Analysis of water quality monitoring in the Morice Water Management Area

Prepared for the Morice Water Monitoring Trust
by Allison A. Oliver, Ph.D.
December, 2018

Executive Summary

The Morice Water Management Area (MWMA) was established in 2007 by the Morice Land and Resource Management Plan with the intent to protect the hydrological integrity, water quality, water quantity, and fisheries of the upper Morice River watershed. Although various water quality sampling efforts had occurred throughout the area, most of these efforts had been short-term and spatially-limited. In order to establish water quality baseline conditions and understand spatial and seasonal variability a multi-year, systematic monitoring program was needed. In 2015, the Morice Water Monitoring Trust (MWMT) initiated a water quality monitoring program to address objectives outlined in the MWMA Multi-Year Operational Plan (2009). The initial focus of this program was to establish a scientifically valid baseline of water quality data that accounts for natural variation. Sampling was conducted at various time steps at five sites from 2015 through 2017. These data were also considered in the context of water quality data collected within the MWMA by various agencies at these and 37 additional sites from 1996- 2015. The major objectives of this report are to summarize water quality monitoring data for the period of record held by the MWMT and the Office of the Wet'suwet'en (OW), interpret the results, and provide recommendations and reference material for a framework of future monitoring, data management, and analyses.

Much of the MWMA is relatively natural and undisturbed with high fisheries, watershed protection, and recreation values. However, there have still been extensive environmental changes, including land use associated with forestry, mineral exploration, road construction, and climate change. These practices continue in much of this area, and a portion of the proposed TransCanada Coastal GasLink pipeline route is located within the MWMA. Understanding water quality baseline conditions and variability is therefore essential for evaluating current and potential future effects of land and water uses.

Based on water quality data collected at sites monitored from 2015-2017, conditions within the MWMA are generally in the range of values expected for least-impacted, natural surface water bodies in this region, although certain constituents at specific sites were routinely high and regularly exceeded B.C. Water Quality Guidelines for the protection of aquatic life. These patterns likely represent natural variability in background conditions associated with watershed characteristics but warrant future monitoring and investigation of downstream trends in dilution and evolution of conditions along the river continuum. Where constituents consistently exceed B.C. Water Quality Guidelines, we recommend adopting Water Quality Objectives to protect high quality fisheries and watershed values from future change. Water quality was more different between sites than within sites, and therefore sites were distinct from one another and represent unique water quality conditions at each location. Certain constituents showed seasonal variability, but seasonal cycling was site-specific and when considered across all sites, seasonal differences for most constituents were rare. Based on initial investigation of power analysis requirements, sample size is currently too low to evaluate meaningful effect sizes, and several examples are provided of how statistical power may be used in future monitoring designs and analysis to address specific objectives.

Finally, terms of reference are provided for development of a template approach to long-term monitoring, including consideration of land use and climate change effects on current and future water quality conditions as well as recommendations for future monitoring (2019 and beyond), data management, data analysis, and reporting.

Acknowledgements

The information summarized in this report is the product of years of collaboration between various organizations and individuals. Thank you to the Morice Water Monitoring Trust, the Office of the Wet'suwet'en, Wet'suwet'en Hereditary Chiefs, BC Ministry of Environment and Climate Change (ENV), Bulkley Valley Research Centre, and all other individuals and organizations involved in past work related to monitoring water quality in the Morice River watershed. You have contributed invaluable efforts and years of planning, field work, data management, and reporting that contributed the foundation for this report. Special thanks to Ian Sharpe, David Dewit, Paul Wojdak, Lisa Torunski, and Greg Tamblyn for additional guidance, support and expertise related to the project. Finally, thank you to the Skeena Knowledge Trust, including Johanna Pfalz, Ekaterina Daviel, and Lizzy Hoffman, for their expertise, input and development of the maps included in this report. A huge component of this project would not have been possible without them. Finally, thank you to the Morice Water Monitoring Trust for funding this effort and for advancing water quality monitoring objectives and stewardship in the Morice River watershed. Cover photo by Walter K.B. Joseph.

Glossary of abbreviations

AMP – Annual Monitoring Plan
ANOVA – analysis of variance
AU – Watershed Assessment Unit
DIN – dissolved inorganic nitrogen
DOC – dissolved organic carbon
EMS – BC Environmental Monitoring System
ENV – Ministry of Environment and Climate Change Strategy
FREP – Forest and Range Evaluation Plan
LOD – limit of detection
MDC – minimum detectable change
MWMA – Morice Water Management Area
MWMT – Morice Water Monitoring Trust
ORP – orthophosphate
OW – Office of the Wet'suwet'en
PC – principal component
PTP – Pacific Trails Pipeline
QA/QC – quality assurance/quality control
SEC – specific conductivity
WQG/O –Water Quality Guideline/Objective
TAN – total ammonia nitrogen
TDS – total dissolved solids
TKN – total Kjeldahl nitrogen
TN – total nitrogen
TON – total organic nitrogen
TDP – total dissolved phosphorus
TP – total phosphorus
TSS – total suspended solids
WQG/O – Water Quality Guideline/Objective

Table of Contents

1. Introduction

1.1 Background and objectives

The Morice Water Management Area (MWMA) was established as part of the Morice Land and Resource Management Plan with the intent to protect the hydrological integrity, water quality, water quantity, and fisheries of the upper Morice River watershed (MLRMP, 2007). Overarching objectives for the MWMA included the development of an area-based water management plan and a water monitoring program. Initial objectives of the water monitoring program were to establish baseline data for the development of water quality objectives. Water quality data are used to characterize waters, identify trends over time, identify emerging problems, determine whether pollution control programs are working, help direct pollution control efforts to where they are most needed, and respond to emergencies such as floods and spills (U.S. EPA, 2017). A framework for water quality monitoring and assessment for the MWMA ("upper Morice watershed") was prepared in June 2008, and initial monitoring was conducted by the Office of the Wet'suwet'en (OW), with guidance from the B.C. Ministry of Environment and Climate Change Strategy (ENV) in the summer of 2008, and a multi-year operational workplan for water monitoring was proposed in 2009 (see MWMP Multi-Year Operational Plan, 2009). Since 2008, there have been a variety of independent monitoring activities undertaken in the watershed by various entities including the Province of British Columbia, Office of the Wet'suwet'en, the Bulkley Valley Research Center, and various industry-funded programs (e.g., PTP, FREP). These programs focused largely on monitoring potential impacts from past disturbance or collecting baseline data. While these efforts constitute a substantial amount of work accomplished within the watershed, there was need for a longer-term, scalable, and consistent program that could adapt with developing partnerships and provide opportunities for additional resources over time.

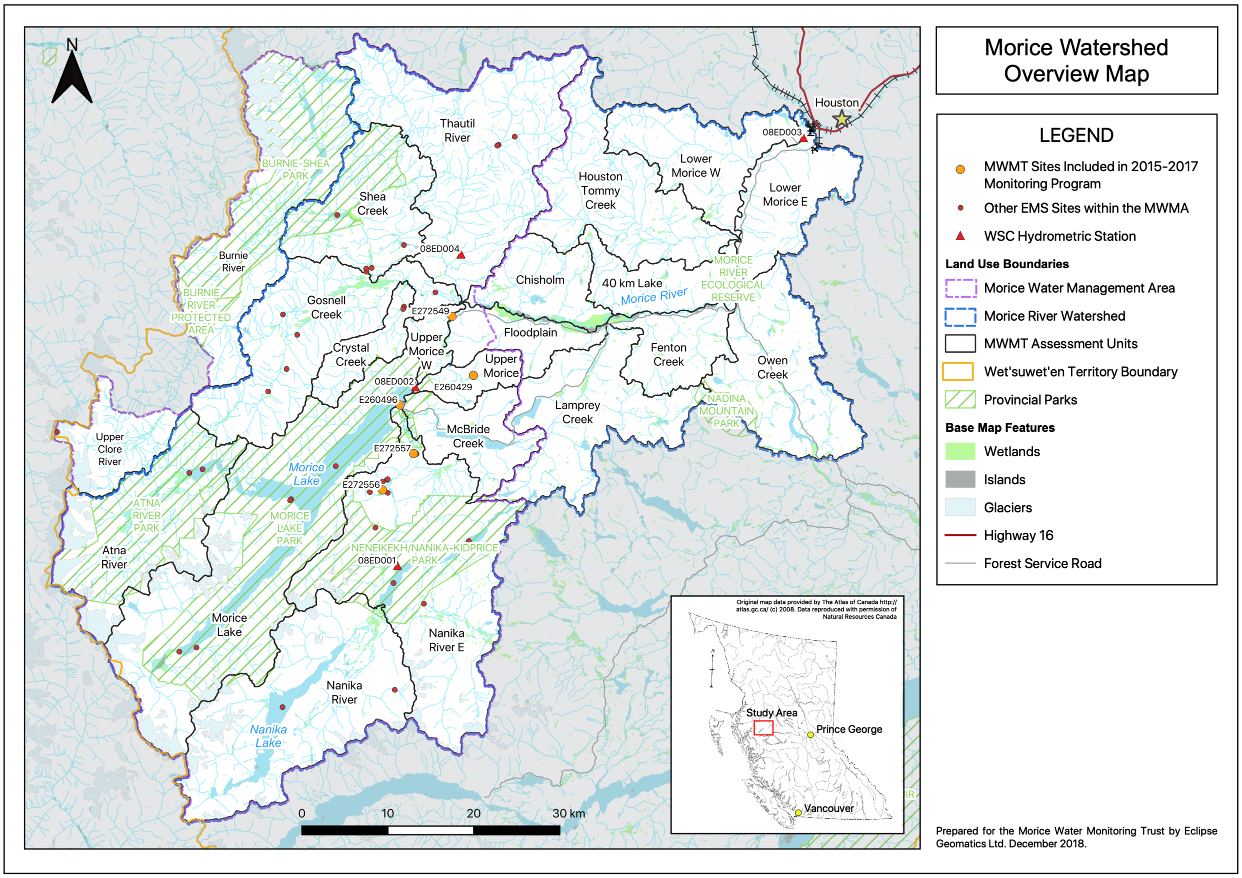
The Morice Water Monitoring Trust (MWMT) was established in 2012 to enable longer-term monitoring of the MWMA and establish a path forward for addressing objectives and guidelines. In order to provide data to support environmental effects monitoring and continuous improvement of management plans, the MWMT facilitated regular baseline water quality monitoring in the MWMA from September 2015 through October 2017. The objectives of this report are:

1) Summarize and analyze water quality monitoring data collected for the continuous period of record held by the MWMT and the OW (2015-2017) and for the full period of record (1996-2017) available in the BC Environmental Monitoring System database.
2) Provide recommendations for additional annual monitoring plans based on results from previous efforts.
3) Provide a complete report of monitoring efforts to-date to serve as the terms of reference for a long-term monitoring framework.

1.2 Description of the Morice River Watershed and Morice Water Management Area

The Morice River watershed has a total catchment area of 4,349 km^2 comprised of tributaries draining the Interior Plateau and the glaciated Coast Mountains (Fig. 1). The Morice River originates from Morice Lake and flows 80 km northeast to join the Bulkley River near the

Figure 1: The Morice River watershed and the Morice Water Management Area.

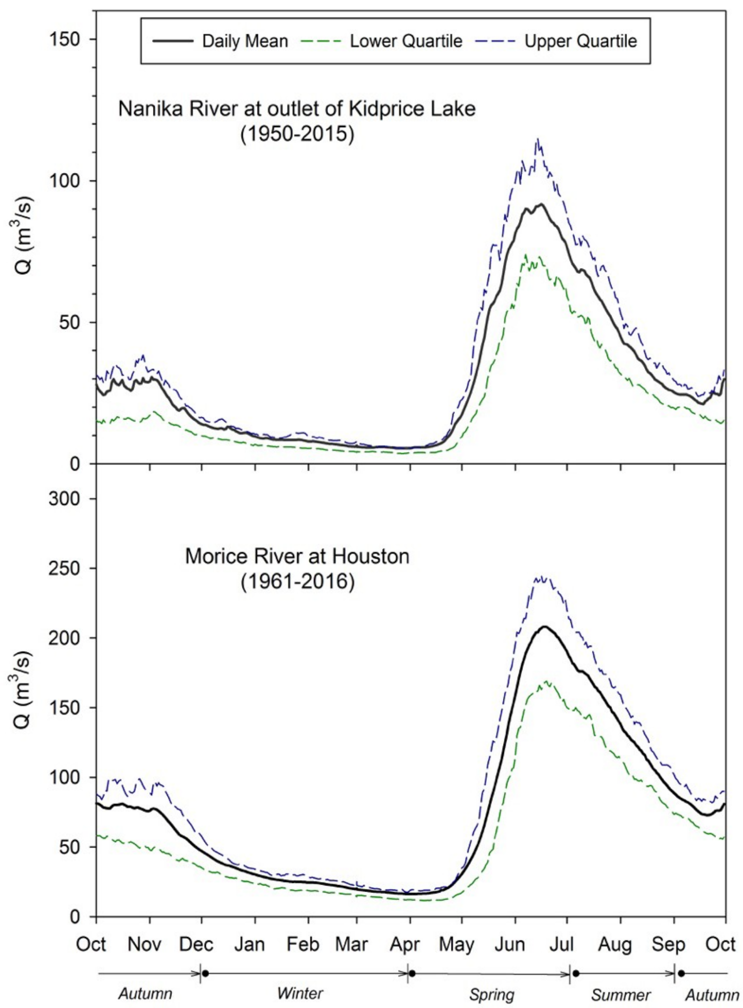


town of Houston. Other major tributaries within the Morice River watershed and the MWMA include the Nanika River (895 km^2) and the Atna River (300 km^2), which flow into Morice Lake, and Gosnell Creek and the Thautil River (535 km^2), which combine to flow into the mainstem Morice River (~river kilometer 13) and largely influence sediment inputs and flood flows downstream of Morice Lake (Gottesfeld et al. 2002).

The climate of the region is borderline humid continental/subarctic with a summer mean temperature of 12.5°C and winter mean of -7.8°C at Morice Lake.[1] Within the MWMA the seasonal hydrograph is influenced by a combination of glacial and snow melt, lake storage, and autumn rains (Fig. 2). As a result, freeze-up typically occurs in November and the lowest flows occur in late winter (February to mid-April, depending on elevation). Melting of winter snow pack contributes to annual peak flows in the late spring/early summer. On the west side of Morice Lake, larger tributaries drain snow and icefields resulting in moderate summer flows. However, tributaries to the east drain the Interior Plateau, which has less snow and ice and may be more susceptible to low summer flows. Autumn rain events, and especially rain-on-snow events, can also lead to episodic high flows; research suggests that peak flows in autumn and winter are increasing in frequency and intensity and that this trend is likely to increase in future years (Pike et al., 2008).

[1] Available atwww.climatewna.com

Figure 2: Historic discharge at Water Survey of Canada hydrometric stations 08ED001 (Nanika River at outlet Kidprice Lake) and 08ED002 (Morice River near Houston). Seasonal periods used in this study are based on periods of distinct hydrological character and are identified at the bottom of the figure.



Geology in the Morice River watershed is diverse and includes intrusive, volcanic, and sedimentary rocks, as well as large areas of glacial till and other fluvial coverage. Examples of intrusive rock types in the MWMA include the Nanika Plutonic Suite, a quartz monzonitic porphyry, and unnamed intrusive areas of rhyolite, quartz-feldspar porphyry. Sedimentary rock types in the MWMA include the Sifton assemblage of undivided sandstone, siltstone, coaly shale, coal and tuff, and the Skeena Group of undifferentiated marine sedimentary rocks, sandstone, siltstone, argillite, and chert pebble. Volcanic rock type in the MWMA include the Hazelton Group, Telkwa Formation of cal-alkaline volcanic rocks that include andesitic to dacitic feldspar phyric flows, pyroclastic and epiclastic rocks, augite phyric to aphyric basalt breccia, and welded tuff.[2]

Based on the BC Ministry of Forest, Lands and Natural Resource Operations Biogeoclimatic Ecosystem Classification, terrestrial ecosystem types within the MWMA include Sub-Boreal Spruce, Englemann Spruce-Subalpine Fir, Coastal Western Hemlock, Mountain Hemlock, and Alpine Tundra. The Morice River watershed has very high fisheries values and is one of the most important salmon and steelhead rivers in the Skeena River basin; many of the water bodies in the Morice River watershed support fish (Appendix A). In addition to fisheries, the area supports a range of critical and sensitive wildlife habitat, including old growth forests, high elevation meadows, wetlands, riparian forests, and avalanche debris fields, as well as a variety of wildlife. These characteristics are a testament to the extent of wilderness and lack of development in the Morice River watershed, and especially in the MWMA.

First Nations have maintained a presence in the Morice River watershed and greater region for thousands of years. There are five First Nations with traditional territories in the Morice River watershed area: Office of the Wet'suwet'en, Carrier Sekani (Wet'suwet'en), Cheslatta Carrier, Lake Babine, and the Yekooche Nations. These First Nations utilize their traditional territories for hunting, fishing, and gathering for sustenance, ceremonial, and medicinal purposes. After European contact, many First Nations also practiced agriculture and trapping.

Over the past century, land use in the Morice River watershed included extensive forestry (logging, road-building, silviculture, family-owned and large-scale sawmills, etc.) and mining, as well as agriculture, recreation and tourism. Current land management within the MWMA has been designed to address conservation objectives for the upper Morice River watershed (Appendix A). At present, much of the MWMA is protected as Provincial Park, or designated "No Timber Harvest Areas," (e.g., headwaters, areas designated as high-value wilderness experience, high value wildlife habitat), however there are also areas within the MWMA designated for Area-Specific Management or General Management to accommodate forestry and mineral exploration.

2. Methods

2.1 MWMT surface water quality monitoring from 2015-2017

The MWMT facilitated a monthly baseline surface water quality monitoring program within the MWMA from September 2015 through October 2017 (from here, "MWMT 2015-2017"). Although additional parameters (e.g., sediment, benthic macroinvertebrates or "CABIN") were also sampled as part of monitoring efforts during this time, this report focuses only on surface water quality data in the MWMA. A list of all water quality-related sampling sites within the greater Morice River watershed (e.g., surface water, sediments, CABIN, etc.) is provided in Appendix C, and a map of these sites is also provided in Appendix A.

In order to capture between-watershed variability and differences between catchments associated with land use impacts or other distinguishing watershed features, the MWMA was subdivided into watershed Assessment Units (AU), or high order watershed units delineated by the height of

[2] For detailed information on bedrock geology please see http://maps.skeenasalmon.info/maps/271 or iMAP BC Provincial layer "Geological Bedrock" at https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc.

land surface water contributing area and aggregated from BC Freshwater Atlas assessment watersheds by the Bulkley Valley Research Centre in 2014 (Fig. 1).

AUs were categorized as “Non-Core Area” or “Core Area” watersheds. Non-Core Areas represent AUs that are considered least-impacted by land use change and disturbance, and Core-Areas represent AUs with a higher degree of land use change and greater impacts due to disturbance. Non-Core Areas therefore represent AUs for background/baseline monitoring and Core Areas represent AUs for impact assessment monitoring. Site selection was then based on stream representation of specific Non-Core or Core Areas, and additional considerations such as accessibility.

Five sites were selected for MWMT 2015-2017 monitoring within the MWMA: McBride Creek, Morice River, Nado Creek, Cutthroat Creek, and Nanika River (Table 1; Fig. 1). These sites represent streams within four AUs and include one Non-Core Area (Nanika River East) and three Core Areas (McBride Creek, Upper Morice West, and Upper Morice). Stream order was designated using the Strahler method (Strahler, 1957).

- *Cutthroat Creek*: A 2nd order stream originating from a small lake and a tributary to the Nanika River. Cutthroat Creek is ~8 km in length and proximal influences include extensive wetlands and some logging, however the upper reaches of this catchment are relatively high gradient and have not been extensively logged. This catchment has the lowest road density of any of the sites represented in this study. A portion of Cutthroat Creek is utilized by coho for spawning and rearing habitat. The sampling site is located on river right 10 m upstream of a bridge ~ 1.65 km upstream from the confluence with the Nanika River.

- *McBride Creek*: A 3rd order stream ~11 km in length originating from McBride Lake and a tributary to Morice Lake. McBride Creek is well-described for its coho spawning and rearing habitat. Proximal anthropogenic influences include older logging sites and road development, which are of intermediate intensity in comparison to other sites in this study. The sampling site is located on river right ~150 m upstream from the confluence with Morice Lake.

- *Morice River*: A 7th order stream ~108 km in length originating from Morice Lake and receiving inputs from all tributaries within the Morice River watershed. Sampling was conducted ~13.5 km downstream of Morice Lake. Possible upstream anthropogenic influences include logging, road building, and potential mineral site development. Upstream from this site, logging efforts have been more intense on the east side of the Morice River than on the west, however cuts on the west side are more recent (1990-2017), and all cuts in closest proximity to the river on both sides are most recent (2011-2017). The Morice River is world-famous for its salmon and steelhead fisheries and is a major tributary to the Bulkley River and ultimately the Skeena River. The sampling site is located on river right upstream of the bridge over the Morice River at 66 km.

- *Nado Creek*: A 2nd order stream ~10.5 km in length and a tributary to the Morice River. However, there are several small tributaries that enter below the sampling site and the confluence, making Nado Creek a 1st order stream at the location of sampling. The catchment above the sampling site is relatively small and has no lakes. Upstream portions of the catchment are steeper and yield to a lower-gradient basin dominated by wetlands that serve as the headwaters of Nado Creek. Upstream anthropogenic influences include extensive logging prior to 2010, although some portions of the upper watershed remain intact. The Nado Creek catchment (or "Upper Morice" AU) has the highest road density of any of the catchments in the MWMT 2015-2017 sampling. The sampling site is located on river right ~4 km upstream of the confluence with the Morice River.

- *Nanika River*: A 5^{th} order stream ~36 km in length originating from high altitude lakes (Kidprice and Nanika Lakes) influenced by a gradient of glaciers and snowpack as well as a variety of ecosystems of lower elevation, including lower angle terrain that contains many wetlands and other mid-sized tributaries. Although logging has occurred on the Nanika River, it has not been as extensive as within other catchments in the MWMA. The Nanika River is a tributary to Morice Lake and is important salmon habitat within the Morice River watershed. Upstream anthropogenic influences are relatively minimal but include some logging and mining activity. The sampling site is on river right 20 m upstream of the bridge located approximately 8.7 km upstream from the Nanika River confluence with Morice Lake.

Table 1: Sites sampled within the Morice Water Management Area from 2015-2017 under the Morice Water Monitoring Trust sampling program. Sites designated by * are located in AUs defined as Non-Core Areas (least impact/land use) designated for monitoring of baseline/background conditions. Stream order is relative to stream position within the watershed at 1:50,000.

Site Name	EMS ID	Stream Order	Area (km^2)	Elev. (m)	Latitude	Longitude	Assessment Unit	n (2015-2017)	n (pre-2015)
Cutthroat Creek*	E272556	2	24	849	54.00875	-127.48102	Nanika River E	29	8
McBride Creek	E260496	3	112	768	54.09749	-127.4528	McBride Creek	29	1
Morice River	E272549	7	1,989	734	54.19075	-127.36364	Upper Morice W	24	33
Nado Creek	E260429	2	19	814	54.12984	-127.32343	Upper Morice	22	1
Nanika River*	E272557	5	841	809	54.04733	-127.42732	Nanika River E	31	6

2.2 MWMT 2015-2017 surface water sample collection and analysis

Water grab samples were collected at each of the five sites from September 2015 through October 2017. At four of the sites, samples were collected year-round at approximately monthly intervals. Samples at Nado Creek were not collected from December-March due to challenges with winter access. A typical approach to water quality sampling for determination of water quality guideline exceedances is the 5-in-30 day approach (ENV, 2013). However, in this study samples were collected for a longer duration of time at regular intervals in order to determine background conditions over a larger temporal period.

Sampling protocols followed those described in the *British Columbia Field Sampling Manual: Part E Water and Wastewater Sampling* (2013). Field water quality parameters (temperature, pH, dissolved oxygen and specific conductivity (SC)) were collected using a pre-calibrated YSI Professional Plus hand held meter. Grab samples were collected from a central well-mixed portion the waterbody and capped underwater to eliminate headspace. Samples were stored on ice and in the dark and shipped to Maxxam Analytics in Burnaby, B.C., immediately or the following morning. Additional samples were also sent as QA/QC checks including duplicates, field blanks, and lab blanks. Samples were analyzed using standard protocols approved for ISO/IEC 17025:2005 accredited facilities. Constituents analyzed included basic physicochemical parameters (SEC, pH, total suspended solids (TSS), total dissolved solids (TDS), turbidity, and hardness), nutrients (total nitrogen (TN), total organic nitrogen (TON), total Kjeldahl nitrogen (TKN), nitrate (NO_3^-), nitrite (NO_2^-), total ammonia nitrogen (TAN), total phosphorus (TP), total dissolved phosphorus (TDP) and orthophosphate (ORP)), miscellaneous inorganics (alkalinity, bicarbonate, carbonate), dissolved organic carbon (DOC), major anions (chloride (Cl^-), sulfate (SO_4^-)), major cations (calcium (Ca^{2+}), magnesium (Mg^{2+}), potassium (K^+), sodium (Na^+)), total and dissolved metals.

2.3 Pre-2015 surface water quality samples within the MWMA

Between 1996-2017, a total of 42 sites are documented to contain some level of water quality data from within the MWMA (Table 2, Fig. 3). A number of water quality samples (n= 211) were collected within the MWMA prior to 2015. Sampling locations and their corresponding BC Environmental Monitoring System (EMS) site IDs were sourced from various maps produced by the OW and the Skeena Knowledge Trust, and data accessed from the EMS database. QA/QC procedures removed identical, redundant samples, or samples with perceived errors. Relevant site-specific data were considered in the context of 2015-2017 MWMT results for purposes of evaluating potential longer-term temporal trends.

2.4 Hydrometric data

Hydrometric data were obtained from three Water Survey of Canada hydrometric gauging stations located in the Morice River watershed: 1) 08ED001 Nanika River at outlet Kidprice Lake, 2) 08ED002 Thautil Corner Creek near outlet Morice Lake, 3) 08ED002 Morice River near Houston (Table 3). Additional information on characteristics for specific study site catchments such as catchment area, mean discharge, topography, land cover and climate interactions were obtained from the Northwest Water Tool[3] and are provided in Appendix D.

2.5 Data analysis

Due to the variety of data sources, data formats were inconsistent and required additional post-processing. Data was first transformed to reflect consistent units and number of significant figures based on the recommended analytical limit of detection (LOD) for each constituent. Samples below LOD were represented by <LOD in original data sheets. For purposes of analysis, values of <LOD were substituted with a single value equivalent to ½ LOD. The single substitution method was selected over generally more robust methods based on data distribution and maximum likelihood estimation because of potential bias associated with low sample size (Helsel, 1990). For some constituents in samples pre-2015, values of LOD were adjusted as laboratories updated their method of analysis. For these samples, ½ of the lowest LOD value was substituted for all values <LOD. Values for duplicate and triplicate samples from historical data were averaged and entered as a single value.

[3] The Northwest Water Tool is available online at www.bcwatertool.ca/nwwt. Note that while the NWWT is effective at rapidly documenting watershed characteristics and summarizing surface water allocation, it contains limitations and caveats. The NWWT uses mean monthly flows as an indicator of flow sensitivity and lacks resolution for capturing sub-monthly variability and annual low flow timing. As a result, stream flow sensitivity may be misrepresented and data less reliable for smaller catchments. The NWWT also likely misrepresents the importance of groundwater in catchments.

Figure 3: Number of samples per year (a), total number of samples and number of samples per season per site collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017 (b), and total number of samples and number of samples per season collected from each watershed Assessment Unit within the Morice River watershed (c).

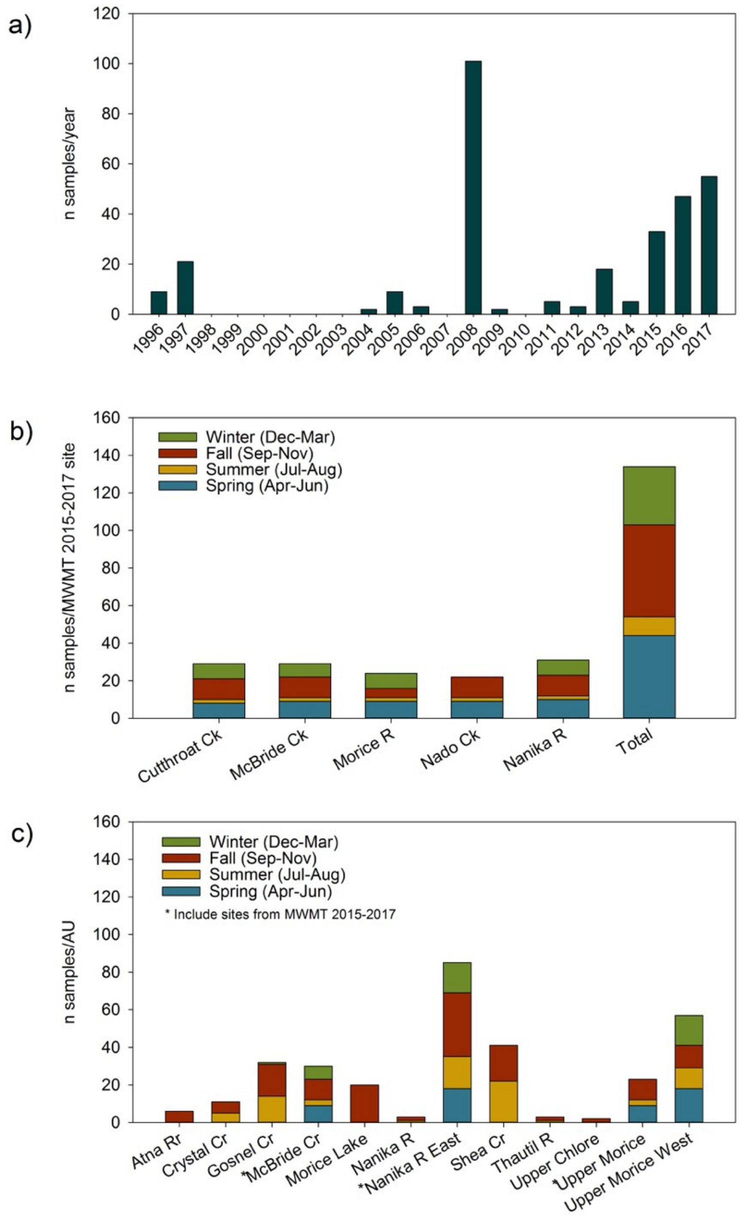


Table 2: All sites sampled within the Morice Water Management Area from 1996-2014.

Site Name	EMS ID	Latitude (N)	Longitude (W)	Assessment Unit	# samples	Start Date	End Date
Morice Lake (Center)✦	1131112	54.0325	-127.565	Morice Lake	2	2008-09-04	2008-09-15
Nanika Lake✦	1131113	53.7806	-127.6497	Nanika River	2	2008-09-04	2008-09-15
Holland Lake	E223327	54.264	-127.4519	Shea Creek	3	1996-08-05	1996-08-05
Shea Lake	E223338	54.2938	-127.5724	Shea Creek	4	1996-07-10	1996-08-10
Unnamed 019, Deep Hole	E223350	53.9362	-127.4721	Nanika River E	2	1996-08-14	1996-08-14
Shea Creek (u/s site)	E228745	54.2395	-127.5088	Shea Creek	12	1997-07-15	2011-09-20
Shea Creek (d/s site)	E228746	54.2354	-127.5178	Shea Creek	12	1997-07-11	1997-11-04
PR-03608 Hirsch Creek	E251384	54.0606	-128.0619	Upper Clore River	2	2005-11-21	2006-10-16
Loljuh Creek	E256936	54.378887	-127.2575	Thautil River	2	2004-09-07	2011-09-07
Deny`s Creek	E256937	54.3701	-127.2861	Thautil River	2	2004-09-07	2009-08-31
Raina Creek	E256938	54.3692	-127.2885	Thautil River	2	2004-09-07	2011-09-07
Crystal Creek FSR	E260427	54.19988	-127.44957	Crystal Creek	1	2009-08-31	2009-08-31
Redslide Creek	E260428	53.96939	-127.49239	Nanika River E	2	2005-08-23	2005-08-31
Nado Creek*	E260429	54.12984	-127.32343	Upper Morice	23	2005-08-31	2017-10-29
Gosnell at bridge	E260493	54.10846	-127.68828	Gosnell Creek	2	2005-08-29	2011-09-20
Unnamed at 24 Crystal	E260494	54.13238	-127.65656	Gosnell Creek	2	2005-08-29	2011-09-20
McBride Creek*	E260496	54.09749	-127.4528	McBride Creek	30	2005-08-29	2017-10-29
Kidprice Trib	E260565	53.89128	-127.40356	Nanika River E	1	2005-08-30	2005-08-30
Bergfar Field	E260566	53.80115	-127.45204	Nanika River	1	2005-08-30	2005-08-30
Outlet of Cutthroat Lake	E263581	54.00628	-127.50342	Nanika River E	1	2006-07-19	2006-07-19
Nanika River u/s	E263582	54.00594	-127.47166	Nanika River E	1	2006-07-19	2006-07-19
Nanika River Trib	E267342	54.008577	-127.48093	Nanika River E	1	2007-07-11	2007-07-11
Nanika River Trib 2	E267343	54.017547	-127.48093	Nanika River E	1	2007-07-11	2007-07-11
Nanika River Trib 3	E267344	54.01943	-127.47341	Nanika River E	1	2007-07-11	2007-07-11
Nanika River Trib 4	E267345	54.020072	-127.47246	Nanika River E	1	2007-07-11	2007-07-11
Nanika River Trib 5	E267346	54.047086	-127.42187	Nanika River E	1	2007-07-11	2007-07-11
Morice River*✦	E272549	54.19075	-127.36364	Upper Morice W	57	2008-07-22	2017-10-29
Gosnell Creek✦	E272551	54.21537	-127.39415	Gosnell Creek	10	2008-07-22	2008-11-11
Joshua Creek✦	E272553	54.18889	-127.66523	Gosnell Creek	9	2008-07-22	2008-10-22
Crystal Creek✦	E272554	54.19752	-127.4509	Crystal Creek	10	2008-07-22	2008-11-11
Gosnell Tributary South✦	E272555	54.16818	-127.63894	Gosnell Creek	8	2008-07-22	2008-10-22
Cutthroat Creek*	E272556	54.00875	-127.48102	Nanika River E	37	2008-07-22	2017-10-29
Nanika River*✦	E272557	54.04733	-127.42732	Nanika River E	37	2008-07-22	2017-10-29
Shea Creek✦	E272563	54.23864	-127.51854	Shea Creek	10	2008-07-22	2008-11-11
Morice Lake 4✦	E272564	53.997083	-127.642931	Morice Lake	4	2008-09-04	2008-10-29
New Moon Creek✦	E272565	53.995875	-127.644744	Morice Lake	4	2008-09-04	2008-10-29
Delta Creek✦	E272567	53.835692	-127.834461	Morice Lake	6	2008-09-04	2008-10-29
Cabin Creek✦	E272568	53.840419	-127.804436	Morice Lake	4	2008-09-04	2008-10-29
Kidprice Lake✦	E273263	53.9122	-127.4582	Nanika River E	2	2008-09-04	2008-09-15
Stepp Lake✦	E273264	53.9574	-127.326	Nanika River E	2	2008-09-04	2008-09-15
Atna Bay✦	E273266	54.0259	-127.8015	Atna River	2	2008-09-04	2008-09-15
Atna River✦	E273267	54.0217	-127.8249	Atna River	4	2008-09-04	2008-10-29

*Site included in MWMT water sampling program from 2015-2017

✦ Site included in OW 2008 water quality sampling program

Table 3: Hydrometric stations within the Morice River Watershed. All stations are operated by Water Survey of Canada.

ID	Station Name	Status	Latitude (N)	Longitude (W)	Drainage (km^2)	Period of Record	Real Time Data	Sediment Data
08ED002	Morice River near Houston	Active	54.0705	-127.2526	1900	1929-2018	Yes	No
08ED001	Nanika River at outlet of Kidprice Lake	Active	53.5550	-127.2710	732	1950-2018	Yes	No
08ED004	Thautil Corner Creek Near Morice Lake	Active (Seasonal)	54.1522	-127.2056	4.22	1997-2018	No	No

All analyses were performed in R (R Core Team 2017). Summary statistics were calculated for each constituent by site for MWMT 2015-2017. In addition, summary statistics were calculated for each constituent by AU for all data, including historical (1996-2015) and MWMT 2015-2017. Principal component analysis was conducted to explore spatial variability between sites (for MWMT 2015-2017) and between AUs (all data). Constituents with a high degree of covariation with other constituents were removed from analysis and significant principal components selected based on scree plots and Kaiser criterion (Costello and Osborne, 2005).

In order to describe seasonality and temporal patterns that may reflect differences in catchment hydrology and biogeochemical processing throughout the year, four seasonal periods were chosen to represent times of distinct hydrologic character (see Fig. 2).[4] Seasonal periods were selected based on characteristics of average daily flows from the period of record at Water Survey of Canada hydrometric stations 08ED002 (Morice River near Houston), 08ED004 (Thautil Corner Creek near outlet Morice Lake) and 08ED001 (Nanika River at outlet Kidprice Lake). Spring (Apr-Jun) represents the period of freshet when winter snowmelt flushes watersheds and results in sustained high flows that peak and then taper as the season progresses. Note that although the hydrograph doesn't begin to respond to snow melt until typically late April/early May when high elevation snowpack begins to thaw, the spring period was designated to begin in early April as this is when most systems are becoming ice-free. Summer (Jul-Aug) represents a period of decreasing flow following freshet progressing to low summer baseflow. Autumn (Sep-Nov) represents a rain-dominated period with higher flows than summer baseflows and punctuated autumn rain events that can produce high peak flows and may also reflect rain-on-snow events. Winter (Dec-Mar) represents the snow-dominated winter low flow period when most of the surface water is frozen in ice and snow and stream flows are generally at their annual low.

2.6 Determining exceedance of BC water quality guidelines and need for site-specific water quality objectives

Water quality guidelines (WQG) are developed by jurisdictions to protect water quality. In British Columbia, approved WQG are meant to represent safe levels of substances that protect different water uses, for example, the protection of aquatic life, drinking water, agriculture, and

[4] Note that data figures are presented as time series (as opposed to seasonal summaries) to increase resolution of variability both within and across seasons.

recreation. Generally, the most stringent of these guidelines is the protection of aquatic life. Although exceeding a WQG does not necessarily imply an unacceptable level of risk, it suggests an increased potential for adverse effects and therefore warrants further investigation. In addition, because WQG were designed to be broadly applicable at a provincial scale, they may be over or under-protective for certain sites. In these circumstances, water quality objectives (WQO) can be developed in order to more adequately protect existing water quality (ENV, 2013). In order to assess current water quality conditions in the MWMA in comparison with BC WQG, and determine potential need for site-specific WQO, data from MWMT 2015-2017 were compared with approved and working water quality guidelines for British Columbia (ENV, 2018) and recommendations from the Canadian Council of Ministers of the Environment (CCME, 1999). Based on these findings, candidate constituents were further examined for potential development of site-specific water quality objectives.

3. Results

3.1 Distribution of surface water quality samples within the MWMA

The MWMT 2015-2017 water monitoring program collected 135 surface water quality samples from five sites. Prior to these efforts, from 1996-2014, 185 samples[5] were collected from an additional 37 sites. Therefore, a total of 320 samples were collected at 42 sites within the MWMA from 1996-2017. However, the level of sampling effort varied substantially across space and time. Very few data were collected prior to 2013 (Fig. 4a), with the notable exception of 2008. In this year, the OW sampled stream and lake sites from August to October across the greater Morice River watershed, including several sites that were selected for sampling within the MWMA during the MWMT 2015-2017 monitoring program.

Spatially, there is a large difference between the number of sites that have very few samples and those that represent larger sampling efforts. The EMS database contains 52 documented sites for this region, however 10 of these sites contain no data, and 23 sites represent only 1-2 samples/date. The remaining 19 sites include > 4 sample dates, but there are differences in temporal representation and frequency of sampling. Based on the timing and distribution of samples collected in the MWMA, years 2008 and 2013-2017 have more samples collected per site and more even distribution of temporal coverage. Seasonal representation in water quality varies across sites and likely reflects the objectives and resources of different sampling programs and site accessibility. Seasonal sample distribution is relatively good for MWMT 2015-2017 although the summer low flow period, followed by the winter low flow period, appear underrepresented relative to other seasons. However, for the greater MWMA, many AUs lack representative samples from the winter or spring period (Fig. 3).

3.2 MWMT 2015-2017: Summary of spatial and temporal variability

Summary statistics for select major constituents are given in Table 4a, Fig. 4a (physicochemical, carbon, and anions), Table 4b, Fig. 4b, (nutrients and solids), Table 4c, Fig. 4c (dissolved metals), Table 4d, Fig. 4d (total metals), and Table 4e, Fig. 4e (total and dissolved

[5] Although greater than 203 samples are reported in the EMS database, some of these samples were removed from analysis following QA/QC screening procedures or because they were either duplicates or contained little to no relevant data.

cations). Constituents with few or no values above their LOD are not included in Figures 4c and 4d but are included in the summary of all data included in Appendix B (e.g., Boron (B), Beryllium (Be), Bismuth (Bi), Bromide (Br), Lithium (Li), Thallium (Tl), Tin (Sn), Zirconium (Zr)).

On average, physicochemical constituents reflect mild temperatures, low to moderate specific conductivity (SEC) and well-oxygenated, neutral pH waters. Most values are within the typical range observed for relatively less-impacted surface waters in this region (Table 4a). Seasonal cycles in temperature, dissolved oxygen, pH, and SEC were observed at all sites (Fig 5). All sites have relatively low concentrations of major ions, particularly calcium and magnesium (i.e., total and dissolved hardness), and categorized as "soft" water. Values for total alkalinity suggest that sites can be categorized as "moderately-sensitive" or "less-sensitive" to acid inputs, although certain sites varied seasonally between these two categories (Fig. 6). Overall turbidity and TSS were low, with punctuated high values at the Nanika and Morice River sites during high flow events (Fig. 6, Fig. 8). Several high concentrations of TSS were also measured at Cutthroat Creek and did not appear to be associated with high flow events, implying the presence of an alternative source of sediment in this system independent of high stream discharge.

Total dissolved solids (TDS) and SEC varied across sites reflecting differences in underlying geology and catchment weathering. Although overall concentrations of TDS and SEC were not significantly different between sites, sites like Nado Creek and Cutthroat Creek sometimes exhibited higher TDS values relative to other sites (Fig. 8; Fig. 4b; Table 4b). In addition, SEC values maintained a somewhat consistent rank order between sites: higher SEC was typically observed at Nado Creek and Cutthroat Creek, and lower SEC was typically observed at Morice River and McBride Creek. Differences in Cl^- concentrations also suggest differences in catchment hydrology and hydrologic residence time between sites, since Cl^- is not easily absorbed onto surfaces or incorporated into soil minerals and therefore has high inertia and mobility within watersheds (Lovett et al., 2005). Cl^- concentrations respond more rapidly to higher discharge at certain sites, such as Nado Creek and McBride Creek, whereas response appears more delayed at Cutthroat Creek. These differences may potentially reflect differences in catchment characteristics such as longer catchment residence times due to groundwater and wetland retention and storage (Fig. 6). In contrast, sites on the Morice River and Nanika River were consistently lower in Cl^- concentrations and had less of a response to precipitation events, reflecting the different nature of their catchments such as the presence of lakes, greater dilution with larger catchment size, and potential groundwater interactions.

Export of dissolved organic carbon (DOC) from catchments is controlled by watershed attributes that influence carbon cycling (e.g., flow paths, vegetation, lakes, etc.), seasonal hydrology, and residence time (Oliver et al., 2017). Sites reflect distinct differences in DOC concentrations and discharge-concentration relationships across the seasonal hydrograph (Fig. 6; Fig. 4a; Table 4a). Across all sites, average DOC concentrations are similar to average concentrations estimated for global freshwater exports (global average = 5.29 mg/L, Dai et al., 2012; 5.71 mg/L Sobek et al., 2007) and other mountainous locations in B.C. and Alaska with similar watershed features (e.g., Hood et al., 2008; A. Oliver *pers. comm.).* However, site-specific averages reveal large variability between catchments, with higher DOC concentrations at Nado Creek and McBride Creek, and lower concentrations at Morice River and Nanika River. Average DOC concentration at Cutthroat Creek was similar to the average for all sites.

Overall, the study sites in the MWMA are relatively low in nutrients but still exhibit compelling spatial and temporal variability (Fig. 5b; Fig. 4b; Table 4b). In general, TN concentrations were highest at Nado Creek and lowest at Nanika River, although concentrations were also low at Morice River. TN concentrations did not reflect overall seasonal trends, but still appeared to respond to changes in the hydrograph, particularly at Nado, McBride, and Cutthroat Creeks (Fig. 7). Total organic nitrogen (TON) comprised an average 72% of the TN pool and in general, sites representing lower-order streams had a higher percentage of organic nitrogen contribution than sites representing higher-order streams. For most of the year, the dominant form of dissolved inorganic nitrogen (DIN) was TAN, which comprised an average 67% of the DIN pool.

The stoichiometric ratio of C:N:P ("Redfield Ratio", 106:16:1) suggests that these streams are phosphorus-limited (Redfield, 1958). Total phosphorus (TP) concentrations were low to moderate across all sites (Fig. 4b; Table 4b), and all sites designated oligotrophic based on average TP, except Nado Creek, which had higher concentrations and therefore designated mesotrophic (CCME, 2004). TP showed seasonal variation at all sites, with higher concentrations associated with periods of higher flow such as freshet or autumn storm events (Fig. 8). Orthophosphate (ORP) comprised an average of 25% of TP, although occasionally represented the dominant fraction (~75%) at various sites. In lower-order systems, concentrations of ORP were higher and reflected greater seasonal variability. In contrast, on the Morice River, ORP concentrations were low and less seasonally-variable (Fig. 8). Concentrations of both TP and ORP increased following a November 2017 precipitation event, with higher stream-orders (i.e., larger catchment size) showing larger changes from previous concentrations compared to lower stream-orders.

Many different metals (both dissolved and total) were measured in this study. Due to the large number of parameters and the fact that many parameters have few results above the limit of analytical detection, a subset of parameters are summarized in Table 4c-4d, and Figure 4c-4d. Results for all metal species are provided in Appendix B. Select metals with established water quality guideline criteria are presented as seasonal plots in Figure 9, and additional major metals and base cations are shown in Figure 10. Patterns in metal concentrations varied by site, with some sites reflecting consistently higher concentrations of certain metals either throughout the year, or on a seasonal basis. Overall, the concentration of various metals tended to be higher at Cutthroat Creek, Nanika River, and Nado Creek, and lower at McBride Creek and Morice River.

The concentrations of total and dissolved cations (Ca^{2+}, Mg^{2+}, K^{+}, Na^{+}) typically represent the major cation components of surface and ground water naturally produced by rock weathering. These constituents provide information about the general characterization of water quality based on underlying weathering processes and contribute to the determination of measures such as hardness. Results are summarized in Figure 4e and Table 4e. Seasonal trends in the sum of total base cations are shown in Figure 10 (bottom panel). Seasonal patterns in total base cations were much more dynamic at Nado and Cutthroat Creeks than at other sites. Overall, it appears concentrations increase during the winter and peak in early spring at all sites except for Nado Creek, where they increase through the summer months and decrease into autumn. However, the lack of winter data at Nado Creek inhibits current evaluation of summer versus winter concentrations.

One approach frequently used to assess water quality in comparison to water quality guidelines is to look at differences between seasonal periods, which are usually defined based on patterns in discharge (Fig. 11). This is one approach to potentially identifying how seasonal differences may help explain some observations of WQG exceedances. The MWMA lacks thorough categorization of discharge, so the seasonal periods as defined here may not accurately reflect the hydrological trends in individual catchments, and so binning data for each site by season should be done with caution. However, as previously discussed, time series data can also be used to reveal patterns in seasonal variability (Figs. 5-10). For example, NO_3^{-}+NO_2^{-}

concentrations increased in summer, and lower during spring and autumn. In contrast, average TAN concentrations did not vary considerably between seasonal periods. Other examples include turbidity and dissolved Al, which were higher in spring and autumn in comparison to summer and winter, although data was more limited for the latter two seasonal periods. These seasonal differences are more likely to be observed for constituents with high biological demand as well as greater solubility and mobility in relation to discharge.

Principle components (PC) 1-4 were significant in explaining the majority (82.8%) of variation between samples at sites included in the MWMT 2015-2017 surface water monitoring program (Table 5, Fig. 12). Of these, approximately half of the variation was explained by PC1 and PC2 (62.7%). Samples appeared to cluster well by site, with some sites exhibiting more overlap than others. PC1 explains 36.6% of total variance and represents a gradient of carbon, nutrient, sulfate, and metals concentrations with Nado Creek and Nanika River at opposite ends of this gradient. Sites appeared to cluster along PC1. PC2 explains 26.1% of total variance and represents a gradient of dissolved solutes (cations and anions) and pH. Along PC2, sites reflect within-site variability and also exhibit more overlap between sites. Cutthroat Creek and Nado Creek are similar along PC2 and show a wide range of variability along this gradient, whereas Morice River and McBride creek are more clustered and less variable along PC2. This may reflect differences in concentration-discharge relationships between sites as well as differences in watershed controls on exports. In summary, the majority of variability (as explained by PC1 and PC2) within the data occurs between sites rather than within sites, indicating that each site appears to capture distinct watershed characteristics that reflect distinct site-specific conditions. These distinct differences are most effectively explained by looking at relative differences in carbon, nutrients, sulfate, and metals concentrations.

3.3 All data sampled within the MWMA from 1996-2017

Results of all data collected in the MWMA from 1996-2017 are summarized in tables and box-whisker plots in Appendix B. Due to low replication for most sites, sites are aggregated by watershed AU and summary statistics presented for each AU. Principle components (PC) 1-3 were significant in explaining the majority (78.56%) of the variation between samples collected throughout the MWMA from 1996-2017. Of these, over half of the variation is explained by PC1 and PC2 (64.46%) (Table 5; Fig. 13). PC1 represents a gradient of total metals and total nutrients, whereas PC2 represents a gradient of base cations and total alkalinity. Samples also appeared to cluster somewhat by AU, with some grouping more along PC1, and some more along PC2. However, all AUs tended to overlap, suggesting variability in water quality depends on the site more than the individual AU. While some AUs show a wider range in nutrient and metals concentrations, some have a narrower range of variability for these parameters but greater variability in base cation export. However, these differences did not separate out individual AUs. Across the entire Morice River watershed individual AUs were more similar (less variability between AUs) than individual sites. In conjunction with the information derived from analysis of MWMT sites, this suggests that smaller catchments may be more appropriate for capturing total variability in constituents rather than trying to represent individual sites by monitoring at the scale of AU.

Table 4a: Summary statistics for select physiochemical, carbon, and anion data collected at MWMT sites from 2015-2017.

		Temp ˚C	pH	Specific Conductivity uS/cm	Dissolved Oxygen mg/L	DOC mg/L	Alkalinity mg/L $CaCO_3$	Total Hardness mg/L	Dissolved Hardness mg/L	Sulfate mg/L	Chloride mg/L
All MWMT Sites	Count	94	130	130	129	131	135	135	129	135	135
	Mean	5.07	7.28	44.54	10.44	5.76	16.97	19.4	19.3	2.9	0.6
	Med	4.35	7.24	41.90	10.30	4.65	15.70	19.0	18.7	3.2	0.3
	Min	-0.10	5.69	7.95	4.54	0.25	10.00	11.7	11.5	0.3	0.3
	Max	16.80	9.28	90.00	14.55	22.80	30.30	29.1	30.3	7.7	3.3
	Std	4.37	0.50	10.73	2.34	4.96	4.37	3.6	3.6	2.5	0.4
	SE	0.45	0.04	0.94	0.21	0.43	0.38	0.3	0.3	0.2	0.0
	95 CI	0.88	0.09	1.84	0.40	0.85	0.74	0.6	0.6	0.4	0.1
	+95 CI	5.95	7.36	46.38	10.84	6.61	17.71	20.0	19.9	3.3	0.7
	-95 CI	4.19	7.19	42.69	10.03	4.91	16.24	18.8	18.7	2.5	0.5
Nado Creek (E260429)	Count	15	21	21	20	21	22	22	20	22	22
	Mean	5.27	7.27	45.44	10.67	13.31	20.75	22.3	21.9	0.4	1.0
	Med	5.60	7.10	48.60	10.58	13.20	22.15	22.1	22.1	0.3	0.9
	Min	0.00	6.47	7.95	7.13	6.40	10.30	11.7	11.5	0.3	0.3
	Max	12.60	8.30	62.80	13.86	22.80	30.30	29.1	30.0	2.8	1.8
	Std	3.46	0.46	13.41	1.77	3.91	6.59	4.5	4.3	0.6	0.4
	SE	0.89	0.10	2.93	0.39	0.85	1.41	1.0	1.0	0.1	0.1
	95 CI	1.75	0.20	5.73	0.77	1.67	2.76	1.9	1.9	0.2	0.1
	+95 CI	7.02	7.47	51.17	11.45	14.99	23.51	24.2	23.7	0.7	1.1
	-95 CI	3.52	7.07	39.71	9.90	11.64	18.00	20.4	20.0	0.2	0.8
Nanika River at bridge (E272557)	Count	22	30	30	30	30	31	31	30	31	31
	Mean	5.54	7.35	47.75	11.41	1.26	14.37	20.5	20.3	6.3	0.4
	Med	5.70	7.32	46.80	11.28	1.20	14.20	20.6	20.5	6.5	0.3
	Min	-0.10	6.59	40.20	7.13	0.25	12.60	18.0	17.4	5.1	0.3
	Max	13.60	8.25	90.00	14.55	3.06	16.40	23.7	23.9	7.7	1.0
	Std	4.42	0.40	8.73	1.94	0.82	0.97	1.6	1.5	0.8	0.2
	SE	0.94	0.07	1.59	0.35	0.15	0.17	0.3	0.3	0.1	0.0
	95 CI	1.85	0.14	3.12	0.69	0.29	0.34	0.6	0.6	0.3	0.1
	+95 CI	7.39	7.50	50.88	12.10	1.56	14.71	21.1	20.9	6.6	0.5
	-95 CI	3.69	7.21	44.63	10.72	0.97	14.03	20.0	19.8	6.1	0.3

Table 4a *cont.*: Summary statistics for select physiochemical, carbon, and anion data collected at MWMT sites from 2015-2017.

		Temp ˚C	pH	Specific Conductivity uS/cm	Dissolved Oxygen mg/L	DOC mg/L	Alkalinity mg/L $CaCO_3$	Total Hardness mg/L	Dissolved Hardness mg/L	Sulfate mg/L	Chloride mg/L
Morice River (E272549)	Count	16	23	23	23	23	24	24	23	24	24
	Mean	5.11	7.56	42.64	11.90	1.22	16.00	18.4	18.5	3.6	0.3
	Med	4.35	7.50	41.50	12.68	1.05	16.05	18.4	18.2	3.6	0.3
	Min	-0.10	6.73	37.60	8.01	0.25	14.00	15.0	17.5	3.0	0.3
	Max	14.20	9.28	71.30	14.00	3.00	17.50	19.4	22.3	4.2	1.0
	Std	4.35	0.55	6.35	1.87	0.78	0.84	0.9	1.1	0.3	0.2
	SE	1.09	0.11	1.32	0.39	0.16	0.17	0.2	0.2	0.1	0.0
	95 CI	2.13	0.22	2.60	0.76	0.32	0.34	0.4	0.4	0.1	0.1
	+95 CI	7.24	7.79	45.24	12.67	1.54	16.33	18.8	18.9	3.7	0.4
	-95 CI	2.98	7.34	40.05	11.14	0.90	15.66	18.1	18.0	3.5	0.3
McBride Creek (E260496)	Count	21	28	28	28	28	29	29	28	29	29
	Mean	5.12	7.17	40.39	10.33	9.41	17.60	16.2	16.2	0.3	0.7
	Med	4.20	7.07	39.10	10.13	9.47	15.90	16.4	16.4	0.3	0.7
	Min	-0.10	6.56	29.20	5.40	6.40	11.70	13.3	13.1	0.3	0.3
	Max	16.80	8.10	74.70	13.36	12.20	30.00	18.0	18.0	1.0	1.2
	Std	4.88	0.37	10.12	1.97	1.47	4.00	1.3	1.3	0.1	0.3
	SE	1.06	0.07	1.91	0.37	0.28	0.74	0.2	0.2	0.0	0.1
	95 CI	2.09	0.14	3.75	0.73	0.55	1.46	0.5	0.5	0.1	0.1
	+95 CI	7.21	7.30	44.14	11.06	9.95	19.05	16.6	16.6	0.3	0.8
	-95 CI	3.03	7.03	36.64	9.60	8.86	16.14	15.7	15.7	0.2	0.5
Cutthroat Creek (E272556)	Count	20	28	28	28	29	29	29	28	29	29
	Mean	4.31	7.07	46.13	8.12	5.04	17.08	20.0	20.2	3.1	0.6
	Med	3.35	7.21	46.00	8.25	5.21	15.90	20.5	20.0	2.7	0.3
	Min	-0.10	5.69	27.30	4.54	1.90	10.00	12.6	12.8	0.3	0.3
	Max	15.80	8.26	80.70	12.50	11.40	26.30	28.1	30.3	7.1	3.3
	Std	4.70	0.59	12.81	2.11	2.18	4.60	4.5	5.0	2.0	0.6
	SE	1.05	0.11	2.42	0.40	0.41	0.85	0.8	0.9	0.4	0.1
	95 CI	2.06	0.22	4.75	0.78	0.80	1.67	1.6	1.8	0.7	0.2
	+95 CI	6.37	7.29	50.88	8.90	5.83	18.75	21.7	22.1	3.8	0.9
	-95 CI	2.25	6.85	41.39	7.33	4.24	15.40	18.4	18.4	2.4	0.4

Figure 4a. Box and whisker plots for select physicochemical, carbon, and anion data (Table 4) collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

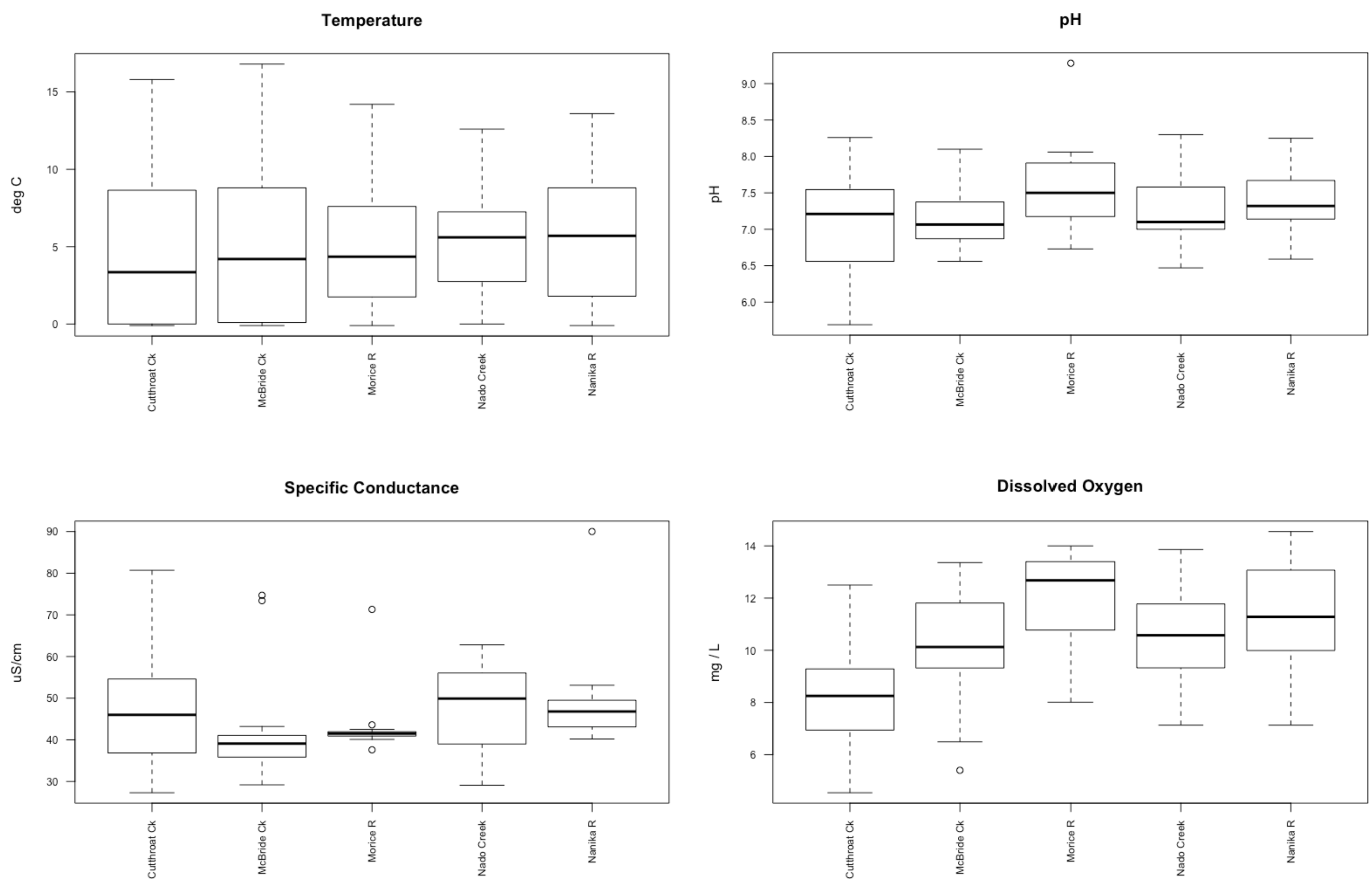


Figure 4a *cont:* Box and whisker plots for select physicochemical, carbon, and anion data (Table 4) collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

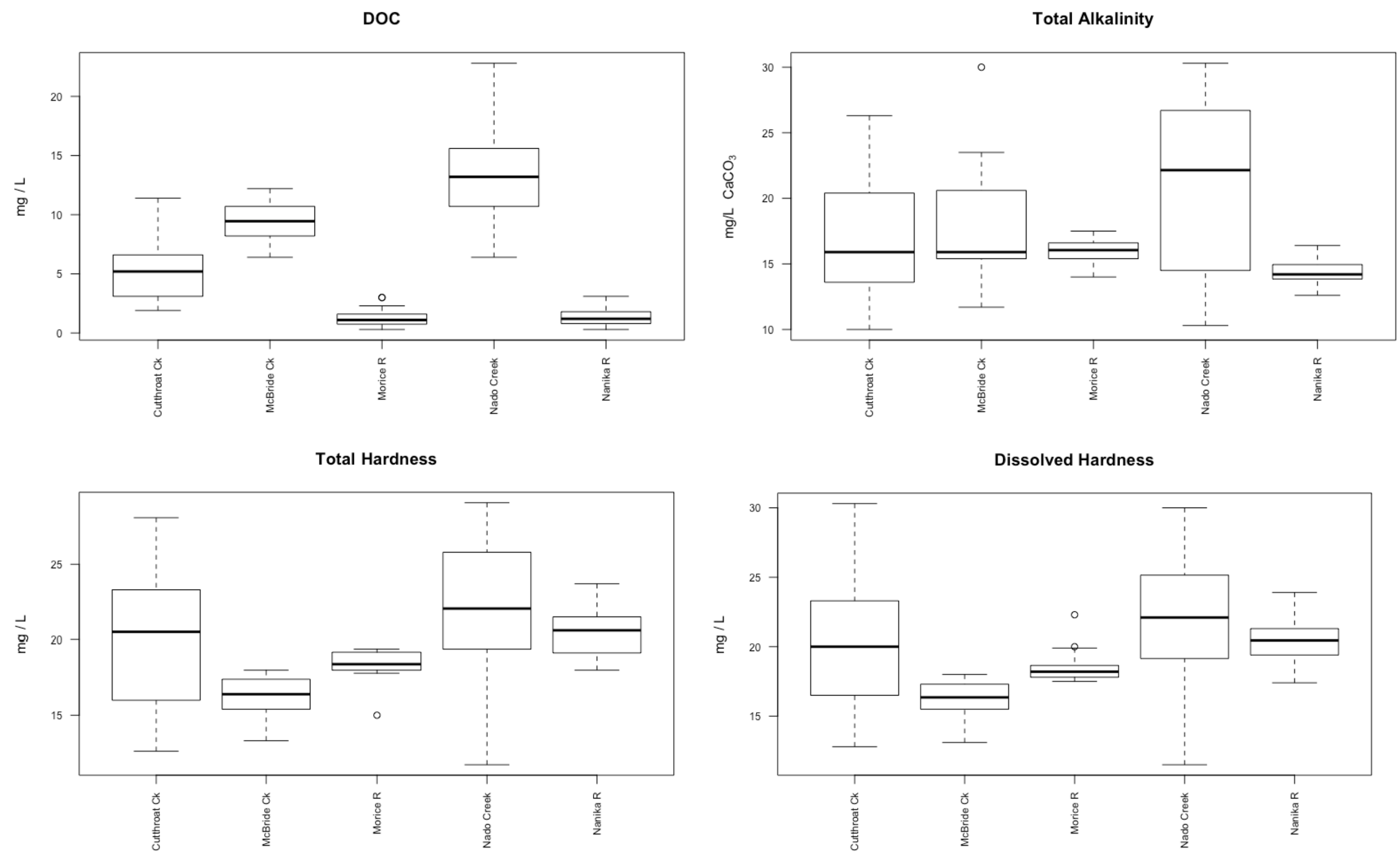
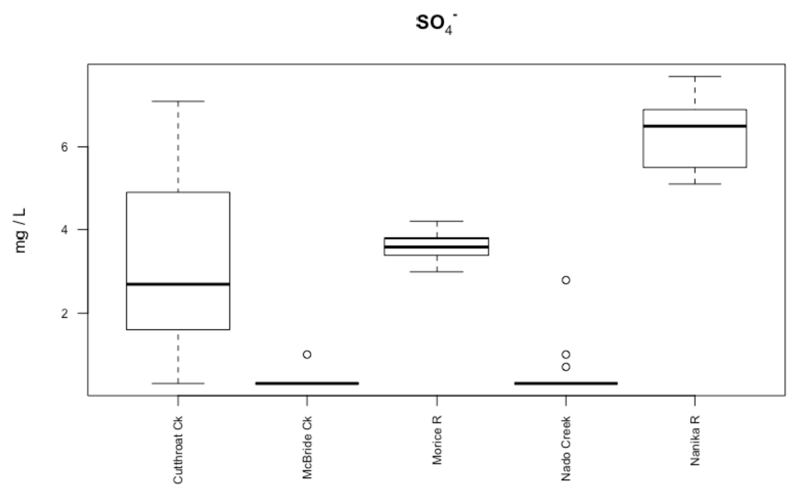


Figure 4a *cont:* Box and whisker plots for select physicochemical, carbon, and anion data (Table 4) collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).



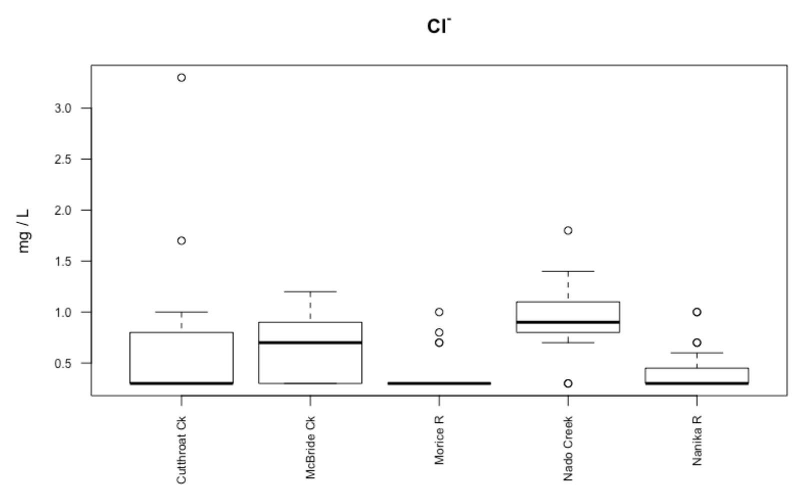


Table 4b: Summary statistics for select nutrient and solids data collected at MWMT sites from 2015-2017

		TN	TON	TAN	NO_3+NO_2	TP	ORP	TSS	TDS	Turbidity
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	NTU
All MWMT Sites	Count	130	127	131	131	130	131	134	135	131
	Mean	0.244	0.195	0.030	0.020	0.007	0.001	2.4	36.7	1.3
	Med	0.221	0.189	0.020	0.009	0.006	0.001	2.0	34.0	0.6
	Min	0.031	0.010	0.003	0.001	0.001	0.001	2.0	16.0	0.2
	Max	0.689	0.647	0.150	0.333	0.040	0.015	16.0	102.0	43.9
	Std	0.150	0.140	0.029	0.043	0.006	0.002	2.1	13.7	4.0
	SE	0.013	0.012	0.002	0.004	0.001	0.000	0.2	1.2	0.4
	95 CI	0.026	0.024	0.005	0.007	0.001	0.000	0.4	2.3	0.7
	+95 CI	0.270	0.219	0.035	0.027	0.009	0.002	2.8	39.0	2.0
	-95 CI	0.218	0.170	0.025	0.013	0.006	0.001	2.1	34.3	0.6
Nado Creek (E260429)	Count	21	21	21	22	22	22	22	22	22
	Mean	0.478	0.384	0.035	0.057	0.014	0.002	2.1	54.1	0.9
	Med	0.461	0.366	0.020	0.022	0.011	0.001	2.0	50.0	0.6
	Min	0.283	0.201	0.010	0.001	0.004	0.001	2.0	16.0	0.3
	Max	0.689	0.647	0.150	0.333	0.033	0.008	5.0	102.0	3.4
	Std	0.114	0.115	0.038	0.093	0.008	0.002	0.6	18.2	0.8
	SE	0.025	0.025	0.008	0.020	0.002	0.001	0.1	3.9	0.2
	95 CI	0.049	0.049	0.016	0.039	0.003	0.001	0.3	7.6	0.3
	+95 CI	0.526	0.433	0.051	0.096	0.017	0.003	2.4	61.7	1.2
	-95 CI	0.429	0.335	0.020	0.018	0.010	0.001	1.9	46.5	0.5
Nanika River (E272557)	Count	30	29	30	30	29	30	29	28	29
	Mean	0.107	0.072	0.023	0.011	0.004	0.001	30.0	31.0	30.0
	Med	0.090	0.057	0.017	0.010	0.003	0.001	2.8	31.4	3.0
	Min	0.031	0.010	0.003	0.001	0.001	0.001	2.0	32.0	0.8
	Max	0.330	0.324	0.077	0.024	0.016	0.011	2.0	20.0	0.3
	Std	0.064	0.064	0.019	0.007	0.004	0.002	16.0	48.0	43.9
	SE	0.012	0.012	0.003	0.001	0.001	0.000	3.1	8.1	8.0
	95 CI	0.023	0.023	0.007	0.003	0.001	0.001	0.6	1.5	1.5
	+95 CI	0.130	0.095	0.030	0.013	0.005	0.002	1.1	2.8	2.8
	-95 CI	0.084	0.048	0.017	0.008	0.003	0.001	3.9	34.3	5.8

Table 4b *cont.*: Summary statistics for select nutrient and solids data collected at MWMT sites from 2015-2017

		TN mg/L	TON mg/L	TAN mg/L	NO_3+NO_2 mg/L	TP mg/L	ORP mg/L	TSS mg/L	TDS mg/L	Turbidity NTU
Morice River (E272549)	Count	22	22	23	23	23	23	24	24	23
	Mean	0.142	0.077	0.032	0.034	0.003	0.001	2.4	28.1	1.1
	Med	0.119	0.054	0.020	0.036	0.002	0.001	2.0	26.0	0.5
	Min	0.067	0.010	0.003	0.011	0.001	0.001	2.0	16.0	0.2
	Max	0.366	0.336	0.130	0.046	0.022	0.015	11.0	44.0	12.9
	Std	0.074	0.077	0.035	0.009	0.005	0.003	1.8	8.1	2.6
	SE	0.016	0.016	0.007	0.002	0.001	0.001	0.4	1.7	0.5
	95 CI	0.031	0.032	0.014	0.004	0.002	0.001	0.7	3.2	1.1
	+95 CI	0.173	0.109	0.046	0.037	0.005	0.003	3.1	31.3	2.1
	-95 CI	0.111	0.045	0.018	0.030	0.001	0.000	1.6	24.8	0.0
McBride Creek (E260496)	Count	28	27	29	28	28	28	29	29	28
	Mean	0.303	0.271	0.029	0.004	0.008	0.001	2.0	36.7	0.5
	Med	0.303	0.277	0.020	0.001	0.007	0.001	2.0	36.0	0.5
	Min	0.206	0.166	0.003	0.001	0.004	0.001	2.0	22.0	0.3
	Max	0.474	0.474	0.110	0.015	0.021	0.004	2.0	52.0	0.9
	Std	0.073	0.070	0.022	0.005	0.004	0.001	na	7.0	0.2
	SE	0.014	0.014	0.004	0.001	0.001	0.000	na	1.3	0.0
	95 CI	0.027	0.026	0.008	0.002	0.001	0.000	na	2.5	0.1
	+95 CI	0.330	0.297	0.038	0.006	0.009	0.002	na	39.2	0.6
	-95 CI	0.276	0.244	0.021	0.002	0.007	0.001	na	34.2	0.4
Cutthroat Creek (E272556)	Count	29	28	29	28	28	28	29	29	28
	Mean	0.237	0.199	0.034	0.007	0.009	0.001	2.6	36.1	0.9
	Med	0.221	0.188	0.022	0.001	0.008	0.001	2.0	34.0	0.7
	Min	0.105	0.075	0.007	0.001	0.004	0.001	2.0	18.0	0.3
	Max	0.506	0.506	0.120	0.031	0.040	0.005	16.0	70.0	2.6
	Std	0.088	0.079	0.031	0.009	0.006	0.001	2.7	12.3	0.5
	SE	0.016	0.015	0.006	0.002	0.001	0.000	0.5	2.3	0.1
	95 CI	0.032	0.029	0.011	0.003	0.002	0.000	1.0	4.5	0.2
	+95 CI	0.269	0.228	0.045	0.010	0.011	0.001	3.6	40.5	1.1
	-95 CI	0.206	0.170	0.022	0.003	0.007	0.001	1.6	31.6	0.7

Figure 4b: Box and whisker plots for select nutrient and solids data at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

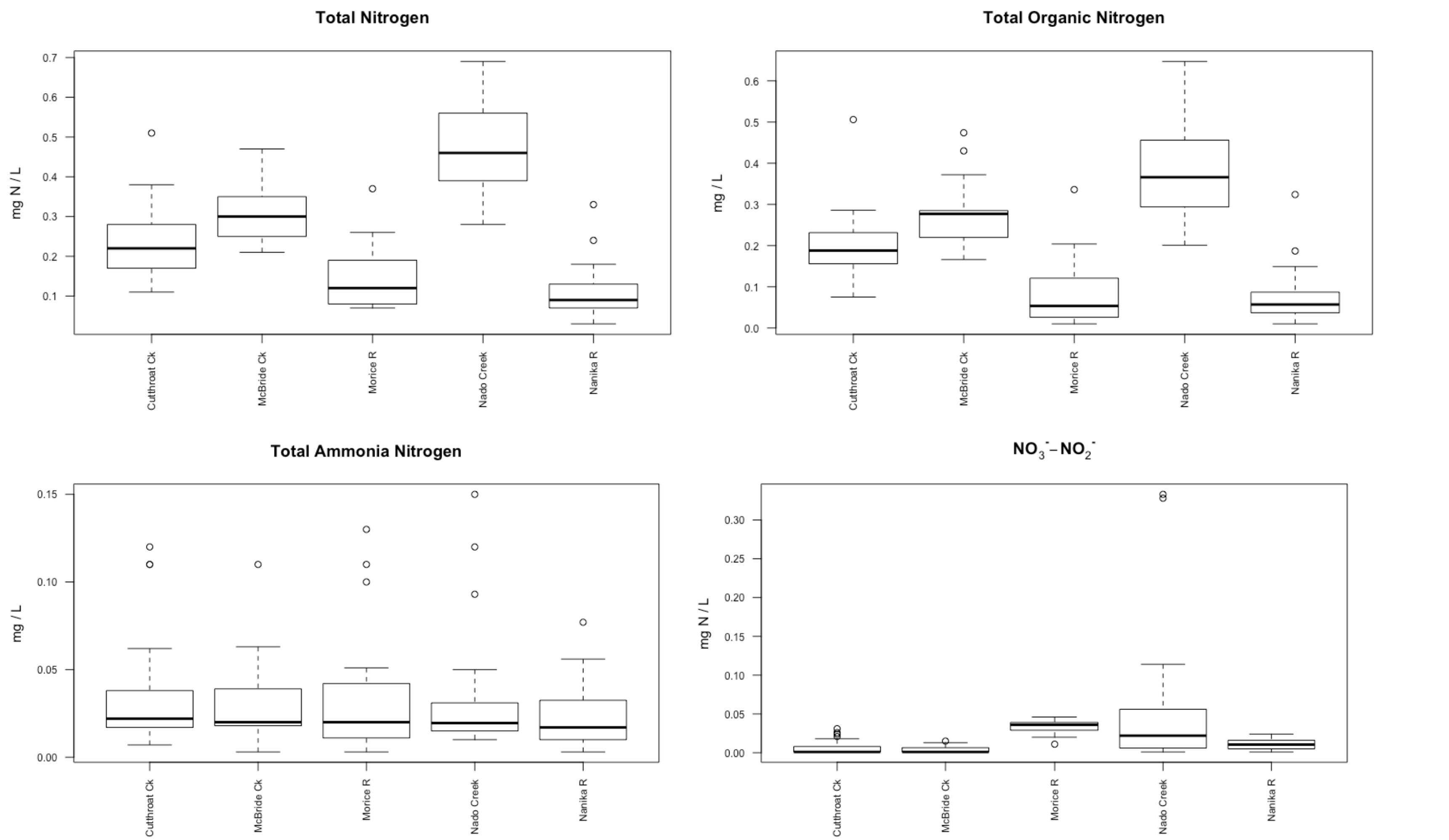


Figure 4b *cont.*: Box and whisker plots for select nutrient and solids data at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

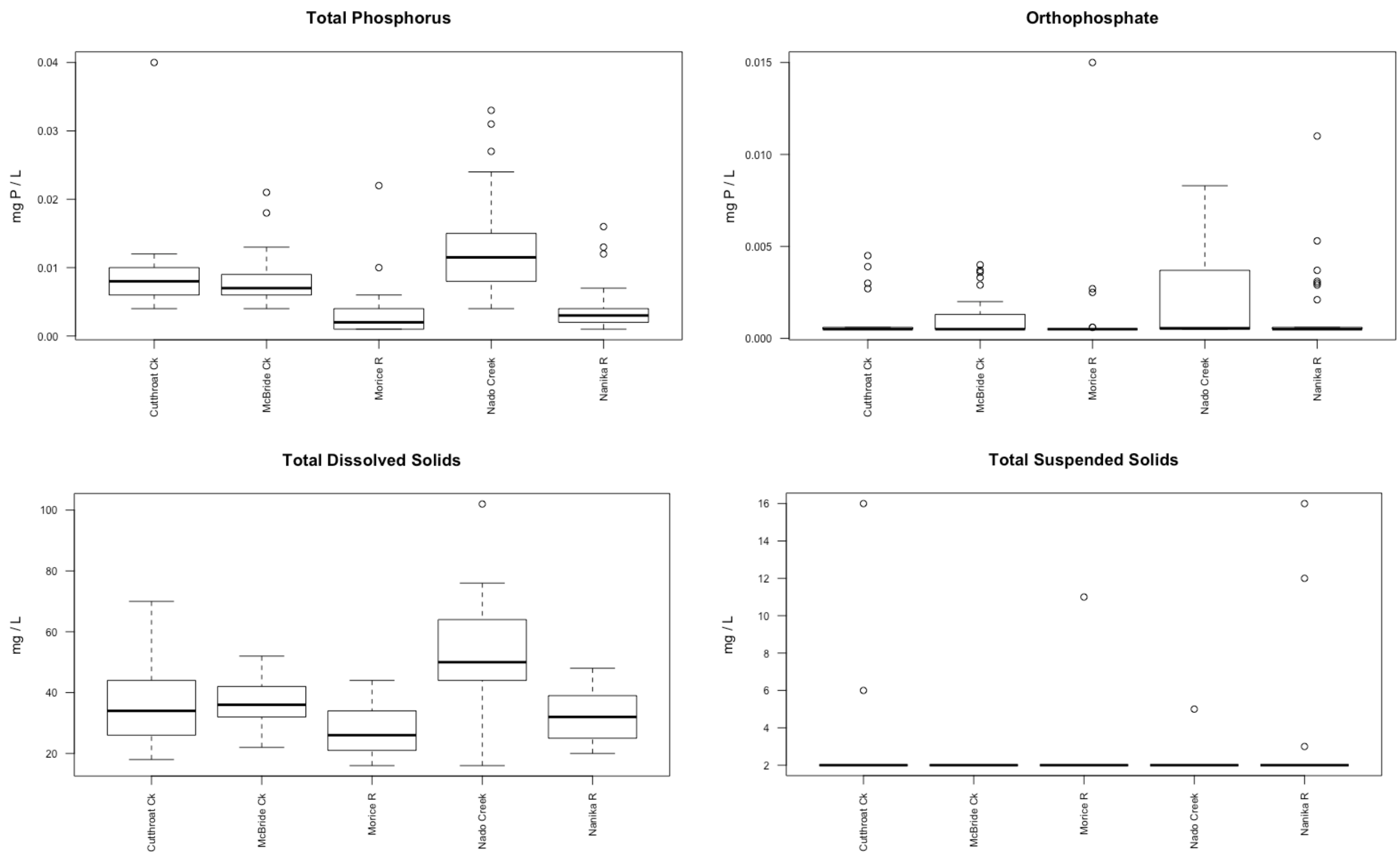


Figure 4b *cont.*: Box and whisker plots for select nutrient and solids data at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

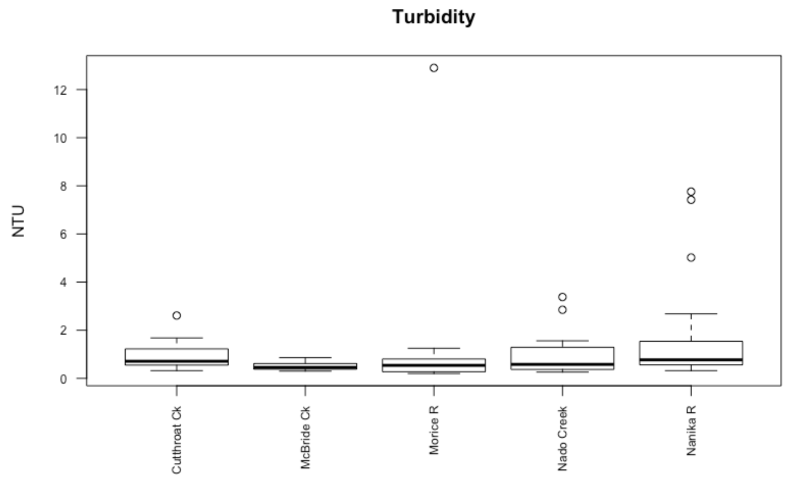


Table 4c: Summary statistics for select dissolved metals data collected at MWMT sites from 2015-2017

	Dissolved	Al µg/L	As µg/L	Cd µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Pb µg/L	Mn µg/L	Ni µg/L	Zn µg/L
All MWMT Sites	Count	130	130	130	130	130	130	130	130	130	130	130
	Mean	66.29	0.177	0.0063	0.0315	0.14	0.919	127.5	0.0174	7.780	0.264	0.70
	Med	48.65	0.160	0.0025	0.0200	0.05	0.722	82.0	0.0140	2.430	0.155	0.57
	Min	5.88	0.056	0.0025	0.0025	0.05	0.261	3.7	0.0025	0.210	0.031	0.05
	Max	343.00	0.376	0.0200	0.4670	0.51	2.870	1170.0	0.0659	226.000	1.060	4.10
	Std	65.59	0.076	0.0054	0.0481	0.11	0.573	156.1	0.0135	22.725	0.264	0.57
	SE	5.75	0.007	0.0005	0.0042	0.01	0.050	13.7	0.0012	1.993	0.023	0.05
	95 CI	11.27	0.013	0.0009	0.0083	0.02	0.098	26.8	0.0023	3.906	0.045	0.10
	+95 CI	77.56	0.190	0.0072	0.0397	0.16	1.017	154.4	0.0197	11.687	0.309	0.79
	-95 CI	55.01	0.164	0.0054	0.0232	0.12	0.820	100.7	0.0151	3.874	0.219	0.60
Nado Creek (E260429)	Count	21	21	21	21	21	21	21	21	21	21	21
	Mean	162.63	0.172	0.0031	0.0528	0.30	0.918	142.4	0.0179	2.735	0.824	0.55
	Med	125.00	0.167	0.0025	0.0500	0.30	0.906	146.0	0.0150	2.400	0.825	0.48
	Min	61.20	0.134	0.0025	0.0310	0.16	0.572	35.6	0.0025	0.615	0.632	0.31
	Max	343.00	0.241	0.0070	0.0937	0.50	1.390	283.0	0.0410	9.560	1.060	1.08
	Std	92.40	0.030	0.0014	0.0165	0.10	0.240	71.2	0.0117	1.829	0.124	0.21
	SE	20.16	0.006	0.0003	0.0036	0.02	0.052	15.5	0.0025	0.399	0.027	0.05
	95 CI	39.52	0.013	0.0006	0.0070	0.04	0.103	30.4	0.0050	0.782	0.053	0.09
	+95 CI	202.15	0.185	0.0036	0.0598	0.34	1.020	172.9	0.0229	3.517	0.877	0.64
	-95 CI	123.11	0.159	0.0025	0.0457	0.26	0.815	112.0	0.0129	1.952	0.772	0.46
Nanika River (E272557)	Count	30	30	30	30	30	30	30	30	30	30	30
	Mean	23.65	0.141	0.0151	0.0123	0.07	1.791	33.1	0.0160	3.075	0.150	0.86
	Med	20.45	0.142	0.0150	0.0103	0.05	1.730	28.3	0.0140	2.105	0.146	0.81
	Min	10.30	0.106	0.0100	0.0025	0.05	1.000	9.9	0.0025	0.832	0.093	0.45
	Max	52.30	0.232	0.0200	0.0337	0.51	2.870	72.1	0.0659	7.300	0.269	1.85
	Std	11.29	0.027	0.0024	0.0074	0.08	0.494	19.2	0.0129	1.883	0.036	0.30
	SE	2.06	0.005	0.0004	0.0013	0.02	0.090	3.5	0.0023	0.344	0.007	0.06
	95 CI	4.04	0.010	0.0009	0.0026	0.03	0.177	6.9	0.0046	0.674	0.013	0.11
	+95 CI	27.69	0.150	0.0160	0.0149	0.10	1.968	39.9	0.0206	3.749	0.163	0.97
	-95 CI	19.61	0.131	0.0143	0.0097	0.04	1.614	26.2	0.0114	2.401	0.138	0.75

