COLUMBIA BASIN TRUST
a legacy for the people

CLIMATE CHANGE, IMPACTS AND ADAPTATION IN THE CANADIAN COLUMBIA BASIN

FROM DIALOGUE TO ACTION

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FOREWARD

In 2006, Columbia Basin Trust (CBT) commissioned the Pacific Climate Impacts Consortium (PCIC) at the University of Victoria to work with a number of scientific researchers to prepare *A Preliminary Assessment of Climate Trends, Variability and Change in the Canadian Portion of the Columbia Basin – Focusing on Water Resources*. The results of this 2006 study were summarized in *Climate Change in the Canadian Columbia Basin – Starting the Dialogue*[1], which was used to launch CBT's Communities Adapting to Climate Change Initiative.

Since 2008, the Communities Adapting to Climate Change Initiative has worked with eight communities (Kimberley, Elkford, Castlegar, Kaslo/RDCK Area D and Rossland, Revelstoke, Sparwood and the Regional District of East Kootenay) on climate change adaptation planning and implementation, established a climate change adaptation Learning Network for Basin communities and assisted additional Basin communities in the identification of initial adaptation actions. In addition, CBT—with the assistance of the BC Regional Adaptation Collaborative, Ministry of Environment and Ministry of Community, Sport and Cultural Development—commissioned three new studies by the Pacific Climate Impacts Consortium to update the scientific information about climate change, impacts and adaptation in the Basin.

From Dialogue to Action is an update to the publication *Starting the Dialogue*. It incorporates information from the new studies and the knowledge gained from the community planning processes, including adaptation options for communities. This report is a compilation of the best available scientific information on climate change relevant to the Basin at the time of publishing. It is intended to assist Basin residents in gaining a better understanding of how the climate has changed in the past and what potential changes may be in store in the future. *From Dialogue to Action* provides an overview of projected climate changes in the Basin, examines impacts on the natural environment and communities, and outlines potential adaptation strategies for Basin residents, businesses, communities and governments.

Climate change adaptation is complex. Significant gaps in information and understanding remain. It is important to continue building knowledge about climate change adaptation in the Basin and to support Basin communities in undertaking climate change adaptation. *From Dialogue to Action* is an example of that ongoing learning and support. CBT will continue to work with a range of partners to increase Basin residents' awareness of local climate change impacts, and to provide credible, science-based information and updates as the science of climate change evolves.

To learn more about the Communities Adapting to Climate Change Initiative, visit: www.cbt.org/climatechange.

FROM DIALOGUE TO ACTION

There is strong scientific consensus that the climate is changing on a global scale. Studies commissioned by CBT in 2006[2] and 2011[3] concluded that the climate of the Canadian part of the Columbia River Basin (the Basin) has changed in the last century and will likely continue to change over the next century. Projected changes include average temperature increases of 1.6 to 3.2 C, median decreases in summer precipitation by 6% and median increases in winter precipitation of 7% by the 2050s when compared to Basin climate conditions during 1961 to 1990. The number of extremely hot days, frequency of warm spells and intensity of rainfall events are also projected to increase.

These climate changes are expected to result in a wide range of changes to the natural environment, including retreating glaciers, changes in stream flows, more frequent wildfires and changes in biodiversity, which will in turn alter the way people live in the Basin. Basin residents, businesses, communities and governments will all benefit from taking these projected changes into account when planning their social, economic and environmental futures.

This document provides information about:

- climate changes in the past century;
- projected future climate changes;
- the impacts of these changes on the environment in the Basin; and
- what Basin residents, businesses, communities and governments can do to make better decisions, take advantage of opportunities and adapt and be resilient in a changing climate.

What Is Climate Change Adaptation?

Climate change adaptation and mitigation are closely related and often confused. Climate change adaptation focuses on reducing the impacts of climate change. It is about being ready for a future that is different from what the community has experienced in the past, due to changes in weather and climate. Climate change mitigation is the act of reducing greenhouse gas emissions that contribute to climate change.

How This Document Is Organized

- Section One outlines changes in Basin climate over the past century.
- Section Two provides an overview of how Basin climate might change in the future.
- Section Three links these changes in climate to changes in the environment.
- Section Four provides an overview of how to make decisions to adapt to a changing climate.
- Section Five outlines how the changes in climate and in the environment may affect Basin residents, businesses, communities and governments, and identifies key adaptation strategies.

1. WHAT IS HAPPENING TO THE CLIMATE IN THE COLUMBIA BASIN?

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

Climate Change

Climate change is defined as a detectable shift in the average (mean) and/or variability of a climate factor from one time period (typically decades or longer) to another.

The Climate is Changing in the Basin

As a result of extensive study of Earth's past climate, including measurement of changes in global temperatures and precipitation patterns, there is widespread scientific consensus that the average temperature of Earth's land surface and oceans has increased in the last century and will continue doing so.[4] Changes occurring throughout the Basin over the last century are consistent with this global increase in temperature.[5]

These changes in temperature have led to changes in other climate factors, such as the amount and type of precipitation and will further affect, additional climate factors, such as wind patterns and the types and frequency of severe weather events.

Climate Vs. Weather

Climate refers to the prevailing factors—such as temperature, precipitation, atmospheric pressure, wind velocity and humidity—in a given region, measured over several decades. *Weather* is the day-to-day condition of the atmosphere: e.g., whether it is raining, snowing, sunny, hot or cold.

Climate in the Basin is Highly Variable

Basin climate historically has been highly variable from year to year and season to season due to local, regional and continental conditions. In a highly variable climate, it is sometimes difficult to detect a change in the climate because a change may be masked by year-to-year variability. In the Basin, the historical variability complicates climate change analyses and can prompt questions about whether the climate has actually changed or if a series of particularly hot/dry or cool/wet years are happening.

At the local scale, compared to regions with flat, unbroken terrain, the large elevation differences and varied terrain of the Basin create climate conditions that differ substantially over small distances. Regionally, the Basin climate is heavily influenced by dominant weather patterns that move east and release precipitation as they pass over mountain ranges. Wetter climates occur on the west side of mountain ranges, with drier areas to the east.

Climate Variability

Year-to-year, season-to-season and day-to-day *variability*—how much the temperature, precipitation and other climate factors vary within a specified time frame compared to the average for that time frame—is a critical climate characteristic.

At the continental scale, two major climatic patterns influence year-to-year variability in the Basin: El Niño/La Niña and the Pacific Decadal Oscillation (PDO). El Niño/La Niña tend to alternate every few years in an irregular cycle called the El Niño/Southern Oscillation (ENSO). Periods when neither El Niño nor La Niña is present are called ENSO-neutral.

The PDO has warm and cool phases that alternate and persist over several decades. There have been two full PDO cycles in the past century: cool PDO phases from approximately 1890 to 1924 and 1947 to 1976, and warm PDO phases from approximately 1925 to 1946 and 1977 to 1998.[6] The combination of ENSO and PDO can result in weather conditions that are substantially different than the average climate. For example, the unusually wet and cold weather conditions in winter and spring 2010/11 were in large part due to the convergence of a La Niña and PDO cool phase.[7]

El Niño/La Niña and the Pacific Decadal Oscillation (PDO) Influences

Typical Influence on Basin Temperatures

- El Niño winter temperatures up to 1.8 C above average in the northern parts of the Basin, and 1.0 C warmer in the southwest portions.
- La Niña winter temperatures 0.4 to 1.5 C below average across the Basin.
- Warmer temperatures during the PDO warm phase and cooler temperatures during the PDO cool phase in winter and spring across most of the Basin.

Typical Influence on Basin Precipitation

- El Niño annual precipitation 10% to 20% below average across most of the Basin.
- La Niña winter season precipitation 5% to 15% above average across most of the Basin.
- Cool and warm PDO phases affect precipitation to a lesser degree than El Niño/La Niña.

Small Climate Changes Can Make a Big Difference

When climate scientists highlight differences of 1 C or 2 C between average annual or seasonal temperatures, it can be hard to understand why this is important. Since ecosystems and human systems in a specific geographic area are adapted to the historical climate variability of that area, climate conditions outside the range of historical variability may result in changes to ecosystems and human systems if the changes are significant enough.

The projected warming for the Columbia Basin is 1.6 C to 3.2 C by the 2050s, with a median warming of 2.3 C in average annual temperatures. While these numbers may seem small, these are actually quite considerable changes. This is illustrated by BC's historical temperature record, where the difference between the warmest of the warm years and the coldest of the cold years has rarely been more than 2 C.[8]

Since the effects of warm or cold spells get averaged out during the year, it takes a lot to affect the annual average temperature even by 1 C. To put this into context, imagine a hypothetical year with temperatures 10 C warmer than normal for 35 days and temperatures that are exactly average for the rest of the year: that year would still be less than 1 C warmer than normal.

The table below shows the climate conditions for a number of Basin locations and other communities. In some cases, the mean annual temperatures of various locations are not very different, yet each community has its own distinctive climate and local ecology. This concept is illustrated by Figure 1 on the next page. It is important to note that while the warmer locations in Figure 1 are all drier than the colder locations, climate projections indicate warming throughout the Basin as well as an overall increase in precipitation, particularly in the winter season.

Table 1: Mean Annual Temperature and Precipitation During 1961 to 1990 Baseline Period for 13 Communities

Community	Mean Annual Temperature (C)	Mean Annual Precipitation (mm)
Calgary International Airport	3.9	400
Golden	4.6	490
Fernie	4.9	1175
Cranbrook	5.6	385
Revelstoke	6.7	950
Nakusp	7.3	860
Kaslo	7.3	860
Vernon/Coldstream	7.5	445
Creston	8.0	595
Nelson	8.2	750
Castlegar	8.3	730
Kamloops Airport	8.6	270
Vancouver International Airport	9.9	1165
Osoyoos	10.0	340

Data Source: National Climate Data and Information Archive – Canadian Climate Normals: http://climate.weatheroffice.gc.ca/climate_normals/index_1961_1990_e.html

