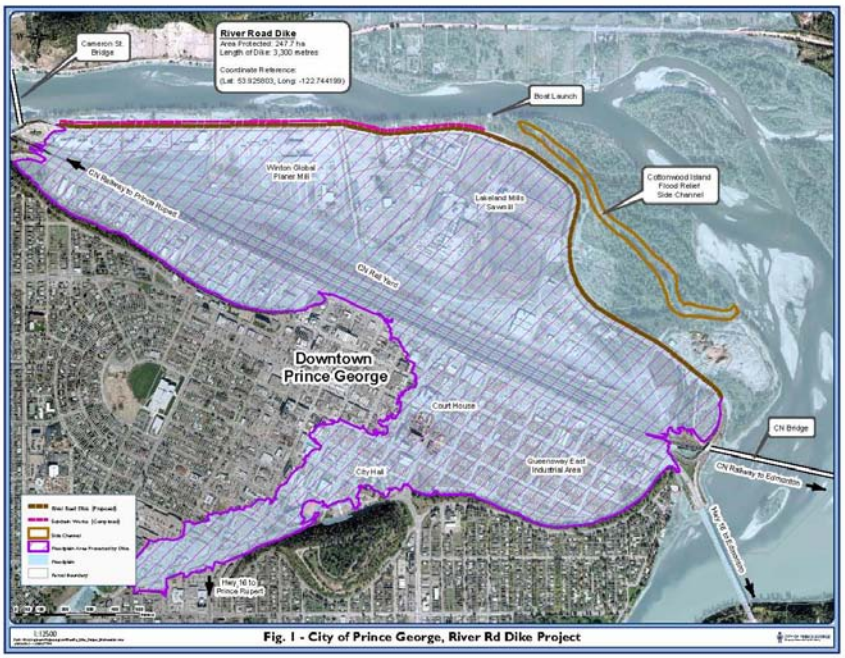
Implementing Climate Change Adaptation

in Prince George, BC

Volume 4: Flooding



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Executive Summary:

Implementing Climate Change Adaptation in Prince George, BC
Volume 4: Flooding

Climate change is affecting the number and severity of flooding events that are occurring, and that are expected to occur in the future. Communities need to adapt to climate change by preparing for anticipated changes in flooding to avoid significant social, environmental and economic consequences. Many actions can be taken to help to avoid future flooding and/or to be more prepared for a flooding event should one occur.

As Prince George lies at the confluence of the Fraser and the Nechako Rivers, it is very susceptible to flooding. The Fraser River is vulnerable to springtime freshet flooding events, while the Nechako River is more prone to experiencing ice-jam floods. In 2007-2008 Prince George experienced flooding conditions three times; including a winter ice jam in the Nechako which pushed waters above the 200 year flood plain and caused significant damage (see Figure 1). These events made flood mitigation an urgent priority, and not surprisingly flooding was selected as the second highest priority for climate change adaptation in Prince George. Therefore ongoing local adaptation work, supported through the federally funded Regional Adaptation Collaborative (RAC) program, focused on flooding for the Prince George case study.

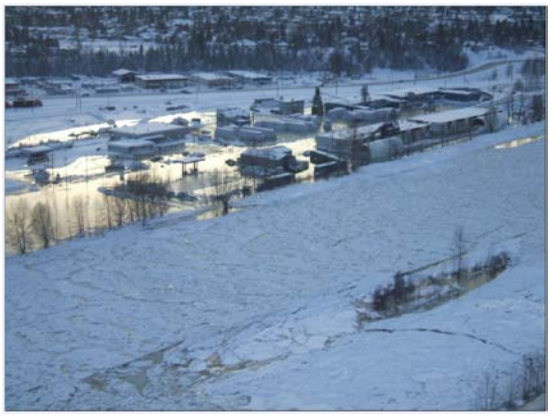

Figure 1. The Nechako River during the ice jam event in January 2008.

