ALBERTA-NWT TRANSBOUNDARY
WATER QUANTITY
FOR SLAVE AND HAY RIVERS

2018 | 2019

QUANTITÉ DES EAUX TRANSFRONTALIÈRES ENTRE L'ALBERTA ET TNO
POUR LA RIVIÈRE DES ESCLAVES ET LA RIVIÈRE AU FOIN

A technical companion report to the

Alberta-Northwest Territories Bilateral Management Committee Annual Report to Ministers 2018-2020

03 November 2021

Prepared by:

Ryan F. Connon, Ph.D.
Hydrologist,
Water Management and Monitoring Division,
Environment and Natural Resources,
Government of the Northwest Territories

- - and - -

Carmen de la Chevrotière, P.Eng.
Transboundary Team Lead,
Resource Stewardship Division,
Alberta Environment and Parks,
Government of Alberta

Table of Contents

Executive Summary

The 2018 and 2019 Alberta-Northwest Territories Transboundary Water Quantity Technical Report provides an overview of 2018 and 2019 hydrology and water quantity data in the Hay and Slave River basins. Total annual streamflow in the Slave River was slightly lower than average in both 2018 (93% of normal) and 2019 (88% of normal), while total annual flow in the Hay River was lower than average (59% of normal) in 2018 and much lower than average (39% of normal) in 2019. On the Slave River, annual consumptive use was well below the 2.0 billion m^3 threshold, at 1.2 billion m^3 in 2018 and 1.3 billion m^3 in 2019. The pre-defined threshold of 2.0 billion m^3 remained at 1.9% of the long-term mean annual streamflow. Transfers out of the Mackenzie River basin remain a very small portion of the allocation for all years including 2018 and 2019. The total volume of groundwater and surface water allocation in the Hay River basin exceeded 2.5% of the natural flows at the border in five months (January, February, March, April, and December) in 2018 and three months in 2019 (January, February, and March). This exceeded Trigger 1 and prompted analysis of the actual water use for Trigger 2. The actual water use for all months in both 2018 and 2019 was below 2.5% of natural border flows, well below the Trigger 2 threshold of 4%.

Sommaire

Le rapport technique sur la quantité des eaux transfrontalières entre l’Alberta et les Territoires du Nord-Ouest de 2018 et 2019 donne une vue d’ensemble des données hydrologiques et hydrométriques en 2018 et 2019 dans les bassins de la rivière des Esclaves et de la rivière au Foin. Le débit annuel total de la rivière des Esclaves était légèrement inférieur à la moyenne tant en 2018 (93 % de la normale) qu’en 2019 (88 % de la normale), tandis que le débit annuel total de la rivière au Foin était inférieur à la moyenne (59 % de la normale) en 2018 et bien inférieur à la moyenne (39 % de la normale) en 2019. Sur la rivière des Esclaves, la consommation annuelle a été bien en deçà du seuil de 2 milliards de m^3, soit 1,2 milliard de m^3 en 2018 et 1,3 milliard de m^3 en 2019. Le seuil prédéfini de 2 milliards de m^3 est resté à 1,9 % du débit annuel moyen à long terme. Les transferts hors du bassin du Mackenzie restent un très petit pourcentage de l’allocation pour toutes les années, y compris 2018 et 2019. Le volume total de l’allocation des eaux souterraines et de surface dans le bassin de la rivière au Foin a dépassé de 2,5 % les débits naturels à la frontière pendant cinq mois (janvier, février, mars, avril et décembre) en 2018 et trois mois (janvier, février et mars) en 2019, ce qui a dépassé le déclencheur 1 et donné lieu à une analyse de l’utilisation réelle de l’eau pour le déclencheur 2. L’utilisation réelle de l’eau pour tous les mois à la fois en 2018 et 2019 a été de moins de 2,5 % des débits naturels à la frontière, soit bien en deçà du seuil du déclencheur 2 de 4 %.

1.0 Introduction

In 2015, the Government of Alberta and the Government of the Northwest Territories signed a Bilateral Water Management Agreement to cooperatively manage shared transboundary waters. As part of the Alberta (AB)-Northwest Territories (NWT) Bilateral Water Management Agreement (the Agreement), a Bilateral Management Committee (BMC) was established which is responsible for implementing and reporting on the Agreement.

This Water Quantity Technical Report is a companion report to the BMC's fourth annual report to Minsters, "Working Together to Manage Our Shared Waters, 2018-20". This report combines two years of reporting data (2018 and 2019) and includes activities from the fiscal years 2018-19 and 2019-20. For clarity, this technical report provides an overview of the hydrology of the shared waterways between AB and the NWT and describes analysis of the 2018 and 2019 water quantity data and activities that occurred from April 1, 2018 to March 31, 2020. For a summary of the information in this technical report, refer to the Surface Water Quantity section of the Committee's fourth annual report.

1.1 Water quantity monitoring and derived datasets

The interim transboundary objectives and triggers of the Agreement are based on long-term monitoring of streamflow, water allocations for use, as well as reporting data for actual water use in Alberta. The Water Survey of Canada (WSC), a section of Environment and Climate Change Canada (ECCC), is the agency responsible for hydrometric measurements and associated data in Canada. The WSC partners with each of the provinces and territories to cost-share hydrometric monitoring.

Water use is tracked through water permitting systems in AB and NWT. For the analysis in this report, key data on upstream uses in Alberta, licensed under Alberta's *Water Act*, (e.g., total annual allocation, return flow, type of use, location of use) were obtained from Alberta's Environmental Management System. The Alberta Energy Regulator (AER) regulates uses under the *Water Act* for the upstream oil, gas and coal sectors, and Alberta Environment and Parks (AEP) regulates uses for all other sectors.

Almost all water licences require the licensee report actual water use. Many licences have been updated to require online reporting to Alberta's Water Use Reporting System. Monthly, and in some cases daily, reporting data are provided by the licensees according to deadlines specified in their licence documents. This electronic database was queried for the water uses in the Hay River basin in Alberta, for Trigger 2 analysis. Paper files of water use reporting may be available but were not gathered for the analysis. Table 1 lists the locations of monitoring and derived flow datasets.

Table 1: Hay and Slave River flow monitoring sites and derived flow datasets for assessment of interim objectives and triggers

Monitoring Station/Assessment Point	Site Status and/or description of data	Purpose
Hay River near Town of Hay River (flow monitoring, 1963-present; level monitoring, 2002-present)	Continuous monitoring since July 1963, one incomplete month (July 2010) Drainage Area: 51,700 km²; coordinates of hydrometric station: 60.743 N, 115.8596 W	To derive estimated flow at the border.
Hay River near AB-NWT Border (level monitoring, 1986-2016)	Intermittent monitoring between 1986 and 1998, and continuous measurements from 2004 to present. Drainage area: 48,800 km²; coordinates of hydrometric station: 60.0039 N, 116.9721 W	To obtain drainage area for estimating flow at the border.
Hay River at the AB-NWT Border (calculated/derived flow)	This value is calculated by reducing the flow to the smaller drainage area at the border, which is 94 percent of the flow near the town of Hay River	To derive estimated flow at the border.
Hay River at the AB-NWT Border (estimated natural flow)	This value is calculated by adding the upstream monthly surface water and groundwater allocation total for locations in the basin to the ‘Hay River at the AB-NWT Border (calculated flow estimate)’ above.	To derive naturalized flow at the border, to assess Trigger 1 for the Hay River basin.
Hay River at the AB-NWT Border (estimated natural flow)	This value is calculated by adding the upstream monthly surface water and groundwater actual or estimated consumptive use for locations in the basin to the ‘Hay River at the AB-NWT Border (calculated flow estimate)’ above.	To derive naturalized flow at the border, to assess Trigger 2 for the Hay River basin.
Slave River at Fitzgerald (flow monitoring, 1960-present)	Intermittent monitoring 1921-1922, 1930-1931, and 1953-1958 Continuous daily monitoring since May 1959, nine incomplete months (2011-2014)	To assess whether the two billion cubic metres (m^3) consumptive use threshold becomes significantly different from 1.9 percent of the long-term average annual flow.

1.2 Water quantity triggers, objectives, and daily flow conditions

The Agreement commits Alberta and the NWT to establish and implement transboundary water quantity objectives and monitoring according to the Risk Informed Management approach. Classification of water bodies considers the level of upstream development and other factors including the extent of traditional use and drinking water use in downstream communities, observed changes in the hydrology of a basin, and the sensitivity of the related ecosystem. Both the Hay and Slave rivers are designated as ‘Class 3’ water bodies, which require the development and monitoring of site-specific objectives. Because the Hay and Slave rivers are the only rivers designated as ‘Class 3’, this report will focus on these basins.

A transboundary water quantity objective refers to the minimum amount of water calculated at the border that the upstream Party must pass to the downstream Party. This minimum amount of water must satisfy ecological integrity needs of the aquatic ecosystem. After these needs are met, at least 50 per cent of the remaining water must also be passed to the downstream Party. The interim ecological integrity need is based on a “modified desktop method” and can be found in Appendix D of the Agreement.

1.3 Hay River triggers and objectives

For the Hay River, objectives and triggers have been set on an interim basis. The interim objective is for 95% of the natural flow to pass from Alberta to the NWT each month. Two triggers have been defined. Triggers are specific conditions that will require a response, such as further discussion on flow objectives, refinements to calculations, or more detailed work on determining ecosystem needs. The two interim water quantity triggers are:

- Trigger 1: If the volume of water licensed is greater than 2.5% of the monthly natural flow at the border, or half of Alberta’s share of water, in at least one month, further work is done to evaluate Trigger 2.
- Trigger 2: If the water used is greater than 4% of the monthly natural flow, or 80% of Alberta’s share of the water, further data and research on ecosystem needs will be discussed.

The analysis of ‘water licensed’ (Trigger 1) or ‘water used’ (Trigger 2) includes all types of Alberta *Water Act* licences (i.e. long-term licences, temporary diversions, and traditional agricultural registrations), for surface water and groundwater. It also includes a licence held by AEP for annual net water balance losses from Hutch Lake, a lake created for wildlife management.

The monthly allocation is determined by distributing annual allocation evenly. The only exception was for evaporative losses at Hutch Lake, which was distributed proportional to evaporation rates throughout the year, with higher values in summer and zero values in winter months as ice cover and snow cover on the lake prevent an evaporative flux. The distribution was based on shallow lake evaporation estimates (Table 2) calculated with climate data from High Level, AB.

