Integrated Land Management Bureau

BRITISH COLUMBIA
Ministry of Agriculture and Lands

Guidance and Technical Background Information for Biodiversity Management in the Interior Cedar Hemlock Zone within the Prince George Land and Resource Management Plan Area

Approvals:
The undersigned approved this guidance.

Project Sponsor: Howard Madill
Acting Regional Executive Director, Northern Region

Howard Madill April 1, 2008

Marc Imus
Acting Manager, Regional Client Services, Ominica

March 28, 2008

Project Manager: Justin Calof, R.P.F.
Planning Officer, Prince George Planning Group

March 28, 2008

Purpose of Document

The purpose of this document is to share information with other forest professionals on biodiversity management in Interior Cedar Hemlock (ICH) forests in the Prince George Land and Resource Management Plan Area. It is the intention of the Integrated Land Management Bureau (ILMB) that this paper will provide useful information; however, ILMB would like to stress at the outset that this is not to be interpreted as direction. This paper is intended as guidance only and is not legally binding. ILMB will work with the Ministry of Forest and Range and forest licensees to implement this guidance. If biodiversity management in the ICH is significantly inconsistent with this guidance, future legal objectives may be considered by government.

Through project work, staff in ILMB have collected and synthesized available scientific and technical information on biodiversity management in the ICH into both technical guidance, maps and background information which is intended to assist professionals in the development of operational plans. The background also discusses socio-economic information that may assist both professionals and statutory decision makers in future planning in the ICH area.

Table of Contents

1.0 Executive Summary

The Interior Cedar Hemlock forests near Prince George are globally unique. They contain cedar trees in excess of 1500 years old, rare plant species and endangered caribou. Indeed there are few forests in the world that parallel its biodiversity value. Within this unique area, there are stands of trees that are considered by science as global hotspots for biodiversity.

Since the early 1990's the Interior Cedar Hemlock forests in the Prince George forest district have been the subject of public scrutiny and debate. Unprecedented levels of public comment received during reviews of various government initiatives, international conferences and official investigations of forest management by government agencies indicate the highly contentious nature of these cedar forests.

The objective of this Forest Investment Account project was to develop scientifically based spatial Old Growth Management Areas that capture the highest proportion of rare and biologically valuable forest types, minimize the impact on the current timber flow for the Prince George Timber Supply Area and facilitate implementation of the *Forest and Range Practices Act.*

The project concluded that the environmental and social risks of current biodiversity management enactments are significant, and that Old Growth Management Areas can substantially address these risks while not introducing additional or undue economic impacts to government or the forest tenure holders.

This project identifies 4,770 hectares of Old Growth Management Area within the Prince George Land and Resource Management Plan (LRMP) area. These Old Growth Management Areas are consistent with established enactments and will not introduce additional harvest constraints or costs to the area. This is because the current legal enactment for biodiversity management requires area from the timber harvesting land-base in an amount greater than that identified in this report. The project also identifies areas of high and medium biodiversity value that are outside Old Growth Management Areas and parks. These areas can contribute biodiversity management in the ICH.

At this time the areas identified as Old Growth Management Areas and the areas identified as high and medium biodiversity value are intended as guidance and best available information for biodiversity management in the area. The guidance and background information contained in this document is not legally binding and is intended to assist professionals in the preparation of results and strategies under the *Forest and Range Practices Act* (FRPA). It is expected that this information will augment biodiversity management in the area however evolving scientific understanding should be continually incorporated into planning.

2.0 Background

Since 1990 local communities, researchers, public stakeholders and the environmental sector have been adamant over the need for spatial biodiversity planning in the Interior Cedar Hemlock (ICH) forests near Prince George. The global significance of the biodiversity resources in the area, specifically the old cedar forests, has been verified by a number of independent scientists and was highlighted by the Chief Forester during the second Timber Supply Review (TSR II).

Consistent with existing policy in 2002, Old Growth Management Areas (OGMA's) in three landscape units were established to address social pressures and biological risks. Information gained through research since then, however, indicates a need for additional planning.

In 2004 the "*Order Establishing Landscape Biodiversity Objectives for the Prince George Timber Supply Area*" (hereafter the '*order*') was completed. Largely based on the work of the Craig Delong through the Ministry of Forest and Range, this *order* is the current policy tool for managing biodiversity in the area. It establishes non-spatial targets for old forest, old interior forest and young forest patch size.

This non-spatial approach however, may pose environmental and social risks in areas of high biodiversity value, as those areas may not be captured in a non-spatial framework. These risks were the subject of much debate during the establishment of the *order*. Since 2004 independent study further indicates the significance of the biodiversity resources that exist in these ICH forests and the risks that further resource development presents to them.

3.0 Structure of Report

This project considered socio-economic as well as scientific information in the formulation of biodiversity management guidance. This report is divided into two parts.

Part 1 presents guidance for biodiversity management in the ICH. Section 4.0 includes suggested strategies and results for spatial biodiversity management in the ICH. This section is supported by maps for use in operational planning.

Part 2 provides background information on the scientific and socio-economic justification for biodiversity management in the ICH. Section 5.0 contains scientific and technical information about biodiversity risks and requirements in the ICH area. Section 6.0 presents some of the socio-economic data that may assist professional foresters, as well as Statutory Decision Makers (SDM) in developing future objectives for the area. Section 7.0 contains timber supply information that may also support professionals and SDM's in future decision making. Maps and spatial datasets (Appendix 1) were built based on the indicators outlined in section 5.0 and were developed consistent with the requirements of the Land Use Objectives Regulation.

Part 1 – Guidance for Biodiversity Management in the ICH

4.0 Operational Guidance for Biodiversity Management in the ICH

This project identified areas important for biodiversity in the ICH zone. The spatial biodiversity guidance is intended to assist with harvest decisions occurring in Forest Development Units in the ICH area. The guidance for additional biodiversity management in the ICH provides the location of spatially explicit areas that contain significant biodiversity resources. This guidance is intended to provide useful information; however, ILMB would like to stress that this is not to be interpreted as direction. This is intended as guidance only and is not legally binding.

4.1 Spatial Biodiversity Guidance

Within the areas identified on the map in appendix 1 as Guidance – Old Growth Management Areas 2008, the following results or strategies are recommended:

- Reserve all timber within identified Old Growth Management Area (OGMA) boundaries;
- Access structures should be located at least 200m away from OGMA boundaries;
- Harvesting near the boundaries of OGMA's should not increase the risk of windthrow in OGMA's.

4.2 Guidance for Additional Biodiversity Management in the ICH

The specificity of the biodiversity resources in the ICH may require a spatial approach to management. The area identified on the map in appendix 1 as High Biodiversity Value (HBV) and Medium Biodiversity Value (MBV), can contribute to old forest representation, which is an important surrogate for biodiversity. This guidance is recommending the following strategies for ongoing biodiversity management in the ICH;

- Prioritize retention of areas identified as High Biodiversity Value as indicated on the map in appendix 1;
- If all of the High Biodiversity Area is retained, prioritize Medium Biodiversity Value areas for retention as indicated on the map in appendix 1.

Part 2 – Backgound for Biodiversity Management in the ICH

5.0 Biodiversity Assessment and Risk Analysis

This section will provide professionals and decision makers with scientific and technical background information intended to inform future decisions in the management of biodiversity in the ICH area in the Prince George LRMP area. It will outline key indicators and information that was used to locate guidance Old Growth Management Areas (OGMA) attached in appendix 1, and will support future biodiversity management efforts in the ICH. Other relevant information on the role of biodiversity in forest management is presented to provide further guidance to professionals making operational decisions under current landscape enactments in the ICH. Planning context and history will be included to provide important context in regards to the current risks associated with further forest development in the area. This scientific rational and planning context will characterize the risks of the current management approach in the area and justify the recommendation for additional management considerations.