Flooding is closely related to many other impacts of climate change, and many strategies can address multiple impacts. Some of these related impacts include:

- **Storm-water**: many storm-water management facilities remove run-off from a site as quickly as possible which increases flood risk, and natural storm-water retention areas can store run-off and mitigate flood risk
- **Transportation infrastructure**: roads are often susceptible to flooding, they are needed to respond to flooding emergencies and they can be designed to act as dikes to mitigate risk
- **Transportation and building infrastructure**: human structures can be damaged by flooding and are typically impervious; thus precipitation does not enter the ground and water flows directly back into waterways
- **Forests:** forests are an important part of the hydrological cycle and the mountain pine beetle (MPB) has had a huge effect on the hydrology of northern BC, resulting in an increased flood risk.

In 2008 the City began a major project with many consultants to assess the local flooding risk, develop and prioritize flood relief options, suggest practical solutions to manage the risk, and update the existing floodplain maps. The assessment resulted in a risk analysis report, and two documents evaluating the risk and proposing flood control strategies. After an extensive process involving public consultation, the second phase of the project was completed. In this phase, potential flood control options in Prince George were each evaluated in 14 identified high-risk areas. Factors such as cost and environmental impact were considered, and recommendations were made for each area. To address all areas will cost an estimated $35 million.

Because Prince George has identified flooding as a major local adaptation priority, and was examining past and future climate change in partnerships with the Pacific Climate Impacts Consortium (PCIC), they decide to incorporate climate change into the flood risk assessment. The flooding consultants worked with PCIC to utilize climate change projection information in the analysis. The report found that the current effects of climate change do not appear to be having a significant impact on flooding in Prince George. Using projected climate changes for the 2050s, the report states that climate change will result in an overall increase in spring flows. Climate change may result in flow conditions conducive to ice-jam events, but this might be offset by warming winter temperatures. Therefore the relationship between climate change and ice-jam flooding is still not well understood. The consultants ultimately called for a freeboard allowance (i.e. the vertical distance added to the flood plain as a safety factor) of 1.0 metres to account for the potential impacts of climate change and the mountain pine beetle. The common practice in BC is to use a 0.6 m freeboard allowance.

In addition to the flood risk analysis, Prince George is taking many actions to minimize flood risk. These include a new emergency response bylaw, a new flood plain bylaw, and the inclusions of actions to mitigate flooding in the *myPG* plan. Additional future initiatives can help to further prepare Prince George to the potential impacts of increased flooding. Some of these adaptation actions include:

- Buying and rezoning land to uses that will help mitigate flooding risk, and encouraging land use (such as parkland and agriculture) in vulnerable areas that will result in less damage if a flood occurs
- Improving local capacity to effectively respond to floods and other extreme events
- Educating homeowners and residents to minimize risks of personal injury and property damage
- Encourage forestry practices that minimize negative hydrological effects
- Designing storm-water infrastructure to retain run-off and mitigate flooding risk
- Design infrastructure to minimize potential negative impacts on flooding, and also to be resilient to a potential increase in flooding

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 (NRCan) the Regional Adaptation Collaboration (RAC).

Natural Resources Canada

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

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., 2009), which was received by City Council in November 2009.

The Volumes of *Implementing Climate Change Adaptation in Prince George BC* 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

Many actions and events have occurred in Prince George that have begun to raise awareness of climate change and its impacts. The results of several research events were used to create the adaptation strategy, *Adapting to Climate Change in Prince George* (Picketts et al., 2009a), which describes flooding as the second highest concern among City of Prince George staff, residents, and local stakeholders. This volume provides information about flooding and its relationship to climate change, and discusses the significance of this impact in Prince George. A summary of the actions taken to address the impact of flooding locally is provided as along with recommendations for further related research and activities. This document will help Prince George as it continues to manage flooding locally and can also provide ideas to other communities concerned about climate change adaptation and flooding.