Changes in the Basin Climate

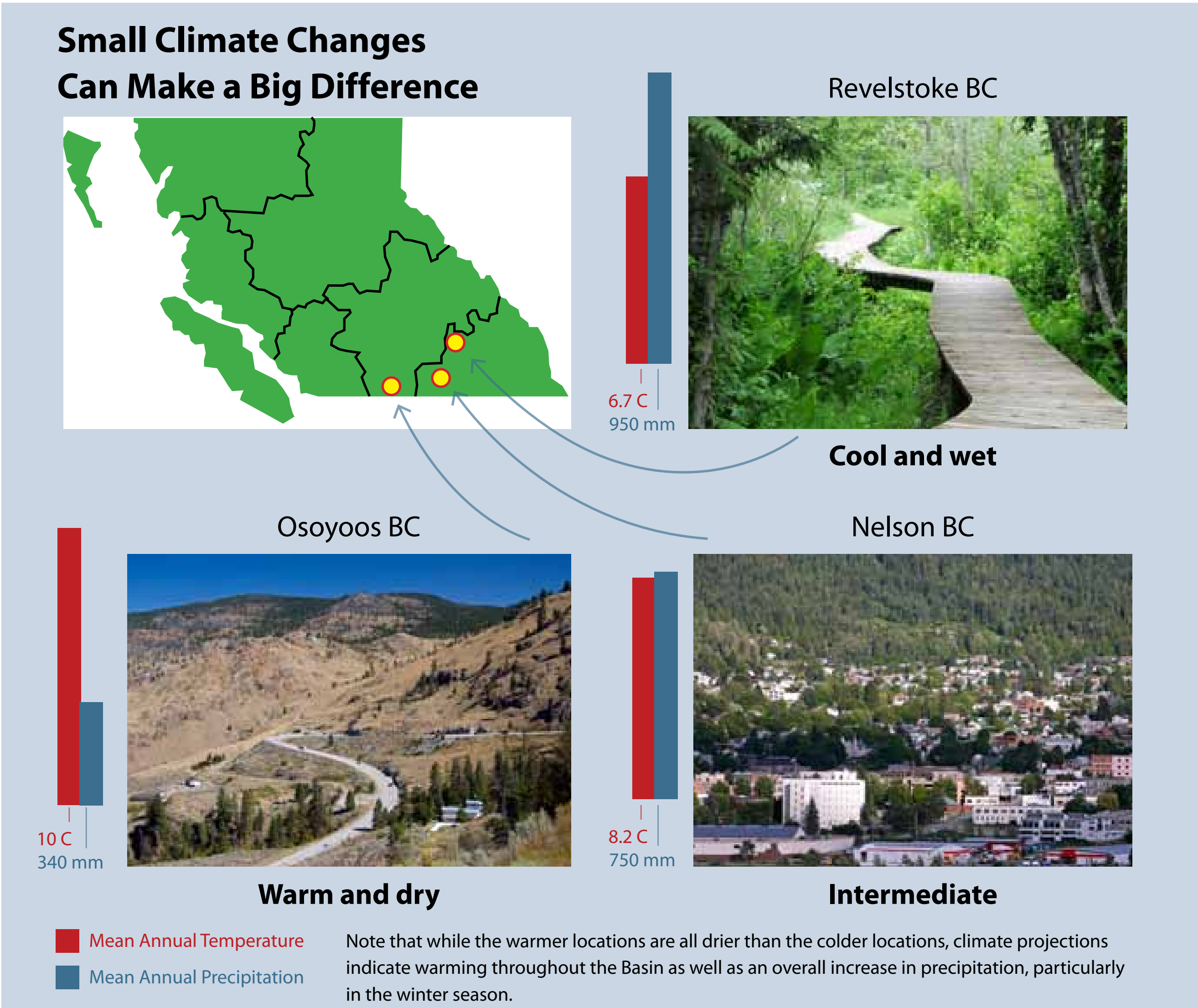
The Changing Basin Environment

How these changes have affected the Basin environment is described in Section Three: The Changing Basin Environment.

Observations confirm that the Basin climate has changed. The Pacific Climate Impacts Consortium's (PCIC's) most recent review of historical records from weather stations across the Basin—which have records that span most of the past century—found that the average recorded annual temperature has increased over the last century by 0.7 C to 1.7 C. Rates of warming have been higher at night and in winter.[9,*] This warming has resulted in a considerably longer frost-free period, on average.

[*] Unless otherwise noted, all data and projections are from PCIC's *Canadian Columbia Basin Climate Trends and Projections: 2007 – 2010 Update*.

Figure 1. Differences in Mean Annual Temperature and Precipitation throughout the Basin.



Recorded annual precipitation (rain and snow) also has increased over the past century by as much as 4% per decade. Increases occurred in all seasons, but in some seasons and locations the increase was not statistically significant. The greatest increase occurred in spring and ranged from 3% to 7% per decade. Summer precipitation increased 1% to 4% per decade over most of the Basin.

Community participants in Communities Adapting to Climate Change Initiative community-planning processes and workshops have consistently reported that the climate where they live seems to have become less consistent from year to year and season to season. They also have noted more extreme weather events, such as high winds, intense rain and droughts.

2. HOW MIGHT THE CLIMATE CHANGE IN THE FUTURE?

Given that the climate of the Basin is changing, it is important to understand what the future might hold. In PCIC's publications *Canadian Columbia Basin Climate Trends and Projections: 2007 – 2010 Update* and *Climate Extremes in the Canadian Columbia Basin: A Preliminary Assessment*, PCIC used the most recent global and regional climate models developed by leading global research centres to prepare projections of the future Basin climate. PCIC also used a range of future greenhouse gas emissions scenarios from the Intergovernmental Panel on Climate Change (IPCC).

Because a number of models and scenarios of future emissions were used in PCIC's studies, the resulting projections presented in this document describe a range of possible future conditions. Each of the emissions scenarios reflects a plausible future but it is not possible to say which one is more likely to occur.[10]

Recent studies report that global emissions are currently exceeding the highest emissions estimates in the IPCC's emissions scenarios.[11] If emissions continue along the same trajectory, they will exceed the highest estimates in the scenarios used to create the climate projections described below. In addition, most numbers presented in PCIC's studies are Basin averages. They are more refined for the Basin than the results presented in global climate models, but climate changes in specific locations could be greater than the Basin averages, particularly with respect to extreme events, such as hot days or intense precipitation. It takes decades for greenhouse gas emissions to dissipate. Even if mitigation strategies prove successful and emissions are dramatically reduced in the near future, some level of climate change is believed to be inevitable. Communities that prepare for climate change now are more likely to be the resilient, sustainable communities of the future.

Higher Average Annual Temperatures

Warming is projected to continue over the next century, with the average annual temperature in the Basin becoming 1.6 C to 3.2 C warmer by the 2050s compared to the average temperature for 1961 to 1990.[**] This warming is expected across all seasons and is projected to be more rapid than the warming that occurred over the past century. This scale of warming, even at the low end of the estimates, will result in annual average temperatures in the 2050s that are outside the range of the historic year-to-year variability in the Basin as highlighted in Figures 2, 3 and 4 on the next page.

** For more information on how this range was computed, please refer to Murdock, T.Q. and A.T. Werner. (2011). *Canadian Columbia Basin Climate Trends and Projections: 2007 – 2010 Update*. Pacific Climate Impacts Consortium report. http://pacificclimate.org/news/2011/new-publication-canadian-columbia-basin-climate-trends-andprojections-2007 – 2010-update

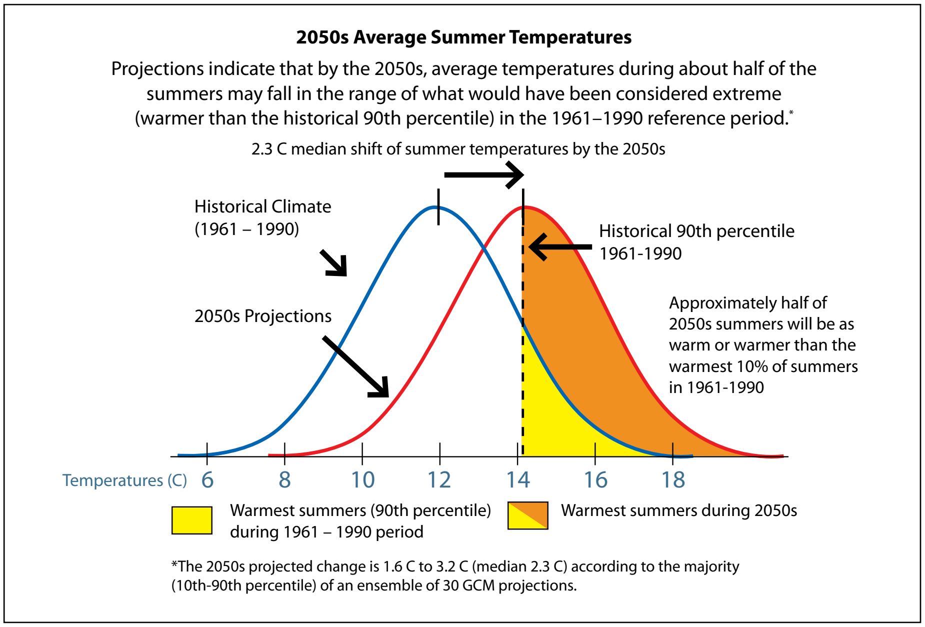


Figure 2. Average Summer Temperatures for the 2050s. Projected summer temperatures for the 2050s (red) relative to the 1960 to 1990 baseline period (blue).

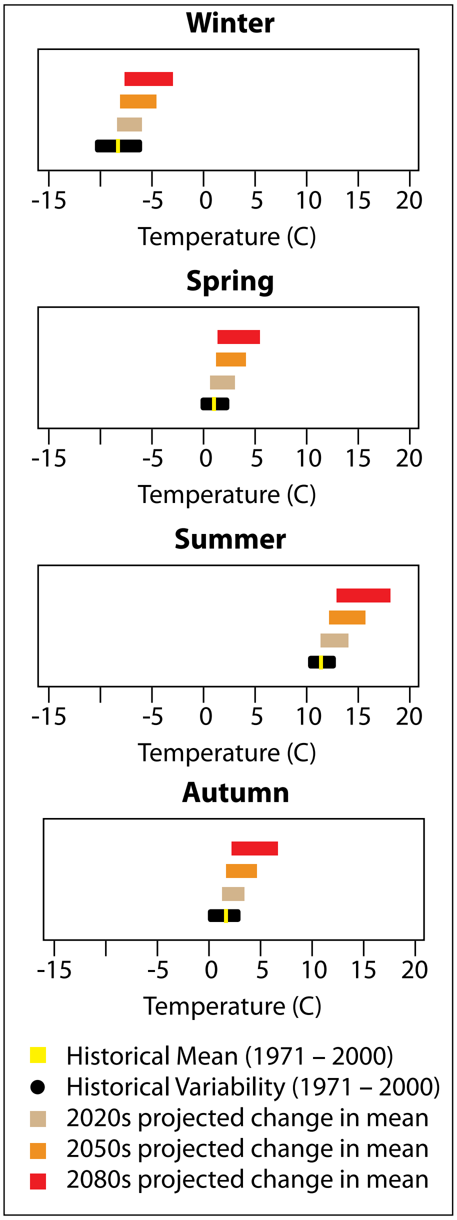


Figure 3. Projected Future Temperatures in Relation to Historical Variability. This figure illustrates the degree to which projected future temperature means are outside the historical variability. The historical variability is represented by +/- one standard deviation of interannual historical climate during 1961–1990.

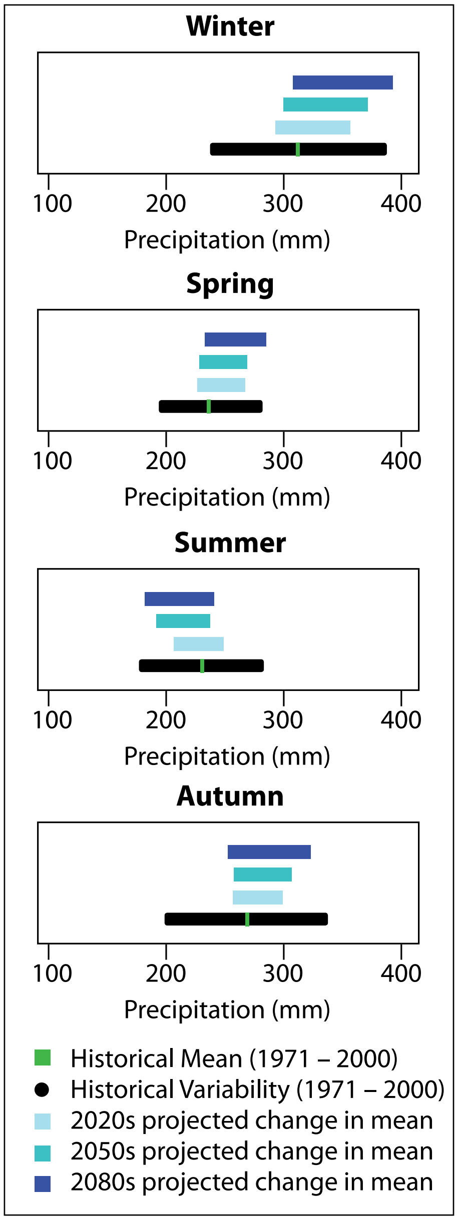


Figure 4. Projected Future Precipitation in Relation to Historical Variability. This figure compares projected future precipitation means with the historical variability. The historical variability is represented by +/- one standard deviation of interannual historical climate during 1961–1990.

