BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT



HYDROMETEOROLOGY ANALYSIS REPORT

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VA101-640/6-4
Rev 0
June 6, 2018

Knight Piésold
CONSULTING
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Rev	Description	Date
0	Issued in Final	June 6, 2018

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EXECUTIVE SUMMARY

BMC Minerals (No.1) Ltd. (BMC) is proposing to develop the Kudz Ze Kayah (KZK) Project, a polymetallic mining project located approximately 110 km southeast of Ross River, Yukon Territory.

The Project is located in the Yukon Plateau North Ecoregion, near the border of the Pelly Mountains Ecoregion. Mean annual air temperature in the valleys of the Yukon Plateau North Ecoregion is approximately -5 °C, with mean January temperatures of -30 °C and mean July temperatures of 15 °C. Precipitation in the region ranges from approximately 300 mm in the Tintina Tench rain shadow, up to 600 mm over higher terrain near the Selwyn Mountains. Precipitation is relatively low through the winter, with the most precipitation falling in summer (July to September), either due to frontal systems or intense convective events. The annual streamflow hydrograph in small watersheds shows a strong snowmelt freshet peak, but similarly high flows also occur in summer due to rainfall. Intense rainstorms often generate peak flows.

BMC's KZK Project Proposal is currently undergoing a Screening Assessment by the Yukon Environmental and Socioeconomic Assessment Board's (YESAB) Executive Committee, under the *Yukon Environmental and Socioeconomic Assessment Act* (*YESAA*). During the Adequacy stage of the Assessment, YESAB requested that BMC submit a number of updated water related reports, prior to YESAB preparing the draft Screening Report. Subsequently, the 2015-2017 Hydrometeorology Baseline Report was prepared by Alexco Environmental Group (AEG). AEG's report presents hydrology and climate data collected at the KZK Project site, including data collected during 2017, and regional datasets collected by Environment and Climate Change Canada (ECCC). These data are analysed in this report to provide long-term estimates of average and extreme hydrometeorology conditions at the Project site, which are suitable to support engineering and environmental assessments of the proposed Project.

The key findings of this study are summarized below.

Climate

All values below are given for the Kudz Ze Kayah climate station (elevation 1,542 masl):

- The long-term mean annual temperature is estimated to be -2.8°C, with minimum and maximum mean monthly temperatures estimated to be -12.9°C and 9.9°C in December and July, respectively.
- The long-term mean annual precipitation (MAP) is estimated to be 520 mm. This value is less than values previously estimated for the site, but is supported by site and regional datasests, and the Baseline Watershed Model analysis, which integrates precipitation, losses (e.g. evapotranspiration) and streamflow to generate a consistent hydrologic cycle at the Project site.
- Precipitation at the site is split between rain and snow, with approximately 37% of it estimated to fall as snow, on average.
- The 24 hour 100 year, 200 year, and probable maximum precipitation (PMP) values are estimated to be 89 mm, 95 mm, and 274 mm, respectively.
- The 1 in 10 year wet annual precipitation is estimated to be 646 mm, and the 1 in 10 year dry annual precipitation is estimated to be 394 mm.

Hydrology

- Measured streamflow records for seven hydrology stations (operated in the Project area since 2015) indicate annual mean unit discharge values ranging from less than 5 L/s/km² (158 mm) up to 20 L/s/km² (630 mm), depending on catchment cover and surficial geology, location, elevation and windblown snow redistribution. Instantaneous flow measurements were collected at six other sites, and these data were considered in developing an overall understanding of the site hydrological conditions.
- Flows recorded in the 2015-2016 hydrologic year are significantly lower than those recorded during the 2016-2017 hydrologic year, which is consistent with the precipitation totals for those two periods. Precipitation during 2016-2017 appears to be above average.
- The annual hydrograph is bimodal, with the lowest flows occurring during the winter, and the peak flows occurring during the spring freshet and summer periods, due to snowmelt and rainfall, respectively.
- Long-term Project specific synthetic flow series will be developed for a number of locations using a Baseline Watershed Model, and is currently being developed.
- Peak flows for the Project area typically occur during the spring and early summer freshet period as a result of snowmelt, or combined rainfall and snowmelt events. However, rainfall generated peak flows due to convective storms are also common during summer months.
- Project flood estimates were developed, following the procedure outlined in Design Flood Estimating Guidelines for the Yukon Territory. This procedure presents an envelope curve for estimating peak discharges. To validate the regional model for the Project site, peak flows were calculated for recent, proximal ECCC station data. The envelope curve, with an additional 15% climate change adjustment factor as recommended by APEGBC (2012), is used to develop design flood estimates for watersheds larger than approximately 10 km^2. For smaller watersheds, rainfall-runoff modelling will be used to predict peak flow conditions.

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ABBREVIATIONS

Project	Kudz Ze Kayah Project
AET	Actual Evapotranspiration
AEG	Alexco Environmental Group Inc.
APEGBC	Association of Professional Engineers and Geoscientists of British Columbia
BMC	BMC Minerals (No. 1) Ltd.
°C	Degrees Celsius
CN	Curve Number
ECCC	Environment and Climate Change Canada
IDF	Intensity-Duration-Frequency
km	Kilometre
KP	Knight Piésold Ltd.
L/s/km²	Liters per Second per Square Kilometre
MAD	Mean Annual Discharge
MAP	Mean Annual Precipitation
MAT	Mean Annual Temperature
MAUD	Mean Annual Unit Discharge
masl	Metres above Sea Level
m/s	Metres per Second
m³/s	Cubic Metres per Second
PMF	Probable Maximum Flood
PMP	Probable Maximum Precipitation
SCS	Soil Conservation Service
SWE	Snow Water Equivalent
tpd	Tonnes per day
T_c	Time of concentration
WSC	Water Survey of Canada
YCS -WFM	Yukon Community Services – Wildland Fire Management
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board

GLOSSARY

Adiabatic cooling: when a parcel of air rises, the atmospheric pressure reduces and the volume of the parcel of air increases, thus reducing the temperature of the air.

Gauge Undercatch: a correction factor applied to the data collected by a precipitation gauge to account for wind undercatch, evaporation, and gauge specific wetting losses.

Evapotranspiration: the process by which water is transferred from the land to the atmosphere by evaporation from land and water surfaces and by transpiration from plants.

Potential Evapotranspiration: the amount of evapotranspiration that would occur given an infinite supply of water from a crop surface.

Sublimation: the process of snow and ice changing into water vapor in the air without first melting into a liquid.

Yukon Environmental and Socio-economic Assessment Board: an independent body, responsible for implementation of the assessment responsibilities under the *Yukon Environmental and Socio-economic Assessment Act*.

1 – INTRODUCTION

1.1 PROJECT DESCRIPTION

BMC Minerals (No.1) Ltd. (BMC) is currently proposing to develop the Kudz Ze Kayah Project (the Project), a copper-zinc-lead mine. The Project is located in the Saint Cyr Range area of the Pelly Mountains approximately 250 km northeast of Whitehorse, Yukon Territory, Canada. The Project location is shown on Figure 1.1.

