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WATER QUANTITY IN CANADIAN RIVERS

CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

Canada

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CANADIAN ENVIRONMENTAL SUSTAINABILITY INDICATORS

WATER QUANTITY IN CANADIAN RIVERS

March 2024

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Water quantity in Canadian rivers

Canada is a water-rich country. However, too much or too little water can lead to serious problems, such as flooding or drought. Depending on the region in Canada, changes to the amount of water flowing in rivers can be linked to changes in weather and climate along with other drivers such as human development and demand.

The water quantity indicator provides information about water flows in rivers across Canada from 2001 to 2021 and by monitoring station for 2021. Longer-term trends provide an assessment of significant changes in flows, including very high and very low flows that can result in flooding or drought, from 1970 to 2021.

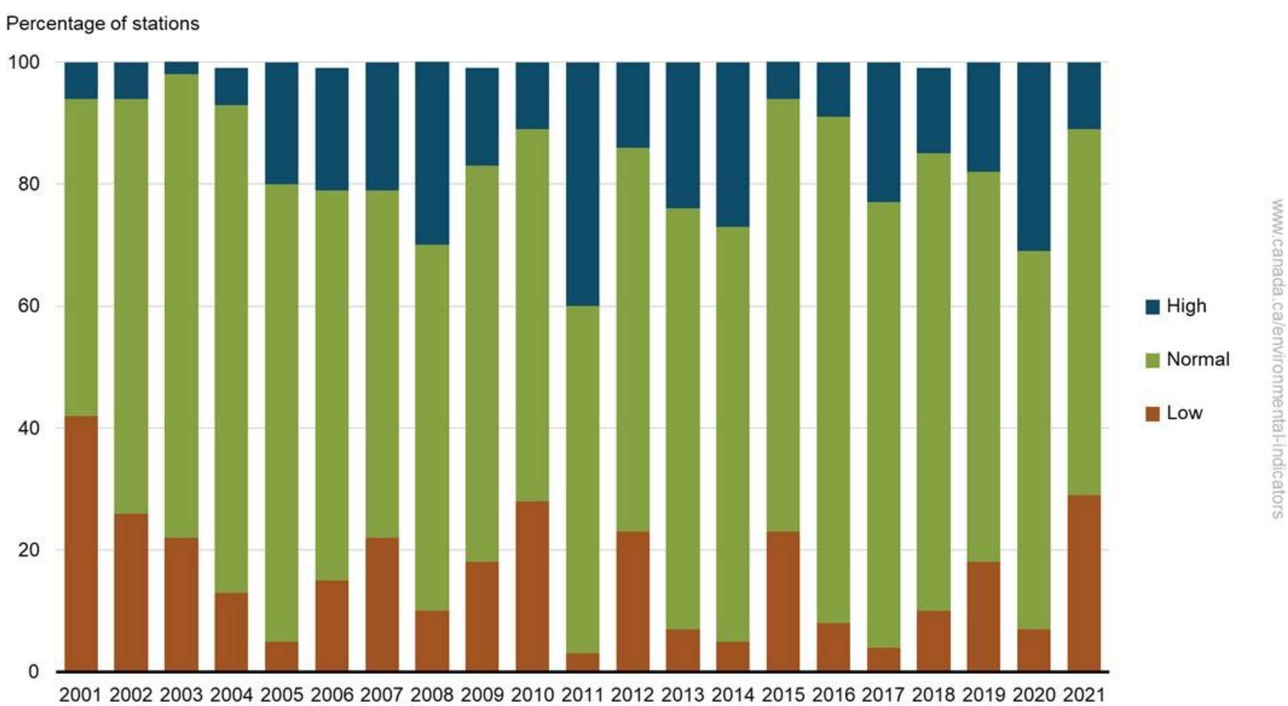
National water quantity in Canadian rivers

Key results

Overall, in 2021, water quantity in Canada was:

- higher than normal at 11% of the stations
- normal at 60% of the stations
- lower than normal at 29% of the stations

Figure 1. Water quantity at monitoring stations, Canada, 2001 to 2021



Data for Figure 1

Note: The water quantity classification for a station is based on a comparison of the annual water quantity in a given year with typical annual water quantity at that station between 1991 and 2020. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

From 2001 to 2021,

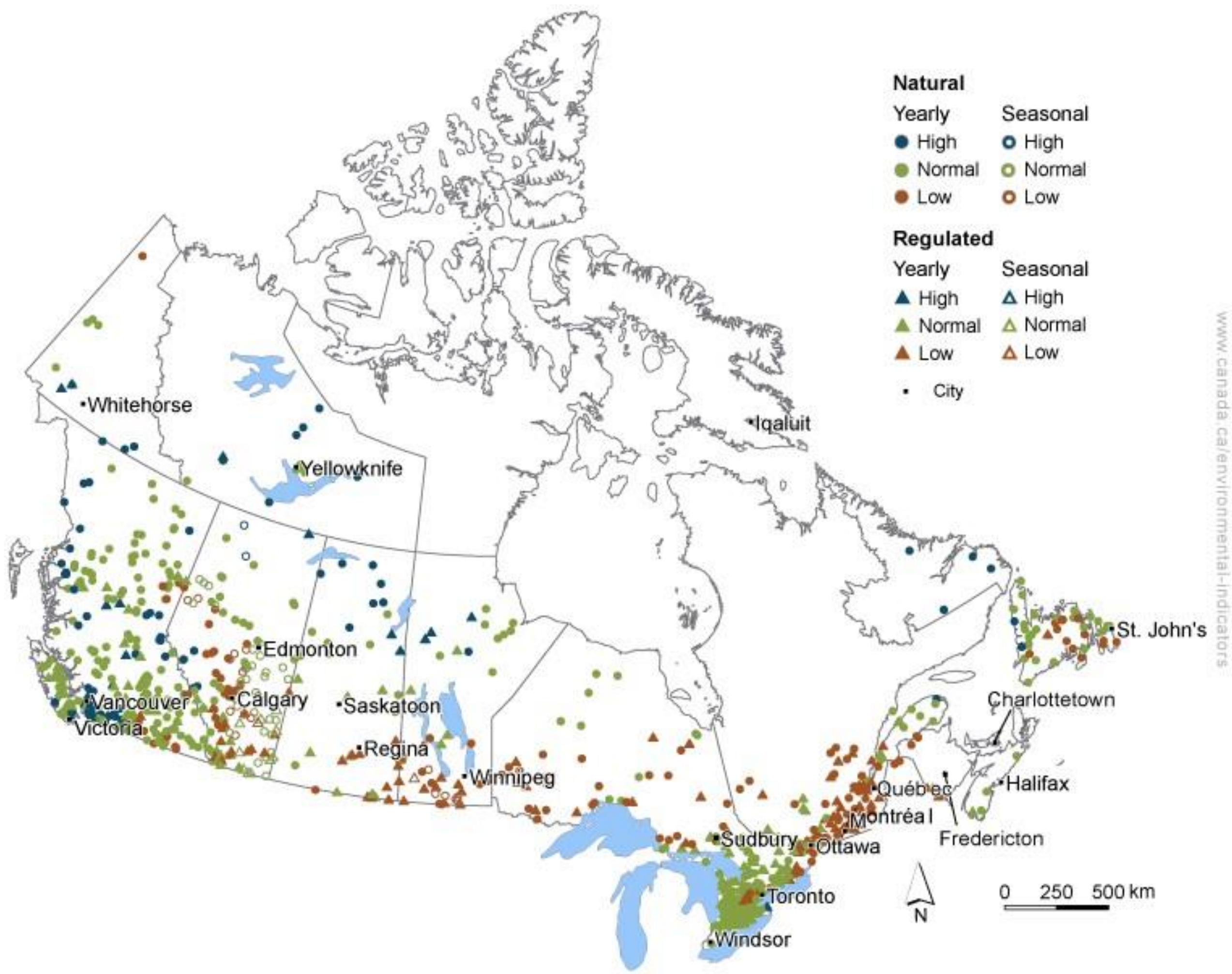
- The majority of the monitoring stations report normal water quantity conditions in any given year
- Around 20% of the monitoring stations report high water quantity conditions in any given year
- Around 20% of the monitoring stations report low water quantity conditions in any given year
- In dry years (such as the year 2001), very few stations report high water quantity conditions
- In wet years (such as the year 2011), very few stations report low water quantity conditions

Water quantity in Canadian rivers is measured as water flow or discharge measured as the volume of water per time (cubic meters per second). Water flows in rivers generally follow changes in rainfall, snowmelt, and temperature throughout the year. More precipitation increases the amount of water in rivers, whereas less rainfall or snowfall will result in less water.

