APPENDIX 15C

Mackenzie Valley Highway: Desktop-based Assessment of Water Availability

Mackenzie Valley Highway: Desktop-based Assessment of Water Availability

Prepared for:

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Project No.: 144903284

Executive Summary

Water volumes available for withdrawal have been assessed for 22 watercourses and 24 waterbodies along the proposed Mackenzie Valley Highway (MVH) alignment, spanning roughly from Wrigley, Northwest Territories (NT) to Norman Wells.

For the purposes of this document, a watercourse is defined as surface water that flows in a natural defined channel (e.g., creeks, streams, and rivers), and a waterbody is "*any water-filled basin that is potential fish habitat. A waterbody is defined by the ordinary high water mark of the basin, and excludes connecting watercourses*" (DFO 2010).

Water will be used for construction-related activities, compaction, and dust control in winter and non-winter periods. The amount and timing of water withdrawals are not yet known; however, the majority is anticipated to be needed in early winter (November-December) for winter road construction.

General findings are summarized in the summary figure and summary tables below.

For watercourses, water available for withdrawal was calculated as 10% of monthly flow in months where discharge is greater than 30% of mean annual discharge (MAD) (DFO 2013) Monthly flows were sourced using regional analysis (n=16), monitored flows (n=5), or reproduced from previously published reports (n=1; Great Bear River near the Mackenzie River).

For watercourses:

- water is likely typically available for withdrawal from approximately from April to October, and not available for withdrawal over winter due to low flows in winter (Summary Table 1).
- the main exception is Great Bear River near the Mackenzie River, where extremely large volumes of water are available year-round due to winter outflow from Great Bear Lake.
- volumes available for withdrawal are likely to be large compared to waterbodies (Summary Figure).
- not all the annual volume available for withdrawal may be useful. Much of this water is available in May when there may be limited water demand and accessibility (Summary Table 1).
- potential sources are relatively spatially extensive. For example, the largest gap between watercourses is about 41 km (Gotcha to Big Smith creeks; Summary Table 1).
- water availability generally scales with upstream watershed area and varies by orders of magnitude.

For waterbodies, water available for withdrawal in ice covered periods ('winter') was evaluated using criteria intended to protect oxygen levels under ice for fish (DFO 2010) and littoral habitat (MVLWB 2021a; MVLWB 2021b). Conservative potential withdrawals in ice covered periods are calculated for lakes with maximum depths greater than 3.0 m as the *lesser of* (1) 10% of the under ice water volume (DFO 2010) and (2) the volume equivalent of 0.1 m of drawdown based on the lake surface area (MVLWB 2021a; MVLWB 2021b). The MVLWB protocol is considered here because it provides guidance for preservation of littoral habitat and because it is regionally applicable; however, its intended use is for small projects.

Water withdrawals in the open water period ('non-winter') are evaluated here using the MVLWB method, since it is intended to preserve littoral zone habitat. The DFO (2010) method is not applied in the open water period since lakes typically experience wind-generated mixing and seasonal overturn which oxygenates the water column.

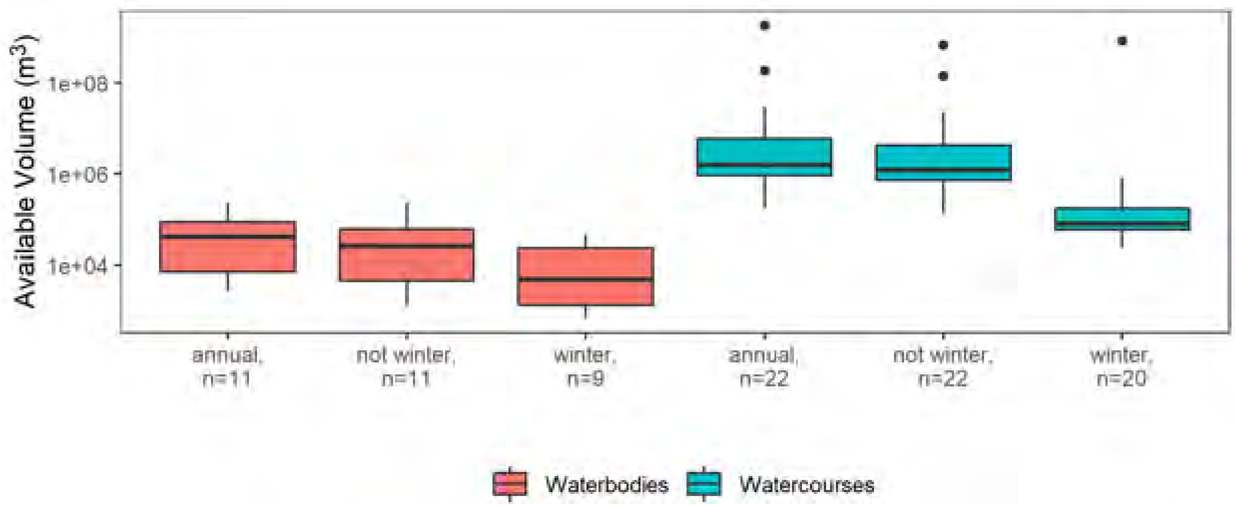
For waterbodies:

- in the ice-covered period there are nine lakes where data are available that meet criteria for winter withdrawals. In the open water period, there are eleven lakes (Summary Table 2).
- volumes available for withdrawal from waterbodies are small compared to watercourses (Summary Figure).
- there are long distances between lakes that meet assessment criteria and where data are available (Summary Table 2).
- additional lakes have been identified as candidates for future bathymetric surveys based on their surface area and depth (where known). However, even if the bathymetry of these lakes is surveyed and the lakes are found to meet withdrawal criteria, large gaps between lakes will remain along the proposed MVH alignment.

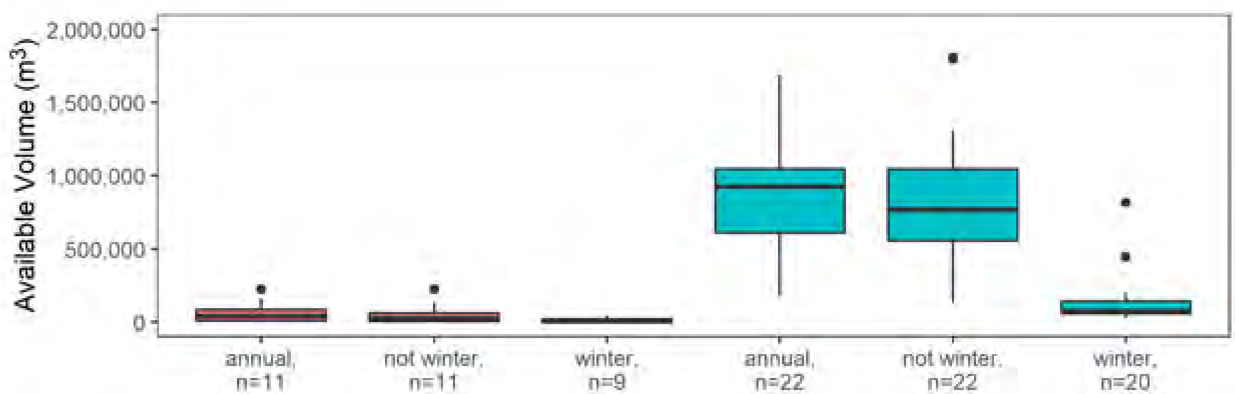
The provided volumes are estimates based on desktop studies. Additional data on a site-specific basis may be required by regulators in support of authorizations. Additional limitations are described in Section 2.

Summary Figure: Summary of Available Water for Withdrawal for Waterbodies and Watercourses

(a) all waterbodies and watercourses (log_{10} y-axis)



(b) waterbodies and watercourses, excluding the largest ten watercourses (linear y-axis)



NOTES:

- Boxplots summarize distributions of available water volumes for all waterbodies or watercourses annually and by season. They show the median (heavy line inside box) and interquartile range (IQR; spanning from 25^{th} to 75^{th} percentiles). The upper whisker extends from the top of the box to the largest value no further than 1.5 * IQR from the lower and upper edges of the box (the 'hinge'). The lower whisker extends from the bottom of the box to the smallest value at most 1.5 * IQR of the hinge. Data beyond the end of the whiskers are outliers and are plotted individually where present (Wickham 2016).
- 'Winter' as used here is November through April and 'not winter' is May through October, which aligns with approximate freeze up and breakup dates for waterbodies in the region.
- Positive outliers in panel A are the Great Bear and Blackwater rivers.
- n = sample size.
- A total of 24 waterbodies were assessed. Results shown here are for those waterbodies where sufficient data were available to calculate water availability or where waterbodies passed withdrawal criteria.
- Except for Great Bear River, watercourses do not have water available for withdrawal over most of the winter (Summary Table 1). However, most smaller watercourses have some water availability in April. One watercourse other than Great Bear River has availability in November (Hodgson Creek).

Summary Table 1: Calculated Water Availability at Assessed Watercourses Along the Proposed Mackenzie Valley Alignment

Watercourse Location	MVH Alignment (km)	Watershed Area (km^2)	Monthly Water Availability (m^3)												Annual Water Availability (m^3)
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Hodgson Creek Bridge	695.6	358	0	0	0	253,860	2,561,344	745,800	781,913	700,817	576,570	386,663	193,710	0	6,200,677
Ochre River Bridge	725.7	1,207	0	0	0	813,120	13,287,561	3,524,820	3,443,046	3,780,326	3,758,520	1,439,857	0	0	30,047,250
Whitesand Creek Bridge	733.8	346	0	0	0	179,340	2,346,545	788,370	524,396	490,668	426,300	313,658	0	0	5,069,277
Big Strawberry Creek Culvert	748.5	59	0	0	0	67,140	511,097	98,280	67,146	73,005	63,240	59,458	0	0	939,366
Small Strawberry Creek Culvert	748.6	49	0	0	0	60,570	435,705	79,050	54,157	59,799	51,780	49,941	0	0	791,002
Vermillion Creek South Bridge	752.3	68	0	0	0	72,630	577,592	116,160	79,174	85,064	73,710	67,952	0	0	1,072,282
Bob's Canyon Creek Culvert	755.3	9	0	0	0	23,880	102,765	10,980	7,719	9,827	8,490	10,323	0	0	173,984
Dam Creek Bridge	764.8	110	0	0	0	94,890	874,200	204,630	138,477	142,786	123,840	106,795	0	0	1,685,618
Blackwater Bridge	785.3	10,716	0	0	0	0	57,512,502	59,656,980	31,846,269	15,246,389	13,791,420	10,055,470	0	0	188,109,030
Steep Creek Bridge	816.5	154	0	0	0	114,390	1,168,204	304,050	204,724	205,158	178,020	146,537	0	0	2,321,083
Devil's Canyon Bridge	828.4	21	0	0	0	37,800	209,870	29,130	20,212	23,994	20,760	22,506	0	0	364,272
Saline River Bridge	831.9	317	0	0	0	170,850	2,176,076	711,180	473,680	446,524	387,900	288,858	0	0	4,655,068
Seagrams Creek Bridge	844.3	57	0	0	0	65,850	496,124	94,380	64,511	70,339	60,930	57,567	0	0	909,701
Little Smith Creek Bridge	852.3	439	0	0	0	204,720	2,880,799	1,043,340	691,486	634,105	551,130	392,336	0	0	6,397,916
Big Smith Creek Bridge	872.1	1,076	0	0	0	0	9,012,816	4,527,960	1,438,524	1,730,141	1,973,850	827,545	0	0	19,510,836
Gotcha Creek Bridge	912.7	155	0	0	0	114,810	1,174,745	306,360	206,274	206,615	179,280	147,436	0	0	2,335,520
Twelve Mile Creek Bridge	922.0	42	0	0	0	55,830	384,028	66,510	45,663	51,057	44,220	43,524	0	0	690,832
Four Mile Creek Culvert	931.5	17	0	0	0	33,630	174,933	22,710	15,810	19,096	16,530	18,445	0	0	301,154
Great Bear River Bridge	937.2	158,400	141,955,200	126,524,160	139,276,800	132,710,400	182,666,880	169,257,600	168,739,200	169,810,560	162,000,000	160,704,000	144,892,800	145,972,800	1,844,510,400
Jungle Ridge Creek Bridge	967.8	60	0	0	0	39,960	550,219	168,660	60,419	78,864	88,890	48,701	0	0	1,035,713
Notta Creek Bridge	971.5	65	0	0	0	70,830	555,582	110,160	75,144	81,034	70,200	65,131	0	0	1,028,081
Vermillion Creek North Bridge	973.4	92	0	0	0	85,920	749,456	165,810	112,530	117,800	102,120	90,272	0	0	1,423,908

NOTES:
Watercourses are sorted from south to north along the proposed MVH alignment.
Zero water availability indicates that discharge in that month is less than 30% of mean annual discharge (DFO 2013).

Summary Table 2: Calculated Water Availability at Waterbodies Along the Proposed MVH Alignment

Waterbody	Alignment (km)	Surface Area (m^2)	Available Volume (m^3)		
			Winter	Not winter	Annual
WR2	702.2	364,955	4,277	36,496	40,773
WR6	804.0	796,473	682	79,647	80,330
WR8	820.0	251,743	25,174	25,174	50,349
WR10	835.0	13,160	1,316	1,316	2,632
WR16	882.5	56,631	4,899	5,663	10,562
WR18	892.0	1,385,441	22,937	138,544	161,481
WR19	903.0	35,950	1,181	3,595	4,776
WR22	916.0	2,254,359	0	225,436	225,436
WR21	921.3	30,606	0	3,061	3,061
WR25	944.6	461,128	46,113	46,113	92,226
WR28	950.4	204,493	20,449	20,449	40,899

NOTES:

- A total of 24 waterbodies were assessed. Results shown here are for those waterbodies where sufficient data were available to calculate water availability or where waterbodies passed withdrawal criteria.
- 'Winter' as used here is November through April and 'not winter' is May through October, which aligns with approximate freeze up and breakup dates for waterbodies in the region.
- There is zero reported water availability for WR21 and WR22 in winter because volume data are not available for these waterbodies.

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Abbreviations

A. .... watershed area
b. .... regression line intercept
BCOGC. .... British Columbia Oil and Gas Commission
e.g. .... example
DFO .... Fisheries and Oceans Canada
EFN .... Environmental Flow Needs
ENV .... Ministry of Environment and Climate Change Strategy
FLNRORD .... Ministry of Forests, Lands, Natural Resource Operations and Rural Development
GBR .... Great Bear River
i.e. .... that is to say
IQR .... Inter Quartile Range
m .... regression line slope
MAD .... Mean Annual Discharge
masl .... Metres Above Sea Level
MVH .... Mackenzie Valley Highway
MVLWB .... Mackenzie Valley Land and Water Board
MVWR .... Mackenzie Valley Winter Road
n .... sample size
NHC .... Northwest Hydraulic Consultants
NT .... Northwest Territories
PCAR .... Prohibition Creek Access Road
Q .... Discharge
QAQC .... Quality Assurance/Quality Control
TOR .... Terms of Reference
WSC .... Water Survey of Canada

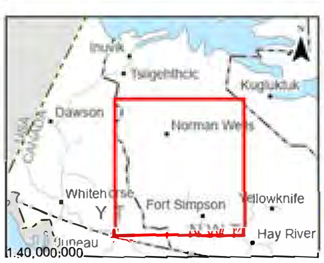
1 Introduction

This document provides flow and water withdrawal volume estimates for watercourses and waterbodies near the proposed Mackenzie Valley Highway alignment (MVH; Figure 1.1) identified for assessment as potential water sources for construction and operations of the MVH. The assessed area spans roughly from Wrigley, Northwest Territories (NT) in the south to Prohibition Creek, 18 kilometres (km) south of Norman Wells, NT in the north (an approximately 260 km straight line distance). The proposed MVH alignment distance between the southernmost and northernmost assessed sites is about 275 km (the ‘Study Area’). The proposed alignment typically parallels the east bank of the Mackenzie River, mostly along the alignment of the Mackenzie Valley Winter Road (MVWR). Watercourse crossings and water availability between Prohibition Creek and Norman Wells are published elsewhere (K’alo-Stantec 2022a). Twenty-two watercourses and twenty-four waterbodies were evaluated for potential future water withdrawals within approximately 500 m of the proposed MVH alignment between Wrigley and Prohibition Creek (Figure 1.2, Figure 1.3). These sources were identified based on their size and proximity to the alignment. Larger waterbodies and all watercourses with existing bridge crossings were included in the study.

The objectives and scope of the study are to:

- Review potential water withdrawal sources along the proposed MVH alignment.
- Review existing available data to identify sources that are likely to support water withdrawal (based on watershed, flow data, hydrographs, etc.) during certain times of the year.
- Identify monthly and/or seasonal withdrawal magnitudes that are likely to meet environmental flow needs (EFN); i.e., the volume and timing of water flow required for proper functioning of the aquatic ecosystem. EFN criteria were assessed and applied from the Mackenzie Valley Land and Water Board (MVLWB), Fisheries and Oceans Canada (DFO), Ministry of Forests, Lands, Natural Resource Operations and Rural Development (FLNRORD), and the Ministry of Environment and Climate Change Strategy (ENV) (FLNRORD and ENV 2022; DFO 2013; DFO 2010).
- Identify additional studies required to verify the findings of this desktop study (Section 7) and to support environmental assessment and licensing of water withdrawal.

During construction and operation of the MVH, water will be used for winter road construction, compaction, and dust control. The amount and timing of water withdrawals are not yet known. This document aims to research potential water withdrawal sources that could support withdrawals throughout the year while meeting EFN, and therefore could be supported by regulators for purpose of licensing. It is understood that the majority of water for winter road construction is needed in early winter (November–December); whereas water is used for compaction and dust control from June to September (Stevens, pers. comm., 2022).



Notes
1. Coordinate System: NAD83 Northwest Territories Lambert
2. Data Sources: Government of Northwest Territories, Open Data Canada, Government of Canada, ESRI Base Layers

Legend
- Water Survey of Canada Hydrometric Station
- Winter Road
- All Weather Road
- Project Alignment
- Region Boundary
- Community Boundary

0 40 80 120 160 km
1:3,847,888 (at original document size of 8.5x11)

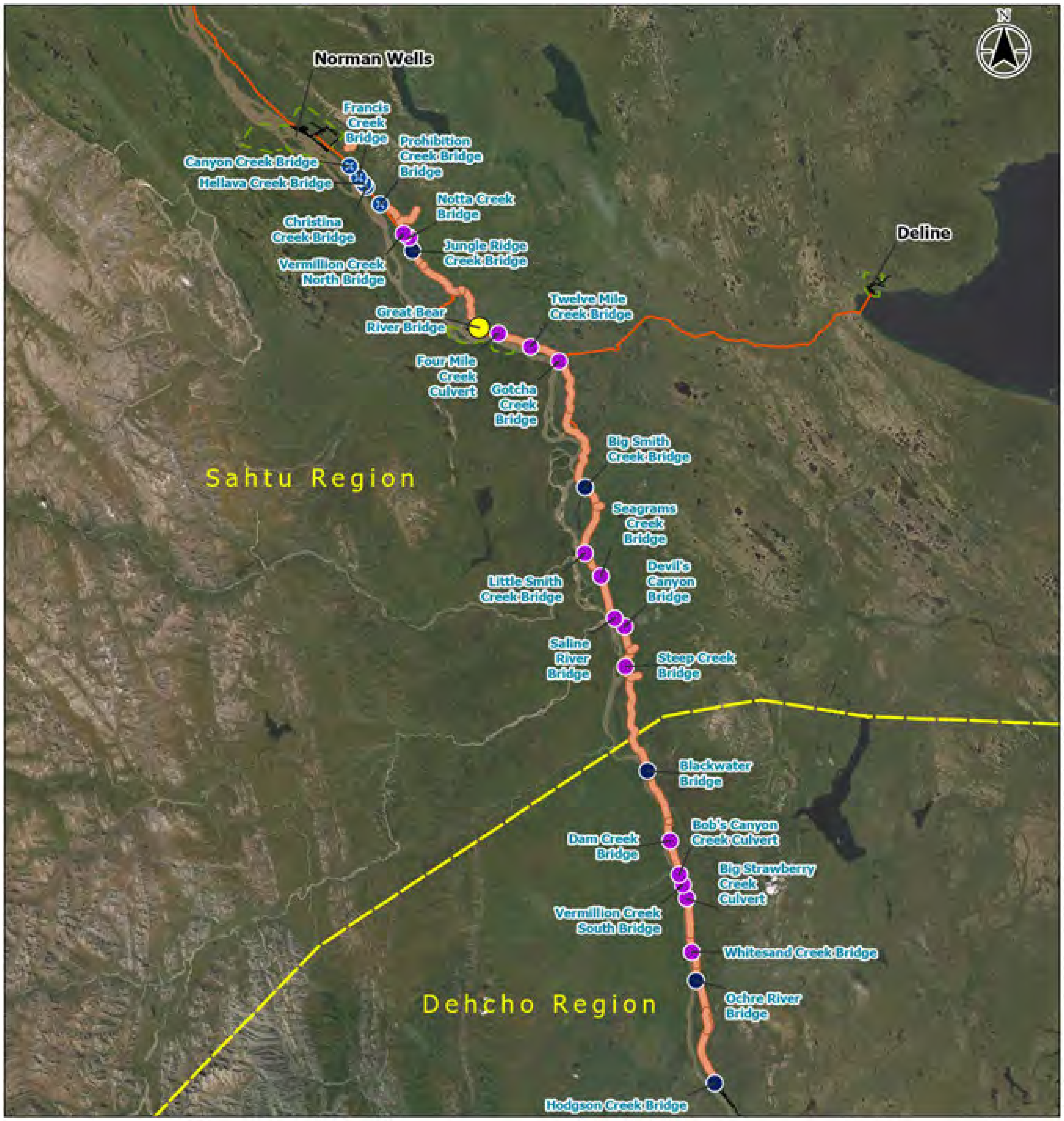
Stantec

Project Location: Northwest Territories, Canada
Project Number: <144903284>
Prepared by EHERTZMAN on 20220908
Requested by TLEWIS on 20220908

Client/Project/Report
Mackenzie Valley Highway
Mackenzie Valley Highway: Desktop Based Assessment of Water Availability

Figure No.
1.1

Title
Mackenzie Valley Highway Proposed Alignment: Regional Map and Selected Water Survey of Canada Stations



Prediction Type

- Regional Analysis (MVH)
- Regional Analysis (PCAR)
- WSC Scaling
- NHC
- Winter Road
- All Weather Road
- Project Alignment
- Region Boundary
- Community Boundary

0 10 20 30 40 km

1:1,600,000 (at original document size of 8.5x11)

Notes
1. Coordinate System: NAD83 Northwest Territories Lambert
2. Data Sources: Government of Northwest Territories, Open Data Canada, Government of Canada, ESRI Base Layers

Stantec

Project Location: Northwest Territories, Canada

Project Number: <144903284>
Prepared by EHERTZMAN on 20220908
Requested by TLEWIS on 20220908

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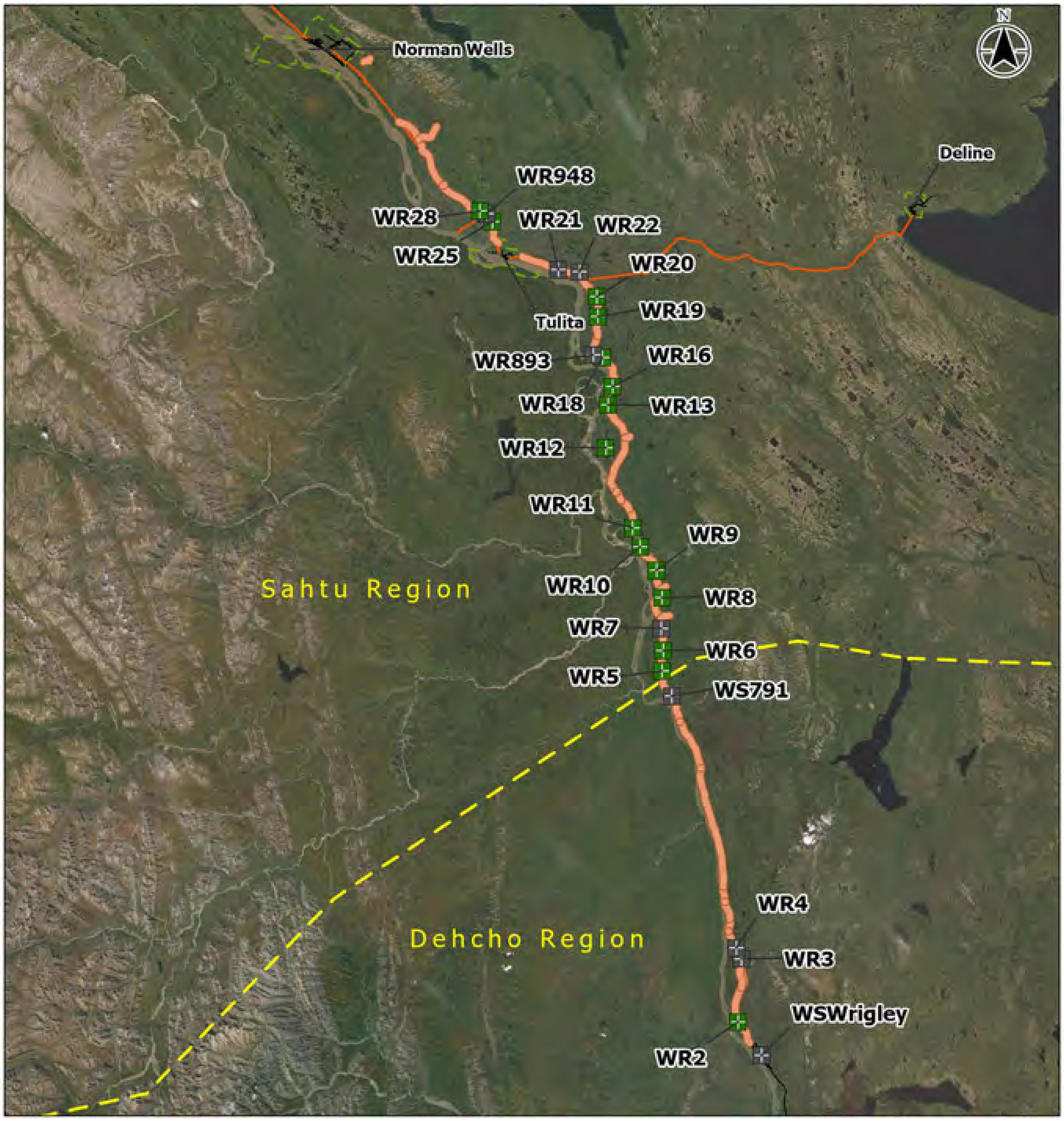
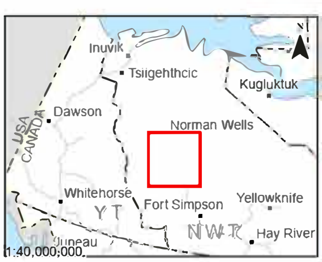
Mackenzie Valley Highway
Mackenzie Valley Highway: Desktop Based Assessment of Water Availability

Figure No.
1.2

Title
Potential Watercourse Water Sources along the Mackenzie Valley Highway Proposed Alignment

Revised: 2022-09-22 By: ehertzman





Potential Waterbody Water Sources

- Bathymetry Data Available
- No Bathymetry Data Available
- Winter Road
- All Weather Road
- Project Alignment
- Region Boundary
- Community Boundary

0 10 20 30 40 km

1:1,525,000 (at original document size of 8.5x11)

Notes

1. Coordinate System: NAD83 Northwest Territories Lambert
2. Data Sources: Government of Northwest Territories, Open Data Canada, Government of Canada, ESRI Base Layers

Stantec

Project Location: Northwest Territories, Canada

Project Number: <144903284>

Prepared by EHERTZMAN on 20220908
Requested by TLEWIS on 20220908

Client/Project/Report

Mackenzie Valley Highway
Mackenzie Valley Highway: Desktop Based Assessment of Water Availability

Figure No.

1.3

Title

Potential Waterbody Water Sources near the Mackenzie Valley Highway Proposed Alignment

Revised: 2022-09-22 By: ehertzman

For watercourses, this document provides average monthly and annual volumes available for withdrawal designed to meet EFN and Fisheries and Oceans Canada (DFO) protocols (DFO 2013). This requires flows to be known. Of the 22 studied watercourses:

- Five are gauged by the WSC and these gauged data are appropriate for deriving flows at ungauged MVH crossings.
- One is gauged by the WSC, but the gauge is far upstream of the proposed bridge crossing, and several large tributaries contribute to flows between the gauge and the crossing. This site is the proposed bridge over the Great Bear River (GBR) near Tulita and the Mackenzie River. Flow data at this crossing were obtained from previous studies (NHC 2006; NHC 2018).
- Flows at the remaining 16 proposed MVH crossings were calculated using a regional analysis approach based on the principle that streamflow from ungauged basins can be reasonably estimated from gauged basins of similar physiographic, geologic, or climatic factors (MOE 1991). Regional flow analysis was conducted by compiling flow data from 21 regional WSC stations and relating monthly flows to watershed size. Regression equations were then used to predict flows using the watershed area of each ungauged catchment.

For waterbodies, this document provides estimates of water volumes that will protect littoral habitat and oxygenated water for fish in winter, and follows protocols developed by DFO (DFO 2010) and the Mackenzie Valley Land and Water Board (MVLWB; called the ‘MVLWB method’ here) (MVLWB 2021a; MVLWB 2021b). Recommendations are made for withdrawal protocols from waterbodies that could protect flows in downstream watercourses (Section 6.3, Section 7).

2 Limitations

Flows, water volumes, and water withdrawals provided here are estimates. Most studied withdrawal sources are ungauged, and bathymetric surveys have not yet been conducted at many waterbodies. Results are approximations and are intended to focus efforts on watercourses, waterbodies, and seasons where withdrawals will have the least ecological impacts. Limitations include:

- Flows and water volumes provided here are not precise assessments of water availability in a given year. Flow predictions are reflective of average conditions in the years regional data were collected.
- Flows during floods and changes in flow due to climate change have been evaluated elsewhere (Tetra Tech 2021; Tetra Tech 2022; Tetra Tech 2020; K'alo-Stantec 2021).
- Results presented here should not be used for purposes other than those stated. For example, data presented here do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) would require a separate study tailored for such purposes.
- Analysis and recommendations are based on data available at the time of the report and rely on data provided by others which we assume to be correct but were not verified as part of this study.
- Cumulative withdrawals are not accounted for here.
- Results provided here do not consider potential effects on specific species of interest, cultural values, or on downstream flows (Section 6.3 and Section 7).
- Further site-specific study or evaluation may be required to support regulatory approval for water withdrawal.
- Changes in flows and water availability due to backwatering have not been considered. Backwatering causes river levels to rise independently from discharge, often in response to a downstream obstruction (e.g., ice, beaver dams), or a downstream waterbody or watercourse.

Recommendations for refining estimates provided here are presented in Section 6.3 and Section 7.

3 Regional Hydroclimatic Context

The watercourses and waterbodies evaluated in this study are located between approximately Wrigley, NT in the south to Prohibition Creek in the north (Figure 1.1) and are within about 500 m of the proposed MVH alignment. Climate at the northern and southern ends of the alignment is summarized in Table 3.1. Overall, climatic normal conditions (1991-2020) are similar at the southern and northern ends of the Study Area (Table 3.1). Air temperatures cool slightly from south to north. Annual total precipitation decreases slightly, i.e., by about 2%. Potential evapotranspiration (ET) increases by about 3%. These north-south differences are negligible from a hydrologic perspective. At both locations. ET exceeds precipitation (Wang 2022; Wang et al. 2012; K'alo-Stantec 2022a); i.e., there is a potential annual moisture deficit in the region.

Table 3.1 Summary Climate Data from Norman Wells and Wrigley, NT

Community	Elevation (masl)	Air Temperature (°C) Mean Annual	Air Temperature (°C) Maximum	Air Temperature (°C) Minimum	Annual Total Precipitation (MAP, mm)	Annual Total Potential Evapotranspiration (ET, mm)	MAP-ET (mm)
Norman Wells	72	-4.5	16.4	-24.3	323	389	-66
Wrigley	150	-3.6	17.1	-25.4	316	401	-85
Difference (Wrigley-Norman Wells)	**78**	**0.9**	**0.7**	**-1.1**	**-7**	**12**	**-19**
Difference (%; Wrigley-Norman Wells)	**n/a**	**n/a**	**n/a**	**n/a**	**-2**	**3**	**n/a**

NOTES:
Elevations in metres above sea level (masl) are at the airstrip in both communities.
Climate data are interpolated 1991 to 2020 climate normals from ClimateNA (Wang 2022).
Evapotranspiration (ET) is Hargreaves reference potential ET.
Maximum and minimum air temperatures are monthly averages for the warmest and coolest months.
n/a = not applicable.

Climate normal data used here are from ClimateNA, which uses peer-reviewed gridded climate data (Wang 2022; Wang et al. 2012). This data source was selected over station data (ECCC 2022a) because (a) climate normal data are available from Wrigley which allowed assessment of north-south climate trends along the proposed alignment, and (b) because it provides evapotranspiration data from land surfaces, while climate normal data from stations do not. There are therefore slight differences between climate normal data presented here from gridded datasets, and climate normal data presented elsewhere based on station data (K'alo-Stantec 2022b).

The Study Area is within the 'extensive discontinuous' (50-90%) permafrost zone (GNWT 2022a). Most of the Study Area falls within the 'Taiga Plains, Norman Range LS Ecoregion'; vegetation is a "*complex of mixed-wood forests on westerly slopes and lacustrine deposits, mixed spruce stands on the interior plateau and slopes, and extensively burned areas*" (GNWT 2009). The entirety of the Study Area is south of the tree line (GNWT 2022b).

Elevations in the Study Area decrease generally from south to north (Table 3.1), and close to the Mackenzie River. Watercourses generally drain westward from highlands to the east towards the Mackenzie River.

The Study Area is part of the Dehcho and Sahtu regions. Runoff patterns in both regions are similar and are classified as nival, i.e., a "*large portion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of regional stream hydrographs*" (Kokelj 2001). The period of snowmelt runoff in spring is called freshet, and typically starts in May. Flows decline after freshet, with occasional increases in response to rainfall, then decline through winter (October to April). The ability of a watercourse in the region to sustain flows over winter depends watershed area as well as "*watershed-specific factors including precipitation, channel slope, upland storage and particularly the presence of springs*" (Golder Associates 2006). Watersheds larger than 50-100 km^2 may be perennial (MGP 2004; K'alo-Stantec 2021).

Annual runoff changes outside of the Study Area. For example, runoff increases to the west of the Mackenzie River in the Mackenzie Mountains, decreases to the east towards Great Bear Lake, and north towards the Arctic Ocean (Cole 2013).

Precipitation and ET are similar at the northern and southern ends of the Study Area (Table 3.1). This helps explain the north-south similarity of runoff noted above.

Gauged runoff in the Sahtu region spans from 60 to about 330 mm/year, not including stations in the Mackenzie Mountains (Kokelj 2001). In the Dehcho region, the Study Area falls within the 'Interior plains' regime, where annual runoff at gauging stations spans from 55 to almost 200 mm (Faria 2002). Mean annual runoff in the Study Area was found to range between 151 and 220 mm (K'alo-Stantec 2021). Differences among published ranges may be more reflective of local site conditions and the relatively sparse gauging network than general spatial hydroclimatic trends (e.g., storage in muskeg and lakes that locally affects the timing and magnitude of flows).

4 Methods

Methods are described below for watercourses and waterbodies. Each section begins by presenting regionally applicable criteria for water withdrawals, then provides the methodologies used to assess these criteria at candidate withdrawal sites.

The MVH alignment used here is the IFAE21 alignment, and KPs cited here are relative to this. Data were collected, filtered, analyzed, and plotted using R (R Core Team 2022).

4.1 Watercourses

For the purposes of water availability calculations, all watercourses are conservatively considered to be potential fish habitat.

4.1.1 Criteria for Assessment of Environmental Flow Needs in Watercourses

For watercourses, DFO guidance (DFO 2013) is:

- "*cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a "natural flow regime" have a low probability of detectable negative impacts to ecosystems*"; and
- "*cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of impacts to ecosystems that support fisheries*". Periods below 30% MAD were identified as 'highest risk'.

Mean monthly flows are predicted here in place of instantaneous flows as a desktop-based means of estimating monthly and annual low risk withdrawals. MAD is calculated from mean monthly flows to identify the months with the 'highest risk'. This approach allows for: (a) an assessment of which months are likely candidates for low-risk water withdrawal; and (b) an estimation of water available for withdrawal during low-risk conditions.

Flow data are required to apply these criteria and calculate water availability. Flow and water availability methodologies are described below.

4.1.2 Calculation of Volumes Available for Withdrawal in Watercourses

Volumes of water potentially available for withdrawal were calculated using criteria described above (DFO 2013). Application of these criteria require flow data. Methodologies for compiling and calculating flow data are described below.

Table 4.1 Mackenzie Valley Highway Watercourse Crossings where Water Availability was Assessed

Watercourse Location	MVH Alignment (km)	UTM Easting (m)	UTM Northing (m)	UTM Zone	Region	Watershed Area (km^2)	Watershed Area Source	Prediction Type
Hodgson Creek Bridge	695.6	475,755	7,011,710	10	Dehcho	358	(K'alo-Stantec 2021)	WSC Scaling
Ochre River Bridge	725.7	465,971	7,038,047	10	Dehcho	1,207	(K'alo-Stantec 2021)	WSC Scaling
Whitesand Creek Bridge	733.8	463,508	7,045,441	10	Dehcho	346	(K'alo-Stantec 2021)	Regional Analysis
Big Strawberry Creek Culvert	748.5	459,694	7,059,416	10	Dehcho	59	(K'alo-Stantec 2021)	Regional Analysis
Small Strawberry Creek Culvert	748.6	459,640	7,059,510	10	Dehcho	49	herein	Regional Analysis
Vermillion Creek South Bridge	752.3	457,967	7,062,906	10	Dehcho	68	(K'alo-Stantec 2021)	Regional Analysis
Bob's Canyon Creek Culvert	755.3	456,550	7,065,460	10	Dehcho	9	(Tetra Tech 2020)	Regional Analysis
Dam Creek Bridge	764.8	452,501	7,074,004	10	Dehcho	110	(K'alo-Stantec 2021)	Regional Analysis
Blackwater Bridge	785.3	443,181	7,091,526	10	Dehcho	10,716	(K'alo-Stantec 2021)	WSC Scaling
Steep Creek Bridge	816.5	432,421	7,118,214	10	Sahtu	154	(K'alo-Stantec 2021)	Regional Analysis
Devil's Canyon Bridge	828.4	430,299	7,128,819	10	Sahtu	21	(K'alo-Stantec 2021)	Regional Analysis
Saline River Bridge	831.9	427,270	7,130,500	10	Sahtu	317	(K'alo-Stantec 2021)	Regional Analysis
Seagrams Creek Bridge	844.3	421,623	7,141,075	10	Sahtu	57	(K'alo-Stantec 2021)	Regional Analysis
Little Smith Creek Bridge	852.3	416,273	7,146,420	10	Sahtu	439	(K'alo-Stantec 2021)	Regional Analysis
Big Smith Creek Bridge	872.1	413,214	7,163,972	10	Sahtu	1,076	(K'alo-Stantec 2021)	WSC Scaling
Gotcha Creek Bridge	912.7	400,354	7,196,273	10	Sahtu	155	(K'alo-Stantec 2021)	Regional Analysis
Twelve Mile Creek Bridge	922.0	392,054	7,198,761	10	Sahtu	42	herein	Regional Analysis
Four Mile Creek Culvert	931.5	382,829	7,200,812	10	Sahtu	17	(K'alo-Stantec 2021)	Regional Analysis
Great Bear River	937.2	377,381	7,201,412	10	Sahtu	158,400	(NHC 2006; NHC 2018)	NHC
Jungle Ridge Creek Bridge	967.8	638,257	7,218,483	9	Sahtu	60	(K'alo-Stantec 2021)	WSC Scaling
Notta Creek Bridge	971.5	636,476	7,221,655	9	Sahtu	65	(K'alo-Stantec 2021)	Regional Analysis
Vermillion Creek North Bridge	973.4	634,748	7,222,289	9	Sahtu	92	(K'alo-Stantec 2021)	Regional Analysis

NOTES:
UTM coordinates use the WGS84 datum and are approximate.
Watercourses are sorted from south to north.
Watershed delineation methodologies for this document are described in Section 4.1.2.2. 'Watershed Area Sources' noted as 'herein' were calculated as part of this study.
'Prediction types' are described in the text.

