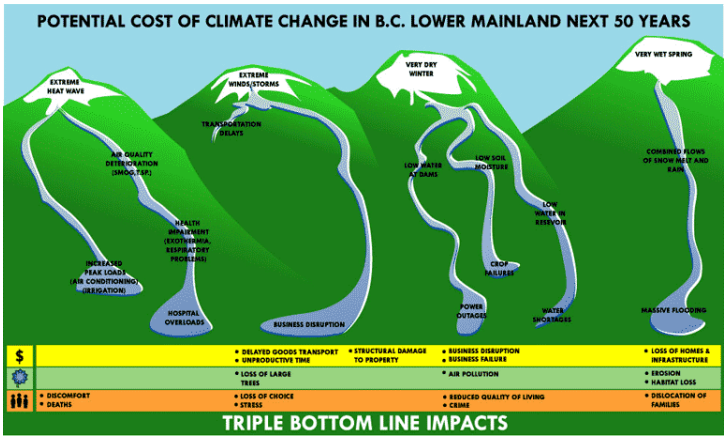
Climate Change Impacts and Adaptation Strategies for Urban Systems in Greater Vancouver

Volume 1:

Preliminary Assessment

cities PLUS
Planning for Long-term Urban Sustainability

Prepared for Natural Resources Canada



Prepared by The Sheltair Group

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Introduction

Background

The Canadian Team was awarded the Grand Prize for the International Urban Systems Design Competition in Tokyo in June 2003 for its 100-year sustainability plan for Greater Vancouver.

As part of the cities^{PLUS} process - or *cities Planning for Long-Term Urban Sustainability* - a 100-year staged sustainability plan was developed for Greater Vancouver. This project was part of the International Urban Systems Design Competition, involving eight countries and organized and partly sponsored by the International Gas Union. Greater Vancouver represented Canada in the competition and cities^{PLUS} was the name selected for Canada's process. In June 2003 in Tokyo, the international judging panel awarded the competition's grand prize to the Canadian Team.

The cities^{PLUS} plan was developed in 2002 and early 2003 and involved an intensive consultative process. As part of this process, a Climate Change Adaptation Foundation Team[1] was established to review work on this subject. At the same time, a set of 17 urban systems were identified, such as energy, mobility, and water. These systems were then integrated into a single urban system by emphasizing the interrelationships.

There are three related cities^{PLUS} reports on climate change impacts adaptation:

- ***Adaptability, Resilience, Climate Change and Sustainability for GVRD: A Background Paper prepared for cities^{PLUS}***
- ***Climate Change Impacts and Adaptation, and***
- ***Forces Shaping the 21st Century: Climate Change***

Due to the long-term nature of the plan, it was necessary to address the impacts of climate change that have already begun to manifest themselves in Greater Vancouver and that will continue to do so. This report presents a preliminary assessment of the impacts of climate change on each of the urban systems in Greater Vancouver. The report also includes a description of key adaptation and general resiliency strategies for the region. Volume 2 of this report includes influence diagrams of the potential impacts of climate change by urban system and selected adaptation strategies are shown for illustrative purposes.

Three other cities^{PLUS} reports supplement this one - **Forces Shaping the 21st Century: Climate Change** (a summary prepared by The Sheltair Group)**,** a report on **Adaptability, Resilience, Climate Change and Sustainability for GVRD: A Background Paper Prepared for cities^{PLUS}** (principle authors: Peter Russell & Associates and Facing the Future Inc.) and **Climate Change Impacts and Adaptation** (principle author: Rick Williams).

Planning in the Face of Uncertainty

Many forces will contribute to sudden changes and surprise in the 21st Century. Climate change is one such force that will affect Greater Vancouver. There are other forces that will also affect the region including the increasing pace of technological change, the

[1] We would like to thank and acknowledge the Climate Change Adaptation Foundation Team for their substantive and valuable contributions.

interdependency of the global economy, and increasing environmental stresses associated with an increasing world population. Such shocks individually or acting together can easily disrupt urban infrastructure systems and threaten our quality of life and our ability to move towards long-term sustainability. Moreover the increasing complexity and interdependencies both within our economic systems and within the built environment are certain to complicate the management process. Surprises are an inevitable by-product of complexity and surprises will become an unavoidable element of urban life.

See the report "Planning in the Face of Increasing Uncertainty: Resilience as a Foundation for Long Term Urban Planning - A cities[PLUS] Discussion Paper" (August 2002) for further information (available on the cities[PLUS] website at www.citiesplus.ca)

At the same time, a long-term plan must recognize that climate models are highly imprecise and tenuous. Humanity has a poor track record of successful forecasting, and climate has a history of rapid change and surprise. From this perspective, the force of climate change not only requires adaptation to global warming, but also an urban system that is highly resilient and capable of surviving climate discontinuities.

Due to the uncertainties that we face, it is prudent in long-term planning to use the precautionary principle. This involves promoting community planning and development that does not proceed in haste but rather considers the long-term benefits and consequences of strategies and actions. Assessments such as cost/benefit analysis, full cost accounting, and risk analysis should be factored into the decision-making process to ensure societal and environmental costs and uncertainties are acknowledged and considered.

Adopting a Long-term Perspective and a One-systems Approach

Taking a long-term planning perspective is key to ensure that systems are sufficiently flexible to adapt to unexpected rapid changes in climate. Our infrastructure investments have lifespans of 40 to 100 years, therefore we must take a long-term perspective to make sure that what is designed and installed today meets the needs of the region in the future.

The conventional approach to defining urban systems is as a series of infrastructure mechanisms that transform raw resources into essential services. The hallmark of this approach is large, centralized water, waste, sewage, transportation, and energy grids, each with a single purpose and planned with little coordination or integration with other systems. A desirable long-term view of the region needs to be based on a much broader and more integrated view. The concept is of one urban system wherein the infrastructure systems are integrated. By using this approach, positive synergies can be established among the different systems. Similarly, investments in one urban system to address climate change impacts can help to improve resiliency in another individual

system. The one system approach begins with the purpose of integrating resiliency as an on-going goal in every aspect of urban planning and in every urban system investment.

Moving from many to one requires much greater levels of integration -- across different geographic scales, between infrastructure elements, amongst different land uses, and between different disciplines. Such integration requires that planners and designers adopt a 'systems approach' and investigate synergistic solutions -- an approach that sharply contrasts with the linear mechanistic methods that underlay 19th and 20th century infrastructure planning. Inherent within the concept of long-term planning is the need for a far more integrated planning approach. The potential impacts and implications of climate change are huge and cross-cutting. It therefore requires a cross-sectoral approach which is well suited to the one systems approach.

A Three-Pronged Approach: Mitigation, Adaptation and Resiliency

In general, cities^{PLUS} adopts a three-pronged approach of mitigation, adaptation and resiliency to address climate change, each pursued simultaneously.

This report is focused on climate change impacts and adaptation. Mitigation measures for reducing greenhouse gas emissions are included in other cities^{PLUS} reports, such as The Story Behind the Energy Backcast Scenario.

Mitigation

The first prong of this approach is mitigation: to reduce greenhouse gas emissions with the aim of stabilizing greenhouse gas emissions. As this is the cause of the greenhouse effect and global climate change, it gets to the root of the problem. Each country and region must do its fair share to reduce greenhouse gas emissions. The GVRD and its member municipalities are already investing in mitigation measures to reduce per capita greenhouse gas emissions. In particular, the cities^{PLUS} 100-year plan for Greater Vancouver has a target to reduce greenhouse gas emissions to less than 1 tonne/capita/year (baseline in 1999 was 7 tonnes/capita/year), which is the International Panel on Climate Change's target for climate stabilization.

