Implementing Climate Change Adaptation

in Prince George, BC

Volume 6: Natural Areas and Ecosystems

Chelsea Coady

March 2012

Acknowledgement of Sponsors

The preparation of the eight volumes of *Implementing Climate Change Adaptation in Prince George, BC* the production of educational videos, participation of the project team during the City of Prince George *myPG* process and the organization of several workshops and meetings with local government, provincial government, academics/researchers and stakeholders was made possible by funding from Natural Resources Canada's (NRCan) Regional Adaptation Collaboration (RAC) Program.

Natural Resources Canada | Ressources naturelles Canada | Canada

The City of Prince also acknowledges the administrative support and assistance of the Fraser Basin Council during the RAC program.

Executive Summary:

Implementing Climate Change Adaptation in Prince George, BC

Volume 6: Natural Areas and Ecosystems

Natural areas contribute significantly to the environmental, social, and economic health of a community. For example wetlands recharge groundwater resources and mitigate flood hazards, and naturally forested areas provide aesthetic, recreational, and educational services and also increase the value of adjacent properties. Approximately 22,000 ha of naturally forested areas and parks exist within the City of Prince George, representing over 65% of the city's land base.

In 2010, as part of the larger Natural Areas Project, the City commissioned terrestrial ecosystem mapping (TEM) and sensitive ecosystem inventory (SEI) mapping for the undeveloped natural areas within the city (wetlands, grasslands, naturally forested lands, and parks larger than 1 ha). TEM is a standard approach to mapping different ecological communities across the landscape that share similar vegetation, soil moisture and nutrients, and climatic conditions. SEI is an additional informative layer that maps the most sensitive ecosystems in an area such as rare ecosystems, important wildlife habitat, or areas at risk due to climate change.

There are four major phases in Prince George's Natural Areas Project. Phases 1 and 2 have been completed and phases 3 and 4 are currently being developed.

Phase 1

Phase 1 is the actual mapping and inventory project that provides the City with detailed baseline ecological information. Phase 1 also provides important wildlife habitat information and invasive plant species identification. This information is needed to inform proper decision making by City planners and managers and is the basis for the remaining three phases of the project.

Phase 2

Using the detailed, species-level information from Phase 1, the City had modelling and analyses performed to provide information on how undeveloped, natural areas could be impacted by climate change. Climate change may potentially alter the characteristics, functions, and thus the values of these areas; changing the appropriateness of specific future planning and development decisions. Prior to the Natural Areas Project, the community identified several priority areas for climate change adaptation. Table 1 below shows how Phase 2 of the Natural Areas Project addresses several of these areas.

Phase 2 focused on climate change impacts to soil moisture because drought is considered to be one of the leading climate-induced impacts on natural areas. A soil-moisture risk-analysis tool was used to estimate the risk of drought-induced mortality and related harm to species health for forested sites and individual tree species. This analysis tool identified that the most dramatic change in soil moisture, and thus climate-induced risk, occurs between the years 2011 and 2020. By 2080, the "sensitive" areas in Prince George, such as the Douglas-fir (*Pseudotsuga menziesii*) stands along the dry cutbanks of the Nechako River, will be most impacted by climate change and are predicted to have very dry to extremely dry soil moisture.

Individual tree species most at risk for climate change are deciduous species, such as birch (*Betula papyrifera*), cottonwood (*Populus trichocarpa*), and aspen (*Populus tremuloides*), primarily due to the fact that these species inhabit areas with fresh to slightly dry soil moisture, which are expected to become drier and less hospitable for these species with changes to climate. Climate change may result in increases in the prevalence and distribution of

invasive species, such as cheatgrass (*Bromus tectorum L.*), which was found on the cutbanks of the Nechako River in Prince George.

Table 1. Climate change adaptation priority areas, climate-related impacts, and benefit of the Natural Areas Project for Prince George.

Priority Area	**Climate-Related Impact**	**Connection with Natural Areas Project**
Forests	Species composition changes Vulnerability to drought, invasive species, pest outbreaks and diseases Increased wildfire risk	Forested areas and parks represent approximately 65% of the land within the City of Prince George; the Natural Areas Project identifies how these areas may be impacted by climate change
Flooding	Changes to natural erosion and flood mitigation functions if trees and vegetation are impacted	Climate change impacts may have hydrological implications if trees and vegetation are affected, potentially impacting flood plain mapping decisions in the future
Agriculture	Impacts on soil moisture, drought impacts, invasive species, crop diseases and pests	Predicted impacts to natural, undeveloped areas may provide insights on potential impacts to nearby agricultural land
Slope Stability	Impacts to soil moisture and related plant mortality affect slope stability	The Natural Areas Project can identify sensitive natural areas that provide extensive slope stabilization

Phases 3 and 4

Phases 3 and 4 will utilize the City's current online mapping tool, *PGMap*, to translate this technical information into a user-friendly format. These phases will also require that the City determine what values certain natural areas have in order to develop proper management and planning recommendations. The City plans to develop a monitoring strategy that will assess the health and composition of certain monitored natural areas to determine if certain climate change impacts are occurring. The City can use this information to effectively adapt development and local policy decisions based on predicted climate change impacts.

