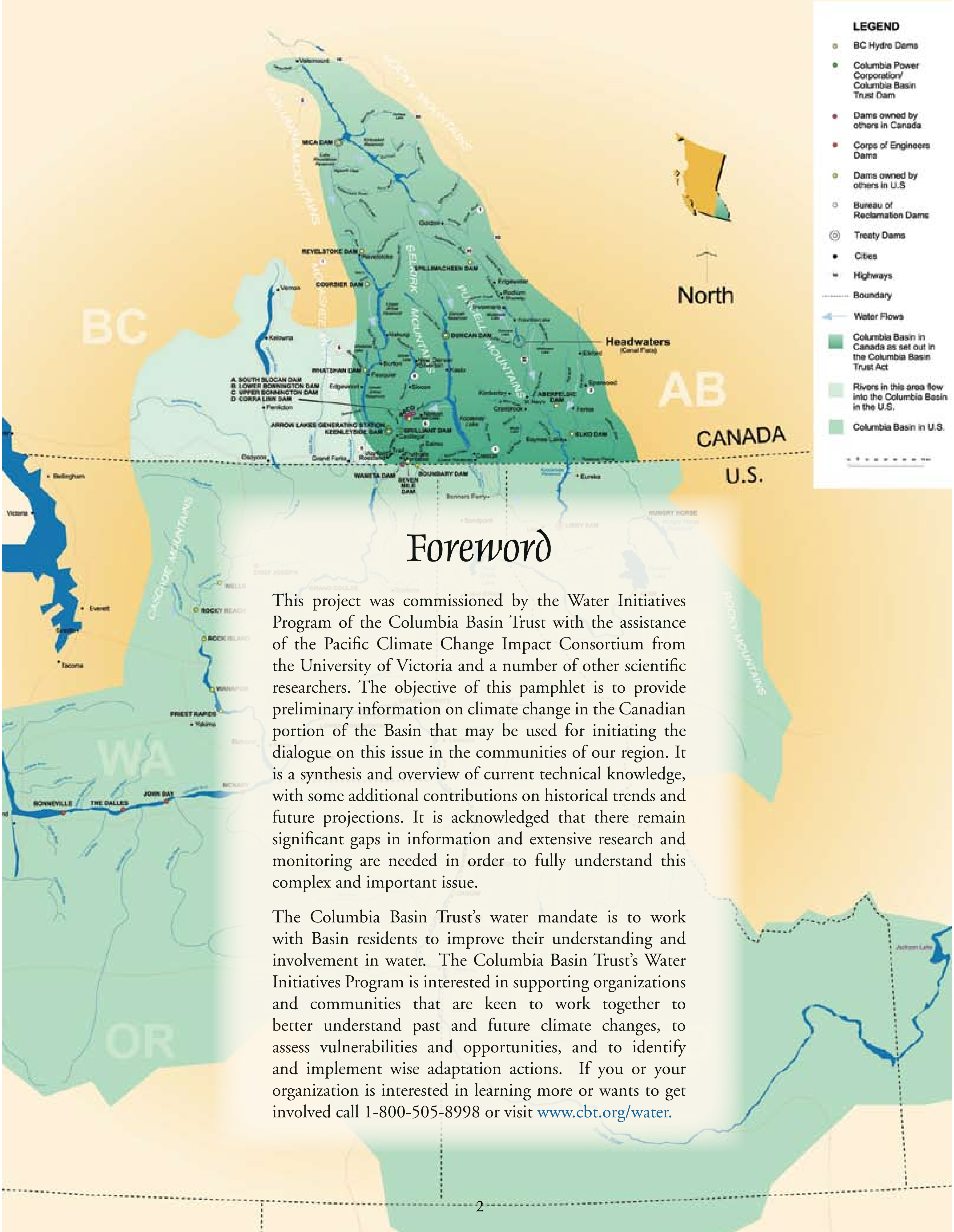
Climate Change
in the
Canadian Columbia Basin

Starting the Dialogue

COLUMBIA BASIN TRUST
a legacy for the people



Foreword

This project was commissioned by the Water Initiatives Program of the Columbia Basin Trust with the assistance of the Pacific Climate Change Impact Consortium from the University of Victoria and a number of other scientific researchers. The objective of this pamphlet is to provide preliminary information on climate change in the Canadian portion of the Basin that may be used for initiating the dialogue on this issue in the communities of our region. It is a synthesis and overview of current technical knowledge, with some additional contributions on historical trends and future projections. It is acknowledged that there remain significant gaps in information and extensive research and monitoring are needed in order to fully understand this complex and important issue.

The Columbia Basin Trust's water mandate is to work with Basin residents to improve their understanding and involvement in water. The Columbia Basin Trust's Water Initiatives Program is interested in supporting organizations and communities that are keen to work together to better understand past and future climate changes, to assess vulnerabilities and opportunities, and to identify and implement wise adaptation actions. If you or your organization is interested in learning more or wants to get involved call 1-800-505-8998 or visit www.cbt.org/water.

The Climate is Changing in the Columbia Basin

Higher summer and winter temperatures, declining mountain snowpack, reduced snowfall, long, dry summers, sudden heavy rains – the residents of the Columbia River Basin in Canada are experiencing different weather conditions than in the past. They are also seeing changes in natural systems including melting glaciers, lower summer streamflows, more frequent wildfires, and outbreaks of forest pests such as the mountain pine beetle. Many are asking if these differences are a product of climate change, or if they are just extremes in natural variation in our climate. There is also widespread concern about what actions people in the Basin should be taking to reduce human risks while adapting to new climate circumstances.

