Tunkwa Provincial Park
Vegetation Management Plan

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VEGETATION MANAGEMENT PLAN

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Summary

The vegetation of Tunkwa Provincial Park has changed greatly from past natural and human-caused disturbances. This includes the current and past mountain pine beetle outbreaks, past fire resulting from past mountain pine beetle outbreaks, extensive harvesting of Douglas-fir forests in the park, grazing by cattle, and infrastructure developments. Park managers need direction for managing the vegetation of the park in a post-mountain pine beetle epidemic landscape. The objectives of this study were:

- To provide a description of potential changes to forest structure and composition and the vegetation community over time,
- To provide a description of changes to the properties of large and small fuels for fires over time, and
- To describe the potential benefits and negative impacts of the different management options

Tunkwa Park is a heavily used park with large campgrounds and a highly valued recreational fishery in Tunkwa and Leighton lakes. Backcountry trails are used by ATV's, horseback riding, hiking, cycling and hunting. Cattle grazing has been occurring in the park since the mid-1800s, and continues today with an extensive system of fences assisting grazing management. The park also has a long and important history of cultural use by local First Nations peoples though details of this usage are not documented. A cultural heritage assessment is needed to address this deficiency.

The natural values of the park include high elevation grasslands, and Douglas-fir and lodgepole pine dominated forests, with smaller areas of spruce forest, numerous small wetlands and small sagebrush areas. There is a long history of disturbance in the park from wildfire, previous mountain pine beetle outbreaks, forest harvesting, linear developments and cattle grazing. Many of these disturbances were clearly visible on historical and recent airphotos of the park, which were compared to determine what changes had occurred to the park vegetation over a 56 year time period.

These disturbances have shaped and changed the vegetation of the park, especially by producing forests with a young age structure. Fire frequency has likely declined since the arrival of Europeans, further changing the structure and age of the forests, by allowing in-filling of previously open forests. Some encroachment of grasslands has occurred, but this has not been extensive.

Numerous wildlife species use the park including mule deer, moose, black bear, cougar, lynx, bobcat, and numerous bird species. There is a colony of yellow-bellied marmots near Bluff Lake. The lakes and wetlands support large numbers of a wide variety of waterfowl, both for nesting and during migration.

Management direction for the park recognizes the importance of natural processes, including fire, and sees prescribed fire as an acceptable management tool. Tree removal is also a management option, but to be consistent with BC Parks policy needs to be done in conjunction with the restoration of natural processes such as fire.

There will be widespread changes to the ecosystems and wildlife of the park due to the MPB epidemic; however, these effects cannot be counteracted by prescribed fire or

mechanical treatments. These management actions would create disturbances that would be additive to the current disturbance.

The make up of future forests in the park will depend on regeneration patterns following the MPB epidemic and the harvesting that occurred in the Douglas-fir stands. At current regeneration densities, over 50% of the MPB killed forests will have >500 stems per hectare, with lodgepole pine and Douglas-fir dominating these stands. The Douglas-fir stands are much more densely stocked and are dominated by young Douglas-fir trees with Interior spruce the main secondary species.

The fuels in the MPB killed stands will be declining as the red phase of the MPB attack passes. Ground fuels will increase over the next 10 to 30 years as the dead trees decay and fall. A wildfire in these heavy fuels could be detrimental to the park, as it would likely be very hot, exposing bare soil, thus facilitating establishment of invasive plant species. Establishing a fuel break near high use areas to prevent fire spreading from these areas to a larger area would diminish this risk. This fuel break could be established by tying together existing fuel breaks, such as pipeline and hydro right-of-ways.

There is no need for management actions over the areas affected by mountain pine beetle from an ecological perspective. There is no clear benefit from prescribed burning these areas to either wildlife habitat supply or in the resulting vegetation types.

The Douglas-fir forests have changed to younger and denser stands as a result of harvesting, and the subsequent regeneration processes. Thinning and pruning could promote older, open stands resembling the pre-harvest stands, but this would add additional disturbances to the forests of the park and are not recommended. These treatments are suitable over small areas, in conjunction with creating fuel breaks.

Acknowledgements

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1. Introduction

The mountain pine beetle[1] (MPB) epidemic has been changing the forest landscape across much of British Columbia. The effects of MPB are also changing the provincial parks in which many people recreate. Parks have dual purposes, conservation and recreation, so managing parks means balancing these two purposes. This is especially true in a park such as Tunkwa, where there are very high levels of recreational usage and high conservation values. Also, parks are always set in landscapes that have different use patterns than those in the park. This means that park managers must be cognizant of values outside the park that could be impacted by management activities within the park.

Tunkwa Park has been afflicted by the MPB epidemic that has been killing lodgepole pine forests through much of British Columbia. The large number of dead trees resulting from the MPB epidemic presents a number of challenges for park managers. The most significant issues in Tunkwa Park are:

- Maintaining other park values while managing for the current epidemic
- Determining what actions are needed to maintain conservation and other values in the park
- Understanding forest dynamics and future forest conditions to guide decision making

Other vegetation issues in the park include the long-term dynamics of the grasslands in the park, specifically, whether trees are encroaching upon the grasslands.

1.1. Project Objectives

The objective of this project is to provide direction to the Ministry of Environment, Environmental Stewardship Division on managing the vegetation, especially the forests, of Tunkwa Park in a post-mountain pine beetle landscape. This report has the following objectives:

- To provide a description of potential changes to forest structure and composition and the vegetation community over time,
- To provide a description of changes to the properties of large and small fuels for fires over time, and
- To describe the potential benefits and negative impacts of the different management options

This report also provides possible vegetation management options with recommendations for vegetation management treatments and a priority list of actions.

Values and uses of concern in the park are:

- Biodiversity, including vegetation, fish and wildlife
- First Nations cultural values and archaeological sites
- Park infrastructure
- Recreational values
- Adjacent private land holdings
- Cattle grazing

[1] Latin names of all species used in the text are given in Appendix 1

Management of areas close to park infrastructure and private land holdings, with recommendations for visitor safety and fire hazard abatement, was addressed in a report by Morrow (2005). These recommendations have mostly been implemented by BC Parks, so management of these values will not be discussed further. Cattle grazing is also a management issue in the park, but is dealt with in the Range Use Plan for the Guichon Creek Range Unit.

2. Study Area Description

2.1. Overview

Tunkwa Park covers 5,138 ha of forest, grassland and lakes in the Southern Thompson Uplands Ecosection. The park is located 15 km north of Logan Lake, 20 km south of Savona, and 45 km southwest of Kamloops (Map 1). Tunkwa Park was created in 1996 as a result of recommendations in the Kamloops Land and Resource Management Plan (LRMP) (Government of British Columbia 1995). A management plan background document for Tunkwa Park was written in 1997 (BC Parks 1997a), and a management plan for Tunkwa Park was completed in 1999 (BC Parks 1999a).

The elevation of Tunkwa Park ranges from 1100 m along Guichon Creek to 1350 m. Being in the rainshadow of the Coast Mountains, the area is relatively dry receiving about 400 mm of precipitation per year. The park lies in a wide, open generally south-facing basin that contains Tunkwa, Leighton and several smaller lakes (BC Parks 1997a). Tunkwa Park is in the Interior Douglas-fir dry cool subzone Thompson variant (IDFdk1), with the grasslands in the grassland phase - IDFdk1a (Lloyd *et al.* 1990) (Map 2).

2.2. Natural Values

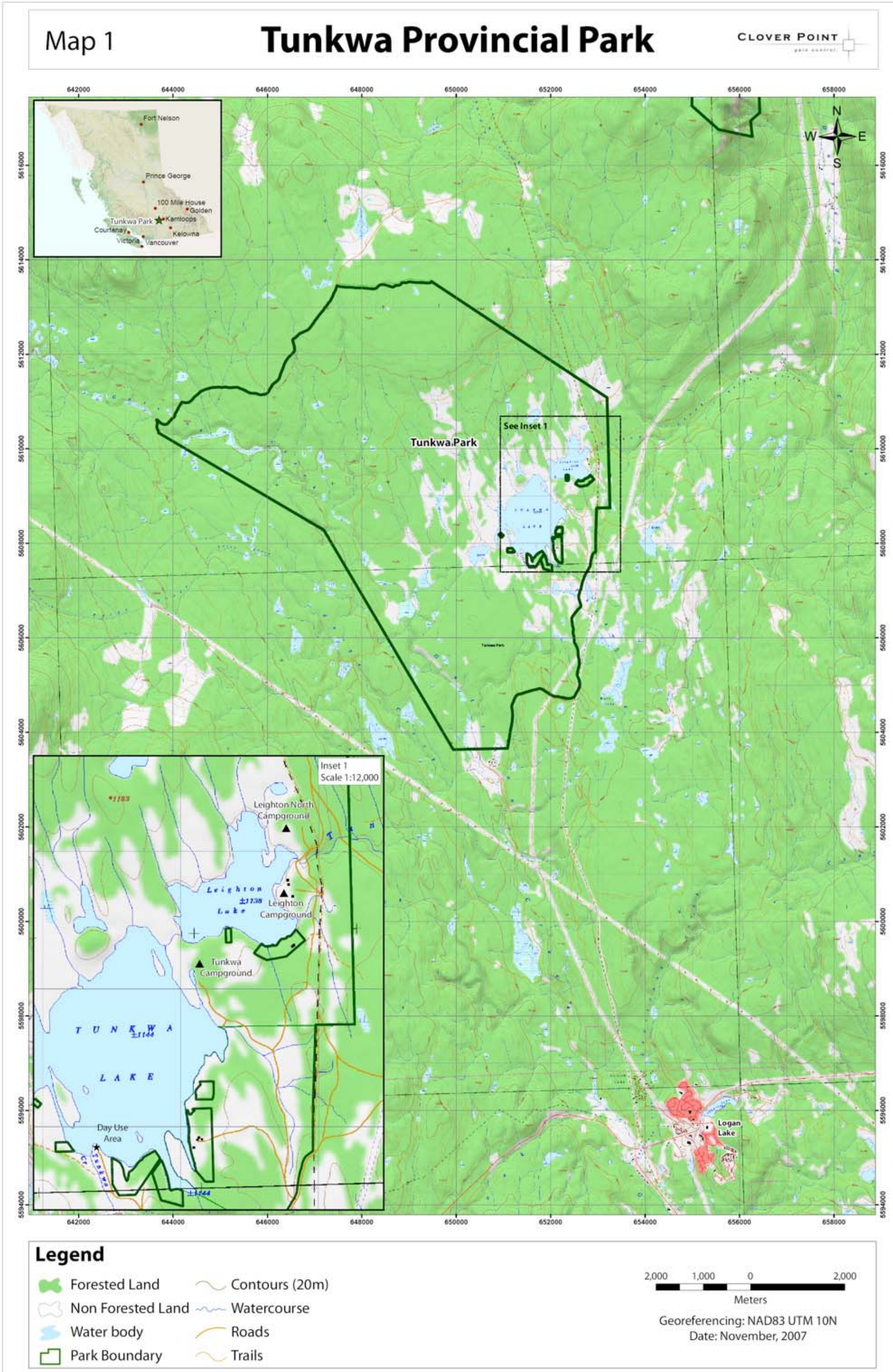
2.2.1. Vegetation

The vegetation of Tunkwa Park is a mixture of lodgepole pine, Douglas-fir, spruce and aspen forests, grasslands, small wetlands, and small areas of sagebrush and disturbed vegetation (Maps 3 and 4, Table 1). Lodgepole pine and Douglas-fir are by far the dominant forest types in the park. Interior spruce commonly forms a minor component of most forests in the park, but is dominant in wetter areas such as near waterways. Trembling aspen is scattered through some stands, with there being two areas of aspen/pine forest (BC Parks 1997a). A more detailed description of the forests is presented in Section 7.1 Present Forests.

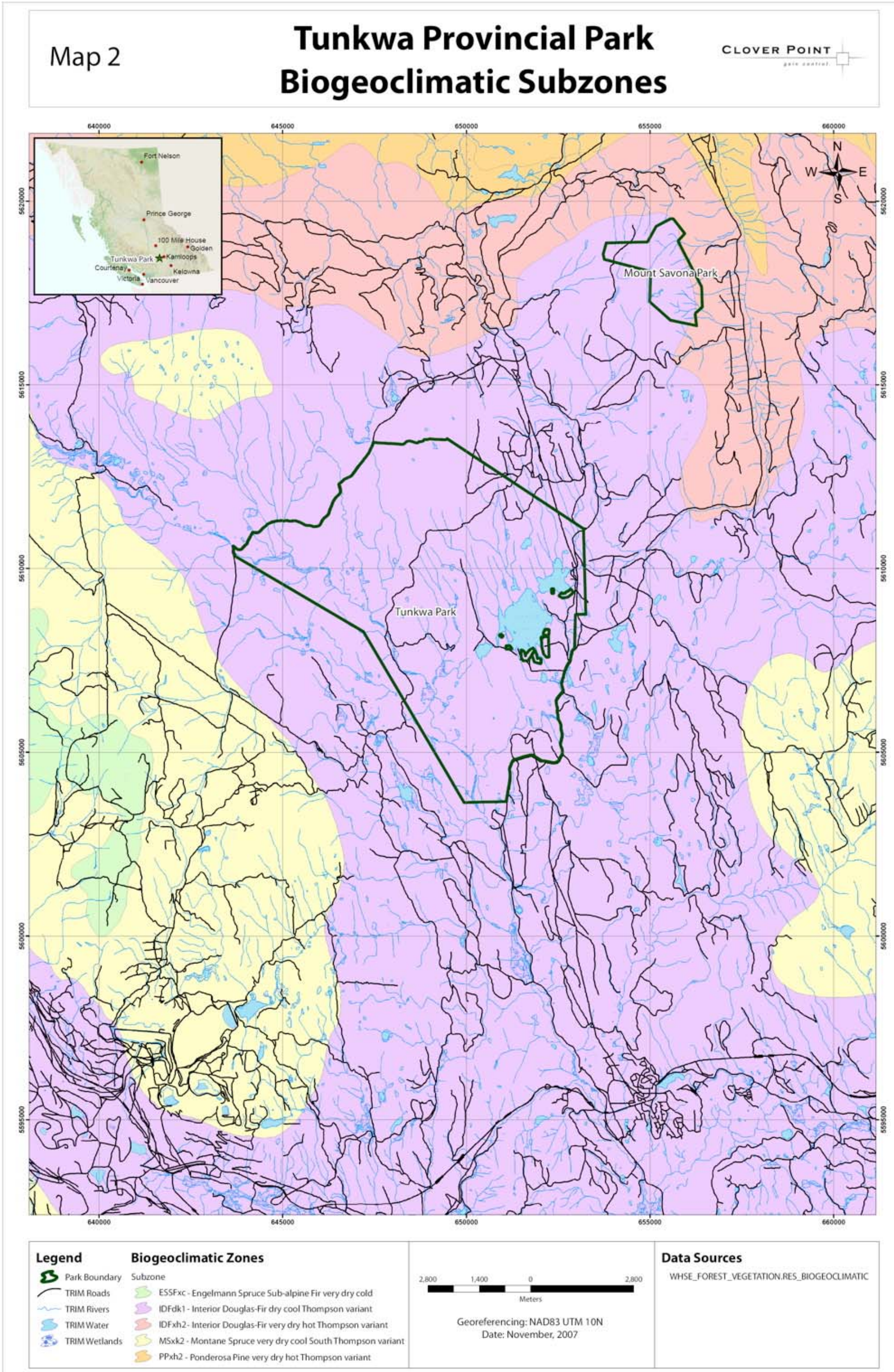
Table 1. Area of park in different vegetation types[a]

Vegetation Type	Hectares[b]	% of park
Lodgepole pine forest	2,919	56.6
Douglas-fir forest	795	15.4
Grassland	773	15.0
Interior spruce forest	271	5.2
Lake/Open water	229	4.4
Wetland	83	1.6
Trembling aspen forest	61	1.2
Sagebrush	15	0.2
Total	**5,146**	

