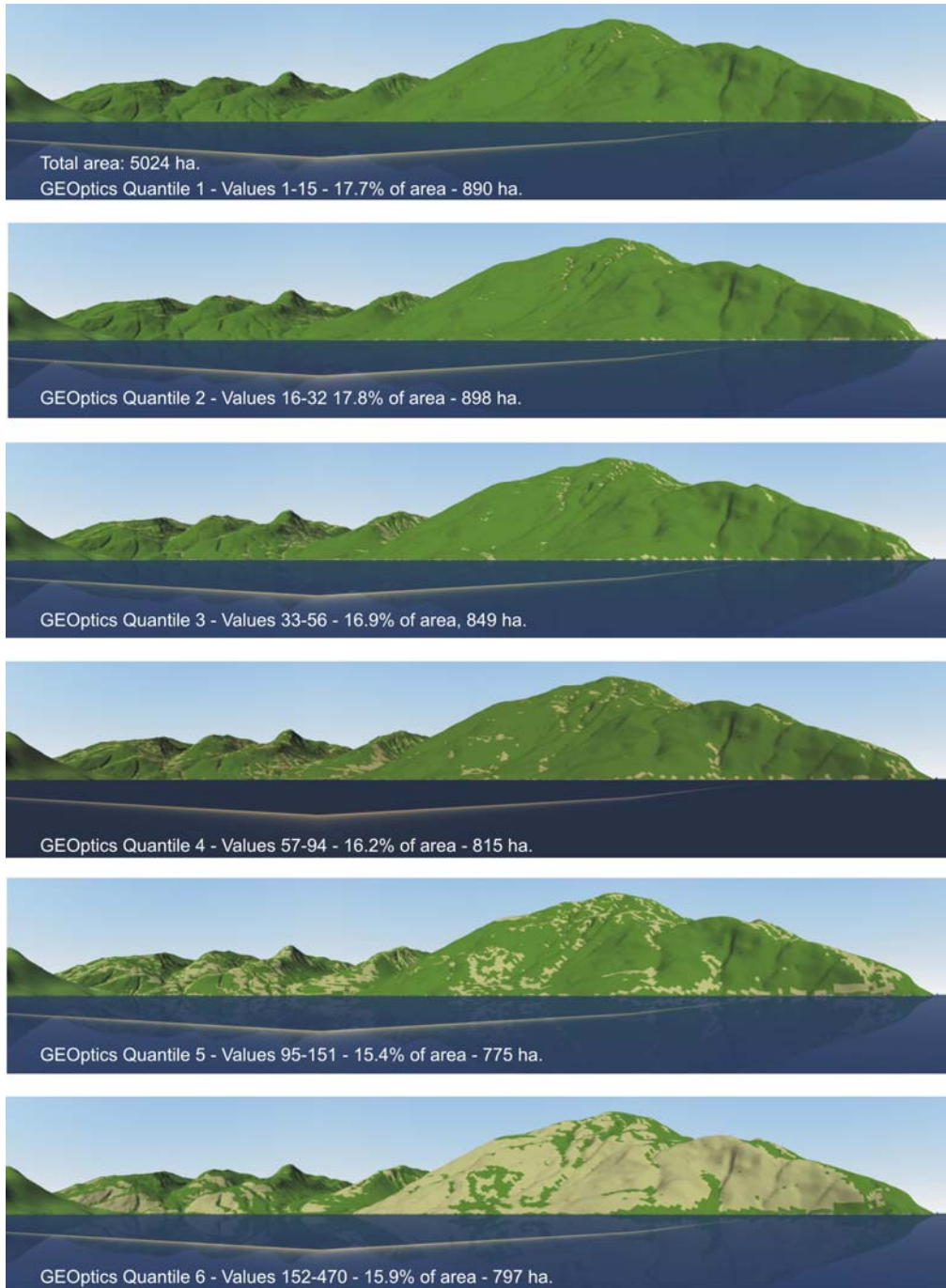
**Figure 51 Polygonized Howe Sound project forest height map on left and same map with cells selected for tree heights 25 m or greater combined with moderately low or lower cumulative apparency (RGB 56 value or lower within the additive cumulative range of RGB 470) on right, with selected cells on right outlined in blue colour, as selected and portrayed in ArcMap.**

The ability to select cells based on their attributes, such as unstable terrain, steep slopes, riparian, or other environmental constraint areas, could greatly assist further analysis and planning (Stages 5 and 6). The polygonized planning cells also were directly importable, as shapefiles with their full set of attributes, in VNS for visualization, impact assessment and further analysis (see Stage 6, Sec. 4.6.4).

## 4.5 Stage 5: Analysis

In Stage 5, Analysis, Research Question 2 (Can GEOptics improve planning?) is addressed. Specifically, Stage 5 is focused on strategic level analysis, management planning, and timber supply within a controlled forest environment, including the utility of the apparency tool for derivation of plan to perspective ratios (P2Ps), and more accurate and precise determination of timber supply constraints (VQOs). As discussed in Sec. 2.2.2.3, the P2P ratios are applied when converting the percent alteration of forest alteration (cutblocks) in perspective view to the equivalent percent alteration in plan view.

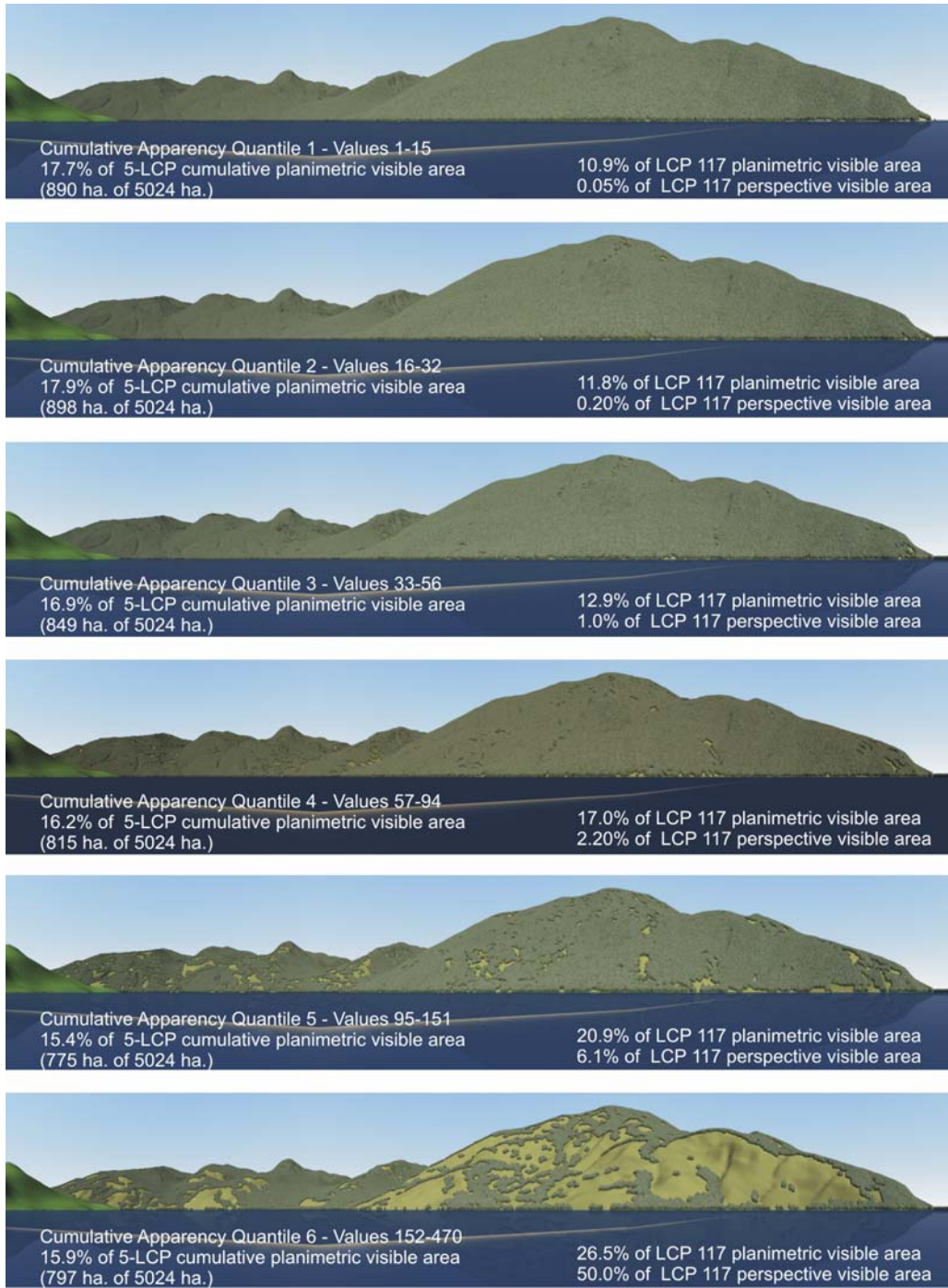
The 6-quantile apparency grid cell groupings (Fig. 50) were imported, individually, into the Howe Sound west side VNS model and projected in perspective view from each of the five LCPs. The terrain was first displayed as bare land to allow easy recognition and comparison of the location and extent of each quantile group (Fig. 52).



Stage 5 P2P LCP 117 - GEOptics Apparency by Quantiles - Bare Land

**Figure 52 VNS bare land rendering (from Howe Sound LCP 117) of six quantile classes of additive method cumulative apparency from 5 LCPs depicting the visible change contribution of each quantile group (pale brown) in the bare green terrain, with planimetric measures in hectares for total apparency map area from all five LCPs.**

Next, a generic VNS forest cover was assigned to the model, having 300 trees per hectare and 25-30m tree heights in order to factor in the effect of tree screening when determining percent contribution and P2Ps (Fig. 53). Planimetric area contribution percentages and perspective (picture) area contribution percentages were determined for the quantiles. Plan-to-perspective ratios were determined by dividing the planimetric percentages by the perspective percentages. The planimetric percentages are shown for each quantile based on total cumulative apparency area from all five LCPs.



**Figure 53 Cumulative apparency by quantile group – Howe Sound VNS forest model, LCP 117, depicting the amount of visible change that would be caused by individual quantile groups (tan colour) in the forested terrain, if harvested, with cumulative and LCP-specific planimetric apparency map area measures, and LCP-specific perspective measures; full-width view.**

Two sets of apparency analysis were prepared using the Howe Sound dataset: Set 1 portrayed each quantile of apparency individually, and is presented in Sec. 4.5.1; Set 2 portrayed aggregated quantiles, added consecutively, one at a time, from lowest to highest visual risk grouping, and is presented in Sec. 4.5.2.

The percentage contribution of each quantile (Set 1) and each quantile aggregation (Set 2) was measured in plan and perspective views in order to calculate the P2Ps for each. To accomplish this task, two methods were required in order to determine overall and LCP-specific findings: Method 1, using the 6 quantile cumulative apparency map area determined for all LCPs, as the base measure from which the quantile groups were derived (e.g. the cumulative apparency inset map in Fig. 54, and shown previously in Fig. 50); and Method 2, using only the apparency map area determined at each individual LCP, using the LCP 117 apparency map as an example (the single LCP apparency map inset in Fig. 54). Method 2 was necessary to provide the correct planimetric apparency map area for the LCP-specific calculations. It should be noted that the perspective area is the same regardless of method, as that area comprises all that may be seen (i.e., the viewshed) from a single, static viewpoint. There is no way to statically portray a "cumulative" viewshed seen from multiple viewpoints in perspective 3-D view. The cumulative viewing experience can be sensed, visually, through animations produced with the viewpoint camera moving along the viewing track (as with videography or 3-D VNS animation), however, only static views taken from them can be measured. For demonstration, the distinctions between the two methods were calculated and tracked for LCP 117 only.

In the cumulative approach (Method 1), the planimetric visible change contribution of each quantile was determined within the entire planimetric LCP apparency map area for the 5 LCPs. In the LCP-specific approach (Method 2), the planimetric visible change contribution of each quantile was determined within the LCP-specific apparency map extent (using the LCP 117 apparency map). The overall measure provided a project overview taking into account cumulative apparency; the second method considered only the apparency map area pertaining to the given viewpoint, LCP 117, and therefore provides a more precise measure for the P2P, without contribution of apparency area from other LCPs. For ease of identification, the visible change contribution<sup>34</sup> by each quantile (Set 1) and each aggregated quantile set (Set 2) in the landscape was depicted in VNS simulations as land-use alteration within a controlled forest environment of 300 trees per hectare and tree heights of 25-30m in the VNS forest model. The demonstration by quantiles is not a necessary step in the implementation of apparency for operational planning purposes, nor was it intended to be a logging plan. The application of apparency for timber harvest planning was tested in Stage 6.

#### **4.5.1 Set 1 Cumulative and LCP-specific Apparency**

Set 1 cumulative and LCP specific apparency in planimetric and perspective views were used to generate overall (Method 1) and LCP-specific (Method 2) percent contribution

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<sup>34</sup> In more familiar terminology in visual resource management, planimetric and perspective "contribution" is usually termed "alteration" when considering the effect of land-use change (such as timber harvesting) in the landscape, and particularly when considering the percent visible change contribution (alteration) relative to the larger landscape. The terms could be used interchangeably in this application as the contribution of the quantiles, when rendered in perspective view, was provided with an appearance of alteration used typically for representing clearcutting in visual simulations.

and P2P ratios and to examine the visual results, though never intended as a logging plan. To determine P2P ratios, the planimetric percent contribution (calculated earlier for each quantile within the visible landbase) was divided by the perspective percent contribution of each quantile within the apparency visible landbase "viewshed" seen only from that LCP, in perspective view measurements. The measures are summarized in Table 9 and presented along with Method 2 results in the visual portrayals (full width images in Fig. 53; close-up images Figs. 54-59).

**Table 9 Method 1 change contribution in forest canopy by apparency quantile, with cumulative apparency map planimetric area and percent change from 5 LCPs and perspective visible area percent from LCP 117, with P2P ratios; Howe Sound.**

Quantile	Apparency RGB Value / Visual Risk Class*	Method 1 Area (ha)	Method 1 Planimetric Change Contribution (%)	Method 1 Perspective Visible Change Contribution LCP 117 (%)	Method 1 Plan to Perspective Ratio
1	1-15 (VL)	889.7	17.71%	0.05%	354.2
2	16-32 (L)	898.4	17.88%	0.20%	89.4
3	33-56 (ML)	849.1	16.90%	1.00%	16.9
4	57-94 (MH)	814.9	16.22%	2.20%	7.4
5	95-151 (H)	774.6	15.42%	6.10%	2.5
6	152-470 (VH)	796.9	15.86%	50.00%	0.3
SUM		5023.6	100.00%	(not additive due to tree screening)	

\*VL – Very Low; L – Low; ML – Moderately Low; MH – Moderately High; H – High; VH – Very High

The apparency value used in the quantile groups is the summed illumination value of each grid cell calculated by raster addition of the values contributed from each of the 5 LCP lights (RGB 1-470). Planimetric contributions are additive to 100%, but perspective contributions are not additive due to tree screening.

The LCP-specific area measures for viewpoint (Method 2) were similarly used to calculate the P2P ratios derived for the LCP-specific apparency map area alone (Table 10). The perspective percent contribution in each table is the same (that is, both methods utilize the same perspective rendering revealing all that can be seen in the LCP apparency "viewshed"). The measures are summarized in Table 10 and presented along with Method 1 results in the visual portrayals (Figs. 54-59).

**Table 10 Method 2 change contribution in forest canopy by cumulative apparency quantile, in LCP-specific plan and perspective from LCP 117 with P2P ratios; Howe Sound.**

Quantile	Apparency RGB Value / Visual Risk Class*	Method 2 Area (ha)	Method 2 Planimetric Change Contribution (%)	Method 2 Perspective Visible Change Contribution LCP 117 (%)	Method 2 Plan to Perspective Ratio
1	1-15 (VL)	248.8	10.88%	0.05%	217.5
2	16-32 (L)	270.3	11.81%	0.20%	59.1
3	33-56 (ML)	296.2	12.95%	1.00%	12.9
4	57-94 (MH)	388.5	16.98%	2.20%	7.7
5	95-151 (H)	477.9	20.89%	6.10%	3.4
6	152-470 (VH)	606	26.49%	50.00%	0.5
SUM		2287.8	100.00%	(not additive due to tree screening)	

\*VL – Very Low; L – Low; ML – Moderately Low; MH – Moderately High; H – High; VH – Very High

The two measurement methods (Method 1 – overall area; Method 2 – LCP-specific area) provide distinctions in total planimetric area, planimetric percent alteration, and P2P calculations. The percent planimetric contribution of each quantile in the overall project (Method 1) was approximately 16% (Table 9). When calculated for the contribution to the view-point specific area, the planimetric contribution of each cumulative apparency quantile varied considerably, ranging from 11% (Quantile 1) to

over 26% (Quantile 6). The choice of method could have management implications at different planning levels, with operational planning perhaps more concerned with the viewpoint-specific approach in designing for specific views. The perspective visual change in the quantiles presumed to have lower visual risk was exceedingly low, not rising above 1% visible change in any of the 3 quantiles (both methods having the same perspective measure as described earlier). The amount of perspective visual change rises strongly in the quantiles presumed to have higher visual risk, from 2.2% in Q4 to 50% in Q6, which is fully half of the visible landbase in perspective seen from LCP 117 while only 16% of the planimetric area (Method 1) and 26% in the LCP-specific method (Method 2). The inference of increasing rate of contribution (alteration) in the higher quantiles is that the presumed higher visual risk translates directly into high visual impact potential in those areas, while in the lower quantiles, lower presumed visual risk translates into very low or no visual impact potential.

The P2P ratios provide further indication of the potential for the use of apparency for influencing rates of timber supply allocation and restriction. The 3 "lower risk" quantiles (1-3), occupying over 50% of the cumulative apparency classified (visible) land area, ranged from 17:1 to 354:1, well in excess of the BCMoFR's conventionally determined P2P ratio of 2:1, even with slope adjustment (Table 1). Similarly, the 36% of the LCP-specific apparency land area in the same 3 low risk classifications had P2Ps ranging from 13:1 to 217:1. The results suggest that the low risk areas might be able to support much higher levels of land-use alteration per degree of visual impact created than would be indicated by the current P2Ps set broadly by the BCMoFR. Areas in both approaches

included moderate to steep slopes, where conventionally determined P2Ps would be even lower (under 2:1), and further restriction with the conventional approach.

The 3 "higher risk" quantiles (4-6) have P2P ratios that are virtually identical in the two methods, and more in line with conventionally derived P2Ps (0.3:1 to 7.4:1 for Method 1 and 0.5:0 to 7.7:1 for Method 2), suggesting that the restrictiveness brought by conventionally applied P2Ps is appropriate in the high risk areas (47% and 64% of each total area, respectively). However, those areas do not incorporate any of the substantial low risk areas which would support some reduction in restrictiveness. P2P ratios produced in the overall Method 1 would be useful and accurate for consideration in timber supply calculations and constraint mapping, while LCP-specific Method 2 P2P ratios would be more precise and accurate for planning considerations from a particular viewpoint.<sup>35</sup>

The following series of illustrations depict the appearance of each of the six quantiles, if their areal extent was cleared or "harvested", for both cumulative apparency produced by the additive method (Set 1), from lowest apparency (least presumed visual risk) to highest (greatest presumed visual risk) as seen from a single viewpoint, LCP 117. The results for cumulative apparency by quantiles (Set 1) are presented in Figures 54-59 for LCP 117.

The quantile apparency demonstration was not intended to suggest an actual logging plan, and has not considered environmental or operational requirements. The images have the northern portion (right half) of the landscape clipped away to provide a closer look at

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<sup>35</sup> Note: the results reveal important differences in P2Ps in the landscape with different levels of cumulative visual risk. These findings are indicators, but are not suggested to change policy direction.

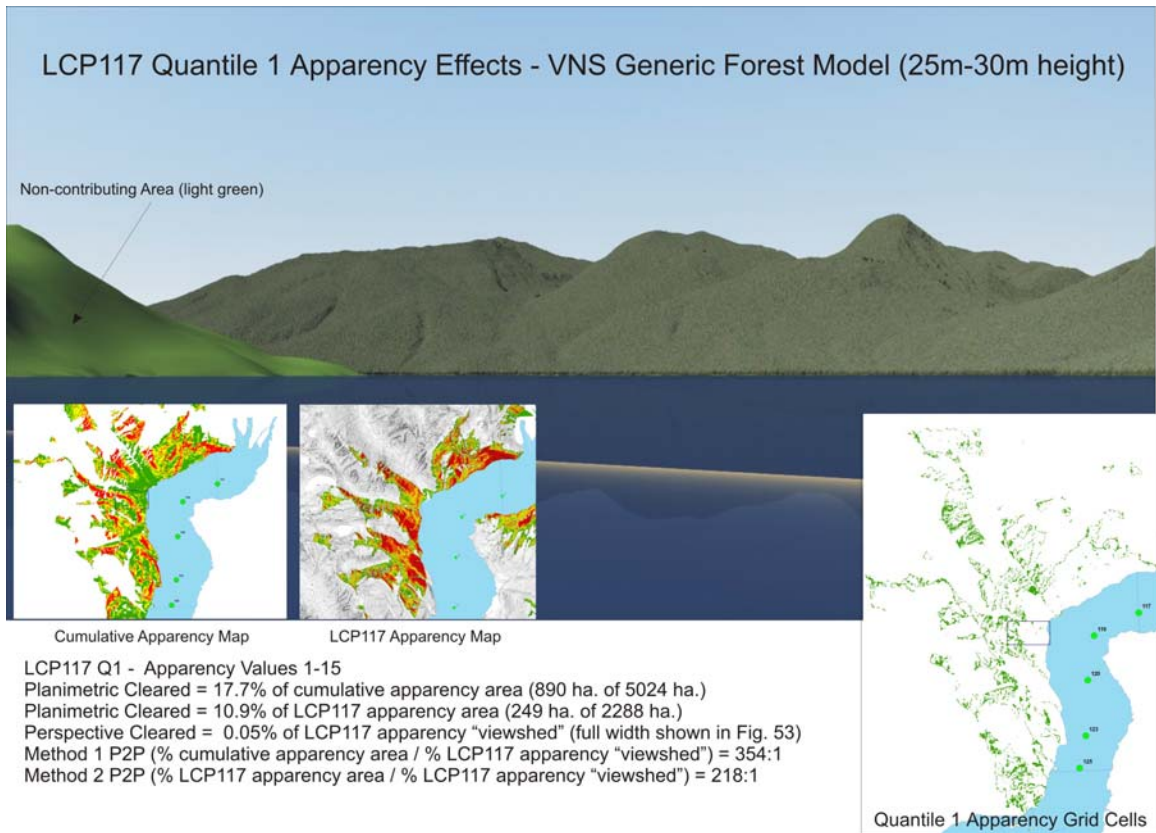
the southern portion and therefore do not show the full extent of the unit used for perspective percent alteration calculation. However, the full width views were as shown in Fig. 53. The images also have a shoulder of land entering from the left, portrayed as bare green land, which is outside of the study area and therefore non-contributing to the apparency measures. The map insert that is in the bottom right in each of the figures reveals the location and extent of cells within each cumulative quantile grouping. The 5-light cumulative apparency map and the viewpoint-specific single LCP light apparency map (for LCP 117) are added to each figure in the bottom left for reference. The P2P measures, calculated for the total visible area (Method 1) and for the specific viewshed area (Method 2), are also provided in each quantile group illustration. Results were summarized for each of the sets of illustrations (Tables 9, 10).

Percent alteration and P2P measures shown for each quantile are the calculations derived from the entire apparency "viewshed" from that LCP<sup>36</sup>. The full width view of the terrain (Fig. 53) was used when determining percent alteration for each quantile perspective view, and for the resulting P2P ratios for each quantile as seen from LCP 117. The renderings of each quantile as seen from each of the other 4 viewpoints are presented for purposes of visual comparison (Figs. 60-63), following those for LCP 117 (Figs. 54-59).

### **Apparency Results Set 1 – Individual Quantiles of Apparency in Perspective View** (Figures 54-59).

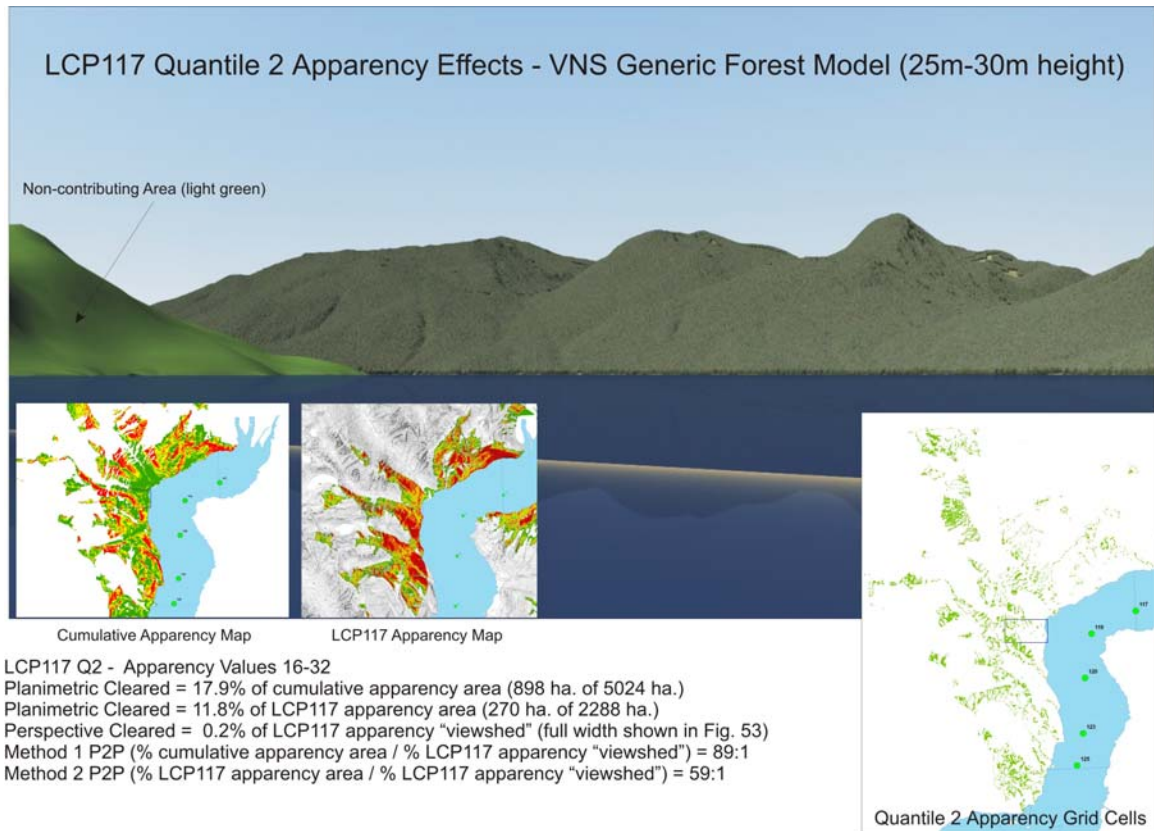
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<sup>36</sup> The apparency "viewsheds" were determined to be identical to the conventionally produced viewsheds (Sec. 4.2.6; Fig. 39).



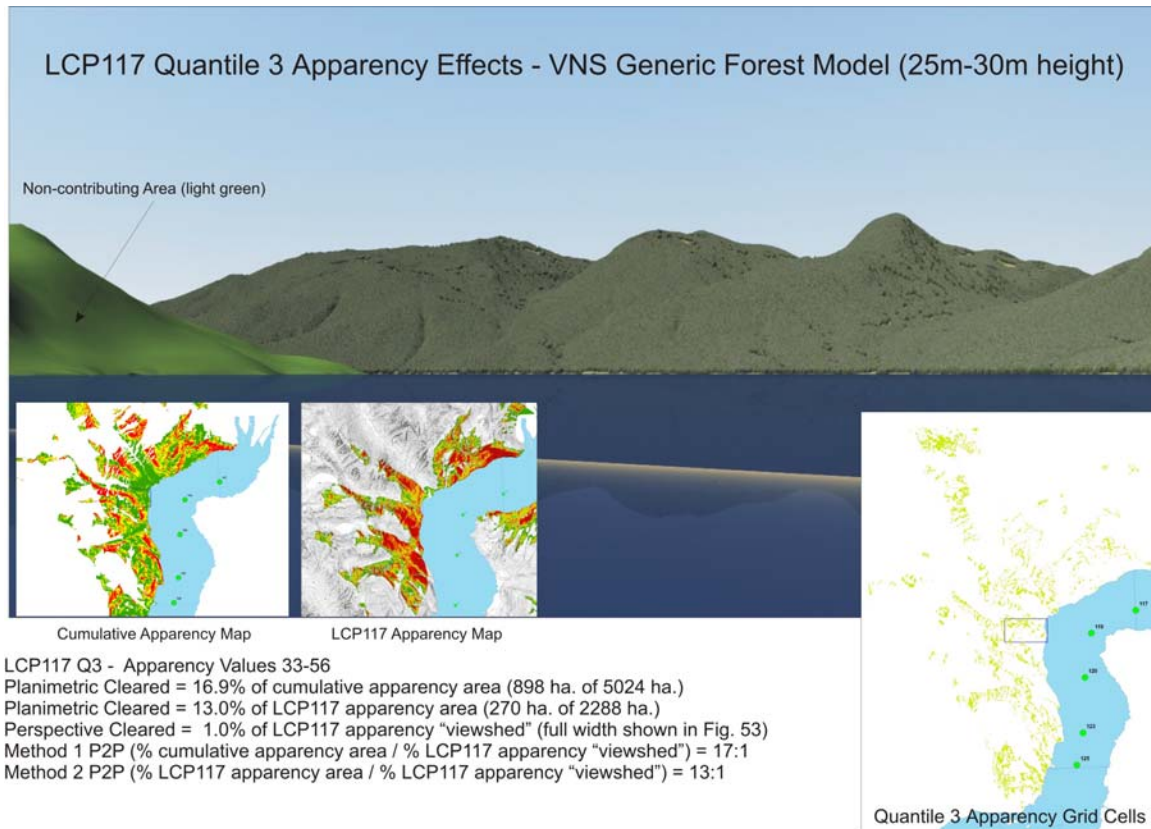
**Figure 54 Cumulative Apparency Quantile 1 (very low visual risk) depicting the amount of change that would be generated by the quantile group (tan colour – non-evident in Quantile 1) in the forested terrain, if harvested; Howe Sound VNS forest model, close-up view, LCP 117.**

The visual results for quantile 1, if harvested, would emulate Preservation or Retention visual quality, with no or very little visual exposure (using the BCMoFR categories of visual quality objectives/classes presented in Table 4).



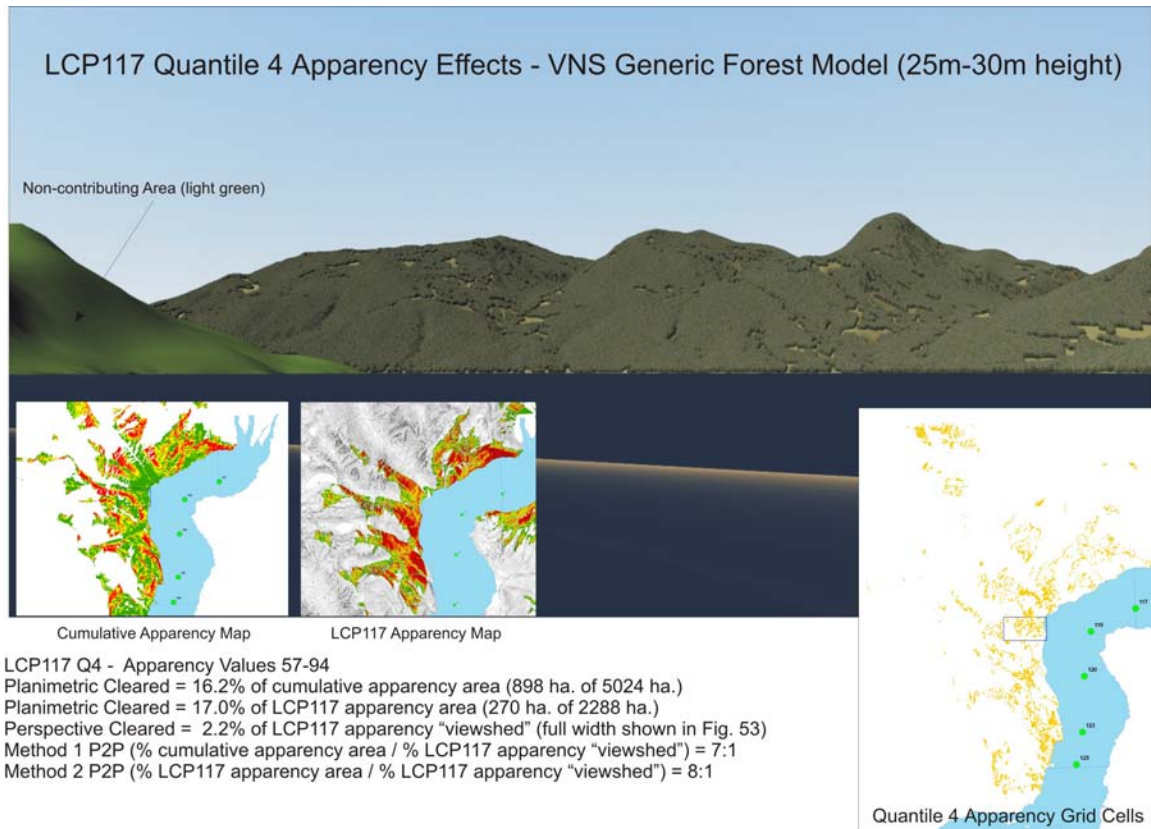
**Figure 55 Cumulative Apparency Quantile 2 (low visual risk) depicting the amount of change that would generated by the quantile group (tan colour) in the forested terrain, if harvested; Howe Sound VNS forest model, close-up view, LCP 117.**

The visual results for quantile 2, if harvested, would emulate Retention visual quality, with very little visual exposure.



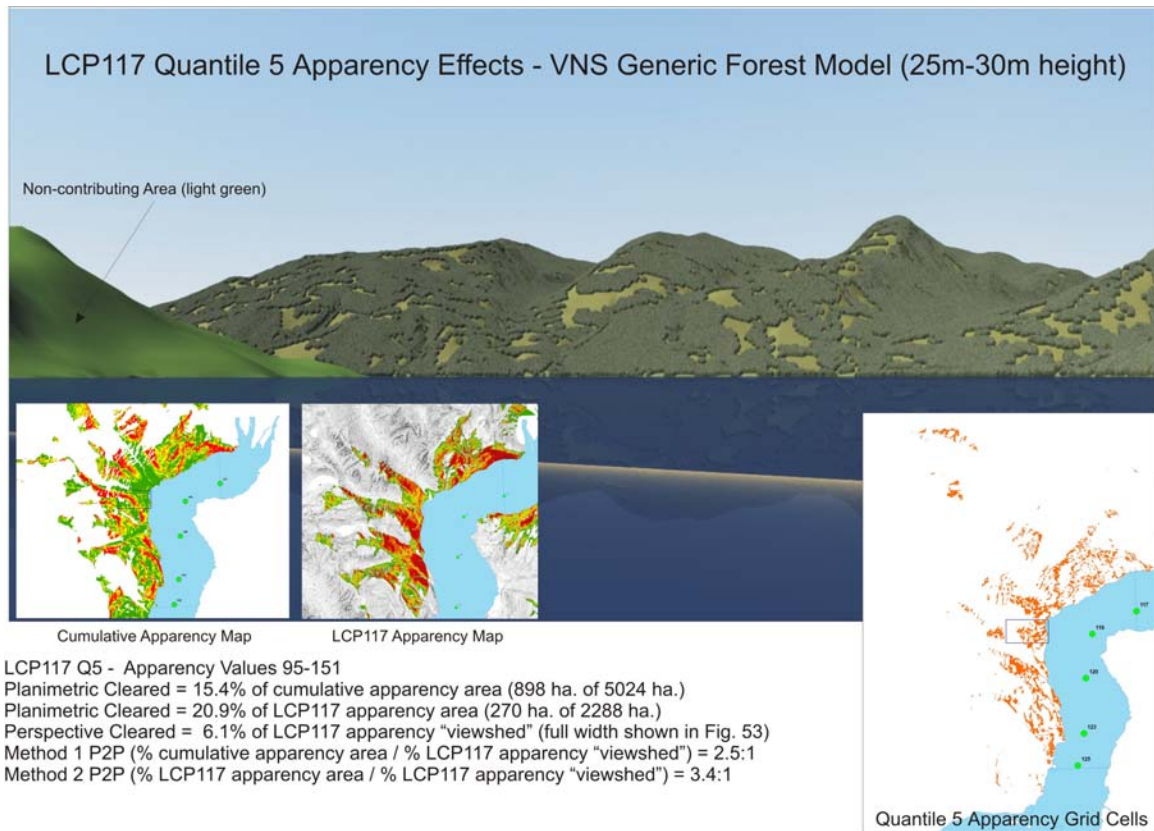
**Figure 56 Cumulative Apparency Quantile 3 (moderately low visual risk), depicting the amount of change that would be generated by the quantile group (tan colour) in the forested terrain, if harvested; Howe Sound VNS forest model, close-up view, LCP 117.**

The visual results for quantile 3, if harvested, would emulate Retention or Partial Retention visual quality, with minor visual exposure, subordinate in the landscape.



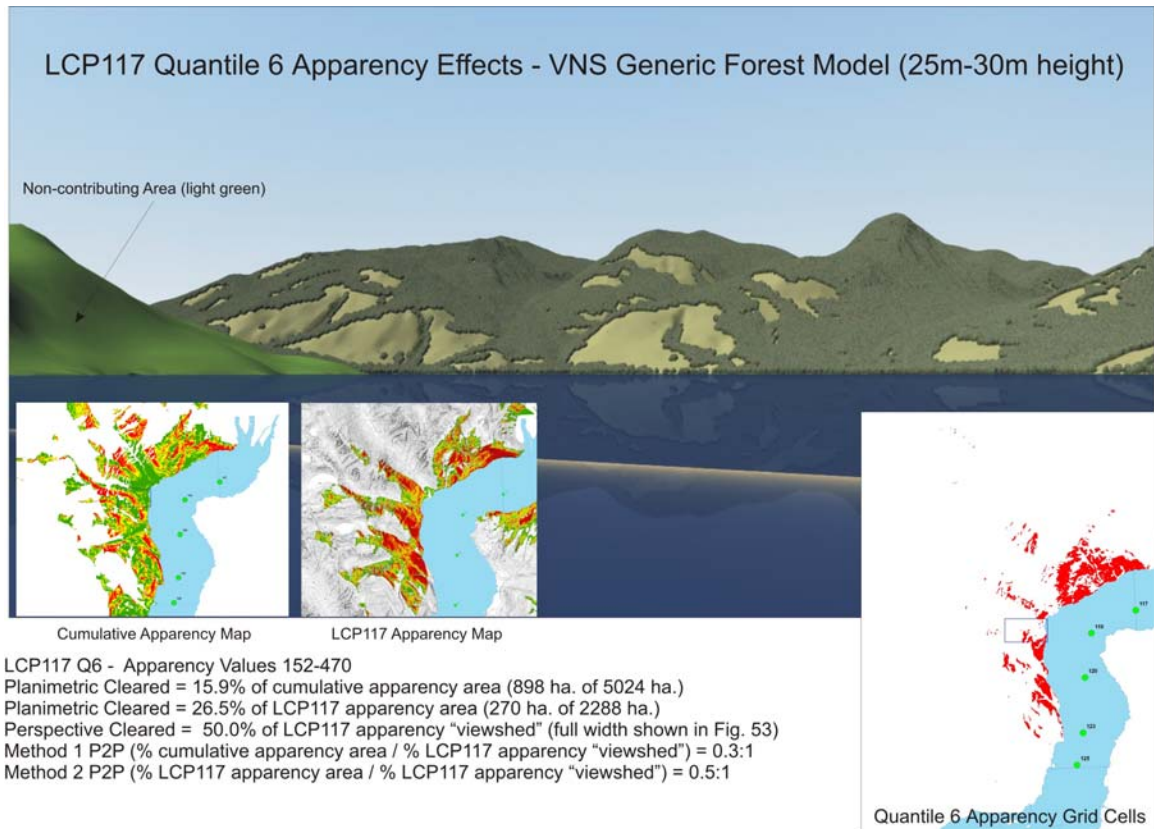
**Figure 57 Cumulative Apparency Quantile 4 (moderately high visual risk). depicting the amount of change that would be generated by the quantile group (tan colour) in the forested terrain, if harvested; Howe Sound VNS forest model, close-up view, LCP 117.**

The visual results for quantile 4, if harvested, would emulate Partial Retention visual quality, with visual exposure which is subordinate in the landscape, but follows line and form.