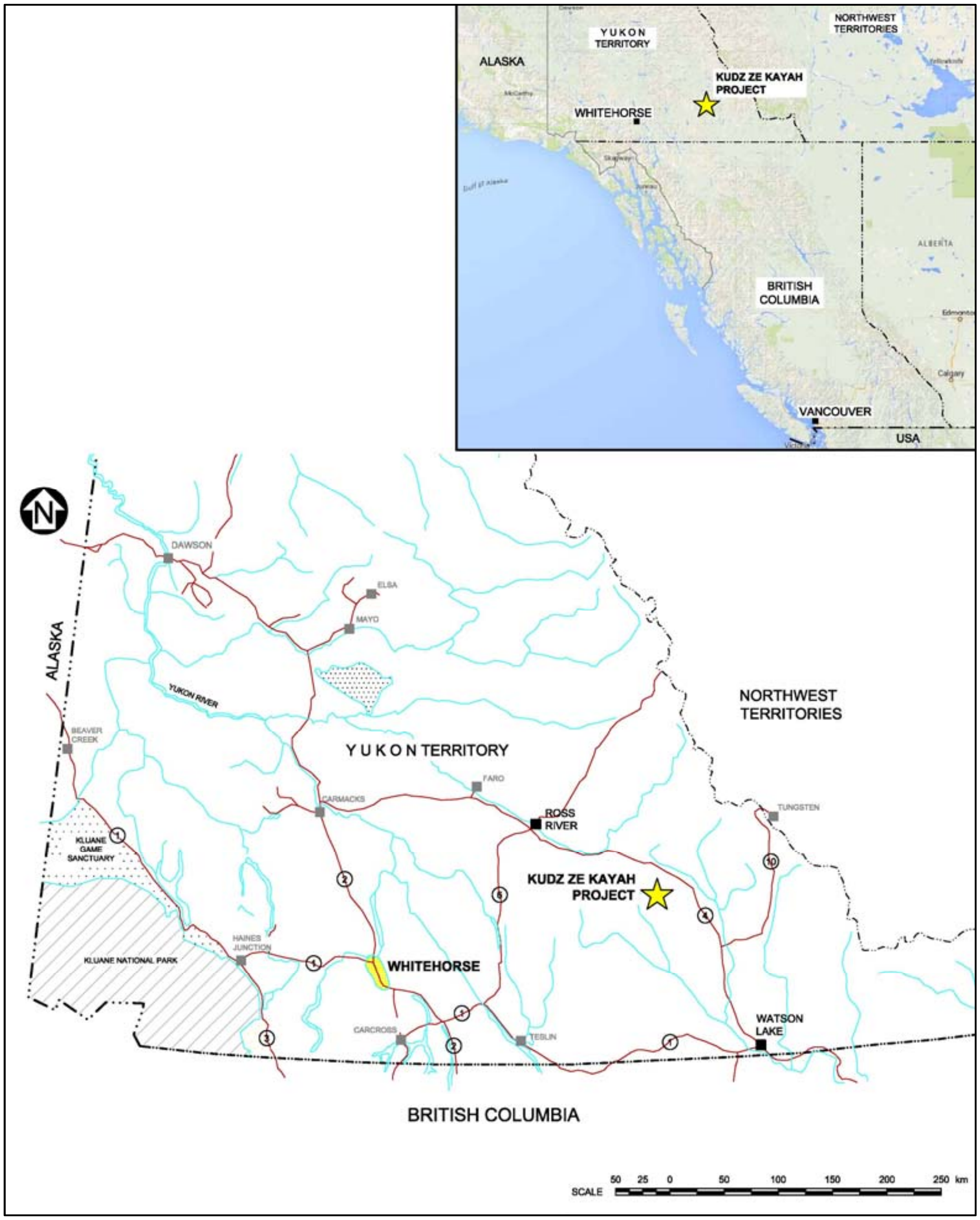


Figure 1.1 Project Location

Development of the proposed Project will be by open pit and underground mining methods at a process plant throughput rate of a nominal 5,500 tonnes per day (tpd) over an approximately 10 year mine life.

1.2 PREVIOUS STUDIES

The Project Proposal (BMC, 2017) included the 2015-2016 Hydrometeorology Report (AEG, 2016) as Appendix D-2 of the submission. In order to address YESAB Screening requests, this report has been revised and separated into two documents. The first document is the 2015-2017 Hydrometeorology Baseline Report, prepared by Alexco Environmental Group (AEG). AEG's report presents hydrology and climate data collected at the KZK Project site, including data collected during 2017, and regional datasets collected by Environment and Climate Change Canada (ECCC). The second document is the Hydrometeorology Analysis Report (this report), prepared by Knight Piesold Ltd. (KP). KP uses the data presented by AEG to provide long-term estimates of average and extreme hydrometeorology conditions at the Project site, which are suitable to support engineering and environmental assessments of the proposed Project.

The 2015-2017 Hydrometeorology Baseline Report (AEG, 2018) is attached to this report as Appendix A.

1.3 SCOPE OF REPORT

1.3.1 General

This report provides climatic and hydrological characterizations for the Project site, which are presented in terms of expected long-term climatic and hydrologic conditions at the site. Average monthly and annual values are presented, along with statistical analyses of wet, dry and extreme conditions. The report integrates and analyses data collected at the Project site with regional data from ECCC, Environment Yukon, and Water Survey of Canada (WSC). Other data sources such as Yukon Community Services – Wildland Fire Management and Yukon Zinc Corporation are considered, where appropriate.

1.3.2 Climatology

One climate station – Kudz Ze Kayah, along with three snow course survey stations – Baseline Low, Mid and High, were installed to collect site specific climate data for the Project. The collected climate data are described in detail in Appendix A. The meteorological assessment of conditions in the study area is primarily based on the two-year (2015-2017) record collected at Kudz Ze Kayah and is supported by a 1995 record collected at two historical climate stations, which are identified as the Low Elevation/Camp, and High Elevation stations. The site specific data were used in conjunction with data from several regional stations with longer records to develop long-term Project-specific records, as discussed in Section 2 of this report.

1.3.3 Hydrology

Seven continuously recording hydrology stations have been, or are currently, active in the Project area. The station history, rating curve, and discharge hydrograph for each hydrology station are presented in Appendix A. The hydrological assessment of conditions in the Project area is based primarily on data from these seven site stations, which generally have the longest and most complete records. Discrete discharge data from six additional stations and data collected during 1995 are utilized to support the analysis, as appropriate. Long-term Project specific synthetic flow series will be developed with a Site Wide Watershed Model (KP, In progress).