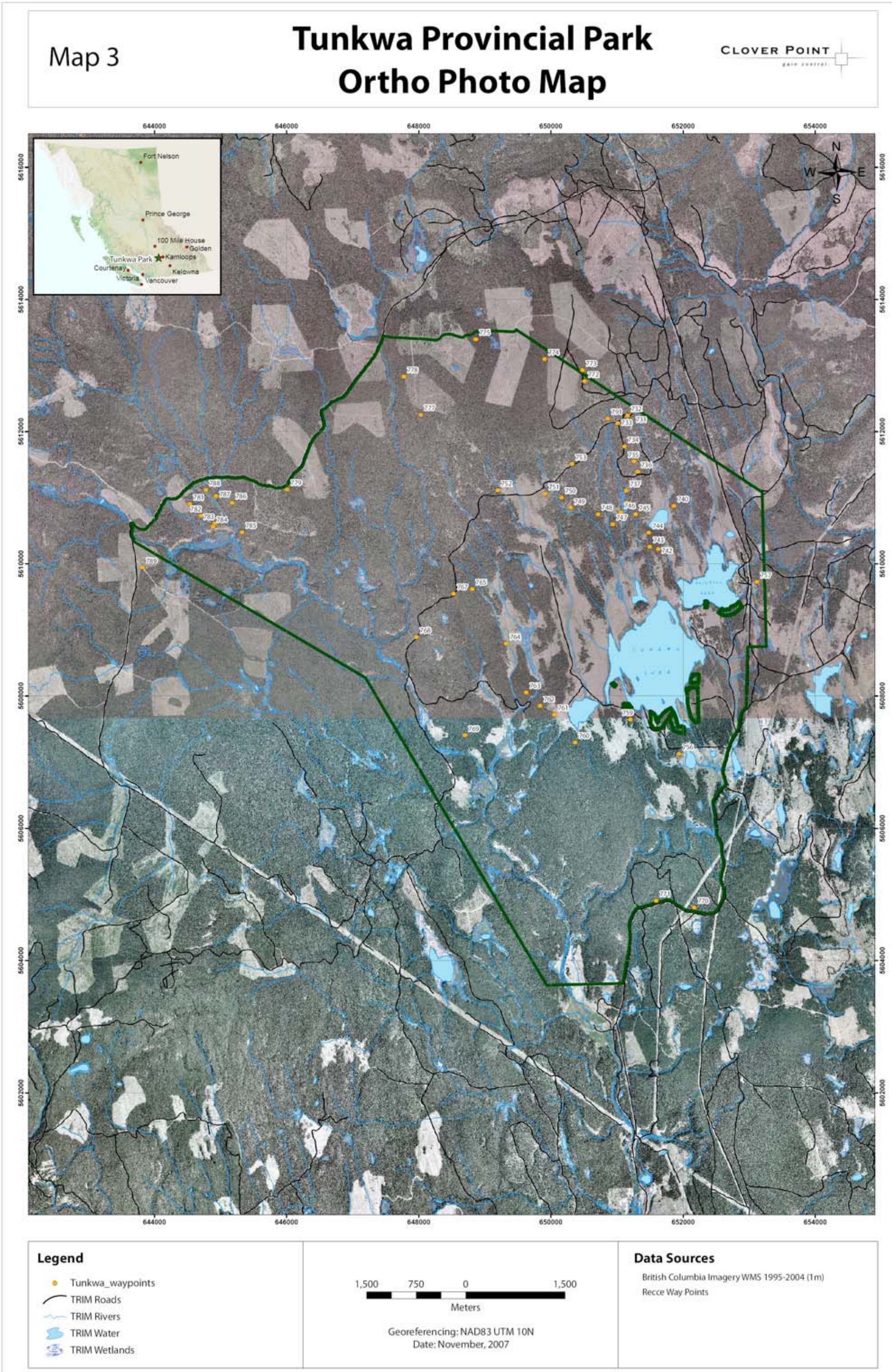
a - community types based on forest cover maps with inaccuracies corrected based on fieldwork and airphoto interpretation.
b - total area is slightly higher than gazetted park area but is based on park boundary layer in the provincial database.



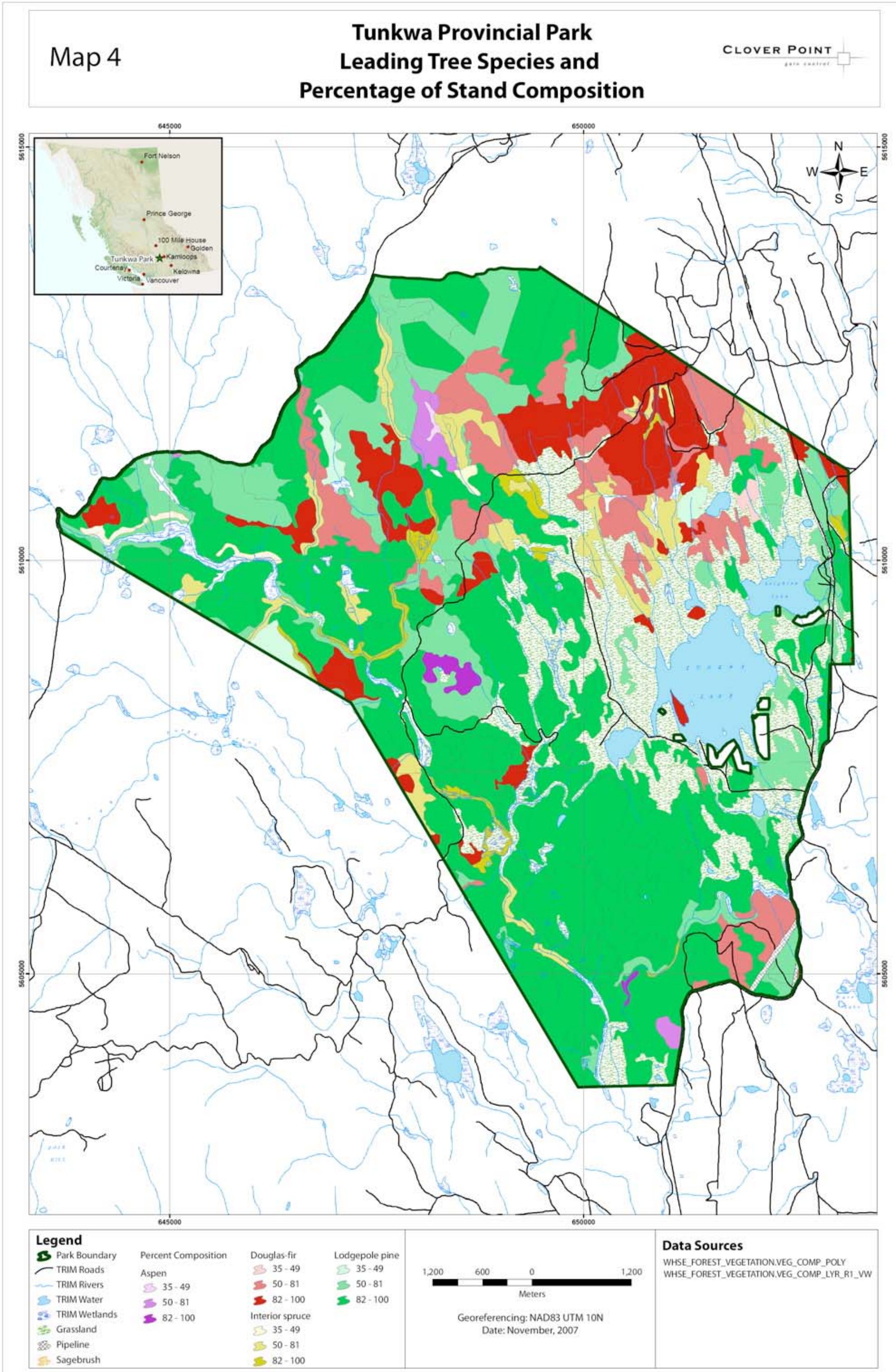
Map 1. Tunkwa Provincial Park location and facilities



Map 2. Biogeoclimatic subzones



Map 3. Orthophoto and waypoint locations



Map 4. Leading tree species and percent of stand composition

A number of disturbances have altered the forests of Tunkwa Park in the last 100 years. A previous mountain pine beetle outbreak killed many lodgepole pine trees in the area in the 1930s; local ranchers subsequently ignited fires to remove the accumulated dead trees (Bob Haywood-Farmer, Indian Garden Ranch, *pers. comm.*). In the airphotos from 1948 and 1949 obtained for this project, significant portions of the park area appears to have been relatively recently burnt. The background report for the park mentions that fires burnt some of the park in the 1950s, producing dense pine forests (BC Parks 1997a). The Ministry of Forests and Range's historical fire database, which covers the 1950s, has no record of large fires in Tunkwa Park in the 1950s (Armitage 2008). It may be that the fires referred to in BC Parks (1997a) were incorrectly dated. Most of the Douglas-fir stands were selectively harvested from 1963 to 1967 with the stumps and skid trails still readily visible. More recently, eleven cutblocks from the 1990's are partly or entirely in the park. In some of these cutblocks, large Douglas-fir trees were retained adding structure to the regenerating forests in the cutblocks. Also, the cattle grazing that has occurred in the park since the mid-1800s has likely altered forest development through reducing graminoid cover, which compete with conifer seedlings; reducing fine fuels, thus affecting fire frequency; compacting soils; reducing water infiltration rates; and increasing soil erosion rates (Belsky and Blumenthal 1997).

The IDF zone is classified as being in Natural Disturbance Type 4 (NDT4), which are considered "ecosystems with frequent stand-maintaining fires" (Ministry of Forests and Ministry of Environment 1995). These ecosystems were considered to experience frequent low intensity fires that maintained the open character of the forests. More recent evidence has indicated that a regime of frequent low-intensity stand maintaining fires and less frequent high intensity stand replacing fires was more likely (Arsenault and Klenner 2004). This makes using a reference condition approach for ecosystem restoration impossible, as there are multiple forest conditions possible (Arsenault and Klenner 2004). However, using the concept of range of natural (or historical) variability (RNV) for fire regimes for dry interior forest of British Columbia (Wong and Iverson 2004), it is clear that in general the historical fire frequency has not been maintained in the Kamloops Fire District (Arsenault and Klenner 2004); this would affect the proportion of the landscape in different forest types. Some changes that could be expected include the infilling of open old stands resulting in mixed age stands, and a general aging of closed forest types.

Open grasslands cover approximately 773 ha in the park (15% of park area), mostly on slopes north of Tunkwa and Leighton lakes. The extent of these grasslands is unusual at this elevation in this part of the southern Thompson Plateau. The grasslands reflect the dry climate, warm aspect, and the poorly-developed infertile soils on stony moraine (BC Parks 1997a). Fire also likely played an important role in maintaining these upper elevation grasslands (Iverson 2004). These grasslands would have been dominated by rough fescue and blue-bunch wheatgrass. Open Douglas-fir forests with a grass-dominated herbaceous layer are often an important component of the grassland landscape. These forests appear to have been present in Tunkwa Park around the grasslands in the park (see Section 6.3 Grasslands). There is anecdotal evidence that the grasslands in the park are being encroached upon by forests (Grasslands Conservation Council of BC 2003). More detail on the grasslands in the park is presented in Section 8 Managing Grasslands.

Numerous small wetlands occur in the park, mostly along Guichon Creek and other waterways in the park, but there are also isolated sedge wetlands. Many of the wetlands are dominated by red-osier dogwood and willow, but in some areas the wetlands transition into grassland making defining them on airphotos difficult. There are also some small, dry, open sagebrush plant communities on steep south-facing slopes above Guichon Creek in the southwest corner of the park. These sagebrush communities also have some cover of Douglas-fir, aspen and Rocky Mountain juniper (Figure 1).

Figure 1. Sagebrush area with Rocky Mountain juniper, Douglas-fir, Trembling aspen and Kinnikinnick. Also, notice dead pine forests in the background.

The Red-listed plant species freckled milk-vetch (*Astragalus lentiginosus*) occurs within the park near Tunkwa Lake in a dry grassland (BC Conservation Data Centre 2007). The occurrence has excellent or good estimated viability and is in a special management zone of the park, in which there is no grazing or motorized access. The Red-listed moss species alkaline wing-nerved moss (*Pterygoneurum kozlovii*) occurs immediately adjacent to the park on the edge of an alkaline lake (BC Conservation Data Centre 2007).

Nine rare ecological communities potentially occur in Tunkwa Park (Table 2) (BC Conservation Data Centre 2007). They are mostly wetland and grassland communities. An inventory of rare ecological communities was not conducted as part of this project, but information potential rare ecological communities is presented here for information purposes.

Table 2. Rare ecological communities that could occur in Tunkwa Park			
Common name	**Latin name**	**BEC Code**	**List**
Nuttall's alkaligrass - foxtail barley	*Puccinellia nuttalliana - Hordeum jubatum*	IDFdk1/Gs02	Red
Baltic rush - field sedge	*Juncus balticus - Carex praegracilis*	IDFdk1/Gs03	Blue
Tufted hairgrass	*Deschampsia cespitosa*	IDFdk1/Gs04	Blue
Slender sedge / common hook-moss	*Carex lasiocarpa / Drepanocladus aduncus*	IDFdk1/Wf05	Blue
MacCalla's willow / beaked sedge	*Salix maccalliana / Carex utriculata*	IDFdk1/Ws05	Blue
Rough fescue - bluebunch wheatgrass	*Festuca campestris - Pseudoroegneria spicata*	IDFdk1a/91	Red
Bluebunch wheatgrass - junegrass	*Pseudoroegneria spicata - Koeleria macrantha*	IDFdk1a/92	Red
Spreading needlegrass	*Achnatherum richardsonii*	IDFdk1a/93	Blue
Trembling aspen / common snowberry / Kentucky bluegrass	*Populus tremuloides / Symphoricarpos albus / Poa pratensis*	IDFdk1a/94	Red

2.2.2. Wildlife and Fish

Tunkwa Park has a number of wildlife species including mule deer, moose, black bear, cougar, lynx, bobcat, and numerous bird species. There is a colony of yellow-bellied marmots near Bluff Lake. The lakes and wetlands support large numbers of a wide variety of waterfowl, both for nesting and during migration. The grasslands support a number of ground-nesting bird species including meadowlarks and vesper sparrows, with curlews also known to occur. No Red- or Blue-listed forest or grassland dwelling vertebrate species are known to reside or nest in the park, though some may occur in the park, including short-eared owl, sandhill crane, long-billed curlew, Lewis' woodpecker and badger (BC Parks 1997a). Critical moose winter range has been identified along the wetlands and riparian areas surrounding Guichon Creek on the western side of the park (Government of British Columbia 1995).

Leighton and Tunkwa lakes are highly productive for rainbow trout, with trout reaching 3 kg. The high productivity is due to the basic pH of the water and the extensive shallow areas in the lakes. The lakes are very heavily used for recreational angling, and are stocked annually. The fish in the lakes are used as a source for eggs for the provincial stocking program (BC Parks 1997a, Freshwater Fisheries Society of BC 2004).

2.2.3. Cattle and Horses

Grasslands in the park have been used for grazing cattle since the mid-1800s, and grazing continues today. The Kamloops LRMP direction was that the current level of grazing was to continue, subject to regulations of the range section of the Ministry of Forests. There are many fences in the park to control when and where grazing occurs. The objective of the fencing is to allow a rotational grazing system and improve the condition of the grassland and riparian areas.

Feral horses also range within the park, with an estimate of 100 horses between this area and Highland Valley. The management plan strategy for feral species is to monitor the presence and impact of feral species and implement appropriate management strategies as required.