Table 2: Hutch Lake monthly shallow lake evaporation. Shallow lake evaporation estimates are based on average monthly Morton's model estimates from 1972-2009. The dataset can be found in 'Evaporation and Evapotranspiration in Alberta, April 2013' ISBN: 9781-4601-1121-5 (On-line). Evaporation estimates for the months of January, February, November and December were set to zero.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Evaporation (mm)	-2	-1	15	59	106	131	132	96	41	11	-4	-3
Evaporation (mm)	0	0	15	59	106	131	132	96	41	11	0	0
% Distribution	**0**	**0**	**3**	**10**	**18**	**22**	**22**	**16**	**7**	**2**	**0**	**0**
Hutch Lake Licence (m^3)												
960,052	0	0	24,367	95,843	172,192	212,803	214,428	155,948	66,603	17,869	0	0

In order to estimate the monthly natural flow, the total monthly allocation is added to the monthly flow at the border for Trigger 1. For Trigger 2, the monthly estimated and monthly reported use is added to the monthly flow. This assumes a direct, instantaneous effect of all diversions throughout the basin. This is a simplified and conservative estimate; it does not consider routing of each diversion, residence time or storage in lakes or wetlands, and when it would reach the border if not diverted.

1.4 Slave River triggers and objectives

Because the volume of water used by communities and industry is very low compared to the total volume of discharge on the Slave River every year, water quantity objectives for the Slave River have not yet been set. According to the Agreement, further discussions will be held if any of the following occur:

- Annual consumptive use in Alberta reaches two billion cubic metres;
- Two billion cubic metres (2 km^3) becomes significantly different from 1.9% of the long-term average annual streamflow; or
- 50% of the consumptive use in Alberta is for use outside of the Mackenzie River basin.

Alberta's current annual allocation, of both surface and groundwater in the Slave River basin, is used as an estimate for annual consumptive use. Based on assessment of water use as part of Alberta's water management program under Alberta's *Water Act*, the actual use of water in a given year is often 50 percent or less.

The allocation is the maximum volume allowed, assuming no low flow restrictions. The maximum volume for a licence includes consideration of emergency water demands in addition to typical annual needs for the long-term operation of the diversion. Low flow restrictions are specific to each licence and are not included in the maximum annual diversion volume. For more details on an individual licensee's conditions for water use, licence documents can be accessed online through Alberta's 'Authorization Viewer'.

2.0 Hay River

2.1 Hydrology of the Hay River basin

The Hay River basin (Figure 1) primarily occupies an area in northwestern Alberta, while also covering a small area in northeastern British Columbia and southern Northwest Territories. The Hay River drains an area of approximately 51 300 km^2 (WSC, 2021) and enters Great Slave Lake at the Town of Hay River. The headwaters of the Hay River originate in the foothills of the Rocky Mountains, where it generally flows northeast. The majority of the basin is comprised of peatland (i.e., muskeg) terrain (Stanley and Gerrard, 1991), before the river drops over Alexandra Falls in the southern NWT.

The peatlands of the Hay River basin help to attenuate (i.e., slow down) precipitation inputs, meaning that snowmelt and rain water take longer to get to a river than other environments (e.g., Canadian Shield). Mean annual **runoff** in the Hay River basin (at gauging stations at the Town of Hay River) is very low - one of the lowest in Canada - with a value of 66 mm per year. For comparison, the Slave River (at the gauging station at Fitzgerald, AB) has a mean annual runoff of 173 mm per year, meaning that precipitation is both greater and can flow to the river networks more easily than in the Hay River basin. A mountain river, such as the South Nahanni River, has a mean annual runoff of 500 mm.

Runoff: is a measurement often used by hydrologists to compare streamflow of river basins of different sizes, as the total amount of water flowing through basin is directly proportional to the basin size. Runoff is calculated by dividing volumetric discharge (cubic metres (m^3)), by the basin area (square metres (m^2)) and then multiplied by 1000 to produce a runoff depth in millimetres (mm) over a specified time period (e.g. one year). The result is a value of mm per year.

In peatlands, precipitation can (usually) easily infiltrate the surface and percolate to the water table. Once it hits the water table it slowly flows through the peat to the basin outlet. The amount of water that the peat can hold is dependent on the amount of water already in the soil (i.e. antecedent moisture conditions). If these antecedent moisture conditions are low, this means that the soil can hold onto large volumes of rain, so rain events may not produce a large spike on the **hydrograph**.

Hydrograph: graph used by hydrologists to show the timing (when) and magnitude (how much) of streamflow over the course of a year. Large spikes in hydrographs are usually indicative of snowmelt or rain events that provide water to the system. The hydrograph for a basin is dependent on the land surface, precipitation inputs, and temperature. For example, a rain event of 20 mm will produce 20 mm of runoff over an impermeable (e.g. pavement) surface. That same rain event, would produce a small amount of runoff (e.g. 2 mm), or even no runoff, over a surface that has a high infiltration rate and can hold onto a lot of water (e.g. a peatland).

If antecedent moisture conditions are high, much more water from incoming precipitation will be made available to the stream network and this will be noticed through increased water levels and streamflow. During the spring snowmelt season, when soils are frozen, much of this water is not able to infiltrate into the soil and will be made available as surface runoff. During the spring snowmelt period, the entire moisture supply from the winter is made available as temperatures increase and exceed 0°C, producing what is called the 'spring freshet' and often resulting in the highest water levels of the season. Because the Hay River is a north-flowing river, snowmelt and river ice breakup begins in the south and moves north, often hitting competent ice. When this happens, ice-jam flooding can be initiated as the ice acts as a dam and backs up the water. This phenomenon is common in the Town of Hay River.

The northern part of the basin is underlain by sporadic discontinuous permafrost, with maximum extents underlying 30% of the basin (Brown et al., 1997; Pawley and Utting, 2018). The permafrost in this region is protected by surface organic material but is highly sensitive to any disturbance (Jorgenson et al. 2001). The permafrost in this region has been found to thaw rapidly (Kwong and Gan, 1994), but other studies have suggested that a thick organic cover can maintain permafrost, even as warming trends continue (Holloway and Lewkowicz, 2019). Studies in locations adjacent to the Hay River basin, but with similar land cover features, have found that permafrost thaw has the potential to change the surface and near-surface hydrological connectivity and increase basin runoff over time (Connon *et al*., 2015). It has been suggested that analyzing changes to winter flow rates in permafrost basins can help determine increased baseflow (i.e. groundwater inputs) contributions (Walvoord and Striegl, 2007; St. Jacques and Sauchyn, 2009). There has been a statistically significant ($p < 0.01$) increase in winter flows in the Hay River basin since records began in 1964 (Figure 2). There is ongoing work between the Parties to better determine the impact of how climate change is affecting permafrost distribution in this region, and what impact this is expected to have on basin discharge.

Despite small increases to winter baseflow, total annual runoff on the Hay River has not significantly changed over time (Figure 2). Also, note the differences in scale on the y-axis in Figure 2, which shows that winter contributions are low relative to total annual runoff. Although increases in winter discharge can be indicative of changing permafrost conditions, it does not appear that these changing permafrost conditions have had an impact on total basin runoff. This is likely because the total proportion of the basin underlain by permafrost is relatively low. Inter-annual variability to runoff is a response of inter-annual variability to precipitation, and antecedent moisture conditions.

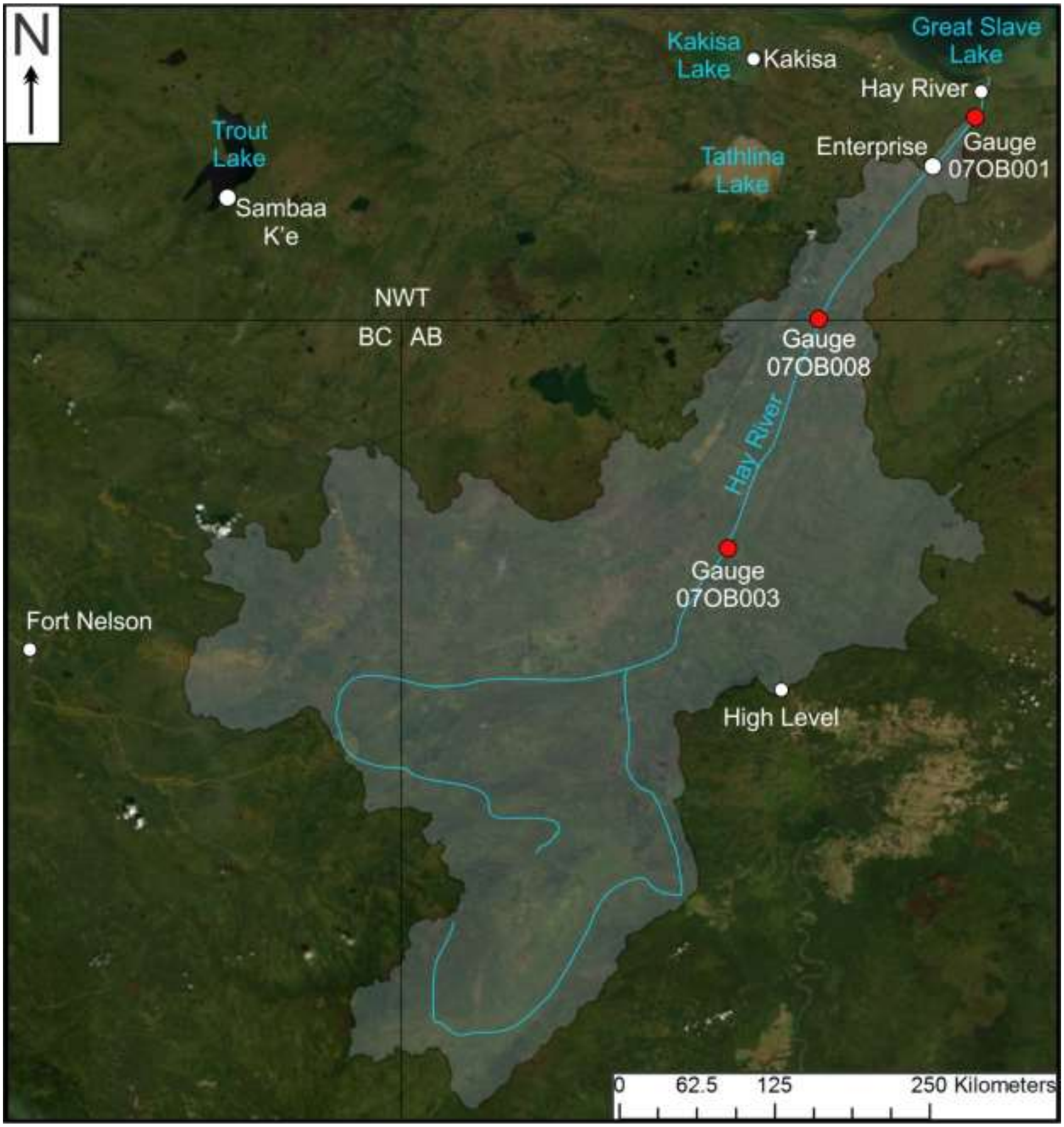

Figure 1: Map of the Hay River basin, including Water Survey of Canada hydrometric gauges on the Hay River. Note that the superimposed renderings of the river network are for illustrative purposes only.