Table 4c *cont.*: Summary statistics for select dissolved metals data collected at MWMT sites from 2015-2017

	Dissolved	Al	As	Cd	Co	Cr	Cu	Fe	Pb	Mn	Ni	Zn
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Morice River (E272549)	Count	23	23	23	23	23	23	23	23	23	23	23
	Mean	14.45	0.078	0.0036	0.0038	0.06	0.653	10.7	0.0052	0.528	0.081	0.24
	Med	11.20	0.074	0.0025	0.0025	0.05	0.626	8.8	0.0025	0.443	0.077	0.19
	Min	5.88	0.056	0.0025	0.0025	0.05	0.484	3.7	0.0025	0.210	0.031	0.05
	Max	41.60	0.106	0.0090	0.0109	0.33	0.886	48.2	0.0142	1.820	0.121	0.59
	Std	8.56	0.013	0.0020	0.0027	0.06	0.123	9.9	0.0036	0.359	0.023	0.15
	SE	1.78	0.003	0.0004	0.0006	0.01	0.026	2.1	0.0008	0.075	0.005	0.03
	95 CI	3.50	0.005	0.0008	0.0011	0.02	0.050	4.0	0.0015	0.147	0.009	0.06
	+95 CI	17.95	0.083	0.0044	0.0049	0.09	0.703	14.7	0.0067	0.675	0.090	0.30
	-95 CI	10.95	0.072	0.0028	0.0027	0.04	0.602	6.7	0.0038	0.381	0.072	0.18
McBride Creek (E260496)	Count	28	28	28	28	28	28	28	28	28	28	28
	Mean	87.84	0.274	0.0031	0.0211	0.22	0.706	159.8	0.0129	3.347	0.284	0.49
	Med	86.80	0.280	0.0025	0.0200	0.21	0.699	143.0	0.0125	3.285	0.286	0.44
	Min	44.60	0.180	0.0025	0.0150	0.15	0.493	62.1	0.0025	0.869	0.192	0.19
	Max	161.00	0.376	0.0110	0.0330	0.30	1.030	298.0	0.0250	10.900	0.367	1.31
	Std	29.08	0.048	0.0020	0.0048	0.03	0.137	70.7	0.0056	1.830	0.053	0.24
	SE	5.50	0.009	0.0004	0.0009	0.01	0.026	13.4	0.0011	0.346	0.010	0.05
	95 CI	10.77	0.018	0.0007	0.0018	0.01	0.051	26.2	0.0021	0.678	0.020	0.09
	+95 CI	98.61	0.292	0.0039	0.0229	0.23	0.757	186.0	0.0149	4.025	0.303	0.58
	-95 CI	77.07	0.256	0.0024	0.0193	0.21	0.655	133.6	0.0108	2.670	0.264	0.40
Cutthroat Creek (E272556)	Count	28	28	28	28	28	28	28	28	28	28	28
	Mean	60.75	0.205	0.0047	0.0692	0.06	0.415	281.2	0.0330	26.996	0.096	1.21
	Med	56.20	0.195	0.0025	0.0375	0.05	0.399	177.5	0.0310	12.300	0.090	0.89
	Min	17.90	0.125	0.0025	0.0190	0.05	0.261	63.6	0.0140	0.775	0.048	0.47
	Max	138.00	0.337	0.0140	0.4670	0.13	0.771	1170.0	0.0570	226.000	0.185	4.10
	Std	33.83	0.058	0.0032	0.0882	0.03	0.116	244.8	0.0120	44.330	0.036	0.88
	SE	6.39	0.011	0.0006	0.0167	0.01	0.022	46.3	0.0023	8.378	0.007	0.17
	95 CI	12.53	0.022	0.0012	0.0327	0.01	0.043	90.7	0.0044	16.420	0.013	0.33
	+95 CI	73.28	0.226	0.0059	0.1018	0.08	0.458	371.9	0.0374	43.416	0.109	1.54
	-95 CI	48.22	0.183	0.0035	0.0365	0.05	0.372	190.5	0.0285	10.577	0.083	0.89

Figure 4c: Box and whisker plots for select dissolved metals data collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

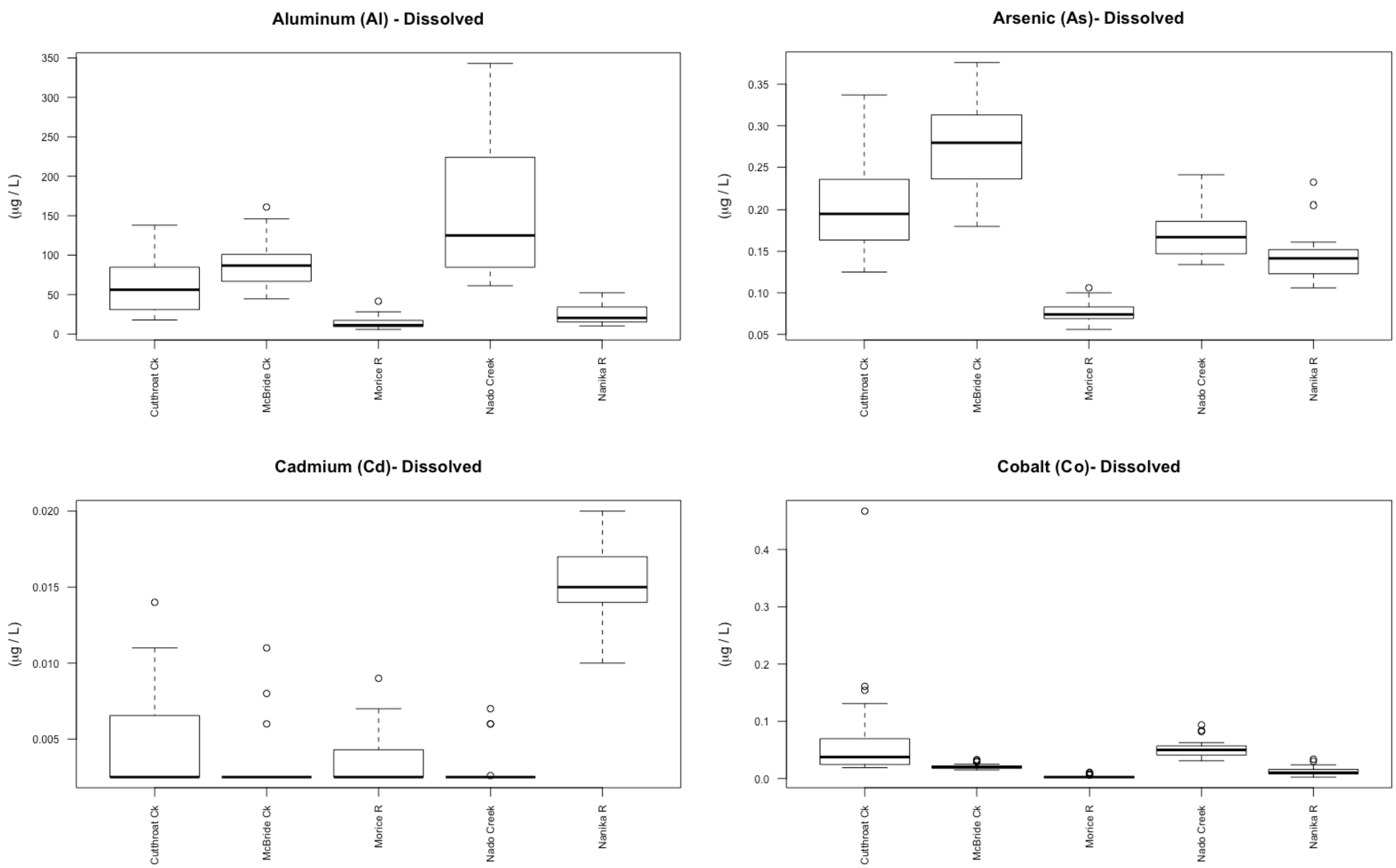


Figure 4c *cont*: Box and whisker plots for select dissolved metals data collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

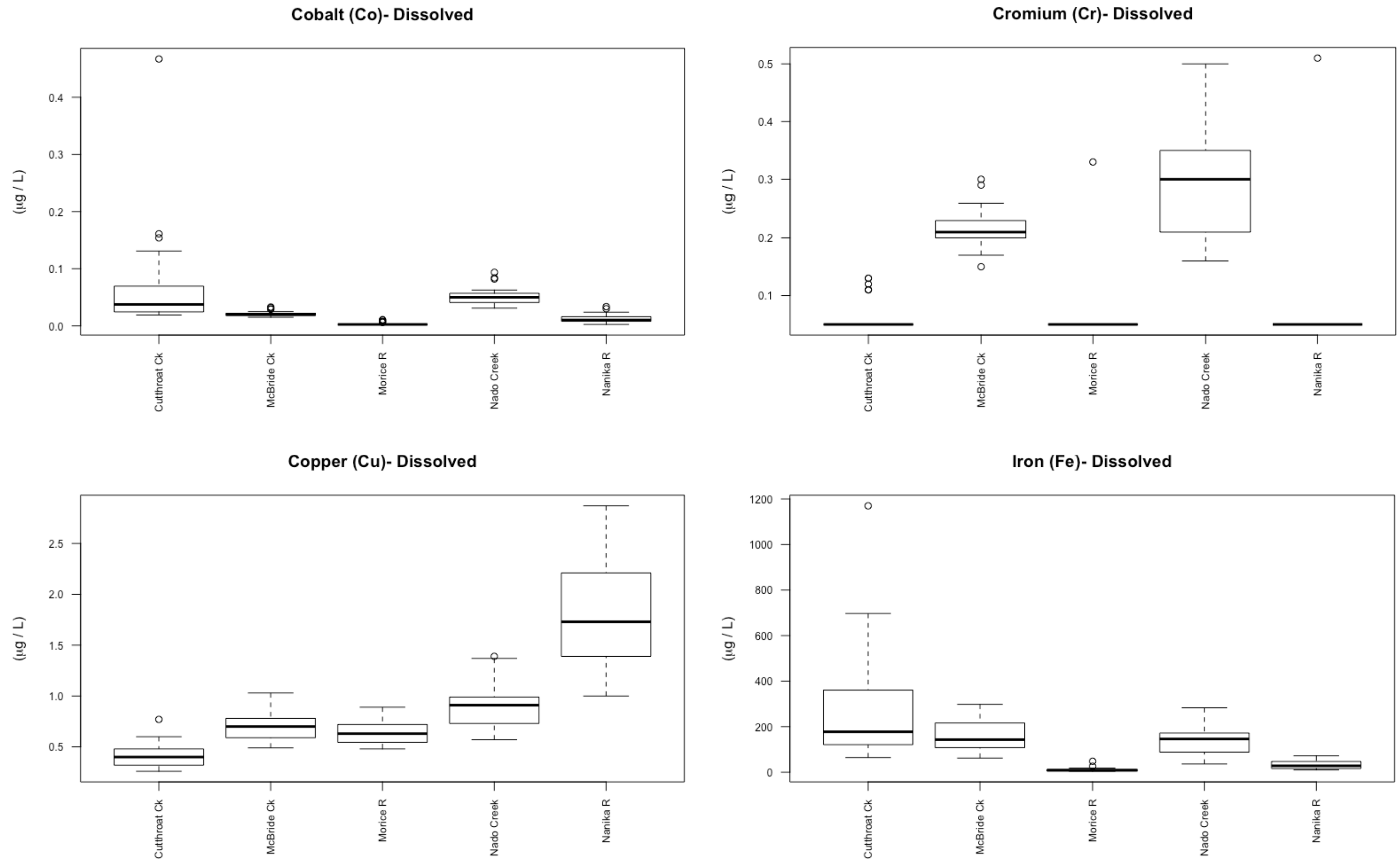


Figure 4c *cont*: Box and whisker plots for select dissolved metals data collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

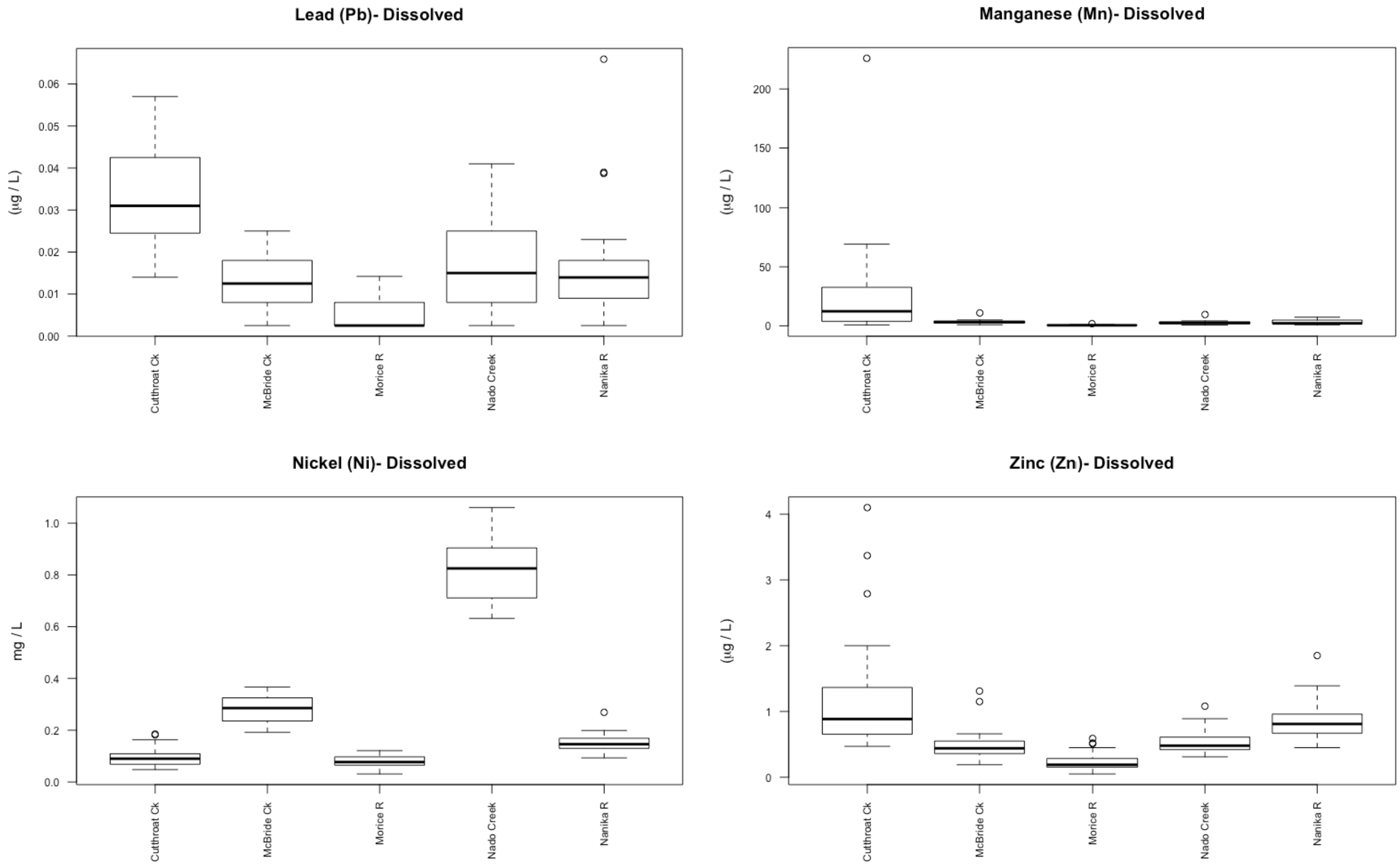


Table 4d: Summary statistics for select total metals collected at MWMT sites from 2015-2017

	Total	Al µg/L	As µg/L	Cd µg/L	Co µg/L	Cr µg/L	Cu µg/L	Fe µg/L	Pb µg/L	Mn µg/L	Ni µg/L	Se µg/L	Zn µg/L
All MWMT Sites	Count	135	135	135	135	135	135	135	134	135	135	135	135
	Mean	109.53	0.208	0.0084	0.0579	0.18	1.215	200.4	0.0481	11.684	0.316	0.027	1.38
	Med	79.60	0.191	0.0025	0.0360	0.13	0.817	140.0	0.0355	5.890	0.210	0.020	1.00
	Min	7.68	0.050	0.0025	0.0025	0.05	0.284	5.1	0.0025	0.313	0.050	0.020	0.14
	Max	1060.00	1.250	0.0613	0.6000	0.90	7.890	1270.0	0.276	220.000	1.770	0.076	14.70
	Std	119.43	0.121	0.0090	0.0706	0.17	1.052	209.5	0.047	22.667	0.311	0.014	1.69
	SE	10.28	0.010	0.0008	0.0061	0.01	0.091	18.0	0.0041	1.951	0.027	0.001	0.15
	95 CI	20.15	0.020	0.0015	0.0119	0.03	0.178	35.3	0.0081	3.824	0.053	0.002	0.28
	+95 CI	129.68	0.229	0.0099	0.0698	0.20	1.392	235.8	0.056	15.507	0.369	0.029	1.66
	-95 CI	89.38	0.188	0.0069	0.0460	0.15	1.037	165.1	0.040	7.860	0.264	0.024	1.09
Nado Creek (E260429)	Count	22	22	22	22	22	22	22	22	22	22	22	22
	Mean	213.41	0.187	0.0040	0.0685	0.39	1.051	195.2	0.0352	4.410	0.874	0.046	1.28
	Med	173.00	0.177	0.0025	0.0540	0.37	0.990	176.0	0.0300	3.690	0.863	0.050	1.00
	Min	76.00	0.132	0.0025	0.0350	0.19	0.633	51.3	0.0025	2.100	0.644	0.020	0.31
	Max	534.00	0.275	0.0130	0.1500	0.90	2.150	457.0	0.1140	10.400	1.200	0.076	4.50
	Std	132.30	0.040	0.0030	0.0316	0.18	0.364	115.9	0.0278	2.431	0.157	0.018	1.05
	SE	28.21	0.009	0.0006	0.0067	0.04	0.078	24.7	0.0059	0.518	0.033	0.004	0.22
	95 CI	55.28	0.017	0.0013	0.0132	0.07	0.152	48.4	0.0116	1.016	0.066	0.008	0.44
	+95 CI	268.70	0.204	0.0052	0.0818	0.46	1.204	243.6	0.0468	5.426	0.940	0.054	1.72
	-95 CI	158.13	0.170	0.0027	0.0553	0.31	0.899	146.7	0.0236	3.394	0.808	0.038	0.84
Nanika River (E272557)	Count	31	31	31	31	31	31	31	30	31	31	31	31
	Mean	119.09	0.224	0.0218	0.0814	0.11	2.737	138.7	0.0863	11.163	0.284	0.025	1.87
	Med	68.90	0.186	0.0180	0.0510	0.05	2.320	91.7	0.0585	8.040	0.200	0.020	1.72
	Min	21.80	0.131	0.0120	0.0160	0.05	1.440	40.7	0.0084	3.470	0.117	0.020	0.89
	Max	1060.00	1.250	0.0613	0.6000	0.82	7.890	1070.0	0.2760	56.200	1.770	0.054	8.60
	Std	185.56	0.195	0.0093	0.1044	0.15	1.247	184.0	0.0716	9.901	0.325	0.011	1.34
	SE	33.33	0.035	0.0017	0.0187	0.03	0.224	33.0	0.0131	1.778	0.058	0.002	0.24
	95 CI	65.32	0.069	0.0033	0.0367	0.05	0.439	64.8	0.0256	3.485	0.114	0.004	0.47
	+95 CI	184.41	0.292	0.0251	0.1181	0.16	3.176	203.5	0.1119	14.648	0.398	0.029	2.34
	-95 CI	53.77	0.155	0.0186	0.0447	0.05	2.298	74.0	0.0607	7.677	0.169	0.022	1.40

Table 4d *cont.*: Summary statistics for select total metals collected at MWMT sites from 2015-2017

	Total	Al	As	Cd	Co	Cr	Cu	Fe	Pb	Mn	Ni	Se	Zn
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
Morice River (E272549)	Count	24	24	24	24	24	24	24	24	24	24	24	24
	Mean	42.28	0.089	0.0048	0.0221	0.05	0.806	43.2	0.0280	2.612	0.10	0.020	0.46
	Med	35.15	0.089	0.0043	0.0225	0.05	0.824	31.5	0.0198	1.975	0.10	0.020	0.38
	Min	7.68	0.050	0.0025	0.0025	0.05	0.495	5.1	0.0025	0.313	0.06	0.020	0.14
	Max	115.00	0.116	0.0100	0.0760	0.14	1.210	154.0	0.1010	9.660	0.19	0.020	1.90
	Std	27.50	0.019	0.0025	0.0174	0.02	0.206	34.2	0.0246	2.239	0.03	0.000	0.36
	SE	5.61	0.004	0.0005	0.0035	0.00	0.042	7.0	0.0050	0.457	0.01	0.000	0.07
	95 CI	11.00	0.008	0.0010	0.0069	0.01	0.082	13.7	0.0098	0.896	0.01	0.000	0.15
	+95 CI	53.28	0.097	0.0059	0.0290	0.06	0.888	56.8	0.0378	3.508	0.11	0.020	0.61
	-95 CI	31.27	0.082	0.0038	0.0151	0.05	0.724	29.5	0.0182	1.717	0.09	0.020	0.32
McBride Creek (E260496)	Count	29	29	29	29	29	29	29	29	29	29	29	29
	Mean	103.22	0.290	0.0031	0.0264	0.26	0.760	193.7	0.0200	6.013	0.31	0.023	0.77
	Med	98.80	0.280	0.0025	0.0270	0.23	0.755	173.0	0.0160	5.360	0.31	0.020	0.48
	Min	57.20	0.202	0.0025	0.0170	0.17	0.555	85.7	0.0090	2.270	0.22	0.020	0.27
	Max	187.00	0.417	0.0100	0.0360	0.53	1.000	346.0	0.0500	12.300	0.40	0.071	3.20
	Std	30.72	0.054	0.0020	0.0050	0.09	0.111	81.3	0.0109	2.231	0.05	0.011	0.64
	SE	5.70	0.010	0.0004	0.0009	0.02	0.021	15.1	0.0020	0.414	0.01	0.002	0.12
	95 CI	11.18	0.020	0.0007	0.0018	0.03	0.040	29.6	0.0040	0.812	0.02	0.004	0.23
	+95 CI	114.40	0.310	0.0039	0.0282	0.30	0.801	223.3	0.0239	6.825	0.32	0.027	1.00
	-95 CI	92.04	0.271	0.0024	0.0246	0.23	0.720	164.1	0.0160	5.201	0.29	0.019	0.53
Cutthroat Creek (E272556)	Count	29	29	29	29	29	29	29	29	29	29	29	29
	Mean	82.48	0.225	0.0057	0.0860	0.10	0.505	407.2	0.0632	30.937	0.12	0.022	2.30
	Med	66.30	0.216	0.0025	0.0650	0.05	0.457	307.0	0.0520	19.500	0.10	0.020	1.30
	Min	26.40	0.128	0.0025	0.0240	0.05	0.284	111.0	0.0230	2.520	0.05	0.020	0.51
	Max	343.00	0.371	0.0164	0.4690	0.50	1.000	1270.0	0.1560	220.000	0.28	0.058	14.70
	Std	58.53	0.068	0.0041	0.0866	0.09	0.153	294.0	0.0321	42.552	0.05	0.008	2.85
	SE	10.87	0.013	0.0008	0.0161	0.02	0.028	54.6	0.0060	7.902	0.01	0.001	0.53
	95 CI	21.30	0.025	0.0015	0.0315	0.03	0.056	107.0	0.0117	15.487	0.02	0.003	1.04
	+95 CI	103.78	0.250	0.0071	0.1175	0.14	0.561	514.2	0.0749	46.424	0.14	0.025	3.34
	-95 CI	61.18	0.200	0.0042	0.0545	0.07	0.449	300.2	0.0515	15.450	0.10	0.019	1.27

Figure 4d: Box and whisker plots for select total metals collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

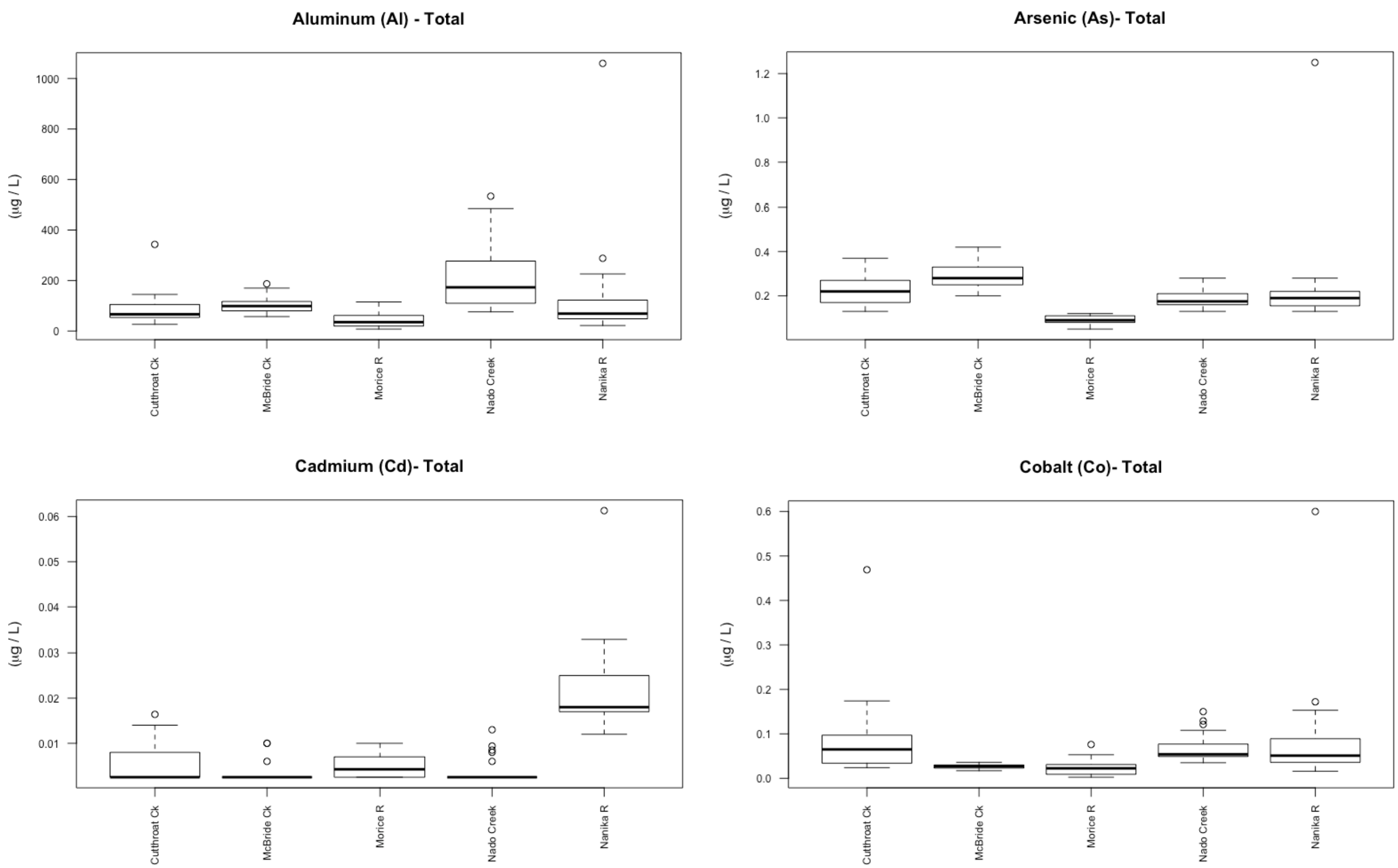


Figure 4d *cont.*: Box and whisker plots for select total metals collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

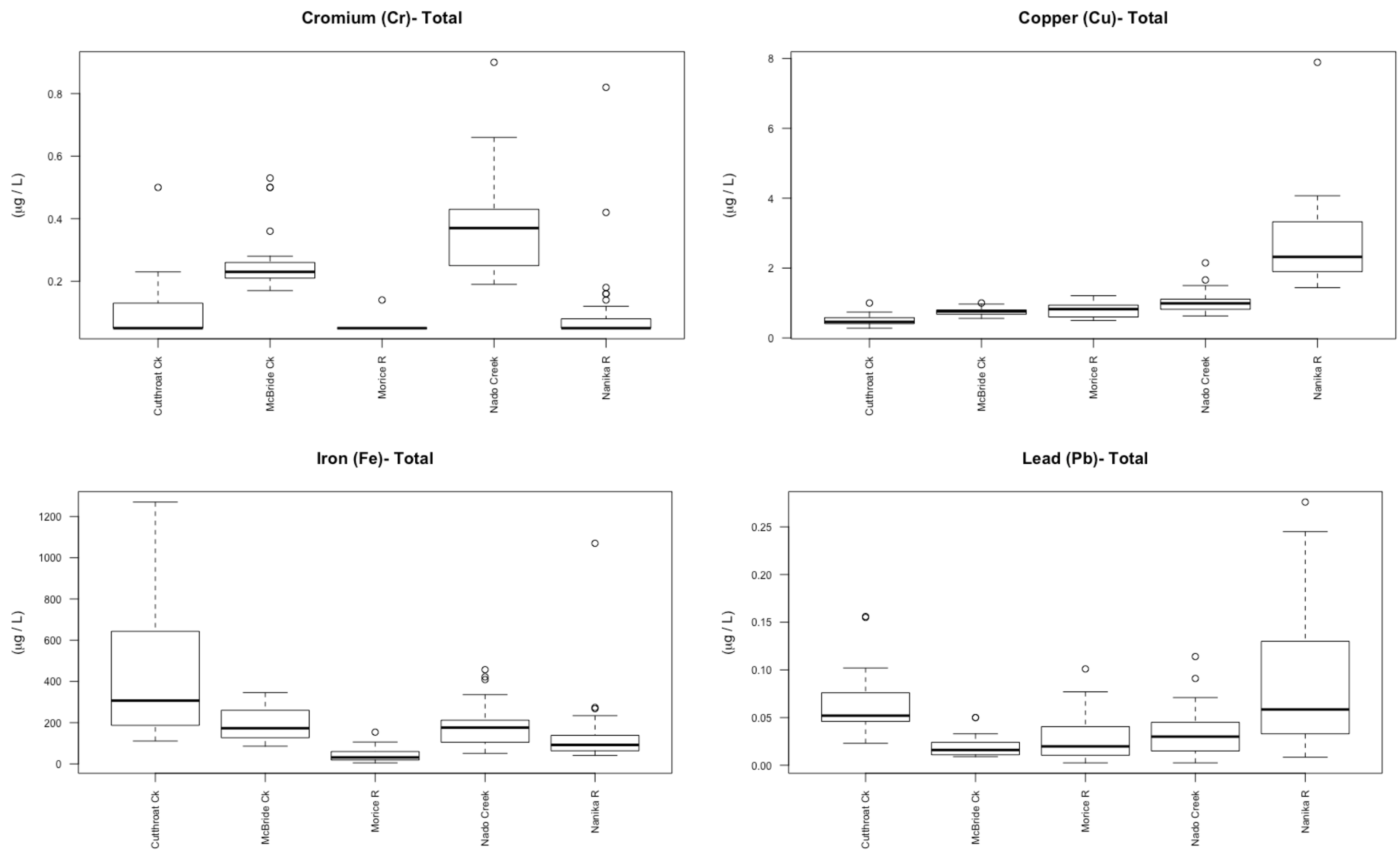


Figure 4d *cont.*: Box and whisker plots for select total metals collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

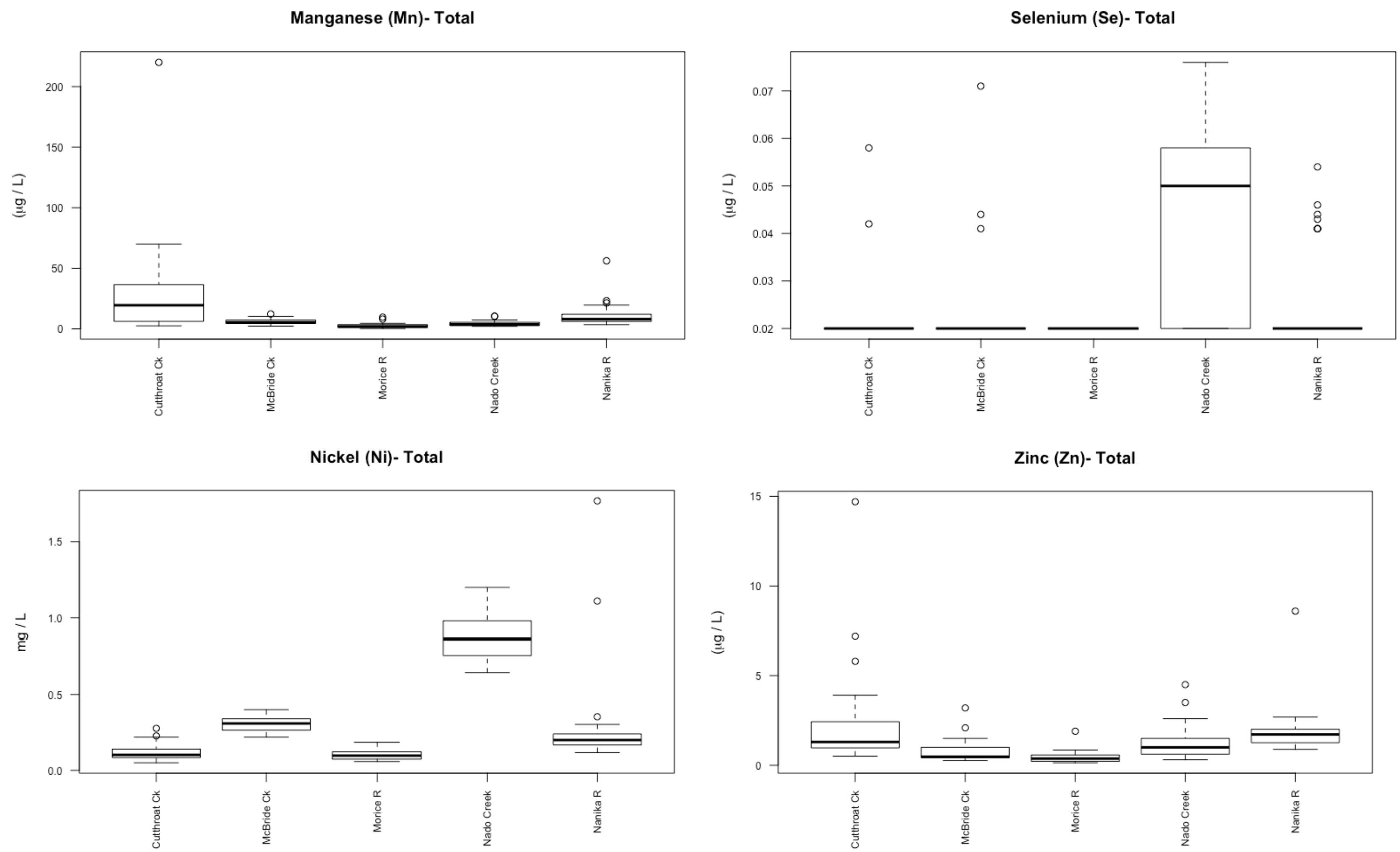


Table 4e: Summary statistics for total and dissolved cations collected at MWMT sites from 2015-2017

		Dissolved				Total			
		Ca	Mg	K	Na	Ca	Mg	K	Ca
		µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
All MWMT Sites	Count	130	130	130	130	135	135	135	135
	Mean	6.407	0.811	0.239	1.276	6.403	0.829	0.249	1.283
	Med	6.485	0.716	0.243	0.897	6.450	0.747	0.250	0.911
	Min	3.240	0.395	0.052	0.579	3.420	0.381	0.059	0.530
	Max	10.700	1.610	0.529	3.010	9.900	1.710	0.543	3.100
	Std	1.364	0.276	0.092	0.673	1.324	0.288	0.090	0.685
	SE	0.120	0.024	0.008	0.059	0.114	0.025	0.008	0.059
	95 CI	0.234	0.047	0.016	0.116	0.223	0.049	0.015	0.116
	+95 CI	6.641	0.859	0.255	1.391	6.627	0.877	0.264	1.399
	-95 CI	6.172	0.764	0.223	1.160	6.180	0.780	0.234	1.168
Nado Creek (E260429)	Count	21	21	21	21	22	22	22	22
	Mean	6.751	1.227	0.323	2.216	6.875	1.247	0.319	2.203
	Med	6.950	1.230	0.329	2.240	6.900	1.195	0.308	2.140
	Min	3.240	0.828	0.228	1.570	3.420	0.760	0.204	1.460
	Max	9.360	1.610	0.412	3.010	8.860	1.710	0.427	3.100
	Std	1.337	0.219	0.053	0.393	1.406	0.259	0.061	0.467
	SE	0.292	0.048	0.012	0.086	0.300	0.055	0.013	0.100
	95 CI	0.572	0.094	0.023	0.168	0.587	0.108	0.025	0.195
	+95 CI	7.323	1.321	0.346	2.384	7.463	1.355	0.345	2.398
	-95 CI	6.179	1.133	0.301	2.048	6.288	1.138	0.294	2.008
Nanika River (E272557)	Count	30	30	30	30	31	31	31	31
	Mean	6.995	0.697	0.163	0.718	7.012	0.736	0.190	0.731
	Med	7.040	0.696	0.161	0.699	7.080	0.730	0.176	0.721
	Min	5.930	0.568	0.129	0.579	6.110	0.596	0.132	0.548
	Max	8.130	0.878	0.232	0.952	8.130	1.030	0.420	1.100
	Std	0.530	0.062	0.020	0.102	0.566	0.080	0.056	0.110
	SE	0.097	0.011	0.004	0.019	0.102	0.014	0.010	0.020
	95 CI	0.190	0.022	0.007	0.036	0.199	0.028	0.020	0.039
	+95 CI	7.185	0.719	0.170	0.755	7.211	0.764	0.209	0.770
	-95 CI	6.805	0.674	0.156	0.682	6.813	0.707	0.170	0.692

Table 4e *cont.:* Summary statistics for total and dissolved cations collected at MWMT sites from 2015-2017

		Dissolved				Total			
		Ca µg/L	Mg µg/L	K µg/L	Na µg/L	Ca µg/L	Mg µg/L	K µg/L	Ca µg/L
Morice River (E272549)	Count	23	23	23	23	24	24	24	24
	Mean	6.502	0.543	0.261	0.681	6.489	0.543	0.258	0.670
	Med	6.410	0.530	0.264	0.667	6.465	0.546	0.252	0.658
	Min	6.130	0.504	0.227	0.600	5.270	0.440	0.221	0.530
	Max	7.840	0.649	0.286	0.853	6.830	0.631	0.300	0.844
	Std	0.384	0.039	0.017	0.069	0.328	0.038	0.018	0.064
	SE	0.080	0.008	0.004	0.014	0.067	0.008	0.004	0.013
	95 CI	0.157	0.016	0.007	0.028	0.131	0.015	0.007	0.026
	+95 CI	6.659	0.559	0.268	0.709	6.620	0.558	0.265	0.696
	-95 CI	6.345	0.527	0.254	0.653	6.358	0.527	0.250	0.645
McBride Creek (E260496)	Count	28	28	28	28	29	29	29	29
	Mean	4.765	1.034	0.336	1.979	4.745	1.047	0.335	1.997
	Med	4.855	1.035	0.329	1.975	4.820	1.030	0.316	2.010
	Min	3.710	0.921	0.270	1.680	3.920	0.858	0.250	1.620
	Max	5.390	1.160	0.529	2.330	5.280	1.480	0.543	2.890
	Std	0.416	0.065	0.053	0.165	0.403	0.120	0.068	0.244
	SE	0.079	0.012	0.010	0.031	0.075	0.022	0.013	0.045
	95 CI	0.154	0.024	0.020	0.061	0.147	0.044	0.025	0.089
	+95 CI	4.919	1.059	0.355	2.040	4.892	1.090	0.360	2.085
	-95 CI	4.611	1.010	0.316	1.918	4.598	1.003	0.311	1.908
Cutthroat Creek (E272556)	Count	28	28	28	28	29	29	29	29
	Mean	7.083	0.620	0.141	0.952	6.981	0.630	0.164	0.970
	Med	6.925	0.652	0.129	0.890	7.120	0.660	0.167	0.920
	Min	4.460	0.395	0.052	0.589	4.430	0.381	0.059	0.585
	Max	10.700	0.898	0.243	1.420	9.900	0.862	0.250	1.420
	Std	1.792	0.132	0.055	0.225	1.592	0.132	0.071	0.231
	SE	0.339	0.025	0.010	0.042	0.296	0.025	0.013	0.043
	95 CI	0.664	0.049	0.020	0.083	0.579	0.048	0.026	0.084
	+95 CI	7.746	0.669	0.162	1.035	7.560	0.678	0.190	1.054
	-95 CI	6.419	0.571	0.121	0.869	6.402	0.582	0.139	0.886

Figure 4e: Box and whisker plots for total cations collected at each MWMT site from 2015-2017. Boxes represent the 25th and 75th percentiles and the middle band represents the 50th percentile (median).

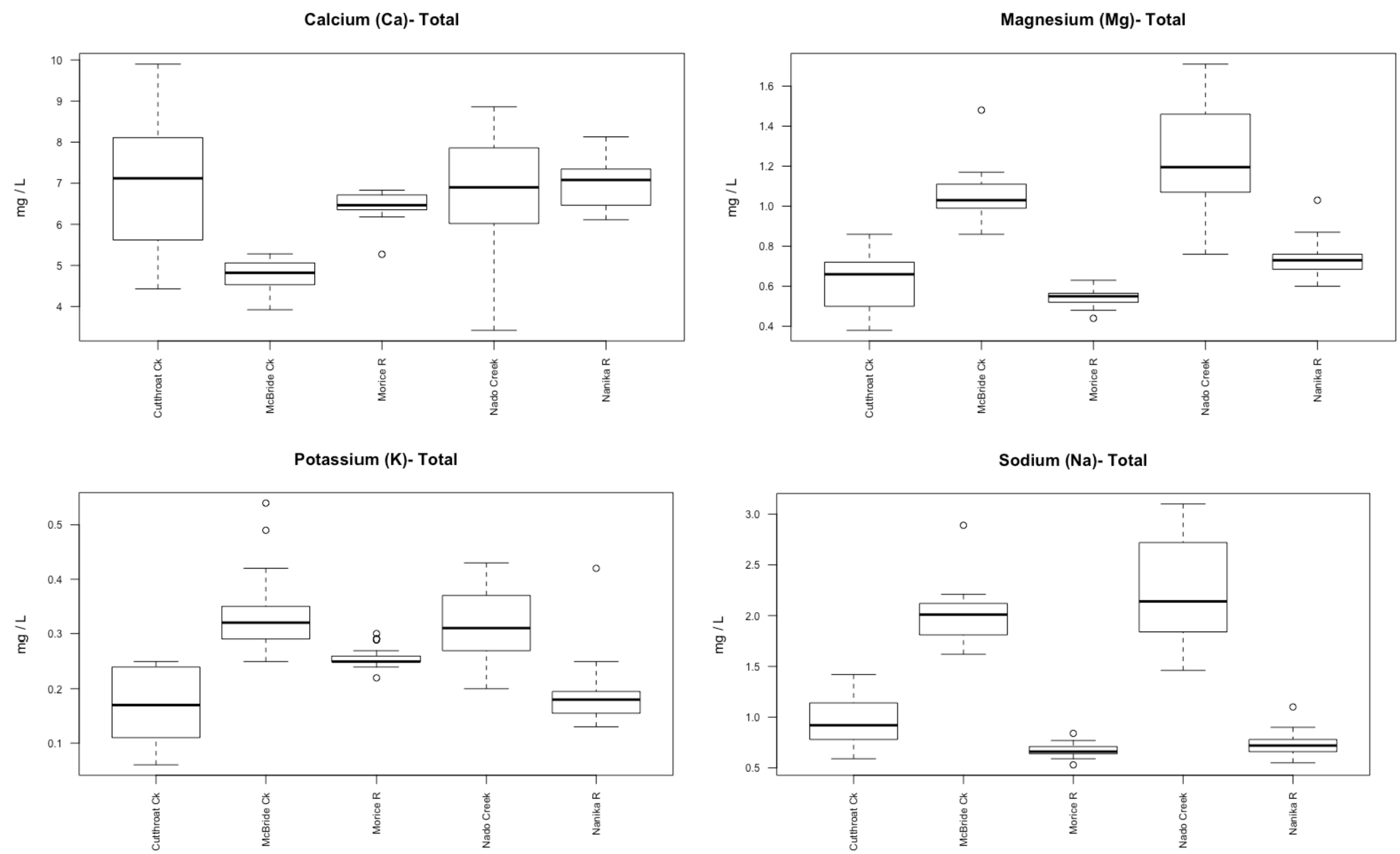


Figure 5: Time series for physicochemical constituents collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017. The top panel represents mean daily discharge at Water Survey of Canada hydrometric station 08ED001 (Nanika River at outlet Kidprice Lake). Dotted lines represent thresholds listed under the B.C. Water Quality Guidelines for the protection of aquatic life.

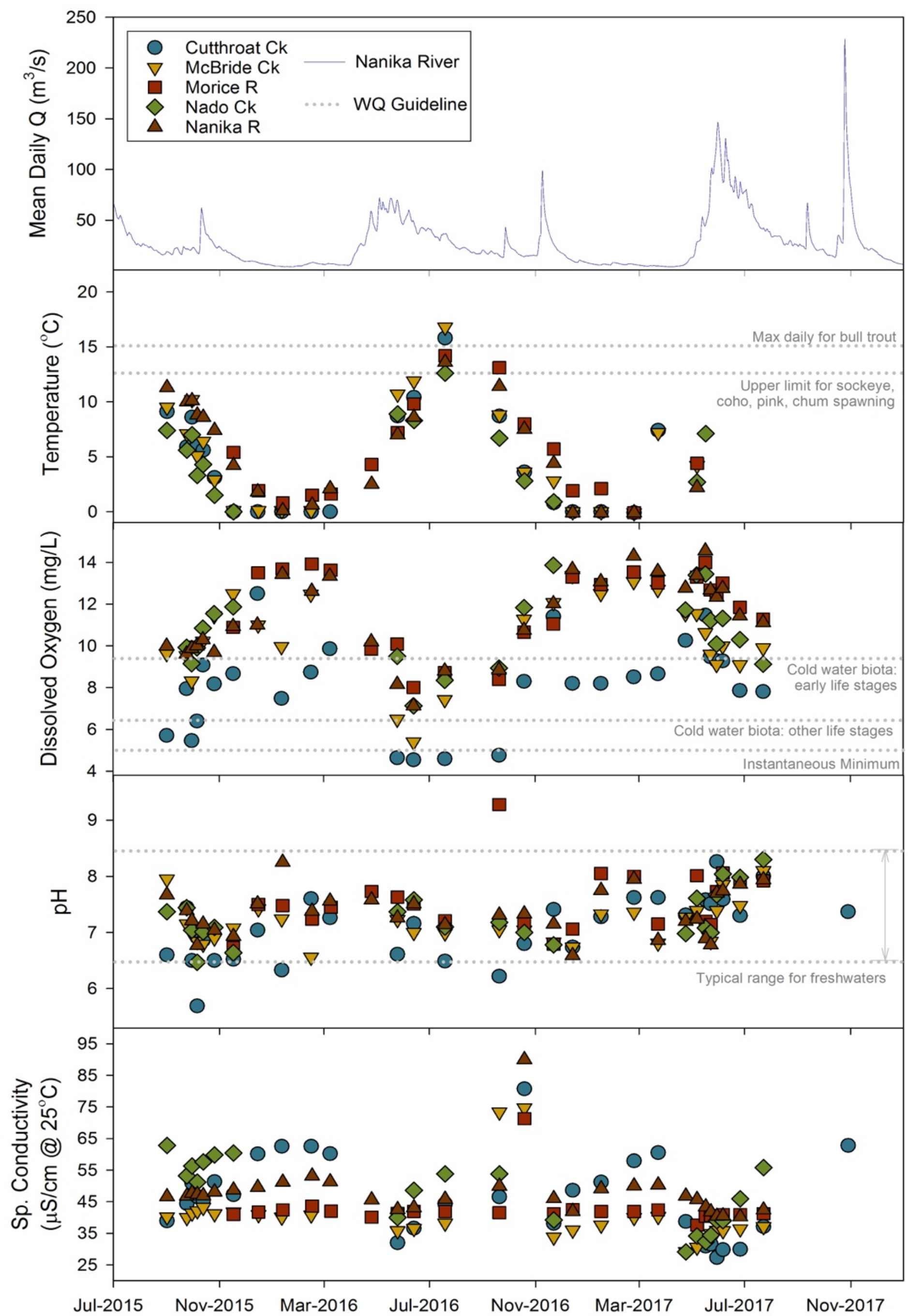


Figure 6: Time series for anions, carbon and turbidity constituents collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017. The top panel represents mean daily discharge at Water Survey of Canada hydrometric station 08ED001 (Nanika River at outlet Kidprice Lake). Dotted lines represent thresholds listed under the B.C. Water Quality Guidelines for the protection of aquatic life.

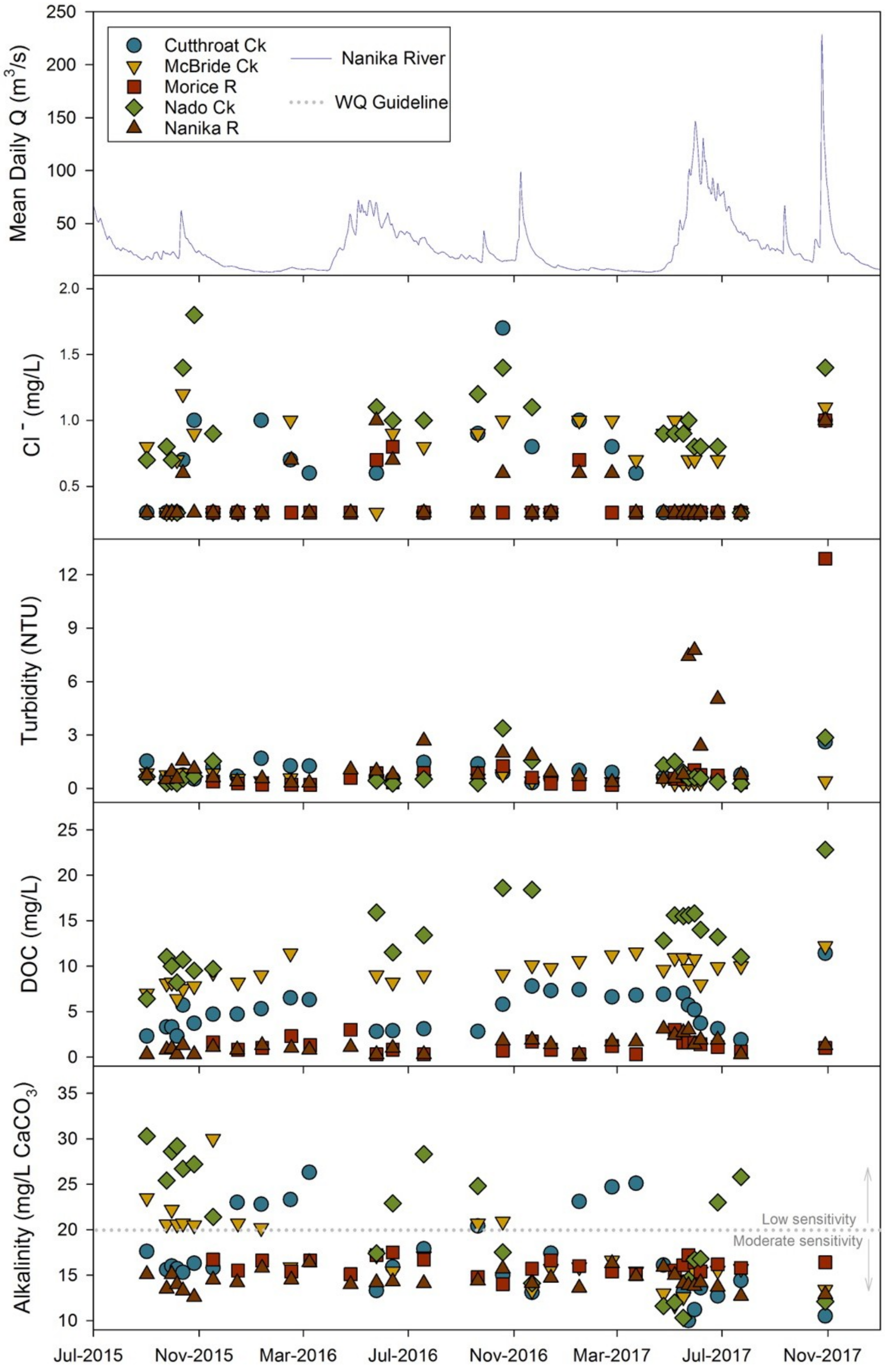


Figure 7: Time series for nitrogen constituents collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017. The top panel represents mean daily discharge at Water Survey of Canada hydrometric station 08ED001 (Nanika River at outlet Kidprice Lake). Dotted lines represent thresholds listed under the B.C. Water Quality Guidelines for the protection of aquatic life.

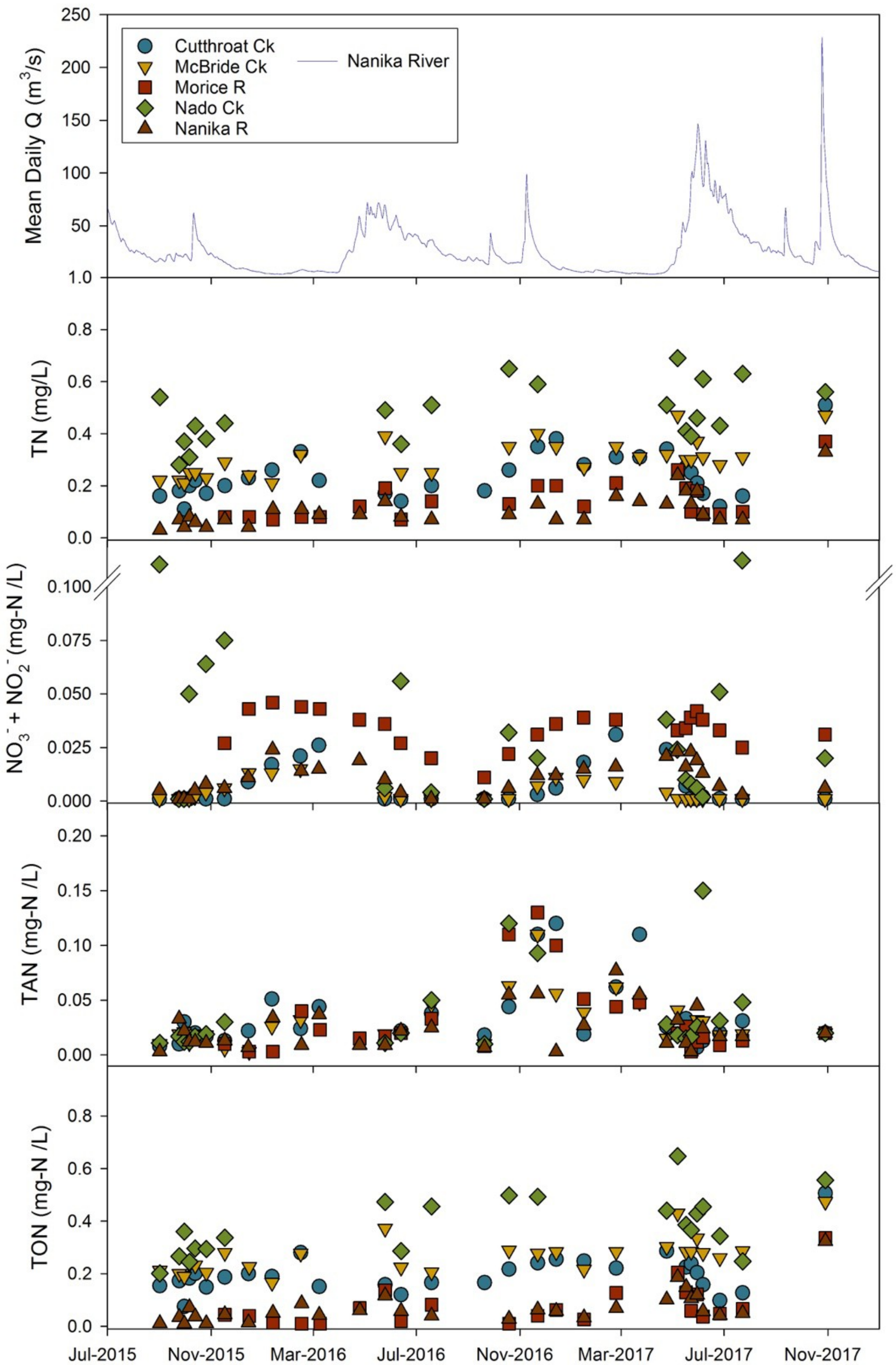


Figure 8: Time series for phosphorus and solids constituents collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017. The top panel represents mean daily discharge at Water Survey of Canada hydrometric station 08ED001 (Nanika River at outlet Kidprice Lake). Dotted lines represent thresholds listed under the B.C. Water Quality Guidelines for the protection of aquatic life.

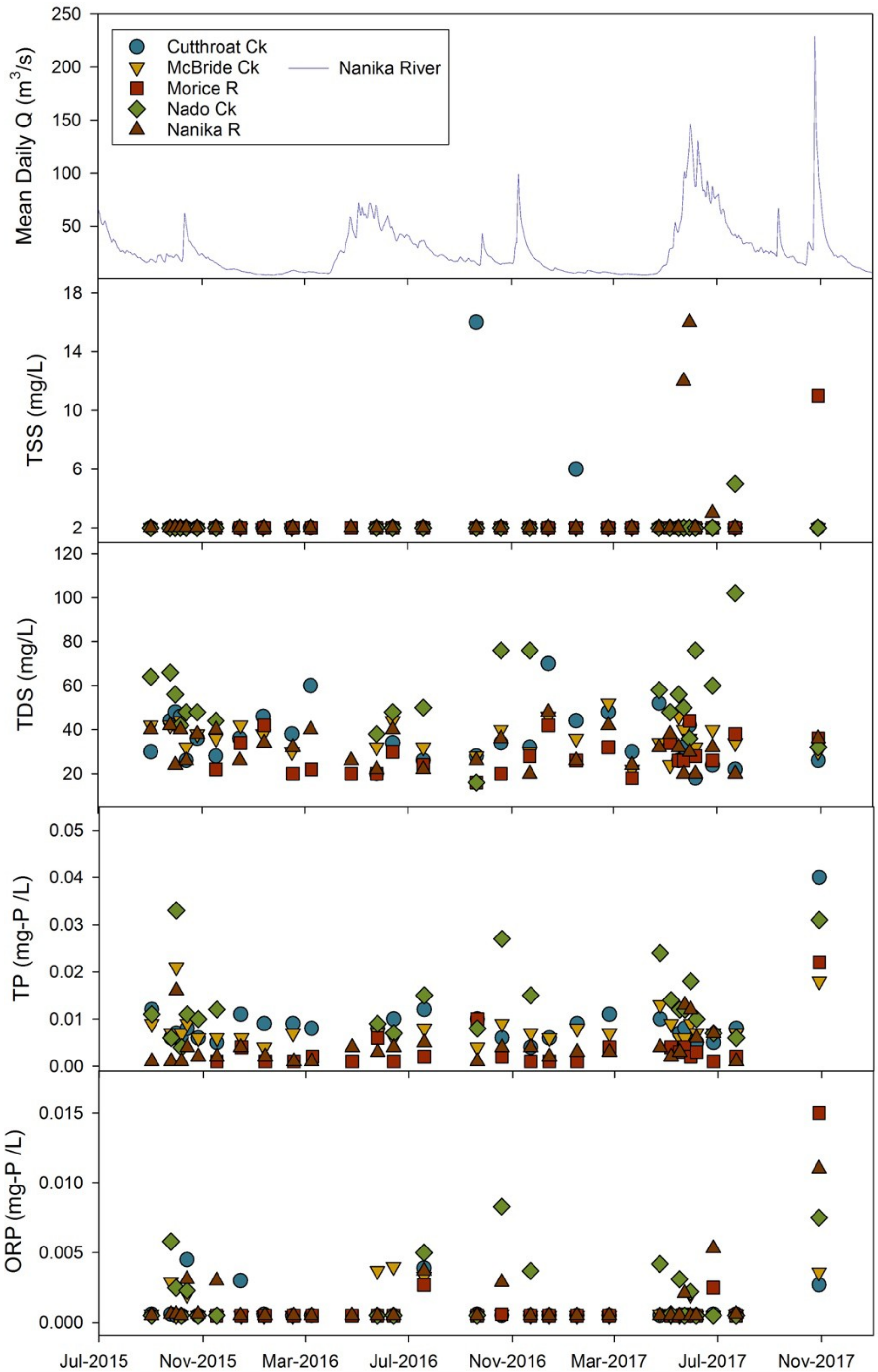


Figure 9: Time series for select metals constituents collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017. The top panel represents mean daily discharge at Water Survey of Canada hydrometric station 08ED001 (Nanika River at outlet Kidprice Lake). Dotted lines represent thresholds listed under the B.C. Water Quality Guidelines for the protection of aquatic life.

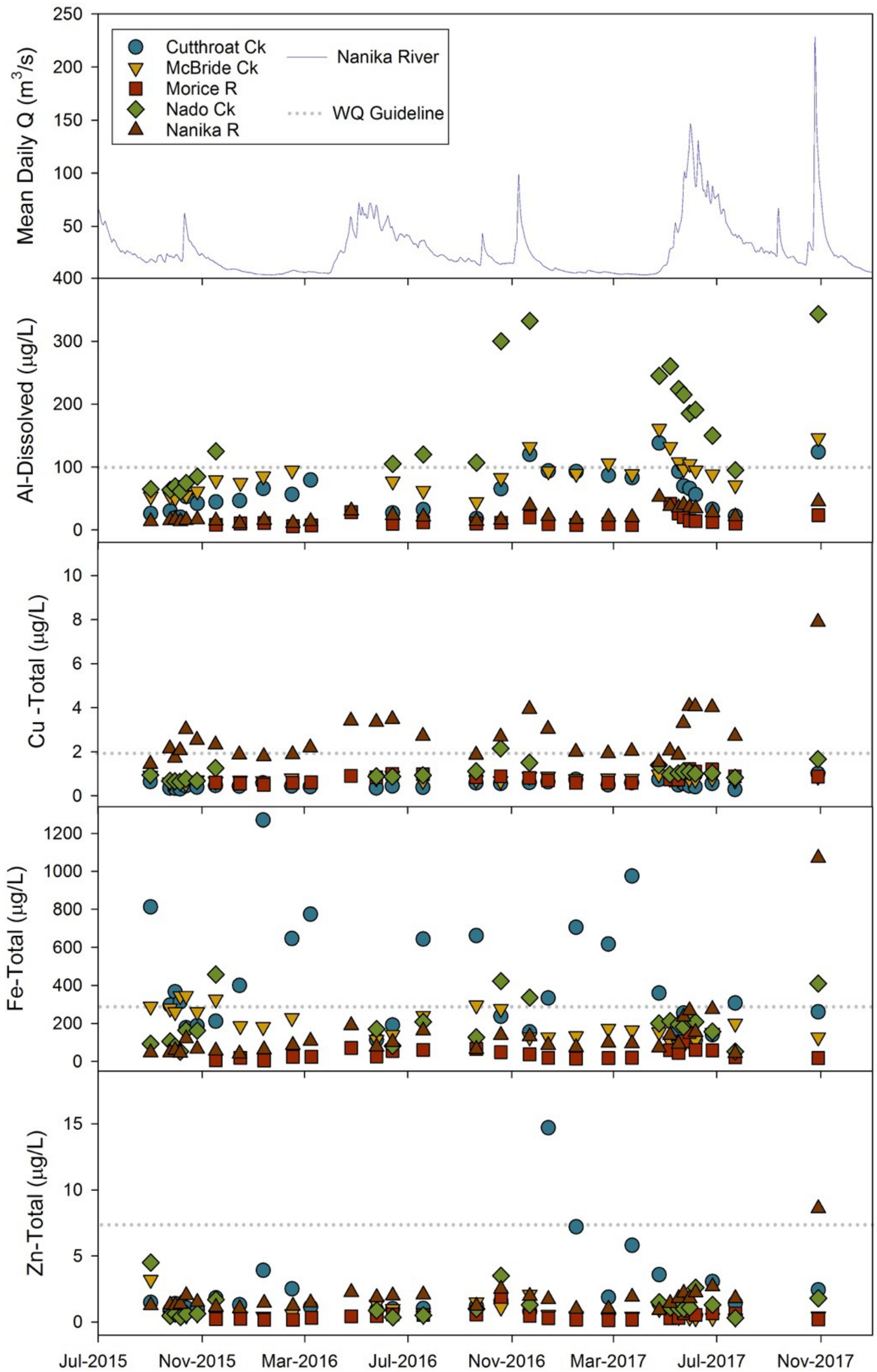


Figure 10: Time series for select metals and cation constituents collected as part of the Morice Water Monitoring Trust water monitoring program from 2015-2017. The top panel represents mean daily discharge at Water Survey of Canada hydrometric station 08ED001 (Nanika River at outlet Kidprice Lake). Dotted lines represent thresholds listed under the B.C. Water Quality Guidelines for the protection of aquatic life.

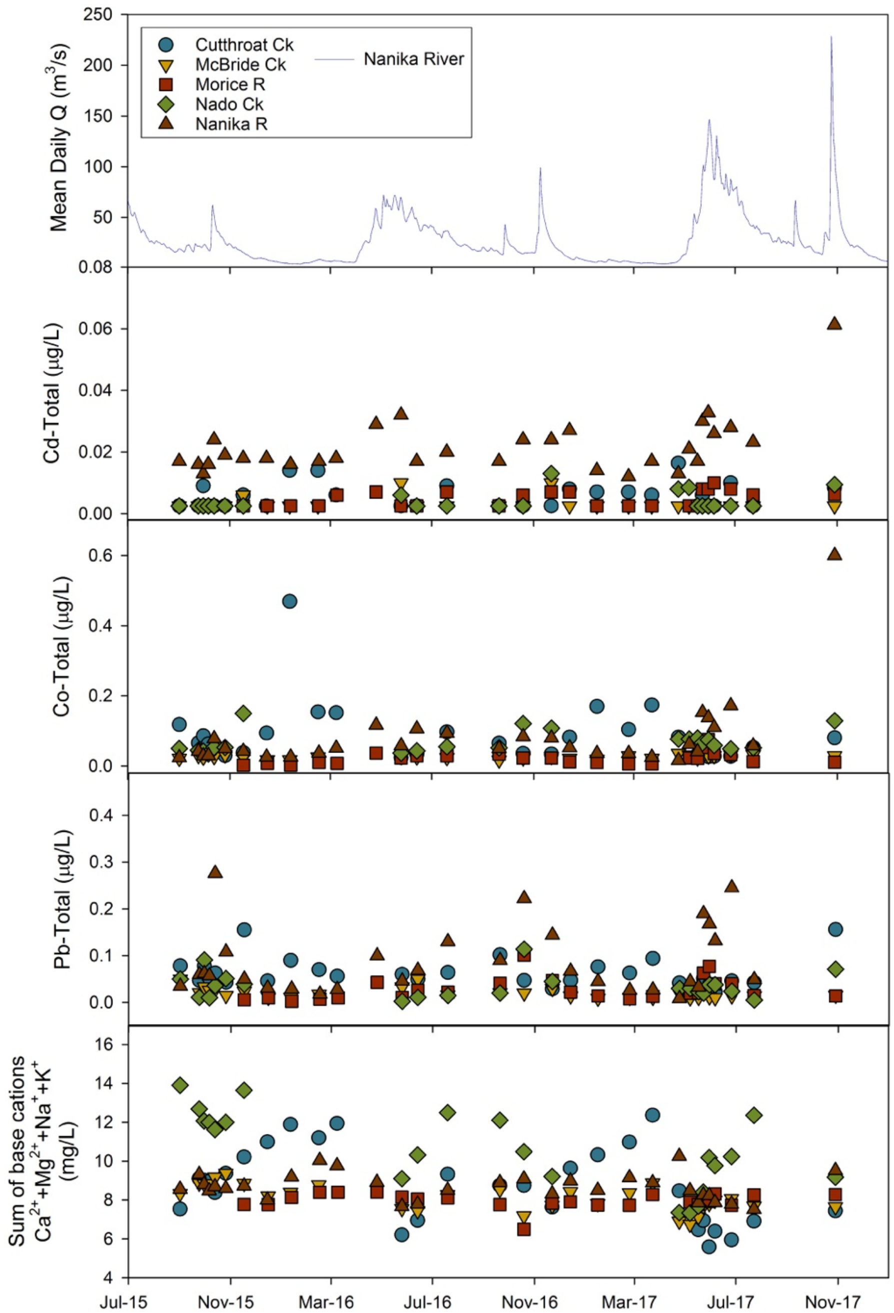


Figure 11: An example of one approach to understanding temporal variability in water quality data is summarizing by site for defined seasonal periods. Here, seasonal periods were selected based on flow characteristics at nearby Water Survey of Canada hydrometric stations (see Figure 2 for more details; spring= Apr-Jun, summer= Jul-Aug, autumn= Sep-Nov, winter= Dec-Mar). The dashed line in the bottom panel is the BC Water Quality Guideline for maximum dissolved Al.

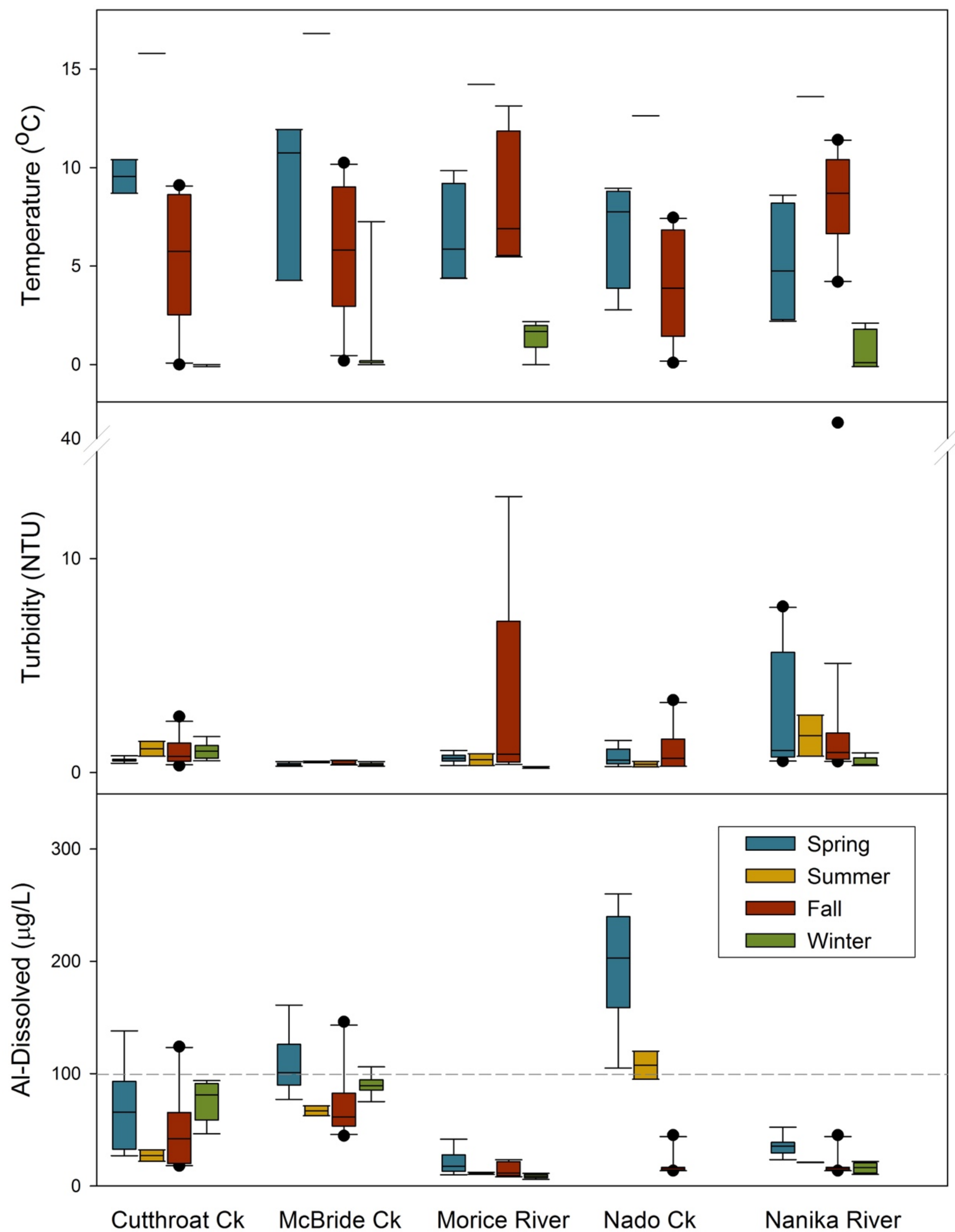


Figure 12: Principle component 1 (PC1) and 2 (PC2) for samples collected from sites sampled as part of the 2015-2017 MWMT water monitoring program (MWMT 2015-2017).

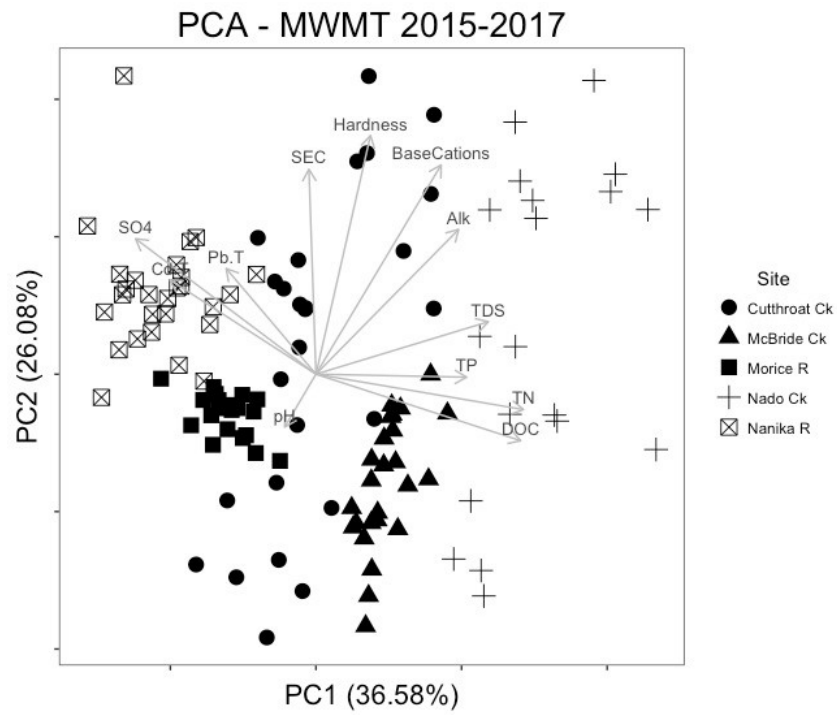


Figure 13: Principle component 1 (PC1) and 2 (PC2) for samples collected at various watershed Assessment Units (AU) sampled within the MWMA from 1996-2017 (All MWMA AUs 1996-2017).

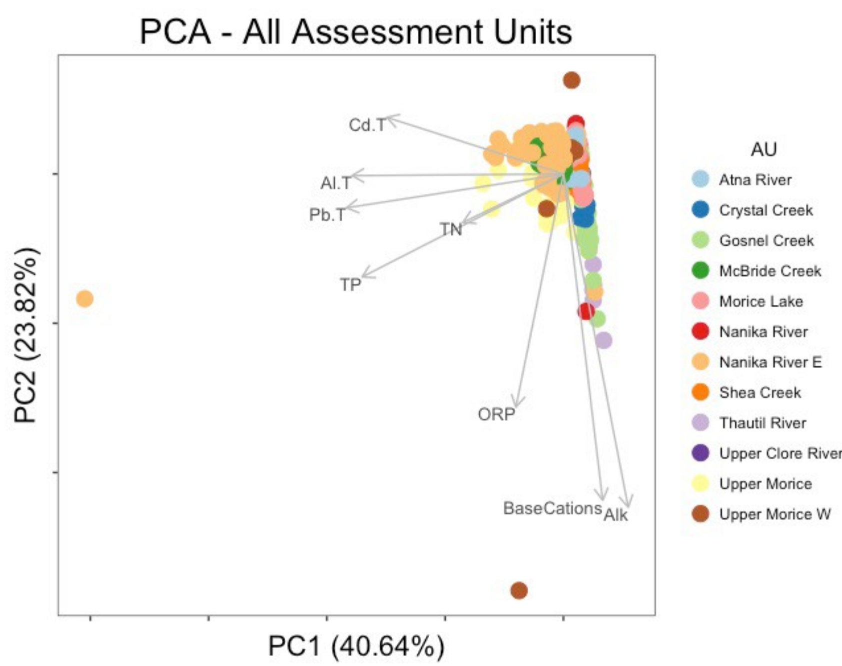


Table 5: Results from principle components analysis of samples collected from: 1) sites sampled as part of the 2015-2017 MWMT water monitoring program (MWMT 2015-2017) and, 2) Assessment Units (AU) sampled within the MWMA from 1996-2017 (All MWMA AUs 1996-2017). Only significant principle components (PC) based on Kaiser's criterion of variance > 1 and visual examination of scree plots are shown.

		PC1	PC2	PC3	PC4
MWMT 2015-2017	Standard Deviation	2.0951	1.7692	1.1799	1.0103
	Variance	4.3896	3.1300	1.1799	1.0208
	Proportion of Variance	0.3658	0.2608	0.1160	0.0851
	Cumulative Proportion	0.3658	0.6266	0.7426	0.8278
All MWMA AUs 1996-2017	Standard Deviation	1.8031	1.3805	1.0622	-
	Variance	3.2511	1.9057	1.1282	-
	Proportion of Variance	0.4064	0.2382	0.1410	-
	Cumulative Proportion	0.4064	0.6446	0.7856	-

3.4 MWMT 2015-2017: Guideline exceedances and water quality objectives

To evaluate current water quality conditions in the MWMA, data from the MWMT 2015-2017 water monitoring program were compared to existing provincial and/or federal WQG for the protection of aquatic life (Table 6, Table 7). For parameters with existing guidelines, a subset of samples exceeded provincial recommendations for various metals (Al- Dissolved, Cu- Total, Fe- Dissolved, Fe- Total), temperature, and dissolved oxygen. Although no provincial WQG exist for TP in flowing waters, site-specific WQG have been proposed for the Skeena River and are used for comparison in this report (Tri-Star, 2005); a small subset of TP samples exceeded these WQGs. Morice River is the only site that did not exceed any guideline thresholds for chemical constituents during the course of the water monitoring project.

Additional inquiry is recommended in cases where constituents exceed provincial WQG. Exceedance values of temperature and dissolved oxygen warrant further study, as point measurements may not capture the highly dynamic nature of these variables. For sites with elevated metal or nutrient concentrations, it is necessary to determine whether conditions represent natural background levels or reflect disturbance. This is challenging as background concentrations should represent natural stream flows from relatively unaltered, pristine catchments, and all 2015-2017 MWMT sites have had some degree of upstream human influence. However, some of these sites can be considered "least-impacted" relative to other locations. Despite varying degrees of upstream influences at sites included in this study, the majority of WQG exceedances are likely the result of elevated natural background concentrations associated with watershed features such as geology or glacial influence. However, Additional studies may further examine whether certain observed constituent concentrations, such as metals or sediment, represent anthropogenic impacts or natural background conditions (see Section 5.0).

For sites where constituent values were lower than existing WGQ, these should be established as WQO for those sites. For sites where certain constituents regularly exceeded WGQ, WQO should be established as the upper limit of background concentrations (95th percentile). These WQO can be used for assessing future fish habitat protection values to allow no change from current conditions. Additional sampling of underrepresented time periods (e.g., summer and winter) or of longer term means (e.g., 5-in-30 day sampling) will increase statistical rigor of the current dataset, allow for mean value WQG comparisons and, where necessary, provide seasonal-specific WQO recommendations.

Table 6: Parameters collected in the Morice Water Management Area from 2015-2017 in exceedance of provincial and/or federal water quality guidelines for protection of aquatic life. Values used for water quality guidelines to determine exceedance are provided in Table 7. Numbers shown in table indicate number of samples in exceedance/number of samples collected. Note that data were not available to determine mean, or long-term, exceedances (e.g., 5-in-30 day samples) so exceedances are based comparisons of single point values with guidelines for maximum concentrations.

	All Sites	Cutthroat Creek (E272556)	McBride Creek (E260496)	Morice River (E272549)	Nado Creek (E260429)	Nanika River (E272557)
Temperature	6[a], 2[b]/ 94	1[a], 1[b]/20	1[a], 1[b]/21	2[a]/16	1[a]/15	1[a]/22
Dissolved Oxygen	42/129	16[c], 7[d], 4[e] /28	5[c], 2[d]/28	3[c]/23	5[c]/20	4[c]/30
TP[f]	4/130	1/28	0/28	0/23	2/22	1/29
Al – Dissolved[f]	24/130	3/28	7/28	0/23	14/21	0/30
Cu – Total[f]	22/135	0/29	0/29	0/24	1/22	21/31
Fe – Total[f]	2/135	1/29	0/29	0/24	0/22	1/31
Fe – Dissolved[f]	7/135	7/29	0/29	0/24	0/22	0/31

[a] exceed incubation temperature for known fish distribution (note: measured in water column)
[b] exceeds maximum daily temperature for bull trout
[c] exceeds minimum value for cold water biota early life stages
[d] exceeds minimum value for cold water biota other life stages
[e] exceeds site-specific instantaneous minimum value
[f] exceeded maximum value

Table 7: Water quality guidelines used to determine the number of exceedances in Table 6. Note that data were not available to determine mean (i.e., long-term) exceedances (e.g., 5-in-30 day samples) so exceedances are based comparisons of single point values with guidelines for maximum concentrations.

Parameter	Water Quality Guidelines for the Protection of Aquatic Life
Temperature[a,d]	- Streams with bull trout and/or Dolly Varden: Max Daily Temp is 15°C, Maximum Incubation Temp is 10°C, Min Incubation Temp is 2°C, Max Spawning Temp is 10°C - Streams with known fish distribution: + or – 1°C change beyond optimum temperature range for each life history phase of the most sensitive salmonid species present[6]; Hourly rate of change not to exceed 1°C (e.g., sockeye and coho salmon 7.2-15.6 °C for migration, max 12.8 °C for spawning) - Streams with unknown fish distribution: Mean Weekly Maximum Temp = 18°C (Max Daily Temp = 19°C) Hourly rate of change not to exceed 1°C; Max Incubation Temp = 12°C (in the spring and fall) - Lakes and impoundments: + or – 1°C change from natural ambient background
Dissolved Oxygen[a, b, c]	- Site Specific Instantaneous minimum: 5 mg/L for all life stages other than buried embryo/alevin - Lowest acceptable dissolved oxygen concentration: cold water biota: early life stages = 9.5 mg/L cold water biota: other life stages = 6.5 mg/L
TP[e]	0.03 mg/L when turbidity < 10 NTU
Al – Dissolved[b]	pH ≥ 6.5, WQG = 0.1 mg/L pH < 6.5 WQG = e^(1.209 - 2.426 (pH) + 0.286 (K)) where K = (pH)^2
Cu – Total[b]	For average hardness ≤50 mg/ L 30-day average Cu- Total (µg/L) ≤ 2 µg/L Maximum Cu- Total (µg/L) = 0.094*hardness + 2 For hardness > 50 mg/L, 30-day average Cu-Total (µg/L) ≤ 0.04 *mean hardness Maximum Cu- Total (µg/L) = 0.094*hardness + 2
Fe – Tota1[b]	Maximum = 1000 µg/L
Fe – Dissolved[b]	Maximum = 350 µg/L

[a]A Compendium of Working Water Quality Guidelines for British Columbia (http://www.env.gov.bc.ca/wat/wq/BCguidelines/working.html#table1)
[b]Water quality guidelines used by British Columbia (https://www2.gov.bc.ca/assets/gov/environment/air-land-water/water/waterquality/wqgs-wqos/approved-wqgs/wqg_summary_aquaticlife_wildlife_agri.pdf)
[c]Ambient Water Quality Criteria for Dissolved Oxygen (http://www.env.gov.bc.ca/wat/wq/BCguidelines/do/do_over.html)
[d]Water Quality Guidelines for Temperature (http://www.env.gov.bc.ca/wat/wq/BCguidelines/temptech/temperature.html)
[e] There are no provincial WQG for TP in rivers, exceedances in this report are based on site-specific Water Quality Guidelines recommendations for the Skeena River at Usk (Tri-Star, 2005).

Table 8: Proposed Water Quality Objectives (WQO) for sites and constituents in frequent exceedance of established BC WQG. WQO are adopted from WQG established by the Province of British Columbia based on the 95th percentile of data collected at each site from 2015-2017[6] (ENV, 2013). WQO represent the recommended upper limit of concentrations for maintaining fisheries and watershed values.

Site	Parameter	WQG	WQO
All sites	Temperature	Max. Daily Temp for most sensitive species/life history stage present: Bull trout (spawn)= 15 (10)°C Sockeye salmon migrate (spawn)= 15.6 (12.8)°C Coho salmon migrate (spawn)= 15.6 (12.8)°C Chinook salmon migrate/spawn= 19 (13.9)°C Unknown fish distribution= 19°C	none
Cutthroat Creek (E272556)	Fe-Dissolved	Max. concentration= 350 μg/L	372 μg/L
Nado Creek (E260429)	Al-Dissolved	Max. concentration= 100 μg/L	202 ug/L
Nanika River (E272557)	Cu-Total	For hardness 50 mg/ L Max. concentration= 0.094*hardness + 2	3.18 μg/L

3.5 Options for power analysis

A challenge in water quality monitoring is being able to determine or detect changes in water quality beyond the range of normal variation in background conditions. This can be addressed using a variety of approaches guided by the underlying question. For example, investigating whether there is a change in seasonal trends over time, requires a different approach than determining whether constituent concentrations exceed an established 95th percentile confidence interval more often at certain sites or time periods than at others. For any approach, it is necessary to know whether there is an adequate number of samples for detecting statistical differences. This is addressed by conducting power analysis prior to an experiment or study to help inform the number of observations required to detect a desired effect. One key component to power analysis is specifying the effect size one is interested in detecting. However, in basic biological research the "appropriate" effect size is often unclear. In this case, a power analysis can also help inform what range of effect size is detectable with various sample sizes.