More Very Hot Days and Longer Warm Spells

While average annual and seasonal temperatures are important, extreme temperatures can have the greatest impact on individuals, communities and ecosystems. The frequency and magnitude of warm summer days and nights, warm spells, and extremely hot days are projected to increase. PCIC's preliminary analysis of climate extremes in the Basin projected the following by the 2050s, compared to 1971 to 2000:

- Up to four times as many warm summer days and nights. Warm days and nights occur when temperatures are above the 90th percentile for that day of the year compared to 1971 to 2000;
- Increases in the temperature of the Basin-average hottest day of the month by a range of 0.4 C to 4.7 C;
- A two- to 11-fold increase in the occurrence of 25-year record extremely hot days, such that these extremely hot days would occur every three to 13 years; and
- Increases in the number of times warm spells lasting six days or longer occur annually, ranging from every second year to once a year during 1971 to 2000, to one to six times a year by the 2050s.

Increase in Growing-Degree Days and Longer Growing Season

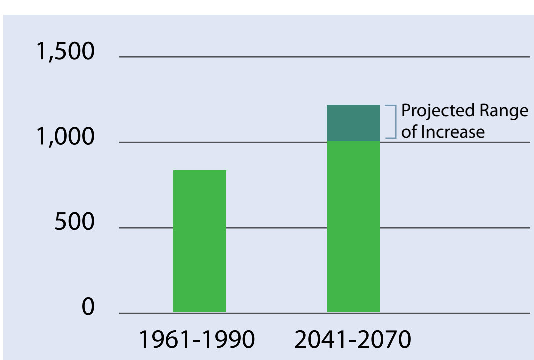
A longer growing season is projected in the Basin—by up to 18 to 35 days by the 2050s compared to 1971 to 2000 [12]—and with expanded growing-degree days (a measure of heat energy for plant growth) within the growing season. Growing-degree days help determine when crops reach maturity. The average number of growing-degree days in the Basin is projected to increase almost 50% from 840 in 1961 to 1990 to 1100 in 2041 to 2070.[13]

Growing- and Heating-degree Days

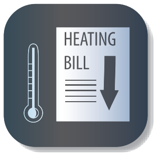
Growing-degree days are calculated by subtracting a base temperature (below which plant growth is zero) from the average temperature each day and cumulatively adding each day's growing-degree contribution as the season progresses.

Heating-degree days are calculated by multiplying the number of days with an average daily temperature below 18 C by the number of degrees below 18 C. If the average temperature on a certain day was 14 C (4 C below 18 C), that day would contribute four heating-degree days to the total annual number of heating-degree days.

Figure 5. Projected Increase in Growing Degree Days.

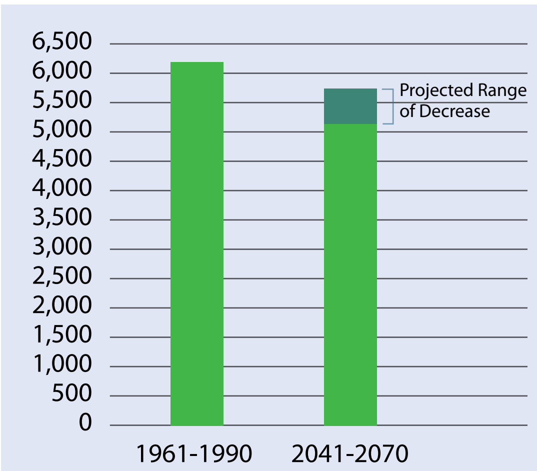


Decrease in Heating-Degree Days



Heating-degree days refer to the demand for energy to heat homes or businesses. They are determined based on the number of days the outside temperature is at or above the temperature at which a building requires no heating. The average annual number of heating-degree days in the Basin is expected to decrease from 6,100 heating-degree days in 1961 to 1990 to 5,500 heating-degree days in 2050.[14]

Figure 6. Projected Decrease in Heating-Degree Days.



Decrease in Summer Precipitation and Increase in Winter Precipitation

By the 2050s, projected changes in summer precipitation in the Basin range from a 14% decrease to a 1% increase, with a median decrease of 6% when compared to 1961 to 1990 levels. This projected decrease in summer precipitation differs from the Basin trend over the past century of increased precipitation in all seasons. By the 2050s, projected changes in winter precipitation in the Basin range from a 15% increase to a 2% decrease, with a median increase of 7% when compared to 1961 to 1990.

More Rain and Decreased Snow at Low Elevations in Winter

At lower elevations where temperatures are near 0 C, small temperature increases can change precipitation from snow to rain. As a result, warmer winter temperatures will likely cause more precipitation to fall as rain at these lower elevations than in the past. A study for the Castlegar community-planning process found that rain-on-frozen-ground and rain-on-snow events could triple in frequency by the 2050s.[15] At higher elevations where temperatures are consistently below 0 C in winter, increased winter precipitation is likely to fall as snow and may result in deeper snowpacks.

Increase in the Frequency of Extreme Precipitation Events

Projecting extreme precipitation events in the Basin is challenging due in part to the historic variability in precipitation patterns. PCIC's preliminary analysis of climate extremes found that more frequent and heavier precipitation events can be expected throughout the Basin. Extreme precipitation events with five-, 10- and 25-year return periods are projected to occur two to three times more frequently by the 2050s. A study completed for the Castlegar community-planning process that used more localized data projected up to a four-fold increase in extreme rainfall events that occurred historically only once every 30 years.[16] These results are consistent with the with findings from global climate projections.[17]

Increase in the Variability of Temperature and Precipitation

Global climate models suggest the possibility of increases in climate variability in the future, particularly with respect to precipitation.[18] However, more research is required to be certain of the specific types of changes that could occur in the Basin.

Table 2: Summary of Projected Climate Changes by the 2050s*

Averages (compared to 1961 – 1990)	**Extremes (compared to 1971 – 2000)**
Temperature	Temperature
▪ 1.6 C to 3.2 C average annual increase.	▪ Up to four times as many warm summer days and nights. ▪ Increases in Basin-average hottest day of the month by 0.4 C to 4.7 C. ▪ Two- to 11-fold increase in the occurrence of 25-year record extremely hot days.
Precipitation	Precipitation
▪ Summer: median decrease of 6%. ▪ Winter: median increase of 7%.	▪ Two- to threefold increase in frequency of extreme precipitation events with five-, 10- and 25-year return periods.

* There is a slight difference in the baseline periods used for Averages and Extremes. For details, see Murdock, T.Q., S.R. Sobie, 2012: *Climate Extremes in the Canadian Columbia Basin: A Preliminary Assessment*. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC.

3. THE CHANGING ENVIRONMENT

A changing climate will have impacts on the Basin environment, creating changes in watersheds and ecosystems. This section summarizes past and potential future impacts of climate change on these systems in the Basin. Section Four explores the impacts on human economic and social systems in our communities that may occur directly as a result of climate changes and as a result of climate-related changes to the natural environment.

Changes in Glacial Runoff

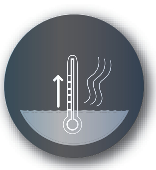
Between 1986 and 2000, there was a 16% loss of total glacial area in the Canadian Columbia River Basin.[19] The greatest thinning (reduction in volume) occurred in glaciers below 2,500 metres in elevation.[20]

Glacier melt can lag behind changes in climate. Studies suggest that the large glaciers in the Basin may be responding to temperature increases that occurred decades ago. With continued increases in temperature, glacier retreat is expected to continue. Most of BC's glaciers are losing mass, and many may disappear within the next 100 years.[21] Some projections indicate that climate conditions approximating those that support glaciers may disappear from the Basin as early as the 2050s.

The loss of the Basin's glaciers will have a substantial impact on aquatic and terrestrial ecosystems. Glaciers act as frozen freshwater reservoirs and are valuable cold water sources during summer and fall when aquatic ecosystems are most vulnerable to low flows and higher water temperatures. Glacial runoff in the Columbia River measured at The Dalles, Oregon in 1986 accounted for 10% to 20% of annual flows and up to 50% of late summer flows, with most of that runoff originating in the BC portion of the Basin.[22]

As glacier melt accelerates, summer stream flow in glacier-fed streams initially increases. At some point, however, as the volume of ice declines, glacial runoff also declines, leading to reductions in summer stream flows until the glacier disappears completely. One study found declines in August stream flows between 1976 and 1996 for most glacier-fed streams in BC, particularly in the south, indicating that these glaciers may have already passed the initial phase of warming-induced increased runoff, suggesting the likelihood of further declines in summer flows in these streams.[23]

Increases in Water Temperatures



Water temperature is one of the main regulating factors of aquatic ecosystems. Rising summer air temperatures are expected to increase water temperatures in streams and lakes in the Basin. The projected changes in glacial runoff described above may reduce cold water inputs to Basin watersheds and contribute to increased water temperatures.

Different species will respond differently to warming temperatures. For temperature-sensitive species, increases in water temperature could result in increased disease, an increased requirement for energy expenditure, altered growth, thermal barriers to migration and reduced reproductive success.[24] Some species, including salmonids like bull trout, will likely be negatively impacted and displaced in locations where they are currently close to their tolerated temperature ranges.[25] Conversely, in locations where water temperatures are currently below-optimal for fish, increased water temperatures may promote fish growth and survival.[26] Warmer water temperatures may also lead to changes in water quality.[27]

Earlier Spring Peak Flows, Decrease in Late Summer Flows and More Rapid Runoff

The seasonal flow patterns of Basin rivers and streams have changed. While most of the stream systems in the Basin have historically been snow-dominated, some streams in low-elevation watersheds are shifting toward being hybrid or rain-dominated as the climate changes.[28]

A study of the Columbia River Basin found that the spring peak flow occurred 20 days earlier between 1984 and 1995 than between 1970 and 1983.[29] Another study of flows in the Columbia River at the Canada-U.S. border from 1970 to 2000 found a decreasing trend in maximum annual flows, with an approximate 25% reduction over that period. It also found that maximum flows during this period occasionally occurred in winter rather than summer, potentially associated with major winter melting episodes.[30] However, due to the operation of dams in the Basin affecting the timing of storage and release of water these findings cannot directly be attributed to a changing climate.

Snow- Vs. Rain-dominated Watersheds

Watershed systems are generally either *snow-dominated*, with peak flows occurring in spring when peak snowmelt happens; *rain-dominated*, with peak flows in winter when rain falls on already saturated soils; or *hybrid*, displaying characteristics of both.

A study projecting future stream flows for the Canadian Columbia Basin indicated that the median total annual flow for the Columbia River will increase by 10% by the 2050s, with increases ranging between 3% and 19% depending on the location.[31] Projected seasonal changes include: an earlier onset of spring melt; substantially higher flows during spring and early summer, with peak flows shifting one month earlier (from July to June); lower late summer and early fall flows; and, an increase in monthly flows during late fall and winter. Another study found slightly different shifts, projecting earlier spring peak flows and reduced runoff volumes in the Columbia River from April to September by the 2040s.[32]

Changes in stream flow are expected to impact the timing and quantity of water available and the quality of that water. Higher peak flows may result in increased water turbidity and lower flows may result in higher water temperatures. This is expected to impact aquatic ecosystems, as well as individual aquatic species. The study that projected reduced runoff volumes in the Columbia River by 2045 from April to September suggested that the reductions will be large enough to cause negative impacts on fish.[33] As well, the expected increase in winter flows may affect fish species. For example, eggs of fall- and winter-spawning fish, like bull trout, may suffer higher levels of mortality during increased winter flows in rain-dominated and hybrid regimes.