2.2.4. Cultural Values

There is a long and important history of First Nations use of the Tunkwa Park area before contact with European people, especially by members of the Skeetchestn Indian Band who live in Savona and use the surrounding landscape. For First Nations people, the Tunkwa Lake area was easily accessible, and was a major area for fishing, hunting and other traditional activities. Despite this historical use, a cultural heritage assessment has not been conducted for the park. The Skeetchestn Indian Band feels that without a cultural heritage assessment, it is unable to properly comment on management plans and activities in the park.

The Skeetchestn Indian Band feels that fire is an important component of ecosystem function in the area, and that the grasslands in the park area are maintained in their grassland state by fire. With much of the landbase surrounding the park being managed for its timber values, Tunkwa Park is one of the few areas where fire can play its historical role on the landscape. Further, they feel the risk of fire will be increasing due to the fuel build-up resulting from the Mountain Pine Beetle epidemic combined with high levels of recreational usage. As such, the Skeetchestn Indian Band feels fire should be looked upon as a management tool in the park; however, with the present levels of grazing by cattle and horses, there may not be sufficient fuel loading to carry a fire in the grasslands.

If there are cultural or historical structures in the park, as there may be because of the long history of use by First Nations, ranchers, anglers and other recreationists, they have not been documented.

2.2.5. Recreational Use

Tunkwa Park is heavily used recreationally, mostly by anglers but also by people on ATVs, snowmobiles, motorcycles, and for hiking, hunting, horseback riding and cycling. There are a number of trails in the park; they are mostly old roads that are not maintained. Other activities include dog field trials. The park sees over 55,000 user days per year, with much of this use in spring and fall when angling is the best (BC Parks 1997a).

Users mostly stay in the three provincial park campgrounds, one on Tunkwa Lake and two on Leighton Lake; these campgrounds have a total of 55 traditional and 210 informal campsites. There are also a numerous private dwellings on the lake and Tunkwa Lake Resort, which has 17 cabins and numerous sites for RVs and tents. Recommendations for visitor safety and fire hazard abatement in the developed portions of the park were made by Morrow (2005), and these recommendations have been implemented.

2.3. Mountain Pine Beetle History in Tunkwa Park

Mountain pine beetle was first detected in Tunkwa Park in the late 1990’s. At that time control measures, such as fall and burn, were used to reduce the spread if mountain pine beetle within the park. Though initially successful, these measures were eventually overwhelmed and the MPB spread throughout the region.

In 2004, BC Parks had an assessment of the safety issues in the park conducted. This report led to the removal of dead trees in the high use areas of the park in 2005. Dead trees were removed from campgrounds, and along private properties and roadways. In the fall/winter of 2007, dead trees near approximately 15 km of fenceline in the park were felled, and then either limbed and left or bucked and burned, to prevent damage to fences in the future (R. Enns, BC Parks Area Supervisor, *pers. comm.*). By the fall of 2007, most of the larger lodgepole pine trees in the park had been attacked and killed by mountain pine beetle. Current attack is still visible in stands with smaller trees; attack on trees of this size are an indication that the epidemic is nearly finished in this area as the beetle use sub-optimal sized trees.

3. BC Parks Policy and Management Framework

3.1. BC Parks Vegetation Management Policy

When providing management direction to BC Parks, it is important to fit this direction within the policy framework of the agency. BC Parks has a Vegetation Management Policy to guide managers (BC Parks 1999b). This policy contains 10 components, several of which contain direction relevant to this project (bold items in text box). General policy and relevant direction from these components are given below.

BC Parks Vegetation Management Policy Components (BC Parks 1999b)

- Management for Representation
- Management for Biological Diversity
- ***Management of Ecosystem Processes***
- Conservation and Use
- ***Management of Special Features***
- ***Ecosystem Manipulation of Vegetation***
- ***Management for Restoration***
- Collection of Vegetation
- Management of Exotic Plant Species
- Management of Knowledge

Management of Ecosystem Processes

"*Natural ecosystem processes affecting vegetation including fire, insects, disease, weather (i.e., wind, avalanches, etc.), herbivory by wildlife, and tree mortality due to age, are recognized as natural occurrences shaping vegetation. Ecosystems will be managed to maintain ecological processes in as natural a state as possible.*"

- Vegetation management in British Columbia's protected areas will normally aim at maintaining functioning ecosystems, rather than emphasizing single species.
- Vegetation species as well as ecological processes affecting them will be maintained in as natural a state as possible.
- BC Parks' primary responsibility in fire management, after the protection of life and property, is to maintain natural ecosystems within parks and ecological reserves.
- Prescribed burning may be used as a tool to reintroduce natural fire events where fire suppression has effectively removed it from the ecosystem or to reduce fuel accumulations that have become a fire hazard (e.g., blowdowns).
- As burned areas are prime sites for alien plant invasions, invasive plant monitoring and control will be carried out following all wild and prescribed fires in protected areas.

Management of Special Features

"*Management priority will be given to special or unique vegetation communities, rare, threatened, and endangered species.*"

- Recognizing that the protection of rare and unusual habitats and ecosystems is important to conservation goals and to the protection of endangered, threatened, and vulnerable species, rare habitats will be identified and fully assessed.

Ecosystem Manipulation of Vegetation

"*Deliberate manipulation of vegetation may occur in parks and ecological reserves under special circumstances.*"

Situations where manipulation may occur include those where:

- natural processes put irreplaceable forest stands, species or specimens of plants at risk,
- restoration of natural processes is desirable (i.e., reintroduction, fire), and
- where fire suppression has altered the natural vegetation pattern over the landscape.

Management for Restoration

"*Restoration of natural ecosystem processes and major vegetative and landscaping projects within British Columbia's park and ecological reserve system will use native plant species appropriate to the site and ecosystem.*"

- BC Parks will endeavour to restore disturbed or lost natural ecosystem processes where compatible with essential protected area objectives. Examples are reforestation of logged or human-damaged forested areas, restoration of natural fire regimes or of predator/prey relationships. An essential condition of all restoration programs is the necessity for follow-up effectiveness surveys.

This policy contains clear direction that maintaining natural processes and ecosystems are a priority in protected areas, and that prescribed fire is an acceptable activity in certain situations. Priority is given to rare species and plant communities when managing protected areas, and intervention into natural processes to maintain them is acceptable. A broad view of restoration is taken, which includes the restoration of ecosystem processes as restoration. In this context it could be argued that prescribed fire is ecosystem restoration, with fire suppression activities having been the degrading force.

3.2. Tree Removal Policy for Parks and Protected Areas

This section is an excerpt from the Tree Removal Policy for Parks and Protected Areas (BC Parks 1997b).

This Policy has been developed as a general overview of tree removal, and specifies: "Tree removal is an acceptable management option in parks and Protected Areas when required for human health and safety, to facilitate approved development, to protect infrastructure or for ecological restoration or forest health management projects. In all cases, tree removals will be conducted with minimal environmental impacts. While tree removal may be an acceptable management activity in parks and Protected Areas, commercial logging is prohibited".

This Policy emphasizes the importance of ecologically sensitive prescriptions for all tree removal projects. In addition, it clearly states that trees cannot be removed for commercial gain. Highlights from this document include:

General Policy

- All tree removal projects are subject to the BC Parks Impact Assessment Process.
- All tree removal projects (outside single tree removal) must be identified in, and subject to, an ecosystem restoration, ecosystem management or vegetation management plan.

- Tree removal will be undertaken using the most environmentally sensitive approaches, and sites disturbed by tree removal will be rehabilitated.
- Tree removal will not be considered to finance infrastructure development or for use in facility construction, maintenance or repair.

Single Tree Removal – Wildlife/Danger Tree

- Trees in developed areas may be removed if they present an identified risk to human health and safety, or to facilities. Determination of danger trees will be consistent with the BC Parks Wildlife/Danger Tree Assessment Process.

Multiple Tree Removal

- Multiple or large-scale tree removals may be considered if there is an identified risk to human health and safety, or to park or adjacent values. All multiple or large-scale tree removal projects must be determined through assessments from independent, accredited professionals.
- Multiple or large-scale tree removals for human health and safety should be part of an overall restoration strategy whenever possible.
- Where re-introduction of natural processes for ecological restoration is constrained due to human health and safety or facility protection reasons, the sole use of multiple or large-scale tree removal may be acceptable.

Ecological Restoration

- Returning natural processes to areas with impaired ecological function will be a priority for restoration.
- Where appropriate, fallen trees should be left within the area of the removal.
- In some cases, tree removals may be necessary to ensure environmental conditions are suitable to reintroducing natural processes.
- Tree removal alone cannot be used to mimic natural processes; tree removal can be used to enable the reintroduction of natural processes such as fire.

Forest Health

- Returning natural variability to areas with forest health issues will be a restoration objective.
- Treatments emulating natural processes will be used whenever possible.
- If treatments emulating natural processes cannot be used and the park's forest health situation presents a high risk to adjacent values, affected tree removal may be considered as a treatment option.

Tree Disposal

- Funds resulting from tree disposal may be retained by the Ministry and applied to project costs including: planning, inventory, tree removal, site restoration, and monitoring.
- Funds not expended on project costs may be managed through the British Columbia Parks Fund and applied to high priority provincial parks and protected areas conservation projects.

- Generation of funds will not be considered as a reason for tree removal and/or disposal.

3.3. Mountain Pine Beetle Emergency Response Strategy

The provincial and federal government have developed a Mountain Pine Beetle Emergency Response Implementation Strategy to deal with the MPB epidemic. This strategy is based upon the Mountain Pine Beetle Action Plan 2006-2011 (Government of British Columbia 2005), and contains specific direction for how to respond to the MPB epidemic in parks and protected areas. The relevant direction from the Implementation Strategy is excerpted below, and can be found at: http://www.for.gov.bc.ca/HFP/mountain_pine_beetle/can_bc_implement.htm

Working under the guidance of the provincial Mountain Pine Beetle Action Plan 2006-2011, the Ministry of Environment (MOE) has initiated a strategy to address the impacts and implication of the mountain pine beetle (MPB) epidemic and related management activities. Ministry of Environment staff at headquarters and in regions are addressing areas within the MOE mandate affected by MPB. The primary focus of MOE's Parks and Protected Areas (PPA) mitigation activities will be associated with:

- Coordinating spread control activities in Parks and Protected Areas, in collaboration with Ministry of Forests and Range control activities, especially in areas that border Alberta;
- Coordinating fuel management activities in Parks and Protected Areas primarily in the vicinity of communities, in collaboration with Ministry of Forests and Range;
- Collecting information on Parks and Protected Areas values to enable better informed land use and resource management decisions; and
- Monitoring the effects of the epidemic and associated management on environmental values within MOE mandate.

The mandate for the mitigation of MPB impact on parks and park values arises from Objective 2 and 4 of the provincial Mountain Pine Beetle Action Plan 2006-2011.

Objective: Maintain and protect worker and public health and safety.

Three specific tasks under this objective are:

- Carry out fuel management and implement wildfire mitigation activities where necessary for public safety;
- Identify and monitor critical water supplies that may be impacted by the infestation or forestry mitigation activities; and
- Monitor air quality and minimize the public health effects of smoke from increased use of prescribed burning.

Work by MOE staff occurs primarily in Parks and Protected Areas to address wildland urban interface fuel reduction. The objective is to plan for and implement measures to reduce the fire hazard on Parks and Protected Area land and should a fire start within a Park or Protected Area, to reduce the risk of fire leaving the park and impacting private land or important adjacent Crown values.

Objective: Conserve the long-term forest values identified in land use plans.

Four specific tasks under this objective are:

- Carry out a detailed, qualitative assessment of the impacts to strategic resource values.
- Ensure management of parks and protected areas incorporates an assessment of the impacts of the epidemic on conservation values.
- Examine the opportunities and costs, including possible funding sources, for techniques to restore non-timber values (e.g. wildlife habitat, hydrological function).

Most strategic land use planning processes made recommendations for Parks and Protected Areas. MOE staff are ensuring Park and Protected Area management incorporates an assessment of the impacts of the epidemic on conservation values and recreational use. Parks and Protected Areas that are highly impacted may require a detailed study to categorize impacts and make recommendations for mitigation. In all cases, the MOE are responding to priority management issues identified in impact reports. Management needs include public safety, risk to infrastructure, habitat restoration, recreation management, fuel management and wildfire protection planning, and MPB spread control.

Funding allocation is guided by criteria and analysis established in the recently completed reports, Wildfire Threat Assessment for Parks and Protected Areas and Parks and Protected Areas Mountain Pine Beetle Assessment, in combination with regionally identified threats and specific park assessments and plans.

3.4. Tunkwa Park - Existing Management Direction

Existing management direction for Tunkwa Park comes from the Kamloops Land and Resources Management Plan (LRMP) (Government of British Columbia 1995) and the Tunkwa Park Management Plan (BC Parks 1999b). Management direction in these plans that is relevant to this document is summarized in **Table 3** and **Table 4**.

Table 3. Relevant direction for protected area management in the Kamloops LRMP

Objective	Management Strategy
Protect viable, representative examples of British Columbia's natural diversity and recreational opportunities and to protect special natural, cultural heritage and recreational features.	Appropriate control methods will be undertaken to control disease, insect infestation, noxious weeds (control methods will emphasis biological and cultural control methods), and fire where this is consistent with maintaining values within and outside of Protection RMZs and is consistent with local level plans.

Table 4. Relevant direction for protected area management in the Tunkwa Park Management Plan

Objective	Strategies
Maintain forests in their natural condition.	Respond to fire, insect disease and alien plant and animal infestations to maintain high recreational and conservation values. Implement co-operative management strategies with adjacent land managers for protection of surrounding land and forest values. Emphasis will be placed on allowing natural processes to occur but active management techniques (such as prescribed fire) may be employed to mimic natural processes in a controlled environment. Work with other agencies to develop contingency plans for wildfire, insect and disease to protect park and adjacent values.
To improve the condition of the grasslands	Allow natural processes to prevail as long as park recreation, conservation, grazing and important adjacent forest values are not compromised. Control noxious weeds as part of the strategy for grasslands improvement.

The management direction for Tunkwa Park in the Kamloops LRMP contains direction on what to when an insect outbreak occurs but none on what to do after an outbreak except that fire can be controlled if consistent with maintaining values inside and outside the park. The park management plan provides more direction regarding vegetation management. Allowing natural processes to occur is emphasized, but intervention is possible where recreational, conservation, and values external to the park are at risk. Prescribed fire is given as a possible management tool in forested areas but not in grasslands, though it is implied that intervention can take place if important values are at risk.

4. Effects of Mountain Pine Beetle

4.1. Mountain Pine Beetle Ecology

Information in this section has been summarized from Safranyik and Carroll (2006) and Taylor *et al*. (2006).

The mountain pine beetle is native to western North America with its range extending from northern Mexico in the south to northwestern British Columbia in the north, and from the Pacific coast in the west to South Dakota in the east. The main host tree species are lodgepole pine, ponderosa pine and western white pine; however, all native pine species and some exotic pine species are susceptible to attack.

Mountain pine beetle preferentially attack primarily mature, large diameter lodgepole pine trees, where a thicker phloem provides adequate resources for brood production. Adults generally emerge from attacked trees from late July to mid August to attack new host trees. Females lay eggs in galleries just beneath the bark, where larvae feed on phloem tissue. Eggs are the least cold-tolerant life stage of the MPB while the larval stage is most cold tolerant, able to sustain temperatures down to almost -40^{o} C. Cold tolerance is greatest between December and February. Cold temperature is often the largest single source of mortality, however, other mortality factors such as predators, parasites, and interspecific competition could also have an influence when MPB population levels are low.

Trees are killed by a combination of larval foraging and introduction of blue stain fungi. Blue stain fungi penetrate the phloem and xylem, causing desiccation and interruption of transpiration. Trees die due to loss of moisture with needles fading from green to yellow in late May to early June the year following attack. Needles turn red by late summer of the year following attack and red needles may persist on trees up to 3 to 5 years following attack.