Adaptation

As greenhouse gas emissions are emitted from countries around the world, achieving climate stabilization is clearly outside the sphere of influence of the GVRD and its member municipalities. The second prong of the approach is adaptation to identify the scope and intensity of expected impacts, and to adopt policies that ensure appropriate adaptation to climate change at the regional level.

This report primarily focuses on the second prong, adaptation but with some discussion and consideration of resiliency. The

International Panel on Climate Change (IPCC) approach to adaptation is used. *Adaptation* is defined in terms of adaptive capacity, which is a function of the systems' sensitivity and vulnerability. *Adaptive capacity* is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities, or to cope with consequences. The IPCC defines *sensitivity* as the degree to which a system is affected either adversely or beneficially by climate related stimuli. The effect may be direct or indirect. *Vulnerability* is the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change. Vulnerability is a function of climatic variation, its sensitivity and its adaptive capacity.

The cities^{PLUS} Climate Change foundation paper indicates several specific areas of vulnerability that could benefit from adaptation planning, such as:

- Incorporation of uncertain changes in storm surge, rise in sea level, increased winter precipitation and related changes to local streams and rivers into current flood protection plans;
- Protection of Fraser River estuary and wildlife habitat;
- Protection of communities through increased dyke control;
- Protection and enhancement of water supplies, water delivery systems and water quality;
- Development of policy for the long-term protection, enhancement or loss of protected areas such as parks and other sensitive ecosystems;
- Incorporation of the potential for more significant extreme weather events into engineering planning (e.g. storm sewer design and transportation systems); and,
- Planning for potential impacts in conjunction with a rapid increase in population that will raise the demand for potable water, more robust sewer and storm water systems, more parks and protected areas, and better transportation systems.

Information on the David Suzuki Foundation website also lists additional vulnerabilities relevant to Greater Vancouver, such as:

- Alpine ecosystems, which are inherently vulnerable and are expected to experience the most extreme warming;
- Human settlements in low-lying coastal areas are particularly vulnerable to flooding from sea-level rise and from more intense precipitation events; and,
- The agriculture system is expected to experience predominantly negative impacts from climate change.

Other vulnerable systems include forestry, coastal zones and fisheries, energy, insurance and other financial services, human health and water resources.

Resiliency

A cities^{PLUS} morning workshop was held on June 26, 2002 in Vancouver on Resiliency, Adaptability and the Role of Long Term Planning. Over 50 participants attended and discussed the question of "how do we plan for increasing uncertainty?"

The third prong of the approach is resiliency: to assume that the future will include a major element of surprise, and that urban systems must be designed and operated in ways that accommodate sudden and unexpected changes in climate. A prudent approach is to assume that some of the predictions will be wrong, and that the system may react in surprising ways. Resiliency is "a concept that embraces two characteristics: the robustness or strength of a system when subjected to stress, and the adaptability of a system in response to changing conditions and objectives. The term can be applied both to governance systems and to the many elements and features of the built environment. Resiliency implies responsive governance systems - decision-making processes that can quickly identify and respond to new priorities or new threats."[2]

Incorporating resiliency into our urban systems means that the region must enhance the personal and collective capacity of individuals and institutions to respond to unexpected economic, social, and environmental change. Self-organization is a feature of resilient systems, since self-organized systems respond more quickly to changing circumstances, allowing for more innovative solutions.

A two day national cities^{PLUS} symposium was held in Vancouver on September 17 and 18, 2002, entitled The City in the World: Security, Resiliency, and the Role of Long-term Urban Planning, Just under 100 participants attended the national symposium, including representatives from municipalities across the country. The event included several speakers on climate change and subsequent discussions. Proceedings from the symposium are available on the cities^{PLUS} web site.

Adaptability is another key aspect of resiliency, and can be broken down into a number of simple elements such as:

- Flexibility, or enabling minor shifts in how systems function or spaces are used;
- Convertibility, or allowing for changes in use for parcels of land or buildings, or changes in inputs for infrastructure systems; and
- Expandability, or facilitating additions (or deletions) to the quantity of land or space dedicated to particular uses.

Compartmentalization, modularization and 'clustering' are design concepts that help to reduce the vulnerability of systems to the failure of any single part. When such concepts are applied to urban systems, the result is sometimes referred to as 'distributed infrastructure'. Redundancy and self-reliance are design strategies that also reduce vulnerability for urban systems. Redundancy compensates for weak links in the system as a whole. Self-reliance provides a contingency plan, to ensure that critical goods and services can be provided should all the links be compromised.

All these characteristics – such as robustness, adaptability, durability, redundancy, and self-reliance - contribute to resilient systems, and in so doing, may reduce the region's vulnerability to climate change and other shocks to the urban system.

[2] Sebastian Moffatt, The Sheltair Group. August 2002. The City in the World Paper: Security and Resiliency as a Foundation for Long Term Urban Planning. A cities^{PLUS} Discussion Paper.

Manifestation of Climate Change in Greater Vancouver

Between 1895 and 1995, the Georgia Depression, which includes Greater Vancouver, has already experienced a 0.5ºC increase in temperature, or an increase at roughly the same rate as the global average.

Climate change has already manifested itself in Greater Vancouver and BC. The following are some of the impacts that have been observed over the last century[3]:

- Average annual temperature warmed by 0.6ºC on the coast, 1.1ºC in the interior, and 1.7ºC in northern BC.
- Night-time temperatures increased across most of BC in spring and summer.
- Precipitation increased in southern BC by 2 to 4% per decade.
- Lakes and rivers become free of ice earlier in the spring.
- Sea surface temperatures increased by 0.9ºC to 1.8ºC along the BC coast.
- Sea level rose by 4 to 12 cm along most of the BC coast.
- Two large BC glaciers retreated by more than a kilometer.
- The Fraser River discharges more of its total annual flow earlier in the year.
- Water in the Fraser River is warmer in summer.
- More heat energy is available for plant and insect growth.
- Between 1895 and 1995, the Georgia Depression has already experienced a 0.5°C increase in temperature, or an increase at roughly the same rate as the global average.
- Between 1909 and 1999, sea levels rose 4 cm along the Greater Vancouver coastline reflecting the combined impacts of the rise in sea levels and vertical movement of the shoreline.

There are various models that show both warming and cooling scenarios for the impact of climate change. The following are the main manifestations of climate change that are expected to occur in Greater Vancouver over the 21st Century[4]:

- Average annual temperature in BC may increase by 1ºC to 4ºC.
- Average annual precipitation may increase by 10 to 20%
- More extreme precipitation events
- Sea level may rise by up to 88 cm along parts of the BC coast.
- Many small glaciers in southern BC may disappear
- Some interior rivers may dry up during summer and early fall
- Salmon migration patterns and success in spawning are likely to change, and
- The mountain pine beetle — an important pest — may expand its range.