There are numerous ways of conducting power analysis. The approach depends upon the specific question or hypothesis to be tested. Following are four examples of using power analysis in the context of assessing water quality within the framework of the MWMT monitoring program.

Example 1: Is the average temperature higher for samples collected in autumn of 2018 compared to samples collected in autumn prior to 2018?

You are interested in whether temperature across all sites was higher in autumn (September-November) of 2018 compared to temperatures across all sites during all previous autumn periods. You use a power analysis to determine how many samples you need to collect during autumn of

[6] Although some data was also collected from some of these sites between 2008-2014, it is relatively sparse, temporally inconsistent relative to more recent data, or may be considered outdated. Therefore, only data from 2015-2107 is used for proposing WQO.

2018 to determine if overall temperatures are increasing an effect size of 20% from the mean of 5.98 ± 0.50°C ("small effect size" as defined for standard t-tests by Cohen, 1969). You have a previous autumn period sample size of n=44. You evaluate this by testing for the difference between two independent means (t-test) at a significance level of α = 0.05 (two- tailed α), and ß = 20% (probability of accepting the null hypothesis, even though it is false, when the real difference is equal to the minimum effect size). Since power = 1- ß, this equals a power of 80%. From this power analysis you learn that to detect a 20% effect size between these two groups with 80% power, you need a sample size of n = 394 from autumn of 2018, and n = 394 samples from autumn pre-2018. However, if you are looking for an effect size of 200%, you only need 6 samples from each group. Figure 13a shows the range of minimum samples that are required from each group in order to evaluate a variety of effect sizes using a t-test with 80% power.

Example 2: Is the mean concentration of total copper during summer the same at Morice River for 2008, 2013, and 2017?

You are interested in whether the average summer concentration of total copper (Cu) is different between years at the Morice River site. You evaluate this by comparing the means for summer across three different years of sampling at the Morice River site using a one-way ANOVA. You use a power analysis to determine what effect size you can detect with 80% power (ß = 20%) at a significance level of α = 0.05 (two-tailed α). From this power analysis you determine that with a total of 36 samples we can detect a 60% effect size with 80% power. However, if you can decrease your level of acceptance of power to 60%, the effect size decreases to 50% (i.e., capable of detecting a smaller change) or if you are willing to accept a significance level of α = 0.10, your effect size decreases still further to 40%. If your original study design requires determining an effect size of 20% between these groups based on the original requirements of power and significance, you would need to collect a minimum of 285 samples. Figure 13b shows the range of minimum samples required from each group to evaluate a variety of effect sizes using a one-way ANOVA with 80% power.

Example 3: Can we detect trends in water quality parameters measured at fixed locations over time?

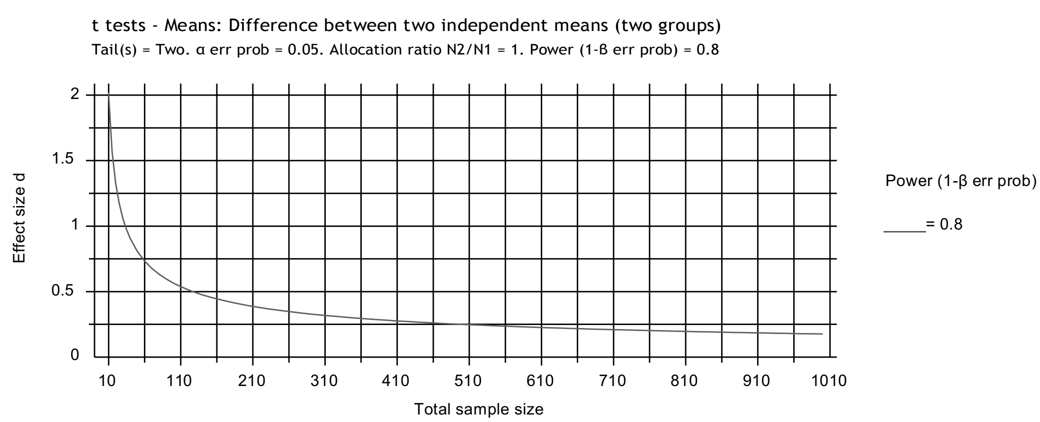
Power analysis can also be used to detect whether there is a non-zero trend in data. There are various ways to evaluate these types of questions. An example of one approach is to use the seasonal Mann-Kendall tau test ("seasonal Kendall test") for detecting monotonic trends in seasonal time series data (Hirsch and Slack, 1984). The seasonal Kendall test assumes that at least one observation is available within each season and year as well as limitations for parameters that consistently fall below the detection limit. It also requires the assumption of a large sample size (>10 years), however if less than 10 years are available hypothesis testing can be approached using a bootstrap approach. One of the major assumptions of this approach is that variability in conditions will remain similar in the future. Overall this method requires a more extensive analytical and modeling framework, as well as thoughtful consideration around biologically meaningful rates of change. For an example of this approach see Irvine et al. 2012.

Example 4: What is the minimal detectable change (MDC), or the smallest amount of change, in a constituent over a given period of time required for the change to be considered statistically significant?

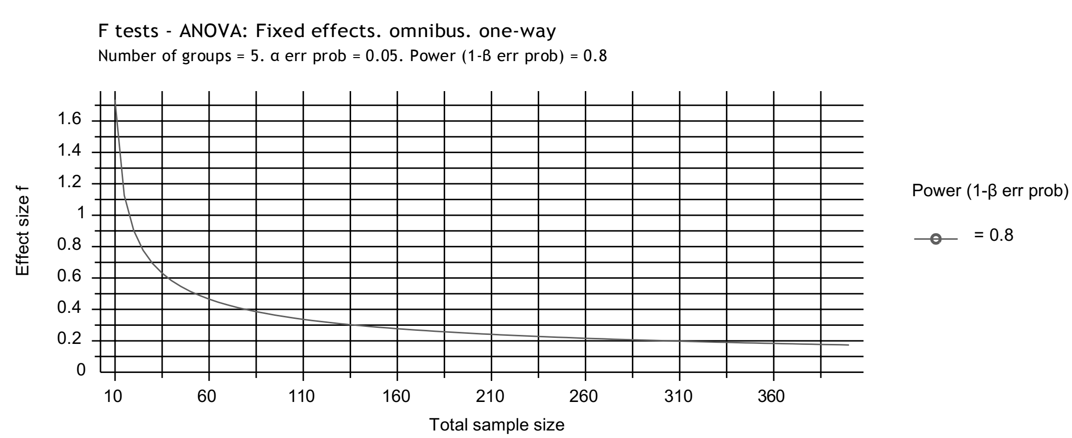
This approach can be used to estimate the amount of change in a constituent concentration or load needed for detection when monitoring at a specific frequency. This approach is most commonly used when evaluating best management practices (BMP) pre- and post-BMP implementation. Alternatively, one can use the same approach to determine how frequently one needs to sample based on an anticipated change in constituent concentration or load. Data collected in the first several years of a project can be used to determine the amount of change that must be measured in a system to be considered statistically significant and not an artifact of site or seasonal background variability. Calculation of MDC can also help provide feedback regarding whether a monitoring design is sufficient to accomplish and detect changes in water quality over a specified length of time and helps determine the magnitude of water quality change (i.e., the effect size) required to detect changes. One of the major assumptions of this approach is that variability in conditions will remain similar in the future. Overall this method requires a more extensive modeling framework and model selection, as well as accounting for changes in other explanatory variables such as discharge, precipitation, groundwater level, etc. Greater length of monitoring period and increased sample frequency will help reduce the magnitude of the MDC. For additional information and examples of power curve calculations using the MDC approach see Harcum and Dressing, 2015.

Figure 13: Examples of using power analysis to determine range of minimum samples required in order to evaluate a variety of effect sizes.

a)



b)



4.0 Discussion

Appropriate watershed management and decision making requires best-available information regarding historical, current and future ecosystem conditions. Without historical and/or current data, it is challenging and less efficient to design management targets for improving or maintaining ecosystem conditions. In a large and complex watershed like the Morice River, monitoring priorities need to balance a wide variety of factors, including but not limited to: appropriate representation of least-impacted and impacted systems, representation of historical and present-day disturbance and landscape alteration, continuity in data collection over space and time, accounting for variation in underlying watershed characteristics, understanding variation in relation to climate, capturing priority needs for fish and water resources, and anticipating future change. In addition, monitoring priorities must address priorities for First Nations values (e.g., high value fisheries, high quality fish and wildlife habitat, etc.). In the MWMA, the overarching water quality management objective is to maintain hydrological integrity, including water quality and quantity, to ensure that habitat and water resources supporting salmon and other fish are not negatively impacted. In other words, the only acceptable scenarios for management within the MWMA are those where current conditions are either maintained or improved.

Water quality sampling conducted in the Morice River watershed over the past decade provides the foundation for evaluating the status of MWMA management objectives. Consistent, long-term time series data on water quality and water quantity is a powerful tool for improving our understanding of ecosystem health; this approach becomes even more powerful when combined with biological (e.g., fish, benthic macroinvertebrates, periphyton), sediment, hydrometric, and landscape-level information and provides a comprehensive picture of current conditions, gaps in understanding, and future directions for monitoring and management. For a long-term monitoring program to be successful, it is also critical to recognize and consistently re-evaluate components of that program, such as site selection, parameter selection, sample frequency, and data quality, while also recognizing the importance of consistency and program endurance. These considerations are crucial for establishing baseline conditions that accurately represent site conditions and the objectives/questions of a monitoring program.

4.1 Seasonal and annual water quality variability in the MWMA

Consistent and long-term sampling with high-temporal resolution provides insight into seasonal and annual variability in water quality. Monthly surface water quality data collected within the MWMA from 2015-2017 demonstrate variability likely associated with seasonal changes in temperature and productivity, as well as seasonal and episodic changes in catchment hydrology and stream flow. Certain constituents appear to more strongly reflect seasonal cycles than others. For example, pH, specific conductivity, NO_3^-+NO_2^-, TP, and certain metals (e.g., Co, Fe, Pb), appear to exhibit some degree of annual seasonal cycling across almost all sites. For other constituents, seasonal patterns are highly site-specific or absent. For example, DOC and alkalinity show distinct sinusoidal trends in seasonal variability at Cutthroat Creek, less range of variability at Morice River, and no clear seasonal pattern at McBride Creek or Nado Creek. These patterns suggest underlying differences in watershed characteristics that uniquely affect water quality between sites, and may also interact differently with changes in drivers of water quality patterns such as stream discharge, flow pathways, temperature, etc. These differences were also observed in the exercise with principal component analysis, which indicated samples tend to cluster by site based on properties that are more similar within sites than between sites.

Discharge can be a major driver of total concentration and changes in concentration for certain constituents, especially those that directly reflect solids or particulates (e.g., TSS, turbidity), or that tend to be associated with particles (e.g., TP). Discharge can also be a major driver for increased concentrations in certain solutes as well, although the relationship is often more complex (e.g., House and Warwick, 1998). This can also be the case for certain pools of metals and metalloids but is dependent on the adsorption/complexation characteristics of soils and an array of competing reactions such as changes in oxidation state, precipitation/dissolution, complexation with organic matter, ion exchange, etc., as well as discharge-concentration relationships. For sites included in MWMT 2015-2017, higher discharge was associated with increased concentrations of TSS, turbidity, and TP, as well for certain metals at individual sites. However, increased discharge also decreased concentrations of certain metals at other sites, suggesting that discharge-concentration relationships vary between sites. For example, both total Cu and Cd increased at sites during periods of higher flow and decreased during periods of low flow, especially at Nanika River. Higher flows appeared to coincide with higher concentrations of total Cu that exceeded maximum water quality guidelines. In contrast, total Fe decreased at Cutthroat Creek to values below water quality guideline exceedance during high flow and increased in value during low flow. However, solute concentrations are not always simply influenced by a fixed solute volume diluted by an increased flux of water and often reflect a variety of watershed processes that aren't captured solely by discharge (Godsey et al., 2009). Variation in discharge may also affect things like solubility, buffering capacity, or alter flow paths and surface-subsurface or sediment-water exchange, which ultimately affect water quality (Bencala and Walters, 1983; Mulholland et al., 1990). If discharge and seasonality are both drivers in constituent export, and constituent concentration is strongly influenced by discharge and its interaction with watershed processes, future changes in seasonality and hydrology may result in changes to patterns of seasonal cycling (Raymond et al., 2007).

Despite large differences in temperature and discharge between seasons, when data for all sites are combined there are almost no differences in parameters between seasons. This is despite observations of seasonal trends in certain parameters at individual sites. This suggests that seasonal differences are more representative when observed at the site level, or across systems with similar catchment characteristics. The time series figures used in this report are useful for observing seasonal changes and variability within seasons, and also allow observation of individual data points outside of combing data into specific "seasons", as the selection of seasons can be somewhat subjective, as well as a shifting window in the face of climate change. Future analysis of parameters of interest could explore the interactions of seasonality and site, particularly with consideration given to differences in flow, drainage area, temporal difference in the intensity of land use, and water source for individual catchments.

The lack of seasonal differences for most parameters across all sites also suggests that additional samples are needed to better constrain the normal range of variability during certain seasonal periods. Although seasonal representation for all sites was relatively good, summer and winter low flow periods were under-represented compared to other periods, especially across the greater Morice watershed for specific AU's. For the Nado Creek site included in MWMT 2015-2017, the lack of winter samples makes it difficult to identify annual patterns in seasonal cycling, although comparisons between the remaining periods of the year are still valid and valuable. Additional winter samples would help further understanding of baseline conditions by providing valuable insight into background contributions from ground water and snowmelt when the majority of the watershed is low in productivity and overland flow/interstitial flow is limited.

Additional samples during summer low flows would also be valuable as they reflect stream conditions after months of saturated soils and interstitial transport, when higher productivity and higher temperatures increase catalyzation of biogeochemical reactions and lower discharge may contribute to higher concentrations or warmer temperatures that may stress fish and other aquatic organisms. Additional, higher resolution sampling such as collecting 5 samples in 30 days, would allow for additional comparison of parameters with appropriate water quality guidelines as many water quality guidelines are based on this type of sampling approach.

4.2 Water quality concerns related to forestry

The Morice River watershed has experienced various types of land use change with the potential to affect water quality. The location and intensity of change will have a strong influence on impacts to downstream water quality. Major land use change and disturbance within the greater Morice River watershed includes forest harvest, mining exploration, and future pipeline development. These activities have produced extensive road networks and stream crossings (see maps in Appendix A and http://maps.skeenasalmon.info/), extensive areas of modified forest ecosystems, increased exposure and disturbance of sediment and mineral layers, and likely altered hydrologic timing and flow paths. While these activities have been somewhat less widespread in the MWMA relative to the greater Morice River watershed, all sites sampled in this study reflect catchments that have been influenced to some degree. The degree of these impacts and the potential influence on historical changes to water quality are difficult to ascertain from the current record of data. However, establishing current baseline conditions allows us to describe potential areas of concern, as well as monitor for future change.

Major concerns associated with forestry include changes in forest ecosystems and soil disturbance that can alter stream temperatures, the timing and amount of water, nutrients, sediment, and dissolved solids runoff, or impacts to stream continuity due to stream road crossings and culvert or road failures. From a water quality perspective, the sampling design and sites sampled in this study suggest low levels of impact associated with widespread forestry activity. This includes measures of TSS, turbidity, nutrients (e.g., NO_3^- -NO_2^- and TAN), and solutes (e.g., specific conductivity, base cations, TDS). However, data suggest more detailed investigation is warranted. For example, large increases in TSS, turbidity, TP, and NO_3^--NO_2^- during fall rain events were measured at Cutthroat Creek and Nado Creek, but these sites have very different levels of road density, wetland influence, and clearcutting, as well as differences in underlying watershed characteristics, suggesting different controls on constituent export. In contrast, changes in water quality parameters during fall rain events within more glacially-influenced systems like the Nanika River may appear to reflect conditions like those expected from heavily-logged landscapes, but actually reflect the products of rain-on-snow or glacial melt during periods of very warm weather conditions. It is likely that some of these effects may be short-term, and measurable primarily during periods of heavy rain. A more detailed, targeted investigation of catchment runoff along with major forestry drivers and additional discharge-weighted sampling, particularly during storm-events, would provide a great deal of additional information about the impacts of historical and present-day logging on overall water quality.

4.3 Water quality concerns related to mining

The Morice River watershed is underlaid by several major geological rock types with variable influence on water quality (see maps in Appendix A and effect http://maps.skeenasalmon.info/). The southwest area of the MWMA (i.e., head of Morice Lake and Atna River) is largely comprised of Mesozoic granite and similar rocks that are not highly subject to chemical weathering and likely have little influence on water chemistry. The area around McBride Lake is largely comprised of sedimentary rock (Skeena Group) and also likely contributes little influence on water chemistry. The majority of the remaining area is underlain by volcanic rock (Jurassic Hazelton Group), which is quite diverse but likely have the greatest impact on water quality. Most of these rocks are andesite, which contain higher levels of most metals than the aforementioned rock types, and more subject to chemical weathering. In addition, these rocks are often fractured and contain pyrite, which allows surface water to penetrate into the rock and further contributes to chemical weathering via production of acidic groundwater and leaching of metals. The Hazelton Group also contains andesite, which contains calcite, and when weathered produces a basic solution that further enhances element solubility. Coverage by glacial till is also extensive in the area and may further alter the chemical composition of water draining through rock debris. High amounts of finely-produced glacial till contain high surface area and may contribute rock-loving elements ("lithophiles") to solute runoff. This may alter predictions of geological influence on water quality for regions comprised of otherwise unreactive bedrock such as granite bedrock at the head of Morice Lake and Atna River (P. Wodjak, *pers comm*).

Throughout this area, porphyry mineral intrusions (deposits) are often targeted for mineral exploration. One area of major porphyry influence is the Berg copper-molybdenum deposit located in the region above Nanika lake. This deeply incised porphyry mineral system contains a variety of major and minor metals including copper, molybdenum, lead, silver, iron, sulfur, etc., and likely dominates certain aspects of water quality in downstream catchments. There are also smaller porphyry deposits in other catchments within the MWMA and Morice watershed and these can have a variety of effects on water quality: from no influence, to those such as Berg that influence more than one system. Other mineral occurrences in the region that may be significant include: Lucky Ship (Minfile 93L053) located between McBride and Morice Lake, largely a molybdenum prospect, New Moon (Minfile 93E100) west of Morice Lake that contains copper, lead, zinc, silver, gold, sulfur, and iron, Copper Star (Minfile 93L326) a copper, molybdenum prospect located northwest of Chisholm Lake, and a cluster of small occurrences on the northern boundary of the Thautil River (Minfile 93L061 to 070). A high number of Notices of Work and mineral tenures are listed in the Morice watershed, including within the MWMA (Appendix A). Similar to forestry, based on the data obtained from MWMT 2015-2017 it is difficult to know what degree mineral exploration may have affected changes in water quality at given monitoring sites. This is especially challenging for sites such as Nanika River, Nado Creek, and to a lesser extent McBride Creek, which reflect drainages containing naturally occuring rock types known for high acid and metal concentrations. The water chemistry at these sites reflects some of those characteristics; high concentrations of metals that have been chemically-weathered and leached from bedrock.

Metals concentration data are noteworthy at several MWMT sites. High concentrations of dissolved Al (in excess of BC WQG) are frequently measured at McBride Creek and Nado Creek. Al is the most abundant element in the earth's crust and occurs in most types of rocks. Al ions form a variety of soluble salts that enter surface waters via natural processes like rock weathering, or via anthropogenic processes such as mining, industrial processing, and waste water treatment. Because no large-scale mining or industrial operations have occurred upstream from these sites, it is likely rock weathering contributes high Al concentrations to these streams. Aluminum exhibits complicated chemical cycling in surface waters due to various reaction properties, including complexation with organic matter. Previous studies have indicated that within pH range of 6.5-7.5 soluble aluminum increases notably in water containing organic matter, especially concentrations of fulvic and humic acids (Wang et al. 2010). Fulvic and humic acids comprise major pools of total DOC. For sites monitored in this study, high dissolved Al concentrations were strongly correlated with high concentrations of DOC ($r^2 = 0.911$, $p < 0.0001$, $n = 126$). The toxicity of Al depends on its molecular species, which can shift under conditions of changing pH, dissolved oxygen, or complexing cations and organic compounds and become toxic to fish species (Rosseland et al., 1992). Therefore, even if local aquatic communities at these sites currently appear unaffected, it is important to consider how changes in other variables may affect downstream or future effects of Al toxicity.

Total Cu and total Fe also frequently exceeded WQG at Nanika River and Cutthroat Creek, respectively, and total Fe exceeded WQG on a few dates at McBride Creek and Nado Creek. Similar to Al, these metals are abundant in the earth's crust (especially volcanic rocks) and are introduced to surface waters naturally through chemical weathering. Anthropogenic activities can also contribute Cu and Fe through activities such as mining, agriculture, manufacturing, ore refining, sludge from public works, pesticide use and more. Again, there are no obvious upstream anthropogenic sources of these metals, suggesting observed concentrations represent current background levels. Under conditions of low oxygen, Fe can be released from the insoluble form of ferric Fe (Fe^{3+}) to soluble ferrous Fe (Fe^{2+}). In addition, in highly humic, "tannic" limnetic (non-flowing) waters Fe^{3+} can exist in natural organometallic or humic compounds and colloidal forms. Both of these conditions are possible within the catchment above the Cutthroat Creek site, which contains extensive beaver ponds and wetlands conducive to decomposition and low concentrations of dissolved oxygen. Because high concentrations are not similarly observed downstream at Nanika River, it suggests that Fe is either diluted or returns to an insoluble form once it encounters more oxygenated conditions downstream.

Any activity involving mineral exploration or mining has the potential to increase the concentration of metals in surface waters, but it is impossible to conclude whether historical activity in the area has increased concentrations to the levels observed at sites included in MWMT 2015-2017. However, baseline conditions have now been established at these sites to support further inquiry and to provide future reference if further mineral exploration or mining activities are pursued in these catchments. Additional sampling for corresponding biological community data (e.g., CABIN), or periodic higher-resolution data, such as continuous measures of water quality parameters that affect or correlate with metal solubility and speciation (e.g., pH, dissolved oxygen, hardness, conductivity, etc.) would contribute to better understanding of background conditions and controls. In particular, establishing sampling sites at locations that are located directly upstream/downstream of porphyry deposits (such as Nado Creek) and above/below the next relevant tributary will allow for better understanding of background conditions, the effect of local aquatic communities, and how conditions change along the downstream river continuum.

4.4 Water quality concerns related to climate change

Climate change is occurring at an unprecedented rate and predicted to have major implications for freshwater resources, surface water quality and quantity, aquatic ecosystems, and fisheries (Ficke et al., 2007; Scheffers et al., 2016; Kernan et al., 2011; Whitehead et al., 2008). Many of the predicted effects on water quality and fisheries resources are already observed, such as changes to precipitation and temperature regimes, changes in catchment hydrology and soil chemical processing, changes in physical stream conditions and food resources for fish, and shifts in species distribution (e.g., Heino et al., 2009, Kernan et al., 2011, Lynch et al., 2016, Woodward et al., 2010). Region-specific predictions for northern

B.C. will likely affect the Morice River watershed and include drier and hotter summers, increases in the frequency and intensity of autumn precipitation events resulting in more erosion, decreases in snowpack and glacial area, increases in wildfire frequency and intensity, and increases in forest stress resulting in susceptibility to diseases and pests such as mountain pine beetle.

If climate change continues to progress under a "business as usual" emission scenario, the glaciated headwaters of the Morice River will continue to retreat, reducing cold water glacial inputs and altering downstream patterns in chemical and sediment loading. Increased water temperatures, reduced dissolved oxygen, and reduced summer and winter low flows may create challenging conditions for cold water fish species. Summer maximum temperatures and spot measures of dissolved oxygen in smaller systems measured in this study are considered to be of concern for many anadromous fish species, but because these data were not collected continuously, they may not accurately represent true daily or seasonal maxima. These data also do not take into consideration water levels and flows, which may further restrict habitat for fish. Interactions between climate change effects and land use activities such as forestry and mining may increase the rate and amount of watershed erosion and sediment loading to streams. Changes in catchment hydrology may also have implications for nutrient and metals transport or shift the composition of metals to more toxic forms, as well as increase rates of chemical weathering or other controls on metals solubility, such as changes in dissolved organic matter concentrations or pH. Further increases in metals concentrations in systems with naturally high background concentrations could potentially create harsh conditions for aquatic organisms and shift distributions within the Morice and adjacent watersheds. Changes in residence time, water source, and thermal regimes in lakes can alter lake limnological status, potentially shifting lake trophic status and productivity. Detecting and interpreting these complex responses requires carefully designed monitoring plans and strategic data considerations. Long-term monitoring data can also be supplemented with historical data, such as lake cores, tree-rings, etc., to further constrain and characterize historic conditions and identify potential shifts over time. As a start, more detailed information regarding changing patterns in flows and temperatures will provide a first look into potential shifts occurring within the MWMA. Modeling exercises or further exploration with online tools[6] may also prove useful for designing future climate change and water quality monitoring strategies.

4.5 Water quality concerns related to sockeye salmon habitat suitability

Sockeye survival during their freshwater life cycle depends on specific habitat requirements for adult migration to spawning areas, spawning, egg incubation, juvenile rearing, and juvenile migration. Salmon habitat includes abiotic and biotic components of water quantity, water quality, stream and river physical features (e.g., sediment, substrate, woody debris), upstream terrestrial ecosystem conditions, and other ecosystem interactions. Optimal water conditions for salmonids include cool, well-oxygenated water flowing at adequate (natural) rates for each freshwater life stage. Ideal natural conditions for salmon also include moderate to low levels of electrical conductivity, total dissolved solids, and circumneutral pH. Of these requirements, water quantity should be considered a master variable, as adequate stream flow is

[6]Some examples of online tools for investigating climate change effects include BC Climate Explorer (http://www.bc-climate-explorer.org/), Climate Map BC (http://www.climatewna.com/climateBC_Map.aspx), Pacific Climate Impacts Consortium (https://pacificclimate.org/data), Engineers and Geoscientists British Columbia Climate Change Information Portal (https://www.egbc.ca/Practice-Resources/Climate/Climate-Change-Information-Portal).

necessary for fish to access habitat as well as to maintain healthy water quality conditions. Low stream flows can also alter water quality by increasing temperatures, decreasing dissolved oxygen, and concentrating toxic materials such as metals. Unprecedented low flow conditions in 2018 raise significant concerns about the current and future availability of abundant, cool, well-oxygenated, moderate to low conductivity water for salmon to migrate, spawn, and rear. Similarly, extremely high flows in autumn can pose challenges to redd survival through scour of gravel substrate or increased erosion and sedimentation, which can choke out developing eggs. Groundwater-surface water interactions can also play a critical role in moderating flows and temperatures in salmon-bearing streams, yet little is known about the extent of groundwater influence in the MWMA. Further information on flows and surface water-groundwater interactions is therefore necessary for adequately describing challenges to sockeye recovery.

Beyond water quantity, water quality is also critical in supporting the ecosystem structure and function necessary for salmon productivity. High temperatures and high rates of fine-grain sedimentation are problematic for spawning success and survival of offspring. Nutrients are critical for fueling food webs that support juvenile salmon production, but changes in nutrient stoichiometry can alter the community composition of food resources or change chemical conditions within a waterbody. Exposure to chronically high metal concentrations can also have toxic effects on sockeye salmon, especially during development and rearing, but can be equally as problematic for adults experiencing lethal or sublethal toxicity. Of the sites included in MWMT 2015-2017, sockeye salmon are documented to directly utilize areas of the Nanika River and Morice River. Water quality measured at these sites is within the range considered ideal for sockeye salmon, although temperatures in summer 2016 (and likely subsequent years, although not included here) exceeded the upper limit for spawning. The other three sites are not listed as currently utilized by sockeye salmon, however these systems still contribute water and water quality to downstream salmon habitat. However, suboptimal conditions at some of these sites (e.g., high concentrations of metals, low dissolved oxygen) did not appear to translate downstream to larger systems, probably as a result of dilution. In other cases, there is not enough information to know whether water quality effects are impacting salmon or their downstream habitat. For example, not enough information is available to determine whether sediment mobilization during autumn rain events is an issue for salmon or red survival, or if water quality constituents from some of these smaller catchments (e.g., Nado Creek, McBride Creek) have a localized negative effect on conditions at their confluence with the Morice River and Morice Lake, respectively.

Many sockeye salmon spawn in rivers adjacent to or near lakes, or along lake shores, and juvenile sockeye typically rear in lakes for 1-3 years. High quality lake habitat is therefore the most crucial habitat for sockeye salmon spawning and rearing. In the MWMA, this may include Morice Lake, Nanika Lake, and Atna Lake. Although extensive limnology and related lake work has been conducted on Morice Lake in the past, currently there are no regular monitoring programs included within the framework of the MWMT monitoring program. Monitoring ongoing limnological conditions, including physicochemical lake dynamics, trophic status, and overall production and health of juvenile sockeye salmon, is essential for understanding current limitations to habitat suitability and developing a strategy for sockeye salmon recovery.

4.6 Additional monitoring, data and analytical needs

Additional monitoring and analysis are required to further evaluate long-term trends in water quality and address specific hypotheses regarding impacts to water quality. Data collected by the MWMT from 2015-2017 provides high quality, broad understanding of current baseline conditions at monthly time steps and provides a strong foundation for future water quality trend analysis. In order to further understand annual and seasonal variability, as well as evaluate long-term changes in water quality conditions, additional sampling of parameters of interest should be continued at a similar time step, and/or by using a stratified design to focus on seasonal periods or events of interest. Specific recommendations for the amount and frequency of additional monitoring will depend on interests and specific questions of the MWMT, however this report provides several recommendations in Section 5.0.

Future monitoring efforts to understand water quality characteristics in the MWMA would benefit from the collection of additional media and environmental characteristics such as flow, continuous temperature and other *in situ* parameters, sediment composition, benthic macroinvertebrate communities, and limnological parameters. Valuable information could also be obtained by assessing the growth and survival of juvenile salmonids to determine current limitations to productivity and relationships to water quality variables, as well as additional fisheries-relevant data that may better identify stressors or limitations to salmon.

A first principle of successful monitoring programs is a reliable approach to data management and analysis. There is already a substantial amount of water quality data available for the Morice watershed, and undoubtedly more will be collected in the future. Priorities for future work should include development of a consistent and robust long-term strategy for maintaining the legacy of these data and metadata, as well as integration with future data. In addition to the methods already being employed, there are various other tools and protocols available for archiving, analyzing and reporting. Establishing a standard operating procedure for managing and storing data will help increase data visibility and interpretation, as well as reduce costs and time associated with collating, compiling, and checking data. In addition, tools or protocols can be selected or designed to provide basic summary analysis. High-level requirements of an online water quality data management system should 1) control access to data, 2) securely store data and allow easy retrieval for the duration of the time series and in perpetuity, 3) include capacity to import and store grab sample and sensor measurement data at specified time frequencies, 4) allow for performance of basic QA/QC to determine if data are valid and quality is sufficient to assess water quality, 5) generate flags based on water quality or sensor data, 6) generate basic analysis and summaries, and 7) generate basic standard reports.

There are a variety of tools available to streamline data collection, including electronic applications for use in the field, digital data templates, analysis programs, and more complex database systems. Selection of methods and tools depends on a variety of considerations, including cost, computing power, viewing or accessibility requirements, sensitivity of data, maintenance, and integration with other systems. Paramount to any water quality monitoring program is a robust data repository. Currently data from the MWMT 2015-2017 and other water quality, sediment, or biological monitoring data sampled from within the Morice watershed can be found in the EMS database, but it is stored individually by site and sometimes contains error. This system is useful for storing raw site-level data, but additional data management options should be considered for storage of compiled datasets and for incorporating new data, especially for use in analysis and reporting. A template may be designed to standardize the integration of new information into compiled datasets, which could then be stored in a database for access, sorting, analyzing and viewing. There are many options for databases, including developing and maintaining in-house or with a third party, or by integrating into existing networks. Several "local" examples of data platforms that provide various approaches for archiving, visualizing, and analyzing water quality data include the Skeena Knowledge Trust, the MacKenzie Datastream, the Aquarius Time-Series database (real-time data), or the Hakai Data Portal (access required) and Hakai Ecological Information Management System.[7]

There are various electronic applications currently available for automating or standardizing data collection in the field and performing basic QA/QC (e.g., Device Magic, FastField Mobile Forms). These tools are ideal for reducing human or faulty equipment errors, for ensuring that data is collected in a standardized format, and for reducing errors associated with entering, uploading and integrating data into existing data platforms. Water quality instrumentation, such as hand held or *in situ* sensors, often include software that allow the user to automate the export and flagging of data or integrate with mobile applications or computer-based software to automate uploads and perform basic QA/QC (e.g., Data Manager Desktop software for YSI Pro Plus and ProODO, Onset Hoboware Pro). There are a variety of ways to perform data analysis and reporting, but for descriptive statistics and basic time series viewing, it may be useful to develop a data template to automate the production of basic analytical information. Simple water quality data analysis can be performed using freely available code within the open source software, R (R Core Team, 2018). The Province of British Columbia is currently developing the program code to distribute for this purpose and release anticipated in early 2019 (J. Penno, ENV, *pers comm*). These approaches require additional computer technological expertise to develop and initiate, but are designed to ultimately reduce overall time, effort, and error associated with compiling and integrating data from across various locations, operators, and formats.

5.0 Recommendations and proposed elements of a 2019 Annual Monitoring Plan

Flexibility and adaptation in study design, data management, analysis and program needs are critical for maintaining and enhancing monitoring programs. Program adaptation is also important for identifying and addressing new questions and challenges by designing appropriate monitoring approaches. The following are recommended major objectives for a 2019 Annual Monitoring Plan (AMP) and future work intended to highlight monitoring considerations and advance objectives of the MWMT.

Major Objectives - 2019 Annual Monitoring Plan

Objective 1: Increase statistical rigor of water quality monitoring dataset by filling in data gaps and increasing uniformity of data across sites and seasons. Addressing data gaps will add resolution and credibility to the range of variability (i.e., 95th percentile) used for establishing WQO. Seasonally-stratified 5-in-30 day sampling can determine mean values for constituents that exceed current maximum WQG and also allow for comparison with mean WQG values and/or constituents that may potentially be impacted by future land use change. In addition, this increases total sample size and increases options for future time series analysis. Major priorities for 2019 sampling should include: 1) increase the number of samples for the summer period (July – August), 5-in-30 day samples would be especially useful for evaluating WQG and setting WQO at all sites, 2) increasing the number of samples for the winter period (December – March), 5-in-30 day samples would be especially useful for evaluating WQG and setting WQO at all sites, 3) Only sampling Nado Creek during high flow periods, or dropping Nado Creek and replacing with a high value fish habitat tributary such as Crystal Creek or Gosnell Creek.

[7]The Skeena Salmon Data Centre is available at: https://data.skeenasalmon.info/
The Mackenzie DataStream is available at: https://mackenziedatastream.ca/
The Aquarius Time Series is available at: http://aqrt.nrs.gov.bc.ca/
The Hakai Ecological Information Management System is available at: https://data.hakai.org/

Objective 2: Collaborate with upcoming efforts to add eDNA tools to existing CABIN biomonitoring activities. As part of a Canada-wide project funded by Genome Canada, researchers will be examining the utility of eDNA to inform biomonitoring and are interested in building collaborations with existing monitoring efforts. Collaboration with these efforts will provide opportunity to further advance the MWMT monitoring program by broadening and deepening information about the watershed. In addition, adapting MWMT program priorities to facilitate ongoing opportunities, resources, and collaboration potential ultimately maximizes the program's long-term sustainability and success.

Objective 3: Initiate efforts towards basic limnology monitoring. There are a number of lakes in the MWMA and Morice River watershed, yet current MWMT water monitoring sites only represent flowing surface waters. Morice Lake is a major waterbody within the MWMA; a variety of work has been conducted on the lake in the past, and recently annual sampling was conducted from 2015-2017. However, at present there does not appear to be regular monitoring of Morice Lake. Monitoring lake conditions can serve as a bellwether for identifying long-term change with major implications for salmon populations. Basic *in situ* measurements of parameters like temperature and dissolved oxygen are relatively cost-effective and can contribute substantial information about the behavior of the lake. More complete limnology surveys that include water quality and food web information (e.g., phytoplankton, zooplankton, etc.) provide even greater resolution on lake conditions. Identifying opportunities to initiate or collaborate on regular lake monitoring efforts would greatly further understanding of changing conditions within this major lotic component of the MWMA.

Objective 4: Develop clear monitoring objectives for 2019 and beyond. This includes identifying specific questions of interest/relevant to goals of program, study design and appropriate analytical approach to provide for statistical rigor. It also includes identifying the resources necessary to address these questions. For suggestions of potential additional monitoring questions/objectives please see final point below under "suggested topics for future inquiry."

Additional Recommendations:

- Options to reduce overall program cost include monitoring a subset of sites and parameters during spring and autumn months, or reducing sample frequency during these periods (e.g., every 4-6 weeks). However, if there is interest in future time series analysis it is recommended that routine sampling continue at all sites throughout the year. If only a selection of subsites from MWMT 2015-2017 are to be monitored, this should include discussion of the objectives of the program and why these sites were selected. To address the objective of long-term monitoring for understanding overall water quality in the MWMA, the recommended site priority is as follows: Morice River, Nanika River, McBride Creek/Nado Creek, and Cutthroat Creek.

- Develop and adopt a standardized approach to long-term data archiving, analysis, interpretation and reporting. Data will continue to be uploaded and archived within the EMS system, however additional improvements to data management may also include options such as a template approach to data compilation and summaries, coupled with approaches for data archiving and reporting. Reporting may include standardized annual or quarterly summaries, figures, analysis, and provide opportunities to regularly review data and sites/objectives. The selected approach should include provisions that address an evolving monitoring and reporting program as new program partners are included, new information is gathered and compiled, land and water use changes, and budgets fluctuate.

- In addition to limnology, additional major information gaps in the Morice watershed include temperature dynamics and measurement/estimation of in-stream flows. Establish several *in situ* continuous monitoring sites for temperature, dissolved oxygen, stream stage, etc., at locations that reflect important water bodies for fish resources, and where additional measures of flows, biology/biomonitoring, and water quality will be collected. Ideally these locations will reflect sites with different hydrological and catchment characteristics, but representative of a broader group of catchment types (e.g., small catchments, non-lake headed, glacial or non-glacial fed, recently clear cut versus historically cut, etc.) See "suggestions for future work" for additional questions related to in situ monitoring below.

- Recommend in-depth more advanced analytical approaches to analyzing future data results once a suitable sample size is achieved (for monthly data this is often estimated as 50-60 samples or 3-5 years of data minimum (Hyndman and Kostenko, 2007)) such as minimum detectable change (MDC) analysis and/or trend-analysis to determine required frequency of additional sampling and changes in trends over time. For evaluating specific questions or objectives, additional explanatory or predictive types of statistical analysis such as multivariate mixed models, regression random forest models, or other statistical approaches may also be useful. These approaches will likely evolve as new questions and objectives arise, and as new data is available.

Suggestions for future work:

- What are the hydrologic regimes (i.e., flows) in systems being monitored or in other catchments of interest? This is especially important for streams and river that do not originate from lakes, as current existing hydrometric information does not represent these types of systems. Information on flow, both/either modeled or measured, would be extremely useful for resolving patterns in water quality data, understanding the ecological effects of observed water quality parameters and how they may be affected by various changes in land use and climate, and establishing environmental flow criteria.

- What are the current impacts of forestry land use on water quality, especially during large storm events and summer low flows? What are effects on parameters such as sediment loading, conductivity, temperature, dissolved oxygen, and nutrient and carbon export. In particular, additional sediment concentrations and transport data is essential to answering this question. Sampling locations should be stratified in locations that represent different levels of disturbance and sampling efforts should capture data across the hydrograph of precipitation events when the majority of sediment transport occurs.

- How might pipeline or further linear development alter water quality? Establishing new monitoring site(s) along the proposed development route of the TransCanada Coastal GasLink pipeline would enable collection of pre-disturbance baseline data and allow for monitoring of conditions during pipeline development (should it occur). These sites should also aim to incorporate some degree of routine (annual) sediment and biological monitoring.

- What are water quality conditions in other systems with different catchment characteristics and high fish value, such as Gosnell Creek and Thautil Rivers? Additional monitoring sites should be considered for strategic locations within these catchments.

- What is the current limnological status of Morice Lake? How might lake conditions be evolving over time and what are the implications for juvenile salmon? Establishing a limnology monitoring station coupled with yearly limnology surveys would call attention to current and changing lake conditions. This work could be linked with the BC ENV Provincial Lakes monitoring program and be useful for establishing future salmon recovery strategies.

- Additional information on juvenile salmon would further inform understanding of watershed conditions and salmon habitat suitability.

- Additional questions and analyses related to trends observed in this report, such as downstream transport and dilution of constituents such as metals, seasonal speciation of metals and relation to flows and other variables, further insight into relationships between export and watershed characteristics such as total areal coverage or spatial relation to specific forms of bedrock geology, etc.

References

Bencala, K.E., and R.A. Walters. 1983. Simulation of solute transport in a mountain pool-and-riffle stream: A transient storage model. Water Resources Research. 19: 718-724.

CCME, 1999. Canadian water quality guidelines for the protection of aquatic life. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg. Accessed online Sep 1, 2018 at http://ceqg-rcqe.ccme.ca/en/index.html

CCME, 2004. Phosphorus: Canadian Guidance Framework for the Management of Freshwater Systems. Canadian Water Quality Guidelines for the Protection of Aquatic Life. Canadian Council of Ministers of the Environment, Publication No. 1299, Hull, Quebec. 6 pp.

Cohen, J. 1969. Statistical power analysis for the behavioral sciences. New York: Academic Press.

Costello, A.B. and J.W. Osborne. 2005. Best practices in exploratory factor analysis: Four recommendations for getting the most from your analysis. Practical Assessment Research and Evaluation. 10(7).

Dai, M., Z. Yin, F. Meng, Q. Liu, and W. Cai. 2012. Spatial distribution of riverine DOC inputs to the ocean: An updated synthesis. Current Opinion in Environmental Sustainability. 4:170-178.

Ficke, A.D., C.A. Myrick, and L.J. Hansen. 2007. Potential impacts of global climate change on freshwater fisheries. Reviews in Fish Biology and Fisheries. 17:581-613.

Godsey, S.E., Kirchner, J.W., and D.W. Clow. 2009. Concentration-discharge relationships reflect chemostatic characteristics of US catchments. Hydrological Processes. 23:1844-1864.

Gottesfeld, A.S., K. Rabnett, and P.E. Hall. 2002. Conserving Skeena Fish Populations and Their Habitat. Skeena Fisheries Commission. Skeena Stage I Watershed-based Fish Sustainability Plan. 281 pp.

Harcum, J.B., and S.A. Dressing. 2015. Technical Memorandum #3: Minimum Detectable Change and Power Analysis, October 2015. Developed for U.S. Environmental Protection Agency by Tetra Tech, Inc., Fairfax, VA. 10 pp. Available online at https://www.epa.gov/nps/data-models-and-other-technical-resources-watershed-approach

Heino, J., R. Virkkala, and H. Toivonen. 2009. Climate change and freshwater biodiversity: detected patterns, future trends and adaptations in northern regions. Biological Reviews. 84:39-54.

Helsel, D.R. 1990. Less than obvious: Statistical treatment of data below the detection limit. Environ. Sci. and Technol. 24:12, 1766-1774.

Hirsch, R.M., and J.R. Slack. 1984. A nonparametric trend test for seasonal data with serial dependence. Water Resources Research. 20:727-732.

House, W.A., and M.S. Warwick. 1998. Hysteresis of a solute concentration/discharge relationship in rivers during storms. Water Research. 32: 2279-2290.

Hyndman, R. and A. Kostenko. 2007. Minimum sample size requirements for seasonal forecasting models. Foresight, Issue 6.

Irvine, K. M., K. Manlove, and C. Hollimon. 2012. Power analysis and trend detection for water quality monitoring data: An application for the Greater Yellowstone Inventory and Monitoring Network. Natural Resource Report NPS/GRYN/NRR—2012/556. National Park Service, Fort Collins, Colorado.

Kernan, M., R.W. Battarbee, and B. Moss (eds). 2011. Climate change impacts on freshwater ecosystems. Wiley-Blackwell, Chinchester, UK. 328 pp.

Lovett, G.M., G.E. Likens, D.C. Buso, C.T. Driscoll, and S.W. Bailey. 2005. The biogeochemistry of chloride at Hubbard Brook, New Hampshire, USA. Biogeochemistry, 72: 191-232.

Lynch, A.J., B.J.E. Myers, C. Chu, L.A. Eby, J.A. Falke,
R.P. Kovach, T.J. Krabbenhoft, T.J. Kwak, J. Lyons, C.P. Paukert and J.E. Whitney. 2016. Climate Change Effects on North American Inland Fish Populations and Assemblages, Fisheries, 41:7, 346-361, DOI: 10.1080/03632415.2016.1186016

ENV, 2013. Guidance for the Derivation and Application of Water Quality Objectives in British Columbia. Water Protection and Sustainability Branch, Environmental Sustainability and Strategic Policy Division, Ministry of Environment. 147 pp.

ENV, 2018. British Columbia Approved Water Quality Guidelines: Aquatic Life, Wildlife, and Agriculture Summary Report. Water Protection and Sustainability Branch, Ministry of Environment and Climate Change Strategy. 36 pp.

MLRMP, 2007. Morice Land and Resource Management Plan. Ministry of Agriculture and Lands Integrated Land Mangement Bureau, Febuary 2007. 259 pp.

Mulholland, P.J., Wilson, G.V., and P.M. Jardine. 1990. Hydrogeochemical response of a forested watershed to storms: Effects of preferential flow along shallow and deep pathways. Water Resources Research. 26:3021-3036.

Morice Water Management Area - Multi-Year Operational Plan. 2009. M.R. Gordon and Associates Ltd., Available at http://moricetrust.ca/reports.php

Oliver, A.A., S.E. Tank, I. Giesbrecht, M.C. Korver, W.C. Floyd, P.Sanborn, C. Bulmer, and K.P. Lertzman. 2017. A global hotspot for dissolved organic carbon in hypermaritime watersheds of coastal British Columbia. Biogeosciences, 14, 3743-3762.

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate change and watershed hydrology part I – Recent and projected changes in British Columbia. Streamline Watershed Management Bulletin, 11:2, 1-12.

R Core Team. 2017. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. URL https://www.R-project.org/.

Raymond, P.A., and N. Oh. 2007. An empirical study of climactic controls on riverine C export from three major U.S. watersheds. Global Biogeochemical Cycles. 21:2.

Redfield A.C. 1958. The biological control of chemical factors in the environment. American Scientist. 46:205-221.

Rosseland, B.O., Blakar, I.A., Bulger, A., Kroglund, F., Kvellstad, A., Lydersen, E., Oughton, D.H., Salbu, B., Staurnes, M., and R. Vogt. 2009. The mixing zone between limed and acidic river waters: complex aluminium chemistry and extreme toxicity for salmonids. Environmental Pollution, 78:3-8.

Scheffers, B.R., et al. 2016. The broad footprint of climate change from genes to biomes to people. Science. 354: 6313.

Sobek, S., L.J. Tranvik, Y.T. Prairie, P. Kortelainen, and J.J. Cole. 2007. Patterns and regulation of dissolved organic carbon: An analysis of 7,500 widely distributed lakes. Limnology and Oceanography, 52:1208-1219.

Strahler, A.N. 1952. Hypsometric (area-altitude) analysis of erosional topography. Geological Society of America Bulletin, 63: 1117-1142.

Tri-Star Environmental Consulting (Tri-Star). 2005. Site-specific water quality guidelines for Skeena River at Usk for the purpose of national reporting. Prepared for Environment Canada, 41 pp.

U.S. Environmental Protection Agency (EPA). 2017. Water Quality Standards Handbook: Chapter 3: Water Quality Criteria. EPA-823-B-17-001. EPA Office of Water, Office of Science and Technology, Washington DC. Accessed November 2018 at https://www.epa.gov/sites/production/files/2014-10/documents/handbook-chapter3.pdf

Wang, W., Yang, H., Wang, X., and J. Jiang. 2010. Effects of fluvic acid and humic acid on aluminum speciation in drinking water. Journal of Environmental Sciences. 22:211-217.

Whitehead, P.G., R.L. Wilby , R.W. Battarbee , M. Kernan and A. J. Wade. 2009. A review of the potential impacts of climate change on surface water quality, Hydrological Sciences Journal, 54:101-123.

Woodward, G., D.M. Perkins, and L.E. Brown. 2010. Climate change and freshwater ecosystems: impacts across multiple levels of organization. Philosophical Transactions of the Royal Society B: Biological Sciences. DOI: https://doi.org/10.1098/rstb.2010.0055

Appendices:
Analysis of water quality monitoring in the Morice Water Management Area

Prepared for the Morice Water Monitoring Trust

by Allison A. Oliver, Ph.D.

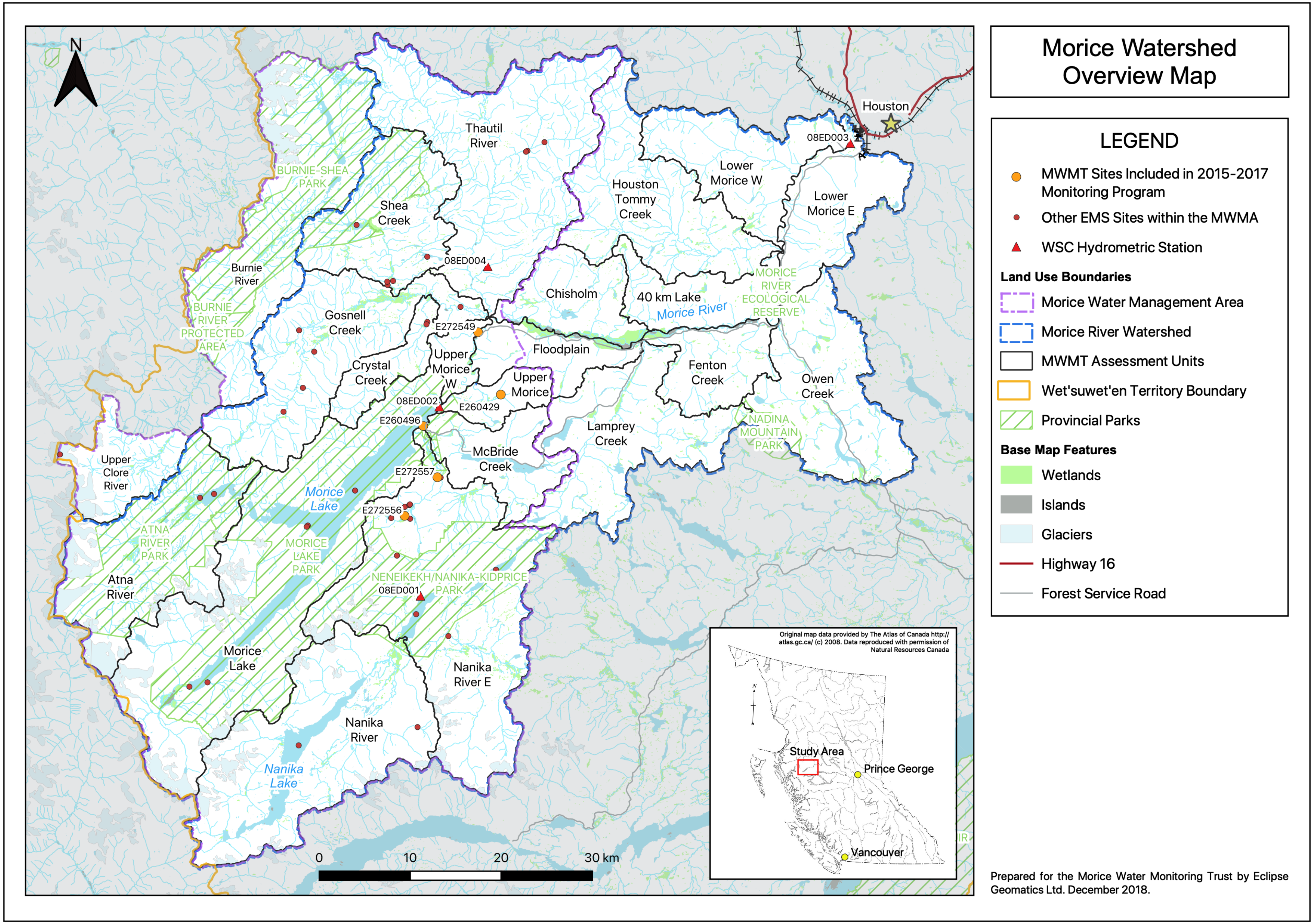
December, 2018

Appendix A. Maps of the Morice River/Morice Water Management Area

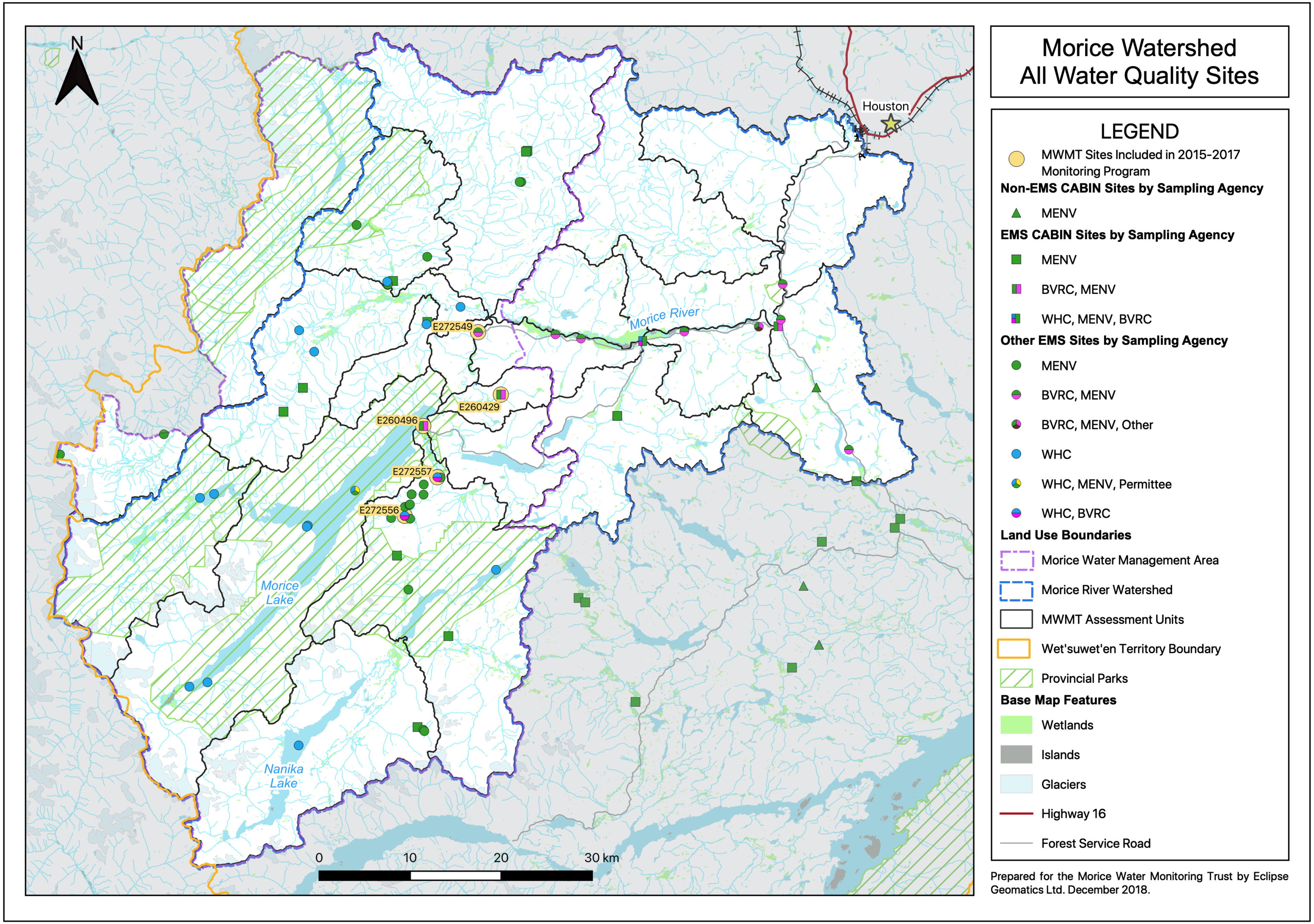
All maps were produced for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd., December 2008. Interactive, electronic maps and additional information on map derivation can be found online at Skeena Maps Portal (Skeena Knowledge Trust): http://maps.skeenasalmon.info/maps/

The following maps depict the Morice Water Management Area within the greater Morice River watershed and include information on the following:

1. Overview
2. All Water Quality Sites
3. Land Use Zoning
4. Road Density
5. Forestry
6. Mining
7. Energy
8. Fish Habitat

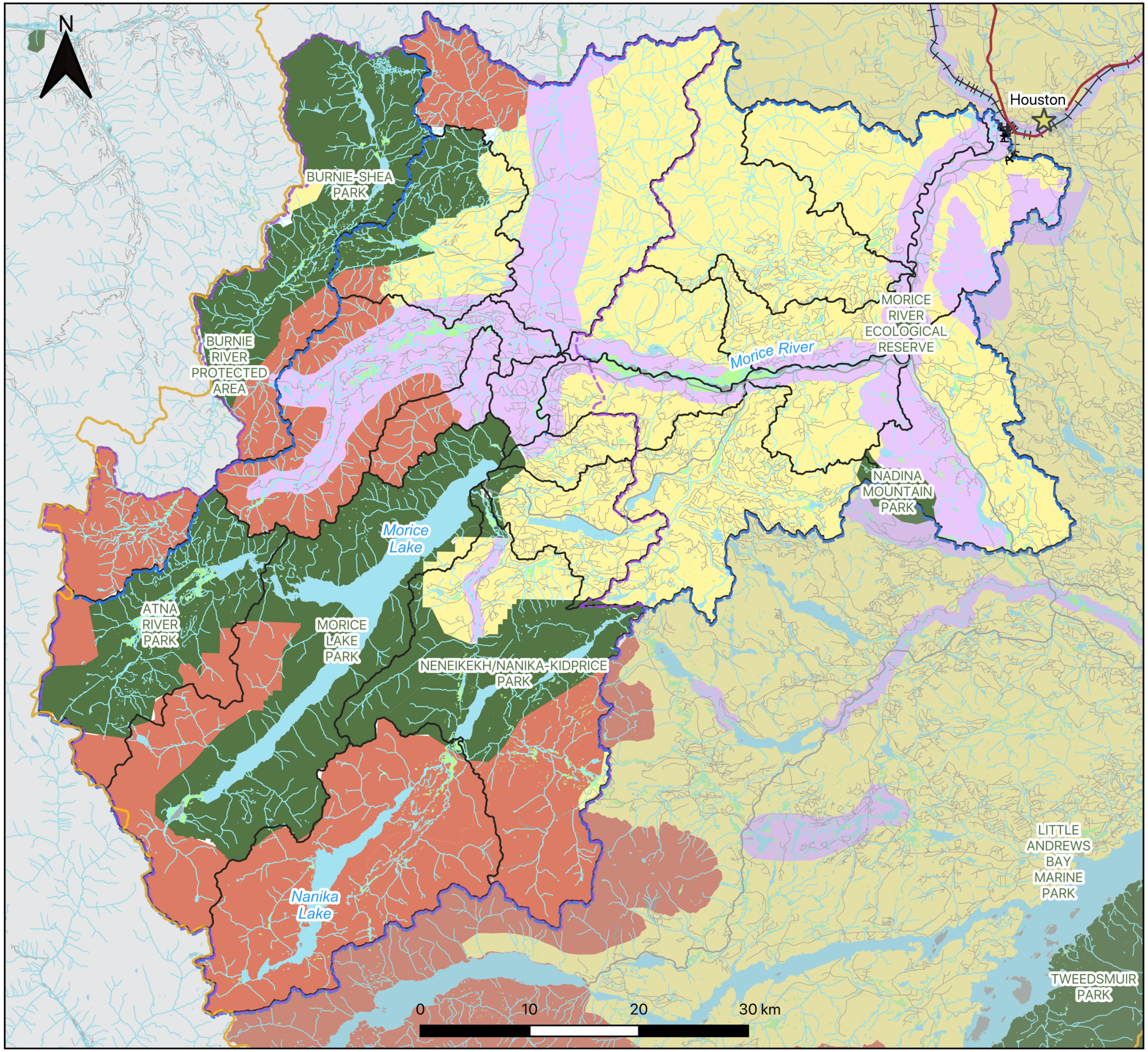


Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.



Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.

Morice Watershed Land Use Zoning Map



LEGEND

2007 Morice Land Resource Management Plan Zones

- No Timber Harvest
- General Management
- Area Specific Management

Land Use Boundaries

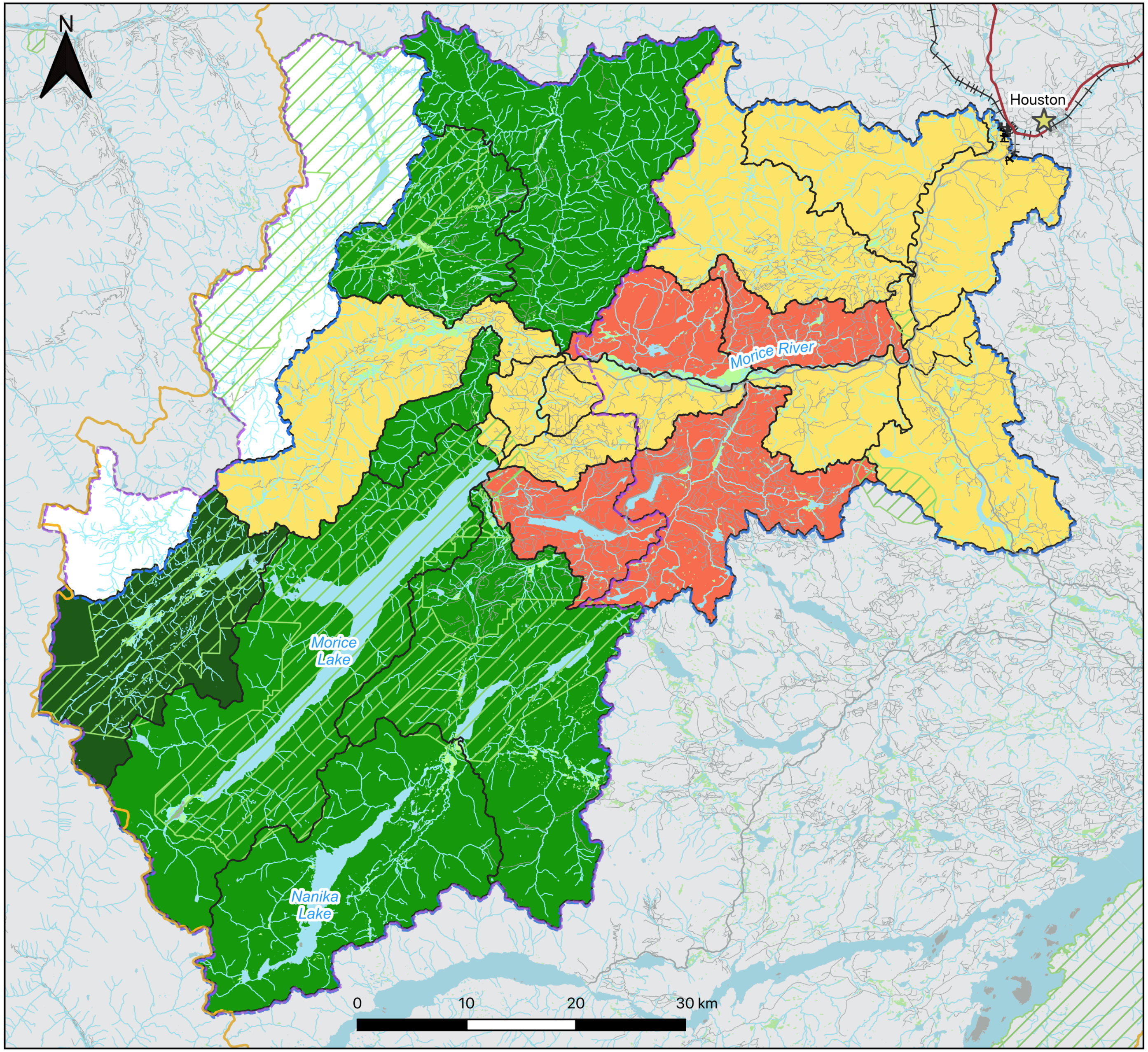
- Morice Water Management Area
- Morice River Watershed
- MWMT Assessment Units
- Wet'suwet'en Territory Boundary
- Provincial Parks

Base Map Features

- Wetlands
- Islands
- Highway 16
- Road Network

Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.

Morice Watershed Road Density Map



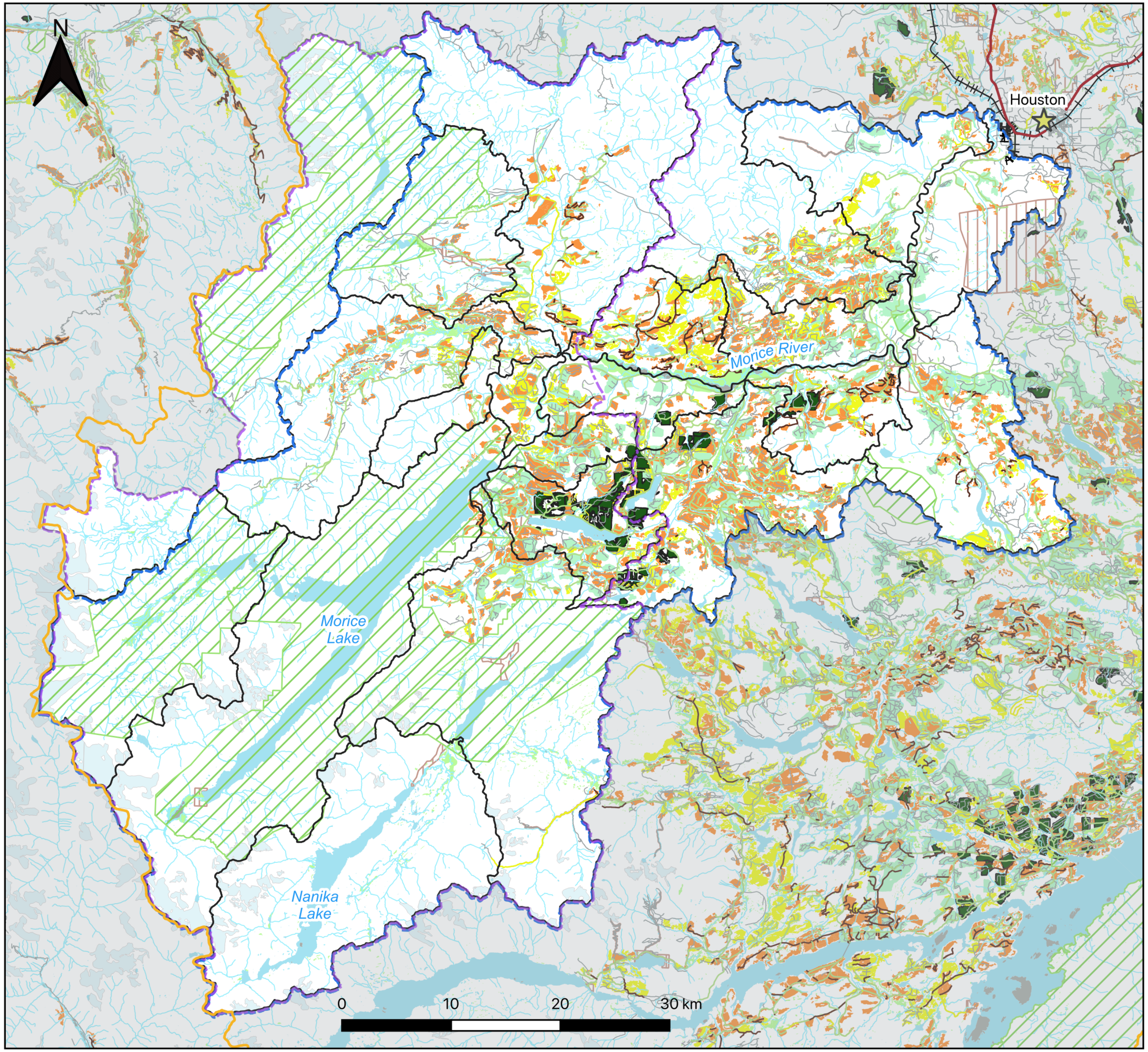
LEGEND

Road Density (km/km²)
- No Roads
- Less than 0.4
- 0.4 to 1.2
- 1.2 and Greater

Land Use Boundaries
- Morice Water Management Area
- Morice River Watershed
- MWMT Assessment Units
- Wet'suwet'en Territory Boundary
- Provincial Parks

Base Map Features
- Wetlands
- Islands
- Highway 16
- Road Network

Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.



Morice Watershed Forestry Map

LEGEND

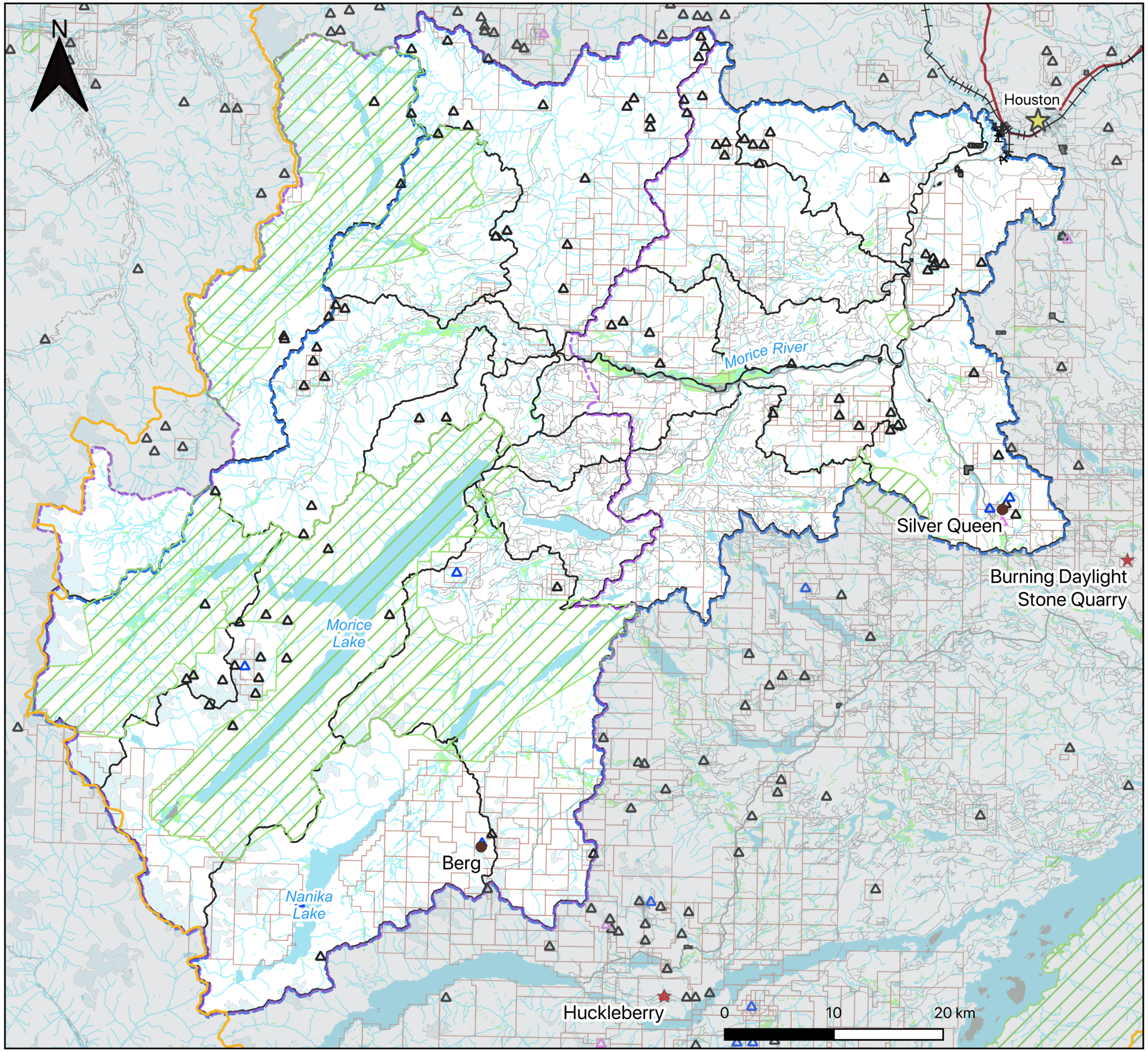
Consolidated Cutblocks (May 2018)
- 1950-1971
- 1971-1990
- 1990-2010
- 2010-2018

Forestry Roads
- Active
- Pending
- Retired

Land Use Boundaries
- Morice Water Management Area
- Morice River Watershed
- MWMT Assessment Units
- Wet'suwet'en Territory Boundary
- Provincial Parks
- Provincial Recreation Areas

Base Map Features
- Wetlands
- Islands
- Glaciers
- Highway 16
- Road Network

Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.



Morice Watershed Mining Map

LEGEND

Significant Mining Projects
- Active Mine
- Exploration

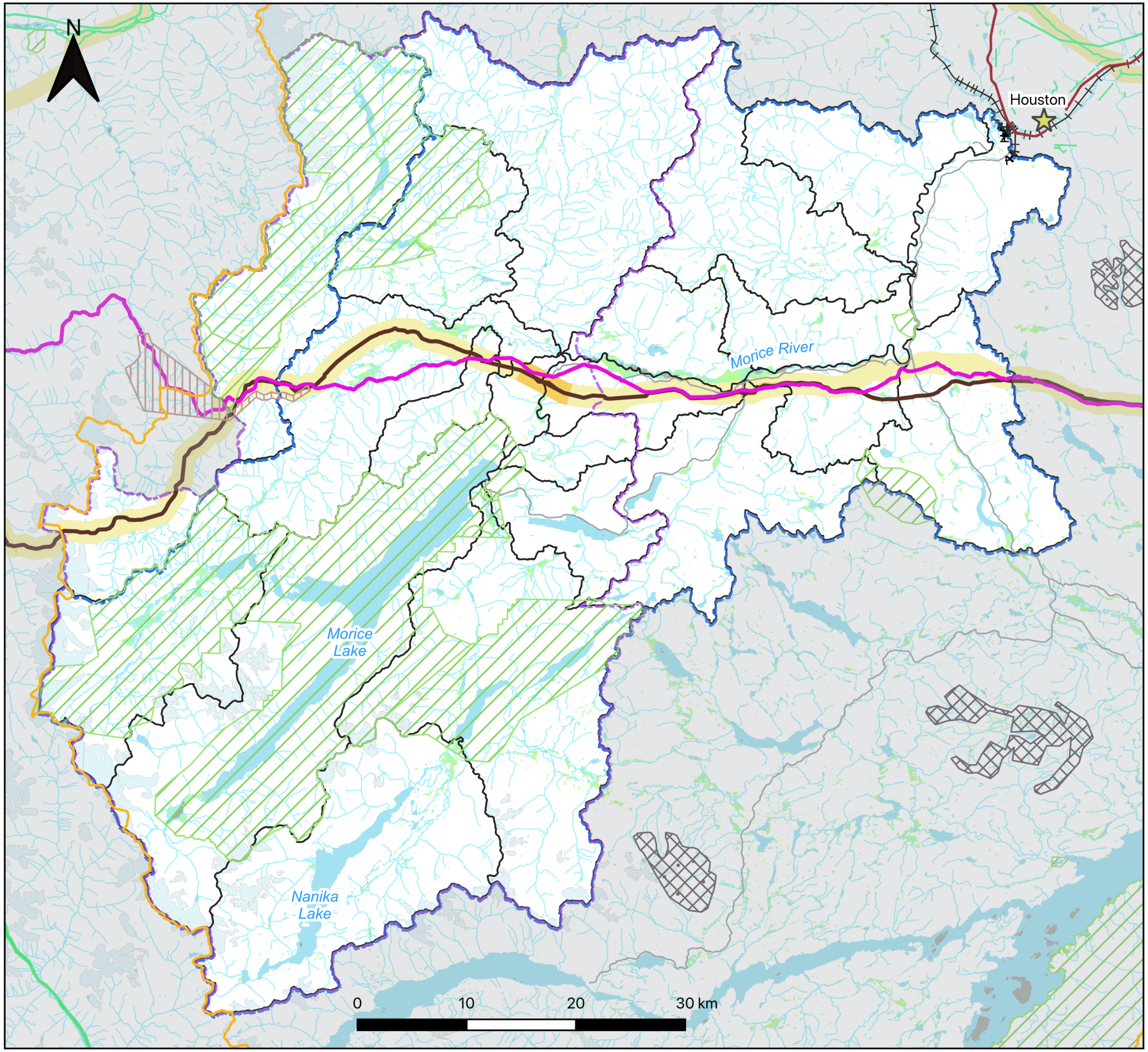
MINFILE Mineral Occurrence
- Producer
- Past Producer
- Developed Prospect
- All Others

Crown Tenures
- Mineral
- Coal
- Placer
- Quarry

Land Use Boundaries
- Morice Water Management Area
- Morice River Watershed
- MWMT Assessment Units
- Wet'suwet'en Territory Boundary
- Provincial Parks

Base Map Features
- Wetlands
- Islands
- Glaciers
- Highway 16
- Road Network

Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.



Morice Watershed Energy Map

LEGEND

OGC Pipeline Permit (Approved Construction Plan)
- Coastal GasLink Pipeline Ltd.
- Pacific Trail Pipelines Management Inc.

Utility Crown Tenure - Oil and Gas
- Application
- Tenure
- Gas Utility Line

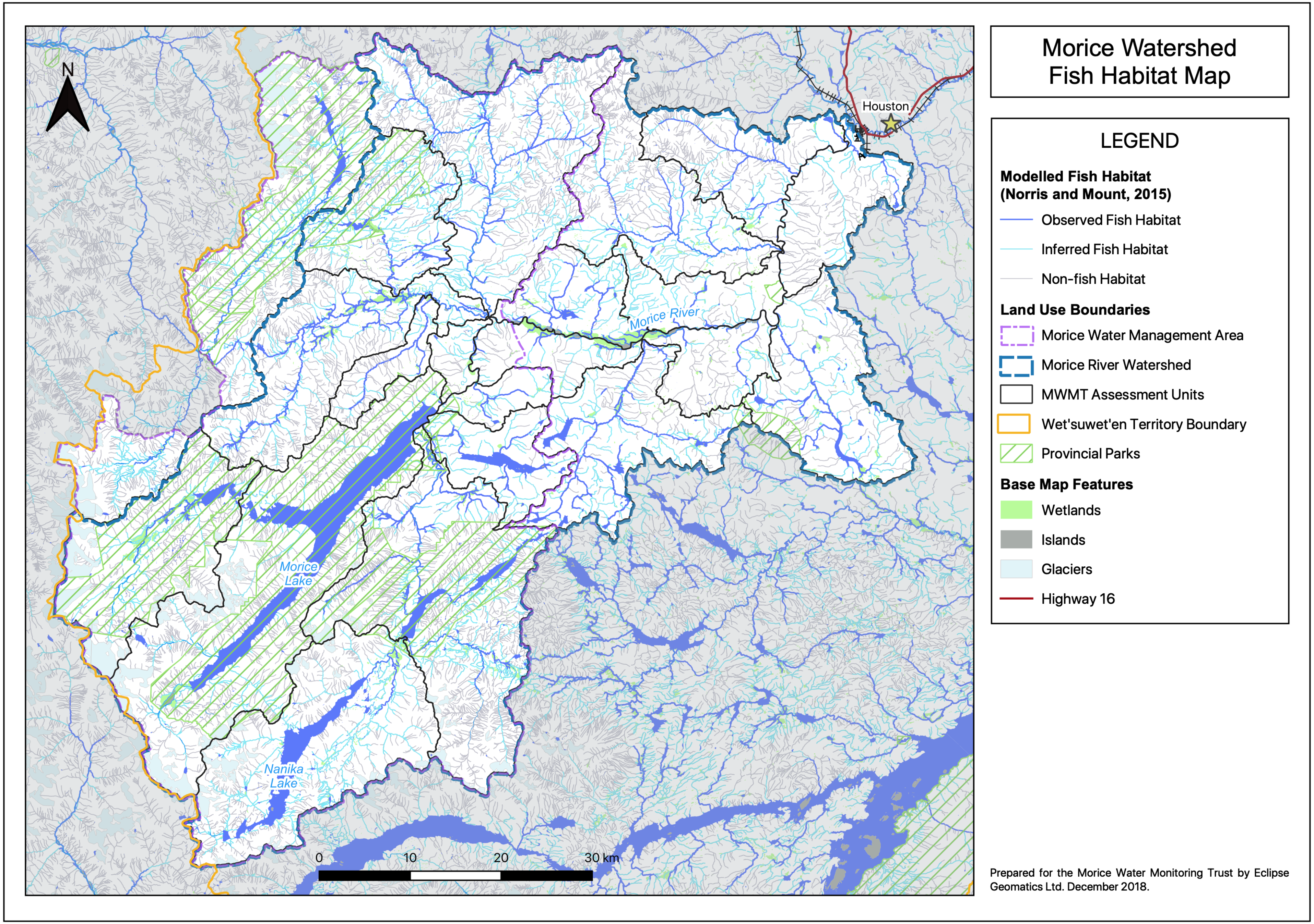
Waterpower Crown Tenure
- Investigative Phase

Windpower Crown Tenure
- Investigative Phase

Land Use Boundaries
- Morice Water Management Area
- Morice River Watershed
- MWMT Assessment Units
- Wet'suwet'en Territory Boundary
- Provincial Parks

Base Map Features
- Wetlands
- Islands
- Glaciers
- Highway 16
- Forest Service Road

Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.

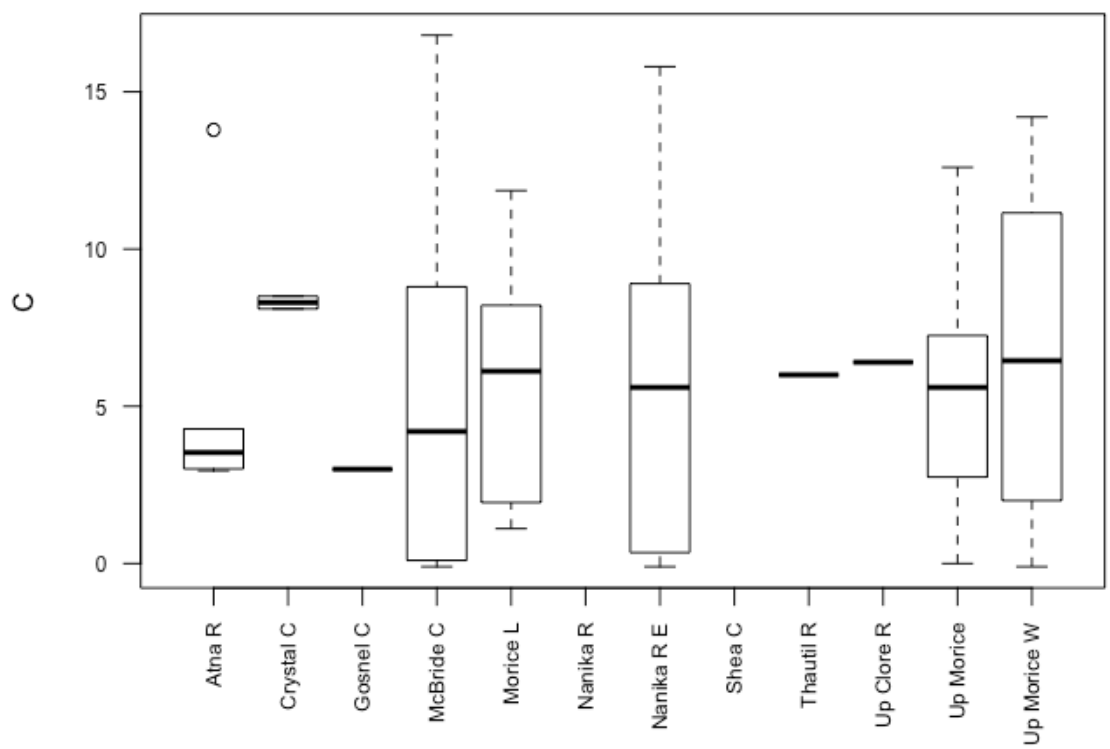


Prepared for the Morice Water Monitoring Trust by Eclipse Geomatics Ltd. December 2018.