Generally, water flows are highest right after the snow melts in the early spring and gradually dry up through the summer. These high and low flows can result in flooding or water shortages.

Over longer time scales, the amount of water in rivers is also affected by weather patterns and ocean surface temperatures which interact to influence the amount of rain or snow that falls. For example, extended summer droughts on the Prairies tend to take place when the southern Pacific Ocean warms during El Niño Southern Oscillation events. In an El Niño year, lower-than-normal water flows are generally seen on the Prairies. The Prairies experience more rain and snow when the ocean cools during La Niña events.[1] When this happens, higher-than-normal flows are found in the Prairies.

Figure 2. Water quantity at monitoring stations, Canada, 2021



Navigate data using the interactive map

Note: The 2021 water quantity classification for a station is based on a comparison of annual water quantity in that year with the typical annual water quantity at that station between 1991 and 2020. Normal water quantities are specific to each region and do not refer to the same amount of water in each drainage region (for example, the normal water quantity on the Prairies is different from the normal water quantity in the Maritimes). Natural stations are those where human activity upstream of the station has little impact on water flows. Regulated stations have

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[1] Bonsal B and Shabbar A (2010) Large-scale climate oscillations influencing Canada, 1900-2008. Canadian Biodiversity: Ecosystem Status and Trends 2010, Technical Thematic Report No. 4. Retrieved on September 1, 2023.

water withdrawals, dams, diversions or other structures upstream that may change the water quantity in the river. Water quantity data for seasonal stations are only collected for part of the year. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

In 2021,

- higher-than-normal water quantity was more frequent at monitoring stations in British Columbia, the northern Prairies,[2] the Northwest Territories and Labrador
- lower-than-normal water quantity was more frequent at monitoring stations in central Alberta, the southern Prairies, northern Ontario, Quebec and Newfoundland

Low water quantity

Where water quantity is classified as low, drought conditions likely exist. In Canada, droughts normally last for 1 or 2 seasons and can be very damaging. Agriculture, industry and municipalities are especially affected by long-term droughts because they rely on water. Droughts can also affect water quality in lakes and rivers, and threaten the survival of ecosystems.

An example of this is the low water quantity shown on the map across parts of southern Canada which is in line with some of the driest conditions observed across the country in 2021. Southern regions between British Columbia's Lower Mainland and Interior, to the eastern Prairies and Northwestern Ontario faced one of their driest summers in 75 years. The exceptionally dry conditions were widespread, severe and long lasting, comparable to conditions observed in the 1930s.[3]

High water quantity

High water quantity at a water quantity monitoring station indicates a wet year, but does not mean flooding has occurred. Floods tend to be short lived, lasting on average about 10 days,[4] and may not change the water quantity classification in this indicator.

An exception to this was British Columbia's flood in the fall of 2021. The southwestern region of the province received twice the normal amount of precipitation in September and October. The warm temperatures and rain melted the snow in the mountains and the region received the equivalent of one month of rain in less than 3 days. This flood was one of the largest observed on the south coast. This event followed an extraordinarily warm and dry spring and summer across the province, with very dry conditions.

In Canada, nearly every year is marked by weather extremes in parts of the country. These extreme events do not always translate into major changes in seasonal or long-term water quantity, but can be reflected when the conditions are persistent through the year.

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[2] The Prairies include the provinces of Alberta, Saskatchewan and Manitoba.

[3] Government of Canada (2021) Canada's top 10 weather stories of 2021. Retrieved on August 2, 2023.

[4] Dartmouth Flood Observatory (2004) Interannual Evolution of Flood Duration (since 1985). Retrieved August 2, 2023.

Annual water quantity at monitoring stations, Canada, 2001 to 2021

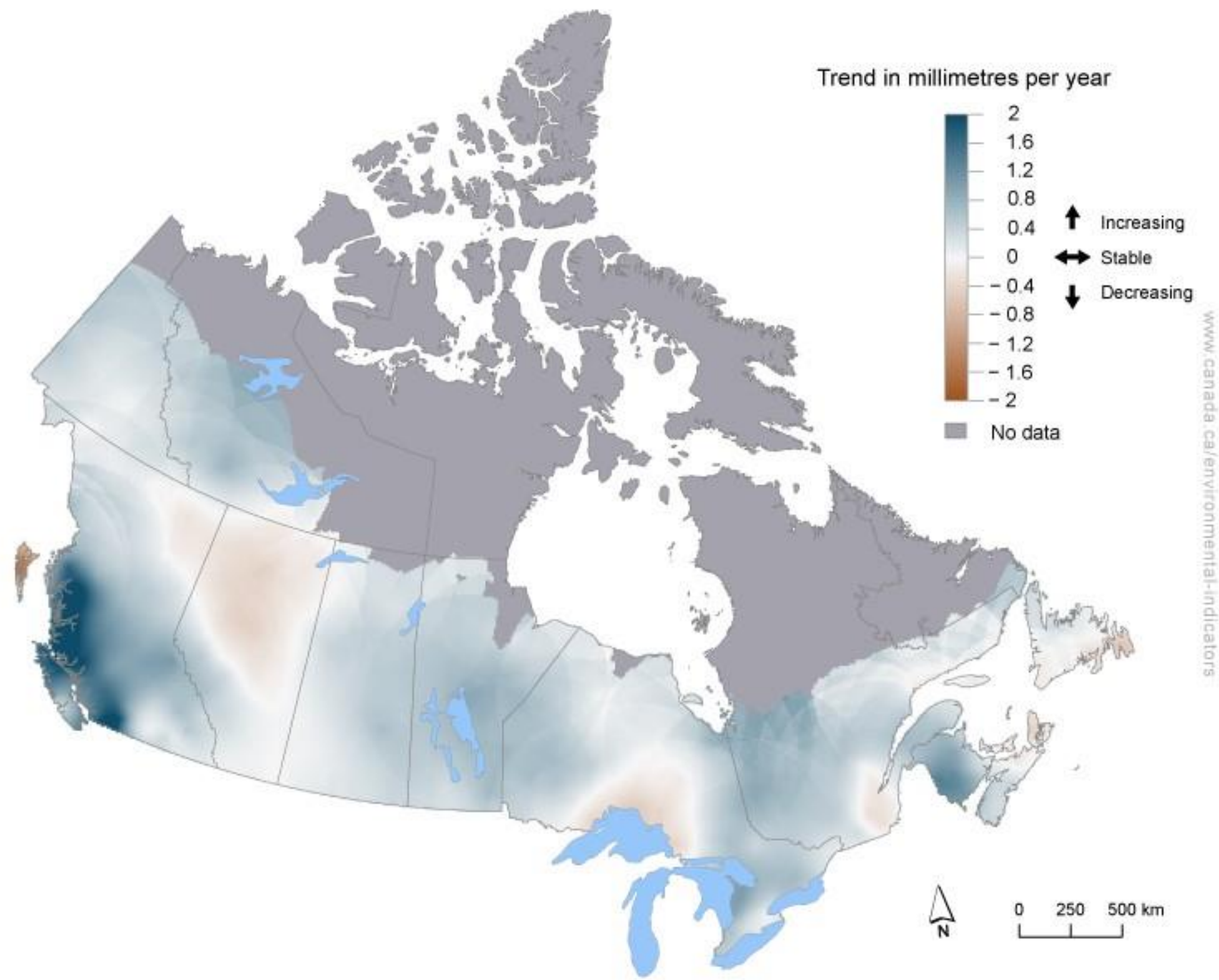
Note: The annual water quantity classifications were calculated for each monitoring station by adding the daily average water flows over an entire calendar year and dividing the total water quantity by the area of the watershed. The resulting values were compared to typical water flows over a 30-year normal period (1991 to 2020) for the station. Monitoring stations from the Reference Hydrometric Basin Network (RHBN), which is a subset of stations from the Water Survey of Canada's National water data archive (HYDAT), were used in the analysis. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