Background on flooding and climate change

The frequency of large floods has increased over the last hundred years and models predict that this trend will continue (Milly et al. 2002). By examining records from rivers around the world, the Intergovernmental Panel on Climate Change (IPCC) (2007) found that there has been a strong increase in 100-year flooding events in the last 15 years, and an intermittent increase over the last 35 years. The economic, social, and environmental costs of flooding events on communities are large, but difficult to assess. Towns and municipalities can spend large amounts of money to prepare for anticipated future conditions, but the actions they take may not actually prevent damages from flooding. Furthermore, it is difficult to provide a value for avoiding a flood, or to know if an adaptation action was responsible for avoiding or limiting the consequences of an event. Communities may elect to not take actions to prepare for flooding and climate change and accept the costs and liabilities associated with the possibility of increased flooding.

Urban areas are at a higher risk of flooding because transportation and building infrastructure (such as pavement roads) are usually impervious, and thus rainfall is prevented from filtering into the ground. Urban development typically leads to more pavement and more compacted soil structures. These changes to what was once a natural environment increase runoff flow rates and more water flows directly back to rivers rather than being temporally stored in the soil. Furthermore, most storm-water management strategies remove runoff from a site and return it to the river as quickly as possible (Holman-Dodds et al. 2003). When managing for flooding it is important to also examine storm-water management as it can be both a cause of and a potential solution to flooding risks.

Flooding is also very closely related to transportation infrastructure and emergency response, as roads are needed to respond to extreme events and may need to be designed to withstand a greater magnitude and frequency of floods. As discussed later, flooding is also closely related to forest impacts (particularly the mountain pine beetle epidemic that has had a huge affect on hydrology in BC).

Flooding in Prince George

Prince George is affected by flooding from both the Fraser and the Nechako rivers but at different times of the year. Within the City limits, the Fraser River is susceptible to springtime freshet flooding, and the Nechako River is more vulnerable to experiencing ice-related flooding during freeze-up conditions (NHC 2009). The peak freshet flows in the Nechako are 25% of those in the Fraser (NHC, 2009). The Nechako River Basin is larger (47,100 km^2) than that of the upper Fraser River watershed above Prince George (32,400 km^2) and is partially regulated by the Kenney Dam, which was constructed to supply the Kemano power plant near Kitimat in 1952. The reservoir behind the dam diverts flow away from the Nechako River through the Coastal Mountains to Kemano consequently reducing flows in the Nechako.

A high snow pack in the Nechako Basin in the winter of 2006-2007 reaching a reported 200% of normal led to the highest discharge ever recorded in the Nechako River at the Isle Pierre Water Canada Survey gauge, which is located approximately 50 kilometres upstream of Prince George, during the spring of 2007.

An investigation of provincial records conducted as part of the City's Flood Risk Assessment (M. Miles and Associates Ltd., 2008a) reveals a long history of flooding events in the City. A historical review showed evidence of 16 freshet-related events including the floods in 2007 and 2008, and 21 ice-related high water level events including the 2007-2008 ice jam flood (NHC, 2009). Development in Prince George appears to have had an impact on the Nechako River near the confluence with the Fraser, as many distributary channels in flood plain area over the past 70 years were filled in by industrial development at the confluence and by commercial development in the City's downtown. These natural features may provide alternative paths or "flood relief channels" for the river to flow during ice-related (ice jam) flood events, mitigating flooding for some areas within the flood plain. This was observed by City staff during the 2007-2008 ice jam event as the one remaining side channel through Cottonwood Island Park handled an estimated 30% of the Nechako discharge (D. Dyer, P.Eng., Chief Engineer, pers. comm., 2011).