Appendix B.1 Summary Statistics for watershed Assessment Units (AU) in Morice Water Management Area 1996-2017: Physiochemical Properties, Anions, Carbon, and Nutrients

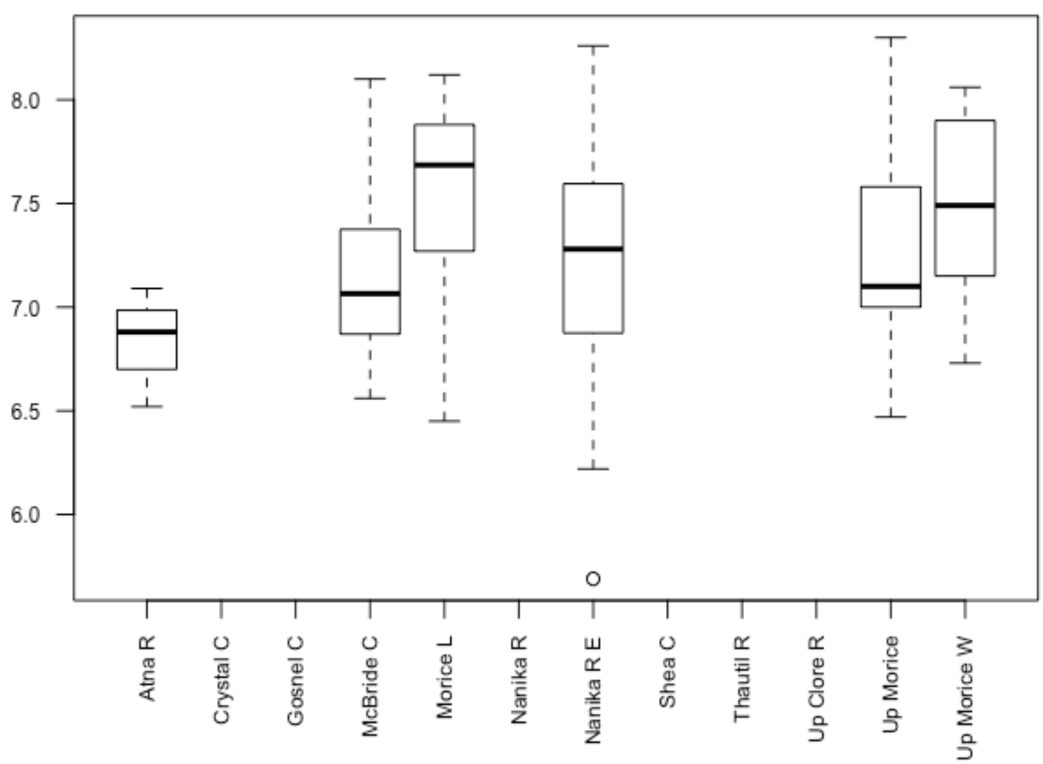
Temperature (°C)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	5.5	3.5	4.7	3.0	13.8	2.1	5.8
Crystal C	2	8.3	8.3	0.3	8.1	8.5	0.2	2.5
Gosnel C	1	3.0	3.0	NA	3.0	3.0	NA	NA
McBride C	21	5.1	4.2	4.9	-0.1	16.8	1.1	2.2
Morice R	10	5.7	6.1	3.5	1.1	11.9	1.1	2.5
Nanika R	0	NA	NA	NA	NA	NA	NA	NA
Nanika R E	47	5.6	5.6	4.9	-0.1	15.8	0.7	1.4
Shea C	0	NA	NA	NA	NA	NA	NA	NA
Thautil R	1	6.0	6.0	NA	6.0	6.0	NA	NA
Up Clore	1	6.4	6.4	NA	6.4	6.4	NA	NA
Up Morice	15	5.3	5.6	3.5	0.0	12.6	0.9	1.9
Up Morice W	24	6.9	6.5	4.7	-0.1	14.2	1.0	2.0



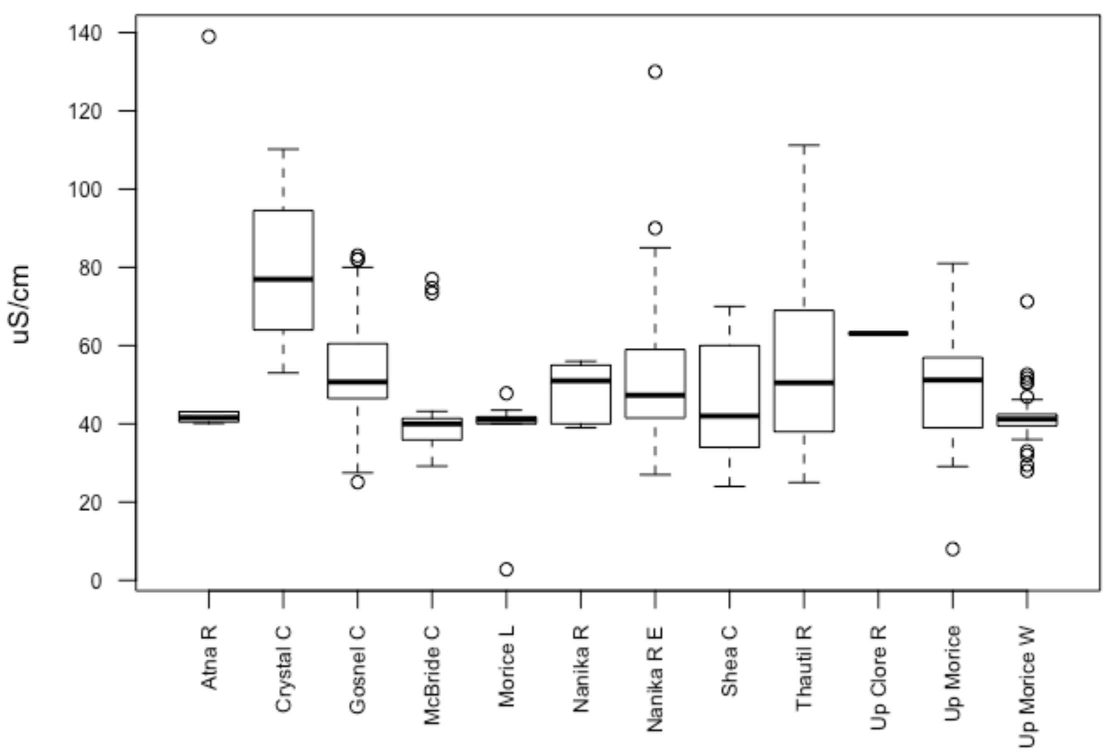
pH

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	3	6.8	6.9	0.3	6.5	7.1	0.2	0.7
Crystal C	0	NA	NA	NA	NA	NA	NA	NA
Gosnel C	0	NA	NA	NA	NA	NA	NA	NA
McBride C	28	7.2	7.1	0.4	6.6	8.1	0.1	0.1
Morice R	10	7.5	7.7	0.6	6.5	8.1	0.2	0.4
Nanika R	0	NA	NA	NA	NA	NA	NA	NA
Nanika R E	63	7.2	7.3	0.5	5.7	8.3	0.1	0.1
Shea C	0	NA	NA	NA	NA	NA	NA	NA
Thautil R	0	NA	NA	NA	NA	NA	NA	NA
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	21	7.3	7.1	0.5	6.5	8.3	0.1	0.2
Up Morice W	22	7.5	7.5	0.4	6.7	8.1	0.1	0.2



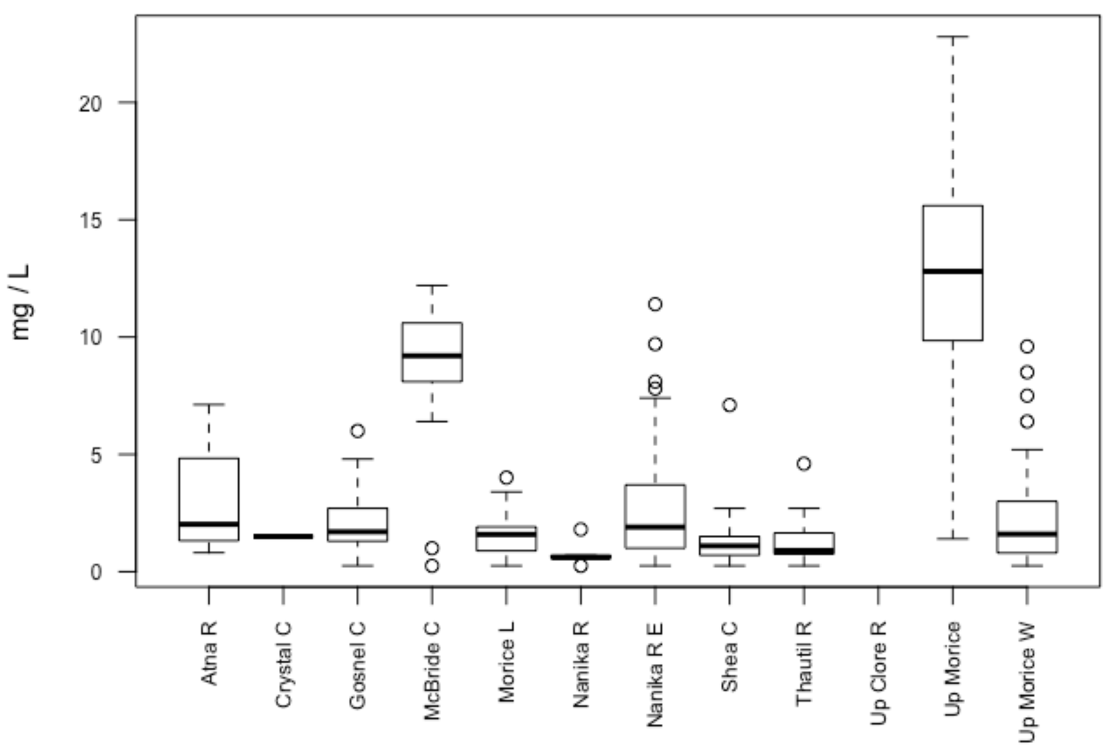
Specific Conductivity (μS/cm @ 25°C)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	57.7	41.6	39.9	40.1	139.0	16.3	41.8
Crystal C	4	79.3	77.0	23.6	53.0	110.2	11.8	37.5
Gosnel C	27	54.9	50.7	15.5	25.1	83.0	3.0	6.1
McBride C	30	41.7	40.0	11.8	29.2	77.0	2.2	4.4
Morice R	18	39.4	41.1	9.3	2.8	47.8	2.2	4.6
Nanika R	6	48.7	51.0	7.4	39.0	56.0	3.0	7.8
Nanika R E	85	51.6	47.3	16.4	27.0	130.0	1.8	3.5
Shea C	33	45.7	42.0	14.4	24.0	70.0	2.5	5.1
Thautil R	26	52.7	50.5	20.3	25.0	111.2	4.0	8.2
Up Clore	1	63.1	63.1	NA	63.1	63.1	NA	NA
Up Morice	23	48.5	51.2	16.4	8.0	81.0	3.4	7.1
Up Morice W	51	41.6	41.2	6.3	28.0	71.3	0.9	1.8



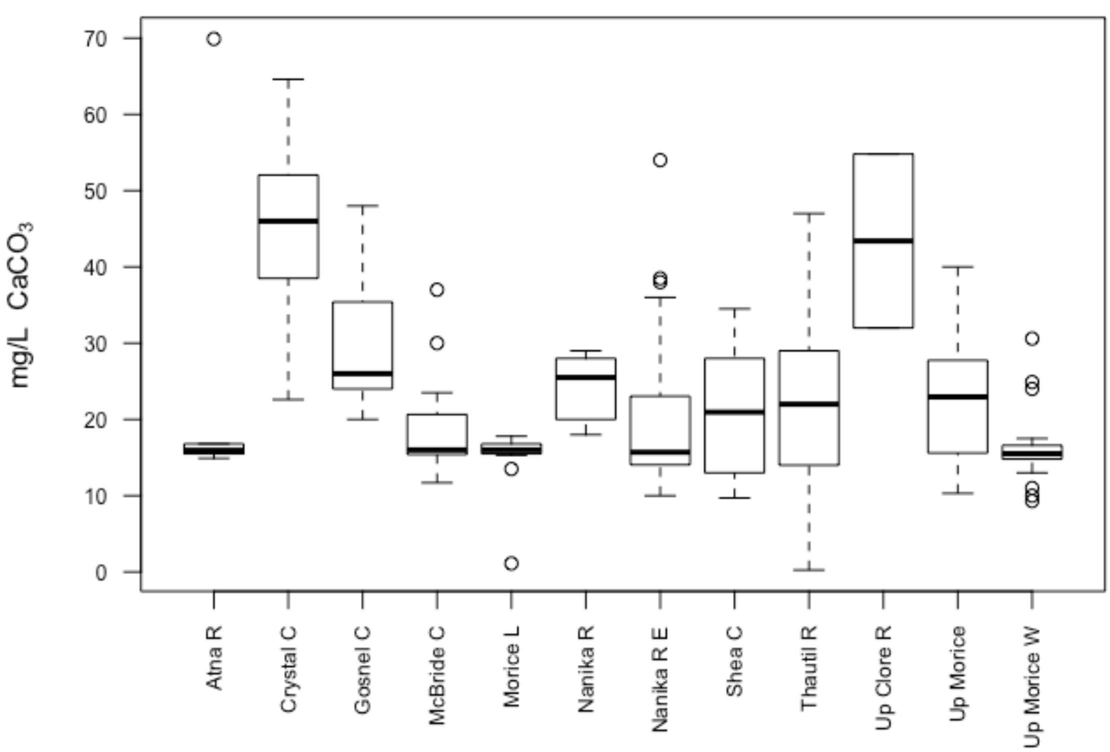
Dissolved Organic Carbon (DOC) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	3.02	2.02	2.44	0.81	7.12	1.00	2.56
Crystal C	1	1.50	1.50	NA	NA	NA	NA	NA
Gosnel C	17	2.23	1.70	1.62	0.25	6.00	0.39	0.83
McBride C	30	8.82	9.20	2.64	0.25	12.20	0.48	0.99
Morice R	18	1.68	1.59	0.97	0.25	4.01	0.23	0.48
Nanika R	6	0.76	0.60	0.53	0.25	1.80	0.22	0.56
Nanika R E	85	2.81	1.90	2.46	0.25	11.40	0.27	0.53
Shea C	26	1.33	1.10	1.32	0.25	7.10	0.26	0.53
Thautil R	23	1.25	0.90	0.99	0.25	4.60	0.21	0.43
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	12.39	12.80	4.84	1.40	22.80	1.01	2.09
Up Morice W	41	2.41	1.60	2.30	0.25	9.60	0.36	0.73



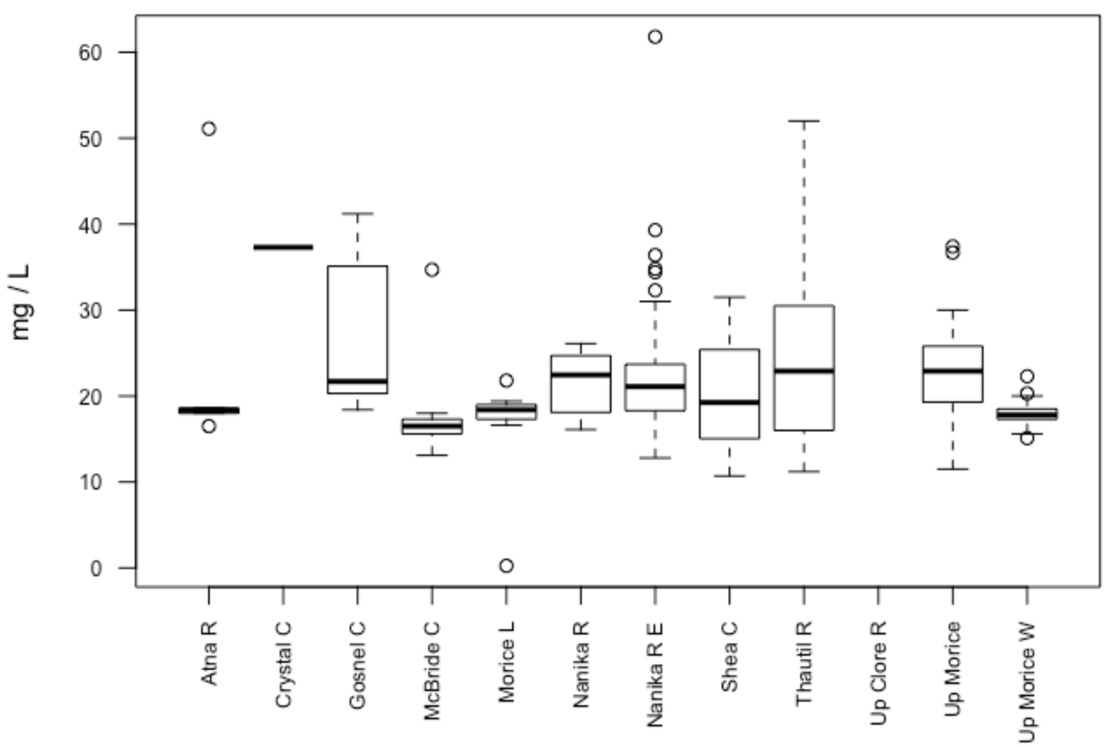
Total Alkalinity (mg/L $CaCO_3$)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	24.8	16.0	22.1	14.9	69.9	9.0	23.2
Crystal C	7	44.9	46.0	13.7	22.6	64.6	5.2	12.7
Gosnel C	21	29.4	26.0	8.0	20.0	48.0	1.7	3.6
McBride C	31	18.2	16.0	5.2	11.7	37.0	0.9	1.9
Morice R	18	15.3	16.0	3.7	1.1	17.8	0.9	1.8
Nanika R	6	24.3	25.5	4.5	18.0	29.0	1.8	4.7
Nanika R E	88	19.3	15.7	8.2	10.0	54.0	0.9	1.7
Shea C	38	20.5	21.0	7.4	9.7	34.5	1.2	2.4
Thautil R	30	22.2	22.0	10.3	0.3	47.0	1.9	3.9
Up Clore	2	43.4	43.4	16.1	32.0	54.8	11.4	144.9
Up Morice	24	22.2	23.0	7.9	10.3	40.0	1.6	3.3
Up Morice W	45	15.9	15.5	3.5	9.3	30.6	0.5	1.0



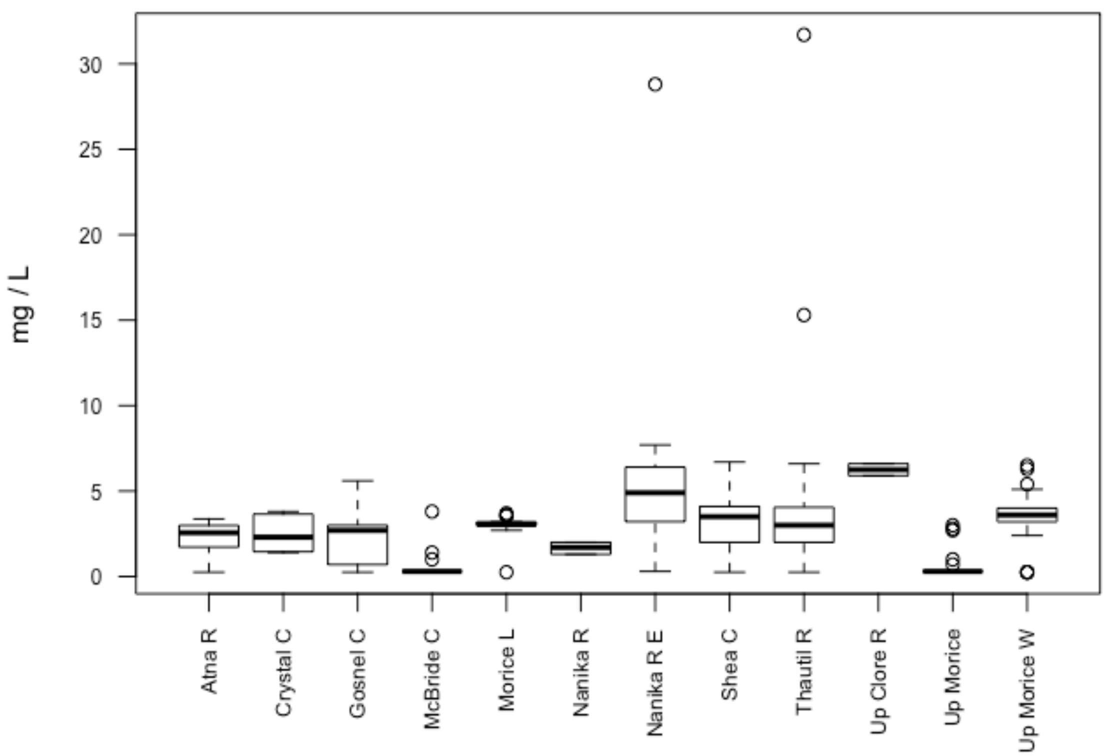
Hardness (Dissolved) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	23.5	18.4	13.6	16.5	51.1	5.5	14.2
Crystal C	1	37.3	37.3	NA	NA	NA	NA	NA
Gosnel C	14	26.0	21.7	8.2	18.4	41.2	2.2	4.7
McBride C	30	16.8	16.5	3.6	13.1	34.7	0.7	1.3
Morice R	18	17.4	18.4	4.5	0.3	21.8	1.0	2.2
Nanika R	6	21.7	22.5	3.9	16.1	26.1	1.6	4.1
Nanika R E	81	22.3	21.1	7.0	12.8	61.8	0.8	1.5
Shea C	28	20.3	19.3	6.2	10.7	31.5	1.2	2.4
Thautil R	26	23.7	22.9	9.3	11.2	52.0	1.8	3.8
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	22	23.2	22.9	6.1	11.5	37.4	1.3	2.7
Up Morice W	41	17.9	17.8	1.4	15.1	22.3	0.2	0.4



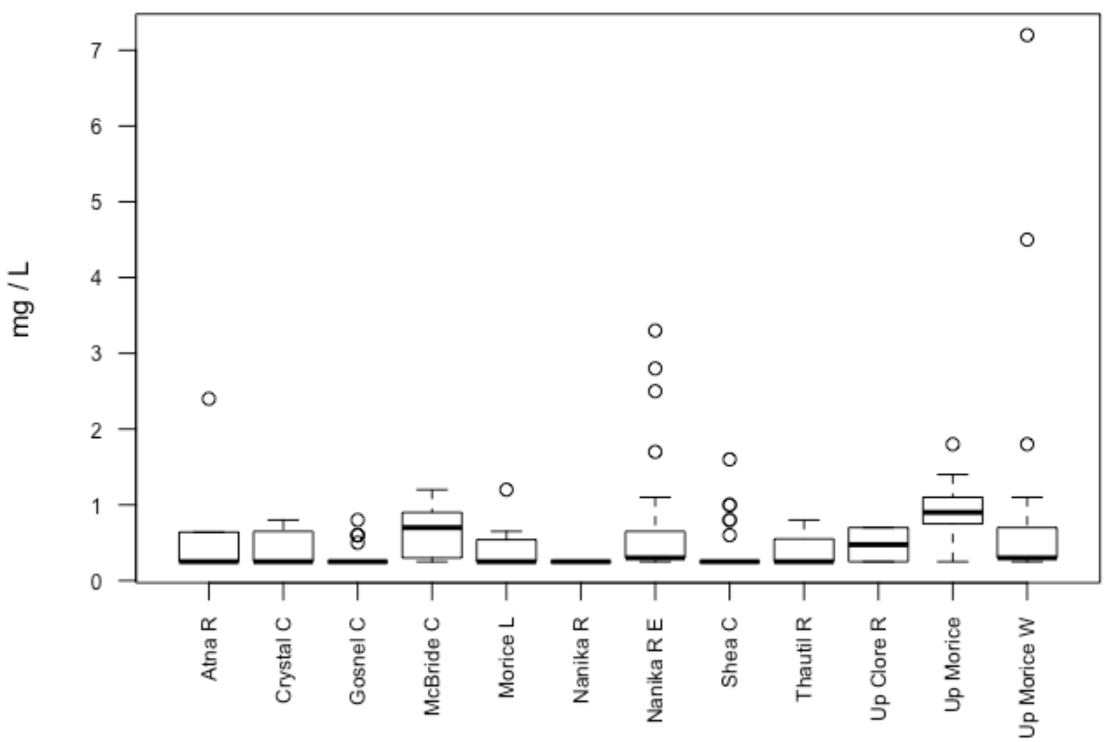
Sulfate (SO_4^-) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	2.24	2.56	1.13	0.25	3.37	0.46	1.18
Crystal C	7	2.53	2.30	1.14	1.40	3.80	0.43	1.06
Gosnel C	21	2.20	2.70	1.65	0.25	5.60	0.36	0.75
McBride C	31	0.47	0.30	0.66	0.30	3.80	0.12	0.24
Morice R	17	3.00	3.04	0.76	0.25	3.70	0.18	0.39
Nanika R	6	1.67	1.70	0.37	1.30	2.00	0.15	0.39
Nanika R E	84	4.79	4.90	3.31	0.30	28.80	0.36	0.72
Shea C	31	3.28	3.50	1.71	0.25	6.70	0.31	0.63
Thautil R	27	4.47	3.00	6.11	0.25	31.70	1.18	2.42
Up Clore	2	6.25	6.25	0.49	5.90	6.60	0.35	4.45
Up Morice	24	0.66	0.30	0.85	0.30	3.00	0.17	0.36
Up Morice W	45	3.45	3.60	1.41	0.25	6.50	0.21	0.42



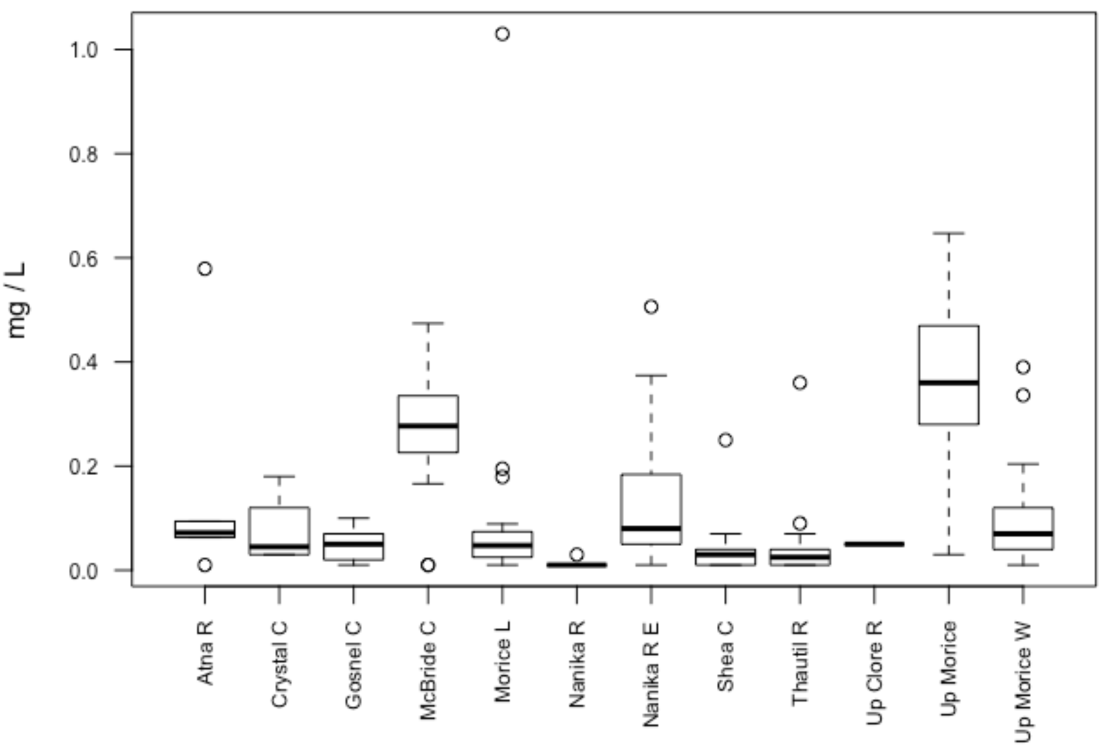
Chloride (Cl^-) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.67	0.25	0.86	0.25	2.40	0.35	0.90
Crystal C	7	0.44	0.25	0.25	0.25	0.80	0.09	0.23
Gosnel C	21	0.34	0.25	0.17	0.25	0.80	0.04	0.08
McBride C	31	0.67	0.70	0.31	0.25	1.20	0.06	0.11
Morice R	17	0.39	0.25	0.26	0.25	1.20	0.06	0.13
Nanika R	6	0.25	0.25	0.00	0.25	0.25	0.00	0.00
Nanika R E	84	0.55	0.30	0.53	0.25	3.30	0.06	0.12
Shea C	31	0.39	0.25	0.32	0.25	1.60	0.06	0.12
Thautil R	28	0.36	0.25	0.19	0.25	0.80	0.04	0.07
Up Clore	2	0.48	0.48	0.32	0.25	0.70	0.23	2.86
Up Morice	24	0.90	0.90	0.39	0.25	1.80	0.08	0.16
Up Morice W	45	0.70	0.30	1.20	0.25	7.20	0.18	0.36



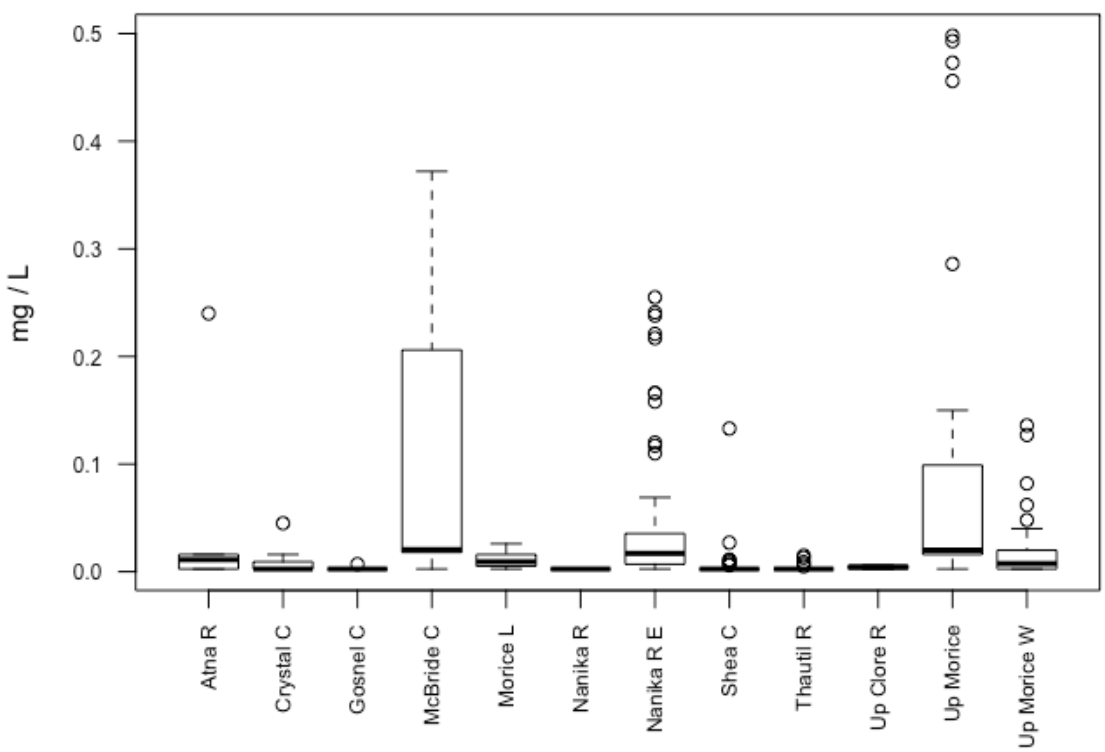
Total Organic Nitrogen (TON) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.148	0.072	0.213	0.010	0.579	0.087	0.223
Crystal C	4	0.075	0.045	0.071	0.030	0.180	0.036	0.114
Gosnel C	14	0.048	0.050	0.029	0.010	0.100	0.008	0.017
McBride C	29	0.252	0.277	0.095	0.010	0.474	0.018	0.036
Morice R	18	0.113	0.048	0.235	0.010	1.030	0.055	0.117
Nanika R	6	0.013	0.010	0.008	0.010	0.030	0.003	0.009
Nanika R E	81	0.114	0.070	0.095	0.010	0.506	0.011	0.021
Shea C	31	0.036	0.030	0.043	0.010	0.250	0.008	0.016
Thautil R	26	0.039	0.025	0.069	0.010	0.360	0.013	0.028
Up Clore	2	0.050	0.050	0.000	0.050	0.050	0.000	0.000
Up Morice	23	0.354	0.360	0.148	0.030	0.647	0.031	0.064
Up Morice W	42	0.081	0.061	0.079	0.010	0.390	0.012	0.025



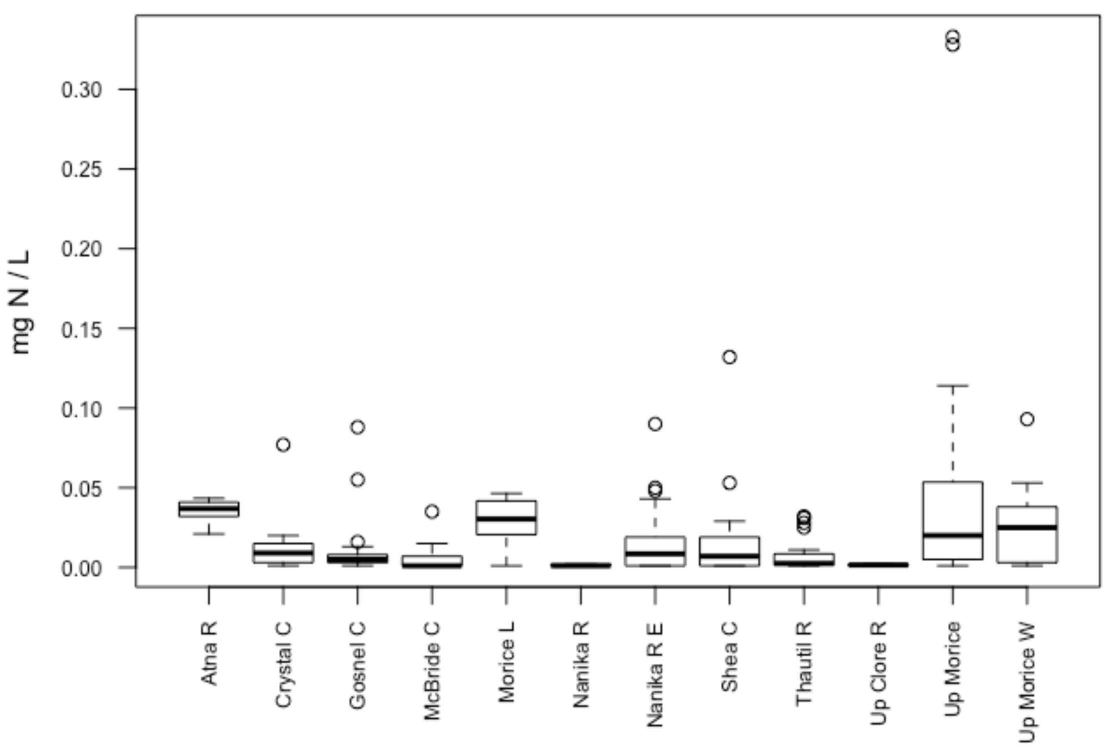
Total Ammonia Nitrogen (TAN) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.047	0.011	0.095	0.003	0.240	0.039	0.099
Crystal C	7	0.011	0.003	0.016	0.003	0.045	0.006	0.015
Gosnel C	18	0.003	0.003	0.001	0.003	0.007	0.000	0.001
McBride C	31	0.028	0.020	0.023	0.003	0.110	0.004	0.001
Morice R	18	0.011	0.009	0.007	0.003	0.026	0.002	0.004
Nanika R	6	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Nanika R E	85	0.022	0.013	0.024	0.003	0.120	0.003	0.005
Shea C	37	0.008	0.003	0.022	0.003	0.133	0.004	0.007
Thautil R	26	0.004	0.003	0.003	0.003	0.015	0.001	0.001
Up Clore	2	0.004	0.004	0.002	0.003	0.006	0.002	0.022
Up Morice	24	0.033	0.019	0.037	0.003	0.150	0.007	0.016
Up Morice W	45	0.019	0.008	0.028	0.003	0.130	0.004	0.009



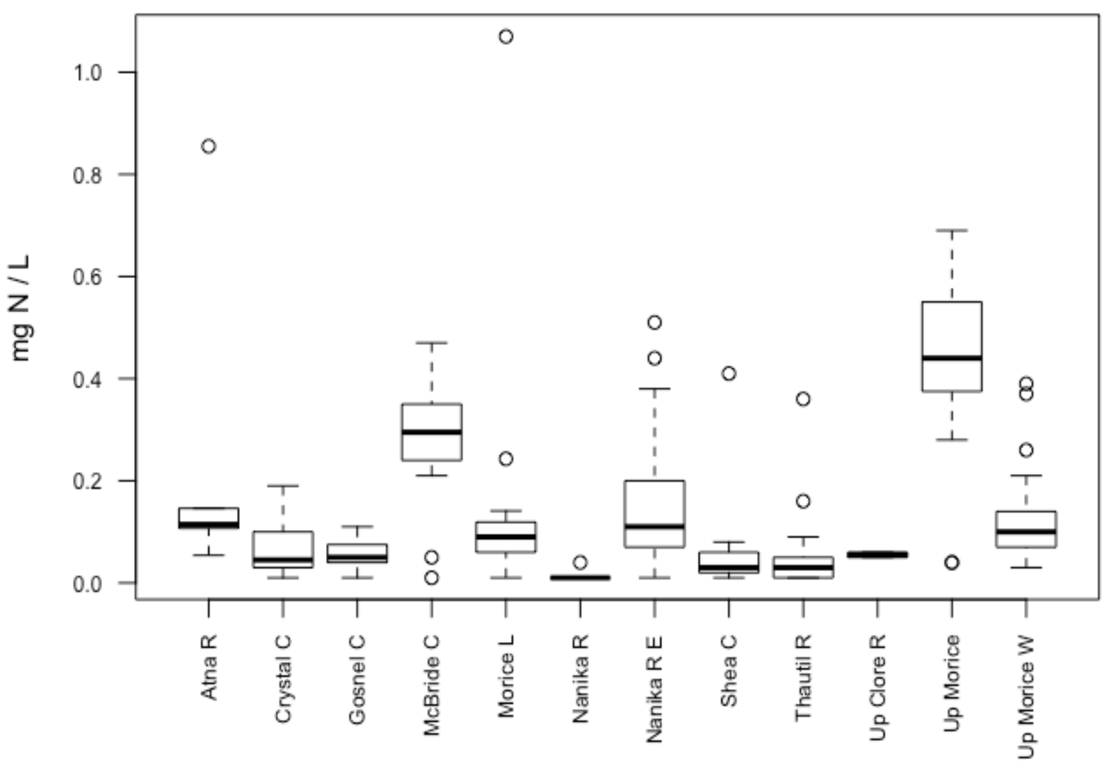
Nitrate-Nitrite ($NO_3^- + NO_2^-$) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.035	0.037	0.008	0.021	0.043	0.003	0.008
Crystal C	7	0.018	0.009	0.027	0.001	0.077	0.010	0.025
Gosnel C	22	0.012	0.005	0.020	0.001	0.088	0.004	0.009
McBride C	30	0.005	0.001	0.007	0.001	0.035	0.001	0.003
Morice R	18	0.030	0.030	0.013	0.001	0.046	0.003	0.006
Nanika R	6	0.001	0.001	0.001	0.001	0.002	0.000	0.001
Nanika R E	86	0.013	0.009	0.014	0.001	0.090	0.002	0.003
Shea C	38	0.014	0.007	0.023	0.001	0.132	0.004	0.008
Thautil R	28	0.007	0.003	0.010	0.001	0.032	0.002	0.004
Up Clore	2	0.002	0.002	0.001	0.001	0.002	0.001	0.006
Up Morice	24	0.052	0.020	0.090	0.001	0.333	0.018	0.038
Up Morice W	45	0.022	0.025	0.020	0.001	0.093	0.003	0.006



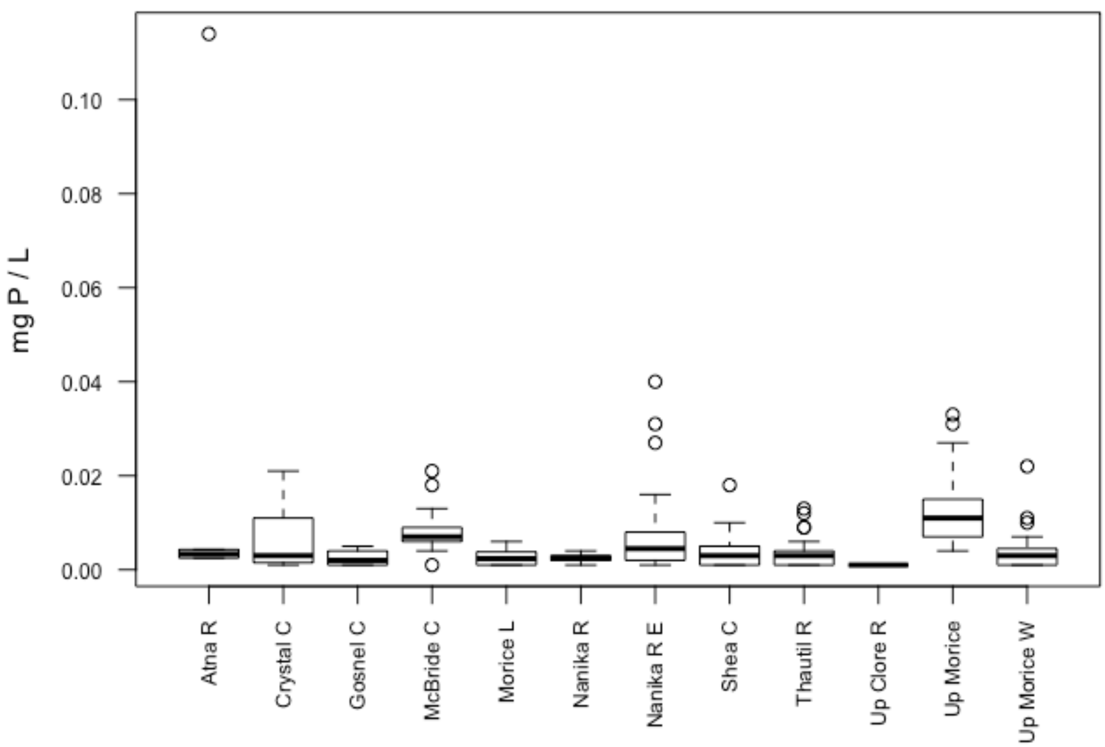
Total Nitrogen (TN) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.232	0.115	0.307	0.054	0.855	0.125	0.322
Crystal C	6	0.070	0.045	0.066	0.010	0.190	0.027	0.069
Gosnel C	15	0.057	0.050	0.029	0.010	0.110	0.007	0.016
McBride C	30	0.285	0.295	0.098	0.010	0.470	0.018	0.037
Morice R	17	0.148	0.090	0.244	0.010	1.070	0.059	0.125
Nanika R	6	0.015	0.010	0.012	0.010	0.040	0.005	0.013
Nanika R E	83	0.147	0.110	0.105	0.010	0.510	0.011	0.023
Shea C	31	0.049	0.030	0.070	0.010	0.410	0.013	0.026
Thautil R	28	0.046	0.030	0.070	0.010	0.360	0.013	0.027
Up Clore	2	0.055	0.055	0.007	0.050	0.060	0.005	0.064
Up Morice	23	0.440	0.440	0.167	0.040	0.690	0.035	0.072
Up Morice W	43	0.120	0.100	0.080	0.030	0.390	0.012	0.025



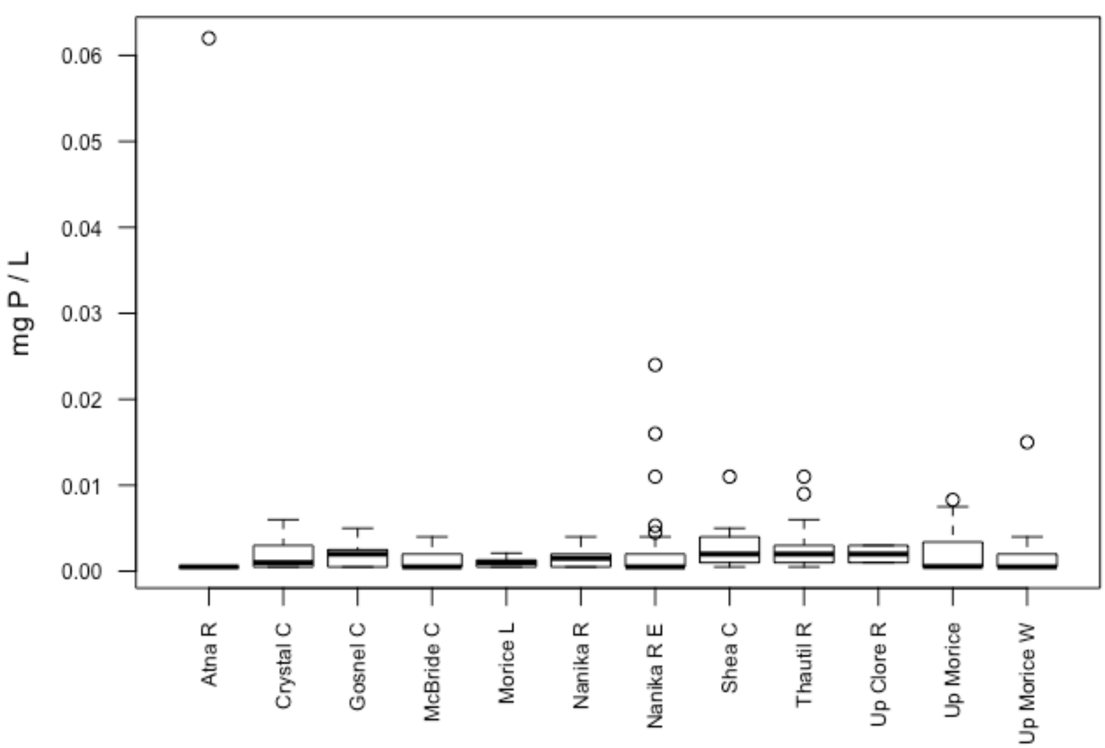
Total Phosphorus (TP) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.022	0.003	0.045	0.003	0.114	0.018	0.047
Crystal C	11	0.007	0.003	0.007	0.001	0.021	0.002	0.005
Gosnel C	25	0.003	0.002	0.002	0.001	0.005	0.000	0.001
McBride C	30	0.008	0.007	0.004	0.001	0.021	0.001	0.001
Morice R	16	0.003	0.002	0.002	0.001	0.006	0.000	0.001
Nanika R	6	0.003	0.003	0.001	0.001	0.004	0.000	0.001
Nanika R E	86	0.006	0.005	0.006	0.001	0.040	0.001	0.001
Shea C	40	0.004	0.003	0.003	0.001	0.018	0.001	0.001
Thautil R	33	0.004	0.003	0.003	0.001	0.013	0.001	0.001
Up Clore	3	0.001	0.001	0.000	0.001	0.001	0.000	0.000
Up Morice	24	0.013	0.011	0.008	0.004	0.033	0.002	0.003
Up Morice W	48	0.004	0.003	0.004	0.001	0.022	0.001	0.001



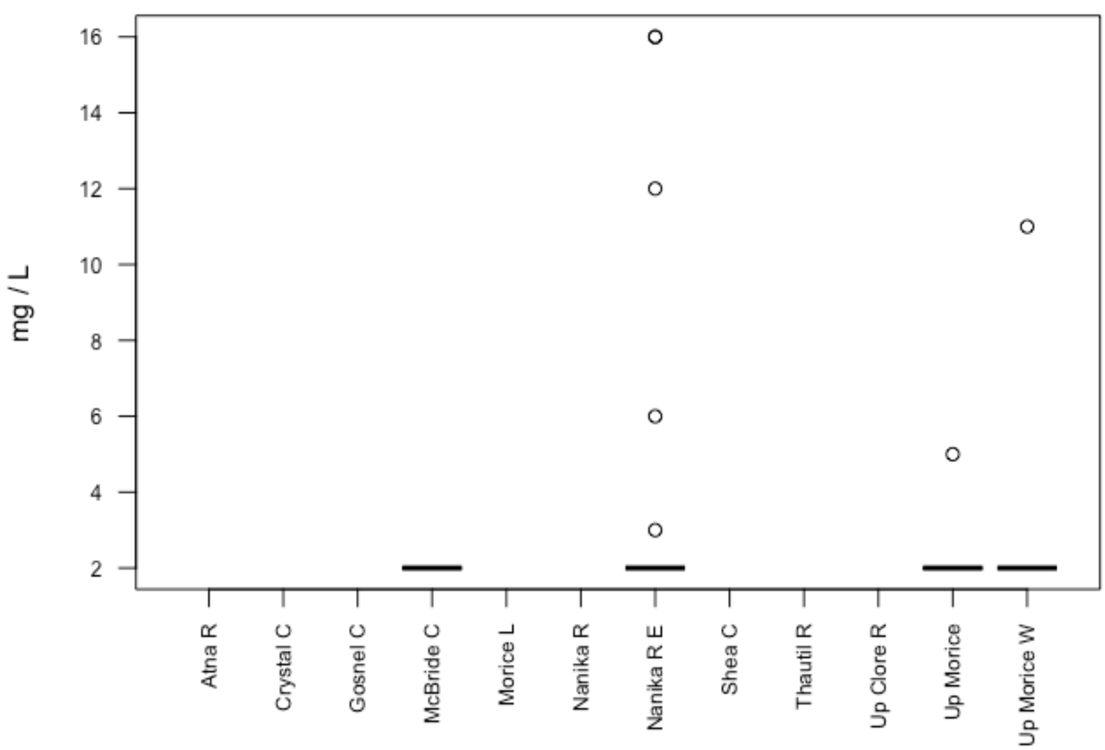
Orthophosphate (ORP) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.011	0.001	0.025	0.001	0.062	0.010	0.026
Crystal C	7	0.002	0.001	0.002	0.001	0.006	0.001	0.002
Gosnel C	19	0.002	0.002	0.001	0.001	0.005	0.000	0.001
McBride C	30	0.001	0.001	0.001	0.001	0.004	0.000	0.000
Morice R	18	0.001	0.001	0.001	0.001	0.002	0.000	0.000
Nanika R	6	0.002	0.002	0.001	0.001	0.004	0.001	0.001
Nanika R E	82	0.002	0.001	0.003	0.001	0.024	0.000	0.001
Shea C	30	0.003	0.002	0.002	0.001	0.011	0.000	0.001
Thautil R	26	0.003	0.002	0.003	0.001	0.011	0.000	0.001
Up Clore	2	0.002	0.002	0.001	0.001	0.003	0.001	0.013
Up Morice	24	0.002	0.001	0.002	0.001	0.008	0.000	0.001
Up Morice W	45	0.002	0.001	0.002	0.001	0.015	0.000	0.001



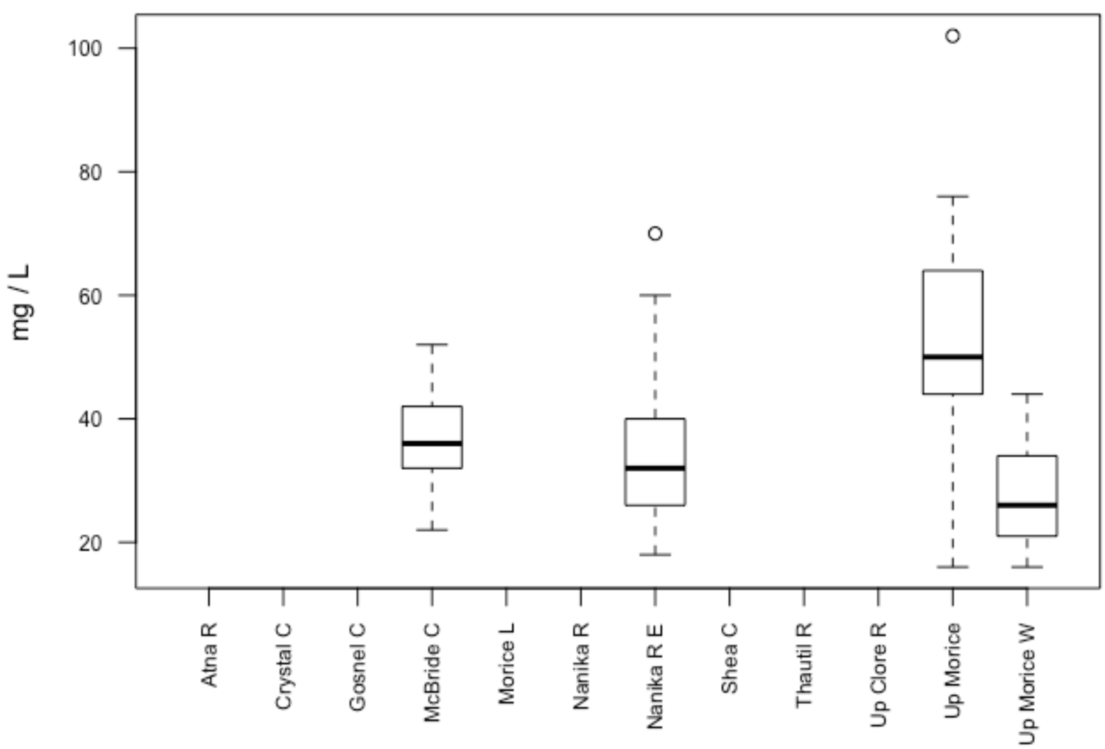
Total Suspended Solids (TSS) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	0	NA	NA	NA	NA	NA	NA	NA
Crystal C	0	NA	NA	NA	NA	NA	NA	NA
Gosnel C	0	NA	NA	NA	NA	NA	NA	NA
McBride C	29	2.0	2.0	NA	NA	NA	NA	NA
Morice R	0	NA	NA	NA	NA	NA	NA	NA
Nanika R	0	NA	NA	NA	NA	NA	NA	NA
Nanika R E	59	2.7	2.0	2.9	2.0	16.0	0.4	0.7
Shea C	0	NA	NA	NA	NA	NA	NA	NA
Thautil R	0	NA	NA	NA	NA	NA	NA	NA
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	22	2.1	2.0	0.6	2.0	5.0	0.1	0.3
Up Morice W	24	2.4	2.0	1.8	2.0	11.0	0.4	0.8



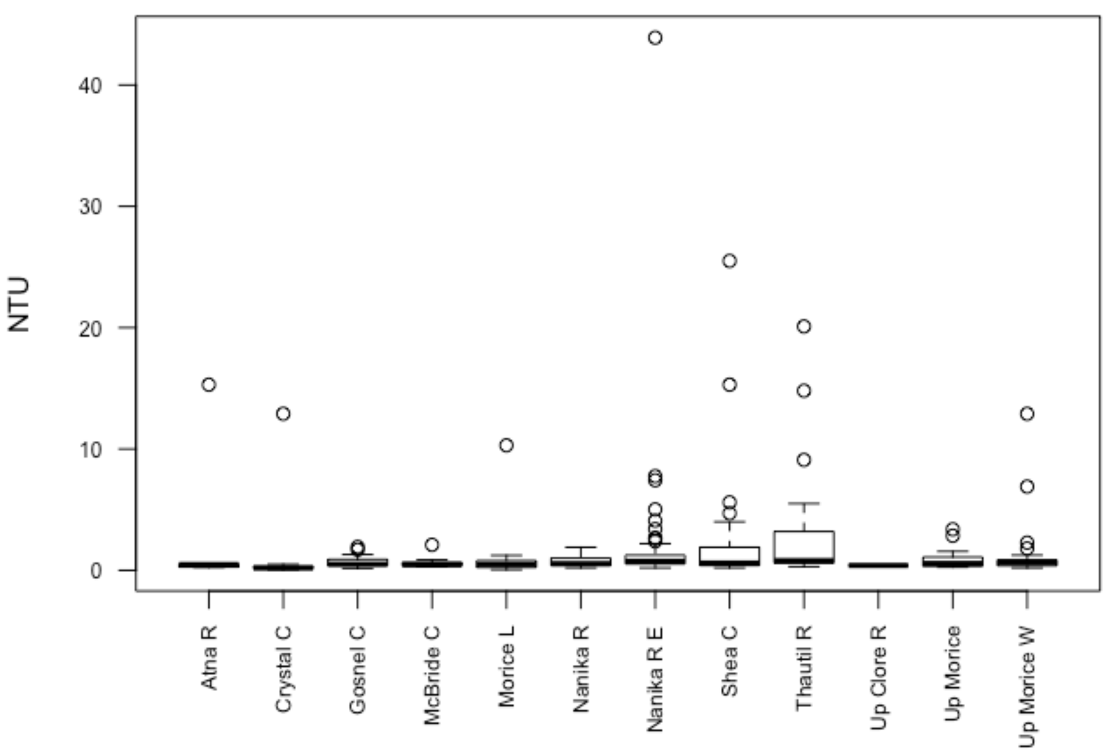
Total Dissolved Solids (TDS) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	0	NA	NA	NA	NA	NA	NA	NA
Crystal C	0	NA	NA	NA	NA	NA	NA	NA
Gosnel C	0	NA	NA	NA	NA	NA	NA	NA
McBride C	29	36.7	36.0	7.0	22.0	52.0	1.3	2.6
Morice R	0	NA	NA	NA	NA	NA	NA	NA
Nanika R	0	NA	NA	NA	NA	NA	NA	NA
Nanika R E	60	33.7	32.0	10.5	18.0	70.0	1.4	2.7
Shea C	0	NA	NA	NA	NA	NA	NA	NA
Thautil R	0	NA	NA	NA	NA	NA	NA	NA
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	22	54.1	50.0	18.2	16.0	102.0	3.9	8.1
Up Morice W	24	28.1	26.0	8.1	16.0	44.0	1.7	3.4



Turbidity (NTU)

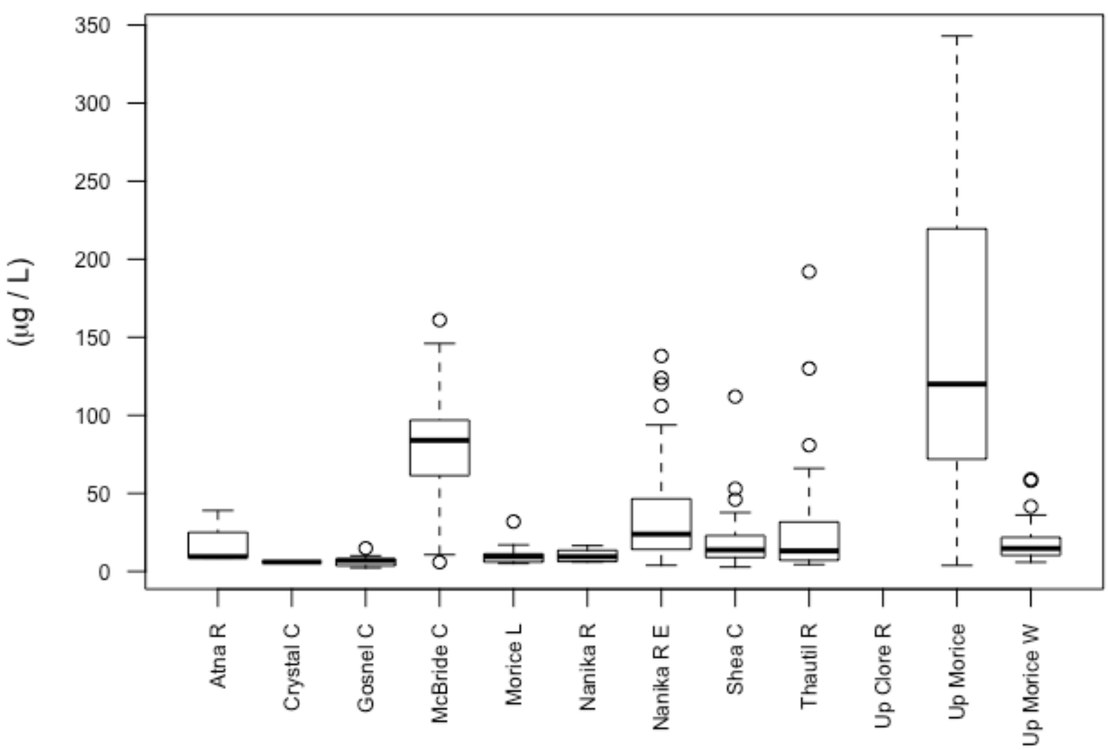
AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	2.88	0.48	6.08	0.24	15.30	2.48	6.39
Crystal C	7	2.01	0.18	4.80	0.05	12.90	1.82	4.44
Gosnel C	23	0.72	0.50	0.46	0.16	1.93	0.10	0.20
McBride C	30	0.56	0.46	0.34	0.30	2.10	0.06	0.13
Morice R	18	1.05	0.48	2.33	0.05	10.30	0.55	1.16
Nanika R	6	0.77	0.55	0.62	0.20	1.90	0.25	0.65
Nanika R E	82	1.67	0.74	4.90	0.20	43.90	0.54	1.08
Shea C	29	2.55	0.60	5.33	0.20	25.50	0.99	2.03
Thautil R	26	2.90	0.80	4.78	0.30	20.10	0.94	1.93
Up Clore	2	0.40	0.40	0.00	0.40	0.40	0.00	0.00
Up Morice	24	0.85	0.57	0.81	0.26	3.38	0.17	0.34
Up Morice W	46	1.06	0.63	2.05	0.20	12.90	0.30	0.61



Appendix B.2 Summary Statistics for watershed Assessment Units (AU) in Morice Water Management Area 1996-2017: Dissolved and Total Metals

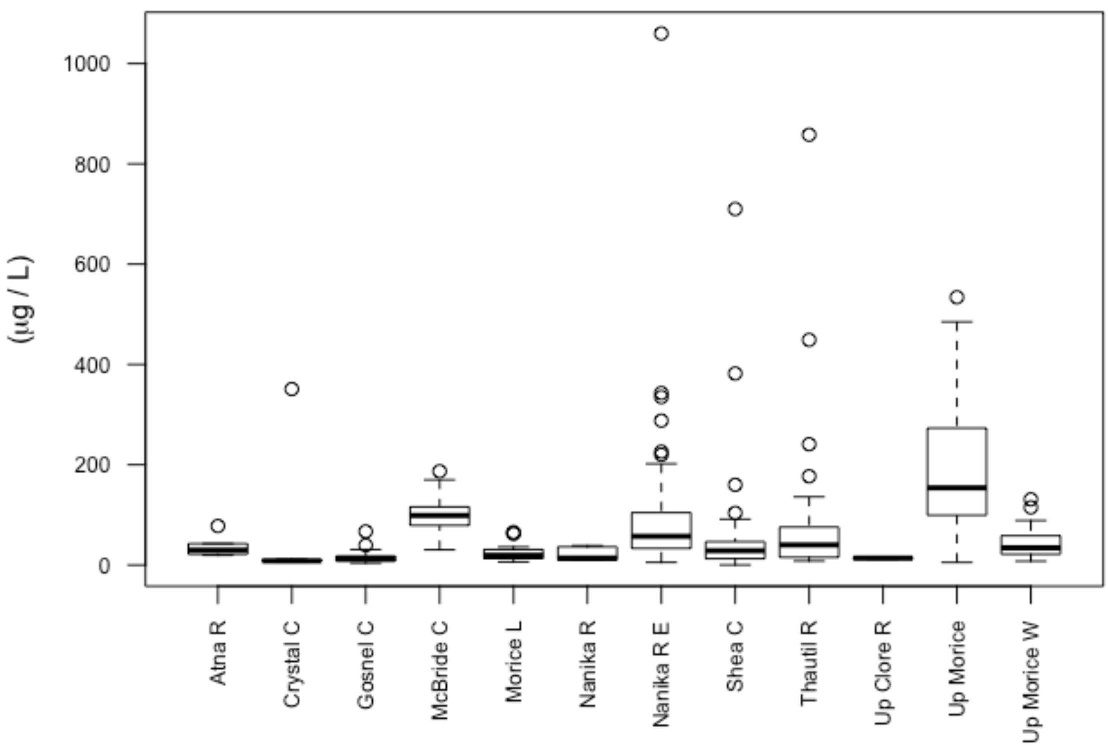
Aluminum – Dissolved (Al-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	24.8	16.0	22.1	14.9	69.9	9.0	23.2
Crystal C	7	44.9	46.0	13.7	22.6	64.6	5.2	12.7
Gosnel C	21	29.4	26.0	8.0	20.0	48.0	1.7	3.6
McBride C	31	18.2	16.0	5.2	11.7	37.0	0.9	1.9
Morice R	18	15.3	16.0	3.7	1.1	17.8	0.9	1.8
Nanika R	6	24.3	25.5	4.5	18.0	29.0	1.8	4.7
Nanika R E	88	19.3	15.7	8.2	10.0	54.0	0.9	1.7
Shea C	38	20.5	21.0	7.4	9.7	34.5	1.2	2.4
Thautil R	30	22.2	22.0	10.3	0.3	47.0	1.9	3.9
Up Clore	2	43.4	43.4	16.1	32.0	54.8	11.4	144.9
Up Morice	24	22.2	23.0	7.9	10.3	40.0	1.6	3.3
Up Morice W	45	15.9	15.5	3.5	9.3	30.6	0.5	1.0



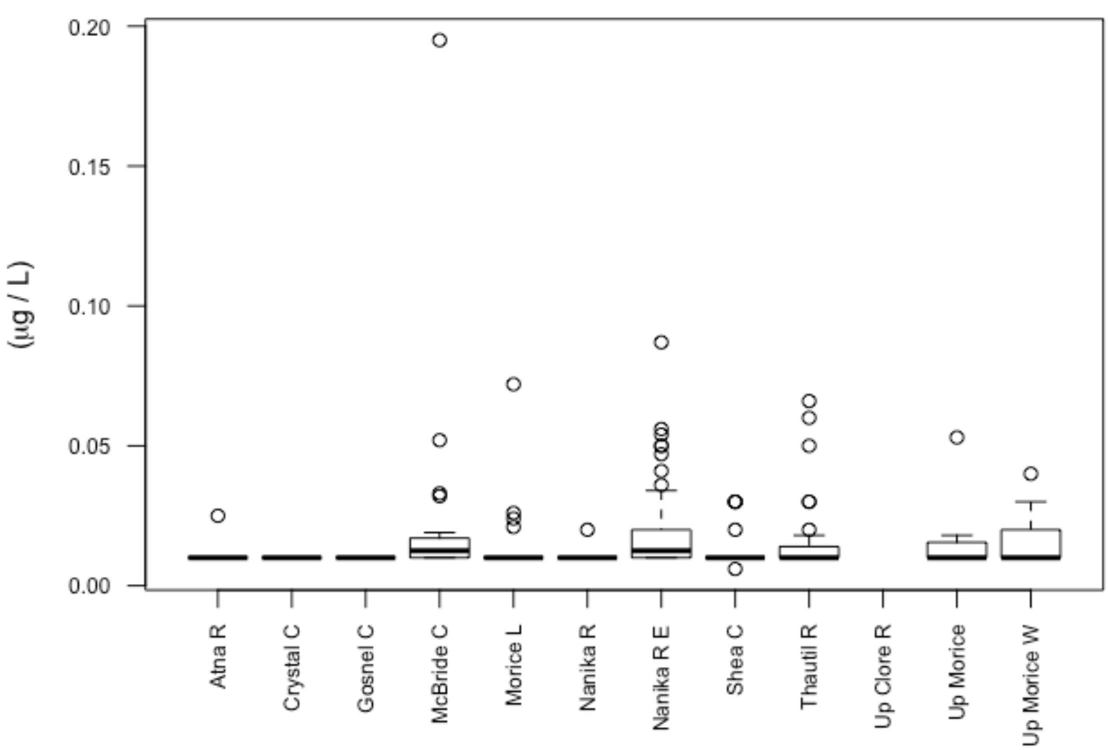
Aluminum – Total (Al-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	42.45	36.25	23.66	19.60	77.90	9.66	24.83
Crystal C	7	57.37	8.10	129.49	5.80	351.00	48.94	119.76
Gosnel C	21	16.45	13.00	14.63	3.90	67.00	3.19	6.66
McBride C	31	100.83	98.80	32.43	30.40	187.00	5.82	11.89
Morice R	18	25.99	19.45	19.24	6.30	65.50	4.54	9.57
Nanika R	6	20.47	13.95	13.38	9.70	38.70	5.46	14.04
Nanika R E	91	87.34	57.30	122.68	5.40	1060.00	12.86	25.55
Shea C	39	58.24	28.60	125.34	0.25	710.00	20.07	40.63
Thautil R	29	93.85	40.20	173.08	8.10	858.00	32.14	65.84
Up Clore	2	13.85	13.85	2.62	12.00	15.70	1.85	23.51
Up Morice	24	196.13	154.00	139.33	5.30	534.00	28.44	58.83
Up Morice W	45	41.45	34.40	26.85	7.70	131.00	4.00	8.07



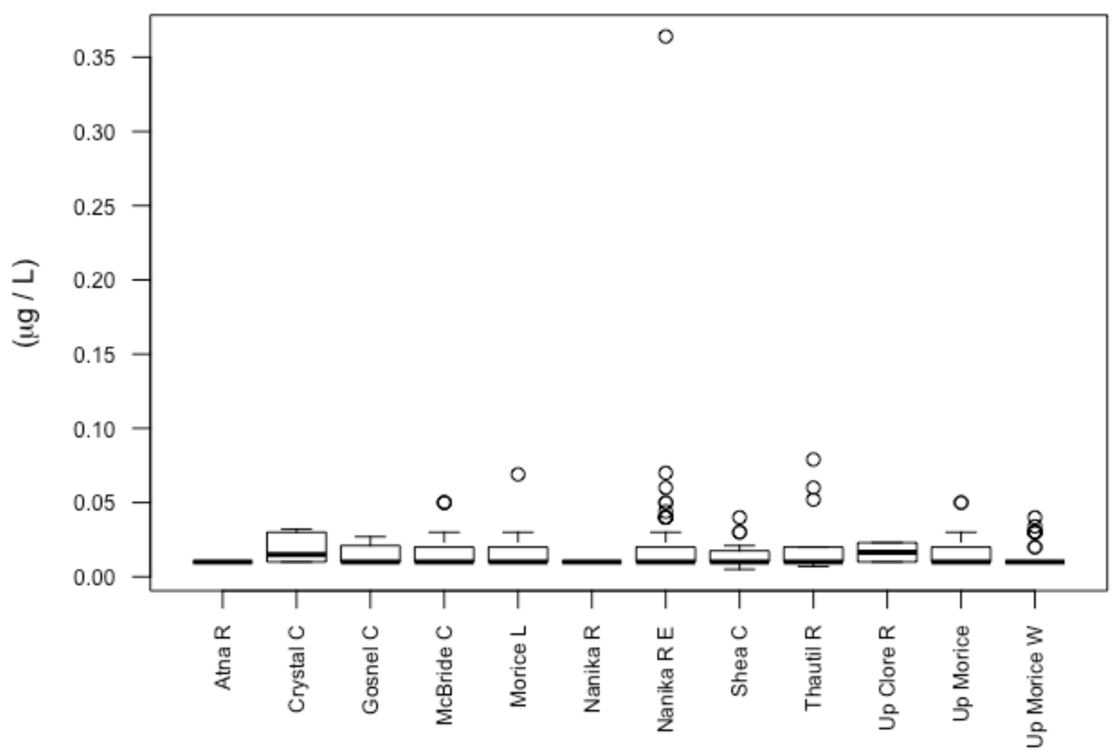
Antimony – Dissolved (Sb-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.015	0.010	0.008	0.010	0.025	0.003	0.008
Crystal C	1	0.010	0.010	NA	NA	NA	NA	NA
Gosnel C	14	0.010	0.010	0.000	0.010	0.010	0.000	0.000
McBride C	30	0.021	0.013	0.034	0.010	0.195	0.006	0.013
Morice R	18	0.016	0.010	0.015	0.010	0.072	0.004	0.007
Nanika R	6	0.012	0.010	0.004	0.010	0.020	0.002	0.004
Nanika R E	82	0.019	0.013	0.014	0.010	0.087	0.002	0.003
Shea C	28	0.013	0.010	0.007	0.006	0.030	0.001	0.003
Thautil R	27	0.018	0.010	0.016	0.010	0.066	0.003	0.006
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.014	0.010	0.009	0.010	0.053	0.002	0.004
Up Morice W	41	0.014	0.010	0.008	0.010	0.040	0.001	0.003



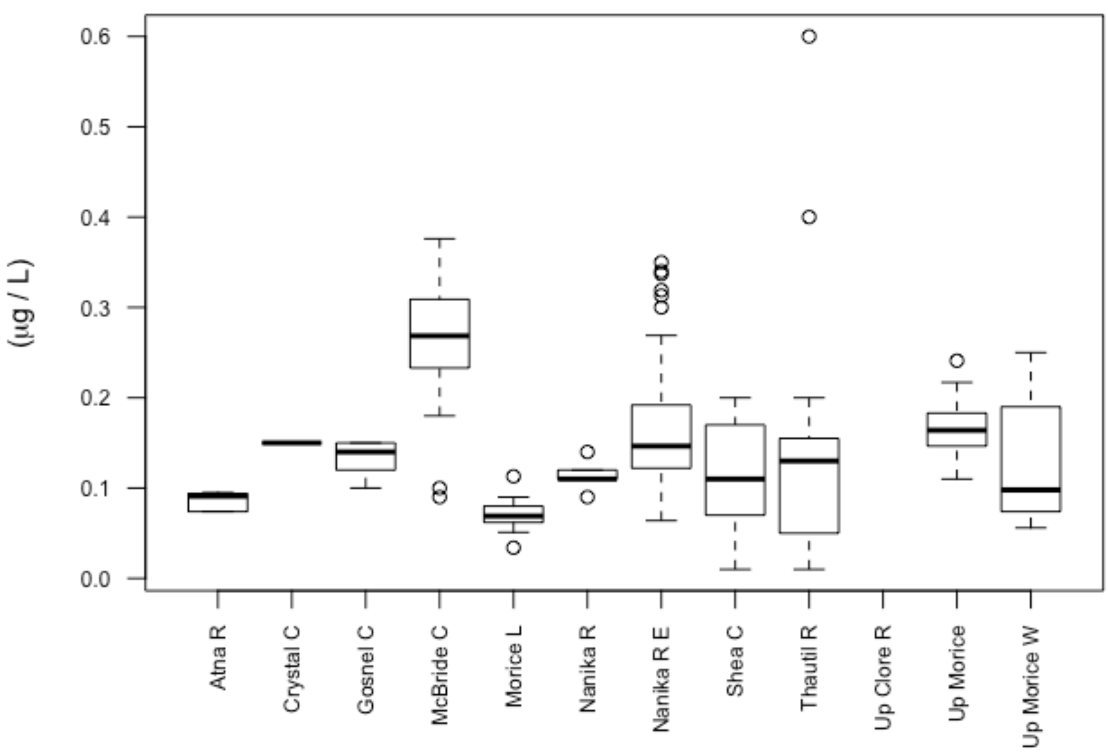
Antimony – Total (Sb-T) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	6	0.013	0.010	0.008	0.010	0.030	0.003	0.009
Crystal C	7	0.020	0.015	0.011	0.010	0.032	0.004	0.010
Gosnel C	21	0.014	0.010	0.006	0.010	0.027	0.001	0.003
McBride C	31	0.017	0.010	0.012	0.010	0.050	0.002	0.004
Morice R	18	0.017	0.010	0.014	0.010	0.069	0.003	0.007
Nanika R	6	0.010	0.010	0.000	0.010	0.010	0.000	0.000
Nanika R E	91	0.023	0.010	0.038	0.010	0.364	0.004	0.008
Shea C	39	0.014	0.010	0.007	0.005	0.040	0.001	0.002
Thautil R	29	0.018	0.010	0.017	0.007	0.079	0.003	0.006
Up Clore	2	0.017	0.017	0.009	0.010	0.023	0.007	0.083
Up Morice	24	0.018	0.010	0.012	0.010	0.050	0.002	0.005
Up Morice W	45	0.014	0.010	0.009	0.010	0.040	0.001	0.003



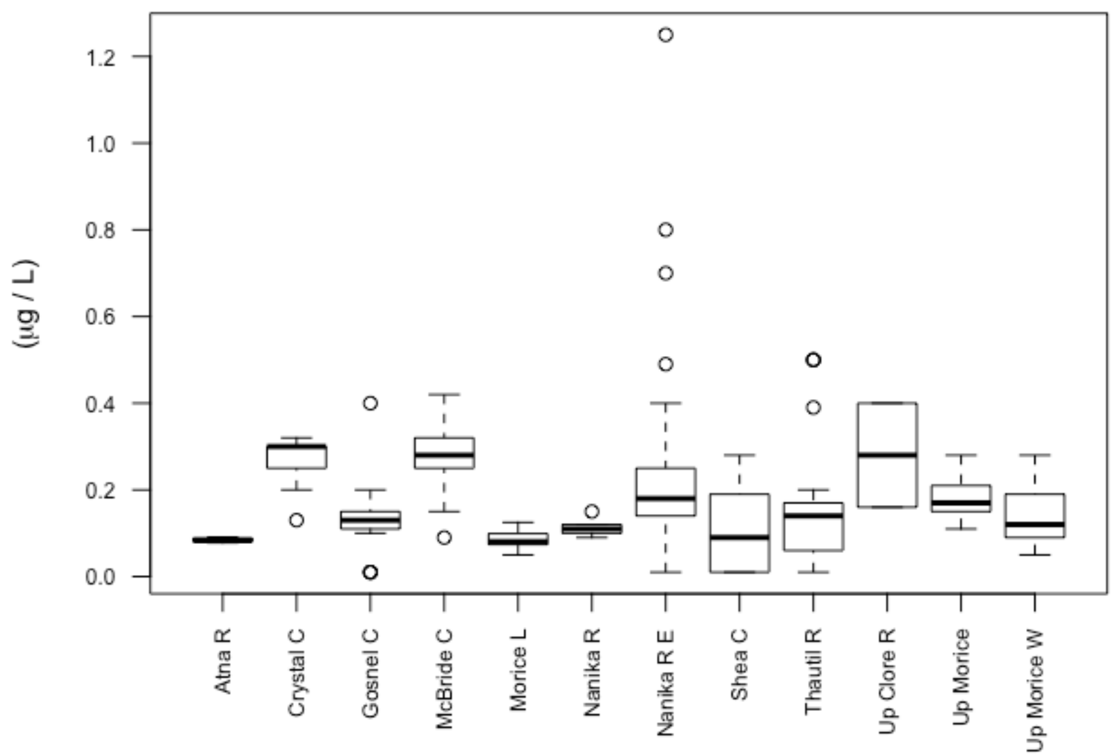
Arsenic – Dissolved (As-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.086	0.091	0.011	0.074	0.095	0.005	0.013
Crystal C	1	0.150	0.150	NA	NA	NA	NA	NA
Gosnel C	14	0.134	0.140	0.017	0.100	0.150	0.005	0.010
McBride C	30	0.262	0.269	0.065	0.090	0.376	0.012	0.024
Morice R	18	0.071	0.069	0.017	0.034	0.113	0.004	0.008
Nanika R	6	0.113	0.110	0.016	0.090	0.140	0.007	0.017
Nanika R E	82	0.163	0.147	0.064	0.064	0.350	0.007	0.014
Shea C	28	0.114	0.110	0.060	0.010	0.200	0.011	0.023
Thautil R	27	0.137	0.130	0.123	0.010	0.600	0.024	0.049
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.167	0.164	0.032	0.110	0.241	0.007	0.014
Up Morice W	41	0.127	0.098	0.064	0.056	0.250	0.010	0.020



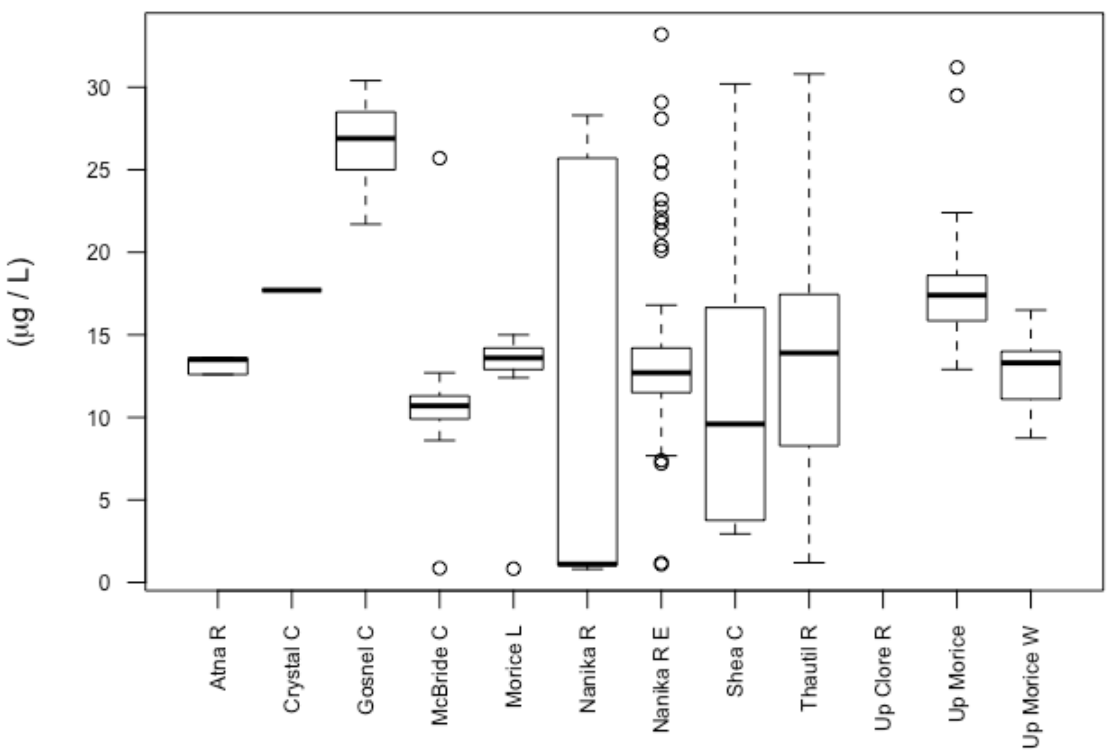
Arsenic – Total (As-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.084	0.083	0.005	0.078	0.091	0.002	0.007
Crystal C	7	0.264	0.300	0.071	0.130	0.320	0.027	0.066
Gosnel C	21	0.130	0.130	0.085	0.010	0.400	0.019	0.039
McBride C	31	0.280	0.280	0.068	0.090	0.420	0.012	0.025
Morice R	18	0.084	0.081	0.018	0.050	0.125	0.004	0.009
Nanika R	6	0.113	0.110	0.021	0.090	0.150	0.008	0.022
Nanika R E	91	0.217	0.180	0.160	0.010	1.250	0.017	0.033
Shea C	39	0.107	0.090	0.084	0.010	0.280	0.013	0.027
Thautil R	29	0.161	0.140	0.140	0.010	0.500	0.026	0.053
Up Clore	2	0.280	0.280	0.170	0.160	0.400	0.120	1.525
Up Morice	24	0.182	0.170	0.044	0.110	0.280	0.009	0.018
Up Morice W	45	0.138	0.120	0.062	0.050	0.280	0.009	0.019



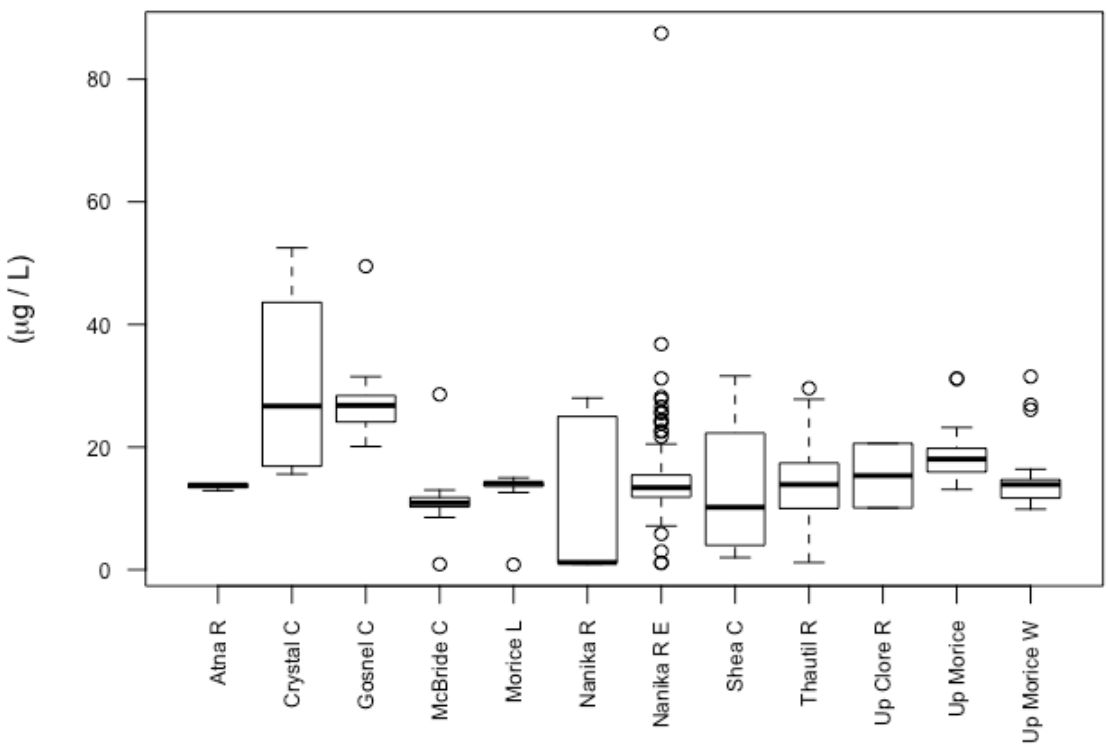
Barium – Dissolved (Ba-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	13.2	13.5	0.5	12.6	13.6	0.2	0.7
Crystal C	1	17.7	17.7	NA	NA	NA	NA	NA
Gosnel C	14	26.6	26.9	2.7	21.7	30.4	0.7	1.5
McBride C	30	10.8	10.7	3.5	0.9	25.7	0.6	1.3
Morice R	18	12.9	13.6	3.1	0.8	15.0	0.7	1.6
Nanika R	6	9.7	1.1	13.4	0.8	28.3	5.5	14.1
Nanika R E	82	13.7	12.7	5.3	1.1	33.2	0.6	1.2
Shea C	28	12.0	9.6	9.0	2.9	30.2	1.7	3.5
Thautil R	27	14.2	13.9	8.0	1.2	30.8	1.5	3.1
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	18.3	17.4	4.4	12.9	31.2	0.9	1.9
Up Morice W	41	12.8	13.3	2.0	8.7	16.5	0.3	0.6



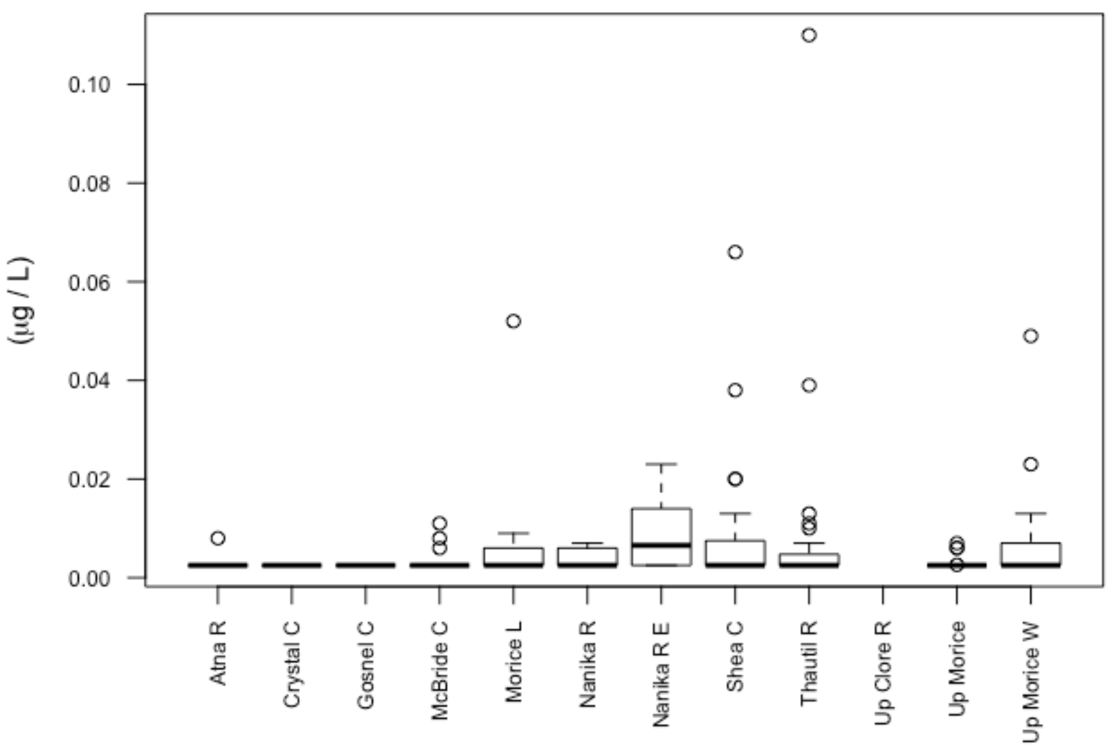
Barium – Total (Ba-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	13.62	13.80	0.47	12.90	14.00	0.21	0.59
Crystal C	7	30.83	26.70	15.59	15.60	52.50	5.89	14.41
Gosnel C	21	27.40	26.80	5.94	20.10	49.50	1.30	2.70
McBride C	31	11.14	10.90	3.86	0.91	28.60	0.69	1.42
Morice R	18	13.28	14.10	3.18	0.83	15.00	0.75	1.58
Nanika R	6	9.57	1.19	13.15	0.95	28.00	5.37	13.80
Nanika R E	91	15.34	13.40	9.71	1.10	87.50	1.02	2.02
Shea C	39	13.69	10.20	9.75	2.00	31.60	1.56	3.16
Thautil R	29	14.80	13.90	7.09	1.17	29.60	1.32	2.70
Up Clore	2	15.35	15.35	7.42	10.10	20.60	5.25	66.71
Up Morice	24	18.79	18.05	4.50	13.10	31.20	0.92	1.90
Up Morice W	45	14.23	13.90	4.20	9.88	31.50	0.63	1.26