5.1 The Critical Role of Biodiversity in Forest Planning

Overwhelmingly, the literature emphasizes that biodiversity should be maintained at multiple spatial and temporal scales to sustain desirable system states as environmental conditions change over time (Drever et al. 2006, Walker and Salt 2006, Gunderson and Holling, 2002). The cumulative pressures on ecological services (i.e. timber production, water filtration, carbon storage) resulting from, most significantly, resource development and climate change, have created the imperative for comprehensive approaches to maintaining biodiversity. A failure to accommodate biodiversity in planning can diminish the capacity of forests to continue providing ecological services, namely the production of timber, of the same quality and quantity in perpetuity (Constanza et al. 2000, Holling and Meffe, 1996).

Based on simple correlation between diversity and measures of ecosystem functioning, consensus is growing for the argument that biodiversity must be represented and conserved to maintain ecosystems (Lyons, et al., 2004). In addition to representative elements of a given ecosystem, rare species can play an important role in the maintenance of this ecosystem function. For example, studies examining the role of keystone species with low abundance at landscape scales indicate a disproportionate role in the maintenance of ecosystem function. As well less common plant species may have an important role in the maintenance of ecosystem productivity (Power et al. 1996; Theodose et al., 1996).

This guidance has a considerable linkage to the importance of rare and representative species in the maintenance of ecosystem function. The entire temperate rainforest area is globally rare and represents less that 0.5% of the forest world’s forests (Goward and Spribille. 2005). The ICH is a subset of the forest type and is unique among temperate rainforest regions, emphasizing the need for this guidance, and careful biodiversity planning that maintains old forest representation. While science has not defined the role of each component in the ICH ecosystems, the growing scientific consensus around the critical role of representative and rare biodiversity is compelling and should be considered in FRPA implementation.

5.2 Project Area Context

Biodiversity planning in the province was initiated in 1990 through the identification candidate areas that contained significant old growth resources. At that time, the *Strategy Toward Old Growth*[1] identified the Prince George ICH forests as candidates for deferment. In 2000, the Interior Cedar Hemlock Stewardship Conference held at the University of Northern British Columbia outlined the scientific basis for prioritizing biodiversity planning in the ICH[2]. During the second timber supply review (TSR) the Chief Forester noted the significance of the forests in the ICH and directed staff to complete landscape unit planning for the area[3].

In 2002, old growth management for three landscape units in the ICH was undertaken, resulting in the legal establishment of OGMAs. In 2004 the "Order Establishing Landscape Biodiversity Objectives for the Prince George Timber Supply Area" (hereafter the '*order*') was legally established. This *order* was based on the ecologically derived landscape units that are driven by common natural disturbance regimes and ranges of natural variation (DeLong, 2007). These 'Natural Disturbance Units' (NDU) provided the framework for old forest representation targets, similar to the approach taken in the 1995 Biodiversity Guidebook and the subsequent 1999 Landscape Unit Planning Guide. These units were felt to better separate areas based on differences in disturbance processes, stand development, and temporal and spatial landscape pattern (DeLong, 2007). These old forest targets in the *order* have guided non-spatial old forest management in the project area since 2004, which has since experienced further development in areas considered biologically significant under a replaceable forest license issued in 2000.

The implementation policy of the *order* indicated that further clarification of the definition of old forest in the ICH was needed to adequately implement its provisions. This guidance will move toward implementation of those provisions. Those provisions, consistent with the biodiversity guidebook and the principals of ecosystem management, insist that not only old forest be maintained, but old forests across the range of site conditions that are present in a given ecosystem.

Since the previous TSR, and the issuance of a replaceable forest license in the ICH partition, additional research has been completed which has identified the specific characteristics found in rare and representative old forests in the ICH. Consistent with the recommendations of the previous TSR, this assessment and risk analysis will inform spatial management of biodiversity resources and may enhance forest stewardship in the region through the identification of rare and representative old forest types for potential management as OGMAs. This guidance may further management in the

[1] See "Towards and Old Growth Strategy: Short Term Deferrals for Old Growth Protection" Recommendation of the Conservation of Areas Team Sub-Committee. September 5, 1990.

[2] See: http://wetbelt.unbc.ca/publications.htm

3 The TSR 2 rational states that the "Protection of several rare biogeoclimatic site series may be required beyond that currently provided and modeled in the base cases…. I encourage staff to complete landscape unit planning objectives for the ICH to ensure that rare biogeoclimatic sites series are identified and protected in OGMAs. I also encourage and support the on-going research being conducted in the ICH. This research will help improve forest management policies and practices, which can be reflected in future timber supply analyses."

ICH in a manner consistent with; existing policy, relevant science, and will positively contribute to the ecological resilience of the area.

5.3 Rational for Spatial Old Growth Management in the ICH

The *Biodiversity Guidebook* states that “given the high degree of ecological variability in our forests, managers need to consider biological diversity on a site-specific basis.” The concept behind this recommendation is well documented in scientific literature. Because ecosystems exist at multiple spatial scales, conservation of biodiversity at multiple scales increases the chances of success (Poiani *et al.*, 2000). Maintaining representative ecosystems in suitable abundance and distribution across watersheds, landscapes and regions may be the only way to maintain these species and processes (Franklin, 1993). This assessment and risk analysis will clarify the importance of the project area globally and the key indicators of rare and important forest types that are required for representation to maintain ecosystem function. This assessment will assist in the identification of rare and representative ecosystem types in the ICH and recommend areas that may, in future, be designated as OGMA’s or, in the interim, provide guidance to managers for use in the implementation of the existing *order*.

5.4 Requirements for Old Forest Representation in the ICH Forests

The ICH forests in the Prince George forest district have been classified as inland temperate rainforests based on climatology and plant complexes also found in coastal temperate rainforests (Goward and Spribille, 2005). This is important as this rainforest ecosystem type is highly disjunct and globally rare, accounting for less than 0.5% of the world’s forest area (Goward and Spribille, 2005). Globally, the Pacific Northwest contains the majority of this rare forest type. The inland rainforest region occurs primarily in British Columbia and, in many ways, the flora that occur is many times richer that that of coastal temperate rainforests. Within this forest type (ICH), there are stand types that are very limited in spatial extent, in particular wet cedar sites in the northern extent of the zone ($ICHvk_2$). The inland temperate rainforest therefore represents a very small portion of this 0.5% area.

These stands contain flora and fauna similar to that found in coastal temperate forests, hence their classification as rainforests. A key indicator of this ‘rainforest’ type is the presence of epiphytic lichens, which require specific in canopy humidity, long ecological continuity (i.e. long time spans between disturbance) and are made up of trees regenerated through gap dynamic processes (Goward, 1994). Lichen sensitivity to the subtle environmental conditions required for their establishment in old growth forests make them an appropriate indicator for these rainforest conditions (Kershaw, 1985). Recent studies concluded that 40% of oceanic epiphytic lichens occurring in coastal temperate forests also occur in the inland rainforest area (Goward and Spribille, 2005) indicating a strong correlation between the two systems. The northern ICH forests experience an even higher correlation of common lichens (91% at similar latitudes) then the southern ICH zone, further indicating the conditions needed to assign rainforest classification to the area. In particular, a recent study showed a strong correlation between the presence of specific cyanolichens in ICH old growth stands that did not occur in ICH younger stands (Radies and Coxson, 2004), further supporting the use of lichens as an old growth indicator. The presence of specific lichen species and the strong indications that ICH forests are part of a globally rare forest type are of particular relevance for the project.