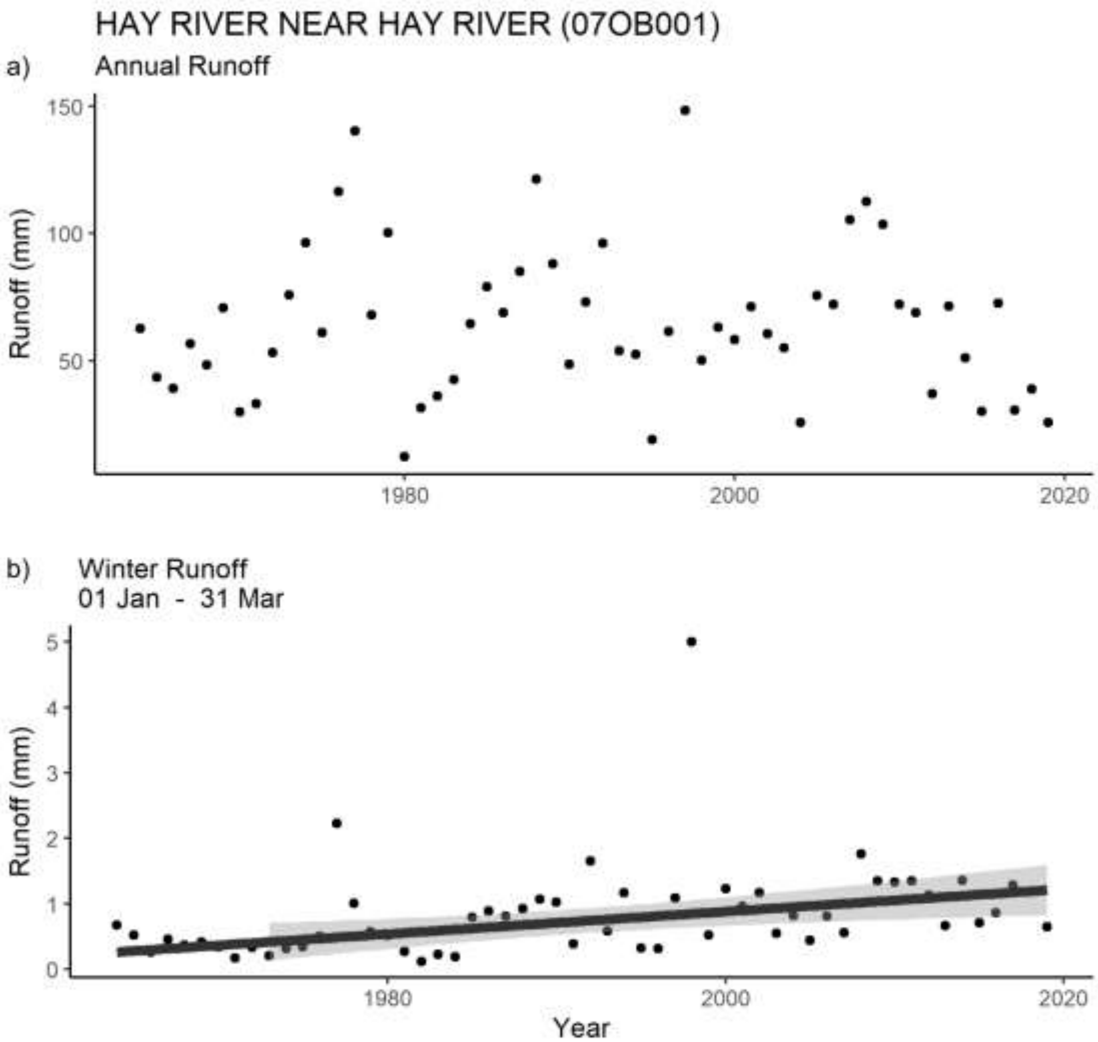

Figure 2: Trend analysis of annual runoff (mm) and winter runoff (mm; 01 Jan to 31 Mar) for the Hay River, using the Mann-Kendall trend test, WSC data 1963 to 2019; a) no statistically significant change in annual runoff volume (grey: $p > 0.05$); b) statistically significant increases in winter runoff ($p < 0.01$).

2.2 Hay River hydrology, allocation, and use data for 2018 and 2019

Total annual streamflow on the Hay River was lower than average in 2018 (59% of normal), and much lower than average in 2019 (39% of normal) (Figure 4).

> **Total annual streamflow:** the total volume of water that passes through a river over the course of one year. This is a function of the total amount of precipitation that falls on a basin. Because of this, it is useful to analyze an integrated precipitation record of stations within the basin or in close proximity to the basin.

There are three communities around the Hay River basin that provide climate data: Hay River, High Level, and Fort Nelson (see Figure 1). Cumulative precipitation at all three locations was approximately normal or slightly lower than average for the years 2018 and 2019 (Figure 3). The Town of Hay River received more precipitation in 2018 than 2019, including a very large rainfall event in the month of June in 2018. Precipitation in Fort Nelson was higher in 2019 than 2018, with large rainfall events in June and July, 2019. High Level received similar amounts of precipitation in 2018 and 2019, where 2018 had an extended moisture deficit from February to June.

In 2018, the timing and magnitude of the snowmelt peak was about average and the recession limb from this event also followed a normal trajectory, although it dropped to a low of about 100 $m^3 s^{-1}$ by early June because of low precipitation amounts. Rain events in June and July brought water levels above average by mid-July; however, low rainfall at the end of summer resulted in low water levels in advance of freeze-up. In 2019, annual streamflow was very low, and an abnormal warm spell in mid-March ripened the snowpack in advance of an early snowmelt. The spring freshet peak was very low, and low water levels persisted into June and July. A rain event in early August brought flow rates back to normal and they remained about average into the fall and freeze-up period.

Section 1.3 describes the triggers for the Hay River. For the Hay River in 2018, Trigger 1 was exceeded for six months (January, February, March, April, November, December) (Figure 5a). Trigger 1 is hit when monthly allocations are greater than 2.5% of natural border flow. Because the annual allocation is divided evenly between all months, not accounting for any licensee conditions or measures during low flow months, this means that there is a higher chance of exceeding the Trigger 1 threshold during low flow months. Because Trigger 1 was reached in 2018, the resulting action was to evaluate actual water use as a percentage of natural border flow (Trigger 2). Figure 5b shows that actual water use was well below the threshold of 4.0% in all months.

For the Hay River in 2019, Trigger 1 was exceeded for three months (January, February, March) (Figure 6a). Evaluation of Trigger 2 (Figure 6b) shows that actual use remained well below the threshold of 4.0% in all months in 2019.

Trigger 2 includes the same long-term allocations, temporary diversions, and traditional agricultural registrations for surface water and groundwater as in Trigger 1, but instead of using the allocation volume, it uses actual water use data submitted by licensees to Alberta's online Water Use Reporting System (WURS). As there is no reporting for the wildlife management licence for Hutch Lake, the same monthly volumes, as used for Trigger 1, were used for Trigger 2.

Not all licensees are required to submit actual water use data to WURS. For example, the Alberta Energy Regulator recently began requiring reporting for new temporary diversion licences (TDLs), but it is not required for other sectors regulated by Alberta Environment and Parks (e.g. forestry, transportation, and downstream oil and gas activities). Beginning in 2017, further details of the reporting by sector were included in the AB-NWT annual report.

Table 3 and
Table 4 provide reporting data for surface water and groundwater licences by sector for 2018 and 2019 respectively. The reporting rates were similar to previous years. In both 2018 and 2019, 98 percent of the allocations by volume were reported for the upstream oil and gas sector (the same as 2017). The reporting rate is nearly 100 percent for sectors required to report. There are two licences for the 'Urban' sector, one of which is for the Dene Tha' First Nation, which does not require reporting to WURS. 'Agricultural Registrations', 'Water Management' licences, and the one 'Environmental' licence do not have reporting requirements. The 'Environmental' licence is for the creation of Hutch Lake for wildlife management. There is one licence for 'Recreation' that did not report as required in its licence.

Of the available actual use data from WURS, far less than the maximum allocation volume was used. In 2018, 16.0 per cent of the surface water allocation, 4.0 per cent of the groundwater allocation, and 13.9 per cent of the total allocation volume of both surface water and groundwater was used. In 2019, 15.5 per cent of the surface water allocation, 4.0 per cent of the groundwater allocation, and 13.0 per cent of the total allocation volume of both surface water and groundwater was used.

In order to estimate the monthly natural flow for Trigger 2, the actual water use was added to the monthly volume of flow at the border. When WURS data on actual use was not available, consumption was estimated at 33 per cent and 31 percent for 2018 and 2019, respectively. This estimated consumption calculation followed the same procedure as in the 2016 and 2017 analysis, where the estimated consumption is double the reported use for both surface water and groundwater (*i.e.*, 2018: 13.9% x 2 = 27.8%; 2019: 13.0% x 2 = 26%). The exception to this estimation was for the Hutch Lake environmental licence, for which consumption was assumed to be equal to the allocation distributed proportional with evaporation rates, as described in Section 1.4 Slave River triggers and objectives
Because the volume of water used by communities and industry is very low compared to the total volume of discharge on the Slave River every year, water quantity objectives for the Slave River have not yet been set. According to the Agreement, further discussions will be held if any of the following occur:

- Annual consumptive use in Alberta reaches two billion cubic metres;

- Two billion cubic metres (2 km^3) becomes significantly different from 1.9% of the long-term average annual streamflow; or
- 50% of the consumptive use in Alberta is for use outside of the Mackenzie River basin.

Alberta's current annual allocation, of both surface and groundwater in the Slave River basin, is used as an estimate for annual consumptive use. Based on assessment of water use as part of Alberta's water management program under Alberta's *Water Act*, the actual use of water in a given year is often 50 percent or less.