2 – CLIMATOLOGY

2.1 INTRODUCTION

The Project is located in the Yukon Plateau North Ecoregion, near the boarder of the Pelly Mountains Ecoregion. Mean annual air temperature in the valleys of the Yukon Plateau North Ecoregion region is approximately -5 °C, with mean January temperatures of -30 °C and mean July temperatures of 15 °C. During summer, temperatures typically decrease with increasing elevation (due to adiabatic cooling); however, during winter, temperatures often increase with elevation as cold, dense air flows into the valleys (known as an inversion). Extreme temperatures in the region range from -62 to 36 °C. Precipitation in the region ranges from approximately 300 mm in the Tintina Tench rain shadow, up to 600 mm over higher terrain near the Selwyn Mountains. Typically, July and August are the wettest months, as both frontal and convective weather systems occur during these periods (Smith et. al., 2004).

The spatial distributions of precipitation and temperature, as predicted by the Climate WNA (Western North America) model for the period from 1961 to 1990 (Wang et. al. 2016), are shown on Figures 2.1 and 2.2, respectively. This model indicates that both Faro and Ross River are in the Tintina Trench rain shadow. Precipitation at the Project site is higher than at these stations, but likely not as high as in areas on the windward side of the northern Cassiar Ranges. The Climate WNA model also suggests that mean annual temperature in the region decreases slightly with elevation, and that the mean annual temperature at the Project site is likely colder than at Faro or Ross River, but not significantly, presumably due to the effect of winter temperature inversions.

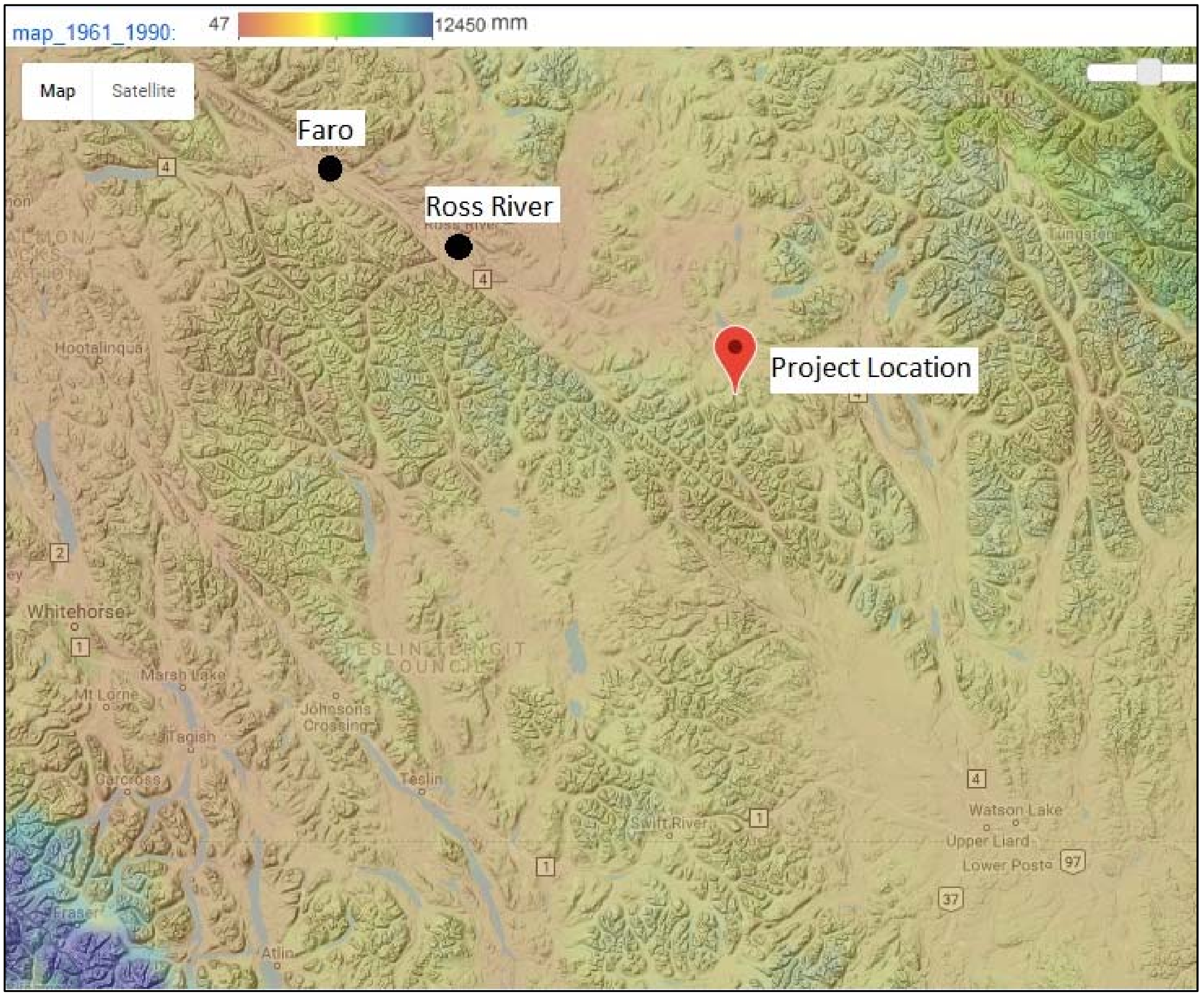


Figure 2.1 Mean Annual Precipitation Spatial Variability (Wang et. al., 2016)