Old growth forests in the ICH region are characterized by large Cedar and Hemlock trees, some >600 years old. A fire return interval of 600 years provided the basis for old forest representation targets for use in the ICH NDU's (DeLong, 2004). However, through carbon dating soil samples, fire intervals up to 1200 years were found in some $ICHwk_3$ areas, indicating similarities to old stands found in coastal rainforest areas (Sandborn *et al.*, 2006). The $ICHvk_2$ (NDU 23) is the wetter of the two ICH variants in the project area, therefore may contain sites with longer disturbance return intervals. These areas of very old trees are maintained through unique mesohabitat heterogeneity (i.e. lack of summer moisture deficit) (Newmaster *et al*., 2003) and contain high levels of species diversity. The spatial pattern of these biologically valuable forest areas will therefore be dispersed across the landscape on receiving sites (i.e. toe slope positions) that will not have been affected by fires that would otherwise affect drier sites (Coxson, 2007). These unique stand conditions should be represented at appropriate levels to maintain the genetic and species diversity that characterizes old stands in the project area.

The oldest stands in the ICH have been classified as 'antique' (Goward, 1994, cited in Coxson *et al.*, 2006) in recognition of the fact that some stand attributes continue to develop well after the attainment of old growth status at approximately 140 years. Generally antique forests are those that have not experienced major disturbance events over a period of time greater than the age of the oldest trees in the stand (Coxson, 2007). Indeed findings showed that the development of old growth characteristics that support cyanolichens growth, which are a primary indicator of old forest in the ICH Goward and Arsenault, 2001), take well in excess of 120-140 years to develop (Radies and Coxson, 2004). These antique stands support many lichen species not found elsewhere in regional landscapes, and are commonly found on toe slope positions, where moist nutrient rich soils favor tree growth and limit their susceptibility to fire (Coxson *et al.*, 2005).

5.5 Methodology for Locating Rare Sites

Old growth management that does not include areas of advanced old growth structure on wet, rich Cedar leading sites will fail to maintain certain stand characteristics, and increase risk to biodiversity (Holt *et al.*, 2002, Goward and Arsenault, 2000,). Currently certain elements of the ecosystem are not represented at the thresholds indicated in the *order*. In particular some rare sites, including those with rare cedar, require careful planning to ensure their adequate representation.

The map in appendix 1 was developed to locate these sites, and will provide valuable guidance to operations in the ICH. It used the key indicators outlined above. These biodiversity indicators include; slope position, relative soil moisture, leading species composition, age class, aspect and crown closure. Two of the current available datasets; Vegetation Resource Inventory (VRI), and Predictive Ecosystem Mapping (PEM), contain some of the information required for this analysis. However, both of these data sets have accuracy problems that were addressed using additional tools. To overcome these inaccuracies three custom datasets were developed to produce a result that would more accurately predict locations containing desired stand elements. Those three datasets are Topographic Position Index (TPI), Topographic Wetness Index (TWI) and Aspect.

The combination of VRI, TPI, TWI, Aspect and PEM allows for the definition of parameters that then assign a predictability value to specified areas. The resultant indicates areas with a high probability of containing desired rare stand attributes, and medium probability of containing these same attributes. These areas have been verified and adjusted through detailed field surveys.

5.6 Current Policy Instruments used in the Management of ICH Forests in the PG LRMP

The most significant policy instruments used to manage old growth resources in the ICH are legally established spatial OGMAs in three landscape units and the regional non-spatial *order* that sets old forest representation targets for the NDU's in the project area. The current definition of old in the '*order*' are those >140 years, however in the case of the ICH, old forests are more appropriately classified as >250 years[4]. Currently the old forest target for both NDU 22 and 23 is 53%[5]. This is primarily based on forest cover age class and is considered non-spatially in the *order*. While not included in the *order*, the implementation policy directs that retained old forests should also be representative of the ecosystem, consistent with best management and a strong scientific consensus. What constitutes representative and adequate old forest was identified as an outstanding issue in the *order* and in the previous TSR. This document offers some clarity on that definition and indicates that certain forest types are a risk of being under-represented, which is a primary driver for this guidance.

Other regulatory tools include the *Identified Wildlife Management Strategy* (IWMS). In 2006, the ICH vk_2 05 ecosystem was listed on the IWMS *Accounts and Measures for Managing Identified Wildlife*. While the ecosystem is red listed by the BC Conservation Data Centre, it is not classified as a species at risk under the *Wildlife Act*, and does not have any general wildlife measures established through the *Government Actions Regulation* that would require a result or strategy in a Forest Stewardship Plan. In addition to the ecosystem itself, a number of rare lichen species occurring in these forests have recently been discovered and are known to only occur in the northern portions of the ICH at this point in time. These species may be the first of many unknown species that contribute to the unique biological diversity of the area (Goward pers. comm., 2007). The status of these species is currently being reviewed, and may likely be classified as rare and subsequently listed in IWMS or COSEWIC in the future.

An additional tool for old growth management is the *Landscape Unit Planning Guide* (LUP) which provides guidance for the delineation of OGMAs. The LUP recommends that OGMAs should primarily occur in the non-contributing land-base, while maximizing contributions to biodiversity conservation. The LUP notes that rare site series should be captured wherever possible, and contains special provisions to ensure rare areas are represented in OGMAs. These provisions include the ability to establish OGMAs in previously approved cutblock's and an ability to place OGMAs in the Timber Harvesting Land-Base (THLB) when the location of the rare site is known. In the case of the

[4] The PG Biodiversity Order alluded to further discussion defining old forest for the ICH. While no formal discussion has occurred since the order was made legal in 2004, published science reviewed in this analysis, as well as discussions with experts confirms that old forests in the ICH would more appropriately be classifies as old growth in stands that are well beyond 600 years.

[5] This target includes parks and protected areas in the region, which under the guidance of the LUPG and the order, contribute to old growth targets. Currently, a total of 23,545 ha in NDU 23 and 10,507 ha in NDU 22 are located in legally designated reserves.

ICH these conditions with respect to rare sites, are met and should inform biodiversity management in order to maximize contributions to the maintenance of biodiversity and ecological resilience.

The current policy framework contains some gaps that create a risk to biodiversity resources in the project area. These gaps were highlighted in TSR 2 as well as the implementation policy of the *order*. This guidance has presented information on the representative ecosystem types that are required to maintain the ongoing functionality of the ICH forests.

5.7 Risk Analysis

A combination of GIS analysis, digital imagery and field verified data was used to construct a predictability model that identified the rare cedar stands that are considered 'Antique' as demonstrated by literature, and have a demonstrated high level of social significance. The analysis was also used to identify a range of risks to these stands. Available literature on the risks associated with different thresholds of landscape level retention was also reviewed in relation to the old forest representation targets.

The scientific information for old forest representation in the project area, based on the range of natural variation, indicated a range between 76% and 84% (DeLong, 2004). However, a 1.4% impact in the allowable cut was determined to be reasonable while still maintaining adequate levels of biodiversity. Thus an old forest target of 53% was established (DeLong, 2007) in the ICH. The legal portion of the *order* does not specify the exact nature of those stands retained for old forest purposes, rather only specifies that the age of the stand be greater than 140 years. It is difficult to quantify the risk, if any, between the differences in these different levels of old forest representation, however the nature of these forests and their associated sensitivity to environmental change (Benson, *et al.*, 2002, Coxson and Stevenson, 2004, Radies and Coxson 2004) indicates some risk to their on going persistence should further resource development occur.

