87 Extension Note

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A Summary of Climate Change Effects on Watershed Hydrology[1]

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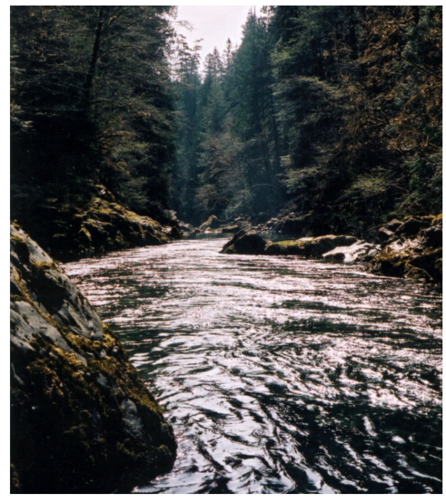
The climate of British Columbia is changing, and with these changes will come many adjustments in watershed hydrology and, ultimately, in the use of water-related resources. Yet, because British Columbia is hydrologically diverse, the local responses to these anticipated changes will differ.



Historical Trends in Temperature and Precipitation

Analysis of British Columbia climate data for the last 100 years indicates an overall rise in air temperatures for all seasons, with the greatest warming occurring in the winter. This warming has been greater in northern British Columbia than in the southern and coastal regions. Trends in annual precipitation across British Columbia for the last century are more varied than for temperature. The increase in average annual precipitation is more spatially varied than for temperature, with larger increases occurring in regions with comparatively low annual precipitation. During the last 50 years there has been an increase in the occurrence of extreme wet and extreme dry conditions in the summer and a decrease in winter snowpack.

Historical Trends in Glacier Recession and Streamflow

Most British Columbia glaciers are out of equilibrium with the current

1 This summary was extracted with permission from:
Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate change and watershed hydrology Part I – Recent and projected changes in British Columbia. Streamline Watershed Management Bulletin. Vol. 11. No 2.
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climate and are slowly adjusting to changes in seasonal precipitation and elevated temperatures, resulting in widespread glacial volume loss/retreat. For example, the Illecillawaet Glacier in Glacier National Park has receded over a kilometre since measurements began in the 1880s.

Streamflow responses to historical changes in precipitation and temperature are variable and differ by region (i.e., hydrologic regime). In snowmelt-driven systems there is generally an earlier onset of snowmelt runoff followed by an increasingly long and dry summer. Across Canada, in the past 30–50 years, mean annual streamflow has decreased in most areas (see exceptions below). There has also been an earlier starting date of spring high flows. Annual minimum daily mean streamflow has decreased in southern Canada and increased in northern British Columbia and Yukon.

The magnitude and direction of these climate-induced streamflow changes vary across British Columbia. For example, mean annual streamflow is decreasing in southern British Columbia, increasing in the central and interior, and decreasing in the northwest part of the province. This is not surprising, given the relative importance of the different hydrologic processes on the coast vs. in the interior and differing drivers of streamflows (e.g., winter rainstorms vs. spring snowmelt).

Future Temperature and Precipitation Regimes

Overall, British Columbia will experience greater warming and greater changes in precipitation than the global average. All models and emissions scenarios project an increase in winter and summer temperatures, with the greatest increase for the higher-emission scenarios. Warming will be greater in northern than in southern British Columbia. Changes in precipitation are expected to vary in space as well as in time. Southern and central British Columbia are expected to get drier in the summer, while northern British Columbia will more likely be wetter. Winters will be wetter across British Columbia. Except for an area in the central and southern interior, the increase in winter precipitation is large enough to result in an increase in the annual total. There will also be increases in the intensity and the maximum amount of precipitation. For both temperature and precipitation there will be a reduction in return periods of current extreme events.

Hydrologic Implications for British Columbia

Projected changes in temperature and precipitation will have a strong influence on watershed hydrology. Subsequent changes in watershed hydrology will have important implications for fisheries, agriculture, forestry, recreation, hydroelectric power, and water resources. The following hydrology-related changes may be expected in British Columbia:

- Increased atmospheric evaporative demand
- Altered vegetation composition affecting evaporation and interception
- Increased stream and lake temperatures
- Increased frequency and magnitude of storm events and disturbances
- Accelerated melting of permafrost, lake ice, and river ice
- Decreased snow accumulation and accelerated snowmelt
- Glacier mass balance adjustments
- Altered timing and magnitude of streamflow

Increased atmospheric evaporative demand
Climate scenarios indicate that the atmosphere's ability to evaporate water will increase. This will have a significant effect on water resources through evaporative losses from streams, lakes, and reservoirs, and through changing water demand for irrigation and supply for domestic purposes. Increased evaporation may also reduce vegetation survival and growth through reduced water availability, and will likely increase wildfire risk.

Altered vegetation composition affecting evaporation and interception
Vegetation influences water balance through the interception of precipitation and the removal of water from the soil through transpiration. Increases in the length of the snow-free season and an increase in the atmospheric evaporative demand are likely to increase annual plant transpiration. Projected changes in climate are sufficient to have an impact on forest productivity and on the species that could grow on a site. Changes in age class distribution and in the form of vegetation (e.g., forest die-off, alpine encroachment, grassland expansion) may also result.

Increased stream and lake temperatures
Stream and lake temperatures are projected to rise, resulting in a number of specific concerns for water and for fish. With respect to fish, increased temperatures in some systems may result in increased frequencies of disease, increased energy expenditures, altered growth, thermal barriers to both adult and juvenile migration, delayed spawning, reduced spawner survival, altered egg and juvenile

development, changes in biological productivity and other rearing conditions, and altered species distribution.