**Figure 58 Cumulative Apparency Quantile 5 (high visual risk), depicting the amount of change that would be generated by the quantile group (pale brown) in the forested terrain, if harvested; Howe Sound VNS forest model, close-up view, LCP 117.**

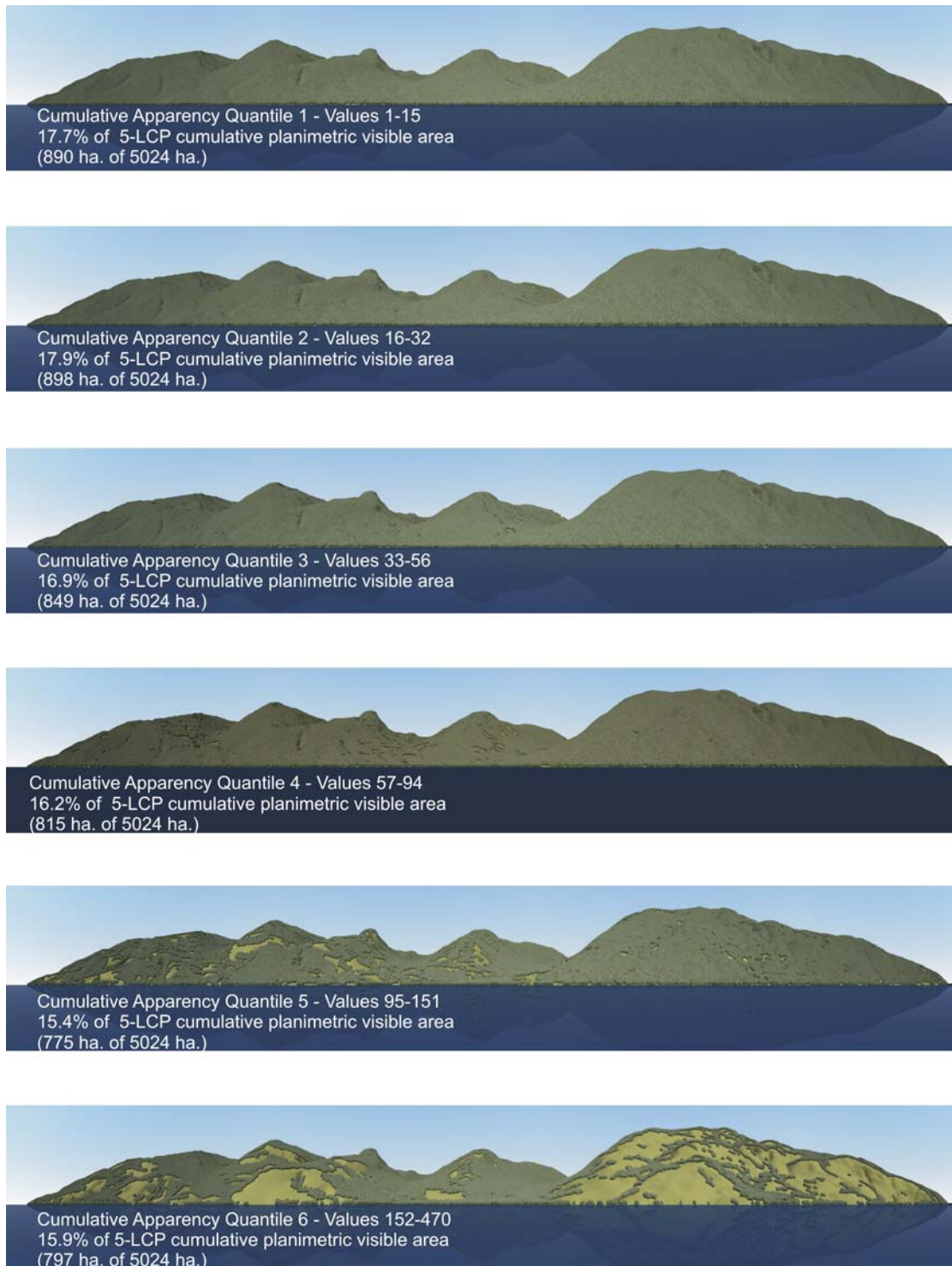
The visual results for quantile 5, if harvested, would emulate Modification visual quality, with visual exposure which begins to dominate the landscape, but follows line and form, and has natural characteristics.



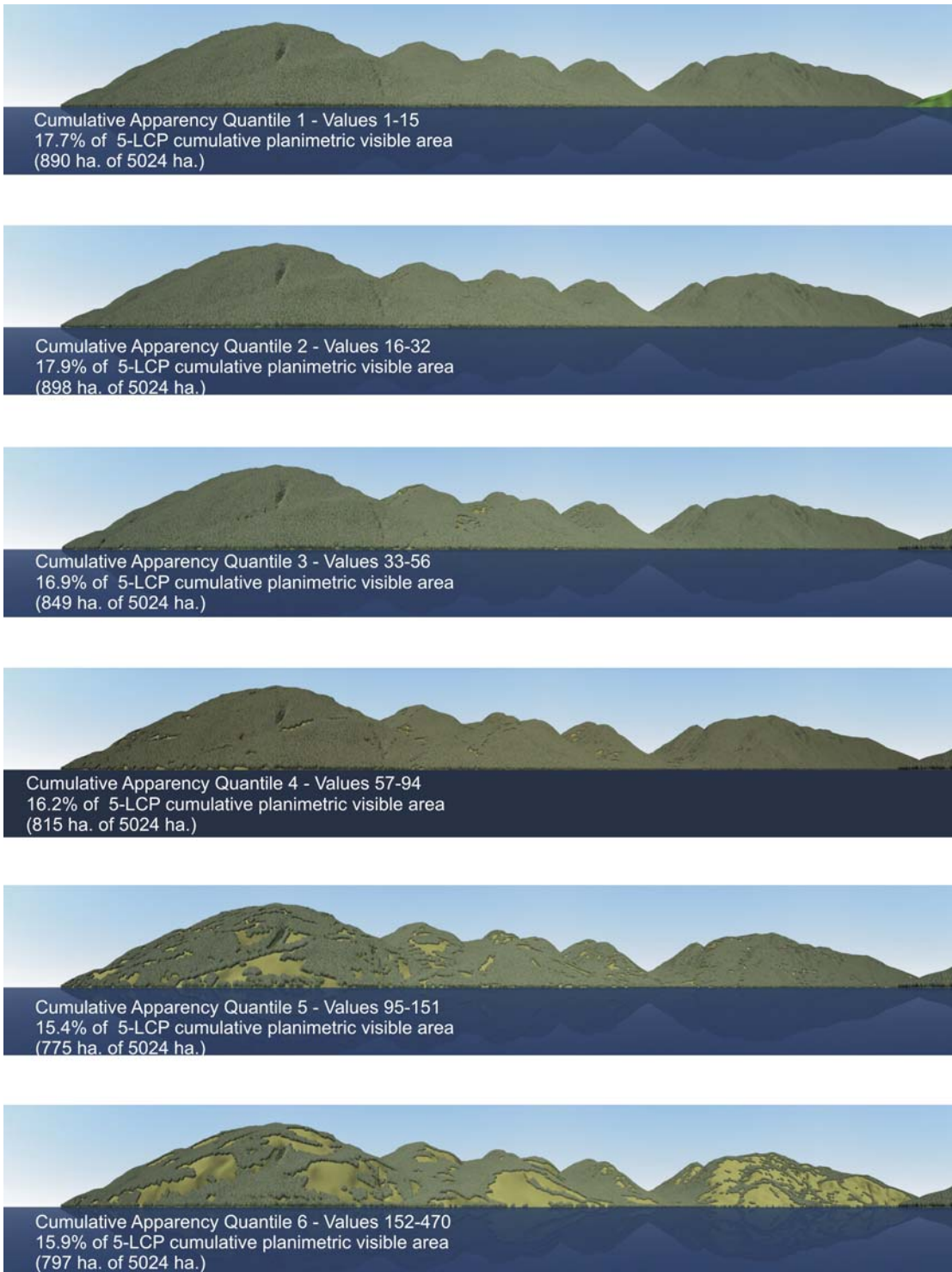
**Figure 59 Cumulative Apparency Quantile 6 (very high visual risk), depicting the amount of change that would be generated by the quantile group (tan colour) in the forested terrain; Howe Sound VNS forest model, close-up view, LCP 117.**

Very significantly, the 16% of cumulative apparency landbase in quantile 6, if "harvested", would visually alter fully one-half of the LCP-specific viewshed, and would result in P2Ps of less than 1:1, the lowest of all quantiles (Fig. 59). The visual results would emulate Excessive Modification visual quality in scale (>30% visible change), but would appear to be natural occurrences in distant views, with shaping along major lines of force (ridges and hollows), thus emulating more closely Maximum Modification.

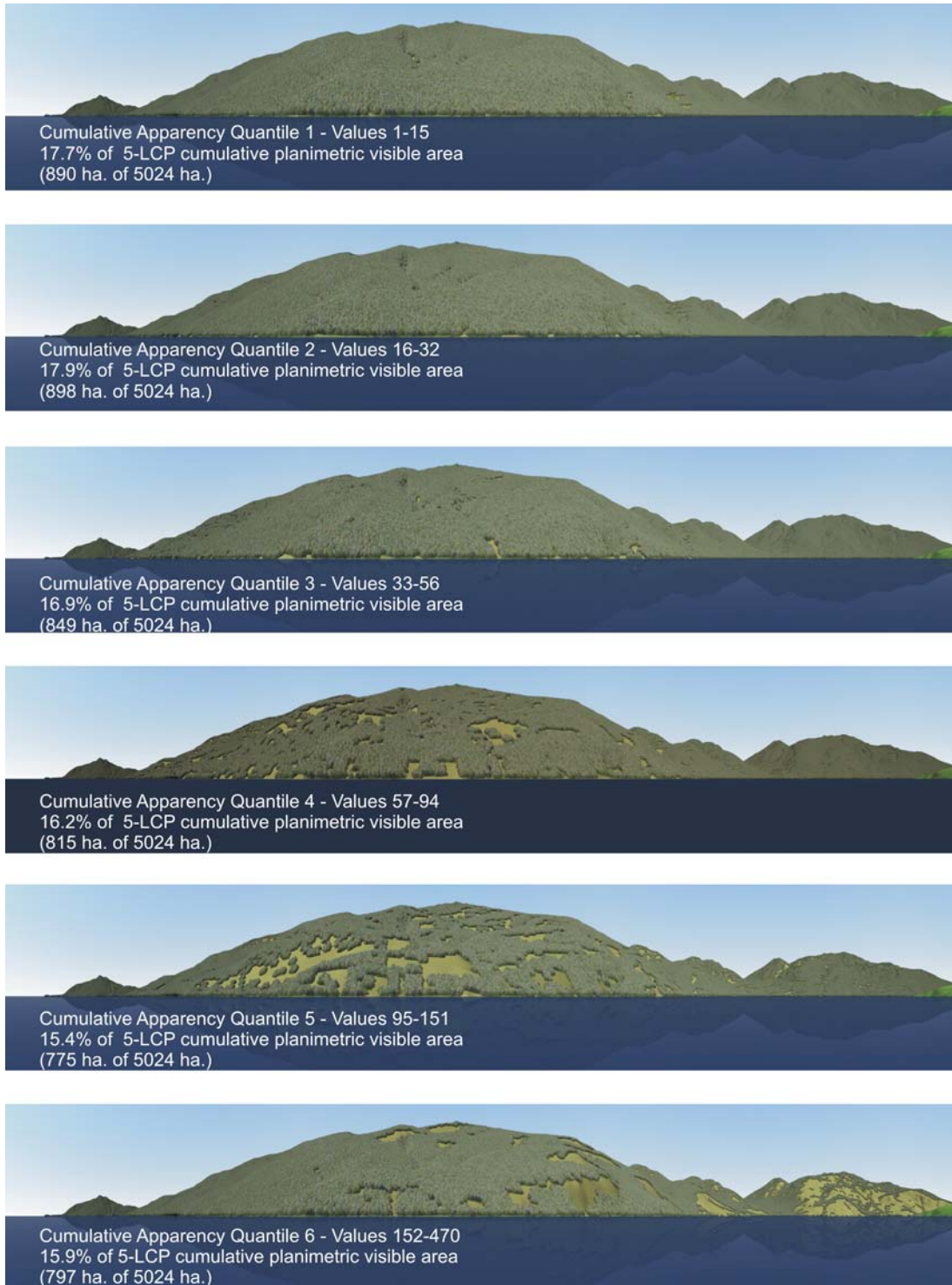
Figure 53 showed all quantiles together as rendered from LCP 117, in full width view. The renderings from each of the other viewpoints are presented next for purposes of visual comparison (Figs. 60-63). The full width views were used for the percent change and P2P calculations (Tables 9, 10).



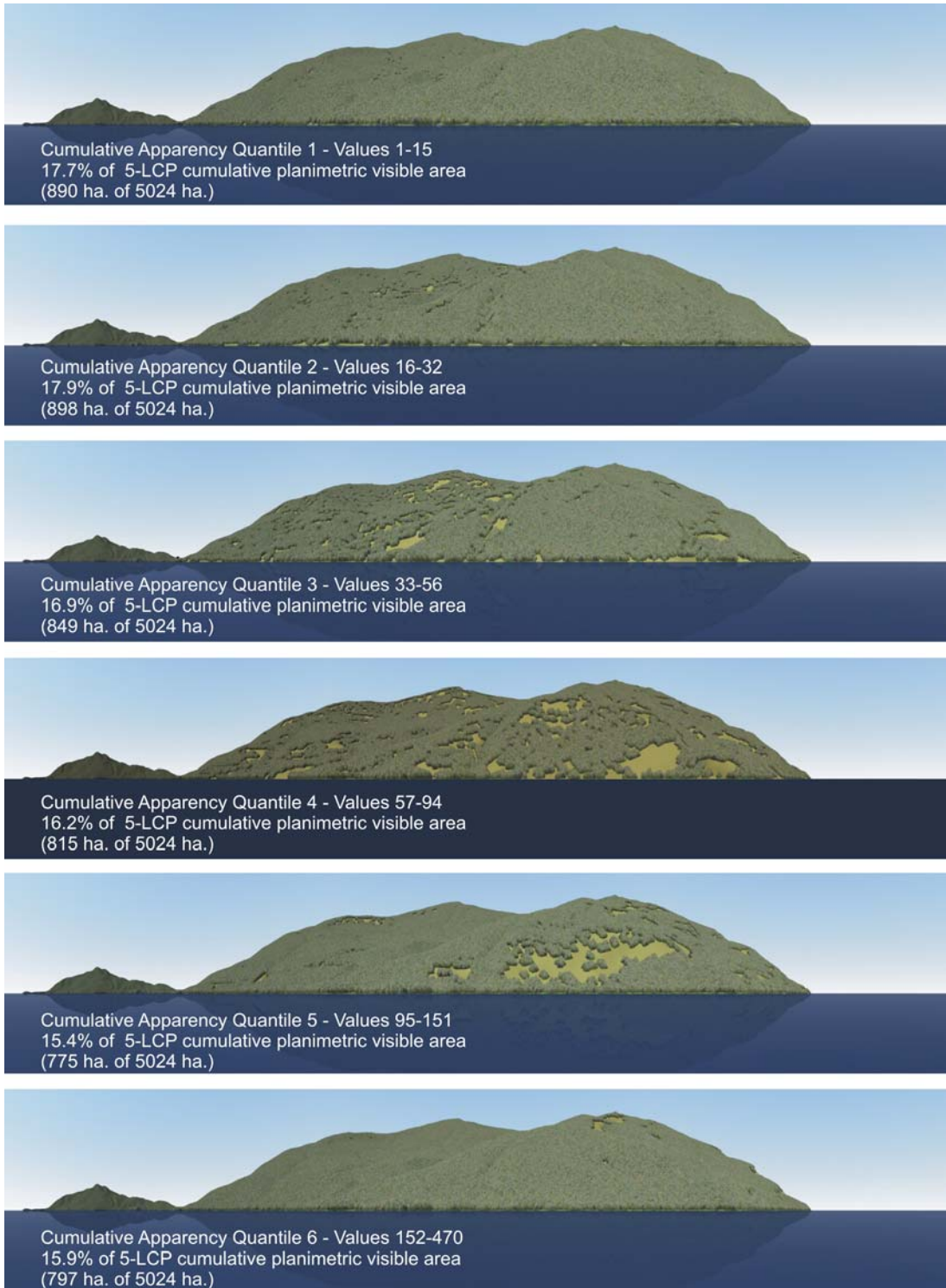
**Figure 60 Cumulative apparency by quantile group – Howe Sound VNS forest model LCP 119, depicting the amount of change that would be generated by individual quantile groups (tan colour) in the forested terrain, if harvested; full-width view.**



**Figure 61 Cumulative apparency by quantile group – Howe Sound VNS forest model LCP 120, depicting the amount of change that would be generated by individual quantile groups (tan colour) in the forested terrain, if harvested.**



**Figure 62 Cumulative apparency by quantile group – Howe Sound VNS forest model LCP 123, depicting the amount of change that would be generated by individual quantile groups (tan colour) in the forested terrain, if harvested.**



**Figure 63 Cumulative apparency by quantile group – Howe Sound VNS forest model LCP 125, depicting the amount of change that would be generated by individual quantile groups (tan colour) in the forested terrain, if harvested.**

Visualization of each of the six "equal area" quantiles from each of the five viewpoints in the Howe Sound project provided a means for visual comparison of the extent and pattern of each quantile. Generally, the visual effect of the first three quantiles, rendered as if harvested, was minor to very minor in the landscape, representative of retention to partial retention visual quality. Quantiles 4 to 6 become increasingly evident generally, but emulate visual design elements of partial retention to modification. Even Quantile 6 shows elements of visual design and conformity with the landscape although the scale of visual change is much more dominant. LCP 125 reveals greater alteration in earlier quantiles, likely due, in part, to closer proximity to the viewpoint and exclusion of large portions of the overall landscape visible to other viewpoints. LCP 125 is also an outlier, being the most southerly viewpoint, less influenced by other LCPs in the cumulative illumination mapping process. The positioning of VNS light sources relative to the landscape characteristics and proximity was shown to have an influence on apparency, and as such, is a sensitivity factor.

The implications of apparency classification methods are discussed in Sec. 6.1.3 under the Stage 3 (classification) heading.

#### **4.5.2 Set 2 – Aggregated Cumulative and Viewpoint-specific Apparency**

The second set of quantile groups analysed (Set 2) was aggregated from the data just presented, starting with the lowest apparency grouping (assumed to be the grouping exhibiting the least visual risk) and adding each higher apparency quantile consecutively, and rendering that image from the viewpoint until all groups were enabled and rendered.

Only LCP 117 perspective views were rendered for Set 2. As with Set 1, Set 2 planimetric and perspective area and percent contributions were determined. P2P ratios were calculated for both the cumulative and LCP-specific methods, and the visual results examined, though never intended as a logging plan. Table 11 reveals the results of the cumulative area approach (Method 1), while Table 12 reveals the LCP-specific results (Method 2).

**Table 11 Method 1 aggregated quantile groups with cumulative 5 LCP planimetric apperency areas and visible change percent contribution for LCP 117, with P2P ratios.**

<b>Aggregated Quantile Grouping</b>	<b>Method 1 Area (ha)</b>	<b>Method 1 Planimetric Change Contribution (%)</b>	<b>Method 1 Visible Change Perspective Contribution LCP 117 (%)</b>	<b>Method 1 Plan to Perspective Ratio</b>
1	889.7	17.71%	0.05%	354.2
1-2	1788.1	35.59%	1.00%	35.6
1-3	2637.2	52.50%	4.30%	12.2
1-4	3452.1	68.72%	12.20%	5.6
1-5	4226.7	84.14%	28.20%	3.0
1-6	5023.6	100.00%	100.00%	1.0

The individual quantile groups were aggregated consecutively, one increment at a time, from lowest (least presumed risk) to highest (greatest presumed risk), to derive the aggregate results. P2P with all groups together, was 1:1, a confirmation of the model.

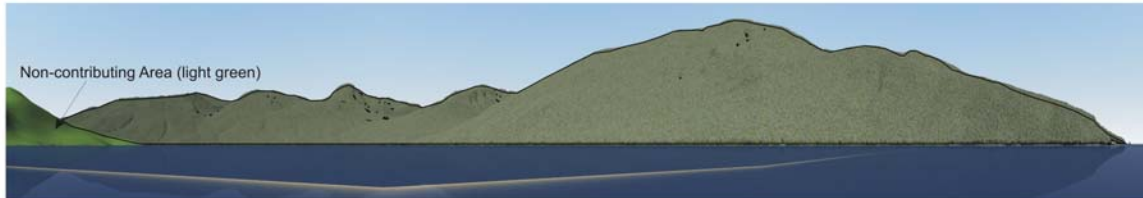
**Table 12 Method 2 aggregated quantile groups with LCP 117 LCP-specific planimetric apparency areas and visible change percent contribution for LCP 117, with P2P ratios.**

<b>Aggregated Quantile Grouping</b>	<b>Method 2 Area (ha)</b>	<b>Method 2 Planimetric Change Contribution (%)</b>	<b>Method 2 Visible Change Perspective Contribution LCP 117 (%)</b>	<b>Method 2 Plan to Perspective Ratio</b>
1	248.8	10.88%	0.05%	217.5
1-2	519.1	22.69%	1.00%	22.7
1-3	815.3	35.64%	4.30%	8.3
1-4	1203.8	52.62%	12.20%	4.3
1-5	1681.7	73.51%	28.20%	2.6
1-6	2287.7	100.00%	100.00%	1.0

Percent visible change in perspective view is the same in both cumulative and LCP-specific approaches, using, by necessity, the same perspective rendering which determines the same viewshed with either method (discussed earlier with Set 1). The LCP-specific measure of area in the apparency "viewshed" is much more precise when determining P2P ratios, as much of the area outside the LCP-specific apparency area but within the total cumulative apparency area is eliminated. As with the individual quantile analysis, the aggregated approach provided distinctions in total planimetric area, planimetric percent alteration and P2P calculations between the two calculation methods.

The visible contribution in perspective view is slow to change as quantiles 1-3 are aggregated (0.05%-4.3%) even though at the 3rd aggregation 52% of the total landbase and 36% of the LCP-specific landbase was cleared ("harvested"). An inference can be made that less visual restrictions could be placed on those large, but lower risk, portions of the visually sensitive area while potentially meeting Retention or Partial Retention VQOs. Visual simulations of each aggregation are presented in Figs. 64-69, with the

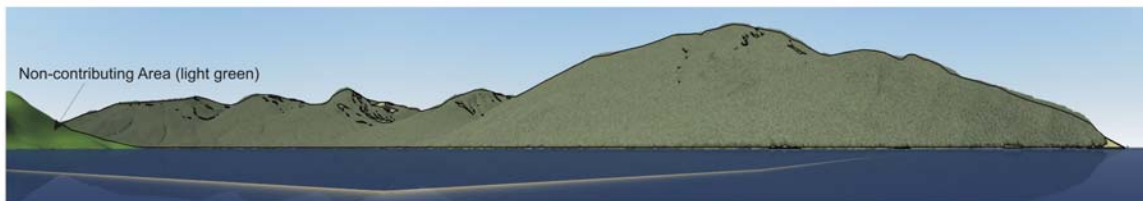
image depicting the amount of change that would be generated by the aggregated quantiles (pale brown) in the VNS forest model, if "harvested".



**LCP117 Q1 only - Cumulative Apparency Values 1-15**

Method 1 Planimetric Cleared = 18% of cumulative apparency area (890 ha. of 5024 ha.)  
 Method 2 Planimetric Cleared = 11% of LCP117 apparency area (249 ha. of 2288 ha.)  
 Perspective Cleared = 0.05% of LCP117 apparency "viewshed"  
 Method 1 P2P (% cumulative apparency area / % LCP117 apparency "viewshed") = 354:1  
 Method 2 P2P (% LCP 117 apparency area / % LCP117 apparency "viewshed") = 218:1  
 VNS Generic Forest Model (25m-30m height); contributing clearings outlined in black

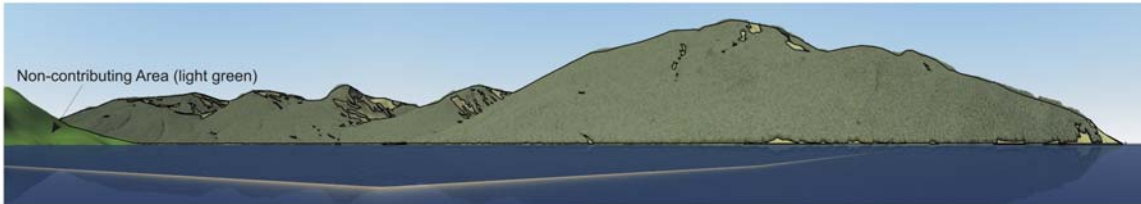
**Figure 64 Aggregated cumulative apparency visible contribution, with Quantile 1 only as baseline, depicting the amount of change that would be generated by the quantile group (pale brown) in the VNS forest model, if "harvested".**



**LCP117 Q1+Q2 - Aggregated Cumulative Apparency Values 1-32**

Method 1 Planimetric Cleared = 36% of cumulative apparency area (1788 ha. of 5024 ha.)  
 Method 2 Planimetric Cleared = 23% of LCP117 apparency area (519 ha. of 2288 ha.)  
 Perspective Cleared = 1.0% of LCP117 apparency "viewshed"  
 Method 1 P2P (% cumulative apparency area / % LCP117 apparency "viewshed") = 36:1  
 Method 2 P2P (% LCP 117 apparency area / % LCP117 apparency "viewshed") = 23:1  
 VNS Generic Forest Model (25m-30m height); contributing clearings outlined in black

**Figure 65 Aggregated cumulative apparency visible contribution, Quantiles 1 and 2, depicting the amount of change that would be generated by the quantile group (pale brown) in the VNS forest model, if "harvested".**



LCP117 Q1 to Q3 - Aggregated Cumulative Apparency Values 1-56

Method 1 Planimetric Cleared = 53% of cumulative apparency area (2637 ha. of 5024 ha.)  
 Method 2 Planimetric Cleared = 36% of LCP117 apparency area (815 ha. of 2288 ha.)  
 Perspective Cleared = 4.3% of LCP117 apparency "viewshed"  
 Method 1 P2P (% cumulative apparency area / % LCP117 apparency "viewshed") = 12:1  
 Method 2 P2P (% LCP 117 apparency area / % LCP117 apparency "viewshed") = 8:1  
 VNS Generic Forest Model (25m-30m height); contributing clearings outlined in black

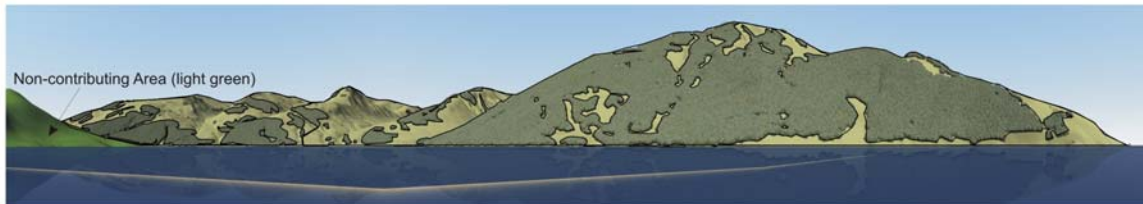
**Figure 66 Aggregated cumulative apparency visible contribution, Quantiles 1 to 3, depicting the amount of change that would be generated by the quantile group (pale brown) in the VNS forest model, if "harvested".**



LCP117 Q1 to Q4 - Aggregated Cumulative Apparency Values 1-94

Method 1 Planimetric Cleared = 69% of cumulative apparency area (3452 ha. of 5024 ha.)  
 Method 2 Planimetric Cleared = 53% of LCP117 apparency area (1204 ha. of 2288 ha.)  
 Perspective Cleared = 12% of LCP117 apparency "viewshed"  
 Method 1 P2P (% cumulative apparency area / % LCP117 apparency "viewshed") = 6:1  
 Method 2 P2P (% LCP 117 apparency area / % LCP117 apparency "viewshed") = 4:1  
 VNS Generic Forest Model (25m-30m height); contributing clearings outlined in black

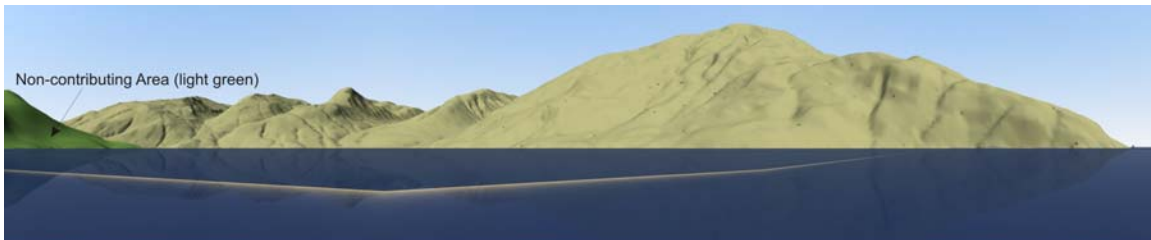
**Figure 67 Aggregated cumulative apparency visible contribution, Quantiles 1 to 4, depicting the amount of change that would be generated by the quantile group (pale brown) in the VNS forest model, if "harvested".**



### LCP117 Q1 to Q5 - Aggregated Cumulative Apparency Values 1-151

Method 1 Planimetric Cleared = 84% of cumulative apparency area (4227 ha. of 5024 ha.)  
 Method 2 Planimetric Cleared = 74% of LCP117 apparency area (1682 ha. of 2288 ha.)  
 Perspective Cleared = 28% of LCP117 apparency "viewshed"  
 Method 1 P2P (% cumulative apparency area / % LCP117 apparency "viewshed") = 3:1  
 Method 2 P2P (% LCP 117 apparency area / % LCP117 apparency "viewshed") = 2.6:1  
 VNS Generic Forest Model (25m-30m height); contributing clearings outlined in black

**Figure 68** Aggregate apparency visible contribution, groups 1 to 5, depicting the amount of change that would be generated by the quantile group (pale brown) in the VNS forest model, if "harvested".



### LCP117 Q1 to Q6 - Aggregated Cumulative Apparency Values 1-470

Method 1 Planimetric Cleared = 100% of cumulative apparency area (5024 ha. of 5024 ha.)  
 Method 2 Planimetric Cleared = 100% of LCP117 apparency area (2288 ha. of 2288 ha.)  
 Perspective Cleared = 100% of LCP117 apparency "viewshed"  
 Method 1 P2P (% cumulative apparency area / % LCP117 apparency "viewshed") = 1:1  
 Method 2 P2P (% LCP 117 apparency area / % LCP117 apparency "viewshed") = 1:1  
 VNS Generic Forest Model (25m-30m height); entire surface contributing

**Figure 69** Aggregated cumulative apparency visible contribution, groups 1 to 6, depicting the amount of change that would be generated by the quantile group (pale brown) in the VNS forest model, if "harvested" (100%).

Visualization of each of the five aggregations from LCP 117 provided a means for visual comparison of the extent and pattern as aggregations increased. The visual effect of the "low visual risk" Q1 to Q3 aggregation (Fig. 66), occupying 36% of the LCP-specific landbase and 4.3% in perspective view, when rendered as if harvested, was subordinate in the landscape, representative of Partial Retention visual quality. An inference was already made following the individual quantile demonstration, but bears repeating: less visual restrictions could be placed on those large (greater than one-third of the planimetric area) but lower visual risk portions of the visually sensitive area while potentially meeting Retention or Partial Retention VQOs. The Q1 to Q4 aggregation shown in Fig. 67, occupying 53% of the LCP-specific landbase and 12% in perspective view, begins to dominate (Modification VQO), and the Q1 to Q5 aggregation exceeds maximum modification (occupying 74% of the LCP-specific landbase and 28% in perspective view but has elements that fit the landscape such as conformity with ridges and hollows. The Q1 to Q6 aggregation confirms only that the model is accurate – all cells having been accounted for (and harvested). Rendering of the aggregations from the other four viewpoints was foregone due to time and space constraints.

Whereas the classification methods and their aggregations provided insight into the visual results of apparency groupings and some indication of P2P effects of these groupings, the exercises must not be confused with the preparation of actual logging plans. Tactical and operational planning and design applications using apparency as a guide are examined in the next section (Sec. 4.6).

## **4.6 Stage 6: Tactical and Operational Planning**

Stage 6 addresses the final 2 research questions summarized in Table 8: (3: Can GEOptics improve design? and 4: Can GEOptics improve operational planning?). The stage also addresses the evaluation criteria of effectiveness and utility. A series of trial applications was conducted using apparency as a driver for decision-making: A) Nadina Integrated Visual Design Plan (IVDP) (Fairhurst 2007); B) Atlas-Nadina Automated Visual Design project; C) Apparency as a guide to cutblock layout; and D) visualization of grid cell polygons selected by combined attributes (forest cover height and apparency). Each are described, together with the results, in separate sections.

### **4.6.1 Trial A: Nadina Integrated Visual Design**

The Nadina Lake IVD was produced by RDI Resource Design Inc (RDI) in 2006 for West Fraser Timber's Houston Forest Products Division. Nadina Lake is located in West-Central British Columbia, 58 km south-west of Houston and Highway 16 (Fig. 70).



**Figure 70 Location of Nadina Lake, south of Houston (adapted from iMAPBC).**

The planning approach applied the integrated visual design concepts outlined in the FIA: Integrated Visual Design Interim Procedures and Standards (BCMofR 2002) and the Ministry of Forests' Visual Landscape Design Training Manual (BCMofR 1994). The goal of the Nadina Lake Integrated Visual Design (IVD) project was to produce an integrated visual design for Nadina Lake Scenic Area along the north and east shore of Nadina Lake. The objectives were to design appropriate leave and clearcut harvest area options for a full rotation that would be capable of meeting the VQOs established for the area, using the three criteria of 1) verbal definition (text description of each VQO); 2) design quality; and 3) percent alteration as provided in the Visual Assessment Guidebook (BCMofR 2001). As well, the plan was to be environmentally sustainable, technically

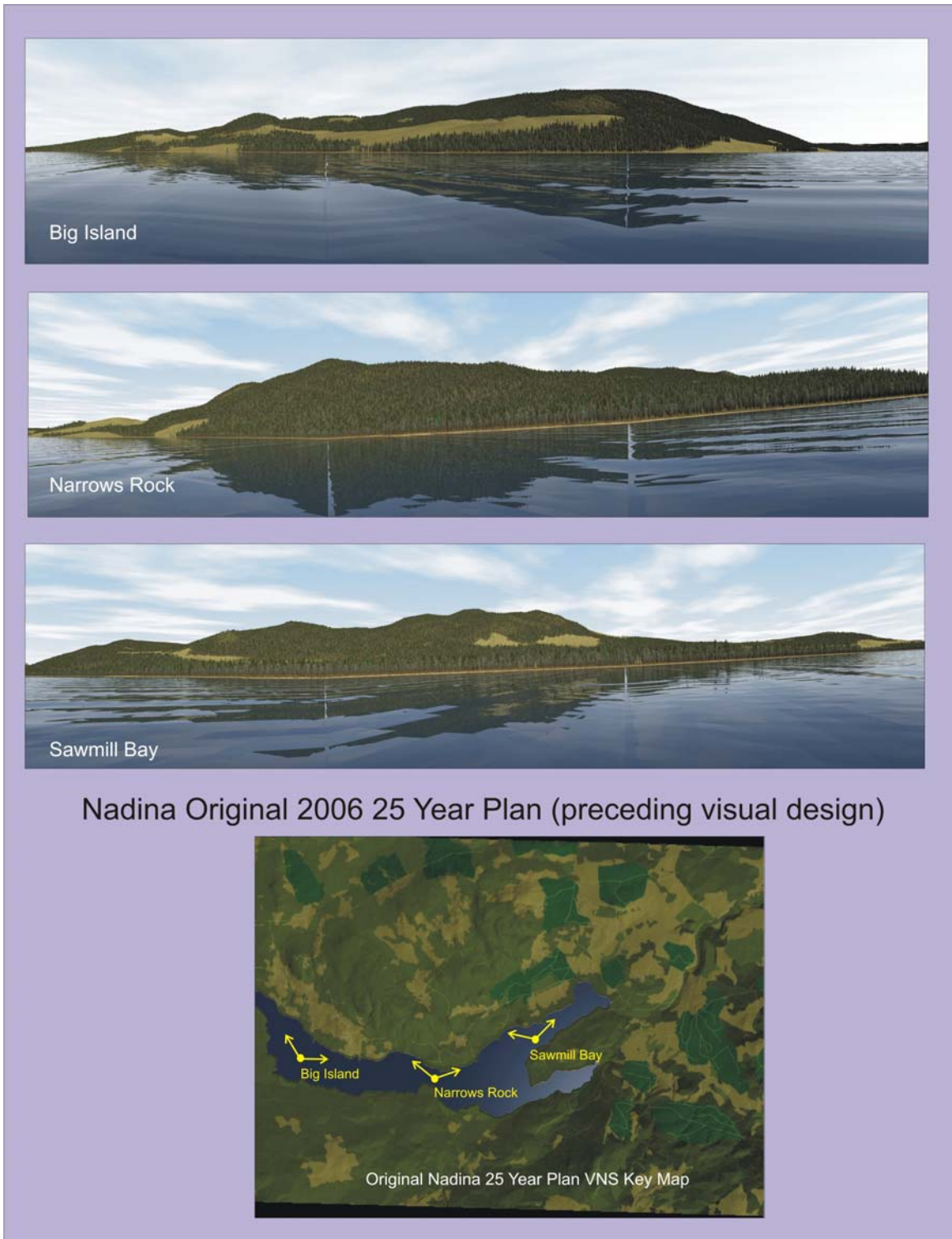
feasible, and economically viable over the short and longer term. Of primary consideration were the pine-leading forest types under attack from beetles. The project served as a practical test of the dissertation research process for which Jaret van der Giessen, HFP Project Administrator, kindly granted use of the Nadina Lake IVDP database.

RDI was provided with digital files containing a large array of potential harvest units, irregular in shape and averaging 1 hectare each in extent, generated by a harvest planning computer model (Tesera Scheduling Model, Tesera Systems Inc.<sup>37</sup>) for the entire Morice and Lakes Innovative Forest Practices Agreement<sup>38</sup> area. The source data included a conceptual single pass 25 year plan for the entire HFP landbase which included previously planned harvesting within the Nadina Lake viewshed (Fig. 71). The plan was a conventional "pre-visual landscape design" approach which incorporated 4441 ha of operable forest within the Nadina Lake viewshed, or an average of 18 ha/year. The plan would have created too much concentration from one viewpoint in particular (Big Island) shown in Fig. 71, and therefore visual impact would be expected if no adjustments were made for visual design considerations. The 25 year plan provided a baseline for comparison of the IVD results, presented in this section, and for the results of the apperency-guided automated design approach (Sec. 4.6.2).