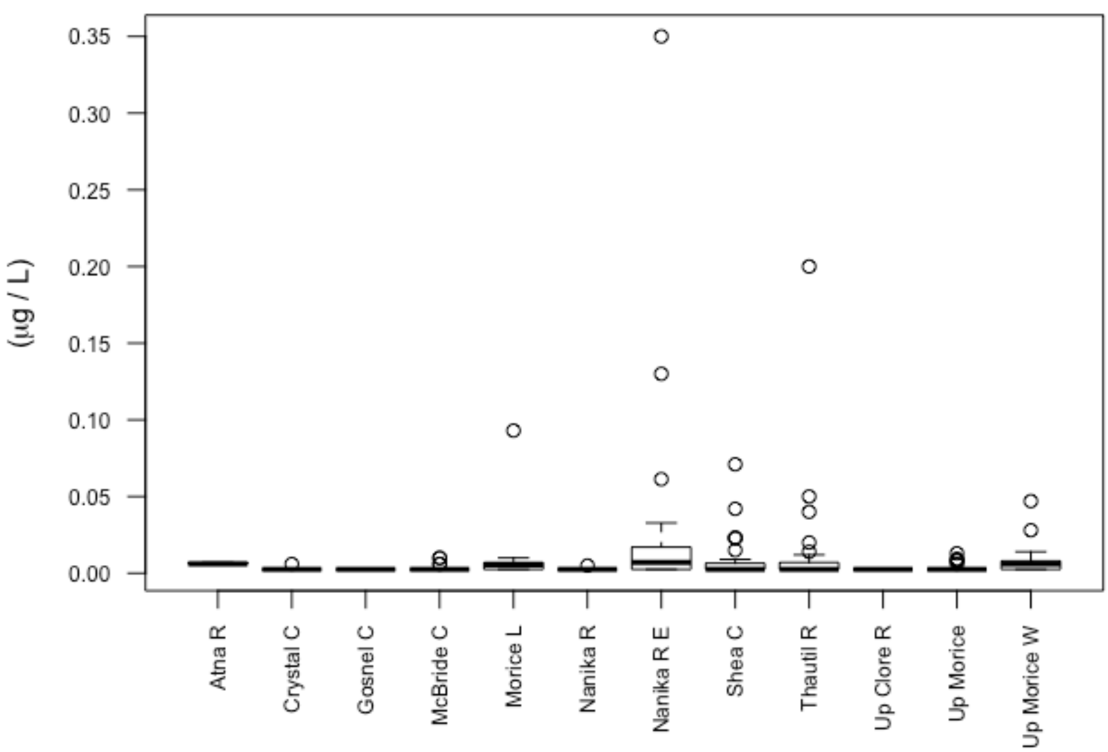
Cadmium– Dissolved (Cd-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.004	0.003	0.002	0.003	0.008	0.001	0.003
Crystal C	1	0.003	0.003	NA	NA	NA	NA	NA
Gosnel C	14	0.003	0.003	0.000	0.003	0.003	0.000	0.000
McBride C	30	0.003	0.003	0.002	0.003	0.011	0.000	0.001
Morice R	18	0.007	0.003	0.011	0.003	0.052	0.003	0.006
Nanika R	6	0.004	0.003	0.002	0.003	0.007	0.001	0.002
Nanika R E	82	0.008	0.007	0.006	0.003	0.023	0.001	0.001
Shea C	28	0.008	0.003	0.014	0.003	0.066	0.003	0.005
Thautil R	27	0.009	0.003	0.021	0.003	0.110	0.004	0.008
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.003	0.003	0.001	0.003	0.007	0.000	0.001
Up Morice W	41	0.006	0.003	0.008	0.003	0.049	0.001	0.003



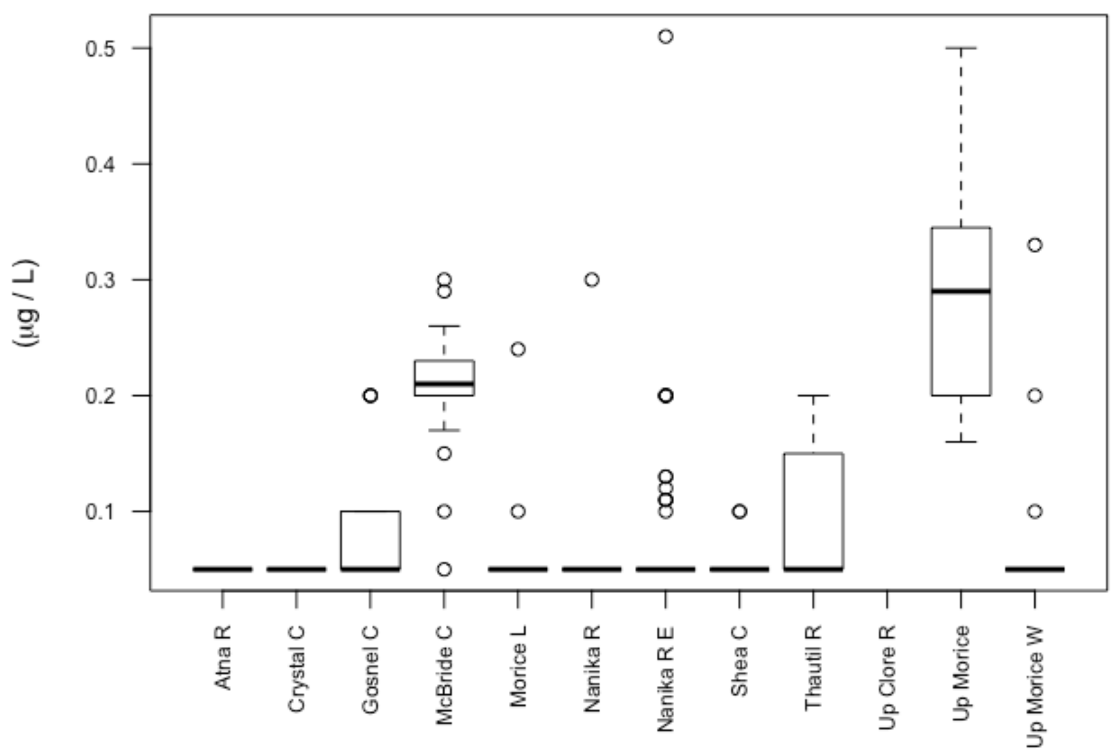
Cadmium– Total (Cd-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.006	0.006	0.001	0.006	0.007	0.000	0.001
Crystal C	7	0.003	0.003	0.001	0.003	0.006	0.001	0.001
Gosnel C	21	0.003	0.003	0.000	0.003	0.003	0.000	0.000
McBride C	31	0.003	0.003	0.002	0.003	0.010	0.000	0.001
Morice R	18	0.010	0.006	0.021	0.003	0.093	0.005	0.010
Nanika R	6	0.003	0.003	0.001	0.003	0.005	0.000	0.001
Nanika R E	91	0.016	0.007	0.039	0.003	0.350	0.004	0.008
Shea C	39	0.008	0.003	0.013	0.003	0.071	0.002	0.004
Thautil R	29	0.014	0.003	0.037	0.003	0.200	0.007	0.014
Up Clore	2	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Up Morice	24	0.004	0.003	0.003	0.003	0.013	0.001	0.001
Up Morice W	45	0.007	0.006	0.008	0.003	0.047	0.001	0.002



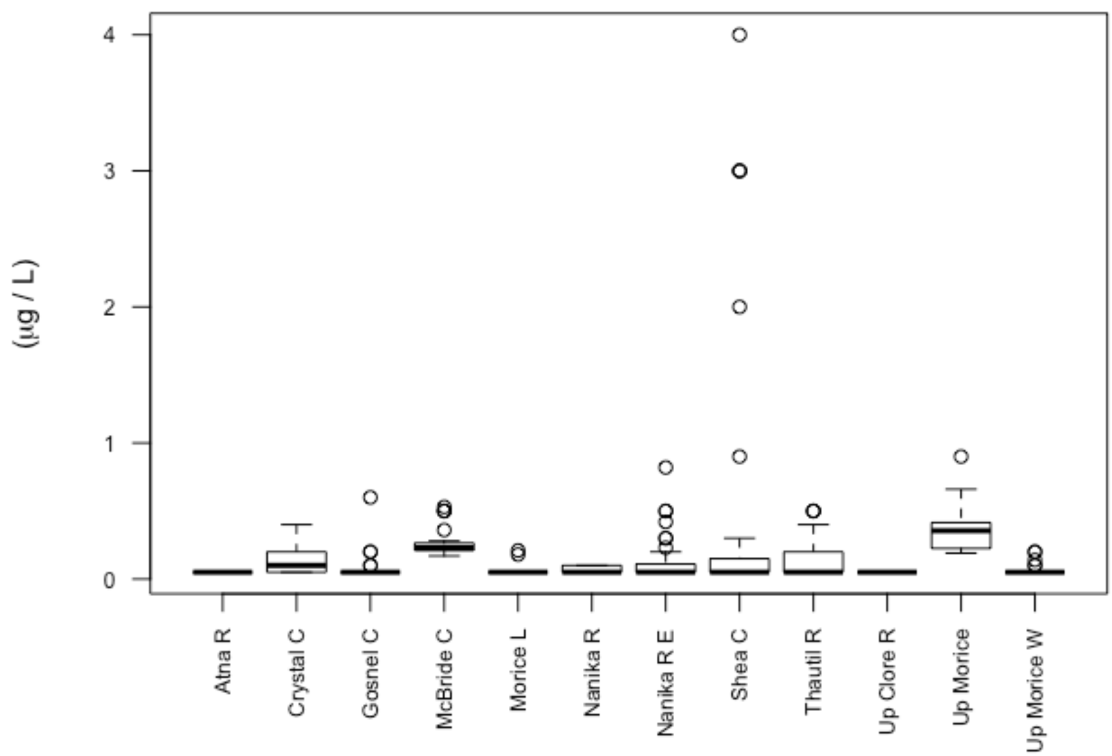
Chromium– Dissolved (Cr-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.050	0.050	0.000	0.050	0.050	0.000	0.000
Crystal C	1	0.050	0.050	NA	NA	NA	NA	NA
Gosnel C	14	0.086	0.050	0.063	0.050	0.200	0.017	0.037
McBride C	30	0.209	0.210	0.049	0.050	0.300	0.009	0.018
Morice R	18	0.063	0.050	0.046	0.050	0.240	0.011	0.023
Nanika R	6	0.092	0.050	0.102	0.050	0.300	0.042	0.107
Nanika R E	82	0.069	0.050	0.061	0.050	0.510	0.007	0.013
Shea C	28	0.054	0.050	0.013	0.050	0.100	0.002	0.005
Thautil R	27	0.091	0.050	0.067	0.050	0.200	0.013	0.026
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.291	0.290	0.100	0.160	0.500	0.021	0.043
Up Morice W	41	0.062	0.050	0.049	0.050	0.330	0.008	0.016



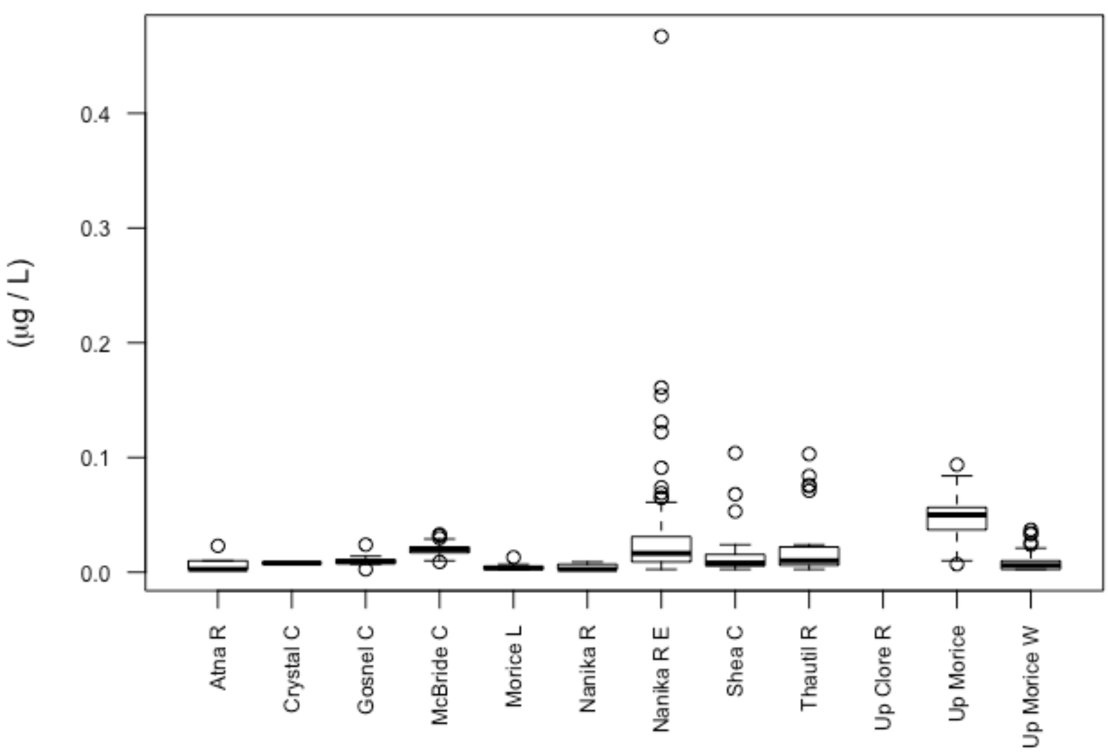
Chromium– Total (Cr-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.050	0.050	0.000	0.050	0.050	0.000	0.000
Crystal C	7	0.150	0.100	0.129	0.050	0.400	0.049	0.119
Gosnel C	21	0.095	0.050	0.124	0.050	0.600	0.027	0.057
McBride C	31	0.268	0.230	0.100	0.170	0.530	0.018	0.037
Morice R	18	0.066	0.050	0.047	0.050	0.210	0.011	0.023
Nanika R	6	0.067	0.050	0.026	0.050	0.100	0.011	0.027
Nanika R E	91	0.103	0.050	0.117	0.050	0.820	0.012	0.024
Shea C	39	0.472	0.050	1.019	0.050	4.000	0.163	0.330
Thautil R	29	0.164	0.050	0.156	0.050	0.500	0.029	0.059
Up Clore	2	0.050	0.050	0.000	0.050	0.050	0.000	0.000
Up Morice	24	0.372	0.355	0.178	0.190	0.900	0.036	0.075
Up Morice W	45	0.061	0.050	0.035	0.050	0.200	0.005	0.010



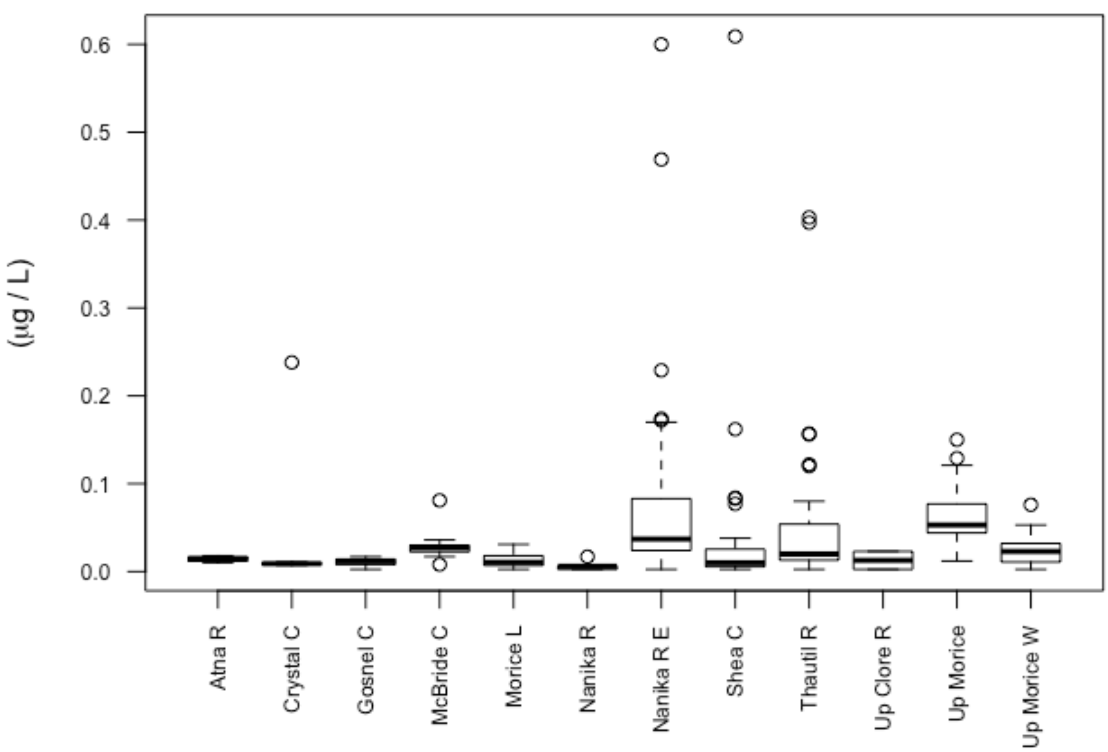
Cobalt– Dissolved (Co-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.008	0.003	0.009	0.003	0.023	0.004	0.011
Crystal C	1	0.008	0.008	NA	NA	NA	NA	NA
Gosnel C	14	0.010	0.009	0.005	0.003	0.024	0.001	0.003
McBride C	30	0.020	0.020	0.005	0.009	0.033	0.001	0.002
Morice R	18	0.004	0.004	0.003	0.003	0.013	0.001	0.001
Nanika R	6	0.004	0.003	0.003	0.003	0.009	0.001	0.003
Nanika R E	82	0.032	0.016	0.058	0.003	0.467	0.006	0.013
Shea C	28	0.016	0.008	0.023	0.003	0.104	0.004	0.009
Thautil R	27	0.023	0.010	0.030	0.003	0.103	0.006	0.012
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.049	0.050	0.020	0.007	0.094	0.004	0.009
Up Morice W	41	0.009	0.006	0.009	0.003	0.037	0.001	0.003



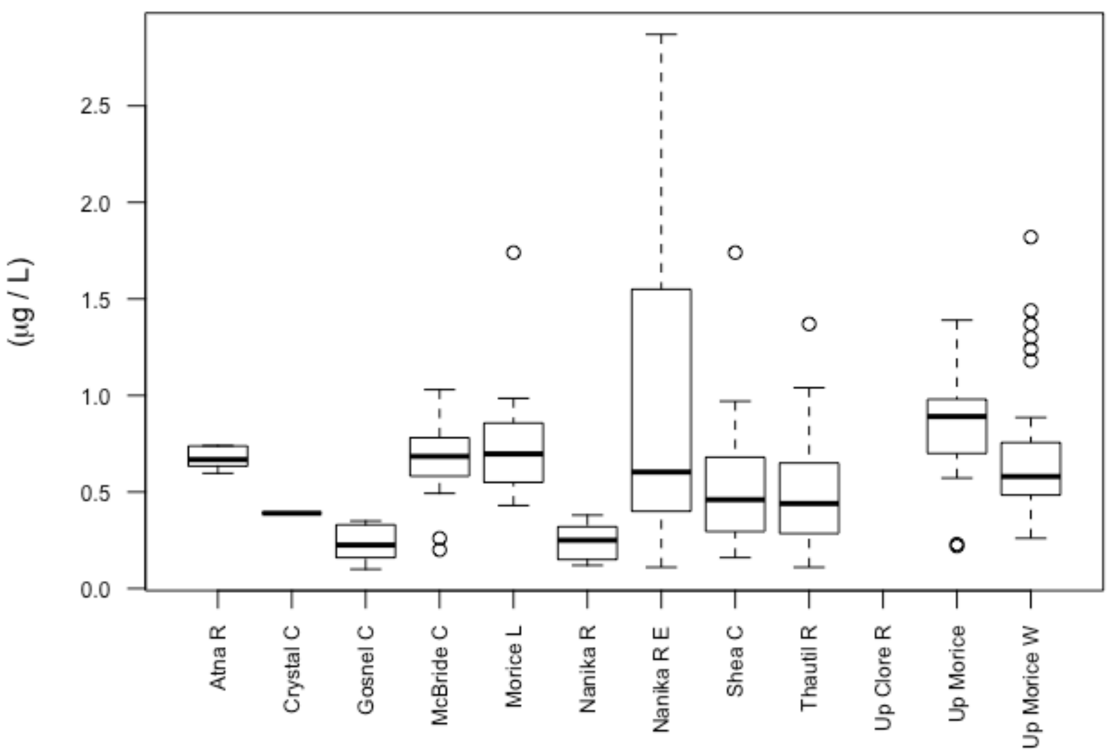
Cobalt– Total (Co-T) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.014	0.014	0.003	0.010	0.018	0.001	0.004
Crystal C	7	0.041	0.009	0.087	0.007	0.238	0.033	0.080
Gosnel C	21	0.011	0.012	0.004	0.003	0.017	0.001	0.002
McBride C	31	0.028	0.027	0.012	0.008	0.081	0.002	0.004
Morice R	18	0.012	0.011	0.008	0.003	0.031	0.002	0.004
Nanika R	6	0.007	0.006	0.005	0.003	0.017	0.002	0.006
Nanika R E	91	0.067	0.037	0.086	0.003	0.600	0.009	0.018
Shea C	39	0.037	0.010	0.099	0.003	0.609	0.016	0.032
Thautil R	29	0.064	0.020	0.103	0.003	0.403	0.019	0.039
Up Clore	2	0.013	0.013	0.014	0.003	0.023	0.010	0.130
Up Morice	24	0.064	0.053	0.034	0.012	0.150	0.007	0.014
Up Morice W	45	0.023	0.023	0.015	0.003	0.076	0.002	0.005



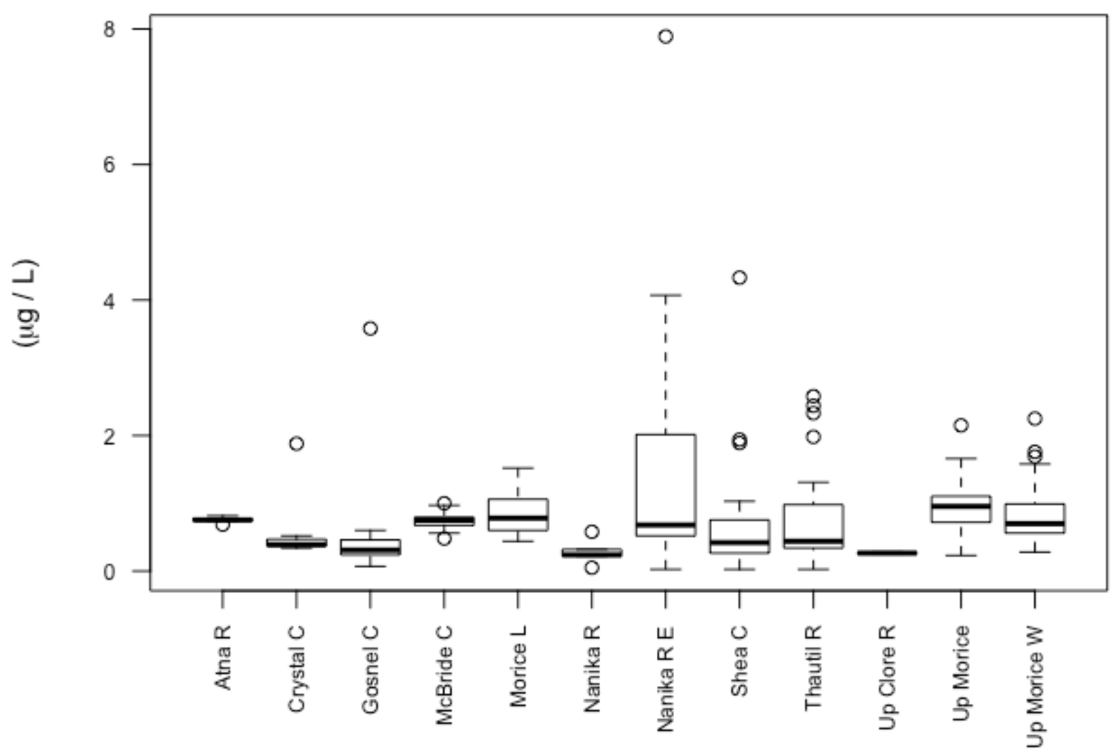
Copper– Dissolved (Cu-D) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.675	0.668	0.063	0.597	0.740	0.028	0.079
Crystal C	1	0.390	0.390	NA	NA	NA	NA	NA
Gosnel C	14	0.236	0.225	0.092	0.100	0.350	0.024	0.053
McBride C	30	0.675	0.685	0.180	0.200	1.030	0.033	0.067
Morice R	18	0.734	0.697	0.298	0.430	1.740	0.070	0.148
Nanika R	6	0.245	0.250	0.106	0.120	0.380	0.043	0.111
Nanika R E	82	0.972	0.604	0.723	0.110	2.870	0.080	0.159
Shea C	28	0.524	0.460	0.326	0.160	1.740	0.062	0.127
Thautil R	27	0.504	0.440	0.315	0.110	1.370	0.061	0.125
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.857	0.891	0.304	0.220	1.390	0.063	0.131
Up Morice W	41	0.684	0.580	0.346	0.260	1.820	0.054	0.109



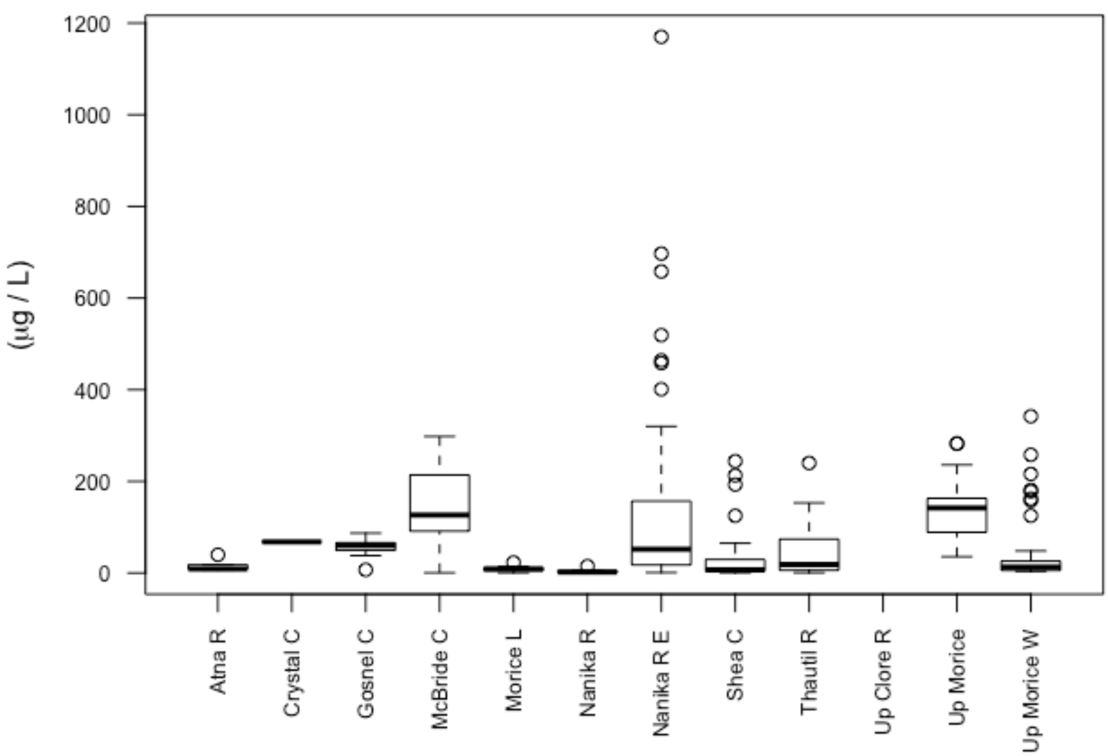
Copper– Total (Cu-T) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.754	0.755	0.048	0.685	0.817	0.022	0.060
Crystal C	7	0.613	0.390	0.562	0.340	1.880	0.212	0.520
Gosnel C	21	0.481	0.310	0.727	0.070	3.580	0.159	0.331
McBride C	31	0.751	0.750	0.118	0.480	1.000	0.021	0.043
Morice R	18	0.821	0.782	0.292	0.440	1.520	0.069	0.145
Nanika R	6	0.275	0.240	0.174	0.050	0.580	0.071	0.183
Nanika R E	91	1.360	0.680	1.277	0.025	7.890	0.134	0.266
Shea C	39	0.602	0.420	0.754	0.025	4.330	0.121	0.244
Thautil R	29	0.785	0.440	0.715	0.025	2.580	0.133	0.272
Up Clore	2	0.265	0.265	0.021	0.250	0.280	0.015	0.191
Up Morice	24	0.986	0.955	0.412	0.230	2.150	0.084	0.174
Up Morice W	45	0.818	0.700	0.432	0.280	2.250	0.064	0.130



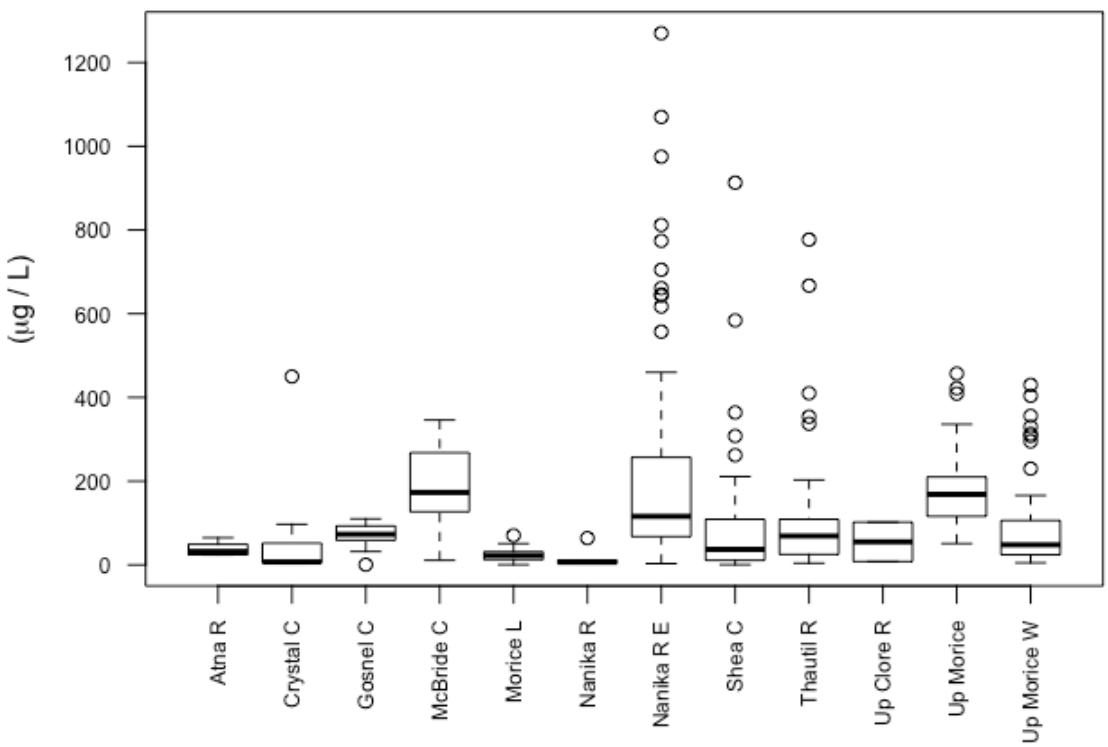
Iron– Dissolved (Fe-D) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	16.2	8.8	13.9	6.4	39.8	6.2	17.3
Crystal C	1	68.0	68.0	NA	NA	NA	NA	NA
Gosnel C	15	56.0	60.0	18.4	7.0	87.0	4.7	10.2
McBride C	30	151.7	126.5	75.5	0.5	298.0	13.8	28.2
Morice R	18	8.8	8.9	5.1	0.5	23.0	1.2	2.5
Nanika R	6	4.3	2.0	5.5	0.5	15.0	2.2	5.8
Nanika R E	81	121.7	51.9	186.4	1.0	1170.0	20.7	41.2
Shea C	28	39.5	7.0	68.1	0.5	244.0	12.9	26.4
Thautil R	26	47.9	18.5	60.6	0.5	240.0	11.9	24.5
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	140.0	142.0	68.7	35.6	283.0	14.3	29.7
Up Morice W	41	49.9	13.0	81.8	3.7	342.0	12.8	25.8



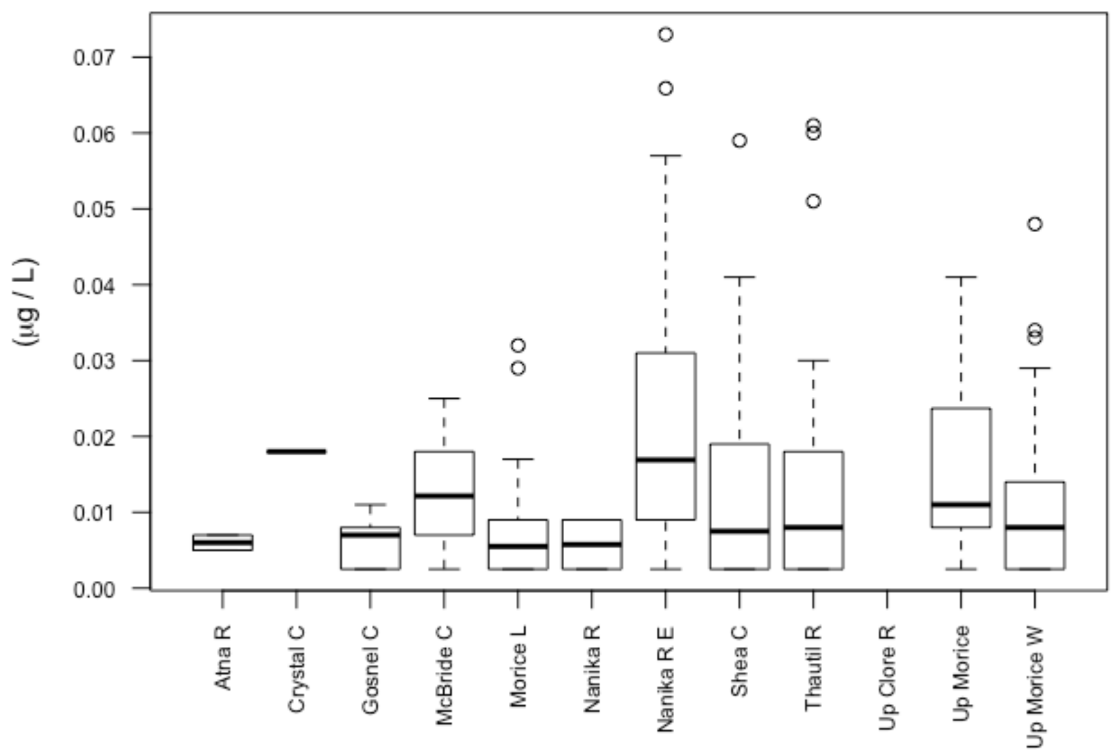
Iron– Total (Fe-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	38.8	32.1	17.8	24.0	64.8	8.0	22.1
Crystal C	7	82.1	7.0	165.8	3.0	450.0	62.6	153.3
Gosnel C	21	71.5	73.0	26.3	0.5	110.0	5.7	12.0
McBride C	31	191.6	173.0	88.0	11.0	346.0	15.8	32.3
Morice R	18	24.1	22.3	17.4	0.5	70.4	4.1	8.7
Nanika R	6	16.0	6.5	23.7	4.0	64.0	9.7	24.8
Nanika R E	88	214.6	116.0	251.0	3.0	1270.0	26.8	53.2
Shea C	39	105.5	37.0	179.7	0.5	913.0	28.8	58.3
Thautil R	29	138.5	69.0	194.3	4.0	777.0	36.1	73.9
Up Clore	2	55.0	55.0	66.5	8.0	102.0	47.0	597.2
Up Morice	24	191.7	168.5	111.5	51.0	457.0	22.8	47.1
Up Morice W	45	97.8	48.0	118.8	5.0	430.0	17.7	35.7



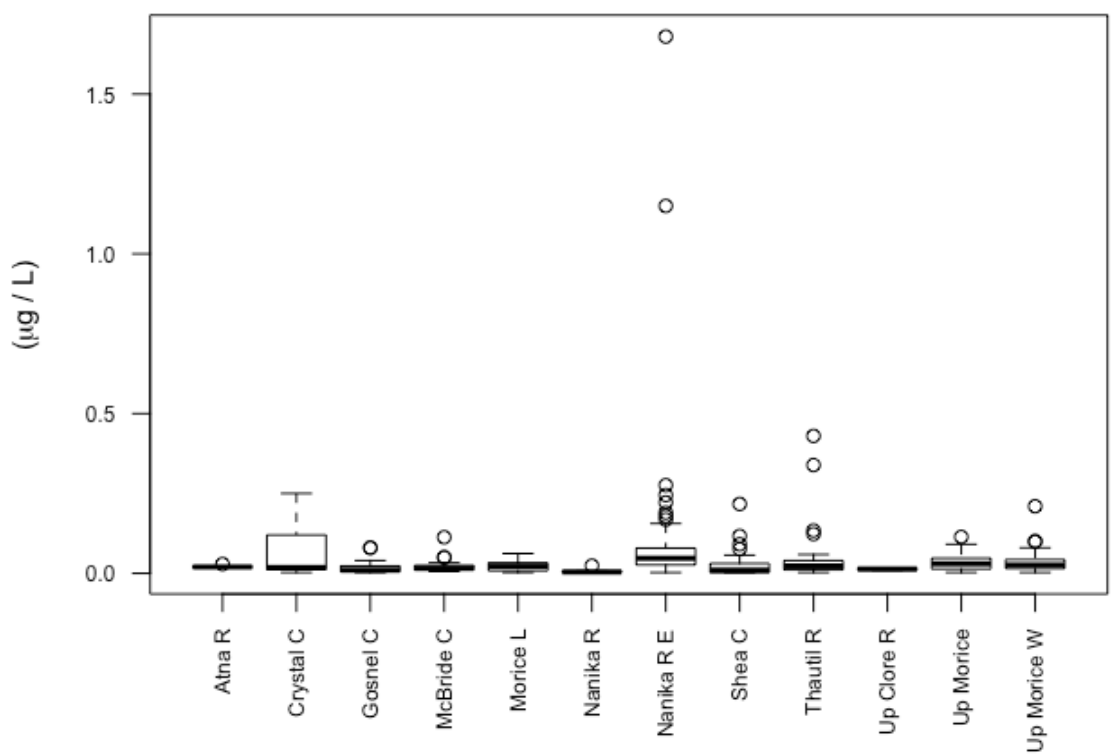
Lead– Dissolved (Pb-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.006	0.006	0.001	0.005	0.007	0.000	0.001
Crystal C	1	0.018	0.018	NA	NA	NA	NA	NA
Gosnel C	14	0.006	0.007	0.003	0.003	0.011	0.001	0.002
McBride C	30	0.012	0.012	0.006	0.003	0.025	0.001	0.002
Morice R	18	0.009	0.006	0.009	0.003	0.032	0.002	0.004
Nanika R	6	0.006	0.006	0.004	0.003	0.009	0.001	0.004
Nanika R E	82	0.022	0.017	0.016	0.003	0.073	0.002	0.003
Shea C	28	0.013	0.008	0.014	0.003	0.059	0.003	0.005
Thautil R	27	0.015	0.008	0.017	0.003	0.061	0.003	0.007
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.017	0.011	0.012	0.003	0.041	0.002	0.005
Up Morice W	41	0.011	0.008	0.011	0.003	0.048	0.002	0.003



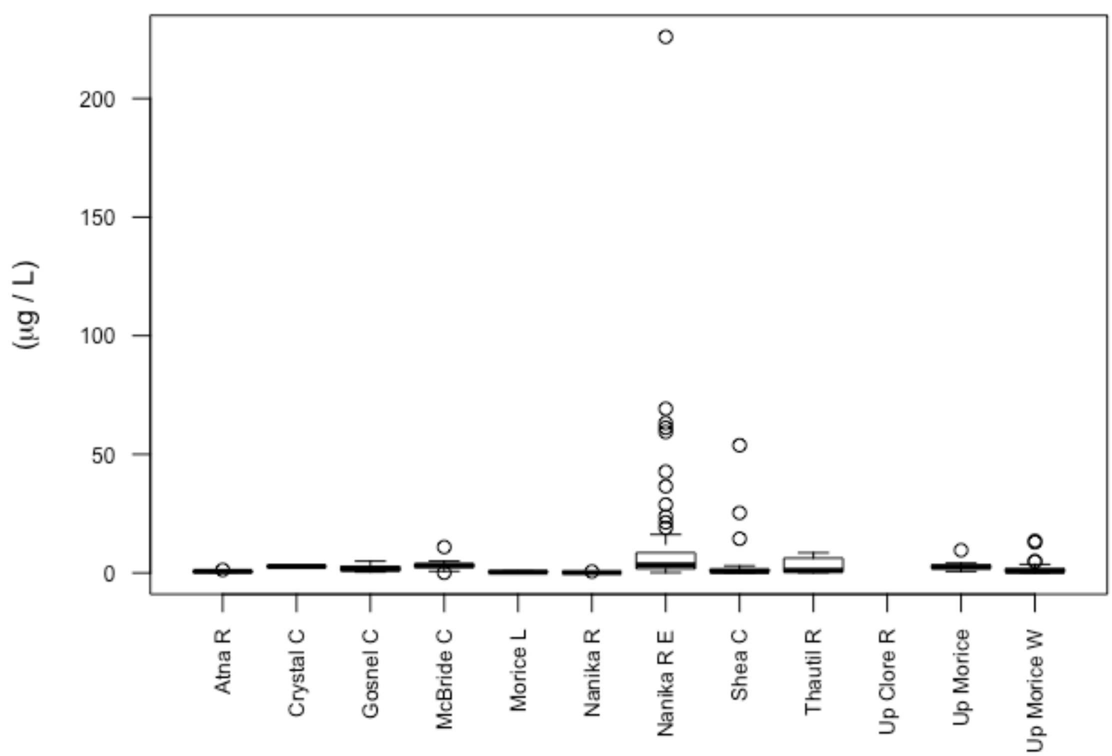
Lead– Total (Pb-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.021	0.020	0.005	0.018	0.029	0.002	0.006
Crystal C	7	0.076	0.018	0.092	0.003	0.250	0.035	0.085
Gosnel C	21	0.020	0.010	0.023	0.003	0.080	0.005	0.010
McBride C	31	0.023	0.016	0.020	0.006	0.113	0.004	0.007
Morice R	18	0.024	0.022	0.018	0.003	0.062	0.004	0.009
Nanika R	6	0.007	0.004	0.008	0.003	0.024	0.003	0.009
Nanika R E	91	0.092	0.047	0.210	0.003	1.680	0.022	0.044
Shea C	39	0.026	0.010	0.041	0.003	0.217	0.007	0.013
Thautil R	29	0.054	0.023	0.097	0.003	0.430	0.018	0.037
Up Clore	2	0.014	0.014	0.005	0.010	0.017	0.004	0.044
Up Morice	24	0.036	0.030	0.028	0.003	0.114	0.006	0.012
Up Morice W	45	0.037	0.026	0.035	0.003	0.210	0.005	0.011



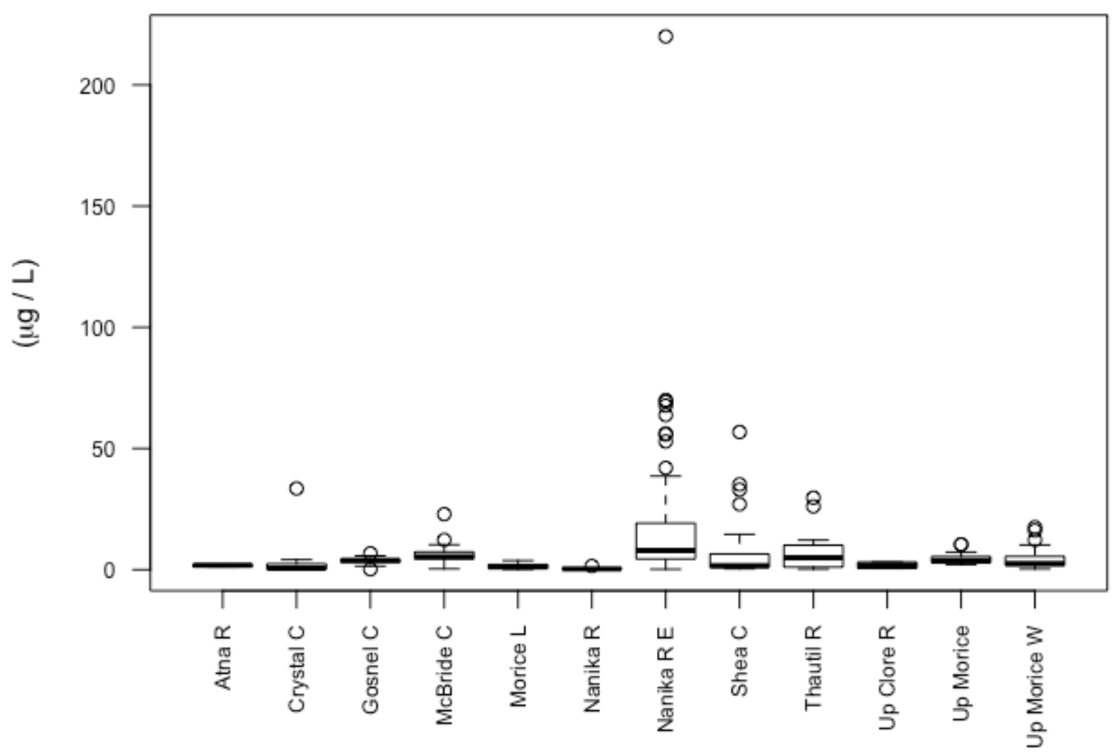
Manganese – Dissolved (Mn-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.69	0.62	0.35	0.39	1.26	0.16	0.43
Crystal C	1	2.73	2.73	NA	NA	NA	NA	NA
Gosnel C	15	1.96	1.57	1.43	0.37	4.94	0.37	0.79
McBride C	30	3.15	3.18	1.92	0.05	10.90	0.35	0.72
Morice R	18	0.39	0.34	0.17	0.17	0.66	0.04	0.09
Nanika R	6	0.20	0.12	0.20	0.07	0.58	0.08	0.20
Nanika R E	82	11.48	3.37	28.09	0.13	226.00	3.10	6.17
Shea C	28	4.06	0.58	11.07	0.20	53.80	2.09	4.29
Thautil R	27	3.23	1.06	3.21	0.13	8.48	0.62	1.27
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	2.76	2.40	1.77	0.62	9.56	0.37	0.77
Up Morice W	41	1.77	0.64	2.90	0.19	13.50	0.45	0.92



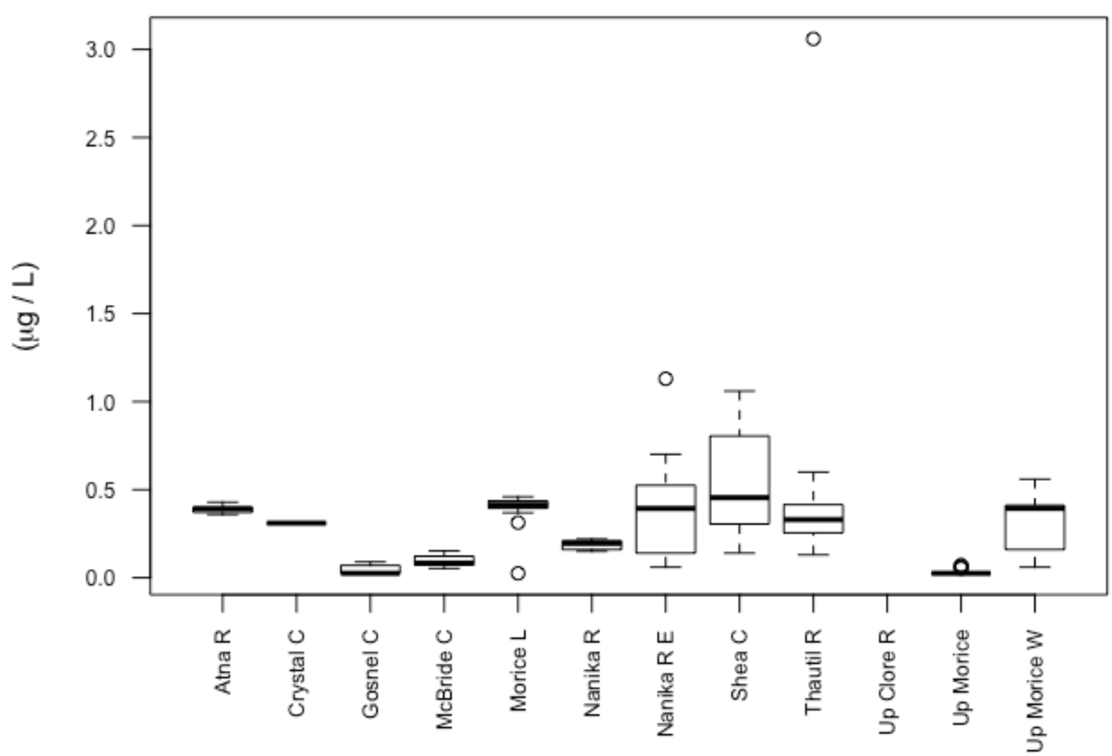
Manganese – Total (Mn-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	1.69	1.86	0.40	1.23	2.05	0.18	0.50
Crystal C	7	5.66	0.62	12.36	0.13	33.50	4.67	11.43
Gosnel C	21	3.73	3.88	1.45	0.17	6.77	0.32	0.66
McBride C	31	6.38	5.36	3.88	0.35	22.90	0.70	1.42
Morice R	18	1.38	1.14	0.98	0.15	3.78	0.23	0.49
Nanika R	6	0.52	0.32	0.53	0.17	1.56	0.22	0.55
Nanika R E	91	16.72	7.93	27.24	0.19	220.00	2.86	5.67
Shea C	39	6.79	1.65	11.80	0.41	56.80	1.89	3.83
Thautil R	29	6.60	4.93	7.17	0.23	29.70	1.33	2.73
Up Clore	2	1.84	1.84	1.83	0.55	3.13	1.29	16.42
Up Morice	24	4.43	3.73	2.33	2.10	10.40	0.48	0.99
Up Morice W	45	4.30	2.56	4.09	0.31	17.50	0.61	1.23



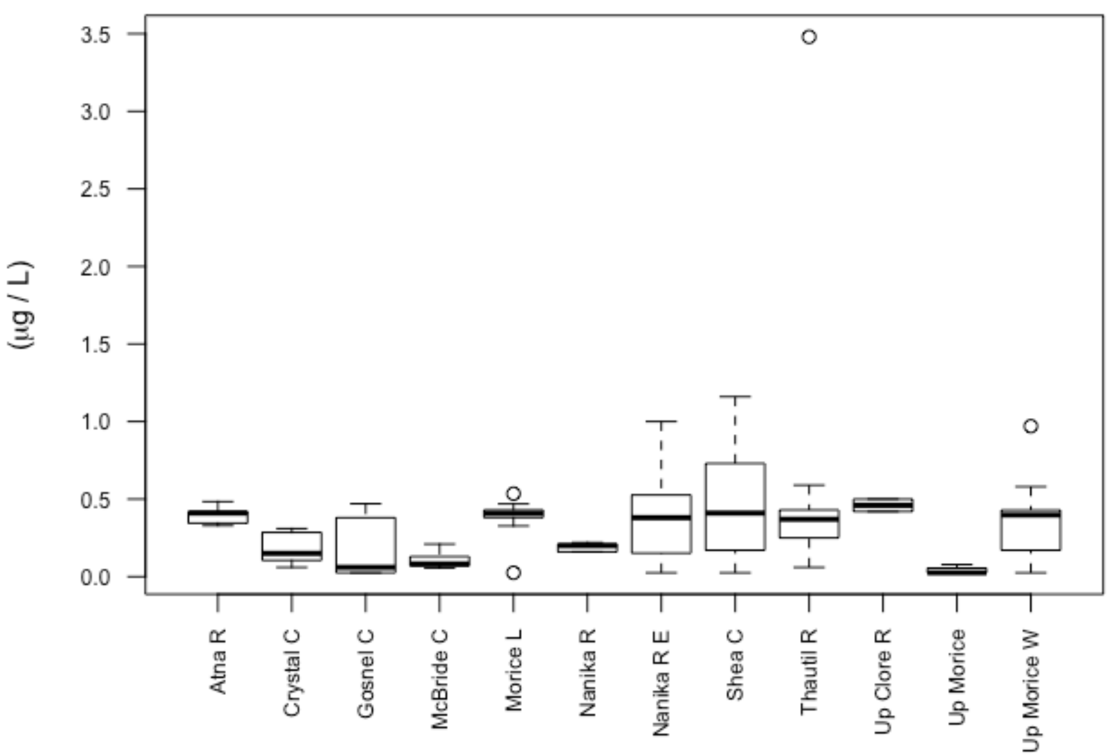
Molybdenum – Dissolved (Mo-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.390	0.392	0.027	0.359	0.429	0.012	0.034
Crystal C	1	0.310	0.310	NA	NA	NA	NA	NA
Gosnel C	14	0.043	0.025	0.026	0.025	0.090	0.007	0.015
McBride C	30	0.094	0.083	0.030	0.053	0.152	0.005	0.011
Morice R	18	0.392	0.414	0.098	0.025	0.460	0.023	0.049
Nanika R	6	0.188	0.195	0.028	0.150	0.220	0.011	0.029
Nanika R E	82	0.343	0.394	0.206	0.060	1.130	0.023	0.045
Shea C	28	0.547	0.455	0.290	0.140	1.060	0.055	0.113
Thautil R	27	0.442	0.330	0.536	0.130	3.060	0.103	0.212
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.031	0.025	0.015	0.025	0.070	0.003	0.006
Up Morice W	41	0.341	0.394	0.148	0.060	0.560	0.023	0.047



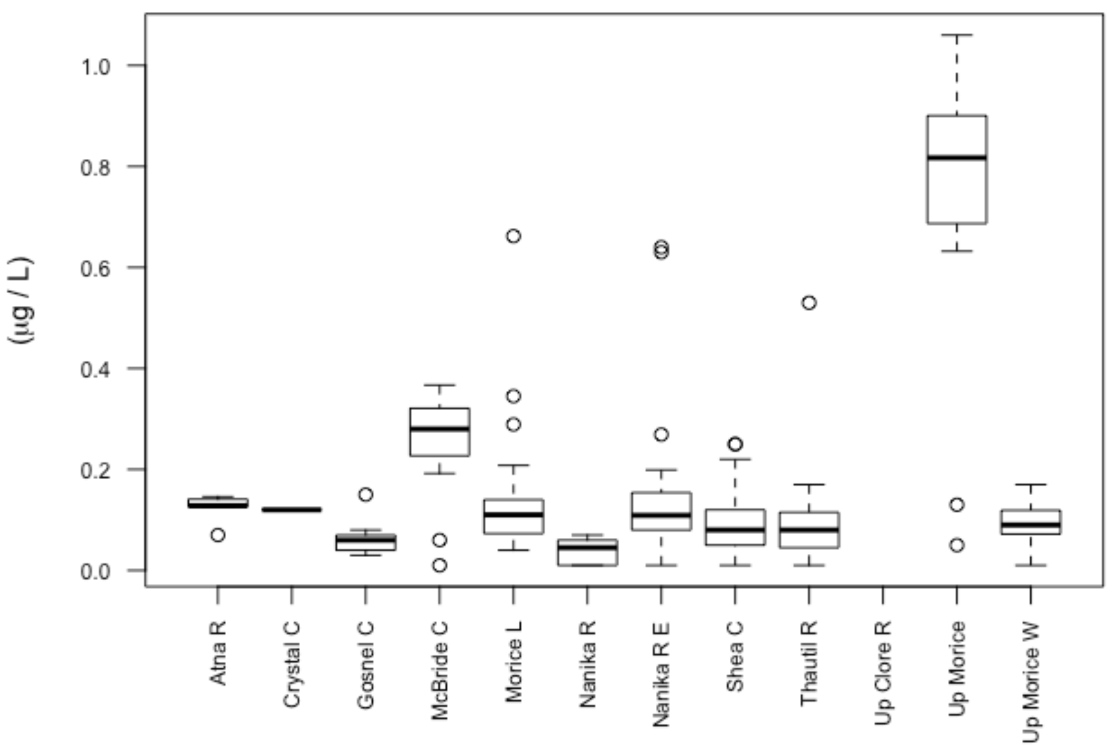
Molybdenum – Total (Mo-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.397	0.410	0.062	0.329	0.484	0.028	0.077
Crystal C	7	0.186	0.150	0.105	0.060	0.310	0.040	0.097
Gosnel C	21	0.165	0.060	0.184	0.025	0.470	0.040	0.084
McBride C	31	0.100	0.082	0.040	0.056	0.210	0.007	0.015
Morice R	18	0.392	0.408	0.102	0.025	0.535	0.024	0.051
Nanika R	6	0.192	0.200	0.026	0.160	0.220	0.010	0.027
Nanika R E	91	0.356	0.380	0.205	0.025	1.000	0.021	0.043
Shea C	39	0.446	0.410	0.350	0.025	1.160	0.056	0.114
Thautil R	29	0.459	0.370	0.595	0.060	3.480	0.110	0.226
Up Clore	2	0.460	0.460	0.057	0.420	0.500	0.040	0.508
Up Morice	24	0.037	0.025	0.019	0.025	0.078	0.004	0.008
Up Morice W	45	0.348	0.398	0.184	0.025	0.970	0.027	0.055



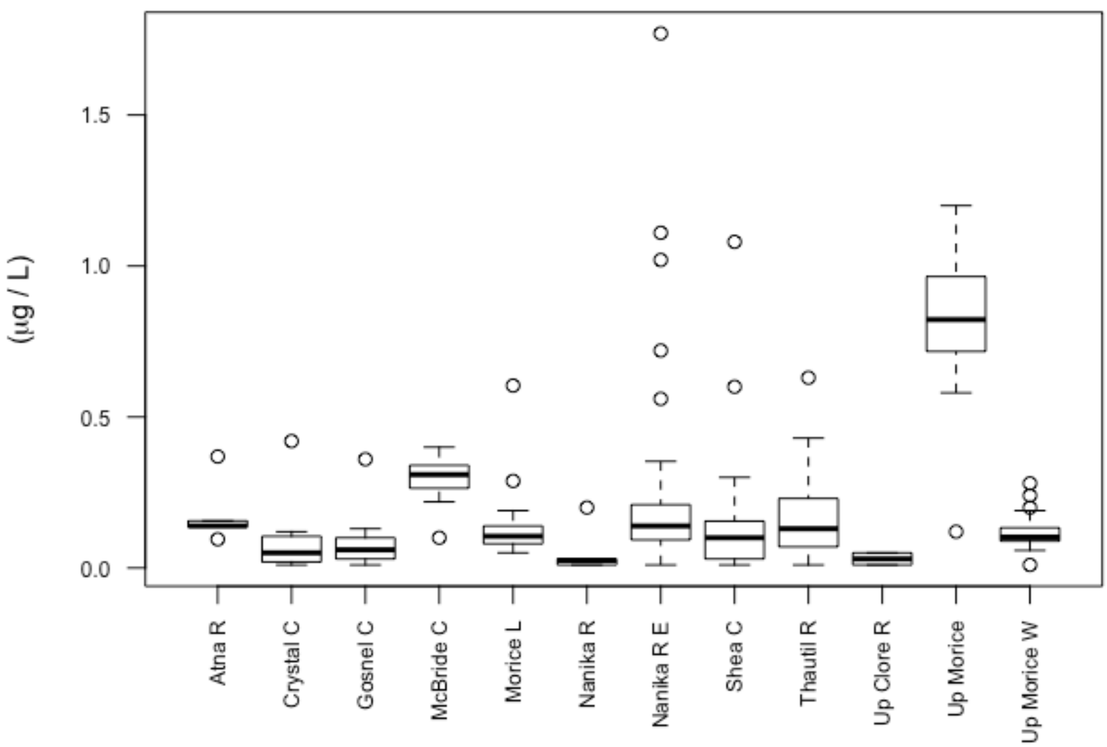
Nickel – Dissolved (Ni-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.122	0.128	0.030	0.070	0.146	0.014	0.038
Crystal C	1	0.120	0.120	NA	NA	NA	NA	NA
Gosnel C	14	0.061	0.060	0.030	0.030	0.150	0.008	0.017
McBride C	30	0.267	0.280	0.082	0.010	0.367	0.015	0.030
Morice R	18	0.154	0.110	0.151	0.040	0.662	0.036	0.075
Nanika R	6	0.040	0.045	0.025	0.010	0.070	0.010	0.027
Nanika R E	82	0.128	0.109	0.093	0.010	0.640	0.010	0.020
Shea C	27	0.095	0.080	0.063	0.010	0.250	0.012	0.025
Thautil R	27	0.095	0.080	0.098	0.010	0.530	0.019	0.039
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.761	0.817	0.242	0.050	1.060	0.051	0.105
Up Morice W	41	0.094	0.090	0.038	0.010	0.170	0.006	0.012



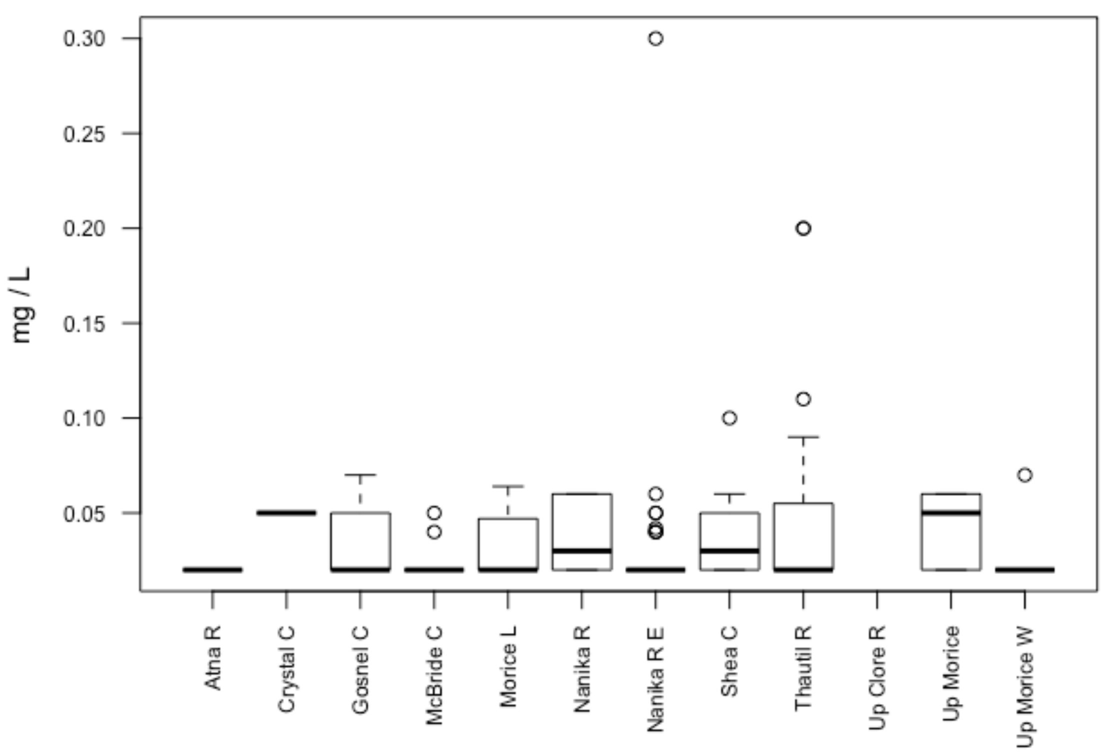
Nickel – Total (Ni-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.179	0.139	0.108	0.095	0.369	0.049	0.135
Crystal C	7	0.104	0.050	0.145	0.010	0.420	0.055	0.134
Gosnel C	21	0.077	0.060	0.075	0.010	0.360	0.016	0.034
McBride C	31	0.302	0.309	0.061	0.100	0.400	0.011	0.022
Morice R	18	0.143	0.105	0.129	0.050	0.604	0.030	0.064
Nanika R	6	0.050	0.025	0.074	0.010	0.200	0.030	0.078
Nanika R E	91	0.193	0.139	0.238	0.010	1.770	0.025	0.050
Shea C	39	0.136	0.100	0.192	0.010	1.080	0.031	0.062
Thautil R	29	0.162	0.130	0.140	0.010	0.630	0.026	0.053
Up Clore	2	0.030	0.030	0.028	0.010	0.050	0.020	0.254
Up Morice	24	0.830	0.823	0.221	0.120	1.200	0.045	0.093
Up Morice W	45	0.116	0.102	0.050	0.010	0.280	0.008	0.015



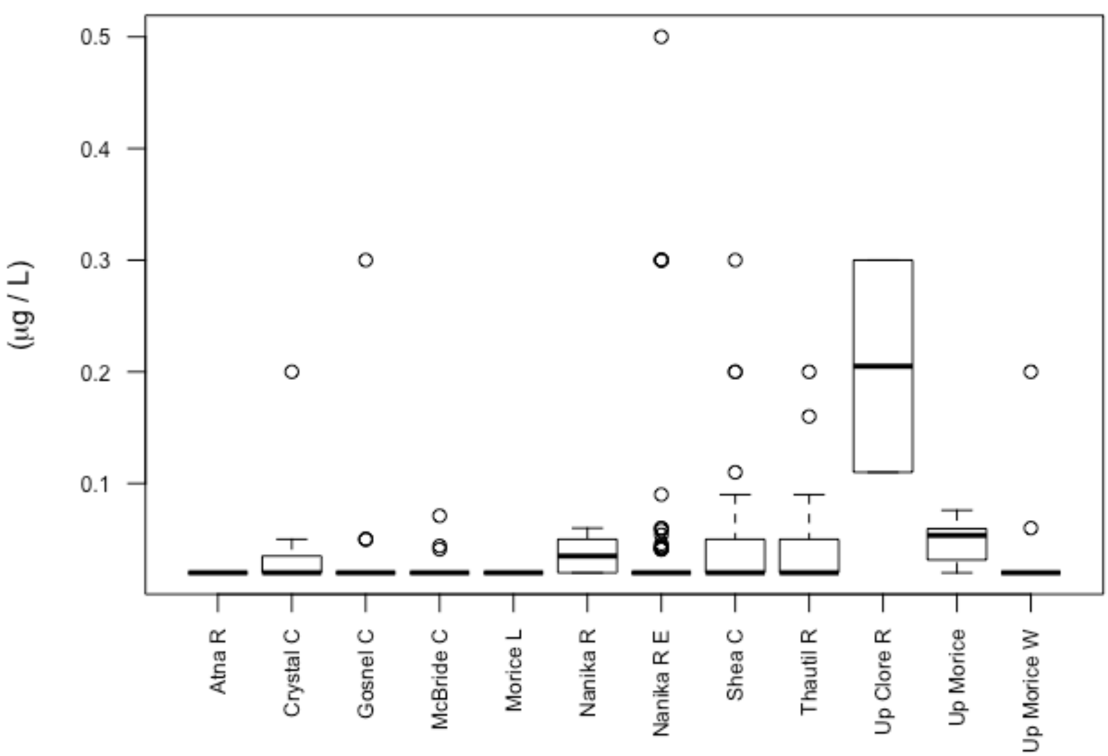
Selenium – Dissolved (Se-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.020	0.020	0.000	0.020	0.020	0.000	0.000
Crystal C	1	0.050	0.050	NA	NA	NA	NA	NA
Gosnel C	14	0.033	0.020	0.019	0.020	0.070	0.005	0.011
McBride C	30	0.022	0.020	0.006	0.020	0.050	0.001	0.002
Morice R	18	0.030	0.020	0.015	0.020	0.064	0.004	0.008
Nanika R	6	0.037	0.030	0.020	0.020	0.060	0.008	0.021
Nanika R E	82	0.026	0.020	0.032	0.020	0.300	0.003	0.007
Shea C	28	0.038	0.030	0.020	0.020	0.100	0.004	0.008
Thautil R	27	0.050	0.020	0.050	0.020	0.200	0.010	0.020
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.041	0.050	0.019	0.020	0.060	0.004	0.008
Up Morice W	41	0.021	0.020	0.008	0.020	0.070	0.001	0.002



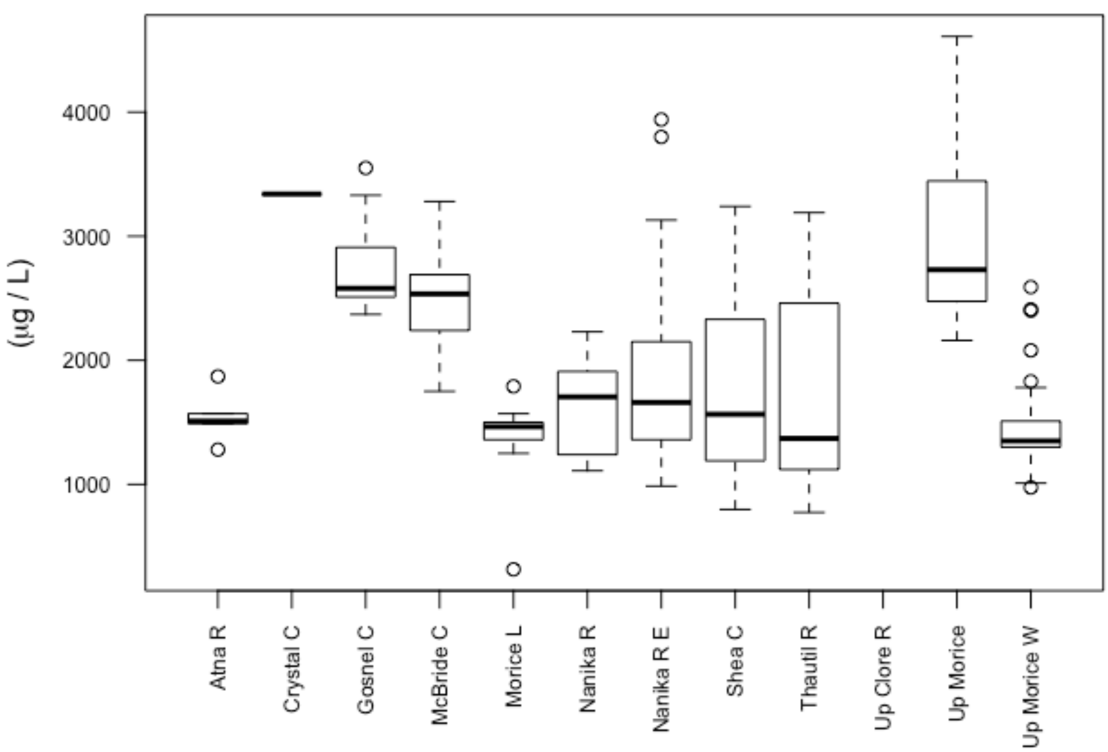
Selenium – Total (Se-T) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.020	0.020	0.000	0.020	0.020	0.000	0.000
Crystal C	7	0.050	0.020	0.067	0.020	0.200	0.025	0.062
Gosnel C	21	0.038	0.020	0.061	0.020	0.300	0.013	0.028
McBride C	31	0.023	0.020	0.011	0.020	0.071	0.002	0.004
Morice R	18	0.020	0.020	0.000	0.020	0.020	0.000	0.000
Nanika R	6	0.037	0.035	0.019	0.020	0.060	0.008	0.020
Nanika R E	91	0.042	0.020	0.076	0.020	0.500	0.008	0.016
Shea C	38	0.048	0.020	0.060	0.020	0.300	0.010	0.020
Thautil R	29	0.043	0.020	0.043	0.020	0.200	0.008	0.016
Up Clore	2	0.205	0.205	0.134	0.110	0.300	0.095	1.207
Up Morice	24	0.047	0.054	0.018	0.020	0.076	0.004	0.008
Up Morice W	45	0.025	0.020	0.027	0.020	0.200	0.004	0.008



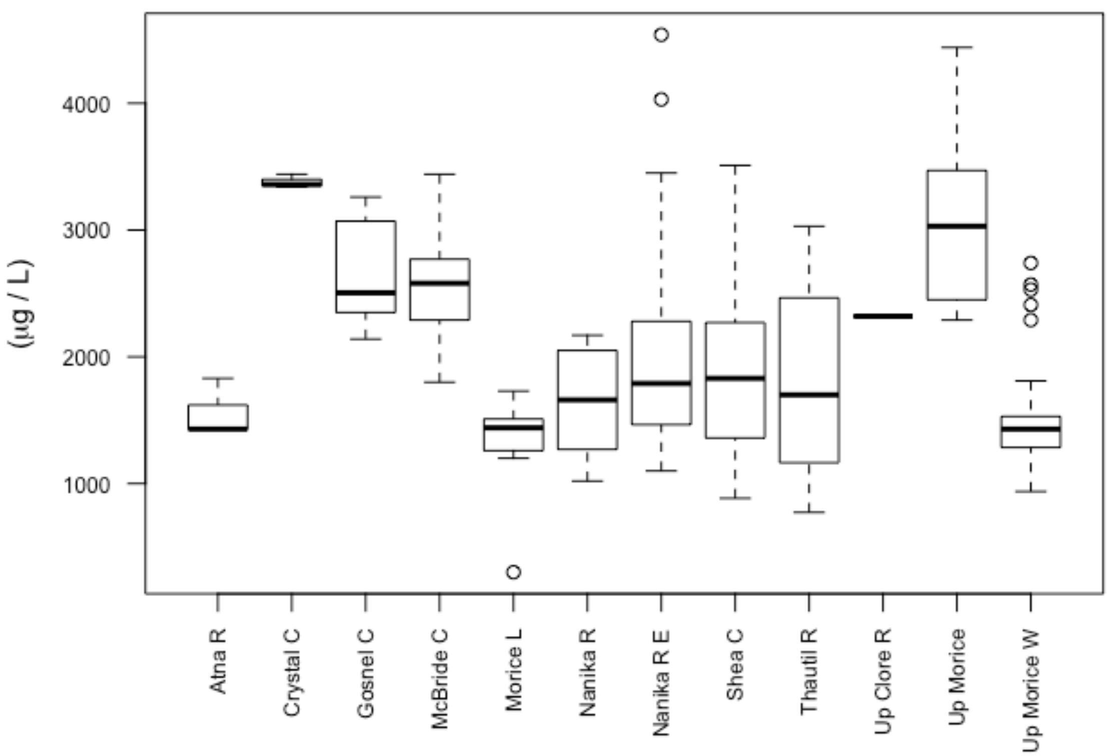
Silicon – Dissolved (Si-D) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	1544	1510	213	1280	1870	95	264
Crystal C	1	3340	3340	NA	NA	NA	NA	NA
Gosnel C	14	2756	2580	379	2370	3550	101	219
McBride C	30	2491	2535	375	1750	3280	68	140
Morice R	18	1400	1465	297	315	1790	70	148
Nanika R	6	1650	1705	417	1110	2230	170	438
Nanika R E	81	1868	1660	649	986	3940	72	143
Shea C	26	1768	1565	749	798	3240	147	303
Thautil R	23	1734	1370	800	774	3190	167	346
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	2984	2730	671	2160	4610	140	290
Up Morice W	41	1469	1350	354	975	2590	55	112



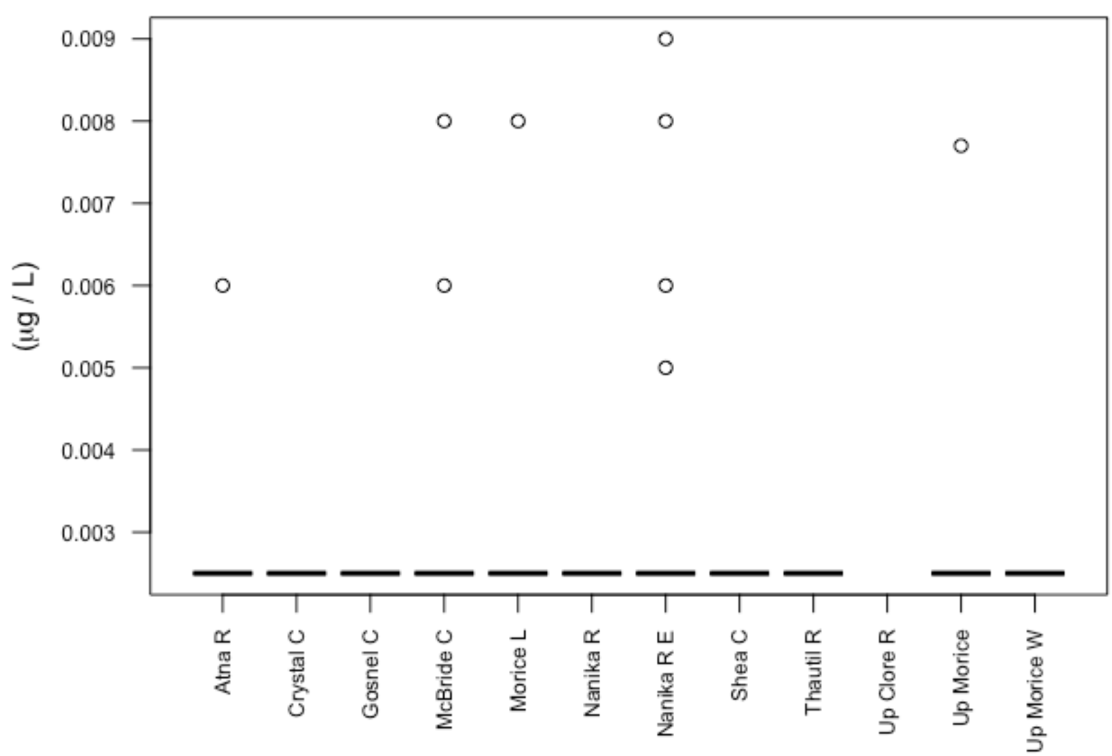
Silicon – Total (Si-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	1548	1430	178	1430	1830	80	221
Crystal C	3	3380	3360	53	3340	3440	31	131
Gosnel C	14	2622	2505	401	2140	3260	107	231
McBride C	31	2558	2580	377	1800	3440	68	138
Morice R	18	1371	1440	302	301	1730	71	150
Nanika R	6	1638	1660	445	1020	2170	182	467
Nanika R E	84	1995	1790	688	1100	4540	75	149
Shea C	35	1874	1830	666	884	3510	112	229
Thautil R	24	1827	1700	748	773	3030	153	316
Up Clore	1	2320	2320	NA	NA	NA	NA	NA
Up Morice	24	3094	3030	693	2290	4440	141	292
Up Morice W	43	1517	1430	408	938	2740	62	125



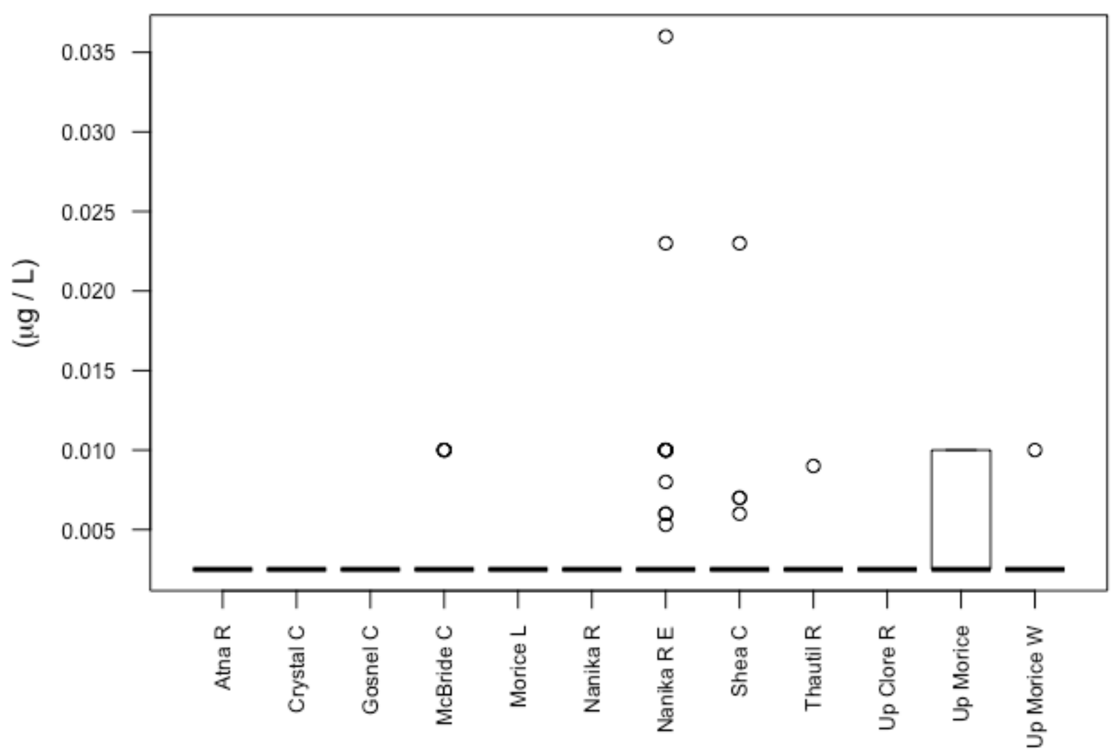
Silver – Dissolved (Ag-D) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.0032	0.0025	0.0016	0.0025	0.0060	0.0007	0.0019
Crystal C	1	0.0025	0.0025	NA	NA	NA	NA	NA
Gosnel C	14	0.0025	0.0025	0.0000	0.0025	0.0025	0.0000	0.0000
McBride C	30	0.0028	0.0025	0.0012	0.0025	0.0080	0.0002	0.0004
Morice R	18	0.0028	0.0025	0.0013	0.0025	0.0080	0.0003	0.0006
Nanika R	6	0.0025	0.0025	0.0000	0.0025	0.0025	0.0000	0.0000
Nanika R E	82	0.0027	0.0025	0.0010	0.0025	0.0090	0.0001	0.0002
Shea C	28	0.0025	0.0025	0.0000	0.0025	0.0025	0.0000	0.0000
Thautil R	27	0.0025	0.0025	0.0000	0.0025	0.0025	0.0000	0.0000
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.0027	0.0025	0.0011	0.0025	0.0077	0.0002	0.0005
Up Morice W	41	0.0025	0.0025	0.0000	0.0025	0.0025	0.0000	0.0000



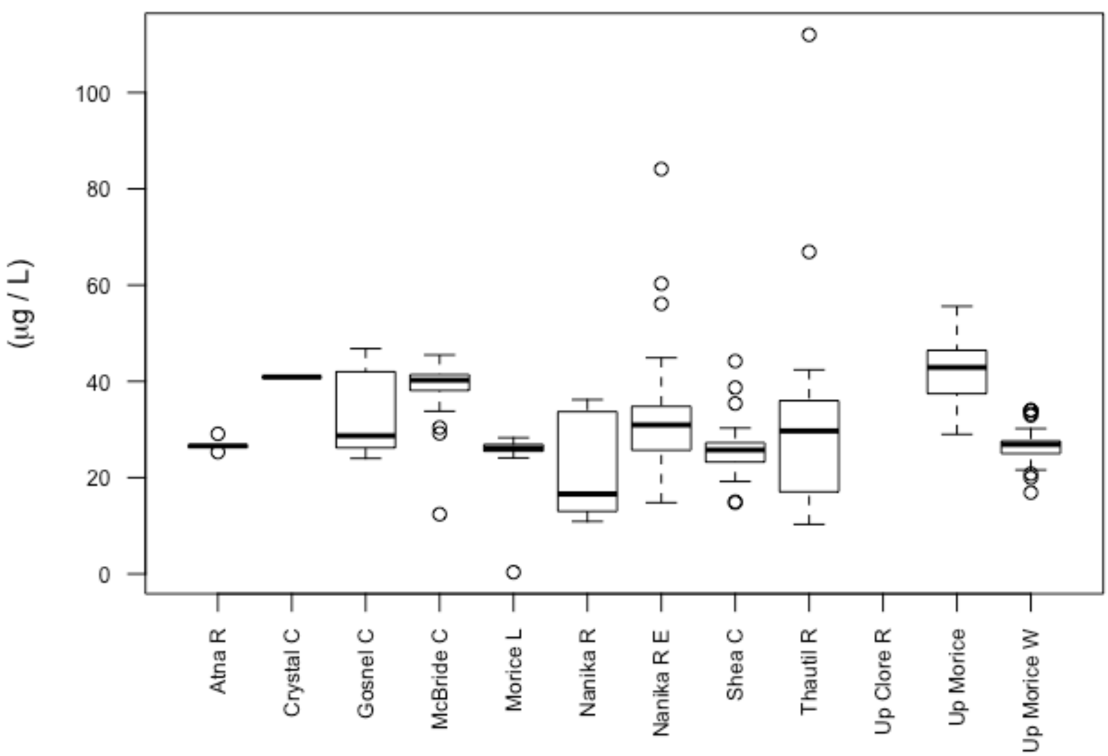
Silver – Total (Ag-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Crystal C	7	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Gosnel C	21	0.003	0.003	0.000	0.003	0.003	0.000	0.000
McBride C	31	0.004	0.003	0.003	0.003	0.010	0.001	0.001
Morice R	18	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Nanika R	6	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Nanika R E	91	0.004	0.003	0.005	0.003	0.036	0.000	0.001
Shea C	39	0.003	0.003	0.003	0.003	0.023	0.001	0.001
Thautil R	29	0.003	0.003	0.001	0.003	0.009	0.000	0.000
Up Clore	2	0.003	0.003	0.000	0.003	0.003	0.000	0.000
Up Morice	24	0.006	0.003	0.004	0.003	0.010	0.001	0.002
Up Morice W	45	0.003	0.003	0.001	0.003	0.010	0.000	0.000