The population cycle of MPB has four phases: endemic, incipient-epidemic, epidemic (i.e. outbreak) and post-epidemic (i.e. declining) populations. During the endemic phase MPB populations area very low, and beetles can only successfully attack trees with low vigour. If a beetle population grows it enters the incipient-epidemic phase. The main factors that permit the populations to escape the endemic phase are a decline in host resistance combined with favourable conditions for beetle establishment and survival. Climatic conditions such as a period of drought, or forest stand conditions such as of senility, disease or damage, could be the cause of decreased tree resistance.

Epidemic populations arise as a result of the growth and expansion of local incipient-epidemic populations combined with long-range dispersal. Outbreaks may spread over many thousands of hectares if large areas with a susceptible host, such as mature lodgepole pine, coincide with sustained favourable weather conditions for beetle establishment, development, and survival. Epidemic populations will collapse if there is either a period of very cold weather in the late fall or early spring, or when there is no longer any susceptible hosts left on the landscape.

Post-epidemic populations will affect the landscape differently depending on the cause of the decline. When cold weather is the cause of the decline, beetles will continue to attack a similar tree profile to those that were attacked during the epidemic, but the lower number of beetle may mean that many trees are only partially attacked. However, if the decline is due to a lack of suitable host trees, the beetles will be forced to attack trees with reduced nutritional quality, or increased resistance, which will likely result in a higher mortality than during the epidemic phase.

4.2. Mountain Pine Beetle, Forests and Wildlife

4.2.1. Forests

A large mountain pine beetle epidemic, such as the one currently sweeping through British Columbia, can kill the majority of lodgepole pine trees in the affected area. Mountain pine beetle attack can produce young seral stands different from fire or harvesting initiated stands. Young seral stands created by MPB have a legacy of structural attributes, including dead standing trees and coarse woody debris (CWD). These stands have been called "young, wild stands" to distinguish them from young managed stands (Stadt 2002), and may provide more wildlife habitat than stands developed after fire or forest harvesting (Forest Practices Board 2007).

This legacy of structural attributes will have a lasting effect on stand function and structure for an extended period of time (Dykstra and Braumandl 2006), and will contribute to ecological processes, wildlife habitat, visual quality and hydrologic recovery of the forest (Coates *et al.* 2006, Forest Practices Board 2007). For example, stands disturbed by MPB 65 years ago were found to have more young regeneration and coarse woody debris than undisturbed stands and stands disturbed 25 years ago; the undisturbed stands had the most live basal area of the 3 stand types; and, the stands disturbed 25 years ago had the most vegetation volume, mostly as shrubs (Dykstra and Braumandl 2006). These results indicate an initial growth response by understory vegetation to tree death, whereas regeneration and CWD take longer to respond or build-up. The end result was an increase in stand and landscape heterogeneity.

Fires that are stand-replacing will further reduce wildlife habitat in mixed stands where non-pine conifers are present in either the canopy or understory layers (Stadt 2002, Chan-McLeod 2006). This is because the fire will eliminate structural complexity provided by the non-pine tree species (Chan-McLeod 2006), reducing the amount of structural complexity provided by dead wood in the stand, and impact the increased shrub cover that results after canopy tree death. These changes will go against objectives to retain habitat structure and wildlife diversity in a post-MPB landscape (Klenner 2006). A stand-replacing fire will also favour the establishment of a new lodgepole pine stands. While widespread fire would be detrimental on a landscape scale, small, targeted fires may be beneficial in selected areas.

When considering using prescribed fire, one must compare the composition and successional pathway of the present stand to that of the likely resulting vegetation. The successional pathway of the present stand will vary depending on species composition, seed availability, understory competition, stand density, light availability and seedbeds (Kimmins *et al.* 2005). The successional pathway of a post-fire stand will be more dependent on the ability of species to withstand fire or recolonize the area after fire through either surviving propagules or seed dispersal.

4.2.2. Fire

The quantity and spatial distribution of forest fuels in mountain pine beetle attacked forests will change over time. In the red attack phase, there may be an increased chance that a fire would start in the crown, but there may not be a greater probability of a crown fire spreading due to the influence of other factors (Romme *et al.* 2006). The initial change in fuel characteristics following successful MPB attack is a change in the moisture content of the foliage as the needles die. Live foliar moisture contents vary seasonally and can range from a minimum of about 85% to a maximum of 120%. (Forestry Canada Fire Danger Group 1992). In contrast, the moisture content of red pine needles has been measured as low as 6% and will vary depending on temperature and relative humidity levels throughout the day (B.C. Min. of Forests and Range Protection Branch unpubl. data 2004). This low moisture content in the red needles creates the potential for extreme crown fire behaviour and long spotting distances.

Ground fuel loading will increase as dead trees fall. At this time the hazard of crown fire may increase through the growth of understory trees providing ladder fuels to the canopy and through high levels of ground fuels providing enough heat and flame lengths to reach the crown (Romme *et al.* 2006).

Approximately 2 to 5 years after the tree dies, these red needles fall to the ground, which increases the surface fuel loading. The increase in surface fine fuels can result in an increase in surface fire behaviour. This increase in surface fuel loading may decrease over time depending on site conditions and decomposition rates.

Once the red attack phase is over, and the red needles have fallen to the ground, the hazard of a crown fire may be lower than in unaffected stands. Research in other areas has shown that the probability of a crown fire occurring in post-MPB stands does not always increase over unaffected stands, but where the level of tree mortality was high the likelihood of crown fire was reduced somewhat (Romme *et al.* 2006). This is due to the reduced crown density and gaps in the crown (Romme *et al.* 2006), which reduces the stand's ability to initiate and maintain an active crown fire.

As the dead pine trees eventually fall to the ground, the surface fuel loading increases, which can result in fires with increased fire behaviour potential since more surface fuel is available for consumption. The intensity of fires that do occur, however, is much greater due to the large volume of ground fuels. These intense ground fires can burn all the duff layers and expose the bare soil, increasing the potential of weed invasion and compromising conservation values. Prescribed fire to reduce the volume of ground fuels may thus be warranted when a proportion of the dead trees have fallen. Prescribed fire also allows fire to be timed for periods when the risk of damage to other values, such as infrastructure, is lower.

Research on dead tree fall rates is on-going, but Hawkes *et al.* (2004) reported that in the Chilcotin Plateau and Kamloops Forest Region, the density of standing dead pine in sampled stands 18 years post attack were reduced by 52% (289 to 140 stems/ha) and 26% (370 to 273 stems/ha), respectively. The Forest Practices Board (2007) found that 55% of dead trees had fallen 25 years after MPB attack in the Sub-Boreal Pine Spruce (SBPS) zone. Fall down rates in the IDF zone are yet to be determined; however, given the studies to date, it is reasonable to assume that surface fuel loading will continue to increase for the next 10-30 years. Predictions for the drier part of the Sub-Boreal Spruce zone are that 25-50% of attacked trees will have fallen ten years after they are attacked (Lewis and Hartley 2005).

Since the current Fire Behaviour Prediction System fuel types were developed for natural stands without large quantities of beetle-killed surface fuels, it is likely that fires in these stands will exhibit fire behaviour characteristics beyond what is predicted by the Fire Behaviour Prediction System once the surface fuels increase due to fall down of the lodgepole pine.

4.2.3. Wildlife

Mountain pine beetle primarily affects wildlife through indirect processes. The only direct effect is the dramatic change in food supply for those species that utilize MPB as a food source; all other effects are caused by changes to habitat resulting from the death of trees (Table 5). The importance of these effects and nature of these effects will be mediated through a number of factors (**Table 6**) (Chan-McLeod 2006). One effect not addressed by Chan-McLeod (2006), is the loss of canopy snow interception once needles drop, and resulting changes in snow depths and conditions on winter ranges.

Table 5. Effects of mountain pine beetle on wildlife[a]

Process	Effect on Wildlife	Species or Species Groups Affected
Source of food	A number of bird species use MPB larvae and adults as food. Populations may respond by increased productivity and hence population size due to increased food availability. Populations will decline after epidemic subsides.	woodpeckers, brown creeper, red-breasted nuthatch, olive-sided flycatcher, chickadees and other insectivorous birds (Martin *et al.* 2006)
Canopy defoliation	Canopy is important because: 1) needles are a food source, 2) invertebrates, which are used as a food source, live on needles, 3) resting or nesting habitat in canopy, and 4) shelter provided by canopy from weather, and cover for hiding, escape and hunting.	1) snowshoe hare, blue grouse, spruce grouse may feed on pine needles 2) foliage gleaners, including chickadees, kinglets, vireos, crossbills, warblers 3) various birds (e.g. northern goshawk [Mahon and Doyle 2003]) and mammals 4) various birds and mammals, especially ungulates
Loss of live bark	1) bark is used as a food source 2) bark harbours invertebrates that are a food source, but degree of negative effect may not be significant	1) voles, porcupine, moose 2) bark-gleaning birds such as nuthatches, woodpeckers, sapsuckers, brown creeper
Cessation of cone production	Pine seeds are used as a food source	Affected species include crossbills, voles, red squirrel and flying squirrel.
Increase in the number of standing dead trees (snags)	Snags are used for nesting, roosting, denning, perching and foraging. But lodgepole pine are not preferred snags and too many may be available to be used.	Mostly cavity-nesting birds and mammals, but also animals that glean invertebrates from decaying wood.

Table 5. Effects of mountain pine beetle on wildlife[a]

Process	Effect on Wildlife	Species or Species Groups Affected
Fall of dead trees (increase in Coarse Woody Debris (CWD))	CWD is used in many ways by wildlife, including: 1) perches or cover, 2) burrowing habitat, 3) moisture retention and microhabitat provision, 4) travel corridors, and 5) invertebrates, which are used as a food source, live in CWD	A wide variety of small birds and mammals use CWD.
	CWD may also hinder travel by some wildlife in high densities	Ungulates such as moose, deer and caribou
Increased understory production, especially shrubs	1) shrubs can provide food from its berries, foliage, seeds, and associated ectomycorrhizal fungi and insects	1) mammals including shrews, voles, mice, snowshoe hare, ungulates
	2) shrubs can provide cover/ nesting habitat	2) understory nesting birds, marten

a – summarized from a review by Chan-McLeod (2006)

Table 6. Factors influencing on the magnitude and nature of the effects of mountain pine beetle on wildlife[a]

Factor	Effect
Time since death	The influence of different processes and the strength of the effects of MPB will change over time as regeneration grows and dead trees fall over and decay. As dead trees fall, wildlife that prefers open conditions or CWD will benefit.
Residual green component	Habitat values following the MPB epidemic will be high in 1) uneven aged stands where young trees were not attacked, 2) mixed species stands with live, mature non-pine species, 3) stands with a well-established shrub layer. The response of advance regeneration to the changed environmental conditions will vary greatly between tree species, and the health, size, density and spatial arrangement of the trees (Griesbauer and Green 2006).
Ecosystem type	1) Ecosystems will have different wildlife values before mountain pine beetle attack, stands with high wildlife values will continue to have high values; the converse is true for stands with low wildlife values. 2) Ecosystems will vary in their ability to respond to the changed conditions after the MPB epidemic. For example, soil moisture conditions may limit the response of shrubs and advance regeneration to increased light availability. 3) The benefits of snags may not be attained where they fall over early, such as in areas exposed to high winds, or high soil moisture.
Landscape effects	1) The effects of the MPB epidemic on wildlife will be lower in landscapes where pine is a small component of the forest cover, or attack is localized. 2) The negative effects of the MPB epidemic will be greatest in landscapes with extensive areas of dead pine trees, but there may be beneficial effects for species that use early seral vegetation.

a – summarized from a review by Chan-McLeod (2006)

Overall, there may be major negative effects to some wildlife species as a result of the MPB epidemic, for example, on species that us live foliage for food or cover, or species that depend on mature forests. Conversely, there will be species that will benefit from the epidemic, both in the short-term (insectivorous species) and in the longer-term (species that depend on decayed snags and downed wood) (Chan-McLeod 2006). The question that park managers must ask is “will the proposed management actions lessen or mitigate the impact on those species most affected in either the long-term or short-term?”.

Increased wildlife habitat quality has been associated with the overall changes to the forest 25 to 65 years after MPB attack, though the changes do not benefit all wildlife species (Forest Practices Board 2007, Dykstra and Braumandl 2006).

Unsalvaged areas with beetle kill will be dramatically changed. The temporal pattern will be complex, but unsalvaged beetle-killed areas will increase amounts, at least in the short term, of some habitat elements often in short supply: snags, downed wood, shrubs, and likely early seral stages (Bunnell *et al.* 2004).

4.2.3.1. Ungulates

Effects of MPB on ungulates will depend on the extent of MPB attack across the landscape and the proportion of affected trees in each stand. Mountain pine beetle attack in high value habitat could result in potential positive and negative effects on ungulates. Increased abundance of favoured shrubs, herbs and grasses following MPB attack could benefit moose and mule deer. Stone (1995) found that moose and mule deer fecal pellet counts increased with the percentage of tree mortality in lodgepole pine stands in Utah following MPB mortality; however, he did not distinguish between winter and summer pellet groups so it is unclear whether increased use occurred in winter or summer or both.

Ungulate movements could be affected by MPB attack through: loss of canopy snow interception resulting in increased snow depths or altered snow conditions; and/or, accumulation of coarse woody debris once beetle-killed trees fall over impeding travel. Changes to snow depth/conditions will affect winter habitat, while increased accumulation of coarse woody debris will affect both summer and winter habitat. Factors affecting ungulate movements (altered snow depth/conditions, coarse woody debris) could also affect predator movements. This could result in either positive (ungulate movements less affected by obstructions than predator movements) or negative (ungulate movement more affected by obstructions than predator movements) effects on ungulate populations.

4.2.3.2. Other Mammals

Marten are sensitive to the structural composition of forests; they particularly favour forests with abundant coarse woody debris (CWD), such as downed logs and stumps, and a mixed canopy of shrubs, saplings and trees (Banner *et al.* 1993).

Forests that have been attacked by MPB will provide abundant CWD as the dead trees topple over time. In areas with pure stands of pine, there may not be sufficient trees remaining to provide the tree canopy component required. Prescribed fire will remove CWD by burning, and will also kill non-pine trees in burnt areas. Removal of CWD and killing of live trees will be detrimental to marten habitat.

The effect of MPB on red squirrels and flying squirrels may be minimal. Populations will likely begin to decline about 10 years after tree death, but will have a fairly rapid recovery as a new forest gets established (Steventon 2006).

4.2.3.3. Cavity-nesting Birds

The effects of MPB on bird communities are not fully understood, but research is starting to shed some light on the issue. One of the most important guilds of forest dependent birds is the cavity-nesting guild. These birds can be divided into three groups: primary cavity nesters, who excavate their own cavities; secondary cavity nesters, who use cavities made by other animals; and small cavity nesters, who make their own cavities or use existing cavities. Secondary cavity nesters also include bats and squirrels.

Lodgepole pine is not a preferred tree for nesting sites of cavity-nesting birds (Bunnell *et al.* 2004). The abundance of cavity nesting birds may initially increase due to MPB, but will likely decrease as the food supply decreases in later stages of the epidemic (Martin *et al.* 2006). The amount of available habitat in the post-epidemic stage is of most concern over the long-term.

The habitat needs of cavity nesting of birds can be varied. For example, most of the woodpeckers, nuthatches and chickadees in this guild tend to nest in aspen trees but feed on invertebrates that live in conifer trees (Martin *et al.* 2006). Most research on habitat supply in a post-MPB landscape is focussed on harvested landscapes, not on the unharvested landscapes found in protected areas.

4.2.4. Recreational Values

The impact of MPB on recreational values and activities are diverse and will vary with the values or perspective of the individual. One of the concerns in the park is the risk posed by large numbers of dead trees in areas used recreationally. One aspect of managing this risk is knowing how long dead trees are likely to stand before falling over.

The Forest Practices Board (2007) found that 55% of dead trees had fallen 25 years after MPB attack in the Sub-Boreal Pine Spruce (SBPS) zone. Soil moisture content appears to be the most important factor in determining the rate of tree fall, with trees in wetter areas decaying the fastest and thus falling the soonest (Lewis and Hartley 2005).