In addition to phases 3 and 4, the City can continue with this work by taking the following actions:

- Actively communicate the information provided from the Natural Areas Project to all City departments and public stakeholders to ensure the tools and resources developed from Phase 3 and Phase 4 are being utilized
- Consider climate change impacts not examined in the Phase 2 modelling such as extreme events (e.g. windstorms and freeze-thaw events), which can increase mortality of less hardy, more sensitive species; these impacts should be considered when making decisions related to the planning and potential development of all natural areas
- Consider modelling climate change impacts to natural areas not examined in Phase 2 modelling (e.g. wetlands, grasslands)

- Consider all opportunities to collaborate or seek advice from local and regional organizations (such as the Northwest Invasive Plant Council) and provincial ministries with expertise in understanding climate impacts on plant and animal species

Background

Natural Resources Canada established the Regional Adaptation Collaborative (RAC) program in 2008 to assist communities and regions across the country as they adapt to climate change. Adaptation refers to actions that respond to or prepare for changes in the climate that are either expected or already occurring. Actions can be taken to become more prepared for unexpected events, to minimize the negative impacts of events already occurring or expected, or to maximize any positive benefits that may arise. Adaptation is different than climate change mitigation, which refers to actions that reduce the amount of greenhouse gases (GHGs) in the atmosphere.

Prince George has become a leader in community adaptation, and has been pursuing this topic for over five years in partnership with many organizations. The City was selected to be one of four community case studies to participate as part of the British Columbia (BC) RAC program (NRCan, 2011). The RAC funding allows for Prince George to build upon its climate change adaptation efforts to incorporate adaptation into local plans and begin implementing actions to address priorities within city administration. The City of Prince George has worked closely with the University of Northern BC (UNBC) and the Fraser Basin Council on this project, along with many other collaborators.

Although the focus of the Prince George RAC project is on adaptation, actions that address both adaptation and mitigation are encouraged whenever possible. Both adaptation and mitigation will be necessary for communities to prepare for and respond to climate change. Adaptation is needed to respond to the changes that are occurring in the climate, and mitigation is required to prevent further changes that may severely impact natural and human systems in the future.

The adaptation work conducted in Prince George under the RAC program is documented in this written case study, consisting of eight volumes. Each volume discusses an impact priority or a specific project from the many and varied community initiatives that RAC team members have contributed to in Prince George. Where applicable, the case study draws direct links to Prince George's adaptation priorities, as identified in the strategy document, *Adapting to Climate Change in Prince George: an overview of adaptation priorities* (Picketts et al., 2009a), which was received by City Council in November 2009.

The Volumes of *Implementing Climate Change Adaptation in Prince George* are:

Volume 1: The *myPG* Integrated Community Sustainability Plan

Volume 2: The Official Community Plan

Volume 3: Forests

Volume 4: Flooding

Volume 5: Transportation Infrastructure

Volume 6: Natural Areas and Ecosystems

Volume 7: Precipitation and Freeze-Thaw

Volume 8: Ongoing and Future Initiatives

Contents

Introduction

Natural areas are often not recognized as an important part of a city or town, but undeveloped natural areas are integral parts of a healthy and sustainable community. They contribute to the environmental, social, and economic health of a community and provide many services that we depend on. Wetlands provide essential ecosystem services such as purifying water, recharging important groundwater resources, and mitigating flood hazards. Open grasslands provide important grazing habitat for wildlife and forested ecosystems absorb greenhouse gases, stabilize steep slopes, and mitigate flooding hazards and erosion. These natural areas increase the economic value of adjacent properties and attract new residents and businesses to the community. Natural areas also enhance community well-being and health through the aesthetic, recreational, and educational services they provide.

In Prince George, undeveloped natural areas represent a large portion of the land within and around the city, which is why Prince George is often referenced as a “city within a forest” (Figure 1). Approximately 22,000 ha of natural forested areas and municipal parks exist within the city, representing over 65% of the city’s land base (City of Prince George, 2005). It is therefore important to assess the current function and services of these undeveloped natural areas to help guide future land use, development, and planning decisions. Evaluating potential risks to natural areas in the city is also required to effectively manage and monitor critical ecosystems.

Figure 1. Aerial view of central Prince George with surrounding forested lands.
(Photo: courtesy of the City of Prince George)

In an effort to better understand and manage the natural areas within city limits, the City of Prince George embarked on a Natural Areas Project involving a series of studies undertaken between 2010 and 2012. This work is organized in four phases:

- Phase 1: Complete Ecosystem Mapping of Natural Areas
- Phase 2: Model Effects of Climate Change on Natural Areas
- Phase 3: Produce User-Friendly Online Mapping Products
- Phase 4: Develop Management and Monitoring Plans for Natural Areas

In Phase 1 of the Natural Areas Project, the City of Prince George commissioned terrestrial ecosystem mapping (TEM) and a sensitive ecosystem inventory (SEI) for all of the undeveloped land within the city. This project was funded by the Real Estate Foundation of BC. The TEM and SEI mapping projects provide quantitative information about the physical and vegetation characteristics of Prince George's undeveloped areas (e.g. forested areas, wetlands, and grasslands). Ecosystem maps provide a foundational inventory of natural areas and are used in different ecological assessments such as biodiversity monitoring and wildlife habitat suitability, and they can also be used to inform future land development decisions (Bio-Geo Dynamics Ltd, 2011). If, for example, an area is found to possess characteristics that make it ideal habitat for a species of interest, or if the vegetation within a natural area provides extensive slope stabilization, city planners and managers can take these characteristics into consideration when deciding how and if to develop the land.

As this information is intended to inform future land management and development decisions, it is also important to consider how other factors, such as the future climate, may impact undeveloped land. Climate change may alter the characteristics, functions, and thus the value of these areas, potentially changing the appropriateness of specific land use planning and development decisions. Since 2007, the City of Prince George, in collaboration with local climate change adaptation researchers and the community, has developed the adaptation strategy *Adapting to Climate Change in Prince George* to assist in preparing for future changes (Picketts et al., 2009b). This process is important for Prince George, which has already experienced big changes to the surrounding natural environment with the outbreak of the mountain pine beetle (MPB; *Dendroctonus ponderosae*).[1] Both the MPB epidemic and the associated increases in wildfires can be partially attributed to warmer temperatures and the changing climate.