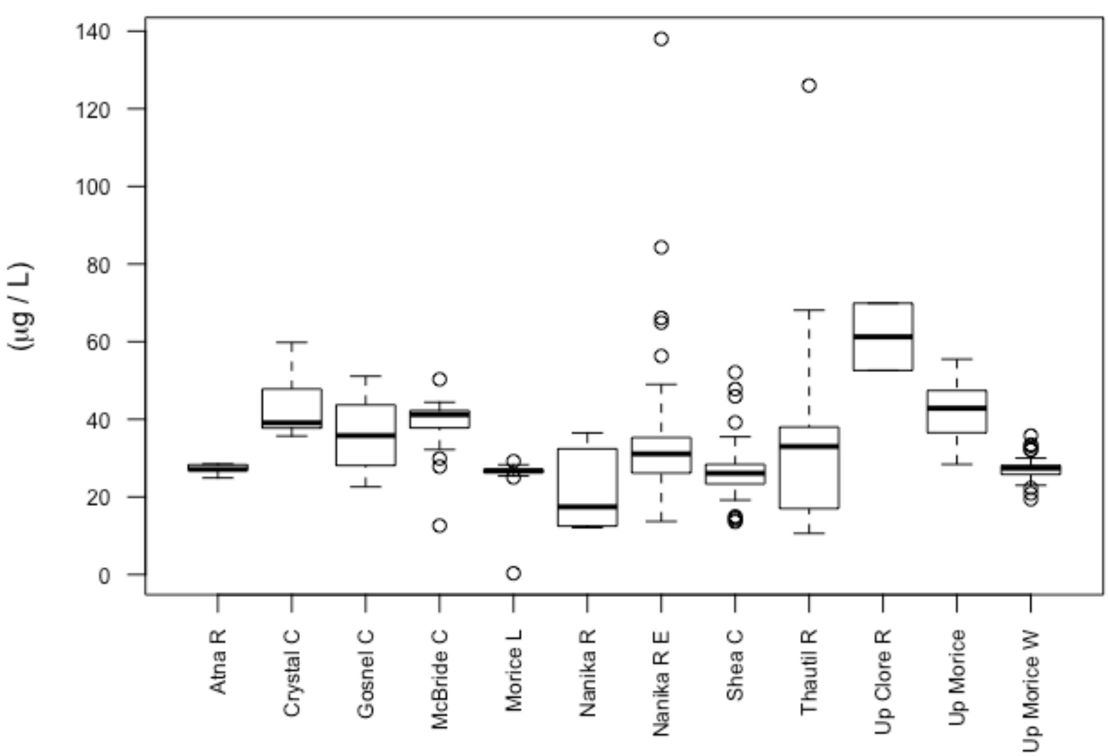
Strontium – Dissolved (Sr-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	26.80	26.60	1.39	25.30	29.10	0.62	1.73
Crystal C	1	40.90	40.90	NA	NA	NA	NA	NA
Gosnel C	14	32.14	28.70	8.34	24.00	46.80	2.23	4.82
McBride C	30	38.47	40.25	6.08	12.40	45.50	1.11	2.27
Morice R	18	24.88	26.10	6.20	0.35	28.30	1.46	3.08
Nanika R	6	21.17	16.60	10.95	10.90	36.20	4.47	11.49
Nanika R E	82	31.11	30.95	10.15	14.80	84.10	1.12	2.23
Shea C	28	26.00	25.75	6.14	14.80	44.20	1.16	2.38
Thautil R	27	30.76	29.70	20.73	10.30	112.00	3.99	8.20
Up Clore	0	NaN	NA	NA	NA	NA	NA	NA
Up Morice	23	42.46	42.90	6.70	29.00	55.60	1.40	2.90
Up Morice W	41	26.77	26.90	3.63	16.90	34.00	0.57	1.14



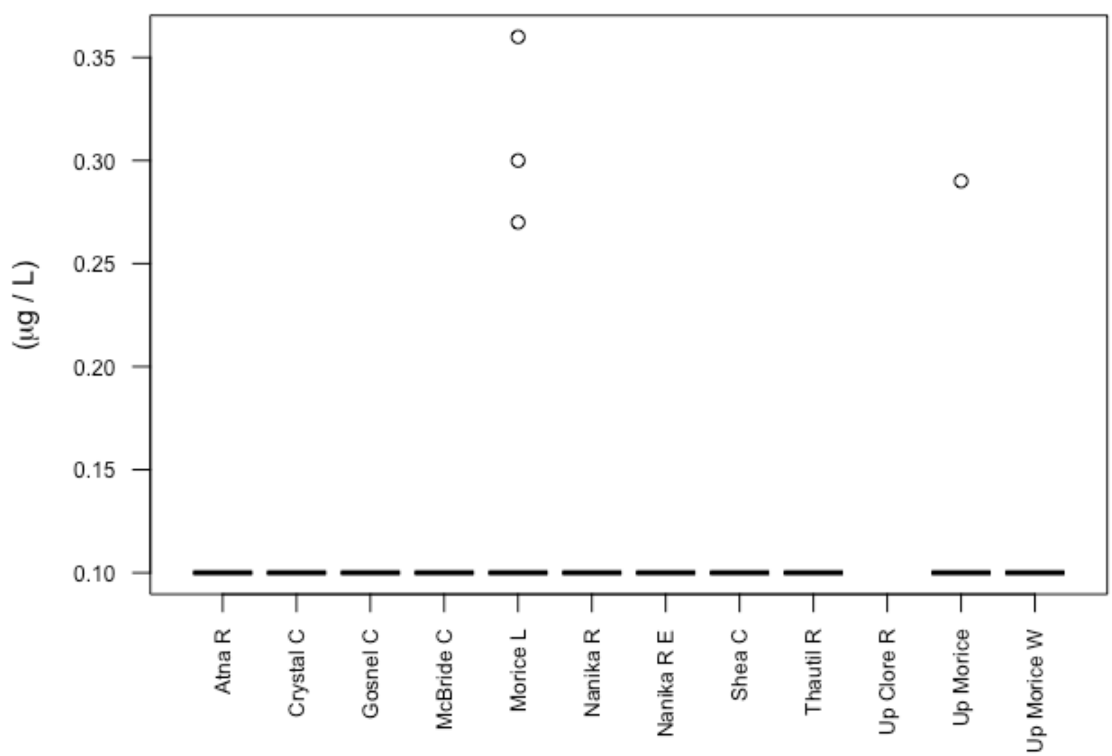
Strontium – Total (Sr-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	27.14	27.10	1.44	24.90	28.50	0.64	1.79
Crystal C	7	43.67	39.10	9.73	35.70	59.80	3.68	9.00
Gosnel C	21	35.50	35.80	8.50	22.60	51.10	1.86	3.87
McBride C	31	39.03	41.20	6.70	12.60	50.30	1.20	2.46
Morice R	18	25.39	26.70	6.33	0.32	29.20	1.49	3.15
Nanika R	6	21.40	17.45	10.49	12.10	36.50	4.28	11.01
Nanika R E	91	33.08	31.10	15.72	13.70	138.00	1.65	3.27
Shea C	39	26.86	26.10	8.24	13.60	52.10	1.32	2.67
Thautil R	29	33.49	33.00	22.49	10.60	126.00	4.18	8.56
Up Clore	2	61.25	61.25	12.23	52.60	69.90	8.65	109.91
Up Morice	24	42.28	42.85	7.15	28.40	55.50	1.46	3.02
Up Morice W	45	27.14	27.40	3.10	19.40	35.80	0.46	0.93



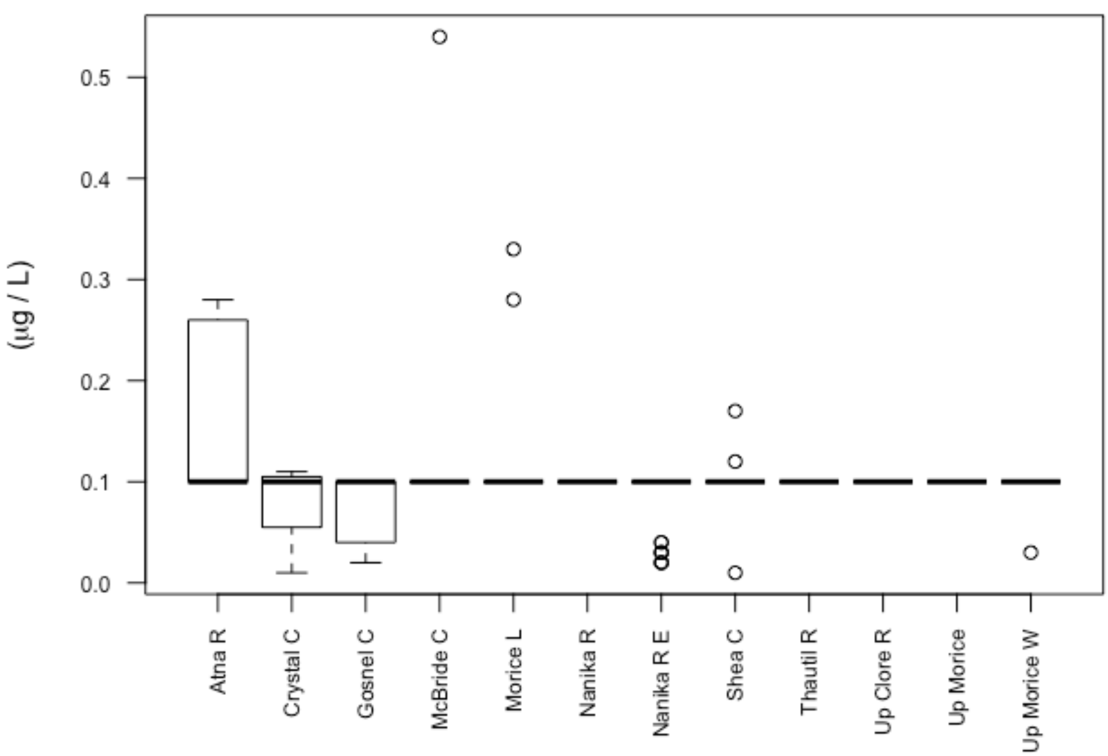
Tin – Dissolved (Sn-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Crystal C	1	0.100	0.100	NA	NA	NA	NA	NA
Gosnel C	14	0.100	0.100	0.000	0.100	0.100	0.000	0.000
McBride C	30	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Morice R	18	0.135	0.100	0.082	0.100	0.360	0.019	0.041
Nanika R	6	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Nanika R E	82	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Shea C	27	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Thautil R	26	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.108	0.100	0.040	0.100	0.290	0.008	0.017
Up Morice W	41	0.100	0.100	0.000	0.100	0.100	0.000	0.000



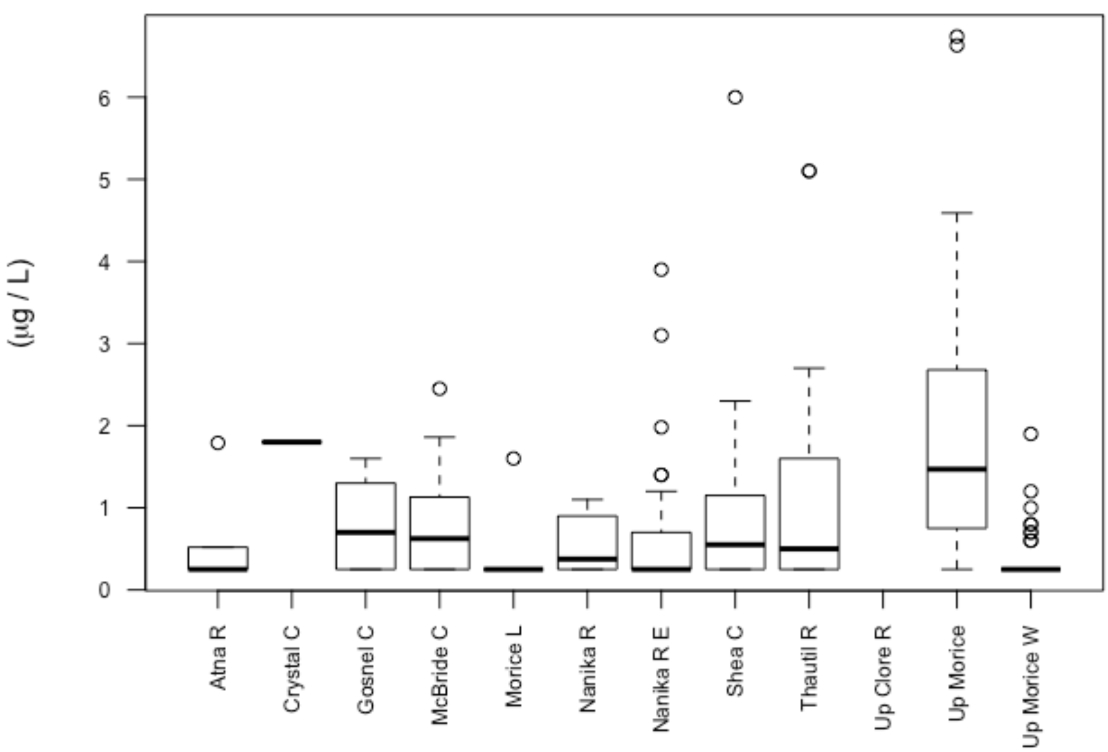
Tin – Total (Sn-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.168	0.100	0.093	0.100	0.280	0.042	0.116
Crystal C	3	0.073	0.100	0.055	0.010	0.110	0.032	0.137
Gosnel C	6	0.077	0.100	0.037	0.020	0.100	0.015	0.039
McBride C	31	0.114	0.100	0.079	0.100	0.540	0.014	0.029
Morice R	16	0.126	0.100	0.071	0.100	0.330	0.018	0.038
Nanika R	6	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Nanika R E	86	0.093	0.100	0.021	0.020	0.100	0.002	0.004
Shea C	32	0.100	0.100	0.021	0.010	0.170	0.004	0.007
Thautil R	29	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Clore	2	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Morice	24	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Morice W	44	0.098	0.100	0.011	0.030	0.100	0.002	0.003



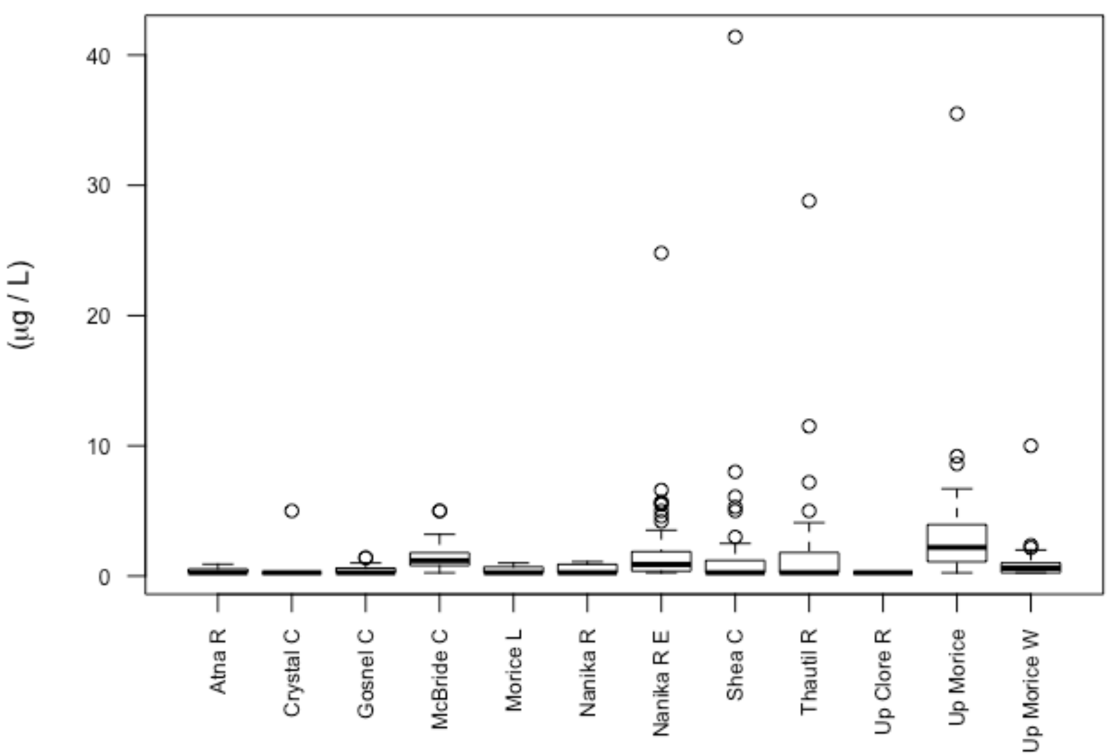
Titanium – Dissolved (Ti-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.612	0.250	0.669	0.250	1.790	0.299	0.830
Crystal C	1	1.800	1.800	NA	NA	NA	NA	NA
Gosnel C	14	0.775	0.700	0.501	0.250	1.600	0.134	0.289
McBride C	30	0.784	0.625	0.576	0.250	2.450	0.105	0.215
Morice R	18	0.325	0.250	0.318	0.250	1.600	0.075	0.158
Nanika R	6	0.542	0.375	0.373	0.250	1.100	0.152	0.392
Nanika R E	81	0.532	0.250	0.594	0.250	3.900	0.066	0.131
Shea C	28	0.932	0.550	1.159	0.250	6.000	0.219	0.450
Thautil R	26	1.100	0.500	1.383	0.250	5.100	0.271	0.558
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	2.071	1.470	1.811	0.250	6.740	0.378	0.783
Up Morice W	41	0.398	0.250	0.337	0.250	1.900	0.053	0.106



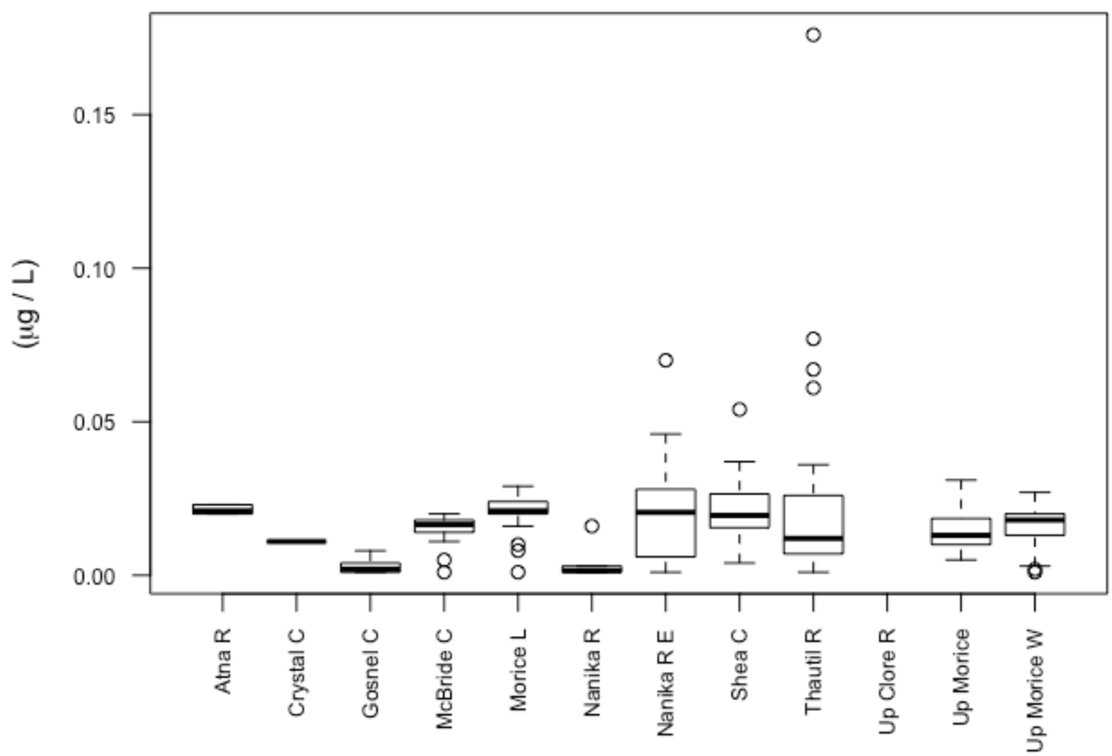
Titanium – Total (Ti-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.168	0.100	0.093	0.100	0.280	0.042	0.116
Crystal C	3	0.073	0.100	0.055	0.010	0.110	0.032	0.137
Gosnel C	6	0.077	0.100	0.037	0.020	0.100	0.015	0.039
McBride C	31	0.114	0.100	0.079	0.100	0.540	0.014	0.029
Morice R	16	0.126	0.100	0.071	0.100	0.330	0.018	0.038
Nanika R	6	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Nanika R E	86	0.093	0.100	0.021	0.020	0.100	0.002	0.004
Shea C	32	0.100	0.100	0.021	0.010	0.170	0.004	0.007
Thautil R	29	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Clore	2	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Morice	24	0.100	0.100	0.000	0.100	0.100	0.000	0.000
Up Morice W	44	0.098	0.100	0.011	0.030	0.100	0.002	0.003



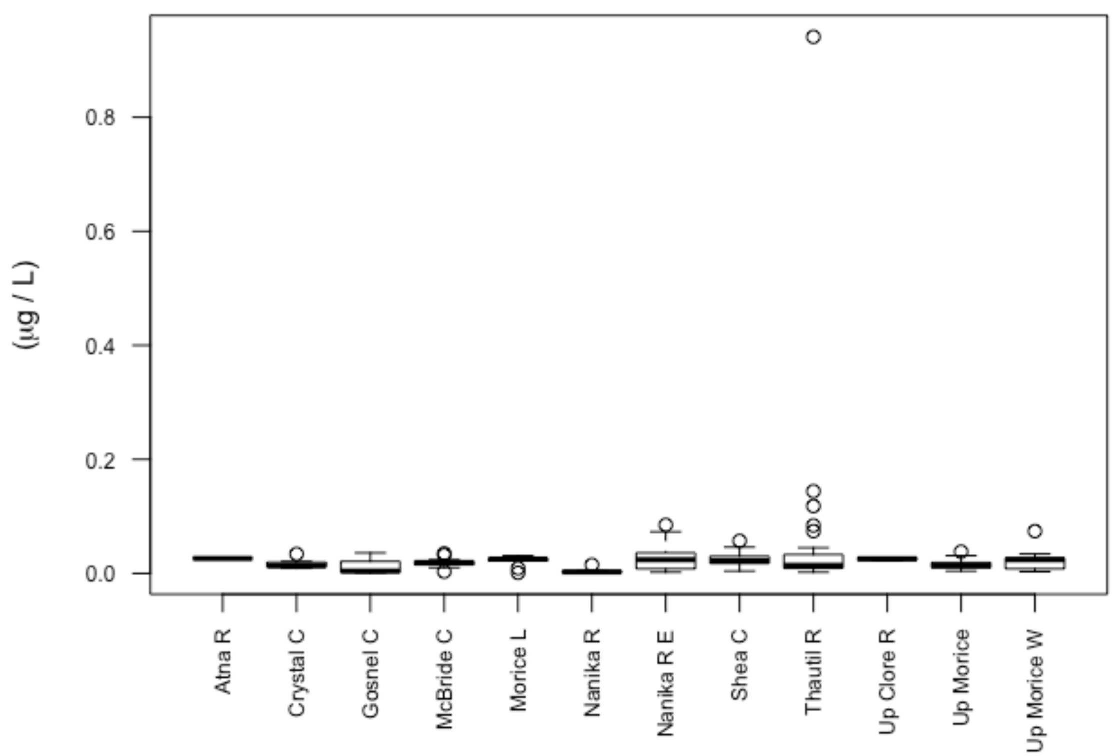
Uranium – Dissolved (U-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.021	0.021	0.002	0.020	0.023	0.001	0.002
Crystal C	1	0.011	0.011	NA	NA	NA	NA	NA
Gosnel C	14	0.003	0.002	0.002	0.001	0.008	0.001	0.001
McBride C	30	0.016	0.017	0.004	0.001	0.020	0.001	0.002
Morice R	18	0.020	0.021	0.007	0.001	0.029	0.002	0.003
Nanika R	6	0.004	0.002	0.006	0.001	0.016	0.002	0.006
Nanika R E	82	0.019	0.021	0.014	0.001	0.070	0.002	0.003
Shea C	28	0.021	0.020	0.011	0.004	0.054	0.002	0.004
Thautil R	27	0.025	0.012	0.036	0.001	0.176	0.007	0.014
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.015	0.013	0.008	0.005	0.031	0.002	0.003
Up Morice W	41	0.016	0.018	0.007	0.001	0.027	0.001	0.002



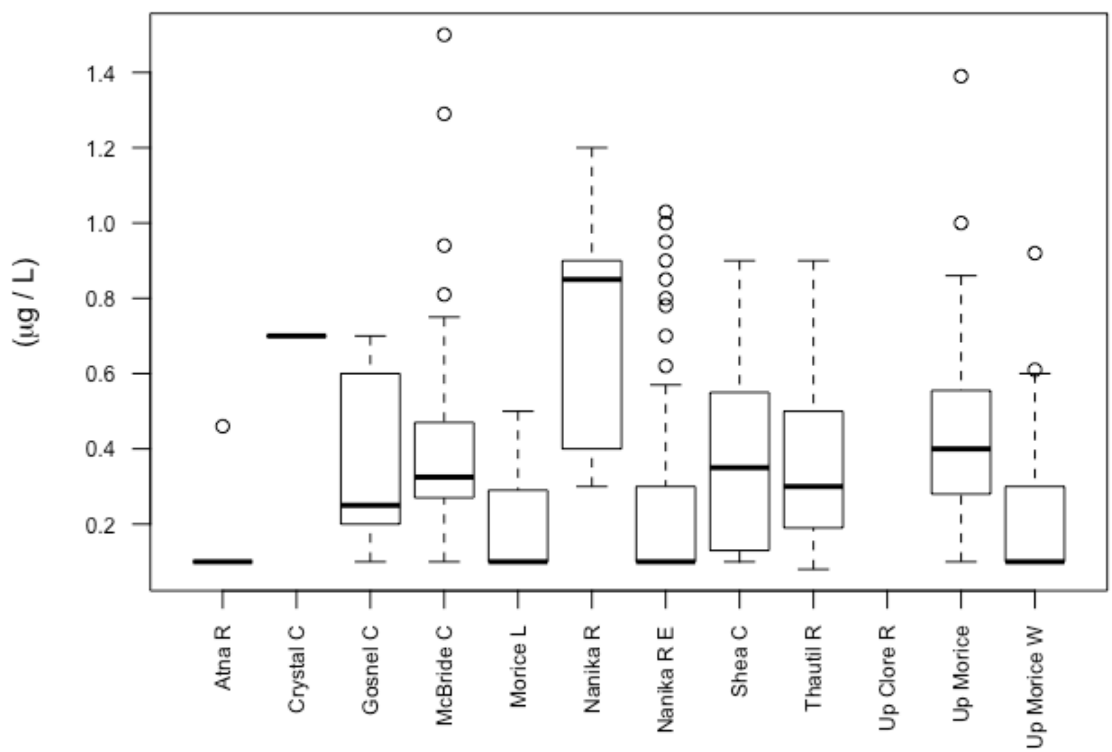
Uranium– Total (U-T) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.026	0.026	0.001	0.025	0.027	0.000	0.001
Crystal C	7	0.017	0.013	0.009	0.009	0.034	0.003	0.008
Gosnel C	21	0.011	0.004	0.012	0.001	0.036	0.003	0.006
McBride C	31	0.018	0.019	0.006	0.003	0.035	0.001	0.002
Morice R	18	0.023	0.025	0.007	0.001	0.031	0.002	0.003
Nanika R	6	0.004	0.003	0.005	0.001	0.015	0.002	0.006
Nanika R E	90	0.025	0.024	0.017	0.002	0.085	0.002	0.004
Shea C	31	0.024	0.022	0.012	0.004	0.057	0.002	0.004
Thautil R	29	0.060	0.014	0.173	0.002	0.941	0.032	0.066
Up Clore	2	0.026	0.026	0.004	0.023	0.028	0.003	0.032
Up Morice	24	0.016	0.014	0.009	0.004	0.038	0.002	0.004
Up Morice W	45	0.021	0.024	0.013	0.003	0.074	0.002	0.004



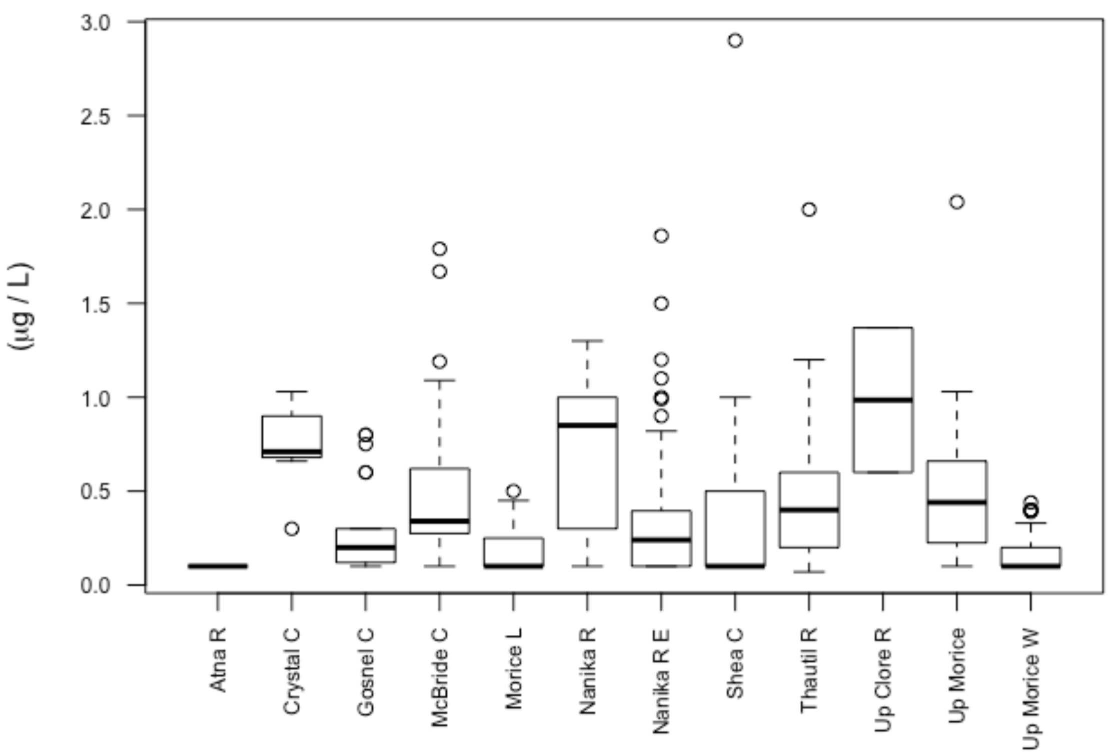
Vanadium – Dissolved (V-D) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.17	0.10	0.16	0.10	0.46	0.07	0.20
Crystal C	1	0.70	0.70	NA	NA	NA	NA	NA
Gosnel C	14	0.35	0.25	0.21	0.10	0.70	0.06	0.12
McBride C	30	0.45	0.33	0.32	0.10	1.50	0.06	0.12
Morice R	18	0.17	0.10	0.13	0.10	0.50	0.03	0.06
Nanika R	6	0.75	0.85	0.34	0.30	1.20	0.14	0.36
Nanika R E	82	0.26	0.10	0.24	0.10	1.03	0.03	0.05
Shea C	28	0.38	0.35	0.25	0.10	0.90	0.05	0.10
Thautil R	27	0.36	0.30	0.22	0.08	0.90	0.04	0.09
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.48	0.40	0.31	0.10	1.39	0.06	0.13
Up Morice W	41	0.20	0.10	0.18	0.10	0.92	0.03	0.06



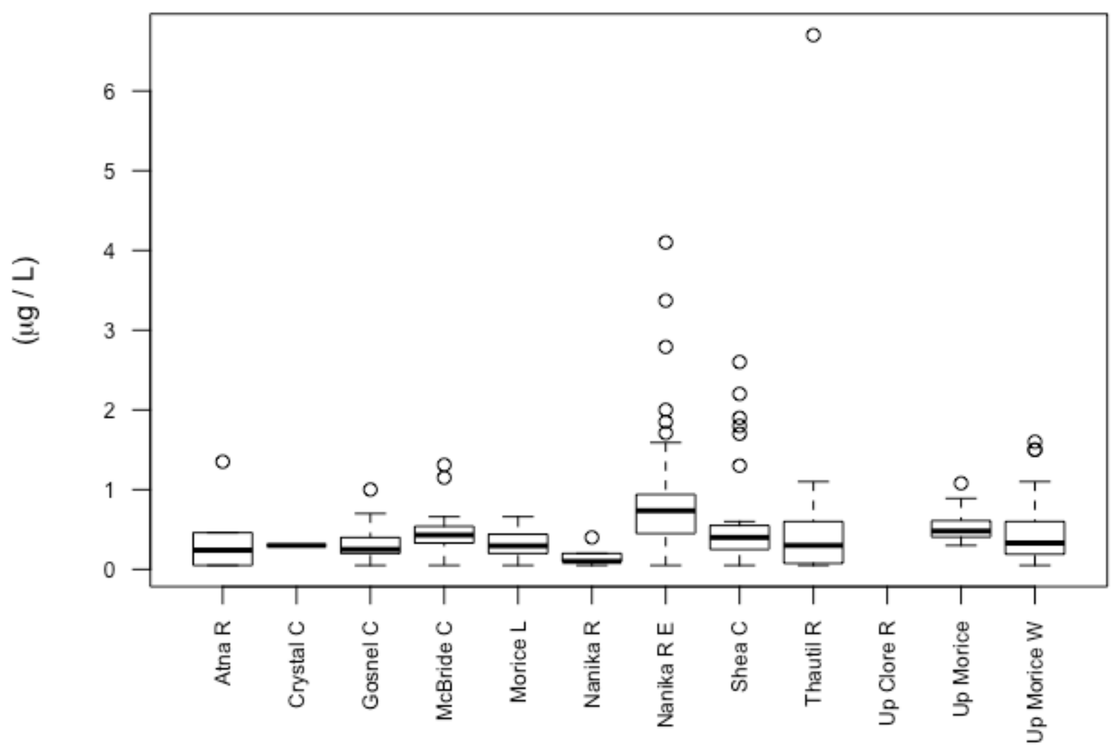
Vanadium– Total (V-T) (µg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.10	0.10	0.00	0.10	0.10	0.00	0.00
Crystal C	7	0.74	0.71	0.24	0.30	1.03	0.09	0.23
Gosnel C	21	0.30	0.20	0.25	0.10	0.80	0.05	0.11
McBride C	31	0.52	0.34	0.42	0.10	1.79	0.08	0.16
Morice R	18	0.20	0.10	0.15	0.10	0.50	0.03	0.07
Nanika R	6	0.73	0.85	0.45	0.10	1.30	0.18	0.47
Nanika R E	91	0.32	0.24	0.33	0.10	1.86	0.03	0.07
Shea C	39	0.39	0.10	0.50	0.10	2.90	0.08	0.16
Thautil R	29	0.48	0.40	0.42	0.07	2.00	0.08	0.16
Up Clore	2	0.99	0.99	0.54	0.60	1.37	0.39	4.89
Up Morice	24	0.50	0.44	0.42	0.10	2.04	0.09	0.18
Up Morice W	45	0.16	0.10	0.11	0.10	0.44	0.02	0.03



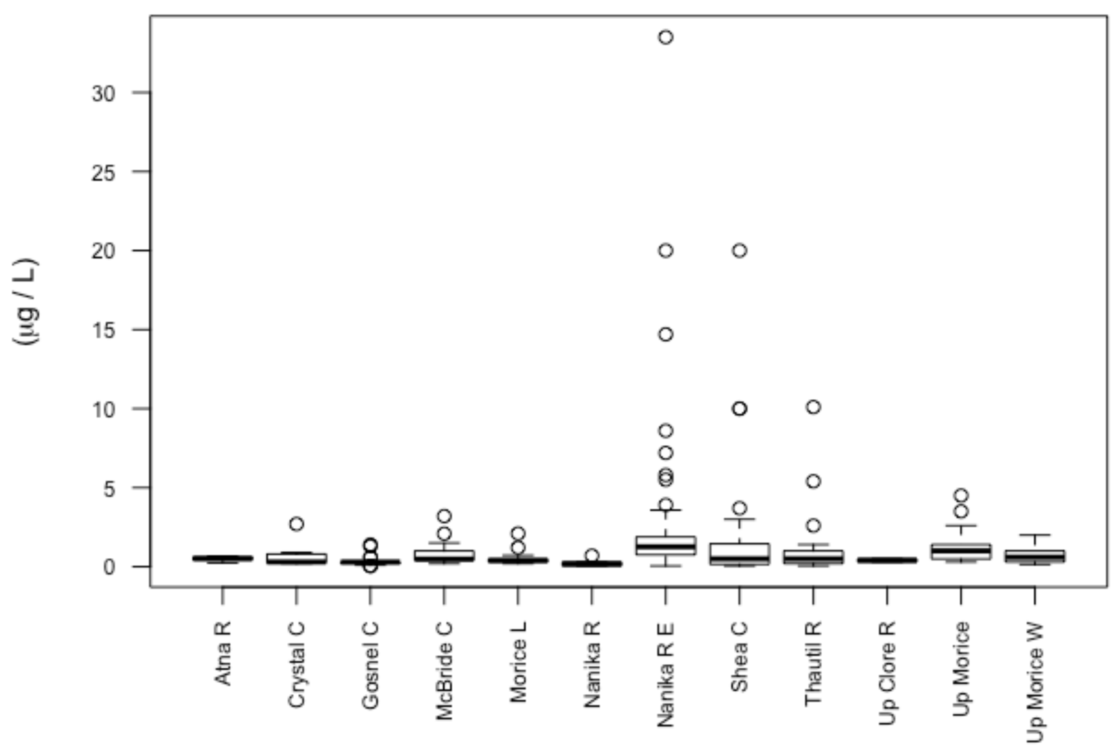
Zinc – Dissolved (Zn-D) (μg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.43	0.24	0.54	0.05	1.35	0.24	0.67
Crystal C	1	0.30	0.30	NA	NA	NA	NA	NA
Gosnel C	14	0.34	0.25	0.25	0.05	1.00	0.07	0.14
McBride C	30	0.47	0.43	0.25	0.05	1.31	0.05	0.09
Morice R	18	0.32	0.30	0.16	0.05	0.66	0.04	0.08
Nanika R	6	0.16	0.10	0.13	0.05	0.40	0.05	0.13
Nanika R E	82	0.83	0.74	0.66	0.05	4.10	0.07	0.15
Shea C	28	0.66	0.40	0.71	0.05	2.60	0.13	0.27
Thautil R	27	0.58	0.30	1.26	0.05	6.70	0.24	0.50
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.54	0.48	0.20	0.30	1.08	0.04	0.09
Up Morice W	41	0.49	0.33	0.41	0.05	1.60	0.06	0.13



Zinc – Total (Zn-T) (µg/L)

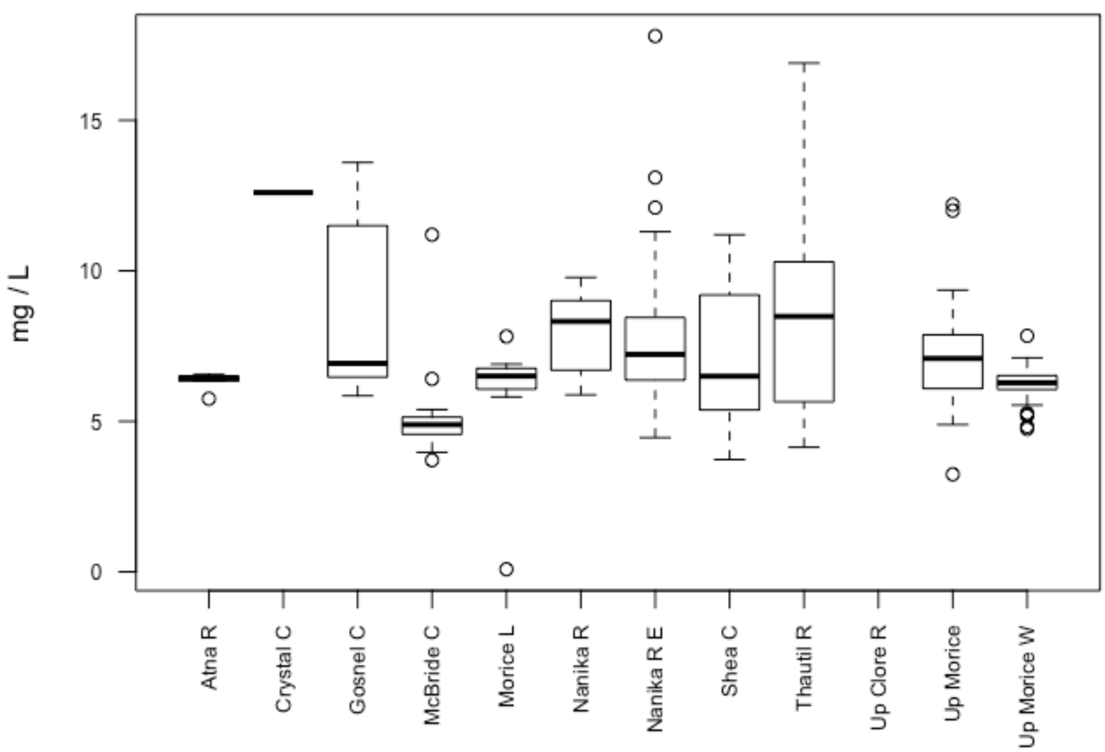
AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.50	0.50	0.17	0.24	0.67	0.08	0.21
Crystal C	7	0.76	0.30	0.90	0.20	2.70	0.34	0.83
Gosnel C	21	0.35	0.30	0.36	0.05	1.40	0.08	0.16
McBride C	31	0.76	0.48	0.63	0.20	3.20	0.11	0.23
Morice R	18	0.52	0.40	0.46	0.20	2.10	0.11	0.23
Nanika R	6	0.24	0.18	0.26	0.05	0.70	0.10	0.27
Nanika R E	91	2.22	1.26	4.31	0.05	33.50	0.45	0.90
Shea C	39	1.74	0.50	3.74	0.05	20.00	0.60	1.21
Thautil R	29	1.10	0.50	2.02	0.05	10.10	0.38	0.77
Up Clore	2	0.40	0.40	0.14	0.30	0.50	0.10	1.27
Up Morice	24	1.20	1.00	1.04	0.30	4.50	0.21	0.44
Up Morice W	45	0.71	0.60	0.51	0.14	2.00	0.08	0.15



Appendix B.3 Summary Statistics for watershed Assessment Units (AU) in Morice Water Management Area 1996-2017: Dissolved and Total Cations, Sulfur

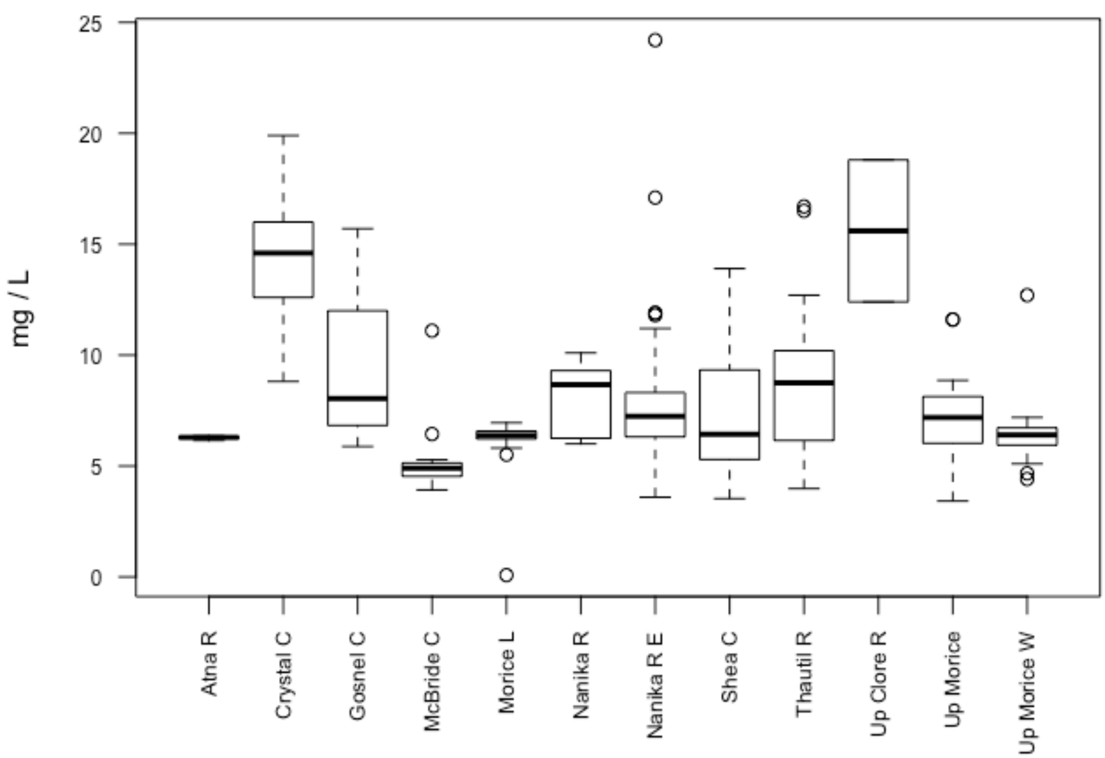
Calcium – Dissolved (Ca-D) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	6.32	6.45	0.33	5.75	6.56	0.15	0.41
Crystal C	1	12.60	12.60	NA	NA	NA	NA	NA
Gosnel C	14	8.38	6.93	2.76	5.85	13.60	0.74	1.60
McBride C	30	5.03	4.89	1.27	3.71	11.20	0.23	0.47
Morice R	18	6.16	6.51	1.59	0.09	7.82	0.37	0.79
Nanika R	6	8.00	8.32	1.47	5.88	9.78	0.60	1.54
Nanika R E	82	7.66	7.23	2.08	4.46	17.80	0.23	0.46
Shea C	28	7.22	6.50	2.28	3.73	11.20	0.43	0.88
Thautil R	26	8.34	8.49	2.95	4.14	16.90	0.58	1.19
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	7.22	7.09	2.00	3.24	12.20	0.42	0.87
Up Morice W	41	6.21	6.28	0.60	4.75	7.84	0.09	0.19



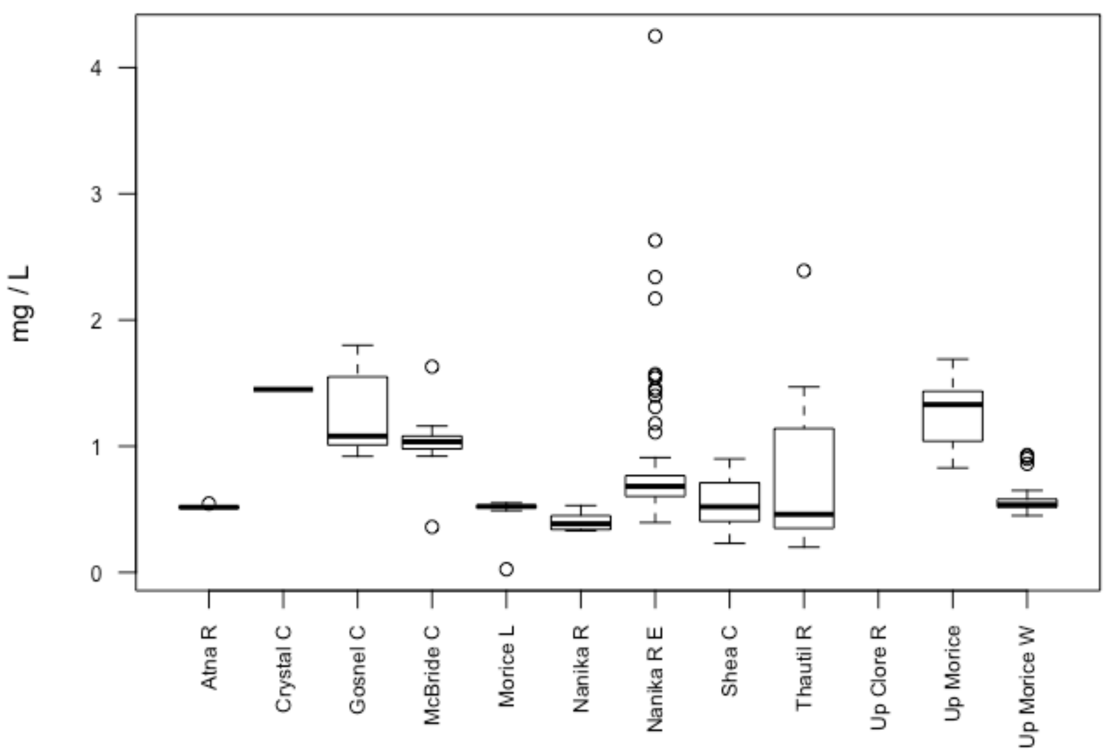
Calcium – Total (Ca-T) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	6.27	6.29	0.08	6.15	6.36	0.04	0.10
Crystal C	7	14.36	14.60	3.49	8.81	19.90	1.32	3.23
Gosnel C	21	9.27	8.04	2.89	5.88	15.70	0.63	1.32
McBride C	31	5.00	4.90	1.23	3.92	11.10	0.22	0.45
Morice R	18	6.02	6.38	1.52	0.08	6.95	0.36	0.76
Nanika R	6	8.16	8.67	1.67	6.00	10.10	0.68	1.75
Nanika R E	87	7.76	7.24	2.70	3.59	24.20	0.29	0.57
Shea C	39	7.34	6.43	2.59	3.53	13.90	0.42	0.84
Thautil R	29	8.76	8.75	3.23	3.98	16.70	0.60	1.23
Up Clore	2	15.60	15.60	4.53	12.40	18.80	3.20	40.66
Up Morice	24	7.27	7.19	1.89	3.42	11.60	0.39	0.80
Up Morice W	45	6.39	6.40	1.14	4.41	12.70	0.17	0.34



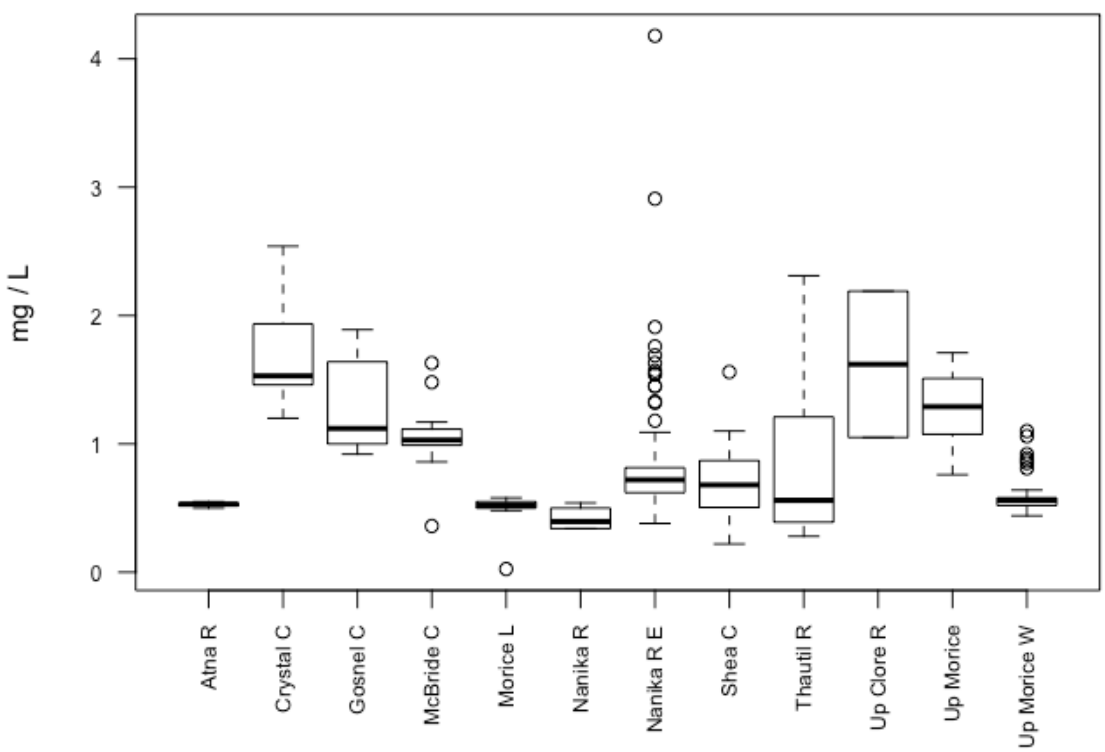
Magnesium – Dissolved (Mg-D) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.523	0.516	0.013	0.514	0.546	0.006	0.017
Crystal C	1	1.450	1.450	NA	NA	NA	NA	NA
Gosnel C	14	1.234	1.080	0.309	0.920	1.800	0.083	0.179
McBride C	30	1.032	1.035	0.179	0.360	1.630	0.033	0.067
Morice R	18	0.495	0.523	0.118	0.025	0.551	0.028	0.059
Nanika R	6	0.403	0.385	0.077	0.330	0.530	0.031	0.081
Nanika R E	82	0.837	0.682	0.560	0.395	4.250	0.062	0.123
Shea C	28	0.558	0.520	0.184	0.230	0.900	0.035	0.071
Thautil R	26	0.688	0.460	0.525	0.200	2.390	0.103	0.212
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	1.265	1.330	0.243	0.828	1.690	0.051	0.105
Up Morice W	41	0.575	0.537	0.117	0.450	0.930	0.018	0.037



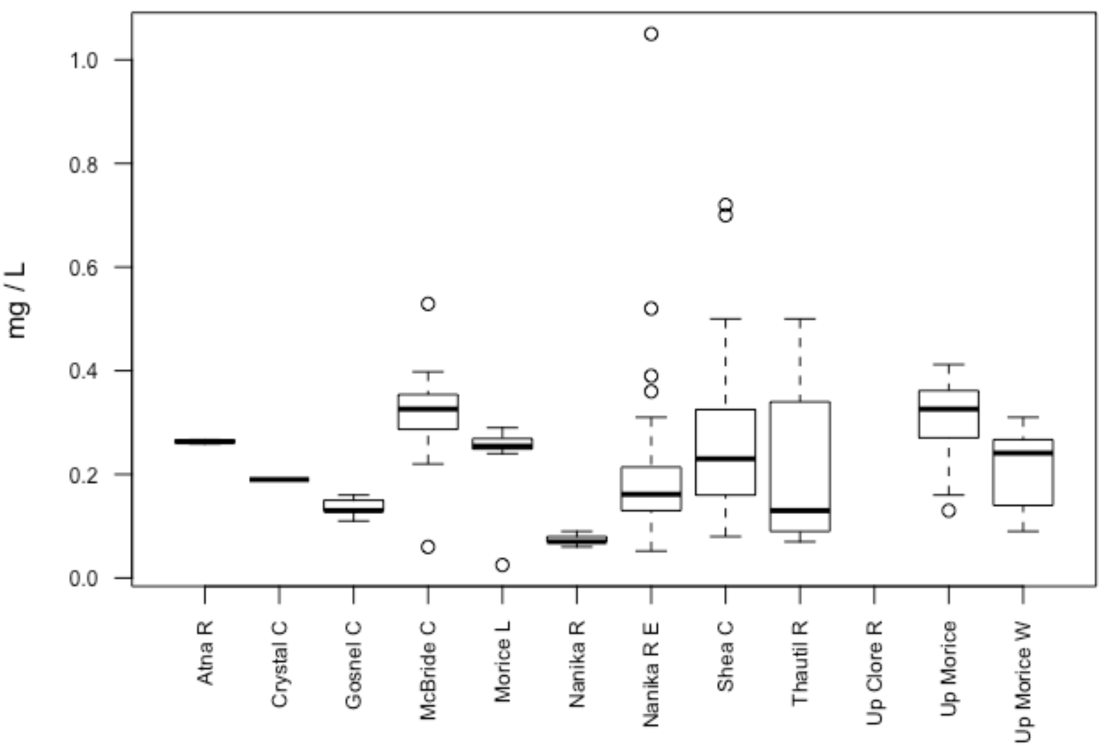
Magnesium – Total (Mg-T) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.528	0.530	0.019	0.500	0.550	0.009	0.024
Crystal C	7	1.723	1.530	0.476	1.200	2.540	0.180	0.440
Gosnel C	21	1.268	1.120	0.341	0.920	1.890	0.074	0.155
McBride C	31	1.044	1.030	0.201	0.360	1.630	0.036	0.074
Morice R	18	0.503	0.520	0.122	0.025	0.580	0.029	0.061
Nanika R	6	0.418	0.395	0.086	0.340	0.540	0.035	0.091
Nanika R E	87	0.858	0.720	0.539	0.380	4.180	0.058	0.115
Shea C	39	0.696	0.680	0.275	0.220	1.560	0.044	0.089
Thautil R	29	0.803	0.560	0.543	0.280	2.310	0.101	0.207
Up Clore	2	1.620	1.620	0.806	1.050	2.190	0.570	7.243
Up Morice	24	1.273	1.290	0.263	0.760	1.710	0.054	0.111
Up Morice W	45	0.602	0.560	0.152	0.440	1.100	0.023	0.046



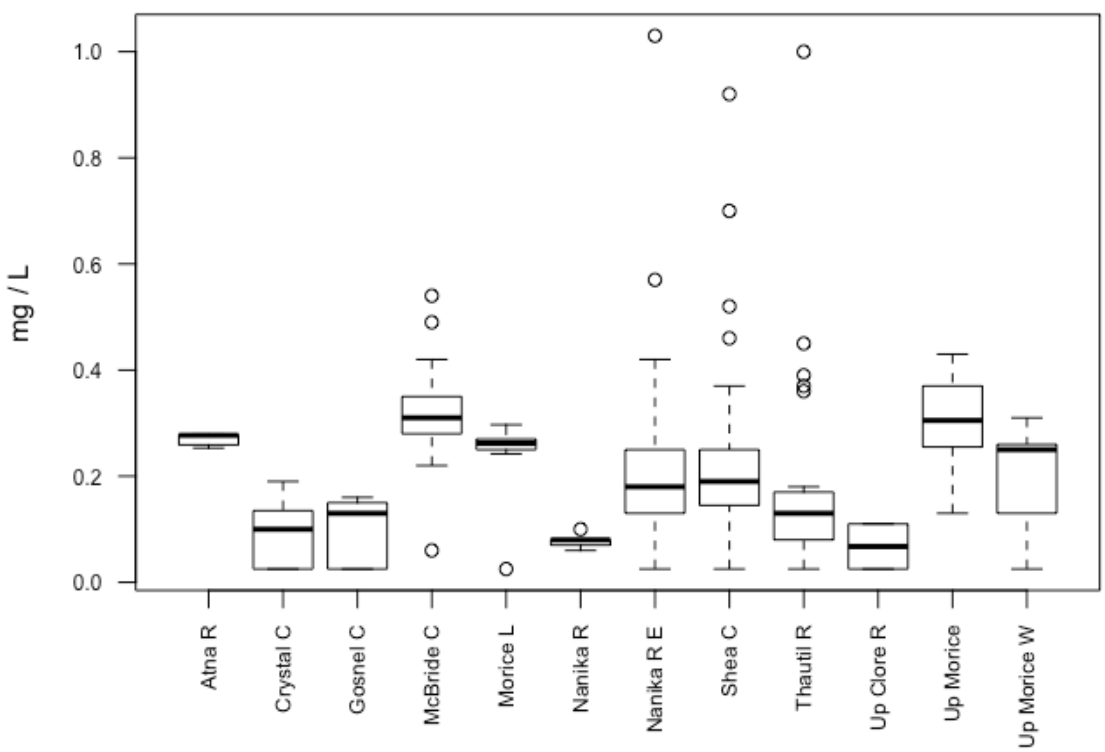
Potassium – Dissolved (K-D) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.263	0.263	0.003	0.259	0.267	0.001	0.004
Crystal C	1	0.190	0.190	NA	NA	NA	NA	NA
Gosnel C	14	0.136	0.130	0.016	0.110	0.160	0.004	0.009
McBride C	30	0.323	0.326	0.075	0.060	0.529	0.014	0.028
Morice R	18	0.246	0.255	0.057	0.025	0.290	0.013	0.028
Nanika R	6	0.073	0.070	0.010	0.060	0.090	0.004	0.011
Nanika R E	82	0.189	0.162	0.124	0.052	1.050	0.014	0.027
Shea C	28	0.274	0.230	0.170	0.080	0.720	0.032	0.066
Thautil R	26	0.195	0.130	0.144	0.070	0.500	0.028	0.058
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	0.308	0.326	0.073	0.130	0.412	0.015	0.031
Up Morice W	41	0.209	0.241	0.068	0.090	0.310	0.011	0.022



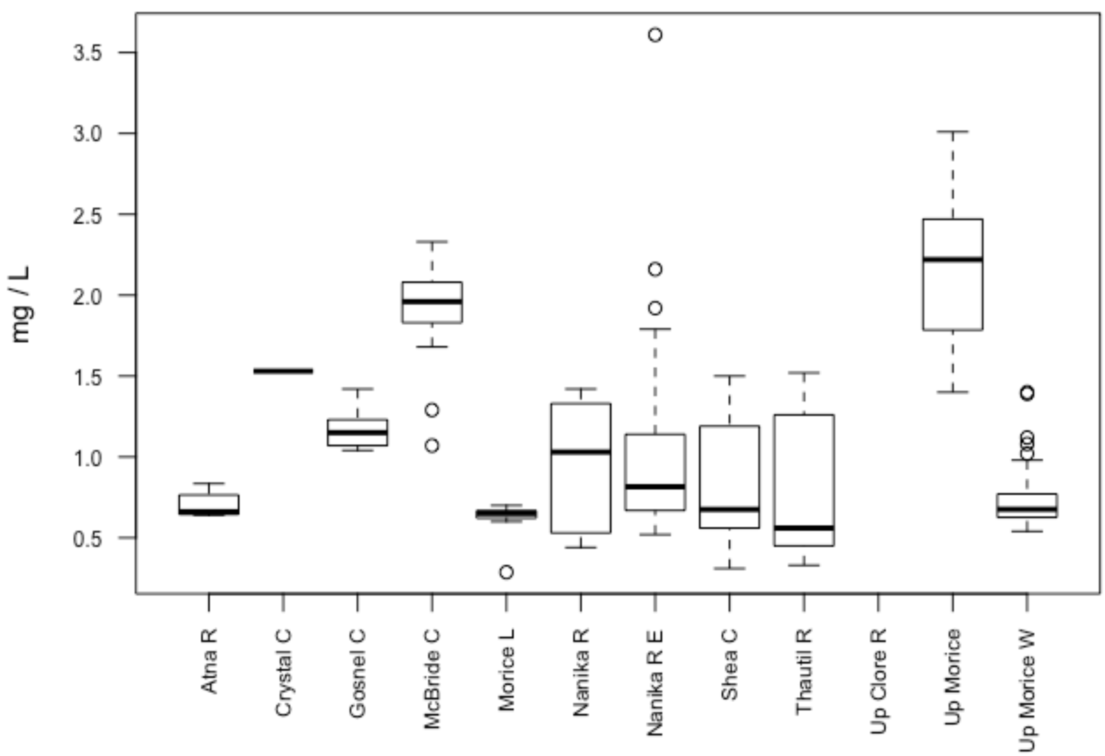
Potassium – Total (K-T) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.269	0.277	0.012	0.253	0.279	0.005	0.015
Crystal C	7	0.091	0.100	0.067	0.025	0.190	0.025	0.062
Gosnel C	21	0.102	0.130	0.057	0.025	0.160	0.012	0.026
McBride C	31	0.323	0.310	0.084	0.060	0.540	0.015	0.031
Morice R	18	0.249	0.262	0.058	0.025	0.297	0.014	0.029
Nanika R	6	0.078	0.080	0.013	0.060	0.100	0.005	0.014
Nanika R E	86	0.194	0.180	0.126	0.025	1.030	0.014	0.027
Shea C	31	0.236	0.190	0.193	0.025	0.920	0.035	0.071
Thautil R	29	0.174	0.130	0.194	0.025	1.000	0.036	0.074
Up Clore	2	0.068	0.068	0.060	0.025	0.110	0.043	0.540
Up Morice	24	0.305	0.305	0.078	0.130	0.430	0.016	0.033
Up Morice W	45	0.200	0.250	0.075	0.025	0.310	0.011	0.023



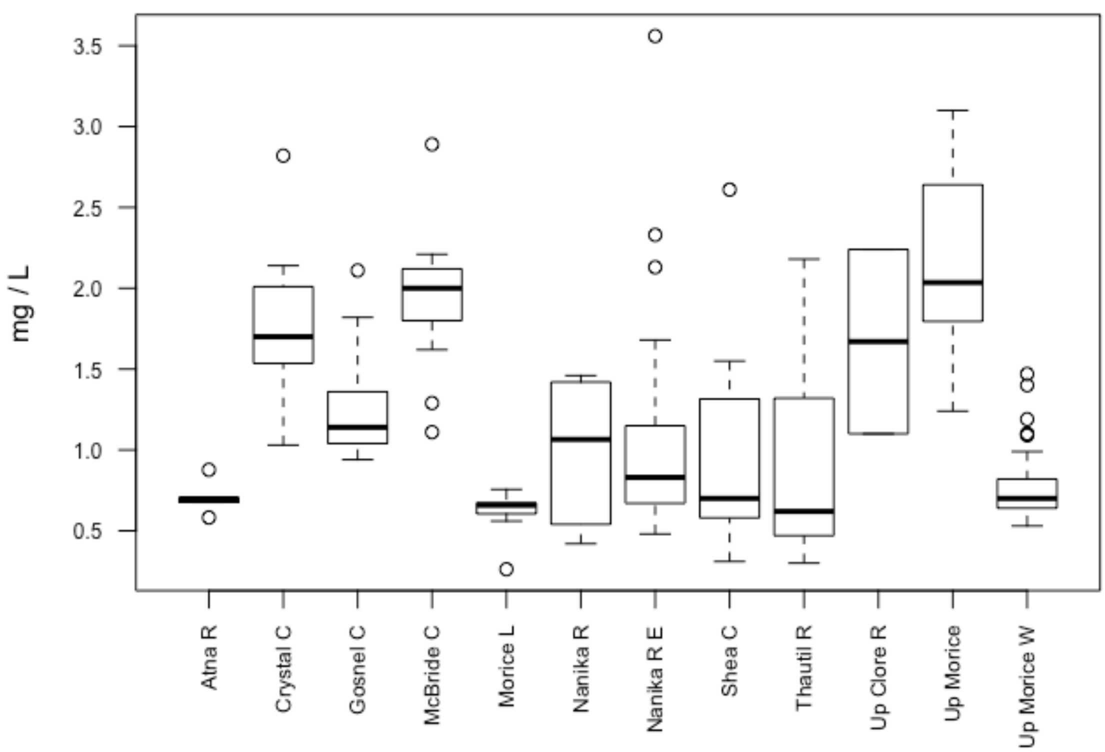
Sodium – Dissolved (Na-D) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.709	0.661	0.087	0.640	0.835	0.039	0.108
Crystal C	1	1.530	1.530	NA	NA	NA	NA	NA
Gosnel C	14	1.179	1.150	0.124	1.040	1.420	0.033	0.072
McBride C	30	1.926	1.960	0.259	1.070	2.330	0.047	0.097
Morice R	18	0.628	0.651	0.090	0.287	0.700	0.021	0.045
Nanika R	6	0.963	1.030	0.404	0.440	1.420	0.165	0.424
Nanika R E	82	0.956	0.816	0.442	0.520	3.610	0.049	0.097
Shea C	28	0.839	0.675	0.388	0.310	1.500	0.073	0.150
Thautil R	26	0.805	0.560	0.438	0.330	1.520	0.086	0.177
Up Clore	0	NA	NA	NA	NA	NA	NA	NA
Up Morice	23	2.146	2.220	0.440	1.400	3.010	0.092	0.190
Up Morice W	41	0.748	0.676	0.203	0.540	1.400	0.032	0.064



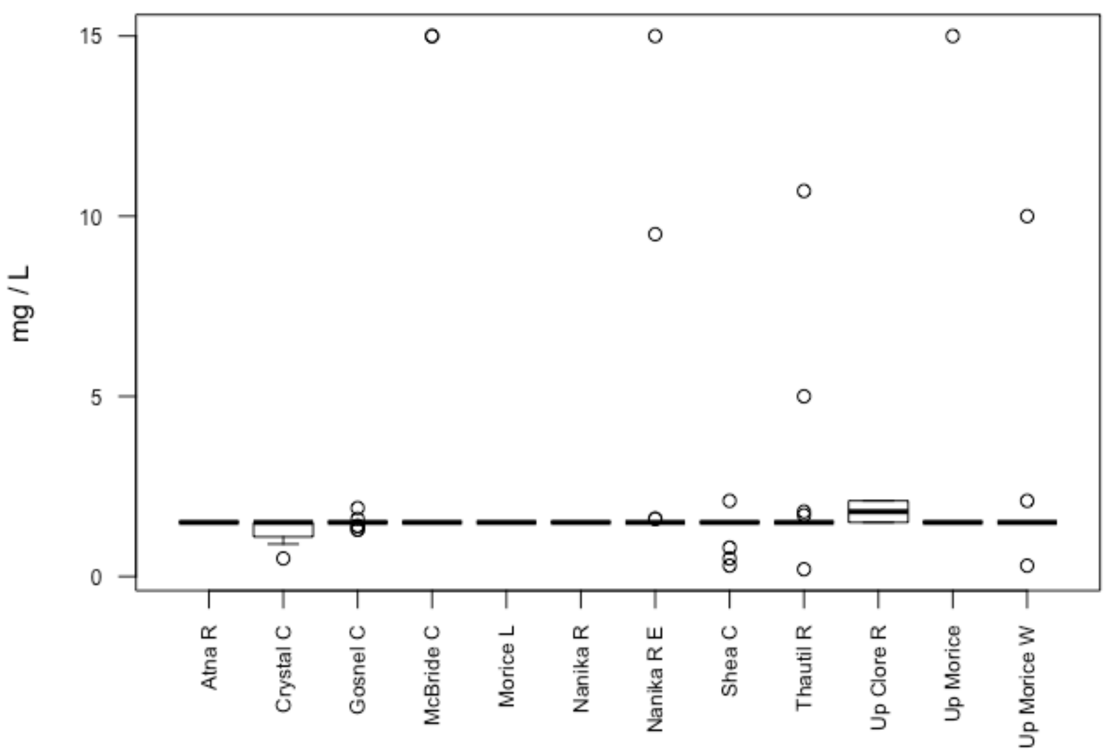
Sodium – Total (Na-T) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	0.708	0.698	0.107	0.582	0.877	0.048	0.133
Crystal C	7	1.806	1.700	0.564	1.030	2.820	0.213	0.521
Gosnel C	21	1.239	1.140	0.289	0.940	2.110	0.063	0.131
McBride C	31	1.945	2.000	0.309	1.110	2.890	0.056	0.113
Morice R	18	0.630	0.658	0.102	0.262	0.756	0.024	0.051
Nanika R	6	0.995	1.065	0.435	0.420	1.460	0.177	0.456
Nanika R E	86	0.964	0.830	0.443	0.480	3.560	0.048	0.095
Shea C	31	0.932	0.700	0.509	0.310	2.610	0.091	0.187
Thautil R	29	0.908	0.620	0.533	0.300	2.180	0.099	0.203
Up Clore	2	1.670	1.670	0.806	1.100	2.240	0.570	7.243
Up Morice	24	2.125	2.035	0.519	1.240	3.100	0.106	0.219
Up Morice W	45	0.763	0.700	0.217	0.530	1.470	0.032	0.065



Sulfur – Total (S) (mg/L)

AU	N	Mean	Median	SD	Min	Max	SE	CI
Atna R	5	1.50	1.50	0.00	1.50	1.50	0.00	0.00
Crystal C	7	1.24	1.50	0.40	0.50	1.50	0.15	0.37
Gosnel C	21	1.50	1.50	0.12	1.30	1.90	0.03	0.05
McBride C	31	2.37	1.50	3.37	1.50	15.00	0.61	1.24
Morice R	18	1.50	1.50	0.00	1.50	1.50	0.00	0.00
Nanika R	6	1.50	1.50	0.00	1.50	1.50	0.00	0.00
Nanika R E	86	1.75	1.50	1.68	1.50	15.00	0.18	0.36
Shea C	31	1.43	1.50	0.32	0.30	2.10	0.06	0.12
Thautil R	29	1.91	1.50	1.83	0.20	10.70	0.34	0.70
Up Clore	2	1.80	1.80	0.42	1.50	2.10	0.30	3.81
Up Morice	24	2.06	1.50	2.76	1.50	15.00	0.56	1.16
Up Morice W	45	1.68	1.50	1.29	0.30	10.00	0.19	0.39



Appendix C. Previously established and proposed sites for watershed monitoring activities in the greater Morice River watershed.

Table C.1: Established sites for watershed monitoring in the greater Morice River watershed.

EMS ID	Site Name	AU	Latitude	Longitude	Sampling Agency	n samples	Start date	End date
1131112	MORICE LAKE (CENTER)	Morice Lake	54.0325	127.565	Wetsuweten Hereditary Chiefs, Skeena, Permittee	11	2008-09-04	2017-09-12
1131113	NANIKA LAKE	Nanika River	53.7806	127.6497	Wetsuweten Hereditary Chiefs	2	2008-09-04	2008-09-15
E223327	HOLLAND LAKE, DEEP HOLE	Shea Creek	54.264	127.4519	Skeena	1	1996-08-05	1996-08-05
E223338	SHEA LAKE, DEEP HOLE	Shea Creek	54.2938	127.5724	Skeena	2	1996-07-10	1996-08-10
E223350	UNNAMED019, DEEP HOLE	Nanika River E	53.9362	127.4721	Skeena	2	1996-08-05	1996-08-05
E228741	FENTON CREEK	Fenton Creek	54.2006	126.8908	Independent Agent or Other, Skeena, Bulkley Valley Research Centre	34	1997-09-03	2015-10-20
E228742	JOHNSON CREEK (UPSTREAM SITE)	Upper Clore River	54.0833	127.8884	Skeena	0	1997-10-14	1997-10-14
E228745	SHEA CREEK (UPSTREAM SITE)	Shea Creek	54.2395	127.5088	Skeena	2	2004-09-15	2011-09-20
E228746	SHEA CREEK (DOWNSTREAM SITE)	Shea Creek	54.2354	127.5178	Skeena	1	1997-08-27	1997-08-27
E229137	SHEA CREEK	Shea Creek	54.236	127.5172	Skeena	0	1997-10-15	1997-10-15
E236753	CHISHOLM RD 53KM U/S	Thautil River	54.3393	127.2955	Skeena	0	1999-08-09	1999-08-09
E236754	CHISHOLM RD 53KM D/S	Thautil River	54.3393	127.2983	Skeena	0	1999-08-09	1999-08-09
E236826	SILVER QUEEN	Nanika River E	54.05	127.46	Skeena	1	1999-03-31	1999-03-31
E236827	SILVER QUEEN OWEN LAKE 10M FROM WRINCH CREEK OUTLET	Nanika River E	54.04	127.45	Skeena	1	1999-03-31	1999-03-31
E236828	SILVER QUEEN OWEN LAKE 80M FROM WRINCH CR OUTLET	Nanika River E	54.03	127.45	Skeena	1	1999-03-31	1999-03-31
E236829	SILVER QUEEN OWEN LAKE 10M FROM RANCH GATE CR OUTLET	Nanika River E	54.03	127.47	Skeena	1	1999-03-31	1999-03-31
E236830	SILVER QUEEN OWEN LAKE 120M FROM RANCH GATE CR	Nanika River E	54.03	127.47	Skeena	1	1999-03-31	1999-03-31
E251384	PR-03608 HIRSCH CREEK UPSTREAM OF KITIMAT LANDFILL	Upper Clore River	54.0606	128.0619	Skeena	2	2005-11-21	2006-10-16

Table C.1: continued

EMS ID	Site Name	AU	Latitude	Longitude	Sampling Agency	n samples	Start date	End date
E256936	LOLJUH CREEK	Thautil River	54.6375	127.2576	Skeena	2	2004-09-07	2011-09-07
E256937	DENY`S CREEK	Thautil River	54.3701	127.2861	Skeena	2	2004-09-07	2009-08-31
E256938	RAINA CREEK	Thautil River	54.3692	127.2885	Skeena	2	2004-09-07	2011-09-07
E256979	OWEN CREEK LOWER	Owen Creek	54.2012	126.8585	Bulkley Valley Research Centre, Skeena	33	2004-09-15	2015-10-19
E256980	LAMPREY CREEK @ REC SITE	Lamprey Creek	54.1849	127.0853	Wetsuweten Hereditary Chiefs, Skeena, Skeena-Terrace, Bulkley Valley Research Centre	40	2004-09-15	2015-10-20
E260427	CRYSTAL CREEK FSR, BRIDGE CROSSING AT KM5	Crystal Creek	54.19988	127.44957	Skeena	1	2009-08-31	2009-08-31
E260428	REDSLIDE CREEK	Nanika River E	53.96939	127.49239	Skeena	2	2005-08-23	2005-08-31
E260429	NADO CREEK	Upper Morice	54.12984	127.32343	Bulkley Valley Research Centre, Skeena	21	2005-08-31	2017-10-29
E260493	GOSNELL @ BRIDGE	Gosnel Creek	54.10846	127.68828	Skeena	2	2005-08-29	2011-09-20
E260494	UNNAMED @ 24 CRYSTAL	Gosnel Creek	54.13238	127.65656	Skeena	2	2005-08-29	2011-09-20
E260496	MCBRIDE CREEK 2005	McBride Creek	54.09749	127.4528	Bulkley Valley Research Centre, Skeena	28	2005-08-29	2017-10-29
E260563	BERG EFFLUENT	Nanika River	53.79866	127.44221	Skeena	1	2005-08-30	2005-08-30
E260564	BERG REF SITE	Nanika River	53.79735	127.44044	Skeena	1	2005-08-30	2005-08-30
E260565	KIDPRICE TRIB	Nanika River E	53.89128	127.40356	Skeena	1	2005-08-30	2005-08-30
E260566	BERGFAR FIELD	Nanika River	53.80115	127.45204	Skeena	1	2005-08-30	2005-08-30
E263581	OUTLET OF CUTTHROAT LAKE	Nanika River E	54.00628	127.50342	Skeena	1	2006-07-19	2006-07-19
E263582	NANIKA RIVER UPSTREAM	Nanika River E	54.00594	127.47166	Skeena	1	2006-07-19	2006-07-19
E267342	NANIKA RIVER TRIBUTARY	Nanika River E	54.008577	127.48093	Skeena	1	2007-07-11	2007-07-11
E267343	NANIKA RIVER TRIBUTARY 2	Nanika River E	54.017547	127.48093	Skeena	1	2007-07-11	2007-07-11
E267344	NANIKA RIVER TRIBUTARY 3	Nanika River E	54.01943	127.47341	Skeena	1	2007-07-11	2007-07-11
E267345	NANIKA RIVER TRIBUTARY 4	Nanika River E	54.020072	127.47246	Skeena	1	2007-07-11	2007-07-11
E267346	NANIKA RIVER TRIBUTARY 5	Nanika River E	54.047086	127.42187	Skeena	1	2007-07-11	2007-07-11
E272549	MORICE RIVER AT MORICE WEST BRIDGE	Upper Morice W	54.19075	127.36364	Bulkley Valley Research Centre, Skeena	67	2008-07-22	2017-10-29

Table C.1: continued

EMS ID	Site Name	AU	Latitude	Longitude	Sampling Agency	n samples	Start date	End date
E272551	GOSNELL CREEK @ MORICE WEST FSR BRIDGE	Gosnel Creek	54.21537	127.39415	Wetsuweten Hereditary Chiefs	10	2008-07-22	2008-11-11
E272553	JOSHUA CREEK @ JOSHUA ROAD BRIDGE	Gosnel Creek	54.18889	127.66523	Wetsuweten Hereditary Chiefs	9	2008-07-22	2008-10-22
E272554	CRYSTAL CREEK	Crystal Creek	54.19752	127.4509	Wetsuweten Hereditary Chiefs	10	2008-07-22	2008-11-11
E272555	GOSNELL TRIBUTARY SOUTH	Gosnel Creek	54.16818	127.63894	Wetsuweten Hereditary Chiefs	9	2008-07-22	2008-10-22
E272556	CUTTHROAT CREEK U/S CUTTHROAT FSR BRIDGE	Nanika River E	54.00875	127.48102	Wetsuweten Hereditary Chiefs, Bulkley Valley Research Centre	35	2008-07-22	2017-10-29
E272557	NANIKA RIVER @ CUTTHROAT FSR BRIDGE	Nanika River E	54.04733	127.42732	Wetsuweten Hereditary Chiefs, Bulkley Valley Research Centre	36	2008-07-22	2017-10-29
E272563	SHEA CREEK @ GOSNELL FSR BRIDGE	Shea Creek	54.23864	127.51854	Wetsuweten Hereditary Chiefs	10	2008-07-22	2008-11-11
E272564	MORICE LAKE 4 (CLIFF CREEK CONFLUENCE)	Morice Lake	53.997083	127.642931	Wetsuweten Hereditary Chiefs	4	2008-09-04	2008-10-29
E272565	NEW MOON CREEK	Morice Lake	53.995875	127.644744	Wetsuweten Hereditary Chiefs	4	2008-09-04	2008-10-29
E272567	DELTA CREEK @ MORICE LAKE	Morice Lake	53.835692	127.834461	Wetsuweten Hereditary Chiefs	6	2008-09-04	2008-10-29
E272568	CABIN CREEK @ MORICE LAKE	Morice Lake	53.840419	127.804436	Wetsuweten Hereditary Chiefs	4	2008-09-04	2008-10-29
E273264	STEPP LAKE	Nanika River E	53.9574	127.326	Wetsuweten Hereditary Chiefs	2	2008-09-04	2008-09-15
E273266	ATNA BAY	Atna River	54.0259	127.8015	Wetsuweten Hereditary Chiefs	2	2008-09-04	2008-09-15
E273267	ATNA RIVER	Atna River	54.0217	127.8249	Wetsuweten Hereditary Chiefs	5	2008-09-04	2008-10-29
E290235	SILVER QUEEN - WRINCH CREEK BELOW MORICE OWEN FSR CULVERT	Owen Lake	54.0806	126.736816	Bulkley Valley Research Centre, Skeena	30	2012-06-25	2015-10-19
E292089	FLOODPLAIN	Floodplain	54.190008	127.23334	Bulkley Valley Research Centre, Skeena	30	2013-01-22	2015-10-20
E292091	PIMPERNELL MT	Fenton Creek	54.19479	127.016234	Bulkley Valley Research Centre, Skeena	25	2013-03-21	2015-10-20
E292092	CEDRIC CREEK	Floodplain	54.186311	127.190185	Bulkley Valley Research Centre, Skeena	27	2013-01-22	2015-10-20

Table C.1: continued

EMS ID	Site Name	AU	Latitude	Longitude	Sampling Agency	n samples	Start date	End date
E292589	OWEN WETLAND	Lower Morice	54.207728	126.853858	Bulkley Valley Research Centre, Skeena	30	2013-02-19	2015-10-19
E292592	LOWER MORICE	Lower Morice	54.242816	126.851392	Bulkley Valley Research Centre, Skeena	27	2013-02-19	2015-10-19

Table C.2: Proposed sites for watershed monitoring in the greater Morice River watershed.