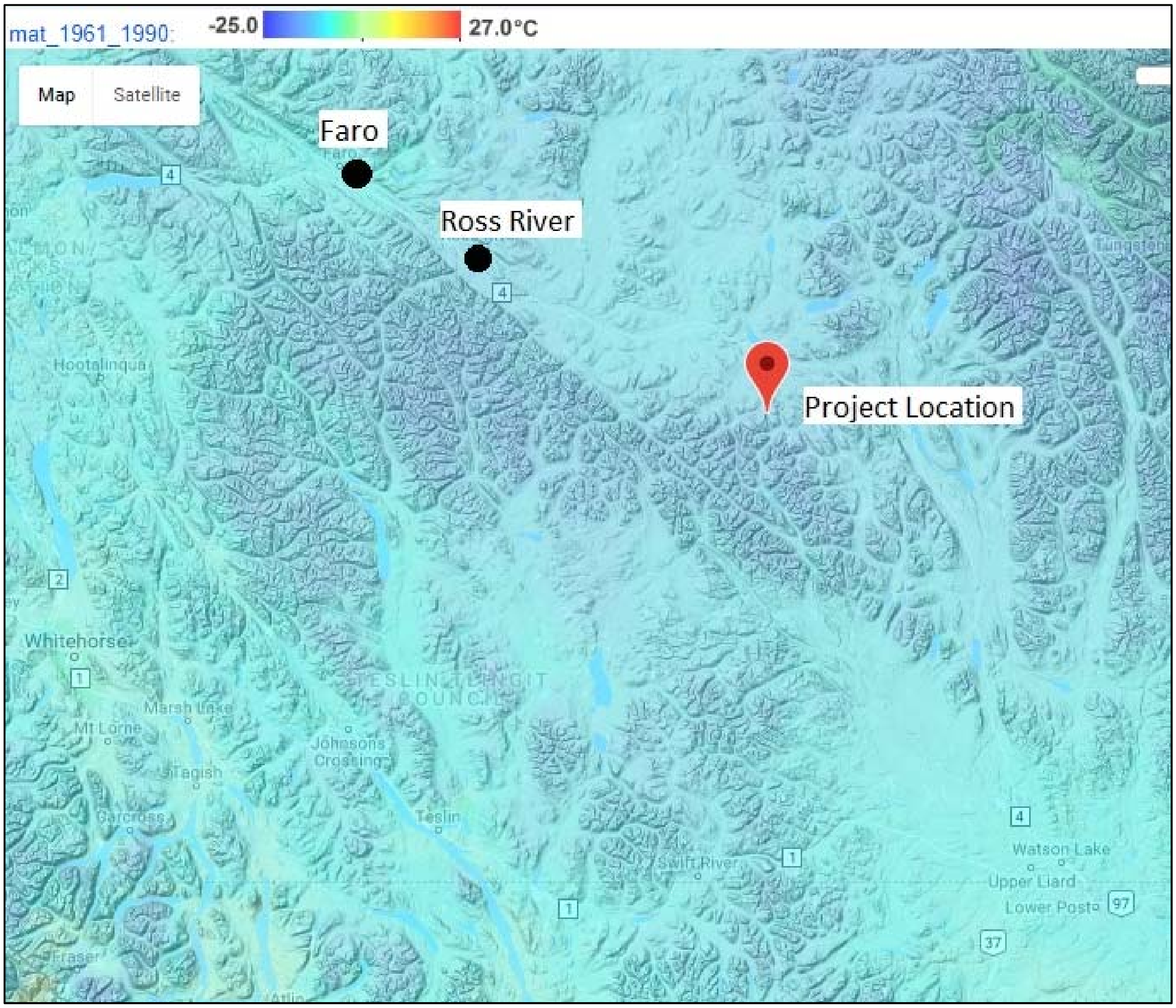


Figure 2.2 Mean Annual Temperature Spatial Variability (Wang et. al., 2016)

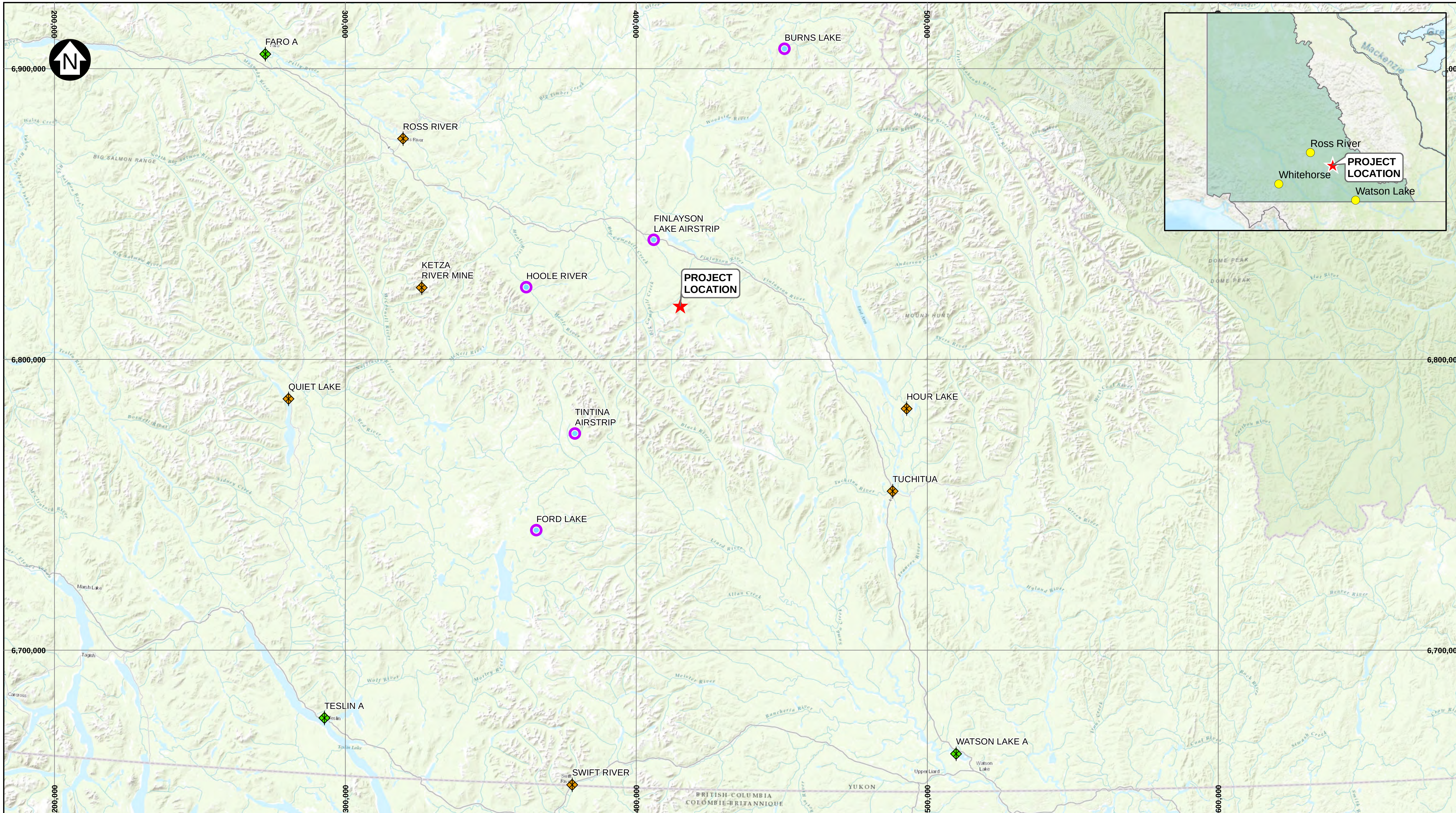
2.2 REGIONAL CLIMATE STATIONS

There are several ECCC climate stations that are either operating or were operated in the general Project area. There are also several climate stations operated by other organizations including Yukon Community Services – Wildland Fire Management (YCS -WFM) and Yukon Zinc Corporation (at their Wolverine Mine). Section 2 of the 2015-2017 Hydrometeorology Baseline report (Appendix A), provides a comprehensive summary of the available regional climate data. Key details of proximal stations are summarized in Table 2.1 and the locations of the regional climate and snow course survey stations are shown on Figure 2.3.