[3] BC Ministry of Water, Land, and Air. 2002. *Indicators of Climate Change for BC 2002.*

[4] BC Ministry of Water, Land, and Air. 2002. *Indicators of Climate Change for BC 2002.*

In addition, an IPCC report identifies specific Water Resource Impacts in Alaska, Yukon, and Coastal British Columbia (source: IPCC Third Assessment Report (2001), WG II TS (p. 58)[5])

- Increased spring flood risks
- Glacial retreat / disappearance in south, advance in north; impacts on flows, stream ecology
- Increased stress on salmon, other fish species
- Flooding of coastal wetlands, and
- Changes in estuary salinity / ecology.

Potential Impacts of Climate Change in Greater Vancouver

In order to identify and visualize the impacts of climate change on the urban systems in Greater Vancouver, a set of influence diagrams were developed. The influence diagrams show impacts of the manifestations of climate change on urban system. A completed set of influence diagrams for each of the urban systems is presented in Volume 2 of this report. A summary of all the impacts by urban system is included in a table in Appendix A.

Of the 17 cities^{PLUS} systems, it is thought that only 13 of these systems would be significantly impacted by climate change in a direct manner. The systems that have not been addressed are: communications, decision support systems, governance, and materials management. The remaining systems are all subject to major impacts, and include:

- Agri-food
- Buildings
- Culture
- Economic Development
- Energy
- First Nations
- Health and Well-being
- Human Security
- Land Use
- Mobility
- Natural Habitat
- Social Equity, and
- Water.

Influence diagrams indicate the chains of influence whereby one element of a system can influence other elements. Each arrow (or

[5] Relative to northern Canada, these manifestations of climate change are significant but much less severe. Northern Canada will experience much more pronounced changes than the southern portion of the country.

link in the chain) indicates a degree of influence or causality, and a direction of influence (in the direction shown by the arrow).

Each influence diagram traces the impacts of climate change from the first order effects of anticipated climate change to impact. Climate change scenarios involving either warming scenarios or cooling scenarios can be used with the diagrams. This report uses scenarios described in *Indicators of Climate Change for BC 2002*[6].

The influence diagrams incorporate these first order impacts for each of the 13 affected urban systems. The influences and effects are followed until there is an impact on something of value to society, such as human health or wildlife. Influence diagrams also indicate the desirability of impacts, whether positive or negative.

Influence diagrams are relatively simplistic since they ignore many lesser variables and influences. Also, the arrows in the diagram do not necessarily imply causality. However they serve the purpose of identifying and prioritizing strategies during the preliminary stages of long-term planning. For example, by focusing as high up in the influence chain as possible, strategies will be most effective.

Illustrative Adaptation Strategies

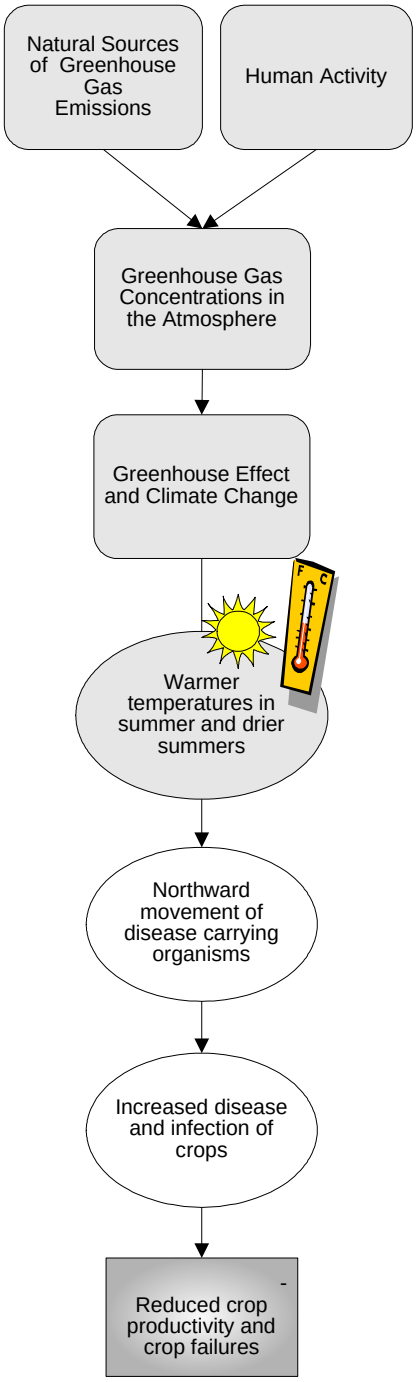
A pair of influence diagrams is included for each system in Volume 2 of this report. The first diagram shows the influences and effects as described above; the second diagram shows the possible adaptation strategies, superimposed on the influence diagram.

Adaptation strategies are shown using "callout" boxes extending from the influence diagram arrows. Also shown are greenhouse gas mitigation measures, which help to break the chain of influences at the beginning, and serve to effectively dampen or eliminate all downstream effects and impacts. In this sense, the location of the adaptation strategy is a type of prioritization: **adaptation can only dampen or eliminate effects to the right, or downstream from the point of intervention on the influence diagram**.

Many of the illustrative adaptation strategies are also best practices for implementing other goals related to sustainability. By focusing on positive synergies of this type, climate change adaptation becomes more practical and affordable. Appendix B provides a table of illustrative adaptation strategies for each urban system. Ultimately these strategies need to be carefully cross-referenced to other goals and measures proposed for sustainability in Greater Vancouver.

[6] BC Ministry of Water, Land, and Air. 2002. *Indicators of Climate Change for BC 2002.*

An example of Impacts and Adaptation Strategies for the Agri-Food Urban System



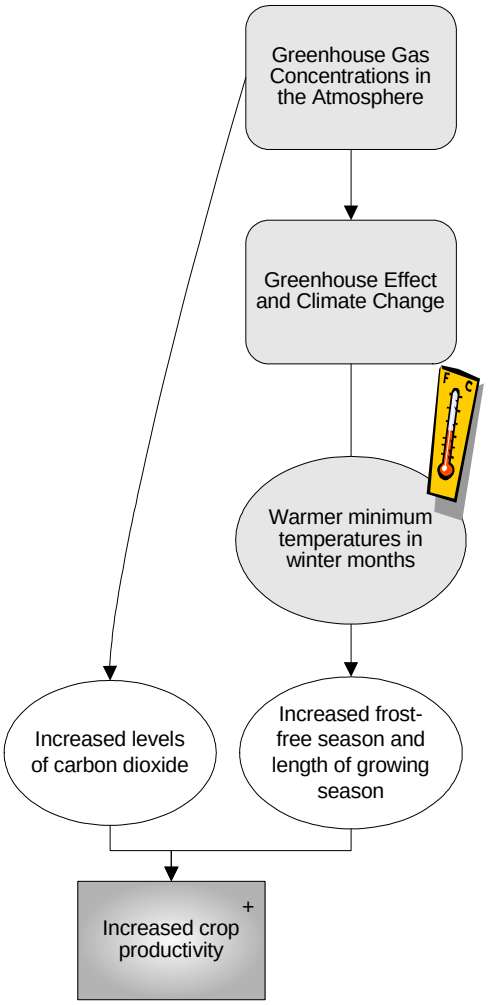
Example of a chain of influence with a negative impact on the Agri-Food System

This section describes how to read and interpret the influence diagrams included in Volume 2, using the Agri-food System as an example. An interpretation key is also included in Volume 2 for reference. The first diagram in the pair is the impact diagram (pages Vol. 2, p. 2 for the Agri-food System) and the corresponding pair is the adaptation strategies diagram (p. 3 for the Agri-food System).