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
E256980	Operational planning 2009	46	Stream	Lamprey Creek upstream of Morice River Rd Bridge	I	Road	Forestry	Medium	Fishing, camping	Fishing	M
E272549	Operational planning 2009	1	Stream	Morice River 66km Bridge	R, I		Harvest, exploration				H
E272551	Operational planning 2009	3	Stream	Gosnell upstream Thautil FSR Bridge	R, I		Road	Low-medium	Fish spawning and rearing	Hunting, camping, trails	H
E272553	Operational planning 2009	7a	Stream	Joshua Creek upstream Joshua Bridge	R		Erodable soils, old and new forest harvesting	Low, wetlands at head	Fish spawning and rearing	Hunting, camping, trails	H
E272554	Operational planning 2009	8a	Stream	Crystal Creek upstream bridge	R		Harvest, stability fans	Medium, glacial	Fish spawning and rearing	Hunting, homeplace	H
E272555	Operational planning 2009	8b	Stream	Gosnell Tributary South	R	Road	Harvest, stability fans	Medium, glacial	Fish spawning and rearing	Hunting, trails	M-H
E272556	Operational planning 2009	13	Stream	Cutthroat Creek Upstream FSR bridge	R	Road	Mining, potential harvest	Low, lake at head	Fish spawning and rearing	Trails, hunting	H
E272557	Operational planning 2009	9	Stream	Nanika River above Cutthroat FSR bridge	I	Road	Mining, forestry, pesticides, roads	Low-medium	Fish spawning and rearing	Fishing camps, trails, homeplace, fish production, hunting	H
E272563	Operational planning 2009	18	Stream	Shea Creek upstream Gosnell FSR bridge	R	Road, Snowmobile	Erodable soils, old and new forest harvesting	Low, lake at head	Fish spawning and rearing	Hunting, camping, trails	H
E272564	Operational planning 2009	29	Lake	Morice Lake at Cliff Creek	R	Boat	Park	Low, lake site	Fish spawning and rearing	Fishing, trails, gravesites, village sites	NA
E272565	Operational planning 2009	21	Stream	New Moon Creek	I	Boat	Mining	Medium-High	Fish spawning and rearing	Graveyard	H
E272567	Operational planning 2009	44	Stream	Delta Creek	R	Boat, Helicopter	Park	Low	Fish spawning and rearing	Potential moose hunting	L-M

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
E272568	Operational planning 2009	45	Stream	Cabin Creek	R	Boat, Helicopter	Park	Low	Fish spawning and rearing	Potential moose hunting	L-M
E273263	Operational planning 2009	37	Lake	Kidprice Lake (deep location)	R	Plane/ Boat	Park	Low, lake site	Canoeing, some fishing	Trails, hunting, fishing	NA
E273265	Operational planning 2009	35	Lake	Anzac	R	Plane/ Boat	Park	Low, lake site	Canoeing, some fishing	Trails, hunting, fishing	NA
E273266	Operational planning 2009	24	Lake	Atna Lake (to be determined)	R	Plane	Park	Low, lake site	Fish spawning and rearing, hunting, wildlife	Trails	L-M
E273267	Operational planning 2009	22	Stream	Atna River	R	Helicopter	Mining, potential	Low-medium	Fish spawning and rearing	Trails, hunting	M
1131112	Operational planning 2009	27	Lake	Morice Lake-east of Atna Bay	R	Boat	Park	Low, lake site	Fish spawning and rearing, fishing and boating	Fishing, trails, gravesites, village sites	NA
	Operational planning 2009	2	Stream	Upper Morice-Chinook Island	R, I						H
	Operational planning 2009	7b	Stream	Upper Gosnell from Joshua FSR	R, I	Road, Snowmobile	Erodable soils, potential pipeline, old and new forest harvesting, stability fans	Low, wetlands at head	Fish spawning and rearing	Hunting, camping, trails	H
	Operational planning 2009	10	Stream	Nanika River above Cutthroat Creek Confluence	R, I/Future	Road	Forestry	Low-medium	Fish spawning and rearing	Fishing camps, trails, homeplace, fish production, hunting	VH
	Operational planning 2009	19	Stream	Thautil River upstream Gosnell confluence	R, I/Future	Road	Harvest, pipeline	High, glacial	Fish spawning and rearing	Fishing, trails, village sites	H
	Operational planning 2009	20	Stream	Upper Thautil	R, I	Road	Old harvest	High, glacial	Fish spawning and rearing	NA	H
	Operational planning 2009	31	Lake	McBride Lake-west	I	Boat	Mining, tailings pond	Low, lake site	Fish spawning and rearing	Village sites, camping, hunting	H
	Operational planning 2009	32	Lake	McBride Lake-middle (deep station)	I	Boat	Mining, tailings pond	Low, lake site	Fish spawning and rearing	Village sites, camping, hunting	H
	Operational planning 2009	33	Lake	McBride Lake-east	I	Boat	Mining, tailings pond	Low, lake site	Fish spawning and rearing	Village sites, camping, hunting	H
	Operational planning 2009	15	Stream	Bergland Creek (site to be chosen)	I	Helicopter	Mining	High, snow melt	Fish, park	Trails, hunting	M

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	Operational planning 2009	26	Lake	Morice Lake at Nanika River	R	Boat	Park	Low, lake site	Fish spawning and rearing, fishing and boating	Fishing, trails, gravesites, village sites	M
	Operational planning 2009	28	Lake	Morice Lake-south	R	Boat	Park	Low, lake site	Fish spawning and rearing, fishing and boating	Fishing, trails, gravesites, village sites	M
	Operational planning 2009	30	Lake	Morice Lake-north end	R	Boat	Park	Low, lake site	Fish spawning and rearing, fishing and boating	Fishing, trails, gravesites, village sites	M
	Operational planning 2009	12	Stream	Objective Creek (site to be chosen)	I	Road	Forestry, potential mining	NA	Fish spawning and rearing	Trails, structures	L-M
	Operational planning 2009	14	Stream	Glacier Creek (site to be chosen)	R	Helicopter, boat	Currently none, long-term mining	NA	Bulltrout spawning	Limited	L-M
	Operational planning 2009	17	Stream	Kidprice Creek (site to be chosen)	R	Helicopter	Mining, park	NA	Bulltrout, cutthroat, park, canoeing	Limited- trails	L-M
	Operational planning 2009	23	Lake	Atna Lake (deep station)	R	Plane	Park	Low, lake site	Fish spawning and rearing, hunting, wildlife	Trails	L-M
	Operational planning 2009	25	Lake	Morice Lake-Atna Bay	R	Boat	Park	Low, lake site	Fish spawning and rearing, fishing and boating	Fishing, trails, gravesites, village sites	L-M
	Operational planning 2009	36	Lake	Stepp Lake (deep station)	R	Plane/ Boat	Park	Low, lake site	Resident spawning, some fishing, canoeing	Trails, hunting, fishing	L-M
	Operational planning 2009	38	Lake	Nanika Lake-near Fenton Creek	I	Plane/ Boat	Park	Low, lake site	Some rec value	Trails, gravesites	L-M
	Operational planning 2009	41	Lake	Nanika Lake-south end (deep station?)	R	Plane/ Boat	Park	Low, lake site	Some rec value	Trails, gravesites	L-M
	Operational planning 2009	39	Lake	Nanika Lake-north end (near outlet)	R	Plane/ Boat	Park	Low, lake site	Some rec value	Trails, gravesites	L-M
	Operational planning 2009	47	Lake	Julian Holland Lake	I	Road/Boat	Logging	Low, lake site	Fishing	Trails, hunting, fishing	L-M
	Operational planning 2009	11	Stream	Nanika River 6 km downstream from waterfall	R	NA	Forestry	NA	Fish spawning and rearing	Fishing camps, trails, homeplace, fish production, hunting	L
	Operational planning 2009	34	Lake	McBride Lake inlet-east end	R, I/Future	Road	Park	NA	Fish spawning and rearing	Trails, gravesites	L
	Operational planning 2009	42	Lake	Burnie Lake North	R	Plane	Park	Low, lake site	Recreation, tourism, park, resident fish	Trails	L

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	Operational planning 2009	43	Lake	Burnie Lake South	R	Plane	Park	Low, lake site	Fishing	Trails	L
	LRMP 2007	1	Other	Tahlo Watershed	NA	NA	Upstream influences on downstream spawning areas; temperature	NA	Non-enhanced sockeye run	NA	NA
	LRMP 2007	2	Other	Booker Mine	NA	NA	Acid drainage, heavy metals - downstream impacts	NA	NA	NA	NA
	LRMP 2007	3	Stream	Morrison Main Stem	NA	NA	Temperature	NA	Spawning and rearing habitat; non-enhanced sockeye; coho; pink	NA	NA
	LRMP 2007	4	Stream	Hautete Creek	NA	NA	Temperature	NA	Rainbow trout; char; kokanee	NA	NA
	LRMP 2007	5	Stream	9-Mile/Wilkinson Creek	NA	NA		NA	Babine Lake rainbow trout spawning	NA	NA
	LRMP 2007	6	Stream	Tachet Creek	NA	NA	Temperature	NA	Spawning - sockeye; coho	NA	NA
	LRMP 2007	7	Stream	Sockeye Creek	NA	NA		NA	Sockeye; coho; rainbow trout	NA	NA
	LRMP 2007	8	Stream	Upper Bulkley, upstream of Buck Creek	NA	NA	Needs a full monitoring strategy developed throughout	NA	NA	NA	NA
	LRMP 2007	9	Stream	Upper Bulkley-Morice confluence	NA	NA		NA	NA	NA	NA
	LRMP 2007	10	Stream	Buck Creek	NA	NA		NA	Drinking water; steelhead; largest triburary and fish producer for Upper Bulkley	NA	NA
	LRMP 2007	11	Stream	Goosly outlet/Klo Creek	NA	NA	Mine influences	NA	NA	NA	NA
	LRMP 2007	12	Stream	Mouth of Morice River	NA	NA	Needs a full monitoring strategy developed	NA	Coho; sockeye; pink; Chinook; steelhead; resident fish	NA	NA
	LRMP 2007	13	Stream	Mouth of Houston/Tommy	NA	NA	Sediment due to terrain stability issues	NA	Spawning - coho	NA	NA
	LRMP 2007	14	Stream	Owen Creek	NA	NA	Temperature; beaver dams	NA	Coho; steelhead; resident fish	NA	NA

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	LRMP 2007	15	Stream	Lamprey Creek	NA	NA	Temperature	NA	Coho; steelhead; resident fish	NA	NA
	LRMP 2007	16	Stream	Mouth of Thautil	NA	NA	Erosion in excess of natural; temperature (bull trout)	NA	Coho; steelhead; bull trout (natural bedload and erosion)	NA	NA
	LRMP 2007	17	Stream	Denys Creek	NA	NA	Terrain stability	NA	Bedload	NA	NA
	LRMP 2007	18	Stream	Starr Creek	NA	NA	Terrain stability	NA	Bedload; bull trout	NA	NA
	LRMP 2007	19	Stream	Mouth of Gosnell	NA	NA	Hydrologic regimes/flow; temperature	NA	Wetlands; steelhead; coho; bull trout; (pinks?)	NA	NA
	LRMP 2007	20	Stream	Confluence of Shea and Gosnell	NA	NA	Temperature; terrain stability	NA	Steelhead; bull trout; coho	NA	NA
	LRMP 2007	21	Stream	Major confluence downstream of Shea Lake	NA	NA	Temperature; terrain stability	NA	Steelhead; bull trout; coho	NA	NA
	LRMP 2007	22	Stream	McBride	NA	NA	Temperature	NA	Coho	NA	NA
	LRMP 2007	23	Stream	Nanika River	NA	NA		NA	Spawning - sockeye; steelhead; bull trout	NA	NA
	LRMP 2007	24	Stream	Above Red Slide confluence on Nanika River	NA	NA	Terrain stability	NA	Sockeye	NA	NA
	LRMP 2007	25	Stream	Atna Creek	NA	NA	Important benchmark site	NA	Coho; wetlands	NA	NA
	LRMP 2007	26	Stream	Nadina/Peter Aleck Creek	NA	NA	Temperature (refer to LRUP)	NA	Spawning - late run sockeye; Chinook; rainbow trout; bull trout	NA	NA
	MWMA Proposed 2014	GC-5	Stream	Gosnell Creek (Morice W Bridge)							
	MWMA Proposed 2014	MC-3	Stream	Nanika River (Cutthroat Bridge)							
	MWMA Proposed 2014	GC-3		Joshua Creek							
	MWMA Proposed 2014	CC-1	Stream	Crystal Creek							
	MWMA Proposed 2014	GC-1	Stream	Gosnell Tributary South							

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	MWMA Proposed 2014	MC-1	Stream	Cutthroat Creek (U/S Cutthroat Bridge)							
	MWMA Proposed 2014	SC-1	Stream	Shea Creek (Gosnell FSR Bridge)							
	MWMA Proposed 2014	ML-7	Lake	Morice Lake 7							
	MWMA Proposed 2014	ML-6	Stream	New Moon Creek							
	MWMA Proposed 2014	AR-1	Stream	Atna River							
	MWMA Proposed 2014	AR-2	Lake	Atna Bay							
	MWMA Proposed 2014	NE-4	Lake	Anzak							
	MWMA Proposed 2014	NE-1	Lake	Kidprice Lake							
	MWMA Proposed 2014	ML-1	Stream	Delta Creek							
	MWMA Proposed 2014	ML-2	Stream	Cabin Creek							
	MWMA Proposed 2014	BR-3	Lake	Burnie Lake North							
	MWMA Proposed 2014	BR-2	Lake	Burnie Lake South							
	MWMA Proposed 2014	GC-2	Lake	Julian Holland Lake							
	MWMA Proposed 2014	GC-4	Stream	Upper Gosnell (Joshua FSR)							

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	MWMA Proposed 2014	UM-1	Stream	Chinook Island							

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	MWMA Proposed 2014	ML-9	Stream	Morice Lake 9							
	MWMA Proposed 2014	MC-9	Stream	Morice Lake at Nanika River							
	MWMA Proposed 2014	ML-8	Stream	Atna Bay							
	MWMA Proposed 2014	ML-3	Lake	Morice Lake - South							
	MWMA Proposed 2014	NR-1	Lake	Nanika Lake - South End							
	MWMA Proposed 2014	NR-2	Stream	Nanika Lake							
	MWMA Proposed 2014	NR-3	Stream	Bergland Creek							
	MWMA Proposed 2014	NE-2	Stream	Nanika River (6 km downstream from waterfall)							
	MWMA Proposed 2014	MC-2	Stream	Nanika River above Cutthroat Creek							
	MWMA Proposed 2014	NE-3	Lake	Stepp Lake							
	MWMA Proposed 2014	MC-4	Stream	McBride Lake-west							
	MWMA Proposed 2014	MC-8	Lake	McBride Lake Centre							
	MWMA Proposed 2014	MC-6	Stream	McBride Lake-east							
	MWMA Proposed 2014	MC-7	Stream	McBride Lake Inlet							

	MWMA Proposed 2014	TR-1	Stream	Thautil River (u/s Gosnell confluence)							

Table C.2: continued

EMSID	Source	Site	Site Type	Site Name	Ref/ Impact	Access	Land use risks	Flow variability	Ecosystem/ Recreational values	Cultural values	Priority
	MWMA Proposed 2014	TR-2	Stream	Upper Thautil							
	MWMA Proposed 2014	BR-1	Stream	Burnie River							
	MWMA Proposed 2014	UC-1	Stream	Clore River							
	MWMA Proposed 2014	ML-5	Stream	Morice Lake 5							
	MWMA Proposed 2014	ML-4	Stream	Morice Lake 4							
	MWMA Proposed 2014	ML-10	Lake	Morice Lake North							
	MWMA Proposed 2014	MC-5	Stream	McBride Lake - South							

Table C.3: Canadian Aquatic Biomonitoring (CABIN) sites in the Morice River watershed. Additional information can be accessed on the CABIN Network database, https://www.canada.ca/en/environment-climate-change/services/canadian-aquatic-biomonitoring-network/database.html

Study Name	Site Code	ENVIRODAT ID	Site Name	Stream Order	Latitude	Longitude
BC MOE-FSP Skeena Region	MOR06	E256939	Sibola Main R	2	53.82975	-127.08884
BC MOE-FSP Skeena Region	MOR07	E256940	Glacier Main @18	1	53.93111	-127.18694
BC MOE-FSP Skeena Region	MOR08	E256941	Glacier Main @17	2	53.926941	-127.17555
BC MOE-FSP Skeena Region	MOR12	E256978	Nadina R	5	54.013054	-126.64944
BC MOE-FSP Skeena Region	MOR39	E228745	Shea Ck U/S	6	54.2419444	-127.51611
BC MOE-FSP Skeena Region	MOR40	E256936	Llojuh Ck	4	54.378887	-127.2575
BC MOE-FSP Skeena Region	MOR41	E256937	Deny's Ck	5	54.37	-127.28583
BC MOE-FSP Skeena Region	MOR42	E256938	Raina Ck	4	54.3691667	-127.28833
BC MOE-FSP Skeena Region	MOR45	E256980	Lamprey Ck	5	54.184723	-127.08528
BC MOE-FSP Skeena Region	MOR49	NA	Owen Ck Upper	3	54.141525	-126.79258
BC MOE-FSP Skeena Region	MOR50	E256979	Owen Ck Lower	3	54.201111	-126.85833
BC MOE-FSP Skeena Region	MOR57	NA	Unnamed R2	NA	53.946136	-126.81048
BC MOE-FSP Skeena Region	MOR58	E260496	McBride Creek	4	54.0975	-127.45278
BC-Wetsuweten ESI	MOR61	E260428	Redslide Creek	3	53.9691667	-127.49222
BC MOE-FSP Skeena Region	MOR62	E260427	Crystal Creek	4	54.1997222	-127.44944
BC MOE-FSP Skeena Region	MOR63	E260429	Nado Creek	2	54.1297222	-127.32333

Table C.3: continued

Study Name	Site Code	ENVIRODAT ID	Site Name	Stream Order	Latitude	Longitude
BC MOE-FSP Skeena Region	MOR64	E260580	Peter Aleck Creek	2	54.049721	-126.72361
BC MOE-FSP Skeena Region	MOR66	E260566	Berg Far Field	3	53.8011111	-127.45194
BC MOE-FSP Skeena Region	MOR67	E260493	Gosnell Creek @ Bridge	5	54.1083333	-127.68806
BC MOE-FSP Skeena Region	MOR68	E260565	Kidprice Trib.	5	53.8911111	-127.40333
BC MOE-FSP Skeena Region	MOR70	E260495	Pimpernell Creek	4	54.110832	-127.12695
BC MOE-FSP Skeena Region	MOR71	E260422	Shelford Creek	3	53.865555	-126.82806
BC MOE-FSP Skeena Region	MOR73	E260494	Unnamed @24k Crystal	3	54.1322222	-127.65639
BC MOE-FSP Skeena Region	MOR75	E260582	Haymeadow Creek	3	53.989723	-126.78055
BC MOE-FSP Skeena Region	MOR76	E260581	Gate Creek	3	54.004166	-126.65862
BC MOE-FSP Skeena Region	MOR82	NA	Shelford Hills North	3	53.888611	-126.78333
BC MOE-FSP Skeena Region	MOR83	NA	Shelford Hills S. Trib	2	53.888332	-126.78361

Appendix D: Northwest Water Tool Report

The following pages contain information downloaded from the Northwest Water Tool for catchments draining to sites included in the Morice Water Management Trust water monitoring program from 2015-2017. This information was downloaded from http://www.bcwatertool.ca/nwwt/ on December 8, 2018. Sites are included in the following order:

1. Cutthroat Creek ("unnamed basin") E272556
2. McBride Creek E260496
3. Morice River E272549
4. Nado Creek E260429
5. Nanika River E272557

Please note that while the NWWT is effective at rapid documentation of general watershed characteristics and summarizing surface water allocations, it is not without limitations and caveats. The NWWT uses mean monthly flows as an indicator of flow sensitivity and so lacks resolution for capturing sub-monthly variability and the reality of annual low flow timing. As a result, the NWWT may misrepresent stream flow sensitivity. In addition, data may be less reliable for smaller catchments and potentially result in erroneous information. The NWWT also lacks information on groundwater wells or groundwater hydrologic connectivity and therefore likely misrepresents the importance of groundwater in catchments.

Northwest Water Tool Report

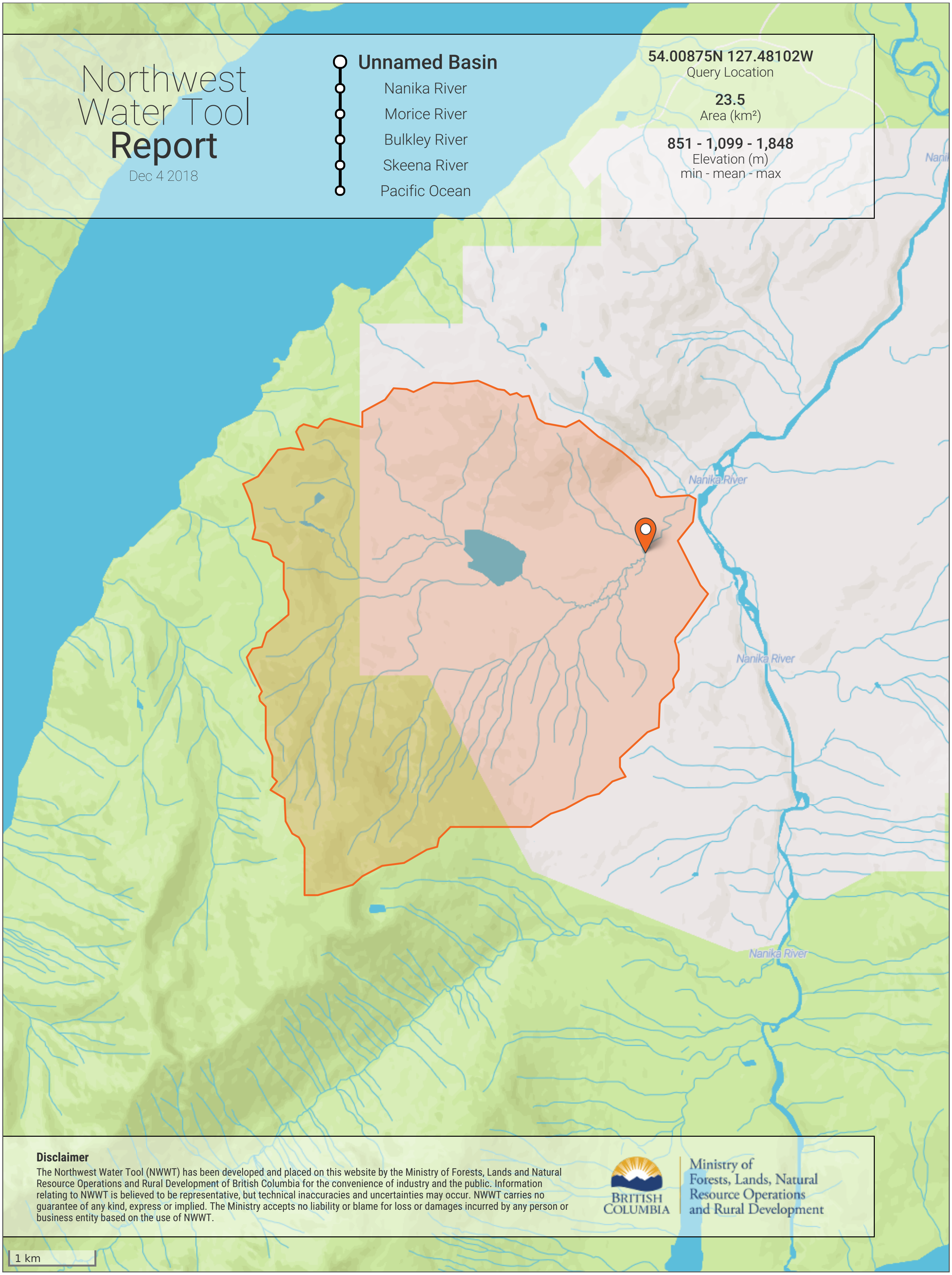
Dec 4 2018

Unnamed Basin
- Nanika River
- Morice River
- Bulkley River
- Skeena River
- Pacific Ocean

54.00875N 127.48102W
Query Location

23.5
Area (km²)

851 - 1,099 - 1,848
Elevation (m)
min - mean - max



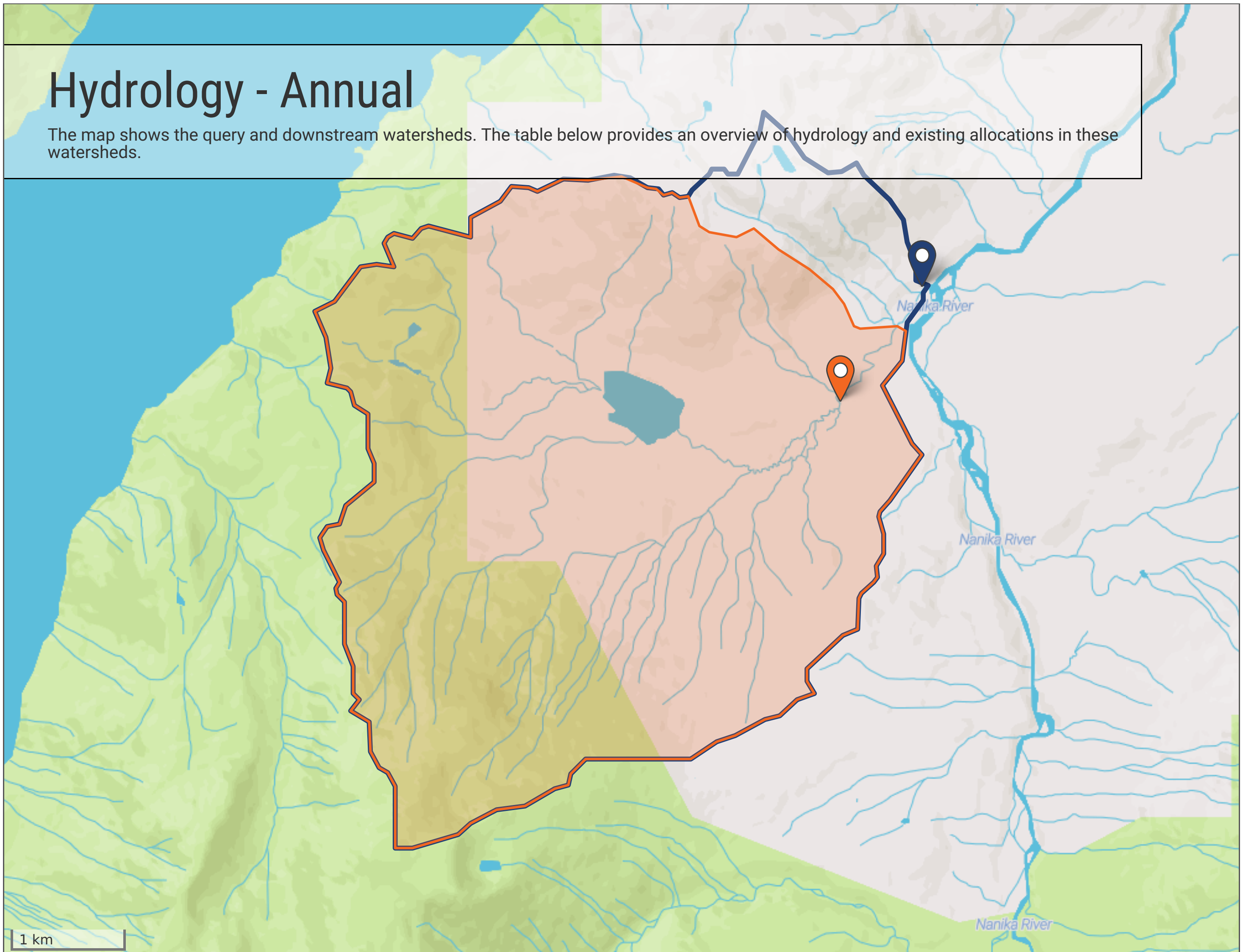
Disclaimer

The Northwest Water Tool (NWWT) has been developed and placed on this website by the Ministry of Forests, Lands and Natural Resource Operations and Rural Development of British Columbia for the convenience of industry and the public. Information relating to NWWT is believed to be representative, but technical inaccuracies and uncertainties may occur. NWWT carries no guarantee of any kind, express or implied. The Ministry accepts no liability or blame for loss or damages incurred by any person or business entity based on the use of NWWT.

BRITISH COLUMBIA
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

Hydrology - Annual

The map shows the query and downstream watersheds. The table below provides an overview of hydrology and existing allocations in these watersheds.



Query Watershed		Downstream Watershed
23.5	Area (km²)	25.5
0.292	Mean Annual Discharge (m³/s)	0.311
0.000	Allocations (m³/s)	0.000
0.0	Allocations (%)	0.0
Present*	Reserves & Restrictions	**Present***
9,205,740	Volume Runoff (m³/yr)	9,828,034
0	Volume Allocations (m³/yr)	0
Winter	Seasonal Flow Sensitivity**	**Winter**

The downstream watershed is defined at the location where the queried drainage meets with another drainage of comparable size. For information further downstream, please generate an additional report at a location of interest. Predictions for small watersheds (generally smaller than 50 sq. km.) may be less accurate due to the lack of hydrometric data available for watersheds of this size.

* For more information on water reserves or restrictions present in the watershed, please visit the links below or contact FrontCounter BC.

FrontCounter BC: www.frontcounterbc.ca **Email:** FrontCounterBC@gov.bc.ca **Toll Free:** 1-877-855-3222 **Outside North America:** ++1-778-372-0729
Water Reservations: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-reservations
Water Restrictions: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-allocation-restrictions

**Ptolemy, R. Environmental Flow Protection in British Columbia. Presentation to 2015 IFC Panel, April 29, 2015.

Hydrology - Monthly Unnamed Basin

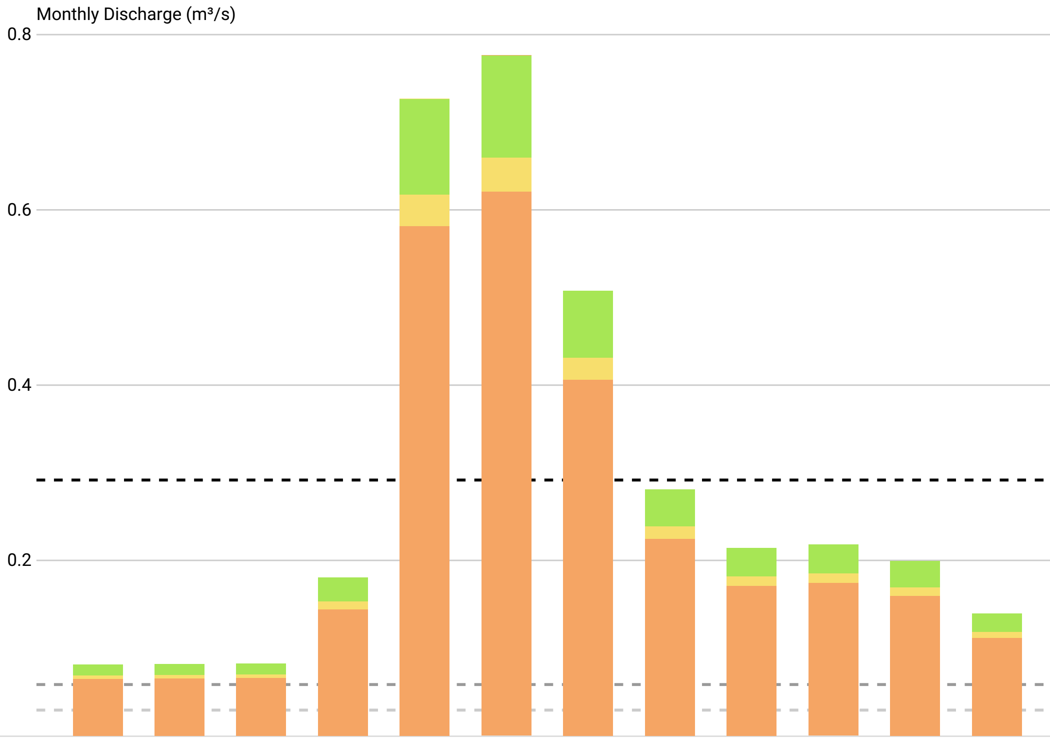
The chart and table show information on modeled hydrology and existing allocations in the query watershed. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy.*

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	0.292 m³/s
20% MAD	0.058 m³/s
10% MAD	0.029 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	0.081	0.082	0.083	0.180	0.727	0.776	0.508	0.281	0.214	0.218	0.199	0.140
% of MAD	27.7%	28.1%	28.3%	61.8%	249.1%	266.1%	174.0%	96.4%	73.3%	74.8%	68.3%	47.9%
Flow Sensitivity	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	0.012	0.012	0.012	0.027	0.109	0.116	0.076	0.042	0.032	0.033	0.030	0.021
Potential Allocation (m³/s, Risk Mgmt 2)	0.016	0.016	0.017	0.036	0.145	0.155	0.102	0.056	0.043	0.044	0.040	0.028
Potential Allocation (m³/s, Risk Mgmt 3)	>0.016	>0.016	>0.017	>0.036	>0.145	>0.155	>0.102	>0.056	>0.043	>0.044	>0.040	>0.028

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Hydrology - Monthly

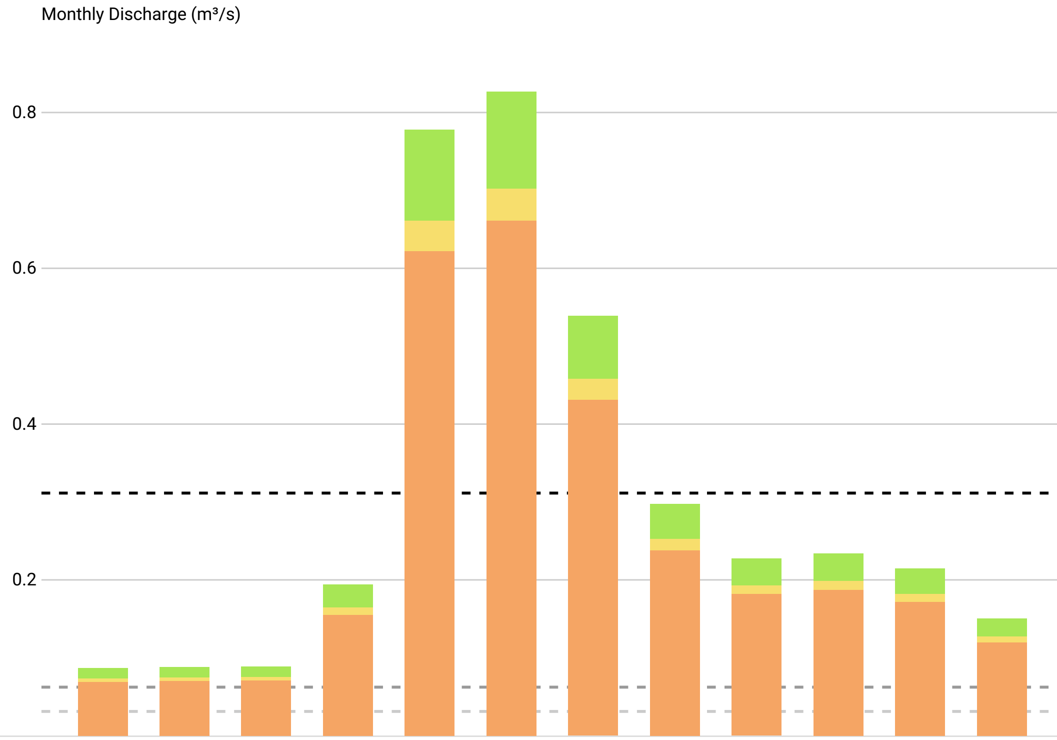
The chart and table show information on modeled hydrology and existing allocations in the downstream watershed, where the subject drainage meets with another drainage of comparable size. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy*.

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	0.311 m³/s
20% MAD	0.062 m³/s
10% MAD	0.031 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	0.087	0.088	0.089	0.194	0.778	0.827	0.539	0.297	0.227	0.234	0.215	0.150
% of MAD	27.9%	28.3%	28.5%	62.3%	249.8%	265.5%	173.0%	95.4%	73.0%	75.1%	68.9%	48.2%
Flow Sensitivity	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	0.013	0.013	0.013	0.029	0.117	0.124	0.081	0.045	0.034	0.035	0.032	0.023
Potential Allocation (m³/s, Risk Mgmt 2)	0.017	0.018	0.018	0.039	0.156	0.165	0.108	0.059	0.045	0.047	0.043	0.030
Potential Allocation (m³/s, Risk Mgmt 3)	>0.017	>0.018	>0.018	>0.039	>0.156	>0.165	>0.108	>0.059	>0.045	>0.047	>0.043	>0.030

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Risk Management Levels and Measures

Guide to interpreting potential allocation amounts in each environmental flow needs risk level as defined in the Province of BC *Environmental Flow Needs Policy.*

Water volumes presented as "Potential Allocations" within this report are determined in consideration of the Province of BC *Environmental Flow Needs Policy*. Within the Policy, risk management measures are suggested to assess or mitigate potential effects of withdrawals from a stream, and provide an ecosystem perspective on environmental flow needs. The measures are associated with risk levels 1, 2, and 3 and are intended to guide where more caution may be needed in reviewing an application or making a decision.

Where there are known species or habitat sensitivities, more detailed, site-specific studies may be required. Where detailed assessments or studies exist, they will supersede policy recommendations.

Risk management levels, for assessing new applications to withdraw water, are determined for each month using the relationship of mean monthly flows to the mean annual discharge, and also using a stream size threshold based on mean annual flows. The calculations presented within this report assume all streams are fish-bearing. Where no water is indicated as available under a risk level, the stream may be very flow sensitive during that time, or the stream may have existing allocations in excess of the relevant threshold.

Inter-annual hydrologic variability may affect the amount of water available in a given year. The impact of this variability on water allocations should be considered separately from the information presented in this report.

The following risk management measures may be appropriate for consideration before a decision is made, could be completed by regional staff to inform a decision, or could be a condition of the licence or approval.

Risk management measures may differ for short-term approvals vs. licences and may vary in relation to withdrawal amounts.

Risk Management Level: 1

Measures to assess or mitigate potential effects on low sensitivity flow periods:

1. Assess veracity of information and ensure appropriate methods are used, (e.g., RISC)
2. Consider downstream users and species/habitats

Risk Management Level: 2

Measures to assess or mitigate potential effects on moderate sensitivity flow periods:

In addition to Level 1 measures:

1. Establish adequate baseline hydrological data before withdrawals
2. Prepare reconnaissance-level fish and fish habitat impact assessment (e.g., Section 4.1.10.1 in Lewis et al. 2004)
3. Issue seasonal licence, or restrictions during low flow periods
4. Development of off-stream storage
5. Inclusion of a daily maximum or inst. withdrawal e.g., greater consideration of instantaneous demand over averages
6. Limit pump intake size
7. Monitor and report water use during higher risk flow periods, e.g., install flow gauge
8. Monitor low flows and limit withdrawals when flows drop below a certain level
9. Ministry staff to conduct audit of basin use/beneficial use review
10. Refuse application to withdraw water

Risk Management Level: 3

Measures to assess or mitigate potential effects on high sensitivity flow periods:

In addition to Level 2 measures:

1. Issue limited licence term, allowing for review and potential adjustment (e.g., 5 years)
2. Prepare detailed habitat assessment (e.g., Lewis et al. 2004; Hatfield et al. 2007)

References

Hatfield, T., A. Lewis, and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts. 2004. Assessment methods for aquatic habitat and instream flow characteristics in support of applications to dam, divert, or extract water from streams in British Columbia. Prepared for Ministry of Water, Land & Air Protection and Ministry of Sustainable Resource Management.

A. Lewis. 2002. Rationale for Multiple British Columbia Instream Flow Standards to Maintain Ecosystem Function and Biodiversity. Draft for Agency Review. Prepared for Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

Resources Information Standards Committee: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/inventory-standards

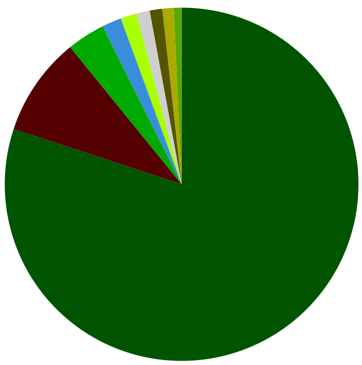
Water Policies, including Environmental Flow Needs: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies

Land Cover and Topography

Characteristics of the query watershed. For more information on watershed characterization in British Columbia please refer to Pike and Wilford (2013).

Land Cover

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

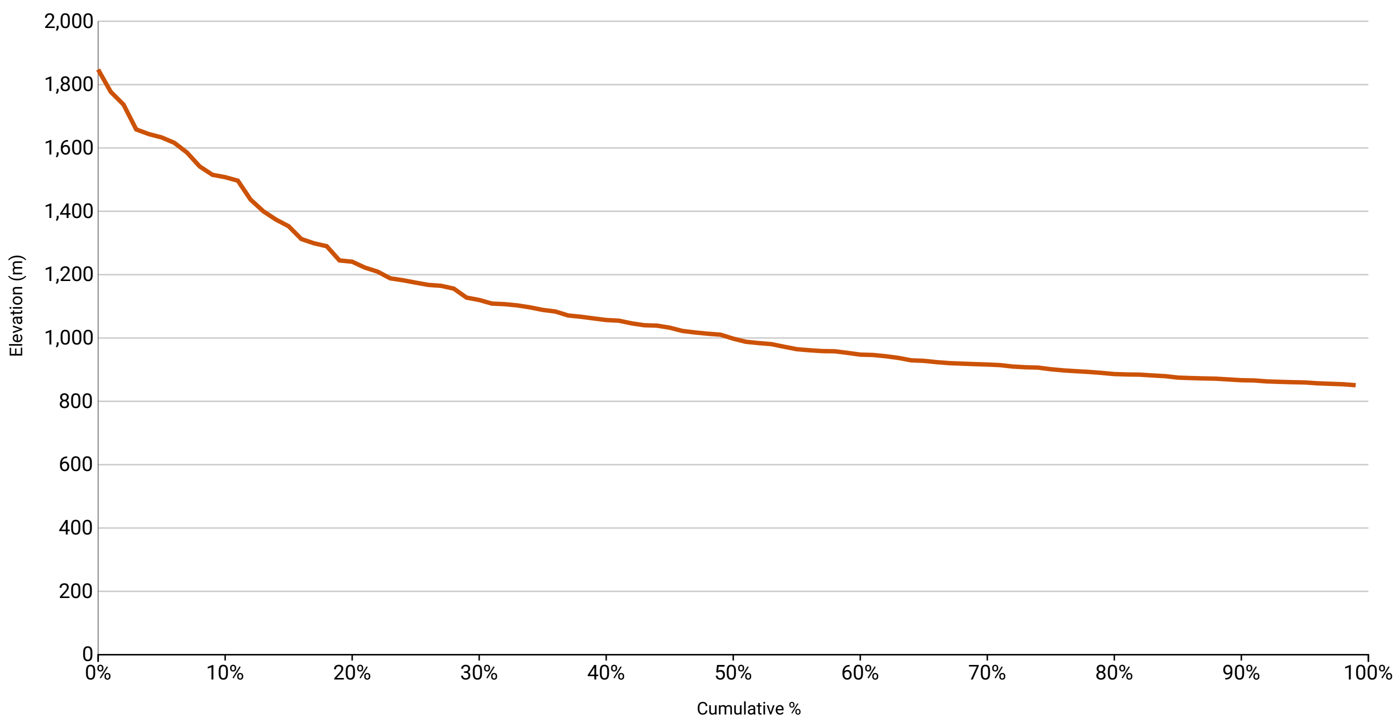


Type	Area (km²)	% of Query Watershed (%)
Barren	2.1	9.1
Coniferous	18.8	80.1
Deciduous	0.2	0.7
Developed	0.0	0.0
Grassland	0.0	0.0
Herb	0.8	3.5
Mixed	0.3	1.2
Shrub	0.3	1.5
Snow / Glacier	0.3	1.2
Water	0.4	1.8
Wetland	0.2	1.0

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

Topography

Elevation of the query watershed influences hydrology in a number of ways. The amount, and state of precipitation (as rain or snow) is influenced by elevation substantially. Likewise, temperatures will vary by elevation in value and also direction of temperature gradient throughout the course of the year.



The elevation characteristics of the query watershed are shown using a hypsometric curve, which shows the cumulative distribution of elevation by area in the watershed. Percent values can be used to identify the percentage of the watershed above a given elevation value.

Reference:
Pike, R.G. and D.J. Wilford. 2013. Desktop watershed characterization methods for British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 079. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr079.htm.

Climate

Historic normal conditions and predicted future change.

The climate of the query watershed has been characterized using ClimateWNA (Wang 2012). In the left hand column, charts are presented for the reference time period 1961-1990. In the right hand column, three illustrative climate change scenarios have been selected to estimate a wide range of potential future change in the query watershed (Murdock and Spittlehouse 2011).

Scenario A illustrates the UKMO HadGEM A1B run 1 global climate model (GCM), scenario B shows the CGCM3 A2 run 4 GCM and scenario C shows the UKMO HadCM3 B1 run 1 GCM. The combination of these three climate models and emissions scenarios were chosen because, over most of British Columbia, they provide a range of generally hot/dry, warm/very wet, and moderately warm/wet for HadGEM A1B, CGCM3 A2, and HadCM3 B1 respectively.

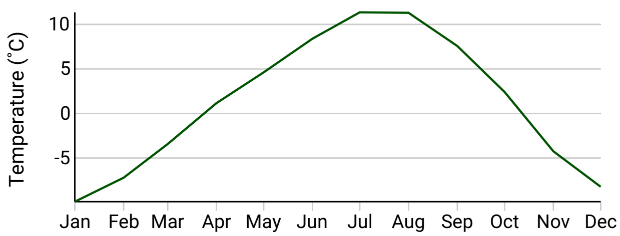
Historic and future climate change information has been provided to assist in understanding potential changes in the basin as temperature and precipitation are intricately related to stream flow. For example, snowpack levels affect many aspects of water resources, from instream flows for fish to community water supplies to soil moisture, groundwater, and aquifer recharge. Climate studies generally indicate a trend of rising air temperatures for all seasons across BC while precipitation trends vary by season and region (Pike *et al.* 2008, Rodenhuis *et al.* 2007). Local responses to changing precipitation and temperature will differ due to BC's inherent hydrological diversity as well as varying climate trends. These charts are intended as a quick glance starting point to basin climate change assessment.

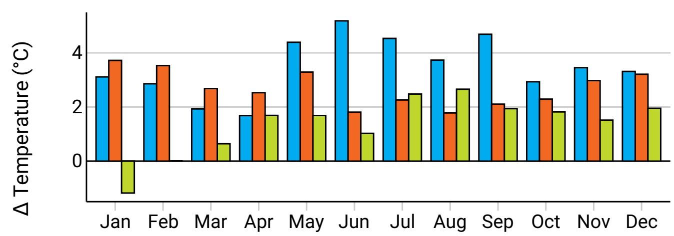
Normal (1961 - 1990)

Predicted Change (2041 - 2070)

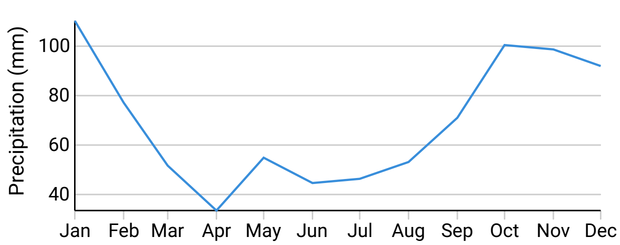
Scenario A Scenario B Scenario C

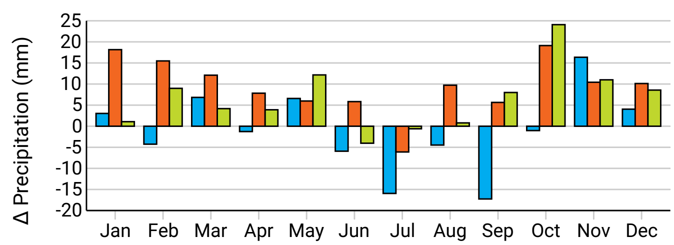
Monthly temperatures are presented as averages of the monthly mean temperature for the query basin as a whole. Projected changes in temperature may affect the hydrology in the watershed by influencing the time of freeze and thaw, evapotranspiration rates, form of precipitation, and vegetation composition, among other factors.



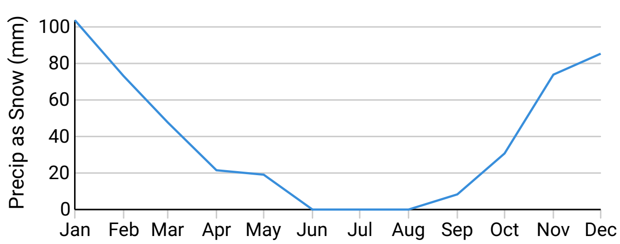


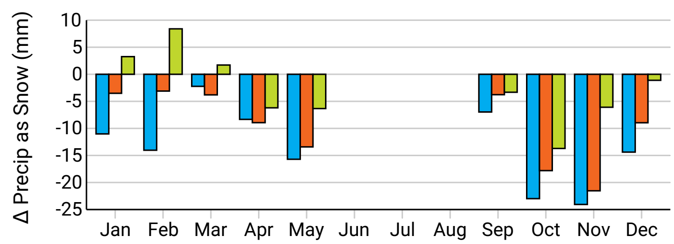
The precipitation in the query watershed is shown as an average unit precipitation for the watershed. Changes in precipitation timing and amount may affect the hydrology in the watershed by influencing the timing and magnitude of peak and low flow conditions. These changes may affect availability of water for environmental flow needs and human use, and modify the physical characteristics of river channels and associated needs for engineered structures.





Precipitation as snow in the query watershed is presented as an average unit precipitation for the query basin as a whole. Changes in the amount of precipitation as snow may affect winter snowpack volumes and associated melt related hydrology in the spring. An increase in rain-on-snow events may be associated with elevated natural hazard risk from avalanche or other slope stability failures.





References

Murdock, T.Q., Spittlehouse, D.L. 2011. Selecting and Using Climate Change Scenarios for British Columbia. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC. http://www.pacificclimate.org/sites/default/files/publications/Murdock.ScenariosGuidance.Dec2011.pdf

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate Change and Watershed Hydrology: Part I - Recent and Projected Changes in British Columbia. Streamline, Watershed Management Bulletin 11-2 8-13. http://www.pacificclimate.org/sites/default/files/publications/Pike.StreamlineHydrologyPartI.Apr2008.pdf

Rodenhuis, D., K.E. Bennett, A. Werner, T.Q. Murdock, and D. Bronaugh. 2007. Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium. http://www.pacificclimate.org/sites/default/files/publications/Rodenhuis.ClimateOverview.Mar2009.pdf

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.

Northwest Water Tool Report

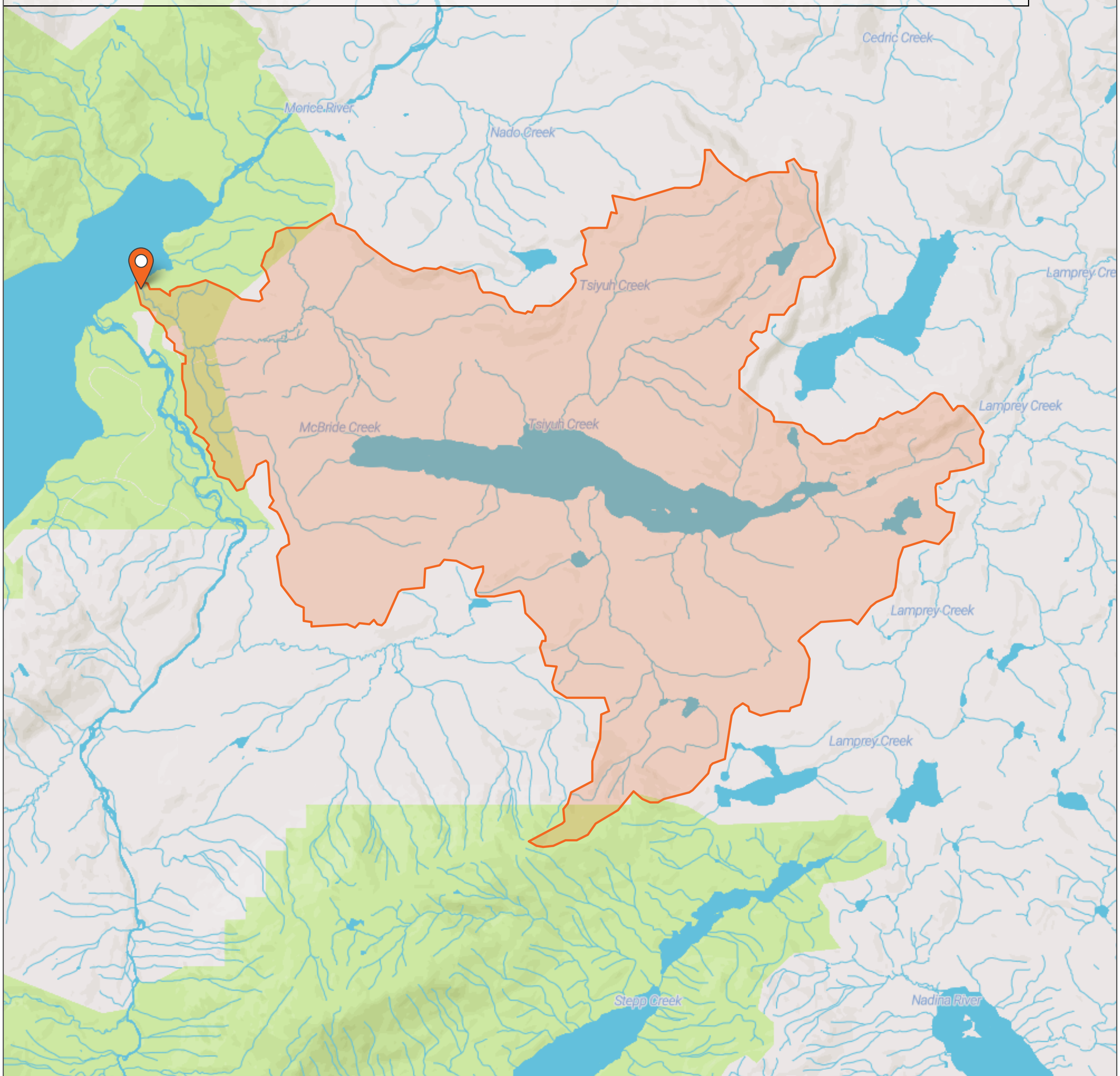
Dec 4 2018

McBride Creek
- Morice River
- Bulkley River
- Skeena River
- Pacific Ocean

54.09749N 127.45280W
Query Location

111.5
Area (km²)

778 - 884 - 1,418
Elevation (m)
min - mean - max

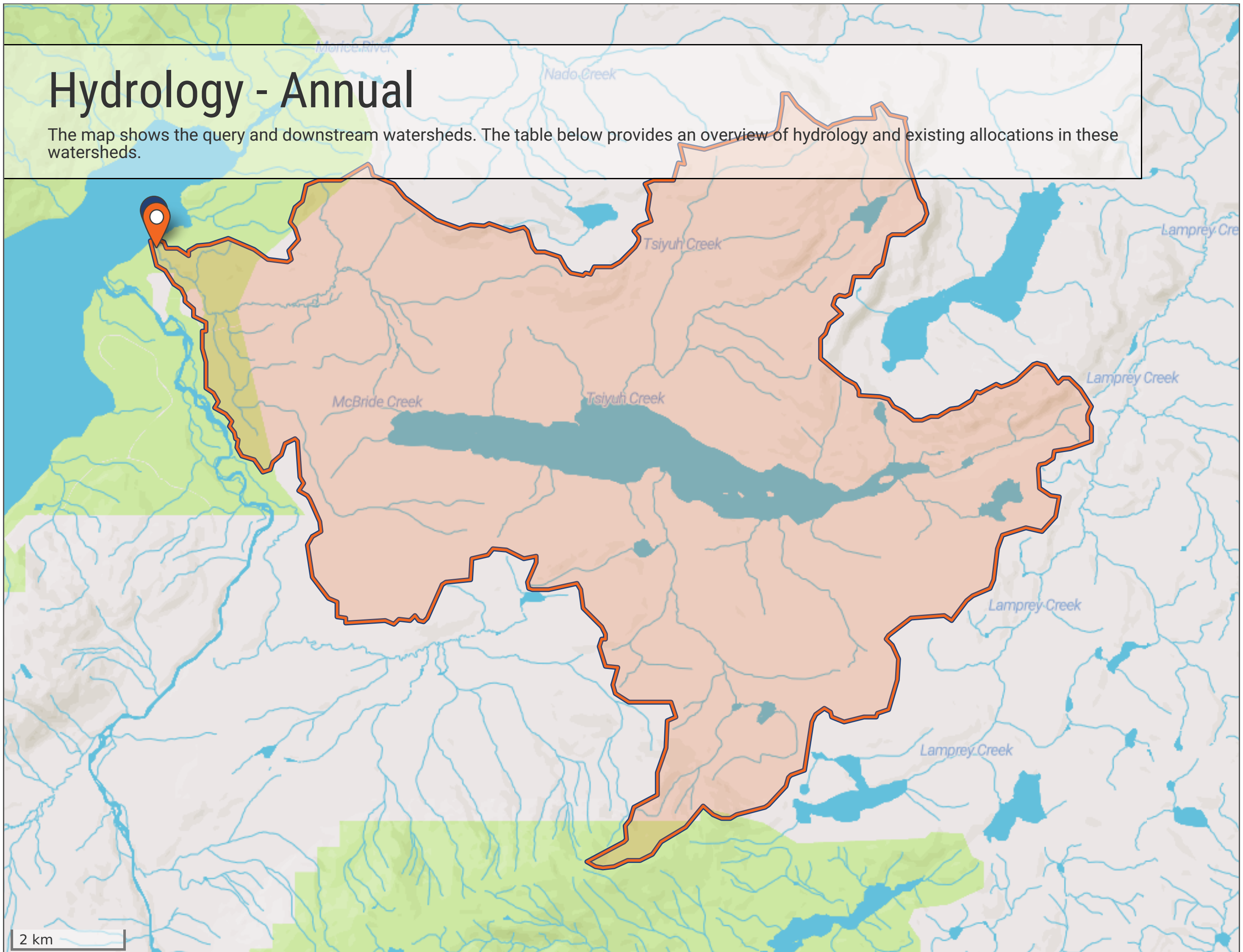


British Columbia
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

2 km

Hydrology - Annual

The map shows the query and downstream watersheds. The table below provides an overview of hydrology and existing allocations in these watersheds.



Query Watershed		Downstream Watershed
111.5	Area (km²)	111.5
0.539	Mean Annual Discharge (m³/s)	0.539
0.000	Allocations (m³/s)	0.000
0.0	Allocations (%)	0.0
Present*	Reserves & Restrictions	**Present***
17,017,783	Volume Runoff (m³/yr)	17,017,783
0	Volume Allocations (m³/yr)	0
Winter	Seasonal Flow Sensitivity**	**Winter**

The downstream watershed is defined at the location where the queried drainage meets with another drainage of comparable size. For information further downstream, please generate an additional report at a location of interest. Predictions for small watersheds (generally smaller than 50 sq. km.) may be less accurate due to the lack of hydrometric data available for watersheds of this size.

* For more information on water reserves or restrictions present in the watershed, please visit the links below or contact FrontCounter BC.

FrontCounter BC: www.frontcounterbc.ca **Email:** FrontCounterBC@gov.bc.ca **Toll Free:** 1-877-855-3222 **Outside North America:** ++1-778-372-0729

Water Reservations: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-reservations

Water Restrictions: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-allocation-restrictions

**Ptolemy, R. Environmental Flow Protection in British Columbia. Presentation to 2015 IFC Panel, April 29, 2015.

Hydrology - Monthly McBride Creek

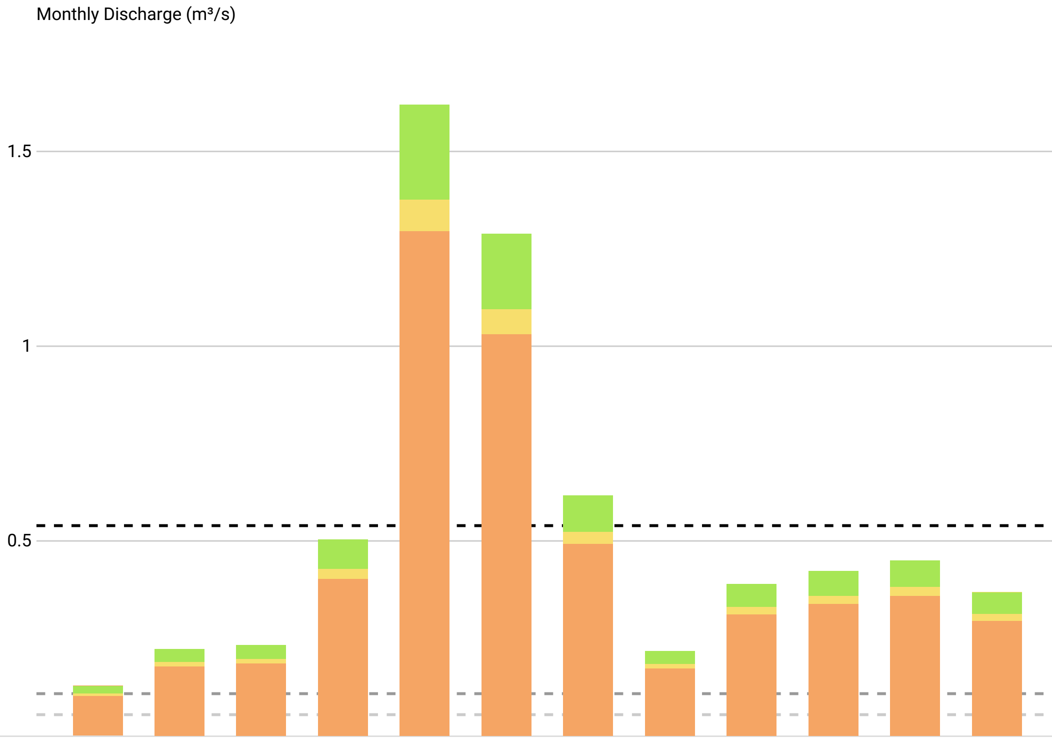
The chart and table show information on modeled hydrology and existing allocations in the query watershed. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy.*

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	0.539 m³/s
20% MAD	0.108 m³/s
10% MAD	0.054 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	0.128	0.222	0.232	0.504	1.619	1.289	0.617	0.217	0.390	0.423	0.449	0.368
% of MAD	23.8%	41.2%	43.0%	93.5%	300.3%	239.1%	114.4%	40.2%	72.2%	78.4%	83.3%	68.3%
Flow Sensitivity	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	0.019	0.033	0.035	0.076	0.243	0.193	0.093	0.032	0.058	0.063	0.067	0.055
Potential Allocation (m³/s, Risk Mgmt 2)	0.026	0.044	0.046	0.101	0.324	0.258	0.123	0.043	0.078	0.085	0.090	0.074
Potential Allocation (m³/s, Risk Mgmt 3)	>0.026	>0.044	>0.046	>0.101	>0.324	>0.258	>0.123	>0.043	>0.078	>0.085	>0.090	>0.074

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Hydrology - Monthly McBride Creek

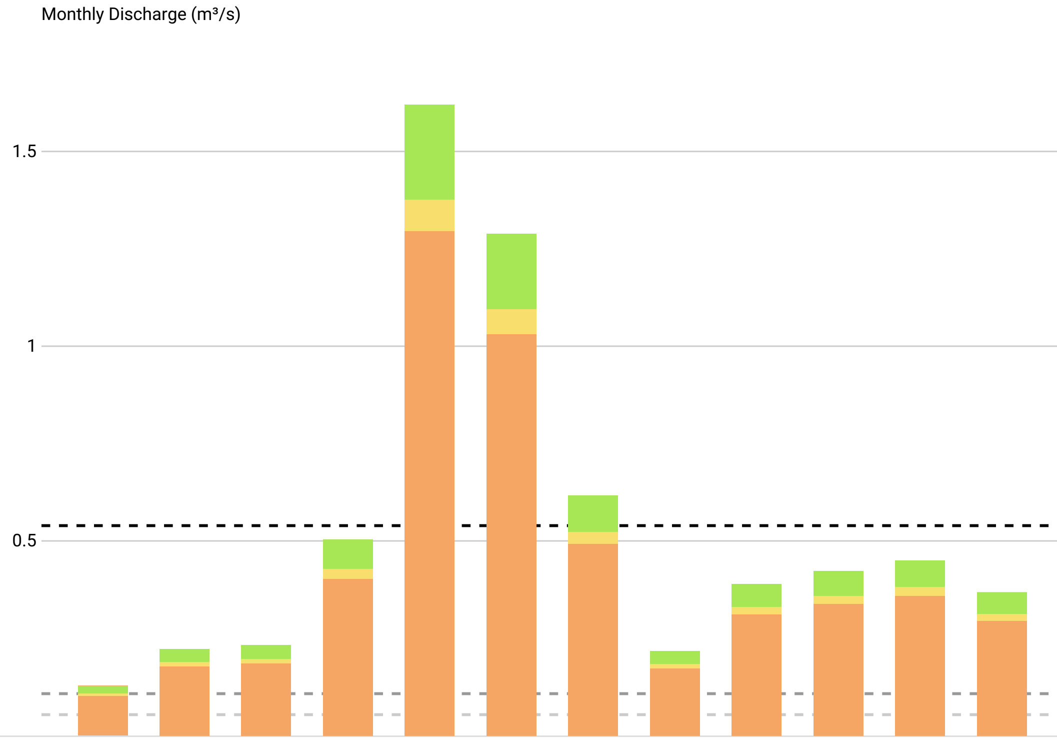
The chart and table show information on modeled hydrology and existing allocations in the downstream watershed, where the subject drainage meets with another drainage of comparable size. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy*.

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	0.539 m³/s
20% MAD	0.108 m³/s
10% MAD	0.054 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	0.128	0.222	0.232	0.504	1.619	1.289	0.617	0.217	0.390	0.423	0.449	0.368
% of MAD	23.8%	41.2%	43.0%	93.5%	300.3%	239.1%	114.4%	40.2%	72.2%	78.4%	83.3%	68.3%
Flow Sensitivity	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	0.019	0.033	0.035	0.076	0.243	0.193	0.093	0.032	0.058	0.063	0.067	0.055
Potential Allocation (m³/s, Risk Mgmt 2)	0.026	0.044	0.046	0.101	0.324	0.258	0.123	0.043	0.078	0.085	0.090	0.074
Potential Allocation (m³/s, Risk Mgmt 3)	>0.026	>0.044	>0.046	>0.101	>0.324	>0.258	>0.123	>0.043	>0.078	>0.085	>0.090	>0.074

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Risk Management Levels and Measures

Guide to interpreting potential allocation amounts in each environmental flow needs risk level as defined in the Province of BC *Environmental Flow Needs Policy.*

Water volumes presented as "Potential Allocations" within this report are determined in consideration of the Province of BC *Environmental Flow Needs Policy*. Within the Policy, risk management measures are suggested to assess or mitigate potential effects of withdrawals from a stream, and provide an ecosystem perspective on environmental flow needs. The measures are associated with risk levels 1, 2, and 3 and are intended to guide where more caution may be needed in reviewing an application or making a decision.

Where there are known species or habitat sensitivities, more detailed, site-specific studies may be required. Where detailed assessments or studies exist, they will supersede policy recommendations.

Risk management levels, for assessing new applications to withdraw water, are determined for each month using the relationship of mean monthly flows to the mean annual discharge, and also using a stream size threshold based on mean annual flows. The calculations presented within this report assume all streams are fish-bearing. Where no water is indicated as available under a risk level, the stream may be very flow sensitive during that time, or the stream may have existing allocations in excess of the relevant threshold.

Inter-annual hydrologic variability may affect the amount of water available in a given year. The impact of this variability on water allocations should be considered separately from the information presented in this report.

The following risk management measures may be appropriate for consideration before a decision is made, could be completed by regional staff to inform a decision, or could be a condition of the licence or approval.

Risk management measures may differ for short-term approvals vs. licences and may vary in relation to withdrawal amounts.

Risk Management Level: 1

Measures to assess or mitigate potential effects on low sensitivity flow periods:

1. Assess veracity of information and ensure appropriate methods are used, (e.g., RISC)
2. Consider downstream users and species/habitats

Risk Management Level: 2

Measures to assess or mitigate potential effects on moderate sensitivity flow periods:

In addition to Level 1 measures:

1. Establish adequate baseline hydrological data before withdrawals
2. Prepare reconnaissance-level fish and fish habitat impact assessment (e.g., Section 4.1.10.1 in Lewis et al. 2004)
3. Issue seasonal licence, or restrictions during low flow periods
4. Development of off-stream storage
5. Inclusion of a daily maximum or inst. withdrawal e.g., greater consideration of instantaneous demand over averages
6. Limit pump intake size
7. Monitor and report water use during higher risk flow periods, e.g., install flow gauge
8. Monitor low flows and limit withdrawals when flows drop below a certain level
9. Ministry staff to conduct audit of basin use/beneficial use review
10. Refuse application to withdraw water

Risk Management Level: 3

Measures to assess or mitigate potential effects on high sensitivity flow periods:

In addition to Level 2 measures:

1. Issue limited licence term, allowing for review and potential adjustment (e.g., 5 years)
2. Prepare detailed habitat assessment (e.g., Lewis et al. 2004; Hatfield et al. 2007)

References

Hatfield, T., A. Lewis, and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts. 2004. Assessment methods for aquatic habitat and instream flow characteristics in support of applications to dam, divert, or extract water from streams in British Columbia. Prepared for Ministry of Water, Land & Air Protection and Ministry of Sustainable Resource Management.

A. Lewis. 2002. Rationale for Multiple British Columbia Instream Flow Standards to Maintain Ecosystem Function and Biodiversity. Draft for Agency Review. Prepared for Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

Resources Information Standards Committee: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/inventory-standards

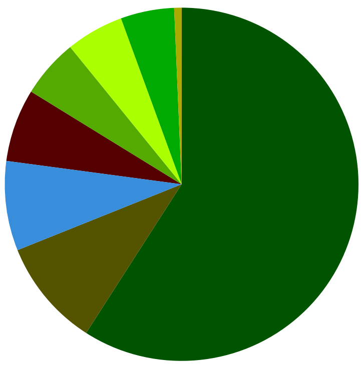
Water Policies, including Environmental Flow Needs: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies

Land Cover and Topography

Characteristics of the query watershed. For more information on watershed characterization in British Columbia please refer to Pike and Wilford (2013).

Land Cover

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

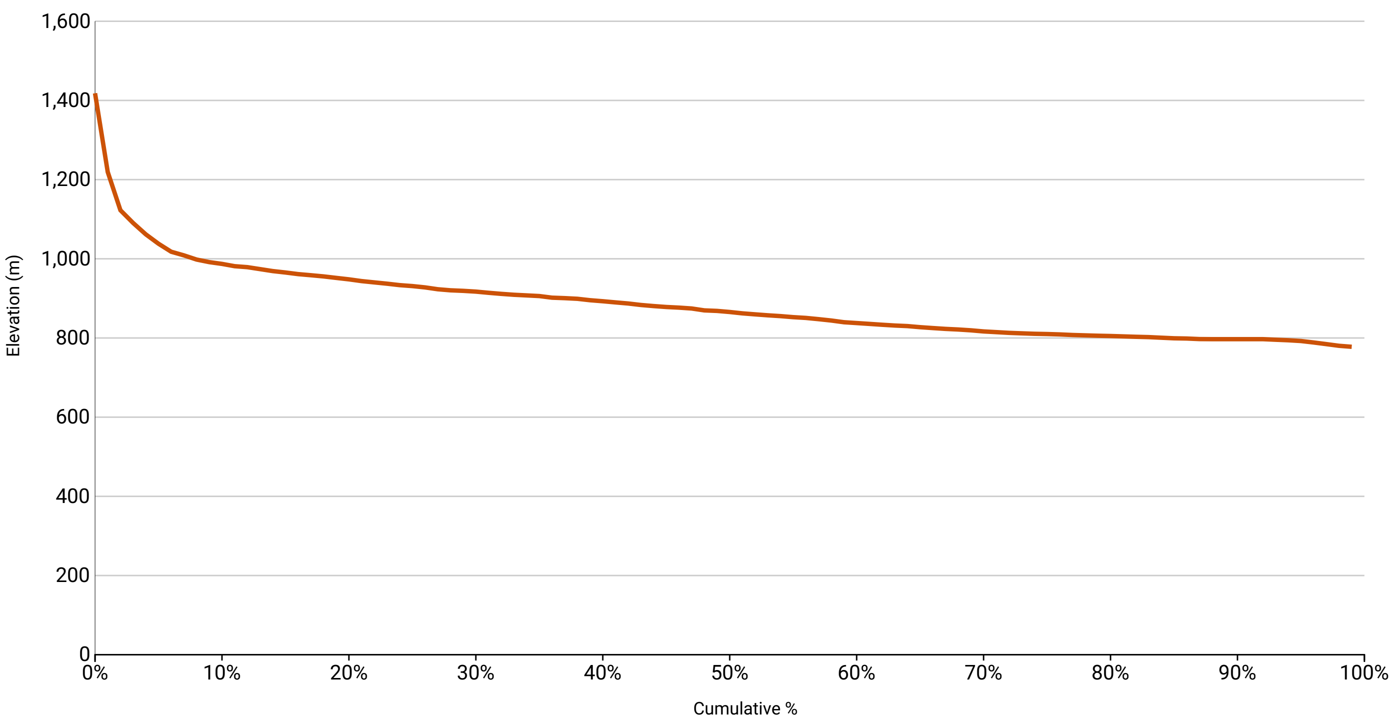


Type	Area (km²)	% of Query Watershed (%)
Barren	7.4	6.7
Coniferous	65.9	59.1
Deciduous	6.0	5.4
Developed	0.0	0.0
Grassland	0.0	0.0
Herb	5.5	4.9
Mixed	11.0	9.8
Shrub	5.9	5.3
Snow / Glacier	0.0	0.0
Water	9.1	8.2
Wetland	0.8	0.7

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

Topography

Elevation of the query watershed influences hydrology in a number of ways. The amount, and state of precipitation (as rain or snow) is influenced by elevation substantially. Likewise, temperatures will vary by elevation in value and also direction of temperature gradient throughout the course of the year.



The elevation characteristics of the query watershed are shown using a hypsometric curve, which shows the cumulative distribution of elevation by area in the watershed. Percent values can be used to identify the percentage of the watershed above a given elevation value.

Reference:
Pike, R.G. and D.J. Wilford. 2013. Desktop watershed characterization methods for British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 079. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr079.htm.

Climate

Historic normal conditions and predicted future change.

The climate of the query watershed has been characterized using ClimateWNA (Wang 2012). In the left hand column, charts are presented for the reference time period 1961-1990. In the right hand column, three illustrative climate change scenarios have been selected to estimate a wide range of potential future change in the query watershed (Murdock and Spittlehouse 2011).

Scenario A illustrates the UKMO HadGEM A1B run 1 global climate model (GCM), scenario B shows the CGCM3 A2 run 4 GCM and scenario C shows the UKMO HadCM3 B1 run 1 GCM. The combination of these three climate models and emissions scenarios were chosen because, over most of British Columbia, they provide a range of generally hot/dry, warm/very wet, and moderately warm/wet for HadGEM A1B, CGCM3 A2, and HadCM3 B1 respectively.

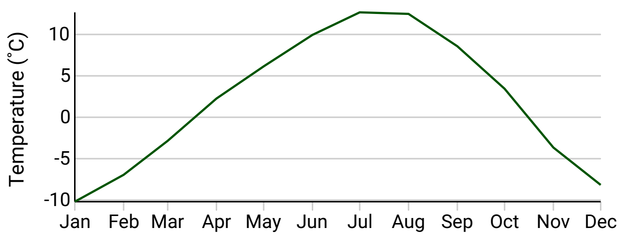
Historic and future climate change information has been provided to assist in understanding potential changes in the basin as temperature and precipitation are intricately related to stream flow. For example, snowpack levels affect many aspects of water resources, from instream flows for fish to community water supplies to soil moisture, groundwater, and aquifer recharge. Climate studies generally indicate a trend of rising air temperatures for all seasons across BC while precipitation trends vary by season and region (Pike *et al.* 2008, Rodenhuis *et al.* 2007). Local responses to changing precipitation and temperature will differ due to BC's inherent hydrological diversity as well as varying climate trends. These charts are intended as a quick glance starting point to basin climate change assessment.

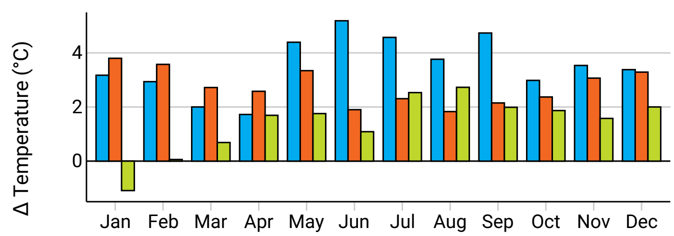
Normal (1961 - 1990)

Predicted Change (2041 - 2070)

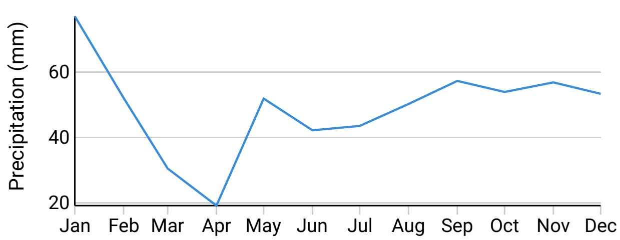
Scenario A Scenario B Scenario C

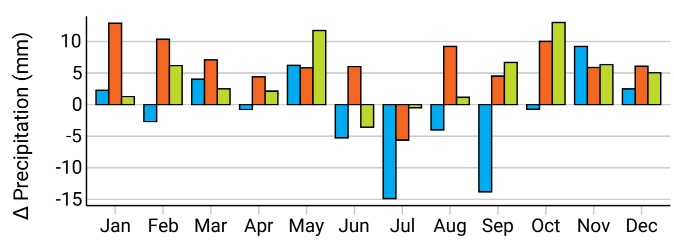
Monthly temperatures are presented as averages of the monthly mean temperature for the query basin as a whole. Projected changes in temperature may affect the hydrology in the watershed by influencing the time of freeze and thaw, evapotranspiration rates, form of precipitation, and vegetation composition, among other factors.



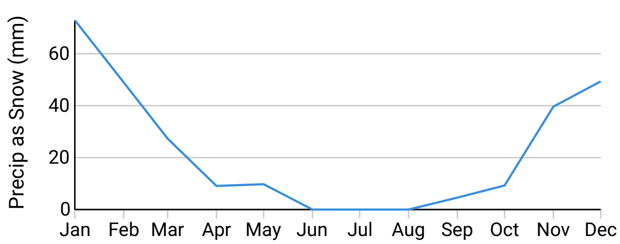


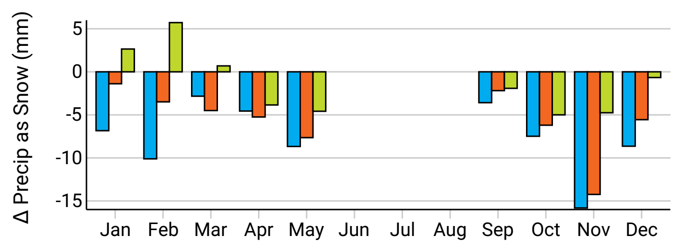
The precipitation in the query watershed is shown as an average unit precipitation for the watershed. Changes in precipitation timing and amount may affect the hydrology in the watershed by influencing the timing and magnitude of peak and low flow conditions. These changes may affect availability of water for environmental flow needs and human use, and modify the physical characteristics of river channels and associated needs for engineered structures.





Precipitation as snow in the query watershed is presented as an average unit precipitation for the query basin as a whole. Changes in the amount of precipitation as snow may affect winter snowpack volumes and associated melt related hydrology in the spring. An increase in rain-on-snow events may be associated with elevated natural hazard risk from avalanche or other slope stability failures.





References

Murdock, T.Q., Spittlehouse, D.L. 2011. Selecting and Using Climate Change Scenarios for British Columbia. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC. http://www.pacificclimate.org/sites/default/files/publications/Murdock.ScenariosGuidance.Dec2011.pdf

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate Change and Watershed Hydrology: Part I - Recent and Projected Changes in British Columbia. Streamline, Watershed Management Bulletin 11-2 8-13. http://www.pacificclimate.org/sites/default/files/publications/Pike.StreamlineHydrologyPartI.Apr2008.pdf

Rodenhuis, D., K.E. Bennett, A. Werner, T.Q. Murdock, and D. Bronaugh. 2007. Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium. http://www.pacificclimate.org/sites/default/files/publications/Rodenhuis.ClimateOverview.Mar2009.pdf

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.

Northwest Water Tool Report

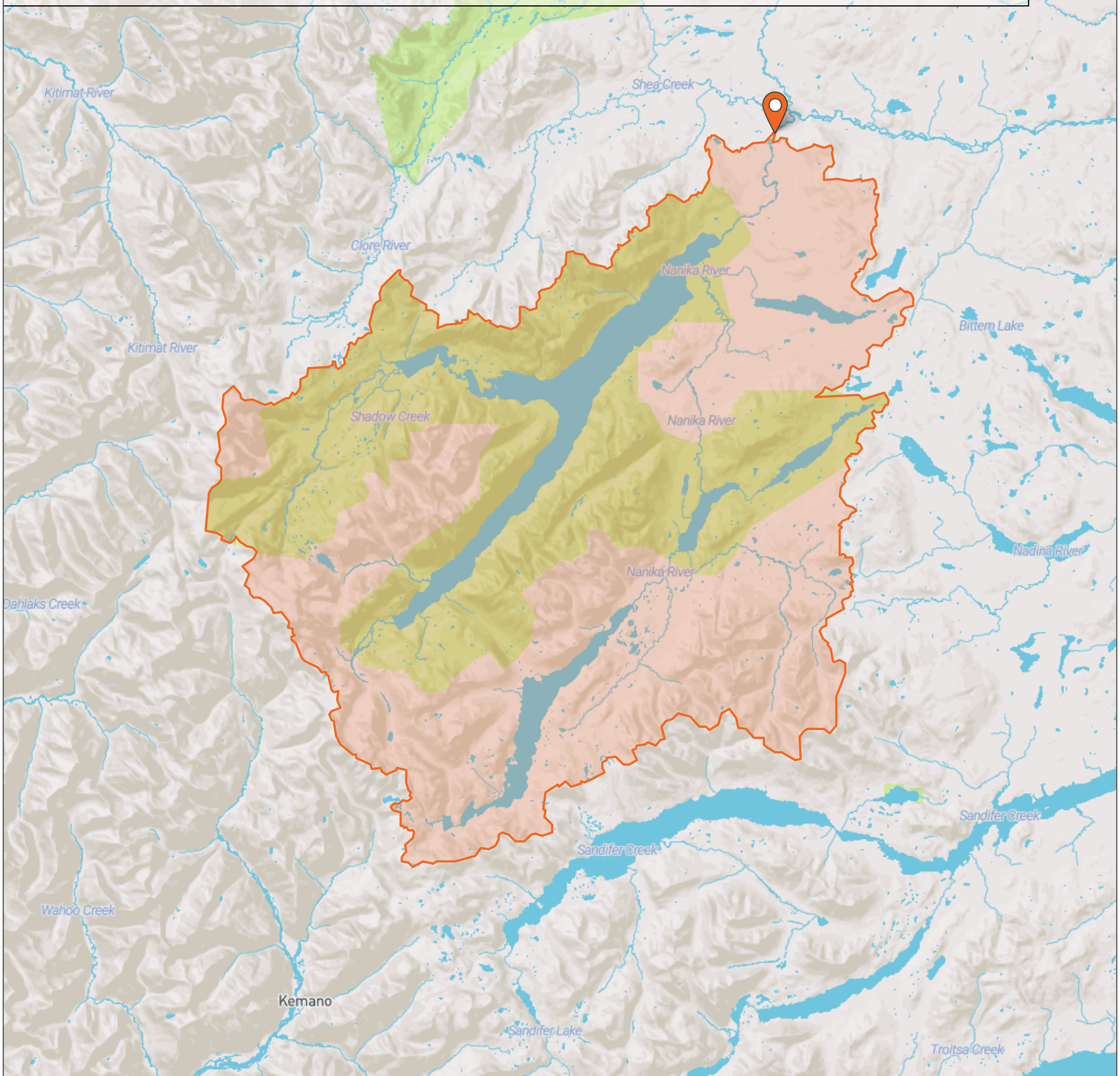
Dec 4 2018

Morice River
Bulkley River
Skeena River
Pacific Ocean

54.19075N 127.36364W
Query Location

1,988.9
Area (km²)

763 - 1,247 - 2,572
Elevation (m)
min - mean - max

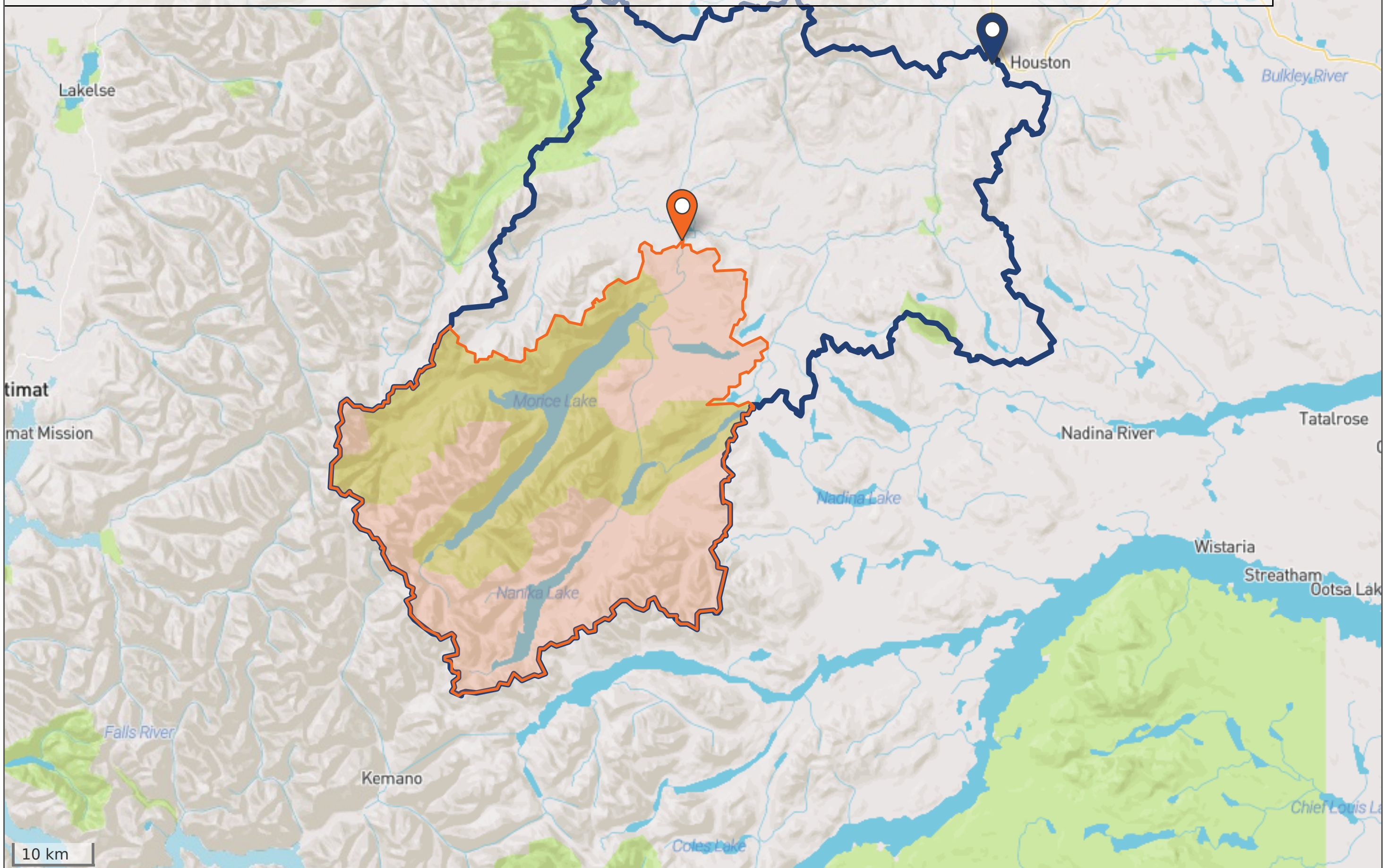


British Columbia
Ministry of Forests, Lands, Natural Resource Operations and Rural Development

5 km

Hydrology - Annual

The map shows the query and downstream watersheds. The table below provides an overview of hydrology and existing allocations in these watersheds.



Query Watershed		Downstream Watershed
1,988.9	Area (km²)	4,379.0
75.487	Mean Annual Discharge (m³/s)	111.872
0.000	Allocations (m³/s)	0.009
0.0	Allocations (%)	0.0
Present*	Reserves & Restrictions	Present*
2,382,126,297	Volume Runoff (m³/yr)	3,530,329,373
0	Volume Allocations (m³/yr)	290,721
Winter	Seasonal Flow Sensitivity**	Winter, Summer

The downstream watershed is defined at the location where the queried drainage meets with another drainage of comparable size. For information further downstream, please generate an additional report at a location of interest. Predictions for small watersheds (generally smaller than 50 sq. km.) may be less accurate due to the lack of hydrometric data available for watersheds of this size.

* For more information on water reserves or restrictions present in the watershed, please visit the links below or contact FrontCounter BC.