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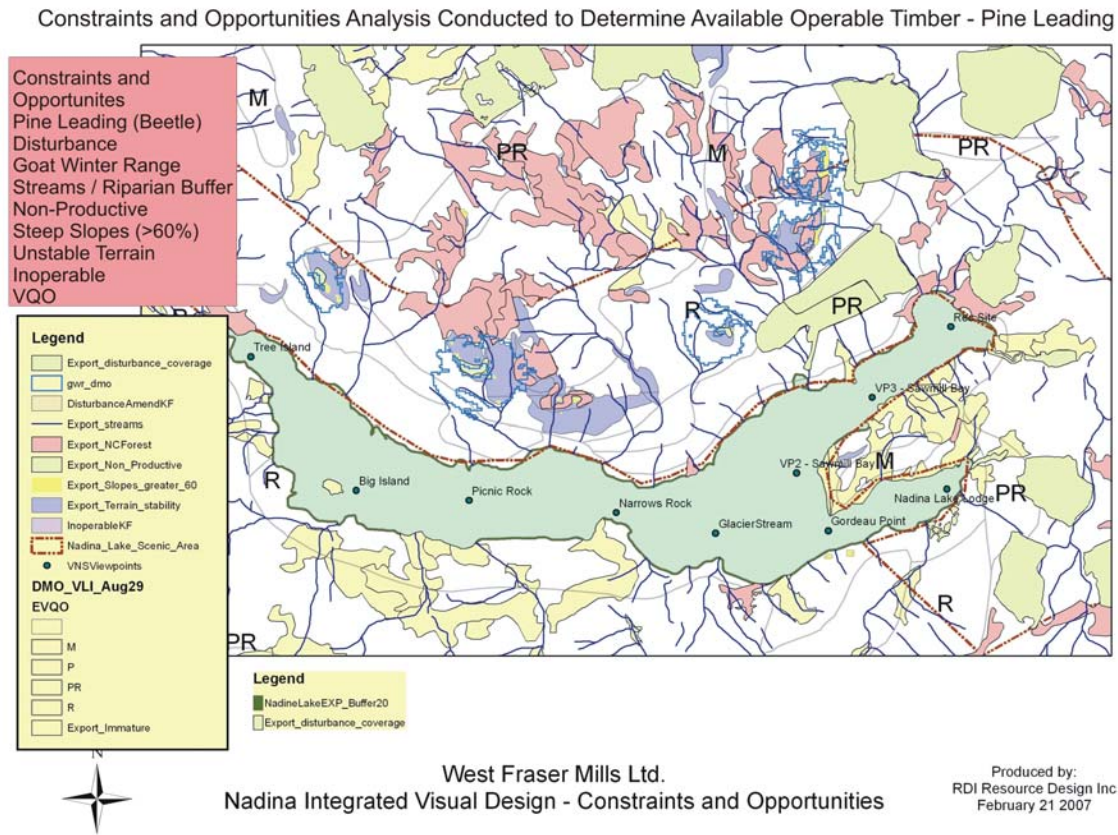
<sup>37</sup> The company website is found at: <http://www.tesera.com/>.

<sup>38</sup> "IFPAs are provincial pilot programs that are intended to encourage new approaches to forest management. They are agreements between major forest companies and the Minister of Forests, and are mandated under the *Forest Practices Code of British Columbia Act* through the Innovative Forest Practices Regulation. Each pilot is tailored to address local conditions and issues". The organization's website is found at: <http://www.moricelakes-ifpa.com//>



**Figure 71** Original HFP 25 year plan preceding visual design process; proposed cutblocks are tan colour, existing regenerating cleared areas are dark green (not seen in the perspective views), and retained forest is mid-green.

Following the guidance of the Forest Investment Account (FIA)<sup>39</sup> standards for integrated visual design, a constraints and opportunities analysis was prepared, considering recent disturbance coverage, wildlife (Mountain Goat winter range), steep slopes (>60%), accessibility, stability, riparian zones, and visual quality objectives ranging from Retention to Modification as shown in Figure 72.



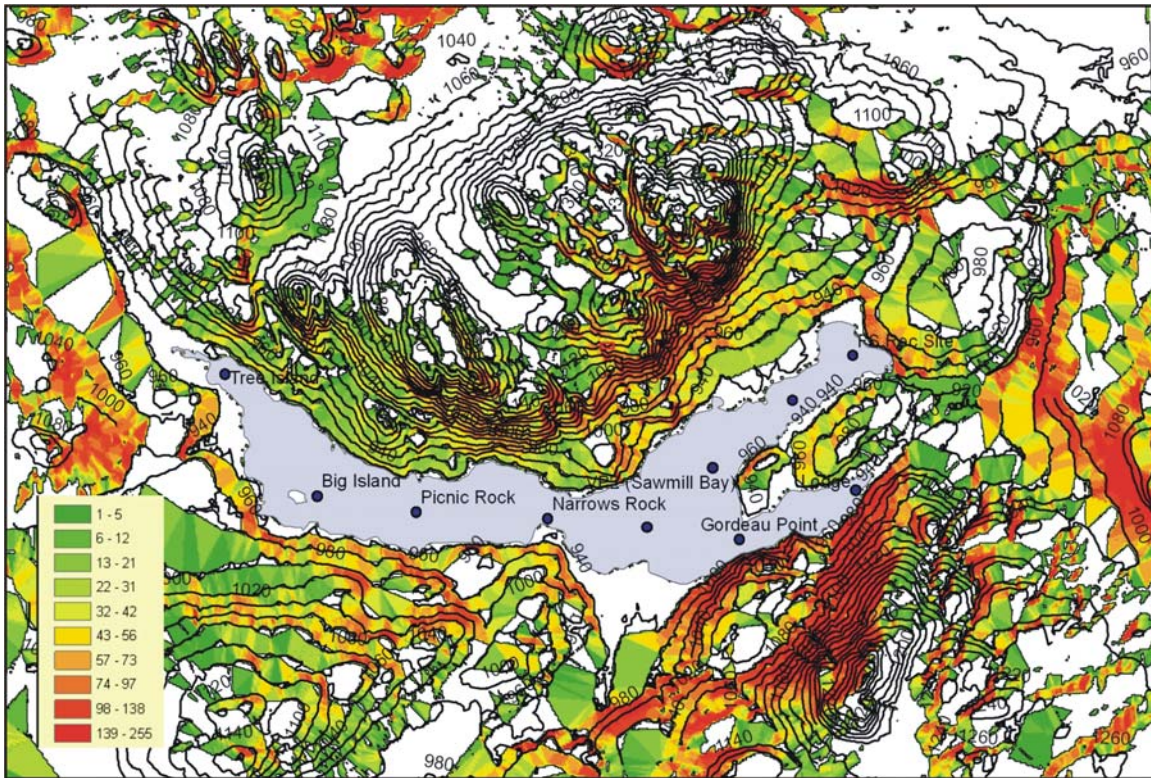
**Figure 72 Nadina Lake constraints and opportunities analysis.**

<sup>39</sup> "The purpose of the Forest Investment Account (FIA) is to assist government to develop a globally recognized, sustainable managed forest industry. Administered by government or government agents, Forest Investment Account programs provide funding to forest sector associations, researchers, tenure holders, manufacturers, and government agencies to: support sustainable forest management practices; improve the public forest asset base; and promote greater returns from the utilisation of public timber" <http://www.for.gov.bc.ca/hcp/fia/>, 2009

Cumulative apparency was generated from a single cumulative illumination (shadow) map, produced in VNS with lights set at eight viewpoints shown in Fig. 72<sup>40</sup>. The lights spanned the 9400 m length of the lake from the east end the north arm (Sawmill Bay) to the western end of the lake, plus an additional 1600 m in Gordeau Bay (the south arm). The average spacing of the lights (at the viewpoints) was 1344 m, with the greatest span of 2380 metres between VP2 in Sawmill Bay (the north arm) and Narrows Rock, and a minimum of span of 927 m between the Forest Service Recreation Site viewpoint and VP3 in Sawmill Bay. A 10-class stratification of apparency was produced, using the "quantile" classification technique in ArcMap, providing an equal number of units in each quantile and approximately total equal area in each (Fig. 73). The number of classes was a planning decision made at the time the project was being conducted to allow a high level of precision for detailed planning.

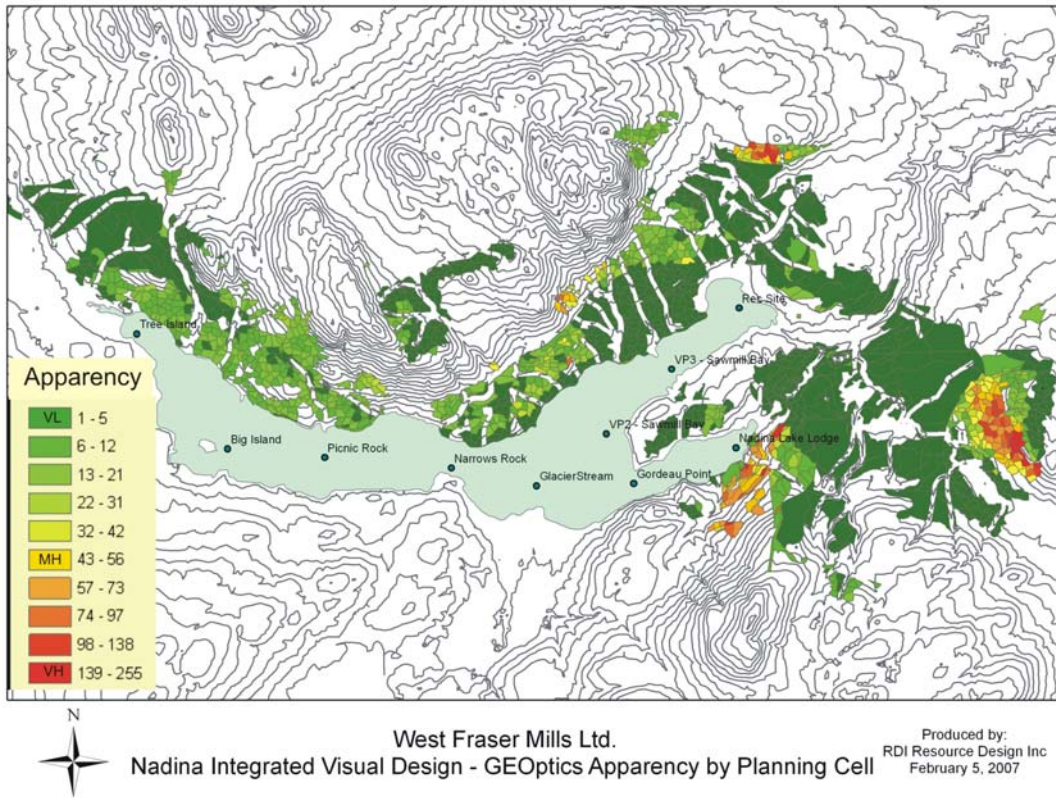
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<sup>40</sup> Glacier Stream, Gordeau Bay, and Nadina Lake Lodge viewpoints were exempted for this exercise, although these viewpoints were used in visualization checks later in the modelling process.



**Figure 73 Ten-quantile cumulative apperancy map for the Nadina project, built from a single cumulative illumination map in VNS with lights set at 8 viewpoints.**

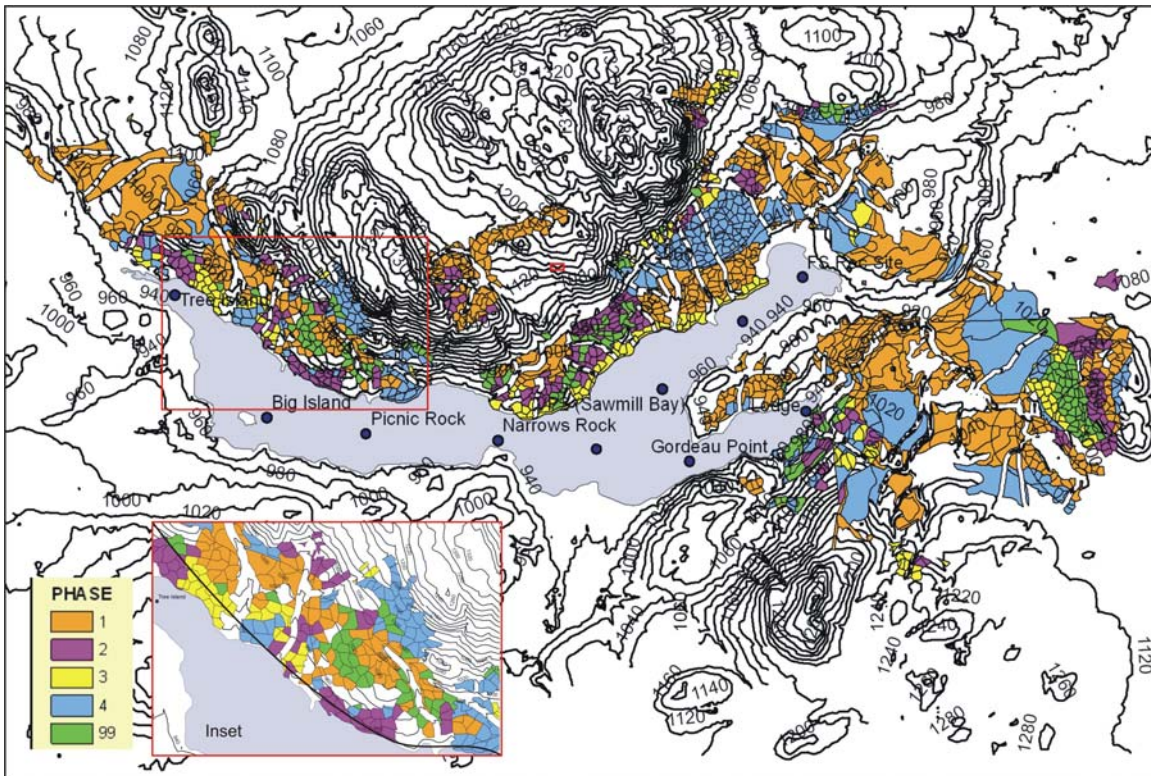
Each potential harvest unit was assigned an apperancy rating derived from, and identical to, the illumination value. The units were classified in the same 10 quantile groups as the original raster (Fig. 74).



**Figure 74** Cumulative apperency values, classified into 10 quantiles were assigned to each potential harvest unit to provide guidance when scheduling the units for harvest phase.

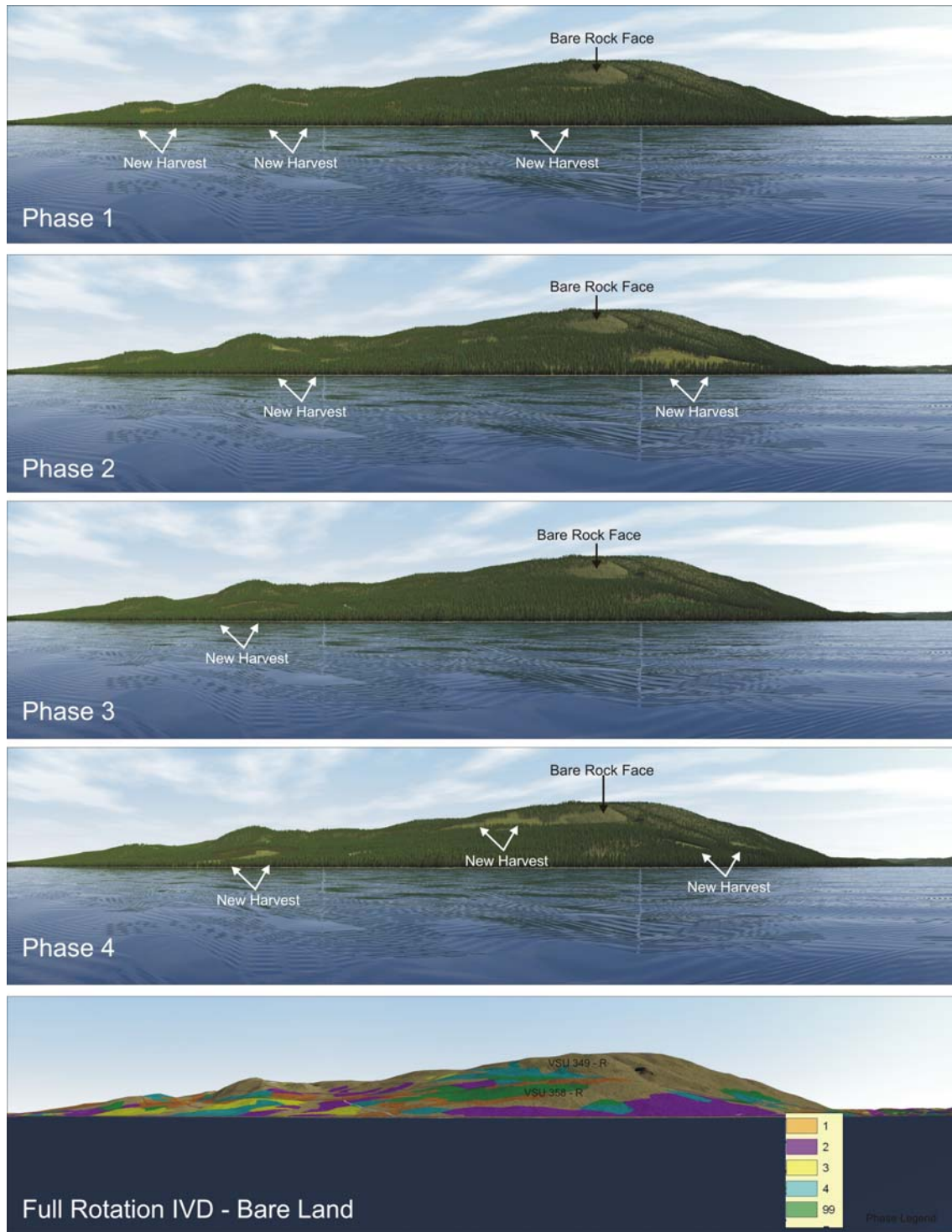
Apperency values were used to guide the design of potential harvest units and assigning them to phases. The general consideration in design was that lower apperency could permit larger alteration and less caution while higher values required more constraint and more caution. The phases were developed with consideration of apperency in conjunction with BCMoFR VIA guidelines for design criteria, verbal definitions, and percent alteration limits. Each phase was approximately 18-20 years in duration, a time period needed to achieve visually effective green-up (VEG), which is the stage of re-growth

where bare land is covered over, and the average viewer can see a re-established forest (BCMoF 1995) before commencing the next phase. As the entire area was subject to bark beetle infestation, requiring maximization of cut, all units with very low or no visual risk were placed into the first phase. Phase 1 provided for the harvesting of 1006 hectares (265,905 m<sup>3</sup>), or 49% of the total available forest. Subsequent Phases had smaller areas of harvesting ranging from 145 to 526 hectares as shown in Figure 75.



**Figure 75 Four pass scheduling to meet VQOs applied to treatment units based on cumulative appency and iterative testing with perspective visualizations, with inset showing closer view of treatment units; Class 99 units were not set to a schedule.**

The effect of each phase on visual quality was checked iteratively as each phase was developed by rendering visual simulations in VNS from each viewpoint, making adjustments to ensure each phase was capable of meeting the established VQOs (Fig. 76). The natural opening on the upper steep face in upper right centre in Figure 76 was allowed to remain bare throughout the visualizations of the four phases for reference. Of the 2052 ha harvestable area within the plan, 145 ha (7.1%) of the harvesting landbase were left unassigned to an operational phase (termed Phase 99), primarily due to plan submission deadlines. These units are shown in green in the planimetric map (Fig. 75) and in the bottom rendering in Fig. 76, but were not rendered in the forested perspective view.



**Figure 76 Four-pass schedule projected from from the Big Island viewpoint, with all phases shown in bare land image at bottom, with legend. Phase 99 (not scheduled for harvest) is evident in the bottom image in green.**

Timber harvest volumes and the areal extent in each phase were determined for each phase of the plan. The first 4 phases allocated 542, 423 m<sup>3</sup> of harvestable timber within 1907 hectares (284 m<sup>3</sup>/ha and 24 hectares per year). Phase 99 contained the residual units not assigned to the first 4 phases (Table 13). The VQO achieved and average percent alteration in perspective view for each of the phases is shown in the right hand column of the table. The low percent alteration in Phases 1 and 3 suggests that a greater amount of harvest area could have been placed into those phases. Averages for Phases 2 and 4 were somewhat low (within VQO of PR, 1.5% to 7%), but specific viewpoints exceeded the limits. While the IVD was limited by contractual deadlines, further analysis could likely of incorporated all or most of the Phase 99 units.

**Table 13 Nadina Integrated Visual Design areas and volumes harvested, by phase.**

<b>Phase</b>	<b>Units</b>	<b>Area (ha)</b>	<b>Volume (m<sup>3</sup>)</b>	<b>Average %ALT and VQO</b>
1	899	1006	265,905	0.4% (R)
2	314	216	56,987	2% (R-PR)
3	195	159	44,606	0.3% (R)
4	373	526	174,925	1.4% (R)
99	176	145	43,079	n/a
Total	1957	2052	585,502	
1-4 only	1781	1907	542,423	1% (R)
Avg./Year Phases 1-4 only (20-year phases)		24	6780	
Avg. Volume/ha Phases 1-4			284	

The Nadina project was a good opportunity to test apparency mapping in a real-world timber harvest planning application. Apparency provided advance knowledge of visual risk from all viewpoints, cumulatively. It served as practical and informative guide when outlining harvest unit aggregations to make cut-blocks, and when setting them to a harvesting schedule. It also was used to locate the 50% of the entire available forest with low or no visual risk and high pine content that could be harvested immediately to avoid further beetle damage, while meeting the restrictive VQOs.

#### **4.6.2 Trial B: Atlas-Nadina Automated Landscape Design Trial**

A second, automated visual landscape design procedure was also examined, using the same Nadina Lake model as for the IVDP, with apparency as the key factor used in setting harvest patterns and schedules. The automation concept explored the idea that, with apparency providing quantified advanced knowledge of visual risk across a visually sensitive landscape, a scheduling program may derive a credible first attempt at a visual landscape design with a long-term planning horizon (12 periods, 220 years in total, starting at year 0). The ATLAS spatially explicit harvest simulation model, renamed as Forest Planning Studio (FPS), was used to schedule timber harvests according to spatial and temporal objectives, including harvest flows, opening size, riparian buffers, seral stage distributions and patch size distributions. Data inputs were the potential harvest unit polygons with attribute layers of apparency classes, forest cover, such as inventory type group, tree height, etc., and relational growth and yield curves. Silviculture systems and rotation ages were assigned to each polygon. Each time step was run, with polygons

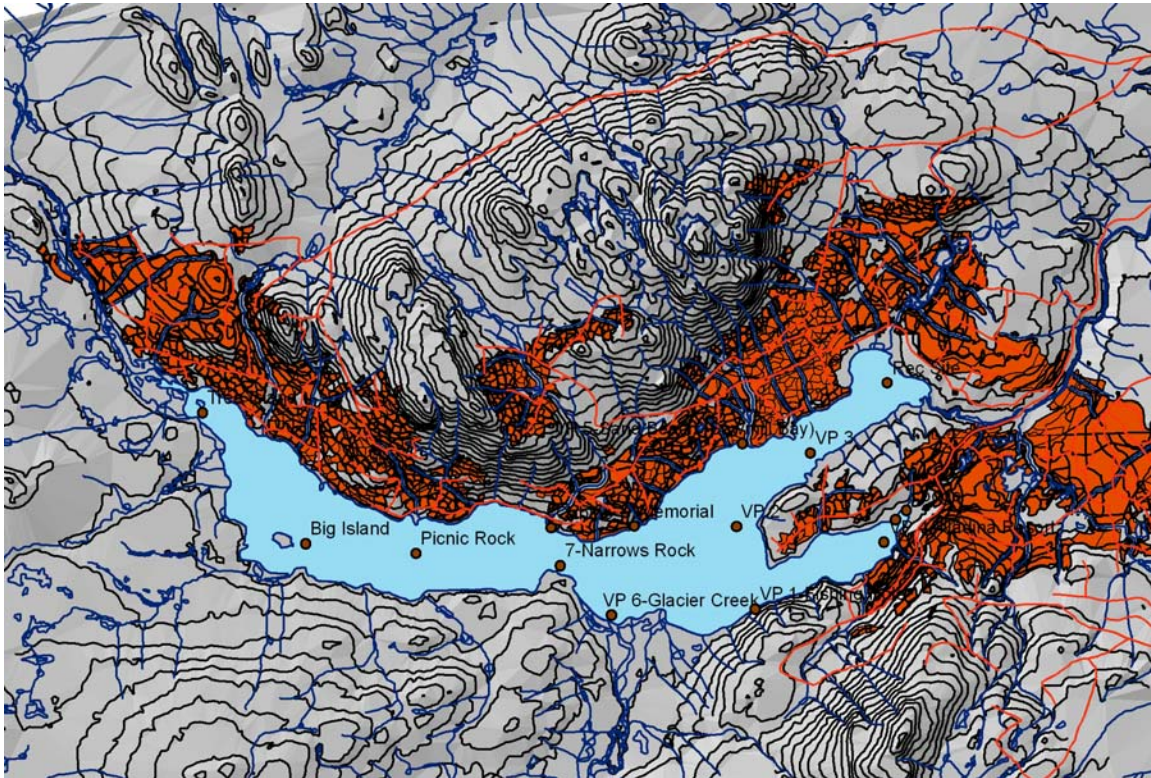
assigned to harvest. Polygons were harvested until either the queue was exhausted or the periodic harvest target was met. At this stage the forest was aged to the next time period, and the process repeated<sup>41</sup>.

With the advanced apperency knowledge, it was considered that the automated approach could reduce the reliance on "expert" design input. FPS was able to utilize apperency values generated in the Nadina Integrated Visual Design Plan together with other forest indicators, including rates of growth, to schedule a sequence of harvest entries over 220 years. The trial determined if a measure of automation in visual landscape design could be successful in meeting visual quality objectives without expert intervention, or if that automation could be used to produce a plan in which expert intervention could be reduced, optimized, or more appropriately focused on problem areas.

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<sup>41</sup> The Forest Planning Studio website is found at: <http://www.forestry.ubc.ca/atlas-simfor/atlas/about.html>.

FPS was used to schedule the same array of harvest cutblocks that were used in the Nadina IVDP, described in Sec. 4.6.1 (Fig. 77).



**Figure 77 Nadina Lake map with viewpoints (on lake) and harvest units (in red) from the IVDP providing input into the Atlas/FPS automated design procedure over 12 periods, with re-growth added over time.**

Scheduling was conducted by Dr. John Nelson using apparency as the main constraint to the schedules. Apparency was classified into 11 classes (10 plus 0, with 0 being no apparency/not seen) by the quantile method in ArcMap, including the area with zero value. The area with zero apparency was scheduled as early as possible given the bark beetle infestation across most of the area affecting the predominant species, Lodgepole pine. Polygons with least apparency were assigned first, and greater apparency were

assigned latest. A maximum of 20% of the zero apparency areas were assigned to any one period to spread the "easy" wood out over the planning horizon, and to assist the even harvest flow. The Nadina scenic area was scheduled by FPS into 12, 20-year periods. The rules sought a steady state of 150 000 m<sup>3</sup> harvest volume per period from 500 ha in each period. Over the course of the full plan, extending over 220 years, each cell was harvested once every 3 periods (every 60 years) or 4 times during the plan, on average.

The resulting Nadina FPS-scheduled plan could produce 1,442,136 m<sup>3</sup> of timber volume from 5180 ha of forested scenic area, averaging 120,178 m<sup>3</sup> per period from an average of 432 ha per period (Table 14). The harvest volume appears large when compared to the Nadina IVD plan (Table 13). This is because the Atlas-Nadina plan extends over twice the number of years as the IVD plan. The table also indicates if the plan appears to have met the "expected" target VQO of Partial Retention in each period and from each viewpoint. Yellow cells in the three right columns in Table 14 indicate which period and from which viewpoint the PR VQO would be achievable or exceeded (R); the green cells indicate when and from what viewpoint the PR VQO is unlikely to be met (achieving M or MM). The harvest unit scheduling configuration for each period was exported as a database (DBF) and attached to the shapefiles of the units in ArcMap. The shapefiles for each period were then imported into VNS for visualization. Each of the 12, 20-year periods was visualized in Visual Nature Studio as a single intervention from each of 3 key viewpoints. The viewpoints were selected to cover west, central and east views: Big Island at the western end of the lake looking obliquely towards the mountain slope, Narrows Rock, which looks directly upon the steep mountain face that was largely

unavailable for timber harvesting due to environmental constraints determined in the Nadina Lake IVDP, and VP2 located in the eastern end of the lake where it divides into its North arm (Sawmill Bay) and South arm, looking directly upon the extensive flats and also towards the mountain (Fig. 72). The viewpoints are also shown in the bottom image (key map) of each period's visualization sheet (Figs 80-82). The determination of whether the visual result of each period could meet the VQO was made by 1) observation of the visual perspective simulations produced in VNS (3 such viewpoint simulation sets, for each phase, are presented in Figs 80-82), 2) by considering the verbal definitions of VQOs (as shown in Tables 4 and 5) and 3) considering general landscape design criteria (BCMoF 1995; BCMoF 2001b). The plan successfully met or exceeded the VQO requirements 75% of the time when each period and each viewpoint were considered (27 of 36 cases). Narrows Rock met the VQOs in 100% of the time periods, Sawmill Bay viewpoint (VP2) was next in success, achieving or exceeding the VQO in 75% of the periods. The Big Island viewpoint received the poorest success, only achieving or exceeding the VQO 50% of the time.

**Table 14 Results of Atlas-Nadina apparency-guided automated landscape design plan, with timber volumes and areas, and achievable VQOs.**

Atlas-Nadina Automated Landscape Design Plan					
Schedule			Achievable* VQO by Period and Viewpoint		
Period (20 years)	Vol. (m3)	Area (ha)	Big Island	Narrows Rock	Sawmill Bay VP2
1	33767	128	R	R	PR
2	109712	431	PR	R	R
3	12824	46	R	R	R
4	131841	480	PR	R	PR
5	133005	513	M	R	M
6	158981	513	M	PR	PR
7	141758	512	PR	PR	PR
8	132880	512	M	R	M
9	153044	512	M	PR	PR
10	140720	511	PR	R	PR
11	133600	510	M	R	M
12	160004	512	M	PR	PR
Sum	1442136	5180			
Avg. Vol./ha	278				
Avg. Vol./Period	120178				
Avg. Vol./Year	6009		6 of 12	0 of 12	3 of 12
Avg. Area/Period		432			
Avg. Area/Year		21.6	50%	0%	25%
* Achievability was determined by visual observation of visualizations by the researcher and verbal definition of VQOs and visual landscape design criteria (BCMoF 1995; BCMoF 2001b).					
Views failing target VQO of Partial Retention by period: Failure rate over all periods					

The plan met 80% of the intended steady period volume average and 86% of the intended steady state average harvest area per period. The initial fall-down in harvest rates (below the 150 000 m3 target) in the first 4 periods, and in particular, Periods 1 and 3, were the result of initial conditions (recently harvested forest). The schedules are shown graphically in Figure 78 (harvest volume) and Figure 79 (harvest area).

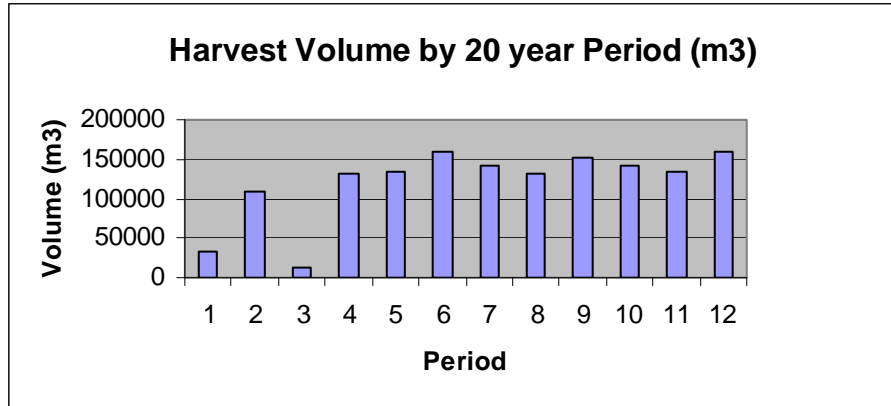


Figure 78 Atlas-Nadina harvest rates by volume in each period.

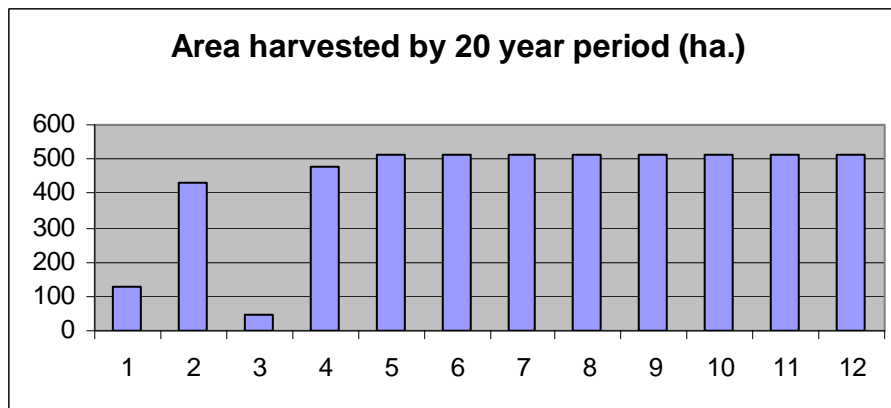
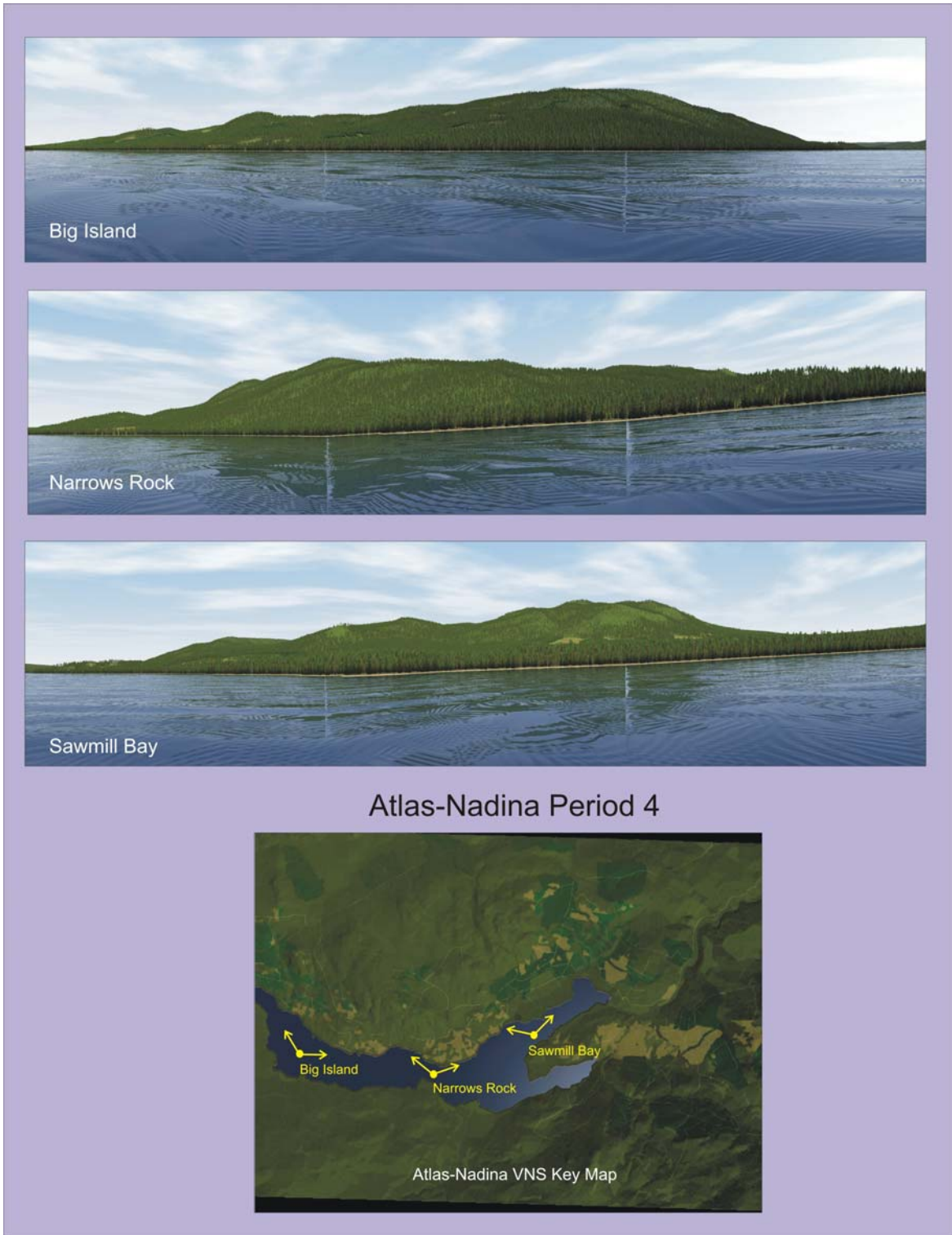
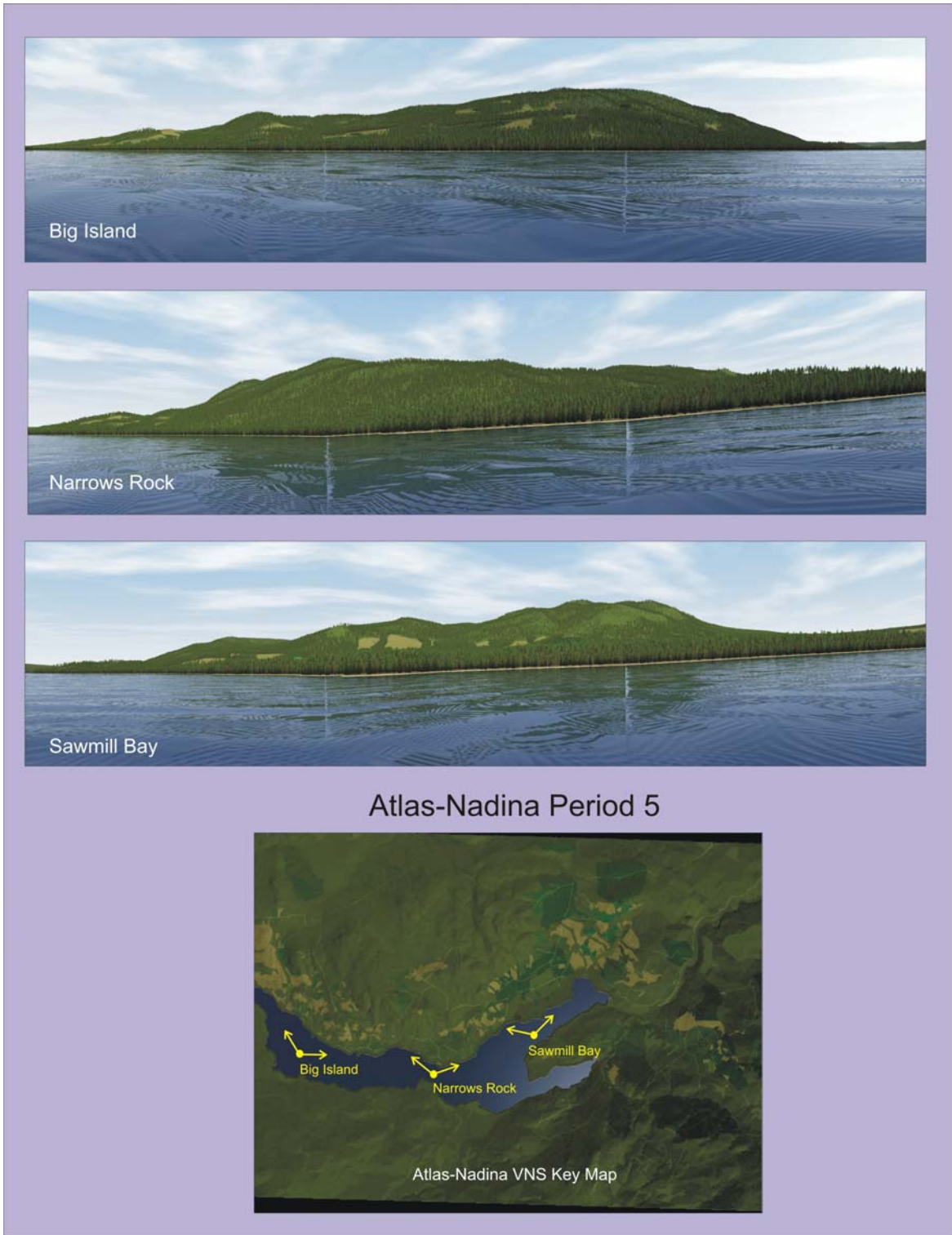


Figure 79 Atlas-Nadina harvest rates by volume in each period.