Trends in annual water quantity in Canadian rivers

Key results

- Across Canada over the 1970 to 2021 period:
    - increasing trends in annual water quantity were observed at monitoring stations in western British Columbia, Ontario, Quebec and New Brunswick
    - decreasing trends were observed in the Haida Gwaii archipelago off the north coast of British Columbia, northern Alberta, southern Ontario, southeastern Quebec and Cape Breton Island in Nova Scotia
- Over the period, the greatest increases in water flows were observed over the Coastal Mountains of British Columbia

Figure 3. Annual rate of change in water quantity at monitoring stations, Canada, 1970 to 2021



Data for Figure 3

Note: The indicator is based on a statistical analysis of annual water quantity at monitoring stations over the 1970 to 2021 period. Annual water quantity for each monitoring station was determined by adding the daily water flows for stations over an entire year and then dividing the annual totals by the area of the contributing watershed for a depth in millimetres. A statistical analysis was then applied to the resulting values to determine if there was a trend. Positive trend values indicate that the annual water quantity at a station has increased over time, negative values indicate a decrease and zero values indicate that the annual water quantity has remained the same over time. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

Across Canada, trends[5] in annual water quantity mirror trends in precipitation. Long term increases in precipitation have been observed over southern coastal British Columbia, New Brunswick, Ontario and in Québec. This is consistent with the increasing trends in annual flows observed over these regions.

For example, from 1970 to 2021, a positive trend of 3.7 millimetres per year in annual water quantity was observed at a station on the Homathko River in the Coastal Mountains of British Columbia. This positive trend translates into an increase in total water quantity of 167 millimetres (or about 12%) over the 50-year period.

In contrast, decreases in water flows have been recorded in the Athabasca and Peace River Basins.[6] In this region, a decreasing trend of -0.9 millimetres per year in annual water quantity was calculated for the station on the Wabaska River in northern Alberta. Over the 50-year period, this negative trend translates into a total decrease in water quantity of 56 millimetres (or about 52%).

Other climate factors can play a role in water quantity variations. For example, in the Mackenzie River basin in the Northwest Territories, melting permafrost may also be contributing to increasing water quantity.[8]

Trends in the number of high flow days in Canadian rivers

High flow days are used to describe days where water flows could have been high enough to cause flooding but do not necessarily represent actual recorded or reported flood events. Floods may be described by how long they last, how often they occur, or how high they rise onto the land.

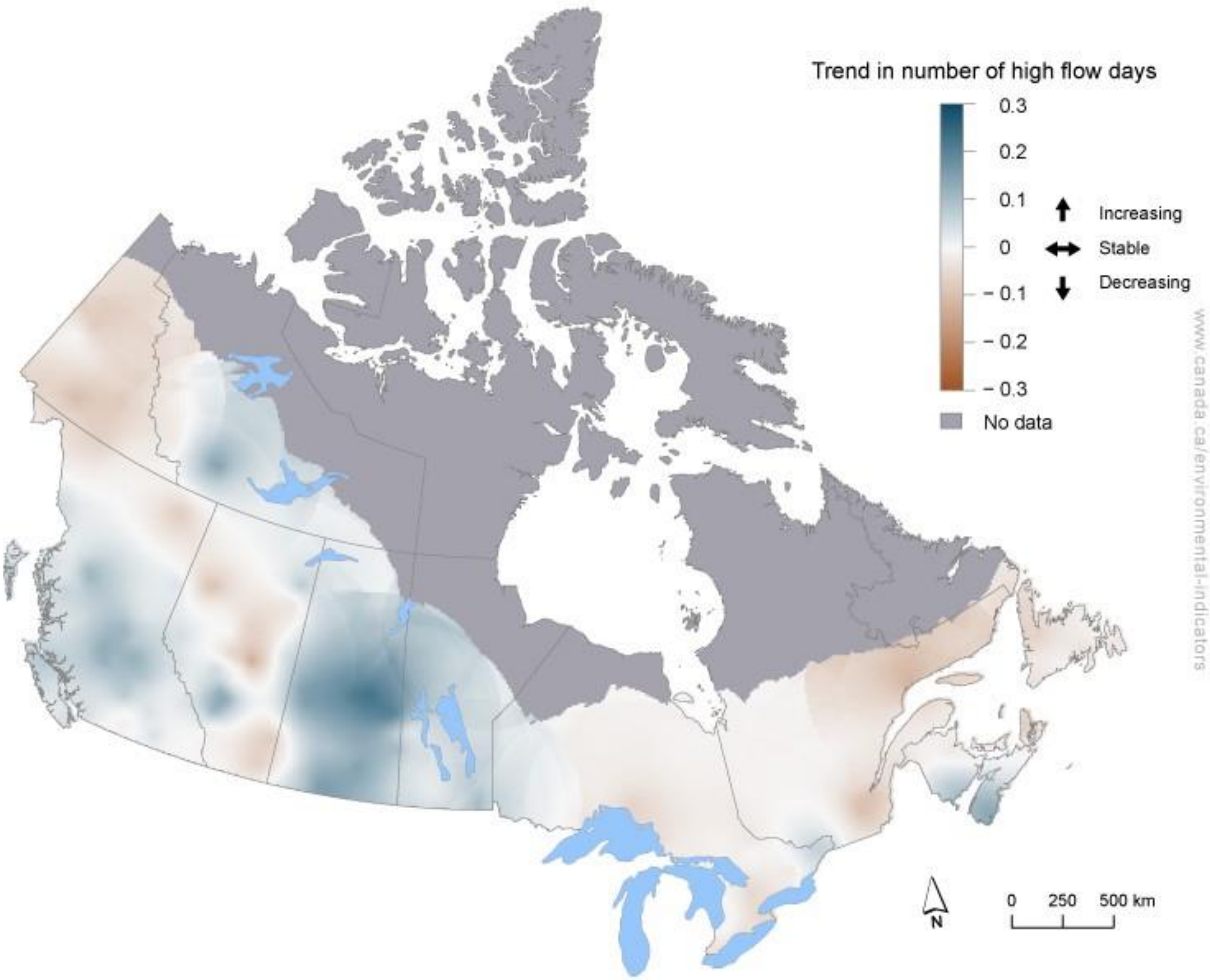
Key results

- Across Canada over the 1970 to 2021 period:
    - increasing trends in the number of high flow days were observed at monitoring stations in south-central Saskatchewan and Manitoba, with smaller increases in British Columbia, the Northwest Territories, southern New Brunswick and Nova Scotia
    - decreasing trends were observed at stations in the Yukon and central Alberta, with smaller decreases across eastern Quebec and Newfoundland

[5] The existence of a trend does not necessarily predict future trends in annual water quantity across Canada. For information on projections of future freshwater trends in Canada, see Canada's Changing Climate Report Chapter 6: Changes in freshwater availability across Canada. Retrieved on September 1, 2023.

[6] Government of Canada (2019) Canada's Changing Climate Report; Chapter 6: Changes in freshwater availability across Canada. Retrieved on September 1, 2023.