The community adaptation research identified several priority areas for climate change action for Prince George. Although natural areas were not identified as a priority in adaptation strategy, forests were the number one priority and represent the majority of the undeveloped, natural areas within the city. Therefore, City staff and climate researchers involved in community adaptation decided to add a climate change element or "layer" to Phase 2, which modeled the effects of climate change on natural areas. With funding support from NRCan through the RAC project, Phase 2 provides information on how forested natural areas could be impacted by climate change. Table 1 is a brief summary of how Phase 2

[1] For more information see Volume 1: Forests

may provide information for many of these climate change adaptation priority areas identified in the adaptation strategy.

Table 1. Climate change adaptation priorities, related impacts, and connections with Phase 2 of the Natural Areas Project.

Priority Area	Climate-Related Impact	Connection with Phase 2
Forests	Species composition changes Vulnerability to drought, invasive species, pest outbreaks, and diseases Increased wildfire risk	Forested areas and parks represent approximately 65% of the land within the City of Prince George Phase 2 provides ecological data on the potential effects of climate change on forests
Flooding	Changes to natural erosion and flood mitigation functions if trees and vegetation are impacted	Climate change impacts may have hydrological implications if trees and vegetation are affected, potentially impacting flood plain mapping decisions in the future
Agriculture	Impacts on soil moisture, drought impacts, invasive species, crop diseases and pests	Predicted impacts to natural, undeveloped areas may provide insights on potential impacts to nearby agricultural land
Slope Stability	Impacts to soil moisture and related plant mortality affect slope stability	Phase 2 can identify sensitive natural areas that provide extensive slope stabilization and how they may be altered with climate change

This report provides a brief background on TEM and SEI as a tool to help understand the ecological composition and structure of natural areas, and reviews Phase 1 of the project for Prince George's natural lands. Phase 2 is described in detail, as it relates directly to climate change adaptation and was completed as part of the Prince George RAC project. Although TEM and SEI mapping are common tools used by municipalities, incorporating climate change modeling into TEM and SEI mapping at the municipal level has not been previously undertaken to our knowledge. Therefore it is important to outline the steps taken to incorporate climate change considerations into this Natural Areas Project.

Currently, Prince George is working on developing tools and resources that will allow the information gathered from Phase 1 and Phase 2 to be put into action through Phase 3 and 4, with additional funding support from NRCan. These upcoming phases will make the information from Phase 1 and Phase 2 accessible and easily interpretable to local planners and managers. City managers and planners can then use the information to effectively adapt their development and local policy decisions based on predicted climate change impacts. This report will only provide information on what is proposed for Phases 3 and 4 of the Natural Areas Project, as they are still in the planning and development stages.

Project reports and updates on the ongoing phases can be found on the adaptation page of the City's website[2].

Phase 1: Mapping undeveloped natural areas

Terrestrial ecosystem mapping (TEM) is a Resource Information Standards Committee (RISC) standard approach to dividing the landscape into map units according to ecological features, such as climate, surficial material, bedrock geology, soil, and vegetation (BC Ministry of Environment). This process of inventorying and mapping areas allows for a better understanding of the biodiversity that exists in these undeveloped areas. City managers and planners can then use a landscape-level ecological framework (i.e. mapped natural areas with similar vegetation structure and composition) when making decisions regarding future land use for these areas.

Sensitive Ecosystem Inventories (SEI) are usually produced using TEM as a foundation, and are an additional informative layer that maps the most sensitive ecosystems in an area such as rare ecosystems, important wildlife habitat or areas at risk due to climate change. (BC Ministry of Environment, NDa). TEM / SEI maps are usually developed for conservation or restoration management plans for rare ecosystems or ecosystems that are valued in their natural state (eg. within tourism-based communities). Although tourism is not a major contributor to the local economy in Prince George, the community uses many of the undeveloped lands within the city for recreation, leisure and other purposes. Prince George takes great pride in its trails and natural areas, and residents often rank it as a major contributor to their quality of life (Nordin, 2008).

Terrestrial ecosystem mapping and sensitive ecosystem inventory mapping in Prince George

In 2010, the City of Prince George hired a consultant to prepare the TEM / SEI maps for all of the undeveloped, terrestrial natural areas within the city. The study area included all undeveloped grasslands, wetlands, and forested areas as well as city parks greater than 1 ha in size. The natural areas in Prince George are diverse in their biological, physical, and even climatic properties; the city's

[2] See: http://www.princegeorge.ca/environment/climatechange/adaptation/pages/default.aspx

elevation ranges from approximately 565 m to 870 m above sea level, representing over a 300 m difference in elevation.

TEM and SEI maps use the Biogeoclimatic Ecosystem Classification (BEC) system for classifying terrestrial ecosystems. BEC incorporates climate, soil, and vegetation data (Meidinger and Pojar, 1991) to provide a framework for resource management at any scale, from provincial level to site level. According to current BEC mapping, the City of Prince George is located within the Sub-Boreal Spruce (SBS) Zone (BC MFLNRO, 2012). Due to the variation in climate, terrain, and topography there are three biogeoclimatic subzones of the SBS identified within the Prince George city limits: moist hot (SBSmh), moist cool (SBSmk1), and dry warm (SBSdw3).