The allocation is the maximum volume allowed, assuming no low flow restrictions. The maximum volume for a licence includes consideration of emergency water demands in addition to typical annual needs for the long-term operation of the diversion. Low flow restrictions are specific to each licence and are not included in the maximum annual diversion volume. For more details on an individual licensee's conditions for water use, licence documents can be accessed online through Alberta's 'Authorization Viewer'.

.

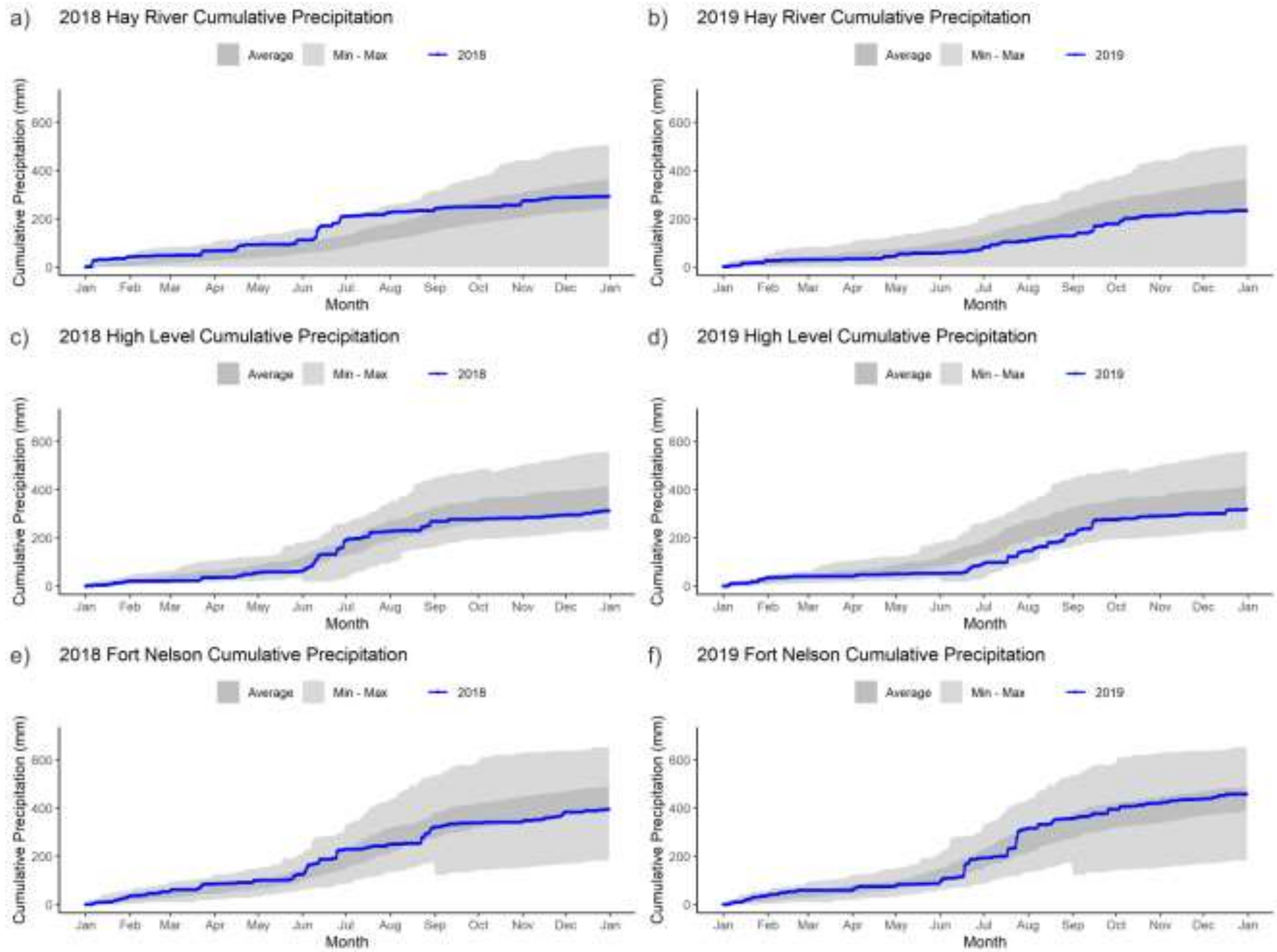

Figure 3: Cumulative precipitation curves for communities in and adjacent to the Hay River basin (a, b: Hay River; c, d: High Level; e, f: Fort Nelson) for 2018 and 2019. Data were collected from Environment and Climate Change Canada climate stations.

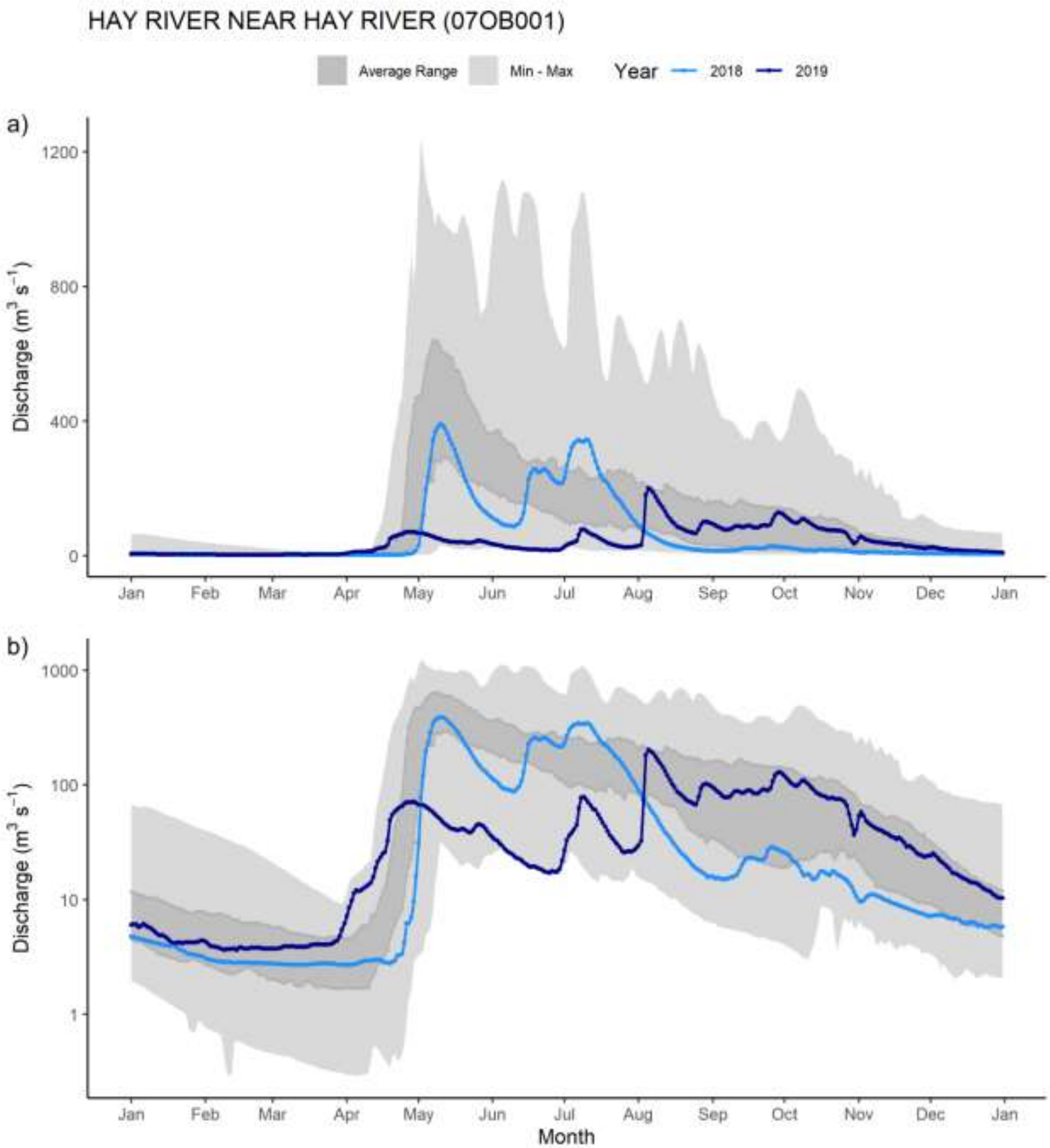

Figure 4: Hay River discharge for the years 2018 and 2019 relative to the historic average range (depicted as the interquartile range), and minimum and maximums on: a) linear scale y-axis; and b) log scale y-axis