Management activities that could reduce the risk to recreational users include falling dead trees and moving recreational infrastructure to areas without dead pine trees. In Tunkwa Park, dead trees have been already removed from the heavily used front-country recreational areas, such as campgrounds. In the backcountry there is fairly high levels of use on trails. Many trees will eventually fall on the trails if not removed. It will be a large task to fall all dead trees that could potentially fall on the trails. Cutting trees after they have fallen may be the most practical policy, but has the added risk of a tree falling on a user.

Trails in the park could also potentially become wetter in MPB killed stands, due to expected rises in water tables. This is caused by reduced evapotranspiration and reduced interception of precipitation by the canopy (Rex and Dubé 2006). Some trails may need drainage structures added to ensure they do not become unusable or braided as users avoid the wet areas.

4.2.5. Cattle Usage

Extensive fencing has been constructed the Tunkwa Park to allow improved livestock management, which is aimed at improving the condition of the grasslands. Many of these fences go through pine-dominated stands that have been killed by mountain pine beetle. When these dead trees fall, this fencing will be damaged, requiring much upkeep. When the dead pine trees fall, cattle movement in forested areas will likely be impeded. In the fall/winter of 2007, dead trees near approximately 15 km of fenceline in the park were felled, and then either limbed and left or bucked and burned, to prevent damage to fences in the future (R. Enns, BC Parks Area Supervisor, *pers. comm.*).

Travel through the park for cattle, and by ranchers to manage and move cattle, will become increasingly difficult as dead trees fall. Ranchers in the area are interested in cut trails through the forest between openings to allow their movement on horseback when trying to move cattle between grazing areas. Windstorms in the fall of 2007 have resulted in extensive blowdown in some parts of the park, making movement very difficult (Bob Haywood-Farmer, Indian Garden Ranch, *pers. comm.*).

Timber milk-vetch (*Astragalus miser*), a native herb found in Tunkwa Park, causes acute and chronic toxicity in cattle and sheep. Timber milk-vetch can survive fire and may even be more abundant after fire (MacDonald 1952, Bob Haywood-Farmer, Indian Garden Ranch, *pers. comm.*).

5. Methods

The park was visited for three days in October 2007, using vegetation maps and airphotos to target visits to areas with different vegetation types (Map 3). Most time was spent in forested areas, as the focus was on forest management after MPB. Visual estimates of the density of live tree species of all sizes were made to guide decision-making for future forest dynamics. Trees were broken down into the following tree layers: established seedlings (10cm to <1.3 m tall), saplings (0.1 cm DBH to <7.5 cm DBH), sub-canopy (7.5 cm DBH to <15.0 cm DBH), and canopy (>15.0 cm DBH). Some observations of shrub, herb and moss layers were made, but this was hindered by a snowfall that covered much of this vegetation. The grasslands were not inventoried or the vegetation in them described, though a variety of grassland types were observed.

To determine changes to the forests and grasslands of the park over time, a comparison of aerial photographs spanning 56 years, from 1948, 1969 and 2004, was done (Table 7). While this was not a quantitative comparison, it allows a visual comparison over the time period.

Table 7. Airphotos used in the project

Year	Flight Line	Photos	Scale	Photo type
1948	BC617	97-101	1:31,680	Black and white
	BC623	41-45, 58-61		
1949	BC612	69-72	1:31,680	Black and white
1969	30BC7122	53-57,71-76,129-133,154-157	1:16,000	Black and white
2004		Orthophoto	1:20,000	Colour

The vegetation of the park was described using Forest Cover data provided by the Ministry of Forests. This data was corrected where obvious errors existed, such as the age an species composition of recent cutblocks in the park was incorrect, and some grasslands were incorrectly identified as forest.

6. Airphoto Analysis Results

6.1. Lodgepole Pine Forests

The area shown in Figure 2, south of Corral Lake, presently contains young lodgepole pine dominated forests (Map 5) that have been killed by MPB. The 1948 photo shows that much of this area had fairly recently been burnt; the patchy nature of the fire is evident in this photo. By 1969 young pine forests had become established over the entire area, with the crown still being fairly open. In 2004, the very dense canopy of the pine forest is evident.

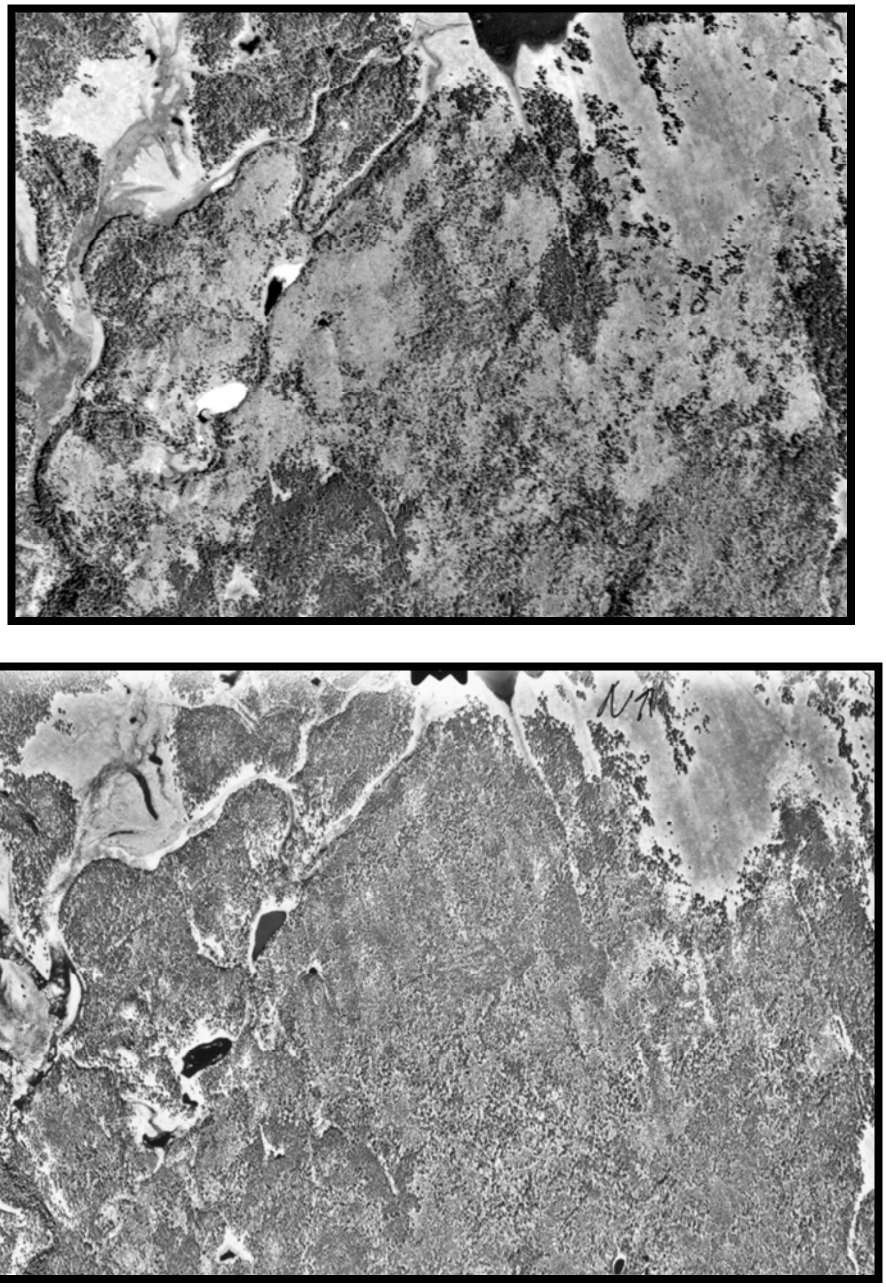


Figure 2. Aerial photos of an area presently in young beetle-killed lodgepole pine forests taken in 1948 (top), 1969 (bottom) and 2004 (next page).

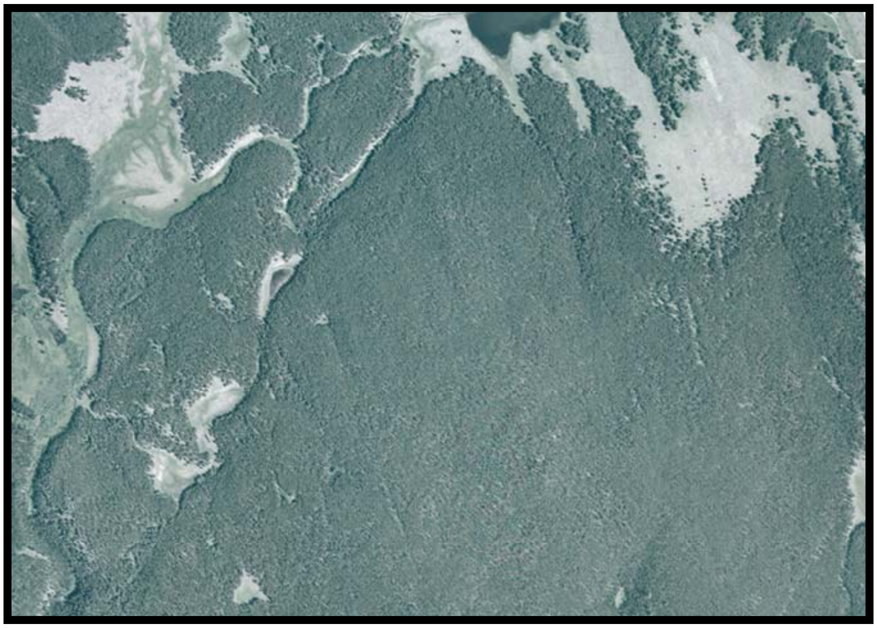


Figure 2 con't. Aerial photos of an area presently in young beetle-killed lodgepole pine forests taken in 1948 (top), 1969 (bottom) and 2004 (next page).

6.2. Douglas-fir Forests

Figure 3 shows some of the complexity of the changes that have occurred to the vegetation in Tunkwa Park, with in-filling and grassland expansion visible, mostly caused by extensive forest harvesting. The 1969 photo shows the selective forest harvesting, and associated network of roads and skid trails. The main trails are still visible in 2004. The open forests that cover much of the centre and upper left of the 1948 photo now contain dense stands, indicating in-filling has occurred in these Douglas-fir forests. The open grasslands north of June Lake have expanded; likely due to the forest harvesting that occurred in the 1960s.

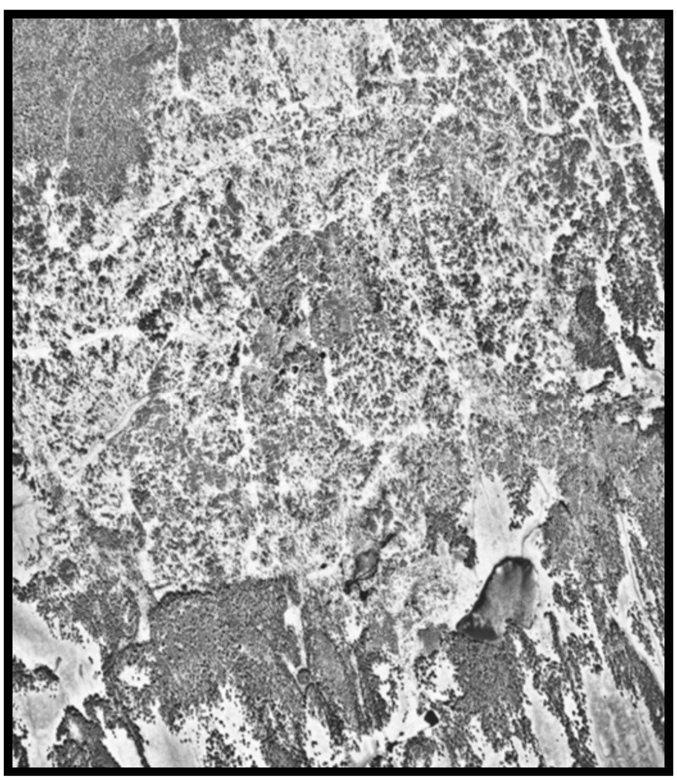


Figure 3. Aerial photos of area presently covered mostly with young Douglas-fir / Interior spruce forests taken in 1948 (top), 1969 (bottom) and 2004 (next page).

Figure 3 con't. Aerial photos of area presently covered mostly with young Douglas-fir / Interior spruce forests taken in 1948 (top), 1969 (bottom) and 2004 (next page).

6.3. Grasslands

There has been some encroachment of the grasslands of Tunkwa Park (Figure 4). This photo series show that the grasslands and forest patched have the same basic shape, but that the forest patches have expanded. Change is especially noticeable on the northern edge of the grassland, where some smaller patches of forest have coalesced to form continuous forest cover. In some areas young trees have become established along the edge of a forested area, encroaching on the adjacent grassland (Figure 5). However, a gradient of tree ages around the edge of grasslands indicating progressive encroachment, or a series of steps of trees of descending age class indicating pulses of encroachment, was not generally noticed. The new openings NE of the main grassland visible at the top of the 2004 photo along the old road appear to have been created by forest harvesting activities. Burnt areas are visible on the right edge of the 1948 photo.

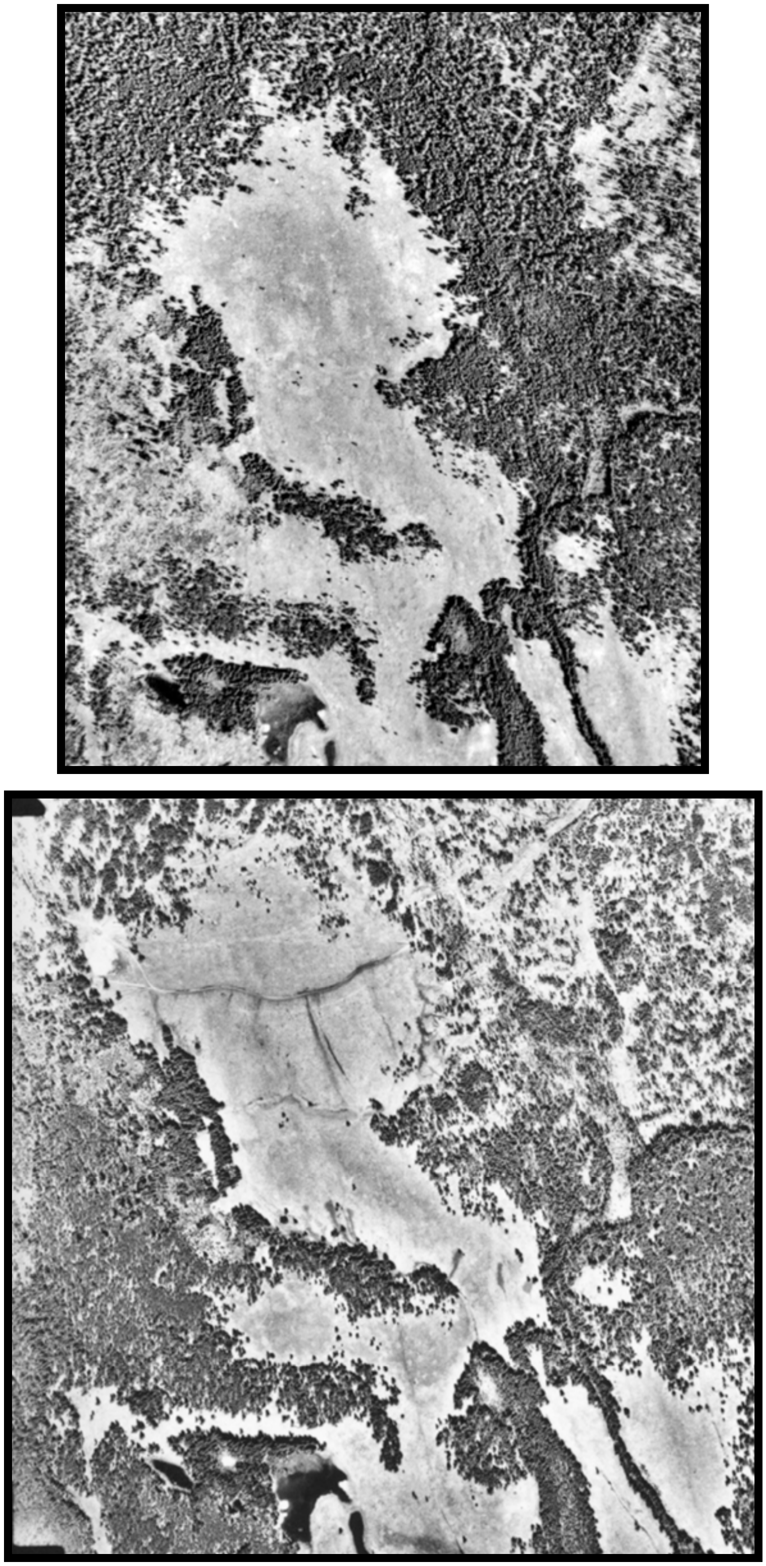


Figure 4. Aerial photos of a mainly grassland area taken in 1948 (top), 1969 (bottom) and 2004 (next page).