4.1.2.1 Flow Estimation for Gauged Basins: WSC Scaling

Five candidate watercourses are gauged by the WSC (Table 4.2), not including Great Bear River (Section 4.1.2.3). Where gauged data are available, they were used to assess water availability, rather than deriving them using regional analyses.

WSC stations and studied withdrawal locations are often not at the same location. Scaling factors were produced that relate the watershed area at each WSC station to the watershed area at each bridge crossing (Table 4.2). Monthly average flows from WSC stations were modified by multiplying by scaling factors.

Table 4.2 Gauged Watercourses along the Proposed Mackenzie Valley Highway Alignment

Water Survey of Canada				Existing Bridge Crossing			
Station Name	Station Number	Watershed Area (km^2)	Delineation Source	Crossing Name	Watershed Area (km^2)	Delineation Source	Scaling Factor
HODGSON CREEK NEAR THE MOUTH	10HC007	303	K'alo-Stantec (this document)	Hodgson Creek Bridge	358	K'alo-Stantec (2022)	1.18
OCHRE RIVER NEAR THE MOUTH	10HC008	1,031	K'alo-Stantec (this document)	Ochre River Bridge	1,207	K'alo-Stantec (2022)	1.17
BLACKWATER RIVER AT OUTLET OF BLACKWATER LAKE	10HC006	7,850	ECCC (2022b)	Blackwater Bridge	10,716	K'alo-Stantec (2021)	1.37
BIG SMITH CREEK NEAR HIGHWAY NO. 1	10HC003	980	ECCC (2022b)	Big Smith Creek Bridge	1,076	K'alo-Stantec (2021)	1.10
JUNGLE RIDGE CREEK NEAR THE MOUTH	10KA006	60	ECCC (2022b)	Jungle Ridge Creek Bridge	47	BP-TEC (2002)	0.78

NOTES:

Stations are sorted from south to north.

'Scaling factor' is the watershed area at each crossing divided by watershed area at each WSC station.

Coordinates for each site are provided in Table 4.1 and Table 4.3.

4.1.2.2 Flow Estimation at Ungauged Basins: Regional Analysis

Monthly average flows and water availability were calculated using linear regressions between monthly average flow and watershed area using flow data from regional WSC stations. Regression equations were then used to calculate monthly flows at proposed crossing locations using the upstream watershed areas for these locations.

Daily flow data from WSC stations were compiled with the R library 'Tidyhydat' (Goetz, Albers and Pike 2018). Tidyhydat uses the WSC database 'Hydat' (ECCC 2022b). The Hydat version used here was published on 2022-04-18 and is the most recent database at the time of writing. The most recent finalized data for regional stations is from 2020. Provisional real-time data that have not yet undergone full quality assurance/quality control (QA/QC) were not used here.

<u>Station Selection Methodologies</u>

To develop an applicable dataset for regional analyses and flow predictions of watercourses in the Study Area, a set of selection criteria were developed and applied to regional WSC stations. Hydrometric data were compiled for all WSC stations in the NT, then filtered to include only:

- Stations falling within a 300 km buffer of the proposed MVH alignment. The start and end points of the buffer are Norman Wells in the north and Wrigley in the south.
- Stations with watershed areas up to 7,400 km^2 (set to include WSC stations 10KB001 and 10KD004; Table 4.3). This is larger than the threshold used in a recent water availability study for the Prohibition Creek Access Road (PCAR), where a ~1,000 km^2 upper limit was applied (K'alo-Stantec 2022a). The larger threshold was applied to: (a) provide more applicable predictions for MVH watercourses with larger watersheds (up to about 440 km^2; Table 4.1) compared to PCAR crossings (up to about 86 km^2), and (b) increase the number of regional WSC stations used in analyses in this data-sparse region. Effects of increasing this threshold are assessed in Section 6.2.1. For reference, proposed PCAR crossings are mapped in Figure 1.2.
- Stations with watersheds that do not drain the Mackenzie Mountains, due to the different hydrologic regime there (Golder Associates 2015) (Section 3).
- Stations where discharge is unlikely to be affected by drainage of large upstream lakes or muskeg, potentially causing delays between snowmelt and rainfall, and runoff (Section 3).
- Months (regardless of the year) with greater than or equal to 92 daily observations (i.e., greater than about three years of data per month; Figure 4.1). The statistical validity of using relatively small sample sizes was explored in the PCAR water availability study (K'alo-Stantec 2022a) and is discussed below for the MVH.

WSC stations remaining after applying the filtering process are summarized in Table 4.3, mapped in Figure 1.1, and monthly data availability at each station is presented in Figure 4.1.

Annual runoff is generally relatively uniform in the Study Area (Section 3). However, regional WSC stations that remain following the filtering process described above extend north and south of the Study Area (Figure 1.1). The relatively invariant north-south trends in runoff described in Section 3 also generally apply to these spatial limits. In the south, runoff decreases eastwards along the Mackenzie River between Fort Simpson and Great Slave Lake. In the north, runoff decreases north of Tsiigehtchic (Figure 1.1) (Cole 2013).

Data from three WSC stations[1] were frequently anomalous when flagged as backwatered and were removed from analyses.

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[1] 10KA005 (SEEPAGE CREEK AT NORMAN WELLS), 10LA004 (WELDON CREEK NEAR THE MOUTH), and 10GB005 (METAHDALI CREEK ABOVE WILLOWLAKE RIVER).

Table 4.3 Regional Water Survey of Canada Stations Used for Flow Predictions in the Study Area along the Proposed Mackenzie Valley Highway Alignment

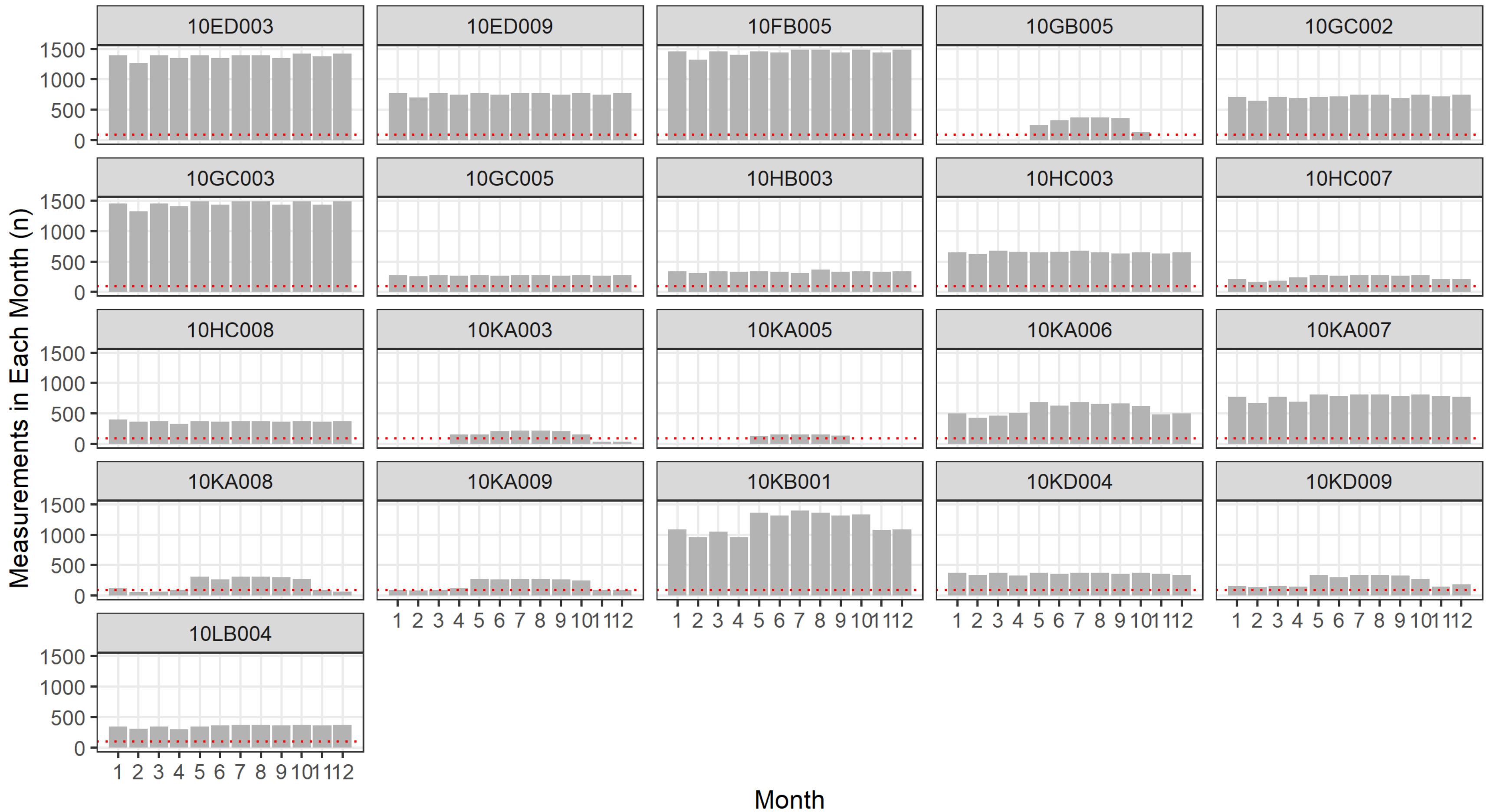
		UTM				Location[a]		Monitoring Period		
Station Number	Station Name	Easting (m)	Northing (m)	Zone	Drainage Area (km^2)	Dist. (km)	Bearing (deg)[b]	Begins	Ends	Data Points (n)[c]
10ED003	BIRCH RIVER AT HIGHWAY NO. 7	548,472	6,800,280	10	542	434	155	1974	2019	16,528
10ED009	SCOTTY CREEK AT HIGHWAY NO. 7	582,393	6,810,134	10	202	440	150	1995	2019	9,131
10FB005	JEAN-MARIE RIVER AT HIGHWAY NO. 1	593,943	6,813,683	10	1,310	442	148	1972	2019	17,380
10GB005	METAHDALI CREEK ABOVE WILLOWLAKE RIVER	504,798	6,946,566	10	344	283	151	1976	1987	4,201
10GC002	HARRIS RIVER NEAR THE MOUTH	589,613	6,861,617	10	701	399	146	1972	1995	8,584
10GC003	MARTIN RIVER AT HIGHWAY NO. 1	572,957	6,863,145	10	2,050	389	148	1972	2019	17,411
10GC005	SAHNDAA CREEK AT HIGHWAY NO. 1	541,293	6,881,332	10	251	358	151	1982	1990	3,287
10HB003	WRIGLEY RIVER NEAR THE MOUTH	465,247	7,005,398	10	1,230	213	154	1977	1988	4,018
10HC003	BIG SMITH CREEK NEAR HIGHWAY NO. 1	413,224	7,164,281	10	980	50	133	1973	1994	7,820
10HC007	HODGSON CREEK NEAR THE MOUTH	475,833	7,012,887	10	**303**	211	150	2006	2014	2,896
10HC008	OCHRE RIVER NEAR THE MOUTH	469,488	7,040,295	10	**1,031**	184	148	2006	2019	4,412
10KA003	BOSWORTH CREEK AT NORMAN WELLS	599,129	7,242,508	9	122	75	-54	1973	1979	1,375
10KA005	SEEPAGE CREEK AT NORMAN WELLS	606,333	7,239,786	9	31	68	-53	1974	1978	1,614
10KA006	JUNGLE RIDGE CREEK NEAR THE MOUTH	635,408	7,217,955	9	60	31	-56	1980	2018	6,796
10KA007	BOSWORTH CREEK NEAR NORMAN WELLS	598,863	7,246,213	9	125	77	-52	1980	2018	9,256
10KA008	OSCAR CREEK NEAR NORMAN WELLS	575,639	7,259,095	9	638	104	-53	2009	2018	2,264
10KA009	CANYON CREEK AT PIPELINE CROSSING	615,995	7,236,583	9	*68*	58	-50	2009	2018	2,199
10KB001	CARCAJOU RIVER BELOW IMPERIAL RIVER	561,399	7,242,010	9	7,400	108	-65	1976	2020	14,321

Table 4.3 Regional Water Survey of Canada Stations Used for Flow Predictions in the Study Area along the Proposed Mackenzie Valley Highway Alignment

Station Number	Station Name	UTM Easting (m)	UTM Northing (m)	UTM Zone	Drainage Area (km^2)	Location[a] Dist. (km)	Location[a] Bearing (deg)[b]	Monitoring Period Begins	Monitoring Period Ends	Data Points (n)[c]
10KD004	RAMPARTS RIVER NEAR FORT GOOD HOPE	487,561	7,332,446	9	7,300	218	-50	1985	1996	4,322
10KD009	CHICK CREEK ABOVE CHICK LAKE	539,521	7,304,005	9	**16**	160	-47	2008	2018	2,870
10LB004	LOON RIVER NEAR THE ARCTIC CIRCLE	508,817	7,377,239	9	2,745	233	-38	2009	2020	4,202

NOTES:
Stations are sorted by station number.
[a] Relative to Tulita, NT.
[b] Bearing is degrees clockwise (+) or counterclockwise (-) from Tulita, NT to the WSC station.
[c] Number of daily observations of flow.
Bolded watershed areas were calculated herein by K'alo-Stantec (see text for methods). The watershed area for Canyon Creek was obtained from hydrotechnical assessment and design documents (Tetra Tech 2021; Tetra Tech 2022).
Coordinates use the WGS84 datum.

Figure 4.1 Histograms for Selected Water Survey of Canada Stations, Showing the Number of Observations in Each Month for the Period of Record



NOTES:

(1) the red horizontal line is at n=92. Months where n<92 at each station were excluded from regression modelling.

(2) Month=1 represents January; Month=12 represents December

Watershed Delineation Methodologies

The regional flow analysis method requires watershed areas for regional WSC stations and for target watercourses. For WSC stations, most watershed areas are available from HYDAT (ECCC 2022b) (Table 4.3). For target crossings, most watershed areas have been published in previous studies (Table 4.1).

Where watershed areas were missing, they were calculated by K'alo-Stantec in ArcGIS. The watershed areas for these stations were calculated using ArcGIS software. National Hydrographic Network basins (Natural Resources Canada 2022) were segmented along topographic ridgelines and flow patterns.

Flow and Water Availability Calculation

Flows were calculated using linear regressions between watershed area and mean monthly discharge for selected regional WSC stations (Table 4.3; Figure 1.2). Discharge and watershed area were log-transformed and regressions were conducted for each month. Watershed area is the predictor and mean monthly flow is the predictand.

Flow data were grouped by station and month, and average flows were retained if at least 92 daily data points remained in each group (Figure 4.1; horizontal red lines). This represents about three years of monitoring in each month if monitoring was continuous. This small sample size threshold may not capture the full range of hydroclimatic variability. Effects of sample size on flow statistics were assessed in the PCAR water availably report; stations with small monthly sample sizes were found to have similar variability as stations with larger samples sizes (K'alo-Stantec 2022a). An assessment of the relationships between sample size and flow variability was also conducted for WSC stations selected here (Table 4.3); variability was also found to be more controlled by site-specific factors than by sample size.

4.1.2.3 Flow Estimation at the Great Bear River near the Mackenzie River: 'NHC' Method

The proposed MVH alignment crosses the GBR near Tulita and the Mackenzie River (Figure 1.2). A WSC gauging station is located on the GBR about 100 km^2 upstream of the proposed crossing, near the outlet of Great Bear Lake (GREAT BEAR RIVER AT OUTLET OF GREAT BEAR LAKE, station number 10JC003). The WSC Scaling approach was not used at this crossing because several large tributaries enter the GBR between the WSC gauge and Tulita, potentially altering the timing and magnitude of flows (NHC 2006; NHC 2018).

The upstream watershed area at the outlet of Great Bear Lake is 145,400 km^2 (ECCC 2022b), and downstream tributaries contribute an additional 12,000 km^2 (NHC 2006; NHC 2018), so the total watershed area at the proposed crossing is about 158,400 km^2. The regional analysis approach used here is also not appropriate for estimating GBR flows because of the extremely large watershed area of both the lake and downstream tributaries.

Monthly flow statistics for the GBR at Tulita have been published (NHC 2006; NHC 2018). These were calculated by combining gauged flows at the WSC station with flows from downstream tributaries estimated using a regional analysis deemed to be appropriate for the scale of the downstream tributaries.

The 50^{th} percentile (median) monthly flow data from this analysis are used here (NHC 2018). Other methodologies used here present monthly mean rather than median flow statistics. Water available from the GBR is likely more constrained by pump capacity than by river flow rates; therefore, this decision is not expected to impact water availability for the Project.

It should also be noted that the Mackenzie River seasonally backwaters into the GBR near the proposed crossing (NHC 2006; NHC 2018). When backwatering occurs, water availability would not be directly related to flows in the GBR. Water availability would increase at these times due to contributions from the Mackenzie River

4.2 Waterbodies

4.2.1 Criteria for Assessment of Environmental Flow Needs in Waterbodies

For the purposes of water availability calculations, all waterbodies with open water maximum depths greater than 1.5 m (the maximum ice depth in the region; DFO, 2010) are potential fish habitat. Lakes shallower than this would freeze to ground in winter.

Criteria for withdrawals vary depending on when lakes are ice covered or ice-free. The ice-covered period for lakes in the region spans from approximately November to April (Bigras 1990), though this period has been shortening (Duguay et al. 2006), and larger lakes would be expected to freeze and break up later than smaller lakes due to their larger thermal inertia. Methods for ice-covered periods are applied for November to April, and methods for open water periods are applied for May through October, with the caveat that these should be adjusted where site-specific information is available.

4.2.1.1 Criteria During Periods of Ice-Cover

DFO (2010) Criteria

The proposed alignment is located south of the tree line, but north of Fort Simpson, NT. Maximum ice thickness is expected to be about 1.5 m (DFO 2010). Given this expected maximum thickness, DFO winter withdrawal guidance is summarized in Table 4.4. To apply these criteria, maximum lake depth and lake volume are needed.

Table 4.4 Fisheries and Oceans Canada (DFO) Winter Water Withdrawal Guidance for Ice-Covered Waterbodies, Applicable to Lakes Located South of the Tree Line but North of Fort Simpson, Northwest Territories

Maximum Open Water Depth	DFO Protocol Guidance (applies to ice-covered waterbodies)
Shallower than 1.5 m	"*exempt from 10% maximum withdrawal limit*". Interpreted as withdrawals cannot occur when ice is at its maximum thickness, and may occur based on site-specific conditions when ice thickness is less than its annual maximum.
Deeper than 1.5 m, and shallower than 3.0 m	waterbodies are "*particularly vulnerable to the effects of water withdrawal*" Interpreted as withdrawals should not occur.
Deeper than 3.0 m	"*total water withdrawal… is not to exceed 10% of the available water volume*"

NOTE:
Guidance is from DFO 2010.

Importantly, these criteria are not applicable if less than 100 m^3 is to be withdrawn over the course of one ice-covered period, or if the waterbody is not potential fish habitat (DFO 2010).

Mackenzie Valley Land and Water Boards Method

The above (DFO) criteria were developed for winter water withdrawals as a means of preserving oxygenated water for overwintering fish (Cott et al. 2008); however, protocols for withdrawal from waterbodies often also include consideration of littoral habitat (BCOGC 2022; Hatfield Consultants 2016).

The Land and Water Boards of the Mackenzie Valley (MVLWB) developed a simple methodology for determining winter water use capacity for small-scale projects in the NT that explicitly considers changes to littoral habitat (MVLWB 2021b; MVLWB 2021a) (called 'MVLWB method' here). The MVLWB method may not be directly applicable to the MVH due to the large size of the MVH project and potential multi-year use of water sources; however, it is considered here because it provides guidance for preservation of littoral habitat and because it is regionally applicable.

Where waterbodies have under-ice water depth of at least 1.5 m and a minimum total (open water) depth of at least 3 m, the MVLWB method defines total available water in winter as (MVLWB 2021b; MVLWB 2021a):

$$\text{Total Available Water Use Capacity } (m^3) = \text{Total Surface Area } (m^2) * 0.10 \text{ m}$$

The MVLWB method has the advantage of not requiring detailed bathymetric surveys to determine water availability, unlike the DFO (2010) protocol.

Where this method is used, seasonal field verification of water depth is recommended, with at least three depth measurements >20 m from shore and approximately 20 m apart recommended (MVLWB 2021b; MVLWB 2021a).

4.2.1.2 Criteria During Periods of Open-Water

Criteria for open water withdrawals from lakes have not been published for the NT. The DFO (2010) method is not directly pertinent since lakes typically experience wind-generated mixing and seasonal overturn which oxygenates the water column (Wetzel 2001). The MVLWB criterion (volume equivalent of 0.1 m of drawdown) is ecologically relevant during periods of open water from the perspective of preserving littoral habitat. This is also a criterion adopted by the British Columbia Oil and Gas Commission (BCOGC)(BCOGC 2022). Therefore, the MVLWB method is applied here for periods of open water.

Lakes with maximum open water depths of less than 1.5 m would freeze to bottom in winter. These are not considered waterbodies by the definition in DFO (2010) and would not be expected to support fish. Therefore, it is proposed that these lakes may be considered for withdrawal in periods of open water. This is supported by discussions with MVLWB. However, MVLWB also noted that these lakes may contain environmental values other than fish; therefore, for these instances MVLWB encourage submission of information demonstrating how impacts would be minimized (Potten, pers. comm., 2022).

Withdrawals from lakes with maximum open water depths between 1.5 and 3.0 m are not allowed during periods of ice cover and were identified as "*particularly vulnerable to the effects of water withdrawal*" (DFO 2010)(Table 4.4). This vulnerability is considered here to extend into the open water period, given that residence time could be low in some lakes and in some months where throughflow is low. This is a conservative assumption that could be refined on a site-specific basis and/or with additional study (Section 6.3).

The criterion used here during periods of open water only requires surface area, not volume from bathymetric surveys. Therefore, a larger set of lakes are available for open water withdrawal calculations (Section 4.2.2).

The criterion applied here for open water withdrawals is intended for the preservation of littoral habitat only. Volumes provided here are coarse estimates for environmental assessment. For the purposes of licensing, other environmental values may need to be considered, for example EFN in watercourses downstream of where withdrawals occur. A potential water balance methodology based on methodologies in British Columbia and Alberta is described in Section 6.3.

4.2.2 Calculation of Volumes Available for Withdrawal in Waterbodies

Waterbodies for consideration for withdrawal were selected based on their previous use by the GNWT for winter road construction and/or proximity to the MVH alignment and are summarized in Table 4.5. Bathymetry, volume, surface area, lake depth, and long axis length for these waterbodies were compiled from previous studies (Golder Associates 2008; Golder Associates 2006; AAR 2003; K'alo-Stantec 2021). Where surface area and long axis length were not available, they were calculated by K'alo Stantec using remotely sensed imagery.

To summarize the criteria for calculating withdrawals from waterbodies used here:

- In periods of ice-cover (November to April), the *minimum* of the DFO (10% of under ice volume) and MVLWB methods (volume equivalent of a 0.1 m drawdown).
- In periods of open-water (May to October), the MVLWB method only (volume equivalent of a 0.1 m drawdown).

For evaluation of DFO criteria, volumes available for withdrawal were calculated at 10% of winter lake volume where available (DFO 2010). For evaluation using MVLWB methods, lake surface areas (units = m^2) were multiplied by 0.1 m (units = m^3) to approximate available under-ice volume (MVLWB 2021b; MVLWB 2021a).

Table 4.5 Waterbodies Considered for Withdrawals Near the Proposed Mackenzie Valley Highway

Waterbody Name			UTM[b]						Depth (m)			Volume (m^3)		Data Sources			
Used Here	Other	MVH Alignment (km)[a]	Easting (m)	Northing (m)	Zone	Region	Long Axis Length (m)	Surface Area (m^2)	Max.	Max. (coarse)[d]	Mean	Non-Winter	Winter[c]	Long Axis	Area	Depth	Bathymetry and Volume
WSWrigley	Lake 686.5	686.5	479,403	7,008,904	10	Dehcho	2,700	902,073						herein	herein		
WR2	DCN3	702.2	472,036	7,016,389	10	Dehcho	800	364,955	5.1		1.1	296,193	42,770	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(AAR 2003)
WR3		718.8	470,063	7,032,542	10	Dehcho	1,235	533,832		2.9				herein	herein	(Golder Associates 2006)	
WR4		721.8	468,228	7,035,063	10	Dehcho	290	36,400		2.9				herein	herein	(Golder Associates 2006)	
WS791		791.0	440,446	7,096,280	10	Dehcho	215	36,388						herein	herein		
WR5	ST24	798.8	436,935	7,102,044	10	Dehcho	1,100	200,168	2.1		0.8	107,350	729	herein	(Golder Associates 2006)	(Golder Associates 2006)	(AAR 2003)
WR6	ST23	804	436,369	7,107,258	10	Sahtu	1,780	796,473	3.4		0.9	743,539	6,823	herein	herein	(Golder Associates 2006)	(AAR 2003)
WR7		810.1	434,895	7,112,780	10	Sahtu	498	207,259		1.5				herein	herein	(Golder Associates 2006)	
WR8		820.0	433,668	7,120,640	10	Sahtu	1,005	251,743	15.2		6.2	1,604,238	1,265,534	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR9	ST21	826.6	431,087	7,127,153	10	Sahtu	195	19,617	2.2		1.1	14,646	1,159	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR10		835.0	425,896	7,132,328	10	Sahtu	200	13,160	15.1		3.3	44,488	30,844	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR11	ST20	839.5	423,158	7,136,740	10	Sahtu	450	43,646	1.9		1.0	29,979	1,492	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR12	Mio Lake	863	412,714	7,155,905	10	Sahtu	8,931	7,432,430	2.3			9,144,746	987,269	herein	herein	(Golder Associates 2006)	(Golder Associates 2008)
WR13	ST18	876.3	411,369	7,166,920	10	Sahtu	1,100	714,769	1.7		0.9	464,479	6,061	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR16		882.5	411,677	7,171,746	10	Sahtu	300	56,631	4.9		2.1	120,505	48,991	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR18		892.0	407,963	7,179,438	10	Sahtu	1,010	1,385,441	9.3		2.8	400,864	229,369	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR893		893	405,318	7,178,932	10	Sahtu	823	190,086						herein	herein		
WR19		903.0	404,789	7,188,754	10	Sahtu	870	35,950	3.8		1.4	51,306	11,811	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR20	ST14	908.9	403,623	7,193,829	10	Sahtu	1,780	3,595,971	2.6		1.1	2,400,015	114,579	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)
WR22		916	398,118	7,199,490	10	Sahtu	2,455	2,254,359		3.4				herein	herein	(Golder Associates 2006)	
WR21		921.3	392,634	7,199,056	10	Sahtu	262	30,606		5.2				herein	herein	(Golder Associates 2006)	
WR948		948.4	371,930	7,210,050	10	Sahtu	163	16,463						herein	herein		
WR25	ST12x	944.6	373,663	7,208,213	10	Sahtu	1,700	461,128	21.7		8.2	3,804,074	3,163,813	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)	(Golder Associates 2008)
WR28	ST11	950.4	370,015	7,210,416	10	Sahtu	800	204,493	14.8		6.6	941,140	746,860	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)	(Golder Associates 2006)

NOTES:
Waterbodies are sorted from south to north.
[a] 'Alignment (km)' is the approximate mid-point of each lake along the proposed MVH alignment.
[b] UTM coordinates use the WGS84 datum.
[c] the liquid water volume is calculated assuming 1.5 m thick ice.
[d] From Table 8.1 in Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.
Data are not available when cells are blank.
Lake metric sources noted as 'herein' were calculated as part of this study.

5 Results

5.1 Watercourses

5.1.1 Flows Estimation and Water Availability for Gauged Basins: WSC Scaling

Results are provided here for each of the watercourses (at the noted location) analyzed for potential water withdrawals as calculated directly from WSC stations (Figure 1.2, Appendix A). This includes Big Smith Creek, Blackwater River, Hodgson Creek, Jungle Ridge Creek, and Ochre River (Table 4.2). Flows from these sites were obtained from WSC stations, then adjusted according to 'scaling factors': the watershed area at each crossing divided by the watershed area at each WSC station (Section 4.1.2.1).

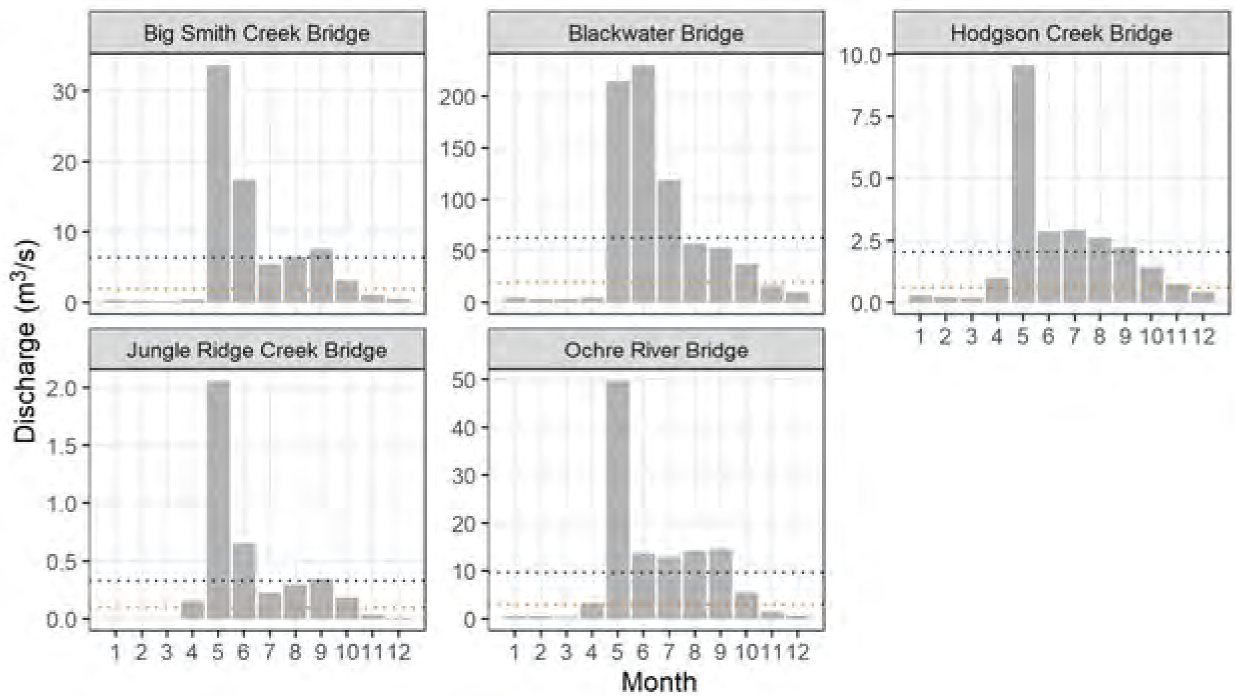
Where WSC stations exist on the same watercourse, scaling factors are typically within ±20% (Table 4.2) indicating that watershed areas are relatively similar.

The exception is Blackwater River (Figure 1.1, Table 4.2). The WSC station 10HC006 (BLACKWATER RIVER AT OUTLET OF BLACKWATER LAKE) is about 55 km upstream of the Blackwater River bridge. In addition, 10HC006 is located at the outlet of Blackwater Lake. Between these two sites, the Blackwater River watershed area increases from 7,850 km^2 to 10,716 km^2 (Table 4.2). Flows from 10HC006 would be expected to be highly influenced by the upstream lake. For example, all other sites analyzed here experience peak flow in May, while peak flow at Blackwater River occurs in June. This delay is likely a result of slow release of water from Blackwater Lake (Faria 2002). Flows at Blackwater River bridge are also likely influenced from the almost 3,000 km^2 of land area downstream of 10HC006.

Flows at Blackwater River bridge were calculated using the 'scaling factor' approach rather than the regression-based approach because of the large watershed size at Blackwater River. The largest target watershed area used in the regression approach was about 440 km^2: about 24 times smaller than the Blackwater River watershed area at the bridge (Table 4.1). Given the large size of the Blackwater River, flows there may have very different timing and magnitudes compared to smaller watersheds; therefore. regional analysis was not used at this site. However, this site was used to evaluate differences between the regional analysis and WSC scaling approaches; results are presented in Section 6.2.1.

Notably, a WSC station briefly operated on the Blackwater River, much closer to the bridge crossing: 10HC005: BLACKWATER RIVER NEAR THE MOUTH. However, this station only operated from 1983 to 1985. Its period of operation did not overlap with 10HC006, preventing comparison of flows at both sites.

Figure 5.1 Monthly Average Discharge at Potential Water Withdrawal Locations Along the Proposed Mackenzie Valley Highway Alignment, Derived Directly from Water Survey of Canada Stations (WSC Scaling Approach)



NOTES:

The upper dark horizontal lines are MAD at each location calculated using the 'scaling factor'. The lower orange lines are 30% of MAD. Month=1 represents January; Month=12 represents December.

5.1.2 Flows and Water Availability at Ungauged Basins Derived Using Regional Analyses

Regressions developed for ungauged watercourses along the proposed MVH alignment are presented in Figure 5.2 and statistics are provided in Table 5.1.

Table 5.1 Regional Analysis Regression Coefficients and Statistics

Month	Slope (m)	Intercept (b)	r^2	p-value	n
Jan	1.352	-4.651	0.60	<0.001	16
Feb	1.918	-6.603	0.68	<0.001	15
Mar	1.439	-5.155	0.59	0.001	14
Apr	0.556	-1.571	0.65	<0.001	16
May	0.862	-1.245	0.91	<0.001	21
Jun	1.177	-2.505	0.96	<0.001	21
Jul	1.162	-2.658	0.92	<0.001	21
Aug	1.077	-2.472	0.90	<0.001	21
Sep	1.079	-2.523	0.85	<0.001	21
Oct	0.940	-2.319	0.93	<0.001	19
Nov	1.104	-3.282	0.90	<0.001	16
Dec	1.101	-3.607	0.74	<0.001	17

NOTES:
Regressions equations are solved using $\log_{10}$-transformed drainage area (see text below). r^2 is a measure of the regression's overall 'goodness of fit' and a p-value >0.05 indicates that a regression is not statistically significant. n = sample size, i.e., the number of flow-area pairs in each regression.

Monthly average discharge (Q) is calculated as follows:

$$\log_{10}Q = m*\log_{10}A + b$$

where '$\log_{10}Q$' is $\log_{10}$ transformed monthly average discharge, 'm' and 'b' are regression coefficient slopes and intercepts (Table 5.1), and '$\log_{10}A$' is the $\log_{10}$ transformed watershed area (*A*, km^2) for the location of interest.

Q in metres cubed per second (m^3/s) is calculated as:

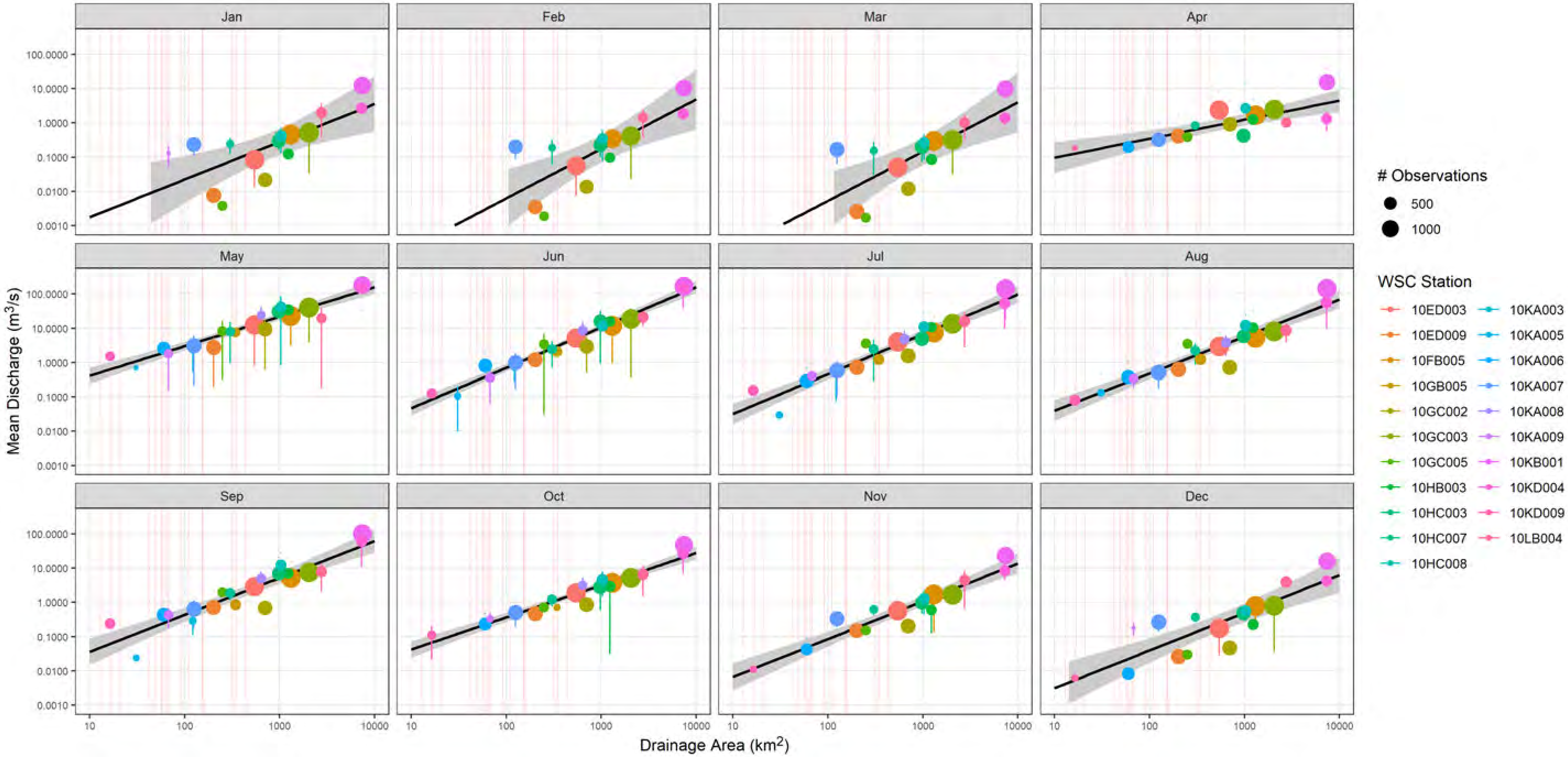
$$Q = 10^{\log_{10}Q}$$

All monthly regressions are statistically significant (p-value less than or equal to 0.05; Figure 5.2; Table 5.1). Correlation coefficients are high (>0.85) from May to November, and lower (but >0.59) from December through April. Correlation coefficients are highest from spring through to early fall when snowmelt and rainfall feed watercourses and flow magnitudes scale with the land area over which water collects (watershed area). This is the period when flows are highest and most of the annual runoff occurs.