The implementation policy of the *order* does specify that stands retained should be representative of the range of ecosystems that exist in the area, although measures to verify this have not been developed. The GIS analysis, which predicted the location of rare antique stands, indicated that past and planned harvesting was concentrated in areas that have a high likelihood of containing antique stands. The analysis indicated that 9.2% of the currently planned harvesting occurs in areas with a high probability of containing antique stands, which are already very limited extent on the land-base. Further analysis indicated that a high degree of past harvesting was located directly adjacent to areas having a high probability of containing antique stands. The Highway 16 corridor is also directly over top likely antique stands as indicated by the nature of the adjacent stands in the analysis. The combination of these results indicates that representation of these highly unique and spatially limited stands is below the current old forest representation threshold. This may pose serious risks to biodiversity, given these stands significance to ongoing ecosystem functionality as indicated by reviewed literature.

The GIS analysis also examined the level to which current reserves (OGMA, Parks, and Protected Areas) captured areas identified as rare antique stands**.** Currently, in the Crown Forest Land Base within the project area, 84% of the areas identified as having a high probability, and 81% of those with a medium probability of containing antique stands, are outside existing reserves. Correspondingly, the amount of areas containing stands with lower biodiversity value constitutes the majority of area in current reserves. The combination of these results indicates that antique stands, or those playing a disproportionate role in biodiversity and the maintenance of ecosystem function, are under-represented in current reserves.

The data required for the identification of old forests to the extent required to maintain ecological resilience is complex. The Landscape Unit Planning Guide and *order* rely primarily on age class and forest cover data in the identification of old growth resources. However, overwhelmingly research indicates that in the case of the ICH, additional information is required to accurately identify priority old growth that contributes significantly to biodiversity. For example, a study that developed criteria for the identification of old growth in the southern ICH completed in 2000 revealed that only 53% of the age estimated in forest cover information were correct as verified by field sampling (Holt, et al. 2002). Harrison et al. 2002 found that between 20% and 40% of the age estimates used in old growth analysis were incorrect, which introduces serious miscalculations into old growth identification. Using age in isolation to locate old growth stands will not differentiate between very old or 'antique' stands (>500) or between high and low structure old growth stands (Holt *et al.*, 2002) which presents a risk to successful biodiversity management[6].

Arsenault and Goward (1999) suggest that old growth forests of the ICH are at risk. They assert that their future contribution to biodiversity may be diminished resulting from a combination of factors including; their limited spatial distribution, their sensitivity to climate changes, and their association with highly productive sites and the historic correlation between productive sites and logging development. Indeed, the likely locations of high biological value sites typically render them easily accessible for harvesting and vulnerable to disturbance from road building (Arsenault and Goward, 2000). An assessment of the location of logging disturbance since 2000 with known rare sites indicates a strong correlation between the two, presenting a significant risk to biodiversity. The results of the GIS analysis and risk assessment confirm these findings.

The legal target threshold for ecosystem representation differs from DeLong's literature, but represents a reasonable risk to biodiversity in the area. The literature on the thresholds of habitat suggests that the effects of habitat loss is the primary cause of species decline and recommends that retaining sufficient habitat structures at both the stand and landscape level is the best strategy to mitigate declines in populations and species (Dykstra, 2004). In this project, the rare antique stands being focused on require specific habitat to maintain integrity and stability over time. Species dependent on old forest habitat, (i.e. lichens, caribou) may be impacted at differing thresholds of habitat supply. While a higher threshold, that is, a greater proportion of ecosystem representation at landscape and watershed scales is supported by literature, it may not satisfy the socio-economic needs for the area. However the 53% threshold, allocated across the range of site series, including

[6] The GIS analysis for this project developed a series of models based on demonstrated indicators of rare antique stand attributes. Among the most important indicators of rare old growth in ICH forests are stand moisture regime and slope position, the presence of lichens and other rare plant complexes, and micro-disturbance regime that differs from adjacent stands (Arsenault, 2004). Verification of the analysis included imagery assessments, recent field data correlation and a comparison to a recent UNBC analysis attempting to identify wet cedar stands. The combination of the GIS analysis, verification of that analysis and subsequent field checks will ensure a high level of accuracy in identifying these stands.

these rare sites, is likely required to maintain the areas characteristics for public benefit over the long term.

There is a significant risk to the long term ecological integrity of forests throughout the province stemming from increased natural disturbances resulting from climate change (Kurzet al. cited in Volney 1995). Studies indicate that fire severity, susceptibility to insects and pathogens, and drought may increase in North America as result of increasing temperatures (Dale et al. 2001). Changes in climate conditions are particularly important in the management of old ICH forests, as they depend on a stable moisture regime that maintains their species richness. Literature indicates the potential for large pest occurrences to increase with temperature (Hunt *et al.,* 2006). The need to enhance the ecological resilience, or the capacity of the ecosystem to absorb stress and recover to a similar condition following disturbance (Haeussler et al. 2006, Gunderson et al. 2002) is therefore critical. The conservation of a diversity of functional ecosystem groups and appropriate levels of species richness are the primary tools to maintain ecological resilience (Noss, 2002;Drever *et al.,* 2006; Berryman, 1993;Kohm and Franklin, 1997).

This discussion of risk likely represents only a portion of the potential risks associated with the ecological integrity of ICH forest types. Some studies concluded recently indicate the potential for single-tree and group-selection silviculture systems to maintain old growth structure (Benson *et al.,* 2002; Coxson *et al.* 2005), but researchers caution that even alternative siliviculture systems together with the cumulative impacts of settlement and environmental change may create stresses in the system that impact its functionality.

This cumulative risk necessitates a robust biodiversity strategy. This guidance and the areas mapped in appendix 1, in the opinion of government, represents the best available information on biodiversity management of the rarest forest types in the ICH. Allocation of old forest targets in the remaining wet cedar stands, or those identified as having medium biodiversity value on the map in appendix 1, would also be appropriate given the emerging science on their importance. The guidance is intended to be incorporated into operational planning by forest licensees and BC Timber Sales and in the medium term assist decision makers in further biodiversity planning in the area.

6.0 Socio-Economic Values

Socio-economic values are helpful in ascribing the appropriate costs and benefits related to the use of biodiversity resources and can inform policy decisions about their management. Generally there are two themes of values associated with the forests in British Columbia, that of use and non-use values. Use values are considered here as the timber and recreation values normally associated with forests in BC. Non-use values are considered those ecological goods and services (e.g. conservation of old growth, carbon sequestration and biodiversity), which, though widely present in BC forests, do not normally have an associated market price. To follow is a discussion on the economic values found in ICH forests. By no means is this a comprehensive assessment, rather presented for discussion purposes to be considered by SDM's and professionals involved in the management of ICH forests.

6.1 Timber Values

This project focused on cedar leading stands and, as such, they are the focus of this timber valuation. The timber value in cedar leading stands is variable due to low lumber quality and limited manufacturing options. The license currently active in cedar lading stands has requested to transfer the volume quota remaining on their license, indicating ongoing limitations to the economic viability of harvesting in these stand profiles.

Table 3 provides a summary of the current annual harvest activity in the ICH and related economic values. The ICH partition is based on a cedar and hemlock harvest. Since there has been virtually no performance in hemlock stands throughout the life of the license, only the cedar component will be presented in the table. The spruce harvest, while not part of the ICH partition, reflects the mixed nature of the stands in the area and is presented here because of their importance for mid-term timber supply. These estimates have considered average volume recovery rates but not other operational adjustment factors, which may influence average appraisal rates. However, the table below provides a reasonable illustration of the current timber value, revenue and employment associated with current ICH harvesting operations.