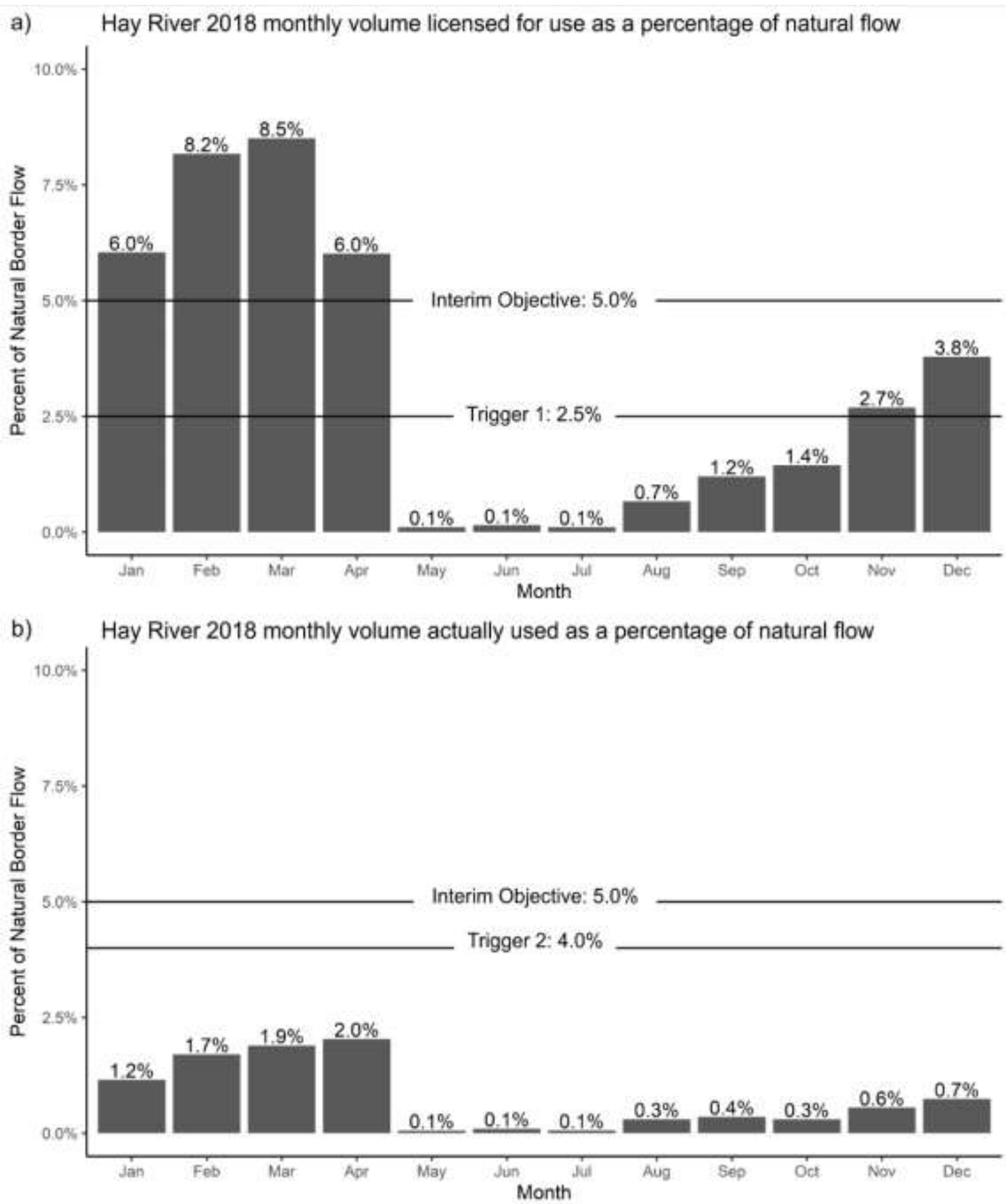

Figure 5: a) Trigger 1: Hay River 2018 monthly allocation as percentage of natural flow; b) Trigger 2: Hay River 2018 monthly use estimate as percentage of natural flow

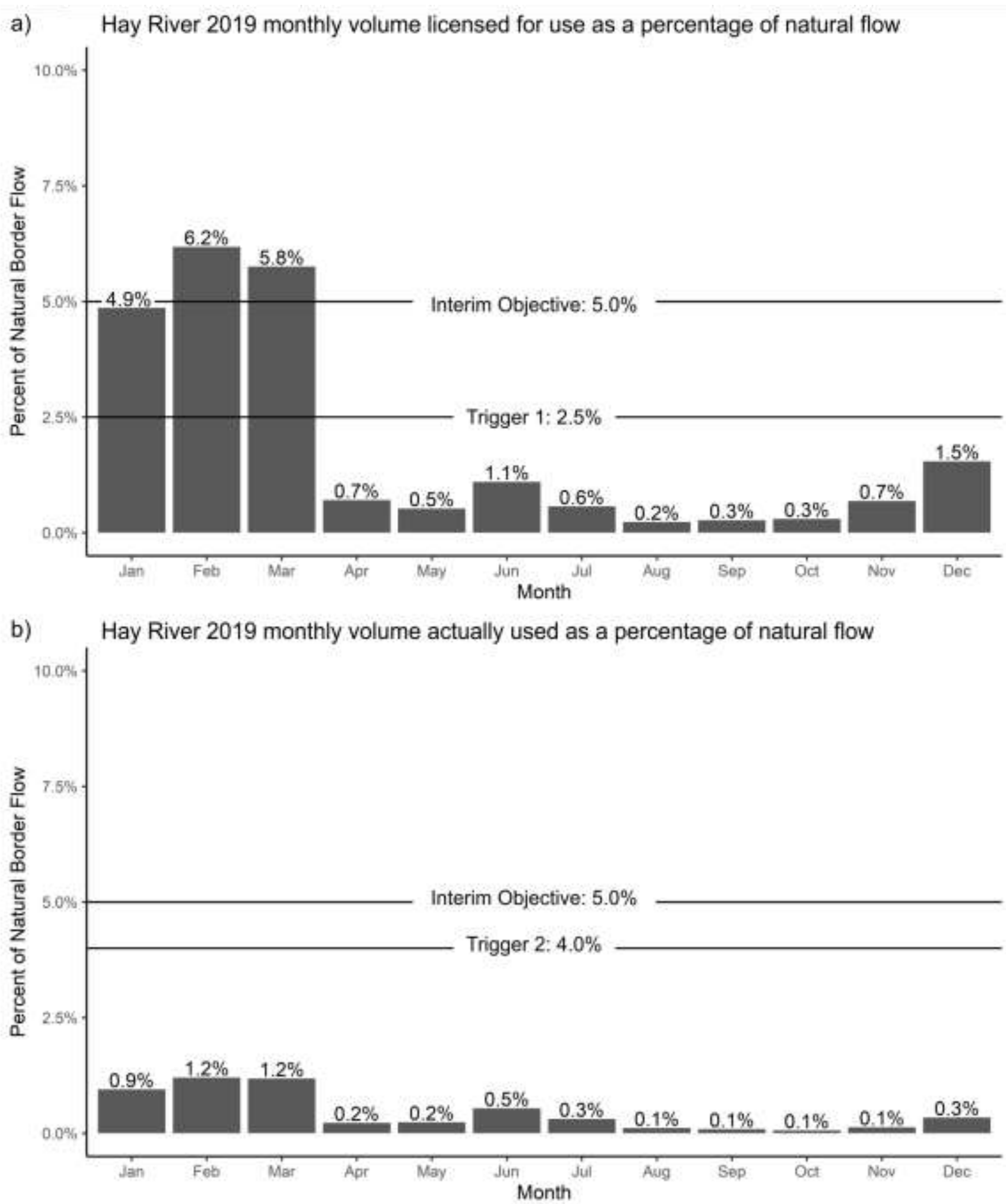

Figure 6: a) Trigger 1: Hay River 2019 monthly allocation as percentage of natural flow; b) Trigger 2: Hay River 2019 monthly use estimate as percentage of natural flow

Table 3: 2018 Reporting for surface water and groundwater licences by sector

Sector	Number of Licences and TDLs with Reports	Total Number of TDLs, Licences, & Registrations	Allocation of Licences with Reports (m^3)	Total Allocation (m^3)	Percentage of Allocation Volume with Reports (%)
Surface Water					
Upstream Oil & Gas	189	255	4,133,830	4,210,414	98.2%
Environmental	0	1	0	960,052	0.0%
Urban	1	2	296,040	602,040	49.2%
Forestry	0	180	0	369,292	0.0%
Downstream Oil & Gas	2	61	42,600	120,000	35.5%
Construction & Transportation	0	103	0	39,575	0.0%
Recreation	0	1	0	19,720	0.0%
Power Generation	0	6	0	1,736	0.0%
Traditional Use	0	21	0	1,451	0.0%
Water Management	0	2	0	10	0.0%
Total:	**192**	**632**	**4,472,470**	**6,324,290**	**70.7%**
Groundwater					
Suburban/Rural	3	5	972,828	973,074	100.0%
Upstream Oil & Gas	4	16	187,975	222,505	84.5%
Oil & Gas Work Camps	1	1	3,650	3,650	100.0%
Recreation	0	1	0	1,234	0.0%
Total:	**8**	**23**	**1,164,453**	**1,200,463**	**97.0%**

Table 4: 2019 Reporting for surface water and groundwater licences by sector

Sector	Number of Licences and TDLs with Reports	Total Number of TDLs, Licences, & Registrations	Allocation of Licences with Reports (m^3)	Total Allocation (m^3)	Percentage of Allocation Volume with Reports (%)
Surface Water					
Upstream Oil & Gas	181	220	4,159,645	4,241,307	98.1%
Environmental	0	1	0	960,052	0.0%
Urban	1	2	296,040	602,040	49.2%
Forestry	0	135	0	234,592	0.0%
Downstream Oil & Gas	2	65	42,600	120,950	35.2%
Construction & Transportation	0	27	0	59,160	0.0%
Recreation	0	1	0	19,720	0.0%
Power Generation	0	6	0	1,736	0.0%
Traditional Use	0	21	0	1,451	0.0%
Water Management	0	2	0	10	0.0%
Total:	**184**	**480**	**4,498,285**	**6,241,018**	**72.1%**
Groundwater					
Suburban/Rural	3	3	972,828	972,828	100.0%
Upstream Oil & Gas	4	14	187,975	207,545	90.6%
Oil & Gas Work Camps	1	1	3,650	3,650	100.0%
Total:	**8**	**18**	**1,164,453**	**1,184,023**	**98.3%**

3.0 Slave River

3.1 Hydrology of the Slave River basin

The Slave River drains an area of approximately 606 000 km^2 (at the WSC gauging site), which includes three major sub-basins (Peace, Athabasca, Fond-du-Lac), as well as the Peace-Athabasca Delta/Lake Athabasca complex (Figure 7). Because of the large geographical expanse of the basin, flow on the Slave River produces an integrated response of runoff generation processes across four major physiographical regions. These include: 1) Western Cordillera, made up of the Rocky Mountains to the west, containing peaks exceeding 2 000 m with glaciers covering the mountain tops; 2) Canadian Shield, occupying the portion of the basin in NW Saskatchewan and southern NWT, which is comprised of lakes and valley-wetlands interspersed by bedrock; and 3) Interior Plains, consisting of boreal forest, wetlands, and lakes (Woo and Thorne, 2003). Annual precipitation is greatest in the mountainous southwest and declines to the northeast. Runoff in the Slave River watershed is highlighted by high flows in the spring resulting from snowmelt, as well as both responses to convectional and frontal rain events in the summer and fall (Woo and Thorne, 2003).

Mean annual runoff is 223 mm on the Peace River, 145 mm on the Athabasca River, and 173 mm on the Slave River. These values are all much higher than the comparatively low mean annual runoff in the Hay River basin (66 mm). The runoff response for each basin is a function of basin physiography and is described in more detail in Woo (2012).

Mann-Kendall trend test results indicate annual runoff volume on the Slave River has decreased significantly ($p < 0.05$) since 1972 (Figure 8a). There is also a significant ($p < 0.05$) decrease in fall runoff volume (September and October) (Figure 8b). The decrease in fall runoff volume is evident on both the Peace and Athabasca tributaries, suggesting that the decrease in annual runoff is driven by fall decreases, and that this trend is driven by climatological factors, rather than basin-specific hydrology.