In winter months, regressions remain statistically significant (p-value >0.05), but correlation coefficients are lower (Figure 5.2; Table 5.1), meaning that discharge is less directly related to watershed area compared to other months. Discharge is low in these months and is a small fraction of MAD. Discharge in winter is likely mainly fed by site-specific occurrence of groundwater seeps (Section 3). Seasonal operation of regional WSC stations also leads to smaller sample sizes for regressions in these winter months, which likely negatively affects regression results in these months (Figure 4.1).

Watersheds where regional analyses were applied span a large range of areas (9 to 440 km^2; Table 4.1). From April to December, regional WSC data exist from stations with watershed areas in the range of those of target watersheds (Table 4.3; vertical lines on Figure 5.2). From January through March, there are fewer data from WSC stations with small watersheds, which contributes to uncertainty in flow predictions in these months.

Figure 5.2 Relationships Between Watershed Area and Mean Monthly Discharge at Selected Regional Water Survey of Canada Stations

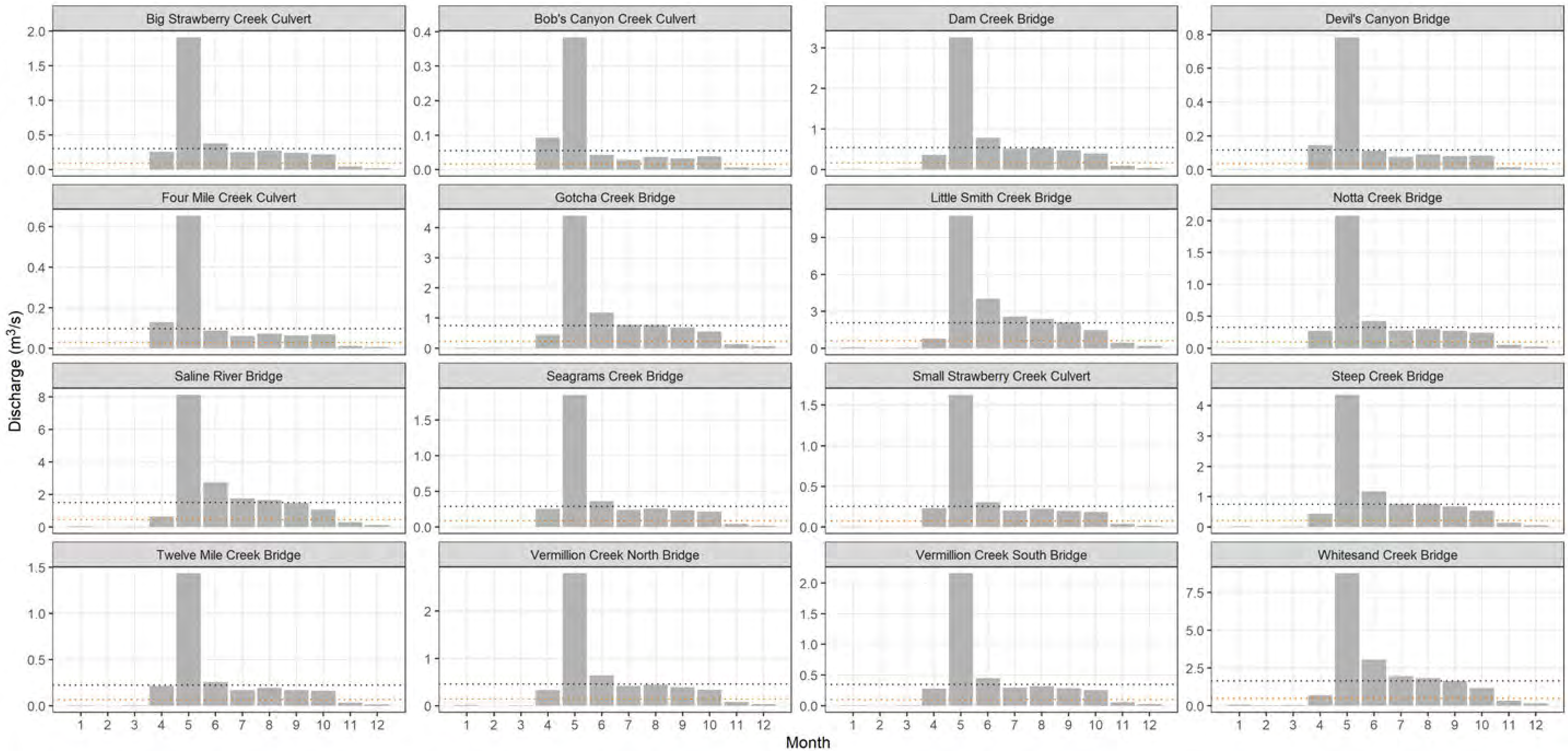


NOTES:

Vertical red lines are the watershed areas of potential withdrawal sites (not including sites where WSC stations exist and the 'WSC scaling' flow prediction approach was used). Black lines are best-fit linear regressions and grey envelopes represent 95% confidence intervals. Confidence intervals are outside y-axis limits for small watersheds in January, February, and March. Vertical error bars on points are +/- one standard deviation and the size of each point is scaled to the number of daily observations. Regression statistics are provided in Table 5.1.

Results are provided for each of the watercourses analyzed for potential water withdrawals predicted with regression-based techniques in Figure 5.3 and Appendix B. Predicted flows follow the nival hydrologic regime of the region, i.e., typically a snowmelt dominated freshet in May, declining flows from June through to early fall, and a small increase in flows due to rainfall runoff in October (Section 3).

Figure 5.3 Monthly Average Discharge at Potential Water Withdrawal Locations Along the Proposed Mackenzie Valley Highway Alignment, Predicted by Regression



NOTES:
The upper dark horizontal lines are MAD at each crossing. The lower orange lines are 30% of MAD. Month=1 represents January; Month=12 represents December. Watercourses are sorted alphabetically.

5.1.3 Flows and Water Availability at the Great Bear River near the Mackenzie River

Flows and water availability at the GBR near the Mackenzie River are summarized in Table 5.2. Unlike all other rivers analyzed here, the GBR has large amounts of flow over winter (*cf.* Appendices A and B). No months have flows that are less than 30% of MAD. Therefore, according to DFO (2013) criteria, water is available for withdrawal in all months. Due to the large size of the GBR, large volumes are available for withdrawal in all months.

Table 5.2 Great Bear River Near the Mackenzie River: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
Month	Median (m^3/s)	% of Annual Discharge[a]	10% Median (m^3/s)	Median	10% Median	Median	10% Median	Available[b]
Jan	530	91	53	4.58E+07	4.58E+06	1.42E+09	1.42E+08	1.42E+08
Feb	523	89	52	4.52E+07	4.52E+06	1.27E+09	1.27E+08	1.27E+08
Mar	520	89	52	4.49E+07	4.49E+06	1.39E+09	1.39E+08	1.39E+08
Apr	512	88	51	4.42E+07	4.42E+06	1.33E+09	1.33E+08	1.33E+08
May	682	117	68	5.89E+07	5.89E+06	1.83E+09	1.83E+08	1.83E+08
Jun	653	112	65	5.64E+07	5.64E+06	1.69E+09	1.69E+08	1.69E+08
Jul	630	108	63	5.44E+07	5.44E+06	1.69E+09	1.69E+08	1.69E+08
Aug	634	108	63	5.48E+07	5.48E+06	1.70E+09	1.70E+08	1.70E+08
Sep	625	107	63	5.40E+07	5.40E+06	1.62E+09	1.62E+08	1.62E+08
Oct	600	103	60	5.18E+07	5.18E+06	1.61E+09	1.61E+08	1.61E+08
Nov	559	96	56	4.83E+07	4.83E+06	1.45E+09	1.45E+08	1.45E+08
Dec	545	93	55	4.71E+07	4.71E+06	1.46E+09	1.46E+08	1.46E+08
Annual Mean	**584**	**n/a**	**58**	**5.05E+07**	**5.05E+06**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**1.84E+10**	**1.84E+09**	**1.84E+09**

NOTES:

Flow data source is NHC (2018); described in Section 4.1.2.3.

No months have less than 30% of mean annual discharge (175 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] 'Available' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

5.1.4 Summary of Flow Predictions and Water Availability at all Studied Locations

Detailed month-by-month flow and water availability predictions are provided in Appendices A and B. Key statistics are summarized and visualized in Table 5.3 and Figure 5.4.

In Table 5.3, the '*Annual Available Withdrawal Volume*' is the water volume available for low-risk withdrawal, using criteria from DFO (2013); i.e., 10% of monthly average flow in months where discharge is greater than 30% of MAD. These volumes are useful as a basis for water license applications and will need to be verified by monitoring/measuring flows in the field (Section 7).

Not all the annual volume available for withdrawal may be useful. Much of this water is available in May when there may be limited water demand and accessibility. Please refer to Appendices A and B for monthly water availability data.

The GBR and Blackwater River are much larger than the other studied watercourses, and water availability is correspondingly high.

At the proposed GBR crossing, water is available for withdrawal year-round according to criteria applied here. Volumes available are extremely large compared to other assessed sources. Water available from this source represents 87% of all water availability from all assessed watercourses.

At the Blackwater River bridge, the watershed area of the river is 10,716 km^2, about 24 times larger than the next largest watershed area where regional analysis was conducted. Excluding the GBR, the annual available withdrawal volume there (~1.9×10^8 m^3) is more than twice what is available at all other studied locations combined (~8.7×10^7 m^3; Table 5.3).

Note that according to DFO protocols (DFO 2013), water is likely to be available for withdrawal from most watercourses from approximately from April to October[2]. Flows in these months are greater than 30% of MAD. In addition, about half of the annual water volume available for low-risk withdrawal occurs in May (Figure 5.4). See Appendices A and B for monthly flow data and volumes.

As described above, the availability of water from watercourses is highly seasonal (Figure 5.4); however, waterbodies provide additional potential water sources in winter. This is assessed in the next section.

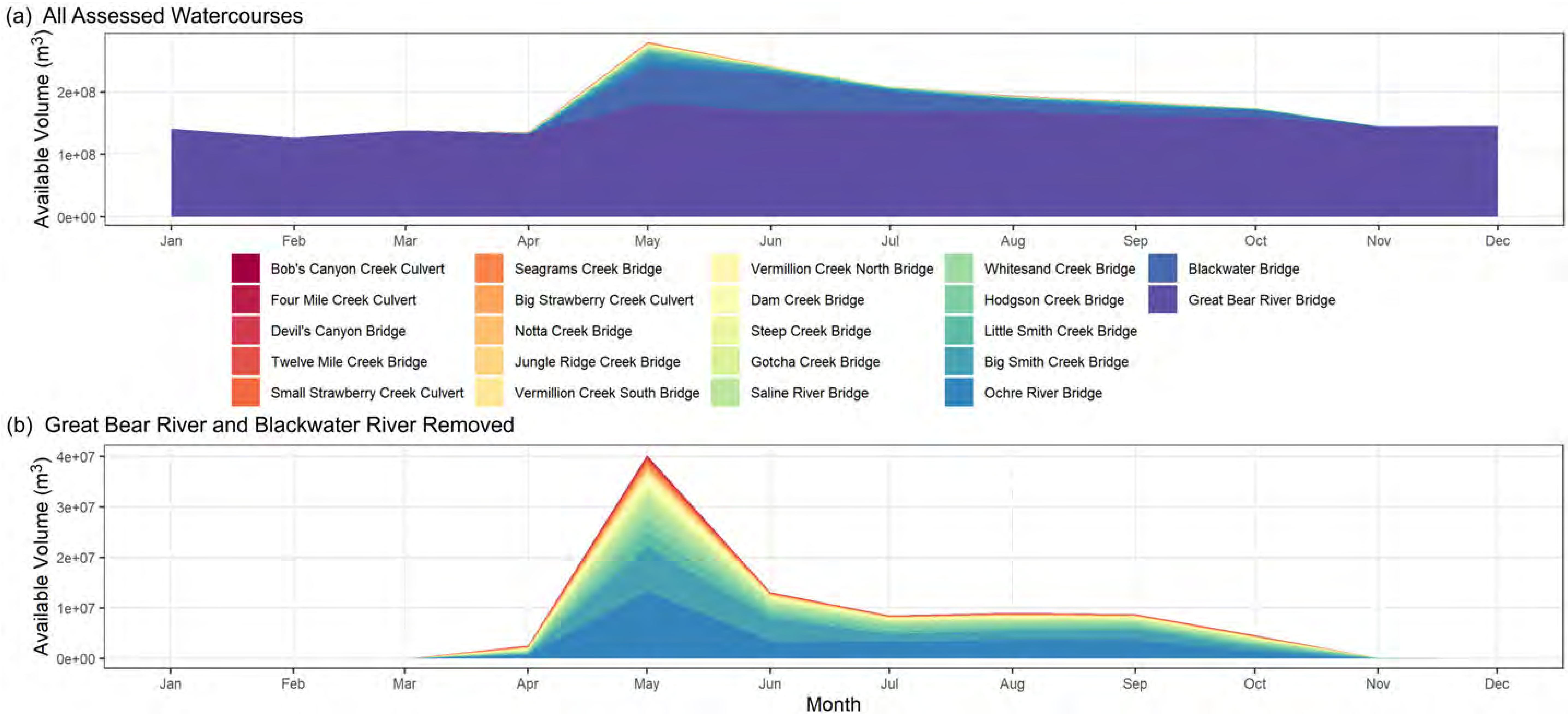
[2] Exceptions are flows at Blackwater River bridge (allowed from May to October) and Hodgson Creek bridge (allowed from April to November).

Table 5.3 Flow Summary Statistics for Flow and Water Availability at Potential Water Withdrawal Locations Along the Proposed Mackenzie Valley Highway Alignment

Watercourse Location	MVH Alignment (km)	Watershed Area (km^2)	MAD (m^3/s)	30%MAD (m^3/s)	Max Discharge (m^3/s)	Potential Annual Available Withdrawal Volume (m^3)[a]	Flow Prediction Type
Hodgson Creek Bridge	695.6	358	2.04	0.613	9.6	6,200,677	WSC Scaling
Ochre River Bridge	725.7	1,207	9.71	2.91	49.6	30,047,250	WSC Scaling
Whitesand Creek Bridge	733.8	346	1.64	0.492	8.8	5,069,277	Regional Analysis
Big Strawberry Creek Culvert	748.5	59	0.30	0.090	1.9	939,366	Regional Analysis
Small Strawberry Creek Culvert	748.6	49	0.25	0.076	1.6	791,002	Regional Analysis
Vermillion Creek South Bridge	752.3	68	0.34	0.103	2.2	1,072,282	Regional Analysis
Bob's Canyon Creek Culvert	755.3	9	0.06	0.017	0.4	173,984	Regional Analysis
Dam Creek Bridge	764.8	110	0.54	0.163	3.3	1,685,618	Regional Analysis
Blackwater Bridge	785.3	10,716	62.8	18.9	230	188,109,030	WSC Scaling
Steep Creek Bridge	816.5	154	0.75	0.224	4.4	2,321,083	Regional Analysis
Devil's Canyon Bridge	828.4	21	0.12	0.035	0.8	364,272	Regional Analysis
Saline River Bridge	831.9	317	1.51	0.452	8.1	4,655,068	Regional Analysis
Seagrams Creek Bridge	844.3	57	0.29	0.087	1.9	909,701	Regional Analysis
Little Smith Creek Bridge	852.3	439	2.08	0.623	10.8	6,397,916	Regional Analysis
Big Smith Creek Bridge	872.1	1,076	6.38	1.91	33.7	19,510,836	WSC Scaling
Gotcha Creek Bridge	912.7	155	0.75	0.226	4.4	2,335,520	Regional Analysis
Twelve Mile Creek Bridge	922.0	42	0.22	0.066	1.4	690,832	Regional Analysis
Four Mile Creek Culvert	931.5	17	0.10	0.029	0.7	301,154	Regional Analysis
Great Bear River Bridge	937.2	158,400	584	175	682	1,844,510,400	NHC[b]
Jungle Ridge Creek Bridge	967.8	60	0.33	0.099	2.1	1,035,713	WSC Scaling
Notta Creek Bridge	971.5	65	0.33	0.099	2.1	1,028,081	Regional Analysis
Vermillion Creek North Bridge	973.4	92	0.46	0.137	2.8	1,423,908	Regional Analysis

NOTES:
Watercourse crossings are sorted from south to north.
'Max Discharge' is the maximum monthly average flow, which typically occurs in May (the exception is Blackwater River, where maximum annual discharge occurs in June).
Flow prediction types are described in Section 4.1.
Please refer to Appendices A and B for the full monthly set of flow and water availability statistics.
[a] calculated as 10% of volumetric flow in months where discharge is more than 30%MAD (DFO 2013).
[b] Flows for the GBR near the Mackenzie River are from the hydrotechnical design document for the proposed GBR bridge (NHC 2018).

Figure 5.4 Area Charts of Monthly Water Availability from Studied Watercourses



NOTE:
Watercourses are sorted in order of increasing annual water availability. Plots are stacked, i.e., the uppermost line represents cumulative monthly total withdrawal volumes from considered watercourses.

5.2 Waterbodies

Potential withdrawal volumes for studied lakes along the proposed MVH alignment are presented in Table 5.5 using criteria presented in Section 4.2.1.1.

5.2.1 Withdrawals During Periods of Ice-Cover

Waterbodies that are too shallow (DFO 2010) for winter withdrawals are first removed from analyses; i.e., lakes with open water maximum depths between 1.5 and 3.0 m. None of the considered lakes have maximum open water depths of less than 1.5 m. A total of 11 lakes are likely sufficiently deep (Table 5.5; '*Max Depth (m)*' columns).

DFO (2010) criteria require lake volume to be known. Volumes are unknown in two of the eleven remaining lakes because bathymetric survey data are not available (WR21 and WR22), leaving nine lakes for consideration (Table 5.5; '*Volume (DFO 2010)*' columns).

Volumes potentially available for winter withdrawal using DFO (2010) criteria were calculated as 10% of the under-ice water volume, assuming a 1.5 m thick ice cover. To assess these volumes relative to MVLWB criteria, depth equivalents were calculated by dividing by lake surface area (Table 5.5, column '*Depth Equivalent of Winter Volume (m)*'). Where this depth equivalent is greater than 0.1 m, the withdrawal volume exceeds that recommended by MVLWB (MVLWB 2021b; MVLWB 2021a). These are flagged as 'littoral zone loss' (Table 5.5; column '*Winter Volume Comments*').

Next, the MVLWB method was applied using lake surface area (i.e., the volume of the lake surface area multiplied by 0.1 m)(MVLWB 2021b; MVLWB 2021a). Lake surface area is available from all considered lakes, so MVLWB method can be applied for all lakes. These volume estimates are cross-checked against volumes calculated using DFO (2010) criteria (Table 5.5, column '*Volume (%)*'). In five out of nine lakes where this is possible to assess, the volume of under ice water lost by solely applying the MVLWB method would exceed 10% (Table 5.5, column '*Surface Area Notes*', flagged as 'Volume Loss').

From the perspective of preserving environmental values, DFO (2010) criteria are explicitly intended to preserve oxygen under ice, while MVLWB method is explicitly intended to preserve littoral habitat. Neither set of protocols are consistently limiting for lakes along the proposed MVH alignment. It is therefore not considered appropriate to only apply one set of criteria. Choosing the *minimum* volume predicted by both sets of criteria is intended to preserve both littoral habitat and under ice oxygen (Table 5.5, column '*Conservative Withdrawal (m^3)*').

Application of both protocols limits assessments to lakes where bathymetric surveys have been conducted (this would also be true if only DFO (2010) criteria were applied). After filtering lakes that are too shallow to support withdrawals, this leaves nine lakes where conservative withdrawal volumes can be provided (Table 5.5, column '*Conservative Withdrawal (m^3)*').

Again, 'conservative' potential winter withdrawal volumes are provided here (Table 5.5) that consider the environmental values of littoral zone habitat and overwinter oxygen levels. Results provided here do not consider other potential environmental values, such as potential effects on specific species of interest, cultural values, or on downstream flows (Section 6.3 and Section 7).

Table 5.4 Potential Withdrawal Limits for Waterbodies Along the Proposed Mackenzie Valley Highway Alignment during Periods of Ice Cover

		Max Depth (m)			Under Ice Volume (DFO 2010)[c]			Surface Area (MVLWB 2021)				Recommended Withdrawals			Candidate for Future Bathymetric Surveys?	
Name	MVH Alignment (km)[a]	Surveyed	Coarse[b]	Too Shallow?	10% of Under Ice Volume (m^3)	Depth Equivalent of Volume (m)	Volume Comments	Surface Area (m^2)	Volume from Surface Area (m^3)[d]	Volume (%)	Surface Area Notes	Conservative Withdrawal (m^3)	Limiting Criterion	Notes	Assessment	Comment
WSWrigley	686.5			UNKNOWN			Volume unknown	902,073	90,207		Volume unknown			Volume unknown	Yes	
WR2	702.2	5.1		NO	4,277	0.01	PASSES CRITERIA	364,955	36,496	85	Volume loss	4,277	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR3	718.8		2.9	YES (Potentially)			Volume unknown	533,832	53,383		Volume unknown			Volume unknown	Yes	If max. depth >3.0 m
WR4	721.8		2.9	YES (Potentially)			Volume unknown	36,400	3,640		Volume unknown			Volume unknown	Yes	If max. depth >3.0 m
WS791	791			UNKNOWN			Volume unknown	36,388	3,639		Volume unknown			Volume unknown	Maybe	Given small surface area, may be shallow
WR5	798.8	2.1		YES			Too shallow to withdraw	200,168	20,017		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR6	804	3.4		NO	682	0.00	PASSES CRITERIA	796,473	79,647	1167	Volume loss	682	DFO (2013)	Conservative volume available. volume anomalously low?	n/a	n/a survey already conducted
WR7	810.1		1.5	YES (Potentially)			Volume unknown	207,259	20,726		Volume unknown			Too shallow to withdraw (based on coarse max depth)	No	Too shallow to withdraw
WR8	820	15.2		NO	126,553	0.50	Littoral zone loss	251,743	25,174	2	PASSES CRITERIA	25,174	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted
WR9	826.6	2.2		YES			Too shallow to withdraw	19,617	1,962		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR10	835	15.1		NO	3,084	0.23	Littoral zone loss	13,160	1,316	4	PASSES CRITERIA	1,316	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted
WR11	839.5	1.9		YES			Too shallow to withdraw	43,646	4,365		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR12	863	2.3		YES			Too shallow to withdraw	7,432,430	743,243		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow to withdraw (based on coarse max depth)
WR13	876.3	1.7		YES			Too shallow to withdraw	714,769	71,477		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow
WR16	882.5	4.9		NO	4,899	0.09	PASSES CRITERIA	56,631	5,663	12	Volume loss	4,899	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR18	892	9.3		NO	22,937	0.02	PASSES CRITERIA	1,385,441	138,544	60	Volume loss	22,937	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR893	893			UNKNOWN			Volume unknown	190,086	19,009		Volume unknown			Volume unknown	Yes	
WR19	903	3.8		NO	1,181	0.03	PASSES CRITERIA	35,950	3,595	30	Volume loss	1,181	DFO (2013)	Conservative volume available	n/a	n/a survey already conducted
WR20	908.9	2.6		YES			Too shallow to withdraw	3,595,971	359,597		Too shallow to withdraw			Too shallow to withdraw	No	Too shallow

Table 5.4 Potential Withdrawal Limits for Waterbodies Along the Proposed Mackenzie Valley Highway Alignment during Periods of Ice Cover

		Max Depth (m)			Under Ice Volume (DFO 2010)[c]			Surface Area (MVLWB 2021)				Recommended Withdrawals			Candidate for Future Bathymetric Surveys?	
Name	MVH Alignment (km)[a]	Surveyed	Coarse[b]	Too Shallow?	10% of Under Ice Volume (m^3)	Depth Equivalent of Volume (m)	Volume Comments	Surface Area (m^2)	Volume from Surface Area (m^3)[d]	Volume (%)	Surface Area Notes	Conservative Withdrawal (m^3)	Limiting Criterion	Notes	Assessment	Comment
WR22	916		3.4	NO			Volume unknown	2,254,359	225,436		Volume unknown			Volume unknown	Yes	
WR21	921.3		5.2	NO			Volume unknown	30,606	3,061		Volume unknown			Volume unknown	Yes	
WR948	948.4			UNKNOWN			Volume unknown	16,463	1,646		Volume unknown			Volume unknown	Maybe	Given small surface area, may be shallow
WR25	944.6	21.7		NO	316,381	0.69	Littoral zone loss	461,128	46,113	1	PASSES CRITERIA	46,113	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted
WR28	950.4	14.8		NO	74,686	0.37	Littoral zone loss	204,493	20,449	3	PASSES CRITERIA	20,449	MVLWB (2021)	Conservative volume available	n/a	n/a survey already conducted

NOTES:
Waterbodies are sorted from south to north.
[a] 'Alignment (km)' is the approximate mid-point of each lake along the proposed MVH alignment.
[b] From Table 8.1 in Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.
[c] under ice water volume is calculated assuming 1.5 m thick ice.
[d] Waterbody surface area (units = m^2) multiplied by 0.1 m.
Data are not available when cells are blank.
Please refer to Table 4.5 for waterbody metadata.

Candidate Lakes for Future Bathymetric Surveys

The number of lakes assessed for withdrawals during periods of ice cover could be increased by conducting additional bathymetric surveys (Section 7). Bathymetry has not been conducted at nine lakes. The 'Candidate for Future Bathymetric Surveys' columns (Table 5.5) identify:

- six lakes (WSWrigley, WR3, WR4, WR893, WR21, WR22) where bathymetric surveys have not been conducted and are potentially deeper than 3.0 m and may support withdrawals. These are primary candidates for future bathymetric surveys. Note that if surveys determined maximum depth to be between 1.5 and 3.0 m, then DFO (2010) criteria would not be met.
- two lakes (WS791, WR948) where bathymetric surveys have not been conducted; however, these lakes have small surface areas and/or long axis lengths. If maximum open water depth were less than 1.5 m or greater than 3.0, then withdrawals may be allowed. These are secondary candidates for future bathymetric surveys.
- one lake (WR7) that has a (coarsely determined) maximum depths of 1.5 m. This lake is not recommended for future bathymetric surveys.

Lakes with larger surface areas and long axes would have a greater chance of being sufficiently deep to support withdrawals, and more water would be available for withdrawal from more voluminous lakes. For (e.g., WSWrigley and WR893). The above assessments could be refined by statistically relating surface area, long axis length, and other morphology indicators to maximum depth and lake volume using regional datasets of lakes where bathymetry is known (AEP 2019; Islam et al. 2018).

5.2.2 Withdrawals During Periods of Open-Water

Volumes of water potentially available for withdrawal using the MVLWB criterion are presented in Table 5.5. Lakes with open water maximum depths less than 1.5 m might be considered for licensing (Section 4.2.1.2), but no candidate lakes have been identified as being this shallow (Table 5.5). Lakes with maximum open water depths between 1.5 and 3.0 m are excluded given their potential sensitivity to withdrawal.

Lakes were categorized based on available maximum depth data (Table 5.6). Lakes that are either known to be too shallow to support open water withdrawals, or where maximum depth is not confidently known, were not carried forward. Eleven lakes remained (Table 5.5; Table 5.6).

In Section 5.2.1, candidate lakes were identified for additional bathymetric surveys to assess winter withdrawal volumes. This would also be beneficial for lakes identified in Table 5.6. However, note that MVLWB may allow maximum depth to be coarsely determined by measuring lake depth "*prior to each season of use, avoiding freshet. This must be measured in at least three locations >20 m from shore and approximately 20 m apart.*" (MVLWB 2021a). This is applicable only in the open water period because under ice volume is required in the ice-covered period.

Neither the DFO nor MVLWB methods are explicitly intended to preserve downstream flows for EFN. Impacts to downstream flows caused by withdrawals in upstream lakes are important to assess both in summer and potentially in winter, given that some of the larger watercourses in the Study Area flow in winter (Section 5.1.1) (K'alo-Stantec 2022a). Please refer to Section 6.3 for potential methods to estimate EFN in watercourses downstream of waterbodies.

Table 5.5 Potential Withdrawal Limits for Waterbodies Along the Proposed Mackenzie Valley Highway Alignment during Periods of Open Water

		Max Depth (m)			Surface Area (MVLWB 2021)		
Name	MVH Alignment (km)[a]	Surveyed	Coarse[b]	Too Shallow?	Surface Area (m^2)	Volume from Surface Area (m^3)[c]	Surface Area Notes
WSWrigley	686.5			UNKNOWN	902,073		Unknown if too shallow to withdraw
WR2	702.2	5.1		NO	364,955	36,496	Sufficiently deep
WR3	718.8		2.9	YES (Potentially)	533,832		Potentially too shallow to withdraw
WR4	721.8		2.9	YES (Potentially)	36,400		Potentially too shallow to withdraw
WS791	791			UNKNOWN	36,388		Unknown if too shallow to withdraw
WR5	798.8	2.1		YES	200,168		Too shallow to withdraw
WR6	804	3.4		NO	796,473	79,647	Sufficiently deep
WR7	810.1		1.5	YES (Potentially)	207,259		Potentially too shallow to withdraw
WR8	820	15.2		NO	251,743	25,174	Sufficiently deep
WR9	826.6	2.2		YES	19,617		Too shallow to withdraw
WR10	835	15.1		NO	13,160	1,316	Sufficiently deep
WR11	839.5	1.9		YES	43,646		Too shallow to withdraw
WR12	863	2.3		YES	7,432,430		Too shallow to withdraw
WR13	876.3	1.7		YES	714,769		Too shallow to withdraw
WR16	882.5	4.9		NO	56,631	5,663	Sufficiently deep
WR18	892	9.3		NO	1,385,441	138,544	Sufficiently deep
WR893	893			UNKNOWN	190,086		Unknown if too shallow to withdraw
WR19	903	3.8		NO	35,950	3,595	Sufficiently deep
WR20	908.9	2.6		YES	3,595,971		Too shallow to withdraw
WR22	916		3.4	NO	2,254,359	225,436	Sufficiently deep
WR21	921.3		5.2	NO	30,606	3,061	Sufficiently deep
WR948	948.4			UNKNOWN	16,463		Unknown if too shallow to withdraw
WR25	944.6	21.7		NO	461,128	46,113	Sufficiently deep
WR28	950.4	14.8		NO	204,493	20,449	Sufficiently deep

NOTES:
Waterbodies are sorted from south to north.
[a] 'Alignment (km)' is the approximate mid-point of each lake along the proposed MVH alignment.
[b] From Table 8.1 in Golder (2006). These are lakes where full bathymetric surveys have not been conducted and may not represent the true maximum lake depth.
[d] Waterbody surface area (units = m^2) multiplied by 0.1 m.
Data are not available when cells are blank.
Please refer to Table 4.5 for waterbody metadata.

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Table 5.6 Open Water Withdrawal Categories based on Maximum Open Water Depth

Category	Category Description	Applies to	Action	Recommendation
Sufficiently deep	Either bathymetric surveys or coarse measurements of depth indicate that open water maximum depth is greater than 3.0 m	WR2, WR6, WR8, WR10, WR16, WR18, WR19, WR21, WR22, WR25, WR28	Calculate open water withdrawal volumes	None
Unknown if too shallow to withdraw	No bathymetric surveys have been conducted and no coarse measurements of maximum depth are available	WSWrigley, WS791, WR893, WR948	Exclude from open water withdrawal volume calculations	Conduct additional measurements* where morphology suggests lakes may be sufficiently deep.
Potentially too shallow to withdraw	No bathymetric surveys have been conducted. However, limited depth measurements indicate that the open water maximum depth may be between 1.5 and 3.0 m, and hence withdrawals may not be permissible.	WR3, WR4, WR7	Exclude from open water withdrawal volume calculations	These are lower priority for additional measurements* surveys given preliminary indications of their maximum depth.
Too shallow to withdraw	Either bathymetric surveys or coarse measurements of depth indicate that open water maximum depth is shallower than 3.0 m and not shallower than 1.5 m	WR5, WR9, WR11, WR12, WR13, WR20	Exclude from open water withdrawal volume calculations	None

NOTE:
*Bathymetry or coarse measurements of depth, see text.

5.2.3 Summary of Water Availability from Waterbodies in the Ice-Covered and Ice-Free Periods

Please refer to Summary Table 2 in the executive summary for a compilation of water availability from watercourses in open-water periods, ice-covered periods, and annually.

6 Discussion

6.1 Licensing Considerations

For 'miscellaneous' projects, the *Northwest Territories Waters Act* and Regulations permit water to be withdrawn from watercourses[3] without a licence for uses less than 100 m^3 *per day* (GNWT 2014; Schedule H). This equates to 36,400 m^3 annually, or about 18,000 m^3 in both the ice covered and open water periods. This implies that:

- if required water volumes from watercourses and waterbodies are less than identified maximums in Table 5.3, Table 5.4, and Table 5.5, then water licenses may not be required.
- if regulators only consider the *Waters Act* criterion, then more water may be available for waterbodies than identified in Table 5.4 and Table 5.5.

In contrast to the *Waters Act*, the MVLWB method and DFO protocols both stipulate non-application below 100 m^3 withdrawal *in a single ice-covered season.* The application of these protocols is preferred for environmental assessment despite being more limiting and more conservative. The *Waters Act* criterion is discussed here only because of its implications for when licensing is —and is not— required.

Note that if desired withdrawals do not meet limits calculated using protocols (e.g., DFO 2010, DFO 2013), a Request for Review could be submitted to DFO.

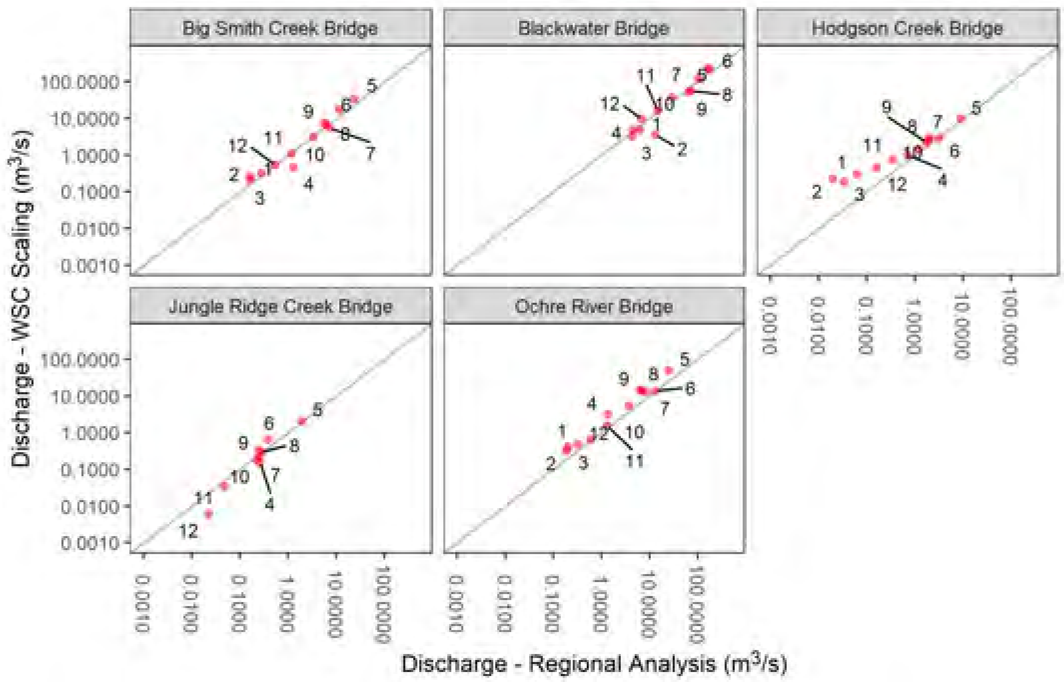
6.2 Assessment of Methods for Determination of Streamflow In Ungauged Catchments

6.2.1 Comparison Results from Regional Analysis and 'WSC Scaling' Methods

Figure 6.1 compares monthly average flows calculated using the WSC scaling approach and the regional regression approach. Results appear similar for both approaches except for Hodson Creek Bridge, where the WSC scaling approach suggests higher flows in winter. Hodgson Creek is the southernmost studied watercourse, and its watershed area is relatively large (Figure 1.1; Table 4.1); winter flows may be higher here than suggested by regional analyses. Monitored flows from Hodson Creek are relatively recent and the period of record is relatively short (2006 to 2014; Table 4.3). Available flow data from this site may not be representative of the full range of hydroclimatic variability, or winter flows may be affected by recent climate change.

[3] The definition of 'watercourse' differs here compared to the Waters Act. The Waters Act defines a watercourse as "a natural watercourse, body of water or water supply, whether usually containing water or not, and includes groundwater, springs, swamps and gulches.", i.e., it includes waterbodies.

Figure 6.1 Comparison of Monthly Flows Predicted using the 'WSC Scaling' Technique and the Regional Analysis Technique



NOTES:

Labeled numbers are months (1=January, 12=December).