Table 1 – Status of ICH Growing Stock and TRC Ltd. Harvest Operations 2000-2007 (values derived from Harvest Billing System)

	Total ICH Crown Forest Land-Base (LOWG 2007)	Total Timber Harvesting Land-Base (TSR 2)	Total THLB Cedar Leading	Total THLB Spruce Leading
Area (ha)	172,836	33,935	24,360	30,560
Volume (m3)	49,258,260	33,581,550	5,310,502	10,696,000
Average Annual Harvest (m^3/yr)			23,557	126
Annual Revenue (Stumpage/yr)			$60,240	$289,398
Person Years Employment**			23.3	14.7

**Person Years employment coefficients are derived from the Socio Economic Analysis in the Robson Valley TSR 2.

The current operation currently harvests < 0.01% of the total cedar and less than 0.01% of the spruce available in the ICH partition. The average revenue to government from operations in the ICH constitutes 0.001% of the total revenue collected in the Prince George TSA in 2006. Based on 2002 statistics, the TRC operation constitutes approximately 8% of the total employment (direct and indirect) in the Robson Valley TSA.

The areas currently constrained in the ICH are considered in the *Timber Supply Impact Analysis* in section 6.0. The economic implications of these constraints were based on the *Timber Supply Analysis for the Forest Practices Code Act 1998*, which capped the magnitude of impact for biodiversity management to 4.1%. The analysis completed through the *order* concluded that these constraints amounted to an average of 1.4% impact on long-term timber supply in the PG TSA. This 1.4% does not reflect the impact in the ICH area specifically but it considered here for discussion purposes. Based on the average volume harvested over the past seven years in the ICH, a 1.4% reduction due to the *order* would be equivalent to ~537m^3/yr, or ~$5,104/yr in average stumpage revenue. The nature of these objectives and their impact on timber supply will become clearer through the timber supply review currently underway for the Prince George TSA.

6.2 Recreation Values

The value of nature based tourism and recreation has been growing steadily in North America at over 4% per year. In British Columbia, for the 2004 fiscal year the tourism sector generated over $10 billion in revenue and accounted for 1 in 13 jobs. A number of studies in Canada have attempted to quantify the value of recreation on a given area of forest land. In two studies examined, values for recreation services range from $17.04/ha (Kooten, 1995) to $18.53/ha (Anielski, 2005) annually. If the value of the Crown Forest Land-base in the ICH is considered in a recreation context, based on the above value ranges, it could be equivalent to between $2,945,125/yr and $3,202,651/yr. Considering the average annual harvest in the ICH as a common measure, the recreation value of the harvested area may be $810,672 annually. This can be considered as the opportunity cost, or value of recreation resources forgone should harvesting continue.

6.3 Conservation Values

In addition to timber and recreation use values, ICH forests contain significant non-use values, which should be considered. The non-use values associated with forest reserves can include option, existence and bequest values. These are values that assess individual willingness to pay for the reserve for use sometime in the future (option), the value a person assigns to the knowledge that the reserve exists (existence), and the value of the knowledge that a future generation could benefit from the reserve (bequest). In addition, the ICH forests include significant non-use values in the form of ecological goods and services. All of these values are difficult to quantify for the ICH specifically, but studies in similar jurisdictions are relevant and will be considered here.

In a 1995 study, a range of non-use values were determined for an old growth reserve proposal in the southern ICH zone. In a separate study for the Canadian boreal forest, a range of values for various ecological services were calculated. These included forest carbon storage, carbon sequestration, pest control, and biodiversity. Table 2 below summarizes some of the non-use values present in the ICH.

Table 2 – Summary of some non-use values estimated for ICH forest lands.

Ecological Good or Service	Estimated Value/ Hectare	Value for total CFLB Area in ICH Partition	Value of CFLB currently constrained	Area of CFLB in Guidance OGMA
Option, existence and bequest value	$18.10	$3,128,331	$1,646,756	$94,554
Estimated value for non-use values	**$1,123**	**$194,094,828**	**$102,100,914**	**$5,889,012**
Average value carbon services	$6,244	$1,079,187,984	$567,691,992	$32,743,536
Forest bird-pest control service	$21.84	$3,774,738	$1,985,649	$114,529
Biodiversity conservation	$16.81	$2,905,373	$1,528,332	$88,152
Total estimated value for non-timber goods and services	**$6,282**	**$1,085,755,752**	**$571,146,876**	**$32,942,808**

The table above cannot be considered at face value. The values for non-use elements of forest resources are difficult to measure and quantify. However since the values above are derived from Canadian studies in areas of similar conservation value, they can give an approximate estimate of the opportunity costs of utilizing ICH forests for purposes other that forest development. As shown in the table, these non use values may be significantly higher than those of use values, as such warrant consideration.

6.4 Multiple Economic Values Analysis – Discussion

Professionals and Statutory Decision Makers often consider the economic values associated with a resource during management deliberations and operational strategy development. This information provides a more comprehensive assessment of the different values present in ICH forests.

Table 3 examines the differences in the use and non-use values associated with the values presented in this section. The short term implications these guidance Old Growth Management Areas may constitute a cost in terms of government revenue from timber. However these losses must be considered in a context of marginal, if not negative performance in ICH stand profiles. In the long term, non-use values are significantly greater than those of use values. This is supported in section 4.0 which demonstrates a strong scientific consensus on the importance of non-use values in the ICH, and the risks that development poses to their ongoing persistence. Given the discussion of values above, biodiversity management consistent with this guidance and the map in appendix 1, may in fact support alternative uses of the ICH, which may contain significantly more value in the long term.

Table 3 – Comparison of use and non-use values for Guidance OGMA.

	Total Crown Forest Land-Base (CFLB/OGMA)	Total Timber Harvesting Land-Base (THLB/OGMA)*	Total THLB/OGMA Cedar Leading	Total THLB/OGMA Spruce Leading
OGMA Area (ha)	4,827	3,772	2,687	407
Short Term Volume (m^3)	1,494,540	1,138,860	615,120	178,150
Long Term Volume (m^3/ha/yr)	12,068	9,430	5,248	1,425
Short Term Projected Revenue Loss ($)	$14,191,725*	$10,814,289*	$1,572,950	$3,477,488
Long Term Projected Revenue Loss ($/ha/yr)	$114,590*	$89,545*	$13,880	$27,806
Opportunity Cost for average non-use values ($/ha)	$5,420,721	$4,235,956	$3,017,501	$457,061
Opportunity cost for total non-timber values ($/ha)	$30,323,214	$23,695,704	$16,879,734	$2,556,774

* These values are based on average blended stumpage rates for the ICH, which may not reflect operational realities. There are presented here for relative comparison and discussion.

7.0 Timber Supply Impact Analysis

This timber supply analysis will indicate how this guidance and the map in appendix 1 will affect available the current timber harvesting land-base in the Interior Cedar Hemlock (ICH) partition of the Prince George Timber Supply Area (PG TSA). While the scope of this guidance includes the entire ICH in the PG TSA, the map in appendix 1 is focused specifically on the rarest stand types. Biodiversity management encompassing additional areas categorized as medium biodiversity value on the map in appendix 1 is appropriate given emerging science, as discussed in section 4.0. It is important to note that the various harvest forecasts and projected volume flows included in this analysis indicate only the timber supply implications of guidance OGMA indicated in appendix 1 and are not allowable annual cut determinations. The values used in this analysis have been derived from data used in TSR 2 and the Ministry of Forests and Range.