Changes in Freeze/Thaw Cycles

Changes in the frequency of freeze/thaw cycles may vary from location to location. At locations where temperatures currently fluctuate near zero during the spring, winter and fall seasons, increased temperatures may result in fewer freeze/thaw events. Where temperatures often hover just below zero, more frequent freeze/thaw cycling may occur. Sites that are consistently well below zero may have a similar frequency of freeze/thaw events as they have had historically, although they may occur later in fall and earlier in spring.

Fall, winter and spring temperatures at lower elevations may fluctuate above and below freezing more frequently than in the past due to increases in average annual temperatures. Participants in several community-planning processes reported observing increases in freeze/thaw cycles.

Increase in Rain-on-snow and Rain-on-frozen-ground Events

The projected warming and increases in winter precipitation falling as rain could result in an increase in rain-on-snow and rain-on-frozen-ground events in the Basin. Rain-on-snow and rain-on-frozen-ground events cause more runoff than rain falling on soil because the soil is less permeable when it is frozen, plus rain can cause a partial melt of the snow or ice.[34] As a result, these types of events can result in landslides, mass-wasting of hill slopes, damage to riverbanks and downstream flooding.[35]

Shifts in Timing and Scale of Flooding

More frequent intense rainstorms, increased glacier melt, rain-on-frozen ground, rain-on-snow and higher winter peak flows may increase the risk of flooding, with more events occurring in late winter/early spring than in the past. Studies on specific expectations for flooding have not yet been undertaken in the Basin. However, projected increases in stream flow suggest a need for flood control and response requirements to be be reviewed and updated as needed.[36]

Flooding was identified as a major concern in the communities of Elkford, Kimberley and Castlegar through community-planning processes. Discussions in these communities highlighted concerns regarding the potential for flooding of buildings, lands and infrastructure (such as sewer lagoons), the potential for damage to bridge integrity and the capacity of culverts and stormwater systems to handle peak flows.

More Frequent and Intense Droughts

The combination of lower winter snowpacks at lower elevations, less summer rainfall and warmer summer temperatures with more hot days and longer warm spells may cause lower summer soil moisture levels, creating more frequent and intense drought conditions. Even if rainfall doesn't decline in summer, higher summer temperatures will cause more evaporation from land and water bodies, as well as transpiration through plants, which could lead to the occurrence of drought conditions more often, and potentially more severe droughts than in the past. In the Cranbrook area, one study projected that the climatic moisture deficit—the amount by which the monthly the monthly precipitation is less than the monthly evaporative demand—will become 30% to 60% larger by the 2080s.[37]

Changes in Diseases and Pathogens

Climate change is expected to result in an increase in diseases spread by water, animals, insects and air.[38] Increases in temperature and increases in precipitation in some seasons and locations, as well as a decrease in cold temperatures or the lengths of periods of colder temperatures, could contribute to the increase or prolonged transmission cycle of certain diseases, such as influenza, food-borne gastroenteritis and water-borne diseases.[39] These changes in climate could also result in an expansion in the ranges of disease-causing agents such as mosquitoes, ticks, rodents, and fungi like *Cryptococcus gatti*, with a resultant expansion in related diseases such as Lyme disease, hantavirus and West Nile virus.[40,41] Originally found in the tropics, *Cryptococcus gatt*i can now be found in Washington, Idaho and Vancouver Island.

Increase in the Frequency and Severity of Wildfires

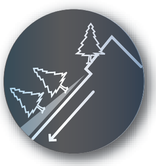
In BC, the amount of area burned by biogeoclimatic zone has declined over the past century,[42] as has the annual area burned in the West Kootenay.[43] However, the wildfire season in BC has been increasing in length by one to two days a year since at least 1980,[44] and the annual area burned in the West Kootenay increased slightly in the last decade of the twentieth century (but remained less than the annual area burned in the early part of the century).[45] Studies in the U.S. and Canada have also noted increases in area burned since the 1980s, and have suggested that this may be linked to climate change.[46,47]

Wildfire frequency and severity is expected to increase due to increases in summer temperature, very hot days, longer warm spells, reduced summer precipitation, fuel accumulation, extended droughts and pest outbreaks. There is considerable variability and uncertainty in models used to predict future wildfire activity. One projection for BC suggests an increase in the seasonal fire severity rating and an increase in fire season length of one to two weeks by 2045.[48] Fire starts in BC have been projected to increase by 21% to 190% by 2100, with regional variation.[49] Modelling for the West Kootenay projects a dramatic increase in average annual area burned by the 2050s: by at least four times in the south and five times in the north.[50]

Wildfires are part of the natural process of forest renewal in Basin forest ecosystems. However, they can be major disturbances and could permanently alter ecosystems depending on the frequency and severity of fire events. After a wildfire in a dry, low-elevation forest, conditions may become unsuitable for tree regeneration, creating opportunities for invasive species, grasses and shrubs to colonize or re-colonize a previously forested area. Over time, these conditions may result in an increase in grasslands and shrub-dominated ecosystems in the Basin. While wildfire is generally a desirable part of grassland regeneration, very intense and large fires that result in the total destruction of vegetation and significant soil damage could damage grassland ecosystems and result in extirpations of important grassland species. Conditions after these events could favour invasive species.

Wildfires also affect air quality and change water flows. After a very hot fire, soils often absorb and hold less water, resulting in increased runoff that can cause erosion, landslides, flooding and damage to aquatic ecosystems, especially in steeper areas.[51] One study in Keremeos showed that soils remained more than 50% strongly water repellent two years after a fire.[52]

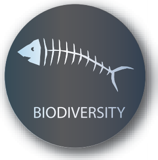
More Landslides and Changes in Avalanche Frequency



Many landslides in British Columbia are triggered by prolonged and intense rainfall, although several other factors can also contribute to landslide occurrence, including warming wind, temperature increases, rain-on-snow events, freeze/thaw cycles, forest fires, beetle infestations and human activities like clear-cutting.[53,54] Projected climate changes—including increases in winter precipitation, and increased frequency of extreme rainfall events,—could contribute to increased landslide frequency in the future. Although no Basin-specific studies have been completed, studies of projected landslide occurrence in the southern coastal mountains of BC[55] and in west-central BC[56] suggest that landslide risk will increase over the next 90 years as a result of climate change.

The effects of climate change on avalanche frequency are uncertain. Avalanches may decrease in frequency in areas where snowpack will decrease as a result of receiving more rain and less snow. In areas that still accumulate snowpack, warmer winter temperatures and increased rain-on-snow events may result in snow layering that could contribute to more frequent avalanches. In considering the impacts of climate change on avalanches in the northern hemisphere, one study suggested that avalanche frequency could increase in areas with historically lower avalanche activity and decrease in areas with historically higher avalanche activity due to changes in snow depth, the number of days with heavy snowfall and the duration of the avalanche period.[57]

Risks to Biodiversity and Increases in Pests



Basin ecosystems offer spectacular beauty, diversity and ecological richness, contribute to quality of life in multiple ways and serve as the foundation for forestry and tourism economies. The combinations of species in Basin ecosystems today are based largely on climatic conditions of the past. Ecosystems will respond to climate and environmental changes in a number of ways—some that can be anticipated and others that may be surprising or unexpected.

There is insufficient data to predict changes in biodiversity due to climate change in anything more than a general way. As the climate changes, some species will be resilient to the new conditions, while others may migrate north or upslope to stay within climate conditions similar to those they inhabit today.[58] Some species may not be able to migrate, and these species may decline. Species that are already under stress due to other factors may be under further pressure due to climate change. As species shift locations and/or disappear, new and unique combinations of species are likely to occur, leading to new dominant species, predator/prey relationships, pest/host relationships and changes to ecosystems.

Climate changes are expected to favour non-native and invasive plant species, insects and disease pests, which will cause them to further establish themselves in disrupted ecosystems,[59] as has already been seen with mountain pine beetle and spruce budworm in parts of the Basin. Extreme temperatures and increases in climate variability may have greater impacts on the abilities of species to adapt than increases in mean temperatures. Climate-change-related disturbances—such as wildfire, flooding and high-intensity rainfall—will also affect ecosystems.[60]

Some changes that could potentially occur in Basin ecosystems are described below.

Table 3: Potential Risks to Biodiversity

Basin Ecosystems	Potential Responses to a Changing Climate
Wetlands	• Initial inundation as glacial runoff increases.[61] • Contraction of wetland areas as the climate warms, summers become drier and stream flows change.[62] • Diminished aquatic habitats and wetland species, with the potential for invasive weeds to thrive.[63]
Grasslands	• Expanding grassland area in valley bottoms as warmer temperatures and drier summers reduce regeneration success of forest species.[64] • Expanding grassland area due to wildfires and pest outbreaks. • Decline in mammal and bird species and gains in reptile and amphibian communities.[65] • Expansion of some species, such as elk and sheep[66], as generalized grassland habitats increase, and extinction/extirpation of others as invasive species move in.[67]
Forests	• Changing distribution of existing forests as hotter and drier climatic regimes replace conditions suitable for forests in some valleys and on drier sites. • Loss of forest productivity in the south, with modest gains in the north.[68] • Shift of some forest species northward and upslope, with some expanding into alpine habitats where soil conditions permit.[69] • Decline or slower growth of tree species that require periods of cold temperatures to break dormancy.[70] • New combinations of species as some species expand ranges and others are stressed or killed by drought, windstorms, wildfires and/or pest outbreaks. • Increases in disturbances that will result in younger forests, changes in species composition and changes in wildlife habitat.[71] • Changes in ungulate populations as a result of changes in forests[72] and denser snowpack that make it difficult for ungulates to travel.[73] • Increases in invasive species.[74] • Increases in interior cedar-hemlock and Douglas fir biogeoclimatic zones.[75] • More favourable climatic conditions for deciduous trees.[76] • Doubling in sites suitable for Douglas fir by the 2050s, but reduction in sites suitable for spruce (Engelmann, white or hybrid).[77]
Alpine	• Loss of alpine tundra species as other species shift to higher altitudes and alpine species have no place to go due to their limited geographic range.[78] • Loss of habitat suitable for alpine ecosystems of 60% by 2020s and 97% by 2080s.[79]

4. ADAPTING TO A CHANGING BASIN

In the Basin, the population and economic growth that has occurred over the last century was founded upon relatively stable climate conditions. There is now strong evidence that the climate is changing. While the exact rate and timing of projected climate changes cannot be predicted, sufficient changes have already occurred such that the past can no longer be a guide to the future. Viewing climate as dynamic rather than static will facilitate better decisions and the potential to plan more effectively for a prosperous future in the Basin.

Changes in temperature and precipitation have direct influences on humans in the form of heat waves, water shortages and more. But climate change impacts on the environment—such as changes in stream flows, landslides or longer growing seasons—can also be significant. Basin residents, businesses, communities and governments will benefit if they consider the chain of reactions initiated by climate changes in the past and projected for the future, and decide how to adapt. Adaptation involves both preparing for future climate and its impacts, and also adjusting or responding to changes that have already occurred or are projected to occur. Some climate changes will present opportunities and others will present real challenges that may not always have obvious solutions.