Figure 4. Annual rate of change in the number of high flow days at monitoring stations, Canada, 1970 to 2021



[Data for Figure 4]

Note: The indicator is based on a statistical analysis of the annual number of high flow days at monitoring stations over the 1970 to 2021 period. It shows the prevalence of very-high flow conditions (above the 95th percentile of all daily flow values for a monitoring station compared to a 30-year normal period from 1991 to 2020) which may be linked to flooding events, but does not necessarily represent actual recorded or reported events. Positive values indicate that the number of days with very-high flows over the 1970 to 2021 period have increased, negative values indicate a decrease, and zero values indicate that the number of high flow days have remained the same. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

The observed trends show the change in the number of days monitoring stations across Canada that have experienced very-high flows (above the 95th percentile) compared to typical flows over a 30-year normal period (1991-2020) for those stations.

For example, over the 1970 to 2021 period, the number of high flow days on Waiparous Creek in Alberta has increased from an average of 8 high flow days per year in the 1970s to an average of 20 high flow days per year in the 2010s. This contrasts with Beaurivage River in Québec where the number of high flow days has decreased from an average of 28 days per year in the 1970s to an average of 15 days per year in the 2010s.

Many factors can contribute to flooding, including intense and/or long-lasting precipitation, snowmelt, ice jams on rivers or rain-on-snow events. Rising temperatures, along with reductions in snow cover, may also reduce the frequency and magnitude of snowmelt-related flooding.[7] The regional variations observed above could be explained by a combination of these factors.

Trends in the number of low flow days in Canadian rivers

Droughts may be defined as meteorological, agricultural, socioeconomic or hydrological.[8] This indicator presents trends in hydrological droughts in rivers during the summer, meaning days with very-low flows.

Key results

- Across Canada over the 1970 to 2021 period:
  - increasing trends in the number of low flow days were observed at monitoring stations along the west coast of the country, northern Manitoba, Ontario, Quebec and the Maritimes
  - decreasing trends were observed at stations in southern Northwest Territories, most of the Prairies and Newfoundland

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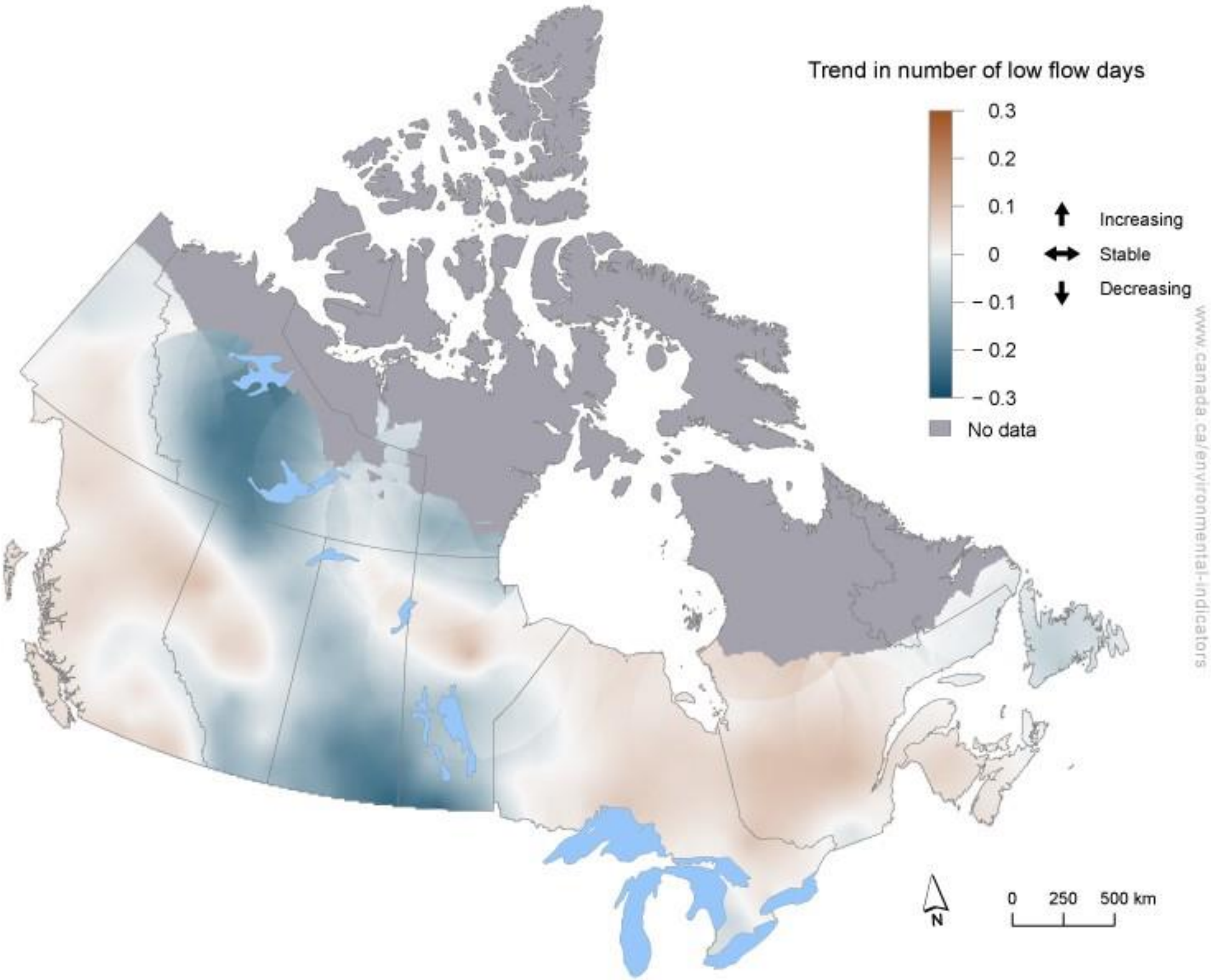
[7] Government of Canada (2019) Canada's Changing Climate Report; Chapter 6: Changes in freshwater availability across Canada. Retrieved on September 1, 2023.

[8] Drought is a prolonged dry period in the climate cycle and there are 4 ways it can be defined: meteorological (when rainfall and snowfall is lower than normal), agricultural (when amount of moisture in soil no longer meets needs of crop plants), socioeconomic (when water shortages begin to affect people) and hydrological (when water supplies in lakes, rivers and groundwater are lower than normal).

Figure 5. Annual rate of change in the number of low flow days at monitoring stations, Canada, 1970 to 2021



Data for Figure 5

Note: The indicator is based on a statistical analysis of the annual number of low flow days at monitoring stations over the 1970 to 2021 period. It shows the prevalence of very-low flow conditions during the summer[20] (when daily flow values fall outside a threshold[21] of all daily flow values for a monitoring station compared to a 30-year normal period from 1991 to 2020) which may be linked to drought events, but does not necessarily represent actual recorded or reported events. Positive values indicate that the number of days with very-low flows over the 1970 to 2021 period have increased, negative values indicate a decrease, and zero values indicate that the number of days have remained the same. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

The observed trends show the change over 50 years in the number of days in summer when monitoring stations across Canada experienced very-low flows (when daily flow values fell outside of a threshold) compared to typical flows during a 30-year normal period for those stations.

Many factors can contribute to low flows including deforestation, wildfires, surface water and groundwater withdrawls, river diversions,dams, low precipitation,and evapotranspiration.[9] The regional variations in flows can be explained by combinations of these factors. The indicator integrates the responses from the factors listed

[9] Evapotranspiration is evaporation from waterbodies, soils and plants.

above but does not measure whether there is enough water to meet the needs of people and ecosystems relying on the available water.