Grey lines are 1:1 lines (i.e., have slopes of one and intercepts of zero). Monthly predictions (red dots) falling exactly on the 1:1 line are identical.

Flows from the regional analysis method were predicted using regression equations provided in Table 5.1.

'WSC scaling' flows were scaled directly from WSC stations on the same watercourse as the proposed crossing.

Table 6.1 compares annual water availability per DFO criteria calculated using the WSC scaling approach and the MVH regional regression approach. Except for the Ochre River, water availability calculated from both approaches is within about 22%. For all five gauged crossings, the MVH regression approach is conservative, as it predicts that less water is available for withdrawal than the WSC scaling approach.

Table 6.1 Comparison of Annual Water Availability per DFO Criteria Predicted Using the 'WSC Scaling' Technique and the Regional Analysis (MVH) Technique

Watercourse	Crossing Watershed Area (km^2)	Availability (m^3/yr)[a]		Difference	
		WSC Scaling	Regional Analysis	m^3	%
Big Smith Creek	1,076	19,510,836	15,220,279	4,290,557	22
Blackwater River	10,716	188,109,030	163,361,027	24,748,003	13
Hodgson Creek	358	6,200,677	5,240,689	959,988	15
Jungle Ridge Creek	60	1,035,713	954,213	81,500	8
Ochre River	1,207	30,047,250	17,097,693	12,949,557	43

NOTE:
[a] calculated as 10% of volumetric flow in months where discharge is more than 30%MAD (DFO 2013).

For the Ochre River, the difference between approaches in annual water availability is 43% (Table 6.1). This is not apparent in the comparison of monthly discharge (Figure 6.1), partly because of the use of log-log axes. The WSC scaling approach predicts about 1.3 x 10^7 m^3 of water available for withdrawal in May, while the regional analysis approach predicts about half this volume: 6.9 x10^6 m^3. This is a large difference in the month with peak annual flows. In addition, the WSC scaling approach suggests that withdrawals are likely permissible in April, while the MVH approach suggests that no water is available for withdrawal in this month due to flows being <30%MAD (DFO 2013). Similar to Hodgson Creek, Ochre River is located far south along the proposed MVH alignment and has a relatively large watershed area (Figure 1.1; Table 4.1), which could affect the accuracy of regional regression-based flow predictions. Also similar to Hodson Creek, the Ochre River monitoring period is relatively short and recent (2006 to 2019). Available flow data from this site may not be representative of the full range of hydroclimatic variability, or winter flows may be affected by recent climate change.

At Blackwater River, flows and water availability calculated using both approaches are relatively similar. This is surprising given the large size of the Blackwater River watershed area and given that its flows are likely influenced by discharge from Blackwater Lake (Faria 2002) (Section 4.1.2.1).

Overall, the regional analysis approach appears to provide conservative estimates of water availability. The WSC scaling approach uses site-specific data where available. These data are preferable over regionally based flow predictions, but results can be susceptible to influences from short records and potentially, climate change.

6.2.2 Comparison of Flows Predicted Using Differing Regression Equations

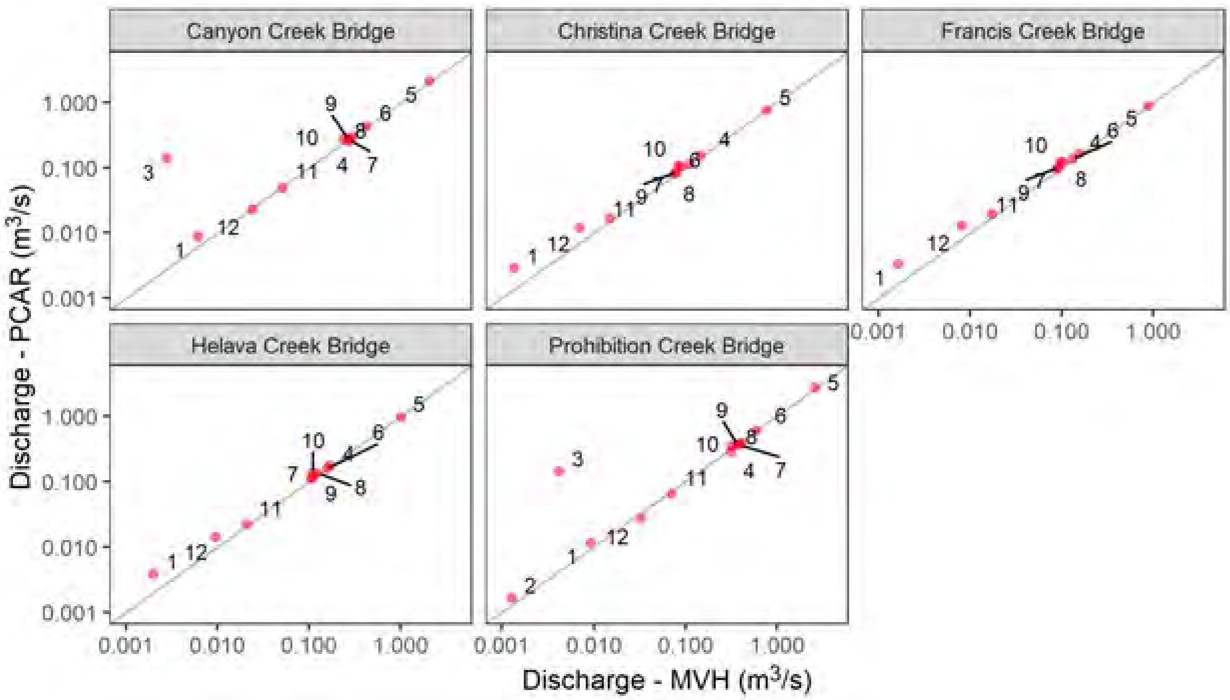
Flow estimates and water availability were recently assessed for five watercourses along the proposed Prohibition Creek Access Road (PCAR) alignment (K'alo-Stantec 2022a) (Figure 1.2). A similar regional analysis methodology was used for flow predictions for both MVH and PCAR. However, regional station selection criteria were tailored to crossings along each alignment. Differences include:

- WSC stations were selected based on a point for the PCAR study rather than a buffered linear feature used here (Section 4.1.2.2). The difference occurs because the proposed PCAR alignment spans only about 14 km while watercourse crossings along the proposed MVH alignment span about 275 km.
- The maximum considered watershed area for regional WSC stations in the PCAR study was about 1,000 km^2, compared to about 7,400 km^2 for the MVH study. WSC stations were chosen to best represent the range of target watershed areas for each study. For example, target watersheds for the PCAR study spanned from 21 to 86 km^2 but reach about 440 km^2 for this study.

Differing station selection criteria produced differing regression coefficients and flow predictions. The PCAR alignment immediately north of the proposed MVH alignment, and the watershed areas of some MVH crossings are smaller than those of PCAR crossings (as small as about 9 km^2; Table 4.1). Therefore, it could be argued that the same regional station selection criteria should be applied to both MVH and PCAR crossings.

To evaluate the effects of differing regional station selection criteria on flow predictions and water availability, flows were predicted for the five previously studied PCAR watercourses using regression coefficients derived in this study and in the PCAR study, and results are compared in Figure 6.2. Flows are similar for both approaches in most months. The exception is March. Regionally, flows are variable in March: flows begin to increase at some sites, while flow is delayed at other sites. March regression equations were not statistically significant in the PCAR study.

Figure 6.2 Comparison of Monthly Flows Predicted Using Differing Sets of Regional Stations



NOTES:
Labeled numbers are months (1=January, 12=December).
Grey lines are 1:1 lines (i.e., have slopes of one and intercepts of zero). Monthly predictions (red dots) falling exactly on the 1:1 line are identical.
MVH flows were predicted using regression equations provided in Table 5.1.
PCAR flows were predicted using regression equations provided in the PCAR water availability study (K'alo-Stantec 2022a) and Appendix B.
Flow predictions from March for Christina, Francis, and Helava creeks are lower than axes limits.

The PCAR water availability study found that withdrawals may be permitted in March, since predicted flows were >30%MAD. However, it was noted that uncertainty was high in spring. This study finds that withdrawals may be permissible at some MVH crossings in March, but uncertainty is high, and site-specific field investigations would be required to assess this possibility.

On an annual basis, the impact of differing methodologies on predicted water availability is small, i.e., less than 11% at PCAR crossings (Table 6.2). Differences are larger for smaller watersheds, reflecting greater uncertainty in predictions from smaller watersheds (Figure 5.2).

Table 6.2 Comparison of Annual Water Availability Predicted Using Differing Sets of Regional Stations

Creek	Watershed Area (km^2)	Availability (m^3/yr)[a]		Difference	
		PCAR	MVH	m^3	%
Canyon	64	1,079,056	1,013,325	65,731	6
Christina	21	402,695	364,272	38,423	10
Francis	24	460,297	411,145	49,152	11
Helava	28	518,448	472,932	45,516	9
Prohibition	86	1,408,600	1,336,324	72,276	5

NOTE:
[a] calculated as 10% of volumetric flow in months where discharge is more than 30%MAD (DFO 2013).

6.3 Approaches for Assessment of Withdrawals from Waterbodies Appropriate for Preserving Downstream Environmental Flow Needs

Withdrawal volumes provided here for waterbodies follow guidelines intended to preserve littoral habitat and under-ice oxygen for aquatic life (MVLWB 2021b; MVLWB 2021a; DFO 2010). However, these guidelines do not explicitly consider impacts to downstream flows from upstream waterbody withdrawals. If this environmental value were to be considered, then appropriate withdrawal volumes in non-winter periods could be assessed as best practice. This may also be important to assess in winter at sites with large upstream lakes or with large watersheds, where flow continues over winter. It is possible in some cases, and at some times, that this environmental value may not be limiting. For example, at lakes with short residence times and during periods of high throughflow, i.e., when and where inflow is much greater than proposed withdrawals.

Impacts to downstream EFN from upstream lake withdrawals are explicitly considered in protocols from neighbouring jurisdictions. For short-term water withdrawals from lakes in the open water period, the British Columbia Oil and Gas Commission (BCOGC) guidance is:

> *"the water availability as calculated by NEWT, NWWT or OWT[4], and limited to the 10 centimetre maximum drawdown limit from the HWL [High Water Level] mark. An estimate of the available water must be provided for the lake based on a 10 centimetre drawdown, and other authorizations"* (BCOGC 2022)

[4] Online water tools that produce discharge and water availability estimates for watercourses for regions in British Columbia.

Similar online water tools do not exist in NT. In Alberta, allocation criteria for lakes also consider downstream flows, but do not rely on data from online water tools. Instead, allocation limits in the open water period are calculated using a site-specific water balance approach. In particular:

- "The cumulative annual allocation limit is ≤12% of the mean annual outflow"; and
- To protect downstream EFN over shorter periods of time "*Mean annual outflow divided equally across April to October. Monthly cumulative limit ≤ 15% of monthly apportioned outflow*".

Withdrawals from Alberta Lakes in winter follow a similar approach, but also consider volumetric equivalents of lake surface area, modified from DFO (2010).

Application of a similar water balance approach to preserving flows downstream of waterbodies in NT would be possible using publicly available data sources or can be readily calculated. Required data include lake area, watershed area, average annual evaporation and precipitation, average annual runoff, and groundwater flux (where relevant). Lake area has been provided here, watershed area can be readily calculated, site-specific precipitation is readily available (Wang et al. 2012; Wang 2022), and runoff can be calculated with the regional analysis approach presented here (Section 4.1). Site-specific evaporation from lakes requires calculation (McMahon et al. 2013), but may be negligible relative to other water balance components in lakes with small surface areas and/or high throughflow.

The water balance approach described above may help satisfy the MVH environmental assessment Terms of Reference (TOR) request to "*describe the recharge ability of lakes that will be used for winter road watering or ice mining*" (MVEIRB 2015).

7 Conclusions and Recommendations

Water volumes available for withdrawal have been assessed for 22 watercourses and 24 waterbodies along the proposed Mackenzie Valley Highway (MVH) alignment, spanning roughly from Wrigley to Norman Wells, NT.

Conclusions for watercourses include:

- For all watercourses except the GBR, water is typically available for withdrawal from approximately April to October, and not available for withdrawal over winter. Over winter, withdrawals are unlikely to be classified as 'low-risk' because flows are likely to be less than 30% of mean annual discharge (DFO 2013). Large volumes of water are expected to be available for withdrawal from the GBR year-round.
- On an annual basis, volumes available for withdrawal are likely to be large compared to waterbodies.
- There are numerous (22) potential watercourse water sources.
- No long gaps exist between candidate watercourses along the proposed MVH alignment ('long' relative to gaps between waterbodies).

Conclusions for waterbodies include:

- Conservative, low-risk, regionally appropriate potential withdrawal volumes have been provided here in ice covered and ice-free periods.
  - In ice covered periods, volumes provided here are the *minimum* of criteria designed to protect littoral habitat (MVLWB 2021a; MVLWB 2021b) and oxygen levels under ice (DFO 2010).
  - In ice-free periods, volumes provided here align with criteria designed to protect littoral habitat (MVLWB 2021a; MVLWB 2021b).
- Volumes available for withdrawal from waterbodies are likely to be small compared to watercourses.
- In ice covered periods, there are nine waterbodies with sufficient data to assess relative to withdrawal criteria. In ice-free periods there are eleven waterbodies.
- There are long distances between lakes that meet assessment criteria and where data are available.

Recommendations related to watercourses include:

- Withdrawal from a watercourse —whether under licence or not— should include a requirement for measurements of instantaneous flow at the time of withdrawal. These flow measurements should be compared to mean annual discharge for each creek to ensure flows are >30%MAD at the time of withdrawal and that withdrawals are <10% of instantaneous flow.
- If water is required in spring and to a lesser extent autumn, then additional site-specific flow measurements would be beneficial, given (a) uncertainties in flow predictions in spring, (b) the months where discharge is greater than 30% of MAD varies regionally, (c) monthly averages have been provided here, and flows will vary within each month and year, and (d) months in spring and autumn where flows pass DFO criteria sometimes vary between the WSC scaling approach and the regional analysis approach.
- Flow measurements over winter would help define the timing and magnitudes of flows. This is recommended since the MVH TOR request a description of watercourses that have year-round flow (MVEIRB 2015), and in the event that over winter withdrawals from watercourses are sought.
- Pertinent supplemental information for winter MVH withdrawals would be defined by DFO and/or MVLWB. Where not already available, this could take the form of a fish periodicity table, baseline hydrological data, detailed fish habitat modelling, reconnaissance-level fish and fish habitat impact assessment, withdrawal rate limits, limited licence terms, and/or requirements to monitor water use (FLNRORD and ENV 2022).

Recommendations related to waterbodies include:

- Candidate lakes where bathymetric data are not available but may have maximum depths greater than 3.0 m were selected based on their surface areas and long axis lengths. The list could be refined by statistically relating surface area, maximum length, and other morphology indicators to maximum depth and lake volume using regional datasets of lakes where bathymetry is known (AEP 2019; Islam et al. 2018).
- Given the absence of published regional protocols for withdrawals from the open water period, discussions should occur with decision makers to identify data requirements for the Project. A potential water balance approach that aligns with EFN methodologies in neighbouring jurisdictions has been described in Section 6.3. This approach could be applied to watercourses and waterbodies in the non-winter period and may also be applicable in the winter period at watercourses that are downstream of large waterbodies and continue to flow through winter. This approach could be combined with targeted flow measurements in the winter and non-winter periods.

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9 Closure

If you have any questions, please do not hesitate to contact the undersigned.

Respectfully Submitted,

K'ALO-STANTEC LIMITED

Original signed by

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Appendix A Average Flows and Statistics for Gauged Crossings ('WSC Scaling' Method)

This Appendix provides flow and water availability statistics at proposed MVH crossings that were compiled from WSC stations on the same watercourse. Monitored flows have been scaled to flows at each crossing using scaling factors that scale crossing watershed area to the watershed area at each crossing (Section 4.1.2.1)

Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m).

Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a “low probability of detectable impacts to ecosystems” (DFO 2013).
Water availability is set to zero in months where flow is <30% of MAD. Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Table A.1 Big Smith Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.33	5	0.033	28182	2818	873,642	87,358	0
Feb	0.25	4	0.025	21646	2165	606,088	60,620	0
Mar	0.22	3	0.022	18,996	1,900	588,876	58,900	0
Apr	0.46	7	0.046	40,090	4,009	1,202,700	120,270	0
May	33.65	528	3.365	2,907,361	290,736	90,128,191	9,012,816	9,012,816
Jun	17.47	274	1.747	1,509,325	150,932	45,279,750	4,527,960	4,527,960
Jul	5.37	84	0.537	464,036	46,404	14,385,116	1,438,524	1,438,524
Aug	6.46	101	0.646	558,106	55,811	17,301,286	1,730,141	1,730,141
Sep	7.62	119	0.762	657,949	65,795	19,738,470	1,973,850	1,973,850
Oct	3.09	48	0.309	266,952	26,695	8,275,512	827,545	827,545
Nov	1.08	17	0.108	92,877	9,288	2,786,310	278,640	0
Dec	0.53	8	0.053	46,002	4,600	1,426,062	142,600	0
Annual Mean	**6.38**	**n/a**	**0.638**	**550,960**	**55,096**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**202,592,003**	**20,259,224**	**19,510,836**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (1.913 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

Table A.2 Blackwater Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	4.92	8	0.492	425188	42519	13,180,828	1,318,089	0
Feb	3.53	6	0.353	305301	30530	8,548,428	854,840	0
Mar	3.27	5	0.327	282,201	28,220	8,748,231	874,820	0
Apr	4.81	8	0.480	415,112	41,511	12,453,360	1,245,330	0
May	214.73	342	21.473	18,552,418	1,855,242	575,124,958	57,512,502	57,512,502
Jun	230.16	366	23.016	19,885,663	1,988,566	596,569,890	59,656,980	59,656,980
Jul	118.90	189	11.890	10,272,987	1,027,299	318,462,597	31,846,269	31,846,269
Aug	56.92	91	5.692	4,918,191	491,819	152,463,921	15,246,389	15,246,389
Sep	53.21	85	5.321	4,597,143	459,714	137,914,290	13,791,420	13,791,420
Oct	37.54	60	3.754	3,243,695	324,370	100,554,545	10,055,470	10,055,470
Nov	16.45	26	1.645	1,421,513	142,151	42,645,390	4,264,530	0
Dec	9.63	15	0.963	832,168	83,217	25,797,208	2,579,727	0
Annual Mean	**62.84**	**n/a**	**6.284**	**5,429,298**	**542,930**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**1,992,463,646**	**199,246,366**	**188,109,030**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (18.852 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

n/a: not applicable.

Table A.3 Hodgson Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.29	14	0.029	25180	2518	780,580	78,058	0
Feb	0.22	11	0.022	19358	1936	542,024	54,208	0
Mar	0.19	9	0.019	16,054	1,605	497,674	49,755	0
Apr	0.98	48	0.098	84,620	8,462	2,538,600	253,860	253,860
May	9.56	468	0.956	826,238	82,624	25,613,378	2,561,344	2,561,344
Jun	2.88	141	0.288	248,600	24,860	7,458,000	745,800	745,800
Jul	2.92	143	0.292	252,228	25,223	7,819,068	781,913	781,913
Aug	2.62	128	0.262	226,072	22,607	7,008,232	700,817	700,817
Sep	2.22	109	0.222	192,193	19,219	5,765,790	576,570	576,570
Oct	1.44	71	0.144	124,731	12,473	3,866,661	386,663	386,663
Nov	0.75	37	0.075	64,569	6,457	1,937,070	193,710	193,710
Dec	0.44	22	0.044	38,297	3,830	1,187,207	118,730	0
Annual Mean	**2.04**	**n/a**	**0.204**	**176,512**	**17,651**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**65,014,284**	**6,501,428**	**6,200,677**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.613 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
n/a: not applicable.

Table A.4 Jungle Ridge Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.00	0	0.000	29	3	899	93	0
Feb	0.00	0	0.000	1	0	28	0	0
Mar	0.00	0	0.000	0	0	0	0	0
Apr	0.15	47	0.015	13,321	1,332	399,630	39,960	39,960
May	2.05	625	0.205	177,491	17,749	5,502,221	550,219	550,219
Jun	0.65	198	0.065	56,225	5,622	1,686,750	168,660	168,660
Jul	0.23	69	0.023	19,492	1,949	604,252	60,419	60,419
Aug	0.29	89	0.029	25,438	2,544	788,578	78,864	78,864
Sep	0.34	104	0.034	29,627	2,963	888,810	88,890	88,890
Oct	0.18	55	0.018	15,713	1,571	487,103	48,701	48,701
Nov	0.03	10	0.003	2,880	288	86,400	8,640	0
Dec	0.01	2	0.001	555	56	17,205	1,736	0
Annual Mean	**0.33**	**n/a**	**0.033**	**28,398**	**2,840**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**10,461,876**	**1,046,182**	**1,035,713**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.099 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
n/a: not applicable.

Table A.5 Ochre River Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)		
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]
Jan	0.49	5	0.049	42240	4224	1,309,440	130,944	0
Feb	0.41	4	0.041	34981	3498	979,468	97,944	0
Mar	0.32	3	0.032	27,318	2,732	846,858	84,692	0
Apr	3.14	32	0.314	271,037	27,104	8,131,110	813,120	813,120
May	49.61	511	4.961	4,286,306	428,631	132,875,486	13,287,561	13,287,561
Jun	13.60	140	1.360	1,174,935	117,494	35,248,050	3,524,820	3,524,820
Jul	12.86	132	1.286	1,110,656	111,066	34,430,336	3,443,046	3,443,046
Aug	14.11	145	1.411	1,219,460	121,946	37,803,260	3,780,326	3,780,326
Sep	14.50	149	1.450	1,252,839	125,284	37,585,170	3,758,520	3,758,520
Oct	5.38	55	0.538	464,469	46,447	14,398,539	1,439,857	1,439,857
Nov	1.51	16	0.151	130,695	13,070	3,920,850	392,100	0
Dec	0.65	7	0.065	56,139	5,614	1,740,309	174,034	0
Annual Mean	**9.71**	**n/a**	**0.972**	**839,256**	**83,926**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**309,268,876**	**30,926,964**	**30,047,250**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (2.914 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
n/a: not applicable.

Appendix B Average Flows and Statistics for Ungauged Crossings Derived Using Regional Analyses

This Appendix provides flow and water availability statistics at proposed MVH crossings that were predicted with regression-based techniques.

Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m).

Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a “low probability of detectable impacts to ecosystems” (DFO 2013). Water availability is set to zero in months where flow is <30% of MAD. Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Table B.1 Big Strawberry Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	478	48	14,818	1,488	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	54	5	1,512	140	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	214	21	6,634	651	0	0.00	0.00	0.59	0.001	14
Apr	0.26	86	0.026	22,376	2,238	671,280	67,140	67,140	0.10	0.50	0.65	0.000	16
May	1.91	634	0.191	164,871	16,487	5,111,001	511,097	511,097	1.40	2.70	0.91	0.000	21
Jun	0.38	126	0.038	32,764	3,276	982,920	98,280	98,280	0.30	0.50	0.96	0.000	21
Jul	0.25	83	0.025	21,660	2,166	671,460	67,146	67,146	0.20	0.40	0.92	0.000	21
Aug	0.27	91	0.027	23,547	2,355	729,957	73,005	73,005	0.20	0.40	0.90	0.000	21
Sep	0.24	81	0.024	21,082	2,108	632,460	63,240	63,240	0.10	0.40	0.85	0.000	21
Oct	0.22	74	0.022	19,179	1,918	594,549	59,458	59,458	0.20	0.30	0.93	0.000	19
Nov	0.05	16	0.005	4,079	408	122,370	12,240	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,900	190	58,900	5,890	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.30**	**n/a**	**0.030**	**26,017**	**2,602**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**9,597,861**	**959,775**	**939,366**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.09 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.2 Bob's Canyon Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge[a]**	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available[b]**	**Lower Conf. (m^3/s)[c]**	**Upper Conf. (m^3/s)[c]**	**r^2**	**p-value[d]**	**n[e]**
Jan	0.00	0	0.000	39	4	1,209	124	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	2	0	56	0	0	0.00	0.00	0.68	0.000	15
Mar	0.00	0	0.000	15	2	465	62	0	0.00	0.00	0.59	0.001	14
Apr	0.09	166	0.009	7,955	796	238,650	23,880	23,880	0.00	0.30	0.65	0.000	16
May	0.38	693	0.038	33,154	3,315	1,027,774	102,765	102,765	0.20	0.70	0.91	0.000	21
Jun	0.04	76	0.004	3,663	366	109,890	10,980	10,980	0.00	0.10	0.96	0.000	21
Jul	0.03	52	0.003	2,490	249	77,190	7,719	7,719	0.00	0.10	0.92	0.000	21
Aug	0.04	67	0.004	3,170	317	98,270	9,827	9,827	0.00	0.10	0.90	0.000	21
Sep	0.03	60	0.003	2,830	283	84,900	8,490	8,490	0.00	0.10	0.85	0.000	21
Oct	0.04	70	0.004	3,332	333	103,292	10,323	10,323	0.00	0.10	0.93	0.000	19
Nov	0.01	11	0.001	522	52	15,660	1,560	0	0.00	0.00	0.90	0.000	16
Dec	0.00	5	0.000	245	24	7,595	744	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.06**	**n/a**	**0.006**	**4,785**	**478**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**1,764,951**	**176,474**	**173,984**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.017 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.3 Dam Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	1109	111	34,379	3,441	0	0.00	0.10	0.6	0.000	16
Feb	0.00	0	0.000	177	18	4,956	504	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	525	52	16,275	1,612	0	0.00	0.00	0.59	0.001	14
Apr	0.37	68	0.037	31,630	3,163	948,900	94,890	94,890	0.20	0.60	0.65	0.000	16
May	3.26	602	0.326	282,001	28,200	8,742,031	874,200	874,200	2.50	4.30	0.91	0.000	21
Jun	0.79	146	0.079	68,207	6,821	2,046,210	204,630	204,630	0.60	1.00	0.96	0.000	21
Jul	0.52	95	0.052	44,670	4,467	1,384,770	138,477	138,477	0.40	0.70	0.92	0.000	21
Aug	0.53	98	0.053	46,063	4,606	1,427,953	142,786	142,786	0.40	0.80	0.90	0.000	21
Sep	0.48	88	0.048	41,280	4,128	1,238,400	123,840	123,840	0.30	0.80	0.85	0.000	21
Oct	0.40	74	0.040	34,449	3,445	1,067,919	106,795	106,795	0.30	0.50	0.93	0.000	19
Nov	0.09	17	0.009	8,116	812	243,480	24,360	0	0.10	0.20	0.90	0.000	16
Dec	0.04	8	0.004	3,771	377	116,901	11,687	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.54**	**n/a**	**0.054**	**46,833**	**4,683**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**17,272,174**	**1,727,222**	**1,685,618**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.163 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

[e] p-values listed as 0.000 are <0.001

n/a: not applicable.

Table B.4 Devil's Canyon Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	1	0.000	118	12	3,658	372	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	7	1	196	28	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	48	5	1,488	155	0	0.00	0.00	0.59	0.001	14
Apr	0.15	126	0.015	12,605	1,260	378,150	37,800	37,800	0.10	0.40	0.65	0.000	16
May	0.78	674	0.078	67,700	6,770	2,098,700	209,870	209,870	0.50	1.20	0.91	0.000	21
Jun	0.11	96	0.011	9,713	971	291,390	29,130	29,130	0.10	0.20	0.96	0.000	21
Jul	0.08	65	0.008	6,522	652	202,182	20,212	20,212	0.00	0.10	0.92	0.000	21
Aug	0.09	77	0.009	7,739	774	239,909	23,994	23,994	0.00	0.20	0.90	0.000	21
Sep	0.08	69	0.008	6,918	692	207,540	20,760	20,760	0.00	0.20	0.85	0.000	21
Oct	0.08	72	0.008	7,262	726	225,122	22,506	22,506	0.10	0.10	0.93	0.000	19
Nov	0.02	13	0.002	1,303	130	39,090	3,900	0	0.00	0.00	0.90	0.000	16
Dec	0.01	6	0.001	609	61	18,879	1,891	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.12**	**n/a**	**0.012**	**10,045**	**1,005**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**3,706,304**	**370,618**	**364,272**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.035 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.5 Four Mile Creek Culvert: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge[a]**	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available[b]**	**Lower Conf. (m^3/s)[c]**	**Upper Conf. (m^3/s)[c]**	**r^2**	**p-value[d]**	**n[e]**
Jan	0.00	1	0.000	89	9	2,759	279	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	5	0	140	0	0	0.00	0.00	0.68	0.000	15
Mar	0.00	0	0.000	36	4	1,116	124	0	0.00	0.00	0.59	0.001	14
Apr	0.13	135	0.013	11,209	1,121	336,270	33,630	33,630	0.10	0.30	0.65	0.000	16
May	0.65	680	0.065	56,431	5,643	1,749,361	174,933	174,933	0.40	1.10	0.91	0.000	21
Jun	0.09	92	0.009	7,574	757	227,220	22,710	22,710	0.10	0.10	0.96	0.000	21
Jul	0.06	61	0.006	5,102	510	158,162	15,810	15,810	0.00	0.10	0.92	0.000	21
Aug	0.07	74	0.007	6,163	616	191,053	19,096	19,096	0.00	0.10	0.90	0.000	21
Sep	0.06	67	0.006	5,508	551	165,240	16,530	16,530	0.00	0.10	0.85	0.000	21
Oct	0.07	72	0.007	5,953	595	184,543	18,445	18,445	0.00	0.10	0.93	0.000	19
Nov	0.01	13	0.001	1,032	103	30,960	3,090	0	0.00	0.00	0.90	0.000	16
Dec	0.01	6	0.001	483	48	14,973	1,488	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.10**	**n/a**	**0.010**	**8,299**	**830**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**3,061,797**	**306,135**	**301,154**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.029 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.6 Gotcha Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge[a]**	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available[b]**	**Lower Conf. (m^3/s)[c]**	**Upper Conf. (m^3/s)[c]**	**r^2**	**p-value[d]**	**n[e]**
Jan	0.02	3	0.002	1762	176	54,622	5,456	0	0.00	0.10	0.6	0.000	16
Feb	0.00	1	0.000	342	34	9,576	952	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	860	86	26,660	2,666	0	0.00	0.10	0.59	0.001	14
Apr	0.44	59	0.044	38,268	3,827	1,148,040	114,810	114,810	0.30	0.70	0.65	0.000	16
May	4.39	583	0.439	378,949	37,895	11,747,419	1,174,745	1,174,745	3.40	5.70	0.91	0.000	21
Jun	1.18	157	0.118	102,125	10,212	3,063,750	306,360	306,360	0.90	1.50	0.96	0.000	21
Jul	0.77	102	0.077	66,538	6,654	2,062,678	206,274	206,274	0.60	1.10	0.92	0.000	21
Aug	0.77	103	0.077	66,647	6,665	2,066,057	206,615	206,615	0.60	1.10	0.90	0.000	21
Sep	0.69	92	0.069	59,759	5,976	1,792,770	179,280	179,280	0.50	1.00	0.85	0.000	21
Oct	0.55	73	0.055	47,555	4,756	1,474,205	147,436	147,436	0.40	0.70	0.93	0.000	19
Nov	0.14	18	0.014	11,853	1,185	355,590	35,550	0	0.10	0.20	0.90	0.000	16
Dec	0.06	9	0.006	5,501	550	170,531	17,050	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.75**	**n/a**	**0.075**	**65,013**	**6,501**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**23,971,898**	**2,397,194**	**2,335,520**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.226 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.7 Little Smith Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.08	4	0.008	7198	720	223,138	22,320	0	0.00	0.20	0.6	0.000	16
Feb	0.03	1	0.003	2521	252	70,588	7,056	0	0.00	0.10	0.68	0.000	15
Mar	0.05	2	0.005	3,847	385	119,257	11,935	0	0.00	0.10	0.59	0.001	14
Apr	0.79	38	0.079	68,238	6,824	2,047,140	204,720	204,720	0.50	1.20	0.65	0.000	16
May	10.76	518	1.076	929,289	92,929	28,807,959	2,880,799	2,880,799	8.70	13.30	0.91	0.000	21
Jun	4.03	194	0.403	347,775	34,778	10,433,250	1,043,340	1,043,340	3.30	4.90	0.96	0.000	21
Jul	2.58	124	0.258	223,058	22,306	6,914,798	691,486	691,486	2.00	3.40	0.92	0.000	21
Aug	2.37	114	0.237	204,554	20,455	6,341,174	634,105	634,105	1.80	3.10	0.90	0.000	21
Sep	2.13	102	0.213	183,707	18,371	5,511,210	551,130	551,130	1.50	3.00	0.85	0.000	21
Oct	1.47	71	0.147	126,556	12,656	3,923,236	392,336	392,336	1.20	1.80	0.93	0.000	19
Nov	0.43	21	0.043	37,429	3,743	1,122,870	112,290	0	0.30	0.60	0.90	0.000	16
Dec	0.20	10	0.020	17,305	1,730	536,455	53,630	0	0.10	0.40	0.74	0.000	17
Annual Mean	**2.08**	**n/a**	**0.208**	**179,290**	**17,929**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**66,051,075**	**6,605,147**	**6,397,916**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.623 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.8 Notta Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge**[a]	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available**[b]	**Lower Conf. (m^3/s)**[c]	**Upper Conf. (m^3/s)**[c]	**r^2**	**p-value**[d]	**n**[e]
Jan	0.01	2	0.001	544	54	16,864	1,674	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	65	6	1,820	168	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	246	25	7,626	775	0	0.00	0.00	0.59	0.001	14
Apr	0.27	83	0.027	23,613	2,361	708,390	70,830	70,830	0.10	0.50	0.65	0.000	16
May	2.07	629	0.207	179,220	17,922	5,555,820	555,582	555,582	1.50	2.90	0.91	0.000	21
Jun	0.43	129	0.043	36,720	3,672	1,101,600	110,160	110,160	0.30	0.60	0.96	0.000	21
Jul	0.28	85	0.028	24,240	2,424	751,440	75,144	75,144	0.20	0.40	0.92	0.000	21
Aug	0.30	92	0.030	26,136	2,614	810,216	81,034	81,034	0.20	0.50	0.90	0.000	21
Sep	0.27	82	0.027	23,403	2,340	702,090	70,200	70,200	0.20	0.50	0.85	0.000	21
Oct	0.24	74	0.024	21,007	2,101	651,217	65,131	65,131	0.20	0.30	0.93	0.000	19
Nov	0.05	16	0.005	4,539	454	136,170	13,620	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	2,113	211	65,503	6,541	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.33**	**n/a**	**0.033**	**28,487**	**2,849**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**10,508,756**	**1,050,859**	**1,028,081**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.099 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.9 Saline River Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge[a]**	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available[b]**	**Lower Conf. (m^3/s)[c]**	**Upper Conf. (m^3/s)[c]**	**r^2**	**p-value[d]**	**n[e]**
Jan	0.05	4	0.005	4635	464	143,685	14,384	0	0.00	0.10	0.6	0.000	16
Feb	0.02	1	0.002	1350	135	37,800	3,780	0	0.00	0.10	0.68	0.000	15
Mar	0.03	2	0.003	2,407	241	74,617	7,471	0	0.00	0.10	0.59	0.001	14
Apr	0.66	44	0.066	56,947	5,695	1,708,410	170,850	170,850	0.40	1.00	0.65	0.000	16
May	8.13	539	0.813	701,959	70,196	21,760,729	2,176,076	2,176,076	6.50	10.10	0.91	0.000	21
Jun	2.74	182	0.274	237,062	23,706	7,111,860	711,180	711,180	2.30	3.30	0.96	0.000	21
Jul	1.77	117	0.177	152,797	15,280	4,736,707	473,680	473,680	1.30	2.30	0.92	0.000	21
Aug	1.67	111	0.167	144,042	14,404	4,465,302	446,524	446,524	1.30	2.20	0.90	0.000	21
Sep	1.50	99	0.150	129,297	12,930	3,878,910	387,900	387,900	1.00	2.10	0.85	0.000	21
Oct	1.08	72	0.108	93,183	9,318	2,888,673	288,858	288,858	0.90	1.30	0.93	0.000	19
Nov	0.30	20	0.030	26,123	2,612	783,690	78,360	0	0.20	0.40	0.90	0.000	16
Dec	0.14	9	0.014	12,092	1,209	374,852	37,479	0	0.10	0.30	0.74	0.000	17
Annual Mean	**1.51**	**n/a**	**0.151**	**130,158**	**13,016**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**47,965,235**	**4,796,542**	**4,655,068**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.452 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

[e] p-values listed as 0.000 are <0.001

n/a: not applicable.

Table B.10 Seagrams Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	456	46	14,136	1,426	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	50	5	1,400	140	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	204	20	6,324	620	0	0.00	0.00	0.59	0.001	14
Apr	0.25	87	0.025	21,952	2,195	658,560	65,850	65,850	0.10	0.50	0.65	0.000	16
May	1.85	635	0.185	160,044	16,004	4,961,364	496,124	496,124	1.30	2.60	0.91	0.000	21
Jun	0.36	125	0.036	31,461	3,146	943,830	94,380	94,380	0.30	0.50	0.96	0.000	21
Jul	0.24	83	0.024	20,810	2,081	645,110	64,511	64,511	0.20	0.40	0.92	0.000	21
Aug	0.26	90	0.026	22,688	2,269	703,328	70,339	70,339	0.20	0.40	0.90	0.000	21
Sep	0.24	81	0.024	20,312	2,031	609,360	60,930	60,930	0.10	0.40	0.85	0.000	21
Oct	0.22	74	0.022	18,567	1,857	575,577	57,567	57,567	0.20	0.30	0.93	0.000	19
Nov	0.05	15	0.005	3,926	393	117,780	11,790	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,829	183	56,699	5,673	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.29**	**n/a**	**0.029**	**25,192**	**2,519**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**9,293,468**	**929,350**	**909,701**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.087 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.11 Small Strawberry Creek Culvert: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	2	0.000	372	37	11,532	1,147	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	38	4	1,064	112	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	164	16	5,084	496	0	0.00	0.00	0.59	0.001	14
Apr	0.23	92	0.023	20,189	2,019	605,670	60,570	60,570	0.10	0.50	0.65	0.000	16
May	1.63	642	0.163	140,553	14,055	4,357,143	435,705	435,705	1.10	2.30	0.91	0.000	21
Jun	0.31	120	0.031	26,347	2,635	790,410	79,050	79,050	0.20	0.40	0.96	0.000	21
Jul	0.20	80	0.020	17,467	1,747	541,477	54,157	54,157	0.10	0.30	0.92	0.000	21
Aug	0.22	88	0.022	19,288	1,929	597,928	59,799	59,799	0.10	0.40	0.90	0.000	21
Sep	0.20	79	0.020	17,264	1,726	517,920	51,780	51,780	0.10	0.40	0.85	0.000	21
Oct	0.19	74	0.019	16,114	1,611	499,534	49,941	49,941	0.10	0.30	0.93	0.000	19
Nov	0.04	15	0.004	3,324	332	99,720	9,960	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,549	155	48,019	4,805	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.25**	**n/a**	**0.025**	**21,889**	**2,189**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**8,075,501**	**807,522**	**791,002**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.076 m²/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.12 Steep Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge[a]**	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available[b]**	**Lower Conf. (m^3/s)[c]**	**Upper Conf. (m^3/s)[c]**	**r^2**	**p-value[d]**	**n[e]**
Jan	0.02	3	0.002	1747	175	54,157	5,425	0	0.00	0.10	0.6	0.000	16
Feb	0.00	1	0.000	338	34	9,464	952	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	852	85	26,412	2,635	0	0.00	0.10	0.59	0.001	14
Apr	0.44	59	0.044	38,131	3,813	1,143,930	114,390	114,390	0.30	0.70	0.65	0.000	16
May	4.36	583	0.436	376,841	37,684	11,682,071	1,168,204	1,168,204	3.40	5.60	0.91	0.000	21
Jun	1.17	157	0.117	101,350	10,135	3,040,500	304,050	304,050	0.90	1.50	0.96	0.000	21
Jul	0.76	102	0.076	66,040	6,604	2,047,240	204,724	204,724	0.60	1.10	0.92	0.000	21
Aug	0.77	102	0.077	66,184	6,618	2,051,704	205,158	205,158	0.60	1.10	0.90	0.000	21
Sep	0.69	92	0.069	59,343	5,934	1,780,290	178,020	178,020	0.50	1.00	0.85	0.000	21
Oct	0.55	73	0.055	47,267	4,727	1,465,277	146,537	146,537	0.40	0.70	0.93	0.000	19
Nov	0.14	18	0.014	11,769	1,177	353,070	35,310	0	0.10	0.20	0.90	0.000	16
Dec	0.06	8	0.006	5,462	546	169,322	16,926	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.75**	**n/a**	**0.075**	**64,610**	**6,461**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**23,823,437**	**2,382,331**	**2,321,083**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.224 m^2/s).