The gauge at the outlet of the Peace River (07KC001) provides an integrated response of the effects of flow regulation resulting from the Williston Reservoir (41 km^3), as well as the predominantly snowmelt driven response from tributaries downstream (Woo and Thorne, 2003). Construction on the W.A.C. Bennett Dam and filling of Williston Reservoir was completed in 1972. A comparison of flow regimes prior to and after regulation shows a larger magnitude of flows in the winter period, along with a smaller snowmelt peak and lower flow volumes throughout the summer (Prowse and Beltaos, 2002) (Figure 9a). These patterns are also displayed on Great Slave Lake, although the seasonal impacts are slightly dampened due to the large size of the lake (Figure 9b).

Atmospheric climate models project that precipitation will increase over the Slave River basin, which has the potential to affect the timing and magnitude of runoff. Ice-jam floods on the Peace and Athabasca rivers are projected to decrease as a result of climate change, primarily because of a smaller alpine snowpack (Prowse et al., 2006). Permafrost is only present in a small portion of the Slave River watershed; permafrost thaw is therefore not expected to be a strong driver of hydrological changes in the basin.

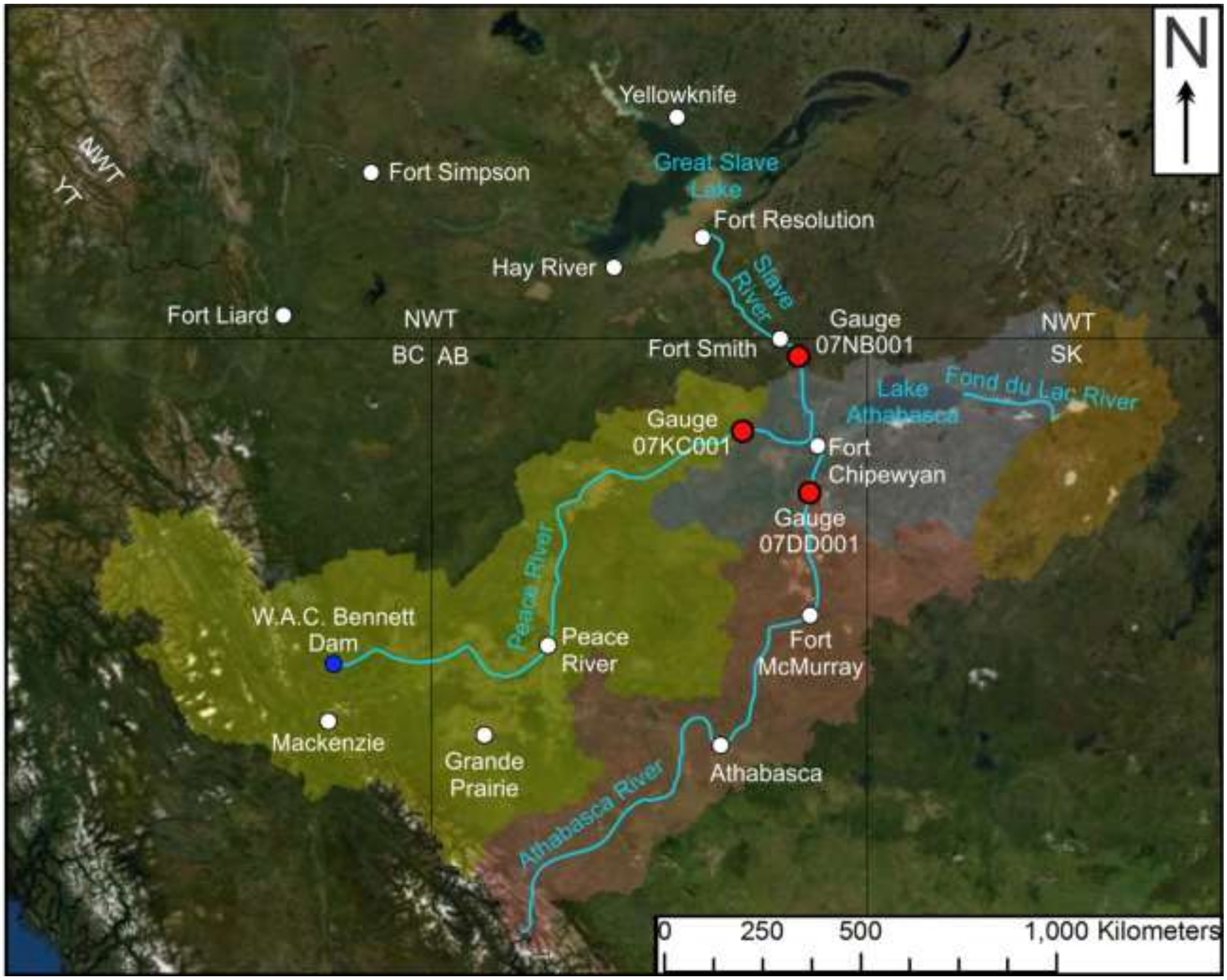

Figure 7: Map of the Slave River basin, upstream of the Water Survey of Canada gauging station at Fitzgerald, AB (07NB001). This map delineates the three major sub-basins of the Slave River watershed: a) Peace River basin (gauge 07KC001); b) Athabasca River basin (gauge 07DD001); and c) Fond du Lac River basin (Saskatchewan).

3.2 Slave River hydrology, allocation, and use data for 2018 and 2019

In 2018, annual flow on the Slave River was about average (93% of normal) (Figure 10). Flow rates were approximately normal, with little fluctuations from January to March, and quickly rose with a large response to snowmelt runoff. There were a few days in early May where hydrometric data were not available, likely due to ice displacing the sensor. Flow rates and water levels dropped to about average levels following the snowmelt peak. Flows rose quickly in early August in response to a rainfall event, but quickly receded thereafter. Flows were between average and below average for the remainder of the year. Precipitation in 2018 was spatially variable, with Grande Prairie receiving nearly a record high amount of precipitation over the year (Figure 11). Sites further north and east received comparatively little, especially after August, which was a contributing factor to the lower-than-average flow rates in November and December. Another contributing factor to low flow events in winter are temperature drops, where flow is reduced because it is being converted to ice.

In 2019, flows on the Slave River were also close to average, but slightly lower than 2018 (88% of normal) (Figure 10). The 2019 hydrograph was comprised of a lower than usual snowmelt runoff peak which followed lower than usual 2018 November and December flows. Flow rates approached the lowest on record for the summer in late June/early July, but quickly rose due to a large rainfall event in early July. Flow rates were between average and above average for the remainder of the year. Precipitation was about average in 2019, with lower than normal snowfall in the early winter months. Consistent summer rainfall helped to re-saturate the basin for the fall and early winter.

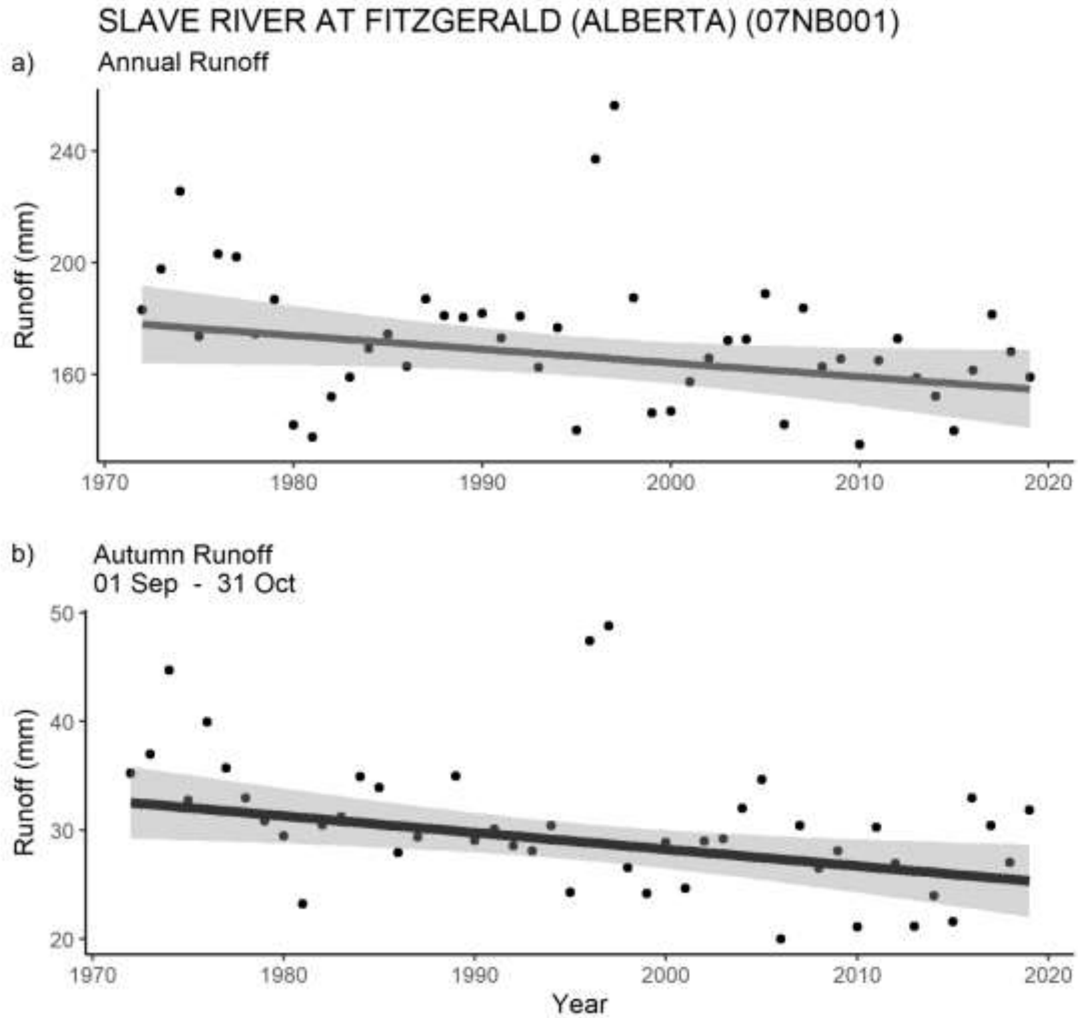

Figure 8: Trend analysis of annual runoff (mm) and autumn runoff (mm) for the Slave River, using the Mann-Kendall trend test, WSC data 1972 to 2019; a) trend line indicates statistically significant decrease in annual runoff volume (grey: $p < 0.05$); b) trend line indicates statistically significant decrease in runoff volume for September and October (black: $p < 0.01$).