Table 2.1 Regional Climate and Snow Course Stations

Station Type	Station Name	Station ID.	Elevation (m)	Distance from Project (km)	Period of Record	Active or Inactive
Climate [1]	Hour Lake	2100FCG	890	83	1982-2015	Inactive
	Tuchitua	2101135	726	97	1967-2014	Inactive
	Ketza River Mine	210FPP	1,380	90	1985-1995	Inactive
	Swift River	2101081	889	167	1966-2008	Inactive
	Teslin A	2101100	705	183	1943-2014	Inactive
		2101102			1992-2018	Active
	Quiet Lake	2100910	815	137	1966-1992	Inactive
	Ross River A	2100940	705	114	1961-1994	Inactive
	Ross River YTG	2100941	698		1993-2008	Inactive
	Watson Lake A	2101200	687	178	1938-2014	Inactive
		2101204			2005-2018	Active
	Faro	2100516	695	172	1972-1977	Inactive
		2100517	716		1977-2015	Inactive
		2100518			1992-2018	Active
Snow Course [2]	Hoole River	09BA-SC03	1,036	52	1977-2018	Active
	Burns Lake	09BA-SC04	1,112	96	1986-2018	Active
	Finlayson Lake Airstrip	09BA-SC05	988	24	1987-2018	Active
	Tintina Airstrip	10AA-SC02	1,067	55	1977-2018	Active
	Ford Lake	10AA-SC04	1,110	90	1987-2018	Active

NOTES:
1. DATA OBTAINED FROM ENVIRONMENT AND CLIMATE CHANGE CANADA.
2. DATA OBTAINED FROM ENVIRONMENT YUKON.



LEGEND:

- PROJECT LOCATION
- ACTIVE CLIMATE STATION
- ACTIVE SNOW SURVEY STATION
- INACTIVE CLIMATE STATION

10 5 0 10 20 30 40 50 km

NOTES:

1. BASE MAP: ESRI ONLINE TOPOGRAPHIC MAP.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 9N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:1,250,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06JUN'18	ISSUED WITH REPORT	KK	KK	ACA

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KUDZ ZE KAYAH PROJECT

REGIONAL CLIMATE STATIONS

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P/A NO.	REF NO.
VA101-640/6	4

FIGURE 2.3 — REV 0

2.3 PROJECT CLIMATE DATA

One climate station is currently installed at the Project. Two climate stations were previously installed in 1995, Kudz Ze Kayah Low and Kudz Ze Kayah High, but have since been decommissioned and only recorded data during that year. Kudz Ze Kayah Low was located just east of Geona Creek adjacent to the proposed overburden stockpile, and Kudz Ze Kayah High was located at the historic Project exploration camp at the head of Geona Creek before being moved to a high elevation location in May 1995. The active Kudz Ze Kayah Climate Station was installed in August 2015 at an elevation of 1,542 masl.

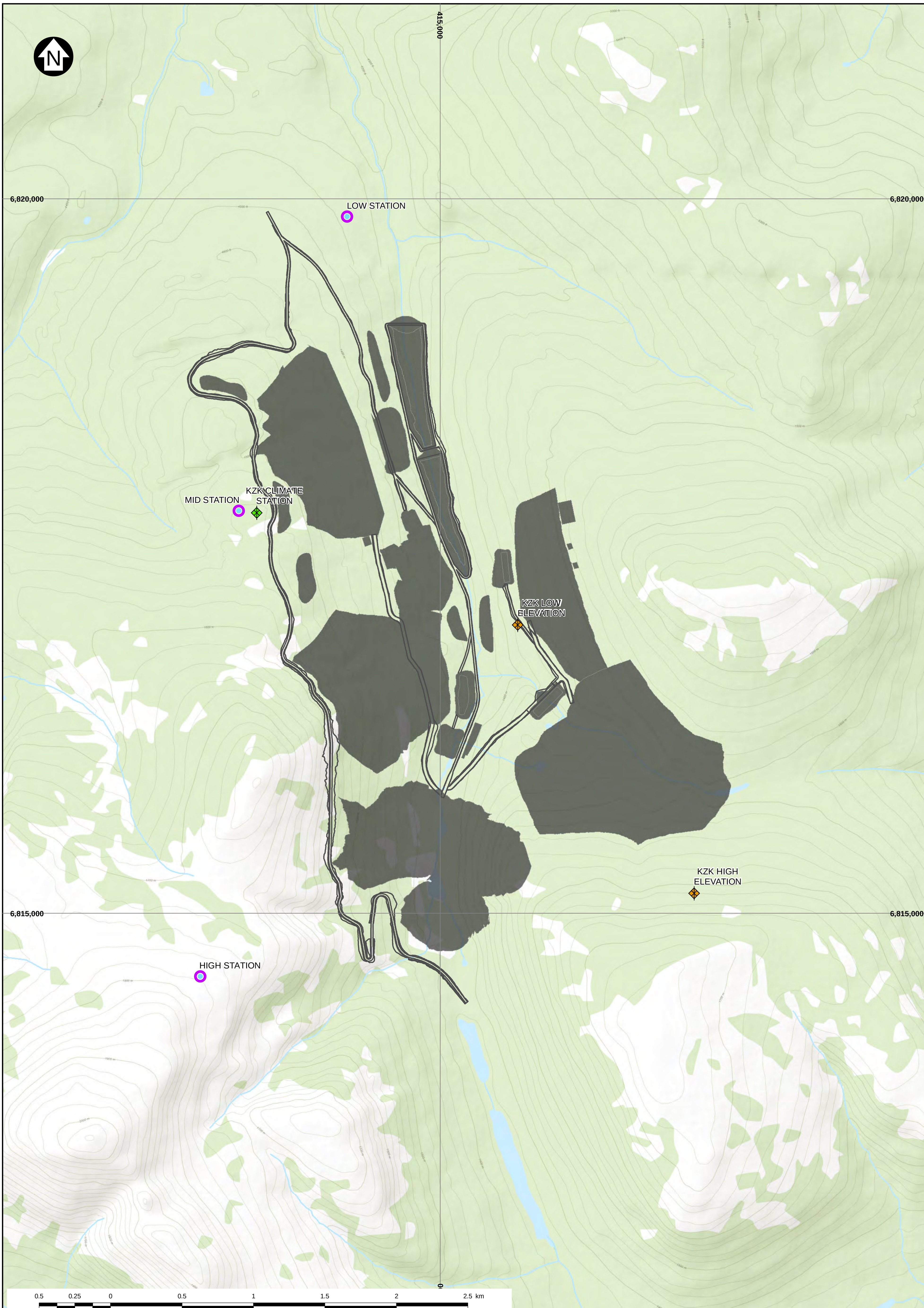
Snow surveys were completed monthly through the 2016 and 2017 winters, at three stations located on east facing slopes at low (1,445 masl), mid (1,519 masl), and high (1,819 masl) elevations. Four additional stations (at mid-elevations ranging from 1,487 masl to 1,551 masl) were also sampled in March of both years, to better characterize peak snowpack variability based on slope and aspect.