Sedimentation in the Nechako River possibly may have increased flood hazards as well. This sedimentation may be attributable to the low flow rates caused by the Kenney Dam (M. Miles and Associates Ltd., 2008a). However, riverbed bathymetric surveys in 2008 by Northwest Hydraulic Consultants (NHC) revealed that there was a net increase in erosion along the Nechako and at the confluence when compared with riverbed cross-sections from 1996. Higher river velocities associated with higher flows during flood events appear to cause more erosion than sedimentation. Further investigation is necessary over several years to confirm if there is a net increase or decrease in sedimentation.

In 2007 and 2008, the city experienced flood conditions three times. This includes a freshet flooding event on the lower Nechako, confluence and Fraser in 2007, a freshet flooding event on the Fraser River in 2008, and the ice jam flood on the Nechako River in the winter of 2007-2008. The 1 in 90 year ice jam flooding event (see Figure 1) pushed waters over the flood plain affecting the CN rail yard and mainline,

flooding industrial and commercial properties and disrupted businesses for two to three weeks, causing evacuations that lasted for several weeks and significantly damaging dozens of homes and properties. A state of emergency lasted 67 days as flood response costs mounted to over $6 million.

Figure 1. The Nechako River during the ice jam event in January 2008. (Photo: courtesy of the City of Prince George)

Climate Change Impact on Flooding

The link between climate change and flooding is not fully understood though some research has been conducted. In a study of river discharges under different atmospheric conditions, Milly et al. (2002) determined that the Fraser River could experience a 100-year flood event every two to five years under a quadrupling of CO_2 atmospheric concentrations. Although it is impossible to attribute individual events to climate change, flooding events have increased in magnitude and frequency in the last 30 years and are predicted to continue to increase (Milly et al. 2002; IPCC 2007a).

NHC, however, was not able to determine from the river gauge data any trends that would suggest that climate change is impacting river flows (NHC 2009) due to a possible increase in annual precipitation. There has been a great deal of speculation in the forest industry and community of Prince George that the mountain pine beetle migration through the central interior of British Columbia between 2000 and 2002 would cause greater runoff as vast stands of pine tree forests die off resulting in higher river flows. Again, NHC reported that no such trend was observed from the river gauge data. Though some computer modeling suggests that dead pine stands in localized drainage areas would result in higher stream flows, further river flow monitoring and hydrological research is necessary for the entire Nechako Basin and Upper Fraser watershed to conclude that these climate change factors (mountain pine beetle and higher precipitation) will significantly impact river flows and cause flooding to increase.

As previously discussed, the Kenney Dam has been reducing flows in the Nechako River since it was built in the early 1950s. The effects of climate change on the regulation of the dam are unknown, though climate change projections for the areas west of Prince George suggest that there could be an increase in overall precipitation. This may lead to higher snowpack levels that could increase freshet flows in the Nechako as was experienced in 2007.

The relationship between ice jam floods and climate change is also not well understood. There could be more frequent high winter river flows as a result of higher precipitation in the Nechako Basin, which not only includes the Kenney Dam reservoir, but also includes unregulated natural lakes - Stuart Lake, Fraser Lake and Francois Lake. High river flows raises the probability that river freeze-up will raise river levels over the river banks due the higher volume. Frazil ice forms as river water temperatures reach and drop below zero degrees Celsius – the colder the ambient temperature, the greater amount of frazil ice that is generated. However, because of the significant increase in fall and winter daily minimum temperatures as a result of climate change, frazil ice is not generated as much as it would if minimum temperatures were colder. The net effect may be that the frequency and severity of ice-related flooding would remain about the same has it has in the past.

Flood Risk Mitigation Planning for Prince George

Flooding protection and response has been a priority for the City of Prince George for decades, but flood risk mitigation became an urgent municipal priority due to the highly publicized ice jam flooding event in the winter of 2007-2008. During the ice jam flood the City combated the floodwaters using several response tactics to mitigate the flood hazard in the short term (City of Prince George 2009b). Some of the response tactics utilized included:

- Constructing over 4000 m of temporary dikes
- Pumping water out of the affected areas
- Discharging warm water on the ice to attempt to melt a channel
- Using an amphibious ice excavator to dig a channel through the ice

Not surprisingly, flooding was identified as a high priority in the adaptation strategy for Prince George (ranked second, under forest impacts). City services identified to address flooding include Police, Fire and Rescue Services, Municipal Emergency and Response, and Long Range Planning.