In response to these questions and concerns, the Water Initiatives Program of the Columbia Basin Trust contracted the Pacific Climate Impacts Consortium at the University of Victoria in 2006 to work with a number of climate scientists to analyze climate change impacts in the geographic area encompassed by the Columbia Basin Trust Act. This area, defined as that part of the drainage of the Columbia River in Canada affected by the Columbia River Treaty of 1964, is bounded by the Monashee Mountains on the west and the Rockies on the east, hereafter referred to as the Basin. The study, *A Preliminary Assessment of Climate Trends, Variability and Change in the Canadian Portion of the Columbia Basin – Focusing on Water Resources,* concluded that the climate of this part of the Columbia Basin has been and will continue to change in ways that will alter the way people derive their livelihood in the Basin. The study underscores the need for residents of the Basin to take these changes carefully into account in the planning of their social, economic and environmental futures.

This pamphlet provides preliminary information about:

- The climate-related changes in our environment that we have been experiencing in the recent past.
- Possible future changes in climate and our environment.
- The impacts these changes might have on the Basin's water resources.
- What we might do in response to these impacts
- How productive dialogue can begin in the Basin about climate and climate related issues.

Citizens are encouraged to think about these findings, and talk with their families and with others in their communities and in their places of work about what can be done individually and together to live safely, reduce vulnerabilities and risks, and take advantage of opportunities created by new climate conditions.

The current climate of the Basin, and indeed of the entire Earth, is maintained through a delicate balance ...

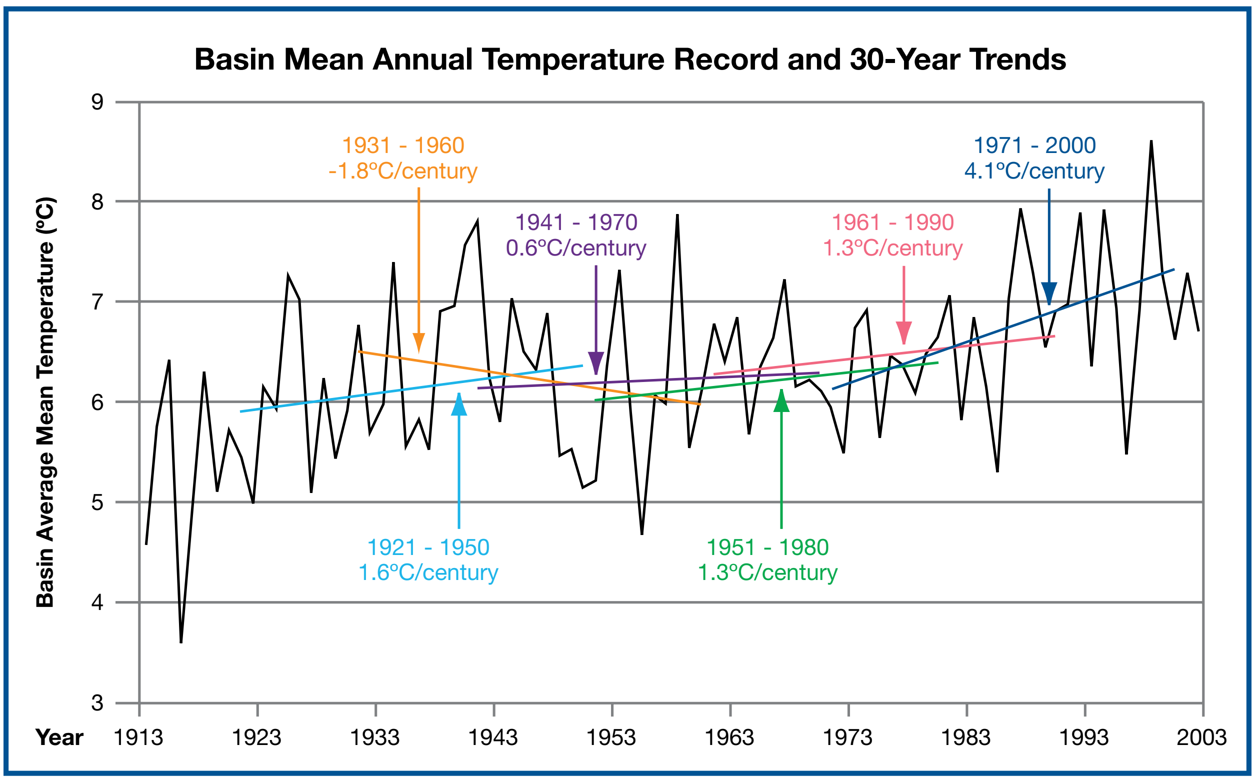
What is Happening to the Climate in the Columbia Basin?

The current climate of the Basin, and indeed of the entire Earth, is maintained through a delicate balance of influences that include heating of the planet's atmosphere by the sun, the moderating influence of clouds and trace gases in the atmosphere, and the action of a greenhouse effect in the atmosphere itself. In addition the sporadic effects of volcanoes, variations in solar output, orientation of the Earth's axis and irregularities in the shape of the Earth's orbit create variations in climate over hundreds to hundreds of thousands of years. Human activities also influence climate.

As a result of exhaustive study of the past climate of the Earth, analysis of historical weather and climate records, measurement of changes in global temperature and precipitation patterns and analysis of historic climate trends, there is now scientific consensus that the mean temperature of the Earth's land surface, oceans and ice has increased. Changes occurring throughout the Columbia River Basin over the last century are consistent with this global increase in temperature.

WARMER WINTER, NIGHTTIME AND SUMMER TEMPERATURES

While the regional average temperature for the Basin is highly variable, we do know that, even including one brief period of decline, the average temperature in the Basin has increased by 1.5°C over the past century. Temperature increases in the Canadian part of the Columbia Basin were higher than the temperature increases in the Pacific Northwest as a whole (which increased 0.8°C over the past century). They were also more than double the average global temperature increase of about 0.6°C over the 20th century. Globally the 1990s were the warmest



The biggest relative temperature increases are occurring at night and in winter.

decade in the last 1000 years. The warming that has occurred in the Basin over the last century has mainly occurred in the last 30-50 years.