Using various data collection methods (e.g. light detection elevation modeling,[3] air photo interpretation, existing resource inventories, and field sampling), each of these subzones was stratified into polygons using recognizable ecological differences (e.g. plant communities) and specific bioterrain features (e.g. slope gradient, soil drainage). These polygons were individually described using the BEC system for site-level classification of ecosystems called "site series." Site series within a subzone are differentiated by unique soil moisture and nutrient classes that produce specific plant communities (Meidinger and Pojar, 1991). This level of detail is imperative for subsequent phases of this project that incorporate modeling, management, and monitoring of climate change impacts at the site level.

Using the TEM information as a foundation, the SEI mapping identified areas that were deemed "sensitive" if they satisfied one of the following criteria:

1. Ecological community is listed as endangered or threatened (red listed) or of special concern (blue listed) by the British Columbia Conservation Data Center (CDC).
2. Area has important wildlife habitat values or is highly specialized for specific environmental conditions (such as riparian and aquatic habitats, or forest ecosystems such as mature Douglas-fir stands).

The consultant used the provincially recognized standard methodology for TEM mapping (Resource Inventory Committee (RIC), 1998) and the Standard for Mapping Ecosystems at Risk In British Columbia (Resources Information Standards Committee (RISC), 2006).[4]

[3] Light Detection and Ranging (LIDAR) is similar to RADAR technology and uses a laser scanner and other equipment to create high-resolution digital elevation models. See: http://vulcan.wr.usgs.gov/Monitoring/LIDAR/description_LIDAR.html

[4] For more information on the RIC and RISC standard approach to TEM and SEI (including specific methodologies and deliverables), access the BC Government website: http://www.ilmb.gov.bc.ca/risc/pubs/teecolo/index.htm

Wildlife habitat and invasive plant species inventories

In addition to producing the TEM / SEI maps, the City also asked the consultant to identify any rare or endangered animal and plant species and any invasive plant species through field observations and point sample data collection. Habitat interpretations were developed for selected wildlife species based on the following:

- Wildlife that have important habitat within the city such as moose (*Alces alces*) and mule deer (*Odocoileus hemionus*).
- Wildlife that are known to inhabit natural areas in the city and are also on the provincial red or blue lists, including grizzly bear (*Ursus arctos*), long billed curlew (*Numenius americanus*), fisher (*Martes pennati*) and western toad (*Bufo boreas*).

Using information produced from the TEM / SEI mapping, details on the general habitat requirements, current habitat suitability in Prince George, and factors that could limit these species' ranges and survival were documented. The consultant recommended several management techniques for retaining and establishing riparian and wetland habitats, which were deemed to be important for many of the wildlife species of interest in the city.

Through field observations, several invasive plant species were identified, many of which were widespread throughout Prince George. The most suitable habitat for each invasive species and the habitat location within the city were documented. Some of the invasive species present in Prince George had limited dispersion but are very prevalent in more southern parts of the province. Therefore, they could present a major future risk for the City with climate change (see *Phase 2 climate change and natural areas* section).

Significance of Phase 1, Natural Areas Project for Prince George

When making management decisions related to natural areas, it is important to have an understanding of their contribution to biodiversity, including the ecological composition, structure, and function of natural areas on the land base. Phase 1 of the Natural Areas Project provides the City with detailed baseline ecological information required for informed decision making by City planners and managers. Specifically, Phase 1 provides:

- Site-level terrestrial ecosystem inventory that can be used in numerous future analyses, including Phase 2, 3 and 4 of this project
- Detailed information on habitat needs of certain wildlife species to allow the City to make decisions on habitat enhancement or protection within the city

- Information on invasive species prevalence and distribution to inform the City on where to monitor and focus efforts for controlling the spread of invasive species
- Record of endangered, threatened, and special concern areas throughout the city

Phase 2: Modeling climate change and natural areas

Prince George's mean annual temperature has risen by 1.3°C over the last century (1918-2006) and temperatures are projected to increase an additional 1.6°C to 2.5°C by the 2050s. Precipitation is also predicted to increase by 3% to 10% by the 2050s, primarily in winter with possible decreases in summer (Picketts et al., 2009b). The mountain pine beetle (MPB) epidemic, which peaked in 2005, can be partially attributable to the warmer winter temperatures that central BC is experiencing. The MPB epidemic has led Prince George to adapt its forest management practices, focusing on removing MPB-affected trees and reducing wildfire hazard areas that have increased due to the additional fuel from the dead pine trees and other fuel types. From 2001 to 2007, the equivalent of 733 truckloads of dead lodgepole pine and other fuel types were harvested within the Prince George city limits.

Regardless of the predicted changes in summer precipitation, the projected warming trends in Prince George will lead to increased evapo-transpiration rates and a net reduction of available soil moisture for natural areas (Pike et al., 2008). The frequency and severity of extreme events (such as droughts) are also expected to increase with climate change (Williamson et al., 2009), further worsening the predicted soil moisture loss for these areas. Climate change impacts on sensitive areas are particularly important, as these areas are often provincially or globally rare ecosystems and may have a limited ability to adapt to climate change. The potential impacts of climate change on natural and sensitive areas are complex and interrelated, and modeling of these potential impacts at the site level can help the community to anticipate and prepare for specific changes to these areas.