The Prairies are more likely to experience drought because of a combination of interrelated factors such as semi-arid climate, location and weather patterns, topography and land cover, as well as historical variability. The Prairies are located inland, far from the moisture sources (oceans), resulting in lower precipitation. Air masses moving eastward are forced to rise over the Rocky Mountains. As the air rises, it cools and releases moisture in the form of precipitation. By the time these air masses reach the Prairies, they have already lost much of their moisture, creating a rain shadow effect where the eastern side of the Rockies (including the Prairies) receives less rainfall. The Prairies have a semi-arid climate with lower average precipitation compared to other parts of Canada. This inherent dryness makes the region more susceptible to drought conditions. Even small variations in precipitation levels can have a significant impact on the availability of water resources. The Prairies have large grassland areas which are more susceptible to moisture loss through evaporation and transpiration, exacerbating the effects of dry conditions. Moreover, agricultural practices and land use changes can also impact the land's ability to retain moisture. The Prairies have a history of experiencing natural climate variability, including periods of drought. These historical trends suggest that the region is more prone to fluctuations in precipitation and the occurrence of extended dry periods.[10]

[10] Bonsal et al. (2011) Drought Research in Canada: A review, Atmosphere-Ocean, 49(4):303-319. doi: 10.1080/07055900.2011.555103

About the indicator

What the indicator measures

The indicator provides a national summary of the annual water quantity status in rivers across Canada from 2001 to 2021 and by monitoring station in 2021.

A station's water quantity status is determined by comparing the measured annual water quantity to typical water quantity observed at that site for 1991 to 2020. A station described as having a low water quantity had a measured value ranking among the lowest 15% of values observed from 1991 to 2020. A station described as having a high water quantity had a measured value ranking among the highest 15% of values observed from 1991 to 2020.

The indicator also offers trends that provide an assessment of whether there have been significant observed changes over time in water quantity, of very-high and very-low flows, at monitoring stations across Canada from 1970 to 2021.

Why the indicator is important

Canada has 0.5% of the world's population and approximately 7% of the world's renewable freshwater supply. Canada may have a lot of water, but water is in short supply in some parts of the country. Canadians use a lot of water in agriculture, in industry and in their homes.

The indicator provides information about the state of the amount of surface water in Canada and its change through time to support water resource management.

Related initiatives

The indicator supports the measurement of progress towards the following 2022 to 2026 Federal Sustainable Development Strategy long-term Goal 6: Ensure clean and safer water for all Canadians.

In addition, the indicators contribute to the Sustainable Development Goals of the 2030 Agenda for Sustainable Development. They are linked to the 2030 Agenda's Goal 6: Clean water and sanitation.

Related indicators

Canada's water use in a global context indicator reports on the amount of water removed from the environment per person per year for use in agriculture, manufacturing and in homes, and as a percentage of each country's total renewable water supply for 9 countries, including Canada.

Data sources and methods

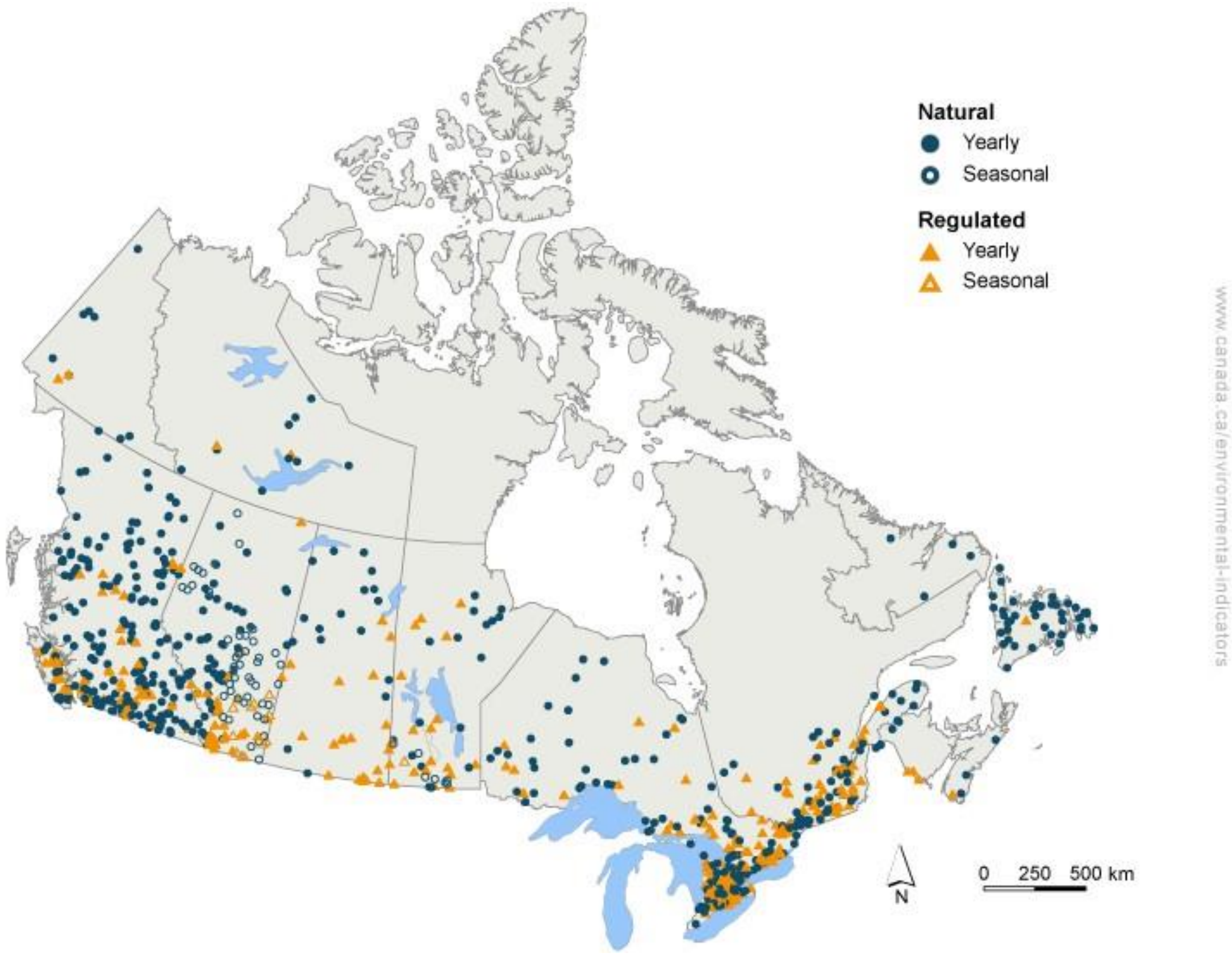
Data sources

Water flow data across Canada for 1970 to 2021 are taken from the Water Survey of Canada's National water data archive (HYDAT).

More information

For 2021, the national indicators include data from 814 continuous (yearly) and seasonal monitoring stations across Canada. At continuous monitoring stations, water flow data are collected 365 days per year. In general, seasonal monitoring stations operate 6 or 7 months per year. Both natural and regulated rivers and all basin sizes were included.