The greatest increase in temperatures, however, is at the low end of the temperature scale. Winter minimums increased the most. This overall pattern suggests that the Basin is warming more because night time low temperatures are increasing rather than because daytime highs are increasing. Summers are becoming a little warmer, but winters are becoming a lot warmer. In this sense, it could be said that the Basin has become "less cold" rather than "warmer."

While the recorded temperature changes may seem slight, their impact can be huge. What might appear to us to be small changes in average temperature have the potential to stimulate sometimes unexpected, large-scale environmental changes that impact the nature and physical character of the Basin itself as well as the social and economic fabric of the Basin. This warming process is expected to continue to accelerate, not only because of the accumulation of carbon dioxide in the atmosphere, but also because of positive feedback from changes that have already occurred. Such changes are already beginning to happen in the Columbia River Basin.

INCREASING GLACIAL MELT

Glaciers in the Canadian Columbia River Basin have diminished in size during the 15 year period ending in 2000. On average, there was a 16% loss of glacial area in the Basin during this time, with two watersheds, the Slocan and the Bull respectively losing 47% and 60% of their total ice area. Rates of recession of this magnitude are consistent with what is being observed worldwide.

It is now known that glacier melt can lag behind temperature increases, sometimes by decades. Studies suggest that the larger glaciers in the Basin may be responding to temperature increases that occurred decades ago. The reduction in glacier size between 1986 and 2000 in the Canadian part of the Columbia Basin alone has been calculated to represent a loss of approximately 67 cubic kilometres of permanent ice. Converting the loss of ice into runoff and distributing flows to the months when glacier runoff occurs would indicate that glacier retreat increased the streamflow of Columbia Basin streams and rivers by an average of 700 to 800 cubic metres per second between 1986 and 2000.

There was a 16% reduction in the area of glaciers in the Canadian portion of the Columbia Basin between 1986 and 2000.

The loss of the Basin's glaciers will have a substantial impact on both aquatic and terrestrial ecosystems. Glaciers act as frozen freshwater reservoirs and are valuable cold water sources during the period when aquatic ecosystems are most vulnerable to low flows and high water temperatures. The importance of this cold runoff is hard to understate especially in a Basin where 10% to 20% of annual flows and up to 50% of late summer flows in some years result from glacial melt.

The recession of the Illecillewaet Glacier at Rogers Pass between 1902 and 2002.

Photographs courtesy of the Whyte Museum of the Canadian Rockies and Dr. Henry Vaux.

LESS WINTER SNOWPACK AT LOW ELEVATIONS

Ski-hill operators, skiers and governments responsible for snow removal have noticed changes in snow conditions in the Basin. They are not alone in observing these changes. Climate scientists at the University of Washington found that between 1950 and 1997, April 1st snowpack declined by 20-40% at a number of locations within the entire Columbia River Basin. The greatest reductions were at lower elevations where temperatures are near 0°C and small temperature increases can change precipitation from snowfall to rainfall. In the US portion of the Columbia River system snowpack has declined at an even faster rate.

CHANGING STREAMFLOW PATTERNS – EARLIER SPRING PEAK FLOWS, LOWER SUMMER FLOWS

Across Western North America, analysis of changes in the timing of peak spring run-off in 279 snow-melt dominated streams found that the peak spring runoff had advanced 10 to 30 days between 1948 and 2000, with the greatest change taking place in the Pacific Northwest. In 2001, climate researchers released data representing the last 30 to 50 years that demonstrated that annual mean Canadian streamflows had decreased particularly

In some areas of the larger Columbia Basin there was a 20% - 40% decline in spring snowpack between 1950 and 1997.

in southern Canada, with March and April the only months with increased streamflow. A study of streams in south central BC, including the Columbia River Basin showed stream flows have changed over the past century. The spring runoff, or freshet, occurred 20 days earlier in the period from 1984 to 1995 than during the period 1970 to 1983. A warmer climate and lower summer precipitation caused longer periods of low flow and lower flows at the end of the summer. During late fall and early winter, warmer air temperatures resulted in more precipitation falling as rain than as snow, yielding increased streamflow in winter.

In the Kootenay portion of the Basin, a survey of streamflows at the end of the hot, dry summer in 2003 found the Moyie and Slocan rivers at their lowest flows in many decades. That year, the Kootenay River had the lowest July flows ever recorded. These conditions were assessed to be the result of low snow packs from the previous winter, hot and extremely dry conditions during summer and a delay in the onset of fall precipitation.

Evidence suggests that the amount of water flowing in the Basin's streams and rivers has been changing. Historical streamflow records in the Canadian watershed of the Columbia River Basin show a general trend towards earlier and larger spring freshet and smaller summer flows. Hydrological models of streamflow at Waneta and Mica dams also indicate a shift to earlier runoff and late summer reductions in streamflow.

WETTER CONDITIONS, WITH HIGH VARIABILITY

Precipitation is naturally more variable in space and time than temperature, and is influenced by local factors such as terrain and elevation. This is particularly the case with the variable geography of the Basin, and especially for snowfall. Although more in-depth studies are needed for precipitation, initial results from five stations in the Basin show increases in total precipitation of 10 to 44% and changes in rainfall of 0 to 45% between 1913 and 2002. Based on these stations, the average increase for total precipitation and rainfall was approximately 30% per century. Results at specific locations varied widely.

Peak stream flows occur 20 days earlier in the spring, low summer flows last for longer periods and there are higher winter flows.

These results are consistent with a general recovery from widespread drought in the early part of the record. These results are also consistent with rising temperatures, which have caused more precipitation to fall as rain, especially at low elevations where the sample stations are located.

More detailed studies over western North America as a whole suggest that modest changes in cool season precipitation amounts, and larger increases in warm season precipitation, are consistent with the findings for the Basin. The variability of cool season precipitation also seems to be changing since the mid-1970s, but we cannot yet be sure that these changes are related to warming.