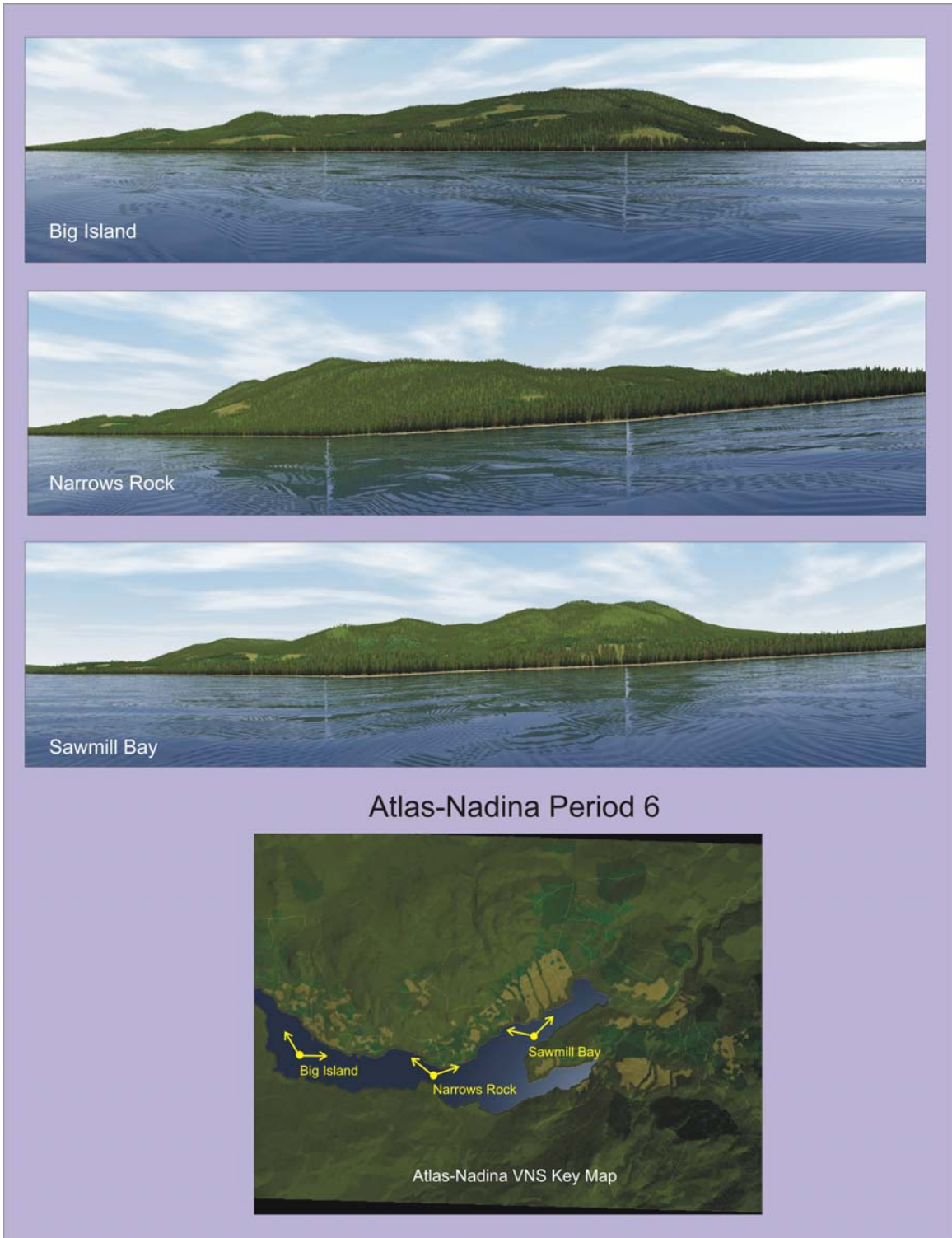
The Atlas scheduling tended to assign the same or similar block sequences every 3 periods (60 years). The visualization results from the 3 viewpoints are presented for 3 selected periods (4, 5, and 6) (Figs. 80-82). The three rendering viewpoints were the same as the three main rendering viewpoints in the Nadina IVDP described in the previous section.



**Figure 80 Atlas-Nadina automated harvest schedule - Period 4. New openings in the schedule are pale brown colour, older regeneration is dark green.**



**Figure 81** Atlas-Nadina automated harvest schedule - Period 5. New openings in the schedule are pale brown colour, older regeneration is dark green.



**Figure 82 Atlas-Nadina automated harvest schedule - Period 6. New openings in the schedule are pale brown colour, older regeneration is dark green.**

As shown in the images, the Atlas-Nadina automated design plan provided a dispersal of harvest intensity over a lengthy time span which met timber harvest objectives and achieved the visual quality objectives 50% to 100% of the time, varying across the three viewpoints. Design appears quite responsive to the landscape, indicating the inherent "knowledge" or fit provided by GEOptics apperency, having been constructed by the cumulative interactions between the landscape and the viewer (VNS lights). Scheduling and visualization of 20-year periods suggested a greater visual impact than when be anticipated when the periods are divided, as normal procedure, into 5-year plans. The Atlas automated approach results were closely equivalent to the IVD approach in terms of volume and area harvested per year (Atlas automated approach: 21.6 ha/year and 6780 m<sup>3</sup>/year; IVD: 24 ha/year and 6009 m<sup>3</sup>/year).

Both the Nadina IVD and the automated plan allocated a greater area/year harvest over their long-term multi-pass approach, which included consideration of re-growth, than the 18 ha/year originally identified in the 25-year single pass harvesting plan. The 25-year plan is not truly comparable with the IVD and automated plans, as it was a single pass, covered a much larger area than the Nadina IVD viewshed, was not necessarily maximized within the viewshed, and was absent of visual design considerations. More discussion is provided in Chapter 6 (Sec. 6.1.6).

### 4.6.3 Trial C: Harvest Location Using Apparency as the Guide

A trial was prepared to examine the potential of using the apparency mapping to guide manual timber harvest cutblock location. The goal was two-fold: 1) to show how the cumulative apparency map can be used when planning harvest operations (including in viewpoint-specific views), and 2) to compare the visual results of the planned operations located in higher and lower apparency areas. In the Howe Sound model, a total of 8 cutblocks were drawn for the test using the 6-class equal area quantile ratings as a guide. These were purposefully located across a range of cumulative apparency levels. Eight cutblocks were placed in areas ranging from higher apparency (on terrain that is face-on to the view) to lower apparency (on terrain that is lateral or oblique to the view).

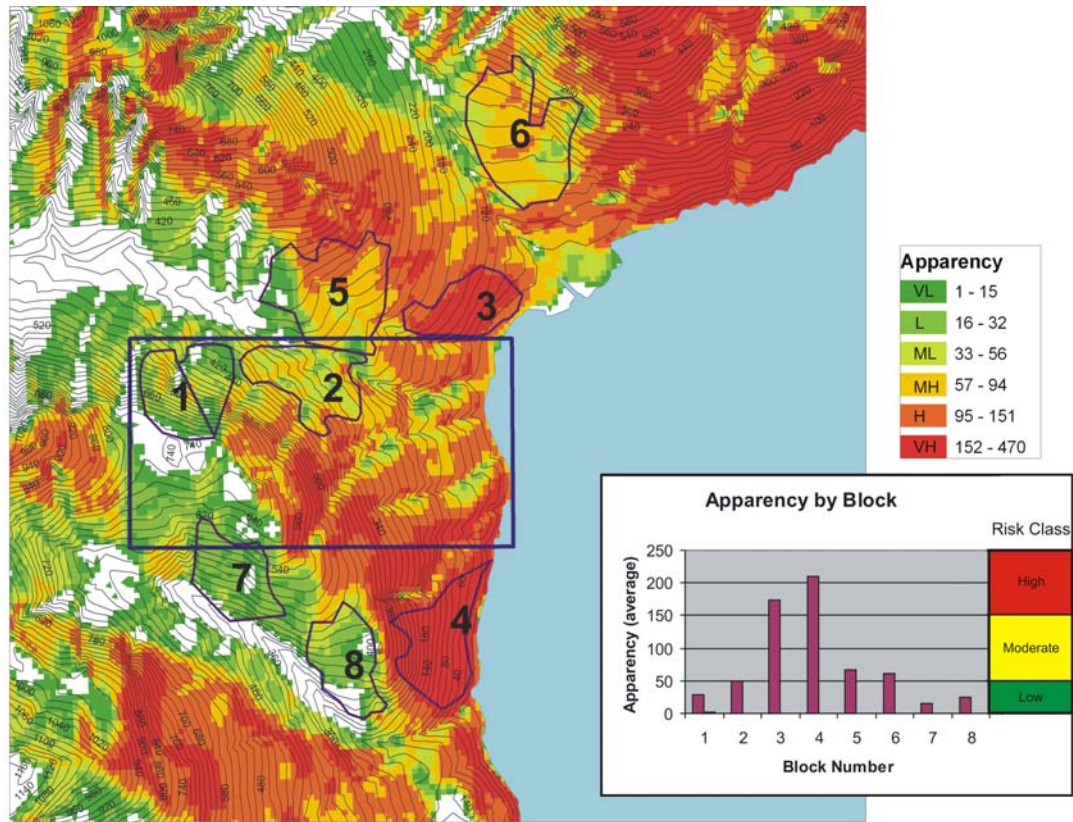
As apparency had already accounted for all viewpoint influences and AVI, and was strongly guided by terrain characteristics, it served as the principle design tool. The patterns of apparency together with an understanding of design principles (e.g. lines of force; up hollows/down ridges) (BCMof 1994) provided guidance when laying out the blocks. Significantly, simple design influences were found to be already identified by apparency in plan view, and confirmed in the visualizations. The patterns themselves, in plan view, emphasized the visible ridges (high risk red/orange), easily distinguished from hollows (low risk green/yellow); and front landscapes (red) distinguished from more laterally seen terrain (green). The patterns gave rise to the cutblock design (Fig. 83). Cutblock 2 follows the green and yellow low risk cells, reaching up into the hollows, merging down below the ridges. Other cutblocks were designed with a similar strategy

(e.g. 5 and 6). Cutblocks placed on the front landscapes were intended to isolate high risk apparence cells but were allowed to merge downwards on the ridges as guided by the orange cells (3,4). Cutblock sizes ranged from 14 hectares (cutblock 3) to 29 hectares (cutblock 6) (Table 15).

**Table 15 Attributes of trial harvest cutblocks, located based on apparence values.**

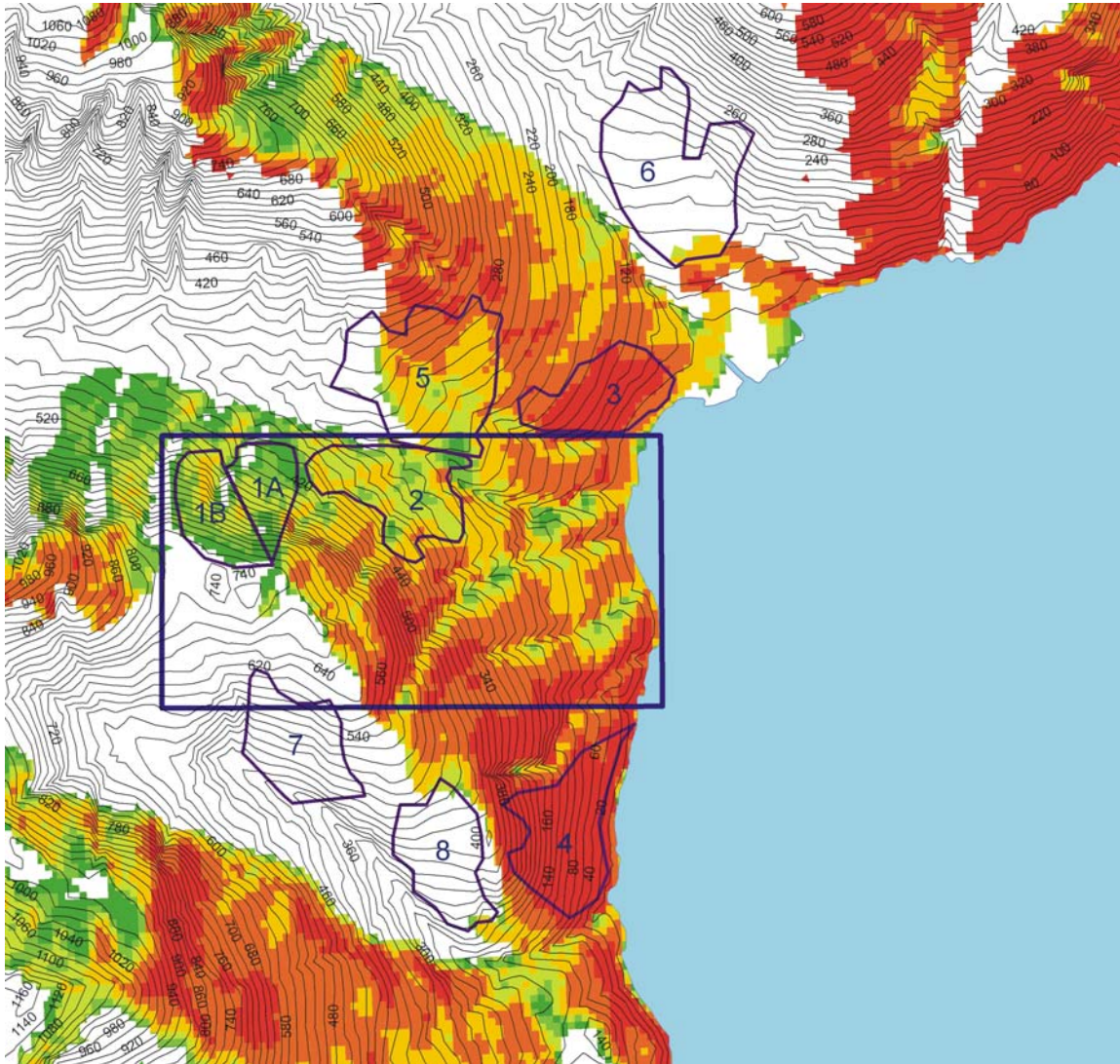
Cutblock #	Area (ha)	Apparence (avg.) (RGB 1-470)
1	19	28
2	18	50
3	14	173
4	19	209
5	28	67
6	29	61
7	15	16
8	15	25

The average apparence of each cutblock was determined from the apparence attribute in each grid cell enclosed by each cutblock. The cutblocks with greatest apparence, cutblocks 3 and 4, are mid-sized cutblocks, and are located frontally on the landscape. The cutblocks would have varying visibility depending on the viewpoint. The graphic inset shows the average apparence ratings within each cutblock) (Fig. 83). A 3-level average visual risk class was developed for this application (lower inset, Fig. 83), corresponding to the additive apparence 6 quantile scale for Howe Sound (upper inset, Fig. 83): High is H/VH in the 6 class scale; Moderate is MH and ML; Low is L/VL; with the equivalent RGB scale ratings. Viewpoint locations were the same as previously used (Fig. 50).



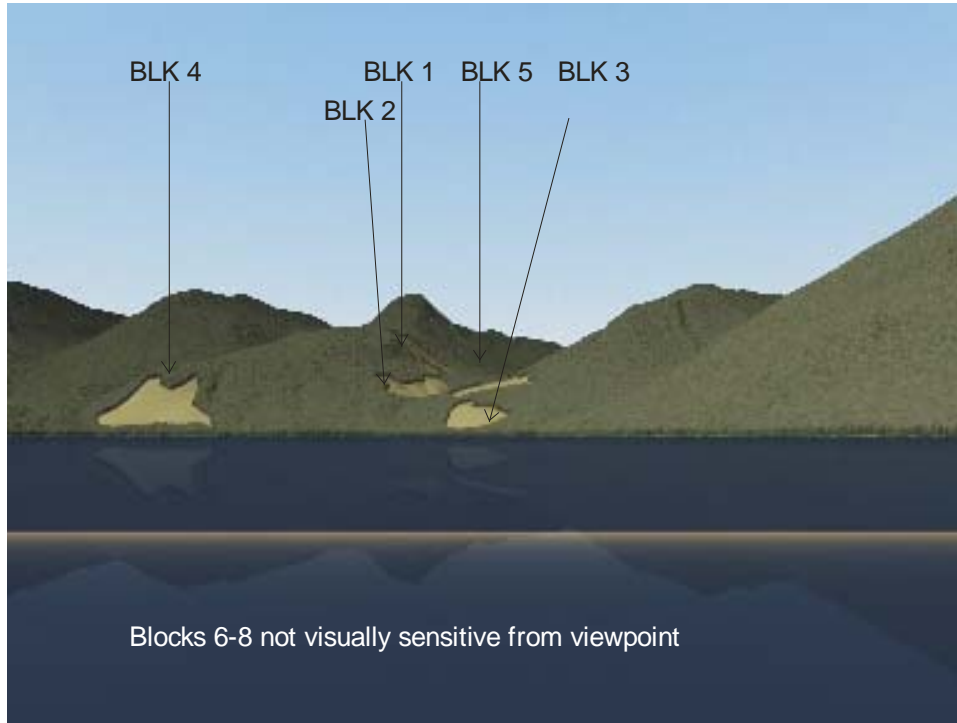
**Figure 83** Howe Sound harvest cutblock location test in higher and lower cumulative apparency areas, with average apparency calculated per cutblock, and coded by average risk class (high, medium, low).

Following the cutblock design exercise which used the cumulative map for reference purposes, cutblock placement was also examined as an overlay on the single LCP apparency map produced from LCP 117 (Fig. 84). Cutblocks 6 through 8 were not visible from that viewpoint.

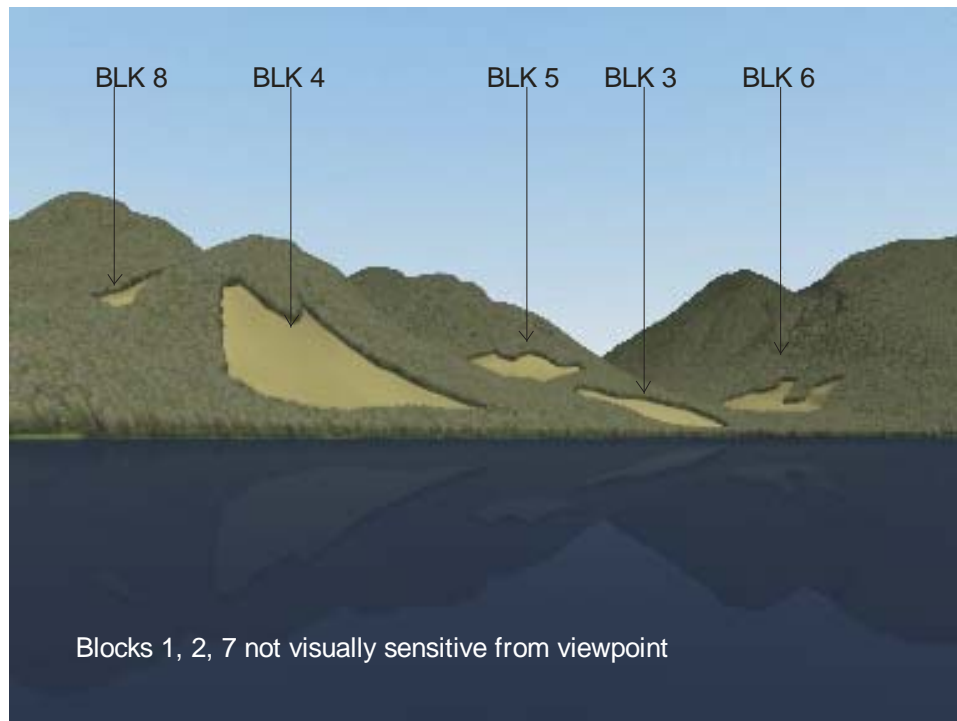


**Figure 84** Howe Sound apperancy map from LCP 117 alone, showing visible (in coloured apperancy zone) and non-visible cutblocks (white zone); see Fig. 22 for viewpoint location.

Visual simulations produced from LCP 117 (Fig. 85) and LCP 119 (Fig. 86) reveal the large scale and dominant visual effect of Cutblock 4 in perspective view, as seen from viewpoints 117 and 119. The scale of Cutblock 3 is smaller, and is also smaller in actual area, compared with Cutblock 4, but is similar in scale to two other much larger cutblocks (5, 6) which have lower apperancy. Cutblocks 6, 7 and 8 were not evident from LCP 117, and Cutblocks 1, 2, and 7 were not evident from LCP 119.



**Figure 85** Howe Sound trial cutblock locations selected by levels of apperency; appearance from LCP 117.



**Figure 86** Trial cutblock locations selected by levels of apperency; appearance from LCP 119.

The application provided rudimentary demonstration of the use of apparency to guide harvest design. GEOptics helped in both the predictability of visual design and provided design sense based on patterns and ratings that guided the designer. The application confirms the results and expectations of apparency mapping.

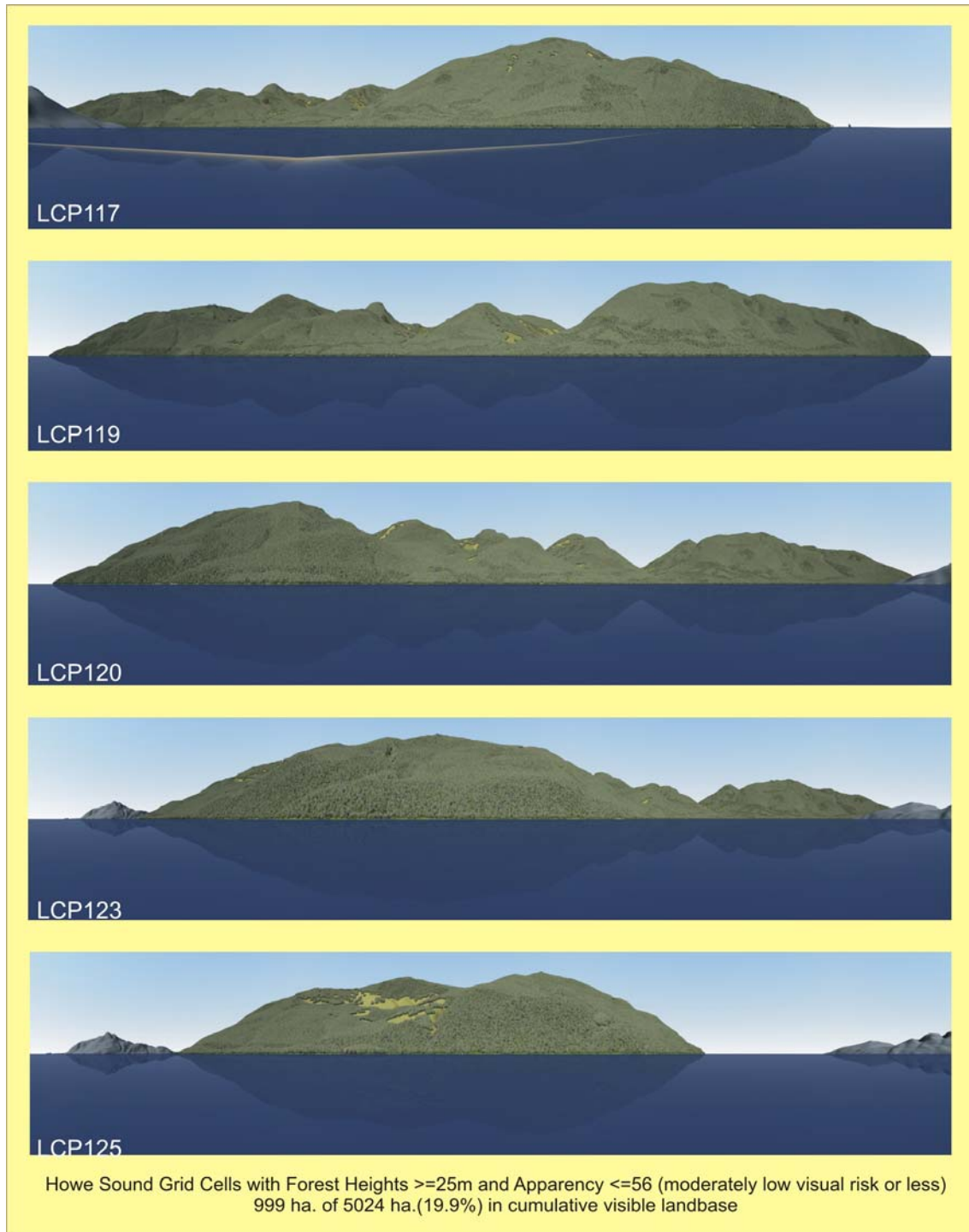
#### **4.6.4 Trial D: Selection by Combination of Apparency and Other Attributes**

A test was conducted to examine the utility of selecting a range cells based on cumulative apparency RGB values and other attributes together to help locate areas of lower visual risk but of high interest for timber harvesting. The selection procedure was described in Sec. 4.4 as a component of Stage 4 (Integration). All forest 25m or greater in height (i.e. tall trees) within a very low to moderately low range of apparency (i.e., low visual risk). A total of 999 hectares of the 5024 ha cumulative visible area (19.9%) fell within that selection (Fig. 87).

The shapefile polygons (grid cells) were imported into VNS and assigned a bare ground (cutblock) texture. The core VRI polygons with selected attributes were also imported and a thematic map, a VNS procedure that reads the stand height of each polygon, was created so that the forest texture would be rendered according to the projected stand heights. Figure 87 portrays the visual results, if the selected cells were harvested, as determined by rendering from the key viewpoints.

The results showed a very small amount of visible change would be created when the 1000 ha of tall trees are harvested, even in areas of moderately low cumulative visual risk. Most occurs in views from LCP 125, probably due to the greatest concentration of older timber there. The visual response to tree-screening has been validated with the use of actual tree heights taken from the forest cover files.

The results indicate the utility of apparency to accurately identify areas with high timber (or other management) values, distinguished by levels of risk of visual impact across multiple viewpoints.



**Figure 87 Visual results, if selected cells were harvested, as seen from each viewpoint of Howe Sound; grid cells selected by forest height from VRI, 25m height or greater, and cumulative apparency, 56 value or less (moderately low to very low visual risk).**

## 4.7 Summary, Chapter 4

Chapter 4 provided a series of apparency tests and applications, and results, structured within the 6 stages of apparency, referencing the research questions and evaluation criteria related to each stage (Table 8). The tests and applications provided answers to all 4 of the research questions, and partial evidence as to the adequacy of the approach for improving the worth of EVA (relative to BCMoFR's VLI) in 4 of its 6 phases (inventory; planning; setting objectives; design) (Table 2). The remaining 2 phases (implementation; monitoring) could not be assessed as there were no on-the-ground operations incorporating apparency to respond to, but there appears to be no major reason why they would not demonstrate similar levels of adequacy.

In Stage 1, the terrain model and its derivation were examined, with the identification of some common flaws in certain areas such as striping, but with the recognition of the general reliance on these mapping products in conventional usage, including for visualization and visibility measurement.

In Stage 2, the illumination procedures and map products were addressed, using 4 models. The qualities of the VNS lights used in illumination were examined, including light dispersion and diminishment (an angle of incidence result), VNS fall-off exponent (not activated in apparency models), the additive and cumulative capabilities and limitations, comparisons with hillshading (ARCGIS), shadow-mapping procedures and corrections (stippling errors), and validation of illumination maps against viewsheds (ARCGIS). None of these issues appear to present major validity problems.

In Stage 3, single light, multiple light, additive, and cumulative apparency classification techniques were assessed, with discussion about the quantile method (approximately equal areas) for assigning visual risk. Apparency was then compared with conventional slope mapping and times-seen mapping to determine where they may converge and where apparency provides more precise and meaningful information to assist resource management.

In Stage 4, apparency was associated with other attributes to test its utility in forest planning and operations. Apparency was shown to clearly differentiate areas of lower and higher cumulative visual risk from multiple viewpoints. The low percent change and high P2Ps that were determined for the lower quantiles were indicators of significant, detailed portions of the visible landbase with less need for restrictive visual constraints than would be indicated by conventionally more broadly derived measures. Also, portions of the visual landbase were accorded high visual risk through the cumulative apparency method, indicating areas within the visually sensitive landbase requiring more attention to be given to visual design and perhaps needing more visual constraint than broadly indicated by conventional methods. The apparency approach was shown to be capable of providing a means to "automate" VLI, and on a finer scale, than currently is available by the BCMoFR VLI system. As well, the P2P differentiation capabilities offered by the apparency approach suggest a potential contribution to timber supply analysis refinement, if that system were open to such refinement.

In Stages 5 and 6, apparency models were applied in various planning structures: refinement of P2P ratios by quantile and quantile aggregation to demonstrate its potential to assist strategic planning (visual constraint levels); use of apparency in Integrated Visual Design; use of apparency in the automation of harvest planning and design (Atlas); and its use in operational planning (where to locate harvesting based on lower or greater visual risk; cutblock design). Several examples of benefits to forest design were demonstrated.

## 5 Focus Group Process, External Tests, and Results

As presented in previous chapters, the research sought to develop and test a terrain-based approach that could potentially contribute to the worth and outcomes of an expert visual assessment system. The research questions (Sec. 2.1) focused on the potential of GEOptics to improve visual landscape inventory, planning, design, and operational planning. The questions, and their evaluation criteria (Sec. 2.1), required exposure to, and response from, potential users (Research Task 5). The focus group questionnaire and discussion opportunities were designed principally to examine two of the evaluation criteria: effectiveness and usability, while providing feedback on the other criteria (feasibility, validity and defensibility). GEOptics apparency modelling was assessed by way of focus group presentations and recorded response by questionnaire and discussion<sup>42</sup>. The process, tests, analyses and results are presented in this chapter.

### 5.1 Focus Group Pre-test

The informal pre-test of presentation subject matter was conducted on December 17, 2008 with Dissertation Committee Member Dr. Michael Meitner and a fellow doctoral candidate Cameron Campbell, as experts in the field of VRM and in research methods.

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<sup>42</sup> The focus group process fell within the non-invasive human ethics type of research that required review and approval by the Behavioural Research Ethics Board (BREB). BREB approval was initially received in January 29, 2007, under the reference number: H06-03535. Approval was extended December 17, 2008, with an expiry date of December 17, 2009. The certificate is provided in Appendix 6. Dr. John Nelson was listed as the Principal Investigator; Dr. Stephen Sheppard, Dr. Michael Meitner, and Ken Fairhurst were listed as Co-Investigators. Three documents were submitted: 1) Focus Group Questionnaire (Appendix 1), 2) Focus Group Invitation Letter (Appendix 2), and 3) Focus Group Research Consent Form (Appendix 3). The research proposal was also submitted with the application.

The questionnaire and discussion topic document were reviewed by the two participants at the pre-test. Their responses to the pre-test helped streamline the presentation. Recommendations from the pre-test helped derive the final version of the questionnaire to avoid ambiguity in the questions and improve consistency in presentations. The discussion led to my deciding to apply a balanced value response scale<sup>43</sup>. The change was implemented to be clear about negative responses as compared with the more common all-positive scale, which can invite unintended bias in responses through different interpretations of what the numbers mean. The questionnaire and presentation content were also reviewed by committee members and modified according to comments received, on an on-going basis, as development progressed. The questionnaire was subsequently re-organized, and placed into three question groups: A) the effectiveness of the presentation, B) the effectiveness of landscape apparency mapping, and C) benefits or disadvantages of the apparency modelling/mapping methods in potential applications, (Appendix 1).

## **5.2 Focus Group Establishment and Organization**

The focus group method was chosen in order to obtain first-hand, expert opinions regarding the GEOptics process. As this is a specialized tool for experts and practitioners, it was important to reach the key people who would have the required experience to assess the tool. The focus groups targeted visual resource and forest management

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<sup>43</sup> ranging from -2 (strongly disagree), through 0 (neutral), to +2 (strongly agree).

specialists, representing the main anticipated user types and experts capable of judging the system. The target groups included VRM specialists<sup>44</sup>, forest management practitioners, and academics with visual landscape and/or forest practitioner skills. Participants were invited by e-mail (Appendix 2), and were provided with a guide to the process at the same time (Appendix 4). There were 44 invitees in total.

The process required a practical demonstration and open discussion. While a hands-on approach was envisioned, time-limitations restricted focus group exposure to the end-products only. The focus group process combined simple quantitative and qualitative response measures in order to get some hard results, while allowing for in-depth discussion and feed-back.

The main focus groups took place in three sessions located in Richmond (February 17, 2009), UBC (March 11, 2009), and Nanaimo (March 17, 2009). Altogether, there were 16 participants, having a range of training levels, working familiarity, and responsibilities in regards to visual resource management concepts and procedures. This purposive sample size was considered adequate for focus group sessions using optimized quantitative and qualitative methods, consistent with common usability studies of computer techniques. While remaining confidential, participants' affiliations and roles were recorded (Appendix 6), and included visual landscape specialists, several BCMoFR forest stewardship practitioners, forest industry and forest research forest operations practitioners and managers, university educators, research scientists and graduate

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<sup>44</sup> There is only a small group of visual experts in the BCMoFR, all of whom attended the sessions.

students. All sessions were conducted by me. Dr. Stephen Sheppard attended the initial session to briefly introduce the project, assist with recording equipment, and help moderate the discussions; the other two sessions were led and presented solely by the researcher.

The first session was attended by BCMoFR Landscape Specialists and Forest District personnel; the second session was attended by primarily university researchers with forest management or VRM experience; the 3rd session had mainly forest practitioners in attendance. A list of participants by session and organization is presented in Appendix 6.

Since the purpose of the focus groups sessions was to provide insights and evidence on the strengths and weaknesses of the apperency modelling/mapping procedure, and not to gain a representative sample for generalization of responses to a wider population, the numbers of participants in the subject groups are considered adequate for the interpretation of evaluation responses. Having said that, 100% of the BC government visual resource specialists were included in the sessions.

The intent of the sessions was not primarily to compare evaluation responses between the 3 groups of subjects, but to obtain perceptions and suggestions from all the potential user types. Consequently, some fairly minor evolution in presentation material was accepted between focus group sessions.

### **5.3 Focus Group Procedures**

The duration of each session was approximately 90-120 minutes covering presentation, questionnaire completion and discussion. Presentation required 45-60 minutes and questionnaire completion and discussion required a further 45-60 minutes. Each session followed the same procedures.

A consent form was distributed to participants at the commencement of the session, advising participants about their rights and access to the results (Appendix 3). Completed consent forms were collected and participants were advised that the entire session, including the open discussions, would be audio recorded, and that the completed questionnaires and audio recordings would be stored in a locked filing cabinet.

A presentation was prepared for each session based on core images and script, and provided to participants at the beginning of the session. Each session was presented with the same set of core graphics projected on a 6 foot wide screen by a liquid crystal display (LCD) projector connected to a laptop computer. Participants sat at tables within 30 feet of the screen, approx., so as to provide a clear view for all participants. The scripted outline for the presentation was read in the first session (Appendix 5) and provided as projected slides and read in subsequent presentations to guide the verbal part of the presentation. Questions and requests for clarifications were handled briefly. Participants were asked to note other points to raise in the open discussion session.

Following the presentation at each session, participants were provided with the questionnaire. Open-ended written comments were invited for the discussion questions that were provided at the end of the questionnaire document (Appendix 1). Respondents spent approximately 15 minutes completing the questionnaire and written discussion comments.

Open discussions ran from 30-45 minutes in each session, following the presentation and questionnaire completion. In the Focus Group #1 session, discussion commenced for approximately 10 minutes, prior to completion of the presentation (prior to Stage 6) and before respondents started with the questionnaire.

Participants were thanked for their time commitment and contributions to the research, and were reminded that they would be receiving the results of the focus group process. The questionnaires were numbered consecutively for each session upon receipt at the conclusion of each session.

#### **5.4 Focus Group Questionnaire and Discussion Results**

The printed questionnaire and discussion topics document, presented in full in Appendix 1, had three main sections: Section 1 provided an introduction to the procedures as well as check boxes for respondent's level of experience and background; Section 2 contained the questions to gauge the effectiveness of the presentation and the perceived feasibility, validity and defensibility, effectiveness, and usability of the model; and Section 3

provided open-ended discussion topics aimed at obtaining more understanding about how the model might be employed, by whom, and what changes were suggested. The same discussion topics would be used to frame the open discussions which followed the written questionnaire. Questionnaire results were summarized and analyzed (Sec. 5.4.1). Discussion responses were also summarized and analysed (Secs. 5.4.2; 5.4.3).

#### **5.4.1 Questionnaire Summary and Results**

The main part of the questionnaire was divided into three subsections in order to provide recipients with some understanding of the distinctions amongst the 19 questions (Table 16). The questions were all positive-leaning in direction to facilitate consistent responses (negative through positive) to both GEOptics and non-GEOptics approaches. Six "Presentation" questions (Part A) were designed to obtain responses regarding the focus group session itself. Four "Mapping" questions (Part B) were designed to learn from the participants how they responded to the mapping methods and output. Finally, nine "Applications" questions were designed to elicit from participants how they felt GEOptics apparency could, or would, actually be applied, and the benefits and disadvantages that they saw in that process. Response averages, shown in Table 16, are discussed later in this section.

Table 16 Average ratings for questionnaire responses, by group and questionnaire section.

		Average Ratings				
	#	Question	All	Richmond	UBC	Nanaimo
Presentation	1	I had adequate time to view the imagery shown.	1.19	1.43	1.00	1.00
	2	The cumulative landscape apparency mapping (GEOptics) method was clearly explained.	1.00	0.57	1.20	1.50
	3	The benefits of conventional Visual Landscape Management (VLM) mapping were clearly outlined.	0.38	0.00	0.80	0.50
	4	The limitations of conventional Visual Landscape Management (VLM) mapping were clearly outlined.	0.38	-0.14	0.80	0.75
	5	The possible benefits of the GEOptics landscape apparency method were clearly outlined.	1.00	0.71	1.20	1.25
	6	The possible limitations of the GEOptics landscape apparency method were clearly outlined.	0.31	0.00	0.40	0.75
Mapping	7	The GEOptics output appeared easy to understand, in general.	0.88	0.29	1.20	1.50
	8	The GEOptics method appeared easy to apply, in general.	0.19	-0.14	0.20	0.75
	9	The GEOptics output appeared to be compatible with conventional GIS resource analysis.	1.13	1.14	1.20	1.00
	10	The GEOptics output appeared capable of providing the degree of detail and accuracy necessary for consideration in resource planning and decision-making.	1.06	1.00	1.20	1.00
Applications	11	Overall, the conventional VLM mapping method provides adequate tools and products to accurately inform forest operations planning and timber supply calculations.	0.56	1.00	-0.20	0.75
	12	The GEOptics apparency mapping method appears to be beneficial in enhancing visual landscape management (VLM).	0.75	0.29	1.00	1.25
	13	The advantages of the GEOptics apparency mapping method outweigh its disadvantages for forest management in general.	0.19	-0.14	0.40	0.50
	14	The GEOptics method appears to be helpful for locating areas of greater and lesser visual risk within seen areas.	1.50	1.57	1.40	1.50
	15	The GEOptics apparency mapping appears to be helpful when designing operations to meet the VQO in visually sensitive areas.	0.44	0.14	0.40	1.00
	16	The GEOptics method appears to be helpful in contributing to economic benefits derived from visually constrained areas.	0.50	0.43	0.40	0.75
	17	GEOptics output could be well suited for total chance integrated visual design over the long-term.	1.06	0.71	1.20	1.50
	18	The GEOptics products could be beneficial to a public involvement process on forest planning.	0.56	-0.14	1.40	0.75
	19	The GEOptics method could provide greater flexibility for managing visually constrained areas relative to conventional VLM.	0.63	0.29	1.00	0.75

Participants were asked, based on the presentation and with regard to their individual experience, to select from a 5-class rating scale provided for each question on Presentation, Mapping, and Applications (Table 17). A neutral response (0 value) indicated a mid value, neither negative nor positive<sup>45</sup>. When making their evaluations, participants were given no specific guidance on whether potential GEOptics users were expected to have "hands-on" use of the tool or just receive the output for use.