Section 2 of the 2015-2017 Hydrometeorology Baseline report (Appendix A) provides a comprehensive summary of the available Project climate data. Key details of the Project climate stations and snow courses are summarized in Table 2.2 and the locations of the both site and regional climate and snow course survey stations are shown on Figure 2.4.

Table 2.2 Project Climate and Snow Course Stations

Station Type	Station Name	Station ID.	Elevation (m)	Period of Record	Active or Inactive
Climate	Kudz Ze Kayah Low Elevation Climate Station	KZK LE[1]	~1,295	1995	Inactive
	Kudz Ze Kayah High Elevation Climate Station	KZK HE[1]	~1,980	1995	Inactive
	Kudz Ze Kayah Climate Station	KZK [2]	1,542	2015-2018	Active
Snow Course [2]	Low Station -		~1,400	1995	Inactive
	Mid Station		~1,500	1995	Inactive
	High Station		~1,600	1995	Inactive
	Low Station	-	1,445	2016-2017	Active
	Mid Station	-	1,519	2016-2017	Active
	High Station	-	1,819	2016-2017	Active

NOTES:
1. DATA OBTAINED FROM AEG (2018). ORIGINAL SOURCE: COMINCO LTD., 1996 (Table 3-2).
2. DATA PROVIDED BY AEG.



LEGEND:

- ACTIVE CLIMATE STATION
- ACTIVE SNOW SURVEY STATION
- INACTIVE CLIMATE STATION
- ProjectCreeks
- PROPOSED INFRASTRUCTURE

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	06JUN'18	ISSUED WITH REPORT	KK	KK	ACA

NOTES:

1. BASE MAP: ESRI ONLINE TOPOGRAPHIC MAP.
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KUDZ ZE KAYAH PROJECT

PROJECT CLIMATE STATIONS

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P/A NO. VA101-640/6 | REF NO. 4

FIGURE 2.4 | REV 0

2.4 AIR TEMPERATURE

Air temperatures are recorded at the KZK Climate Station and monthly summaries of daily average, daily maximum and daily minimum temperatures for the measured period of record are provided in Appendix A. Temperature data was also collected during the spring and summer of 1995 at two climate stations at KZK, the Low Elevation Station and the High Elevation Station (Appendix A).

2.4.1 Estimated Long-term Temperature

In order to develop an estimate of long-term climatic conditions for the Project, concurrent temperature records for the KZK Climate Station and eleven regional climate stations, nine of which are active, were analysed to assess the suitability of the regional climate stations as predictors of air temperature for the Project area. A summary of mean monthly air temperature from KZK and regional climate stations is presented on Figure 2.5.

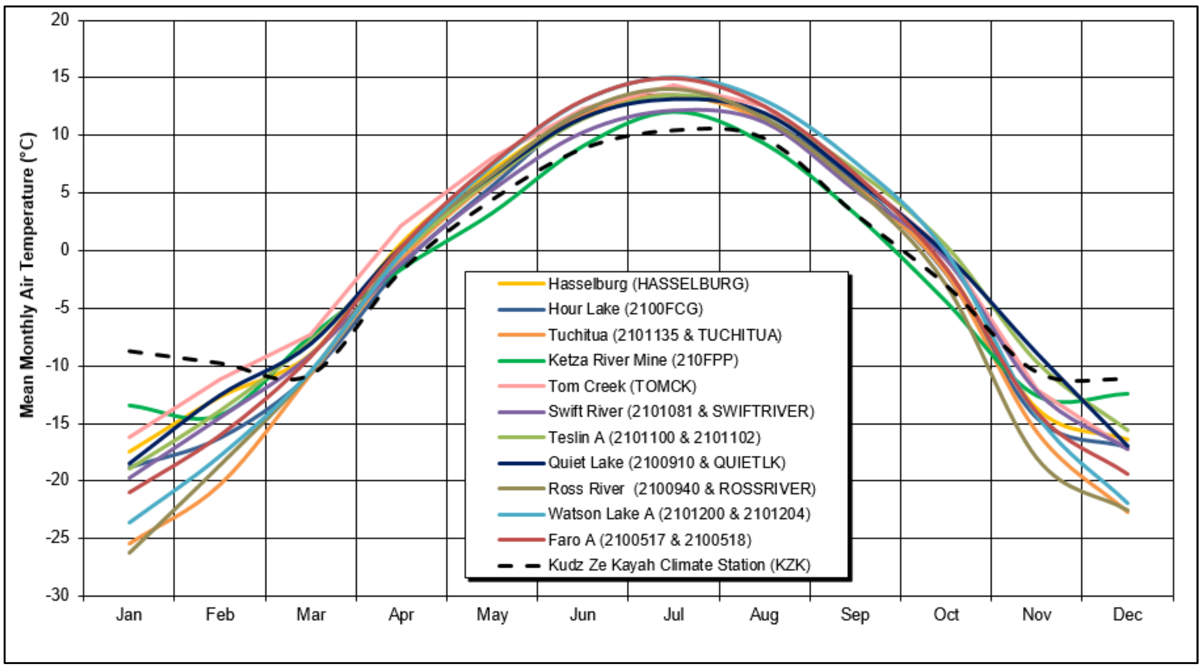


Figure 2.5 KZK and Regional Climate Stations – Mean Monthly Air Temperature

The Faro, Teslin, and Watson Lake regional stations were further investigated as suitable stations based on their locations and available concurrent temperature records. The mean monthly concurrent air temperature from KZK and these three regional climate stations is presented on Figure 2.6. The regional stations are lower elevation that the Project station and have slightly higher temperatures than KZK from April to October and slightly lower temperatures from November to March. This pattern is typical for the region, where summer temperatures typically decrease with increasing elevation (due to adiabatic cooling), but winter temperatures often increase with elevation as cold, dense air flowing into the valleys (Smith et. al., 2004).