Paleoclimate evidence in tree rings, glaciers and other sources tell us that prolonged droughts were more common in the 1700s and 1800s than in the last century, suggesting that we've recently lived through a period of relatively drought-free climate. Evidence from these sources also suggests that the extent of rapid change we are presently experiencing has happened in the past, sometimes without warning, and with substantial changes happening within as short a time period as a decade. In planning for the future it would be prudent to know what the impacts of continuing climate change might be on the Basin's ecosystems and human populations.

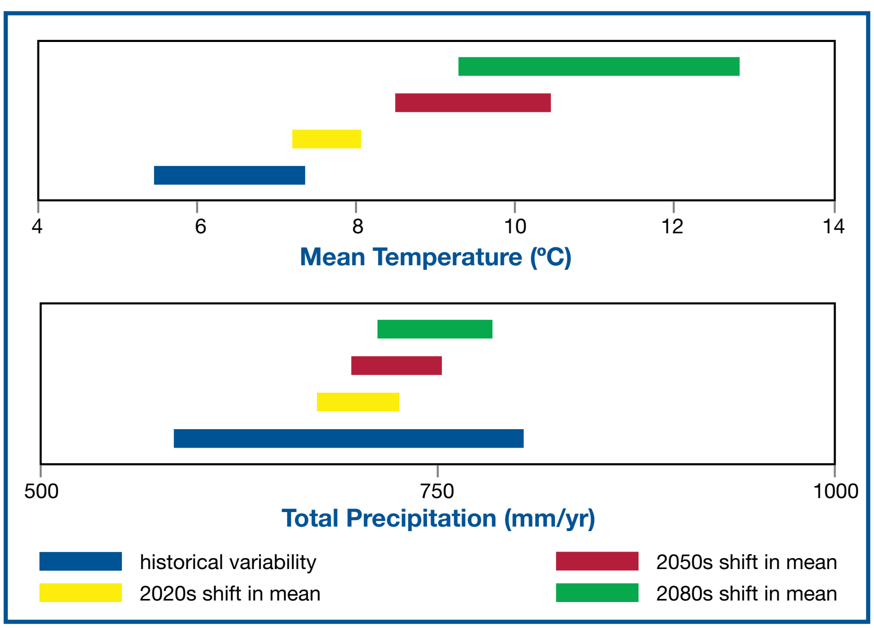
How Might Our Climate Change in the Future?

Given the climate of the Canadian part of the Columbia River Basin is changing, it is important to understand what the future might hold. As part of its work, the Pacific Climate Impacts Consortium used global climate models to prepare scenarios of what the future climate might be like in the Basin. These are computer simulations of the global climate system. Consortium scientists used projections from several models developed by leading research centres around the world representing global atmospheric systems and a range of future greenhouse gas emissions scenarios developed by the Intergovernmental Panel on Climate Change (IPCC). This United Nations agency developed these emission scenarios to reflect varying degrees of success in reducing global greenhouse gas emissions.

The scenario results indicate that in all cases, warming is predicted to continue through the 21st century, further affecting the climate in the Basin. Average annual temperature is expected to increase relative to current conditions by 1.1ºC to 1.3ºC by the 2020s. It is expected to rise by 2.4ºC to 3.0ºC by the 2050s and perhaps by as much as 3.3ºC to 5.0ºC by the 2080s. While these may seem small changes in relative terms, they could have substantial impacts on the nature of current ecosystems. With a 3ºC mean annual temperature increase, as projected by the 2050s, West Kootenay communities would have a mean annual temperature similar to what Osoyoos has today.

The figure below shows the magnitude of the projected changes in temperature and precipitation for the Columbia Basin relative to the historical variability. Note that this shift is in addition to continued variability. All total precipitation changes are expected to be relatively smaller. More rainfall (as opposed to snowfall) can be expected, with less snow due primarily to the warmer temperatures, especially at low elevations. It is also projected that precipitation events may become more intense, meaning there may be more storms of greater intensity and duration than in the past. Seasonal conditions are expected to differ from the present with warmer summers having higher maximum temperatures and warmer winters with projected increases in precipitation, particularly in the form of greater rainfall at lower elevations.

Variability in temperature and precipitation is expected to increase in the Basin. This graph projects the possibility of dramatically higher average temperatures at the end of the century.



Climate Impacts on Water Resources – the Lifeblood of the Basin

Everywhere in the world, mountain landscapes play a disproportionately important role relative to their area in the supply of water to surrounding lowlands. The Columbia River Basin is extraordinarily important as a high quality fresh water resource for agriculture, fisheries, power-generation, and aquatic ecosystems, as a source of drinking water for towns and cities and a foundation for recreational and tourism activities in the Pacific Northwest.

The flow of the river is of economic, social and environmental importance to both Canada and the United States. It is also critical to the vitality and cultural life of First Nations living in both countries. Canada contributes about 40% of the total runoff in the Columbia River, with only 15% of the area. This contribution is most significant in late summer – for example roughly 50% of the flow in the Columbia River at The Dalles, Oregon originates in Canada in late summer. If predicted stream flow changes are correct, the proportion of total flow which originates from Canada in the summer will increase. Even small impacts could have profound effects on our relationship to the Columbia River, and our relations as neighbours and partners in the Basin.

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Recent snowpack and streamflow changes are expected to continue. Increased winter flows due to more rainfall, early freshets and lower summer flows that extend over longer periods are expected to continue based on the projected temperature and precipitation changes. These impacts are likely to be more significant in the US portion of the system. It is also expected that average April 1st snowpacks in the Canadian portion of the Basin will be further reduced by approximately 4% by the 2020s and 12% by the 2040s, with the largest reductions at locations with mid-winter temperatures near freezing. Reduced snow cover will enhance warming by creating more exposed ground that will warm and absorb heat. Snow will melt earlier and further reduce the spatial extent of snow cover. This will happen to a greater extent in the American portion of the Columbia River system because of the larger number of locations with mid-winter temperatures near freezing.