7.1 Base Case Values used in the Analysis

The Prince George TSA covers approximately 7, 508, 000 hectares in the north central interior of BC of that there is 5, 327, 000 ha (71%) that is considered productive forest. Currently 64% of the productive forest, or 45% of the total TSA area, is considered available for harvesting under current forest management practices. The TSA is summarized in Table 4.

Table 4 – PG TSA Summary (ha)

PG TSA Total Area	Total Productive Forest	Total THLB	Total ICH Partition THLB
7, 508, 000	5, 327, 000	3,378,600	117, 830

The Interior Cedar Hemlock (ICH) zone has a small occurrence in the eastern part of the TSA at lower to mid elevations. Within this zone there is approximately 117, 830 ha contributing to the timber harvesting land base. Within this 117, 830 ha, TSR 2 determined that there are approximately 73, 600 ha of stands where cedar or hemlock is the dominant species of which 37, 900 hectares are currently considered unsuitable for harvesting due to steep terrain, riparian buffers, tree quality economics and environmental sensitivity. This TSR determined that 23,700 hectares of leading cedar stands and 12 000 ha of hemlock are available for harvest.

This OGMA analysis used VRI data to determine species composition in order to be consistent with the TSR 4 process currently underway for the PG TSA. Also, while the analysis examined hemlock stands for completeness and consistency with available literature, hemlock was not included in the timber supply analysis consistent with assumptions being applied in the TSR 4.

The VRI data indicates that 24,342 ha of Cedar leading stands are available for harvest in the ICH (THLB). Although the TSR partition for the ICH does not include spruce, this analysis did for completeness and in light of the importance of the area for mid-term timber supply. Within the ICH area 30,413 ha of leading spruce stands are contributing to the timber harvesting land base.

An analysis of harvest flow within the ICH was broken in to short and long term periods. The analysis used m3/ha and m3/ha/yr values derived from the TSR base case, and reported volume recovery in Cedar stands by licensees operating in those profiles for that past 7 years. This data was reviewed by the MoFR. The values for existing volume in cedar leading stands are 220 m3/yr. The mean annual increment based on the TSR base case is 2.02 m3/ha/yr. The value for existing volume in spruce leading stands is 350 m3/yr. The mean annual increment based on the data from the MoFR is 3.00 m3/ha/yr. It should be noted that the VRI reported volumes were much lower than those used in the analysis. Based on the total area of cedar and spruce leading stands in the ICH partition, total available volume in existing stands is indicated below in Table 5.

Table 5 – VRI Derived Values for ICH Partition

Leading Species	TSR Base Case Area (THLB) (ha)	VRI Area (THLB) (ha)	Total (VRI) Volume Existing Stands (m_3)
Cedar	23,700	24,342	5,355,240
Spruce	Not included in Partition	30,560	10, 644, 474
Total Cedar and Spruce Leading Stands	23,700	54,902	15,999,714

7.2 Guidance Old Growth Management Areas - THLB Impacts

The timber supply analysis for this guidance was broken into a number of different themes to present an accurate and complete assessment. Section 4.0 outlines that very old Cedar stands primarily located in the vk_2 variant contain rare ecosystems, and, are currently underrepresented in reserves. As such the timber supply analysis examines the impacts of OGMA in the cedar leading THLB. The guidance is also conscious of the importance of the area for mid-term timber supply, specifically with respect to leading spruce stands. Therefore, the analysis also examines the impact of OGMA guidance on spruce stands.

Table 6 provides an analysis of the total area in each contributing class. This was broken into leading species. The TSR 2 THLB dataset was used in conjunction with the updated VRI dataset. The volume values use that same m_3/ha multipliers discussed above.

Table 6 –ICH Partition Area Analysis

Reporting Unit	Total THLB Area (ha)	Cedar THLB (ha)	Cedar THLB Volume (m3)	Spruce THLB (ha)	Spruce THLB Volume (m3)	Cedar CFLB (ha)	Spruce CFLB (ha)	Cedar NCLB (ha)	Spruce NCLB (ha)
Vk2	95,355	19,720	4,333,459	23,120	8,040,476	32,658	36,804	13,887	18092
Wk3	22,475	4,622	1,016,871	7,440	2,603,999	5,872	9,369	1,336	2827
Total ICH Partition	**117,830**	**24,342**	**5,355,330**	**30,560**	**10,644,474**	**38,530**	**46,173**	**15,223**	**20,919**

Table 7 indicates the timber supply impacts of the guidance OGMA on the total THLB in the ICH zone. It is important to note that this guidance was restricted to the ICH merged-BEC units, and does not consider areas in the SBSvk2 or the ESSF, which contain significant levels of mid-term harvest opportunity.

Table 7–Impact on Guidance OGMAs on Total ICH Partition THLB Area

Reporting Unit	Total THLB Area (ha)	OGMA Guidance Area in THLB (ha)	% Impact
Vk2	95,355	2,814	3%
Wk3	22,475	921	4%
Total ICH Partition	117,830	**3,735**	**3%**

Table 8 indicates the % impact of the OGMA guidance in cedar leading stands for the THLB in the ICH partition area. The area for THLB is consistent with the area identified through TSR 2, but was derived based on VRI data.

Table 8–Impact on Cedar Leading THLB stands from Guidance OGMA's

Reporting Unit	Cedar THLB Total (ha)	Cedar OGMA THLB (ha)	% Impact on Cedar Leading THLB
Vk2	19,720	2,187	11%
T Wk3	4,622	457	10%
Total ICH Partition	24,342	**2,644**	**11%**

The project has attempted to avoid leading spruce stands in order to mitigate any adverse effects on mid-term timber supply opportunities, an analysis of spruce THLB area within OGMA guidance is presented below in Table 9.

Table 9 - Impact on Spruce Leading THLB Stands from Guidance OGMA's

Reporting Unit	Spruce THLB Total (ha)	Spruce OGMA THLB (ha)	% Impact on Spruce Leading THLB
Vk2	23,120	232	1%
Wk3	7,440	175	2%
Total ICH Partition	**30,560**	**407**	**1%**

Table 10 indicates the total Cedar leading THLB area in each licensee operating cell that is removed by the guidance OGMA's. Table 10 is the same as table 11, but for Spruce leading stand impacts.

Table 10–OGMA Guidance Impact by Operating Cell for Cedar THLB

Reporting Unit	Data	BCTS	Canfor	Carrier Lumber Ltd.
ICH vk 2	Ha THLB	3,639	11,252	4,829
	Ha OGMA	428	1,114	652
	Impact %	12%	10%	14%
ICH wk 3	Ha THLB	4,327	0	295
	Ha OGMA	457	0	0
	Impact %	11%	0%	0%

Table 11 - OGMA Guidance Impact by Operating Cell for Spruce THLB

Reporting Unit	Data	BCTS	Canfor	Carrier Lumber Ltd.
ICH vk 2	Ha THLB	1,671	18,770	2,531
	Ha OGMA	37	60	136
	Impact %	2%	0%	5%
ICH wk 3	Ha THLB	6,717	0	723
	Ha OGMA	175	0	0
	Impact %	3%	0%	0%

Since 2002, both the *order* as well as a series of spatial reserves has been established in the area. The *order* constitutes the most significant timber supply constraint in the ICH partition as mentioned in previous sections. Both the existing OGMA's as well as those outlines in this guidance, would be implementing existing constraints in the *order*. Below is a summary of these existing constraints.