[a] Calculated as monthly discharge divided by MAD x100.

[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

[e] p-values listed as 0.000 are <0.001

n/a: not applicable.

Table B.13 Twelve Mile Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.00	2	0.000	305	30	9,455	930	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	28	3	784	84	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	133	13	4,123	403	0	0.00	0.00	0.59	0.001	14
Apr	0.22	97	0.022	18,610	1,861	558,300	55,830	55,830	0.10	0.40	0.65	0.000	16
May	1.43	648	0.143	123,885	12,388	3,840,435	384,028	384,028	1.00	2.10	0.91	0.000	21
Jun	0.26	116	0.026	22,174	2,217	665,220	66,510	66,510	0.20	0.40	0.96	0.000	21
Jul	0.17	77	0.017	14,733	1,473	456,723	45,663	45,663	0.10	0.30	0.92	0.000	21
Aug	0.19	86	0.019	16,472	1,647	510,632	51,057	51,057	0.10	0.30	0.90	0.000	21
Sep	0.17	77	0.017	14,740	1,474	442,200	44,220	44,220	0.10	0.30	0.85	0.000	21
Oct	0.16	74	0.016	14,040	1,404	435,240	43,524	43,524	0.10	0.20	0.93	0.000	19
Nov	0.03	15	0.003	2,828	283	84,840	8,490	0	0.00	0.10	0.90	0.000	16
Dec	0.02	7	0.002	1,319	132	40,889	4,092	0	0.00	0.00	0.74	0.000	17
Annual Mean	**0.22**	**n/a**	**0.022**	**19,106**	**1,910**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**7,048,841**	**704,831**	**690,832**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.066 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.14 Vermillion Creek North Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	**Mean (m^3/s)**	**% of Annual Discharge[a]**	**10% Mean (m^3/s)**	**Mean**	**10% Mean**	**Mean**	**10% Mean**	**Available[b]**	**Lower Conf. (m^3/s)[c]**	**Upper Conf. (m^3/s)[c]**	**r^2**	**p-value[d]**	**n[e]**
Jan	0.01	2	0.001	871	87	27,001	2,697	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	126	13	3,528	364	0	0.00	0.00	0.68	0.000	15
Mar	0.01	1	0.001	406	41	12,586	1,271	0	0.00	0.00	0.59	0.001	14
Apr	0.33	72	0.033	28,640	2,864	859,200	85,920	85,920	0.20	0.60	0.65	0.000	16
May	2.80	612	0.280	241,760	24,176	7,494,560	749,456	749,456	2.10	3.80	0.91	0.000	21
Jun	0.64	140	0.064	55,269	5,527	1,658,070	165,810	165,810	0.50	0.80	0.96	0.000	21
Jul	0.42	92	0.042	36,295	3,630	1,125,145	112,530	112,530	0.30	0.60	0.92	0.000	21
Aug	0.44	96	0.044	37,998	3,800	1,177,938	117,800	117,800	0.30	0.60	0.90	0.000	21
Sep	0.39	86	0.039	34,043	3,404	1,021,290	102,120	102,120	0.20	0.60	0.85	0.000	21
Oct	0.34	74	0.034	29,121	2,912	902,751	90,272	90,272	0.20	0.50	0.93	0.000	19
Nov	0.08	17	0.008	6,662	666	199,860	19,980	0	0.00	0.10	0.90	0.000	16
Dec	0.04	8	0.004	3,098	310	96,038	9,610	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.46**	**n/a**	**0.046**	**39,524**	**3,953**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**14,577,967**	**1,457,830**	**1,423,908**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.137 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.15 Vermillion Creek South Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.01	2	0.001	579	58	17,949	1,798	0	0.00	0.00	0.6	0.000	16
Feb	0.00	0	0.000	70	7	1,960	196	0	0.00	0.00	0.68	0.000	15
Mar	0.00	1	0.000	263	26	8,153	806	0	0.00	0.00	0.59	0.001	14
Apr	0.28	81	0.028	24,213	2,421	726,390	72,630	72,630	0.10	0.50	0.65	0.000	16
May	2.16	627	0.216	186,325	18,632	5,776,075	577,592	577,592	1.60	3.00	0.91	0.000	21
Jun	0.45	130	0.045	38,723	3,872	1,161,690	116,160	116,160	0.30	0.60	0.96	0.000	21
Jul	0.30	86	0.030	25,545	2,554	791,895	79,174	79,174	0.20	0.40	0.92	0.000	21
Aug	0.32	92	0.032	27,438	2,744	850,578	85,064	85,064	0.20	0.50	0.90	0.000	21
Sep	0.28	83	0.028	24,571	2,457	737,130	73,710	73,710	0.20	0.50	0.85	0.000	21
Oct	0.25	74	0.025	21,917	2,192	679,427	67,952	67,952	0.20	0.40	0.93	0.000	19
Nov	0.06	16	0.006	4,771	477	143,130	14,310	0	0.00	0.10	0.90	0.000	16
Dec	0.03	8	0.003	2,221	222	68,851	6,882	0	0.00	0.10	0.74	0.000	17
Annual Mean	**0.34**	**n/a**	**0.034**	**29,720**	**2,972**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**10,963,228**	**1,096,274**	**1,072,282**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.103 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

Table B.16 Whitesand Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value[d]	n[e]
Jan	0.06	4	0.006	5217	522	161,727	16,182	0	0.00	0.20	0.6	0.000	16
Feb	0.02	1	0.002	1597	160	44,716	4,480	0	0.00	0.10	0.68	0.000	15
Mar	0.03	2	0.003	2,731	273	84,661	8,463	0	0.00	0.10	0.59	0.001	14
Apr	0.69	42	0.069	59,785	5,978	1,793,550	179,340	179,340	0.50	1.00	0.65	0.000	16
May	8.76	534	0.876	756,952	75,695	23,465,512	2,346,545	2,346,545	7.10	10.90	0.91	0.000	21
Jun	3.04	185	0.304	262,790	26,279	7,883,700	788,370	788,370	2.50	3.70	0.96	0.000	21
Jul	1.96	119	0.196	169,156	16,916	5,243,836	524,396	524,396	1.50	2.60	0.92	0.000	21
Aug	1.83	112	0.183	158,285	15,828	4,906,835	490,668	490,668	1.40	2.40	0.90	0.000	21
Sep	1.65	100	0.165	142,102	14,210	4,263,060	426,300	426,300	1.20	2.30	0.85	0.000	21
Oct	1.17	71	0.117	101,176	10,118	3,136,456	313,658	313,658	0.90	1.40	0.93	0.000	19
Nov	0.33	20	0.033	28,775	2,878	863,250	86,340	0	0.20	0.50	0.90	0.000	16
Dec	0.15	9	0.015	13,315	1,332	412,765	41,292	0	0.10	0.30	0.74	0.000	17
Annual Mean	**1.64**	**n/a**	**0.164**	**141,823**	**14,182**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**52,260,068**	**5,226,034**	**5,069,277**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:
Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.492 m^2/s).
[a] Calculated as monthly discharge divided by MAD x100.
[b] '*Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD; DFO 2013).
[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.
[d] Number of data points in each monthly regression.
[e] p-values listed as 0.000 are <0.001
n/a: not applicable.

APPENDIX 15D

Prohibition Creek Access Road: Desktop-based Assessment of Water Availability

Prohibition Creek Access Road: Desktop-Based Assessment of Water Availability

Prepared for:

Department of Infrastructure, Government of the Northwest Territories
Yellowknife, NT

Prepared by:

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P.O. Box 176
Tulita, NT

September 16, 2022

Project No.: 144903284

K'alo-Stantec

Executive Summary

Monthly average discharge, mean annual discharge, and water volumes available for withdrawal have been calculated for four ungauged—and one gauged—creeks along the proposed Prohibition Creek Access Road (PCAR) alignment (the Study Area), near Norman Wells, Northwest Territories. Selected results are summarized in the summary table below.

Summary Table: Selected Statistics and Observations for Predicted Discharge and Water Availability for Potential Water Sources Along the Proposed Prohibition Creek Access Road Alignment

Creek[a]	Watershed Area (km^2)	May Mean Discharge (m^3/s)	Mean Annual Discharge (m^3/s)	30% of Mean Annual Discharge (m^3/s)[b]	Annual Volume Available (m^3)[c]	Flows Likely in Winter?	Winter Observation Data Source
Canyon	64	2.12	0.35	0.104	1,079,056	y	Water Survey of Canada gauge 10KA009
Francis	24	0.88	0.15	0.044	460,297	n	Limited qualitative observations
Helava	28	1.00	0.17	0.050	518,448	n	Limited qualitative observations
Christina	21	0.76	0.13	0.039	402,695	n	Limited qualitative observations
Prohibition	86	2.76	0.45	0.135	1,408,600	y	One manual discharge measurement in April 1973

NOTES**:**

[a] At bridge crossings.

[b] The criterion used to define periods of 'low' risk withdrawals (months with greater than 30% of mean annual discharge (MAD) vs. 'high' risk withdrawals (months with less than 30% of MAD

[c] *Annual Water Available'* is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD)

Criteria described above follow: Fisheries and Oceans Canada. 2013. Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada. Canadian Science Advisory Secretariat Science Advisory Report 2013/017

Water will be used for winter and summer construction related activities, compaction, and dust control. The amount and timing of water withdrawals are not yet known; however, the majority is anticipated to be needed in early winter (November-December) for winter road construction.

Flows were predicted with a regional analysis of data from Water Survey of Canada (WSC) stations. Predictions are statistically significant from May to November. Winter flows in regional creeks are conditioned by site specific groundwater inputs as well as watershed size. Therefore, WSC data and historic literature from the area were reviewed for information pertinent to winter flows. The two largest creeks, Canyon and Prohibition, flow in winter. Limited available data suggest that the smaller creeks (Francis, Helava, and Christina) do not flow in winter.

"Cumulative flow alterations that result in instantaneous flows less than 30% of the Mean Annual Discharge (MAD) have a heightened risk of impacts to ecosystems that support fisheries". Periods of heightened risk were assessed (1) locally, using the results of flow predictions calculated here, and (2) regionally, using WSC data. By this definition, periods of heightened risk consistently occur over winter (November through February) both locally and regionally. Regionally, the only exception is a creek that drains several upstream ponds.

Monthly and annual average water volumes potentially available for withdrawal were calculated using DFO's criteria and 'desktop-based' flow estimates produced here. Annual volumes range from about 403,000 m^3 from Christina Creek to about 1,409,000 m^3 from Prohibition Creek (Summary Table). About half of this annual flow volume is in May. No water is predicted to be available using this 'desktop-based' methodology for withdrawal in November through February. Withdrawals during this overwinter period will likely require "*a more rigorous level of assessment… to evaluate potential impacts on ecosystem functions which support fisheries*" as required by DFO.

The region is sparsely gauged. Existing datasets are sometimes short and limited over winter. Stations with the shortest records are located close to the proposed PCAR alignment. Data from these stations were used in analyses because of their proximity to the Project. However, the variability of flows from these stations is similar to that of more distant stations with longer records, suggesting that the limited data available from these local sites adequately capture flow variability.

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Abbreviations

e.g. .... example
DFO .... Fisheries and Oceans Canada
EFN .... Environmental Flow Needs
i.e. .... that is to say
MAD .... Mean Annual Discharge
masl .... Metres Above Sea Level
PCAR .... Prohibition Creek Access Road
QAQC .... Quality Assurance/Quality Control
WSC .... Water Survey of Canada

1 Introduction

This document provides monthly and annual flow estimates for candidate water withdrawal locations on streams crossing the proposed Prohibition Creek Access Road (PCAR) based on a desktop study of historic flows and literature in the region. The PCAR is proposed to be located about 16 to 30 km southeast of Norman Wells, Northwest Territories (NT), about 1.5 km from the north (right) bank of the Mackenzie River (Figure 1.1; Figure 1.2). The existing PCAR water licence authorizes water withdrawal from the Mackenzie River only (water license S20L8-002); this work investigates water availability in creeks along the PCAR alignment for potential future withdrawals.

The objectives and scope of the study are summarized below:

- Review potential water withdrawal sources along the proposed PCAR alignment. The five potential withdrawal sources are all moving waterbodies at existing bridges (Tetra Tech 2021; Tetra Tech 2022) (Table 1.1). An additional 39 proposed culvert crossings were identified that drain relatively small upstream catchments (<8.8 km^2) (Tetra Tech 2021; Tetra Tech 2022). Discharge is not predicted for these small creeks but can be calculated using equations presented here. No lakes or ponds were identified within 500 m of the PCAR alignment to be used as potential water withdrawal sources.
- Review existing available data to identify sources that are likely to support water withdrawal (based on watershed, flow data, hydrographs, etc.) during certain times of the year (Sections 4.1 and 5.2).
- Identify monthly discharge magnitudes and volumes potentially able to be withdrawn while meeting environmental flow needs (EFN; i.e. the volume and timing of water flow required for proper functioning of the aquatic ecosystem (FLNRORD 2022); Section 5.2). Criteria for low-risk withdrawals follow the '*Framework for Assessing the Ecological Flow Requirements to Support Fisheries in Canada*' (DFO 2013) and are described in Section 4.4.
- Identify additional studies required to verify the findings of this desktop study (Section 7) and to support licensing of water withdrawal.

Table 1.1 Potential Water Withdrawal Sources at Creek Crossings Along the Proposed Prohibition Creek Access Road Alignment

Crossing	UTM Easting (m)	UTM Northing (m)	Watershed Area (km^2)
Canyon Creek	615,829	7,235,942	64
Christina Creek	621,630	7,231,762	21
Francis Creek	618,988	7,233,671	24
Helava Creek	620,808	7,232,368	28
Prohibition Creek	626,507	7,228,256	86

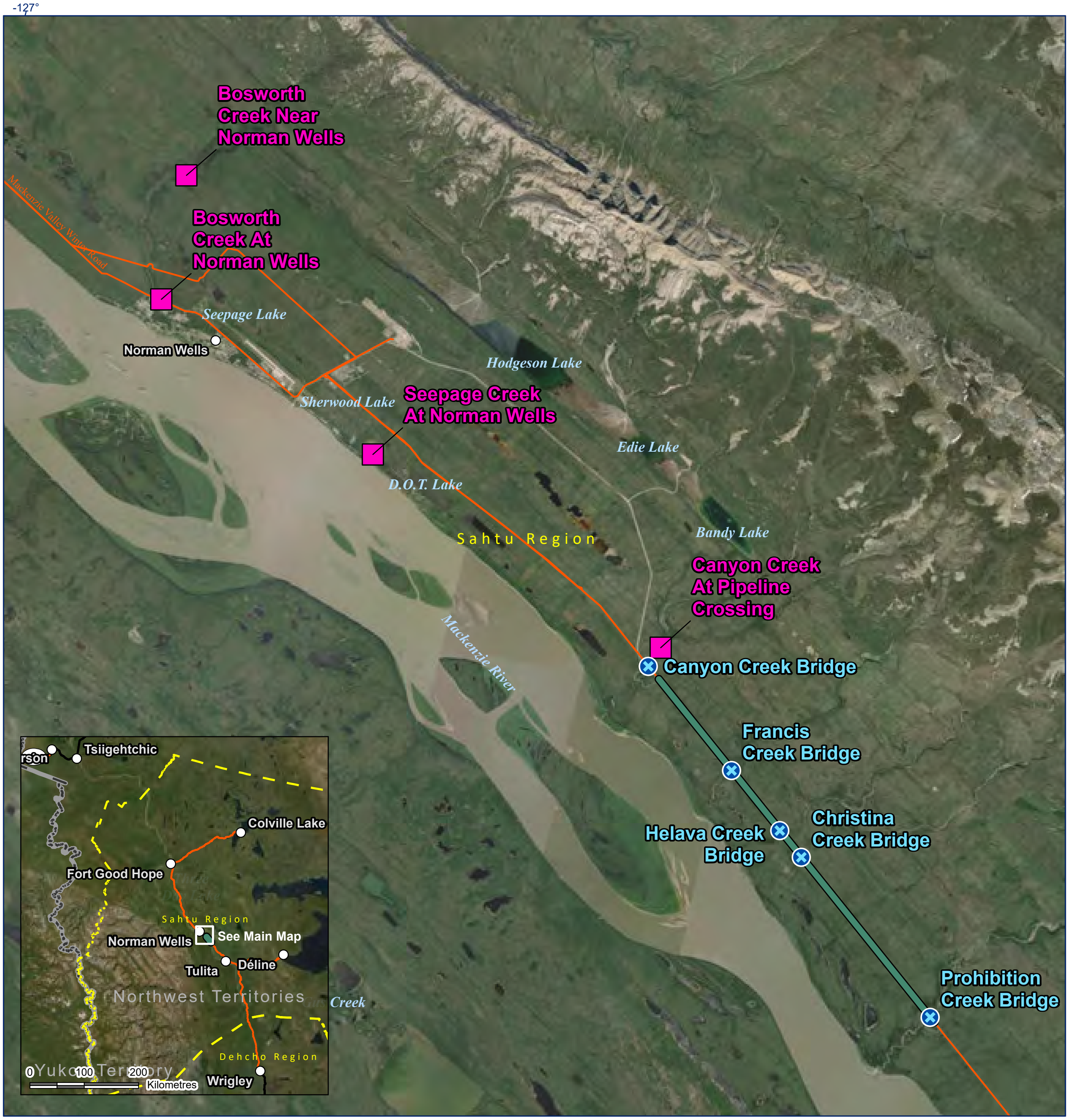
NOTE:

Coordinates are UTM Zone 9, WGS84 Datum. Watershed areas are from hydrotechnical assessments and design documents (Tetra Tech 2021; Tetra Tech 2022).

Fish habitat assessments have been conducted at each of the creeks near the crossings summarized in Table 1.1 (K'alo-Stantec Limited 2020). All creeks are classified as having the potential for fish habitat.

During construction and operation of the PCAR, water will be used for winter road construction, compaction and dust control. The amount and timing of water withdrawals are not yet known. This document aims to research potential water withdrawal sources that could support withdrawals throughout the year while meeting the DFO guidelines, and therefore could be supported by regulators for purpose of licensing. It is understood that the majority of water for winter road construction is needed in early winter (November-December) (Stevens 2022); whereas water is used for compaction and dust control from June to September.

This document provides average volumes available for withdrawal. Previous studies have provided discharges during floods and changes in flow due to climate change (Tetra Tech 2021; Tetra Tech 2022).



Water Survey of Canada Hydrometric Station
Existing Bridge
Prohibition Creek Access Road Proposed Alignment
Community
All-Season Road
Winter Road
Region Boundary

0 1.5 3 Kilometres
(At original document size of 8.5x11)
1:175,000

N

Kálo-Stantec

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

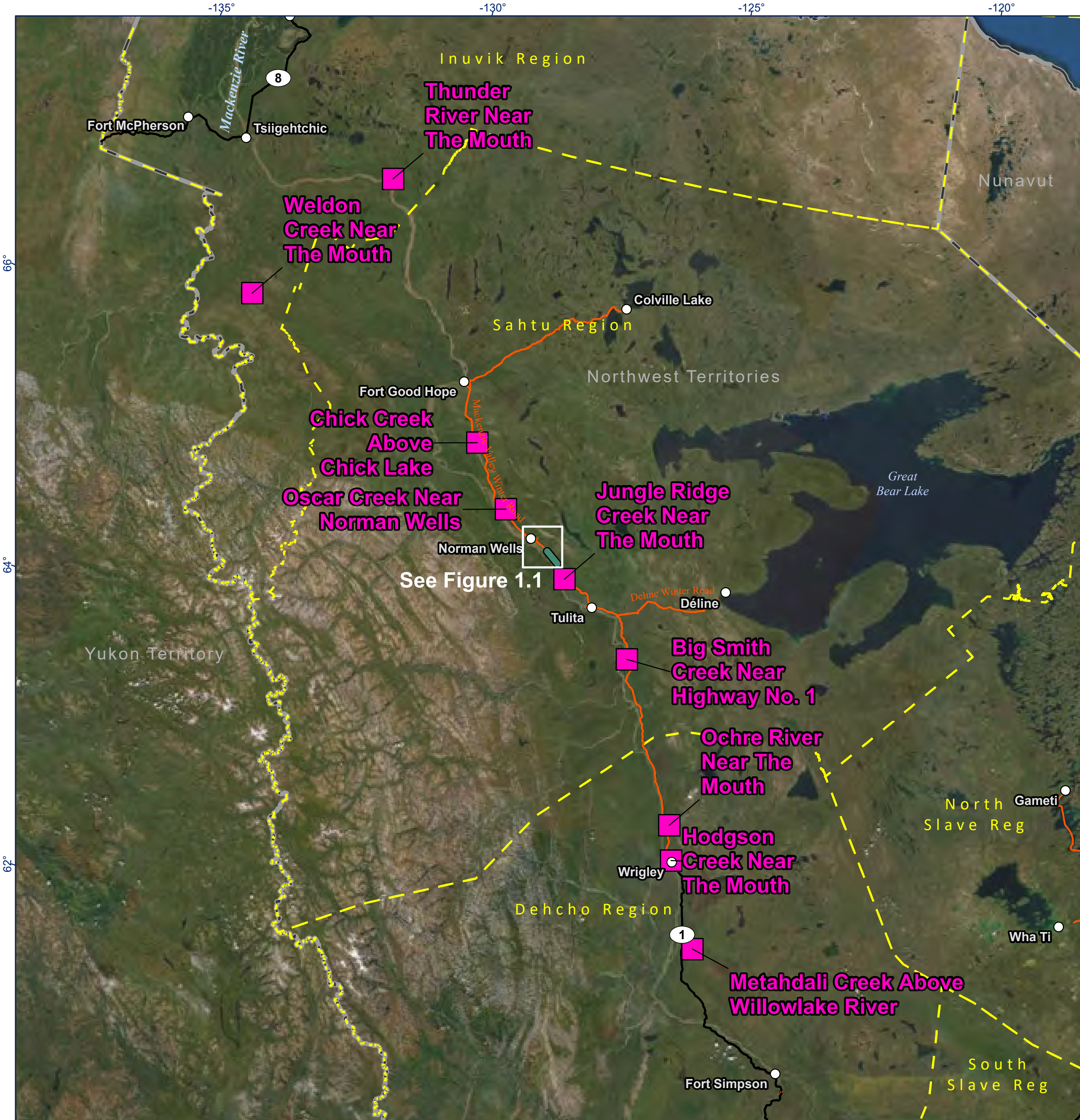
Prepared by DS on 9/1/2022
TR by CES on 9/1/2022

Client/Project
144903025-0156

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
Prohibition Creek Access Road Proposed Alignment, Potential Water Sources, and Analyzed Water Survey of Canada Stations



Water Survey of Canada Hydrometric Station

Prohibition Creek Access Road Proposed Alignment

Community

All-Season Road

Winter Road

Region Boundary

0 50 100 Kilometres

(At original document size of 8.5x11) 1:4,781,845

N

Kalo-Stantec

Project Location

Wrigley to Norman Wells, NWT

Prepared by DS on 9/6/2022
TR by CES on 9/6/2022

Client/Project

144903025-0158

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.

1.2

Title

Regional Water Survey of Canada Stations Selected for Analyses

Notes

1. Coordinate System: NAD 1983 Northwest Territories Lambert

2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec

3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

2 Limitations

Flows and water volumes provided here are estimates for ungauged creeks in a sparsely monitored region (sparse both spatially and temporally). Results are approximations and are intended to focus efforts on creeks and time periods where the ecological impacts of withdrawals will be low. Limitations include:

- Flows and water volumes provided here are not prescriptive assessments of water availability in a given year. Flow predictions are reflective of average conditions in the years regional data were collected.
- Flows during floods and changes in flow due to climate change have been evaluated elsewhere (Tetra Tech 2021; Tetra Tech 2022).
- Results presented here should not be used for purposes other than those stated. For example, data presented here do not provide engineering design parameters. Engineering design and analysis of crossings (e.g., conveyance capacity and channel stability) would require a separate study tailored for such purposes.
- Analysis and recommendations are based on data available at the time of the report and rely on data provided by others which we assume to be correct but were not verified as part of this study.

Recommendations for refining estimates provided here are presented in Section 7.

3 Regional Hydroclimate

The proposed PCAR alignment is within the Mackenzie River Valley, about 30 km southeast of Norman Wells. A long-term climate station operates at Norman Wells (Station 'Norman Wells A', 73 masl). Average annual 30-year normal (1981-2010) air temperature is -5.1°C (ECCC 2022a). Average air temperatures dip below freezing in October and rise above freezing in May. Maximum monthly average air temperature occurs in July (17.1°C). The Mackenzie Valley itself has a somewhat milder climate than adjacent areas to the east and west (Kokelj 2001). Norman Wells receives 294 mm of precipitation annually, about 55% of which falls as snow. Daily rainfall amounts approaching 50 mm have historically occurred. Climate normal Hargreaves reference annual evapotranspiration is 389 mm (Wang et al. 2012); i.e., there is a potential annual moisture deficit in the region.

The proposed PCAR alignment is within the 'extensive discontinuous' (50-90%) permafrost zone (GNWT 2022). Norman Wells falls within the 'Taiga Plains, Norman Range LS Ecoregion'; vegetation is a "*complex of mixed-wood forests on westerly slopes and lacustrine deposits, mixed spruce stands on the interior plateau and slopes, and extensively burned areas*" (GNWT 2009).

The proposed PCAR alignment spans elevations from about 90 to 100 metres above sea level (masl). Creeks drain the Norman Range and Discovery Ridge to the east, with elevations up to about 1,500 masl.

The Sahtu Region has been classified into Arctic, East Mackenzie, Great Bear, and West Mackenzie hydrologic zones; the proposed PCAR alignment falls within the East Mackenzie zone (Golder Associates 2015). Regionally, a "*large portion of the annual precipitation is stored for several months in the form of snow and therefore snowmelt runoff in spring is a dominant feature of regional stream hydrographs*" (Kokelj 2001). Annual runoff for regional watersheds that drain into the Mackenzie River's east bank spans from about 60 mm (Seepage Creek at Norman Wells) to 327 mm (Jungle Ridge Creek near the Mouth)(Kokelj 2001). This is generally lower than runoff in the adjacent West Mackenzie zone.

Flows decline after freshet in May, with occasional increases in response to rainfall, then decline through winter. The ability of a watercourse to sustain flows over winter depends on "*watershed-specific factors including precipitation, channel slope, upland storage and particularly the presence of springs*" (Golder Associates 2006). Watercourses in the Sahtu Region have been described as:

> *"highly influenced by groundwater inflow… where streams with drainage areas larger than 50 km^2 likely maintain some flow over the winter because of groundwater contribution…Depending on local groundwater conditions, stream drainages smaller than 25 km^2 might also exhibit stream flow over the winter, whereas others with less groundwater inflow might freeze completely to the streambed."* (MGP 2004)

4 Methods

The main deliverables of this report are modelled predictions of mean monthly discharge, MAD, and ecologically 'low-risk' water withdrawal volumes at potential PCAR water sources. This was accomplished by conducting regression analyses of monthly mean flow for regional WSC stations and watershed area.

This section begins by describing available data, then describes the flow prediction methodology and criteria used for the assessment of low-risk water withdrawal volumes.

Data were collected, filtered, and analyzed in (R Core Team 2022). All regressions, statistics, and plotting were also conducted in R.

4.1 Data Sources

Daily flow data from WSC stations were compiled with the R library 'Tidyhydat' (Goetz, Albers and Pike 2018). Tidyhydat uses the WSC database 'Hydat' (ECCC 2022b). The Hydat version used here was published on 2022-04-18 and is the most recent database at the time of writing. The most recent finalized data for regional stations is from 2019 Provisional real-time data that have not yet undergone full quality assurance/quality control (QAQC) were not used here.

Hydrometric data were compiled for the WSC stations in the NT, then filtered to include only:

- Stations within 400 km of the Helava Creek crossing (a central point in the Study Area; Figure 1.2)
- Stations with watersheds that do not drain the Mackenzie Mountains, due to the different hydrologic regime there (Golder Associates 2015)(Section 3)
- Stations with relatively small to medium-sized watersheds, i.e., <~1000 km^2 [1]
- Stations whose discharge is unlikely to be affected by drainage of large upstream lakes, potentially causing delays between snowmelt and rainfall, and runoff[2]
- Months with greater than or equal to 92 daily observations (i.e., greater than about 3-years of data; Section 4.3; Section 6.2)

WSC stations included in the analysis after applying the filtering process are summarized in Table 4.1 and mapped in Figure 1.1 and Figure 1.2. Some stations in Table 4.1 have short periods of record, and/or have not recently operated. Several stations also have limited datasets over winter due to seasonal operation (Figure 4.1). Implications for use of relatively small sample sizes are explored in Section 6.2. Data from two stations[3] were frequently anomalous when flagged as backwatered. Backwatering causes river levels to rise independently from discharge, often in response to a downstream obstruction (e.g., ice, beaver dams), or a downstream waterbody or watercourse. These data were removed.

[1] 1,031 km^2. Set to include 10HC008, Oche River Near the Mouth.
[2] 10LB007 TIEDA RIVER NEAR THE MOUTH and 10LD002 JACKFISH CREEK NEAR FORT GOOD HOPE were excluded.
[3] 10KA005 SEEPAGE CREEK AT NORMAN WELLS and 10LA004, WELDON CREEK NEAR THE MOUTH.

4.2 Watershed Delineation

The WSC publish watershed areas for most stations in the NT (ECCC 2022b); however, watershed areas were missing for several stations that remained following the filtering process described above (station numbers 10KD009, 10HC007, 10HC008, and 10LB006; Table 4.1). The watershed areas for these stations were calculated using ArcGIS software. National Hydrographic Network basins (Natural Resources Canada 2022) were segmented along topographic ridgelines and flow patterns. Where watershed areas were available from the '*Prohibition Creek Access Road Hydrotechnical Assessments*' report, they were preferentially used here, since these watersheds were delineated using high-resolution LiDAR data (Tetra Tech 2021). The watershed area at the WSC station at Canyon Creek (10KA009) is about 3% smaller than 0.7 km downstream at the bridge crossing; for the purposes of these analyses, 64 km^2 (Tetra Tech 2021; Tetra Tech 2022) was used for both catchment areas.

Table 4.1 Regional Water Survey of Canada Stations Used for Flow Predictions along the Proposed Prohibition Creek Access Road Alignment

Station Number	Station Name	UTM Easting (m)	UTM Northing (m)	UTM Zone	Drainage Area (km^2)	Location[a] Dist. (km)	Location[a] Bearing (deg)[b]	Monitoring Period Begins	Monitoring Period Ends	Data Points (n)[c]
10KA009	CANYON CREEK AT PIPELINE CROSSING	615,995	7,236,583	9	*64*	6	-46	2009	2018	2,199
10KA005	SEEPAGE CREEK AT NORMAN WELLS	606,333	7,239,786	9	31	16	-60	1974	1978	1,614
10KA006	JUNGLE RIDGE CREEK NEAR THE MOUTH	635,408	7,217,955	9	60	21	137	1980	2018	6,796
10KA003	BOSWORTH CREEK AT NORMAN WELLS	599,129	7,242,508	9	122	24	-63	1973	1979	1,375
10KA007	BOSWORTH CREEK NEAR NORMAN WELLS	598,863	7,246,213	9	125	26	-55	1980	2018	9,256
10KA008	OSCAR CREEK NEAR NORMAN WELLS	575,639	7,259,095	9	638	53	-57	2009	2018	2,264
10HC003	BIG SMITH CREEK NEAR HIGHWAY NO. 1	413,224	7,164,281	10	980	101	131	1973	1994	7,820
10KD009	CHICK CREEK ABOVE CHICK LAKE	539,521	7,304,005	9	**16**	108	-46	2008	2018	2,870
10HC008	OCHRE RIVER NEAR THE MOUTH	469,488	7,040,295	10	**1,031**	233	143	2006	2019	4,412
10HC007	HODGSON CREEK NEAR THE MOUTH	475,833	7,012,887	10	**303**	260	145	2006	2014	2,896
10LA004	WELDON CREEK NEAR THE MOUTH	602,944	7,367,726	8	852	318	-62	1978	1990	4,748
10LB006	THUNDER RIVER NEAR THE MOUTH	418,760	7,488,203	9	**441**	326	-36	2006	2017	3,867
10GB005	METAHDALI CREEK ABOVE WILLOWLAKE RIVER	504,798	6,946,566	10	344	332	147	1976	1987	4,201

NOTES:

Stations are sorted by distance from Helava Creek bridge, a central point along the PCAR proposed alignment.

[a] Relative to the Helava Creek bridge.

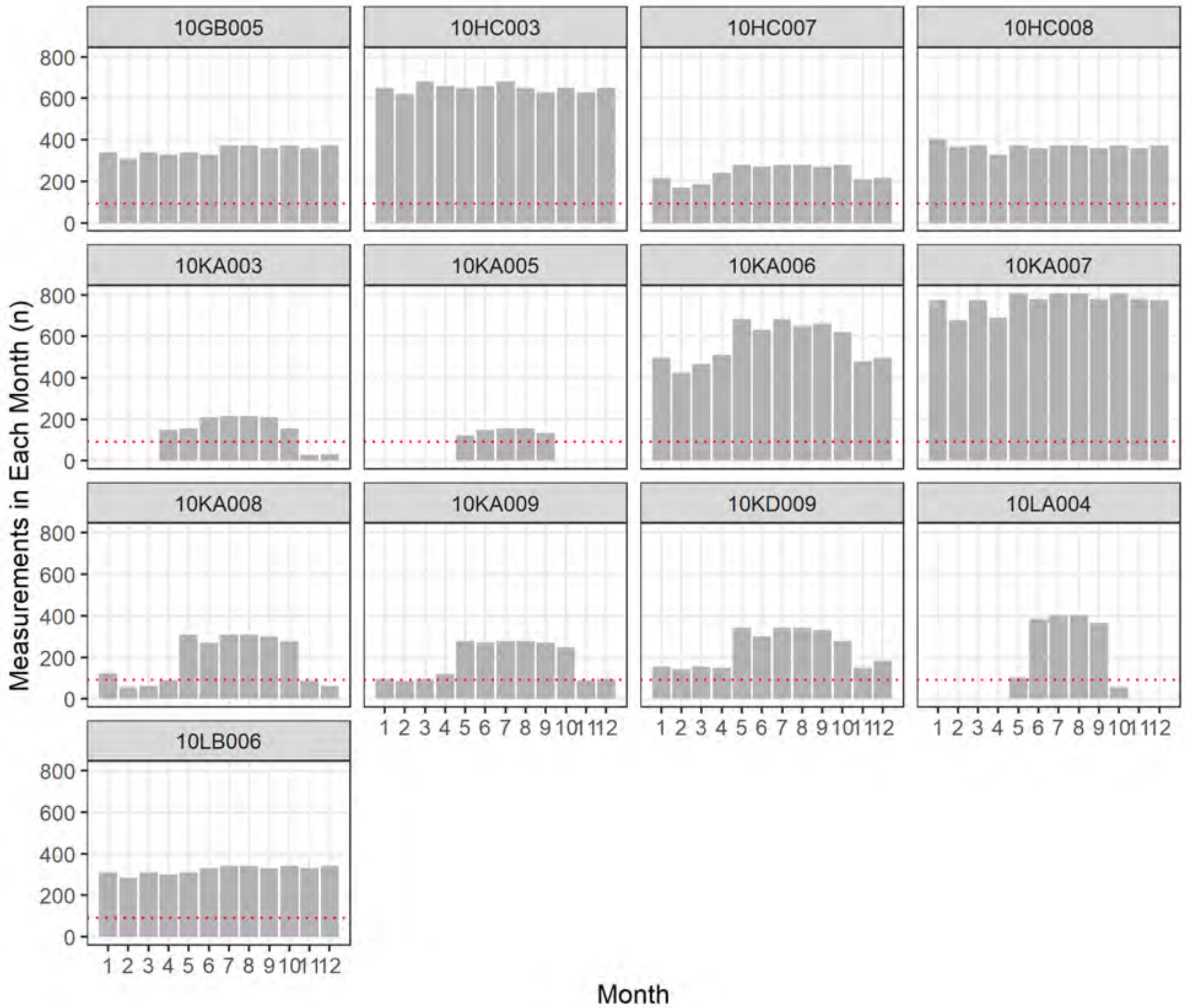
[b] Bearing is degrees clockwise (+) or counterclockwise (-) bearing from the Helava Creek bridge to the WSC station.

[c] Number of daily observations of flow.

*Bolded watershed areas were calculated by K'alo-Stantec (see text for methods). Watershed area for Canyon Creek was obtained from hydrotechnical assessment and design documents (Tetra Tech 2021; Tetra Tech 2022).

Coordinates use the WGS84 datum.

Figure 4.1 Histograms for Selected Water Survey of Canada Stations, Showing the Number of Observations in Each Month for the Period of Record



NOTES:

(1) the red horizontal line is at n=92. Months where n<92 at each station were excluded from regression modelling (Section 4.3).