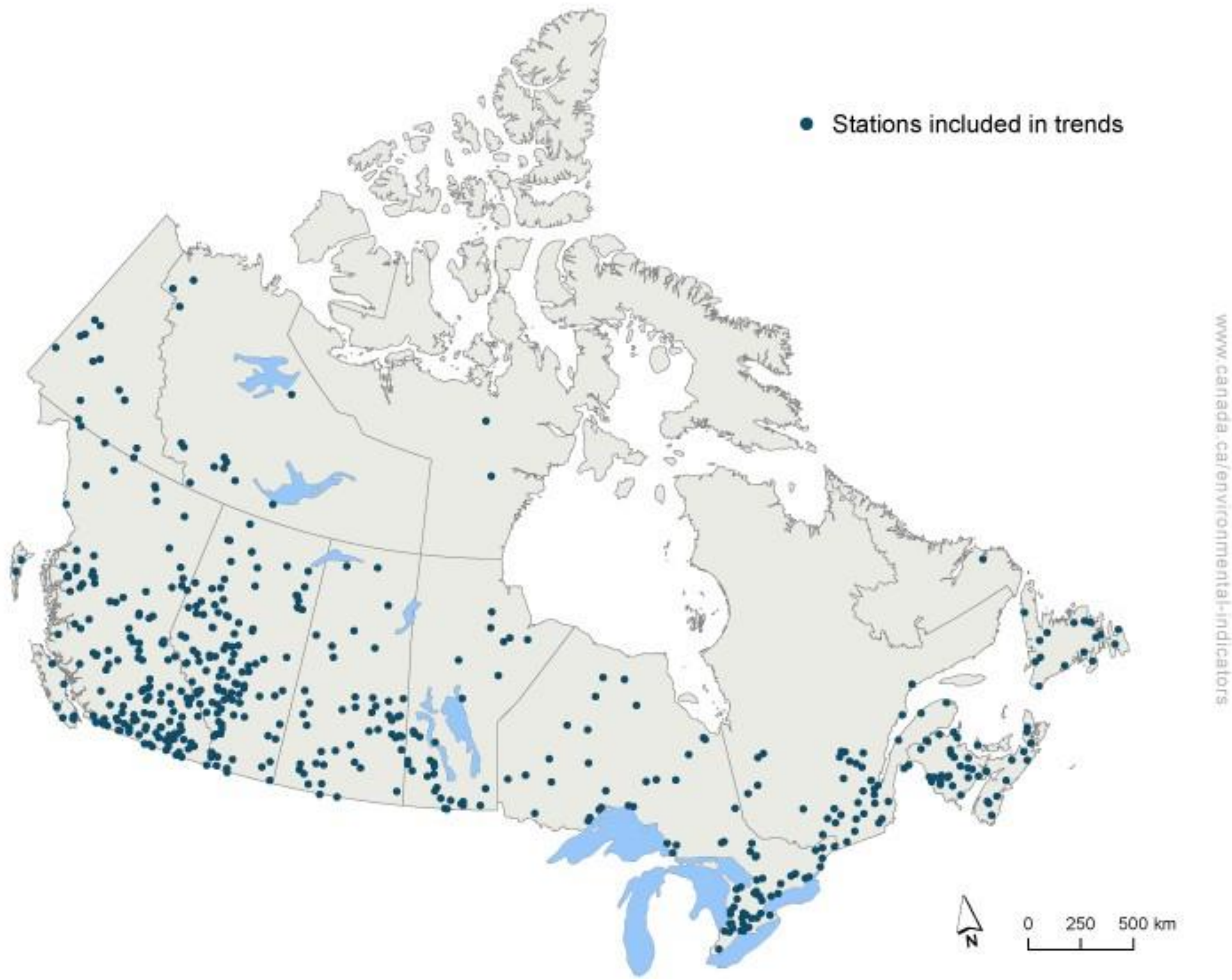
Figure 6. Location of water quantity monitoring stations used for the national indicators, 2021



Note: Natural stations are those where human activity upstream of the station has little impact on water flow. Regulated stations have water withdrawals, dams, diversions or other structures upstream that may change the quantity of water in the river. Water quantity data at seasonal stations are only collected for part of the year.
Source: Environment and Climate Change Canada (2023) Water Survey of Canada.

The trends in annual water quantity, the trends in the number of high flow days and the trends in the number of low flow days indicators include data from 444, 478 and 600, respectively, of 1 014 flow stations across Canada classified as part of the Reference Hydrometric Basin Network (RHBN) which is a subset of HYDAT (Figure 7). The RHBN is a set of stream gauge stations with long records and minimal human impacts that are considered appropriate for studying the potential impacts of climate change on water quantity in Canada.

Figure 7. Location of water quantity monitoring stations used for the trends indicators, 1970 to 2021



Note: All stations with sufficient data to calculate trends are included on this map, though each station did not necessarily have sufficient data to calculate all 3 trend indicators. All stations are part of the Reference Hydrometric Basin Network (RHBN).
Source: Environment and Climate Change Canada (2023) Water Survey of Canada.

Data completeness

Water flow data from each monitoring station are managed by their respective Environment and Climate Change Canada regional offices and stored in the federal HYDAT database. The data used in the indicators are subject to quality assurance and quality control procedures to ensure they adhere to Environment and Climate Change Canada's national standards.

There are gaps in the water flow datasets due to periodic instrument failure. Where possible, regional offices use standardized protocols to estimate flow data to fill these gaps. Estimated flow values are considered to be reliable and are included in the calculation of the water quantity indicators. Only when data cannot be estimated are they considered missing.

For the national indicators, a complete dataset was defined as one having data available for at least 80% of the year:

- 292 days out of 365 for continuous stations, and
- 174 days out of 217 for seasonal stations

Stations not meeting these criteria for a year were not included in the calculation of the indicators for that year.

For the trends indicators, annual water quantity was calculated for stations with sufficient data for each year from 1970 to 2021. Data were considered sufficient when daily flow data was available for 90% (329 days) of the days with recordings at a station in that year.

In order for a station to be included in the trend calculations the following conditions had to be met:

- valid data starting in or before 1975, and
- no gaps of more than 10 years in the data record, and
- valid data for at least 30 years in the period 1970 to 2021

Additional requirements were used for the calculations of trends in the number of high flow and low flow days indicators, which used thresholds calculated from a 30-year normal period[11] from 1991 to 2020. To be included in indicator calculations, stations had to have at least 150 days of valid flow data per year and at least 20 years of data in the normal period. An additional requirement for the trend in number of low flow days for stations with intermittent flows, stations with flowing water during only certain times of the year, was the presence of at least 11 dry spells[12] during the normal period in order to accurately estimate the distribution of the data.

Data timeliness

Data for the indicators were taken from the July 2023 version of HYDAT.

There is a time lag of about 2 years between the last year reported and the publication of the indicators. This time lag is due to several factors, including the time required to verify the raw data, compile the data at the national level from all partners, and analyze, review and report the data.

Methods

National water quantity

The water quantity at a station is classified as low, normal or high by comparing annual water flow values for each station to the 30-year normal values for that station. Specifically, annual water flow for each monitoring station was calculated by adding the daily water flows for stations over an entire year and then dividing the annual totals by the area of the contributing watershed. The resulting annual value was then compared to typical water flows over a 30-year normal period from 1991 to 2020 for the station to determine the station's status for the year. For the national indicators, the percentage of stations in each category was calculated and then presented for each year from 2001 to 2021 as well as the status for each station across Canada in 2021.

Trends in annual water quantity

For the trends in annual water quantity indicator, annual water quantity for each monitoring station was also calculated by adding the daily water flows for stations over an entire year and then dividing the annual totals by the area of the contributing watershed. Dividing the totals by the watershed area allows for direct comparisons to be made between watersheds of different sizes. The resulting annual water quantity values, expressed in millimetres, can be thought of as the volume of annual flow per contributing area. A Mann-Kendall test was used to assess whether there was a statistically significant increasing or decreasing trend in the annual water quantity at a station over the 1970 to 2021 period. If there was no positive or negative trend, a Wald-Wolfowitz test was used to determine if the annual water quantity over the 1970 to 2021 period was stable.

Trends in the number of high flow days

For the trends in the number of high flow days indicator, the daily flow values for a station were compared to a threshold set at the 95th percentile of all daily flows during a 30-year normal period from 1991 to 2020 for that station to determine days with very-high water flows. A negative binomial test or Hurdle-negative binomial test

[11] The 30-year normal for a station refers to the typical water quantity values that were observed at that monitoring station between the 1991 to 2020 period.

[12] Dry spells are periods are defined as the number of days (April 1 – October 31) where daily precipitation is less than 0.5 mm. For more information, consult Dry Spell - Open Government Portal (canada.ca)

was used to determine if there was a trend in the number of days with very-high flow over the 1970 to 2021 period. If there wasn't a positive or negative trend, a Wald-Wolfowitz test was used to determine if the number of days with very-high flow over the 1970 to 2021 period was stable.