In the winter of 2008 following the ice-jam flood event , the City of Prince George retained Northwest Hydraulic Consultants Ltd. (NHC), along with sub-consultants McElhanney Consulting Services Ltd., Environmental Dynamics Inc., M. Miles and Associates Ltd., and Kevin Brown Communications Ltd. to assess the flood risk of the city and to suggest viable solutions to mitigate risks. The purpose of this

study was to investigate long-term solutions for flood protection in Prince George (City of Prince George, 2009c). The main goals were to:

- Prepare a comprehensive flood risk evaluation
- Develop and prioritize flood relief options
- Select suitable flood control solutions and develop conceptual level designs
- Update the existing floodplain maps prepared in 1997

Three reports were prepared by NHC under the title, *Flood Risk Evaluation and Flood Control Solutions*. The documents were prepared under the guidance the City's chief engineer, director of Development Services, and the head of Long Range Planning. The three individual reports are:

1. *Risk Analysis – Progress Report 1* (June 2008-[1])
2. *Flood Risk Evaluation and Flood Control Solutions – Phase 1* (May 2009-[2])
3. *Flood Risk Evaluation and Flood Control Solutions – Phase 2* (September 2009-[3])

The NHC reports analyze and evaluate the spring flooding risks in the Fraser River and the ice-related flooding risk in the Nechako, as well as the many factors that affect river flow in the region (such as the Kenney Dam). The NHC Phase 1 report identifies seven areas of high flood risk along the Nechako, and seven along the Fraser. The report identifies and discusses multiple potential flood control options. The options and a brief description of their predicted effectiveness in Prince George are summarized in Table 1. Some of these flood control options are discussed in more detail in the Adaptation Strategies for Flooding section of this report below.

[1] Available at: http://www.city.pg.bc.ca/city_services/emergency/icejam/doc/RiskAnalysisR3_A.pdf

[2] Available at: http://www.city.pg.bc.ca/city_services/emergency/icejam/doc/0%20full.pdf

[3] Available at: http://www.city.pg.bc.ca/city_services/emergency/icejam/misc/docs/FloodRiskEvalAndSolns_FinalPh2_NHCReport_2009-09.pdf

Table 1. Potential flood control solutions in Prince George. (Adapted from: NHC, 2009)

#	Potential Flood Control Option	Predicted Effectiveness for Prince George
1.	Extract gravel from the river bottom	This method was concluded to be ineffective in alleviating flood risks in both the Nechako and Fraser rivers.
2.	Enlarge existing side channels	This was viewed as a potentially viable solution for flood relief during ice-related flooding events in the Nechako River.
3.	Build dikes	Riverside dikes were concluded to be expensive to build and maintain, and ecologically harmful. However, dikes that are set back from the river were slated as a potentially viable solution if they took into account groundwater seepage and internal drainage. Set-back dikes can be constructed along new and existing roads.
4.	Change land use	Changing the land use in flood-prone areas was shown to be a cost-effective solution in some situations, as it has been in the past in Prince George. This would usually involve purchasing properties and removing the buildings.
5.	Local, small-scale flood-proofing	Flood-proofing individual buildings was deemed to be a potential solution for single-family developments.
6.	Business as usual with reliance on emergency response	Business as usual was not considered in depth due to the degree of damage and public dissatisfaction associated with previous flooding events.

The potential flood control options were evaluated for their efficacy in each of the 14 flood-risk areas. Factors such as cost and environmental impact were considered in this evaluation. The final report provides recommendations for solutions for each of the areas and cost estimates for each action. To address each area as the report recommends, the cost to the City is estimated to be $35 million (NHC 2009).