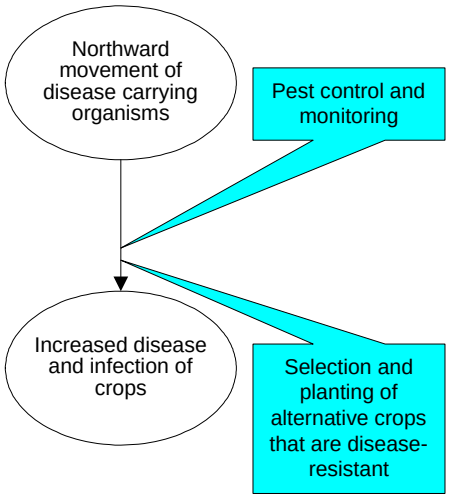
The influence diagrams are to be read from left to right (but are shown on the sidebar vertically for illustration purposes). On the influence diagram showing the potential impacts on the Agri-food System, the set of boxes with rounded rectangles show the primary drivers of climate change at the global scale. The diagram shows that "greenhouse gas concentrations in the atmosphere" are comprised of emissions from "human activity" and "natural sources of greenhouse gas emissions". Together, these influence the "greenhouse effect and global climate change".

The set of four shaded ovals emanating from the "greenhouse effect and climate change" box are the relevant regional manifestations of climate change appropriate to the Agri-Food System. For example, the first regional manifestation of climate change is "warmer temperatures in summer and drier summers". The series of ovals and boxes to the right of the shaded ovals represent the chains of influence that eventually have an impact on a key functioning of the urban system and its inhabitants.

Using the top row of influences as an example, the diagram can be interpreted as "warmer temperatures in summer and drier summers" has an influence on the "northward movement of disease carrying organisms" which then has an influence on "increased disease and infection of crops" which then has an influence on "reduced crop productivity and crop failures". This last step in the chain, depicted as a shaded rectangle, is the impact on the urban system under consideration. The negative sign depicts the direction of impact, either positive, negative, or mixed. Finally, the three lines stemming from the impact box shows the more specific associated ecological, economic, and social impacts (not shown in sidebar). The other chains of influence in the diagram - including decreased size of the annual snowpack, increased evapotranspiration, increased flooding, and salinization of soils - also eventually lead to reduced crop productivity and increased risk of crop failures.



Example of a chain of influence with a positive impact on the Agri-food System



Example of illustrative strategies that can dampen or eliminate downstream effects on the chain of influence

At the bottom of the diagram, there are two chains of influence which actually result in a positive impact on the Agri-food System. "Warmer minimum temperatures in the winter months" result in an "increased frost-free season and length of the growing season" which then can have a positive influence on crop productivity. Similarly, "increased levels of carbon dioxide in the atmosphere" is a basic compound for photosynthesis which can also have an influence in increasing crop productivity, all other factors being equal. Increased crop productivity can then be translated into increased revenues from agriculture as a positive impact.

The paired influence diagram for the Agri-food System shows illustrative adaptation strategies, superimposed on top of the chains of influence. The illustrative adaptation strategies are shown as callout boxes with the tip of the callout box pointing to the link along the chain of influence. If implemented, the illustrative strategy can help dampen or even eliminate the downstream effects of climate change impacts.

It should be noted that the two callout boxes on the far left of the diagram - "greenhouse gas mitigation measures" and "carbon sequestration measures" - are needed to be implemented globally. Therefore, to a certain extent, these measures are outside the sphere of influence of the region. These two mitigation measures are common to all the urban systems.

The location of the illustrative adaptation strategies shows where the intervention can occur in the chain of influence. For example, "pest control and monitoring", "selection and planting of alternative crops that are disease-resistant" and "plant an increased diversity of crops", can reduce or eliminate the impact that the "northward movement of disease carrying organisms" may have on "crop productivity". It should be noted that where there are positive impacts, it is unnecessary to intervene as the impact is desirable.

Due to the lack of space on the diagram, the impacts and illustrative strategies to the fishery and aquaculture system are not shown although they are part of the region's Agri-food system. The impacts to the fishery are shown in a generalized nature in the Natural Habitat System influence diagram. The Agri-food system is also related to the energy, water, land use, economic development, and human security systems. In a computer model, these impacts could be linked and inter-related together, but for the purpose of this report the impacts are shown through separate urban system.

Adaptation and Resiliency General Implementation Considerations and Strategies

Additional ideas regarding adaptation strategies are included in the cities^{PLUS} Climate Change Adaptation Foundation Papers.

This section identifies suggested general implementation considerations and adaptation strategies for addressing climate change impacts in Greater Vancouver.[7] It describes the key features of what would be required to develop an effective general adaptation strategy to climate change impacts. While the previous section included the identification of illustrative implementation measures, this section provides more of the "big picture" thinking. Eventually the big picture strategies must evolve into a comprehensive and integrated implementation strategy for adaptation measures.

1) Assessing the Region's Vulnerability to Climate Change Impacts

Reducing the vulnerability of urban environments to climate change is a force that needs to be addressed in a long term plan for the region. Our current urban system is highly vulnerable to disruption from major shocks, including climate change. For the last hundred and fifty years urban planning and engineering around the world has encouraged a centralized, single-purpose model for each urban system. Commonly referred to as 'supply side', or 'end of pipe approach', this design model was economically efficient, particularly for rapidly growing cities with limited technology and plentiful natural resources.

A major problem with centralized, top-down systems is their inherent fragility when faced with rapid changes in external conditions or local priorities. If the centre falls, the failure cascades throughout the system. The loss of a single power line, pipeline or bridge can now shut down an entire city, as we have seen in the ice storms in Quebec and Ontario or the power surges that cascaded through Ontario and the Eastern U.S. in 2003 leaving 50 million people without power. Although the centralized systems may be economically efficient, they are vulnerable to disruption and failure.

Large and remote generating plants, incinerators, treatment plants and communications facilities are far more vulnerable to catastrophic failure than a network of modular, distributed systems that are closely integrated into the fabric of the city. Even the infrastructure grids in our cities – which in theory provide a basis for a networked, distributed system – are currently designed for one-way flows, and a one-quality-of-service-fits-all approach.

[7] This section only addresses adaptation strategies. Mitigation measures to reduce climate change are equally important and are covered in other cities^{PLUS} reports.

The initial step for this is to assess the current and anticipated future vulnerabilities of the region to climate change, as well as other potential shocks, such as earthquakes, natural disasters, plagues, economic disruptions, and other human security threats. A key aspect of this process is to understand the cause and affect chains of influences and to identify which particular systems are vulnerable to impacts. For example, the Fraser Basin Council is currently conducting a flood plain mapping of the Fraser Basin. This mapping in combination with scenario modeling of potential climate change impacts (such as intense precipitation storms or sea level rise) can show spatially which areas are vulnerable to flooding. In addition, spatial databases showing the distribution of buildings and structures in the region can show how much particular damage may be incurred under various scenarios.

Part of the vulnerability assessment entails identifying weak links to understand where the systems we currently rely on for food, water, energy, and other essential resources and services might fail. When we discover nodes that are integral but not duplicated elsewhere in the system, we have found a weak link. We need to identify fragilities, vulnerabilities or areas in which we do not have backup facilities as part of assessing local capacity to adapt and change. Cities need to be adaptable to anticipated as well as unpredictable changes in the future.