Meeting the Challenge of a Changing Climate

Since 2008, Basin residents, businesses, communities and governments have collaborated with CBT and a team of technical specialists to explore and understand how a changing climate will affect communities and lifestyles in the Basin, and what can be done to adapt. Continuing this Basin-wide dialogue will help foster a more comprehensive understanding of climate changes while promoting appropriate and creative actions to reduce negative impacts and take advantage of opportunities. It may be useful to base this dialogue on the following principles:

Accept that the present is, and the future will be, different from the past, and continue to learn about the changes: Temperatures have already warmed, and the future is expected to be even warmer. A sustained return to cooler temperatures in the foreseeable future is unlikely, and the current and projected changes in temperature most likely represent a fundamental shift in the climate system that has dominated the Basin for many decades.

Expect surprises, and be as prepared as possible: Climate change could result in more frequent wildfires, winter flooding and water shortages in some parts of the Basin. These events could also start occurring in areas that have not ever experienced them. Working to reduce the frequency or impact of these events by addressing known risks is a key part of adaptation. However, surprises may happen. Accordingly, residents, businesses, communities and governments can benefit from planning ahead.

Factor climate change into all decisions, especially long-term investments: Factoring potential climate changes into all decisions that might be affected by weather conditions can result in more appropriate decisions. Considering the implications of future climate conditions is particularly important for long-term investments, such as changes in land use or constructing a house, water system, new school or highway. The lifespan of most infrastructure extends beyond 2050, and some climate change impacts will likely be experienced before 2050. Designing infrastructure to accommodate projected climate changes is usually more cost-effective than renovating or replacing infrastructure before the end of its usual lifespan.]

Table 4: Average Lifespans of Municipal Infrastructure Components

	Lifespan	Major Upgrades or Refurbishment	Reconstruction
Houses and Buildings	50 – 100 years	15 – 20 years	50 – 100 years
Storm/Sanitary Sewer	100 years	25 – 50 years	
Dams/Water Supply	50 – 100 years	20 – 30 years	50 years
Roads	50 – 100 years	10 – 20 years	50 – 100 years
Bridges	50 – 100 years	20 – 25 years	50 – 100 years

Making Decisions in Changing Times

Climate isn't the only factor that's changing in the Basin or creating uncertainty about the future. All communities must contend with the implications of an aging population, global financial instability and technological advances. Climate change adds an additional layer of complexity and uncertainty to decision-making processes.

There are several techniques to support decision-making in times of uncertainty, including scenario planning; decision frameworks; robust, no-regrets and flexible options; strengthening adaptive capacity; and continuous improvement and adaptive management. These decision-making techniques may help residents, businesses, communities and governments adapt as the future unfolds.

Scenario planning: Scenario planning involves constructing a set of plausible scenarios about conditions that could occur in the future. It shifts the focus away from defining the most likely future, toward determining the range of possible futures. Scenarios illustrate, "This is what could happen in the future," and ask the question, "What would we do now if we knew this would happen?"

Decision frameworks: Decision frameworks used in climate change adaptation planning include risk management frameworks, vulnerability assessments and structured decision making.[80, 81] Decision frameworks are useful in complex situations to transparently identify and evaluate options and their capacity to meet identified objectives. Decision frameworks help clarify what people care about, identify creative alternatives and explore trade-offs.

Eight Factors for Success in Increasing Adaptive Capacity

1. Increase awareness and knowledge about challenges.
2. Find and foster effective leadership.
3. Nurture diversity.
4. Promote networking and the exchange of information.
5. Combine different types of knowledge to increase learning (e.g., local, traditional and academic).
6. Enhance redundancy (e.g., cross-training personnel, backup power sources for water systems, emergency preparedness).
7. Take opportunities for self-organization (e.g., community foundations).
8. Learn to live with change and uncertainty.

Robust, no-regrets and flexible options: When the future is characterized by what has been called "deep" uncertainty, selecting options that are robust, flexible and without regrets may set the stage for better outcomes, rather than trying to find single "best" options. Robust options perform well across many plausible futures.[82] No-regrets options have benefits now, even if the future conditions don't materialize.[83] For example, water conservation practices reduce water treatment costs and environmental impacts today, regardless of the future conditions. Flexible options evolve over time in response to changing conditions.

Strengthening adaptive capacity: The uncertainty and surprise element of climate change increases the importance of adaptive capacity. Adaptive capacity is the ability of a human system to monitor, assess and respond to change.[84] The ability to respond includes moderating potential damages, taking advantage of opportunities or coping with consequences. In a general sense, strengthening adaptive capacity means strengthening resilience to and increasing capacity to accommodate change.

Continuous improvement and adaptive management: Continuous improvement involves empowering everyone to achieve continual small improvements. Adaptive management is a process for continually improving policies and practices by learning from outcomes.[85] Both approaches are grounded in repeated cycles of design, implementation, assessment and adjustment. Both include team involvement, monitoring and collective learning. These techniques of "watch, learn and refine together" can support better decision-making in uncertain times.

5. HOW COMMUNITIES CAN ADAPT

The following sections review climate change impacts on communities on a sector-by-sector basis and suggest possible adaptation strategies for Basin residents, businesses, communities and government.

The vast majority of adaptation strategies described in this section were identified by the five Basin communities that undertook community-planning processes with the benefit of a broad range of expert input and guidance from the Initiative's advisory committee and technical support team. The strategies provided are not exhaustive lists of all possible strategies. Rather, they serve as a starting place for broader dialogue on ways communities can adapt to climate change in the Basin. Basin residents, businesses, communities and governments are encouraged to evaluate a range of potential strategies and select the most suitable measures for implementation.

Who Needs to Adapt?

Climate change adaptation involves everyone: individuals, families, community organizations, businesses, and local, First Nations, provincial and federal governments. The climate change adaptation strategies suggested in this document are intended for everyone in the Basin to consider. Local governments in particular will be on the front lines of many climate changes and need to take active roles in climate change adaptation.

Public Safety and Health

Basin residents enjoy a relatively high quality of life with health care services, a healthy natural environment, an extensive safety network and access to adequate food, shelter, education and employment. However, some individuals are particularly vulnerable to changes in climate. These include children, the elderly, those with compromised immune systems, people living in poverty and isolated individuals and families. Some families and communities are also vulnerable to climate change impacts due to their locations, access routes, levels of preparedness and high dependencies on economic sectors that could be negatively impacted by climate change, such as forestry and tourism.

Warm temperatures, very hot days, flooding, landslides, water shortages and wildfires could negatively affect water and air quality, promote the growth of pathogens and impinge on the health and safety of individuals. Extreme events—including flooding, landslides, avalanches and wildfires—could also cause property damage, power failures, death or injury, and cut off access to certain areas of the Basin, resulting in the need for evacuations, temporary housing and the construction of new infrastructure.

Potential Public Safety and Health Adaptation Strategies

Health Planning and Monitoring

1. Improve air quality, extreme-weather and disease warning systems.
2. Realign health services to support heat-sensitive individuals, those susceptible to poor air quality and those experiencing mental and physical exhaustion from repeated emergency events.
3. Include heat wave effects in airshed management planning and local health plans.
4. Incorporate reduced heating and increased cooling infrastructure and costs in decisions.

Emergency Preparedness

1. Strengthen emergency preparedness, evacuation planning and wildfire suppression capabilities.
2. FireSmart public and private properties.

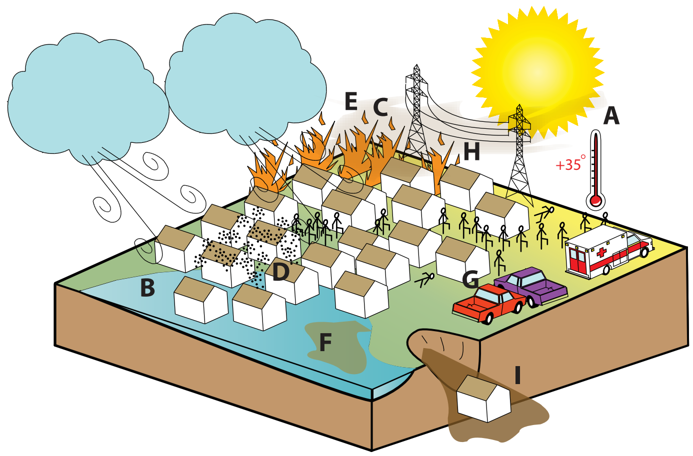
Figure 7.

PUBLIC SAFETY AND HEALTH

Climate Model Projections (2050)

- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation

Potential Environmental Changes



Potential Community Impacts and Opportunities

A- Heat stress related illness and hospital visits
B- Flooding evacuations, property damage and loss of life
C- Health problems from reduced air quality
D- Disease from vector-borne and fungal pathogens
E- Wildfire evacuations, property damage and loss of life
F- Water quality issues
G- Higher road accident rates
H- Power failures
I- Landslide property damage and loss of life

Infrastructure

Infrastructure associated with water supply, transportation, energy distribution, communications, waste disposal, stormwater management, banking and buildings is of critical importance in the Basin. Some of this infrastructure is private (e.g., homes, commercial buildings, pipelines), while the rest is built and maintained by local, regional, First Nations and provincial governments. While most of this section focuses on municipal infrastructure, all infrastructure owners and users may wish to consider adaptation actions.

Infrastructure in many communities is aging. Climate change could contribute to greater infrastructure deterioration and damage through increased flooding and sewer backups in heavy rainfall events; increased freeze/thaw stress on road surfaces, buildings and pipes; and more snow weight on roofs. Extreme events such as landslides, wildfires or windstorms have the potential to cause significant infrastructure damage. Drought and pest outbreaks could cause urban tree dieback. These impacts may increase infrastructure maintenance and insurance costs and risks for Basin residents. Extensive infrastructure upgrades to address climate change impacts may be unlikely due to the costs. Accordingly, adaptation efforts may have to focus on maintenance and other practices.

Potential Infrastructure Adaptation Strategies

General

1. Review and update official community plans (OCP), subdivision and servicing bylaws, flood management plans, master drainage/stormwater management plans and wildfire management plans to reflect climate change considerations.
2. Enhance emergency planning.
3. Prepare climate change design guidelines for new residential builds and renovations.
4. Incorporate climate change considerations into infrastructure assessments, plans and maintenance schedules, replacements and repairs.
5. FireSmart around buildings and infrastructure.
6. Plant drought- and pest-resistant landscaping and trees as part of urban forestry and tree renewal strategies.

Flooding and Stormwater Management

1. Identify critical infrastructure that is at risk of flooding and take protective measures.
2. Consider on-site water retention and management on residential and commercial properties.
3. Update road design standards to improve stormwater management.
4. Increase record keeping and the frequency of maintenance, inspections and cleanups for all drainage infrastructures.
5. Minimize development, disturbance and vegetation removal on and near slopes exceeding 25% to avoid landslide risks, and visually monitor at-risk slopes.