Changes in glacier and snow melt are likely to result in reduced summer streamflows which, coupled with increased summer evaporation and transpiration, is expected to reduce soil moisture leading to increased drought impacts.

Mountain snowpack and glaciers in the Basin are critically important as they act as natural reservoirs for spring and summer stream flow. This is particularly significant in late summer when nearly half of the total flow comes from natural storage in the Basin, mostly from high mountain glaciers.

Climate change has the potential to disturb the current trade offs made in water management between hydropower, flood control, and industrial, agricultural, municipal, environmental and recreation use. Moreover, the water generated in this Basin is shared between Canada and the United States. If the current climate projections are realized, a larger portion of streamflow will likely originate in Canada, creating important implications for Canadian water resources management and for management of transboundary waters shared with the United States.

The reservoir system on the Columbia provides many benefits to the Pacific Northwest and British Columbia based on the current timing and volume of streamflow combined with reservoir management. However, because the man made storage does not have enough capacity to hold a seasonal cycle of water the Columbia River system relies on snowpack, and glaciers to act as natural reservoirs for water supply during the summer. The system is therefore vulnerable to changes in streamflow timing and reduced summer flow caused by diminished snowpack and glacial retreat.

Changes in the water storage capacity of the Columbia River Basin brought about by changes in the timing of runoff will have consequences for the competing water resource interests in the Basin. These issues are expected to become greater in the coming decades. This poses a serious challenge to water managers and users.

Starting a Dialogue on Climate Change in the Columbia River Basin in Canada

In the Columbia Basin the large population and economic growth that has occurred over the last century have been founded upon relatively stable climate conditions. The assumption has been that social and economic planning for the orderly development of the Basin can be predicated on the notion that climate will remain fixed and that we have experienced in recent history all the climatic conditions we should expect in the future. There is enough new information to believe this is no longer true. While we cannot predict the exact rate and timing of projected changes, we do know that if these changes occur, the past will no longer be a guide to the future. By viewing climate conditions as dynamic rather than static we will be able to make better decisions relating to water management and plan more effectively for a prosperous future in the Basin.

The rate of temperature increase in the Columbia Basin has escalated over the last 50 years.

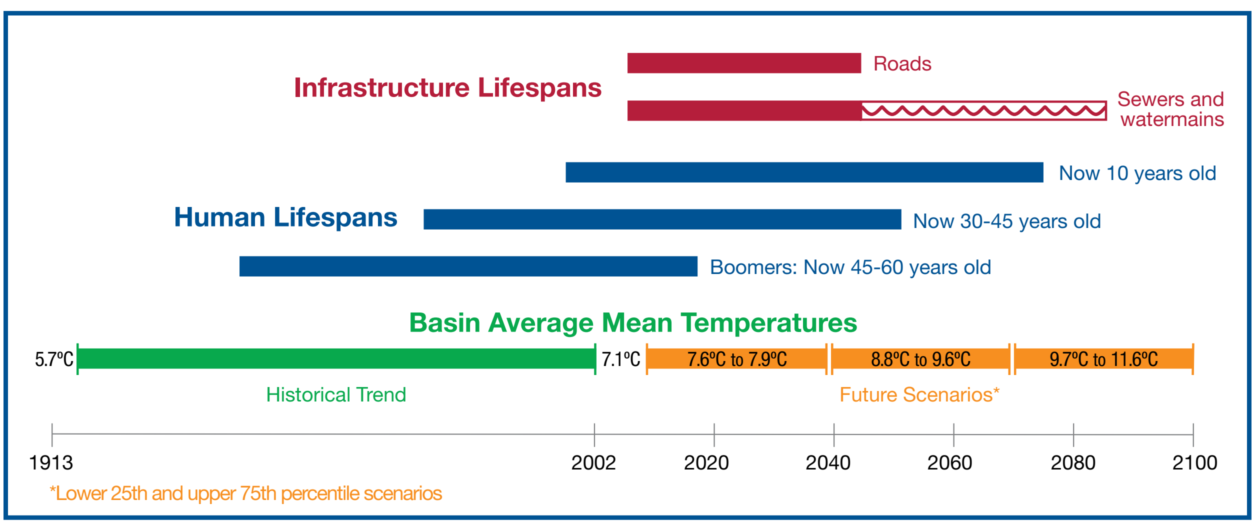
An effective Basin-wide community dialogue will be required to ensure that comprehensive understanding of the issues results in both appropriate mitigation of impacts and creative response to the adaptive opportunities that can only be achieved by working closely together. This dialogue should incorporate acceptance of a number of fundamental circumstances that will likely be imposed upon Basin residents by the scale and nature of the climate change challenge.

1. ***Accept that the present is, and the future will be, different from the past, and continue to learn about the changes*** – Temperatures have already substantially warmed, and the future will be even warmer. A return to cooler temperatures in the foreseeable future is unlikely, and the changes in temperature are a fundamental shift in the climate system.

2. ***Expect surprises, and be as prepared as possible*** – These new climate conditions could create the potential for unexpected environmental conditions such as extreme wildfire seasons, winter flooding and heavy stream bank scouring from extreme precipitation events, and water shortages. Making sure we are prepared personally, as families, communities and regionally, before an event happens, is much safer than having to react to a surprise event with no preparation. Flexible strategies may be more effective than changes that set communities on a single irreversible pathway. So-called "no regrets" strategies may help solve known current problems while preparing for expected future changes.

3. ***Factor in climate change for long-term decisions*** – Whether you are involved in building a house, a new water system, or constructing a new school or highway or considering a far-reaching change in land use, the possible implications of a different set of climate conditions in the future should be considered. Adaptations to changing circumstances will be wide-ranging. Water conservation programs may become necessary in communities where water restrictions are likely. Changes to heating and cooling systems might be necessary in a new school and other public buildings to adapt to a new climate.

Although the timeframes for the projected climate changes may seem far in the future, the figure below links these timeframes to human life-spans and infrastructure decision timelines. Infrastructure investments are long term commitments and, in many cases, are influenced by design standards and risk levels based on the past frequency or return cycles of extreme events. Integrating current information on climate change in infrastructure decisions is critical.