(2) Month=1 represents January; Month=12 represents December

4.3 Flow Predictions

Monthly mean discharge was modelled for each of the five potential PCAR water withdrawal sources (Table 1.1). Modelling consisted of linear regressions between watershed area and mean monthly discharge for selected regional WSC stations (Table 4.1; Figure 1.2). Discharge and watershed area were log-transformed and regressions were conducted for each month. Watershed area is the predictor and mean monthly flow is the predictand.

Several WSC stations have operated very close to the Study Area (Table 4.1; Figure 1.1) and these stations have watershed areas that are relatively close to those of the potential water source creeks (Table 1.1). For example, ‘Canyon Creek at Pipeline Crossing’ (station 10KA009) was monitored by the WSC from 2009 to 2018 about 700 m upstream from the Canyon Creek bridge. ‘Seepage Creek at Norman Wells’ (station 10KA005) has a very small watershed area and is close to the Study Area; however, it only operated between 1974 and 1978. Given their watershed areas and proximity to the Study Area, data from these stations are valuable and were included in analyses whenever possible despite their relatively short period of operation.

It was therefore decided to include these local stations with short records in analyses while acknowledging that flow statistics from these stations may not characterize the full range of hydroclimatic variability. Flow data were grouped by station and month, and average flows were retained if at least 92 daily data points remained in each group (Figure 4.1; horizontal red lines). This would represent about three years of monitoring in each month if monitoring had been continuous. Implications for the use of relatively small sample sizes are discussed in Section 6.2.

An alternative to the methods described above would be to relax the filtering criteria, for example by increasing the maximum distance from PCAR where data should be collected. The disadvantage of relaxing filtering criteria is that distant or hydrologically different sites would be included in analyses. This is sometimes mitigated by incorporating additional predictors such as watershed elevation, air temperature and/or precipitation (Zhang, Balay and Liu 2020).

4.4 Criteria for Assessment of Environmental Flow Needs

For flowing waterbodies, DFO guidance (DFO 2013) is:

- “*cumulative flow alterations of less than +/- 10% of the magnitude of actual (instantaneous) flow in the river relative to a “natural flow regime” have a low probability of detectable negative impacts to ecosystems*”; and
- “*cumulative flow alterations that result in instantaneous flows less than 30% of MAD have a heightened risk of impacts to ecosystems that support fisheries*”. Periods below 30% MAD were identified as ‘highest risk’.

Mean monthly flows are predicted here in place of instantaneous flows as a desktop-based means of estimating monthly and annual low-risk withdrawals. MAD is calculated from mean monthly flows to identify the months with the ‘highest risk’. This approach allows for (a) an assessment of which months are likely candidates for low-risk water withdrawal, and (b) an estimation of water available for withdrawal.

5 Results

Regression model results are first presented below. Next, flow predictions for each water withdrawal candidate are described. Reports describing hydrologic conditions near withdrawal candidate sites were reviewed and are summarized in each section below.

5.1 Regression Model Results

Regressions between watershed area and mean monthly discharge are presented in Figure 5.1 and statistics are provided in Table 5.1.

Table 5.1 Regression Coefficients and Statistics

Month	Slope (m)	Intercept (b)	r^2	p-value	n
Jan	0.997	-3.861	0.11	0.461	7
Feb	2.480	-7.576	0.55	0.153	5
Mar	0.181	-1.188	0.58	0.238	4
Apr	0.444	-1.397	0.47	0.089	7
May	0.913	-1.326	0.86	<0.001	13
Jun	1.202	-2.538	0.95	<0.001	13
Jul	1.068	-2.502	0.83	<0.001	13
Aug	0.942	-2.231	0.78	<0.001	13
Sep	1.060	-2.472	0.77	<0.001	13
Oct	0.835	-2.068	0.86	<0.001	10
Nov	0.959	-3.045	0.61	0.022	8
Dec	0.583	-2.692	0.10	0.400	9

NOTE:
Regressions equations are solved using $\log_{10}$-transformed drainage area (see text below). r^2 is a measure of the regression's overall 'goodness of fit' and a p-value >0.05 (underlined) indicates that a regression is not statistically significant. n = sample size, i.e., the number of flow-area pairs in each regression.

Monthly average discharge (Q) is calculated as follows:

$$\log_{10}Q = m*\log_{10}A + b$$

where '$\log_{10}Q$' is $\log_{10}$ transformed monthly average discharge, 'm' and 'b' are regression coefficient slopes and intercepts (Table 5.1), and '$\log_{10}A$' is the $\log_{10}$ transformed watershed area for the location of interest.

Q in metres cubed per second (m^3/s) is calculated as:

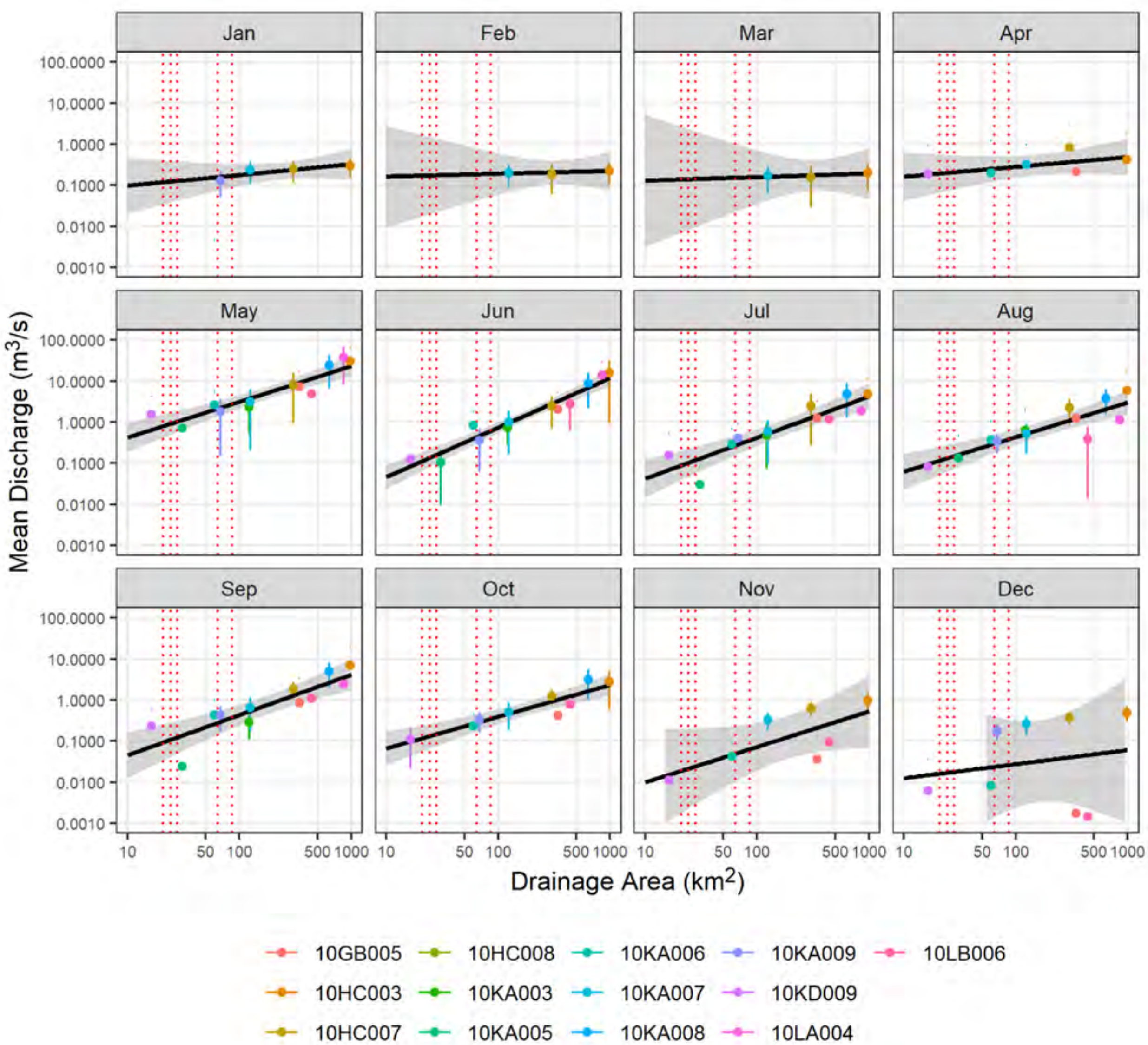
$$Q = 10^{\log_{10}Q}$$

In the ‘thaw period’ and early winter (May to November), monthly regressions are statistically significant (p-value less than or equal to 0.05) and correlation coefficients are generally high (Figure 5.1; Table 5.1). This is the period where snowmelt and rainfall produce the highest flows and most runoff of the year. Snowmelt and precipitation feed watercourses during these months, and the magnitude of discharge is proportional to watershed area.

In the ‘frozen’ period from December to April, regressions are generally not statistically significant (p-value >0.05; and/or low r^2; Figure 5.1; Table 5.1), meaning that discharge in these months is not strongly proportional to watershed area. Discharge is low in these months and is a small fraction of MAD. Discharge in winter is likely mainly fed by groundwater (Section 3). Seasonal operation of regional WSC stations also leads to small sample sizes for regressions in these winter months (Figure 4.1), making it difficult to establish regional relationships.

PCAR target watershed areas are relatively small (21 to 86 km^2; Table 1.1). However, regional WSC data exist from stations with watershed areas in the range of those of target watersheds (Table 4.1; vertical lines on Figure 5.1).

Figure 5.1 Relationships between Watershed Area and Mean Monthly Discharge at Selected Regional Water Survey of Canada Stations



NOTE:
Vertical red lines are the watershed areas of the five considered PCAR withdrawal sites. Vertical error bars on points are +/- one standard deviation. Grey shaded envelopes represent 95% confidence intervals. Where confidence intervals are missing, they are outside the y-axis limits. Regression statistics are provided in Table 5.1.

5.2 Flow Predictions and Historic Observations Pertinent to Flow for Potential PCAR Water Sources

Sections are presented below for each of the five PCAR crossings that were analyzed for potential water withdrawals. Predicted monthly average discharge is provided (units = m^3/s), along with mean daily and monthly flows (units = m^3/d, m^3/m). Results are tabulated in Table 5.2 through Table 5.6.

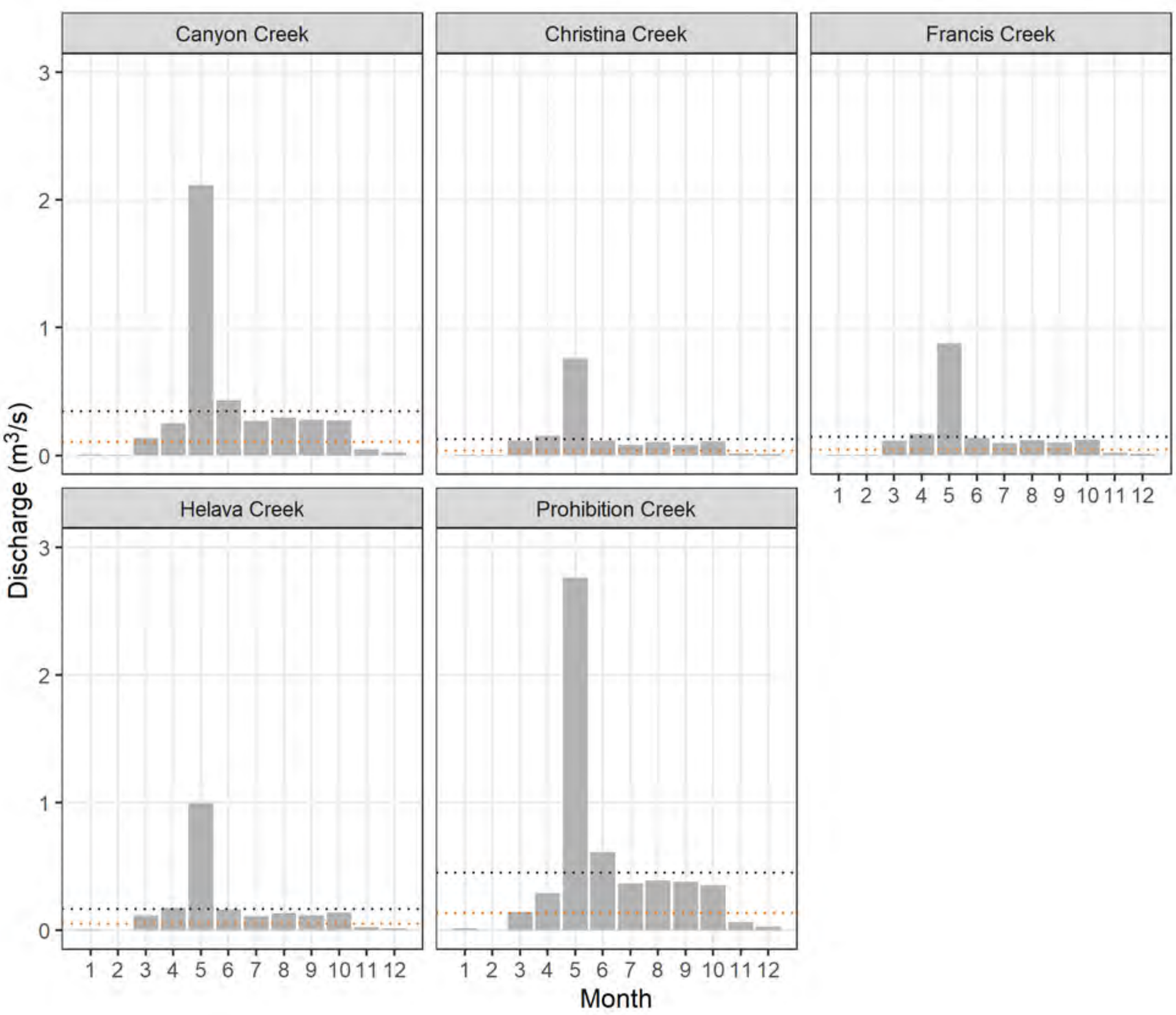
Ten percent of these discharge and flow estimates are provided to indicate the maximum of cumulative withdrawals for a “low probability of detectable impacts to ecosystems” (DFO 2013). Although DFO guidelines are for instantaneous rather than monthly average flows, monthly average flows are useful for initial assessment of typical flow magnitudes and water availability.

Predicted monthly average flows for all candidate water sources are presented in Figure 5.2. Predicted flows follow the nival hydrologic regime of the region, i.e., typically a snowmelt dominated freshet in May, declining flows from June through to early fall, and a small increase in flows due to rainfall runoff in October (Section 3). Flows from December through April are presented in Figure 5.2 but were derived from regressions that are not statistically significant and are not likely to be representative of local flows in these months (see Section 6.2 for a discussion).

Historic reports and datasets pertinent to flow at these crossings were also reviewed and are summarized below. Historic observations of flow in winter were of particular interest given the difficulty of predicting winter flows in ungauged catchments in the region.

Cross sections of creeks at proposed water crossings along with summer and flood water levels have been compiled (Tetra Tech 2022). Depth to bed appears to be sufficiently shallow in all candidate creeks that they could freeze to bottom in the absence of winter groundwater discharge.

Figure 5.2 Predicted Monthly Average Discharge for Potential Water Withdrawal Locations Along the Proposed Prohibition Creek Access Road Alignment



NOTES:

(1) The upper dark horizontal lines are MAD for each creek. The lower orange lines are 30% of MAD;

(2) Month=1 represents January; Month=12 represents December.

Table 5.2 Canyon Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.01	3	0.001	756	76	23,436	2,356	0	0.00	2.20	0.11	0.461	7
Feb	0.00	0	0.000	70	7	1,960	196	0	0.00	2.10	0.55	0.153	5
Mar	0.14	40	0.014	11,879	1,188	368,249	36,828	36,828	0.10	0.40	0.58	0.238	4
Apr	0.25	74	0.025	21,930	2,193	657,900	65,790	65,790	0.10	0.70	0.47	0.089	7
May	2.12	614	0.212	182,924	18,292	5,670,644	567,052	567,052	1.40	3.20	0.86	0.000	13
Jun	0.43	125	0.043	37,348	3,735	1,120,440	112,050	112,050	0.30	0.60	0.95	0.000	13
Jul	0.27	78	0.027	23,208	2,321	719,448	71,951	71,951	0.20	0.50	0.83	0.000	13
Aug	0.30	86	0.030	25,572	2,557	792,732	79,267	79,267	0.20	0.50	0.78	0.000	13
Sep	0.28	81	0.028	24,026	2,403	720,780	72,090	72,090	0.10	0.50	0.77	0.000	13
Oct	0.28	80	0.028	23,878	2,388	740,218	74,028	74,028	0.20	0.50	0.86	0.000	10
Nov	0.05	14	0.005	4,223	422	126,690	12,660	0	0.00	0.20	0.61	0.022	8
Dec	0.02	7	0.002	1,988	199	61,628	6,169	0	0.00	0.30	0.10	0.400	9
Annual Mean	**0.35**	**n/a**	**0.035**	**29,817**	**2,982**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**11,004,125**	**1,100,437**	**1,079,056**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.104 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value >0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD)
(DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.3 Francis Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	N[d]
Jan	0.00	2	0.000	289	29	8,959	899	0	0.00	11.90	0.11	0.461	7
Feb	0.00	0	0.000	6	1	168	28	0	0.00	6.20	0.55	0.153	5
Mar	0.12	78	0.012	9,979	998	309,349	30,938	30,938	0.00	0.50	0.58	0.238	4
Apr	0.17	112	0.017	14,292	1,429	428,760	42,870	42,870	0.00	0.60	0.47	0.089	7
May	0.88	596	0.088	75,744	7,574	2,348,064	234,794	234,794	0.50	1.60	0.86	0.000	13
Jun	0.14	92	0.014	11,703	1,170	351,090	35,100	35,100	0.10	0.20	0.95	0.000	13
Jul	0.10	65	0.010	8,277	828	256,587	25,668	25,668	0.00	0.20	0.83	0.000	13
Aug	0.12	81	0.012	10,302	1,030	319,362	31,930	31,930	0.10	0.30	0.78	0.000	13
Sep	0.10	68	0.010	8,638	864	259,140	25,920	25,920	0.00	0.30	0.77	0.000	13
Oct	0.12	84	0.012	10,667	1,067	330,677	33,077	33,077	0.10	0.20	0.86	0.000	10
Nov	0.02	13	0.002	1,673	167	50,190	5,010	0	0.00	0.10	0.61	0.022	8
Dec	0.01	9	0.001	1,133	113	35,123	3,503	0	0.00	0.60	0.10	0.400	9
Annual Mean	**0.15**	**n/a**	**0.015**	**12,725**	**1,273**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4,697,469**	**469,737**	**460,297**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.044 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable

Table 5.4 Helava Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.00	2	0.000	332	33	10,292	1,023	0	0.00	9.20	0.11	0.461	7
Feb	0.00	0	0.000	9	1	252	28	0	0.00	5.20	0.55	0.153	5
Mar	0.12	71	0.012	10,231	1,023	317,161	31,713	31,713	0.00	0.50	0.58	0.238	4
Apr	0.18	106	0.018	15,196	1,520	455,880	45,600	45,600	0.00	0.60	0.47	0.089	7
May	1.00	600	0.100	85,944	8,594	2,664,264	266,414	266,414	0.60	1.80	0.86	0.000	13
Jun	0.16	96	0.016	13,820	1,382	414,600	41,460	41,460	0.10	0.30	0.95	0.000	13
Jul	0.11	67	0.011	9,595	960	297,445	29,760	29,760	0.10	0.20	0.83	0.000	13
Aug	0.14	82	0.014	11,736	1,174	363,816	36,394	36,394	0.10	0.30	0.78	0.000	13
Sep	0.12	70	0.012	10,002	1,000	300,060	30,000	30,000	0.00	0.30	0.77	0.000	13
Oct	0.14	84	0.014	11,973	1,197	371,163	37,107	37,107	0.10	0.30	0.86	0.000	10
Nov	0.02	13	0.002	1,910	191	57,300	5,730	0	0.00	0.10	0.61	0.022	8
Dec	0.01	8	0.001	1,228	123	38,068	3,813	0	0.00	0.50	0.10	0.400	9
Annual Mean	**0.17**	**n/a**	**0.017**	**14,331**	**1,433**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**5,290,301**	**529,042**	**518,448**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.050 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.5 Christina Creek Bridge: Average Flow Predictions and Statistics

	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
Month	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.00	2	0.000	247	25	7,657	775	0	0.00	16.10	0.11	0.461	7
Feb	0.00	0	0.000	4	0	112	0	0	0.00	7.70	0.55	0.153	5
Mar	0.11	87	0.011	9,700	970	300,700	30,070	30,070	0.00	0.50	0.58	0.238	4
Apr	0.15	120	0.015	13,329	1,333	399,870	39,990	39,990	0.00	0.60	0.47	0.089	7
May	0.76	589	0.076	65,612	6,561	2,033,972	203,391	203,391	0.40	1.40	0.86	0.000	13
Jun	0.11	87	0.011	9,687	969	290,610	29,070	29,070	0.10	0.20	0.95	0.000	13
Jul	0.08	63	0.008	6,998	700	216,938	21,700	21,700	0.00	0.20	0.83	0.000	13
Aug	0.10	80	0.010	8,884	888	275,404	27,528	27,528	0.00	0.20	0.78	0.000	13
Sep	0.09	66	0.009	7,313	731	219,390	21,930	21,930	0.00	0.20	0.77	0.000	13
Oct	0.11	84	0.011	9,355	936	290,005	29,016	29,016	0.10	0.20	0.86	0.000	10
Nov	0.02	13	0.002	1,438	144	43,140	4,320	0	0.00	0.10	0.61	0.022	8
Dec	0.01	9	0.001	1,033	103	32,023	3,193	0	0.00	0.60	0.10	0.400	9
Annual Mean	**0.13**	**n/a**	**0.013**	**11,133**	**1,113**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**4,109,821**	**410,983**	**402,695**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.039 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Table 5.6 Prohibition Creek Bridge: Average Flow Predictions and Statistics

Month	Discharge			Daily Flows (m^3/d)		Monthly Flows (m^3/m)			Regression Statistics				
	Mean (m^3/s)	% of Annual Discharge[a]	10% Mean (m^3/s)	Mean	10% Mean	Mean	10% Mean	Available[b]	Lower Conf. (m^3/s)[c]	Upper Conf. (m^3/s)[c]	r^2	p-value	n[d]
Jan	0.01	3	0.001	1012	101	31,372	3,131	0	0.00	1.50	0.11	0.461	7
Feb	0.00	0	0.000	144	14	4,032	392	0	0.00	1.70	0.55	0.153	5
Mar	0.15	32	0.015	12,522	1,252	388,182	38,812	38,812	0.10	0.30	0.58	0.238	4
Apr	0.29	64	0.029	24,963	2,496	748,890	74,880	74,880	0.10	0.70	0.47	0.089	7
May	2.76	613	0.276	238,844	23,884	7,404,164	740,404	740,404	1.90	4.00	0.86	0.000	13
Jun	0.61	136	0.061	53,055	5,306	1,591,650	159,180	159,180	0.50	0.80	0.95	0.000	13
Jul	0.37	81	0.037	31,703	3,170	982,793	98,270	98,270	0.20	0.60	0.83	0.000	13
Aug	0.39	87	0.039	33,668	3,367	1,043,708	104,377	104,377	0.20	0.70	0.78	0.000	13
Sep	0.38	84	0.038	32,740	3,274	982,200	98,220	98,220	0.20	0.70	0.77	0.000	13
Oct	0.35	78	0.035	30,470	3,047	944,570	94,457	94,457	0.20	0.50	0.86	0.000	10
Nov	0.07	14	0.007	5,588	559	167,640	16,770	0	0.00	0.20	0.61	0.022	8
Dec	0.03	6	0.003	2,358	236	73,098	7,316	0	0.00	0.30	0.10	0.400	9
Annual Mean	**0.45**	**n/a**	**0.045**	**38,922**	**3,892**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**
Annual Sum	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**14,362,299**	**1,436,209**	**1,408,600**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTES:

Grey shading indicates months where discharge is less than 30% of mean annual discharge (0.135 m^3/s).

Underlined values indicate months where regressions are not statistically significant (p-value > 0.05).

[a] Calculated as monthly discharge divided by MAD x100.

[b] *Available*' is the monthly water volume available for withdrawal using DFO's 'desktop-based' criteria (i.e., 10% of monthly flows in months where flow is >30% MAD) (DFO 2013).

[c] Upper and lower confidence intervals (95%) at the mean monthly discharge.

[d] Number of data points in each monthly regression.

n/a: not applicable.

Kalo-Stantec

5.2.1 Canyon Creek

At 64 km^2, the watershed area upstream of the Canyon Creek bridge is the second largest of those assessed. Canyon Creek is unique in that a WSC station operated about 0.7 km upstream of the bridge crossing beginning in 2009, with data available until 2018 (Figure 1.1, Table 4.1).

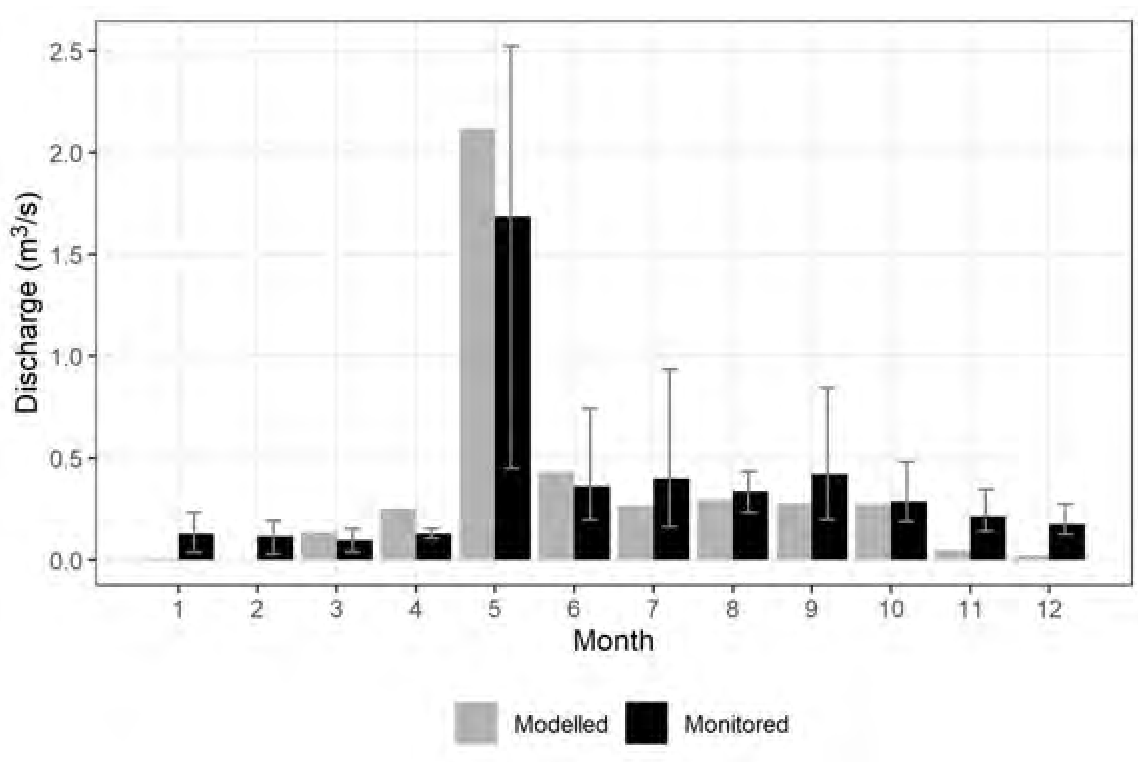
5.2.1.1 Flow Predictions

Flows and water availability predictions for Canyon Creek are presented in Table 5.2.

5.2.1.2 Historic Observations Pertinent to Flow

The Canyon Creek WSC data are highly valuable; therefore, these data are presented, described, and compared to modelled results (Figure 5.3). Flow predictions overlap with monitored flows in all months except in winter when regressions are not statistically significant (Section 5.1). Note that sample sizes for each month of monitored flows range from two in winter to eight to nine for June through to September, and therefore may not represent 'typical' hydrologic conditions, especially in winter.

Figure 5.3 Canyon Creek: Comparison of Monitored to Modelled Discharge (Monthly Averages)



NOTE:
Max/min error bars are presented rather than standard deviation due to low sample sizes in winter.

Predicted flows are lower than monitored flows in winter (Figure 5.3), reflecting the likely presence of groundwater discharge at Canyon Creek. This is supported by field studies on Canyon Creek, for example "*springs that flow year-round have been investigated here*" (Golder Associates 2006), and:

> *"Canyon Creek was noted as having "*open water in winter and a small aufeis area*". On 13-Apr-73, open water and a temperature of 0.5°C was noted, but discharge was not measured. It was noted that "there are several small springs located in the canyon about 3 miles upstream of the [pipeline corridor]."*

5.2.2 Francis Creek

At 24.5 km^2, the Francis Creek catchment has the second smallest of the assessed watersheds (Table 1.1).

5.2.2.1 Flow Predictions

Flows and water availability predictions for Francis Creek are presented in Table 5.3.

5.2.2.2 Historic Observations Pertinent to Flow

Limited historic observations suggest that there is no flow in winter at Francis Creek:

> *"Francis Creek had no winter observations and it was noted that "there are no winter data. It is frozen over in winter and is a doubtful overwintering area." There was no note of springs feeding the creek" (Golder Associates 2006)*

5.2.3 Helava Creek

At 28 km^2, the Helava Creek catchment is the median of those assessed (Table 1.1).

5.2.3.1 Flow Predictions

Flows and water availability predictions for Helava Creek are presented in

Table 5.4.

5.2.3.2 Historic Observations Pertinent to Flow

The same winter observations are available for Helava Creek ad Francis Creek (Golder Associates 2006); winter flow is unlikely.

5.2.4 Christina Creek

At 21 km^2, the Christina Creek catchment is the smallest of those assessed (Table 1.1).

5.2.4.1 Flow Predictions

Flows and water availability predictions for Christina Creek are presented in Table 5.5.

5.2.4.2 Historic Observations Pertinent to Flow

Available manual flow measurements for Christina Creek are summarized in Table 5.7.

Table 5.7 Summary of Historic Instantaneous Discharge Measurements on Christina Creek

Date (dd-mmm-yy)	Instantaneous Discharge (m^3/s)
04-Jun-02	0.04
17-Aug-02	0.1
28-Sep-02	0.07
12-Jul-03	0.01
10-Apr-04	Frozen to bottom

NOTE:
Data were published in Golder Associates (2006), originally from MGP 2004.

In April 2004, the creek was noted to be "*frozen to bottom at location 1.3 km upstream; likely frozen to bottom in winter*". Other assessments also suggest there is little or no flow in winter (Golder Associates 2006):

> "*March 2006, late winter assessments found no water under 0.55 m of ice. Similar, late winter field assessments by McCart and McCart (1982) and MGP (2004) in 1981 and 2002, respectively, also both found the stream frozen to the bed of the watercourse*"

> *"Christina Creek has none-to-low storage and a watershed area small enough that if it was solely fed by surface runoff, it would likely freeze to the bottom in winter. Winter observations in 1981, 2002 and 2006 noted the stream was frozen to bottom (McCart and McCart 1982; MGP 2004). There is some evidence of springs on adjacent creeks, but these are small and have not been noted as sufficient to sustain flows during the winter. Although this stream does not appear to provide overwintering fish habitat, because of low water levels it is an unlikely to be a candidate for winter water supply. If under-ice water is present during early winter months, its use for the construction and maintenance of the winter road would have negligible affects* [sic] *on fish habitat. The road crossing is only 0.4 km from the confluence with the Mackenzie River and no fish were recorded in the vicinity of the road crossing during winter months. Therefore, if under-ice water is present, its use for winter road construction and maintenance, should not adversely affect fish habitat at the site or in downstream environments."*

5.2.5 Prohibition Creek

At 86 km^2, the Prohibition Creek catchment is the largest of those assessed (Table 1.1).

5.2.5.1 Flow Predictions

Flows and water availability predictions for Prohibition Creek are presented in Table 5.6.

5.2.5.2 Historic Observations Pertinent to Flow

Limited observations suggest that there is flow in Prohibition Creek in winter:

> *Prohibition Creek was noted as "no overwintering likely". At the winter road, on 10-Apr-73 open water was noted "in patches" with an ice depth of 1.0 m. Approximately 6 km upstream of the winter road, open-water conditions were observed with a water temperature of 7.5°C and a measured discharge of 0.003 m^3/s."* (Golder Associates 2006)

6 Discussion

6.1 Will winter withdrawals be 'low-risk'?

Flow predictions for potential water sources in the PCAR region are statistically significant and relatively well constrained from May to November.

Flow predictions in winter are not statistically significant and winter flow appears to be controlled more by the occurrence of groundwater discharge than strictly by watershed area. Flow predictions for December through April should therefore not be considered accurate.

DFO identifies periods when flows are less than 30% of MAD as periods of 'highest risk' to river ecosystems (Section 4.4) (DFO 2013). Given that winter flow predictions presented here are uncertain and given the potential for water needs in winter for PCAR, a regional assessment of flows in winter was conducted.

Monthly average flows were calculated at regional WSC stations that operate year-round, and %MAD was calculated for each month. Results are presented in Table 6.1.

Regionally, monthly average flows at stations that operate year-round are consistently less than 30% MAD through winter (i.e., November through March-April) (Table 6.1). In addition, low flows at WSC stations that operate seasonally were summarized in Golder (2006) and found to be zero (at stations 10KA005, 10KA006, and 10LD002).

The notable exception is 10KA007, Bosworth Creek near Norman Wells, where monthly discharges are >30% MAD in all months except March (Table 6.1). Bosworth Creek is fed by a series of upstream lakes, including Hodgson (Jackfish) Lake, Edie Lake, and Bandy Lake (Figure 1.1). Winter flows may be fed by these lakes and/or groundwater discharge. The only other exception is 10HC007, Hodson Creek Near the Mouth in November.

Despite these exceptions, it can be said that regionally the winter period is typically a period of 'highest risk' following DFO guidelines. Guidelines state that "*for instances where the cumulative water use reduces the river flow below the level of 30% of the MAD, a rigorous level of assessment should be required to evaluate potential impacts on ecosystem functions that sustain fisheries, including identification of mitigation measures*" (DFO 2013). This rigorous level of assessment (e.g., fish habitat modelling) may be required if winter withdrawals are to be considered along the PCAR alignment (Section 7).

Table 6.1 Monthly Mean Discharge and Percent of Mean Annual Discharge at Regional Water Survey of Canada Stations That Routinely Operate Year Round

Month	Mean Discharge (m^3/s)									Percent of MAD								
	10GB005 ($344 km^2$)	10HC003 ($980 km^2$)	10HC007 ($303 km^2$)	10HC008 ($1030 km^2$)	10KA006 ($60 km^2$)	10KA007 ($125 km^2$)	10KD009 ($64 km^2$)	10LA004 ($852 km^2$)	10LB006 ($441 km^2$)	10GB005 ($344 km^2$)	10HC003 ($980 km^2$)	10HC007 ($303 km^2$)	10HC008 ($1030 km^2$)	10KA006 ($60 km^2$)	10KA007 ($125 km^2$)	10KD009 ($64 km^2$)	10LA004 ($852 km^2$)	10LB006 ($441 km^2$)
Jan	0.000	0.297	0.247	0.418	0.000	0.236	0.000	0.001	0.000	0	5	14	5	0	36	0	0	0
Feb	0.000	0.228	0.190	0.346	0.000	0.201	0.000	0.000	0.000	0	4	11	4	0	31	0	0	0
Mar	0.000	0.200	0.157	0.270	0.000	0.169	0.000	0.000	0.000	0	3	9	3	0	26	0	0	0
Apr	0.210	0.423	0.829	2.680	0.197	0.321	0.186	0.022	0.000	19	7	48	32	47	49	91	1	0
May	7.192	30.648	8.094	42.376	2.623	3.125	1.529	19.515	4.865	651	528	468	511	625	475	752	571	523
Jun	2.058	15.910	2.435	11.616	0.831	1.002	0.127	14.201	2.762	186	274	141	140	198	152	63	416	297
Jul	1.232	4.892	2.471	10.980	0.288	0.581	0.155	1.831	1.180	112	84	143	132	69	88	76	54	127
Aug	1.243	5.883	2.215	12.056	0.376	0.514	0.080	1.120	0.388	113	101	128	145	90	78	40	33	42
Sep	0.861	6.936	1.883	12.386	0.438	0.640	0.235	2.377	1.079	78	119	109	149	104	97	116	70	116
Oct	0.424	2.814	1.222	4.592	0.232	0.509	0.111	1.752	0.789	38	49	71	55	55	77	55	51	85
Nov	0.036	0.979	0.633	1.292	0.043	0.328	0.011	0.172	0.094	3	17	37	16	10	50	6	5	10
Dec	0.002	0.485	0.375	0.555	0.008	0.264	0.006	0.008	0.001	0	8	22	7	2	40	3	0	0
MAD	**1.105**	**5.808**	**1.729**	**8.297**	**0.420**	**0.658**	**0.203**	**3.417**	**0.930**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**	**n/a**

NOTE:
Cells are shaded grey where monthly discharge is less than 30% of MAD. Regional stations where winter flows were not routinely monitored year-round have been excluded (10KA003, 10KA005, 10KA008, 10KA009).

6.2 What volumes of water are available for withdrawal?

Table 5.2 through Table 5.6 present monthly and annual water volumes available for low-risk withdrawal, using criteria from DFO (2013); i.e., 10% of monthly average flow in months where discharge is greater than 30% of MAD. This is an estimate of the maximum monthly and annual volumes of water available for low-risk withdrawal. On average, annual water available for low-risk withdrawal ranges from a low of 402,695 m^3 at Christina Creek (Table 5.5) to 1,408,600 m^3 at Prohibition Creek (Table 5.6) during the months of May to October only. These volumes are useful as a basis for water license applications and will need to be verified by monitoring/measuring flows in the field (Section 7). Note that about half of the annual water volume available for low-risk withdrawal occurs in only one month: May. Monthly volumes available for low-risk withdrawal are presented in tables Table 5.2 through Table 5.6.

6.3 Is it justifiable to include Water Survey of Canada stations with relatively small datasets for flow predictions?

Several stations local to the PCAR proposed alignment have relatively small datasets due to limited periods of operation and/or seasonal operation (i.e., 10KA003, 10KA005, 10KA008, and 10KA009; Figure 4.1). It was decided to include months with greater than 92 measurements for each station given their proximity to the proposed alignment and the paucity of long-term regional flow data. Statistics derived from small populations might not be indicative of typical conditions, e.g., average flows calculated here might not be indicative of overall average conditions at these sites. For example, a minimum of 20 years of data are recommended for instream flow analyses (DFO 2013).