**Table 17 Questionnaire rating scale.**

-2	-1	0	+1	+2
Strongly disagree	Somewhat disagree	Neutral	Somewhat agree	Strongly agree

The completed questionnaires were kept fully confidential and only distinguishable by number as they were received at the conclusion of each session.

#### **5.4.1.1 Questionnaire Results Summary and Analyses**

A full summary table of results from the questionnaire is presented in Appendix 7.

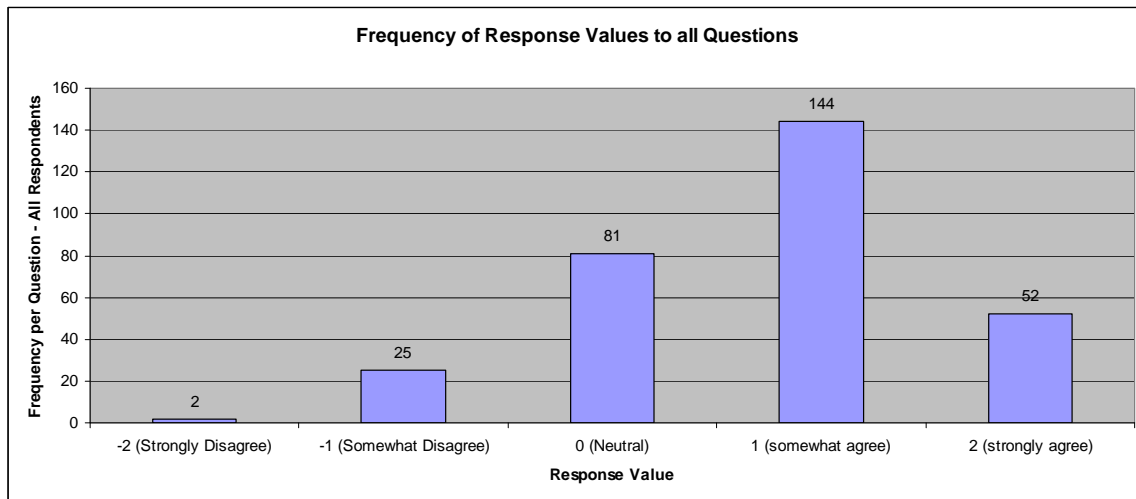
Detailed analyses were prepared for responses: a) frequencies, b) sums, c) averages, d) modes, e) medians, f) ranges, and g) analysis of variance for the differences between the focus groups.

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<sup>45</sup>Participants were allowed to mark an "X" where they did not feel knowledgeable about a particular question to make a response. Only four "X's" were received, as shown in Appendix 7. The "X's" were replaced with zeros (neutral response) to allow consistent analysis with the same number of responses (N=16).

### a) Frequency of Responses per Question

The frequency of responses received from all of the 16 participants across all questions was tallied for each of the 5 potential responses on the rating scale, ranging from strongly disagree to strongly agree (Fig. 88).



**Figure 88** Frequency of response values - all questions.

The response frequencies are strongly on the positive side of the rating scale (above neutral) with 64% (196) in either the "somewhat agree" or "strongly agree" category, while only 9% (27) were on the negative side of the scale (somewhat or strongly disagree). The neutral (neither negative nor positive) response frequency was 27% overall (81).

## b) Summed Responses per Question

There were large variations in responses by question as summarized in Appendix 7. The sum of ratings to each question, as distinguished by question grouping, is presented in Fig. 89.

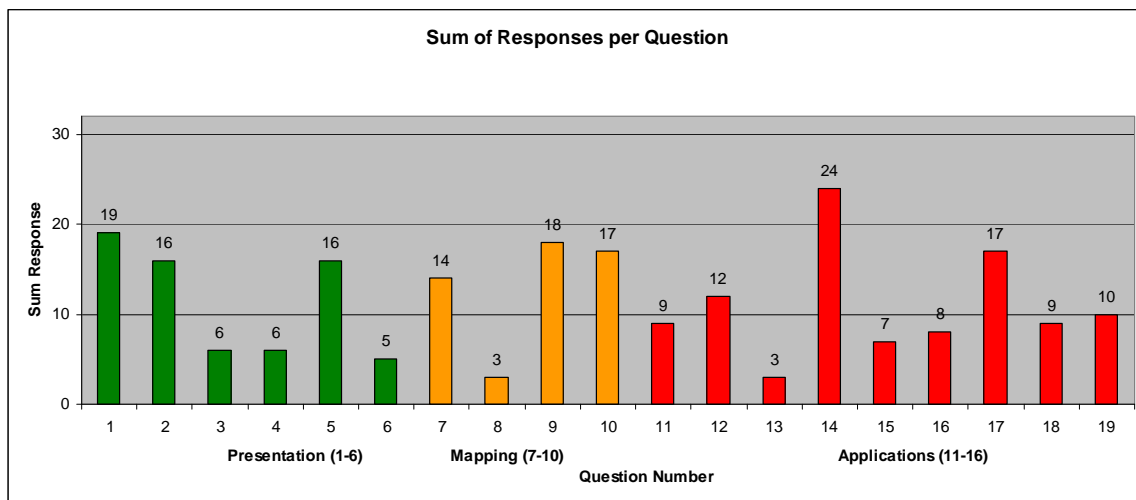


Figure 89 Sum of responses to each question by all participants.

The summation of the response ratings served to bring out the differences amongst the question topics. The overall summed ratings for all 19 questions was 219, or an average summed rating of 11.53. Nine questions had higher summed ratings than the mean, while 10 were lower than the mean. The maximum possible summed rating was 32 for each question, if all 16 respondents rated each question as "strongly agree" (+2), and a minimum of -32 if respondents marked "strongly disagree" (-2). All summed values were above zero (neutral). As such, the graph starts at zero.

These summed responses were examined separately for each of the 3 question groupings to assist the interpretations: 1) Presentation; 2) Mapping; 3) Applications:

### **1) Presentation**

Strong summed responses were received for 3 questions in the Presentation section of questionnaire (Q1 - adequate time was given for the presentation; Q2 - GEOptics method was clearly explained; Q5 - benefits of GEOptics were clearly outlined). The 3 strong responses indicate that moderate success was achieved in the presentations which were able to describe both the new, somewhat complex, tool and its potential benefits.

Lower summed responses were received for the 3 remaining Presentation questions (Q3 - benefits of conventional VLM mapping clearly explained; Q4 - limitations of conventional VLM mapping clearly explained; and Q6 - limitations of GEOptics method clearly explained). The results suggest that more time should be taken to cover these topics sufficiently.

### **2) Mapping**

Above average summed responses were received for 3 questions in the Mapping section (Q7 - GEOptics output easy to understand; Q9 - GEOptics appeared compatible with conventional GIS; and Q10 - GEOptics output capable of detail and accuracy necessary for resource planning and decision-making). The strong response received for all 3 of

these questions about the GEOptics map products indicated the strong perception of the usefulness of GEOptics, particularly for the ability to integrate GEOptics with conventional forest mapping and analysis (Q9) and in forest planning (Q10). These perceptions were confirmed in the written comments (App. 8, Topic 1, "advantages"), and as presented in consolidated form in Sec. 5.4.2; for example, comment from participant #101 - "gives a good idea of where one can get the biggest or smallest bang for one's harvest effort..." and #106 - "very detailed and accurate, most helpful as a tool in the high risk areas".

One of the 2 lowest summed responses overall was in the Mapping section. Responses to Q8 - GEOptics method appeared easy to apply - strongly indicate that the procedure needs to be further simplified and streamlined if it is to be used by experts and practitioners such as the participants.

### **3) Applications**

As is evident in the strong summed responses received for questions 12, 14, and 17, participants perceived GEOptics to be a beneficial enhancement to conventional VLM (Q12), helpful for locating areas of greater and lesser visual risk (the question with by far the highest rating (Q14)), and well-suited for long-term IVD planning (Q17). That Q14 received the highest rating speaks directly to the ability and utility of GEOptics for differentiating visual risk in a unique, cumulative, and comprehensive fashion. The strong responses for both Q12 (helpfulness of GEOptics for determining the visual risk) and

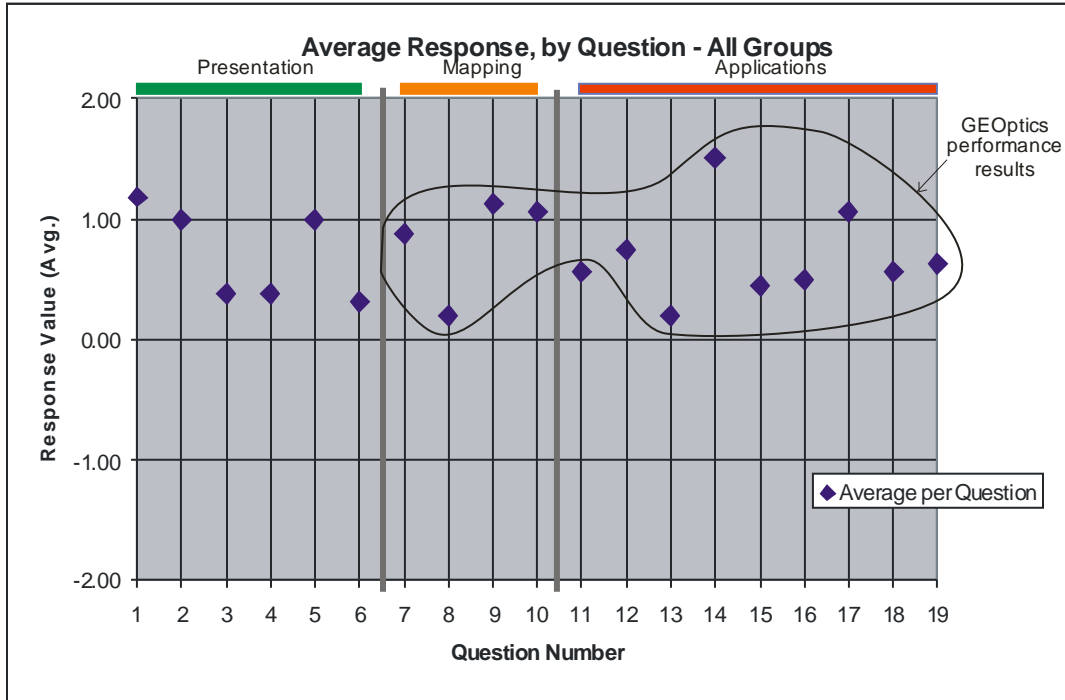
Q17 (suitability for IVD) are an indication of the most appreciated potential applications of GEOptics.

Below average, but moderate, summed responses were received for 5 of the remaining 6 Applications questions (11, 15, 16, 18, 19). One of those, Q11, was not about GEOptics, and indicated that participants found conventional VLM tools to be somewhat lacking in their adequacy or accuracy for informing operational planning and timber supply calculations. The other 4 questions were about the helpfulness of GEOptics for designing operations (Q15), contributing economic benefits (Q16), benefits to a public involvement process (Q18), and the provision of flexibility relative to conventional VRM (Q19), providing insight into potential uses of GEOptics. Design applications (Q15) were not fully developed for the presentations and definitely require more attention. Economic information (Q16) may not have been clearly convincing and requires more development. Public involvement benefits (Q18) were mostly left up to the respondents to consider on their own. Again, more development is required for this topic. The flexibility question (Q19) response, while only slightly below the average rating, suggests a concern among some respondents that more tools mean more restrictions, not fewer. These concerns were expressed in the focus group comments (Appendix 8, Topic 2 - "possible disadvantages") such as from participant # 102 - "producing too refined results", #202 "harder for lay people to understand", and from #205 - "Insignificant differences, increasing complexity, decreasing economic return, operational concerns". Overall, GEOptics map products and applications have high perceived utility, but a somewhat stronger or clearer case for GEOptics was required, particularly for the specialists in attendance.

The lowest ranked response in the Applications section (Q13 - advantages of GEOptics outweighed the disadvantages) was ranked the same as Q8 in the Mapping section regarding its ease of application, and may be related to this concern. Focus group discussions of the advantages were presented in Appendix 8, Topic 1, and the disadvantages in Topic 2 of the same appendix. Both were consolidated and are discussed in Sec. 5.4.2.

### **c) Response Averages**

The average response to each of the 19 questions (Table 16) was determined for all participants together as shown in that table with the divisions by questionnaire section. The same results are presented graphically (Fig. 90). The scale in Fig. 90 shows the minimum and maximum possible ratings (-2 to +2). The results indicated that the average for each question in each section was greater than neutral (all positive). The average responses show the same pattern of highs and lows as the summed responses discussed earlier.

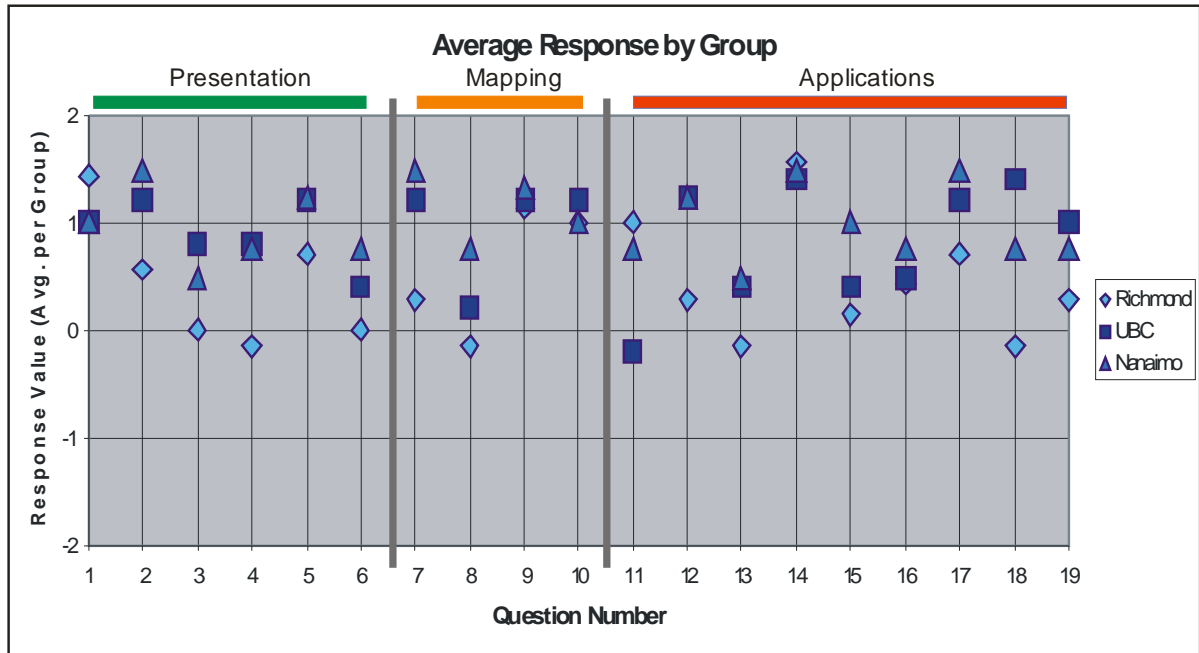


**Figure 90 Average question response rating, by question number.**

Across the set of questions in each section, and all sessions, overall Presentation rating averaged 0.71, Mapping 0.81, and Applications 0.69, all tending towards the 'somewhat agree' rating (+1). When the ratings from each focus group were averaged across all questions, Nanaimo showed the highest average (1.01), followed by UBC (0.88), then Richmond (0.47). The average overall rating across the entire questionnaire was also mildly positive (0.72).

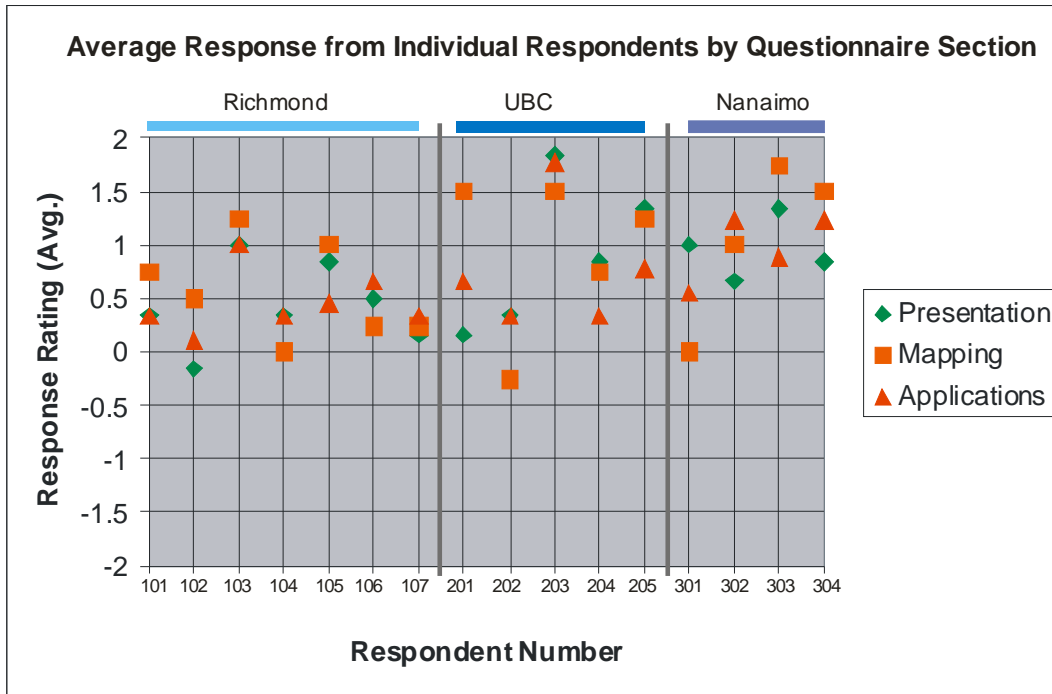
In a further analysis, averages were also determined for each question by focus group location (Fig. 91). Twelve of the 19 response averages were positive, with the highest received from all groups (Q14 about the helpfulness of GEOptics for locating areas of visual risk). Two neutral averages(Q3 and Q6) and 3 slightly below neutral were received

from the Richmond group (Q 4 was about the presentation of VLM (not GEOptics); Q8 about the ease of application of GEOptics; Q13 about advantages of GEOptics outweighing disadvantages). Q4 likely identified the purposeful brevity of conventional VLM in the presentation; Q8 identified a utility concern about GEOptics, while Q13 some scepticism about the benefits GEOptics. The lowest average response (-0.20) to any of the questions was received from the UBC group (Q11 in the Applications section of the questionnaire about conventional VLM mapping method providing adequate tools and products to accurately inform forest operations planning and timber supply calculations). While still only slightly negative, the low average rating suggests a perception that current VLM procedures may not be quite sufficient for the tasks. The VRM specialist-dominated focus group in Richmond had most of the experience with the VLM, and understandably, a closer association with the current system which they have helped design and implement. Results of statistical significance tests between groups are addressed in part "g" of this section.



**Figure 91 Average question response rating, by group.**

The average ratings from individuals to each question (listed and described in Table 16) as distinguished by questionnaire session, also indicated a generally positive response to questions in each section in each group, but with lower values in the Richmond session for each section, more variation, including high values, in the UBC session, and generally higher values in the Nanaimo session (Fig. 92).



**Figure 92 Average ratings by individual respondents by questionnaire section and focus group location.**

#### d) Modes

Modal ratings were examined to simplify broad interpretations of the question results.

Fourteen of the 19 questions (listed and described in Table 16) had a mode<sup>46</sup>, or the most number of ratings (listed in App. 7), of 1 (a response of "somewhat agreed") (Fig. 93).

The scale in Fig. 93 shows the minimum and maximum possible ratings (-2 to +2). One question was rated with a mode of 2 (a response of "strongly agreed"), while 4 questions had a mode of 0 (a response of "neutral"). The question with the highest mode possible (2

<sup>46</sup> O.E.D. definition of "mode", c.II.7.c Statistics. "The value or range of values of a variate for which there is a maximum number of instances in a given population."

out of 2) was Question 14 ("the GEOptics method appears to be helpful for locating areas of greater and lesser visual risk with seen areas"). Question 14 also achieved the highest summed response (Fig. 89), highest mean value (1.5 out of 2) (Fig. 90), and highest median value (2 out of 2).

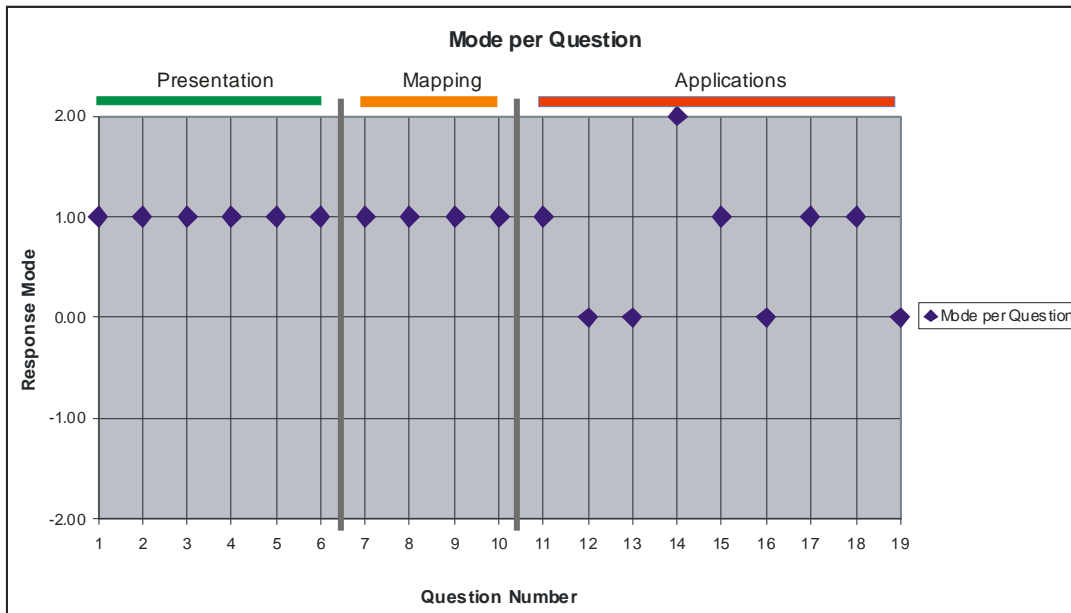


Figure 93 Mode of each question response rating.

### e) Medians

In a further analysis, the median response, the middle value of the number of ratings received for each question listed (Table 16; App. 7)<sup>47</sup>, was determined. The scale in Fig. 94 shows the minimum and maximum possible ratings (-2 to +2). The "somewhat agree"

<sup>47</sup> O.E.D. definition of "median", 3.A.3 Statistics. a.A.3.a: "Used to designate that quantity which is so related to the quantities occurring in a given set of instances that exactly as many of them exceed it as fall short of it."

response of 1 was central in 12 of the 19 questions listed in Table 16, 3 were halfway between "neutral" and "some agree", and 3 were neutral (0). Question 14 received the highest possible median of 2 (strongly agreed).

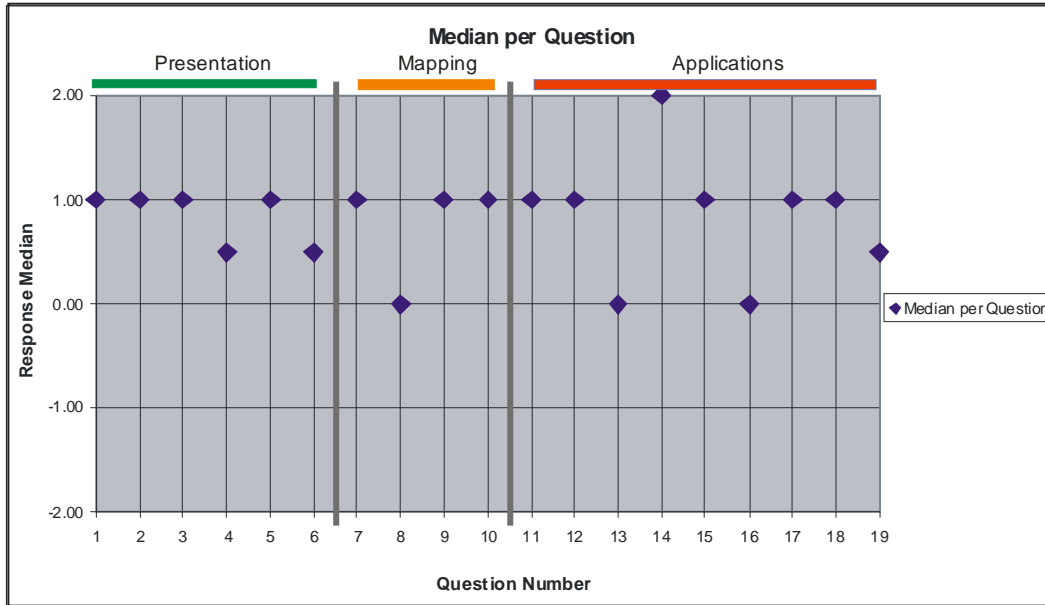
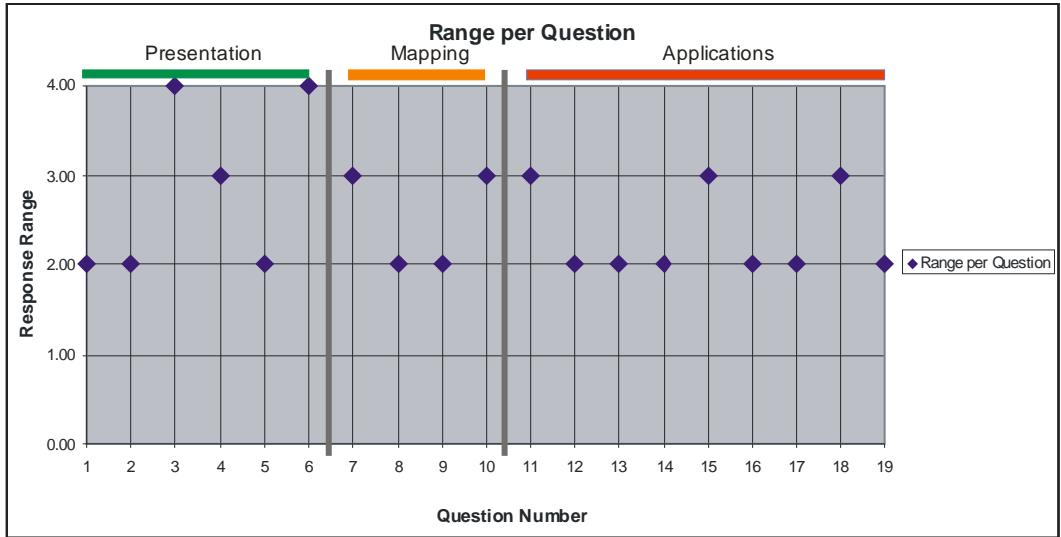


Figure 94 Median of each question response rating, by question.

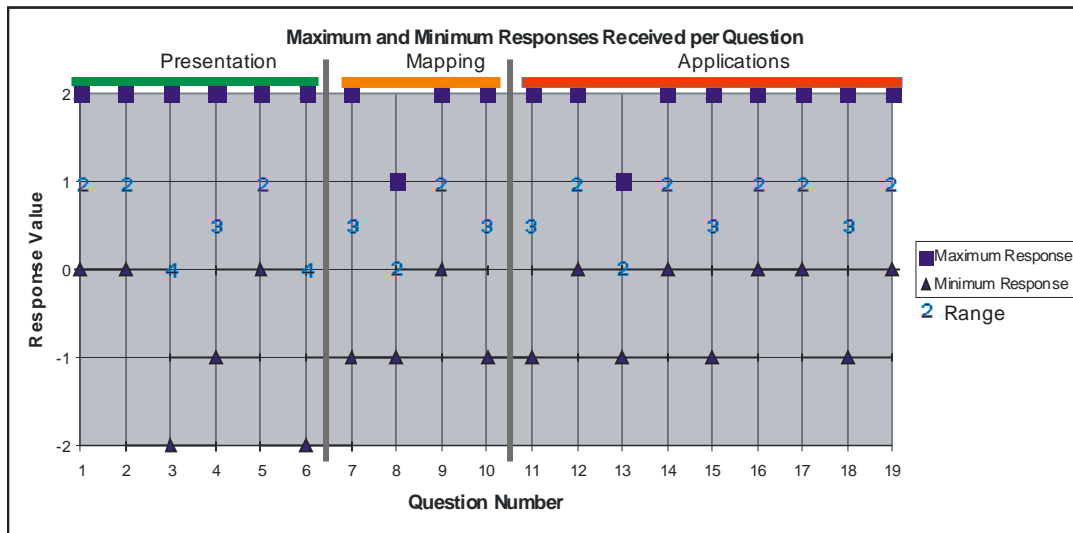
#### f) Ranges

The range of individual response values for each question (the maximum minus the minimum rating) was determined (Fig. 95) as a simple measure of response variance, or disagreement among participants. The scale in Fig. 95 correctly shows the minimum and maximum possible differences (0 to 4). Of the 19 questions (Table 16; App. 7), the majority (11) had a range of only 2, 6 questions had a range of 3, while only 2 questions had the maximum range of 4: Question 3 ("The benefits of conventional VLM mapping were clearly explained") and Question 6 ("The possible limitations of GEOptics landscape apparency method were clearly explained"), both in the "presentation" group of questions, indicating broad disparity in responses to them.



**Figure 95 Response rating range, by question.**

In a further examination of the range of responses to each question, the highest (maximum) and lowest (minimum) response by individuals was mapped. The range is shown numerically at the centre of the gap between the two ratings for each questions (Fig. 96).



**Figure 96 Maximum and minimum individual rating received per question, with ranges for each.**

The highest possible maximum individual ratings (strongly agree) were received from at least one participant for 17 of the 19 questions, while the remaining 2 maximum ratings were accorded a "somewhat agree" response. The lowest possible minimum ratings (strongly disagree) were received for just 2 questions (Question 3: the benefits of conventional VLM were clearly outlined; Question 6: the possible limitations of GEOptics were clearly outlined). Interestingly, both of those questions also received the highest maximum individual ratings. Of the remaining 17 minimum responses, 8 were -1 (somewhat disagree), and 9 were neutral (0), revealing a closer convergence between maximum and minimum than the results for Questions 3 and 6.

### **g) Analysis of Variance**

As a final test, the average response to the full question set was determined for each participant and the results by group (Richmond, UBC, Nanaimo) were subjected to analysis of variance<sup>48</sup>. Results are found in Table 18, and mean comparisons in Figure 97.

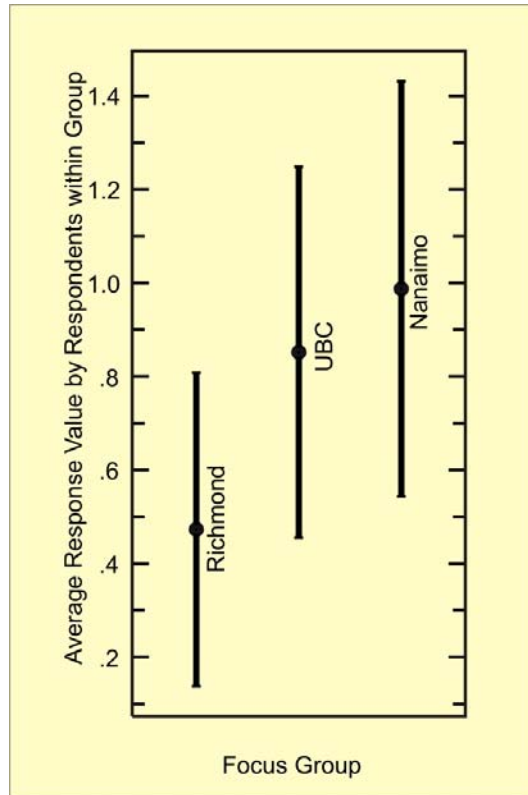
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<sup>48</sup> An on-line ANOVA tool was provided by Professor Tom Kirkman, Department of Physics, College of Saint Benedict / Saint John's University Kirkman, Tom. 2009. "e-mail Re: Analysis of Variance." Pp. Professor Kirkman suggesting use of his on-line ANAOVA calculator, edited by K. Fairhurst: Department of Physics, College of Saint Benedict / Saint John's University (pers.comm., e-mail,.. The link is: <http://www.physics.csbsju.edu/stats/anova.html>.

**Table 18 Analysis of variance between focus groups.**

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F Value
Between	0.8009	2	0.4005	2.374
Error	2.193	13	0.1687	
Total	2.994	15		
Probability of a Null Hypothesis	0.13			

The results found an F value of 2.374 and a probability (null hypothesis) of 0.13, indicating the likelihood that the three groups were from the same population, given the sample size. In other words, the responses from the three separate focus groups were similar, statistically. The same analysis procedure was also used to generate a comparison of the means of each group, with a 95% confidence interval (Fig. 97).



**Figure 97 Plot of focus group means across all questions with 95% confidence intervals, with ranges of group’s individual respondent’s averages, and with centre dot showing the average per group.**

While not statistically different, the average responses from the three groups appear to be graphically distinct, with Richmond lowest in average response, UBC higher, and Nanaimo highest. The trend of increasing averages is possibly indicative of a perception of greater utility of the GEOptics tool by the latter two groups than from the Richmond group. Understandably, the Richmond attendees - mainly VLM specialists - may have been expected to be most discriminating and critical since this is their field of expertise, as well as having the most experience in getting the best out of current conventional methods of VLM, relative to the other groups with a more diverse background, and less

direct knowledge or commitment to current VLM practices. The differences, however, are not definitive, and all response averages are on the positive side of the scale.

#### **h) Summary of Questionnaire Analyses**

The questionnaire was useful for gathering the views of potential users of GEOptics apparenacy map production and applications, notwithstanding time limitations and inability for hands-on exercises during the test. Responses were positive, by frequency, summed response, averages, modes and medians of the results. The fullest possible range of response ratings received for 2 questions (3; 6) raise questions about individual reception and relative experience with VLM systems between participants. Some responses regarding the benefits and limitations of GEOptics (Questions 3, 4, and 6) advantages (Question 13) and ease of application (Question 8), hovered around neutral, indicating a perceived complexity which needs to be addressed by both streamlining the tool and its demonstration methods. The written (Sec. 5.4.2) and audio-recorded (Sec. 5.4.3) discussion analyses provide further insight how potential users consider how GEOptics can and should be implemented.

## 5.4.2 Focus Group Discussion Topics and Results

The discussion section of the questionnaire contained six suggested topics addressing the utility of the apparency map production and applications:

1. What do you see as possible advantages of the GEOptics landscape apparency mapping method, relative to conventional VLM methods?
2. What do you see as possible disadvantages of the GEOptics landscape apparency mapping method, relative to conventional VLM methods?
3. How could GEOptics cumulative landscape apparency (visual risk) mapping be used by resource managers to enhance conventional visual landscape planning and design?
4. How could GEOptics be used by resource managers as a component of Timber Supply Planning?
5. How might the GEOptics method be improved or made more useful?
6. Any other issue or concerns raised in the session?

The intent of the discussion questions was to bring out more response than could be possible in the structured questionnaire, adding more information and insight relative to the specific questionnaire responses. The questions were aimed at having participants compare GEOptics procedures and applications to conventional ones, and if and how improvements could be made. Though not required, each participant quite consistently wrote their responses to the questions on the questionnaire form which was handed in following the open discussion. The respondents were unrestricted as to the number of comments they wished to make. The same questions were suggested for the open discussion session which immediately followed the written questionnaire.

A complete record of all written responses to each open-ended discussion topic is presented in Appendix 8. Every discussion topic received comments from the majority of participants, with an average of 12 of the 17 participants commenting per topic. Only one topic (Topic 6 - other issues or concerns) received a lower number of comments (7) than the average. The majority of participants (13 of 17) commented on most topics (4 or more), and 4 participants commented on all 6 topics. One participant (#204) provided a single comment (Topic 1 - possible advantages of GEOptics). The written responses to each discussion topic were coded and consolidated in relation to the research questions about the ability of GEOptics to improve inventory analysis, planning, and operations, and the evaluation criteria. Key comments representative of each topic are presented as follows:

### **Topic 1 Response Consolidation**

**"What do you see as possible advantages of the GEOptics landscape apperency mapping method, relative to conventional VLM methods?"**

The perceived advantages of GEOptics expressed by focus group participants included the ability to provide a focus of effort where the biggest results will be achieved (#101, #305), highlighting higher and lower visual risk areas (#102, #104, #202, #302), where to clearcut without affecting the VQO (#103), and providing another tool (#105, #201).

Given that utility is an important assessment criteria of EVA's, the GEOptics method was considered very detailed and accurate (#106), very useful (#203), providing greater precision (#201; #205), a move away from binary outputs (#205), and better at informing Timber Supply Review (#301). Further GEOptics output was seen as combinable with

other resource concerns in need of retention (#301), efficient (having considered multiple viewpoints) (#302), providing better comprehensive harvesting plans and developing and testing designs (#303), and fine-tuning sight lines (#304). The positive responses suggest a strong potential with good utility for GEOptics to interface advantageously with conventional VRM methods.

## **Topic 2 Response Consolidation**

**"What do you see as possible disadvantages of the GEOptics landscape apperency mapping method, relative to conventional VLM methods?"**

Evaluating the perceived disadvantages of GEOptics in relation to the assessment criteria of EVA's (Sec. 2.2.1) is important. The disadvantages were largely related to concerns about increased complexity, more planning time, more steps required, and results being too refined (#104, #305) (#103, #104, #106, #203, #204, #205, #305). As well, it was seen to require additional knowledge/expertise and special tools (GIS; VNS) (#101, #106) and additional costs for planning, operations, and software (#201, #205, #305). Concerns were expressed about the potential reduction of timber harvest opportunity (#202); operational practicality (#102); confusion, difficulty of understanding, communicating (#104, #202, #203); increased restrictiveness and needed skills for selecting viewpoints (#304); and about the basic need for the product and whether it provides a significantly better product (#105, #106, #205). One comment mentioned the lack of data about roadside screening (#103). The strong cautionary responses have defined key considerations which must be addressed in further implementation and communications.

### **Topic 3 Response Consolidation**

**"How could GEOptics cumulative landscape apparency (visual risk) mapping be used by resource managers to enhance conventional visual landscape planning and design?"**

Apparency mapping was seen to have high utility as a potential automation method for VLI updates (#103), as way to stratify and focus effort (#104, #305), identifying opportunities (#107), and improving total chance planning and direct operational plans (#301). It was also seen as useful for planning sequences of passes (#203), bringing in time considerations in non-static viewing (#302), and dovetailing with other strategic resource layers at landscape level (#304). Concerns were raised as to who would use it (#106), that it would add another constraint layer (#202), and that it needs to be proven that it outperforms conventional methods (VIA) (#105). In summary, GEOptics was considered by the majority of respondents (on this topic) to be a potential benefit to the VLM process (a significant and comprehensive EVA) in each of inventory, strategic planning (P2P; VQO constraints), and design. The more critical comments suggested further evidence of the benefits of GEOptics needs to be derived and made known.

### **Topic 4 Response Consolidation**

**"How could GEOptics be used by resource managers as a component of Timber Supply Planning?"**

The uses of GEOptics suggested by focus group participants were to build GEOptics apparency into a forest cover constraint layer as a modifier of VQOs (#101), to refine constrained areas for timber supply purposes, and for determining better P2P ratios for

TSR (#301, #103), for making net downs easier (#202), and to balance VQO quotas (#106). As well it could be better at defining available land and volumes (#304), providing a focus on low apparency for timber harvesting (#201), and for modelling rotational plans for harvesting (#203). Cautions were expressed that GEOptics was seen as a fine tool while TSR is a blunt instrument, and while GEOptics shows what may be possible, TSR models current practice - the two might not be the same - it would be better for operations level than TSR (#107, #305). An experienced technician would be required (#104), and advantages remain to be seen based on output shown (#105). There appeared to be a balance between those supportive and those cautionary about GEOptics in timber supply. There may be resistance to changing the current timber supply planning methods, but actual practice adjustments can be made and better information can be submitted for consideration, as stated in the recorded audio comments (App. 9: N26; N28, N32). Presumably adjustments could include GEOptics apparency mapping.