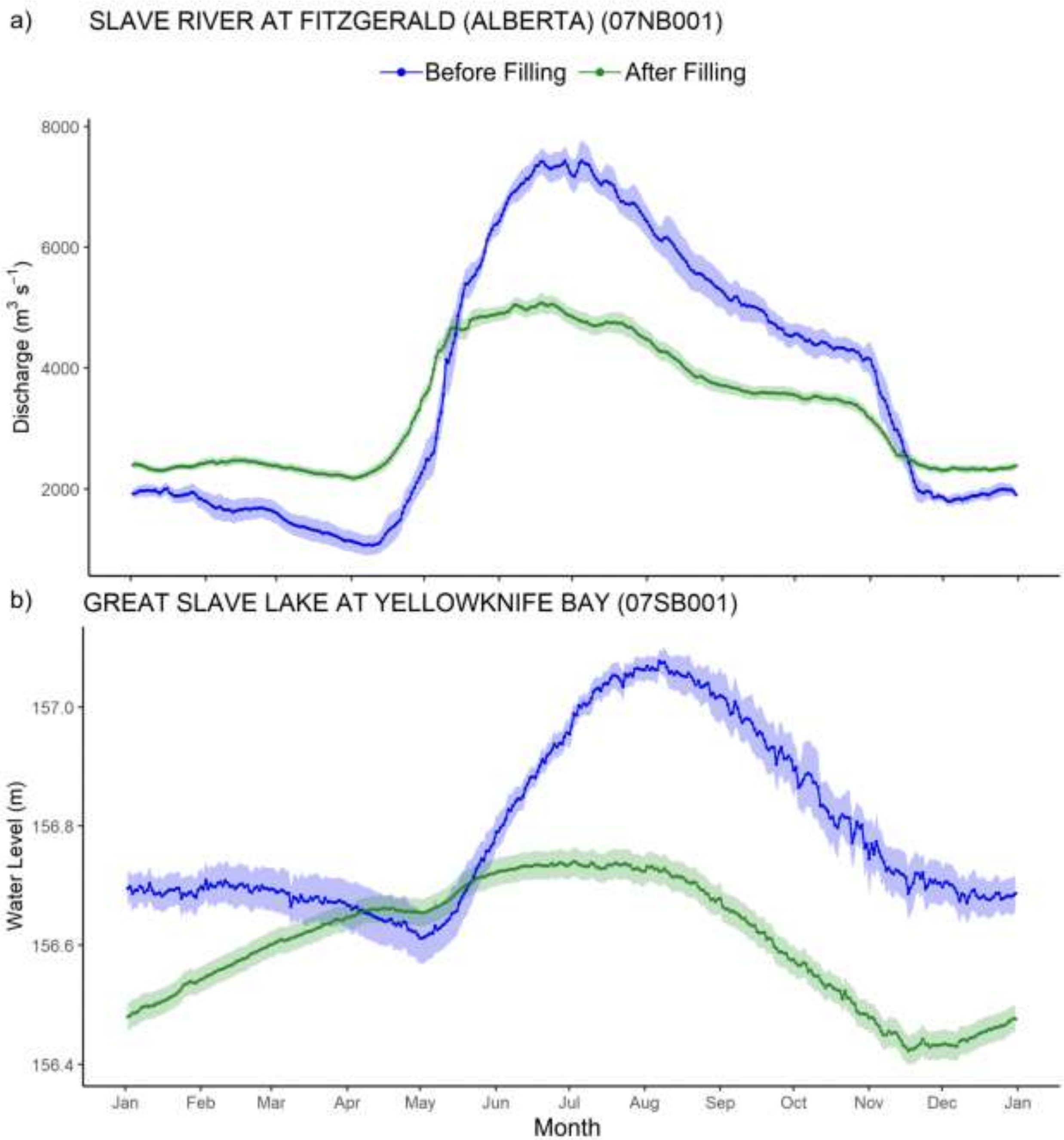

Figure 9: Mean daily discharge and water level, averaged from 1959 to 1968 (blue) and 1972 to 2019 (green) for the a) Slave River and b) Great Slave Lake.

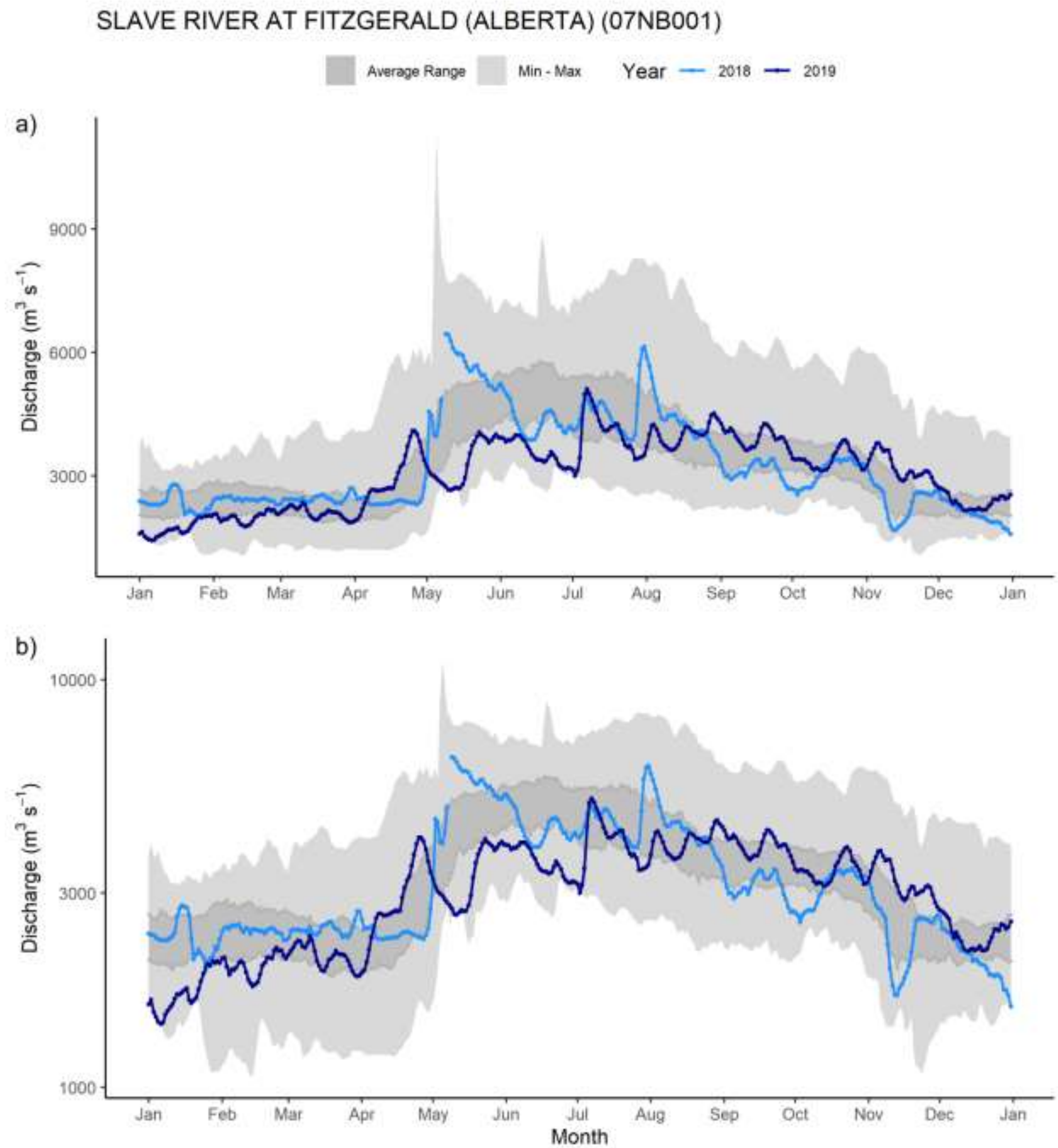

Figure 10: Slave River discharge for the years 2018 and 2019 relative to the historic average range (depicted as the interquartile range), and minimum and maximums on: a) linear scale y-axis; and b) log scale y-axis

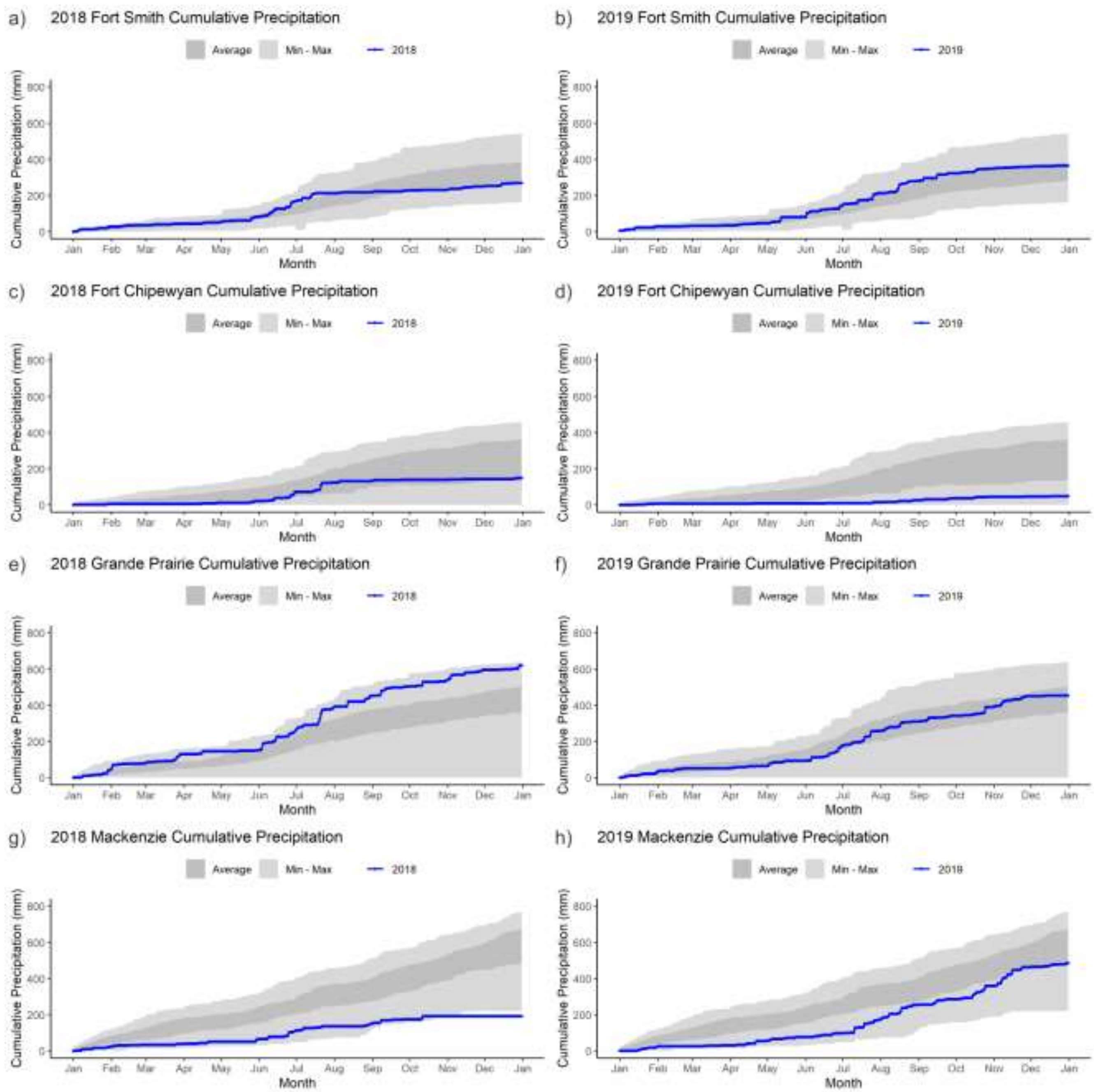

Figure 11: Cumulative precipitation curves for select communities in the Slave River basin (a, b: Fort Smith; c, d: Fort Chipewyan; e, f: Grande Prairie; g, h) Mackenzie for 2018 and 2019. Data were collected from Environment and Climate Change Canada climate stations. Note that there are incomplete precipitation data at Fort Chipewyan and (2018 and 2019) Mackenzie (2018), resulting in low values for the cumulative curves.