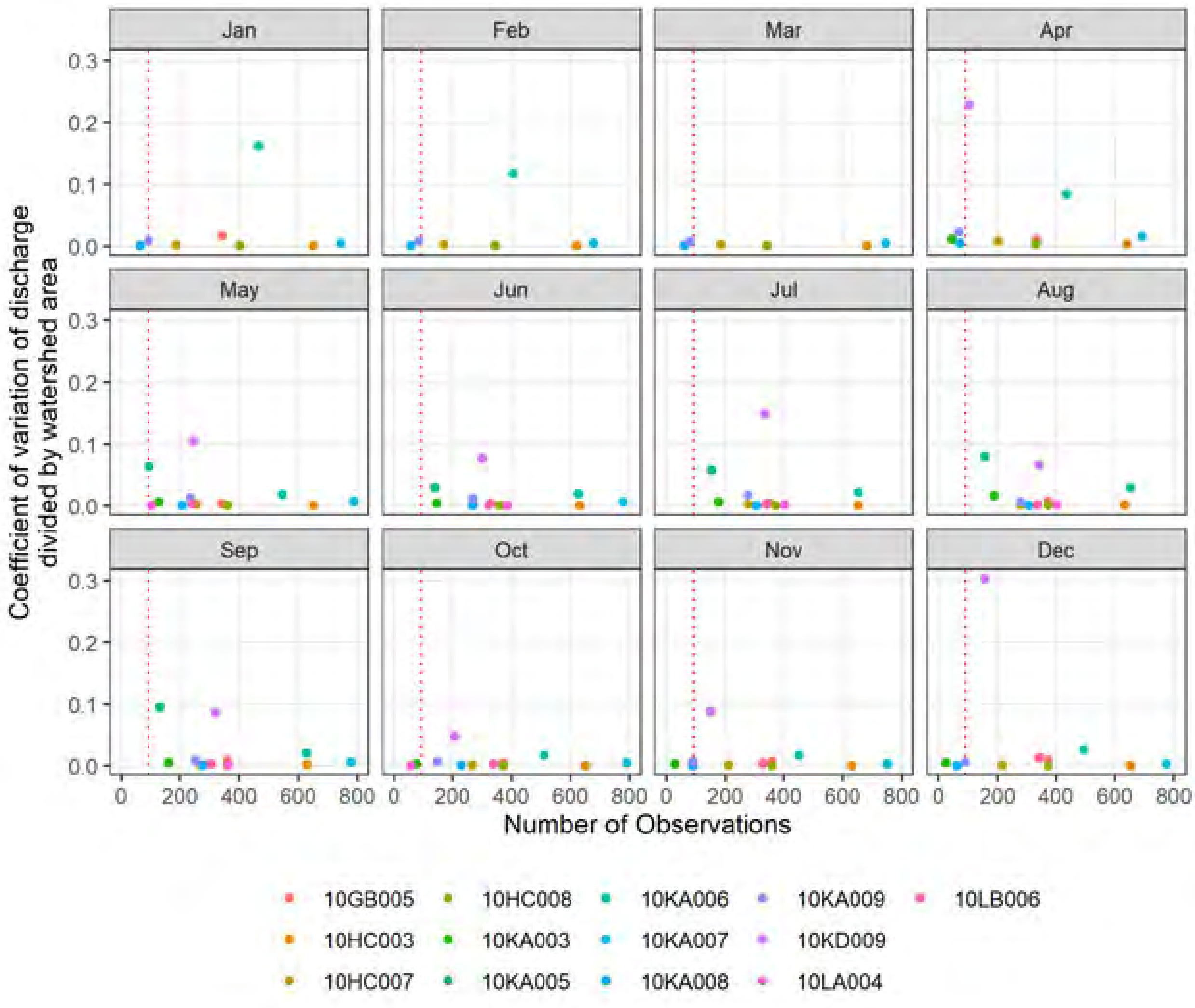
To assess whether stations with small numbers of observations in each month are statistically anomalous relative to stations with large numbers of observations, the monthly coefficient of variation of average flow was divided by basin area. The coefficient of variation is the standard deviation (68% of a normal distribution fall within +/- 1 standard deviation) divided by the mean and was chosen because it normalizes the effects of basin size on discharge. The statistic was further normalized by dividing by basin area.

Stations with small sample sizes might be expected to have smaller variability of flows than stations with larger sample sizes, but this does not consistently occur (Figure 5.1). This shows that the variability of flow in each month is typically not affected by relatively small sample sizes. Instead, Figure 5.1 shows that flow variability is more controlled at the station/site level (e.g., 10KD009 in most months, 10KA006 in January and February).

While the minimum number of observations in a month was set to 92, most months have many more observations than this. For example, the 25th percentile of sample size is a minimum of 120 in November and greater than or equal to 270 for 6 months of the year. Most data points on the left-hand sides of the vertical red lines in Figure 6.1 are in winter months. Any effects of small sample size would be greatest in winter when regressions are not statistically significant.

Given the value of data from stations proximal to PCAR, the methods described above are considered appropriate with the caveat that flow predictions provided here are representative of flows at the times where WSC monitoring occurred.

Figure 6.1 Effects of Sample Size on Flow Variability



NOTE:
Vertical dashed lines are at n=92, the minimum number of observations allowed in each month.

7 Conclusions and Recommendations

Measurements of instantaneous discharge should occur at the time of withdrawal. These flow measurements should be compared to mean annual discharge for each creek to ensure instantaneous flows are <10% of MAD.

Annual volumes of water predicted to be available for withdrawal within DFO's (2013) criteria range from about 403,000 m^3 for Christina Creek to about 1,409,000 m^3 for Prohibition Creek. About half of this annual flow volume is in May. No water is predicted to be available using this 'desktop-based' methodology for withdrawal in November through February.

This assessment has shown that the three creeks along the proposed PCAR alignment with the smallest watersheds (Francis, Helava, and Christina) are unlikely to flow for at least part of the winter. Furthermore, creeks that do flow over winter (Canyon and Prohibition) are unlikely to be classified as 'low-risk' at these times, i.e. flows are likely to be less than 30% of mean annual discharge (DFO 2013).

The 'low' risk period varies regionally. Regression modelling suggests this period is approximately March to October along the PCAR alignment, but uncertainties are high in predicted flows over winter. Regionally, this "low-risk" period spans about April or May to October.

If water is required over winter, potential solutions include (a) withdrawal outside of these periods and storing water for winter, (b) supplying supplemental information/studies (see below), and/or (c) offsetting withdrawals.

Pertinent supplemental information for winter PCAR withdrawals would be defined by DFO but could take the form of the creation of a fish periodicity table, establishment of baseline hydrological data, preparation of a detailed fish habitat modelling, preparation of a reconnaissance-level fish and fish habitat impact assessment, issuance of withdrawal rate limits, issuance of limited licence terms, and/or requirement to monitor water use (FLNRORD 2022).

The rigor of additional studies required depends on the timing and volume of water required. If water is required in spring and to a lesser extent autumn, then additional site-specific flow measurements would be beneficial, given (a) flow predictions are not statistically significant in these months, (b) the months where discharge is greater than 30% varies regionally, and (c) monthly averages have been provided here, and flows will vary within each month and year.

If withdrawals over winter are required, additional flow measurements on Prohibition creek could help define the timing and magnitudes of flows over winter. Additional winter investigations at Francis, Helava, and Christina Creeks would help confirm previous assessments that these creeks freeze to bottom in winter.

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9 Closure

If you have any questions, please do not hesitate to contact the undersigned.

Respectfully Submitted,

K'ALO-STANTEC LIMITED

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APPENDIX 16A

Surface Water and Sediment Quality Technical Data Report

Mackenzie Valley Highway Project Technical Data Report—Surface Water and Sediment Quality

Prepared for:

Government of the Northwest Territories

Prepared by:

K'alo-Stantec Limited

December 2022

Project No.: 144903025

Limitations and Sign-off

This document entitled Mackenzie Valley Highway Project Technical Data Report—Surface Water and Sediment Quality was prepared by K'alo-Stantec Limited ("K'alo-Stantec") for the account of Government of the Northwest Territories (the "Client") to support the regulatory review process for its Developer's Assessment Report (the "DAR") for the Mackenzie Valley Highway Project (the "Project"). In connection therewith, this document may be reviewed and used by the Government of the Northwest Territories Department of Infrastructure participating in the review process in the normal course of its duties. Except as set forth in the previous sentence, any reliance on this document by any other party or use of it for any other purpose is strictly prohibited. The material in it reflects K'alo-Stantec's professional judgment in light of the scope, schedule and other limitations stated in the document and in the contract between K'alo-Stantec and the Client. The information and conclusions in the document are based on the conditions existing at the time the document was published and does not consider any subsequent changes. In preparing the document, K'alo-Stantec did not verify information supplied to it by the Client or others, unless expressly stated otherwise in the document. Any use which another party makes of this document is the responsibility and risk of such party. Such party agrees that K'alo-Stantec shall not be responsible for costs or damages of any kind, if any, suffered by it or any other party as a result of decisions made or actions taken based on this document.

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K'alo-Stantec

Executive Summary

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT).

The Project subject to Part 5 of *the Mackenzie Valley Resource Management Act*. As part of the environmental assessment process, the Developer's Assessment Report (DAR) will assess how development of the proposed Project could affect surface water and sediment quality. The purpose of the technical data report (TDR) is to characterize baseline (i.e., existing) surface water quality conditions within local and regional study areas to support the environmental assessment of the Project presented in the DAR.

The main anthropogenic influences on water quality in the Mackenzie River Basin include historical and existing mines, municipal sewage, oil and gas exploration activities, pulp mills and land disturbances, and climate change. Natural influences include soils, bedrock, and forest fires from which naturally occurring constituents can be released.

This TDR presents a summary of the surface water and sediment data collected over the last 20 years within the Regional Study Area (RSA) and Local Study Area (LSA). These data sources can be used to help characterize existing conditions and to support the DAR, as required by the DAR Terms of Reference.

Surface water quality data was reviewed from various government and industry reports. Collectively, sampling programs have acquired surface water quality data for *in situ* parameters (e.g., pH, turbidity, temperature, conductivity, and dissolved oxygen) and laboratory-analyzed parameters (e.g., metals and nutrients) within the RSA at numerous locations and periods over the last few decades. A source of sediment quality data in the RSA was the baseline sampling results for the Mackenzie Gas Project Environmental Impact Statement conducted in 2002 and 2003. Sediment sampling included metals analyses for sediments collected in nine watersheds within the RSA: Prohibition Creek, Nota Creek, Great Bear River, Big Smith Creek, and Saline Creek in the Sahtu Region, and Blackwater River, Strawberry Creek, White Sand Creek, and Hodgson Creek in the Dehcho Region.

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Abbreviations

ARD/ML ... acid rock drainage and metal leaching

DAR ... Developer's Assessment Report

ECCC ... Environment and Climate Change Canada

EIS ... environmental impact statement

GNWT ... Government of the Northwest Territories

HCO_3^- ... bicarbonate ion

INAC ... Indigenous and Northern Affairs Canada

INF ... Department of Infrastructure

km ... kilometre

km^2 ... square kilometre

LSA ... Local Study Area

m ... metre

mg/L ... milligram per litre

MVEIRB ... Mackenzie Valley Environmental Impact Review Board

MVLWB ... Mackenzie Valley Land and Water Board

MVWR ... Mackenzie Valley Winter Road

NT ... Northwest Territories

PKFN ... Pehdzeh Ki First Nation

RSA ... Regional Study Area

TDR ... technical data report

the Project ... Mackenzie Valley Highway Project

TK ... traditional knowledge

TLRU ... Traditional Land and Resource Use

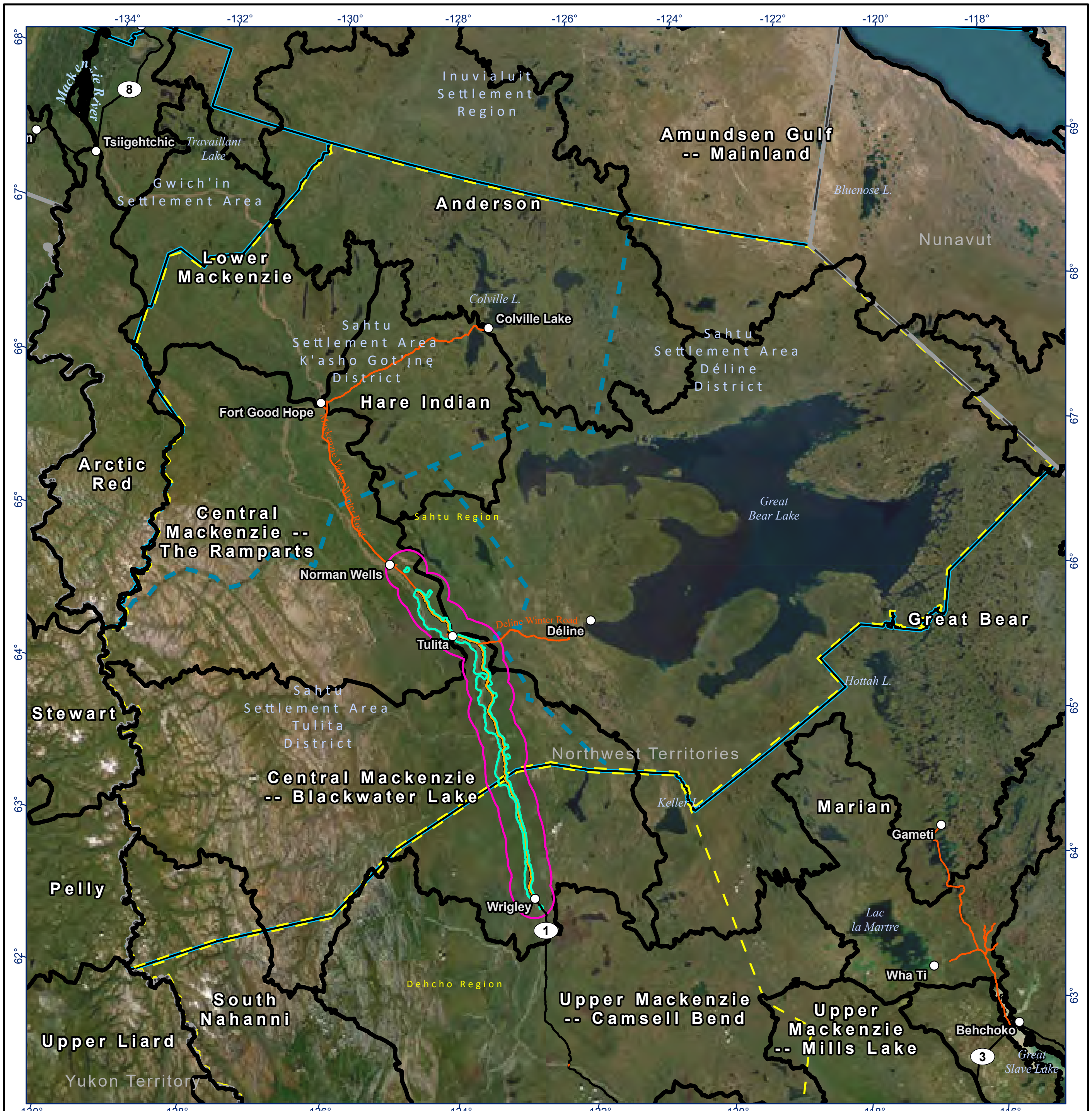
TOR ... terms of reference

1 Introduction

The Government of the Northwest Territories (GNWT), Department of Infrastructure (INF) is proposing the Mackenzie Valley Highway Project (the Project) that will extend the Mackenzie Highway (Northwest Territories Highway #1) from Wrigley to Norman Wells to replace the Mackenzie Valley Winter Road (MVWR) along this portion. The Project includes construction of approximately 281 kilometres (km) of new all-season highway, and the construction and operation of temporary and permanent quarry and borrow sources. The project highway alignment will pass through the Dehcho Region and a portion of the Tulita District of the Sahtu Region within the Northwest Territories (NT) (Figure 1.1).

The Project is subject to an environmental assessment and the requirements of Part 5 of *the Mackenzie Valley Resource Management Act*. This technical data report (TDR) presents the existing conditions for surface water quality to support preparation of the Developer's Assessment Report (DAR), as required by the Terms of Reference (MVEIRB, 2015). This TDR presents a summary of the sampling locations within regional and local study areas for which baseline surface water and sediment data have been collected over the last 20 years.

The study areas are described in Section 2 and the summary of existing data is provided in Section 3.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
- Granular Borrow / Rock Quarry Site and Access
- Local Study Area
- Regional Study Area
- Community
- All-Season Road
- Winter Road
- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin
- Territorial Boundary

0 40 80 Kilometres

(At original document size of 8.5x11)
1:4,500,000

N

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Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0063 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
1.1

Title
MVH Project Overview

2 Study Areas

The Project is in the Mackenzie Valley region of the NT between the current terminus of the existing all-weather highway in Wrigley (Highway #1, km 690) and Prohibition Creek (located approximately 28 km southeast of Norman Wells). The project highway alignment parallels the Mackenzie River, which is to the west, and is in the Mackenzie River basin within the Central Mackenzie-Blackwater Lake, Central Mackenzie-the Ramparts, and Great Bear sub-basins as defined by the Standard Drainage Area Classification (NRCan, 2003; Figure 1.1 and Figure 2.1).

2.1 Project Development Area

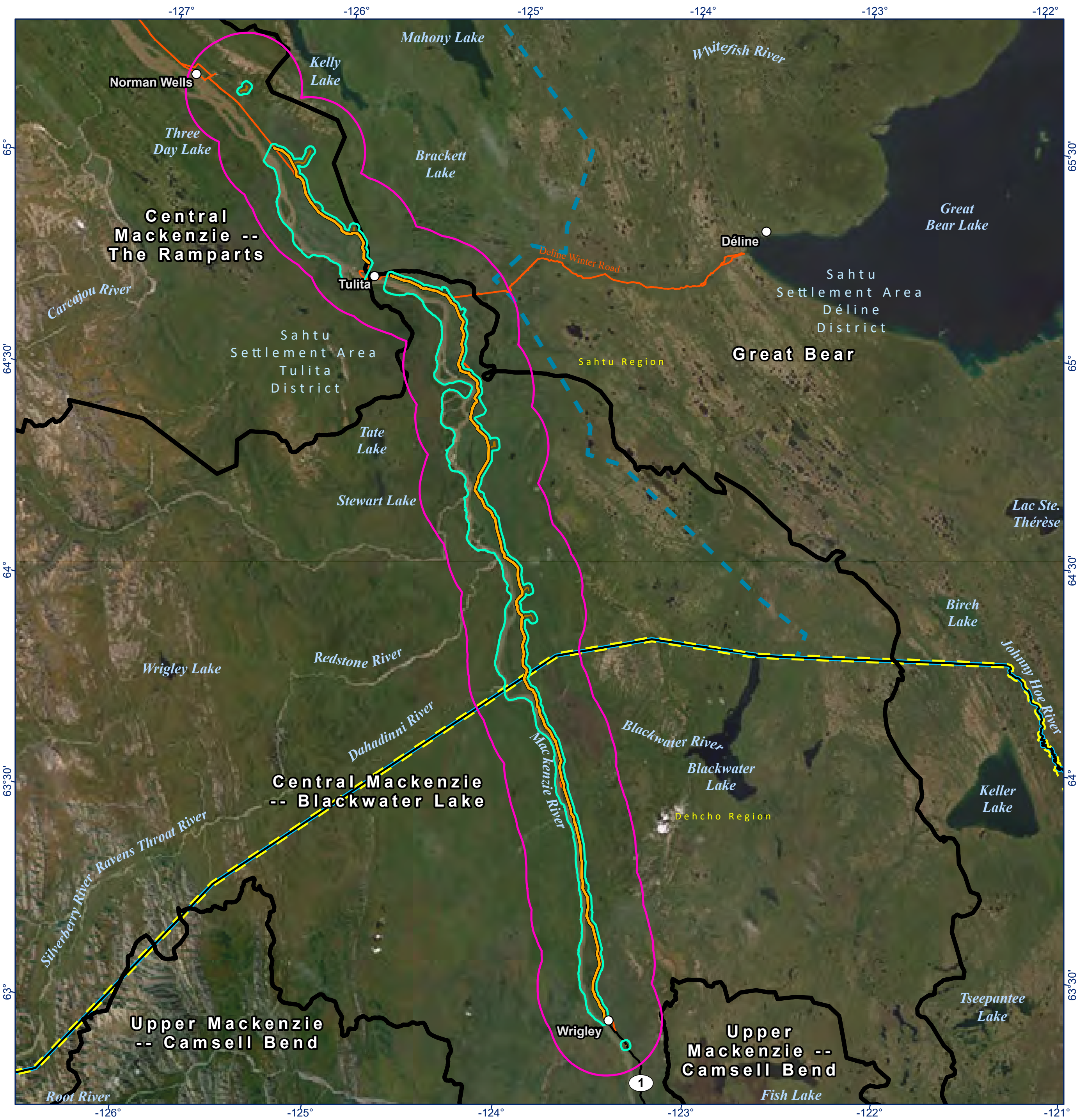
The Project Development Area (PDA) is the area of direct Project disturbance within which works and activities will occur (footprint). This includes a new two-lane gravel highway, 60 m wide highway right-of-way (ROW), laydown and staging areas, maintenance yards, construction camps and quarry/borrow sites with access roads on a 30 m ROW. The PDA is defined as the area to be used by the Project from Wrigley to approximately 25 km Southeast of Norman Wells. The PDA does not include a section of Project (less than 10 km in length) that passes through the hamlet of Tulita.

The local and regional study areas presented in this TDR are the areas where compiled data were collected to allow for an understanding of the environment in support of the Project-specific effects assessment and the cumulative effects assessment.

2.2 Local Study Area

For consistency with the surface water quantity TDR (DAR Volume 4, Appendix 15A, K'alo-Stantec, 2022a), the surface water and sediment quality Local Study Area (LSA) is a 1 km buffer around the alignment, and it is extended to include the mainstem of Mackenzie River and potential water sources for construction of the MVH, so as to encompass the anticipated extent of Project-related direct and indirect effects on surface water quantity (Figure 2.1).

Granular and rock materials for the construction and maintenance of the Project will be sourced from local material sources (quarries and borrow sources). The LSA includes a 1 km buffer around the quarry and borrow source footprints and associated access roads.



- Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022
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- District Boundary
- Region Boundary
- Settlement Area Boundary
- Sub-Basin

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Project Location
Wrigley to Norman Wells, NWT

Prepared by CES on 2023-03-07
TR by CS on 2023-03-07

Client/Project
144903025-0064 REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
2.1

Title
Water and Sediment Quality Assessment Areas

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

2.3 Regional Study Area

For consistency with the surface water quantity TDR (DAR Volume 4, Appendix 15A, K'alo-Stantec, 2022a), the surface water quality Regional Study Area (RSA) is a 15 km buffer around the PDA. The RSA includes surface water quality-related features that could be affected by the cumulative effects of Project activities interacting with the effects of other existing, past or reasonably foreseeable projects in the area. The RSA does not include the entire Central Mackenzie-Blackwater Lake, Central Mackenzie-the Ramparts, and Great Bear sub-basins because:

- the majority of the Central Mackenzie-Blackwater Lake and Central Mackenzie-the Ramparts sub-basins are to the west of the Mackenzie River, which are not affected by the Project.
- the majority of the Great Bear sub-basin is upstream of the Project and, therefore, not likely to be affected by the Project.

3 Review of Existing Data

3.1 Traditional Knowledge and Traditional Use

Traditional knowledge (TK) and traditional land and resource use (TLRU) information and supporting literature were reviewed for the characterization of the existing surface water quality conditions, as summarized below.

3.1.1 Sahtu Region

Golder (2015) provides TK and TLRU information about surface water quality in the Sahtu Region. Golder (2015) states that in the Sahtu Region:

- *Water quality is of the utmost importance to the Dene and Métis in the Sahtu [and] access to clean water is needed for the maintenance of healthy populations of people, fish, and animals.*
- *The Dene have relied on and lived off the clean waters of the Sahtu for many generations, and insist that all water bodies should be kept clean throughout the course of development.*
- *Water quality monitoring should be carried out for developments, even on the smallest of streams, to preserve the integrity of the water quality over the entire area…[these monitoring programs] should be carried out from within communities.*
- *Wastewater associated with developments be removed from site, and that the footprint of [the Project] be limited and work areas be kept clean to minimize runoff and contamination*
- *Shore and wetland vegetation should be kept in place to act as a filter and to provide bank stability*
- *The quality of most waterbodies in the Sahtu is considered by community consultation participants to be good and suitable for drinking*
- *Community participants indicated that when the waterfowl are plentiful and appear healthy, the water must be good.*
- *Big Smith Creek was identified as a good source of drinking water and has been used for many years.*
- *Although many small creeks are not actively used by many people, they are of good, drinkable quality and impacts should be minimized*
- *Community elders have seen waters that were once used for cooking and drinking change so that they are no longer good or safe to use (Golder, 2015).*

As stated in Golder (2015), community concerns regarding changes to water quality because of development in the Sahtu Region include:

- increased sedimentation from construction and clearing of vegetation along the edges of water bodies
- impacts of blasting
- impacts of melting permafrost and the resulting land subsidence, erosion, flooding, and scouring,
- resulting impacts on fish, wildlife, and habitat

Results from the Project-specific TLRU study developed by the Tulita Renewable Resources Council (TRRC, 2022) indicates that:

- Overflows have resulted from previous road construction and operation and has affected valued resources.
- Overflow within the LSA and along existing portions of the MVWR has affected undertaking of TLRU.
- There are many beaver dams within the LSA that have caused overflow.
- All the water resources within the LSA are still used (drinking) and accessed for TLRU.
- More water and wildlife monitoring in the LSA should be used to mitigate potential Project effects.
- There are concerns about potential Project effects on water flowing into the Bear River (community drinking water source).
- The sewer lagoon seeps towards the winter road between Tulita and Four Mile Creek, which causes the overflow on winter road access.
- There are concerns about potential Project effects from vehicle breakdown near open-water sources, specifically near Bear Rock, which is of interest to the community, that have potential to contaminate water sources.
- MVWR flooding occurs near Frank Yalle cabin area, and between the community of Tulita and Four Mile Creek.
- Bear River floods in the spring during the Mackenzie River ice breakup.
- Water is collected from any river or lake nearby the construction of the Bear River Bridge Project which has potential to affect community drinking because the community of Tulita requires a water truck to access water intake from Bear River on the other Bear River Bridge (all year round).
- The MVWR is too close to Plane Lake and could lead to contamination of the water.
- Tulita should be given priority (provide feedback and be the lead) when undertaking Project-related TK studies, monitoring and TK-based monitoring for water, land and wildlife to improve TK-based monitoring, avoid/mitigate potential Project effects and improve safety.

3.1.2 Dehcho Region

Dessau (2012) provides TK and TLRU information pertaining to surface water quality in the Dehcho Region. Dessau (2012) reports that in the Dehcho Region:

- Pehdzeh Ki First Nation (PKFN) have identified watercourses and riverbanks as traditional land use areas, and these traditional areas require protection.
- The PKFN have indicated that the rivers, creeks, and forests should be protected for the future generations and moose, caribou, and fish also need to be protected.
- The PKFN indicated Blackwater River, (which is crossed by the Project's proposed alignment) is one of the watercourses that is very important to protect due to its cultural significance as a sacred burial site.
- Several known fish spawning sites are located near the Project in the Dehcho Region (e.g., spawning sites are located near the mouths of the Ochre River and Blackwater River). Fishing is an important sustenance harvesting activity that is tied to traditional use and non-traditional use (e.g., commercial use) throughout the Mackenzie Valley.
- Drainage areas along the Project are considered potential waterfowl habitat. This includes Mackenzie River, Blackwater River and Ochre River, as well as major creeks and other smaller watercourses.

As stated in Dessau (2012), a Wrigley Community consultation meeting regarding the Project (as "MVH Project") (January 25 and 26th, 2012) included the following community comments and questions pertaining to water quality:

- Environment and safety are a priority for the Project.
- What is the effect of the MVH Project on the Mackenzie River? What are the mitigation measures in case of a spill?
- If the MVH Project is built, will natural resources such as water be protected? Is this resource guaranteed to not be contaminated or destroyed by the chemicals and resources that will be transported for the construction of the highway?

3.2 Literature Review

A literature review was completed to understand the extent of available surface water quality data along the project highway alignment (and within the RSA and LSA). Background information on surface water quality for the Sahtu and Dehcho regions was obtained from the following sources:

- GNWT Community-Based Monitoring Program (GNWT, 2020, pers. comm.)
- GNWT Water Quality Monitoring Network Evaluation report (Summit Environmental Ltd., 2014)
- Environment and Climate Change Canada (ECCC), Northern Water Quality Monitoring Network (ECCC, 2021)

- Mackenzie Gas Project Environmental Impact Statement (EIS), Biophysical Baseline Report for Water Quality (EIS Volume 3, Section 6; IORVL, 2004)
- data from Water Resources, Indigenous and Northern Affairs Canada (INAC) for the Mackenzie Valley Pipeline (GNWT, 2021, pers. comm.)
- Rempel and Gill (2011): *Bioassessment of streams along the Mackenzie River Valley, Canada, using the Reference Condition Approach: biological, habitat, landscape, and climate data*
- Golder (2015): *Central Mackenzie Surface Water and Groundwater Baseline Assessment. Report 1: Technical State of Knowledge*
- Mackenzie River Basin Board (MRBB, 2021): *State of the Aquatic Ecosystem Report (SOAER): Mackenzie-Great Bear Sub-Basin.*
- Mackenzie DataStream open access water quality data hub (DataStream, 2022).

Surface water quality information from the above mentioned resources is summarized in the following sections.

3.2.1 Overview of Study Area Surface Water Quality

The Project is located in the Mackenzie-Great Bear Sub-Basin of the Mackenzie Valley Basin (MRBB, 2021). This Sub-Basin spans roughly a third of the NT and extends from Fort Simpson in the south to the Makenzie River delta in the north, and from the Nunavut border in the east to the Yukon border in the west (MRBB, 2021).

Based on the Standard Drainage Area Classification (NRCan, 2003), the project highway alignment crosses through the Central Mackenzie-The Ramparts, Great Bear Lake, and Central Mackenzie-Blackwater Lake sub-basins of the Mackenzie Valley Basin. Between the southern and northern extents of the Project, the project highway alignment will cross over numerous tributaries of varying size to the Makenzie River, including two major tributaries (i.e., the Blackwater River and the Great Bear River).

Although watercourses within the Mackenzie-Great Bear Sub-Basin are generally of good quality, some localized effects on water quality have been observed nearby anthropogenic influences such as wastewater discharges (MRBB, 2003, 2021). In addition, local Indigenous people have expressed concern about water quality and have reported increasing water temperatures and turbidity compared to past years (MRBB, 2021). However, the most recent State of the Aquatic Ecosystem Report (SOAER) for the Mackenzie-Great Bear Sub-Basin (MRBB, 2021) describes that the "*scientific data generally do not show widespread [anthropogenic] impacts on water quality or on fish health, as indicated by the absence of trends from 2000 to 2018 in water quality parameters that have guidelines*".

Natural water quality of the Mackenzie-Great Bear Sub-Basin, including water flowing through the RSA, is generally influenced by water flowing through the Precambrian Shield of the Mackenzie Mountains, as well as mountains surrounding the Liard River, which drains into the Mackenzie River (Golder, 2015). This flowing water causes streambank erosion, which mobilizes metals and nutrient-rich sediment. Consequently, the Mackenzie River is known for naturally elevated suspended sediment and turbidity compared to other rivers in the arctic. Natural turbidity in the Mackenzie River is highest during the spring snow melt and is often in exceedance of Canadian Water Quality Guidelines (CWQG) for recreation and aesthetics (MRBB, 2003).

Between 2012 and 2018, TSS was measured in the months of July, August, and September in the Mackenzie River at Norman Wells (Figure 3.1), Tulita (Figure 3.2), and Wrigley (Figure 3.3) as part of the NT-wide Community-Based Monitoring Program (data retrieved from DataStream, 2022). Except for a few elevated concentrations, TSS generally remained below 400 mg/L in the Mackenzie River at Norman Wells and Wrigley, and below 200 mg/L at Tulita. In the context of the proposed Project, historical concentrations of TSS in the Mackenzie River are considered background concentrations, regardless of natural or anthropogenic influences. Therefore, the CWQGs generally do not apply to these historical TSS concentrations because the guidelines for TSS are narrative and based on changes relative to background conditions (CCME, 2022).

Overall, the recorded TSS concentrations trended downward at Norman Wells and Wrigley, but generally remained consistent at Tulita (except for one elevated sample in 2017). Summary statistics for TSS at these three locations are provided in Table 3.1.

Figure 3.1 Total Suspended Solids in the Mackenzie River at Norman Wells: 2012 to 2018

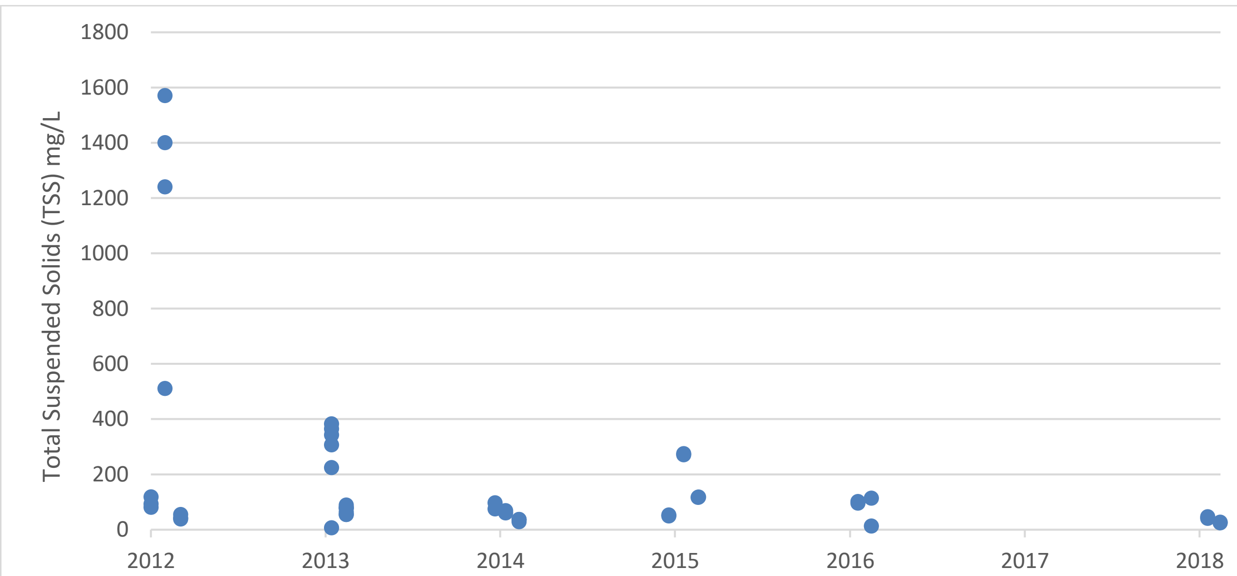


Figure 3.2 Total Suspended Solids in the Mackenzie River at Tulita: 2012 to 2018

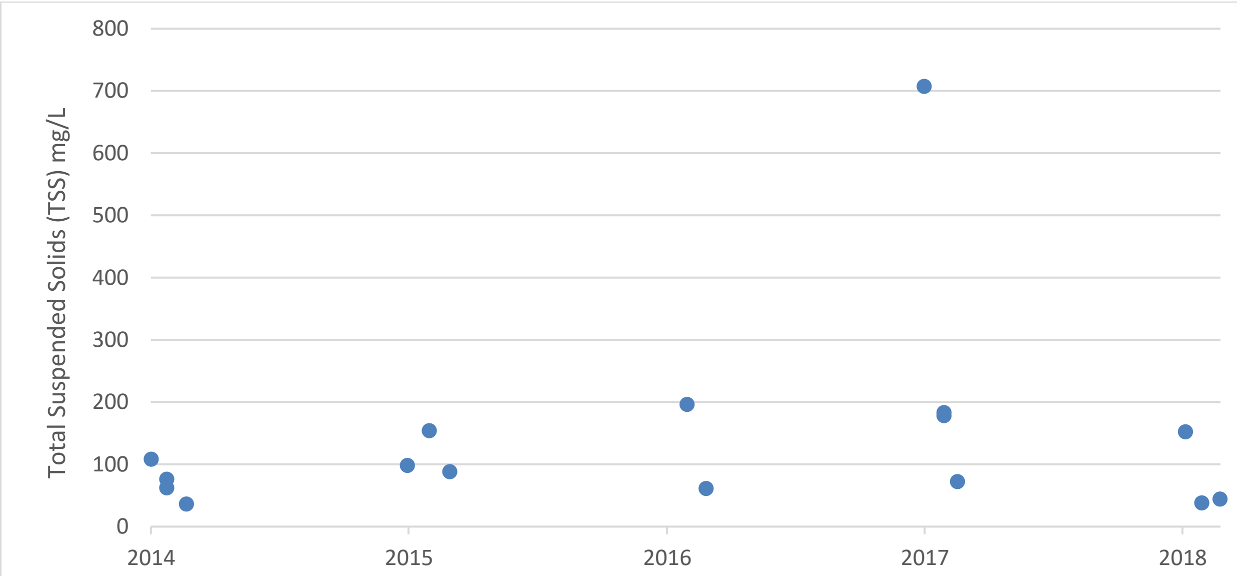


Figure 3.3 Total Suspended Solids in the Mackenzie River at Wrigley: 2013 to 2018

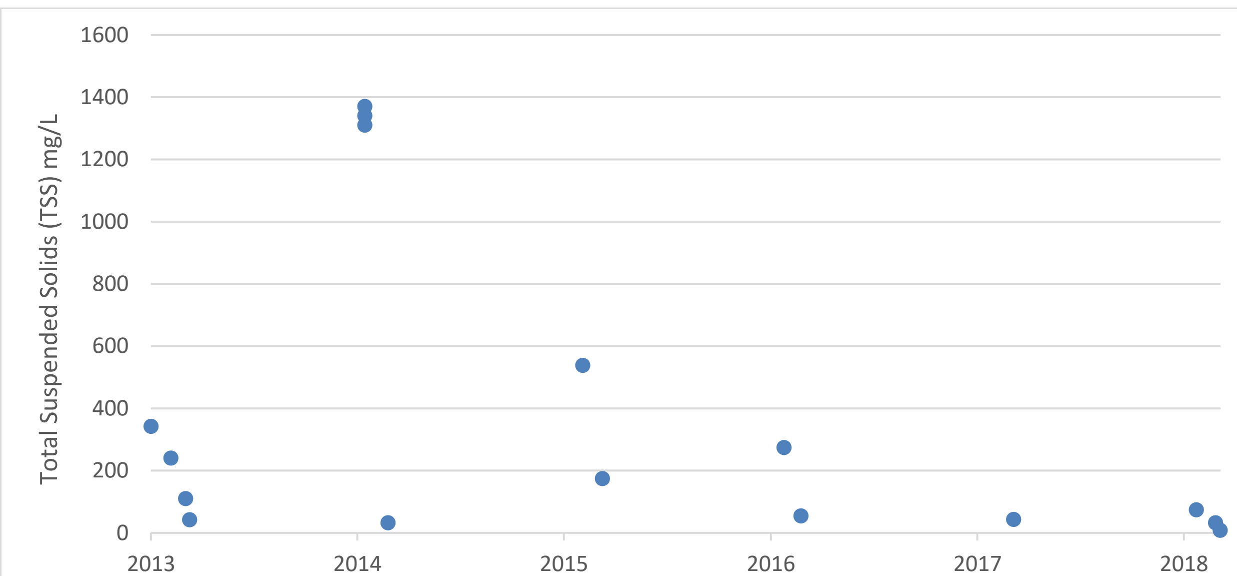


Table 3.1 Total Suspended Solids (TSS) at Different Sites Along the Mackenzie River

Location	Map ID	Date Range	TSS (mg/L)				
			N	Min	Mean	95th P	Max
Norman Wells	1	July 2012 to August 2018	45	6	200	1,352	1,570
Tulita	27	July 2014 to August 2018	16	36	141	324	707
Wrigley	69	June 2013 to August 2018	16	8	374	1,348	1,370

Notes:
TSS = total suspended solids
Map ID = sample site as presented in Figure 3.4 and Figure 3.5;
N = Number of samples collected; 95th P = 95th percentile
Data retrieved from Mackenzie DataStream (https://mackenziedatastream.ca/)

3.2.2 Existing Influences on Surface Water Quality

Surface water quality in the Mackenzie-Great Bear Sub-Basin is influenced by two main sources: local sources and global sources. Local anthropogenic sources (i.e., sources within the Mackenzie-Great Bear Sub-Basin) include historical and existing mines, municipal sewage, oil and gas exploration activities, pulp mills, and other industries (MRBB, 2004, 2021). Local natural sources include soils, bedrock, and forest fires from which naturally occurring constituents can be released. Some water quality parameters observed in the Mackenzie-Great Bear Sub-Basin originate in other parts of the world and travel through the atmosphere before being deposited there (MRBB, 2004, 2021).