Figure 4 con't. Aerial photos of a mainly grassland area taken in 1948 (top), 1969 (bottom) and 2004 (next page).

Figure 5. Grassland with young trees established on the edge of the forest, encroaching on grassland. Also, notice veteran Douglas-fir above canopy of dead pine trees.

6.4. Sagebrush Area

The sagebrush area was examined as a vegetation type that, similar to grasslands, could be experiencing encroachment by trees (Figure 6). The airphotos show that encroachment is occurring in the sagebrush vegetation type. For example, the band of trees at the bottom of the slope on the outside of the creek bend has expanded both along the creek and upslope. The forests in general in the photo appear to have become denser over the 56 year time period. It is also interesting to see that the open water in the larger wetland on the right of the 1948 and 1969 photos is absent in the 2004 photo. It is not possible to say the wetlands are always drier now, as the smaller wetland was dry in 1948 and 2004 but contained open water in 1969.

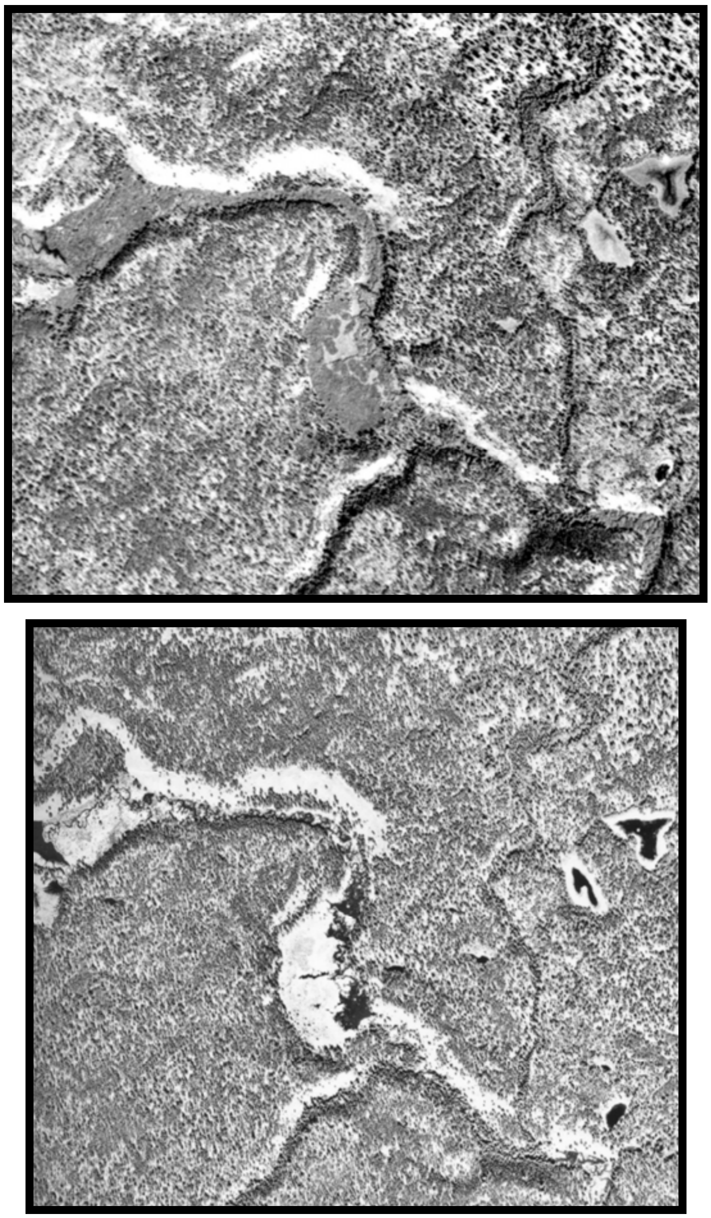


Figure 6. Aerial photos of a sagebrush area surrounded by lodgepole pine stands and Douglas-fir stands taken in 1948 (top), 1969 (bottom) and 2004 (next page).

Figure 6 con't. Aerial photos of a sagebrush area surrounded by lodgepole pine stands and Douglas-fir stands taken in 1948 (top), 1969 (bottom) and 2004 (next page).

6.5. Summary

Change in the vegetation of the park is evident on photos from all years, for example, the photos from 1948 show that much of the park was recently burnt. This is consistent with the anecdotal evidence of fires set by local ranchers after a previous MPB outbreak in the 1930s (Bob Haywood-Farmer, Indian Garden Ranch, *pers. comm.*). The airphotos show that most of the grasslands in the park have experienced little encroachment in the last 56 years. However, some encroachment has occurred as has infilling of sparsely treed areas. Conversely, some areas appear to be grasslands now that were previously forested. Whether these areas are similar to older grasslands or will revert to forests is unknown.

The changing vegetation of the park is ongoing with the recent MPB epidemic. The loss of open forests and grasslands is the greatest concern from a conservation perspective. Frequent low intensity fires maintained these ecosystem types. The lack of fire and disturbance from harvesting, along with other factors such as grazing, has facilitated the in-growth and encroachment that has occurred. A priority for park management should be the development of future open Douglas-fir stands and the maintenance of the grasslands. These ecosystem types historically only covered a portion of the park, with lodgepole pine forests, some with a veteran Douglas-fir component, covering a large portion of the park.

The airphotos show the large changes the landscape has experienced over the 56 years due to development. For example, the signs forest harvesting are widespread; as are the roads, pipeline, power lines, residences and campgrounds, which for the most part have been developed over this time period.

7. Managing Forests and Mountain Pine Beetle

7.1. Present Forests

Lodgepole pine dominates the forests of the park, followed in dominance by Douglas-fir, Interior spruce and trembling aspen (Table 8). Douglas-fir and Interior spruce cover much more area as secondary and minor species than as dominant species. Trembling aspen covers a small area and is mostly a minor species in the park. Most forested areas in the park contain mixed stands; however, in many of the mixed stands the non-dominant species only form a minor proportion of the stand. Lodgepole pine stands are more likely to be pure stands than either Douglas-fir or Interior spruce stands.

Table 8. Summary of stand composition in Tunkwa Park[a]

	Forest type Characterized by Leading Species								Totals	
	Lodgepole pine		Douglas-fir		Interior spruce		Trembling aspen			
	ha.	%	ha.	%	ha.	%	ha.	%	ha.	%
Total area	2,919	-	795	-	271	-	61		4,046	-
Pure stands	893	31	162	20	15	6	3	5	1,073	27
Mixed stands	2,026	69	633	80	256	94	58	95	2,973	73
% of total forest area	72		20		7		2			
Secondary species (≥25% cover) (ha)										
Lodgepole pine	-		135		47		19		201	
Douglas-fir	128		-		39		0		167	
Interior spruce	60		32		-		26		118	
Trembling aspen	54		2		17		-		73	
Minor species (<25% cover) (ha)										
Lodgepole pine	-		376		148		14		538	
Douglas-fir	1,316		-		120		40		1,476	
Interior spruce	1,204		463		-		22		1,689	
Trembling aspen	341		73		79		-		493	
Cottonwood	0		0		6		0		6	

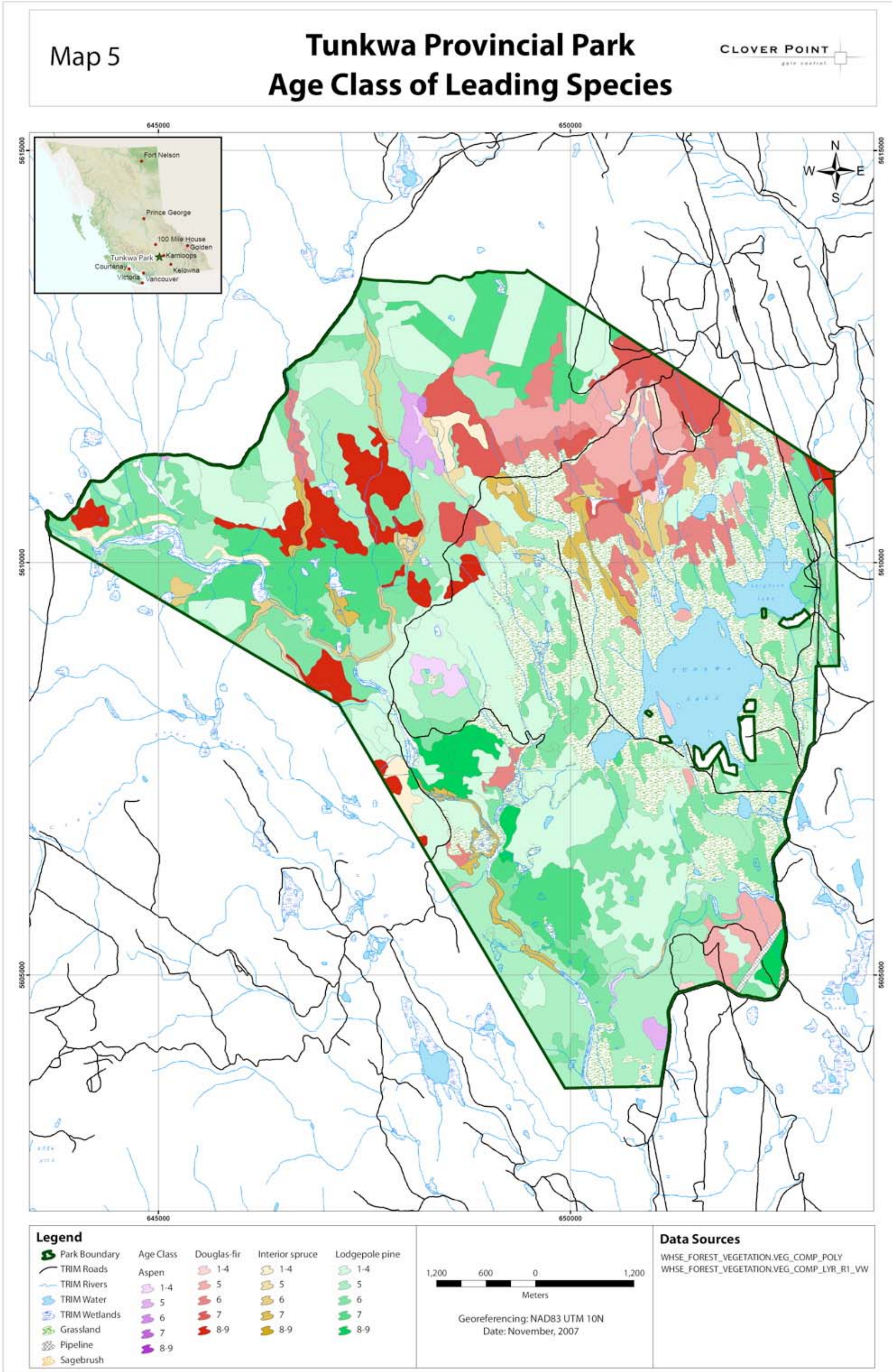
a – based on data from forest cover maps

Forest age ranges from <15 years old in recent cutblocks to 250 years old in some Douglas-fir stands (Map 5, Table 9). The age classes may be misleading in some instances where the stands are multi-aged. This mostly occurs in the higher elevation pine stands in the northwest of the park where large veteran Douglas-fir trees that have survived past fires are scattered throughout (Figure 7 and Figure 8). A larger proportion of the Douglas-fir stands are in older age classes than pine stands. Older age classes have been heavily influenced by the extensive selective harvesting of Douglas-fir that occurring in the park in the mid-1960s, and by earlier fires that burnt parts of the park (Figure 9). The MPB epidemic will create a much younger age structure than that presented here, which is pre-MPB epidemic.

Table 9. Age class distribution in Tunkwa Park

Forest type	Age Class					Totals
	1 - 4 (<80 yrs)	5 (81-100 yrs)	6 (101-120 yrs)	7 (121-140 yrs)	8 - 9 (>140 yrs)	
Douglas-fir	21	226	212	154	183	795
Interior spruce	46	17	122	86	0	271
Lodgepole pine	1,037	764	666	378	74	2,919
Trembling aspen	24	35	2	0	0	61
Totals	1,129	1,042	1,002	618	256	4,047
Percent	27.9	25.7	24.8	15.2	6.3	

Figure 7. Veteran Douglas-fir trees above younger dead pine canopy. In some cutblocks in the park these veteran trees have been retained.



Map 5. Age class of leading tree species

Figure 8. Veteran Douglas-fir tree in lodgepole pine stand showing Douglas-fir regeneration.

Figure 9. Douglas-fir stand with veteran and young Douglas-fir and young Interior spruce trees. In selectively harvested area, old trees are absent and the regeneration can be very dense.

Over 99% of canopy and sub-canopy lodgepole pine trees in all forest types in Tunkwa Park are dead or currently attacked by MPB. Some of the smaller sub-canopy trees have not been attacked, but judging from the small size of current attack trees, it was assumed that all sub-canopy pine trees would eventually be killed. Pine trees in the seedling and sapling layers will likely survive.

The average stocking of the pine stands was nearly 1,100 stems/ha (Table 10), but only half of the stands had greater than 500 stems/ha as some plots were densely stocked (Figure 10 and Figure 11). The median density of stocking in the pine stands was lower than that found by Vyse *et al.* (2007) who found the median density of all stems being 1200 stems/ha in the IDFdk1 in the Kamloops District and the median density of acceptable stems being >500 stems/ha. For the two 1:20,000 mapsheets that Tunkwa Park is in Vyse *et al.* (2007) found an even higher stocking density, with the median total stems being 1600 stems/ha and the median acceptable stems being 650 stems/ha. The species distribution of the stocking in the pine stands was nearly identical to that reported by Vyse *et al.* (2007) for the IDFdk1 in the Kamloops Forest District.

Table 10. Current stand composition of forests in Tunkwa Park

Stand type	Species	Stems per hectare by vegetation layer				Totals	
		Seedling	Sapling	Sub-canopy	Canopy	Stems/ha	%
Pine	Douglas-fir	193	190	45	8	436	39.9
	Lodgepole pine	300	207	0	0	558	51.1
	Spruce	60	60	28	2	150	13.7
						1,093	
Douglas-fir	Douglas-fir	770	960	240	320	2,290	83.6
	Lodgepole pine	0	60	0	0	60	2.2
	Spruce	30	200	80	80	390	14.2
						2,740	

Figure 10. Young dead lodgepole pine stand with no understory regeneration.

Figure 11. Young dead lodgepole pine stand with regeneration.

All of the Douglas-fir stands had greater than 1,000 stems/ha, with Douglas-fir dominating the regeneration in all layers. The few canopy Douglas-fir trees in the pine stands were veterans much older than the subcanopy Douglas-fir and the now dead pine trees, and commonly had old fire scars. By contrast, the Douglas-fir and spruce canopy trees in the Douglas-fir stands were mostly young trees that were released or established after harvesting in the 1960's.