Public consultations were held after the NHC Phase 1 report was received by Council to present the report findings and to gather public feedback about the results. Results of the public consultations were

documented and assisted NHC in prioritizing projects for the flood risk areas. These priorities were presented in the NHC Phase 2 report, which was presented to Council in October 2009. Flood hazard planning projects and proposed flood protection works will be included in the preparation of the City's Capital Expenditure Plan for consideration by City Council. The consultation process took place over two consecutive days and, according to the NHC Phase 2 report was divided into: meetings with regulators; a public open house; technical presentation from the consultants and sub-consultants; a question and answer period; and meetings with interested stakeholder groups. The purpose of the consultations was to review and revise the options outlined in Phase 1 of the report. Please refer to Appendix A of the phase 2 report for the public consultations outcome.

Incorporating Climate Change into the Flood Risk Evaluation and Flood Control Solutions

The opportunity arose that the impacts climate change and possible mitigation measures to withstand the impacts could be included in the scope of the Flood Risk Evaluation and Flood Control Solutions investigation. Because of the work underway by the City on climate change at the time, the consultants were informed that downscaled future climate change projection information was being created for Prince George in partnership with the Pacific Climate Impacts Consortium (PCIC). A conference call between the project leads from NHC, City staff, and PCIC was held to discuss what information could help to inform the flood risk evaluation. As a result of these talks, PCIC was able to produce downscaled projections in time to be incorporated into NHC's analysis.

The NHC Phase 1 report discusses climate change and states that based on river flow records the effects of climate on river flow currently do not appear to be significant. It references the analysis generated by PCIC from the Future Impacts report by Rodenhuis et al. (2007) and the draft of the local Prince George PCIC report (Picketts et al., 2009b) to predict future hydrological conditions for the 2050s. The NHC Phase 1 report states that studies suggest climate change will reduce spring peak flows at Prince George, while the effects of the mountain pine beetle will increase them. For winter flows, the climate studies suggest there will be an increase but by how much is unknown. The NHC Phase 1 report notes that increased flows on the Nechako may result in more frequent flow conditions conducive to ice-related flooding, but that this could be offset by warmer winter temperatures that would reduce frazil ice generation—a key component for ice jamming.

Though river flow levels are not showing a significant trend of increasing, the consultants suggested that a sensitivity analysis be conducted to model river flows on the Fraser 20% greater that the 1:200 year flows used the flood profile analysis. This additional flow would provide for at least a consideration of the impacts of the mountain pine beetle-kill on forests and subsequent effect on river hydrology. The result presented in the NHC Phase 1 report suggested that to allow for potential increases in river flows as a result of climate change that a freeboard allowance of 1.0 m be considered rather than the conventional 0.6m freeboard. The freeboard allowance is a safety factor used in preparing flood plain

mapping and in establishing the regulatory elevation known as the Flood Construction Level. The practice in British Columbia is to use a 0.6 m freeboard above the 1:200-year peak flow.

The report states that more hydrographic analysis and modelling are required to more accurately assess the impacts of climate change and the mountain pine beetle (NHC 2009). Section 4.8 of the Phase 2 report outlines future impacts on flood flows, including climate change and the mountain pine beetle-related effects, and the Nechako river regulation (i.e. control of the reservoir level behind the Kenney Dam). The section recommends that the PCIC information be reviewed again when it becomes available.

Other Adaptation-Related Flooding Initiatives in Prince George

Besides the Flood Risk Mitigation Study, other actions have been taken in Prince George to minimize flood risk. The City regulatory documentation and bylaws related to flooding where climate change has been or will be considered are as follows:

- **Flood Plain Mapping:** Flood plain mapping was updated by NHC in 2010 following the completion of the Flood Risk Evaluation and Flood Control Solutions investigation and reports in 2009. On average the ice-related flood profile for the Nechako was determined to be 1.1 metres higher than the previously adopted level in 1997. The revised Fraser River profile was determined to be 0.3m higher on average.