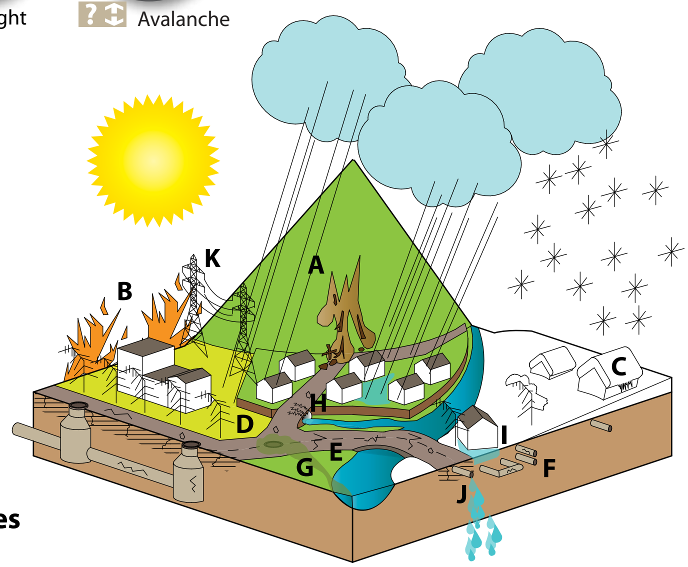
Figure 8.

INFRASTRUCTURE

Climate Model Projections (2050)

- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation

Potential Environmental Changes



Potential Community Impacts and Opportunities

A- Landslide damage
B- Wildfire damage
C- Heavy snow and ice load on roofs
D- Stress on urban trees and parks
E- Stress on roadways and bridges
F- Freezing of buried pipes
G- Sewer backup and overflow
H- Culvert failure
I- Basement flooding
J- Increase in water volume in stormwater systems
K- Damage to power lines

Watersheds and Water

In most of the Basin, water supply is abundant and of good quality, provided by snowmelt and glacier runoff from high-elevation catchments. Climate change could produce changes in watersheds and water quality as a result of increased temperatures, increased spring flow rates and decreased summer flow rates. Wildfires, pine beetles and wildfire salvage logging could lead to increased runoff, sedimentation and turbidity in water sources. Higher water temperatures could contribute to the bacterial contamination of water sources.

Climate change could also result in reduced community water availability due to decreased snowpack, earlier and faster spring runoff, and higher water demand due to increased temperatures and reduced summer precipitation.

Potential Water Adaptation Strategies

Watersheds and Water Quality

1. Create management plans for community watersheds, with guidelines for buffer zones, forest management practices, ecosystem rehabilitation and development.
2. Reduce the potential for wildfire in community watersheds and plan for wildfire response.
3. Increase water quality monitoring.
4. Adjust water system maintenance schedules and equipment.

Water Availability

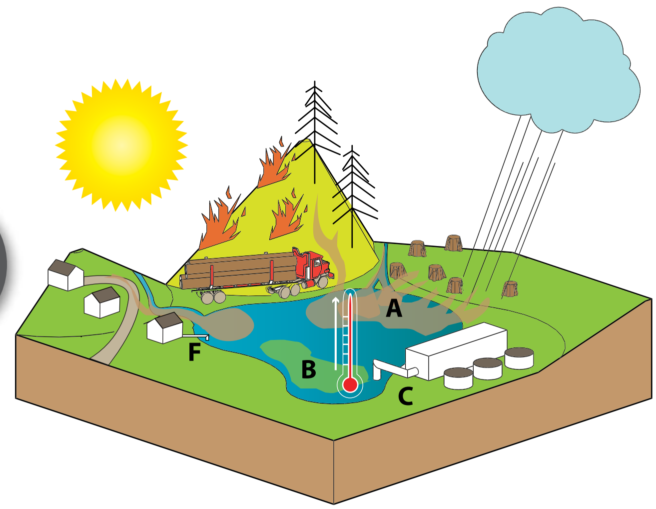
1. Educate water users about future potential water shortages.
2. Reduce water demand.
3. Explore and promote the use of alternative water sources for non-potable uses.
4. Analyze community water supply volumes.
5. Increase water storage capacity.
6. Prepare for droughts.
7. Reduce the potential for water supply interruptions due to electricity failures during flooding or wildfires and system damage from freeze/thaw events.

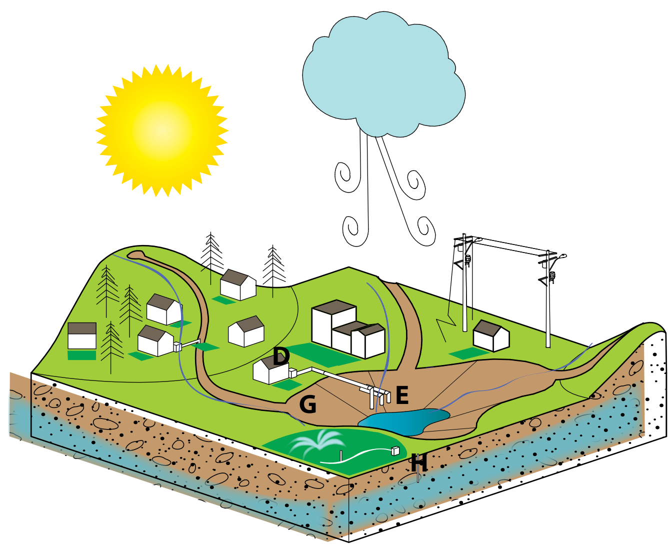
Figure 9.

WATERSHEDS AND WATER

Climate Model Projections (2050)
- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation

Potential Environmental Changes





Potential Community Impacts and Opportunities

A- Soil erosion, sedimentation and turbidity
B- Bacterial contamination of water
C- Higher water treatment costs
D- Electric water pump damage or power failure
E- Reduced water supply in reservoirs when demand is highest
F- Stress on water supply infrastructure
G- Insufficient community water supply
H- Less reliable aquifers

Transportation

Highways and railways link communities within the Basin. These transportation corridors often follow valley bottoms, near rivers, and some cross high mountain passes with severe winter conditions. The BC government is responsible for highways and secondary roads outside municipalities, while municipalities are responsible for the secondary roads within their borders. Air travel, which is critical for tourism and other economic interests, is hosted at regional airports in Castlegar and Cranbrook, and smaller airports in other Basin communities.

Transportation could be affected by climate-change-induced extreme events, including rainstorms, snowstorms, windstorms, wildfires, avalanches and landslides, which could result in increased accidents; road, airport and railway closures; and requirements for transportation infrastructure repair. In addition, changes or fluctuations in temperature and precipitation could increase or decrease road, rail and runway maintenance requirements.

Road construction seasons could be longer due to higher annual average temperatures, but more prone to disruptions from extreme events like extreme precipitation. Snow removal costs could be reduced as a result of more winter precipitation falling as rain at lower elevations.

Potential Transportation Adaptation Strategies

Road Design

1. Identify critical routes with landslide, erosion or flooding risks, and implement protective measures and design changes.
2. Design roads for more frequent storm cycles and higher runoff volumes.

Road Maintenance

1. Improve understanding of vulnerability of roads and rail lines to freeze/thaw cycles, extreme heat and extreme precipitation events.
2. Reassign construction and maintenance expenditures to account for reduced snow removal in lower elevations and possible increases in extreme weather events.

Emergency Preparedness

1. Increase awareness regarding the need for individual emergency preparedness when travelling.

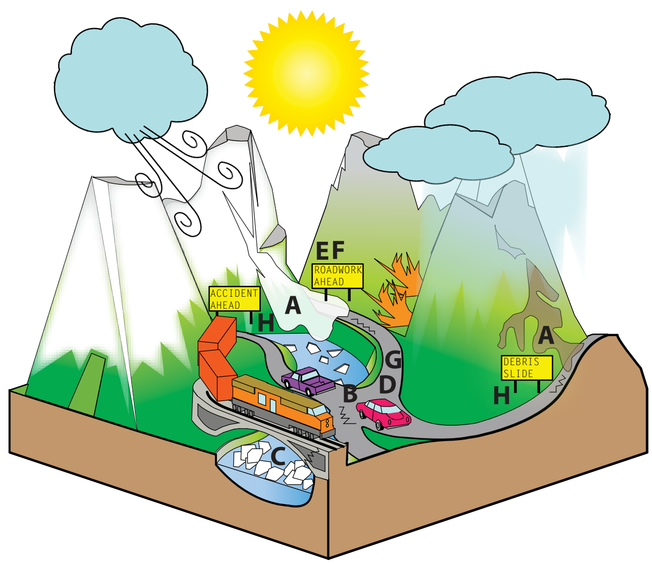
Figure 10.

TRANSPORTATION

Climate Model Projections (2050)

- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation

Potential Environmental Changes



Potential Community Impacts and Opportunities

A- Landslide, avalanche and debris torrent damage to roads/railways
B- Freeze-thaw damage to roads/railways
C- Ice jam flooding and damage to bridges
D- Increase in highway accident rates
E- Longer road construction season
F- Disrupted road construction schedules
G- Lower snow removal costs
H- More road closures

Agriculture and Food

Most of the Basin food supply comes from outside the Basin. Climate change impacts on food producing regions around the world that Basin communities rely on, like California, will have implications for Basin food security. The future of air travel and the safety and reliability of Basin highway infrastructure is another food security factor. A growing diversity of agricultural operations exists in the Basin, from horticulture and dairy and grain production in the Creston area and West Kootenay, to cattle operations in the East Kootenay.

Warming in the Basin will likely increase the length of the growing season, the number of growing-degree days and the suitability of the climate for a broader range of products, including high-value crops. However, higher summer temperatures, more very hot days and extended warm spells may negatively impact some crops and stress livestock. Risks of early- and late-season cold damage may decrease or increase, depending on the degree of temperature variability.

Many agriculture operations are dependent on stream-flow or stored-water irrigation during the summer when precipitation is lowest. As discussed in Section Three, stream flows are expected to change in timing, with lower flows coinciding with higher irrigation demand, while water demands may increase due to longer growing seasons.

More frequent extreme weather events and more intense rainfall increase the potential for soil erosion and crop damage. Smoke from wildfires may also damage crops, and wildfires may increase potential forage production areas if they result in the shift of some forests to grasslands. New climate conditions may favour new weeds, insects and plant diseases.

Potential Agriculture and Food Adaptation Strategies

Increased and Secure Local Agriculture/Household Production

1. Monitor changes in food production capabilities due to climate change.
2. Promote increased local food production, food preservation and seasonal eating.
3. Start or expand vegetable gardens, grow fruits, keep bees and raise chickens and livestock.
4. Maximize access to agricultural land for local growers.
5. Protect agricultural lands and topsoil.
6. Support opportunities for local food producers to increase their food sales (e.g., farmers markets).
7. Participate in and promote community-supported agriculture.
8. Reflect climate change adaptation in agriculture area plans and other long-term food plans.

Agricultural Practices

1. Encourage local growers to use adaptive methods to deal with a changing climate.
2. Use seasonal climate forecasts to plan each season.
3. Implement local seed banks.
4. Establish additional water storage and more efficient irrigation.
5. Diversify crops, particularly to high-value crops with low water needs.
6. Update erosion control practices.
7. Enhance pollinator attraction.
8. Enhance monitoring and refine practices to minimize damage from weeds, insects and disease.