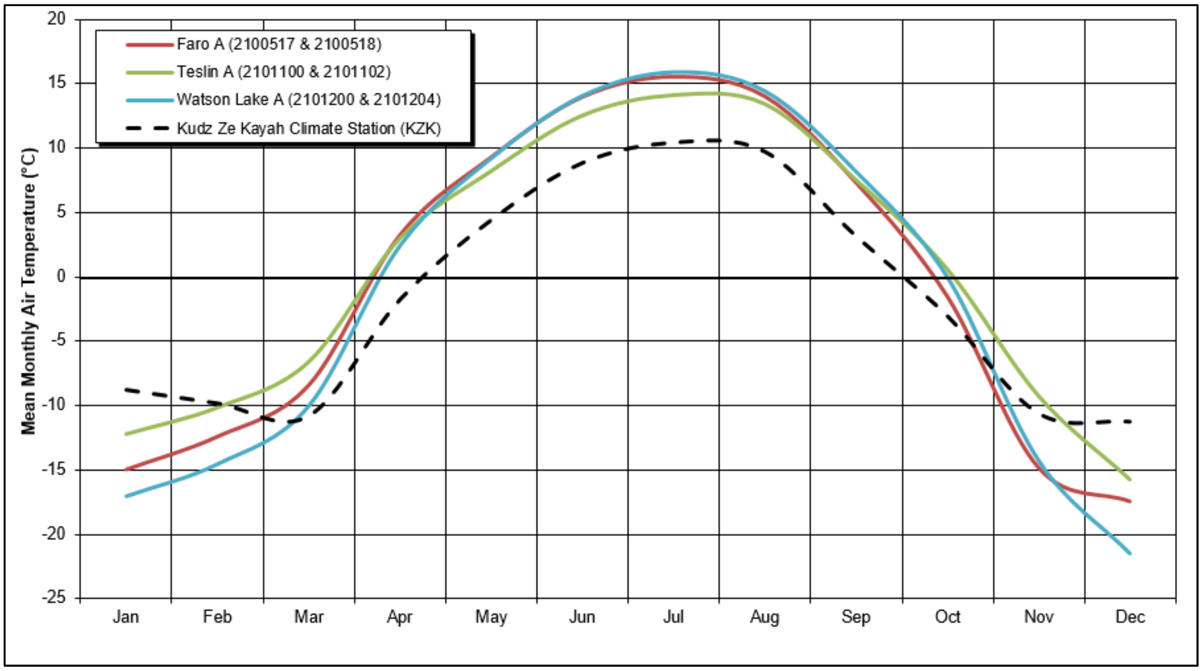


Figure 2.6 KZK and Regional Climate Stations – Concurrent Mean Monthly Air Temperature

The Faro Station was chosen as the most suitable climate station to estimate the long-term temperature for the Project due to its location in a similar geoclimatic zone (Smith et. al., 2004). The Faro Station is about 170 km to the northwest of the Project site at a lower elevation than the KZK Station (716 masl compared to 1,542 masl for KZK).

The concurrent measured air temperature at the KZK and Faro stations is presented on Figure 2.7. This figure indicates that the temperatures at these stations are generally well correlated.

Temperture data collection at Faro (ID: 2100517) started in 1977 and was active until 2015, with 21 complete years of record available. Tempeture data collection at Faro (ID: 2100518) started in 1999 and is currently active with 12 complete years of record available. The combined record has 32 complete years of data.

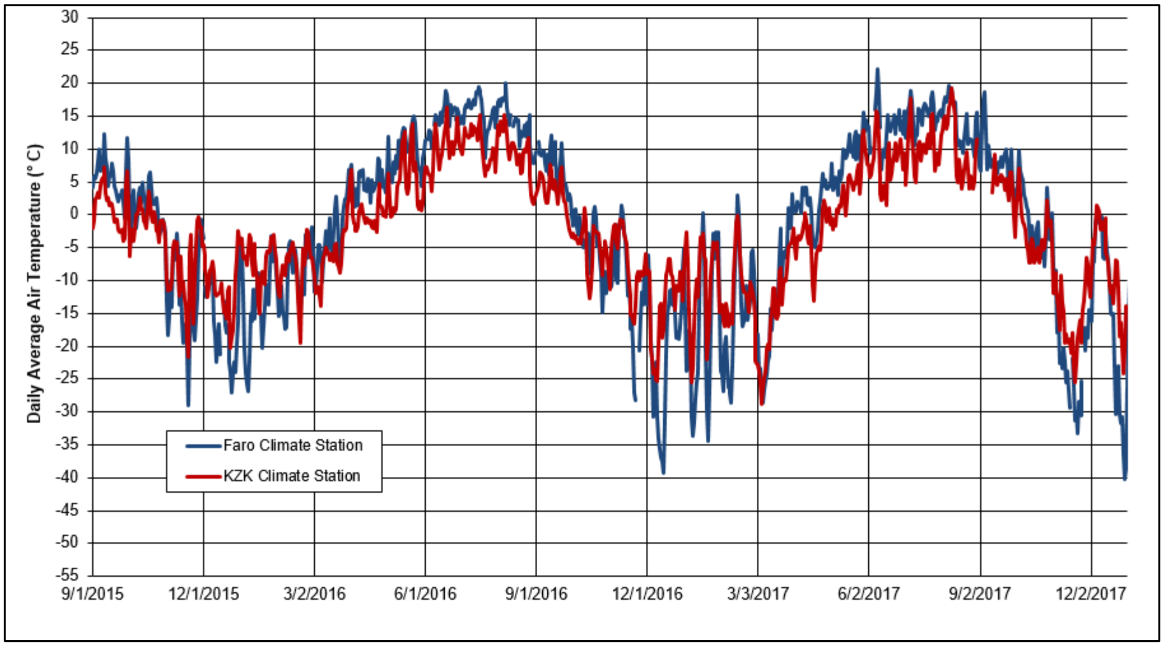


Figure 2.7 KZK and Faro Climate Stations - Concurrent Daily Average Air Temperature

To develop the synthetic long-term KZK temperature series, the concurrent average daily temperature records from the Faro Station and the KZK Station for the period of September 1, 2015 to August 30, 2017 were paired chronologically by month and regression plots were generated. The August regression plot is shown below on Figure 2.8 as an example. Regression equations and R^2 values for all months are shown in Table 2.3.

Table 2.3 Monthly Temperature Correlation Equations – KZK Station versus Faro Station

Month	Regression Equation	R^2 Value
January	y =0.3848* x +-2.9993	0.4151
February	y =0.4962* x +-3.641	0.6052
March	y =0.7963* x +-4.0785	0.9091
April	y =0.9747* x +-4.8885	0.7696
May	y =1.1121* x +-5.8708	0.7406
June	y =1.0429* x +-5.5496	0.6954
July	y =1.0652* x +-6.0653	0.6936
August	y =1.2003* x +-7.1133	0.8293
September	y =0.8833* x +-3.5544	0.7602
October	y =0.5265* x +-1.9826	0.5143
November	y =0.587* x +-1.2782	0.6615
December	y =0.4333* x +-4.5751	0.4200

NOTES:

1. MEAN MONTHLY TEMPERATURE FOR THE PROJECT AREA IS BASED ON THE FOLLOWING EQUATION FORMAT: KZK TEMPERATURE = m * FARO TEMPERATURE + b, WHERE m AND b ARE DEFINED BY MONTH IN THE TABLE.