There is no evidence that most of the existing lodgepole pine stands established on areas that were formerly grassland, thus being encroachment since European arrival. This is due to the lack of veteran Douglas-fir trees in most areas, and indications that the pine stands established after a previous MPB epidemic and fire. The young age of the lodgepole pine forests in more likely due to past stand-replacing fires rather than recent encroachment onto grasslands.

Spruce-dominated stands are located in wetter areas such as on toe slopes and along watercourses; however, not enough spruce sites were visited to present meaningful regeneration data. However, there was little pine in theses spruce stands so vegetation management will not be required in these stands.

Descriptions of the shrub, herb and moss layers were compromised by a snowfall that occurred over the fieldwork period. The herb and shrub layers in the both the pine dominated and Douglas-fir dominated stands are variable. The shrub layer is dominated by soopolallie, common juniper, prickly rose, birch-leaved spirea and snowberry. The herb layers contained pinegrass, kinnikinnick and twinflower. In pine stands in drier areas the herb layer contains more grasses, especially bluebunch wheatgrass, the shrub layer is poorly developed, and the moss layer may be absent. Moss was mostly present in damper areas with the dominant moss being feathermoss.

An outbreak of western spruce budworm has been attacking the Douglas-fir and spruce trees in the park, as evidenced by extensive defoliation in some areas. All ages of trees are attacked, with tree mortality typically occurring more in saplings than older trees. In the region the outbreak to date has been widespread but not severe (Andre Arsenault, Silviculture Systems Researcher, Ministry of Forests and Range, *pers. comm.*). Tree mortality can occur after several years of severe defoliation, with other damage including top-kill, reduced seed production, and reduced height and volume growth (Henigman *et al.* 2001). The long-term effects of this outbreak include the possibility of delayed or slowed understory regeneration, depending on whether the growth of the effected trees is stunted, or if the trees are killed.

7.2. Wildlife

The IDFdk1 is classified as being having moderate snow depth in relation to deer winter range, and shallow in relation to moose winter range (Ungulate Winter Range Technical Advisory Team 2005). As snow depth is more restricting to deer than moose, relevant cover objectives and strategies for deer winter range in moderate snow depth conditions from the above report are presented below. The forage strategies are not presented here, as forage availability is likely to be positively impacted (Chan-McLeod 2006).

Objectives for deer winter range in areas of moderate snow depth:

1. Maintain or enhance high shrub cover of preferred forage species.
2. Maintain or enhance areas of snow interception cover by maintaining original stand characteristics and additional evergreen cover in patches of various sizes.

Recommended cover strategies for deer winter range in areas of moderate snow depth:

- Distribute snow interception cover throughout area but concentrate at lower elevations, adjacent to forage and along travel routes and terrain breaks.

- Thinning-from-below can be used to open the understorey while maintaining snow interception by the canopy.
- Encourage patches of large Douglas-fir for snow interception cover; leave Douglas-fir of the largest size available.
- Maintain original stand characteristics in areas of densest canopy closure (Ungulate Winter Range Technical Advisory Team 2005).

The objectives and strategies above focus retaining snow interception cover through retaining large Douglas-fir trees. In Tunkwa Park many of the older Douglas-fir trees were removed through selective harvesting in the 1960s. Now much cover is being lost through MPB caused tree mortality. It is thus important to ensure that future management actions do not remove additional canopy cover within the park.

For cavity-nesting birds, Martin *et al.* (2006) recommends that habitat management include:

1. retention of all deciduous trees, especially those near conifers,
2. retention patches $\geq$1 ha, with some larger patches (>10-50 ha) for mature-forest-dependent species, and
3. retention of riparian areas and other conifer forests for wildlife refuges.

7.3. Invasive Plant Species

An inventory of invasive plant species was not conducted as part of this project; however, the Ministry of Forests and Range's Invasive Alien Plant Program database (Ministry of Forests and Range 2007) shows ten invasive plant species within and adjacent to Tunkwa Park (**Table 11**). Weeds were occasionally seen in the forested areas of the park, with bull thistle and Canada thistle being the most common. Mapped occurrences of weeds are predominantly near developments in and near the park, such as campgrounds, roads, powerlines and pipelines (Ministry of Forests and Range 2007).

Table 11. Invasive plant species found within or adjacent to Tunkwa Park

Common Name	Latin Name	Comments
Bull thistle	*Cirsium vulgare*	Seen in various places in the park, including forests and wetlands
Canada thistle	*Cirsium arvense*	Seen in various places in the park
Common burdock	*Arctium minus*	
Common tansy	*Tanacetum vulgare*	
Diffuse knapweed	*Centaurea diffusa*	
Hound's tongue	*Cynoglossum officinale*	
Night-flowering catchfly	*Silene noctiflora*	
Oxeye daisy	*Leucanthemum vulgare*	
Spotted knapweed	*Centaurea biebersteinii*	
Sulphur cinquefoil	*Potentilla recta*	

When conducting management activities that involve the disturbance of soils or vegetation, there is potential for creating conditions that facilitate the establishment or increase in invasive plant species. All of the invasive plant species found in or near Tunkwa Park are associated with disturbed habitat conditions (Ministry of Forests and Range 2006). In areas where restoration or rehabilitation activities are planned, the Best

Management Practices for the prevention of invasive plant establishment should be followed (Miller and Wikeem 2006).

Treatments that disturb the ground and expose bare soil would increase the probability of invasive plants getting established. Allowing natural processes occur would not cause direct ground disturbance, and would provide the least opportunity for invasive plants to spread in the park. However, once dead trees begin to fall, exposed soils at the root wad may serve as invasive plant establishment points. With the no treatment option, there is also an increased probability that if a wild fire occurs it will be very intense, burning the entire duff layer and exposing the mineral soil and thus increasing the risk of invasive plant establishment. Conducting a prescribed burn when a proportion of the dead trees have fallen could reduce the hazard of a very hot wildfire and concomitantly, invasive plant establishment.

7.4. Fuel Property Changes

Most of the MPB attacked trees in Tunkwa Park have been dead for some time and have already lost their needles, with current attack mostly occurring on smaller understory trees. This means that the amount of fuels in tree crowns has already declined and likelihood of a crown fire becoming initiated and carrying is diminished in attacked stands. Immediate risk of large severe wildfire is therefore reduced in the short term.

As the dead trees fall, however, the surface fuel loading will increase. The increase of surface fuels due to falldown can be slow as trees decay, or be rapid if there is a large blowdown event. Fall down rates in the IDF zone are yet to be determined; however, given the studies to date, it is reasonable to assume that surface fuel loading will continue to increase for the next 10-30 years. There are anecdotal reports of extensive windfall of dead pine trees in Tunkwa Park in the fall of 2007, with over 50% of the stems down in some areas (Bob Haywood-Farmer, Indian Garden Ranch, *pers. comm.*).

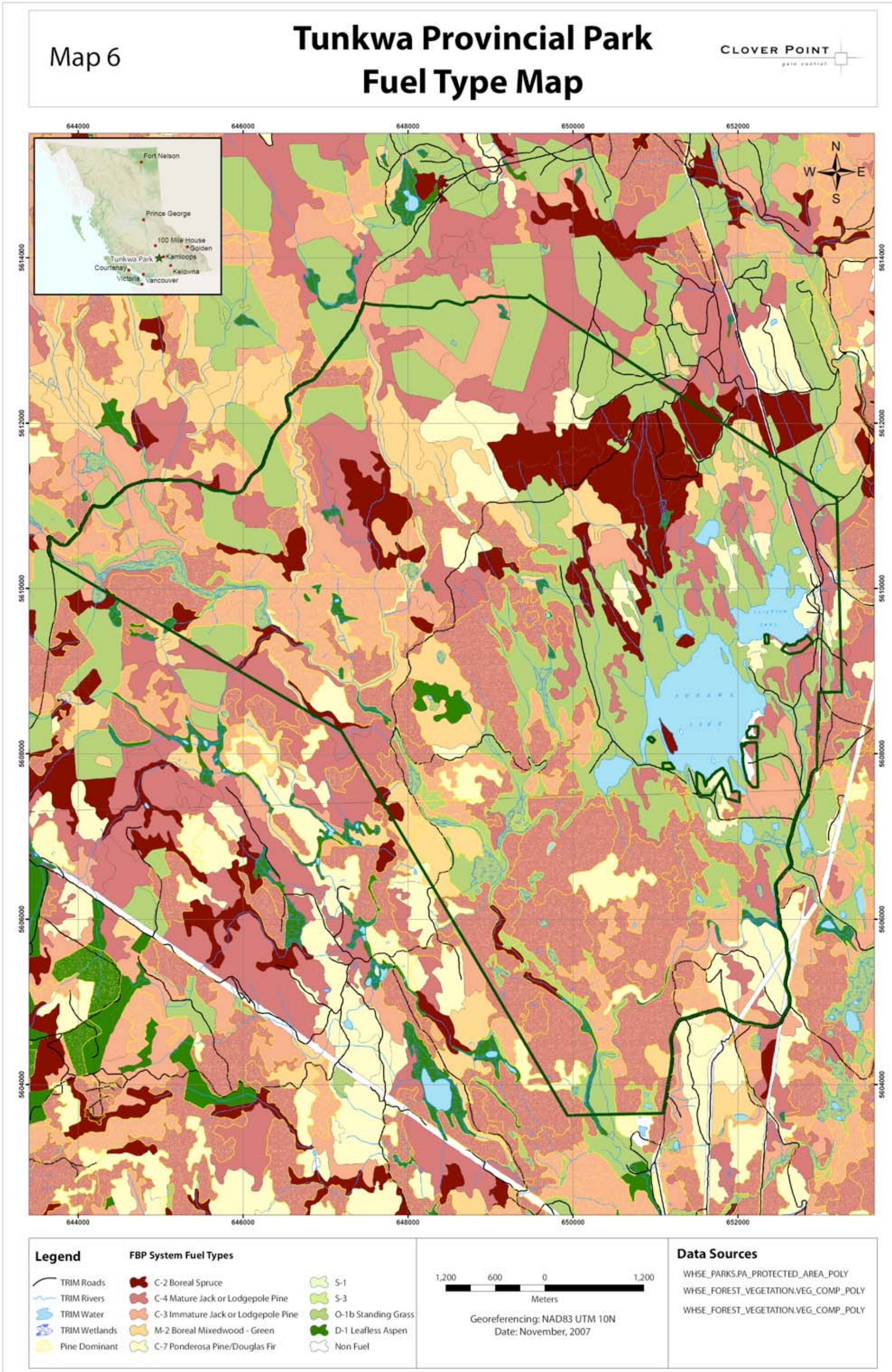
This increased surface fuel loading will result in greater surface fire intensities due to the abundant supply of dead fuel on the ground. The increased surface fire intensities will also make fires more difficult to control and extinguish. The high severity and long duration of fires from the heavy fuels will impact forest soils. These soils can become sterilized of microflora and fauna and may not support healthy vascular plant communities for a considerable time following the burn. These sterilized areas are often colonized by invasive alien plant species that do not require mycorrhizal associations for vigorous growth.

In the Douglas-fir stands, most of which have seen some harvesting activity, the resulting young dense conifer stands have the highest fire behaviour potential in the park (Map 6). The young trees are able to rapidly carry fire to the crown, and the dense stands allow fire to spread rapidly. As these stands develop over time, lower branches will die, lowering the fire behaviour potential. This will be a slow gradual process, however, taking many years.

Mechanical thinning or pruning treatments can be used to change the fuel characteristics of a stand. Whole tree removal can be used to thin stands if the trees were of merchantable size, but this is not the case in Tunkwa Park where the Douglas-fir stands are dense and generally young, and the older, larger trees need to be retained. Thinning dense young stands could be done and a more open stand is desired either to mimic historical conditions or to reduce fire hazard. Pruning the lower branches from trees can reduce the potential for crown fires; however, manual treatments are expensive so not usually practical for large areas.

The fire behaviour potential of the grasslands in the park changes through the year. In the early spring before green-up there are abundant cured grasses and foliar moisture of tree needles is at its lowest, so fires, including crown fires, are possible. In early summer, grass greens up and foliar moisture increases lowering fire behaviour potential, which increases through the summer as grass cures and other fuels dry out. In fall, the grass is fully cured, and the drought code and fuel build-up index can both be high so fires are still possible. At these times the fire behaviour potential of the forests may be lower than during the summer, reducing the potential for a grass fire causing a crown fire in the forests.

For more detailed information on the fuel types in the park, fire climatology, and fire modelling see Armitage (2008).



Map 6. Fuel Types in Tunkwa Park, darker red colours indicate higher fire behaviour potential

7.5. Future Forests

The airphotos showed that the forests of the park have changed substantially since 1948. These past conditions are useful for guiding the conditions that are be desirable in the future. The most obvious change in the forests is the change to young forests caused by recent fires and forest harvesting; this will be exacerbated by the MPB epidemic, and the elimination of open forests. However, these old forests only covered part of the park; those areas harvested in the 1960's.

Future desired conditions for the park, would be more forests with the structural attributes of old forests. Structural attributes of old forests include large old trees, some CWD, and can be defined through stand density, diameter and age distribution, species composition and the spatial arrangement of trees, and amount and size of CWD (Fiedler *et al.* 2007). While detailed numbers to define these structural attributes are not presented, management actions can be directed towards achieving old open forests. Treatment options are presented in Section 7.6.

With the changing climate, the climate of the Tunkwa area may be more favourable to grasslands than forests. In former times under different climatic conditions, grasslands were more extensive in BC, covering areas up to 1300 meters elevation – the upper elevation of Tunkwa Park (Hebda 2007). How species will respond and ecosystems will be transformed by these changed climatic conditions is unknown, but change will occur.

7.5.1. Lodgepole Pine Forests

Based the present tree species composition of regeneration in lodgepole pine stands, if left untreated the pine forests in the park will change from being pine dominated to being mixed forests dominated by pine and Douglas-fir, with a minor spruce component. The mix and density of trees will vary among areas, with some areas having little regeneration and some quite dense. The final composition of the stands will also depend on future tree establishment patterns, which may be different than the recent past due to the changed growing conditions with a dead pine component. In the Sub-boreal Spruce zone, there is no pulse of regeneration following MPB as occurs after more intense disturbances such as fire; this is due to the MPB epidemic not directly causing ground disturbance that would facilitate tree establishment (Astrup *et al.* submitted). Similar results have been found in other parts of the province (Hawkes *et al* 2004, Dykstra and Braumandl 2006). Regeneration may be patchy with shade-tolerant species being favoured, which is different than succession after disturbance by fire where few trees survive and regeneration by shade intolerant pine is favoured (Hawkes *et al.* 2004, Astrup *et al.* submitted).

Residual live trees in stands where MPB has killed the pine component will have a growth response to the increase in light, nutrient and water availability (Romme *et al.* 1986, Heath and Alfaro 1990, Hawkes *et al.* 2004). This can be seen in net primary productivity response of the forests. For example, in Colorado net primary productivity of trees returned to pre-epidemic levels 10-15 years after a MPB epidemic (Romme *et al.* 1986). The result of this increased growth is an accelerated succession to shade tolerant species.

Some of the present pine stands resulted from fires that occurred in the 1930s or 1940s, these stands contain some Douglas-fir and spruce, a similar mix of species could be expected after future fires. In the absence of fires until the Douglas-fir is able to survive fire, these residual Douglas-fir and spruce trees will become the dominant trees in the stands. Eventually, the stands structure could be analogous to the Douglas-fir stands that were harvested in the 1960s.

If prescribed burns were used in the pine forests, the regeneration would most likely be to pine-dominated stands. This is because pine is a pioneer species adapted to regeneration after fire. Fire would release pine seeds from the serotinous cones that are held on the trees. Most of the live trees in burnt areas would be killed due to their young age and thin bark, though older Douglas-fir trees (>40 years old (Steinberg 2002)) may survive fire. The loss of this advance regeneration would not be desirable as it would be an additive disturbance to the effects of MPB (Stadt 2002, Chan-McLeod 2006).