Trends in the number of low flow days

For the trends in the number of low flow days indicator, the summer daily flow values for a station were compared to a threshold determined by the type of stream at the station. Summer was defined as the period between peak spring flow (presumably due to snowmelt) and October 1, unless peak spring flow occurred before May 1 in which case the period was May 1 to October 1. Two (2) stream types were defined:

- perennial streams, where water typically flows all summer long. For these streams, the threshold was set at the 1-in-5-year, 7-day average minimum flow during the 30-year normal period and low flows were defined as those when flows dipped below the threshold. Additional criteria for very-low flow days were set using the streamflow deficit method[13] to eliminate short periods with flows near the threshold; specifically, low flow events were combined if they occurred less than 5 days apart and the volume of water resulting from the period between these events was not enough to cover the water deficit associated with these low flow events. Events were also eliminated if they lasted less than 5 days;
- intermittent streams, where the stream typically runs dry for a period of the summer. For these streams, the threshold was set at the 90th percentile of dry spell duration cumulative distribution following the consecutive dry period method[14] and dry spell days in excess of the threshold were counted as low flow days. Streams were classified as intermittent if, during the summers of the 30-year normal period: more than 25% of the 7-day average minimum flow values were 0, the 1-in-5-year low flow was less than 0.001 m^3/s, or it was not possible to calculate a 1 in 5 year return frequency low flow.

A negative binomial test or Hurdle-negative binomial test was used to determine if there was a trend in the number of days with very-low flow over the 1970 to 2021 period. If there was no positive or negative trend, a Wald-Wolfowitz test was used to determine if the number of days with very-low flow over the 1970-2021 period was stable.

More information

Data extraction

Basic station information and water flow data were extracted from HYDAT according to input parameters, such as record length, data type and drainage area. Scripts in the R computer programming language[15] were used to extract data from HYDAT and calculate the indicators.

Categorizing water quantity at a monitoring station for the national indicators

Water quantity at a monitoring station is classified based on historical data recorded at Water Survey of Canada hydrometric stations. To start, frequency distributions for annual water quantity were calculated using water flow data collected from 1991 to 2020 at each monitoring station. A 30-year period is used to provide a summary of the hydrologic characteristics of a station, while maximizing the number of stations included in the indicators.

Water quantity categories were defined from the frequency distributions:

- low < 15th percentile
- 15th percentile ≤ normal ≤ 85th percentile
- high > 85th percentile

Annual water quantity records for 2001 to 2021 were categorized as low, normal or high by comparing the measured value to the percentiles calculated for the corresponding station over the normal period.

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[13] World Meteorological Organization (2008) Manual on low-flow estimation and prediction. ISBN: 978-92-63-11029-9.

[14] Van Huijgevoort MHJ et al. (2012) A generic method for hydrological drought identification across different climate regions. Hydrology and Earth System Sciences. 16(8): 2437-2451. doi: 10.5194/hess-16-2437-2012.

[15] R Core Team (2019) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. Retrieved on September 1, 2023.

Accordingly, a station described as having a low water flow in 2021, for example, had a measured value ranking among the lowest 15% of the values observed from 1991 to 2020.

Table 1. Number of water quantity monitoring stations used in the national indicators grouped by province and territory, 2021

Province or territory	Number of stations
Newfoundland and Labrador	37
Prince Edward Island	n/a
Nova Scotia	2
New Brunswick	3
Quebec	81
Ontario	233
Manitoba	40
Saskatchewan	38
Alberta	124
British Columbia	240
Yukon	6
Northwest Territories	10
Nunavut	n/a

Note: n/a = not available. For 2021, there were not enough data to represent water quantity for Nunavut and Prince Edward Island. Stations located in the United States are counted in the adjacent territory or province, to which the water flows.

Calculating the Trends in annual water quantity, the Trends in the number of high flow days, and the Trends in the number of low flow days indicators

A Mann-Kendall test was used to assess the presence (or the absence) of consistently increasing or decreasing trends in annual water quantity over the 1970 to 2021 period. This is a statistical process commonly used to analyze data collected over time. The slope of the trend line is based on the Theil-Sen Estimator[16] which calculates the median of the slopes through all pairs of points and can robustly handle most point distributions. For the resulting trends expressed in millimetres, a positive value indicates that the annual average water quantity at a station has increased over the period, a negative value indicates a decrease, and a zero value indicates no statistically significant change over the period. If no positive or negative trend was detected with the Mann-Kendall test, a Wald-Wolfowitz stationarity test was used to determine if the values at the station were stable over time.

In the case of the number of high and low flow days indicators, to assess the presence of trends, Negative Binomial, Hurdle-Negative Binomial and Wald-Wolfowitz tests were used. These tests work in cases where the same indicator value occurs in multiple years, as is the case for the number of high or low flow days for many stations. The Negative Binomial test was used for stations with less than 3 years with zero high or low flow days and the Hurdle-Negative Binomial test was used for stations with 3 or more years with zero high or low flow days. If no positive or negative trend was detected with the first 2 tests, a Wald-Wolfowitz stationarity test was used to determine if the values at the station were stable over time. The indicators are meant to show the trends in the prevalence of very-high or very-low flow conditions across Canada over the 1970 to 2021 period and may not necessarily represent actual recorded or reported flood or drought events.

[16] Theil H (1950) A rank-invariant method of linear and polynomial regression analysis. I, II, III, Nederlandse Akademie van Wetenschappen, Proceedings, 53: 386 to 392, 521 to 525, 1397 to 1412., Sen Pranab Kumar (1968) Estimates of the regression coefficient based on Kendall's tau. Journal of the American Statistical Association 63 (324): 1379 to 1389, doi:10.2307/2285891.

Trends calculated are assessed for potential outliers[17] using Rosner's test.[18] Outlier trends occur mostly at stations when over the 50-year period, there are very few years with low flow days (10% or less) or there was a sharp change in the number of low flow days (as determined using Pettitt's test[19]). Confirmed outlier trends were eliminated from further calculations.

The trends for the high flow days and low flow days is represented in the maps considering the number of days for each station considered in the calculation. The data in the Annex section represents the percentage of those stations in high flow days or low flow days according to the province or the territory.

Interpolation

Kriging was used to interpolate data from stations locations onto a surface map. A semi-variogram model was created to describe the influence of the station value on the areas around it and used to estimate values in areas with no data. A minimum of 8 data points within a 500 kilometre radius are necessary to estimate a value. In certain areas of the country such as the North of Quebec, there was not enough data points to successfully perform kriging. As a result, no trend indicator is shown on the maps for these regions. The kriging operation smooths the data so that a small percentage of very-high and very-low values don't appear as extreme on the map. For example, the trends in annual water quantity values vary from -7.1 to 8.5 mm/year, yet the kriged data ranges from -1.7 to 2.7 mm/year. Overall, 93% of the original data fall within the range of the kriged data.

Recent changes

The methodology to calculate the National water quantity at monitoring stations was revised this year to compare annual water quantity with the 15th and 85th percentiles of typical annual flow during the 30-year normal period. Previous calculations compared the most frequently observed flow condition in a given year with the 25th and 75th percentiles of typical water quantity. Even though both methods produce similar results, the percentiles used are different and this method has a more rigorous accounting for all the water flowing at each station for the year.

The methodology to determine trends has been augmented by a stationarity test to identify those stations where values are stable over time. Previously these stations had been classified as uncertain.

The 30-year reference period for current calculations is 1991 to 2020 because these are the 3 most recent decades for which data is available. In the previous publication, the 30-year reference period was 1981 to 2010 since they were the most recent data available then.

One (1) new indicator has been added to the content: Trends in the number of low flow days in Canadian rivers. This new indicator provides an assessment of whether there have been significant observed changes over time in the number of low flow days at monitoring stations across Canada from 1970 to 2021.

Coverage of the trends analysis for the mapping presentation were also updated by using different assumptions and interpolation methods. Currently, the surface maps are interpolated using inverse distance weighing, which preserve spatial variability when there is spatial autocorrelation in data. As a result, the north of the country does not have enough data points to preserve spatial variability and cannot be calculated for this region.

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[17] Outliers are values much higher or much lower than would be expected given all the other values.

[18] Rosner B (1983) Percentage Points for a Generalized ESD Many-Outliers Procedure. Technometrics. 25(2): 165-172.