  Consideration was made by City staff to use a 1.0m freeboard rather than the 0.6m freeboard. The most affected developed areas were the flood risk areas on the Nechako. Because of the sloping terrain beyond the flood plain, the flood plain area boundary would increase only by about 5% if a 1.0m freeboard were adopted for establishing the Flood Construction Level (FCL). The greater impact would be the increase in elevation – existing development would have a greater height to be raised or flood-proofed should owners wish to expand or renovate their development and obtaining insurance for commercial/industrial properties would be impacted (flood insurance is not available for residential properties). Because the flood level on the Nechako River was already increased by an average of 1.1 metres for ice-related flooding, City staff decided not to use a 1.0m freeboard in establishing the FCL. This allows some breathing room for development to adjust to the new ice-related elevation and perhaps the freeboard consideration can be revisited in future FCL and floodplain mapping updates. The City can consider using a the additional 0.4m freeboard (above the adopted FCL) for its own infrastructure such as new road construction and road re-construction, public works facilities (e.g. water wells, pump stations, sewage treatment facilities, etc.) that are situated in the flood plain.

- **Flood Plain Bylaw:** In 2007, Prince George adopted its first Flood Plain Regulation Bylaw No. 7855, the purpose of which is to designate flood plain land and to regulate the development of these flood-prone areas. The bylaw designates what areas are considered to be in a flood plain and the flood levels for the land within the flood plain. Various setbacks from different bodies of water or

structures (such as dikes or bluffs) are prescribed. There are restrictions on what can be built within the setback (City of Prince George 2007a).

The bylaw, which incorporates the revised flood plain mapping, was updated and approved by City Council in 2011.

- **Incorporation of flooding into the *myPG* report:** the *myPG* document, which outlines a long-term vision for a sustainable Prince George, includes many references to the risk of flooding as a challenge in the community. Reducing development in high-risk areas is a flood risk mitigation strategy that is included in the report. The document explicitly mentions flooding as a climate-related impact that the City should continue to plan for.

- **Emergency Response Bylaw:** Prince George has an emergency bylaw that "provides for the establishment, administration and operation of an Emergency Response and Recovery Plan for the City. In the case of major emergency such as a flood or an earthquake, services might be interrupted without notice. Should this happen, the municipal emergency plan will be ready," (City of Prince George 2009b). City staff hopes arrange meetings to inform the Emergency Planning Committee about the potential impact of climate change on the frequency of flood events.

Adaptation Strategies for Flooding

Many of the strategies for mitigating flood risk in Prince George are discussed in detail in Section 6 of the NHC Phase 1 report (2009). These strategies are outlined in Table 1 (above), and some of them are discussed in further detail below. Please refer to the NHC Phase 1 report for more information about the strategies, and an analysis of their predicted efficacy in key areas in the city.

- **Acquiring land and rezoning:** Acquiring properties through purchase, land swapping and other means over time in flood-prone area is a common and often cost-effective solution to mitigate flooding hazards. This has been done before in Prince George; in 1972, housing was removed from the Island Cache area (near Cottonwood Island) after a flooding event (NHC 2009). In the United States a buyout program was introduced as a flood plain management tool after the Great Midwest Flood of 1993. The Federal Emergency Management Agency and other organizations purchased between 17,000 and 20,000 properties across 36 states as part of this program. By law, all purchased land must revert to natural floodplain or recreational land (Conrad et al. 1998).