The duration of time it takes to alter infrastructure demands that we begin now to react to climate impacts so that we can define these impacts on our terms in the future rather than have them define us.

Improving our Understanding of Basin Climate and Water Resources

Water factors into almost every projected climate change impact. With regards to water resources, there are three recurring monitoring and research priorities:

1) further analysis of the historical and paleoclimate records to provide insights into past climate variability, particularly extreme conditions;
2) detailed analysis of historical records and higher resolution regional modeling to better understand the implications of elevation, geographic location, terrain, land use and warming on precipitation, with an emphasis on snowline elevation and winter activity impacts; and
3) hydrologic system modeling and analysis of past stream flow and future flows under different climate, glacier melt and snowpack regimes.

In addition to water related research, further assessment of the biophysical impacts of climate change in the Basin should be completed, including defining possible relationships between historical pest outbreaks and wildfire trends and climate conditions, and impacts of climate variability and change on growing degree days.

The specific projects that should be undertaken will depend in large part on the information Basin citizens and organizations need to incorporate the realization that climate is changing into their decisions.

Thinking Through Climate Change Impacts and Adaptation Options

Changes in temperature and precipitation have some direct influence on humans, but it is the indirect environmental implications such as changes in streamflows, landslides or longer growing seasons that can be the most significant. Individuals, families, communities, governments and organizations will need to carefully think through the chain of reactions initiated by the past and projected future changes in temperature and precipitation. In the Columbia Basin, some of these implications will be positive and some will be negative.

Once these implications are better understood, the sensitivity of quality of life factors and economic factors to the expected environmental changes should be examined. In addition the adaptive capacity of the individual, family, community, government or organization to this type of change needs to be assessed. Is this change within one's coping ability? If the answer is yes – no adaptation is needed, other than mindfully watching for further changes, and being ready to cope with surprises. If the answer is no, adaptation is needed.

The following sections briefly review possible impact and adaptation strategies for quality of life factors and economic sectors in the Canadian part of the Columbia Basin. These are very preliminary descriptions intended to prompt broader dialogue about the implications of climate change and variability in the Basin.

Our Quality of Life in a Changing Climate

WATER SUPPLY

In most of the Canadian portion of the Columbia Basin water supply is abundant and of good quality, provided by snowmelt and glacier runoff from mostly pristine high elevation catchments. Future climate change could alter not only the volume of water supply but impact water quality. Future conditions are likely to create additional pressures and require management changes at current storage facilities and domestic water systems.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Higher winter streamflows and extreme precipitation events may damage water infrastructure or cause flooding • Higher temperatures and possibly decreasing summer precipitation suggest more prolonged and intense droughts with lower water supply during periods of peak demand • Even in drought periods climate variability may cause flood-producing years amidst otherwise prolonged drier periods • Possible declines in recharge rates for groundwater sources • Higher temperatures encourage the growth of unfavorable algae and bacteria adversely impacting water quality	• Increase flood protection and/or redesign water infrastructure for higher peak flows • Strengthen water conservation education, practices (eg. low flow devices, grey water recycling) and regulation (eg. metering, fines, landscaping bylaws) • Increased emphasis on storage of winter and spring runoff to make up for summer low flow • Develop tools to better understand water use and responses to drought • Improved groundwater information including recharge rates and locations • Shift to groundwater use in areas prone to inadequate summer flows • Technological and operational approaches to combat water quality concerns (eg. reduce nutrient enrichment)

Development of equitable sharing agreements for limited streamflow and groundwater becomes critically important in this context. Such arrangements are not in place at present.

GROUND TRANSPORTATION

Communities within the Columbia Basin are linked internally and externally by national and provincial highways and railways that follow the valley bottoms, often near rivers. Several highways cross high mountain passes with severe winter climate conditions. Two national transportation links, the Trans-Canada Highway and the Canadian Pacific Railway run through the north end of the Basin. Municipalities are responsible for the secondary road networks within their borders.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Higher winter streamflows and extreme precipitation events may increase the risks of more severe or more frequent floods and landslides which may damage infrastructure • Mid-winter thaw events may damage roads and cause ice jams and flooding with damage to infrastructure such as bridges • Increased storm events and precipitation may increase accident and injury rates • Extreme heat and cold events and changes in the frequency of freeze/thaw cycles may impact pavement and rail-lines • Warmer temperatures may mean longer construction seasons but extreme heat or extreme precipitation events may impact schedules • Warmer winters may mean fewer road closures and lower costs for snow and ice removal; more frequent extreme events may cause more closures and higher costs; likely lower long-term average costs but greater inter-annual variability and possibly higher peaks • Increased temperatures could result in changes to snowpack stability and alter prediction and occurrence of avalanche	• Identify critical routes with landslide or flooding risks and implement protective measures • Improved understanding of vulnerability of roads and rail lines to freeze/thaw cycles, extreme heat and extreme precipitation events. • Designing roads for more frequent storm cycles and higher volumes of runoff • Reassigning transportation infrastructure construction and maintenance expenditures to account for reduced snow removal in lower elevations and possible increases in extreme weather events

COMMUNITY INFRASTRUCTURE AND SAFETY

Water supply and transportation infrastructure, both vital to the quality of life in the Basin, are discussed in the sections above. Infrastructure associated with energy distribution (Hydro-lines and pipelines), communications, waste disposal, storm water removal, food distribution, banking and community buildings are also of critical importance.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Higher winter streamflows and extreme precipitation events may increase the risk of floods and landslides which may disrupt critical infrastructure • Increased storm events and precipitation intensity may overpower storm water removal systems • Longer fire seasons may result in more interface fires that threaten communities and infrastructure • Extreme heat and cold events, freeze/thaw cycles and warmer temperatures may impact sewage treatment processes	• Strengthen community emergency preparedness, as well as contingency and evacuation planning for families, communities and the region • Identify landslide hazards and implement protective measures in critical areas • Identify critical infrastructure (eg. emergency service providers) at risk to flooding and implement protective measures • Verify floodplain maps are up-to-date; minimize development in high risk areas; require flood-proofing of new developments • Calculate storm water peaks using climate change information • Implement the "Firesmart" program by all communities and homeowners • Technological and operational approaches for sewage treatment processes