The impacts of climate change can manifest themselves either gradually or acutely. For example, sea level rise is a gradual impact which has a longer early warning period. In contrast, more intense precipitation events can cause more sudden floods, which is an acute impact. Reducing vulnerability to climate change requires addressing both gradual impacts as well as sudden and acute impacts.

Vulnerability can be reduced through designs that incorporate for example: redundancy, fail-safe designs, contingency plans, compartmentalization, adaptability (including flexibility, convertibility, extendibility), and robustness.

2) Reinforcing the GVRD's Livable Region Strategic Plan as a Framework for Adaptation

A key aspect of addressing climate change impacts, is to focus on prevention and planning. The region's growth management strategy is called The Livable Region Strategic Plan, or LRSP. The LRSP can be used as a basis for prevention of many of the key anticipated impacts from climate change, such as increased flooding. The LRSP can be used in the following manners to avoid or reduce potential impacts associated with accommodating population growth and development in the region by:

- Directing population growth and development away from areas prone to flooding from sea level rise or from increased precipitation events.
- Concentrating growth in area where climate change impacts are expected to be smallest
- Continuing the implementation of the Green Zone, and
- Supporting reduced automobile dependence through the region's compact urban form combined with complete communities, resulting in fewer vehicle kilometers traveled, reduced single-occupant-vehicle usage, shorter trips, and reduced fossil fuel consumption and hence fewer air emissions resulting in improved air quality (and also reducing greenhouse gas emissions which is a mitigation strategy).

In addition, climate change adaptation considerations could also be more directly addressed in the updated LRSP as well as in other regional plans through planning processes, particularly infrastructure planning. For example, the anticipated increased precipitation events could be used to ensure pipe sizes are of a certain diameter to accommodate increased precipitation events in the future.

Since some climate change impacts have a spatial distribution and the region's LRSP includes a generalized land use map, the strategy can be used to identify areas that may be vulnerable to climate change, such as increased flooding. As the LRSP is linked to municipal official community plans, the municipalities can reinforce this desired spatial development pattern within their own plans. For example, a municipality can designate development permits for areas that are vulnerable to climate change to avoid or restrict development in these areas.

3) Protecting and Connecting Webs of Green and Ribbons of Blue

Part of being resilient is designing urban systems to emulate the natural environment. One of the most significant impacts of climate change will be the stress that it puts on our natural habitat systems. Therefore, these natural systems need to be protected and enhanced to be more resilient to change. Protect and connect webs of green and ribbons of blue is one of eight catalyst strategies included in the cities^{PLUS} project. The concept entails rehabilitating and protecting natural and built systems through reconnecting viable networks of blue waterways and green spaces and corridors. The strategy creates a web that connects a hierarchy of green spaces, ranging from protected watersheds and agricultural lands, right down to hedgerows and private gardens. The green web incorporates riparian zones, and extends the region's emerging pattern of ecological and recreational greenways. The green web allows the larger parks and bio-reserves to act as

biodiversity reservoirs. The strategy also emphasizes restoring the region's hydrology by integrating streams and water bodies both into the green web and into the built environment. By protecting and enhancing the region's green and blue spaces to emulate natural systems, this will increase the natural environment's ability to adapt to environmental stress and change.

4) Designing Multi-use Spaces and Convertible Structures

Another catalyst strategy in the cities^{PLUS} project is to design multi-use spaces and convertible structures. The concept involves increasing the capability of all pieces of the urban system to be adaptable to multiple uses, simultaneously and in the short and long terms. The concept of convertibility particularly applies to climate change impacts. Convertibility emphasizes the potential for adaptive re-use over the longer term. The region's structures and systems will be designed for adaptability to other uses and functions. This way, the region can transform over time with greater ease and lower cost. Transformation may be required as the economy changes or in response to unexpected migrations, natural disasters, climate change impacts, or changing societal preferences.

5) Planning Short Loops and Integrated Infrastructure Networks

Distributed systems are better able to cope with disruptions than centralized systems.

This is a third cities^{PLUS} catalyst strategy. The concept entails enhancing the flows and connectedness of the region so that all pieces of the urban system are finely linked nodes in an integrated network. The nodal network would extend from a regional scale to that of the block and parcel. An important characteristic of the short loops and networks is their self-managing and sharing capacity. Storage, conversion, treatment or generation functions will move readily from one scale or location to another. Surpluses will be easily shared from node to node. Each building, for example, will contribute water, electricity, heat, and information flows to the benefit of others in the region. The nodes and networks emulate the complexity and efficiency of a natural food web. In this way, Greater Vancouver becomes an urban ecology. This strategy will result in reducing the vulnerability of Greater Vancouver's urban system to disruptions from climate change impacts and from other potential shocks.

6) Maintaining and Increasing Diversity in Urban Systems

Another cities^{PLUS} catalyst strategy concerns enhancing the diversity of choices. Components of the urban system need to be intentionally designed to accommodate a diversity of technologies and resources. The diversity of vegetation species can provide a buffer again disease and unpredictable events.

We also need to have diversity in all urban systems, so that we are not dependent on just one supply source for key resources, such as

energy, water, and food. For energy systems, this means we should utilize a number of different sources of energy, some of which can be obtained locally. For food, this means that we need to maintain local capacity to produce food, while strengthening trade networks around the world. To ensure we have access to a sufficient drinking water supply that is safe to drink, we need to maintain distributed reservoirs around the city, so that if any one reservoir fails, others will be accessible.

7) Creating Shock-resilient Cells and Backup Systems

A cellular structure can be developed to reduce the region's vulnerabilities to threats by developing critical infrastructure capacity and enhancing local ability to adapt rapidly to unexpected shocks

A key cities^{PLUS} catalyst strategy for avoiding sudden shocks is to create shock-resilient cells. It is proposed that a cellular structure be developed to reduce the region's vulnerabilities to threats. This concept involves establishing a cellular structure to reorganize land use and critical infrastructure capacity, enhancing local ability to adapt rapidly to unexpected shocks. The concept begins with a very few large cells or pods characterized by a high level of self-reliance. The structure then sub-divides into a collection of smaller, less autonomous cells. This structure can be used to mitigate threats in a variety of ways.

First, cells can withstand a sudden loss in connectivity by incorporating redundancies and contingencies. This is especially critical for a region where the transportation, water and gas distribution systems depend on the structural integrity of a few bridges. Distributed water storage, for example, might allow many parts of the region to function for days despite the loss of connection to the mountain reservoirs or a drought situation caused by climate change. Second, cells provide a means for halting the cascading of problems from one location or system to another. For example, a cell around the North Shore community might prevent forest fires from entering neighbourhoods. A cell around the ports might help to contain the sudden arrival of pollutants, or invasive plant species, or plagues. Third, cells provide a means for organizing a coordinated response by emergency services, as well as an administration structure for implementing rapid recovery programs. Fourth, the urban cells offer a means for excluding dwellings from especially hazardous lands, such as floodplains, unstable slopes, and soils that may liquefy during the event of an earthquake. In this way, resilience will increase over the long-term and Greater Vancouver will become a region prepared for the unexpected.

8) Conducting Integrated Urban Systems Risk Management

It is not current practice for local agencies to assess resiliency and identify security risks, despite the rapid growth and changing conditions in large centres like Greater Vancouver. Without comprehensive and integrated risk assessment for urban systems, appropriate risk management is difficult. For example, dealing

with climate change impacts without linking it to other similar threats will result in ineffective action. It is proposed an integrated urban systems risk management plan be developed for Greater Vancouver to deal with all major risks to the region, including climate change impacts.