[19] Pettitt AN (1979) A non-parametric approach to the change point problem. Journal of the Royal Statistical Society Series C, Applied Statistics. 28: 126-135.

Caveats and limitations

Some short duration events, including some floods, may not influence the final water quantity classification of a station. Changes to seasonal flow patterns will also affect final classifications.

The status of water quantity assessed by the present indicators is a reflection of the 30-year time period used for the calculations and does not necessarily reflect longer-term trends at the station. Trend maps are only representative of the time period analyzed (1970 to 2021) and may be influenced by long-term climatic fluctuations.

Water flow data collected at a monitoring station are representative of the average conditions of the upstream drainage area. Professional judgment is used to determine whether there were enough stations to describe water quantity in a drainage region.

More information

Extreme short-term events may not be detected with the indicators, since the focus is on frequency of observations in different categories through the year. The Trends in the number of low flow days indicator has been added to help characterize this important aspect of water quantity.

Water quantity generally follows a predictable seasonal pattern with natural, year-to-year variability. The indicators compare daily values to the 30-year normal and assume that water quantity is approximately the same from one year to the next for the same calendar day. A shift in the predictable seasonal pattern (the hydrograph) for one year will influence the results.

Most water quantity monitoring stations in Canada are located in populated areas and do not represent the country's entire geographic extent or all its watersheds.

While 30 years represent a long time series for water quantity data, it represents a relatively short historical time frame for a given river and does not account for all natural variability in a river system.

The number of water quantity monitoring stations included in these indicators fluctuates from year to year because stations may be closed as monitoring networks are optimized. Whether or not the data have been verified and uploaded into HYDAT by the time the data are extracted to calculate the indicator also influences whether the station is included in the calculation that year.

Resources

References

Environment and Climate Change Canada (2021) Real-time Hydrometric Data. July 2023 version. Retrieved on August 2, 2023.

Environment and Climate Change Canada (2021) Water Survey of Canada. Retrieved on August 2, 2023.

Statistics Canada (2003) Standard Drainage Area Classification. Retrieved on August 2, 2023.

Related information

Canada's changing climate report: Changes in freshwater availability across Canada

El Niño

La Niña

Large-scale climate oscillations influencing Canada

Ratio of surface freshwater intake to water yield

Annex

Annex A. Data tables for the figures presented in this document

Table A.1. Data for Figure 1. Water quantity at monitoring stations, Canada, 2001 to 2021

Year	Total number of stations	High quantity (percentage of stations)	Normal quantity (percentage of stations)	Low quantity (percentage of stations)
2001	1 075	6	52	42
2002	1 070	6	68	26
2003	1 101	3	76	22
2004	1 095	6	80	13
2005	1 086	20	75	5
2006	1 096	20	64	15
2007	1 103	21	57	22
2008	1 105	31	60	10
2009	1 108	16	65	18
2010	1 112	11	61	28
2011	1 104	40	57	3
2012	1 115	14	63	23
2013	1 112	24	69	7
2014	1 122	27	68	5
2015	1 100	7	71	23
2016	1 073	9	83	8
2017	1 035	23	73	4
2018	1 069	14	75	10
2019	1 043	18	64	18
2020	963	31	62	7
2021	814	11	60	29

Note: Percentages may not add up to 100 due to rounding. The water quantity classification for a station is based on a comparison of the annual water quantity in a given year with the typical annual water quantity at that station between 1991 and 2020. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

Table A.2. Data for Figure 3. Annual rate of change in water quantity at monitoring stations, Canada, 1970 to 2021

Province or territory	Total number of stations	Increasing trend (percentage of stations)	Stable trend (percentage of stations)	Decreasing trend (percentage of stations)	Uncertain (percentage of stations)
Newfoundland and Labrador	17	24	53	18	6
Prince Edward Island	1	0	100	0	0
Nova Scotia	12	17	50	25	8
New Brunswick	27	63	37	0	0
Quebec	31	45	29	26	0
Ontario	77	44	40	16	0
Manitoba	22	77	14	5	5
Saskatchewan	24	62	21	12	4
Alberta	53	26	38	32	4
British Columbia	151	45	41	9	5
Yukon	13	46	38	8	8
Northwest Territories	14	71	14	7	7
Nunavut	2	100	0	0	0

Note: Percentages may not add up to 100 due to rounding. The indicator is based on a statistical analysis of annual water quantity at monitoring stations over the 1970 to 2021 period. Annual water quantity for each monitoring station was determined by adding the daily water flows for stations over an entire year and then dividing the annual totals by the area of the contributing watershed for a depth in millimetres. A statistical analysis was then applied to the resulting values to determine if there was a trend. Positive trend values indicate that the annual water quantity at a station has increased over time, negative values indicate a decrease and zero values indicate that the annual water quantity has remained the same over time. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

Table A.3. Data for Figure 4. Annual rate of change in the number of high flow days at monitoring stations, Canada, 1970 to 2021

Province or territory	Total number of stations	Increasing trend (percentage of stations)	Stable trend (percentage of stations)	Decreasing trend (percentage of stations)	Uncertain (percentage of stations)
Newfoundland and Labrador	17	12	47	35	6
Prince Edward Island	1	100	0	0	0
Nova Scotia	10	40	40	20	0
New Brunswick	27	22	63	15	0
Quebec	34	0	71	29	0
Ontario	58	12	64	24	0
Manitoba	21	14	76	5	5
Saskatchewan	37	62	27	0	11
Alberta	115	14	71	10	5
British Columbia	133	20	69	5	6
Yukon	13	8	62	31	0
Northwest Territories	12	33	50	17	0
Nunavut	0	0	0	0	0

Note: Percentages may not add up to 100 due to rounding. The indicator is based on a statistical analysis of the annual number of high flow days at monitoring stations over the 1970 to 2021 period and represent the percentage of all the stations for the province or territory. The indicator shows the prevalence of very-high flow conditions (above the 95th percentile of all daily flow values for a monitoring station compared to a 30-year normal period from 1991 to 2020) which may be linked to flooding events, but does not necessarily represent actual recorded or reported events. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

Table A.4. Data for

Figure 5. Annual rate of change in the number of low flow days at monitoring stations, Canada, 1970 to 2021

Province or territory	Total number of stations	Increasing trend (percentage of stations)	Stable trend (percentage of stations)	Decreasing trend (percentage of stations)	Uncertain (percentage of stations)
Newfoundland and Labrador	17	35	24	41	0
Prince Edward Island	1	0	100	0	0
Nova Scotia	11	45	27	27	0
New Brunswick	27	56	37	4	4
Quebec	46	59	13	24	4
Ontario	79	54	16	25	4
Manitoba	41	20	10	56	15
Saskatchewan	64	16	11	59	14
Alberta	120	36	16	46	2
British Columbia	153	61	18	19	1
Yukon	14	57	7	36	0
Northwest Territories	20	15	10	70	5
Nunavut	7	14	29	43	14

Note: Percentages may not add up to 100 due to rounding. The indicator is based on a statistical analysis of the annual number of low flow days at monitoring stations over the 1970 to 2021 period and represent the percentage of all the stations for the province or territory . It shows the prevalence of very-low flow conditions during the summer[20] (when daily flow values fall outside a threshold[21] of all daily flow values for a monitoring station compared to a 30-year normal period from 1991 to 2020) which may be linked to drought events, but does not necessarily represent actual recorded or reported events. For more information, please see the Data sources and methods section.
Source: Environment and Climate Change Canada (2023) National Water Data Archive (HYDAT).

[20] The summer period is defined as the period between peak spring flow due to snowmelt and October 1, unless peak spring flow occurs before May 1 in which case the period is May 1 to October 1.

[21] Thresholds are used to define low flows in rivers and the indicator is the number of days during summer when flows fall outside the threshold. Different types of thresholds are used for streams that flow all year and streams that typically run dry for periods of the summer. For more information, please see the Data sources and methods section.

Additional information can be obtained at:

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