PUBLIC HEALTH

Basin residents enjoy a relatively high quality of life with supportive health care services and an extensive safety network. However, some citizens are vulnerable to changes in climate. These include children, the elderly, those with compromised immune systems and isolated individuals and families. As well some families and communities are vulnerable to climate change impacts due to their location, access routes and preparedness.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Increased occurrence of extreme warm temperatures in summer may make it difficult for heat sensitive individuals to cope • Higher temperatures combined with smoke from wildfires and air pollution emissions during periods of limited dispersion may reduce air quality creating stressful conditions for vulnerable individuals • Higher winter streamflows and extreme precipitation events may increase the risk of floods, especially in low lying areas • Warmer temperatures may trigger changes in vector, water or food-borne diseases	• Increased health services to support heat sensitive individuals and those susceptible to poor air quality • Improved air quality, extreme weather and disease warning systems • Include heat wave effects in airshed management planning • Incorporate reduced heating infrastructure and costs in decisions

Thinking about Our Economy

HYDRO-ELECTRIC POWER

The 1964 Columbia River Treaty between Canada and the United States prompted the construction of three treaty dams in BC, the Hugh Keenleyside, Duncan, and Mica dams, which created Arrow Lakes, Duncan, and Kinbasket reservoirs. A total of 18 major dams now exist on the Columbia River System within Canada. This system generates 50% (approximately 6,000 megawatts) of the province's hydropower as well as helps control flooding and fuels hydropower generation for an extensive hydroelectric system downstream in the US. Through the treaty, the people of the province receive revenues from the United States for these services. Several smaller run-of-the-river power plants also exist within the Basin. This system supplies residents and industries with reliable power at economical rates.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Changing stream flows with earlier spring freshets, possibly higher summer streamflows during the period of glacier retreat followed by longer summer low flow periods create the potential for reduced hydropower production, especially in the summer and fall when demand is likely to increase for air conditioning • Changing stream flows make it difficult to maintain reservoir and flow levels to meet non-power needs with increased conflict between hydro operations and instream flows • Increased climate variability and extreme weather events	• Improved projections of electricity supply and demand • Changes in reservoir operations to meet new demand times • Modify reservoir operations (e.g. flood rule curves) to capture water earlier in the season • Construct additional water storage facilities • Reduce electricity use • Adjust to shifting of peak hydropower demand from winter to increased summer demand

Summer electricity demand is expected to increase over time as customers in the Pacific Northwest install more air conditioning equipment and warming increases the number of days cooling is used. Winter demand is expected to decrease somewhat. Shifts in the seasonal timing of hydropower production may be required to meet these changing demands with more use of storage in summer.

In isolation, winter hydropower production in the Columbia River system is relatively resilient to streamflow timing shifts, but winter hydro production will be affected by the need to mitigate impacts to other system objectives such as flood control and instream flow augmentation. Adaptation decisions will need to respect the water needs of other users, and in-stream uses to protect recreational interests, private property, ecosystems and fisheries, especially with increased competition over increasingly limited summer water supply.

With the snowpack in Canada being much less sensitive to warming than in the U.S. portion of the Columbia River system, over the next 50 years summer snowmelt in Canada is likely contribute more to summer streamflows. These differing impacts have the potential to unbalance the current international agreements, and will likely present serious challenges to meeting instream flows in the United States, especially in the summer. Current Canada-U.S. agreements will need to adopt a more flexible approach to meet new and increasing demands for water as well as changing streamflow scenarios. This emphasizes the necessity of joint long-term planning and cooperation.

FORESTRY

Forests provide the backdrop for life in the Columbia Basin as the viewscapes for communities, places for recreation and the economic backbone of many Basin communities. The ecological condition of Basin forests influences wildlife populations, water systems and most other ecosystems.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Warmer temperatures and precipitation changes may shift the climatic suitability of forest species, including commercial trees, northward and up in elevation, resulting in new assemblages of species in space and time, changes in biodiversity and disturbance regimes, forest productivity and hydrology • Warmer temperatures may increase forest and range productivity, provided replanted species are adaptable to the new climate and water shortages don't limit growth • Warmer temperatures may change insect and disease distribution and the overall health of forests, with the potential for large scale outbreaks that may affect wildlife habitat, peak water flows and fire hazard • Warmer temperatures are expected to increase the frequency and severity of forest-damaging events such as fires, ice storms, floods and drought • Longer and warmer dry seasons may exacerbate forest fire risk with more larger fires of higher intensity which change soil conditions resulting in less rainfall infiltration and higher peak flows in streams with flooding risks, accelerated soil erosion and increased sediment loads in rivers, as well as changes in snow accumulation and melt rates • Warmer winters may reduce the length of the winter logging season, and forests could be closed in summer more often due to fire risk • Changes in precipitation, increased storm frequency and earlier snowmelt may damage roads, bridges and culverts	• Reforest with tree species that are suited to future climate conditions and create diverse forests • Change practices to improve monitoring and response to increasing disturbance agents including insects and disease • Incorporate climate change in long-term timber supply forecasts • Improve preparedness for fires, storms and floods. • New technology to extend winter logging seasons • Refine road construction and maintenance practices to accommodate changing hydrology

Deciding which species to regenerate after timber harvesting and forest fires is crucial as most tree species live for many decades in the Basin. From an economic perspective current research indicates a possible 9% loss in forest productivity is projected if the choice of tree species to regenerate does not consider future climate impacts, with a 21% gain if it does.