Untreated forests will have an abundance of standing dead wood or snags, which will fall with time. These snags will provide habitat structure that will be used by species, though the supply of this habitat feature will likely exceed the capacity of wildlife to use it, and cavity-nesting animals do not generally prefer lodgepole pine snags. Available live trees are more likely to be limiting habitat use than snag availability (Chan-McLeod 2006).

Once fallen, snags become coarse woody debris (CWD). CWD is used by many species, especially once decay has set in and the wood has softened, but this will take some time. Prior to becoming soft, CWD is used primarily as perches or for cover (Chan-McLeod 2006).

The understory vegetation of the park will change over time as a result of the changed growing conditions resulting from the death of the pine canopy. Studies in other areas have found the understory has responded in varied ways, for example Dykstra and Braumandl (2006) found a large increase in tall shrubs, dwarf shrubs and forbs in part of their study area in the Rocky Mountains, while in another part of the Rocky Mountains graminoids or mosses showed the greatest increase depending on the time since MPB attack.

The areas logged in the 1990s were mostly clearcut, except for some large Douglas-fir trees that were retained. These cutblocks have been replanted to pine. There has been some Douglas-fir and spruce establishment in these cutblocks, and more Douglas-fir will likely become established especially near the residual Douglas-fir trees. These trees will be important in providing structure to these young pine stands.

7.5.2. Douglas-fir Forests

The Douglas-fir forests in the park have been regenerating after the extensive selective harvesting that occurred from 1963-1967. These forests are composed of fairly dense young Douglas-fir and spruce stands, mixed with older residual trees and linear openings caused by old skid roads. There is very little pine in these areas. Under the dense young canopy, the understory vegetation can be poorly developed due to a lack of light. As these stands develop, self-thinning may occur, and if it does occur the stands will gradually open up and the understory vegetation will become better developed.

Most of the present Douglas-fir stands would be very susceptible to crown fire due to the large amount of ladder fuels present in the stands. Crown fire would kill most of the trees in the burn area depending on severity, and would not be desirable in the park at this time. This is because much of the park presently contains very young stands because of the recent history of fire, harvesting and mountain pine beetle attack. Removing some of the older stands in the park would exacerbate of the dominance of young stands in the park.

7.5.3. Other Forest Types

The other forest types in Tunkwa Park are spruce forests and aspen forests. Spruce forests are mostly found in wetter areas such as toe slope positions and riparian areas. These forests are, for the most part, not directly affected by the mountain pine beetle epidemic due to the lack of pine trees in these stands. However, in other parts of the province, the water table has risen due to the reduction in evapotranspiration and canopy interception resulting from the death of pine trees. The increase in soils moisture could be greatest in toe slopes and riparian areas due to their moisture receiving position on the landscape, and finer soils (Rex and Dubé 2006).

7.6. Treatment Options

There are numerous considerations and trade-offs to be made with any management decisions regarding responses to MPB, and park management in general, in parks and protected areas, these include:

- Future forest fire hazard, both of ground fire and crown fire,
- Impact of future potential fires on resulting type of vegetation and vegetation dynamics, park infrastructure and adjacent values, and
- Potential benefits and costs of prescribed burning and/or mechanical treatment versus letting natural process occur.

There are three practical options for managing forest values: prescribed burning, mechanical treatment and allowing natural processes proceed (Table 12). Allowing natural processes to proceed is the default option and includes succession and natural fire. Mechanical treatment could consist of whole tree removal, thinning young stands, or pruning trees to prevent crown fire. Tree removal needs to be done in conjunction with the restoration of natural processes, such as fire, to be consistent with BC Parks policy.

Table 12. Pros and cons of potential forest management options		
Method	**Cons**	**Pros**
Prescribed burning of mountain pine beetle killed standsp	• Is an additive disturbance to an already disturbed landscape (Section 4.2.1) • Fire will kill advance regeneration already present and reduce cover for ungulates (Section 7.2) • Will produce young pine stands, which are common on the landscape (Section 4.2.1) • Potential for fire to escape target area and burn other non-target areas including local infrastructure (Section 4.2.2) • May facilitate weed invasion (Section 7.3 and 4.2.2) • Lack of clear benefit to wildlife (Section 4.2.3 and 7.2) or vegetation (Section 4.2.1)	• Will reduce potential of wildfire through reducing fuel loading (Section 4.2.2) • Prescribed fire can be done at a tine that minimizes risk to other values (Section 4.2.2)
Mechanical treatments in Douglas-fir stands	• Treatments are labour intensive (Section 7.4) • Is an additive disturbance to an already disturbed landscape (Section 4.2.1)	• Thinning or pruning trees will reduce the risk or fire spreading to the crown (Section 7.4) • In Douglas-fir stands would create more open stand analogous to a more historical condition (Section 6.2)
Allowing natural processes to proceed	• The risk of wildfire will increase as dead pine trees fall and ground fuel loading increases (Section 4.2.2) • Wildfire, if it occurs, may be much hotter than a prescribed fire consuming the duff layer and facilitating weed invasion (Section 7.4)	• Does not introduce additional disturbances to the landscape (Section 4.2.1) • Studies have shown that wildlife habitat value increases over time in MPB affected stands (Section 4.2.3)

The main reasons to proceed with prescribed fire and/or mechanical treatment would be:

1. if the successional trajectory of the vegetation, including the dead component post-MPB, was projected to have negative effects on wildlife or recreation or safety in the park or not produce the desired vegetation, and these negative effects outweighed any positive effects, and the negative effects could be corrected by treatment, or;
2. if the natural fire risk to natural, cultural or other values either inside or outside the park was high enough to warrant intervention to prevent a large or high intensity natural fire.

Even if these conditions were met, it is unlikely that there will be resources available to conduct treatments over all areas of the park that have been affected by MPB or other disturbances due to the size of the park. Thus, it will be necessary to target the areas where the treatments would be most effective, such as those where the fire hazard or negative consequences of wildfire would be the greatest. Also,

7.7. Recommendations

7.7.1. Lodgepole Pine Forests

There is no need for management actions over most of the MPB affected area in the park in the immediate future, to address conditions resulting from the MPB outbreak from an ecological perspective. However, as fuel loading increases in MPB affected areas there is an increased risk of wildfire in these areas. Preventative measures to reduce the risk of fire spreading from high use areas, where the probability of wildfire starting is the highest, may be warranted. Fuel breaks and small prescribed fires can be used to as a precautionary measure against large uncontrolled wildfires (see Section 7.7.4).

Park managers should work with ranchers to determine methods that can be effective in allowing ranchers to move in the park. This may involve cutting fallen trees along routes between grassland areas to facilitate movement on horseback. Care must be taken that new trails are not constructed that would be used by ATVs.

7.7.2. Douglas-fir Forests

The desired future condition of the Douglas-fir forests should be forests that contain the structural characteristics of old open Douglas-fir forests. Achieving these conditions could be hastened by thinning the stand and pruning trees. However, these forests are still recovering from disturbance caused by past harvesting operations that greatly altered these forests. Additional disturbance caused by thinning and pruning large areas containing dense stands to produce open stands is not necessarily desirable, and is not recommended. Allowing natural processes to occur is the recommended for most areas containing Douglas-fir forests; thinning and pruning may appropriate over small areas as part of producing fuel breaks (see Section 7.7.4 Fire Protection).

7.7.3. Other Forest Types

It is not known if forested areas are getting wetter in the Kamloops area, but if they are it could affect vegetation processes such as regeneration dynamics while the forests affected by MPB recover their hydrological influence as new forests grow. No management actions are needed in spruce-dominated forests at this time.

Aspen stands occur in a small portion of the park. Deciduous stands are important for wildlife habitat due to the preference of deciduous trees for cavity nesting species (Fenger *et al*. 2006). It is not known how aspen will respond to the MPB, but any management actions in the park should work to ensure the retention of aspen. No management actions are needed in aspen-dominated forests at this time.

7.7.4. Fire Protection

Armitage (2008) recommends that fuel breaks be established to tie into existing fuel breaks formed by pipeline and hydro right-of-ways. In other provincial parks shaded fuel breaks have been created by thinning the canopy to approximately 25% crown closure, pruning trees to remove ladder fuels, and removing ground fuels; advance regeneration is removed but deciduous trees are encouraged. The crown cover serves to retain some ground moisture. The width of the fuel break varies with the terrain with steeper terrain requiring wider breaks. These fuel breaks are considered effective against medium intensity fires. Tying the break into natural and human caused breaks such as riparian areas, roads and slope breaks increases their effectiveness. Progressive burns up to the fuel break will also increase their effectiveness (Lyle Gawalko, Forest Ecosystem Officer, Ministry of Environment, *pers. comm.*). The specific location and prescription of fuel breaks in Tunkwa Park will need to be designed on the ground by a qualified professional. A prescription similar to that described above may also serve to establish the open forest conditions that were previously more common in Tunkwa Park.

The area where prescribed fires would most likely be required is north of Leighton and Tunkwa lakes, as these areas are close to the campgrounds and the most probable direction of a fire spreading if one started in the campgrounds (Armitage 2008). Planning for these burns will need to involve fire specialists and biologists.

8. Managing Grasslands

Cattle have grazed the grasslands in Tunkwa Park since the mid 1980s (BC Parks 1997a). This grazing has changed the grasslands from the state they were previous to grazing. Prior to Tunkwa Park being established the grasslands in the park were in a degraded state. Since park establishment an extensive system of fences has allowed better management of grazing in the park. The park is now only grazed late in the season to allow seed production. This has allowed bluebunch wheatgrass and rough fescue to increase in cover over the last 10 years, improving range condition (Bob Haywood-Farmer, Indian Garden Ranch, *pers. comm.*).

A number of different grassland types were observed in the park during the fieldwork; however, the focus of this work was on forested areas so no inventory was done. The lack of detail on grasslands makes it impossible to make specific recommendations on the need for restoration.

Grasslands in many areas of the province have been experiencing encroachment by trees. This encroachment has been attributed to three main factors: 1) changes in the amount of fine grassy fuels due to the introduction of cattle an horse grazing, 2) the disruption of First Nations traditional land management practices, and 3) fire suppression activities (Rocky Mountain Trench Ecosystem Restoration Steering Committee 2006). Combined, these factors led to a reduction of fire frequency, allowing tree seedlings get established and grow to tree size. The species of tree encroaching on grasslands is most commonly Douglas-fir, but may also be aspen in northwestern British Columbia and lodgepole pine. Changed climatic conditions (i.e.: increased moisture) could also be a factor in fire frequency and encroachment.

Restoring grassland is very complicated due to the interaction of biological processes and social factors, including smoke concerns, local infrastructure and the potential for fire escape. Having sufficient fuels to burn grasslands can be a problem, especially if they are grazed. Eliminating grazing for several years before burning may be required to allow fuels to build-up, and also post-burning to allow the vegetation to recover.

Management actions to restore grasslands to their former condition or to a different more desirable state have often been recommended and undertaken. Three actions, used alone or in combination, are most often used when restoring encroached grasslands or in-filled open dry forests: 1) logging to remove overstory trees, 2) brushing or thinning to remove small stems, and 3) reintroducing fire to the grassland ecosystem.

Although some areas have experienced in-filling making stands denser, the MPB killing many trees in the park making stands more open. These stands may eventually resemble the Douglas-fir stands that were harvested, depending on the density of the subsequent regeneration, if fire does not occur killing the Douglas-fir trees in the stands. The stand structure of the newly killed stands may not entirely mimic those that have been in-filled, but may develop this structure over time.

8.1. Recommendations

The amount of encroachment and in-filling that has occurred in Tunkwa Park do not warrant restoration initiatives to restore the grasslands at present. Long-term monitoring to determine if encroachment is on-going or increasing, especially post-MPB, will help guide future park management activities.

The use of fire to maintain the existing grasslands is an appropriate management option and should be considered if it is shown that encroachment of the grasslands is a problem in the park. Fire will likely need to be used in conjunction with brushing, thinning or pruning trees to ensure that the fire has the desired effects and does not become a crown fire. Restoration is a long-term process, so multiple treatments may be needed if restoration is required.

Any grassland restoration efforts need to be carefully planned; the Ministry of Water, Land and Air Protection (2002) provide guidance in their publication Ecological Restoration Guidelines for British Columbia.

Managers need to work with the Skeetchestn First Nation to ensues cultural values are being protected. This could include a Cultural Resource Inventory for the whole park or for the areas in which management activities are being planned for.

9. Knowledge Gaps

As fuel will build up over time, the fire hazard will also change over time. Presently, the knowledge of how fire will behave with these conditions is incomplete. Monitoring fuel loading and keeping up-to-date with improvements in fire behaviour knowledge will allow managers to take actions based on this developing knowledge base.

There is a lack of information on cultural and archaeological values in Tunkwa Park. The Ministry of Environment should work with the Skeetchestn First Nation to identify cultural and archaeological values in the park.

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Appendix 1. Latin Names of Species used in Text

Trees

Douglas-fir	*Pseudotsuga menziesii*
Interior spruce	*Picea glauca* x *engelmannii*
Lodgepole pine	*Pinus contorta*
Mountain pine beetle	*Dendroctonus ponderosae*
Ponderosa pine	*Pinus ponderosa*
Rocky Mountain juniper	*Juniperus scopulorum*
Trembling aspen	*Populus tremuloides*
Western white pine	*Pinus monticola*

Shrubs

Birch-leaved spirea	*Spiraea betulifolia*
Common juniper	*Juniperus communis*
Prickly rose	*Rosa acicularis*
Red-osier dogwood	*Cornus stolonifera*
Sagebrush	*Artemesia tridentata*
Snowberry	*Symphoricarpos albus*
Soopolallie	*Shepherdia canadensis*
Willow	*Salix* spp.

Herbs and Mosses

Alkaline wing-nerved moss	*Pterygoneurum kozlovii*
Bluebunch wheatgrass	*Agropyron spicatum*
Feathermoss	*Pleurozium schreberi*
Freckled milk-vetch	*Astragalus lentiginosus*
Kinnikinnick	*Arctostaphylos uva-ursi*
Pinegrass	*Calamagrostis rubescens*
Rough fescue	*Festuca campestris*
Twinflower	*Linnaea borealis*

Animals

Badger	*Taxidea taxus*
Black bear	*Ursus americanus*
Blue grouse	*Dendragapus obscurus*
Bobcat	*Lynx rufus*
Brown creeper	*Certhia americana*
Caribou	*Rangifer tarandus*
Chickadees	*Parus* spp.
Cougar	*Felix concolor*
Crossbills	*Loxia* spp.
Flying squirrel	*Glaucomys sabrinus*
Kinglets	*Regulus* spp.
Lewis’ woodpecker	*Melanerpes lewis*
Long-billed curlew	*Numenius americanus*
Lynx	*Felix lynx*
Marten	*Martes americana*
Meadowlark	*Sturnella neglecta*
Moose	*Alces alces*

Mule deer	*Odocoileus hemionus*
Olive-sided flycatcher	*Contopus borealis*
Porcupine	*Erethizon dorsatum*
Rainbow trout	*Oncorhynchus mykiss*
Red squirrel	*Tamiasciurus hudsonicus*
Red-breasted nuthatch	*Sitta canadensis*
Sandhill crane	*Grus canadensis*
Sapsuckers	*Sphyrapicus* spp.
Short-eared owl	*Asio flammeus*
Snowshoe hare	*Lepus americanus*
Spruce grouse	*Dendragapus canadensis*
Vesper sparrow	*Pooecetes gramineus*
Vireos	*Vireo* spp.
Voles and mice	*Microtus* spp.
Warblers	Emberizidae
Western spruce budworm	*Choristoneura accidentalis*
Woodpeckers	*Picoides* spp.
Yellow-bellied marmot	*Marmota flaviventris*