Increased frequency and magnitude of storm events and disturbances
It is projected that storm frequency and intensity will increase. An increase in wind and precipitation intensity will likely increase the frequency of windthrow, breakage of trees, flooding, and landslides. This will likely lead to increased rates of erosion/sedimentation, more landslide-derived log jams, increased channel destabilization, and decreased large woody debris (LWD) supply from stream channel banks, ultimately affecting stream channel form and riparian function. Changes to the return period of events also will have implications for engineering design criteria. All these changes will affect stream ecology and fish populations.

Accelerated melting of permafrost, lake ice and river ice
Ice-related hydrologic features will be affected by rising temperatures. Projections of milder winter temperatures mean that river and lake ice could be expected to form later and disappear earlier than normal. These hydrologic changes will have implications for forest harvest scheduling (operable ground, seasonal water tables, timing), transportation (ice bridges), and recreation (fishing opportunities).
In the discontinuous permafrost region, where ground temperatures are within 1–2 degrees of melting, permafrost will likely disappear as a result of ground thermal changes associated with global warming. In areas where the ice content is high, thawing of permafrost can lead to increased thaw settlement and to thermokarst activity, while reduced soil strength in response to melt will lead to ground instability, thereby increasing the incidence of slope failures. The integrity of engineered structures such as bridge footings, building foundations, roads, railways, and pipelines could be affected.

Decreased snow accumulation and accelerated snowmelt
Increased temperatures as a result of climate change will lead to a continued decrease in snow accumulation at all but the coldest locations in British Columbia. Changes will result in earlier snowmelt and less water storage for the spring freshet, and/or to release to groundwater storage. Average snowlines will migrate north in latitude and higher in elevation in response to temperatures increasing with time. It is expected that decreased storage of winter precipitation will likely reduce the magnitude of the spring peak flow, and exacerbate summer low-flow conditions. Changes in seasonal snow accumulation and snowmelt are important for water supply, hydroelectric power, fish, and aquatic habitat. Less snow and less reliability of snowfall also has implications for the winter recreation industry.

Glacier mass balance adjustments (advance/recession)
Given future climate change projections, it is expected that most glaciers in British Columbia will continue to recede, except those at the coldest locations. Negative glacier mass balance should result in increased summer streamflows (less severe low flows) for several years or even decades as glacier melt accelerates due to warming temperatures. This effect will be followed by a larger decrease when the glaciers eventually disappear, or drop to some small proportion of the watershed area. Eventually, the reduction or elimination of the glacial melt component that augments summer low flows in many watersheds will result in an increase of low-flow days on these streams. Already, there is evidence to support this, as a recent report indicated that since 1970, glacier-fed streams in British Columbia have exhibited a decreasing trend for August streamflow.

Altered timing and magnitude of streamflow (peak flows, low flows)
Streamflow is controlled primarily by watershed geology and seasonal patterns of temperature and precipitation. Variations in underlying geology that influence whether snowmelt goes into groundwater reserves or into direct runoff can strongly influence the magnitude and timing of late summertime streamflow and thus influence the magnitude of the response to climate change.

In British Columbia, there are four types of hydrologic regimes: 1) rain-dominated, 2) snowmelt-dominated, 3) mixed/hybrid, and 4) glacier-augmented. The relative impact of climate change will vary by hydrologic regime depending on the regime's sensitivity to regional temperature and precipitation changes.

The response of rain-dominated regimes (winter peak flows, summer low flows) will likely follow predicted changes in precipitation. For example, an increased frequency and magnitude of storm events will result in an increased frequency and magnitude of storm-driven peak flows in the winter. Drier summers will raise concerns about the increased number and magnitude of low-flow days (i.e., less water for a longer period of time).

In snowmelt-dominated systems (spring peak flows, late summer–winter low flows) there will be a shorter snow accumulation season and likely an earlier start to the spring freshet, which may lengthen the period of late summer and early autumn low flows.

In mixed/hybrid regimes there can be significant streamflow (peaks) in both the winter as a result of rain and in the spring as a result of snowmelt from higher elevations. In these regimes, if snowpacks no longer form or are very shallow, typical large mid-winter snowfall events will change to large rain events, thereby increasing the frequency of winter peak flows. Subsequently, spring peak flows will be reduced and will occur earlier due to less precipitation being stored as snow during the winter, and winter low flows will be reduced (i.e., more water) if precipitation falls as rain instead of snow.

In glacier-augmented systems, peak flows would likely decrease and occur earlier in the year, similar to snowmelt-dominated regimes. In the long term, the reduction or elimination of the glacial meltwater component in the summer/early fall would increase the frequency and duration of low-flow days in these systems.

Overall, it could be expected that hybrid/mixed regimes might transition to rain-dominated regimes through the weakening or elimination of the snowmelt component. Similarly, snowmelt-dominated watersheds might exhibit characteristics of hybrid regimes, and glacier-augmented systems might shift to more of a snowmelt-dominated pattern with respect to the timing and magnitude of annual peak flows and low flows.

Conclusions

British Columbia's climate has changed over the last 100 years and will continue to change. The effects on watershed hydrology will have many important implications for fisheries, agriculture, forestry, recreation, hydroelectric power, and water resources. The impacts of climate change on streamflow will vary across the province and hence local mitigation and adaptation strategies will likely be needed to ensure effective stewardship of watershed resources and associated values.

Further Reading

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