Table 12–PG TSA Biodiversity Order Analysis

Reporting Unit	Total CFLB (LOWG 2007)	CFLB Old Target Total (2004)	Total Existing OGMA in CFLB	Total Park Old Area CFLB	Total Guidance OGMA CFLB	Total Reserve CFLB Area (Guidance Included) ha	% CFLB Order target in OGMA
vk2	145,660	77,200	5,929	17,616	3,686	27,231	**18.7%**
wk3	27,176	14,403	4,733	5,774	1,084	11,591	**42.7%**
Total	172,836	91,603	10,662	23,390	4,770	38,822	

Table 12 is an assessment of the proposed OGMA's and existing reserves in relation to the legal old forest targets of 53% for each merged-BEC unit as required by the *order*. The total area from parks and previously established OGMA's is considered to provide a cumulative assessment of reserves. Other reserve types (UWR, VQO) are not considered in this analysis.

During the establishment of the biodiversity *order*, analysis indicated that old forest area in the non-contributing land base was insufficient to meet the 53% old forest target. The implementation of the *order* therefore required old forest area from the timber harvesting land-base. In the two merged BEC units in the ICH, based on FC1 Data, 31,819 ha of THLB old forest, in addition to the total

NCLB area, was required to meet the target. This analysis uses VRI data to calculate the amount of CFLB, NCLB and THLB in these merged BEC units, to determine the location and classification of areas required for old forest retention under the *order*. The CFLB definition will change with TSR 4, these values are not currently available. However, a preliminary analysis indicates that the total required CFLB required for the order in the vk_2, (77,200 ha), minus the total amount of >140 old NCLB available in the vk_2 (39,807 ha) minus the currently established reserves that are >140 years old (23,545 ha), means that additional THLB area (~13,848 ha) will be required to meet the current target in the vk_2. The area in this guidance (2,814 ha in the vk_2) is a small sub-set of what could be considered currently constrained old forest.

The analysis determined that this OGMA guidance, as well as established OGMA's and parks, do not constitute any additional impact on the THLB already accounted for in the *order*. The analysis indicates that, including this OGMA guidance both units will still require ongoing non-spatial management of old forest. The non-spatial management could be directed towards areas of high and medium biodiversity value outside reserves as indicated by the map in appendix 1.

7.3 Guidance Old Growth Management Area Volume Impacts

The overall impact of the guidance OGMA's on existing and long-term volume in the ICH partition was also completed. Overall there are 2,644 ha of cedar leading stands in OGMA guidance that occur within the THLB, approximately 2% of the total timber harvesting land base. Spruce leading stands makes up 407 ha of the OGMA guidance which less than 1% of the total partition THLB.

Over the short term, the analysis indicates that 591,140 m_3 of leading cedar stand volume may be reduced from existing stands in the THLB should this guidance be used. This represents 11.3% of the total Cedar leading stand volume in the ICH partition.

Over the short term the analysis indicates that 142,450m_3 of leading spruce stand volume will be reduced from existing stands in the THLB should this guidance be used. This represents 1.3% of the total spruce leading volume in the ICH partition.

The TSR 2 base case indicates a long term harvest flow of 60,000m_3 from the ICH partition. This flow assumes the continued contribution of Hemlock stands, but as was discussed previously, opportunity for hemlock salvage no longer exists, so this long term flow is likely to change through TSR 4. Nonetheless, using the 60,000m_3 flow level, the long term impact of this OGMA guidance constitutes a loss of approximately 8,603 m_3/yr or a 14% reduction in long term harvest flow. This was calculated using the total THLB area of OGMA guidance (3,772 ha) and the average MAI of 2.5m_3/ha/yr.

8.0 Literature Cited

Anielski, M., Wilson, S., 2005. “Counting Canada’s Natural Capital: Assessing the Real value of Canada’s Boreal Ecosystems” p. 43. Pembina Institute.

Arsenault, A., Goward, T. 1999 “Ecological Characteristics of Inland Rain Forests” Proceedings of a conference on the biology and management of species and habitat at risk. Kamloops, BC. Ministry of Environment.

Arsenault, A. 2003. “A note on the ecology and management of old-growth forests in the Montane Cordillera” The Forestry Chronicle 79(3) 441:454

Arsenault, A. 2004. “Distribution of epiphytic cyanolichens and caliciod microlichens in the upper Incomappleux river valley: implication for landscape unit planning” prepared for the District Manager of the Arrow-Boundary Forest District. Ministry of Forests. File 17210-01 (Biodiversity)

Benson, S., Coxson, D.S. 2002. “Lichen Colonization and Gap Structure in Wet-Temperate Rainforests of Northern British Columbia.” The Bryologist 105(4) 673:692

Coxson, D.S., Stevenson, S.K., 2004. “Retention of canopy lichens after partial-cut harvesting in wet-belt interior cedar-hemlock forests, British Columbia, Canada” Forest Ecology and Management. 204 (2005) 97:112.

Berryman, A.A. 1993. Food-web connectance and feedback dominance, or does everything really depend on everything else? *Oikos* 68:183-185.

Boyle, T.S.B. 1991. “Biodiversity of Canadian Forests: Current Status and Future Challenges,” *The Forestry Chronicle* 68:444-52.

Costanza, R., Daly, H., Folke, C., Hawken, P., Holling, C.S., McMichael, A.J., Pimentel, D., Rapport, D. 2000 “Managing Our Environmental Portfolio” Bioscience Vol. 52 No.2.

DeLong, S.C. 2007. “Implementation of natural disturbance-based management in northern British Columbia.” The Forestry Chronicle. Vol. 83 (3) 338:346

Drever, C.R., Peterson, G., Messier, C., Bergeron, Y., Flannigan, M. 2006. “Can Forest Management Based on Natural Disturbance Maintain Ecological Resilience?” Canadian Journal of Forest Research. 36:2285-2299.

Foster, B. 1993. “The importance of British Columbia to Global Biodiversity,” in *Our Living Legacy: Proceedings of a Symposium on Biological Diversity*, ed. M.A. Fenger, E.H. Miller, J.E. Johnson and E.J.R. Williams. Victoria, BC: Royal British Columbia Museum

Franklin, J. F. 1993. “Preserving Biodiversity: species, ecosystems, or landscapes?” ecological Applications 3:202-205

Goward, T., Arsenault, A. 1999. “Inland Old Growth Rain Forests: Safe Havens for Rare Lichens?” Proceedings of a conference on the biology and management of species and habitat at risk. Kamloops, BC. Ministry of Environment.

Goward, T., Arsenault, A. 2000. “Cyanolichens and conifers: implications for global conservation” Snow Landscape Research. 75(3) 303-318.

Goward, T., Spribille, T. 2005. “Lichenological evidence for the recognition of inland rain forests in western North America” Journal of Biogeography, 32, 1209-1219

L.H. Gunderson, and C.S. Holling, editors. “Panarchy: understanding transformations in human and natural systems”, Island Press, Washington, DC.

Lyons, K.G., Brigham, C.A., Traut, B.H., Schwartz, W. 2005. “Rare Species and Ecosystem Functioning” Conservation Biology 19(4) 1019:1024

Harrison, M., DeLong, C., Burton, P.J. 2002. “A comparison of the ecological characteristics in stands of differing age class in the $ICHwk_3$, $ESSFwk_2$, ICHmm and ESSFmm: Development of an index to assess old growth features” Prepared for the Robson Valley Enhanced Forest Management Project.

Holt, R.F.,MacKilop, D.J., Braumandl, T.F. 2002. “Defining old-growth forests in the $ICHwk_1$ BEC variant in the Nelson forest region.” Prepared for the Revelstoke Community Forest Corporation, Downie Street Sawmills and Pope and Talbot.

Holling, C.S., and Meffe, G.K., 1996. “Command and Control and the Pathology of Resource Management” Conservation Biology 10:328:337.