- **Flood-proofing existing buildings:** The US Federal Emergency Management Agency (FEMA) has been warning citizens about the increased risks of disasters (such as flooding) as a result of climate change for many years. The agency provides resources to show how buildings can be retrofitted in

many ways to be more resistant to floods (FEMA, 2009).[4] Some of the mechanisms to flood-proof buildings, as outlined by FEMA (2009), include:

- Elevating buildings on walls, piers, piles, or fill
- Wet flood-proofing buildings by allowing floodwater to inundate selected portions of building that are not vulnerable to water damage
- Dry flood-proofing buildings by ensuring that floodwater does not enter

There are also many Canadian guides for flood-proofing buildings. A couple of examples of these include a guide for flood-proofing historic settlement areas Arlington Group Planning and Architecture (2009) and a handbook for reducing basement flooding by Sandink (2009).

- **Measure capacity to adapt to extreme events as a result of climate change:** In Atlantic Canada, two communities endeavoured to increase their awareness of and ability to respond to climate change impacts by testing their response to emergency events. This was done by running a full-scale storm surge simulation exercise in each community. The exercise report gives an overview of climate change and emergency response, summarizes the events, and gives more than 30 recommendations for improvement.[5] According to Robichaud (2007), the exercises were designed to help the communities:
  - Determine the biophysical, physical and social impacts of extreme events
  - Develop and share best practice responses to actual emergencies
  - Test existing emergency response plans

- **Public education to minimize risk of injury and damage**: The Halifax Regional Municipality (2006: p. 14) outlines adaptation options for residents to minimize their risks from severe weather as a result of climate change. Many relevant severe-weather options for people to minimize their risks of personal injury and property damage are outlined, including:
  - Do not build in high-risk locations such as low areas prone to flooding and coastal areas vulnerable to storm surge and erosion
  - Where possible, bury electrical and telephone cables underground on the property when building a new home
  - Organize community reforestation activities to minimize erosion, flash floods and landslides
  - Recognize the value of water catchment areas such as swales, wetlands, streams and ponds on the property—they handle storm-water flows

[4] See: http://www.fema.gov/.

[5] See: http://adaptation.Natural Resources Canada .gc.ca/projdb/pdf/158d_e.pdf

Recommendations

The Flood Risk Mitigation Study is an excellent step in adapting Prince George to the impacts of increased flooding. With the completion of this study and the implementation of its results the lion's share of the work in addressing the flooding priority are underway. Moving forward, the recommendations from the document should be built upon with alternative flood risk mitigation strategies. Many of the alternative strategies are related to other priority impacts in Prince George and may be incorporated into other impact actions (such as emergency response or transportation infrastructure). The following actions are proposed for the City of Prince George so that the City can continue to be a leader in flood risk mitigation.

- Continue to communicate with NHC and the sub-consultants to ensure that any advances related to climate change adaptation and increased flooding are incorporated into updates of the City's flood risk mitigation strategy. Also, updated climate change scenarios should be considered, and the information incorporated into the strategy. The City and the local adaptation experts should continue to work with the flooding experts (NHC et al.). Furthermore, when considering all long-term actions, the trade-offs and benefits related to climate change mitigation should be discussed.

- Encourage alternative mechanisms to adapt to and mitigate flood risks. There are many opportunities for co-benefits and interrelations with regards to this topic. (Some of these are mentioned in the NHC report, but many of them are not.) Ideas for alternative flood control and response mechanisms include:
    - Improve infrastructure to better facilitate emergency response (e.g. construct roads so that emergency vehicles can access areas during floods)
    - Design transportation infrastructure to be resilient to increased flooding and to help minimize potential flooding damages wherever possible
    - Design building infrastructure to be resilient to increased flooding and to help minimize potential flooding damages wherever possible
    - Encourage responsible forestry practices to minimize the negative effects of climate change and mountain pine beetle on flooding and the hydrological cycle
    - Design storm-water infrastructure (e.g. ponds, sub-surface recharge systems)to retain runoff as much as possible to mitigate flooding risks
    - Maximize permeability throughout the city to decrease runoff back to rivers and mitigate flooding risks
    - Encourage appropriate land use in flood-prone areas throughout the city

Works Cited

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