Emergency Preparedness

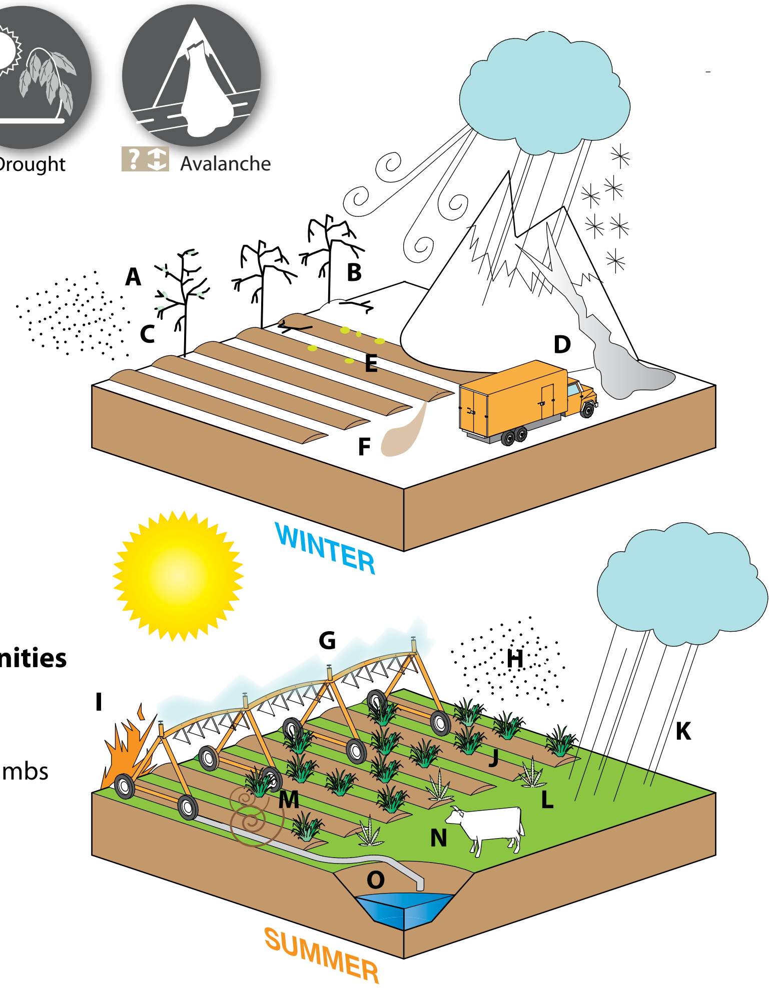
1. Prepare for temporary food shortages due to transportation disruptions or climate-related impacts on food production.

Figure 11.

AGRICULTURE AND FOOD

Climate Model Projections (2050)
- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase in growing degree days
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation
- Longer growing season

Potential Environmental Changes



Potential Community Impacts and Opportunities

WINTER
A- Early budding
B- Heavier snow and freezing rain damage to tree limbs
C- Survival of crop pests
D- Food transportation disruptions
E- Damage to perennials from low snow cover
F- Soil erosion

SUMMER
G- Increased irrigation requirements
H- Changes in pollinators
I- Wildfire damage
J- Greater uncertainty in orchard and crop planning
K- Extreme weather crop damage
L- Increase in weeds and pests
M- Dry soil
N- More stress on livestock
O- Less water for irrigation

Recreation and Tourism

As well as being key economic sectors, outdoor recreation and tourism are significant contributors to quality of life in the Basin. Climate impacts the many recreational activities and defines the length and quality of the tourism and recreation seasons.

Warmer temperatures and a longer summer season could benefit some tourism and recreation activities. However, extreme events such as wildfires, storms, flooding, landslides and avalanches could damage tourism and recreation infrastructure. Drought could affect golf courses and low summer flows could impact opportunities for river-based water sports.

Reduced snowpack, snow-on-rain events and alpine glacier retreat could impact all types of skiing and mountaineering and increase requirements for snow-making. Changes in ecosystems, pest damage, wildfires and salvage logging could affect the quality of viewscapes and recreation experiences.

Potential Tourism and Recreation Adaptation Strategies

New Tourism and Recreation Assets

1. Diversify tourism and recreation products and activities, including expanding warm-season activities.
2. Initiate education programs based on glacial retreat and unusual wildfire and pest events.
3. Develop trails and parks that can also serve as firebreaks and emergency access routes in the event of wildfire.

Existing Tourism and Recreation Assets

1. Continue or consider snow-making at ski hills.
2. Groom ski slopes to reduce the snow cover needed for skiable conditions.
3. Conserve water on golf courses through reduced turf, drought-resistant turf/grass species and irrigation systems that reuse grey water.
4. Protect trails from damage by interface fuel reduction, salvage logging for pest management and wildfires.
5. Reinstate or put in place water-flow monitoring stations on rivers and creeks used for water-based tourism.
6. Increase riparian reserves to retain low water temperatures and quality fisheries habitats.
7. Reconsider the current emphasis on cold-water species in lake fisheries stocking programs.

Emergency Preparedness

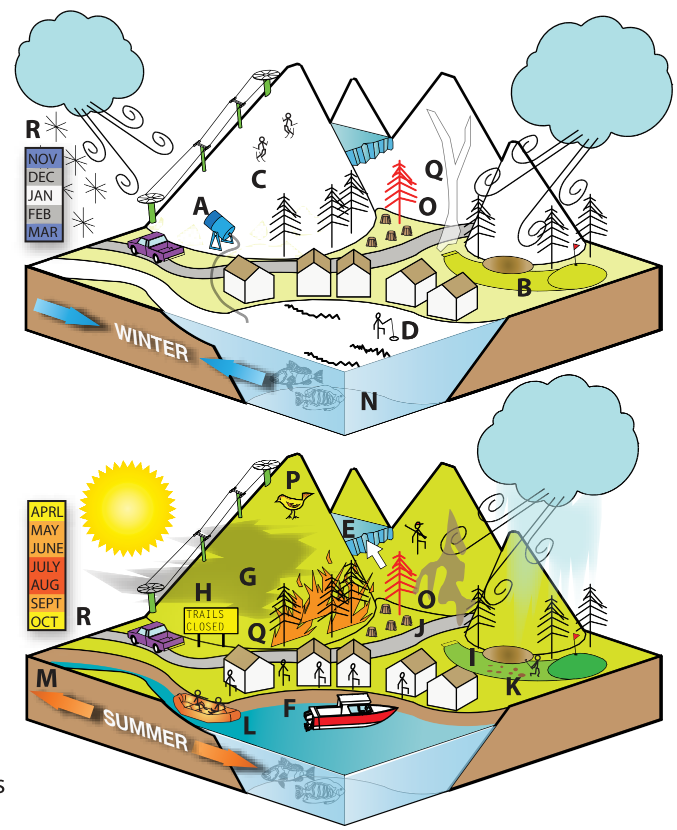
1. Include tourists and tourism operators in safety warnings systems and emergency preparedness planning for climate-related hazards.

Figure 12.

RECREATION AND TOURISM

Climate Model Projections (2050)
- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase in growing degree days
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation

Potential Environmental Changes



Potential Community Impacts and Opportunities

WINTER
A- More water used for snowmaking
B- Golf course turf damage due to ice
C- Shorter ski season
D- Shallow ice cover on lakes causing dangerous conditions for recreational activities

SUMMER
E- Reduced glacier tourism and recreational opportunities
F- Increased water-based recreation and lakeshore development
G- Poor air quality and viewscapes
H- Trail closures
I- Less water available for golf course irrigation
J- Increased logging due to mountain pine beetle
K- Increase in turf diseases and pests
L- Increased unpredictability of rafting and river sports season
M- Longer summer season

All SEASONS
N- Shift in fish species changing the fishing experience
O- Reduced visual quality of forests
P- Changes in wildlife habitat, populations and migration patterns
Q- Tourists and recreational users deterred by avalanches, wildfires, closed roads or extreme weather events
R- Less predictability of the season for tourism operators

Forestry and Mining

Forestry and mining are essential economic sectors in the Basin. Forestry will be affected by shifts in biodiversity and productivity of tree species, pest outbreaks, wildfires and other extreme events. Forest productivity could increase in some areas and decrease in others. While wildfires, pest outbreaks and forest fire fuel reduction strategies may result in the opportunity for salvage logging, wildfire and pests could affect the long-term productivity of Basin forests. Some of these climate change impacts may require adjustments in short- and long-term timber supply, which could impact the local forestry sector, with implications for dependent communities.

Both the forestry and mining sectors are highly dependent on transportation infrastructure across the Basin, particularly the conditions of resource roads. The climate change impacts on transportation described in the transportation section could impact both forestry and mining operations, and resource roads could be impacted by debris flows, landslides and flooding in extreme precipitation events. The length of the active logging and mining season could expand if winters grow shorter and snowpack is reduced.

Potential Forestry and Mining Adaptation Strategies

Forest Management

1. Reforest logged areas and reclaim mining sites with species suited to future climate conditions and create diverse ecosystems.
2. Improve the monitoring of and response to increasing disturbance agents like insects and disease.
3. Incorporate climate change in long-term timber supply forecasts.

Access Management

1. Use new technology to extend the winter logging season.
2. Refine road construction and maintenance practices to accommodate changing stream flows, especially peak flows.

Emergency Preparedness

1. Improve preparedness for fires, storms and floods.

Figure 13.

FORESTRY AND MINING

Climate Model Projections (2050)
- Higher average annual temperatures
- More very hot days and longer warm spells
- Increase in growing degree days
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
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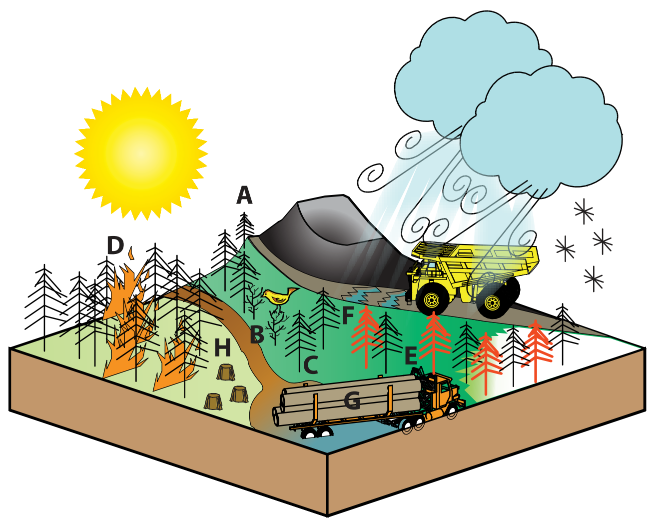
Potential Environmental Changes



Potential Community Impacts and Opportunities

A- Changes in forest composition and harvest levels
B- Changes in biodiversity and wildlife habitat, including new combinations of species
C- Increased forest productivity in some areas; reduced in others
D- Loss of mature timber and plantations to wildfires
E- Pest outbreaks
F- Operational disruptions and road closures
G - Shorter winter logging and mining season
H - Salvage logging and fuel reduction in forests

Transboundary Flood Control and Hydroelectric Power

The Columbia River Treaty (CRT) is an international agreement between Canada and the U.S. for the joint development, regulation and management of the Columbia River to coordinate flood control and optimize electrical energy production on both sides of the border. Approximately half of the hydroelectricity generated in BC comes from the Columbia River Basin.

Under the 1964 Columbia River Treaty (CRT), Canada was required to build and operate three dams in the higher-elevation reaches of the Columbia Basin:

1. 1967- Duncan Dam (Duncan Reservoir)
2. 1968- Hugh Keenleyside Dam (Arrow Lakes Reservoir)
3. 1973 – Mica Dam (Kinbasket Reservoir)

The CRT also allowed the U.S. to construct Libby Dam in Montana. Its reservoir, the Koocanusa, extends 67 km into Canada. Operations at Libby Dam are under the jurisdiction of the U.S. entities. Several smaller run-of-the-river power plants also exist within the Basin.

Reservoir operations in the Basin will likely be affected by changes in stream flows, including an earlier spring freshet and higher summer stream flows in the short term as glaciers retreat, and longer summer low-flow periods in the long term, which could result in conflicts between water users. Demand may also increase in summer and fall due to cooling requirements. Shifts in reservoir operations and hydro production may be required to meet these changing demands.