### **Topic 5 Response Consolidation**

#### **"How might the GEOptics method be improved or made more useful?"**

It was suggested that the process be simplified, made easier to use, streamlined with fewer steps, more automated, made compatible with cutblock reporting systems, and described with use of more familiar terms (#104, #106, #105, #204). Suggestions were received to incorporate GEOptics with other resource constraint information for use in IVD (#101) and to explore its use as a VLI update mechanism (#103). It was further suggested that design improvements be shown in the presentations (#201, #205). Others suggested that the impact of harvest methods needs to be assessed (#202), that viewpoints

(lights) be weighted (#301), that it be made an optimization model with a time function (#302), and combined with times-seen to find most critical areas (#305).

## **Topic 6 Response Consolidation**

### **"Any other issue or concerns raised in the session?"**

Concerns were expressed that the process was a little confusing (#104), that harvest practicality was a limiting factor (#104), and that it should be kept simple and practical (#106). Planners need to recognize the consequences of early passes on later plans (#203) (GEOptics was seen as a useful way to do that by the same respondent in Topic 3).

Concern was expressed why apparency wasn't compared with planning methods and analyses of equal complexity, but rather with simple slope maps (#205), and that limitations were tied to viewpoint choice, and the duration of view was not factored in well (#305). Each of these considerations are compatible with the potential of GEOptics to evolve into an even more effective and useable tool.

### **5.4.3 Focus Group Verbal Discussion Audio-Recorded Results**

The verbal discussions were less structured than the written responses to the discussion topics. Audio recordings for each of the sessions were transcribed and numbered in the order they were voiced (Appendix 9). Some participants made several comments, a few others made none. Names were not recorded to maintain confidentiality.

A selection representative of the wider comments and key points (nuggets) have been brought forward here to further inform the findings from the questionnaire and written discussion comments. These were placed into 4 categories: 1) current challenges for VRM in BC, 2) possible advantages and uses for GEOptics 3) possible disadvantages of GEOptics, and 4) uses of GEOptics as a component of strategic (timber supply) planning. The letters in brackets refer to the focus group session at which the comments were received (R=Richmond; U=UBC; N=Nanaimo).

### **1) Current Challenges for VRM in BC**

Forest practices were stated to be lacking appropriate visual design attributes, as "only 42% of samples have good design" (R14, N2). One suggestion was that operators are "missing design and harvest opportunity" as "slope is overly restricting - the wrong variable" (U24). Also, it was suggested by one commenter that "lower slopes...may have been undervalued previously" and there should be "less blanket exemptions for visual" (U2). There is often a "lack of appreciation for cumulative impacts of land withdrawal" (U10) - currently, operators "tend to take a risk-averse approach" (N19), meaning that high visual risk areas are being avoided. That avoidance can cause BC's Chief Forester to "require operations in restrictive VQOs areas or remove it from the cut" (N31). With good design, there is "public buy-in...more wood harvested...larger openings"(R14). The target in BC for good design of cutblocks is a "55%-70% success rate" (N1). Further considerations in regards to strategic planning are presented separately in point 4.

## **2) Possible Advantages and Uses of GEOptics (Discussion Topics 1; 3)**

The GEOptics process was considered by some to be "advanced landscape planning" (U23), capable of leading "in the direction of space planning and sequence" (U16), for "identifying and prioritizing areas of higher visual risk" (N33), with "precision" (U5; U25), and provides "an integrated level of decision" (U12), with needed "lay of the land" understanding (U2). It was further seen as "a terrific tool" (U7) for a planning system in which "complexity is already there" (U10). It was also said to be "significant leap...to show planners where they can get 60% of the timber" (U21), and capable of assisting operators who "don't have the skills to select viewpoints", suggesting the apparency method could be helpful by considering viewpoints "every 50 m" (N11). Apparency was seen to provide a dual benefit, i.e. for public communication and as information for planners and operators: "taking a plan to the public and stakeholders"(U7).

The process was considered by one as "too broad for cutblock-to-cutblock decisions" (N7).

## **3) Possible Disadvantages of GEOptics (Discussion Topic 2)**

Apparency was seen as "another layer of complexity and operationalizing" with an expected "decreasing economic return" (U9) and could take "landbase out of consideration for harvesting" (U1), it "won't resolve operations issues; TSR" (R17), and could be "difficult to explain to lay people" (U1). One questioned how it can be "converted to the visual system that already exists" (U4) and "we already have (the) tools

and if there is only a 5%<sup>49</sup> difference in assessments...(it) may cause confusion...requires GIS" (R3). Further, it was suggested that the model should "account for tree screening, operational requirements" (R9) and that tree-screening along roadways "is not accurately mapped" (R10). One commenter advised: "(you) can't avoid front high quantiles...or (they) will be removed from the landbase" (R6). Apparency was thought to be "artificially forcing into equal areas - quantiles" (N5); showing "where high risk are, but no way will they be cut that way" (R7), that the approach is "too broad for cutblock decisions" (N7) and "At some point those high risk areas should become obvious to the forest professional with or without this type of modelling" (N35).

#### **4) Use of GEOptics as a Component of Strategic (Timber Supply) Planning**

##### **(Discussion Topic 4)**

As expressed in the written comments for Topic 4 in Sec. 5.4.2, considerable verbal discussion related to the pros and cons of GEOptics related to timber supply planning (Discussion Topic #4). It was mentioned that GEOptics apparency would be a benefit as it "fine-tunes the landbase" (N10); is "a better way to evaluate timber supply impacts by each 25 m cell" (N19); and is "good for total chance planning, P2P, TSR" (N7).

GEOptics apparency was also seen to have potential as "a way to automate VLI" (R4), thereby providing updates for use in TSR.

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<sup>49</sup> An unmeasured "guess" by the participant.

Cautions were raised, generally, about the consideration of spatial resource refinements (such as GEOptics apparency) in TSR because "things get lumped together" (N26), and "BCMoFR's current procedures are using pretty gross assumptions which in practicality would negate the benefit of fine-tuning" (N33). Even though GEOptics was considered to be effective at "showing what might be possible", it must be already being achieved in on-the-ground operations, or "current practice" (R13). If not "then it is not what is modelled (in TSR)" (R13). In fact, it was stated that the BCMoFR is "now only using previous TSR numbers....no one is looking at changing the system" (N22). However, TSR is "starting to incorporate spatial layers (N23), and "actual practice adjustment" is being made, for example, for stand level retention (N26). To implement adjustment, information has to be gathered in an "approved, Chief Forester endorsed process. Until then it is for Chief Forester consideration and assumptions" N28). Further, when considering new input such as could be provided by GEOptics, "operations must prove they are effective at meeting the VQO at a higher range, requiring a review of practices, and making a determination" (N29). In summary, it appears that GEOptics could make a contribution to TSR, but it will require proof that any enhancements that GEOptics might provide can be demonstrated and accomplished through actual operations.

##### **5) Suggestions for Improvement of GEOptics (Discussion Topic 5)**

Respondents suggested that the approach "needs a script; push-button" (R1); should provide "a way to automate VLI" (R4), should "distinguish between management decision and VLI" (R8), and that "a time scale would make this tool even more useful"

(U11). To be more convincing, the presentation should "modify the cuts, take to the public and show how design is used to mitigate impact" (U3). One respondent suggested addressing cost issues, as the: "biggest concern is cost - up front and benefits achieved down the road - how will it impact the rate of harvest, how to justify it economically" (U16). For duration of view, or viewpoint significance, "use a brighter light bulb...professionalizing the model" (N18); "viewpoint variable luminosity" and combine with "distance fall-off" (N34). One respondent suggested changing viewpoint (light) elevation "to account for user type (kayak / cruise ship)" (N6), and another, combining: "times-seen and apparency to add sensitivity" (N13). There was also a suggestion that the presentation needed visualizations of final plans to: "Address skepticism (by providing) proof in the pudding" (U19).

#### **5.4.4 Chapter Summary**

In Chapter 5, the focus group results, summaries, and analyses were presented: questionnaire results (Sec. 5.4.1), written discussion comments (5.4.2), and audio-recorded comments (Sec. 5.4.3). Detailed results are presented in Appendices 7-9. There was considerable similarity between the questionnaire results and comments. The findings from the questionnaire, and written and verbal comments, are further discussed in Sec. 6.2.

## 6 Discussion and Conclusions

In this final chapter, discussions and conclusions are put forward. Firstly, the research questions, evaluation criteria and research tasks are examined, together with the results from the model tests and applications (Sec. 6.1) and from the focus group sessions (Sec. 6.2). Conclusions are presented in Sec. 6.3, derived from a synthesis of key findings of advantages and limitations/criticisms of GEOptics, followed by further research, policy, and implementation recommendations (Sec. 6.4).

The broad goal of my research was to develop and test a modelling approach and procedure that had the potential to improve the worth of an expert visual assessment system (EVA) such as the British Columbia Ministry of Forests and Range's Visual Landscape Management (VLM) system. A terrain-based approach was sought that could potentially contribute to the worth and outcomes of three end-product applications of EVA: 1) the supply of visual resource allocation and protection, 2) integrated resource planning, and 3) visual landscape design. The success of the new approach and measures was determined through internal and external tests and applications. The potential for extension of the concept to other EVA systems and an hierarchical, decision-support system, was also examined.

## **6.1 Research Questions, Tasks, and Evaluation Criteria and Discussion**

Evaluation criteria were applied across the set of research questions and tasks to assess if apparency would provide a useful contribution or improvement to current practices.

These criteria were: 1) feasibility, 2) validity/defensibility, 3) effectiveness, and 4) usability.

### **6.1.1 Research Question Discussion**

The findings from the four research questions that were described in Sec. 2.1 and evaluated in Chapters 4 and 5 were considered in the context of the potential contribution of the landscape apparency concept and GEOptics mapping techniques to the six phases of the VLM system: 1) inventory, 2) analysis 3) setting objectives, 4) design, 5) implementation, and 6) monitoring (Table 2). Apparency was found to be capable of potentially contributing directly to the first four phases. The implementation and monitoring of such plans would potentially demonstrate on-the-ground benefits, though these last 2 aspects were not able to be tested as no established apparency-guided operations were available. The relation of VLM phases to the research questions was shown in Table 6.

### **Research Question 1: Does GEOptics apparency improve landscape inventory?**

Based on years of personal, direct experience in developing and implementing the system, and my own critical judgement, I consider the present BCMoFR Visual Landscape Inventory (VLI) process to be largely adequate for its purposes to map and evaluate the visible landbase for use in broad scale applications, although not for operational cutblock design. As VLI is a major component of the BCMoFR's VLM process, the below average rating about the adequacy of VLM by participants in the questionnaire (Table 16, Q11), and focus group discussions presented in Secs. 5.4.2 and 5.4.3, indicates limitations are being realized with the present VLI system. If refinement was to be contemplated at the broad scale (i.e., not in design of cutblocks), a feasible improvement could be provided by apparency mapping.

Apparency was found to provide a much more accurate and precise measure of visual risk than VAC mapping in general, and topographic slope specifically, as it was capable of incorporating the horizontal and vertical line-of-sight influence on each land plane seen from multiple viewpoints, and generating smaller units than overall VAC zones.

Although not required to be directly measured in the VLI, times-seen mapping, a fairly common GIS analysis, was also improved upon by apparency as a measure of visual risk.

Viewshed mapping and apparency mapping were found to be equal in spatial extent, having been derived from the same terrain model and viewpoints, confirming the accuracy and precision of the GEOptics method. However, apparency mapping provides

a detailed, effective way of mapping and qualifying levels of visibility within a viewshed, and providing meaningful patterns of visual risk within the viewshed boundary.

The capacity of apparency to be classified into greater or fewer categories of visual risk, shows its utility across a range of scales as appropriate to the application, from broad scale VLI to the site-specific, within the hierarchy of a decision support system. One use, as suggested by one of the focus group participants, the refinement VQO (VLI) mapping "in an automated way" (Appendix 8, Topic 3, # 103).

Importantly, visual magnitude and vulnerability are considered in greater detail in a subsequent phase of the VLM – Phase 4, Visual Design. Seen as one system, the VLM carries on from the VLI ( a constituent part of VLM as shown in Table 2) to deal with impact assessments and design solutions through their control mechanisms and site-specific viewpoint-oriented approach. That said, the system is nevertheless a top-down system that generates recommended VQOs for each VSU as the outcome of the analysis phase (Phase 2), and establishes VQOs in Phase 3 which are strongly related to VLI evaluations. The VQOs follow through the remaining 3 phases of the VLM as legal objectives that must be met.

Current problems, as put forward during the focus groups discussions (Appendix 9, Nanaimo focus group), are that only a minority of the VSUs are meeting those objectives, and the timber thought to be available is not there due to VQO restrictions in the design planning phase (Phase 4), possibly contributing to unacceptable implementation practices

which ultimately are discovered in critical audits (Phase 6). The broad-scale, relatively imprecise, VLI therefore influences all phases. Apparency mapping could help alleviate those problems and reduce uncertainty in finding solutions by more carefully and precisely identifying areas suitable for low visual impact timber harvesting.

## **Research Question 2: Does apparency improve landscape planning?**

The apparency mapping tool provides a concrete and objective method for generating visual "constraint and opportunity" ratings to use when setting broad scale planning objectives for visual quality. Derived from detailed analysis, apparency can provide more defensible/replicable P2P ratios than current methods using broad averages and professional judgement. Previous studies (eg. Smardon, 1986) have demonstrated the risks of inconsistent professional judgement in VRM. The GEOptics tool could reduce these risks in supporting professional judgements while still allowing for flexibility in practitioner experience. Unlike slope mapping, apparency provides a method of calculating P2P ratios (at the visual landscape unit scale) which has considered the viewer's perspective of the landscape. As such, apparency can potentially provide visual supply constraint measures of VRM that may improve the management of a wide variety of resources, including timber, wildlife habitat, and recreation in the landscape. A comment from the focus groups is a clue that potential users foresee a potential improvement in broad scale planning by the use of apparency as it "Seems to easily dovetail into other strategic land management resource layers used at a landscape level planning process" (Appendix 8, Discussion Topic 3, Respondent # 304, Nanaimo).

However, caution was stressed by the focus groups against trying to apply a detailed refinement such as apparency-derived P2P in broad-scale TSR as "Things get lumped in timber supply. TSR (is) a bunch of averages - can't take (it) out to 2 decimal places" (Appendix 9, Nanaimo, N26).

### **Research Question 3: Does apparency improve landscape design?**

The tool is capable of providing new, directly useable, spatial information to assist land-use design to fit the landscape better. The apparency stratification can guide the detailed location, intensity, and scale of forest operations. Apparency can potentially improve the efficiency and effectiveness of the planning process by reducing some of the guesswork and need for post-design visualization checks. As suggested in the Richmond focus group: "This, to me, is more precision and more refinement, more resolution, and moves away from a binary tool - in/out, breaks down the margins between classes - a public process tool - a demonstration of sensitivity" (Appendix 9, UBC, U5).

### **Research Question 4: Does apparency improve integrative modelling?**

The modelling tool was shown to be effective as input into integrated visual design (total chance) planning. Hierarchical planning mechanisms, such as UBC-FM (Seely et al. 2004), were able to easily include apparency as a constraint measure. Importantly, GEOptics can provide a dynamic response to changing forest cover and management plan assumptions. Apparency map and database output are fundamentally compatible with

many GIS formats, such as those used in FPS-Atlas. Apparency values were easily and effectively used as the principal control for the placement and schedule of harvesting in the automated design of long term harvest scheduling for the Nadina project (Sec. 4.6.2). Additional inputs could be considered in the future, such as the SIMFOR habitat model as discussed in Wells et al., or for the multi-objective scenario evaluation model for sustainable forest management (Maness and Farrell 2004).

The proposed procedure represents increased complexity, or at least the perception of increased complexity, by the addition of several new tools and subsequent decision factors. That complexity was seen as a limiting factor for its implementation by some focus group participants: "Need to know GIS to run. A bit complicated. Does it really provide a greater or more useful end product? Is the end result really practical?" (Appendix 8, Topic 2, #106). However, as Boyland stated : "Forest management is a complex, and often controversial activity" (2003). Complexity is inherent in the management of forest resources, as also noted in the UBC focus group: "The complexity is already there. The problem is complexity often isn't realized until the second or third pass, and the timber you thought would be there is not there because its going to have significant impact on visuals and other resource values" (Appendix 9, UBC). Boyland (2003) stressed the value of hierarchical planning to reduce that complexity. Apparency is offered as a method to improve and actually simplify resource management decisions over the long term and multiple levels of that planning hierarchy. GEOptics apparency can be considered to be at least potentially capable of informing all three planning levels

(strategic, tactical, and operational), though it is focused primarily at the tactical level which, in turn, can be used to inform both the higher and the lower level plans.

### **6.1.2 Research Tasks and their Evaluation**

There were 6 research tasks (presented in Chapter 2). These were: 1) to examine EVA theory as it relates to apparency; 2) to develop the apparency modelling technique; 3) to refine the evaluation criteria/pre-tests; 4) to evaluate the apparency technique through internal tests and applications; 5) to evaluate the apparency technique through external tests (focus groups); and 6) to discuss the findings, make conclusions, and suggest further needs for research. Discussion of the first task is presented separately, followed by the remaining 5 which are addressed for each stage of GEOptics (Table 7).

#### **1) Examine EVA Theory and Techniques.**

As Task 1, EVA theory and techniques were examined by way of a literature review to help explain factors related to landscape apparency, particularly visual magnitude and vulnerability. These were addressed in Sec. 2.2.1. Of particular note were the challenges raised by a number of authors in regards to present EVA systems, including unreliability, subjectivity, lack of sensitivity, coarseness of resolution, and the "inability to differentiate within and amongst areas of the same rating" (Daniel and Vining (1983)). The apparency procedure and mapping products have made significant advances in response to these challenges. As well, several other authors examined the concepts of visual vulnerability

or risk, visual magnitude, mobility of the viewer, angle of visual incidence, and plan-to-perspective ratios. Each of these were integral to the apparency approach.

The BCMoFR addresses of measures of vulnerability in the VLI through the VAC rating and its components, one of which is topographic slope. These are assigned to fairly large scale VSUs, (as demonstrated in Figs. 43 and 44) with no ability to differentiate within the units. In fact, each of the 8 VSUs enclosing the Howe Sound area used in the apparency analysis had the same VAC (moderate), while the GEOptics technique revealed major patterns of differences in visual risk.

Visual magnitude is not clearly addressed as a factor in VLI, though the visual sensitivity rating is a derivative measure that has considered viewing distance category, viewing angle category, and terrain height category, all of which speak broadly to magnitude and vulnerability. In comparison, apparency fully accounts for the visual magnitude (visual risk) in each land plane, from one or many viewpoints. The relationships of apparency to these other concepts were summarized in Table 6.

## **2) Develop the Apparency Modelling Technique**

The task of apparency development, and related tests and applications, were described in Chapter 4. The approach had 6 stages, the first four of which were considered to be in the category of inventory, the next analysis, and remaining stage, planning (Table 8). Each

received several tests, included in the results (Ch. 4) and discussed separately, by stage, in this section.

### **A) Inventory Stages**

The Inventory stages covered 1) Terrain modelling, 2) Illumination, 3) Classification, and 4) Integration. The four sets of procedures work together to provide the single apparenly "inventory" mapping tool and application-ready database. Complexity was an issue raised in the focus groups, and likely contributed to lower evaluations received for some questions in the questionnaire. Consolidation of the 4 stages in the inventory category into a single "inventory" stage could provide some of the simplification called for by the respondents. The change may provide greater approachability (utility), and easier adaptation to other systems such as BC's VLM.

#### **6.1.1 Stage 1: Terrain Modelling**

As described in Sec. 4.1, digital terrain was obtained from TRIM<sup>50</sup> for each model (BCM<sub>o</sub>ELP, 1992). While its limitations are recognized (e.g. 25m grid resolution, 20m contours), TRIM is a familiar and highly used source of terrain used in broad- and finer-scale planning in BC. The TRIM data and resulting terrain models are considered adequate for the purposes intended. ArcGIS 3D Analyst was also used to construct the viewshed mapping and times-seen mapping using the same terrain information with

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<sup>50</sup> Terrain Resource Information Management Program: <http://www.ilmb.gov.bc.ca/crgb/pba/trim/>.

which the illumination maps were produced in VNS, and to which the resulting apparency maps could be compared.

A striping effect along a north-south orientation produced by the scanning orientation when DEMS was detected in the terrain models produced with TRIM. These could produce minor variations in light intensity along the slightly raised stripe ridges. Multiple light sources appeared to mask the striping effect in illumination maps. A striping removal algorithm could be considered in future testing (Albani 2001).

While these errors in grid resolution and striping could influence apparency to an unmeasured extent, the effect was expected to be minor, based on visual inspection. Forest planners will frequently supplement TRIM with more refined DEM of contour information, usually produced from custom-run aerial photography. The greater resolution will reduce the errors found in TRIM. No finer models were available for comparison.

### **6.1.2 Stage 2: Illumination**

In Stage 2, the apparency models were developed. Six technical topics framed the developmental tests and applications: 1) initial envisionment of GEOptics (Stella Lake) (Sec. 4.2.1); 2) illumination / shadow maps; intensity, fall-off, and apparency effects (Sec. 4.2.2); 3) diffuse reflectance (Sec. 4.2.3); 4) cumulative and additive properties of

illumination / comparison with VLI (Sec. 4.2.4); 5) comparison with hillshading techniques (Sec. 4.2.5); and 6) viewshed-illumination map comparison (Sec. 4.2.6).

## **1. Initial Envisionment**

Preliminary development commenced with the Stella Lake project in 2004 (Sec. 4.2.1). From Stella, it was determined that an illumination technique could be constructed with light sources located at multiple viewpoints using VNS software. The resulting illumination values were found to be able to differentiate visual risk individually, and collectively, from those viewpoints.

## **2. Illumination, Shadow Map Production, Intensity Fall-off, and Apparency Effects**

In Sec. 4.2.2, illumination effects were examined. Illumination map production was the single procedure unique to the GEOptics approach. The light was found to radiate evenly around its source (Fig. 28), and diminished with distance from the light source and the decreasing angle of visual incidence (AVI) as distance increased (Fig. 29). VNS shadow-mapping provided an accurate depiction of terrain visible to the viewpoints (LCPs). Production time was considered to be minor in relation to the value and utility of the output.

Based on the assumption of equal viewpoint importance, illumination intensity was systematically set at 100% for all light in the main models (Howe Sound and Nadina). Illumination intensity could be easily adjusted in VNS to reflect viewpoint importance, which was encouraged by a focus group participant: "I'm not sure if viewpoint variable luminosity could be factored in. For example, a short passing view could have a fairly low viewpoint luminosity factor, whereas a community viewpoint with numerous stationary viewers could be given a much higher luminosity/brightness factor." (Appendix 9, Nanaimo, N33). The determination of the appropriate levels of light intensity relative to viewpoint importance requires more testing.

Consideration was given to the fall-off of light intensity over distance to emulate the diminishment of level of detail and viewer interest, and also was supported in a focus group comment: "Sensitivity/strength (should) decrease with distance from viewpoint(s). so that there is some fall-off with distance which are now indicating equal apparency" (Appendix 9, Nanaimo, N33). The finding of drastic reduction in illumination over short distances in a flat test model appeared to conflict with apparency mapping results in which landforms are illuminated over much greater distances as, for example, in the Howe Sound model (Fig. 20). The possible explanation was that illumination in the flat model diminished rapidly due to very low AVIs, while steep terrain, being more perpendicular to the light source, maintained large AVIs over greater distances. There also may be a yet to be determined, inherent fall-off effect in the VNS lights that should be examined further.

### **3. Diffuse Reflectance**

As presented in Sec. 4.2.3, the diffuse reflectance properties of the terrain in VNS allowed the illumination response to be determined in planimetric view. The results were conclusive in that there was consistency of illumination values regardless of plan or perspective views, provided that the particular cell was visible from those positions. Further, it was determined that the illumination value of an individual cell was identical from all viewing (camera) positions, regardless of the slope angle of that land cell (except absolute vertical where the cell would be non-evident to the planimetric camera). Vertical slope is a rarity in the natural terrain, and was absent in both primary models used in apparency development and testing. The vertical limitation could restrict the use of apparency in areas of vertical cliffs and canyon walls, though these are effectively off limits to most forestry operations.

### **4. Cumulative and Additive Properties of Illumination Maps**

As described in Sec. 4.2.4, the additive capability of illumination was confirmed. There was no upper limit to the percentage as lights were added. The geo-referenced illumination map GEOTIFF output format produced in VNS enabled import and registration in the ArcMap model. However, the RGB approach was limited within the RGB value limits of 0-255 for each pixel. This limitation was recognized to be a potential "sensitivity" issue with cumulative apparency mapping. However, the Howe Sound results indicated only 2% of the classified area reached the top end of the scale. The

topping-out potential of the RGB cumulative illumination map led to the addition of individual light source illumination maps in ArcMap to provide further differentiation of apparency with an unlimited upper scale of illumination. This issue is addressed further in the discussion of Stage 3 (Classification).

## **5. Comparison with Conventional 3-D Hillshade in ArcGIS**

In Sec. 4.2.5, the ArcGIS hillshade function was compared with VNS illumination. The basic functioning of ArcGIS hillshade was found to be not useful for apparency mapping. The limitations were determined to be: 1) the inability to place a light at a specific viewpoint; and 2) 3D Analyst allows illumination of surfaces facing away from the light (non-visible terrain). By contrast, the ease and precision with which lights (or cameras) are positioned in VNS, and the illumination results using VNS shadow map production, clearly supports the VNS procedure over ArcGIS hillshade for producing illumination mapping.

## **6. Viewshed / Illumination Map Comparison**

In Sec. 4.2.6 the individual and cumulative illumination mapping techniques were verified against viewsheds produced in ArcGIS 3D Analyst. Using identical terrain models sourced from TRIM, the two approaches were found to be identical with the exception of about 1% of the fringe pixels of each, which were considered to cancel each other out overall (Figure 39). The pixel-sized (25 m) differences between the VNS

illumination map and the ArcGIS 3D Analyst viewshed map occurred along ridge lines as they would be seen from the viewpoint (LCP). While presenting a minor accuracy issue, the fringe pixels at the same time provide a useful benefit – as indicators of potential skyline ridges where special attention may be required to avoid skyline notching during developmental activity which can cause enduring visual impact and attract attention.

### **6.1.3 Stage 3: Classification; VLI, Plan-to-Perspective**

In Stage 3, illumination maps were: 1) classified (Sec. 4.3.1); and compared with 2) slope mapping (Sec. 4.3.2); and 3) times-seen mapping (Sec. 4.3.3). A discussion of the results of each follows:

#### **1. Apparency Classification; Comparison with VLI**

As compared with VLI in Sec. 4.3.1, apparency mapping was shown to provide a highly detailed map of the locations, patterns, and degree of potential cumulative visual risk within each VSU examined. In contrast, the VSU was assigned just a single overall VAC rating in the VLI without any capacity for differentiation, and under-accounting large areas of visual vulnerability. The detailed apparency was shown to quite easily and effectively be used to inform resource management, such as for timber harvesting, or for levels of protection deemed necessary for higher-risk landscapes.

The results observed for cumulative apparency with multiple LCPs (Fig. 42) and additive cumulative apparency (produced by adding individual illumination maps produced for each of the LCPs (Fig. 43) were very similar when colour-coded using the 5-class quantile method. The expected RGB 255 "topping-out" occurred with only 2% of the land-plane area, suggesting that the cumulative approach is not necessarily limiting, and requires further testing with a greater range of landscape types (steepness/relief), and by the number and positioning of light sources. The additive approach would be preferable to the cumulative approach if topping-out becomes significant, perhaps at greater than 5% of the area.

Quantile classification provided the capability to explore the influence of apparency values in the landscape when grouped into classes which were approximately equal in areal extent. The spatial equivalency provided by the quantile classification approach was essential when determining the plan-to-perspective relationships of each class (Sections 4.5.1; 4.5.2). While 5 or 6 classes appeared to be adequate, increasing the number of classes would provide even greater pattern resolution and detail for integrated design and operational planning. Importantly, the original apparency values are maintained in the database, thereby providing high utility and unrestricted opportunity to investigate and apply the data at any desired scale.

There are some limitations of the quantile method where another method might also prove more useful. One method, equal-interval (EI) provided equal range breaks in the spectrum of RGB values, which would allow cross-comparison of landscapes with

similar RGB ranges (most likely for those with cumulative RGB 255 maximum apparency). Single and cumulative apparency mapping and RGB classification by the quantile method (Appendix 11, Figs. A1 and A3) were compared with the equal-interval method of RGB classification (Appendix 11, Figs. A2 and A4).

Comparing quantile and equal-interval (EI) classification methods for the landscape types used in this study, the quantile approach offers more flexibility across large areas of the visible land base (and for P2P etc), but EI may be better at fine tuning the highest risk areas which tend to get lumped together in the highest apparency quantile. The quantile method with 5 levels of cumulative apparency (and the basis of the 5-level naming convention of VL to VH) can tend to somewhat over-emphasize the highest level of visual risk relative to EI, since it classes as VH (red) about 20% of the land base (Appendix 11, Fig. A3), whereas the EI method classes about 6% of the landbase for the cumulative apparency example (Appendix 11, Fig. A4). The quantile method can also somewhat under-represent the green (lower) apparency levels relative to EI (20% v. 51% VL cumulative apparency for the Howe Sound study area). This is especially true if the spread of RGB values is relatively low (eg. 1-111 for a single viewpoint such as LCP 117, as shown in Appendix 11, Figs. A1 and A2, or with cumulative apparency in flatter landscapes).

The potential of the quantile approach to somewhat over-estimate the highest visual risk is perhaps a strength in that it provides a robust safety margin for unexpected conditions, terrain data inaccuracy, or poor logging practices etc., in meeting VQOs. On the other hand, the EI approach likely places too much area in the very low risk category; the visual result would mean that class is no longer entirely very low in visual risk and could

require further division and/or renaming. As an experimental new technique, it makes sense to err on the side of caution and use conservative estimates. However, both EI and quantile methods demonstrate much higher levels of visual risk in some areas than the VLI mapping of VAC.

The key finding is that even with these visual risk safety margins built in, so much of the visible landscape (including some fairly steep areas) has relatively low apparency/visual risk, using the quantile method. If only EI levels were used, criticism could be expected for opening up too much additional harvesting areas for low-constraint design/logging. EI could be useful to help design in the toughest areas, as could employing more than 5 breaks in either the quantile approach (e.g. 10 classes were shown in Fig. 43), so that flexibility is not lost in with any apparency class; however, there is a trade-off in adding complexity for visual interpretation with this approach. For broad use, the quantile methods appears to be safer (eg. in calculating TSR P2Ps). Another method, "natural breaks" was examined, but, based on visual inspection, provided little distinction beyond that provided by the first two systems, and would lose a systematic and meaningful way of naming different levels. In flatter terrain, it might also be important to test various classification systems, with further work needed to develop guidelines for these kind of issues in the future. Regardless of the method selected, single and cumulative apparency RGB values calculated by the GEOptics method remain unchanged by the classification method, and are available for further analysis by multiple methods. Comparison of landscapes is also possible using RGB values alone (eg. maximum or average values).

## **2. Comparison of Apparency and Slope Mapping**

Topographic slope and apparency, derived from the same terrain models, were compared in Sec. 4.3.2. Knowledge of the topographic slope is essential, not only for operational planning, but also when refining VQO percentages. In the present VLM system, all steep areas in visually sensitive terrain would equally be assigned more restrictive visual constraints, regardless of viewing angle, including terrain that is oblique to the view. Having considered viewpoint-specific and cumulative viewing angles, apparency was found to be a much more refined, reliable and accurate predictor of visual risk than slope. Focus group comments ranged from supportive: "don't use slope - that's why we are missing design and harvest opportunity - using wrong variables." (App. 9, UBC, U24) to cautionary: "Slope used to be used in TSR, now only using previous TSR numbers, no one looking at changing the system". (App. 9, Nanaimo, N22). Also one mentioned the reality of the current situation in which topographic slope is widely utilized as an element of the conventional planning database: "slope is a dominant factor, assuming a certain viewing angle" (App. 9, Richmond, R15).

## **3. Comparison of Apparency and Times-seen mapping**

A spatial comparison between apparency and ArcGIS times-seen mapping was prepared in Sec. 4.3.3. Apparency and times-seen are more closely related than apparency and slope. The number of times-seen classes was fixed by the number of viewpoints in the model and therefore was incapable of further refinement without the addition of more viewpoints. A focus group commenter asked: "Could you combine times seen and

apparency to add sensitivity?" (App. 9, Nanaimo, N13). The response was "Yes" - perhaps that can be examined in future trials. A cautionary note was raised by a focus group participant: "we already have tools....Requires a lot of GIS analysis."(App. 9, Richmond, R3). The comment was directed at the apparency/times-seen comparison, and reasonably considers advantages relative to additional effort, however, GIS analysis is a standard in forest planning. Times-seen analysis is not required in any current procedure, and would itself be an additional GIS procedure (though more simple to construct than apparency). Times-seen mapping does provide for greater differentiation within a VSU, but, unlike apparency, does not consider viewing angles, only if a land-plane is seen or not, regardless of whether the AVI is high or low.

#### **6.1.4 Stage 4: Integration**

Conversion of apparency maps from raster (pixels) to vectors (polygons), discussed in Sec. 4.4, enabled the linking of the apparency attribute with other databases, such as the VRI forest cover layers and environmental constraint areas. The apparency attribute in the polygons allowed their selection when rendering the visual results of each class in VNS. Polygonization enabled the input of apparency into FPS-Atlas to produce the Nadina automated planning project, and greatly assisted further analysis and planning, which area described next (Sections 6.15 and 6.16).

### **6.1.5 Stage 5: Analysis**

Individual and aggregated quantile class analysis were prepared to determine percent alteration and plan-to-perspective relationships. While the tests were applied within a model with a controlled forest height, stand heights in a typical managed forest will vary greatly, from recently logged, through stages of regeneration, to mature. Actual stand heights from the Vegetation Resources Inventory were used in Stage 6 applications (Nadina IVD, Trial D in the Howe Sound model in Sec. 6.1.6). A direct comparison of P2Ps between a controlled forest and actual forest from the forest inventory was not conducted, but would prove to be informative in future considerations.

The results confirmed the ability and sensitivity of the apparency tool to differentiate the landscape based on higher and lower visual risk, thereby providing a pathway for consideration of apparency in strategic planning (timber supply analysis) and operational design. The findings from the 1) individual and 2) aggregated apparency analyses are discussed separately.

#### **1. Individual Quantile Class Analyses**

In the individual quantile analysis in Sec. 4.5.1, taking into account tree-screening based on VNS perspective visualizations, perspective alteration, if cleared, ranged from 0.05% to 6.1% for the first 5 quantiles in the evenly forested landscape for LCP 117 (Figs. 53-59), falling within Preservation, Retention, and Partial Retention VQO categories. This

suggests that all but the highest apparency (visual risk) category could meet with public acceptance, if harvested (BCMoF 1995; BCMoF 1996a). That quantitative measure alone was not considered sufficient as a measure of visual quality; design and verbal definitions also have to be considered (BCMoF 2001b). Even while Quantile 6 was dominant and out of scale (Maximum Modification VQO), its appearance exhibits cohesion, considerable respect for the lines of force, and avoids intermediate ridgelines. Similar results were achieved from the other four viewpoints (Figs. 60-63).

When considering VQOs in Timber Supply Analysis, the BCMoFR considers a P2P of 2:1 to be broadly applicable in the Province, with adjustments made for average slope raising the P2P to near 5:1 in flat terrain (Table 1). The 2:1 average ratio was exceeded in 5 of the 6 quantiles (ranging from 2.5:1 to 353:1). The P2P results indicate that apparency could provide a potentially less restrictive approach for timber supply considerations while still meeting VQOs in visually sensitive areas. It was recognized that BCMoFR's ratios are generated by actual measures of visual alteration within actual forest stands while the apparency approach (in this instance) only regarded simulated quantile alteration within a controlled forest. However, there is little reason to believe that the terrain and forest models used in the controlled apparency test would be highly inaccurate relative to the size of the area tested. The considerable differences between the BCMoFR's P2Ps and those indicated by the apparency approach would thus appear to be due to the role of horizontal AVI. While factored in with predicted P2P, measurement for each cutblock selected for P2P analysis by the BCMoFR is generally only made from an accessible viewpoint which directly faces the cutblock, approximately level with, or

perpendicular to, the cutblock, thereby eliminating the more peripheral or oblique views. As the apperency approach considers all selected views in a particular model, not just face-on ones, P2P will logically will be higher than have been determined in the BCMoFR studies.

## **2. Aggregated Quantile Class Analyses**

In the aggregated approach (Sec. 4.5.2), quantiles were consecutively added, from lowest risk to highest, and each aggregation rendered in VNS from LCP 117 to demonstrate the sensitivity of each aggregation on percent alteration and P2P (Figs. 64-69; Table 12). Results showed that the first three, lowest visual risk, quantiles, when aggregated, imposed 4.2% alteration in the evenly forested landscape in perspective view (which equates to Partial Retention VQO) while occupying fully 36% of the of the viewpoint specific viewshed area in plan view. The P2P ratio of the aggregation was 8:1, well above the BCMoFR standard (2:1) that is broadly applicable in the Province and applied in timber supply analysis (and greater than the Ministry's maximum adjusted P2P in flat terrain of 5:1 (Table 1). Except for the final 100% denudation (1-6), elements of good landscape design were expressed in all aggregations, with a reasonable response to lines of force, and exhibited shaping and patterning, including along the skylines.

Several comments received from the focus groups were an indicator of the potential utility of the approach. The advantages were recognized by the following focus group participants: "Seems to easily dovetail into other strategic land management resource

layers..." (App. 8, Topic 3, Nanaimo, #305); "Tells licencees where they can clearcut without affecting VQO..." (App. 8, Topic 1, Richmond, #103); "Better at informing TSR." (App. 8, Topic 1, UBC, #301); "look into more automation..." (App. 9, Richmond, R8); and a "Better way to evaluate timber supply impacts..." (App. 9, Nanaimo, N19). Cautionary comments were specific about its use in TSR: "...current procedures are using some pretty gross assumptions which in practicality would negate the benefit of fine-tuning" App 9, Nanaimo, N33).

### **6.1.6 Stage 6: Tactical and Operational Planning**

Apparency mapping was used in several tactical and operational planning trials: A) guiding integrated visual design, B) input for automated harvest planning, C) timber harvest design, and D) stratification of the forest cover database to assist detailed operational planning.

#### **A. Nadina Integrated Visual Design Plan**

As presented in Sec. 4.6.1, a trial apparency application was conducted in a comprehensive, integrated visual design plan for long-term timber harvest planning. The trial provided evidence of its utility within a planning hierarchy. Scheduling of the higher risk units required "expert" intervention during the iterative visualization process to ensure VQOs were met at each phase. Several focus group comments were supportive of this type of apparency application: "Better total chance planning, look ahead." (App. 8,

Topic 1 - Advantages, Nanaimo, #303); "...I see cumulative apparency as one factor alone that can lead you in the direction of space planning and sequence" (App. 9, UBC). (App. 8, Topic 3 - Uses, Nanaimo, #301). One commenter enquired: "How can this be converted to the visual system that already exists?" (App. 9, UBC, U4). The current "system" of IVD relies on expert knowledge about harvest patterns and scheduling over the long-term. Apparency can be easily integrated into IVD to assist the experts' decision-making and possibly to reduce the reliance on those experts.

## **B) Atlas-Nadina Automated Design Trial**

Apparency results derived in the Nadina project were next applied to the Atlas-Nadina Automated Visual Design project in Sec. 4.6.2. The trial was successful in showing the utility of integrating apparency with another planning model (Atlas-Forest Planning Studio). The resulting plan extended over 12 20-year periods totalling 240 years.

The harvest patterns appeared to exhibit elements of good landscape design, such as following lines of force, and cohesion. The trial also proved the efficacy and utility of an automated planning system (Atlas), when calibrated with apparency, to produce acceptable results, from a visual landscape design point of view, over the short and long term. The automated approach could reduce the reliance on forest design professionals, and/or improve the efficiency and effectiveness of harvest planning in the hands of forest operations personnel less trained or less experienced in visual landscape design.