Section 1.4 describes the triggers for the Slave River. Surface water and groundwater allocations and flows for 2018 and 2019 are depicted in Table 5 and Figure 12. The two billion cubic meter (2 km^3) consumptive use threshold has remained at 1.9% of the long-term annual flow of the Slave River for both 2018 and 2019.

No new special acts were passed in Alberta to allow for transfer of water out of the Mackenzie River Basin. As reported in "Working Together to Manage our Shared Waters Alberta-Northwest Territories Bilateral Management Committee Annual Report to Ministers 2017-18", the total volume of allocation under special acts (209,000 m^3) remains at 0.02 percent of the total allocation of water in the Slave River basin.

Table 5: Comparison of Slave River basin allocations and mean annual flows. Note that values in the table are presented in km^3 (1 km^3 of water is equivalent to 1 billion m^3).

Parameter	2019 (km^3 $year^{-1}$)	2018 (km^3 $year^{-1}$)	2017 (km^3 $year^{-1}$)	2016 (km^3 $year^{-1}$)	2015 (km^3 $year^{-1}$)
Surface water allocation	1.074	0.935	0.862	0.906	0.904
Groundwater allocation	0.204	0.183	0.167	0.17	0.178
Total allocation	1.277	1.118	1.03	1.075	1.082
Consumptive use threshold	2.0	2.0	2.0	2.0	2.0
Actual flow volume	96.3	102.3	110.0	97.7	84.8
Mean annual flow (from 1972)	105.0	105.2	105.3	105.2	105.3

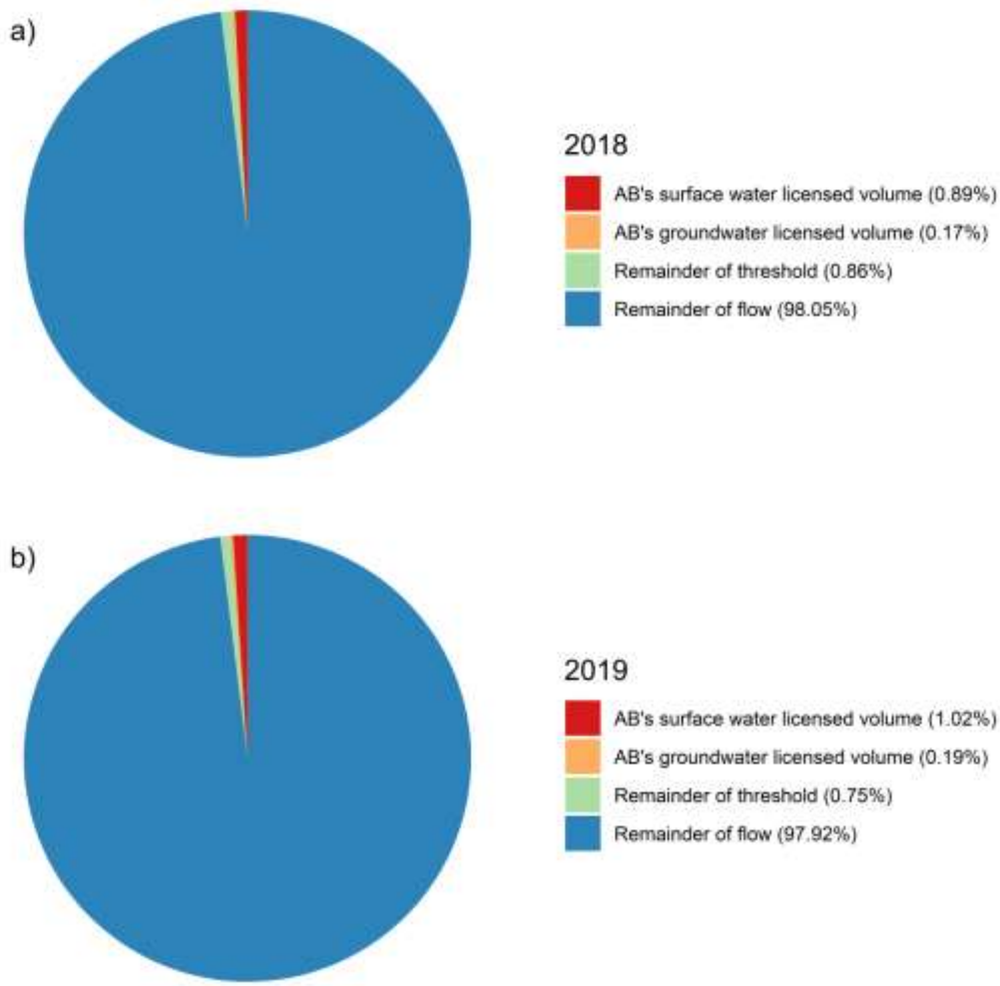

Figure 12: Alberta allocations as percentage of Slave River annual flow for a) 2018; and b) 2019

4.0 Next steps

AB and NWT will continue to share information about ongoing or new hydrometric monitoring occurring in their respective jurisdictions where relevant to the Agreement. The Bilateral Management Committee will update Appendix I (monitoring list) as deemed necessary.

Daily flow conditions, for both the Slave and Hay rivers, will continue to be tracked and reported relative to historical data, and aggregated for reporting on interim water quantity objectives and trigger. The Parties will continue to track and report on the consumptive use threshold (annual consumptive use and recorded flow) for the Slave River. Interbasin transfers will continue to be tracked and reported. The methods for calculating annual consumptive use and mean annual flow will be refined when needed.

The Parties will participate in work led by the Government of Canada, along with Indigenous partners, the Government of British Columbia, and BC Hydro, to support implementation of the Wood Buffalo National Park Action Plan.

The Parties will continue to track and report on the interim objective and triggers for the Hay River. Refinements to estimates of monthly allocation, consumptive use, and natural flow will continue to be discussed as needed.

The Parties are continually working on developing and improving tools to monitor historic and real-time hydrometric and climate data to assess how climate change is impacting the Hay and Slave river watersheds.

5.0 References

Brown, J., Ferrians, O.J., Heginbottom, J.A., & Melnikov, E.S. (1997). Circum-polar map of permafrost and ground-ice conditions, *U.S. Geological Survey, Map CP-45*.

Connon, R.F., Quinton, W.L., Craig, J.R., Hanisch, J., & Sonnentag, O. (2015). The hydrology of interconnected bog complexes in discontinuous permafrost terrains. *Hydrological Processes, 29(18)*, 3831-3847. https://doi.org/10.1002/hyp.10604

Holloway, J.E., & Lewkowicz, A.G. (2019). Half a century of discontinuous permafrost persistence and degradation in western Canada. *Permafrost and Periglacial Processes, 31*, 85-96. https://doi.org/10.1002/ppp.2017

Jorgenson, M.T., Racine, C.H., Walters, J.C., & Osterkamp, T.E. (2001). Permafrost degradation and ecological changes associated with a warming climate in central Alaska, *Climatic Change*, *48*, 551-579. https://doi.org/10.1023/A:1005667424292

Kwong, Y.J., & Gan, T.Y. (1994). Northward migration of permafrost along the Mackenzie Highway and climatic warming. *Climatic Change*, *26(4)*, 399-419. https://doi.org/10.1007/BF01094404.

Pawley, S.M. & Utting, D.J. (2018). Permafrost probability model for Northern Alberta (gridded data, GeoTIFF format), *Alberta Energy Regulator*, AER/AGS Digital Data 2018-0007.

Prowse, T.D., & Beltaos, S. (2002). Climatic control of river-ice hydrology: A review. *Hydrological Processes*, *16*, 805-822. https://doi.org/10.1002/hyp.369

Prowse, T.D., Beltaos, S., Gardner, J.T., Gibson, J.J., Granger, R.J., Leconte, R. … & Toth, B. (2006). Climate change, flow regulation and land-use effects on the hydrology of the Peace-Athabasca-Slave system; Findings from the Northern Rivers Ecosystem Initiative. *Environmental Monitoring and Assessment*, *113*, 167-197. https://doi.org/10.1007/s10661-005-9080-x

St Jacques, J.M., & Sauchyn, D.J. (2009). Increasing winter baseflow and mean annual streamflow from possible permafrost thawing in the Northwest Territories, Canada, *Geophysical Research Letters*, *36(1)*, 1-6. https://doi.org/10.1029/2008GL035822

Stanley, S.J., & Gerard, R. (1991). Ice jam forecasting: Hay River, N.W.T., *Canadian Journal of Civil Engineering*, 212-223.

Walvoord, M.A., & Striegl, R.F. (2007). Increased groundwater to stream discharge from permafrost thawing in the Yukon River basin: Potential impacts on lateral export of carbon and nitrogen, *Geophysical Research Letters*, *34(12)*, L12402. https://doi.org/10.1029/2007GL030216

Woo, M.K. (2012). Permafrost Hydrology. *Springer-Verlag*: Berlin, 519 pp.

Woo, M.K., & Thorne, R. (2003). Streamflow in the Mackenzie Basin, Canada, *Arctic*, *56(4)*, 328-340.