If natural disasters and other shocks are increasing, it follows that cities should collect 'intelligence' on the nature of the new or increased threats, then evaluate the vulnerability of each and every urban system, and finally, where appropriate, develop risk management strategies.

A risk assessment process for cities must use such principles as the precautionary principle, diversity, and redundancy as the basis for evaluating the long-term security, whenever choices are being made about urban development. At the moment, almost no risk assessment occurs within planning processes, other than satisfying standards and regulations related to emergency evacuation, and the traditional threats of fire safety, and exposure to toxic materials.

Risk assessment bodies are as yet not well integrated with local planning bodies. Their mandates may be too narrow to address the many threats faced by cities, or to communicate risks and support decisions at the local level.

9) Developing a Robust Emergency Response and Recovery Plan

The more acute or sudden impacts from climate change have characteristics that are similar to natural disasters. Therefore, it is suggested that these climate change impacts be addressed through regional and municipal emergency response and recovery plans.

The more acute or sudden impacts from climate change have characteristics that are similar to natural disasters. Therefore, it is suggested that these climate change impacts be addressed through regional and municipal emergency response and recovery plans. As the impacts of natural disasters are similar to those of climate change, there will therefore be similar adaptation or response mechanisms required.

To ensure adequate response systems, we must also invest in human capital and training. In the event of catastrophic problems, centralized disaster response is impossible. Instead, local residents must have the training, tools, and expertise to respond to local challenges.

The many dysfunctional relationships between stakeholders is one of the most critical issues to be addressed in emergency planning. All aspects of emergency planning require coordinated action between public and private sectors, and between and among levels of government.

10) Selecting, Prioritizing, and Phasing Implementation of Specific Adaptation Strategies

Prevention and adaptation will require investments. These investments are needed to reduce the vulnerability of our urban systems to climate change impacts and associated environmental, economic and social impacts when climate change impacts occur. Selection of the prevention and adaptation strategies requires an assessment of costs and benefits and prioritization.

Through urban system risk management processes, a number of potential adaptation strategies will emerge that could be implemented to reduce the impacts of climate change on Greater Vancouver's urban systems or its vulnerabilities.

Additional criteria for incorporating climate change impacts into planning are also included in the other cities^{PLUS} Climate Change Adaptation Foundation Papers.

A process will need to be developed to select, prioritize and identify the phasing of the implementation of the specific adaptation strategies. The following criteria are offered to assist with this process. First adaptation strategies which have no cost or short-term payback periods should be implemented as soon as possible. This will also include the implementation of 'no regret' adaptation strategies. Secondly, many of the illustrative adaptation strategies offer benefits other than just reducing impacts of climate change. For example, energy and water conservation and demand side management have the benefits of reducing expenditures on these resources and fostering sustainability. Therefore, these adaptation strategies can be implemented for reasons other than reducing climate change impacts. Thirdly, as can be seen in the influence diagrams for each of the urban systems, adaptation strategies that intervene higher up in the chain of influence diagrams (i.e. further to the left on the diagrams) will have greater effect, as they impact all downstream elements. It may be more effective to implement one adaptation strategy high up in the influence chain rather than five adaptation strategies that are towards the end of a particular chain of influence. A fourth criteria is if the adaptation strategy is robust and can address a number of impacts from climate change or from other potential shocks, such as natural disasters. If so, then the adaptation strategy should receive higher weight, all other factors being equal.

Various organizations such as the regional chapter of the Canadian Climate Impacts and Adaptation Research Network (C-CIARN), can be used to facilitate the discussion of adaptation strategies and improve the communication of climate change research and policy development in Greater Vancouver.

Various organizations such as the Canadian Climate Impacts and Adaptation Research Network (C-CIARN), can be used to facilitate this process and improve the communication of climate change research and policy development. The key will be to translate research into policy prescription.

The phasing of adaptation strategies is an important consideration for addressing climate change impacts. Implementation of some of the adaptation strategies may need to be incremental. The

Establishing a sustainability endowment fund as legacy of the 2010 Winter Olympics could be used to implement initiatives that foster climate change adaptation as well as sustainability.

identification and implementation of adaptation strategies will also need to be tied to the planning and budgeting process of regional agencies and municipalities as well as the capital budget planning process. For example, when infrastructure upgrades are scheduled, it would be desirable to also address climate change impacts that are anticipated decades into the future. For example, storm sewer pipes could be designed to be wider to account for higher anticipated winter precipitation events. Similarly, when dykes need to be repaired for routine maintenance, it may be desirable to raise their height to a level that is higher than the anticipated sea level rise from climate change.

The cities^{PLUS} Climate Change Adaptation Foundation Papers provide additional information on some suggested phasing of climate change adaptation strategies.

11) Applying an Adaptive Management Framework and Monitoring Climate Change Impacts

Planning processes for addressing climate change and other shocks must also be adaptable and flexible - a rigid plan won't work. .

Planning processes for addressing climate change and other shocks must also be adaptable and flexible - a rigid plan won't work. The cities^{PLUS} process used an Adaptive Management Framework for structuring its analysis for each urban system. A key feature of the adaptive management framework are feedback loops that can be used to adjust plan implementation to account for change and surprise.

The monitoring of climate change impacts is important to understand the rate and magnitude of impacts in the region. Regional state of the environment reports can be used to monitor impacts of climate change (e.g. pine beetle infestation, etc.; increase in temperature, change in species distribution, etc.). This reporting then can be used to adjust implementation if necessary.

To be truly effective, adaptive management and continuous improvement become intrinsic features of all regional institutions. Finally, we also need to learn from other areas that will be impacted by climate change first and hardest hit, such as Northern Canada. Lessons learned can then be incorporated into the planning and risk management process and adaptation strategies can be developed or modified as needed for Greater Vancouver.

Conclusions

Influence diagrams proved to be a useful conceptual and visual tool for understanding the full range of impacts on a variety of urban systems for a specific region. They also helped determine where and how intervention in the system can occur. Developing diagrams for a broad scope of systems facilitated the identification of multiple impacts and the selection of high priority, synergistic strategies. Displaying all categories of climate change impacts, both negative and positive, helps create a balanced view and more effective assessment of trade-offs.

The GVRD is at the early stages of trying to address the impacts of climate change. Most of its efforts have gone towards climate change mitigation rather than adaptation.

Taking both a long-term perspective and a one-systems approach offers major benefits for addressing climate change impacts. The 100-year time horizon helped us to look past immediate preoccupations and vested interests, discover powerful unifying ideas and consider our responsibilities to successions of future generations. Climate change will have a long-term impact and solutions to climate change also need to reflect this long-term perspective.

Addressing climate change impacts is similar to addressing other shocks. Using a one-systems approach while addressing a broader range of related shocks could result in the identification of solutions that offer exceptionally positive synergies.

The costs and benefits of implementing adaptation strategies needs to be considered against the increased vulnerability and potential costs that can occur from various climate change impacts.

The GVRD is at the early stages of trying to address the impacts of climate change, but a more balanced approach may be desirable. Most of its efforts have gone towards climate change mitigation rather than adaptation. For example, it has already begun to bring experts from a range of issue areas together to discuss opportunities and coordinate action on reducing greenhouse gas emissions. The Partners for Climate Protection Program is a good model of having local governments take the lead and set an example of working with the community. In the GVRD, there are an unprecedented 19 of the 21 municipalities participating in the program. A similar program for climate change adaptation could provide a useful model for moving ahead on climate change adaptation in the region.