FrontCounter BC: www.frontcounterbc.ca **Email:** FrontCounterBC@gov.bc.ca **Toll Free:** 1-877-855-3222 **Outside North America:** ++1-778-372-0729

Water Reservations: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-reservations

Water Restrictions: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-allocation-restrictions

**Ptolemy, R. Environmental Flow Protection in British Columbia. Presentation to 2015 IFC Panel, April 29, 2015.

Hydrology - Monthly Morice River

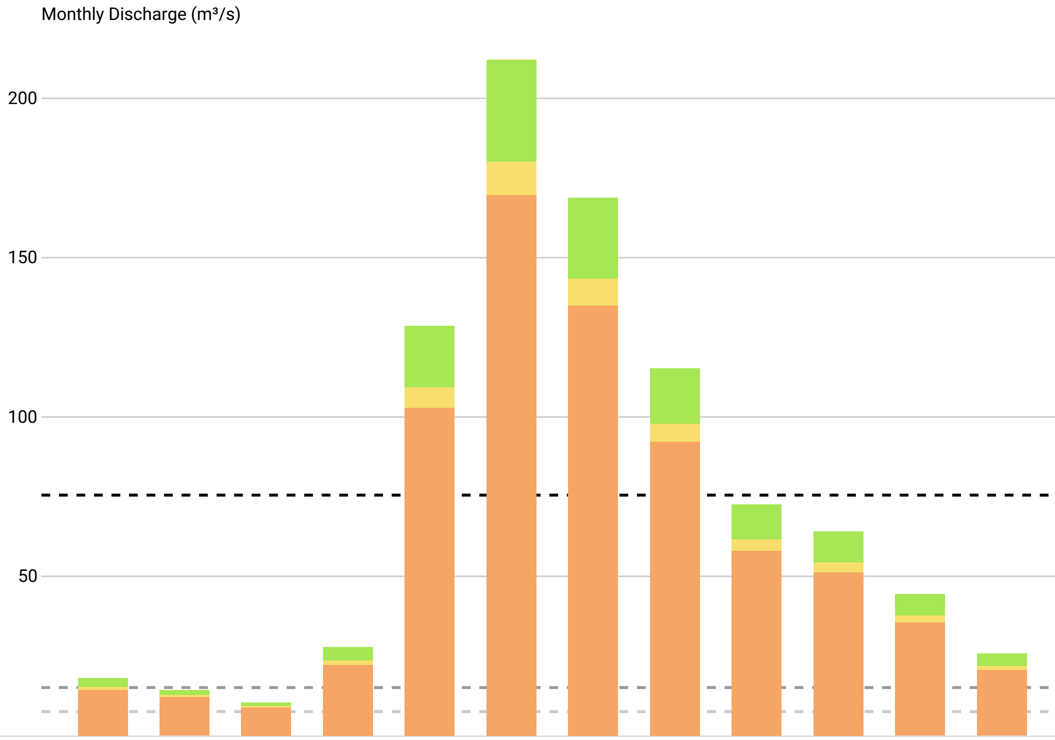
The chart and table show information on modeled hydrology and existing allocations in the query watershed. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy.*

Legend

Risk Management Level 1
Risk Management Level 2
Risk Management Level 3
Existing Allocations

Mean Annual Discharge (MAD)

MAD	75.487 m³/s
20% MAD	15.097 m³/s
10% MAD	7.549 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	17.998	14.257	10.453	27.854	128.681	212.064	168.809	115.290	72.599	64.004	44.404	25.747
% of MAD	23.8%	18.9%	13.8%	36.9%	170.5%	280.9%	223.6%	152.7%	96.2%	84.8%	58.8%	34.1%
Flow Sensitivity	Low	Mod	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	2.700	1.426	1.045	4.178	19.302	31.810	25.321	17.294	10.890	9.601	6.661	3.862
Potential Allocation (m³/s, Risk Mgmt 2)	3.600	2.138	1.568	5.571	25.736	42.413	33.762	23.058	14.520	12.801	8.881	5.149
Potential Allocation (m³/s, Risk Mgmt 3)	>3.600	>2.138	>1.568	>5.571	>25.736	>42.413	>33.762	>23.058	>14.520	>12.801	>8.881	>5.149

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Hydrology - Monthly Morice River

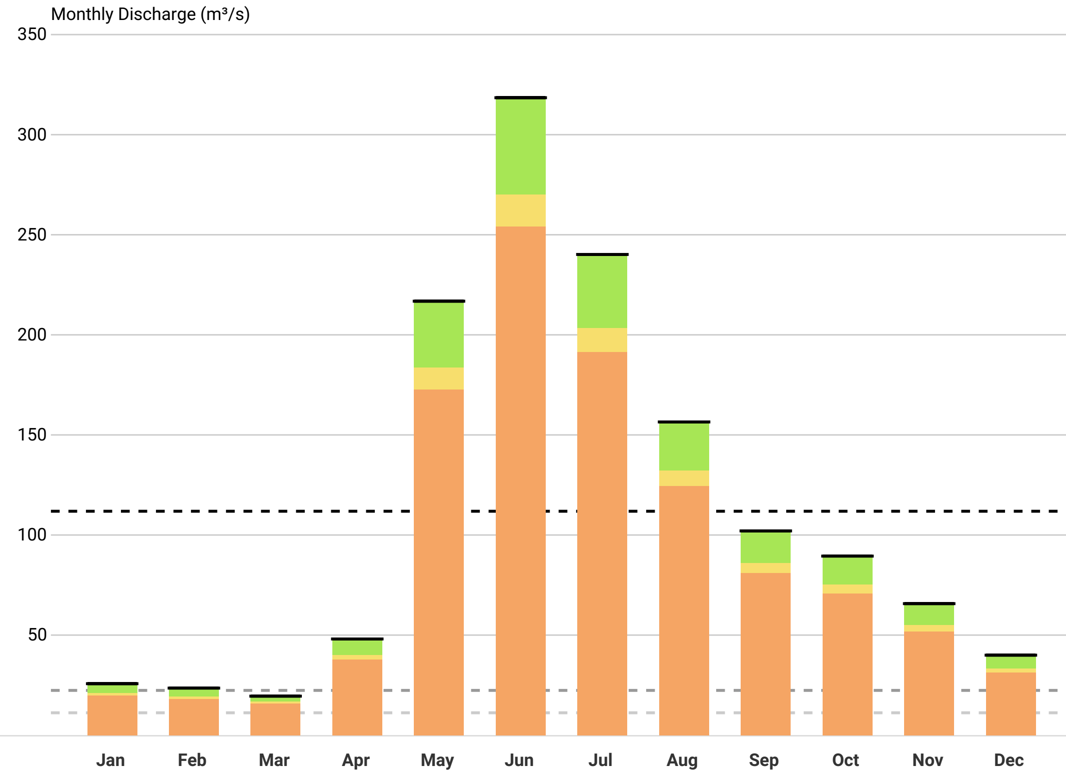
The chart and table show information on modeled hydrology and existing allocations in the downstream watershed, where the subject drainage meets with another drainage of comparable size. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy*.

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	111.872 m³/s
20% MAD	22.374 m³/s
10% MAD	11.187 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	24.999	22.791	18.770	47.338	216.086	317.748	239.443	155.766	101.325	88.738	64.986	39.248
% of MAD	22.3%	20.4%	16.8%	42.3%	193.2%	284.0%	214.0%	139.2%	90.6%	79.3%	58.1%	35.1%
Flow Sensitivity	Low	Low	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.004	0.004	0.004	0.004	0.004	0.022	0.021	0.021	0.010	0.004	0.004	0.004
Potential Allocation (m³/s, Risk Mgmt 1)	3.745	3.414	1.872	7.096	32.408	47.640	35.895	23.344	15.189	13.306	9.743	5.883
Potential Allocation (m³/s, Risk Mgmt 2)	4.995	4.554	2.811	9.463	43.213	63.528	47.867	31.132	20.255	17.743	12.993	7.845
Potential Allocation (m³/s, Risk Mgmt 3)	>4.995	>4.554	>2.811	>9.463	>43.213	>63.528	>47.867	>31.132	>20.255	>17.743	>12.993	>7.845

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Risk Management Levels and Measures

Guide to interpreting potential allocation amounts in each environmental flow needs risk level as defined in the Province of BC *Environmental Flow Needs Policy.*

Water volumes presented as "Potential Allocations" within this report are determined in consideration of the Province of BC *Environmental Flow Needs Policy.* Within the Policy, risk management measures are suggested to assess or mitigate potential effects of withdrawals from a stream, and provide an ecosystem perspective on environmental flow needs. The measures are associated with risk levels 1, 2, and 3 and are intended to guide where more caution may be needed in reviewing an application or making a decision.

Where there are known species or habitat sensitivities, more detailed, site-specific studies may be required. Where detailed assessments or studies exist, they will supersede policy recommendations.

Risk management levels, for assessing new applications to withdraw water, are determined for each month using the relationship of mean monthly flows to the mean annual discharge, and also using a stream size threshold based on mean annual flows. The calculations presented within this report assume all streams are fish-bearing. Where no water is indicated as available under a risk level, the stream may be very flow sensitive during that time, or the stream may have existing allocations in excess of the relevant threshold.

Inter-annual hydrologic variability may affect the amount of water available in a given year. The impact of this variability on water allocations should be considered separately from the information presented in this report.

The following risk management measures may be appropriate for consideration before a decision is made, could be completed by regional staff to inform a decision, or could be a condition of the licence or approval.

Risk management measures may differ for short-term approvals vs. licences and may vary in relation to withdrawal amounts.

Risk Management Level: 1

Measures to assess or mitigate potential effects on low sensitivity flow periods:

1. Assess veracity of information and ensure appropriate methods are used, (e.g., RISC)
2. Consider downstream users and species/habitats

Risk Management Level: 2

Measures to assess or mitigate potential effects on moderate sensitivity flow periods:

In addition to Level 1 measures:

1. Establish adequate baseline hydrological data before withdrawals
2. Prepare reconnaissance-level fish and fish habitat impact assessment (e.g., Section 4.1.10.1 in Lewis et al. 2004)
3. Issue seasonal licence, or restrictions during low flow periods
4. Development of off-stream storage
5. Inclusion of a daily maximum or inst. withdrawal e.g., greater consideration of instantaneous demand over averages
6. Limit pump intake size
7. Monitor and report water use during higher risk flow periods, e.g., install flow gauge
8. Monitor low flows and limit withdrawals when flows drop below a certain level
9. Ministry staff to conduct audit of basin use/beneficial use review
10. Refuse application to withdraw water

Risk Management Level: 3

Measures to assess or mitigate potential effects on high sensitivity flow periods:

In addition to Level 2 measures:

1. Issue limited licence term, allowing for review and potential adjustment (e.g., 5 years)
2. Prepare detailed habitat assessment (e.g., Lewis et al. 2004; Hatfield et al. 2007)

References

Hatfield, T., A. Lewis, and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts. 2004. Assessment methods for aquatic habitat and instream flow characteristics in support of applications to dam, divert, or extract water from streams in British Columbia. Prepared for Ministry of Water, Land & Air Protection and Ministry of Sustainable Resource Management.

A. Lewis. 2002. Rationale for Multiple British Columbia Instream Flow Standards to Maintain Ecosystem Function and Biodiversity. Draft for Agency Review. Prepared for Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

Resources Information Standards Committee: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/inventory-standards

Water Policies, including Environmental Flow Needs: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies

Existing Allocations Water Licences

Current approved and active applications for term water licences.

BC Water Sustainability Act - Water Licences - 1 Licence, 0.00 m³ Total Annual Volume

Licensee	Number	POD	Priority Date	Quantity (m³/year)	Flag
Fisheries & Oceans Canada Conservation: Use of Water from Nanika River	C026200	PD34501	1960-07-26	4,481,179.20	T, N

Water Licence Flag Description

D : Multiple PODs for PUC/qty at each are known/PODs on different sources
M : Max licenced demand for purpose/multiple PODs/qty at each POD unknown
P : Multiple PODs for PUC/qty at each are known/PODs on same source
T : Total demand one POD

Other

A : Active application status
N : Licence volumes not used in calculations
R : Rediversion

For more information on water licences:

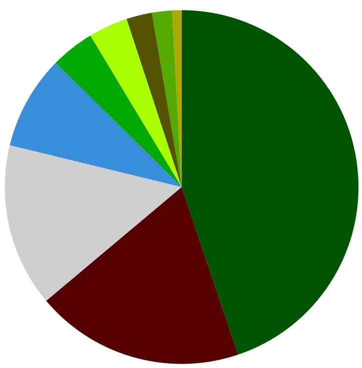
Water Licence Query Tool: http://a100.gov.bc.ca/pub/wtrwhse/water_licences.input
Water Rights Databases: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-licences-approvals/water-rights-databases

Land Cover and Topography

Characteristics of the query watershed. For more information on watershed characterization in British Columbia please refer to Pike and Wilford (2013).

Land Cover

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

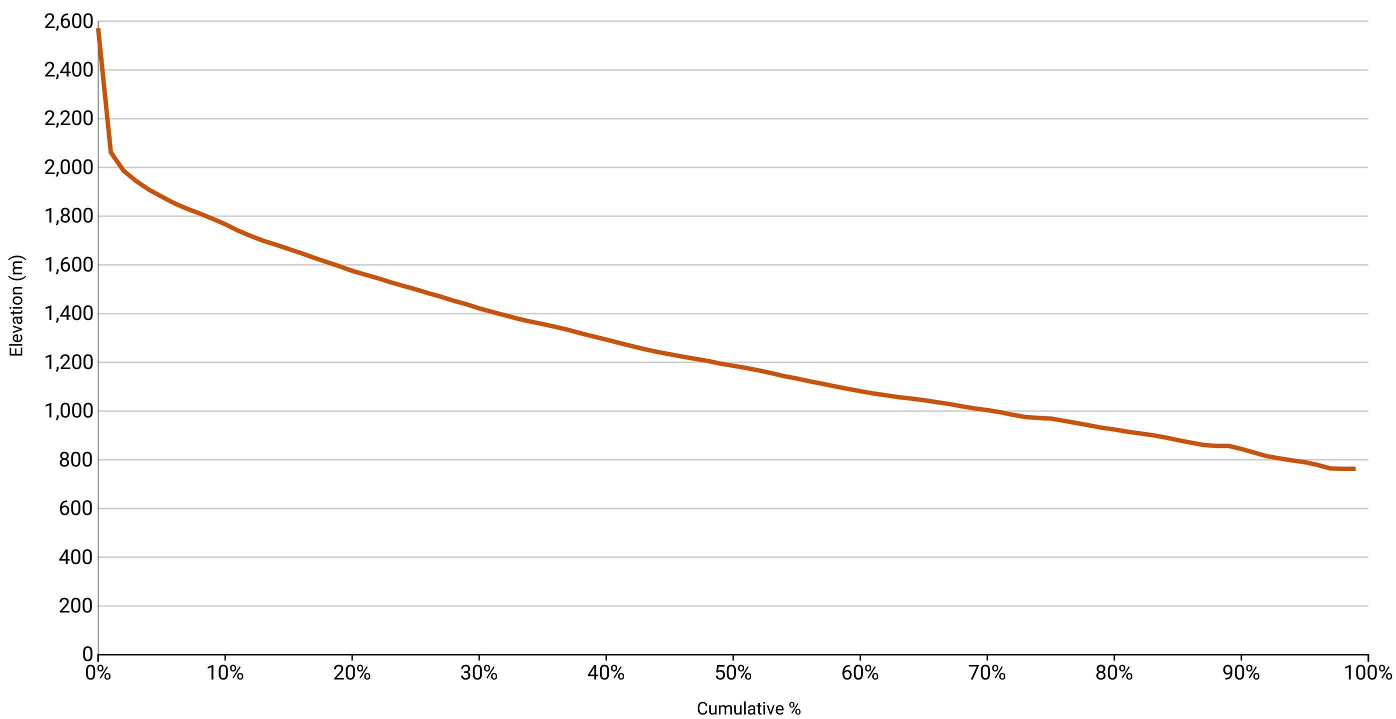


Type	Area (km²)	% of Query Watershed (%)
Barren	378.9	19.0
Coniferous	891.6	44.8
Deciduous	36.7	1.8
Developed	0.0	0.0
Grassland	0.1	0.0
Herb	79.3	4.0
Mixed	46.7	2.3
Shrub	71.4	3.6
Snow / Glacier	296.8	14.9
Water	170.7	8.6
Wetland	16.8	0.8

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

Topography

Elevation of the query watershed influences hydrology in a number of ways. The amount, and state of precipitation (as rain or snow) is influenced by elevation substantially. Likewise, temperatures will vary by elevation in value and also direction of temperature gradient throughout the course of the year.



The elevation characteristics of the query watershed are shown using a hypsometric curve, which shows the cumulative distribution of elevation by area in the watershed. Percent values can be used to identify the percentage of the watershed above a given elevation value.

Reference:
Pike, R.G. and D.J. Wilford. 2013. Desktop watershed characterization methods for British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 079. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr079.htm.

Climate

Historic normal conditions and predicted future change.

The climate of the query watershed has been characterized using ClimateWNA (Wang 2012). In the left hand column, charts are presented for the reference time period 1961-1990. In the right hand column, three illustrative climate change scenarios have been selected to estimate a wide range of potential future change in the query watershed (Murdock and Spittlehouse 2011).

Scenario A illustrates the UKMO HadGEM A1B run 1 global climate model (GCM), scenario B shows the CGCM3 A2 run 4 GCM and scenario C shows the UKMO HadCM3 B1 run 1 GCM. The combination of these three climate models and emissions scenarios were chosen because, over most of British Columbia, they provide a range of generally hot/dry, warm/very wet, and moderately warm/wet for HadGEM A1B, CGCM3 A2, and HadCM3 B1 respectively.

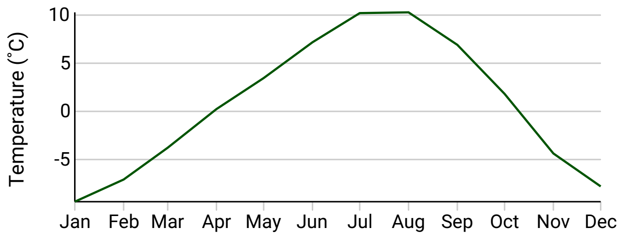
Historic and future climate change information has been provided to assist in understanding potential changes in the basin as temperature and precipitation are intricately related to stream flow. For example, snowpack levels affect many aspects of water resources, from instream flows for fish to community water supplies to soil moisture, groundwater, and aquifer recharge. Climate studies generally indicate a trend of rising air temperatures for all seasons across BC while precipitation trends vary by season and region (Pike *et al.* 2008, Rodenhuis *et al.* 2007). Local responses to changing precipitation and temperature will differ due to BC's inherent hydrological diversity as well as varying climate trends. These charts are intended as a quick glance starting point to basin climate change assessment.

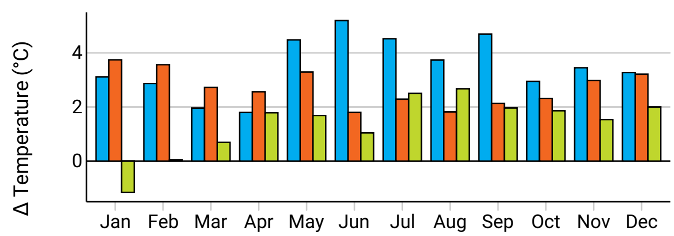
Normal (1961 - 1990)

Predicted Change (2041 - 2070)

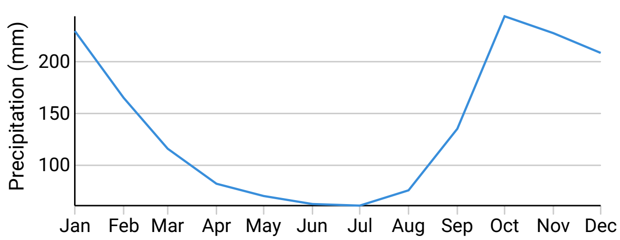
Scenario A Scenario B Scenario C

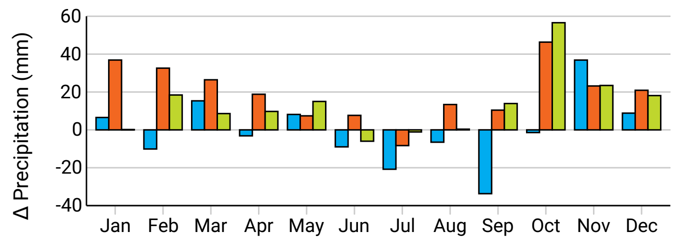
Monthly temperatures are presented as averages of the monthly mean temperature for the query basin as a whole. Projected changes in temperature may affect the hydrology in the watershed by influencing the time of freeze and thaw, evapotranspiration rates, form of precipitation, and vegetation composition, among other factors.



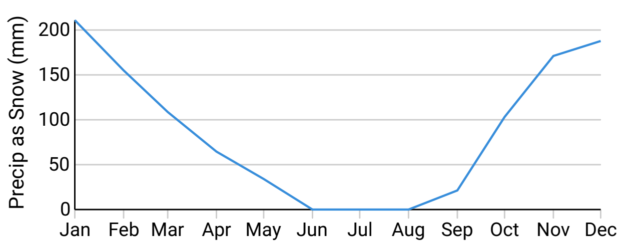


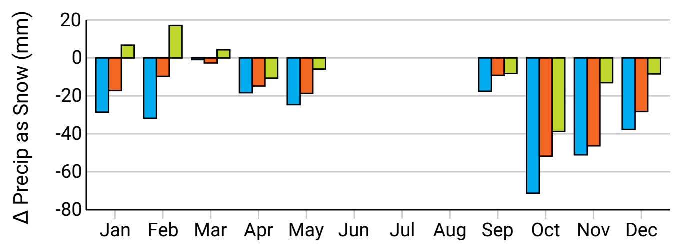
The precipitation in the query watershed is shown as an average unit precipitation for the watershed. Changes in precipitation timing and amount may affect the hydrology in the watershed by influencing the timing and magnitude of peak and low flow conditions. These changes may affect availability of water for environmental flow needs and human use, and modify the physical characteristics of river channels and associated needs for engineered structures.





Precipitation as snow in the query watershed is presented as an average unit precipitation for the query basin as a whole. Changes in the amount of precipitation as snow may affect winter snowpack volumes and associated melt related hydrology in the spring. An increase in rain-on-snow events may be associated with elevated natural hazard risk from avalanche or other slope stability failures.





References

Murdock, T.Q., Spittlehouse, D.L. 2011. Selecting and Using Climate Change Scenarios for British Columbia. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC. http://www.pacificclimate.org/sites/default/files/publications/Murdock.ScenariosGuidance.Dec2011.pdf

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate Change and Watershed Hydrology: Part I - Recent and Projected Changes in British Columbia. Streamline, Watershed Management Bulletin 11-2 8-13. http://www.pacificclimate.org/sites/default/files/publications/Pike.StreamlineHydrologyPartI.Apr2008.pdf

Rodenhuis, D., K.E. Bennett, A. Werner, T.Q. Murdock, and D. Bronaugh. 2007. Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium. http://www.pacificclimate.org/sites/default/files/publications/Rodenhuis.ClimateOverview.Mar2009.pdf

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.

Northwest Water Tool Report

Dec 4 2018

Nado Creek

Morice River

Bulkley River

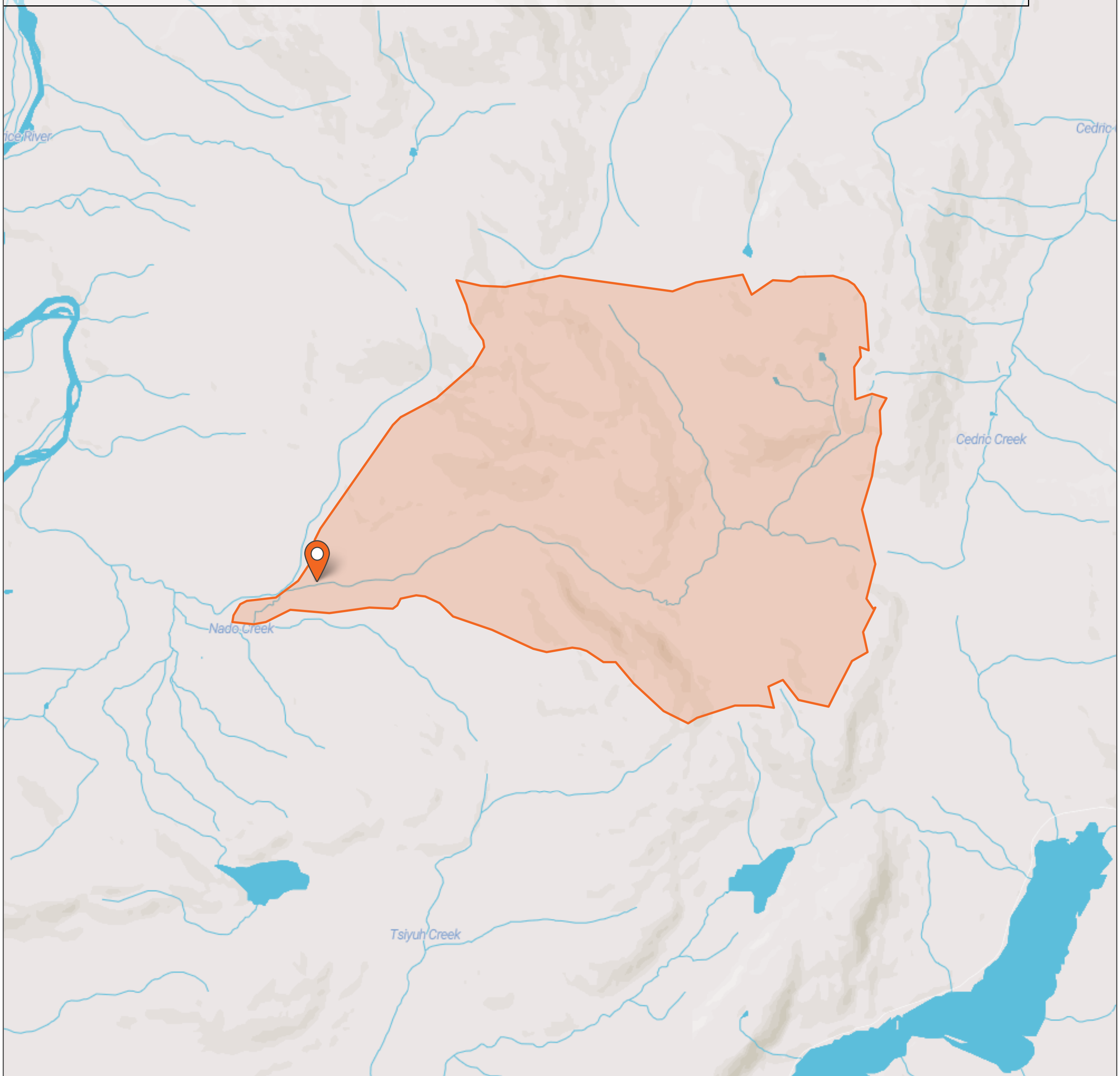
Skeena River

Pacific Ocean

54.12984N 127.32343W
Query Location

18.8
Area (km²)

809 - 1,016 - 1,207
Elevation (m)
min - mean - max



Disclaimer

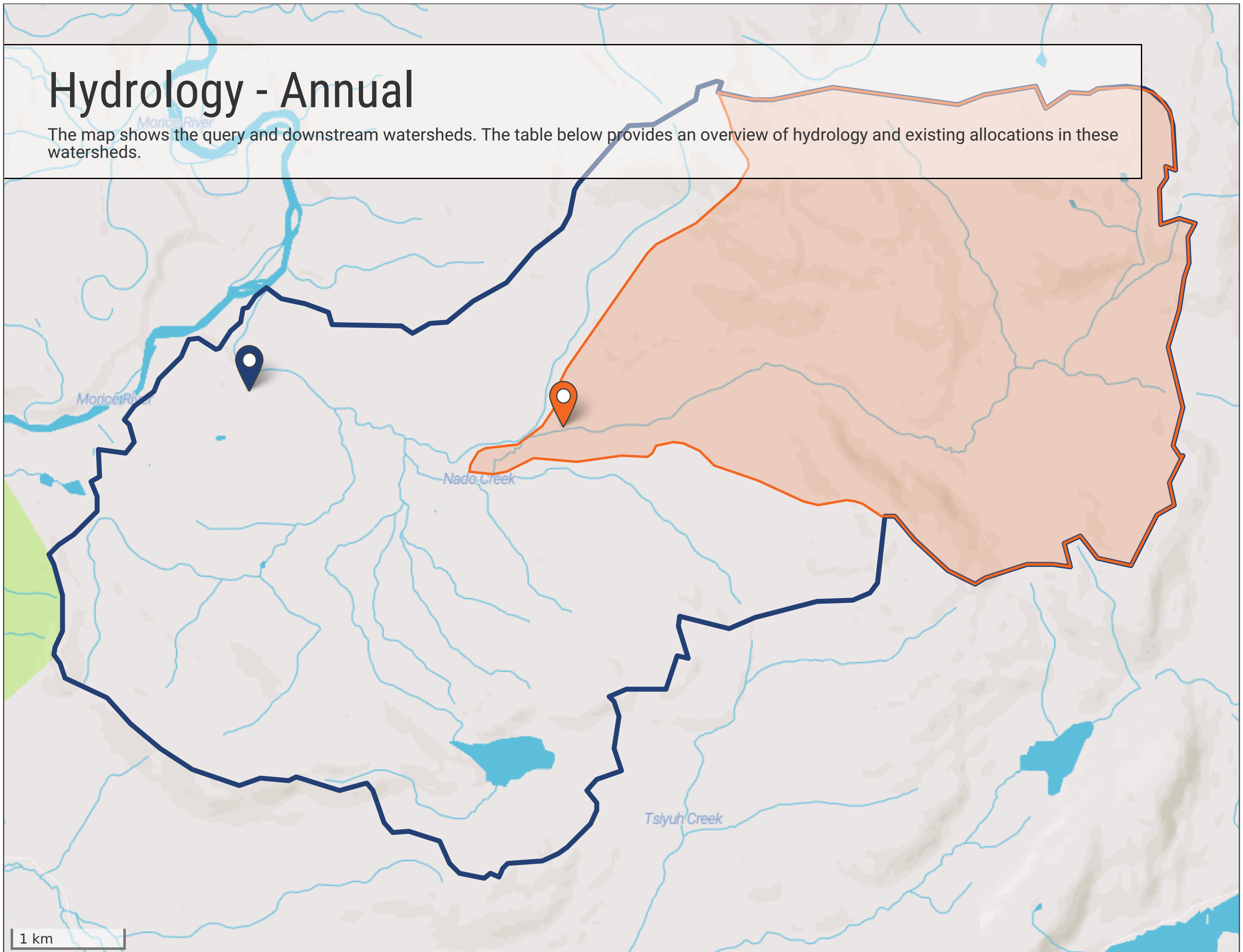
The Northwest Water Tool (NWWT) has been developed and placed on this website by the Ministry of Forests, Lands and Natural Resource Operations and Rural Development of British Columbia for the convenience of industry and the public. Information relating to NWWT is believed to be representative, but technical inaccuracies and uncertainties may occur. NWWT carries no guarantee of any kind, express or implied. The Ministry accepts no liability or blame for loss or damages incurred by any person or business entity based on the use of NWWT.

British Columbia | Ministry of Forests, Lands, Natural Resource Operations and Rural Development

1 km

Hydrology - Annual

The map shows the query and downstream watersheds. The table below provides an overview of hydrology and existing allocations in these watersheds.



Query Watershed		Downstream Watershed
18.8	Area (km²)	44.0
0.127	Mean Annual Discharge (m³/s)	0.293
0.000	Allocations (m³/s)	0.000
0.0	Allocations (%)	0.0
Present*	Reserves & Restrictions	**Present***
3,992,595	Volume Runoff (m³/yr)	9,255,573
0	Volume Allocations (m³/yr)	0
Winter	Seasonal Flow Sensitivity**	**Winter**

The downstream watershed is defined at the location where the queried drainage meets with another drainage of comparable size. For information further downstream, please generate an additional report at a location of interest. Predictions for small watersheds (generally smaller than 50 sq. km.) may be less accurate due to the lack of hydrometric data available for watersheds of this size.

* For more information on water reserves or restrictions present in the watershed, please visit the links below or contact FrontCounter BC.

FrontCounter BC: www.frontcounterbc.ca **Email:** FrontCounterBC@gov.bc.ca **Toll Free:** 1-877-855-3222 **Outside North America:** ++1-778-372-0729

Water Reservations: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-reservations

Water Restrictions: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-allocation-restrictions

**Ptolemy, R. Environmental Flow Protection in British Columbia. Presentation to 2015 IFC Panel, April 29, 2015.

Hydrology - Monthly Nado Creek

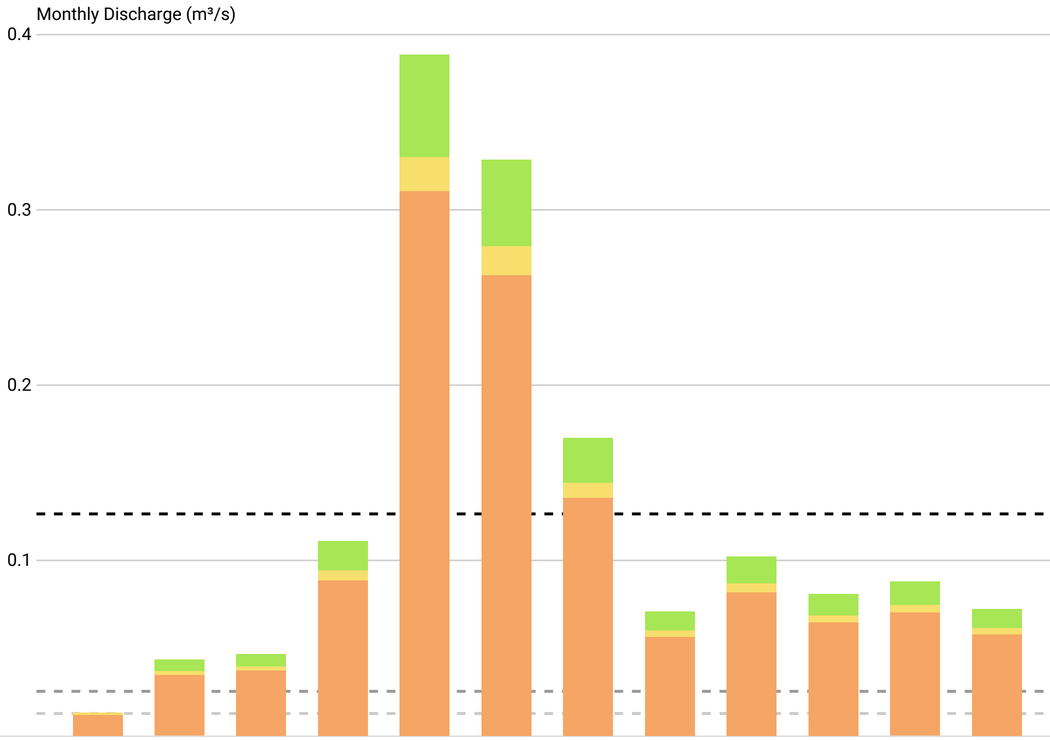
The chart and table show information on modeled hydrology and existing allocations in the query watershed. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy.*

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	0.127 m³/s
20% MAD	0.025 m³/s
10% MAD	0.013 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	0.013	0.043	0.046	0.111	0.389	0.329	0.170	0.071	0.102	0.081	0.088	0.072
% of MAD	10.5%	34.3%	36.7%	87.7%	307.2%	259.7%	134.2%	55.9%	80.8%	63.9%	69.5%	57.1%
Flow Sensitivity	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	0.000	0.007	0.007	0.017	0.058	0.049	0.025	0.011	0.015	0.012	0.013	0.011
Potential Allocation (m³/s, Risk Mgmt 2)	0.001	0.009	0.009	0.022	0.078	0.066	0.034	0.014	0.020	0.016	0.018	0.014
Potential Allocation (m³/s, Risk Mgmt 3)	>0.001	>0.009	>0.009	>0.022	>0.078	>0.066	>0.034	>0.014	>0.020	>0.016	>0.018	>0.014

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Hydrology - Monthly Nado Creek

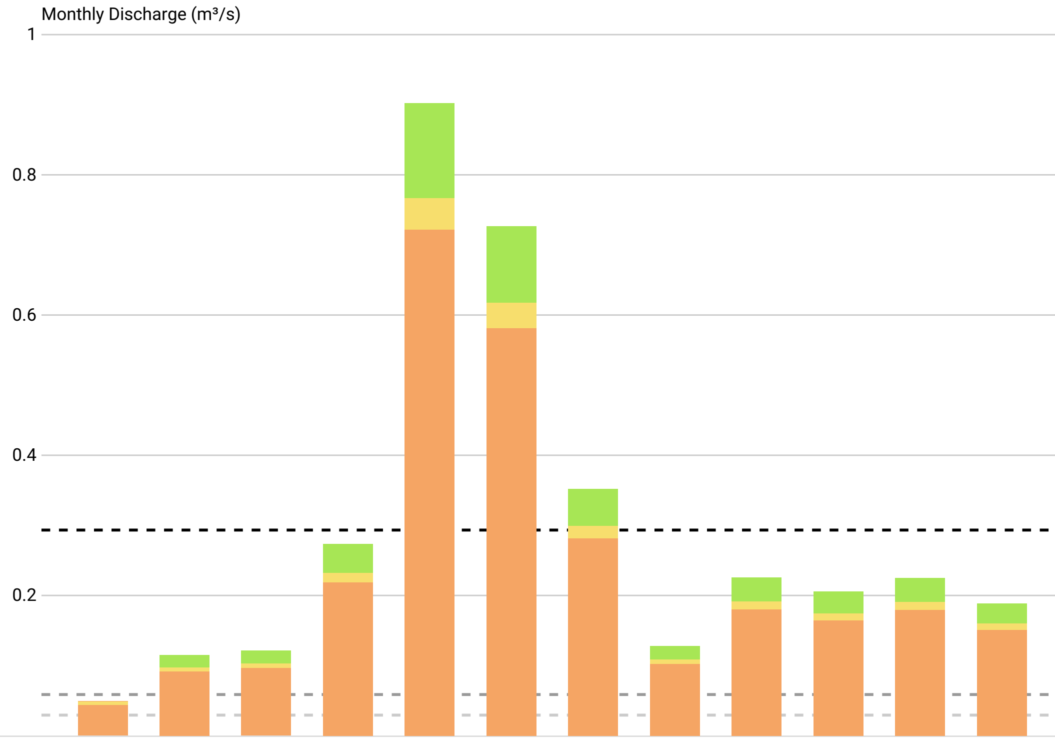
The chart and table show information on modeled hydrology and existing allocations in the downstream watershed, where the subject drainage meets with another drainage of comparable size. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy.*

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	0.293 m³/s
20% MAD	0.059 m³/s
10% MAD	0.029 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	0.049	0.115	0.121	0.273	0.902	0.727	0.352	0.128	0.226	0.206	0.225	0.188
% of MAD	16.7%	39.2%	41.3%	93.1%	307.7%	247.7%	120.0%	43.7%	77.0%	70.1%	76.7%	64.3%
Flow Sensitivity	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	0.000	0.017	0.018	0.041	0.135	0.109	0.053	0.019	0.034	0.031	0.034	0.028
Potential Allocation (m³/s, Risk Mgmt 2)	0.005	0.023	0.024	0.055	0.180	0.145	0.070	0.026	0.045	0.041	0.045	0.038
Potential Allocation (m³/s, Risk Mgmt 3)	>0.005	>0.023	>0.024	>0.055	>0.180	>0.145	>0.070	>0.026	>0.045	>0.041	>0.045	>0.038

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Risk Management Levels and Measures

Guide to interpreting potential allocation amounts in each environmental flow needs risk level as defined in the Province of BC *Environmental Flow Needs Policy.*

Water volumes presented as "Potential Allocations" within this report are determined in consideration of the Province of BC *Environmental Flow Needs Policy*. Within the Policy, risk management measures are suggested to assess or mitigate potential effects of withdrawals from a stream, and provide an ecosystem perspective on environmental flow needs. The measures are associated with risk levels 1, 2, and 3 and are intended to guide where more caution may be needed in reviewing an application or making a decision.

Where there are known species or habitat sensitivities, more detailed, site-specific studies may be required. Where detailed assessments or studies exist, they will supersede policy recommendations.

Risk management levels, for assessing new applications to withdraw water, are determined for each month using the relationship of mean monthly flows to the mean annual discharge, and also using a stream size threshold based on mean annual flows. The calculations presented within this report assume all streams are fish-bearing. Where no water is indicated as available under a risk level, the stream may be very flow sensitive during that time, or the stream may have existing allocations in excess of the relevant threshold.

Inter-annual hydrologic variability may affect the amount of water available in a given year. The impact of this variability on water allocations should be considered separately from the information presented in this report.

The following risk management measures may be appropriate for consideration before a decision is made, could be completed by regional staff to inform a decision, or could be a condition of the licence or approval.

Risk management measures may differ for short-term approvals vs. licences and may vary in relation to withdrawal amounts.

Risk Management Level: 1

Measures to assess or mitigate potential effects on low sensitivity flow periods:

1. Assess veracity of information and ensure appropriate methods are used, (e.g., RISC)
2. Consider downstream users and species/habitats

Risk Management Level: 2

Measures to assess or mitigate potential effects on moderate sensitivity flow periods:

In addition to Level 1 measures:

1. Establish adequate baseline hydrological data before withdrawals
2. Prepare reconnaissance-level fish and fish habitat impact assessment (e.g., Section 4.1.10.1 in Lewis et al. 2004)
3. Issue seasonal licence, or restrictions during low flow periods
4. Development of off-stream storage
5. Inclusion of a daily maximum or inst. withdrawal e.g., greater consideration of instantaneous demand over averages
6. Limit pump intake size
7. Monitor and report water use during higher risk flow periods, e.g., install flow gauge
8. Monitor low flows and limit withdrawals when flows drop below a certain level
9. Ministry staff to conduct audit of basin use/beneficial use review
10. Refuse application to withdraw water

Risk Management Level: 3

Measures to assess or mitigate potential effects on high sensitivity flow periods:

In addition to Level 2 measures:

1. Issue limited licence term, allowing for review and potential adjustment (e.g., 5 years)
2. Prepare detailed habitat assessment (e.g., Lewis et al. 2004; Hatfield et al. 2007)

References

Hatfield, T., A. Lewis, and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts. 2004. Assessment methods for aquatic habitat and instream flow characteristics in support of applications to dam, divert, or extract water from streams in British Columbia. Prepared for Ministry of Water, Land & Air Protection and Ministry of Sustainable Resource Management.

A. Lewis. 2002. Rationale for Multiple British Columbia Instream Flow Standards to Maintain Ecosystem Function and Biodiversity. Draft for Agency Review. Prepared for Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

Resources Information Standards Committee: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/inventory-standards

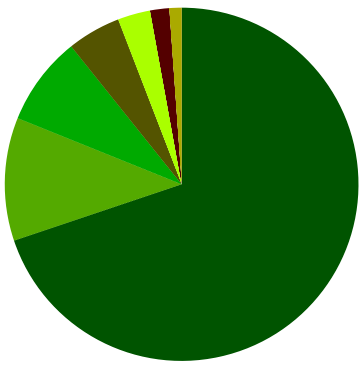
Water Policies, including Environmental Flow Needs: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies

Land Cover and Topography

Characteristics of the query watershed. For more information on watershed characterization in British Columbia please refer to Pike and Wilford (2013).

Land Cover

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

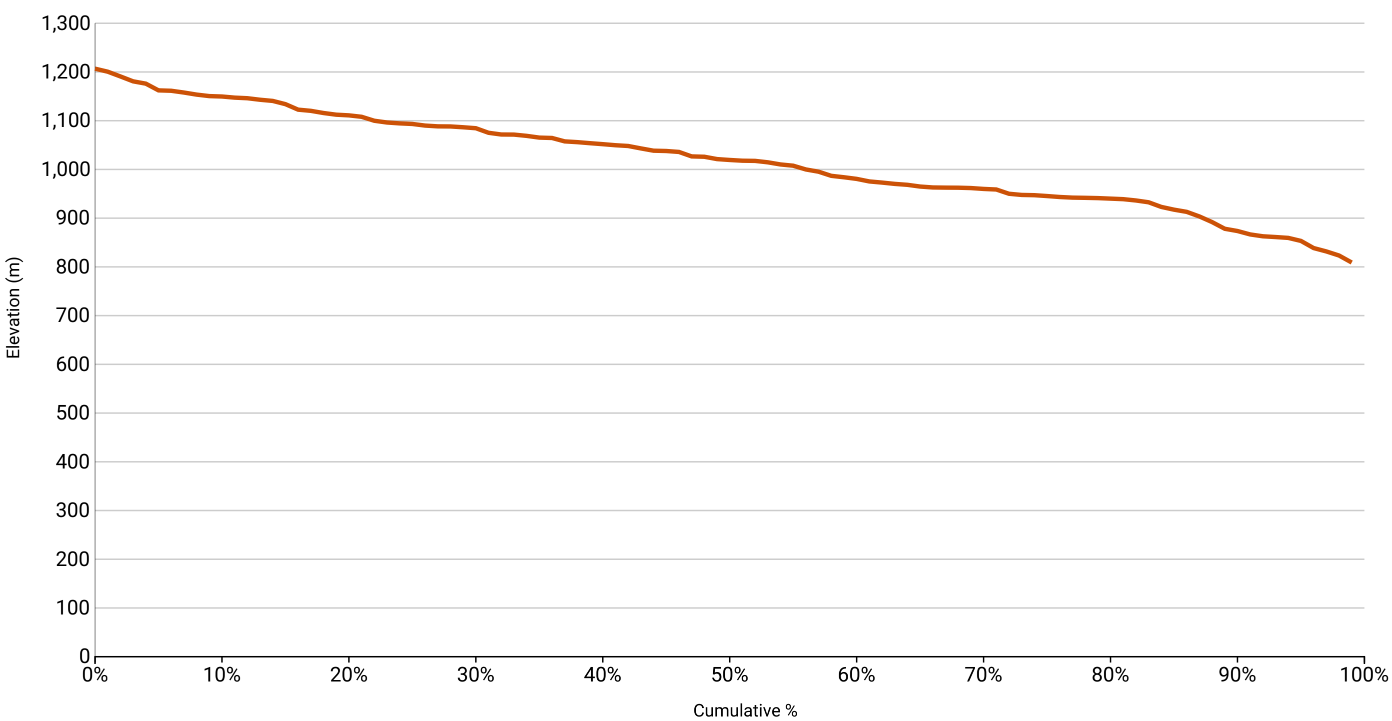


Type	Area (km²)	% of Query Watershed (%)
Barren	0.3	1.7
Coniferous	13.1	69.8
Deciduous	2.1	11.3
Developed	0.0	0.0
Grassland	0.0	0.0
Herb	1.5	8.2
Mixed	0.9	4.9
Shrub	0.6	3.0
Snow / Glacier	0.0	0.0
Water	0.0	0.0
Wetland	0.2	1.1

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

Topography

Elevation of the query watershed influences hydrology in a number of ways. The amount, and state of precipitation (as rain or snow) is influenced by elevation substantially. Likewise, temperatures will vary by elevation in value and also direction of temperature gradient throughout the course of the year.



The elevation characteristics of the query watershed are shown using a hypsometric curve, which shows the cumulative distribution of elevation by area in the watershed. Percent values can be used to identify the percentage of the watershed above a given elevation value.

Reference:
Pike, R.G. and D.J. Wilford. 2013. Desktop watershed characterization methods for British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 079. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr079.htm.

Climate

Historic normal conditions and predicted future change.

The climate of the query watershed has been characterized using ClimateWNA (Wang 2012). In the left hand column, charts are presented for the reference time period 1961-1990. In the right hand column, three illustrative climate change scenarios have been selected to estimate a wide range of potential future change in the query watershed (Murdock and Spittlehouse 2011).

Scenario A illustrates the UKMO HadGEM A1B run 1 global climate model (GCM), scenario B shows the CGCM3 A2 run 4 GCM and scenario C shows the UKMO HadCM3 B1 run 1 GCM. The combination of these three climate models and emissions scenarios were chosen because, over most of British Columbia, they provide a range of generally hot/dry, warm/very wet, and moderately warm/wet for HadGEM A1B, CGCM3 A2, and HadCM3 B1 respectively.

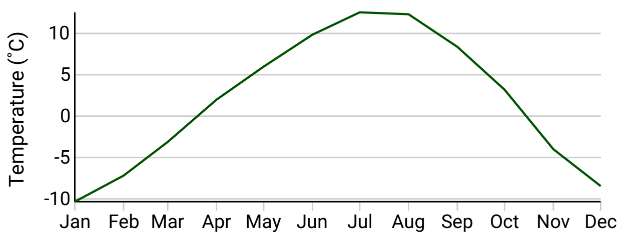
Historic and future climate change information has been provided to assist in understanding potential changes in the basin as temperature and precipitation are intricately related to stream flow. For example, snowpack levels affect many aspects of water resources, from instream flows for fish to community water supplies to soil moisture, groundwater, and aquifer recharge. Climate studies generally indicate a trend of rising air temperatures for all seasons across BC while precipitation trends vary by season and region (Pike *et al.* 2008, Rodenhuis *et al.* 2007). Local responses to changing precipitation and temperature will differ due to BC's inherent hydrological diversity as well as varying climate trends. These charts are intended as a quick glance starting point to basin climate change assessment.

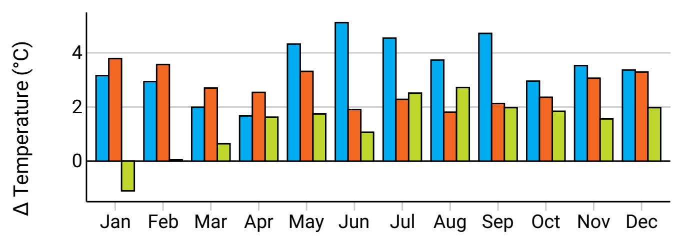
Normal (1961 - 1990)

Predicted Change (2041 - 2070)

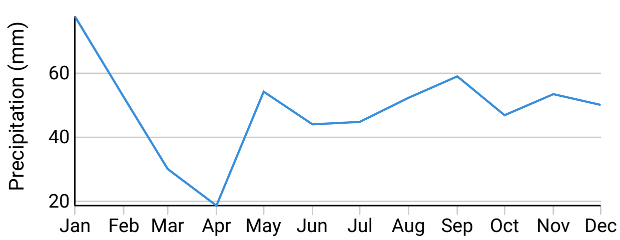
Scenario A   Scenario B   Scenario C

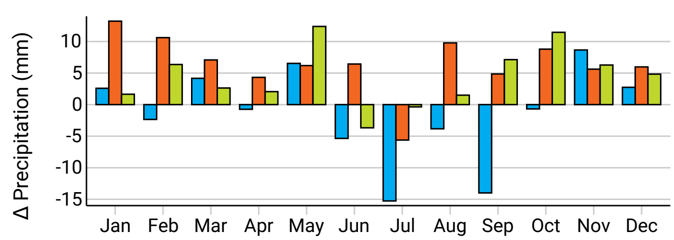
Monthly temperatures are presented as averages of the monthly mean temperature for the query basin as a whole. Projected changes in temperature may affect the hydrology in the watershed by influencing the time of freeze and thaw, evapotranspiration rates, form of precipitation, and vegetation composition, among other factors.



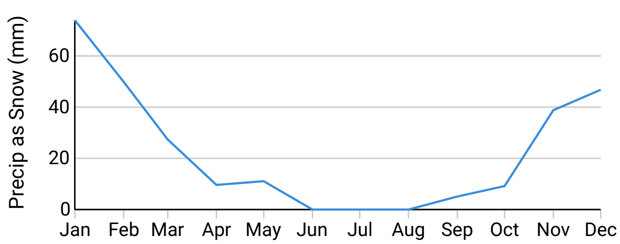


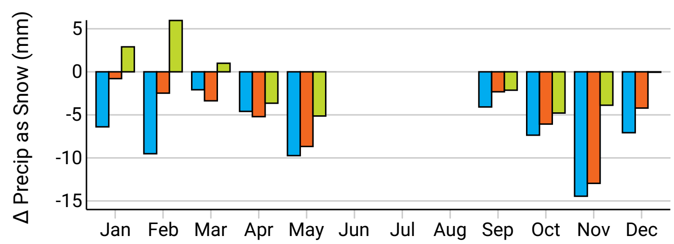
The precipitation in the query watershed is shown as an average unit precipitation for the watershed. Changes in precipitation timing and amount may affect the hydrology in the watershed by influencing the timing and magnitude of peak and low flow conditions. These changes may affect availability of water for environmental flow needs and human use, and modify the physical characteristics of river channels and associated needs for engineered structures.





Precipitation as snow in the query watershed is presented as an average unit precipitation for the query basin as a whole. Changes in the amount of precipitation as snow may affect winter snowpack volumes and associated melt related hydrology in the spring. An increase in rain-on-snow events may be associated with elevated natural hazard risk from avalanche or other slope stability failures.





References

Murdock, T.Q., Spittlehouse, D.L. 2011. Selecting and Using Climate Change Scenarios for British Columbia. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC. http://www.pacificclimate.org/sites/default/files/publications/Murdock.ScenariosGuidance.Dec2011.pdf

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate Change and Watershed Hydrology: Part I - Recent and Projected Changes in British Columbia. Streamline, Watershed Management Bulletin 11-2 8-13. http://www.pacificclimate.org/sites/default/files/publications/Pike.StreamlineHydrologyPartI.Apr2008.pdf

Rodenhuis, D., K.E. Bennett, A. Werner, T.Q. Murdock, and D. Bronaugh. 2007. Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium. http://www.pacificclimate.org/sites/default/files/publications/Rodenhuis.ClimateOverview.Mar2009.pdf

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.

Northwest Water Tool Report

Dec 4 2018

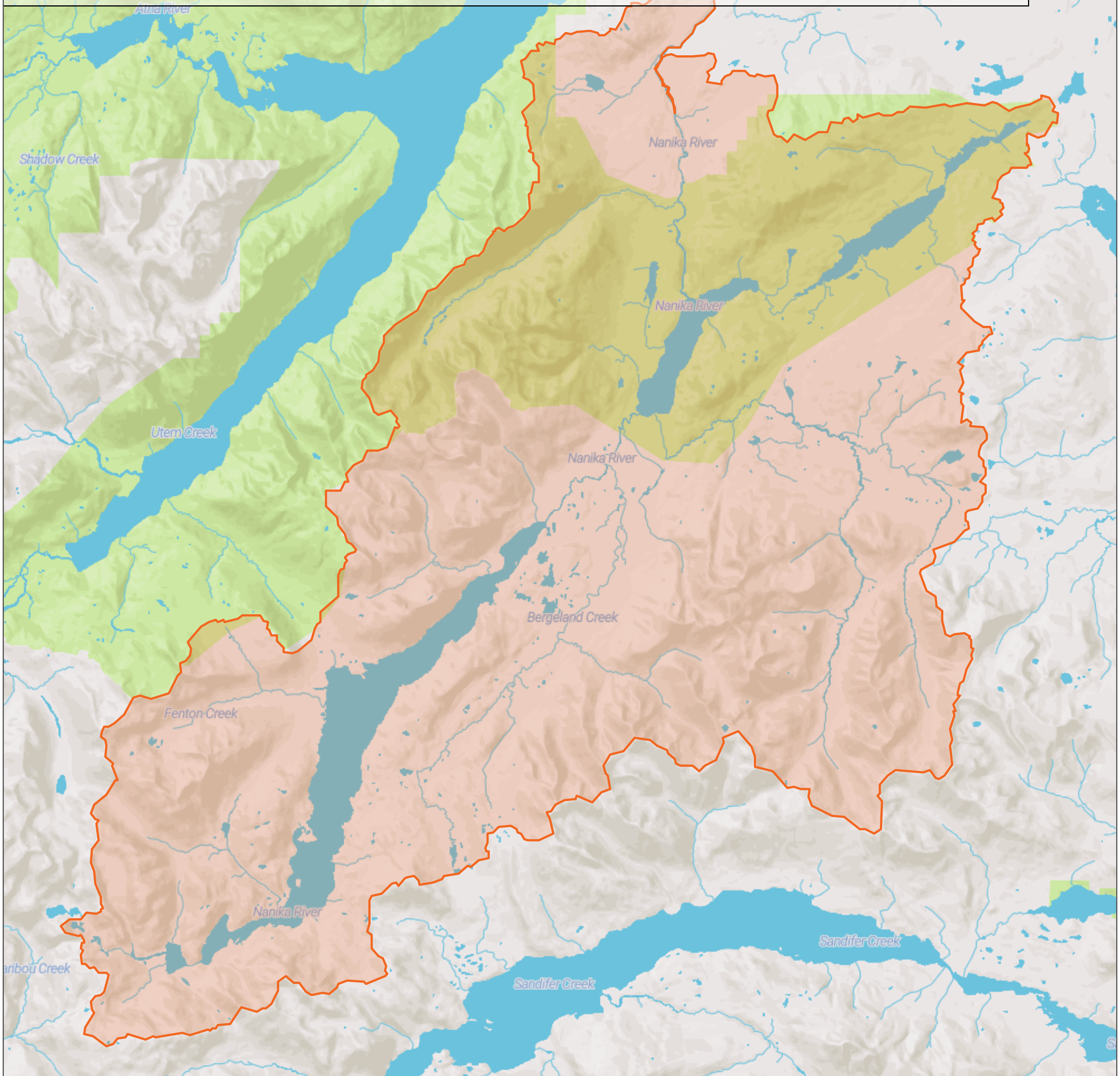
Nanika River

- Morice River
- Bulkley River
- Skeena River
- Pacific Ocean

54.04733N 127.42732W
Query Location

840.7
Area (km²)

876 - 1,311 - 2,334
Elevation (m)
min - mean - max



Disclaimer

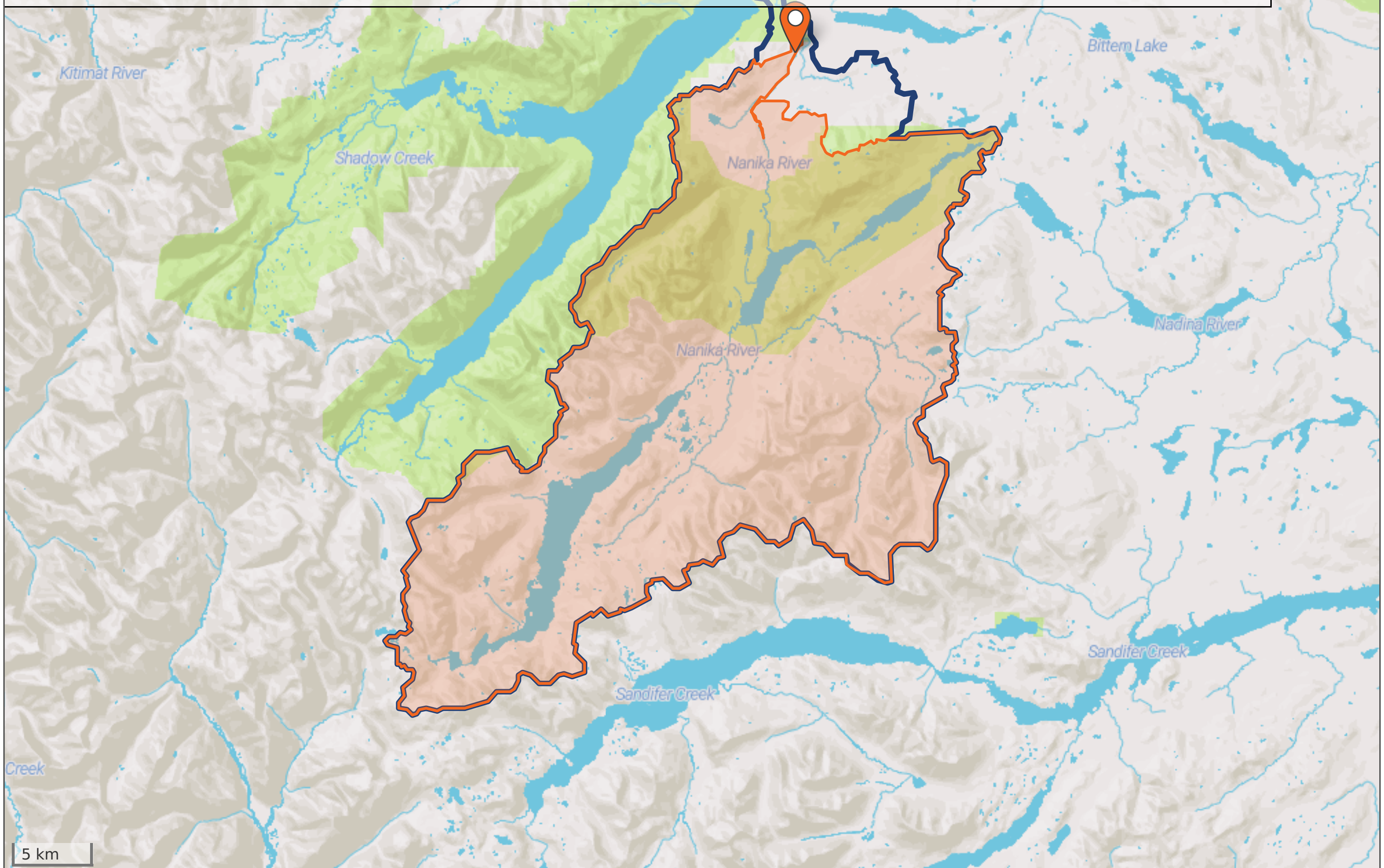
The Northwest Water Tool (NWWT) has been developed and placed on this website by the Ministry of Forests, Lands and Natural Resource Operations and Rural Development of British Columbia for the convenience of industry and the public. Information relating to NWWT is believed to be representative, but technical inaccuracies and uncertainties may occur. NWWT carries no guarantee of any kind, express or implied. The Ministry accepts no liability or blame for loss or damages incurred by any person or business entity based on the use of NWWT.

British Columbia | Ministry of Forests, Lands, Natural Resource Operations and Rural Development

3 km

Hydrology - Annual

The map shows the query and downstream watersheds. The table below provides an overview of hydrology and existing allocations in these watersheds.



Query Watershed		Downstream Watershed
840.7	Area (km²)	889.7
31.567	Mean Annual Discharge (m³/s)	32.018
0.000	Allocations (m³/s)	0.142
0.0	Allocations (%)	0.4
Present*	Reserves & Restrictions	Present*
996,152,964	Volume Runoff (m³/yr)	1,010,403,733
0	Volume Allocations (m³/yr)	4,481,179
Winter	Seasonal Flow Sensitivity**	Winter

The downstream watershed is defined at the location where the queried drainage meets with another drainage of comparable size. For information further downstream, please generate an additional report at a location of interest. Predictions for small watersheds (generally smaller than 50 sq. km.) may be less accurate due to the lack of hydrometric data available for watersheds of this size.

* For more information on water reserves or restrictions present in the watershed, please visit the links below or contact FrontCounter BC.

FrontCounter BC: www.frontcounterbc.ca **Email:** FrontCounterBC@gov.bc.ca **Toll Free:** 1-877-855-3222 **Outside North America:** ++1-778-372-0729

Water Reservations: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-reservations

Water Restrictions: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-allocation-restrictions

**Ptolemy, R. Environmental Flow Protection in British Columbia. Presentation to 2015 IFC Panel, April 29, 2015.

Hydrology - Monthly Nanika River

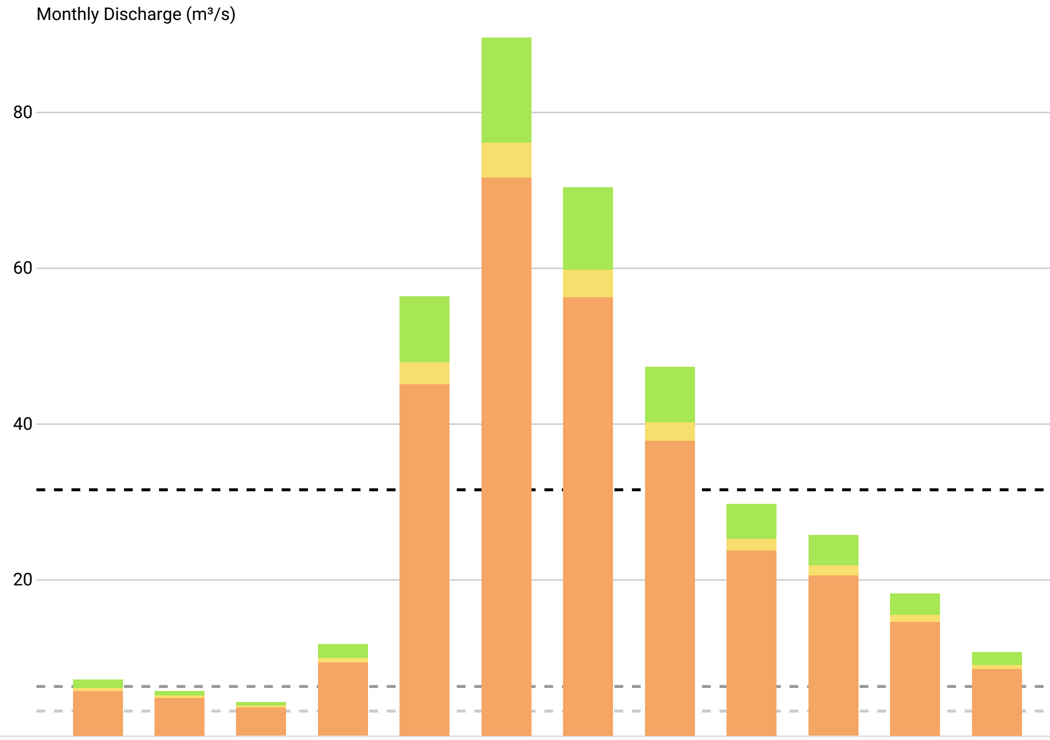
The chart and table show information on modeled hydrology and existing allocations in the query watershed. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy.*

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	31.567 m³/s
20% MAD	6.313 m³/s
10% MAD	3.157 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	7.197	5.751	4.292	11.747	56.432	89.609	70.404	47.339	29.754	25.749	18.245	10.731
% of MAD	22.8%	18.2%	13.6%	37.2%	178.8%	283.9%	223.0%	150.0%	94.3%	81.6%	57.8%	34.0%
Flow Sensitivity	Low	Mod	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Potential Allocation (m³/s, Risk Mgmt 1)	1.079	0.575	0.429	1.762	8.465	13.441	10.561	7.101	4.463	3.862	2.737	1.610
Potential Allocation (m³/s, Risk Mgmt 2)	1.439	0.863	0.644	2.349	11.286	17.922	14.081	9.468	5.951	5.150	3.649	2.146
Potential Allocation (m³/s, Risk Mgmt 3)	>1.439	>0.863	>0.644	>2.349	>11.286	>17.922	>14.081	>9.468	>5.951	>5.150	>3.649	>2.146

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Hydrology - Monthly Nanika River

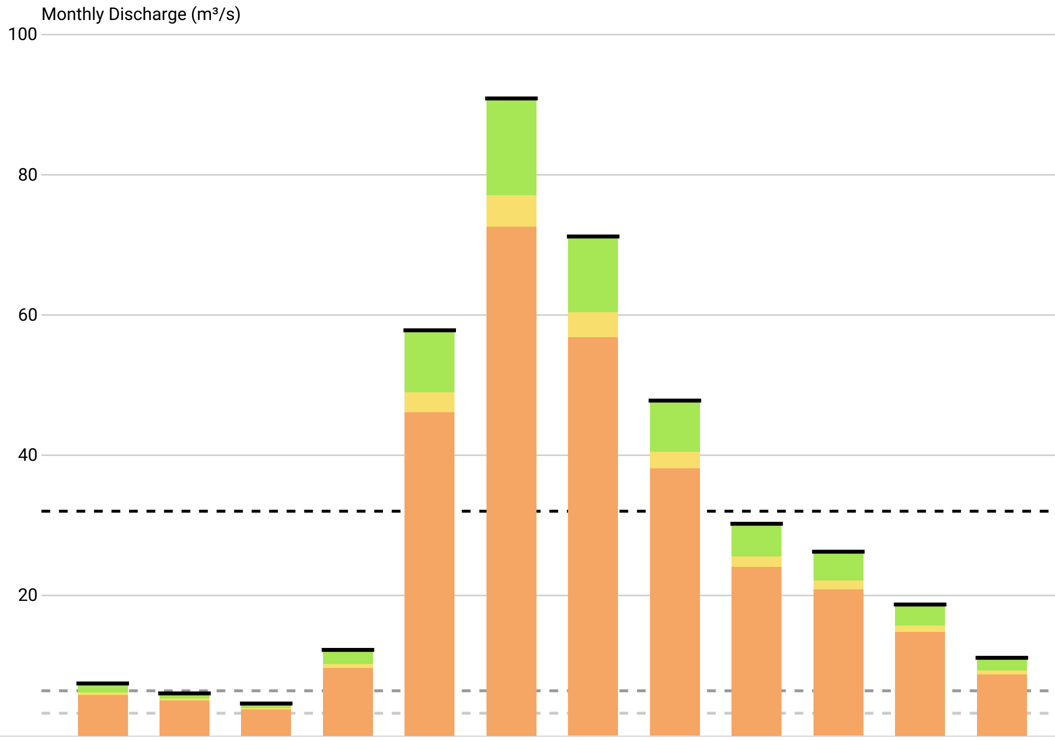
The chart and table show information on modeled hydrology and existing allocations in the downstream watershed, where the subject drainage meets with another drainage of comparable size. Notes are provided at the bottom on data sources, methods, and interpretation. Environmental flow needs risk levels are as defined in the Province of BC *Environmental Flow Needs Policy*.

Legend

- Risk Management Level 1
- Risk Management Level 2
- Risk Management Level 3
- Existing Allocations

Mean Annual Discharge (MAD)

MAD	32.018 m³/s
20% MAD	6.404 m³/s
10% MAD	3.202 m³/s



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Discharge (m³/s)	7.308	5.894	4.444	12.099	57.684	90.759	71.068	47.661	30.090	26.106	18.568	10.970
% of MAD	22.8%	18.4%	13.9%	37.8%	180.2%	283.5%	222.0%	148.9%	94.0%	81.5%	58.0%	34.3%
Flow Sensitivity	Low	Mod	Mod	Low	Low	Low	Low	Low	Low	Low	Low	Low
Existing Allocations (m³/s)	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142	0.142
Potential Allocation (m³/s, Risk Mgmt 1)	0.954	0.447	0.302	1.673	8.511	13.472	10.518	7.007	4.372	3.774	2.643	1.504
Potential Allocation (m³/s, Risk Mgmt 2)	1.320	0.742	0.525	2.278	11.395	18.010	14.072	9.390	5.876	5.079	3.572	2.052
Potential Allocation (m³/s, Risk Mgmt 3)	>1.320	>0.742	>0.525	>2.278	>11.395	>18.010	>14.072	>9.390	>5.876	>5.079	>3.572	>2.052

Methods: Monthly discharge estimates have been generated from a hydrologic model. Existing allocation volumes have been summarized from government water licence and short term approval databases. Potential allocations are determined using criteria established in the Province of BC *Environmental Flow Needs* (EFN) Policy. Risk management levels have been calculated assuming the presence of fish. If the source can be classified as non-fish bearing, this may affect risk management levels. For more information on the EFN policy: *https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies/environmental-flow-needs*

Risk Management Levels: The Province of BC Environmental Flow Needs Policy establishes risk management levels to be used in the evaluation of applications for water rights. Risk Management Levels and associated Risk Management Measures are discussed on page 5 of this report.

Error: The query watershed is within the Skeena Region. The hydrologic modeling study conducted in this region employed a water balance approach to estimate runoff in ungauged basins. The model was calibrated using stream flow measurements from the Water Survey of Canada, and validated using a leave-one-out cross validation. The model used 123 watersheds with hydrometric gauges, and included detailed information on watershed climate, evapotranspiration, topography, vegetation and land cover. Error metrics calculated for the entire model domain are: Mean error = -2.8%, Median Error = -4.2%, Mean Absolute Error = 13.9%, Watersheds within +/- 20% = 80.5%.

Allocations: Existing allocation volumes are determined from digital databases and include *BC Water Sustainability Act* licences and short term approvals. These represent a maximum amount of water authorized, not actual use. In many cases, licences may have additional terms and conditions to those represented in the digital version which are not represented. This may result in existing allocation volumes being presented as larger than are actually approved, either in total (on an annual basis) or for individual months. On subsequent pages of this report, information on each licence occurring in the watershed is provided, along with links to scanned copies of complete water licence information. For more information on specific areas of concern, please contact Water Stewardship Staff via FrontCounter BC. Contact information for FrontCounter BC is provided on page 2 of this report.

Risk Management Levels and Measures

Guide to interpreting potential allocation amounts in each environmental flow needs risk level as defined in the Province of BC *Environmental Flow Needs Policy.*

Water volumes presented as "Potential Allocations" within this report are determined in consideration of the Province of BC *Environmental Flow Needs Policy*. Within the Policy, risk management measures are suggested to assess or mitigate potential effects of withdrawals from a stream, and provide an ecosystem perspective on environmental flow needs. The measures are associated with risk levels 1, 2, and 3 and are intended to guide where more caution may be needed in reviewing an application or making a decision.

Where there are known species or habitat sensitivities, more detailed, site-specific studies may be required. Where detailed assessments or studies exist, they will supersede policy recommendations.

Risk management levels, for assessing new applications to withdraw water, are determined for each month using the relationship of mean monthly flows to the mean annual discharge, and also using a stream size threshold based on mean annual flows. The calculations presented within this report assume all streams are fish-bearing. Where no water is indicated as available under a risk level, the stream may be very flow sensitive during that time, or the stream may have existing allocations in excess of the relevant threshold.

Inter-annual hydrologic variability may affect the amount of water available in a given year. The impact of this variability on water allocations should be considered separately from the information presented in this report.

The following risk management measures may be appropriate for consideration before a decision is made, could be completed by regional staff to inform a decision, or could be a condition of the licence or approval.

Risk management measures may differ for short-term approvals vs. licences and may vary in relation to withdrawal amounts.

Risk Management Level: 1

Measures to assess or mitigate potential effects on low sensitivity flow periods:

1. Assess veracity of information and ensure appropriate methods are used, (e.g., RISC)
2. Consider downstream users and species/habitats

Risk Management Level: 2

Measures to assess or mitigate potential effects on moderate sensitivity flow periods:

In addition to Level 1 measures:

1. Establish adequate baseline hydrological data before withdrawals
2. Prepare reconnaissance-level fish and fish habitat impact assessment (e.g., Section 4.1.10.1 in Lewis et al. 2004)
3. Issue seasonal licence, or restrictions during low flow periods
4. Development of off-stream storage
5. Inclusion of a daily maximum or inst. withdrawal e.g., greater consideration of instantaneous demand over averages
6. Limit pump intake size
7. Monitor and report water use during higher risk flow periods, e.g., install flow gauge
8. Monitor low flows and limit withdrawals when flows drop below a certain level
9. Ministry staff to conduct audit of basin use/beneficial use review
10. Refuse application to withdraw water

Risk Management Level: 3

Measures to assess or mitigate potential effects on high sensitivity flow periods:

In addition to Level 2 measures:

1. Issue limited licence term, allowing for review and potential adjustment (e.g., 5 years)
2. Prepare detailed habitat assessment (e.g., Lewis et al. 2004; Hatfield et al. 2007)

References

Hatfield, T., A. Lewis, and S. Babakaiff. 2007. Guidelines for the collection and analysis of fish and fish habitat data for the purpose of assessing impacts from small hydropower projects in British Columbia.

Lewis, A., T. Hatfield, B. Chilibeck, and C. Roberts. 2004. Assessment methods for aquatic habitat and instream flow characteristics in support of applications to dam, divert, or extract water from streams in British Columbia. Prepared for Ministry of Water, Land & Air Protection and Ministry of Sustainable Resource Management.

A. Lewis. 2002. Rationale for Multiple British Columbia Instream Flow Standards to Maintain Ecosystem Function and Biodiversity. Draft for Agency Review. Prepared for Ministry of Water, Land and Air Protection and Ministry of Sustainable Resource Management.

Resources Information Standards Committee: https://www2.gov.bc.ca/gov/content/environment/natural-resource-stewardship/natural-resource-standards-and-guidance/inventory-standards

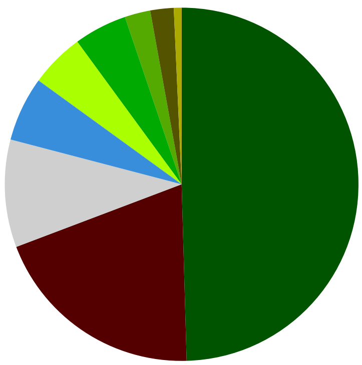
Water Policies, including Environmental Flow Needs: https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/water-licensing-rights/water-policies

Land Cover and Topography

Characteristics of the query watershed. For more information on watershed characterization in British Columbia please refer to Pike and Wilford (2013).

Land Cover

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

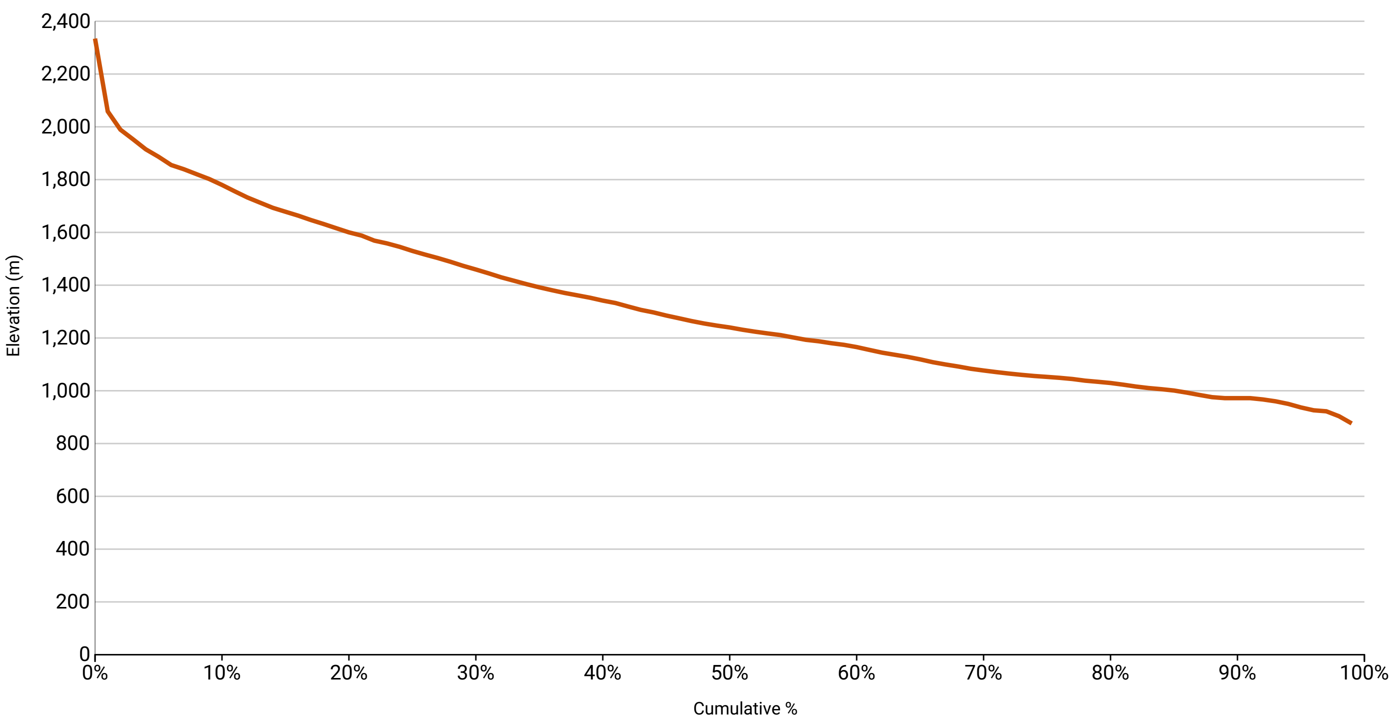


Type	Area (km²)	% of Query Watershed (%)
Barren	165.5	19.7
Coniferous	416.6	49.5
Deciduous	19.8	2.3
Developed	0.0	0.0
Grassland	0.0	0.0
Herb	40.8	4.8
Mixed	18.0	2.1
Shrub	41.7	5.0
Snow / Glacier	82.8	9.9
Water	49.8	5.9
Wetland	5.9	0.7

The land cover characteristics chart illustrates the composition of vegetation and land cover types in the query watershed. These land cover components are incorporated in the hydrologic model, to represent the variations in evapotranspiration rates amongst the classes.

Topography

Elevation of the query watershed influences hydrology in a number of ways. The amount, and state of precipitation (as rain or snow) is influenced by elevation substantially. Likewise, temperatures will vary by elevation in value and also direction of temperature gradient throughout the course of the year.



The elevation characteristics of the query watershed are shown using a hypsometric curve, which shows the cumulative distribution of elevation by area in the watershed. Percent values can be used to identify the percentage of the watershed above a given elevation value.

Reference:
Pike, R.G. and D.J. Wilford. 2013. Desktop watershed characterization methods for British Columbia. Prov. B.C., Victoria, B.C. Tech. Rep. 079. www.for.gov.bc.ca/hfd/pubs/Docs/Tr/Tr079.htm.

Climate

Historic normal conditions and predicted future change.

The climate of the query watershed has been characterized using ClimateWNA (Wang 2012). In the left hand column, charts are presented for the reference time period 1961-1990. In the right hand column, three illustrative climate change scenarios have been selected to estimate a wide range of potential future change in the query watershed (Murdock and Spittlehouse 2011).

Scenario A illustrates the UKMO HadGEM A1B run 1 global climate model (GCM), scenario B shows the CGCM3 A2 run 4 GCM and scenario C shows the UKMO HadCM3 B1 run 1 GCM. The combination of these three climate models and emissions scenarios were chosen because, over most of British Columbia, they provide a range of generally hot/dry, warm/very wet, and moderately warm/wet for HadGEM A1B, CGCM3 A2, and HadCM3 B1 respectively.

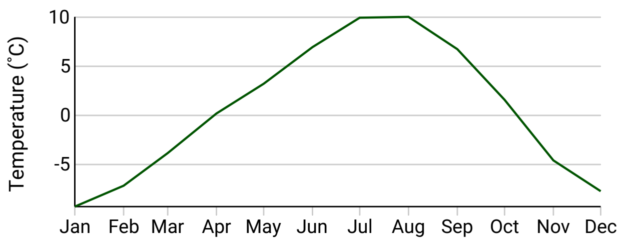
Historic and future climate change information has been provided to assist in understanding potential changes in the basin as temperature and precipitation are intricately related to stream flow. For example, snowpack levels affect many aspects of water resources, from instream flows for fish to community water supplies to soil moisture, groundwater, and aquifer recharge. Climate studies generally indicate a trend of rising air temperatures for all seasons across BC while precipitation trends vary by season and region (Pike *et al.* 2008, Rodenhuis *et al.* 2007). Local responses to changing precipitation and temperature will differ due to BC's inherent hydrological diversity as well as varying climate trends. These charts are intended as a quick glance starting point to basin climate change assessment.

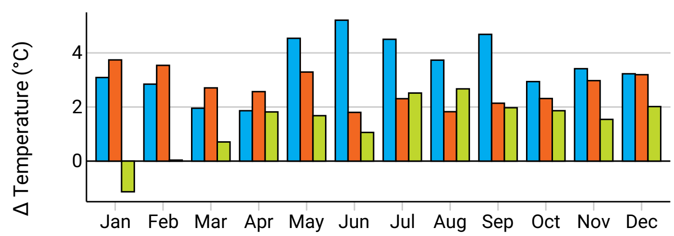
Normal (1961 - 1990)

Predicted Change (2041 - 2070)

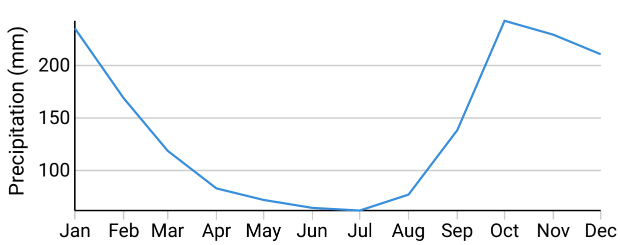
Scenario A   Scenario B   Scenario C

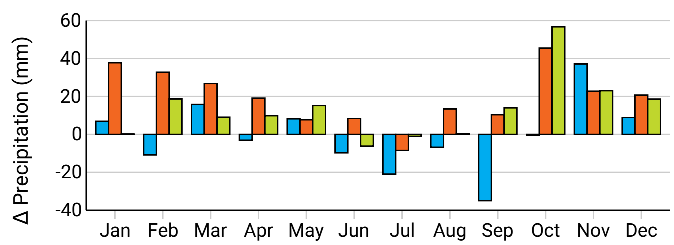
Monthly temperatures are presented as averages of the monthly mean temperature for the query basin as a whole. Projected changes in temperature may affect the hydrology in the watershed by influencing the time of freeze and thaw, evapotranspiration rates, form of precipitation, and vegetation composition, among other factors.



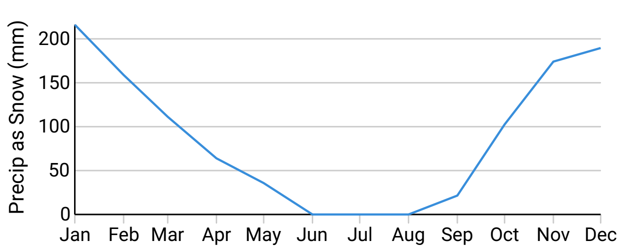


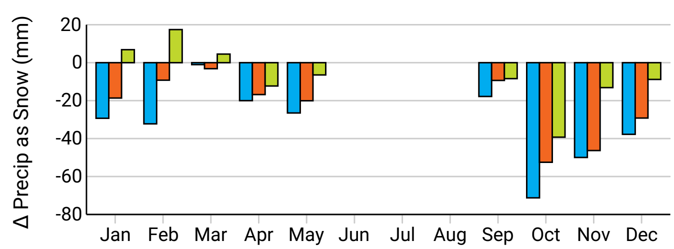
The precipitation in the query watershed is shown as an average unit precipitation for the watershed. Changes in precipitation timing and amount may affect the hydrology in the watershed by influencing the timing and magnitude of peak and low flow conditions. These changes may affect availability of water for environmental flow needs and human use, and modify the physical characteristics of river channels and associated needs for engineered structures.





Precipitation as snow in the query watershed is presented as an average unit precipitation for the query basin as a whole. Changes in the amount of precipitation as snow may affect winter snowpack volumes and associated melt related hydrology in the spring. An increase in rain-on-snow events may be associated with elevated natural hazard risk from avalanche or other slope stability failures.





References

Murdock, T.Q., Spittlehouse, D.L. 2011. Selecting and Using Climate Change Scenarios for British Columbia. Pacific Climate Impacts Consortium, University of Victoria, Victoria, BC. http://www.pacificclimate.org/sites/default/files/publications/Murdock.ScenariosGuidance.Dec2011.pdf

Pike, R.G., D.L. Spittlehouse, K.E. Bennett, V.N. Egginton, P.J. Tschaplinski, T.Q. Murdock, and A.T. Werner. 2008. Climate Change and Watershed Hydrology: Part I - Recent and Projected Changes in British Columbia. Streamline, Watershed Management Bulletin 11-2 8-13. http://www.pacificclimate.org/sites/default/files/publications/Pike.StreamlineHydrologyPartI.Apr2008.pdf

Rodenhuis, D., K.E. Bennett, A. Werner, T.Q. Murdock, and D. Bronaugh. 2007. Hydro-climatology and future climate impacts in British Columbia. Pacific Climate Impacts Consortium. http://www.pacificclimate.org/sites/default/files/publications/Rodenhuis.ClimateOverview.Mar2009.pdf

Wang, T., Hamann, A., Spittlehouse, D., and Murdock, T. N. 2012. ClimateWNA – High-resolution spatial climate data for western North America. Journal of Applied Meteorology and Climatology 61: 16-29.