In the Mackenzie Valley, uses of water and deposits waste as subject to the *Waters Act* and Waters Regulations. According to the Sahtu Land and Water Board, there are six active water licenses within the RSA as of May 2022:

- The Hamlet of Tulita municipal operations (SI6L8-002)
- Imperial Oil Norman Wells Operations (S13L1-007)
- Town of Norman Wells municipal operations (S18L3-003)
- Geotechnical drilling for the proposed bridge development crossing the Great Bear River at Tulita (S19LI-004) - completed
- Norman Wells Soil Treatment Facility (Sahtu Land and Water Board license S18L1-002)
- Prohibition Creek Access Road (S20L8-002) – not yet constructed

Of these, generally only the Hamlet of Tulita municipal operations has the potential to currently influence water quality in the LSA because the others are either completed or occur at the northern limit of the RSA or downstream of the Project. Other local sources of potential anthropogenic constituents of interest for surface waters within the RSA include land disturbances associated with existing or proposed quarry/borrow in the RSA. Some of these existing borrow sites are proposed to be repurposed for the construction and maintenance of the Project and its associated infrastructure. The twenty primary quarry and pit locations (and their associated watersheds) selected as candidate borrow sites for the Project are discussed in Section 3.2.3.1.

Climate change also has the potential to influence water quality in the Mackenzie River Basin, including the RSA. Climate change has altered and will continue to alter the cryosphere (e.g., seasonal snow cover, glaciers, ice caps, permafrost, and ice covering surface waters) and the hydrologic cycle in the arctic (MRBB, 2004; Derksen et al., 2019). These effects, including later freeze-ups in the fall and earlier break-ups in the spring, may contribute to increased streambank erosion and increased mobilization of metals and nutrients from the environment to surface waters (MRBB, 2004, 2021).

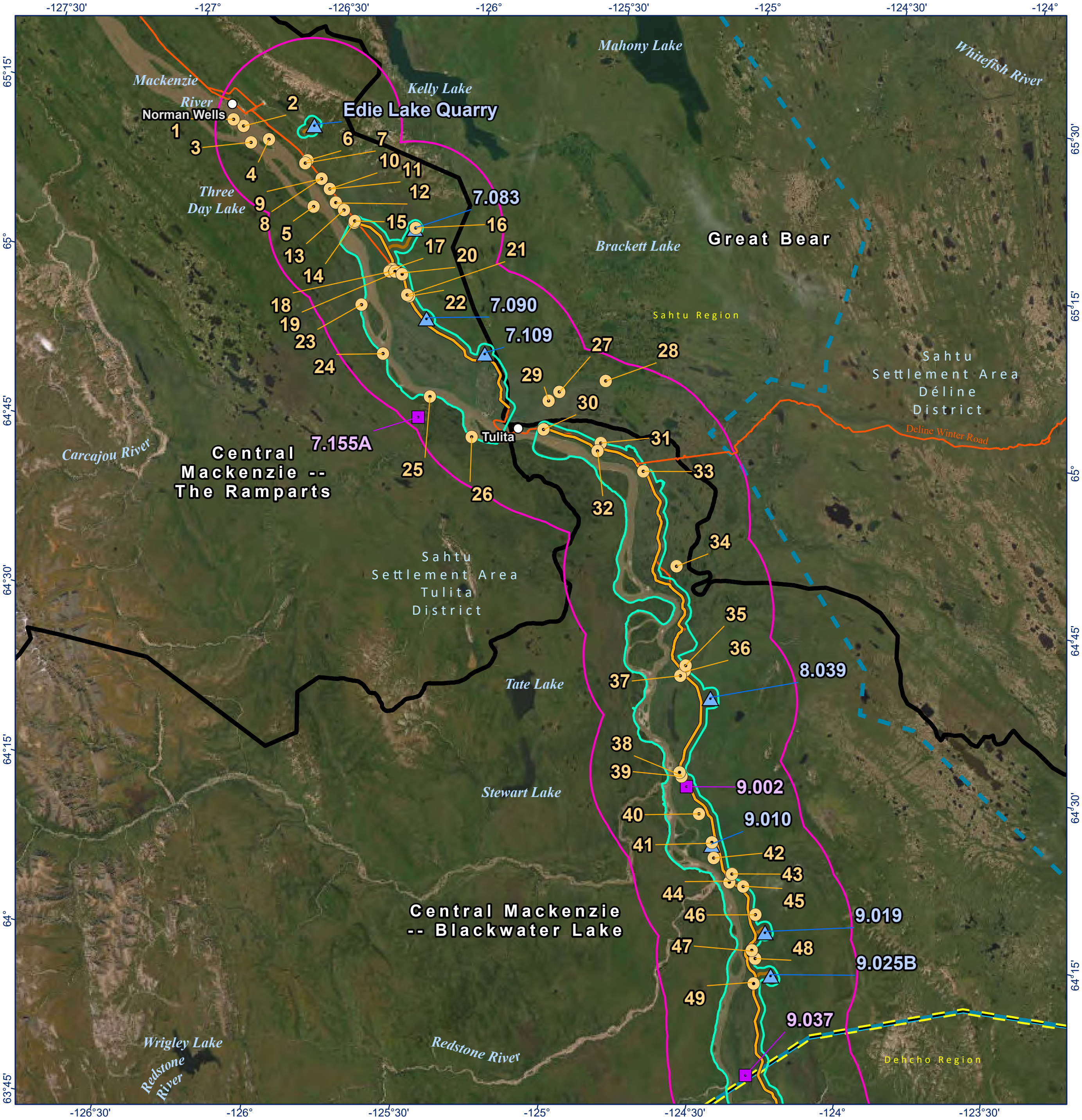
3.2.3 Surface Water Quality Data Sources for the Study Area

Various surface water quality monitoring programs have been conducted in the Mackenzie River Basin, including long-term monitoring conducted by ECCC, Fisheries and Oceans Canada, community-based monitoring programs supported by GNWT, and monitoring conducted for industrial projects. Collectively, these programs have acquired data for in situ parameters (e.g., pH, turbidity, temperature, conductivity, and dissolved oxygen) and laboratory-analyzed parameters (e.g., metals and nutrients) at different locations and periods over the last few decades.

The search for relevant sources of surface water quality data that could be used to characterize baseline surface water quality for watercourses within the RSA focused primarily on data collected within the last 20 years. Identified surface water quality data includes data for the Mackenzie River and multiple watersheds and tributaries to the Mackenzie River between Wrigley in the Dehcho Region and Norman Wells in the Sahtu Region.

Most of the identified surface water quality monitoring sites in the Dehcho Region are within the RSA but outside the LSA. Watersheds in the RSA for which sources of surface water quality data were not identified include Bob’s Canyon in the Dehcho Region, and Bluefish Creek and No Name Creek in the Sahtu Region. Surface water quality downstream of the Project is not consistently represented in each watershed, and seasonal variability in water quality across sites in the RSA is not well characterized with the existing data.

Figure 3.4 and Figure 3.5 show the identified surface water quality monitoring sites in the RSA within the Sahtu Region and Dehcho Region, respectively. Table 3.2, Table 3.3 and Table 3.4 summarize the identified sources of surface water quality data for the RSA watersheds located in the Ramparts sub-basin (Sahtu Region), the Great Bear River and Blackwater Lake sub-basins (Sahtu Region), and the Blackwater Lake sub-basin (Dehcho Region), respectively. The watersheds presented in these tables include the major streams (i.e., tributaries of the Mackenzie River), which the project highway alignment will cross.



Water Quality Sampling Site

Borrow Source

- Primary - Granular
- Primary - Quarry

Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022

Granular Borrow / Rock Quarry Site and Access

Local Study Area

Regional Study Area

Community

All-Season Road

Winter Road

District Boundary

Region Boundary

Settlement Area Boundary

Sub-Basin

0 10 20 Kilometers

(At original document size of 8.5x11)
1:1,000,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

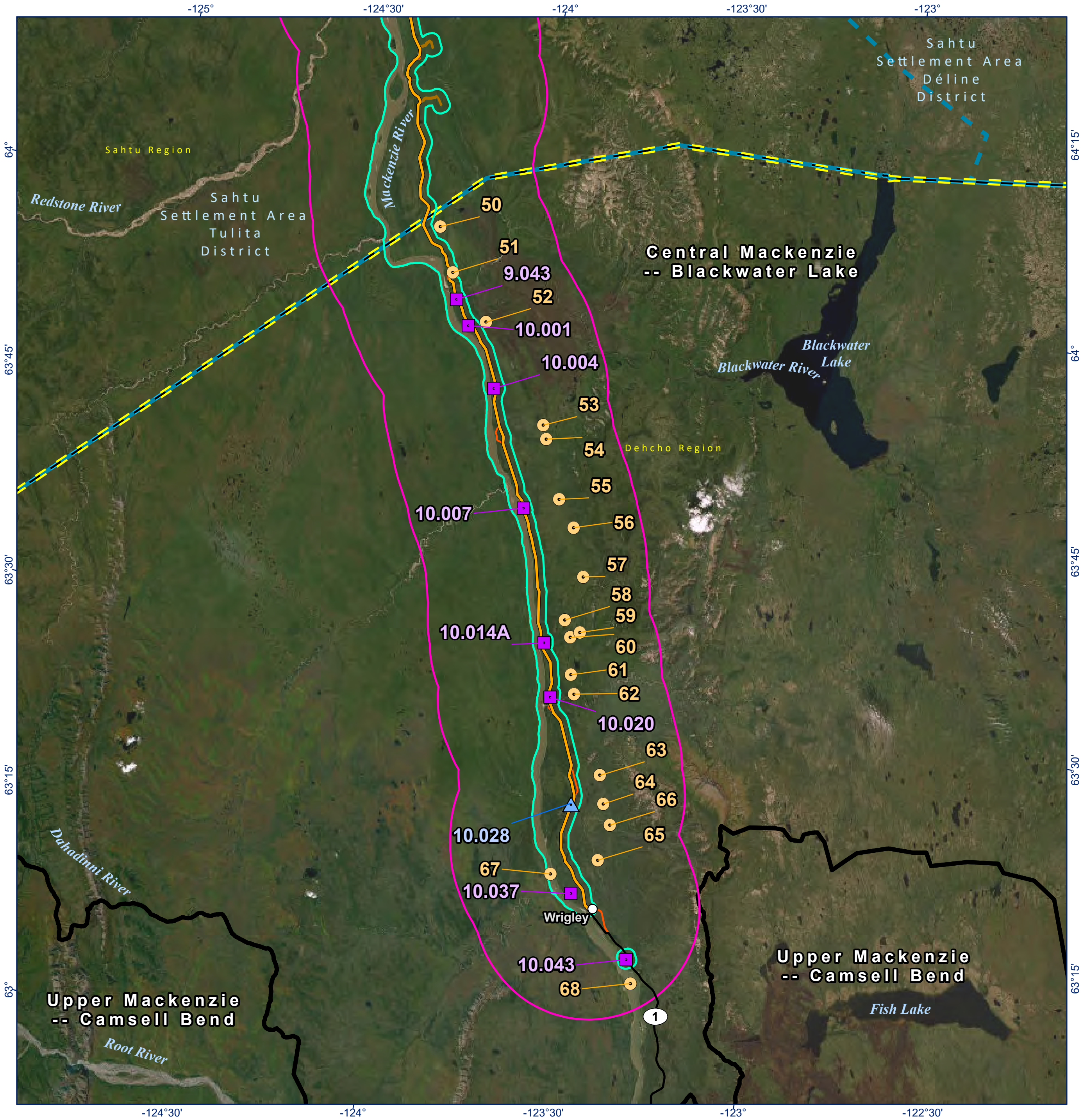
Client/Project
144903025-0070-REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.4

Title
Identified Water Quality Monitoring Sites in the RSA (Sahtu Region)

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Government of Canada
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS



Water Quality Sampling Site

Borrow Source

- Primary - Granular
- Primary - Quarry

Proposed Mackenzie Valley Highway Alignment - Issued for EA 2022

Granular Borrow / Rock Quarry Site and Access

Local Study Area

Regional Study Area

Community

All-Season Road

Winter Road

District Boundary

Region Boundary

Settlement Area Boundary

Sub-Basin

0 7.5 15 Kilometres

(At original document size of 8.5x11)
1:800,000

N

Kálo-Stantec

Project Location
Wrigley to Norman Wells, NWT

Prepared by AT on 2023-03-07
TR by AJ on 2023-03-07

Client/Project
144903025-0069-REVB

Government of Northwest Territories
Mackenzie Valley Highway Project

Figure No.
3.5

Title
Identified Water Quality Monitoring Sites in the RSA (Dehcho Region)

Notes
1. Coordinate System: NAD 1983 Northwest Territories Lambert
2. Data Sources: Centre for Geomatics Government of NWT, Government of Canada, Stantec
3. Background: World Topographic Map: Esri, FAO, NOAA, USGS, NRCan
World Imagery: Earthstar Geographics
World Hillshade: Esri, USGS

Table 3.2 Identified Sources of Surface Water and Sediment Quality Data for RSA and LSA Watersheds Located in The Ramparts Sub-Basin (Sahtu Region)

Watershed/ Watercourse	Map ID[1]	Sampling Site in LSA or RSA	Water Quality Data			Sediment Quality Data	Years of Water Quality Data	UTM Coordinates[2]			Source Site ID or Object ID	Source(s)
			In situ parameters	Metals and Nutrients	Total Suspended Solids			Zone	Easting	Northing		
Mackenzie River at Norman Wells	1	RSA	YES	YES	YES	-	2012	9W	601910	7239319	Mack-NW-02	1
Mackenzie River at Norman Wells	2	RSA	YES	YES	YES	-	2012	9W	603856	7238703	Object ID 427	1
Mackenzie River at Norman Wells	3	RSA	YES	YES	YES	-	2012 to 2018	9W	605801	7236373	Mack-NW-01	1
Mackenzie River at Norman Wells	4	RSA	YES	YES	YES	-	2013	9W	608614	7237661	Object ID 426	1
Mackenzie River at Norman Wells	5	RSA	YES	YES	-	-	2000 to 2019	9W	618938	7228696	NW10KA0001	2
Canyon Creek	6	RSA	YES	YES	YES	-	2002, 2003, 2005, 2006, 2007	9W	615838	7235994	RPR-306	3, 4
Canyon Creek	7	RSA	YES	YES	YES	-	2005	9W	615611	7235425	Canyon Ck	5
Francis Creek	8	RSA	YES	YES	YES	-	2002, 2003, 2005, 2006	9W	618967	7233677	RPR-308	3, 4
Francis Creek	9	RSA	YES	YES	YES	-	2005	9W	618969	7233614	Francis Ck	5
Helava Creek	10	RSA	YES	YES	YES	-	2002, 2003, 2005, 2006	9W	620763	7232296	RPR-310	3, 4
Helava Creek	11	RSA	YES	YES	YES	-	2005	9W	620781	7232324	Heleva Ck	5
Christina Creek	12	RSA	YES	-	YES	-	2002, 2003	9W	**622383**	**7230390**	RPR-311	3
Unnamed Creek	13	RSA	YES	-	YES	-	2002, 2003	9W	**624057**	**7229536**	RPR-312	3
Prohibition Creek	14	LSA	YES	YES	YES	YES	2002, 2003, 2005, 2006	9W	626292	7227921	RPR-313	3, 4
Prohibition Creek	15	LSA	YES	YES	YES	-	2005	9W	626304	7228212	Prohibition Ck	5
Vermillion Creek North	16	LSA	YES	-	-	-	2020	9W	636588	7229804	7.083-SW-1	6
Vermillion Creek North	17	LSA	YES	YES	YES	-	2002, 2003, 2005, 2006	9W	634623	7222098	RPR-323	3, 4
Vermillion Creek North	18	LSA	YES	YES	YES	-	2005	9W	634277	7221560	Vermillion Ck	5
Nota Creek	19	LSA	YES	YES	YES	YES	2002, 2003, 2005, 2006	9W	635169	7221789	RPR-324	3, 4
Nota Creek	20	LSA	YES	YES	YES	-	2005	9W	636476	7221669	Nota Ck	5
Jungle Ridge Creek	21	LSA	YES	YES	YES	-	2002, 2005, 2006	9W	638592	7218394	RPR-325	3, 4
Jungle Ridge Creek	22	LSA	YES	YES	YES	-	2005	9W	638206	7218535	Jungle Ridge Ck	5
Bluefish Creek	-	-	-	-	-	-	-	-	-	-	-	-
No Name Creek	-	-	-	-	-	-	-	-	-	-	-	-
Bog Creek at Mackenzie River	23	RSA	YES	YES	YES	-	2014 to 2016	9W	631206	7214889	Mack Tul-05	1
Slater Creek	24	RSA	YES	YES	YES	-	2014 to 2016	9W	636935	7207841	Mack-Tul-04	1
Little Bear	25	LSA	YES	YES	YES	-	2013 to 2018	10W	**362829**	**7202526**	Mack-Tul-03	1
MacKay Creek	26	RSA	YES	YES	YES	-	2014 to 2016	10W	370992	7197018	Mack-Tul-02	1
Mackenzie River at Tulita	27	RSA	YES	YES	YES		2014 to 2021	10W	376412	7198985	TUL-MR	1

Notes:

[1] Map IDs correspond to Figure 3.4 and Figure 3.5.

[2] Sampling coordinates may differ between years and monitoring programs. In cases where sources 3 and 4 are both cited, the coordinates were obtained from source 4 (source 3 did not report sampling site coordinates). **Bold** coordinates were estimated from source maps because the site coordinates were not reported.

Source: 1 = GNWT Community Based Monitoring; 2 = ECCC Northern Water Quality Monitoring Network; 3 = Mackenzie Gas Project EIS Baseline Report (Volume 3, Section 6); 4 = Mackenzie Valley Pipeline (i.e., Mackenzie Gas Project), raw data from INAC; 5 = Rempel and Gill (2011); 6 = Stantec surface water sampling, October 2020

" – " indicates where monitoring data were not identified

Table 3.3 Identified Sources of Surface Water Quality and Sediment Data for RSA and LSA Watersheds Located in The Great Bear and Blackwater Lake Sub-Basins (Sahtu Region)

Sub-Basin	Watershed/Watercourse	Map ID	Sampling Site in LSA or RSA (outside of LSA)	Water Quality Data			Sediment Quality Data	Years of Water Quality Data	UTM Coordinates [2]			Source Site ID or Object ID	Source(s)
				In situ parameters	Metals and Nutrients	Total Suspended Solids			Zone	Easting	Northing		
Great Bear	Great Bear River	28	RSA	YES	YES	-	-	2000 to 2019	10W	384271	7207108	NW10JC0001	2
Great Bear	Great Bear River	29	RSA	YES	YES	YES	-	2013 to 2018	10W	391699	7210301	GBR-Tul-01	1
Great Bear	Great Bear River	30	RSA	YES	YES	YES	YES	2002, 2003	10W	**382752**	**7205332**	RPR-330	3
Blackwater Lake	Four Mile Creek	31	LSA	YES	-	YES	-	2002	10W	**382747**	**7200398**	Site 404	3
Blackwater Lake	Between Four Mile Creek and Gotcha Creeks	32	LSA	YES	-	YES	-	2002	10W	**392694**	**7199822**	RPR-332	3
Blackwater Lake	Between Four Mile Creek and Gotcha Creeks	33	LSA	YES	-	YES	-	2002	10W	**392406**	**7198380**	Site 406	3
Blackwater Lake	Gotcha Creek	34	LSA	YES	-	YES	-	2002	10W	**400623**	**7196362**	RPR-335	3
Blackwater Lake	Between Gotcha Creek and Big Smith Creek	35	RSA	YES	-	YES	-	2002	10W	**408984**	**7181513**	RPR-342	3
Blackwater Lake	Big Smith Creek	36	LSA	YES	-	YES	-	2002	10W	**413466**	**7164316**	RPR-349	3
Blackwater Lake	Big Smith Creek	37	LSA	YES	YES	YES	-	2006	10W	413453	7165223	Big Smith Ck	5
Blackwater Lake	Big Smith Creek	38	LSA	YES	-	YES	YES	2002	10W	**412876**	**7163349**	Site 435/436	3
Blackwater Lake	Little Smith Creek	39	LSA	YES	-	YES	-	2002	10W	**415616**	**7147203**	RPR-351	3
Blackwater Lake	Little Smith Creek	40	LSA	YES	YES	YES	-	2006	10W	416039	7146590	Little Smith Ck	5
Blackwater Lake	Seagrams Creek	41	LSA	YES	-	YES	-	2002	10W	**420085**	**7140860**	RPR-353	3
Blackwater Lake	Between Seagrams Creek and Saline Creek	42	LSA	YES	YES	-	-	2020	10W	423075	7136476	9.010-SW-1	6
Blackwater Lake	Between Seagrams Creek and Saline Creek	43	LSA	YES	-	YES	YES	2002, 2003	10W	**423833**	**7133940**	RPR-355	3
Blackwater Lake	Saline Creek	44	LSA	YES	YES	YES	YES	2002, 2003	10W	**427363**	**7131821**	RPR-358	3
Blackwater Lake	Saline Creek	45	LSA	YES	YES	YES	-	2006	10W	427168	7130338	Saline Ck	5
Blackwater Lake	Devil's Creek	46	LSA	YES	-	YES	-	2002	10W	**429599**	**7130048**	RPR-359	3
Blackwater Lake	Between Devil's Creek and Steep Creek	47	RSA	YES	-	YES	-	2002	10W	**432482**	**7125723**	RPR-367	3
Blackwater Lake	Steep Creek	48	LSA	YES	-	YES	-	2002, 2003	10W	**432915**	**7119668**	RPR-371	3
Blackwater Lake	Steep Creek	49	RSA	YES	YES	YES	-	2006	10W	433727	7118390	Steep Ck	5
Blackwater Lake	Between Steep Creek and Blackwater Creek	50	LSA	YES	-	YES	-	2002	10W	**434212**	**7114190**	RPR-373	3

Notes:

[1] Map IDs correspond to Figure 3.4 and Figure 3.5.

[2] Sampling coordinates may differ between years and monitoring programs. **Bold** coordinates were estimated from source maps because the site coordinates were not reported.

Source: 1 = GNWT Community Based Monitoring; 2 = ECCC Northern Water Quality Monitoring Network; 3 = Mackenzie Gas Project EIS Baseline Report (Volume 3, Section 6); 5 = Rempel and Gill (2011); 6 = Stantec surface water sampling, October 2020

" – " indicates where monitoring data were not identified

Table 3.4 Identified Sources of Surface Water Quality and Sediment Data for RSA and LSA Watersheds Located in The Blackwater Lake Sub-Basin (Dehcho Region)

Sub-Basin	Watershed/Watercourse	Map ID	Sampling Site in LSA or RSA (outside of LSA)	Water Quality Data			Sediment Quality Data	Years of Water Quality Data	UTM Coordinates 2			Source Station ID or Object ID	Source(s)
				In situ parameters	Metals and Nutrients	Total Suspended Solids			Zone	Easting	Northing		
Blackwater Lake	Between Steep Creek and Blackwater Creek	51	RSA	YES	-	YES	-	2002	10V	**439979**	**7099197**	RPR-376	3
Blackwater Lake	Blackwater River	52	LSA	YES	YES	YES	YES	2002	10V	**442738**	**7093381**	RPR-377	3
Blackwater Lake	Between Blackwater River and Dam Creek	53	RSA	YES	-	YES	-	2002	10V	**448340**	**7087520**	RPR-379	3
Blackwater Lake	Dam Creek	54	RSA	YES	-	YES	-	2002	10V	**458431**	**7075122**	RPR-381	3
Blackwater Lake	Dam Creek	55	RSA	YES	YES	YES	-	2006	10V	459162	7073334	Dam Ck	5
Blackwater Lake	Bob's Canyon	-	-	-	-	-	-	-	10V	-	-	-	-
Blackwater Lake	Vermillion Creek South	56	RSA	YES	-	YES	-	2002	10V	**462324**	**7065608**	RPR-383	3
Blackwater Lake	Strawberry Creek	57	RSA	YES	-	YES	-	2002	10V	**464919**	**7062148**	RPR-385	3
Blackwater Lake	Strawberry Creek	58	RSA	YES	-	YES	YES	2002	10V	**467369**	**7055805**	Site 488	3
Blackwater Lake	Between Strawberry Creek and White Sand Creek	59	RSA	YES	-	YES	-	2002, 2003	10V	**465928**	**7049606**	RPR-388	3
Blackwater Lake	White Sand Creek	60	RSA	YES	-	YES	-	2002	10V	**468234**	**7048309**	Site 491	3
Blackwater Lake	White Sand Creek	61	RSA	YES	YES	YES	-	2007	10V	467066	7047426	White Sand Ck	5
Blackwater Lake	White Sand Creek	62	RSA	YES	YES	YES	YES	2002	10V	**468041**	**7042453**	RPR-391	3
Blackwater Lake	Ochre River	63	RSA	YES	YES	YES	-	2007	10V	468926	7039934	Ochre R	5
Blackwater Lake	Hodgson Creek	64	RSA	YES	-	YES	-	2003	10V	**474289**	**7029712**	RPR-398	3
Blackwater Lake	Hodgson Creek	65	RSA	YES	YES	YES	YES	2002	10V	**475442**	**7025964**	RPR-399	3
Blackwater Lake	Hodgson Creek	66	RSA	YES	-	YES	-	2002, 2003	10V	**476019**	**7018323**	RPR-403	3
Blackwater Lake	Hodgson Creek	67	RSA	YES	YES	YES	-	2006	10V	476802	7023301	Hodgson Ck	5
Blackwater Lake	Mackenzie River at Wrigley	68	LSA	YES	YES	-	-	1969 to 1994	10V	470025	7015379	NW10HC0001	2
Blackwater Lake	Mackenzie River at Wrigley	69	RSA	YES	YES	YES	-	2013 to 2018	10V	483308	7002633	Mack-WRI-01	1

Notes:

[1] Map IDs correspond to Figure 3.4 and Figure 3.5.

[2] Sampling coordinates may differ between years and monitoring programs. **Bold** coordinates were estimated from source maps because the site coordinates were not reported.

Source: 1 = GNWT Community Based Monitoring; 2 = ECCC Northern Water Quality Monitoring Network; 3 = Mackenzie Gas Project EIS Baseline Report (Volume 3, Section 6); 5 = Rempel and Gill (2011); 6 = Stantec surface water sampling, October 2020

" – " indicates where monitoring data were not identified

3.2.3.1 Surface Water Quality Data Sources for Watersheds Associated with Borrow Pits and Rock Quarries

Fifteen material sources have been identified for the Project, with seven of these already existing as sources of gravel or rock for other uses in the Sahtu and Dehcho regions. A preliminary assessment of these sources was completed, as reported in (K'alo-Stantec, 2022b). The potential current or historical uses of these existing borrow sites include bridge construction, road construction, winter road maintenance, pipeline maintenance, and municipal uses. The existing surface water quality data for watercourses located in the same watersheds as the 15 proposed primary material sources are listed in Table 3.5.

Table 3.5 Surface Water Quality Data Sources for Watersheds Associated with Borrow/Quarry Sites

Region	Pit or Quarry	Quarry/ Pit Site ID	Existing /New	Associated Watershed(s)	Map ID of Water Quality Site in Same Watershed as Quarry or Pit
Sahtu	Quarry	Edie Lake	Existing	Bosworth Creek	-
Sahtu	Quarry	7.083*	Existing	Vermillion Creek North	16, 17, 18
Sahtu	Quarry	7.090	New	Jungle Ridge Creek	21, 22
Sahtu	Quarry	7.109	New	Bluefish Creek	-
Sahtu	Quarry	8.039	New	Big Smith Creek	35, 36, 37
Sahtu	Granular Pit	9.002	Existing	Little Smith Creek	38, 39
Sahtu	Quarry	9.019	New	Between Devil's Creek and Steep Creek	46
Sahtu	Quarry	9.025B	New	Steep Creek	47, 48
Dehcho	Granular Pit	9.043	Existing	Between Blackwater River and Dam Creek	52
Dehcho	Granular Pit	10.004	New	Between Blackwater River and Dam Creek	52
Dehcho	Granular Pit	10.007	Existing	Between Bob's Canyon Creek and Vermillion Creek	-
Dehcho	Granular Pit	10.014A	New	Between Strawberry Creek and White Sand Creek	58
Dehcho	Granular Pit	10.020	Existing	Between White Sand Creek and Ochre River	-
Dehcho	Quarry	10.028	New	Hodgson Creek	63 to 66
Dehcho	Granular Pit	10.043	Existing	South of Hodgson Creek	-

Notes:
" – " = indicates no water quality data have been identified for the associated watershed
* = Surface water quality has been sampled at the borrow site (October 2020)
Map IDs correspond to Figure 3.4 and Figure 3.5

In most cases, contact water from a material source (i.e., borrow or rock quarry) does not enter the environment from a single point source. Furthermore, the existing hydraulic connectivity from each of these sites to watercourses in the watershed is not well defined and contact water from a material source does not necessarily flow to the corresponding historical water quality monitoring sites listed for the watersheds in Table 3.5. In addition, the development of material sources may alter hydraulic connectivity to the receiving environment. Therefore, the potential for existing and future material sources to influence surface water quality in the RSA is not well understood.

Prospective material sources were accessed in October 2020 (K'alo-Stantec, 2022b). Eleven granular sources, where clast lithology indicated the possibility of Acid Rock Drainage/Metal Leaching (ARD/ML) potential, were sampled (nine of these eleven sites are identified as primary material sources). Results of the preliminary assessment indicate that the ARD/ML potential of the tested prospective material sources is low and is not expected to adversely affect water quality of the receiving watercourses.

3.2.4 Sediment Quality Data Sources for the Study Area

Sediment quality has been sampled less frequently than surface water quality within the RSA. The only identified source of sediment quality data within the RSA was a baseline characterization study performed for the Mackenzie Gas Project EIS (IORVL, 2004). Sediment sampling for the Mackenzie Gas Project EIS baseline study was conducted in 2002 and 2003 and included metals analyses for sediments collected in nine watersheds within the RSA: Prohibition Creek, Nota Creek, Great Bear River, Big Smith Creek, and Saline Creek in the Sahtu Region; and Blackwater River, Strawberry Creek, White Sand Creek, and Hodgson Creek in the Dehcho Region.

Table 3.2, Table 3.3, and Table 3.4 summarize the identified sediment quality data sources for the RSA watersheds located in the Ramparts sub-basin (Sahtu Region), the Great Bear River and Blackwater Lake sub-basins (Sahtu Region), and the section of the Blackwater Lake sub-basin located in the Dehcho Region, respectively. The watersheds presented in these tables represent the major streams (i.e., tributaries of the Mackenzie River) that the project highway alignment will cross.

3.3 Data Gaps and Future Monitoring

Data gaps for existing conditions were identified for this TDR. These data gaps include, but are not limited to, information requested in the DAR Terms of Reference (TOR; MVEIRB, 2015) and are as follows:

- The TOR requires a description of sediment load (suspended and bed load) for each major drainage or major watercourse (TOR Section 5.1.3; MVEIRB, 2015). Historical concentrations of TSS are summarized for three locations in the Mackenzie River (i.e., Wrigley, Tulita, and Norman Wells) in Section 3.2.1. However, suspended sediments and/or sediment bed loads are not identified for each watercourse that may be affected by the Project. Sites within the RSA and LSA for which historical TSS data are available are summarized in Table 3.3, Table 3.4, and Table 3.5.

- The TOR requires the identification of existing water quality and variations for each area of water use that may be affected by the Project (TOR Section 5.1.3; MVEIRB, 2015). Except for TSS described above, information on the seasonal and/or annual variability of surface water and sediment quality for watercourses that may be affected by Project-related activities (i.e., particularly smaller watercourses that intersect the PDA) is limited and not summarized.
- Detailed information about traditional water-use locations that may be affected by the Project are not identified. Protection of water quality in the Mackenzie Valley is of high cultural importance. Watercourses in the RSA are traditionally used as sources of sustenance, including drinking water and for harvesting of fish. Information on specific water uses and locations, if available, could be incorporated in the design of site-specific monitoring programs that reflect the intended use of a watercourse.

For the Mackenzie Valley Highway Project, management plans and mitigation measures will be implemented to reduce effects to surface water and sediment quality from erosion and sedimentation, ARD/ML, and explosives-related nitrogen loading. As a result, collection of additional site-specific baseline water and sediment quality data is not anticipated for supporting the DAR. Additional water quality data, however, will be required for pre-construction and compliance monitoring and to facilitate adaptive management. Surface water quality data will be collected as part of pre-construction and compliance monitoring program at watercourse crossings and in waterbodies adjacent to borrow sources. Suspended sediments (i.e., total suspended solids; TSS) in surface water will also be monitored during construction at upstream and downstream sites.

In specific cases where historical water/sediment quality data may be appropriate to investigate potential Project-related effects, the available surface water and sediment quality data identified for sites within the RSA and LSA (as identified in Table 3.3, Table 3.4, and Table 3.5) may be used to support future Project-specific monitoring programs. Ongoing consultation and engagement with potentially affected parties will also help inform the design of future monitoring programs to account for specific water uses and water-use locations within the RSA and LSA.

4 Summary

The Project is in the Mackenzie-Great Bear Sub-Basin of the Mackenzie Valley Basin (MRBB, 2021). Although watercourses within the Mackenzie-Great Bear Sub-Basin are generally of good quality, some localized effects to water quality have been observed nearby anthropogenic influences such as wastewater discharges (MRBB, 2003, 2021). In addition, Indigenous people have reported increasing water temperatures and turbidity compared to past years. However, the scientific data generally do not show widespread anthropogenic impacts on water quality or on fish health (MRBB, 2021).

Watercourses that will intersect the PDA drain into the Mackenzie River, which is known for naturally elevated suspended sediment and turbidity compared to other rivers in the arctic (MRBB, 2003). Turbidity in the Mackenzie River is highest during the spring snow melt and is often in exceedance of CWQG for recreation and aesthetics (MRBB, 2003). Between 2012 and 2018, TSS generally remained below 400 mg/L in the Mackenzie River at Norman Wells and Wrigley, and below 200 mg/L at Tulita. However, the CWQGs generally do not apply to these historical TSS concentrations because the guidelines for TSS are narrative and are based on changes relative to background conditions (CCME, 2022).The sources of surface water and sediment quality data identified for monitoring sites specific to sub-basins and watersheds in the RSA include data collected by ECCC (2021), Fisheries and Oceans Canada (Rempel and Gill, 2011), GNWT community-based monitoring (GNWT, 2020, pers. comm.), and industry (IORVL, 2004; GNWT, 2021, pers. comm.).

In addition to the identification of monitoring data for the Mackenzie River, sources of water quality data were identified for most watersheds in the RSA that have major streams (i.e., tributaries of the Mackenzie River) that the Project will cross. Watersheds in the RSA for which sources of surface water quality data were not identified include Bob's Canyon Creek in the Dehcho Region, and Bluefish Creek and No Name Creek in the Sahtu Region. Based on the identified sources of water quality data for the RSA, many monitoring sites in the Sahtu Region ware within the LSA (and, therefore, relatively close to the Project); however, most identified monitoring sites in the Dehcho Region are outside the LSA.

The identified sources of water quality data for the RSA were generally collected within the last 20 years, with some sites having broader temporal coverage than others (e.g., several years vs. a single year of monitoring data). Most sites included both in situ measurements (e.g., pH, turbidity, conductivity, dissolved oxygen) and laboratory analyses for metal concentrations and nutrients; however, several sites were only sampled for in situ parameters. Furthermore, sources of water quality data have not been identified for all watersheds within the RSA where candidate borrow/quarry sources have been proposed.

Sediment quality has been sampled in nine watersheds in the RSA (IORVL, 2004). These sites were also sampled for surface water quality. The watercourses sampled were Prohibition Creek, Nota Creek, Great Bear River, Big Smith Creek, and Saline Creek in the Sahtu Region, and Blackwater River, Strawberry Creek, White Sand Creek, and Hodgson Creek in the Dehcho Region.

Prospective material sources were screened for ARD/ML potential in October 2020 (K'alo-Stantec, 2022b). Eleven granular sources where clast lithology indicated the possibility of ARD/ML potential were sampled (nine of these eleven sites are identified as primary material sources). Results of the preliminary screening indicate that ARD/ML potential of the tested prospective material sources is low and is not expected to adversely affect water quality of the receiving watercourses.

5 Closure

This TDR was prepared for the sole benefit of GNWT to describe existing conditions related to surface water quality within the Project LSA and RSA. If you have any questions, please do not hesitate to contact the undersigned.

Respectfully submitted,

K'alo-Stantec Limited

6 References

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