Climate change impacts on Prince George's natural areas

With funding support from NRCan, the City hired local consultants with expertise in modeling climate change impacts on natural areas. The consultants focused on climate change impacts on available soil moisture because drought is considered to be one of the leading climate change impacts on natural areas (Ecora and Griesbauer, 2012). Decreases in soil moisture (due to reduced precipitation, increased evapo-transpiration, and extended drought events) will lead to less available moisture for trees and other vegetation. This will stress these species and make them vulnerable to pests and diseases, providing opportunities for more drought-tolerant species or hardier invasive species to occupy these areas. Therefore, soil moisture changes can have dramatic effects on the structure, composition, and function of natural areas (BC Ministry of Forests, 1998).

A soil-moisture risk-analysis tool developed by DeLong et al. (submitted) was used to estimate impacts of climate change on all of the mapped forested sites as well as estimate impacts on specific tree species. Only forested sites were examined as these represent the majority (over 80%) of the undeveloped, natural areas in Prince George, and as the species' drought tolerance levels were predetermined for tree species within these areas. Due to budget and time constraints, drought tolerance levels of other plant species were not determined, so impacts to forest understory or non-forested sites could not be estimated. However, this climate change risk analysis tool could be easily applied to non-forested natural areas (such as wetlands and grasslands) if the drought tolerance levels of the species were determined.

The risk to individual trees was examined because trees usually represent a considerable portion of the physical space and biomass in a natural area and are important for maintaining the area's structure and function (Ecora and Griesbauer, 2012). The Actual Soil Moisture Regime (ASMR) is a classification system that allows comparison of soil moisture between different BEC zones. Since Prince George has three different BEC subzones within its city limits, ASMRs were used to compare the soil moisture changes for natural areas throughout the entire city (Ecora and Griesbauer, 2012). Soil condition variables such as how far down roots can physically reach (i.e. rooting depth), soil texture, the amount of coarse fragments in the soil (i.e. coarse fragment percentage) and local climate data were used to predict ASMR for each mapped site (Ecora and Griesbauer, 2012). Since climate data is a component of this model, future climate scenarios were used to predict the ASMR changes over time. ASMR measurements were projected through time by applying climate predictions from various climate scenarios for the 2020, 2050, and 2080 time periods.

Table 2. Actual Soil Moisture Regime classification and associated base risk class (Adapted from: Ecora and Griesbauer 2012).

ASMR Classification	Base Risk Number	Base Risk Class
Excessively dry (ED)	>5	Extremely high
Very dry 1 (VD1)	4-5	Very high
Dry (D)	3-4	high
Moderately dry (MD)	2-3	Moderately High
Slightly dry (SD)	1-2	Moderate
Fresh (F)	0-1	Low
Moist (M), Very moist (VM), or Wet (W)	0	Very Low

ASMR classifications, which range from wet to excessively dry, were used to create base risk classes for each site. The risk level was based on the potential of a particular site to have multiple species within that site reach their drought tolerance level and potentially suffer mortality. The drier the ASMR classification, the higher the level of base risk for the site (Table 2). A second risk class assessed the chance of mortality due to drought-induced stress for individual tree species within these sites. Tree species risks were calculated for the three leading tree species within each mapped site. The level of risk for individual tree species was based on the specific site characteristics and ecologists' estimates of the specific sensitivity of the tree species to drought.

Implications of soil moisture changes

Based on the soil moisture modeling, the most dramatic change in soil moisture and base risk is expected to occur between 2011 and 2020. During this time the majority of the sites in Prince George undergo a change in base risk number, transitioning from having slightly dry soil moisture (moderate risk) to moderately dry soil moisture (moderately high risk) (Figure 2).

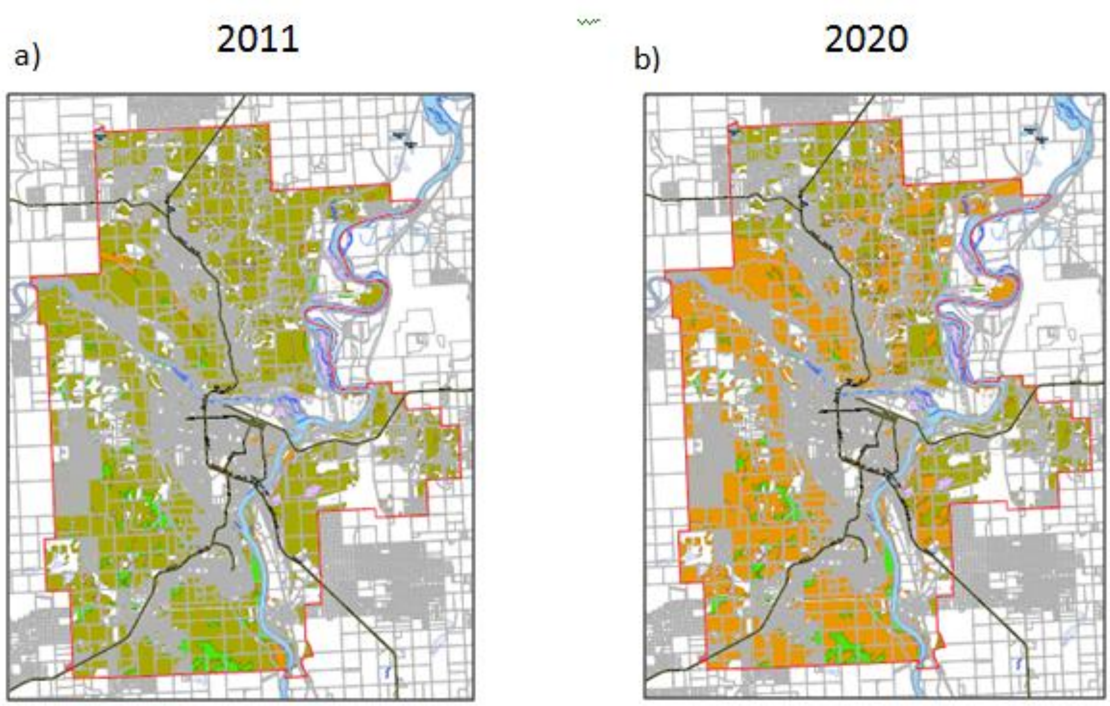

Figure 2. Actual soil moisture regime (ASMR) for the City of Prince George's undeveloped, forested areas in 2011 (a) to 2020 (b). ASMR changed in most sites from slightly dry in 2011 to moderately dry in 2020. (Source: Ecora and Griesbauer, 2012)