The Canadian portion of the Basin contributes approximately 40% of the total runoff. In late summer, this percentage increases. The snowpack in Canada may be less sensitive to warming than that in the U.S. portion of the Columbia River system. Thus, over the next 50 years, summer snowmelt in Canada may contribute relatively more to summer stream flows. This has the potential to create challenges to meeting in-stream flows in the U.S., especially in summer.

The large reservoir systems in place, and their ability to capture water, may serve to ameliorate the impact of low flows in drier summer months. Dams and the existing reservoir system act as an excellent adaptation strategy that can serve to mediate impacts of potentially more extreme weather.

Current Canada-U.S. agreements may need to adopt a more flexible approach to meet new and increasing demands for water and changing stream flow scenarios. This emphasizes the necessity of joint long-term planning and cooperation.

Potential Transboundary Flood Control and Hydroelectric Power Adaptation Strategies

System Operation

1. Improve projections of electricity supply and demand.
2. Change reservoir operations to meet new demand times.
3. Modify reservoir operations (e.g., flood rules curves) to capture water earlier in the season.
4. Construct additional water storage facilities.
5. Adjust to shifts of peak hydropower demand from winter to summer.

Energy Demand and Other Energy Sources

1. Promote reduced electricity use.
2. Develop and implement community and corporate energy plans.
3. Promote infill development and establish higher building code requirements to increase the efficiency of housing and reduce energy demands.
4. Identify and implement energy conservation measures within local government operations.
5. Provide incentives for the development of renewable energy facilities.

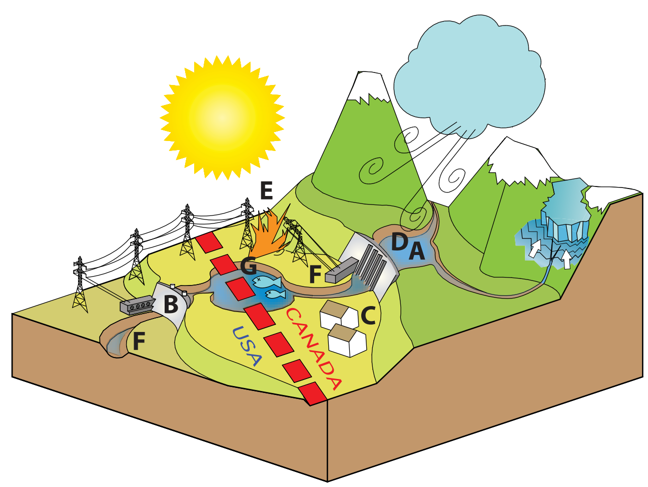
Figure 14.

TRANSBOUNDARY FLOOD CONTROL & HYDROELECTRIC POWER

Climate Model Projections (2050)

- Higher average annual temperatures
- More very hot days and longer warm spells
- Decrease in heating degree days
- Increase in winter precipitation
- More rain and decreased snow at lower elevations in winter
- Decrease in summer precipitation
- Increase in extreme precipitation events
- Increase in the variability of temperature and precipitation

Potential Environmental Changes



Potential Community Impacts and Opportunities

A- Increased need to store water for summer use
B- Reduced hydroelectricity production and potential energy shortages
C- Reduced heating demand in winter and increased demand for cooling in summer
D- More challenging to maintain reservoir and flow levels to meet non-power needs
E- Damage to transmission lines
F- Reduced downstream water flow
G- Impacts on water quality and fish health

6. Conclusion: Working Together to Adapt

The Basin climate is shifting and environmental conditions are changing in response. Basin residents, businesses, communities and governments have already experienced some of the projected changes, and have started planning to adapt. Understanding the potential scope and impact of present and future climate changes is the first step in thinking about how Basin residents, businesses, communities and governments might continue to adapt to overcome vulnerabilities and realize opportunities from these changes.

Continued dialogue will allow Basin residents, businesses, communities and governments to:

- explore options;
- assess information requirements;
- identify institutional, political or practical barriers; and
- consider stresses faced from sources other than climate change.

Focusing on both the positive and negative implications of climate change impacts and possible adaptation strategies, and involving a wide range of individuals and groups in the dialogue and decision-making processes, can contribute to better decision making and more productive discussions. Factoring climate impacts and adaptation into ongoing planning and decision processes—such as municipal water system planning, regional agriculture planning, business planning and hydropower water use planning—may be the easiest way to consider climate change in a systematic manner.

Potential Participants in the Dialogue

Dialogue on climate change adaptation could include: climate specialists; hydrologists; local water managers; wildlife and fisheries biologists; local governments; provincial governments; residents; environmental representatives; economic representatives from sectors like forestry, mining, agriculture, power production and tourism; and social representatives from sectors like public safety, health and education.

CBT will continue to work with a range of partners to increase Basin residents' awareness of local climate change impacts, and to provide credible, science-based information and updates about refinements in climate science and adaptation.

For More Information

To learn more about climate change initiatives supported by Columbia Basin Trust, visit www.cbt.org/climatechange.

Climate Mitigation: As Important as Adaptation

Adaptation planning does not replace the need for greenhouse gas emissions reductions. Mitigation is a critical strategy that helps reduce the climate change impacts Basin residents, businesses, communities and governments will have to adapt to. Understanding the scale of potential impacts from the changing climate makes the need to reduce greenhouse gas emissions even more evident. Both adaptation and mitigation are necessary for people to comprehensively deal with the impacts of climate change. CBT is supporting local governments, including municipalities and First Nations, to reduce their emissions through a multi-year mitigation effort. Many Basin governments are already moving forward with mitigation through the Carbon Neutral Kootenays initiative and community-based energy and emissions plans.

For more information on Carbon Neutral Kootenays, visit www.cbt.org/climatechange.

List of Acronyms and Glossary

Acronyms

CACCI	Communities Adapting to Climate Change Initiative
CBT	Columbia Basin Trust
ENSO	El Niño/Southern Oscillation
IPCC	Intergovernmental Panel on Climate Change
PCIC	Pacific Climate Impacts Consortium
PDO	Pacific Decadal Oscillation

Glossary

Adaptive Capacity: The ability of a country, region, community, group or individual to monitor, assess and respond to change by moderating potential damages, taking advantage of opportunities or coping with the consequences.

Adaptive Management: A process for continually improving policies and practices through ongoing monitoring and learning from outcomes.

Baseline: The state or reference period against which change is measured.

Biodiversity: The degree of variation of life forms within a given ecosystem, biome, region or other geographical location.

Biogeoclimatic zone: A geographical area (large ecosystem) with a relatively uniform macroclimate, characterized by a mosaic of vegetation, soils and, to a lesser extent, animal life reflecting that climate.

Climate: The prevailing climate factors—such as temperature, precipitation, atmospheric pressure, wind velocity and humidity—in a given region, measured over several decades.

Climate Change: A detectable shift in the average (mean) and/or the variability of a climate factor from one time period (typically decades or longer) to another.

Climate Change Adaptation: Adaptation that reduces the impacts of climate change; being ready for a future that is different from what the community has experienced in the past due to changes in weather and climate.

Climate Change Impacts: The positive and negative effects of climate change on natural and human systems; can occur in natural systems and in human systems.

Climate Change Mitigation: The act of reducing greenhouse gas emissions, which contribute to climate change.

Climate Factors: Temperature, precipitation, atmospheric pressure, wind velocity and humidity.

Climate Model: A numerical representation of the climate system based on some or all of the properties of its components—including the atmosphere, oceans, land surface and ice—their interaction and feedback processes.

Climate Variability: How much the temperature, precipitation and other climate factors vary within a specified time frame, compared to the average for that time frame.

Climatic Moisture Deficit: When monthly precipitation is less than monthly evaporative demand; a moisture deficit of 10 mm over a time period means that 10 mm of moisture was removed from the soil that was not replaced by precipitation during that period.

Continuous Improvement: Empowering individuals to achieve continual small improvements in policies and practices.

Drought: When precipitation is significantly below average historic levels, causing serious hydrological imbalances that can negatively affect natural and human systems.

Ecosystem: The interactive system formed by all living organisms and their abiotic (non-living) environment in a given area.

Extreme Weather Events: Events that occur less than 5% of the time, such as extreme precipitation events, thunderstorms, extreme temperatures, cyclones, tornadoes, windstorms and dust storms.

FireSmart: A provincial program for individual homeowners and communities that provides simple steps to reduce the impact of wildfire.

Freshet: Spring thaw resulting from snow and ice melt in rivers located latitudes where rivers are frozen each winter and thaw during the spring

Greenhouse Gas: Gases in the atmosphere that absorb and emit radiation within the thermal infrared range, causing the greenhouse effect. Key greenhouse gases include water vapour, carbon dioxide, nitrous oxide, methane and ozone. The burning of fossil fuels is a major human source of carbon dioxide in the atmosphere.

Greenhouse Gas Emissions Scenario: A plausible representation of the future emissions of greenhouse gases based on a set of assumptions regarding driving forces such as demographic change, socioeconomic development and technological change.

Growing-degree Days: A measure of heat accumulation over a season; help determine when crops will reach maturity. They are calculated by subtracting a base temperature (below which plant growth is zero) from the average temperature each day and cumulatively adding each day's growing-degree contribution as the season progresses.

Heating-degree Days: A measure of the energy demand required to heat houses and buildings. They are calculated by multiplying the number of days with an average daily temperature below 18 C by the number of degrees below 18 C. If the average temperature on a certain day was 14 C (4 C below 18 C), that day would contribute four heating-degree days to the total annual number of heating-degree days. They are often cumulatively added as the season progresses and presented as an annual total.

Mean: The average of a set of numbers, calculated by adding up the numbers and then dividing by how many numbers there are.

Median: The number separating the upper half of a sample from the lower half, found by arranging all the observations from lowest to highest and picking the middle one, if there is an odd number of observations, or taking the mean of the two middle values, if there is an even number of observations.

No-regrets Options: Actions that generate net benefits whether or not climate change occurs.

Precipitation: Any product of the condensation of atmospheric water vapour that falls under gravity, including rain, snow, sleet and hail.

Rain-dominated Watersheds: Watersheds in which peak flows occur in winter when rain falls on already saturated soils.

Rain-on-snow Event: Occurs when rain falls onto frozen ground with a pre-existing snowpack; can cause the snow to melt, creating runoff and, in some instances, lead to flooding.

Resilience: The ability of a human or natural system to absorb, adapt to and recover from changes and disturbances while maintaining the same general structure and ways of functioning.

Risk Management: A systematic approach to selecting the best course of action under uncertainty by analyzing and evaluating the risk (probability and consequences) of an event.

Scenario: A plausible and simplified description of how the future might appear, based on a set of assumptions regarding driving forces and key relationships.

Snow-dominated Watersheds: Watersheds in which peak flows occur in spring when peak snowmelt happens.

Stream Flow: The flow of water in streams, rivers and other channels; a major component of the runoff of water from land to water bodies and a key element of the water cycle; generally derives from runoff from higher elevations from rain, melting snow or groundwater.

Temperature: The physical property of matter that expresses whether it is hot or cold. With respect to climate change, temperature generally refers to the air temperature at or near ground-level.

Vulnerability Assessment: A systematic approach to assessing the vulnerability of a system with respect to climate; related to the degree to which the system is affected by changes in climate (sensitivity), and the ability of the system to accommodate or adjust to changes, moderate potential damages, cope with consequences or take advantage of opportunities (adaptive capacity).

Weather: The day-to-day conditions of the atmosphere: e.g., whether it is raining, snowing, sunny, hot or cold.

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Endnotes

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