### **C) Harvest Block Design Using Apparency as the Guide**

As presented in Sec. 4.6.3, the third application utilized the apparency ratings of the Howe Sound project to guide the location of potential cutblocks. Unlike the quantile-by-quantile trials discussed in Sec. 6.1.5, which were never intended to lead to a harvest plan, Trial C began to approach actual harvest planning by groupings of apparency values in the higher, moderate and lower range of visual risk. The trial was able to prove that the apparency groupings could be quickly and easily selected in GIS to define the cutblocks, and rendered in VNS from the viewpoints. The trial also measured perspective area distinctions related to average apparency in each cutblock. Only rudimentary visual landscape design considerations were applied when shaping the cutblocks (e.g. topography; lines of force). The trial was made with the uniform forest cover applied earlier in the Howe Sound apparency project. Cutblocks placed in the higher visual risk areas as indicated by apparency had greater visual impact (more percent alteration per hectare of land area) compared to the lower risk areas. A focus group commenter was not convinced from the presentation that this approach was an improvement, stating: "Needs to be proven that results generated from GEOptics outperforms conventional existing methods" (App. 8, Topic 3 - Uses, Richmond, #105). The presentation addressed this aspect only briefly, perhaps causing another participant to say: "Would like to see the map products - hands-on" (App. 9, UBC, U6). The ability to differentiate areas of risk was noted in the focus groups for: "Highlighting areas that require greater focus or design planning, i.e. those with higher apparency." (App. 8, Topic 1 - Advantages, Richmond, #104); and for: "Focusing design effort on more apparent and therefore sensitive slopes."

(App. 8, Topic 1 - Advantages, Nanaimo, #305). The trial involved only very simple layouts; more trials and demonstrations are likely required to further prove the utility of apparency in timber harvesting design.

#### **D) Harvest Block Design using a Combination of Apparency and Other Grid Cell Attributes**

Trial D, presented in Sec. 4.6.4, showed the efficiency and utility of apparency in deriving a visually acceptable and economically feasible harvest plan at the operational scale. The trial demonstrated the ability to use apparency to help find all economically viable forest (defined for purposes of this test as trees 25m or greater in height as provided in the VRI, as one economic indicator only) that would have lower visual risk (moderately low visual risk or less). Visual observation of the resulting images by the researcher determined that, without any other guidance, the harvesting of all forest in that selection (19% of the visually sensitive landbase) achieved either "well-designed" Modification VQO or Partial Retention from each LCP. Further operational considerations, such as steep slopes, unstable terrain, riparian areas, harvesting method, and roading restrictions, could necessarily reduce the scale of the plan and further reduce visual impacts. The potential economic advantages of using apparency mapping to hone-in on lower visual risk areas was mentioned in the focus groups as a "... a significant leap in terms of saving money because you can take the cutblocks in areas without the greatest effect than done before." (App. 9, UBC, U15). Caution was raised in the focus groups about "Producing too refined results in potential harvesting / design options that would be

impractical operationally." (App. 8, Topic 2 - Advantages, Richmond, #102). The approach is not intended to be used in isolation, but to assist better forest planning in conjunction with other resource development requirements.

## **6.2 Focus Group Results Discussion**

The focus group process, presented in Chapter 5, provided the opportunity to hear from forest planning and/or visual resource management practitioners, educators, researchers, managers, and advanced students in forestry/planning about their perceptions of the GEOptics apparency approach. The questionnaire responses and discussions shed light on how apparency might begin to contribute to EVA systems, such as the BCMoFR VLM system, and forest planning processes, from a user's standpoint. The questions were shown in Table 16.

The responses to the questions were assessed for their implications (Sec. 6.2.1).

Discussion responses were very informative (Sec. 6.2.2). Both datasets showed some clear variations between respondents and much constructive criticism was offered.

### **6.2.1 Questionnaire**

Questionnaire responses were mainly in agreement with the 19 questions addressing the presentation, GEOptics performance and VLM. Positive responses were received 64% of the time, neutral responses were lower at 27%, and negative responses only 9% (Fig. 88).

While there were large variations in individual responses, the summed response to each question was positive (Fig. 89), as were the averages (Fig. 90), modes (Fig. 93) and medians (Fig. 94). The response to each question was assessed, in relation to the question's topic, and to the category it was placed in: 1) Presentation; 2) Mapping; 3) Applications). As well, inferences were drawn as to 4) distinctions amongst the focus groups.

### **1) Presentation**

Overall, as shown in the average responses Fig. 90 for each of the 6 Presentation questions listed in Table 16, the presentation was considered to be adequate, and provided sufficient exposure to the map products, but several explanations could have been somewhat improved. Based on lower responses to Q3 and Q4 (VLM benefits and limitations clearly outlined), additional information could have been provided to respondents to address these concerns. However, as most participants were already familiar with the existing VLM system, a purposeful focus was placed on the new GEOptics tool in the presentation due to time constraints. Q6 (GEOptics limitations clearly outlined) also received lower ratings, indicates more time and detail is needed for that topic. In an extended version of the presentation, more time would need to be allocated to describe the comparative benefits and limitations of both GEOptics and VLM.

## **2) Mapping**

Strong overall responses for 2 of the 4 Mapping section questions (Fig. 90) showed that respondents regarded GEOptics to have a fairly high utility for integration with conventional forestry planning and decision-making (Q10), and GIS analysis (Q9). This perception of high utility requires was qualified by a somewhat lower overall response regarding the ease of understanding (Q7) the procedure and still lower, but positive, response about its ease of application (Q8). Clearly, the results indicate considerable recognition of the potential of the GEOptics apparency mapping approach, but the process needs to be made more streamlined and easier to use. Possible adjustments, such as through the reduction of the number of steps, are discussed as part of the research, policy, and implementation recommendations (Sec. 6.4).

## **3) Applications**

The most appreciated applications for cumulative landscape apparency were for locating areas of visual risk (Q14 - the highest response rating of all questions), for IVD (Q17), and for enhancing conventional VLM (Q12). These results are even more supportive when considered together with the strongly positive results to several key questions in the Mapping section regarding its utility for integration with conventional forestry planning, mapping, and analysis, particularly since participants found conventional VLM to be somewhat inadequate or inaccurate for informing forest operations planning and timber supply calculations (Q11).

More modest, but positive, results were received about use of GEOptics in operational design (Q15), public involvement (Q18), economics (Q16), and flexibility for managing visually constrained areas (Q19). More design applications are clearly needed in order to demonstrate how the advance knowledge about visual risk differences in the landscape, in conjunction with knowledge of other key constraints and opportunities, can be used to guide timber harvesting location, scale and pattern. The proof of enhanced flexibility will be determined when plans that have been prepared using apparenacy as a guide show where the harvesting effort can be increased (or should be reduced), and where care and attention to visual design criteria are critical (or not so). With that evidence in hand, it would be easier to communicate the benefits, and help generate public acceptance.

The low overall response to Q13 about the advantages of GEOptics apparenacy outweighing the disadvantages, clearly indicated the need to more fully assess both in further implementation. The written and verbal comments suggested that the advantages pertained to the specificity of GEOptics for identifying visual risk areas, while disadvantages were also related to that very same specificity, requiring too much complexity and providing unnecessary (or unwanted) detail (App. 8, Topics 1 and 2; consolidations for Topics 1 and 2, Sec.5.4.2). Responses to Topic 5 in the Discussions (App. 8; consolidation for Topic 5 in Sec. 5.4.2), about how to make the GEOptics tool more useful further emphasized the need for simplification.

The presentation itself may have contributed to the perceived complexity, but the GEOptics mapping was not intended as a method that any forester would necessarily do personally. Question 13 was imprecise as to whether it referred to use of GEOptics products prepared by others as per standard practice, or to the actual preparation of those products. It should be noted that no explicit mention was made in the sessions as to who was expected to do the mapping preparation, versus applying the mapping products, amongst participants. Results might be expected to be influenced by individual skills and responsibilities. GEOptics is a more sophisticated approach, as is timber supply modelling, demanding practical skills and expertise to conduct. As with timber supply modelling, however, other people can use the results prepared by experts, adding new methods to their "toolbox".

The presentations attempted to avoid bias (i.e., not an "over-sell"). The lower, but positive, summed responses may indicate a possible skepticism in the participants, and suggest a possible perception of bias in the presentation (i.e., not receiving the full story). This is not surprising, given the visual specialists' familiarity with the existing system and the author's interest in developing a more effective supplementary tool. However, there may also be an opposite, positive response bias from participants who feel inclined to reward the researcher for his efforts. Further implementation and testing through hands-on involvement by multiple users and/or independent testing of results, through the depth of technical comments, suggestions, and criticisms received from participants, would resolve this issue. Time limitations, presentation materials, and techniques may also have influenced the ratings.

#### **4) Group Distinctions**

While group response averages were not statistically different (Table 18), there was a progressive trend towards improving average positive responses, commencing with the lowest (Richmond), then UBC, and finally Nanaimo (Table 16; Figs. 91, 97). Some inferences might be made as to group composition distinctions. The Richmond session was comprised of mainly the provincial and regional visual landscape specialists – a group which might be expected to have some specific attitudes and perspectives on new tools such as GEOptics. On one hand, there may be an increased interest and enthusiasm for tools that acknowledge their role and help them in tough decision-making or training of others; on the other hand, they may also have a strong interest in maintaining the integrity of the current system in which they are heavily invested, or to avoid further burdening an already high work load. The VRM experts may also be expected to be more discerning and perhaps critical of any perceived weakness in a new system, given their depth of experience and educational background. As such, their criticism and suggestions are very valuable as a rigorous testing ground for new approaches such as GEOptics. The other practitioners in the Richmond group, and the other two groups (UBC and Nanaimo), perhaps might be expected to be more supportive of new expert approaches or more willing to examine them, if they perceived a better outcome or easier solution (without having to do the work themselves).

The differences could also have been indicative of presentation quality and communication improvement from the initial session (Richmond), which was brought

forward at short notice on learning of a unique opportunity to conduct the session with all BCMoFR VRM specialist practitioners from across the province. Core materials and the general script remained the same in all sessions. However, additional text slides and images were added to the presentation in response to key suggestions from each group. While those improvements may have compromised the comparability between groups, presentation effectiveness of a fairly complex modelling process and exploration of potential user's needs were key objectives of the process. The questionnaire remained unchanged for all focus groups.

## **6.2.2 Written and Verbal Discussions**

Written and verbal comments provided an abundance of insight as to personal opinions about the utility of GEOptics appency, and expanded upon the questionnaire responses. The written responses to the discussion questions (summarized in Sec. 5.4.2), and the less structured, and lively open discussions (summarized in Sec. 5.4.3) which followed, provided constructive and useful suggestions for the application of GEOptics to improve its utility and ease of implementation. Many written and verbal comments were received which were supportive of the GEOptics approach. However, some potential applications were questioned such the contribution to TSR (a blunt tool), its complexity, and advantages over conventional practices. In some cases, both supportive and critical comments were received on the same topic (TSR; operational design) which was not unexpected given the range of experience of respondents and their varying levels of involvement in VRM.

### 6.3 Conclusions

The concept of landscape apparency represents a new way of looking at the visual landscape, and enables a new tool to spatialize, analyze, and visualize visual risk. Automated apparency mapping reveals hitherto unseen patterns of relative visual risk in the landscape, quantifying and communicating what was previously held only in the "mind's eye" of skilled forest designers. In this study, the scope and framework for the GEOptics landscape apparency model has been defined. The research design enabled the development of procedures and testing mechanisms for its validation. The limitations of the system were tested and made known. The GEOptics apparency model was determined to potentially offer an improved understanding of the landscape for the landscape specialist and field-level resource management professional. It offers a method to refine visual landscape inventory to address known shortcomings of the current system, whenever refinements are to be made.

The system is expected to be useable by land managers without a strong background in visual resource management, though with some guidance and support from widely available VRM specialists and consultants in that field. Apparency can provide a new, reliable, GIS-based inventory measure that would help guide resource planning and design, and enhance current VRM procedures. While clearly not focusing on estimates of scenic quality or scenic beauty, its utilization as a strategic tool could enhance the effective management of the scenic resource. Given its potential for highly detailed stratification of the landscape into greater and lesser visual zones in advance of land-use activity, GEOptics apparency mapping could reduce the reliance on restrictive VQOs

being applied singularly across large land units (visual sensitivity units) while protecting or enhancing desired levels of scenic quality. While timber supply factors are broadly derived, the knowledge gained in testing apparency for its relation to plan-to-perspective analysis, when derived for specific landbase areas, can potentially provide an indicator for refining resource supply questions such as in Timber Supply Review in British Columbia, in relation to visual resources. In some areas, this may mean providing greater flexibility for resource supply/management, while maintaining or even enhancing visual quality.

Apparency was shown to be an effective measure for learning more about the landscape – by defining more closely where the challenging (higher risk) areas are located vs. the safer (lower risk) areas for management activity. It is not an issue of "hiding" forestry from view so much as providing surer, better ways to design for "fit" in landscapes which must meet multiple demands. This knowledge can assist development planning and long term integrated visual design and total chance planning. As apparency can be accommodated by automated planning systems such as Atlas/Forest Planning Studio, it can assist scheduling and shows it is capable of helping automate visual landscape design, thereby reducing the current reliance on experts and the currently high level of failure to meet visual quality objectives by current planning methods. GEOptics is expected to be applicable to a wide array of resource planning mechanisms and databases, locally and internationally.

The quantile approach provided the opportunity to observe how landscape apparency reveals meaningful inherent patterns of and on the land, providing a more thorough

understanding of the landscape, made possible by connecting viewing angle to the terrain through illumination intensity. It makes visual vulnerability more clearly understood and useable. The Chapter 4 demonstrations and tests of Stages 1-5 of GEOptics apparency, with landscape visualizations of tree cover, were primarily to determine and demonstrate the visual differences amongst the quantile classes (low versus high visual risk) and their aggregations (increasing risk) relative to the planimetric and perspective areas of each grouping. These initial stages of GEOptics were never intended to provide a suggested logging plan, but may have been interpreted by some focus group participant as their purpose. Perhaps the emphasis on the early stages caused some of the mentioned confusion and criticism of the process. The applications presented in Stage 6 showed how apparency could be considered when developing fully vetted harvesting plans, together with forest characteristics, and environmental and operational considerations. The presentation likely tried to accomplish too much - both for the research and for the practical applications. A practice-oriented training presentation would concentrate hands-on on the operational design and implementation procedures only, and would forego all of the research tests and P2P calculations of the different quantile classes required in this dissertation.

While the apparency tests in the Howe Sound model (Stages 3-5) only applied a constant forest cover to derive P2P ratios, it was shown that actual forest cover data was easily considered in the model (Stage 6). An operational procedure would, by necessity, use actual forest data to determine P2Ps, from a single VSU to a landscape inventory corridor.

From discussions with some participants at the focus groups, it was suggested that higher P2P ratios are not considered for use in timber supply calculations if on-the-ground visual design results of current forest practices do not support an increase. Apparency can provide guidance to help improve visual design, requiring less training, in a potentially automated approach. As apparency is ready for multiple-scale applications within a planning hierarchy, it can be applied to guide and improve on-the-ground practices as well as higher level plans, potentially at the same time. While it is acknowledged that the timber supply factors are very broadly derived and applied, an apparency-generated P2P analysis, within a particular land-base or management unit, could at least begin to provide some evidence of appropriate benefit of apparency-derived P2P relationships in relation to visual resources. In some areas, this may mean providing greater flexibility for resource supply/management while maintaining or even enhancing visual quality.

Based on lower focus group responses regarding the adequacy of the presentations for clearly outlining VRM benefits and limitations (questions 3 and 4) and GEOptics limitations (question 6), additional information could have been provided to respondents to address those concerns. However, most participants were familiar with the existing VLM system in BC, and explicit comparison between results from standard procedures and GEOptics were presented. Some limitations of GEOptics, such as the requirement for software purchase and training, were also identified in the presentation. Relatively few major problems with the concept or procedure were encountered. It should be borne in mind that GEOptics apparency mapping was not presented as a substitute for VLM procedures, but as an enhancement. It is possible that the presentation content led some to

some favourable bias in responses, though the occurrence of criticisms and depth of discussion suggests a healthy skepticism from many participants.

#### **6.4 Research, Policy, and Implementation Recommendations**

The apparency tool requires some further adjustment to make it easier to understand and use, and to provide clearer policy and guidance for its use. Firstly, it should be made into a three-level approach: 1) Apparency Inventory, 2) Apparency Planning, and 3) Apparency Design. Apparency Inventory (Level 1) would cover all of the apparency model building and classification, Apparency Planning (Level 2) would incorporate the strategic applications such as P2P and refinement of numerical indices for VQOs, and as a moderating influence in timber supply determination, and Apparency Design (Level 3) would include tactical and operational planning from IVD, Atlas (automated) IVD, timber harvesting plans.

More research is required to understand the implications of viewpoint sensitivity.

Cumulative apparency was found to be greatly responsive to viewpoint selection and may be made even more so by viewpoint weighting for duration and importance of each viewpoint. P2P derivation must be necessarily examined using actual forest cover data to provide an accurate response to current growth characteristics. Estimates of roadside tree screening should be incorporated in the model. These numbers may begin to provide guidance when weighting VQOs for timber supply purposes.

More economic cost/benefits must be determined to confirm the viability and advantages of the apparency approach. Timber harvest design plans must be produced, implemented, and audited to clearly determine the design advantages contributed by incorporating apparency to the forest management community and to the public. Applications by landscape specialists and operational planners are encouraged to build further understanding of the pros and cons of the apparency tool.

Following completion of the above test models which are required to generate the needed answers and information, I propose that the GEOptics concept and tool be applied at the three levels as priority recommendations for consideration in broad EVA systems in BC and internationally:

### **Level 1: Apparency Inventory**

Level 1 would apply to major EVAs such as the VRM systems operated by the BCMoFR, USDA Forest Service, USDI BLM. The measure of visual vulnerability/visual absorption capability addressed in each system presently can be greatly refined by determining detailed landscape apparency (visual risk). The importance of this measure, particularly in conjunction with angle of visual incidence, was recognized very early in the development of VRM (Litton, Iverson, Bergen, etc. referenced in Chapter 2). The inventory level is basic to each planning (Level 2) and design (Level 3) application, and would be scaled to fit the application from broad management units or landscape corridors to individual landscape design units. Planning and design can be carried out

independently, or can work seamlessly together, using the same apparency data from the inventory. In BC, the approach could be examined and pilot-tested as a potential VLI (automated) update mechanism.

## **Level 2: Apparency Planning**

Level 2 would apply to the major EVAs. The potential level of detail contributed by apparency may exceed the capacity and scope of some current systems, particularly when they have coarsely-determined constraints on timber supply (such as the BCMoFR VLM). The tendency then might be to avoid collecting unwanted detail, and continue along with expert assessment leading from inventory through to design. However, apparency can provide a useful determination of what the landscape might be able to accept in terms of visual impact, assisting the further calculation and fine-tuning of planimetric and perspective visual constraints (VQOs), and possibly relieving some of the constraints, and providing a potential economic boost from increased harvesting intensity. Several applications across distinctive/different landscapes in different regions and jurisdictions will be necessary to test the utility of apparency at this scale. Systems which do not have as rigorous a numerical approach for setting visual constraints as the BCMoFR's VLM (such as the Scenery Management System of the US Forest Service and the VRM system of the BLM) may find it easier to adapt the new apparency approach.

### **Level 3: Apparency Design**

The operational planning and design component of EVA systems takes the inventory data and visual constraint objectives and applies them to specific forest operations (short and long term). Broadly-defined visual vulnerability and sensitivity from landscape inventories may be incapable of offering much guidance to design. Landscape apparency information, whether gathered during a broader inventory process or developed for a specific planning unit in Level 1, would provide guidance directly for detailed design.

Several fully-resolved integrated visual designs should be conducted along separate landscape corridors in various regions and jurisdictions, having direct input of landscape apparency. The UK Forestry Commission already has a fine level of detail in their visual management planning approach at the landscape (landform) level which could accommodate, and benefit from, the apparency approach. Detailed timber harvesting operational plans should be prepared within each of the IVDs, in full knowledge of bio-physical, operational, and economic constraints and opportunities, and apparency.

In conclusion, the implementation of GEOptics Landscape Apparency, as suggested, could begin to provide mapping and numerical indices of cumulative visual risk in order to enhance the protection and management of visual resources across inventory, planning, and design levels, adjusted in coverage to fit the scale of application, in a consistent, fully integrated, and effective manner.

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# Appendices

## Appendix 1 Focus Group Questionnaire and Discussion Topics

### Part 1

Please indicate your level of experience with Visual Landscape Management up until today, by checking the most appropriate statement below:

Very experienced	Somewhat experienced	Minor experience	No experience

Background (check one or more as appropriate):

Practitioner	Manager	Educator	Student
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Based on the demonstration session with conventional visual resource mapping and GEOptics landscape apparency products, please answer the following questions by circling the number in the column that best describes your opinion. If you have no opinion on a particular question or don't know, please leave the response line blank & mark beside the question with an X.

You will have the opportunity to discuss the GEOptics process following completion of the questionnaire. A list of suggested discussion topics is provided at the end of the questionnaire with space for optional comments. Feel free to jot down your thoughts before and during the discussion session: both positive and negative comments are welcome, as we need your objective feedback. Verbal comments will be tape-recorded for later transcription (without attribution to any individual by name).

### Part 2

#### A. Effectiveness of the Presentation

1. I had adequate time to view the imagery shown.

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

2. The cumulative landscape apparency mapping (GEOptics) method was clearly explained.

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**3. The benefits of conventional Visual Landscape Management (VLM) mapping were clearly outlined.**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**4. The limitations of conventional Visual Landscape Management (VLM) mapping were clearly outlined**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**5. The possible benefits of the GEOptics landscape apparency method were clearly outlined**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**6. The possible limitations of the GEOptics landscape apparency method were clearly outlined**

-2	-1	0	+1	+2
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**B. Effectiveness of the Landscape Apparency Mapping**

**7. The GEOptics output appeared easy to understand, in general**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**8. The GEOptics method appeared easy to apply, in general**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**9. The GEOptics output appeared to be compatible with conventional GIS resource analysis**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**10. The GEOptics output appeared capable of providing the degree of detail and accuracy necessary for consideration in resource planning and decision-making**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**C. Potential Applications, Benefits or Disadvantages of Methods**

**11. Overall, the conventional VLM mapping method provides adequate tools and products to accurately inform forest operations planning and timber supply calculations**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**12. The GEOptics appency mapping method appears to be beneficial in enhancing visual landscape management (VLM)**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**13. The advantages of the GEOptics appency mapping method outweigh its disadvantages for forest management in general.**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**14. The GEOptics method appears to be helpful for locating areas of greater and lesser visual risk within seen areas**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**15. The GEOptics appency mapping appears to be helpful when designing operations to meet the VQO in visually sensitive areas**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**16. The GEOptics method appears to be helpful in contributing to economic benefits derived from visually constrained areas**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**17. GEOptics output could be well suited for total chance integrated visual design over the long-term**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**18. The GEOptics products could be beneficial to a public involvement process on forest planning**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**19. The GEOptics method could provide greater flexibility for managing visually constrained areas relative to conventional VLM**

-2	-1	0	+1	+2
strongly disagree	somewhat disagree	neutral	somewhat agree	strongly agree

**Part 3 Focus Group Discussion Topics  
(written comments and group discussion)**

- 1. What do you see as possible advantages of the GEOptics landscape apparency mapping method, relative to conventional VLM methods?**
- 2. What do you see as possible disadvantages of the GEOptics landscape apparency mapping method, relative to conventional VLM methods?**
- 3. How could GEOptics cumulative landscape apparency (visual risk) mapping be used by resource managers to enhance conventional visual landscape planning and design?**
- 4. How could GEOptics be used by resource managers as a component of Timber Supply Planning?**
- 5. How might the GEOptics method be improved or made more useful?**
- 6. Any other issue or concerns raised in the session?**

## Appendix 2 Focus Group Invitation Letter

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### Invitation to participate in an expert panel for testing GEOptics: a new visual resource modelling method to enhance forest planning

The Faculty of Forestry, University of British Columbia, is conducting research into a GIS-based technique, termed GEOptics, which may improve the mapping of visual constraints on timber supply and cutblock design. The GEOptics process provides a new mapping tool for predicting **landscape apparency** or "**visual risk**": the relative prominence of potential cutblock locations as seen from multiple viewpoints. This research is being conducted as part of Kenneth Fairhurst's Ph.D. dissertation.

Within areas shown to be visible in viewshed mapping, the GEOptics process maps areas at greater risk of visual impact from harvesting or management operations (where visual resource protection should be emphasized), and areas with lower risk of visual impact (where operations might be intensified). The GEOptics tool uses a modified 3D visualization technique to analyze angle of visual incidence from entire viewing corridors. The research will determine if the GEOptics approach helps predict whether Visual Quality Objectives will be met (prior to detailed design), and helps optimize timber supply and visual quality, relative to existing mapping methods.

Dr. Stephen Sheppard, Ph.D., Department of Forest Resources Management, UBC, is the Supervisor for the GEOptics research. Co-investigators are Dr. Michael Meitner, Dr. John Nelson, and Kenneth Fairhurst, Ph.D. Candidate, at the Department of Forest Resources Management, UBC.

We are seeking participants for two types of "expert panels": Group 1 will include visual resource management (VRM) practitioners who routinely or frequently apply VRM procedures and have greater than 5 years experience in VRM; Group 2 will include operational and planning foresters and other natural resource managers who must implement VRM initiatives, at least occasionally, as a component of their broader resource management activities. Panel members will participate in a 2-3 hour demonstration/practice session of the GEOptics technique and conventional methods, during which you will be asked to complete a questionnaire evaluating the technique, followed by audio-recorded group discussion.

**We would like to invite you and/or your qualified designate(s) to participate in a single session** at a convenient location in the next several weeks. Specific locations and dates will be set after receiving initial responses to this invitation. We also invite you to suggest additional potential candidates who might benefit from this opportunity. Benefits to participants would include the opportunity to learn about, comment on, and perhaps influence the development of new modelling techniques that may help forest managers and visual resource experts achieve their management objectives. Results of the study will be provided to all participants.

If you are willing to participate in the research, or if you have any questions on this study, **please contact Dr. Stephen Sheppard or Kenneth Fairhurst**. If you have any questions about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at (604) 822-8598.

You will be asked to sign a consent form at the session. Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time, without any repercussions. No remuneration is available for study participants; snacks and refreshments will be provided during the session. Your identity on the written questionnaire will be kept strictly confidential and you will not be identified in any reports in the completed study. Survey forms will be identified only by a coded number, and will be kept in a locked filing cabinet, along with the audio tapes. Data on computer hard disk will be password protected to prevent unauthorized access. Only limited confidentiality can be offered in group discussions, as investigators cannot control what other participants do with the information discussed; however, all participants will be encouraged to refrain from disclosing the contents of the discussion outside of the focus group.

Thank you for your consideration in participating in this research. Please respond by email or phone within 7 days with regards to your interest and availability, and/or further suggestions for potential candidates. We will follow-up with a phone call or email with final arrangements.

Yours very truly,



Kenneth B. Fairhurst, Ph. D. Candidate

Stephen R.J. Sheppard, Ph.D.

## **Appendix 3 Focus Group Consent Form**

Department of Forest Resources Management  
Forest Sciences Centre  
2<sup>nd</sup> Floor, 2424 Main Mall  
Vancouver, B.C. Canada V6T 1Z4

### **Consent Form**

#### **Expert panels testing of GEOptics: a dynamic visual resource indicator for multi-functional landscape planning**

##### **Principal Investigator:**

Dr. John D. Nelson, Ph.D., Department of Forest Resources Management, Faculty of Forestry, University of British Columbia.

##### **Co-Investigators:**

Dr. Stephen R.J. Sheppard, Ph.D., Department of Forest Resources Management, Faculty of Forestry and Faculty of Applied Science, University of British Columbia.

Dr. Michael Meitner, Ph.D., Department of Forest Resources Management, Faculty of Forestry, University of British Columbia.

Kenneth B. Fairhurst, Ph.D. Candidate, Department of Forest Resources Management, Faculty of Forestry, University of British Columbia.

##### **Purpose:**

This research is being conducted as part of K.B. Fairhurst's Ph.D. dissertation (thesis). The research, called GEOptics, examines the cumulative illumination intensity of digital 3-dimensional terrain from along viewing corridors. It is an analogue for line-of-sight angle of visual incidence with landscape surfaces.

The approach is intended to be used by resource managers to improve their estimates about what fits in the landscape, and their forecasts of acceptability in the minds of viewers along entire travel corridors and across entire planning units. The research will determine if GEOptics apparency modelling can improve the validity and usefulness of mapping viewer-landscape interactions, relative to conventional landscape inventory techniques such as viewsheds, times-seen mapping, and topographic slope studies. The research will further determine how the GEOptics approach can potentially be applied as a component of operational planning, integrated visual design, total resource planning, and timber supply analysis.

The utility of GEOptics for resource planning and management is being tested with two types of "expert panels". Panels will consist of two groups of up to 15 resource practitioners in each group. The first group will be visual resource management (VRM) practitioners who routinely develop VRM procedures or are frequently responsible for applying (VRM) procedures and have greater than 5 years experience in VRM. The second group will consist of operational forestry and other natural resource managers who must implement VRM initiatives at least occasionally as a component of their broader resource management activities, such as design of harvesting layouts.

### **Study Procedures:**

As a panel member and subject in this study, you will be asked to participate in a 45 minute to 1 hour demonstration to show how the GEOptics model works. This includes how the quantification of GEOptics can be used to differentiate areas of greater and lesser visual apparency (greater or lesser risk), and how its output can be entered in conventional geographic information system (GIS) mapping for multiple constraints and opportunities analyses, and potential use as a component of operational planning, integrated visual design, total resource planning, and timber supply analysis.

Following the demonstration, each participant will be asked to complete a written questionnaire and written comments, taking up to 15 minutes, followed by a 30 minute "focus group" discussion about the GEOptics system's strengths and weaknesses in practice, during which verbal questions from the participants will be answered. The discussion will be recorded on audio tape with participants' permission.

### **Confidentiality**

Your identity outside the panel will be kept strictly confidential. Survey forms will be identified only by a coded number. Survey forms and audio tapes will be kept in a locked filing cabinet. You will not be identified in any reports in the completed study. Data on computer hard disk will be password protected to prevent unauthorized access. Only limited confidentiality can be offered in group discussions, as investigators cannot control what other participants do with the information discussed. All participants are encouraged to refrain from disclosing the contents of the discussion outside of the focus group.

### **Remuneration/Compensation:**

No remuneration is available for study participants. Refreshments will be provided during the session, and results of the study will be provided to all participants.

### **Contact for Information about the Study:**

If you have any questions or desire further information with respect to this study, you may contact Dr. Stephen Sheppard or Kenneth Fairhurst.

**Contact for Concerns about the Rights of Research Subjects:**

If you have any questions about your treatment or rights as a research subject, you may contact the Research Subject Information Line in the UBC Office of Research Services at (604) 822-8598.

Consent:

Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time, without any repercussions. Your signature on the next page indicates that you have received a copy of this consent form for your own records, and indicates that you consent to participate in this study.

(Please remove this sheet from the consent form package, complete, and hand in.)

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**Consent Form**

**Expert panels testing of GEOptics: a dynamic visual resource indicator for multi-functional landscape planning**

Your participation in this study is entirely voluntary and you may refuse to participate or withdraw from the study at any time, without any repercussions.

Your signature below indicates that you have received a copy of this consent form for your own records, and indicates that you consent to participate in this study.

---

Subject's Signature

Date

---

Printed Name of Subject

---

Company or Agency / Position

---

Mailing Address

---

Contact e-mail address to receive study results

## Appendix 4 Focus Group Introduction

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### Background Information on GEOptics: modelling visual risk for multi-functional forest landscape planning



*Howe Sound West Side Landscape and the Former Woodfibre Pulp Mill. Lloyd Davies, 2006.*

Research is being conducted by Ken Fairhurst for his Ph. D. dissertation at the Faculty of Forestry, University of British Columbia. The research is aimed at addressing planning and operational challenges confronting the forest industry in visually sensitive areas throughout the province.

In British Columbia, visual landscape inventory is used to map the cumulative viewing experience when deriving visually sensitive units (VSUs). Each VSU is assigned a visual quality objective (VQO) through a subsequent analysis procedure. The VQOs ultimately are applied to influence timber supply and operational planning. Quite frequently, operational planning in visually constrained areas with restrictive VQOs fails to meet the allotted timber supply. Typically, operational planning derives a wish-list of potential cutblocks in the first pass. The proposed alterations are simulated from a few selected viewpoints using 3-dimensional (3-D) visualization (such as Visual Nature Studio) to determine the potential visual impact. Regardless of the skill levels of operational design personnel, managing the visual landscape remains a key challenge, as the acceptability to the viewer remains unknown until the often final act of 3-D visualization, one viewpoint at a time (an inefficient process).

The viewing public is mobile, and sees the landscape as a cumulative viewing experience. A method to harness that cumulative viewing experience has been lacking beyond the broad scale approach of the VLI. Improved modelling of the relative level of visibility should provide a more detailed understanding of the landscape that may lead to improvements in cutblock location and design, reduced visual impacts, and an increased rate of harvest from visually constrained areas.

GEOptics landscape apparency modelling, or GEOptics for short, maps the levels of visual vulnerability (risk) in the landscape, for an array of viewpoints. Apparency is influenced by the combined horizontal and vertical orientation of each land plane in the landscape as seen from each viewpoint, called the angle of visual incidence. The following graphic is a map of apparency, classified from 0 through 10.

Ken Fairhurst  
Ph. D. Candidate

## **Appendix 5 Focus Group Procedures and Script Outline – Focus Group #1**

The following procedures and script outline was presented verbally at the commencement of the first focus group. The outline was embedded into the presentation PDF for the two subsequent focus groups.

### **GEOptics Apparency**

- A new visual resource modelling method to enhance forest planning

#### **1. Research Protocols**

Consent Form – keep, tear off signed form and hand-in,  
provide email address for follow-up results.

Timing – 30 minutes – study process; 10 minutes Questionnaire

30 min. discussion

Conclusions

#### **2. Introduction**

GEOptics research has been under development since 2004

Initial project developed using Stella lake landscapes, Vancouver Island

Used commercially in Nadina Lake Integrated Visual Design Plan 2006

Presented at 5 international conferences, conferring with experts:

#### **3. Current situation:**

VRM has accomplished recognition and role in resource management and planning.

Positives:

Multiple viewpoints used in VLI – cumulative visibility

Some use of viewshed mapping, times-seen mapping, slope maps

Design training by MOFR

Conventional VRM conducts VLI, determining VSC, VAC, which leads to VQOs.

Negatives:

Criticism that VQOs can lead to reduced timber supply and/or operational constraints.

Mapping units (VSUs) are large, inability to determine what's inside.

Operational design hit and miss, somewhat after-the-fact testing (VIA, visualization)

Expert design skills required

Frequent compliance and enforcement issues

Multiple viewpoint effect not controlled – changing Angle of visual incidence slope not necessarily as seen (not the lay of the land -AVI)

#### **4. Research Questions**

Can we achieve better design by use of a more refined planning and design tool?

Can this have an influence on harvest practices?

Can we obtain more harvest volumes for a degree of impact; less impact for a given harvest volume?

Can a finer resolution of AVI lead to a finer control of visual influences on timber supply?

Can we reduce dependency on experts?

Can we help avoid C&E issues?

Possible solutions: a new tool to quantify AVI – apparency mapping

**5. How to do it? How does it work? Stages (Quick notes 1-4); Image PDF.**

**6. Questions to focus group and the continuing research:**

Does GEOptics provide a more precise and useful analysis?

Can it help practitioners do a better job?

**7. Breather – questions and clarifications (detailed discussion to follow questionnaire)**

**8. How can it be applied (Quick notes 5-6; Image PDF).**

**9. Two-part focus group feedback – an important part of GEOptics development**

**9a. Questionnaire**

**9b. Discussion**

**10. Conclusion and thank you for participating in the research.**

## Appendix 6 List of Focus Group Participants, by Location

Participant # <sup>51</sup>	Richmond February 17, 2009		
1	BC Ministry of Forests and Range	District Stewardship	Practitioner
2	BC Ministry of Forests and Range	Regional Landscape Forester	Specialist
3	BC Ministry of Forests and Range	District Stewardship	Practitioner
4	BC Ministry of Forests and Range	Provincial Landscape Specialist	Specialist
5	BC Ministry of Forests and Range	Provincial Landscape Inventory Specialist	Specialist
6	BC Ministry of Forests and Range	Regional Landscape Forester	Specialist
7**	BC Ministry of Forests and Range	Regional Landscape Forester	Specialist
UBC March 11, 2009			
8	UBC Malcolm Knapp Research Forest	Research Coordinator	Researcher
9	University of British Columbia	Senior Instructor	Researcher
10	University of British Columbia	Ph.D. Student	Researcher
11	University of British Columbia	Research Scientist	Researcher
12	UBC Malcolm Knapp Research Forest	Manager	Researcher
Nanaimo March 17, 2009			
13**	BC Ministry of Forests and Range	Regional Landscape Forester	Specialist
14	BC Ministry of Forests and Range	Regional Stewardship	Practitioner
15	BC Ministry of Forests and Range	Timber Supply Forester	Practitioner
16	Timberwest Forest	Planning Forester	Practitioner
17	Timberwest Forest	Manager	Practitioner

\* The participant number is distinct from the 3-digit questionnaire number which maintained full confidentiality (Appendix 7).

\*\* The same person participated in the Richmond and Nanaimo sessions. Questionnaire results from the Nanaimo session from that individual were not tallied to avoid over-weighting in the analysis (Appendix 7), however verbal and written comments were recorded and utilized. (Appendix 8).

# Appendix 7 Summary of Questionnaire Results and Analyses

GEOptics Focus Group Questionnaire Summary																									
	EXP	BG	Presentation						Mapping				Applications						SUM	N	AVER				
			1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16				17	18	19	
Richmond	101	V	P	1	1	-1	-1	1	1	1	0	1	1	1	0	0	1	0	1	0	0	8	19	0.42	
	102	V	P	1	0	-2	-1	1	0	1	-1	1	1	1	0	-1	2	-1	0	1	-1	0	2	19	0.11
	103	V	P	2	1	1	0	1	1	0	1	2	2	2	1	0	2	1	1	1	1	0	20	19	1.05
	104	V	P	2	1	0	0	0	-1	-1	-1	2	0	1	0	0	2	-1	0	1	-1	1	5	19	0.26
	105	S	P	2	1	1	1	0	0	1	1	1	1	1	0	0	1	0	0	1	1	0	13	19	0.68
	106	N	P	1	0	1	0	1	0	0	0	0	1	1	1	0	1	1	1	0	0	1	10	19	0.53
	107	V	P	1	0	0	0	1	-1	0	-1	1	1	1	0	0	2	1	0	1	-1	0	5	19	0.26
UBC	201	M	ES	2	1	0	-1	1	-2	2	1	1	2	-1	1	1	2	-1	0	1	2	1	13	19	0.68
	202	S	M	0	1	0	1	0	0	-1	-1	1	0	-1	1	0	1	0	0	1	1	0	4	19	0.21
	203	S	PME	1	2	2	2	2	2	2	1	1	2	1	2	2	2	2	2	2	2	2	33	19	1.74
	204	S	P	1	0	1	1	1	1	1	0	1	1	1	0	0	0	0	0	1	1	0	11	19	0.58
	205	S	PS	1	2	1	1	2	1	2	0	2	1	-1	1	0	2	1	0	1	1	2	20	19	1.05
Nanaimo	301	V	P	1	1	1	1	1	1	1	0	0	-1	1	0	-1	2	1	0	2	0	0	11	19	0.58
	302	V	P	1	2	-1	0	1	1	2	1	0	1	1	2	1	2	1	1	2	0	1	19	19	1.00
	303	M	P	1	2	1	1	2	1	2	1	2	2	0	1	1	1	1	1	1	1	1	23	19	1.21
	304	S	M	1	1	1	1	1	0	1	1	2	2	1	2	1	1	1	1	1	2	1	22	19	1.16
Sum			19	16	6	6	16	5	14	3	18	17	9	12	3	24	7	8	17	9	10	219			
Number			16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16	16		AVG. ALL		
Average			1.19	1.00	0.38	0.38	1.00	0.31	0.88	0.19	1.13	1.06	0.56	0.75	0.19	1.50	0.44	0.50	1.06	0.56	0.63			0.72	
Mode			1	1	1	1	1	1	1	1	1	1	1	1	0	0	2	1	0	1	1	0			0.84
Median			1.0	1.0	1.0	0.5	1.0	0.5	1.0	0.0	1.0	1.0	1.0	1.0	0.0	2.0	1.0	0.0	1.0	1.0	0.5				0.82
Maximum			2	2	2	2	2	2	2	2	2	2	2	2	1	2	2	2	2	2	2				1.89
Minimum			0	0	-2	-1	0	-2	-1	-1	0	-1	-1	0	-1	0	-1	0	0	-1	0				-0.63
Range			2	2	4	3	2	4	3	2	2	3	3	2	2	2	3	2	2	3	2				2.53

Averages		
A (1-6)	Presentation	0.71
B (7-10)	Mapping	0.81
C (11-19)	Applications	0.69
Richmond		0.47
UBC		0.85
Nanaimo		0.99
Overall		0.72

0 X (no response) replaced with 0 for analysis

EXP	Experience	V-Very, S-Somewhat, M-Minor, N-None
BG	Background	P-Practitioner, M-Manager, E-Educator, S-Student

## Appendix 8 Focus Group Discussion - Written Responses

The open-ended written responses for each of the 6 discussion topics received from participants at each session were as follows. The responses were unrestricted as to number of statements.