The most effective level of government for dealing with many of the impacts of climate change is the local level of government. The GVRD and its member municipalities have significant influence and jurisdiction over many potential adaptation measures. However,

due to limited resources, the federal and provincial governments need to support their implementation and adaptation initiatives.

It is noted that growth management strategies are a critical component of reducing the vulnerability of urban systems to impacts of climate change. For example, growth management can be used to help direct growth away from areas that are vulnerable to the anticipated impacts of climate change.

To effectively address climate change impacts requires developing a resilient urban system, that incorporates diversity, adaptability, flexibility, and has backup systems and emergency response systems in place to respond to both gradual and sudden climate change impacts.

The GVRD's approach to climate change is likely to benefit from an integrated urban systems risk management strategy and a regional emergency response and recovery plan. It is noted that the GVRD's efforts to address sustainability in the region, should also help implement a more resilient and robust urban system, which in turn should reduce the region's vulnerability to climate change impacts per se.

To effectively address climate change impacts requires developing a resilient urban system, that incorporates diversity, adaptability, flexibility, and has backup systems and emergency response systems in place to respond to both gradual and sudden climate change impacts.

The implementation of adaptation strategies will require collaboration amongst a broader range of stakeholders, disciplines, levels of government, and sectors than currently occurs. The different groups must come together in an integrated way to identify synergies and opportunities and then work individually to transfer the results into discreet actions.

Further Research

Several areas for conducting additional research arise from this study. The first concerns further development and refinement of influence diagrams as a way to illustrate impacts and adaptation strategies. It is recommended that influence diagrams be developed using focus group sessions, where experts agree on the impacts on specific urban systems in a region. Such focus groups could also include brainstorming sessions to identify and prioritize a full range of adaptation strategies.

The use of influence diagrams could also be extended to show the impacts of other threats to urban systems, such as earthquakes, plagues, etc. It is thought that by identifying threats that may have similar impacts or characteristics may also help to identify common adaptation strategies, which would have multiple benefits.

On the influence diagrams, there is no magnitude or quantification of impact on each of the variables. It is suggested that a model be

developed where a sensitivity analysis could be conducted on the range of impact on each system. The sensitivity analysis would show the degree to which a system is affected, either adversely or beneficially, by climate-related stimuli. The model could also be developed to indicate how an adaptation strategy could dampen the impact of a climate change impact.

A full risk assessment needs to be conducted on Greater Vancouver's vulnerabilities to climate change and other anticipated or potential shocks to the urban system. The risk assessment can then be used to develop an integrated urban systems risk management strategy, in which climate change is only one threat amongst many.

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Appendix A: Potential Impacts of Climate Change on Systems in Greater Vancouver over next 50 to 100 years by Urban System

System	Summary of Impacts (positive)	Summary of Impacts (negative)
Agri-food	• Increased crop productivity (due to increased length of frost-free season and length of growing season and increased levels of carbon dioxide)	• Reduced crop productivity and crop failures (due to northward movement of disease carrying organisms, decreased water available for irrigation, increased evapotranspiration, and potential flooding and salinization of soils)
Buildings	• Reduced energy consumption for buildings (due to warmer temperatures in winter)	• Increased energy consumption for buildings (due to warmer temperatures in summer) • Water damage to buildings and structures (from sea level rise or increased precipitation in winter months which can cause flooding)
Culture	• International migration to Canada (can be both positive and negative)	• International migration to Canada (can be positive and negative) • Reduced viability of ski resorts (due to higher mountain snowpack)
Economic Development	• As trees grow/mature faster, more productive forests1	• Reduced timber available for harvest by forest companies (due to increased insect infestations and increased risk of forest fires) • Salmon mortality impact on ecosystems and on fishery • Water damage to buildings and structures (from increased precipitation in winter and flooding) and sea level rise • Diminished sea and airport capacity for handling passenger and cargo due to potential flooding from sea level rise.
Energy	• Decrease in energy consumption and costs in winter (due to warmer winters and reduce need for space heating) • Increased electrical generating capacity in summer (due to warmer temperatures in summer and drier summers contributing to lower water levels in reservoir)	• Increased energy consumption in summer due to increased cooling demand (e.g. for air conditioning and refrigeration) • Decreased electrical generating capacity in summer (due to warmer temperatures and drier summers) • Increased peak loads for air conditioning due to potential for extreme heat waves • Potential power outages associated with extreme events

System	Summary of Impacts (positive)	Summary of Impacts (negative)
First Nations	• Potentially longer season for hunting and gathering activities	• Reduced timber available for harvesting if located on reserve lands (due to increased risk of insect infestations and increased risk of forest fires) • Reduced salmon available for aboriginal fishery (due to increased temperature in salmon-spawning streams and increased ocean temperatures affecting range and migration of salmon) • Water damages to buildings and structures (particularly as many BC First Nation reserves are located in coastal areas or along streams)
Health & Well-being		• Increased incidence of insect-borne disease • Degraded air quality and associated increases in respiratory diseases and death • Heat related deaths and illnesses • Extreme weather event deaths and injuries • Flooding of lands and stress for people in vulnerable areas • Increased anxiety and feeling of helplessness due to cumulative impacts from climate change
Human Security		• Increased incidence of insect-borne diseases • Degraded air quality • Heat related deaths and illnesses • Potential increase in electricity costs or potential power outages in summer • Water shortages in summer • Increased risk of flooding and water damage to buildings and structures
Land Use		• Reduced land available for development and settlement • Water damage to buildings and structure from increased flooding • Transportation infrastructure routes flooded and associated delays

System	Summary of Impacts (positive)	Summary of Impacts (negative)
Mobility		• Increased energy consumption for transportation (due to decreased comfort level of alternative transportation modes) • Degraded air quality • Reduced freight traffic and recreational opportunities • Hinterland supply chains disrupted • Land-based transportation routes flooded • Reduced sea and airport capacity for handling cargo and passengers
Natural Habitat		• Change in range of wildlife populations such as bears and eagles • Salmon mortality (due to increased temperatures in salmon-spawning streams and increased ocean temperatures) • Reduced fish vitality mortality, diversity and abundance. • Increased risk of ecosystem breakdown • Loss of fish habitat • Loss of water fowl habitat for Pacific Flyway
Social Equity		• Degraded air quality and associated respiratory diseases and deaths • Heat related deaths and illnesses • Increased incidence of disease • Impacts on First Nations, homeless, and vulnerable groups such as the elderly
Water		• Impaired water quality in streams and lakes • Increased water consumption • Decreased capacity of wells • Combined sewer overflows • Streambank erosion and landslides • Damage to buildings and structures • Habitat loss

Appendix B: Summary of Illustrative Climate Change Adaptation Strategies for Greater Vancouver by Urban System