Although most of the sites do not reach very dry or extremely dry soil moisture conditions by 2080, the sites that are predicted to reach these levels are mainly the "sensitive" areas identified in Phase 1. Seventy-seven percent (1,597 ha) of the mapped sensitive areas are projected to change to very dry and extremely dry conditions between now and 2080. This is because many of these sensitive areas are currently considered dry; even a small reduction in soil moisture can significantly impact the species within those areas, resulting in increased stress and mortality. The Douglas-fir (*Pseudotsuga menziesii*) forests along the cutbanks of the Nechako River are a prime example of a sensitive area that can be impacted by climate change (Figure 3).

Figure 3. Sensitive Douglas-fir forest on the Nechako River cutbanks. Within the circle are Douglas-fir trees recently attacked by Douglas-fir beetle. (Photo: courtesy of Jeff Burrows)

Although Douglas-fir trees are well adapted to survive drought, an increase in water shortages still stresses these trees and makes them more vulnerable to attacks. The Douglas-fir bark beetle (*Dendroctonus pseudotsugae*) is an example of a pest that can damage or kill the tree. Currently, foresters in Prince George are seeing more bark beetle attacks and greater tree mortality in dry Douglas-fir stands, which could be attributable to stress from drought events, such as the drought in 2010 in Prince George. Since climate change is expected to result in more frequent and severe droughts, Douglas-fir trees may become increasingly vulnerable to mortality due to drought and pests. However, the majority of the land base in Prince George will become drier and thus new areas will become suitable for Douglas-fir and unsuitable for less drought-tolerant tree species, increasing the amount of suitable habitat areas for Douglas-fir trees throughout the city.

For individual tree species, the risk of mortality from climate change or risk of harm to tree health due to unsuitable conditions, was determined by examining site-specific characteristics and using ecologists' estimates of species sensitivity to drought (Ecora and Griesbauer, 2012). Figure 4 illustrates the level of risk of these climate-induced impacts according to area for each leading tree species.

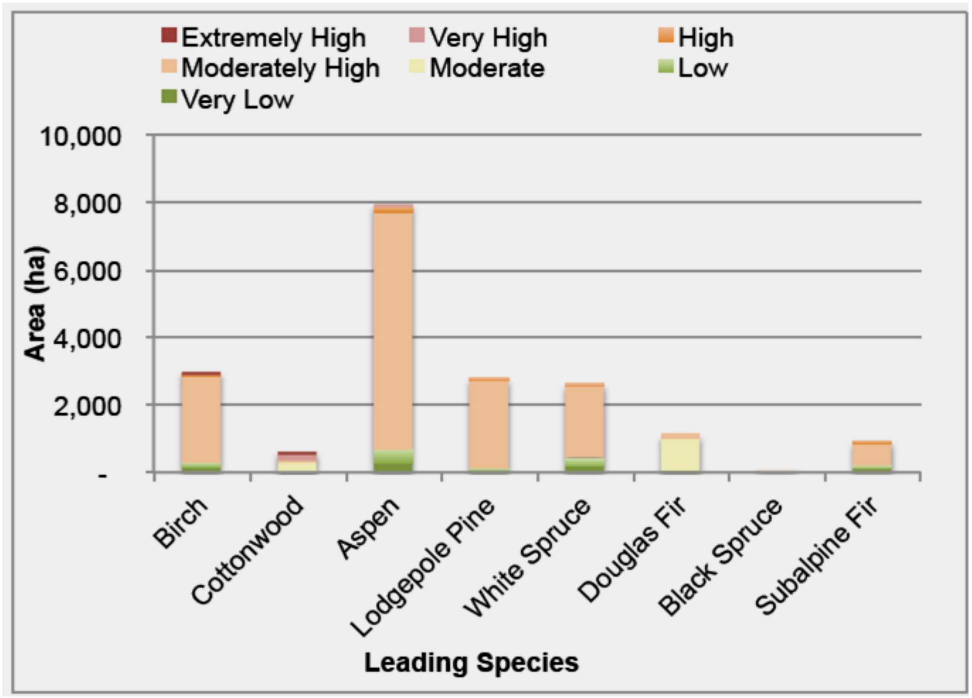

Figure 4. Risk of climate-induced impacts for leading tree species by area covered in Prince George. (Source: Ecora and Griesbauer, 2012)

In Prince George, the trees most at risk from drought impacts are deciduous species. Birch (*Betula papyrifera*), cottonwood (*Populus trichocarpa*), and aspen (*Populus tremuloides*) have the most stands at extremely high, high, or moderately high risk of climate-induced impacts. This is primarily due to the fact that these species inhabit and are most suited to areas with fresh to slightly dry soil moisture (Klinka et al. 2000) and these areas are expected to become drier with climate change.