Hunt, S., Newman, J., Otis, G. 2006. “Threats and Impacts of exotic pests under climate change: implications for Canada’s forest ecosystems and carbon stocks” A BIOCAP Research Integration Program, Synthesis Paper.

Kershaw, K. 1985 *Physiological ecology of lichens.* Cambridge University Press, New York.

Kooten, G.C., “Economics of protecting wilderness areas in old growth timber in British Columbia” 1995. The Forestry Chronicle Vol. 71, NO. 1.

Newmaster, S.G.,Belland, R.J., Arsenault, A., Vitt, D.H. 2003. “Patterns of bryophyte diversity in humid coastal and inland cedar-hemlock forests of British Columbia.” Environmental Review, NRC Canada. 11: S159:S185.

Noss, R.F. 2001. Beyond Kyoto: Forest Management in a Time of rapid Climate Change. Conservation Biology Vol. 15.

Poiani, K.A., Richer, B.D., Andrson, M.G., Richter, H.E. 2000. “Biodiversity conservation at multiple spatial scales: functional sites, landscapes, and networks.” Bioscience 50:133-146.

Power, M. E., et al. 1996.“Challenges in the quest for keystones.”Bio-Science 46:609–620.

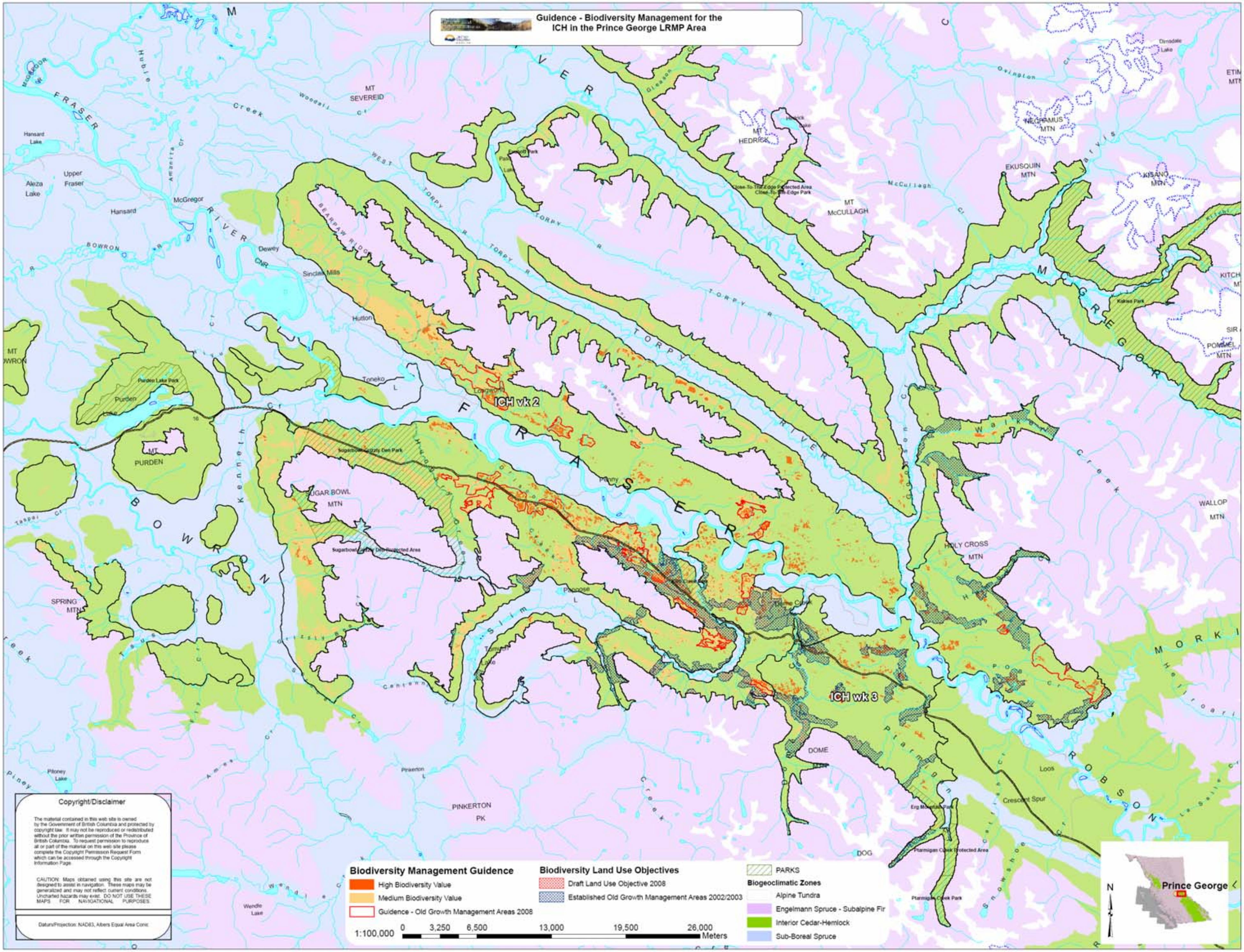
Radies, D.N.,Coxson, D.S. 2004. “Macrolichen colonization on 120-140 year old *Tsuga heterophylla* in wet temperate rainforests of central interior British Columbia: a comparison of lichen response to even-aged versus old-growth stand structures.” The Lichenologuist 36(3&4) 235-247.

Sanborn, P., Geertsema, M., Timothy Jull, A.J.,Hawkes, B. 2006. “Soil and sedimentary charcoal evidence for Holocene forest fires in an inland temperate rainforest, east-central British Columbia, Canada” The Holocene. 16(3) 415:427

Theodose, T. A., C. H. Jaeger, W. D. Bowman, and J. C. Schardt. 1996. “Uptake and allocation of 15N in alpine plants: implications for the importance of competitive ability in predicting community structurein a stressful environment.”Oikos 75:59–66.

Walker, B., Salt, D., 2006. “Resilience Thinking, Sustaining Ecosystems and People in a Changing World” Island Press. ” Island Press.

Wilson, E.O. 1988. “The Current State of Biological Diversity,” in *Biodiversity,* ed. E.O. Wilson and E.M. Peter. Washington, DC: National Academy Press.



Guidence - Biodiversity Management for the
ICH in the Prince George LRMP Area
ICH vk 2
ICH wk 3
FRASER
TORPY RIVER
McGREGOR
ROBSON
BOWRON
MORKILL
Prince George
N
Copyright/Disclaimer
The material contained in this web site is owned by the Government of British Columbia and protected by copyright law. It may not be reproduced or redistributed without the prior written permission of the Province of British Columbia. To request permission to reproduce all or part of the material on this web site please complete the Copyright Permission Request Form which can be accessed through the Copyright Information Page.
CAUTION: Maps obtained using this site are not designed to assist in navigation. These maps may be generalized and may not reflect current conditions. Uncharted hazards may exist. DO NOT USE THESE MAPS FOR NAVIGATIONAL PURPOSES.
Datum/Projection: NAD83, Albers Equal Area Conic
Biodiversity Management Guidence
High Biodiversity Value
Medium Biodiversity Value
Guidence - Old Growth Management Areas 2008
Biodiversity Land Use Objectives
Draft Land Use Objective 2008
Established Old Growth Management Areas 2002/2003
PARKS
Biogeoclimatic Zones
Alpine Tundra
Engelmann Spruce - Subalpine Fir
Interior Cedar-Hemlock
Sub-Boreal Spruce
1:100,000
0 3,250 6,500 13,000 19,500 26,000 Meters