Appendix 8: Topic 1	
Respondent <sup>52</sup>	What do you see as possible advantages of the GEOptics landscape apparency mapping method, relative to conventional VLM methods?
101	Gives a good idea of where one can get the biggest or smallest bang for one's harvest effort (if that is one's primary focus).
102	Defining visual risk factors.
103	Tells licencees where they can clearcut without affecting VQO, e.g. quantile 1-3 (lowest out of 6 apparency classes).
104	Highlighting areas that require greater focus for design planning, i.e. those with higher apparency.
105	Another tool for resource managers.
106	Very detailed and accurate. Most helpful as a tool in the high risk areas.
201	Provides an additional layer of information for the planner, but it seems like conventional VLM methods would use other analyses tools like viewshed, etc. to help. This provides greater precision.
202	Highlights areas of greatest concern. Can show areas with little concern.
203	The cumulative apparency is a very useful tool.
205	Greater precision, refinement, resolution. Move away from binary outputs
301	Better at informing TSR. Provides an understanding of the location of the most visually challenging areas = opportunity to include these areas into retention areas such as OGMAs (old growth management areas), WHAs (wildlife habitat areas).
302	Efficient way to identify high risk / or low risk areas from multiple viewpoints.
303	Better total chance planning, look ahead. Developing and testing designs.
304	Fine tuning "lines of sight" within VLM areas or polygons.
305	Focusing design effort on more apparent and therefore sensitive slopes.
N=15	

Cont'd...

<sup>52</sup> Participants, by respondent number: Richmond (101-107); UBC (201-205); Nanaimo (301-304).

Appendix 8: Topic 2	
Respondent	What do you see as possible disadvantages of the GEOptics landscape apperency mapping method, relative to conventional VLM methods?
101	Need some special tools to do this work (i.e. VNS).
102	Producing too refined results in potential harvesting / design options that would be impractical operationally.
103	Complex. Dependent on tree cover data which is patchy at best. Roadside screening is an issue.
104	Complexity, possible confusion, added planning steps.
105	Is there a need to improve existing products?
106	Need to know GIS to run. A bit complicated. Does it really provide a greater or more useful end product? Is the end result really practical?
107	Highlights area of low relief as areas where P2P is at its greatest. This is intuitive.
201	The cost of the software and expertise
202	Harder for lay people to understand. Knocks front country off the planning table. Would probably take 75% of our tenure out of the THLB (timber harvesting land base.
203	A bit more complex to learn, understand, and communicate (when presenting plans).
204	More complicated.
205	Insignificant differences... Increasing complexity...decreasing economic return? Operational concerns?
301	Individual cutblock(s) - current success requires visual management from most constraining viewpoint.
304	How to select viewpoints.
305	Complexity; planning time; increased operational costs.
N=15	

Appendix 8: Topic 3	
Respondent	How could GEOptics cumulative landscape apparency (visual risk) mapping be used by resource managers to enhance conventional visual landscape planning and design?
103	Explore VLI (visual landscape inventory) update uses from roads; water bodies to refine VQO (visual quality objective) / VSC (visual sensitivity class) mapping in an automated way. There are no resources for conventional updates, automation needs to be explored.
104	Indicate areas which require greater focus or design efforts (high apparency).
105	Needs to be proven that results generated from GEOptics outperforms conventional existing methods. We have a VIA (visual impact assessment) process in place used by many consultants.
106	Just one more tool but not sure who would use it instead of current tools.
107	It identifies opportunities i.e. areas where P2P (plan-to-perspective) opportunities can be realized.
202	Another layer of constraint to add to the library.
203	Seems very useful in planning sequences of passes.
301	Offers improved total chance planning. Could direct more operational plans in visually sensitive locales.
302	Appears to be able to use time as a consideration where views are not static, i.e. along cruise ship routes / highways.
304	Seems to easily dovetail into other strategic land management resource layers used at a landscape level planning process.
305	Yes, stratify so that design effort focused on higher risk / apparent slopes.
N=11	

Appendix 8: Topic 4	
Respondent	How could GEOptics be used by resource managers as a component of Timber Supply Planning?
101	Could be built into cover constraints as a modifier to scale of alteration range for VQOs.
103	By refining constrained areas. Quantiles 1-3 out of 6 are not really constrained from timber supply perspective.
104	It would take a very experienced technician to run these analyses. See #2 comments.
105	Remains to be seen based on output derived.
106	Balancing of VQO quotas. Maybe see if licensees are operating on the more challenging VQOs or just avoiding them.
107	GEOptics is a good model for showing what might be possible. TSR (timber supply review) must model what is current practice. The two might not be the same.
201	As you had mentioned, it provides a means to focus on areas of low apparency as higher priorities for harvesting with regard to visual sensitivity.
202	Net downs are easier to make.
203	Modelling "rotational" plans for harvesting.
301	Determination of better P2P ratios that feed TSR.
302	Use lineal programming to optimize P2P ratio to identify maximal removal of timber with least visual risk.
304	Better define the available land and volumes.
305	GEOptics is a fine level tool but TSR planning (is) a blunt instrument with gross assumptions and accuracies. Better for operational level harvesting not at TSA (timber supply area) level.
N=13	

Appendix 8: Topic 5	
Respondent	How might the GEOptics method be improved or made more useful?
101	The next step would be to incorporate this with other resource and constraint information to help identify areas for development IVD (Integrated Visual Design)-type of process.
103	See #3, explore VSC mapping in regards to VLI updates applications.
104	Simply the apparent complexity of steps, perhaps using more familiar terms like "risk" instead of apparency.
105	Ability to map (overlay) existing visual condition based on openings from FTA (forest tenure application) and/or RESULTS (Reporting Silviculture Updates & Landstatus Tracking System).
106	Make it easier to use. More automation. Less steps.
201	Apparency maps can give an overall landscape perspective, but it doesn't deal specifically with apparency that has a positive or negative visual effect.
202	Consider impact of clearcut, VR (variable retention), STS (silviculture tracking system – RESULTS), Etc.
204	Streamline the process.
205	Show resulting resource <u>designs</u> , not resulting resource <u>classifications</u> .
301	Ability to add more weight (light!) to selected viewpoints.
302	Improve the time function. Optimization model.
305	Combining apparency with times seen to find most critical areas.
N=12	

Appendix 8: Topic 6	
Respondent	Any other issue or concerns raised in the session?
103	No.
104	Found it a little confusing. Harvest/logging practicality is limiting factor.
106	Just need to keep it simple and practical.
203	That planners recognize the consequences/effects of early passes on later passes of harvest.
204	I didn't understand why you placed a source of light to illuminate the landscape at each viewpoint (or is that what you did?)
205	Chose poor "conventional methods" to compare to (of course a slope map doesn't stand up). Would be better to compare two <u>advanced</u> methods/analyses.
305	Limitations tied to choice of viewpoints. Duration of view not factored in well.
N=7	

## Appendix 9 Focus Group Discussion - Audio-recorded Responses

Richmond (numbered as received)
R1. A lot there to read - how to package, needs a script - 6 quantiles - push button - simple.
R2. Apparency gives angle of each terrain cell - times seen doesn't - prove it.
R3. Why go down this road when we already have tools and if there is only a 5% difference in assessments? Can lead to confusion and lack of understanding. Requires a lot of GIS analysis. Had Landscape Manager (a custom-built derivative of World Construction Set 4) - not used. Don't do this anymore - consultants do.
R4. Need something completely out of the box - a way to automate VLI. First 3 quantiles - M, 4 - PR, 5,6 - P or R.
R5. Need screening, reality check.
R6. Can't avoid front high quantiles - start altering or will be removed from landbase.
R7. Tool to tell you where high risk areas are, but no way will they be cut like that, a refined tool then backtrack, need layers, access.
Note: comments to this point were made before presentation of Stage 6 planning. Discussion re-commenced following questionnaire completion
R8. Quantiles 5 and 6 have positive impacts right off the bat, look into more automation, no more money for VLI updates, distinguish between VLI and management decision.
R9. Along highway or rest stop - account for screening, operational requirements.
R10. Screening along roadways is not accurately mapped.
R11. Integrated visual design - choose viewpoints, go out and check. Process is viewpoint dependant, start from outside, move through and look back. Times seen is similar.
R12. Application to timber supply? Larger scale plans? (questions to group from Stephen Sheppard)
R13. GEOptics good, showing what might be possible, from that perspective it is a good tool. If not current practice, what licensees are doing, then that's not what is modelled.
R14. Have had 10 years of training courses, only 42% of samples have good design, failing miserably. One district won't give the top percent because it is not what is being done. 2006 study showed difference in Public Acceptability Rating between design and non-design; public buy-in - better bang for the buck; more wood; larger openings for the same PAR. Shouldn't give credit if working against the process (no design). Ken is correct about P2P and slope, but don't know viewing angles at TSR level.
R15. I know there is a strong relationship between slope and viewing angle; slope is a dominant factor, assuming a certain viewing angle (more slope, more on profile).
R16. Low rolling areas have high P2P; high areas not accessible except by helicopter.
R17. How to lump cells together, add roads, design, force lines, shape; have VIA approach, IVD, people are trying. Just another tool in the toolbox; won't resolve operational issues, TSR, certainly has utility for additional analysis.

## Appendix 9 Focus Group - Audio-recorded Responses (cont`d)

<b>UBC (numbered as received)</b>
U1. Not an expert, lost on most of the presentation. System has benefits, but difficult to explain to people, particularly lay people, showing those maps in public, at a meeting or open house, trying to tell people how they were derived, really have a hard time getting around that. But at the same time, they are powerful in that they are simple visual tools to look at. When I think about it, from our standpoint of our situation, I could see it taking probably 75% of our landbase out of consideration for harvesting, so I think it would be something that would paint us into a difficult planning perspective. With roads on three sides, public response would be "why log?"
U2. Raised the alarm on lower slopes, not unexpected as they are in the public eye, and may have been undervalued previously and were more worried about steep slopes that weren't quite there. I expect to see a bit more of the lay of the land rather than blanket exemptions for visual.
U3. Do you think it will help? Modify the cuts – 5 year, 20 year, partial removal. Know areas of high concern, take to the public and show how design is used to mitigate impact.
U4. How can this be converted to the visual system that already exists? (also says: "it is either seen or not seen").
U5. This, to me, is more precision and more refinement, more resolution, and moves away from a binary tool - in/out, breaks down the margins between classes - a public process tool - a demonstration of sensitivity.
U6. Subtle differences, not binary, not just that we can see an area. Would like to see the map products - hands-on - where are the marginal areas, borders, break them down into levels of sensitivity. Do they actually result in a change in overall visual impact of a cut? Raised the question but didn't see the answer in the presentation.
U7. I saw the answer in the last slide. I have been involved in VRM since the '70's as a practitioner. I see this being applied at least in two very distinct levels. One is taking a plan to the public and stakeholders. Stakeholders are only interested in time, types of sessions - what a current plan will look like. However, for the planners, it is the time and dimension and understanding what is the impact of the base plan on the 20 year plan and the strategic plan - how are you going to get through the whole plan and still achieve all of your objectives, usually in a 20 year plan. VQOs are one of the foremost objectives. If you meet the VQO you usually have hydrology, wildlife, fish, etc., etc., taken care of with a few minor tweaks. So I really see the whole idea as being valuable in that sense. It is a terrific tool for taking to the actual planners. What I really like about what you are doing is the idea that, I guess I'll narrow it down to the cumulative apparency. It's always been a problem, you know, when I started off, taking pictures and sketching what its going to look like, but its being able to accumulate apparency from several viewpoints (light points).
U8. I think that could be a really good new tool, the way I see it.
U9. A planimetric tool - applied - adds another layer of complexity and operationalizing in terms of decreasing economic return.

Cont`d...

## Appendix 9 Focus Group - Audio-recorded Responses (cont`d)

UBC (cont`d)
U10. The complexity is already there. The problem is complexity often isn't realized until the second or third pass, and the timber you thought would be there is not there because its going to have significant impact on visuals and other resource values. There is often a lack of appreciation of the cumulative effect after the first pass - VQO, water, etc., met in the first pass, plans approved, then go out for the second pass - a huge accommodation - VQOs compromised, cut reductions, this is one of those huge, huge factors happening in the coastal areas, specially right now, the cumulative impact of land withdrawal, introduced multiple resource objectives, have taken away the accessibility that would have originally thought to exist with fully accessible timber in the landbase, mature accessible, economic, but because of changing objectives, is not available at this time.
U11. A time scale would make this tool even more useful.
U12. have a more technical background how to do this. Apparency is important but as a time tool, if I want to save money or harvest more, I need to see apparency for each step, and whether or not the place I am looking at is going to have a negative impact or not. Apparency where there are trees might not be an impact. Apparency where there are not trees there is probably going to be a greater impact and if I take x amount out now - a negative impact - is there something that a GIS tool can measure impact?. You can do this - companies will hire you - what is really being provided is an integrated level of decision - a whole gradient..
U13. What is different than other VRM people could have done? KF reply: I think it leads to a pattern, tested in perspective view.
U14. That would be great in terms of presentation - what people are doing right now - VR managers have some tools - high slopes that they may not be their primary concern - and this is why.
U15. Here is where you can save money, addressing this, it is a significant leap in terms of saving money because you can take the cutblocks in areas without the greatest effect than done before.
U16. In visual planning, spatial, time sequence, I see cumulative apparency as one factor alone that can lead you in the direction of space planning and sequence. Biggest concern is cost - up front and benefits achieved down the road - how will it impact rate of harvest, how will you justify it economically – write the answer.
U17. Walk through very clear. The eye doesn't detect differences between quantiles. Does it show the utility of the system to find differences or the insignificance of the system to find things that really matter to my own eye - ultimately the eye (mine, the public) is judge of this. Have I added insignificant complexity to the system?
U18. Hard for public to grasp changes over full image set, picking out details and remembering. Public doesn't have spatial practice. Should graph the differences of apparency and amount of area, cumulative area across viewpoints. Used system in Master's - harvested areas black, all else white, added each view together, correlate with apparency, compare high and low apparency, don't worry about tree screening. Show effect on harvest, then final images - the "ah-ha!).
U19. Address skepticism - proof in the pudding. Final images to see them better. (KF reply: sequential images let the eye pick up difference and patterns).
U20. Shows where to focus your time - 40% harvest is non-red. You can tell where those areas are.
U21. Major concept there - show planners where they can get 60% of the timber. Provide a direct focus, don't leave it to people to draw conclusions.
U22. Your program will take them there; slope won't.

## Appendix 9 Focus Group - Audio-recorded Responses (cont`d)

UBC (cont`d)
U23. Approach is advanced landscape planning vs. simplistic as you can get (slope) - comparing apples to oranges.
U24. Re-writing the rule book - don't use slope - that's why we are missing design and harvest opportunity. Slope over-restricting - using wrong variables.
U25. Important tool - about precision. Planners use hillshade in GIS - compare, say where to use GEOptics approach – higher risk areas where more precision needs.
U26. Demonstrate with different resource designs - post-occupancy analysis, post-use analysis. Pretty neat tool - great idea with the light bulbs.

Nanaimo (numbered as received)
N1. VRM results of random cutblocks around the province are not terribly good, shooting at 55%-70% success rate in meeting the VQO. Percent alteration may be met but failing design. Though there is subjectivity in measuring design achievement, legally not meeting VQO on good percent of cutblocks. One bad cutblock discredits the program.
N2. 42% of cutblocks have good design. Sometimes design might be poor to get the wood out, heath, economic, but meets VQO.
N3. Past 5 years setting the baseline (code cutblocks), now with FRPA hope to see improving trend.
N4. Can the elevation of lights be changed? (KF: yes).
N5. Artificially forcing into equal areas - quantiles, value is the same, regardless of viewpoint. Can't see from some viewpoints, more total area than in single viewpoint (for clarification, KF recalculated individual seen areas following this session).
N6. Can the viewpoint (light) elevation be changed to account for kayakers vs. cruise ships? (KF reply: Yes).
N7. Procedure good for total chance planning, P2P, TSR - better than now. Disadvantage it that it is too broad for cutblock-to-cutblock decisions with many other things in the discussion - a move from landscape to individual cutblock - less beneficial.
N8. Advantage of apparent slope - where to put more design effort. (KF reply: stratifies landbase - risk zones - can work into operational plan).
N9. Know where the easy victories already are - the green apparency zones.
N10. One of the biggest things on central coast at strategic level is co-location - OGMA's, WHA's. Within visual polygons co-locate/ dovetail with OG, MOE ungulate, suitability mapping. Agree that on strategic level that this process fine tunes landbase. Same detail scale 1:20,000, 1:10000 scale - will help people out. Multiple viewpoints lead into length of time from cruise ships - changing experience (they don't park in front of the cutblock).
N11. In some areas, lots of areas, operators don't have enough skill to select viewpoints, could be every 50m, licensees monkey around, choose one or two viewpoints, so GEOptics sophisticated, other "down there".
N12. Forest Practices Board audit of Campbell River area asked if the worst case viewpoint was selected for the analysis. We don't predetermine the worst case VP - selected in the field - head-on shows cutblock in poorer light so it is not offside with the VQO. The rest will fall in ok. Design from multiple viewpoints, don't average, 2 or 3 cutblocks in scene at most. Bottom up better to manage than top of hill down; no inventory lines. Examined overall corridor - 5 1/2 hours "not bad" (the visual appearance).

## Appendix 9 Focus Group - Audio-recorded Responses (cont`d)

Nanaimo (cont`d)
N13. Could you combine times seen and apparency to add sensitivity? (KF reply: yes).
N14. Could you make a brighter light bulb for important viewpoints? (KF reply: yes, can be done graphically).
N15. First nations example – focal on way down Bute Inlet - don't want to see anything, OK on way up (tangential) - moved cutblock around the corner.
N16. Does VLI consider duration of view in the VSU?
N17. VLI uses viewing duration to rank visual sensitivity, but not good - general level of detail, 1:50,000 scale, huge sections, depends on who did the inventory.
N18. Brighter light bulb - flick a switch, professionalizing the model.
N19. Better way to evaluate timber supply impacts by each 25m grid cell - the real strength of the system. Tend to take risk-averse approach now. GEOptics can demonstrate what you're giving up and think about trying this or that.
N20. Assumptions on TSR a broad brush, different scale from GEOptics.
N21. But GEOptics can be used to stratify like slope does presently, have to know how to plug in, works well for a VSU.
N22. Slope used to be used in TSR, now only using previous TSR numbers, go with higher slope; no one looking at changing the system.
N23. At same time, in timber supply, things are becoming more detailed, starting to incorporate spatial layers.
N24. Take whole TSA - all corridors, a lot of detail.
N25. Question for Ken, What scale do you see for this? Landscape level, operational, total chance? (KF reply: yes, all levels - at landscape level (tactical level), begin to build, start informing timber supply (strategic level); assist operational planning).
N26. Things get lumped in timber supply. TSR a bunch of averages - can't take out to 2 decimal places - scary. Stand level retention modelled on code level of impact but actual practice adjustment made. VRM could be the same to refine it - by experience - P2P.
N27. Partial Retention VQO is a hit on TSR; Modification VQO is not.
N28. Better mapping, better contours - different results, greater differences from TSR. Until you gather information in an approved, Chief Forester endorsed process. Until then it is for Chief Forester consideration and assumptions.
N29. Operations must prove they are effective at meeting VQO at higher range - review of practices - make determination.
N30. Forest Practices Board said if VQO is PR and you achieve either R of M, you failed - avoiding the problem.
N31. Chief Forester can require operations in restrictive VQO areas or remove it from cut.
N32. 42% of TFL has VQOs. Lots of cutblocks to calculate P2P on, report on practices, present to Chief Forester. He may say "report back over the next TSR period. "Ad hoc" reporting - working or not - to give an idea if meeting that assumption. We don't go very far back in the landscape to calculate P2P, ranges are 2.3-2.5, foreground-middleground But all visible in VSU - should be included.

## Appendix 9 Focus Group - Audio-recorded Responses (cont`d)

<b>Additional Nanaimo comments - by e-mail following Nanaimo session, March 19, 2009</b>
N 33. If I read the audience correctly, I would summarize they felt that Geoptics holds some potential application in identifying/priorizing areas of higher visual risk. However, this was at a more operational level than at BCMoFR's typical VLI inventory level of 1:50,000 scale. Although it holds potential to fine-tune timber supply analyses, BCMoFR's current procedures are using some pretty gross assumptions which in practicality would negate the benefit of fine-tuning. Similar to other modelling programs, much of the real world application is predicated on the professional having sufficient knowledge to appropriately select a correct number and location of viewpoints.
N34. I don't know if this is pushing the Geoptics application too far. However, it would be interesting if two additional variables could be additional enhancements:
1. Sensitivity/strength decrease with distance from viewpoint(s). So that there is some fall-off with distance which are now indicating equal apparency. For example, foregrounds are more sensitive and at higher risk than distant backgrounds, which are currently showing of equal apparency.
2. I'm not sure if viewpoint variable luminosity could be factored in. For example, a short passing view could have a fairly low viewpoint luminosity factor. Whereas a community viewpoint with numerous stationary viewers could be given a much higher luminosity/brightness factor. In your case study area, examples could be a Howe Sound mid-channel viewpoint (low luminosity) versus a community like Squamish or Britannia Beach (high luminosity factor).
N35. The combination of these two variables (distance fall-off and viewpoint luminosity) with the current Geoptics could yield some interesting differences. I realize this is asking a lot of the application. At some point those high risk visual areas should become obvious to the forest professional with or without this type of modelling.

# Appendix 10 BREB Certificate of Approval



The University of British Columbia  
 Office of Research Services  
**Behavioural Research Ethics Board**  
 Suite 102, 6190 Agronomy Road, Vancouver, B.C. V6T 1Z3

## CERTIFICATE OF APPROVAL- MINIMAL RISK RENEWAL

<b>PRINCIPAL INVESTIGATOR:</b> John D. Nelson	<b>DEPARTMENT:</b> UBC/Forestry/Forest Resources Mgt	<b>UBC BREB NUMBER:</b> H06-03535
<b>INSTITUTION(S) WHERE RESEARCH WILL BE CARRIED OUT:</b>		
<b>Institution</b>		<b>Site</b>
UBC		Vancouver (excludes UBC Hospital)
<b>Other locations where the research will be conducted:</b> 2-3 sessions will be held, at locations selected from UBC Forest Sciences Centre and government offices, e.g. BC Ministry of Forests and Range offices in Nanaimo and Kelowna/Kamloops.		
<b>CO-INVESTIGATOR(S):</b> Michael Meitner Kenneth B. Fairhurst		
<b>SPONSORING AGENCIES:</b> Networks of Centres of Excellence (NCE) - "A systems approach to integrating ecological, economic and social values within the SFM framework for tree farm licence 49"		
<b>PROJECT TITLE:</b> Expert panel review and testing of GEOptics: a dynamic visual resource indicator for multi-functional landscape planning		

**EXPIRY DATE OF THIS APPROVAL: December 17, 2009**

**APPROVAL DATE: December 17, 2008**

<p>The Annual Renewal for Study have been reviewed and the procedures were found to be acceptable on ethical grounds for research involving human subjects.</p> <p style="text-align: center;"><b>Approval is issued on behalf of the Behavioural Research Ethics Board</b></p> <p style="text-align: center;">                 Dr. M. Judith Lynam, Chair                  Dr. Ken Craig, Chair                  Dr. Jim Rupert, Associate Chair                  Dr. Laurie Ford, Associate Chair                  Dr. Daniel Salhani, Associate Chair                  Dr. Anita Ho, Associate Chair             </p>
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## Appendix 11 Apparency Classification Method Comparison

Quantile and equal-interval classification approaches are compared in this appendix for an individual LCP (Figs. A1; A2) and cumulative (5) LCPs (Figs. A3; A4):

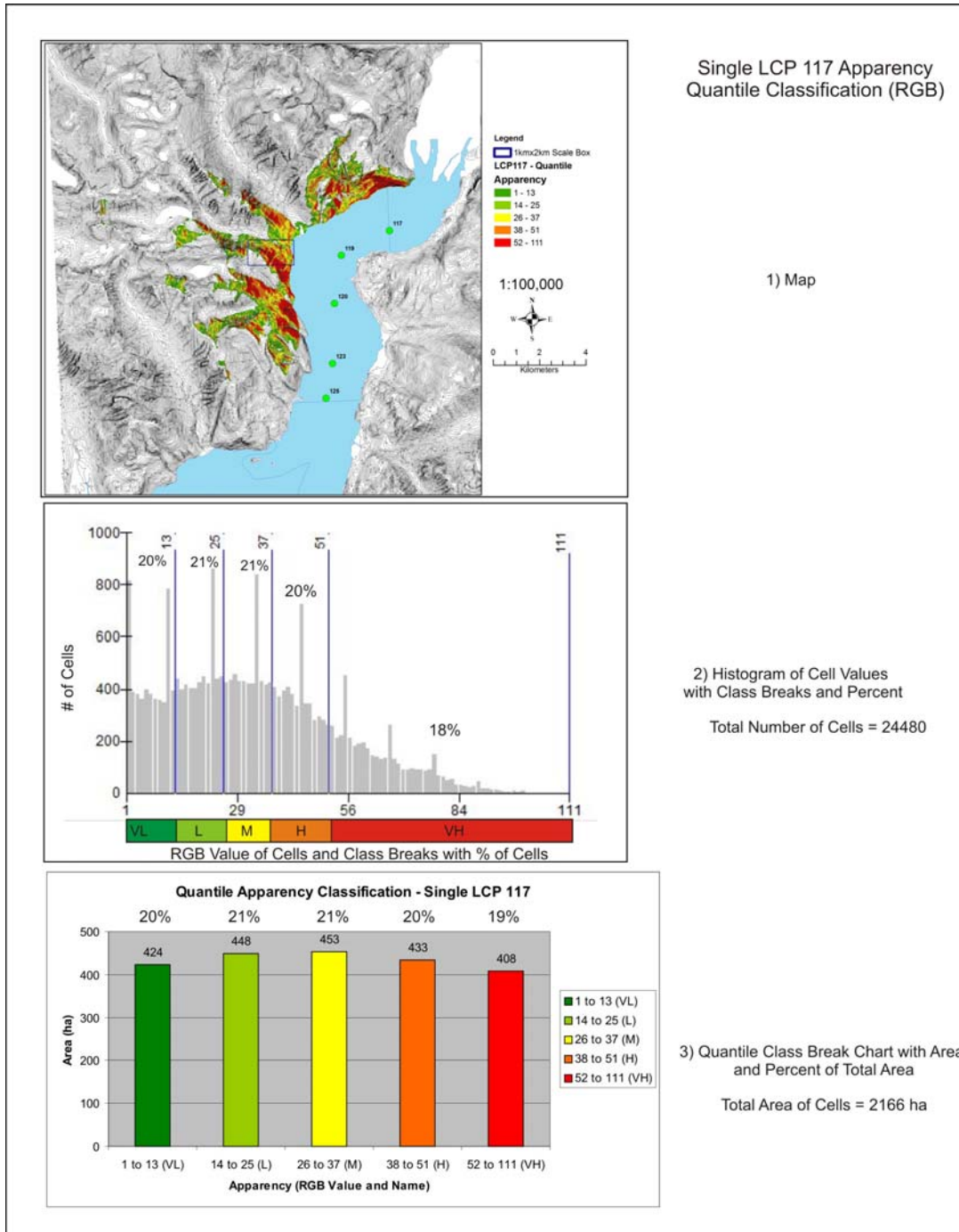
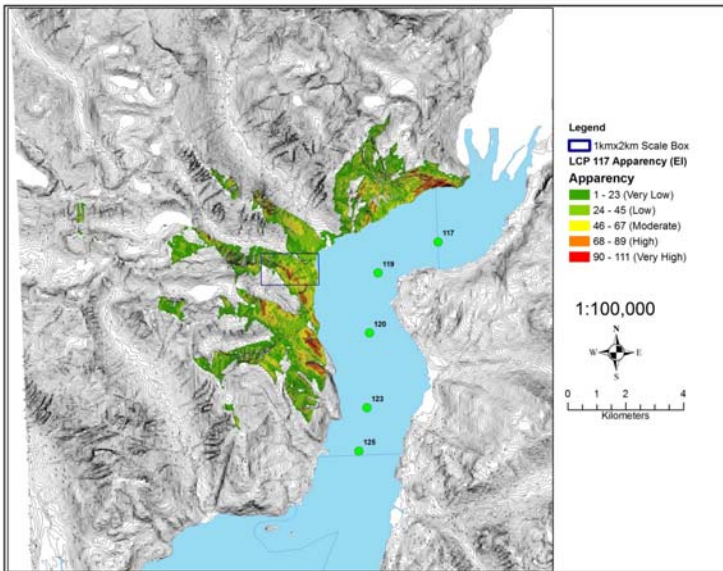
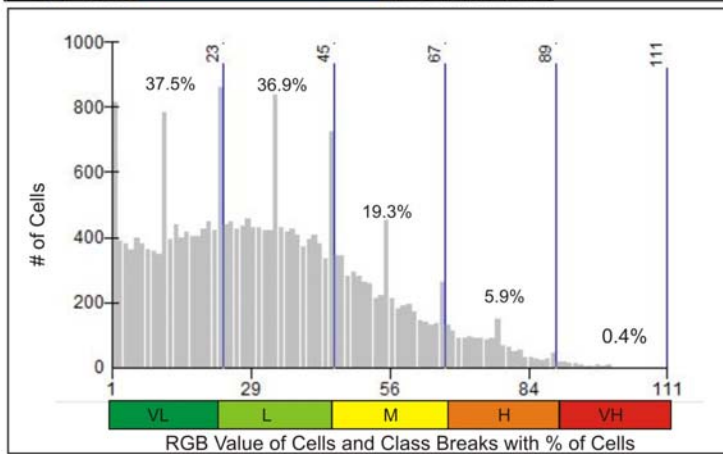


Figure A1 Quantile method of apparency RGB classification - single LCP 117 - Howe Sound.



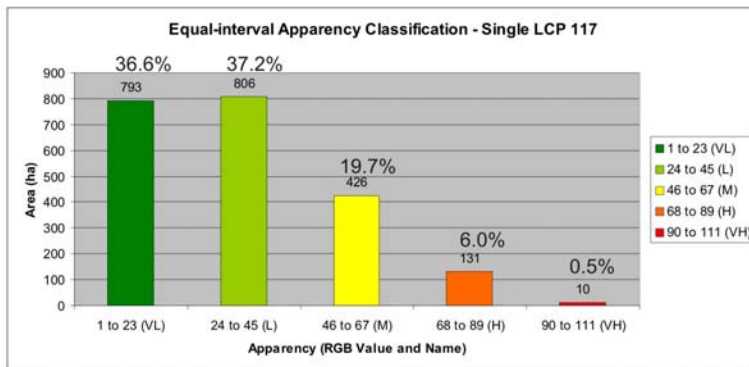
Single LCP Equal-interval Apparency Quantile Classification (RGB)

1) Map



2) Histogram of Cell Values with Class Breaks and Percent

Total Number of Cells = 24480



3) Equal-interval Class Break Chart with Area and Percent of Total Area

Total Area of Cells = 2166 ha

Figure A2 Equal-interval apparency RGB classification - single LCP 117 - Howe Sound.

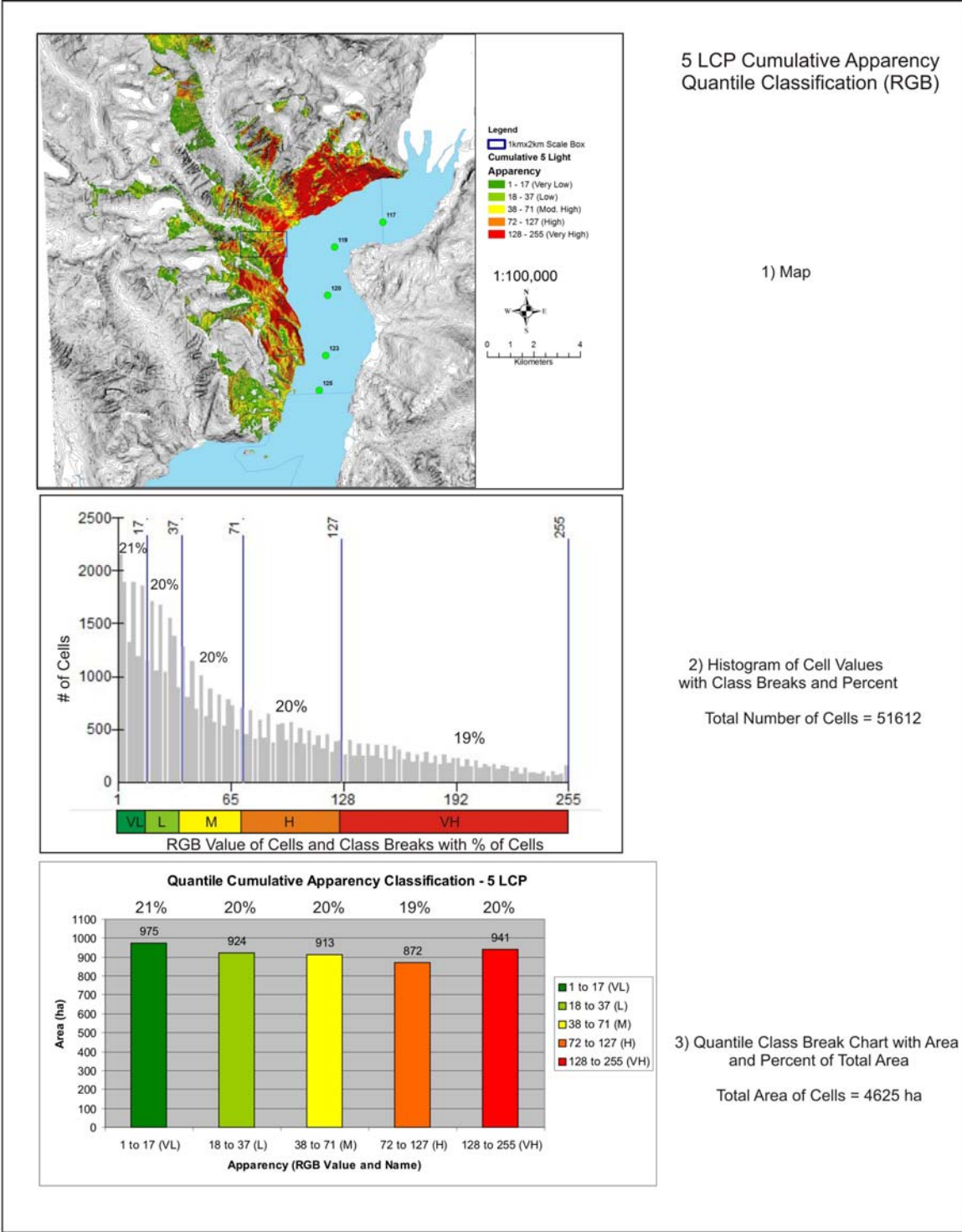
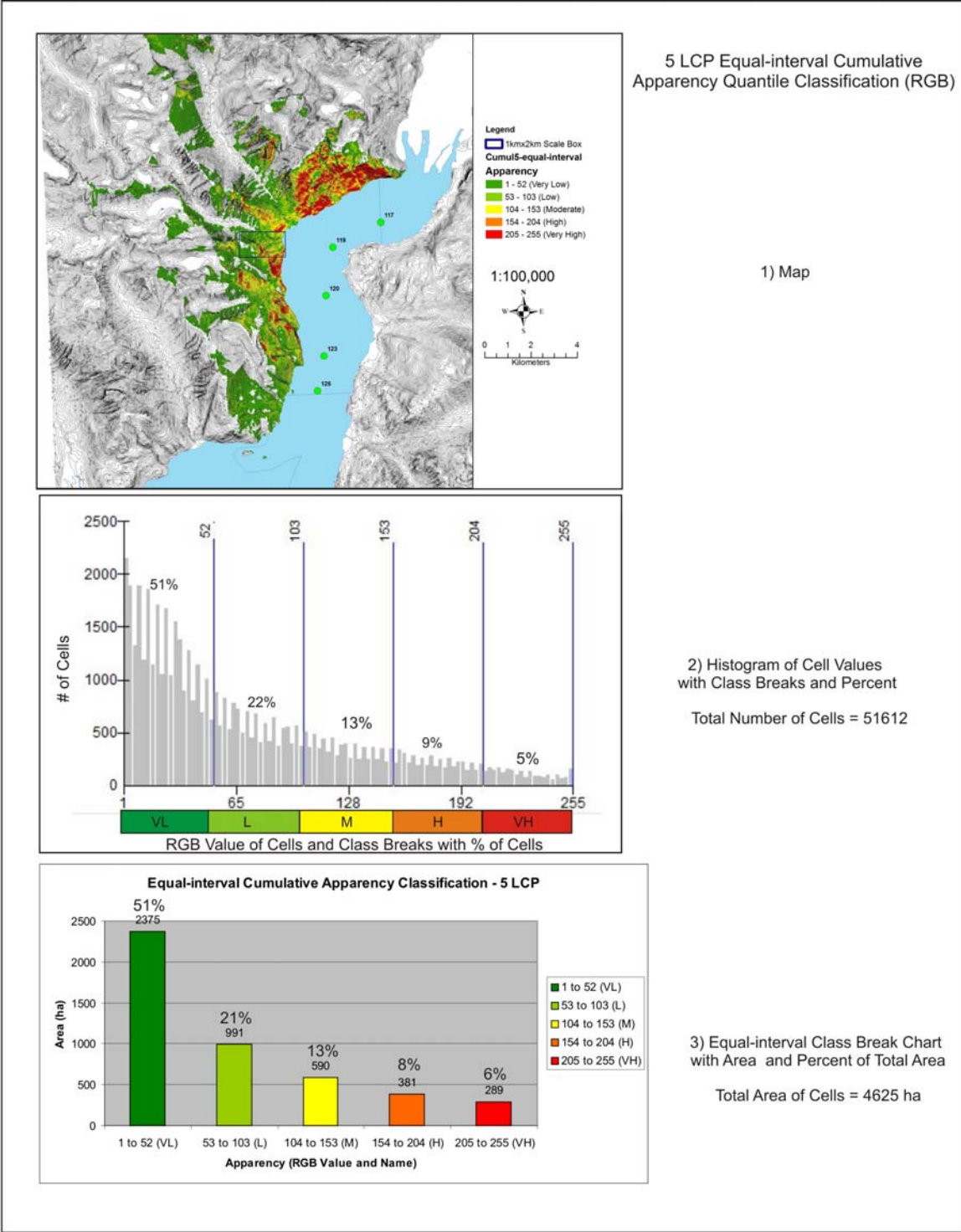


Figure A3 Quantile "equal area" 5 LCP Cumulative apperncy RGB classification - Howe Sound.



**Figure A4 Equal-interval 5 LCP cumulative apperency RGB classification - Howe Sound.**