Climate change may result in increased opportunities for invasive species, or species that have not been previously found (or not found in large numbers) in Prince George. Cheatgrass (*Bromus tectorum* L.) (Figure 4) is an example of an invasive species that has had a big impact in the southern interior of BC. It out-competes other plants due to its ability to crowd out native grasses (Mosley et al. 1999), and its dense formation increases the risk of wildfires (Colorado State Parks 2005). During Phase 1, cheatgrass was found on the cutbanks of the Nechako River in Prince George. With the changing climate and warmer summer temperatures, cheatgrass could become more widespread throughout the city.

Figure 4. Image of cheatgrass (*Bromus tectorum* L.). (Photo: courtesy of John Randall)

Significance of Phase 2, Natural Areas Project for Prince George

Climate change impacts are typically investigated, analyzed, and reported at broad geographic scales. Therefore, site-specific impacts are not usually determined and thus management recommendations are often not detailed enough to be effective. Phase 2 of the Natural Areas Project provides information at fine scale on how climate change may impact the city's undeveloped forested areas. Having this information can allow City staff to make informed decisions specifically related to impacts. Furthermore, because the information provided in Phase 2 is at a finer scale, these impacts can be specifically examined and monitored to determine whether or not they are occurring and at what rate. Such ground truthing will help the City to improve its plans and actions in order to effectively respond to changing conditions in natural areas.

Phase 3 and Phase 4: Putting climate change information into action

The way the information is presented in phases 1 and 2 of the Natural Areas Project is meant for individuals with extensive experience and training working with complex ecological data, and is not easily understandable for other interested parties. Therefore, with funding support from NRCan, the City is currently developing Phases 3 and Phase 4 of the Natural Areas Project; these phases will translate this technical information into a user-friendly format. The end products will include simplified maps and databases, as well as management and monitoring strategies to allow the information to be understandable and transferable to City planners, managers, and other interested parties (e.g. developers, landowners, general public).

Phase 3 will utilize the City's currently free and publicly accessible online mapping tool, PGMap[5] to translate this technical information into a user-friendly format. Phase 3 will provide plain-language information describing the different ecosystems, their values, and the potential risks from climate change and development. In order to provide information on the value of certain natural areas, the City must first identify what areas are considered important and from what perspective. Certain areas may have high recreational value or may perform important functions (e.g. slope stabilization); therefore, climate-related impacts to these areas would have serious implications for the community. Other undeveloped, natural areas could be at an equal risk of climate change impacts, but they may not be as important to the community. A dialogue process between City planners, managers, and other community stakeholders will identify what values are held for the different types of undeveloped, natural areas throughout Prince George. This process will help to direct conservation efforts, growth management, and planning.

With plain-language information on how climate change may impact undeveloped natural areas and an understanding of how each of these natural areas is valued in Prince George, the City can begin to develop Phase 4 of the Natural Areas Project. Phase 4 is where the City will begin to establish management objectives, indicators of success, and monitoring strategies in an effort to prepare for the impacts of climate change. As there is always uncertainty with climate change projections and impacts, an additional component to Phase 4 will be a monitoring strategy that will assess the health and composition of monitored natural areas. The ongoing monitoring will allow the City to continuously adjust management decisions, strategies, and objectives as a greater body of knowledge is developed. Table 4 provides an overview of how phases 2, 3 and 4 of the Natural Areas Project relate to the priority areas for adaptation.

[5] See: http://princegeorge.ca/cityservices/online/pgmap/Pages/Default.aspx

Table 4. Summary of relevant priority adaptation impacts and how they relate to phases 2, 3 and 4 of the Natural Areas Project.

Priority Area	Climate-Related Changes	Connection to Phase 2	Potential Changes in Management and Planning (Phase 3 and Phase 4)
Forests	Species composition changes Invasive species, pest outbreaks, diseases Changes to wildfire risk	Identifies how forested areas may be impacted by climate change	Development decisions in areas with increasing wildfire hazard issues (interface zones) Decisions related to wildfire hazard management (see Volume 3, Natural and Managed Forests) Changes to account for species habitat requirements and corridors Plans to avoid natural areas of high conservation value
Flooding	Changes to natural erosion and flood mitigation functions if trees and vegetation are impacted	Hydrological impacts if trees and vegetation are affected by climate change	Changes to watershed drainage management plans Changes to flood management plans Changes to urban forestry and tree management
Agriculture	Impacts on soil moisture, drought impacts, invasive species, crop diseases and pests	May provide insights on potential impacts to agricultural land using soil moisture modelling	Changes management plans for proposed expansion of Prince George Community Forest (see Volume 3, Natural and Managed Forests)
Slope Stability	Impacts on soil moisture and species composition affect terrain and slope stability	Impacts to slope stability if climate change alters natural areas species compositions	Changes in hazardous area designations (steep slopes)

Recommendations

When phases 3 and 4 of the Natural Areas Project are completed, the information produced can be used by City staff and other stakeholders in multiple ways. The following ongoing actions are recommended ways to utilize the information created and to continue to investigate climate impacts on natural areas:

- Continue to monitor the amount, distribution, structure, composition, and function of natural areas over time
- Ensure specific invasive species identified in Phase 1 are monitored for their distribution and potential impacts to local ecosystems (e.g. prevalence and distribution of cheatgrass along Nechako River cutbanks)
- Examine other climate change impacts unrelated to soil moisture and how they can affect sensitive species and areas (e.g. impacts such as increases in extreme events, changing freeze-thaw cycles, and hotter summers may also increase the mortality of less hardy, more sensitive species)
- Work with local agriculture stakeholders to predict impacts of soil moisture changes on agriculture (e.g. consider impacts to crops and crop suitability in future climate)
- Actively communicate this work to City staff within all departments. Areas of particular importance include the Parks and Long Range Planning departments (e.g. Parks staff may use TEM / SEI information to inform species selections for tree planting in parks.)
- Actively communicate this work, in the form of workshops, informational materials, or sessions to community stakeholders (e.g. environmental consultants, forestry industry) and targeted members of the public (e.g. private land owners with extensive natural areas on their properties)
- Consider all opportunities to collaborate or seek advice from local and regional organizations (e.g. Northwest Invasive Plant Council) and provincial ministries with expertise in understanding climate impacts on plant and animal species
- Encourage collaboration and information sharing between stakeholders involved in climate change adaptation focusing on other priorities (e.g. City staff investigating water supply or forest impacts may find this information relevant and useful)

Works Cited

B.C. Conservation Data Centre. 2012. BC Species and Ecosystems Explorer. B.C. Ministry of Environment. Victoria, B.C. Available from: http://a100.gov.bc.ca/pub/eswp/

Bio-Geo Dynamics Ltd. 2011. Terrestrial Ecosystem Mapping (TEM) and Sensitive Ecosystem Mapping (SEI) for the City Of Prince George. Pp.35.

British Columbia Ministry of Forests, Lands and Natural Resource Operations. 2012. Approved corporate provincial digital Biogeoclimatic Ecosystem Classification (BEC) Zone/Subzone/Variant/Phase map, version 8. Available from: http://www.for.gov.bc.ca/hre/becweb/resources/maps/GISdataDownload.html

British Columbia Ministry of Environment. NDa. Ecology, Terrestrial and Predictive Ecosystem Mapping. Available from: http://www.env.gov.bc.ca/ecology/tem/

British Columbia Ministry of Environment. NDb. Sensitive Ecosystems Inventories. Available from: http://www.env.gov.bc.ca/sei/

British Columbia Ministry of Forests. Forest Practices Branch. 1998. Provincial seedling stock type selection and ordering guidelines. Available from: http://www.for.gov.bc.ca/hfp/publications/00078/sitelimt.htm

(CPG) City of Prince George. 2005. City of Prince George Wildland/Urban Interface Wildfire Management Strategy. Prepared by Diamond Head Consulting Ltd, Davies Wildfire Management Inc. and Timberline Forest Inventory Consultants. Pp82.

Colorado State Parks. 2005. Downy Brome (Cheatgrass) - Best Management Practices - Weed Profile. Available from: http://www.invasivespeciesinfo.gov/plants/downybrome.shtml

Ecora Resource Group Ltd. and Griesbauer, H. 2012. City of Prince George: The Effects of Climate Change on Natural Area Ecosystems. Final Report (Draft) pp. 35.

Klinka, K., Worrall, J., Skoda, L. and Varga, P. 2000. The Distribution and Synopsis of Ecological and Silvical Characteristics of Tree Species of British Columbia's Forests. Canadian Cartographics Ltd., Coquitlam, BC. Available from: http://www.for.gov.bc.ca/hfp/silviculture/Compendium/

Marcoux, D. 2004. British Columbia Ministry of Advanced Education. Biogeoclimatic Ecosystem Classification System in British Columbia. Selkirk College. Available from: http://selkirk.ca/discover/bec/zones/indexzones.html

Meidinger, D. and J. Pojar. 1991. Ecosystems of British Columbia. Province of BC Ministry of Forests, Research Branch, Victoria, BC.

Mosely, J.C., Bunting, S.C. and Monoukian, M.E. 1999. Cheatgrass. In R.L. Sheley and J.K. Petroff, eds. Biology and Management of Noxious Rangeland Weeds. Oregon State University Press, Corvallis, OR.

Nordin, W. 2008. Staff Report to Council: 2008 Quality of Life Survey. Presented to Mayor and Council of Prince George: 12 October 2008.

Picketts, I. Dyer, D. and Curry, J. 2009a. Adapting to climate change in Prince Georeg: an overview of adaptation priorities. City of Prince George. Available from http://www.resourcesnorth .org/downloads/Dev_Ops_Adapting_Climate_Change_adapt_priorities.pdf

Picketts, I., Werner, A. and Murdock,T. 2009b. Climate Change in Prince George: summary of past trends and future projections. Pacific Climate Impacts Consortium, University of Victoria. Available from http://pacificclimate.org/sites/default/files/publications/Werner.ClimateChangePrinceGeorge .Aug2009.pdf

Pike, R.G., Spittlehouse, D.L., Bennett, K.E., Egginton, V.N., Tschaplinski, P.J.,Murdock, T.Q., and Werner, A.T. 2008. Climate Change and Watershed Hydrology: Part I–Recent and Projected Changes in British Columbia. Streamline Watershed Manage. Bull. 11: 1-6.

Resources Information Standards Committee (RISC). 2006. Standard for Mapping Ecosystems at Risk in British Columbia. An Approach to Mapping Ecosystems at Risk and Other Sensitive Ecosystems. Terrestrial Ecosystems Task Force for (RIC).

Resources Inventory Committee (RIC). 1998. Standards for Terrestrial Ecosystem Mapping in British Columbia. RIC Secretariat, Victoria, B.C.

Williamson, T.B., Colombo, S.J., Duinker, P.N., Gray, P.A., Hennessey, R.J., Houle, D., Johnston, M.H., Ogden, A.E., and Spittlehouse, D.L. 2009. Climate change and Canada's forests: from impacts to adaptation. Sustainable Forest Management Network. And Natural Resources Canada, Canada Forest Service, Northern Forestry Centre, Edmonton, AB. pp.104.