System	Illustrative Climate Change Adaptation Strategies
Agri-food	• Crop-failures: Diversify crop and livestock species, change the location of crop and livestock production activities, pest control and monitoring, select and planting of alternative crops that are disease-resistant, use cisterns and on-site water storage, use farm practices that retain soil moisture, increase height of dykes, reallocate ALR land (where lands are flooded) (no net loss), switch to aquaculture or farming techniques where flooding is part of natural cycle, implement flood management practices, use green roofs to increase on-site retention of stormwater, use of permeable surfaces where possible, use stormwater detention ponds and constructed wetlands
Buildings	• Increased energy consumption: employ energy demand side management techniques, increase share of attached and multi-unit buildings, use district energy systems, use energy load management techniques, retrofit buildings to incorporate green building design, design and construct new buildings for natural cooling • Flooding: Disconnect rooftop eavestrough drains to allow infiltration into soil, use swales and on-site water storage, use permeable surfaces where possible, use stormwater retention / detention ponds and constructed wetlands, raise level of dykes, phase-out and relocate buildings in flood/landslide prone areas, employ land use planning and zoning to avoid locating structures and buildings in flood / landslide prone areas
Culture	• Flooding in coastal areas around world: offer climate change adaptation assistance to countries abroad, contribute best practices to vulnerable regions around world, offer disaster assistance programs abroad to countries in need • Viability of ski resorts (from cultural perspective): provide better access to ski areas at higher elevations, Increase snowmaking
Economic Development	• Forestry: Consider short rotations to reduce risks during tree life span • Forestry: Protect existing forests by enhancing fire and pest prevention programs • Forestry: Adjust replanting behaviour, including planting species more tolerant to variable climates • Forestry: Pest and insect control • Forestry: Enhance forest fire prevention activities • Forestry: Install fire breaks around residential areas adjacent to forests • Tourism and Recreation: Reduce or halt participation in recreational activity • Tourism and Recreation: Substitute other activities for impacted activity • Tourism and Recreation: Use alternative recreational locations • Tourism and Recreation: Provide better access to ski areas at higher elevations • Tourism and Recreation: Increased use of snowmaking

System	Illustrative Climate Change Adaptation Strategies
	• Fishery: Plant riparian vegetation • Fishery: Fish for a diversity of species • Natural Threats: Increased use of swales • Natural Threats: Disconnect rooftop eaves trough drains to allow water to infiltrate soil • Natural Threats: Stormwater retention / detention ponds and constructed wetlands • Natural Threats: Land use planning / zoning to avoid locating structures / buildings in flood / landslide prone areas • Natural Threats: Use of permeable surfaces where possible • Natural Threats: Raise level of dykes • Natural Threats: Phase-out and relocate buildings in flood/landslide prone areas • Natural Threats: Assess and retrofit seaport and airport facilities to prevent or mitigate damage from flooding
Energy	• Potential increase in electricity costs or potential power outages in summer: establish secure backup electrical generation system, ensure diversity of energy sources are available, • Increased energy consumption: use energy demand side management techniques • Power outages from extreme events: vegetation maintenance along energy transmission corridors, have an emergency response plan and trained personnel in place
First Nations	• Forestry: Pest and insect control • Forestry: Enhance forest fire prevention activities • Fishery: Conduct fish allocations to ensure minimum allocation to First Nations is always maintained • Fishery: Prevent overfishing of stocks • Settlement protection from flooding: increased use of swales, land use planning / zoning to avoid locating structures / buildings in flood / landslide prone areas, natural shoreline stabilization, increase height of dykes and develop physical protection structures
Health & Well-being	• Increased incidence of insect-borne diseases: early diction and warning system, public education on threats and prevention, aerial spraying to control infestations • Degraded air quality and heat related deaths and illnesses: public education on threats and prevention, delivering bottled water to those at high risk (e.g. homeless) • Extreme weather events: building emergency shelters, having more first responders in place, education about how to respond to extreme events, better coordination of services • Flooding of lands: increased use of swales, disconnect rooftop eavestrough drains to allow water to infiltrate into soil, use of permeable surfaces where possible, stormwater retention / detention ponds and constructed wetlands, land use planning / zoning to avoid

System	Illustrative Climate Change Adaptation Strategies
	locating structures / buildings in flood / landslide prone areas • Flooding of lands through sea level rise: natural shoreline stabilization measures, raise levels of dykes
Human Security	• Increased incidence of insect-borne diseases: early diction and warning system, public education on threats and prevention, aerial spraying to control infestations • Degraded air quality and heat related deaths and illnesses: public education on threats and prevention, delivering bottled water to those at high risk (e.g. homeless) • Potential increase in electricity costs or power outages in summer: establish secure backup electricity generation system, ensure diversity of energy sources are available • Flooding of lands: increased use of swales, disconnect rooftop eavestrough drains to allow water to infiltrate into soil, use of permeable surfaces where possible, stormwater retention / detention ponds and constructed wetlands, land use planning / zoning to avoid locating structures / buildings in flood / landslide prone areas, phase-out or relocate buildings located in flood / landslide prone areas • Flooding of lands through sea level rise: natural shoreline stabilization measures, raise levels of dykes
Land Use	• Flooding: increased use of swales, use of permeable surfaces where possible, disconnect rooftop eavestrough drains to allow water to infiltrate into soil, stormwater retention / detention ponds and constructed wetlands, land use planning / zoning to avoid locating structures / buildings in flood / landslide prone areas, reallocate land uses and rezone for areas experience regular or permanent flooding, phase-out and relocate buildings in flood / landslide prone areas
Mobility	• Increased energy consumption for transportation: increased density, more mixed land uses and zoning, travel demand management • Degraded air quality: travel demand management • Flooding and extreme weather events: raise dykes, increased use of swales, use of permeable surfaces, disconnect rooftop eavestrough drains to allow water to infiltrate into soil, stormwater retention / detention ponds and constructed wetlands, land use planning/zoning to avoid locating structures / buildings in flood / landslide prone areas, ensure alternative transportation routes are available in case of disruption
Natural Habitat	• Salmon mortality, diversity and abundance: Plant riparian vegetation, fish for a diversity of species, revise fish allocations accordingly, green roofs, vegetation planting, increased use of swales, use of stormwater detention ponds, use of naturalized stream corridors • Increased risk of ecosystem breakdown: Develop connected greenways strategy to assist in natural adaptation, ecosystem monitoring • Loss of fish habitat: increase levels of dykes, create artificial wetlands • Loss of water fowl habitat for Pacific Flyway: creation of replacement water fowl habitat

System	Illustrative Climate Change Adaptation Strategies
Social Equity	• Degraded air quality and heat related deaths and illnesses: public education on threats and prevention, delivering bottled water to those at high risk (e.g. homeless) • Increased incidence of disease: pest and insect control and monitoring, aerial spraying to control infestations • Increase risk of forest fires: enhance forest fire prevention activities • Salmon mortality: plant riparian vegetation • Flooding: raise dykes, increased use of swales, use of permeable surfaces where possible, disconnect rooftop eavestrough drains to allow water to infiltrate into soil, stormwater retention / detention ponds and constructed wetlands, land use planning / zoning to avoid locating structures / buildings in flood / landslide prone areas, phase-out or relocate buildings located in flood / landslide prone areas
Water	• Increased water consumption: develop additional reservoir capacity, water demand management, xeriscaping / use drought resistant plants, water metering and increased water prices, water restrictions in periods of drought • Combined sewer overflows, flooding: increase height of dykes, natural shoreline stabilization measures, green roofs to increase on-site retention of stormwater, use of water cisterns for water storage, stormwater retention / detention ponds and constructed wetlands, incorporation of extreme precipitation events into storm sewer design, land use planning and zoning to avoid locating structures and buildings in flood / landslide prone areas • Habitat loss: artificial habitat creation