Water resources in the Columbia Basin are strongly linked to the distribution of forests through interactions such as forest canopies intercepting precipitation, thus affecting the amount of precipitation that reaches the forest floor and the amount of snowfall that accumulates in snowpack. Shading from forests also slows the rate of snowmelt and evaporation which influences soil moisture. Reduction in forest cover through land uses, pest outbreaks or wildfires is likely to have substantial implications for watershed processes.

Reduction in forest cover through land uses, pest outbreaks or wildfires is likely to have substantial implications for watershed processes.

TOURISM AND RECREATION

Tourism is an important and growing economic sector in the Basin and outdoor recreation is a key element of the quality of life for Columbia Basin citizens. Both recreation and tourism are strongly influenced by climate. Climate impacts the physical resources that are a foundation for many recreational activities and defines the length and quality of the tourism and recreation seasons.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Warmer winter temperatures may cause less snowfall, lower snowpacks and earlier snowmelt with reduced ski seasons and reduced reliability of snowfall at lower elevations. • Warmer winters may create shallow ice cover on some lakes with dangerous conditions for ice fishing • Warmer spring and fall temperatures may lengthen the season for warm season activities • Warmer lake temperatures may increase water-based recreational activities and lakeside development • Warmer summer temperatures, longer resident time for water in reservoirs and long periods of low flows may create inhospitable conditions for cold water sensitive sports fishing species (e.g. bull trout, salmonids) with the potential for warm water species to thrive (e.g. bass, bullheads) • High flows and flooding may damage habitats for sport fish • Extensive wildfires and pest outbreaks may change the composition of Basin forests, reducing their visual quality, changing wildlife habitats and shifting their suitability for tourism and recreation activities • Wildfires create smoke; landslides and other extreme weather related events may close transportation routes or create risks that deter tourists	• Increased snowmaking to maintain skiing where possible and groom slopes to reduce snow cover needed for skiable conditions • Diversify activities • Increased riparian reserves to retain low water temperatures and quality fisheries habitats • Expand warm season activities • Reconsider current lake fisheries stocking program emphasis on cold water species • Educational programs based on glacial retreat and unusual wildfire and pest events

AGRICULTURE

A diversity of agricultural operations exist in the Basin, from horticulture, dairy and grain production in the Creston area and West Kootenays to the cattle operations in the East Kootenays. Many operations are dependent on streamflows or stored water from glacier and snow melt runoff delivered to crops via irrigation during summer when precipitation and streamflow is lowest.

Relevant Likely Environmental Changes and Possible Sector Impacts	Potential Adaptations
• Warmer temperatures and less summer precipitation may reduce soil moisture and increase evaporation, increasing irrigation needs at the same time of year that streamflows are expected to decline. • Warmer temperatures will increase the length of the growing season, potentially increasing crop moisture needs, and requirements for irrigation • Warmer temperatures may improve the potential for high value crops, but this will be realized only if sufficient water is available • Extreme events and more intense precipitation increases the potential for soil erosion and crop damage • Smoke from wildfires may damage crops • Warmer temperatures may favour weeds, insects and plant diseases.	• More efficient irrigation (e.g. drip, scheduling, leak repair) • Construct additional water storage facilities • Crop diversification • Grow higher value crops with low water needs • Update erosion control practices • Enhanced monitoring and refined practices to minimize damage from weeds, insects and diseases

Working Together to Adapt

Clearly the climate of the Basin is shifting and environmental conditions are changing in response. Understanding the magnitude of these changes is the first step in beginning to think about how citizens and organizations in the Columbia Basin might adapt to overcome any vulnerabilities and to realize opportunities from these changes.

Climate specialists, hydrologists, local water managers, local governments, residents, environmental interests, economic sectors such as forestry, agriculture, power producers and tourism, and social sector representatives from public safety, health and education must all be included in dialogue and decision making processes related to climate change. Dialogue needs to explore what options exist, what information is needed, whether institutional, political or practical barriers exist, and include consideration of stresses faced from sources other than climate change. The discussion needs to consider the positive and negative implications of each of the impacts and possible adaptation strategies. Ideally, this dialogue should be incorporated in ongoing planning and decision processes such as municipal water system planning and hydropower water use plans to avoid creating additional and potentially isolated discussions.

The Water Initiatives Program of the Columbia Basin Trust is interested in supporting organizations and communities who are keen to work together to better understand past and future climate change, to assess vulnerabilities and opportunities and to identify and implement wise adaptation actions. If you or your organization is interested in knowing more or wants to get involved contact:

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LOOKING FOR MORE INFORMATION?

For more information on climate change in the Basin go to:
- CBT Water Initiatives Program at www.cbt.org/water
- Pacific Climate Impacts Consortium at www.PacificClimate.org
- Climate Impacts Group, University of Washington (CIG) at www.cses.washington.edu/cig

For more information on climate change in BC go to:
- BC Ministry of Environment at http://www.env.gov.bc.ca/air/climate/index.html#6

For more information on climate change in Canada go to:
- Environment Canada at http://www.ec.gc.ca/climate/home-e.html
- Natural Resources Canada at http://www.adaptation.nrcan.gc.ca/index_e.php

For more information on global climate conditions go to:
- Intergovernmental Panel on Climate Change at www.ipcc.ch

For more information on general adaptation go to:
- Canadian Climate Impacts and Adaptation Network (C-CIARNS) at http://c-ciarnbc.ubc.ca/
- Adaptation at http://c-ciarnbc.ubc.ca/adaptation.php
- University of Washington CIG Planning Activities at http://www.cses.washington.edu/cig/fpt/caseplanning.shtm

PACIFIC CLIMATE IMPACTS CONSORTIUM

ACKNOWLEDGEMENTS

This project is a first step in supporting Basin citizens and organizations to access information about the changes in climate we have already experienced and possible future conditions to begin a dialogue about how we might adapt to these changes.

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This report has been prepared with the assistance of the following individuals as a collaborative effort:

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