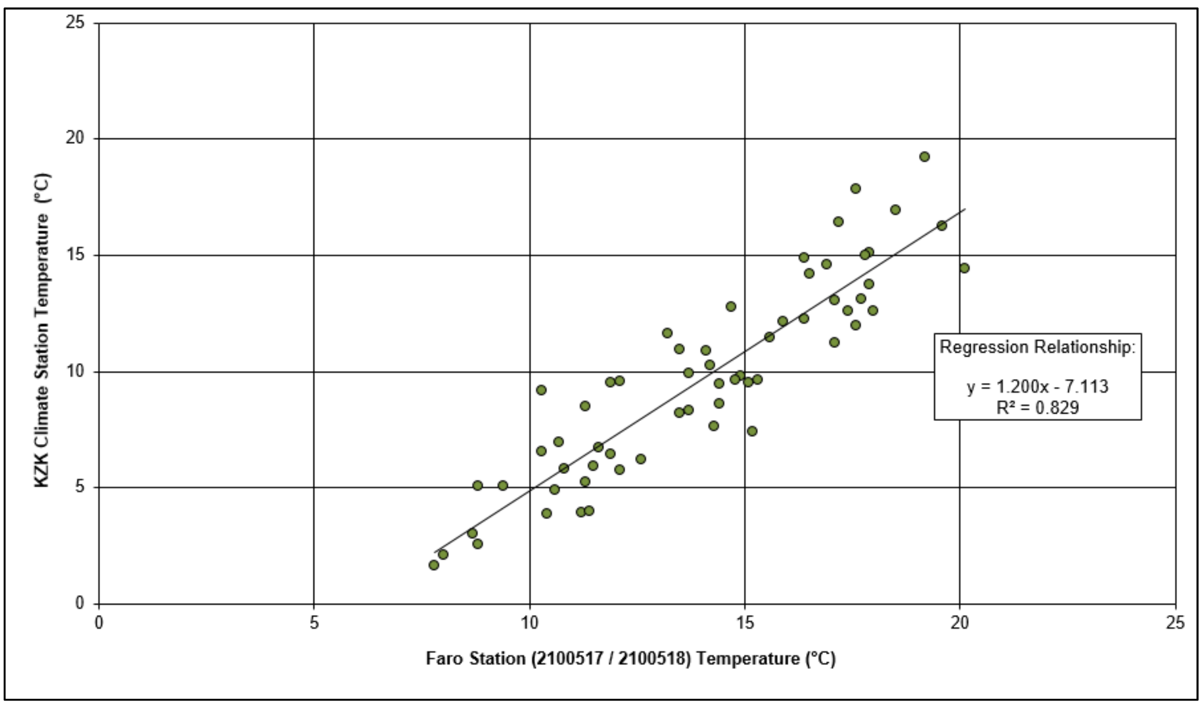


Figure 2.8 Concurrent Daily Average Air Temperature Regression between Faro and KZK Climate Stations - August

The regression relationships presented in Table 2.3 were applied to the long-term Faro record to generate synthetic temperature series, from 1977 to 2017, for the KZK Station. This data series is presented in Appendix B1 and was used to develop long-term mean monthly temperature estimates for the KZK Station, as summarized in Table 2.4 and presented on Figure 2.9. The long-term mean annual temperature (MAT) at the KZK Station is estimated to be -2.8°C, with minimum and maximum mean monthly temperatures estimated to be -12.9°C and 9.9°C in December and July, respectively.

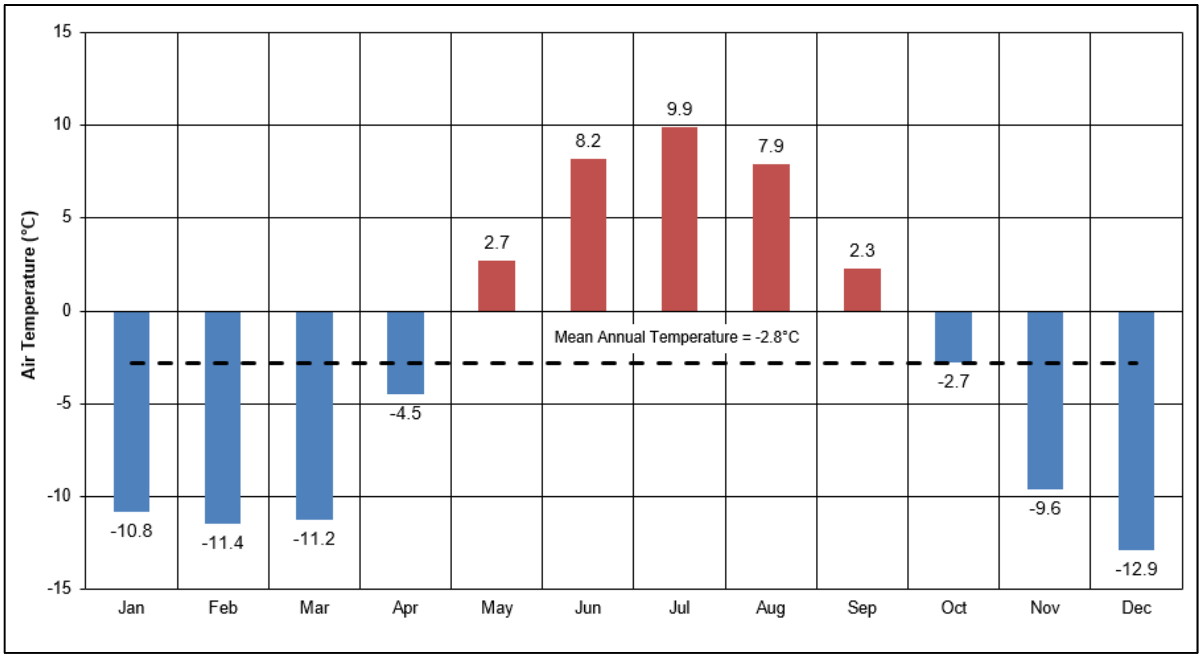


Figure 2.9 Estimated Long-Term Mean Monthly Air Temperature for KZK Climate Station

Table 2.4 Estimated Long-Term Air Temperature at KZK Climate Station

Value	Mean Monthly Temperature (°C)												Annual
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Max	-6.4	-8.3	-6.6	-0.2	6.4	12.1	11.4	12.2	5.3	-0.6	-4.7	-9.5	-1.0
Mean	**-10.8**	**-11.4**	**-11.2**	**-4.5**	**2.7**	**8.2**	**9.9**	**7.9**	**2.3**	**-2.7**	**-9.6**	**-12.9**	**-2.8**
Min	-17.4	-18.8	-15.8	-10.1	-0.3	5.5	7.5	5.3	-2.3	-5.4	-17.2	-19.6	-10.2

2.4.2 Lapse Rate

Air temperature typically decreases with an increase in altitude and a lapse rate describes the rate of temperature change with altitude. Air moisture can also affect the lapse rate. Strong orographic patterns are not evident in the available annual regional temperature records (Appendix A). This may indicate that local factors, such as frequent temperature inversion, are affecting temperatures seasonally.

As seen in Figure 2.6 above, there appear to be seasonal relationships between the KZK Station temperature and that of the regional stations, which are all located at lower elevation. During the warmer months (May through September), temperatures at the KZK Station appear to be consistently 5 °C cooler than at the regional stations. In contrast, during the colder months (November through

January), temperatures appear to be warmer at the KZK Station by approximately 7°C, although the winter relationship appears to be less uniform and is dependent on the predominant weather conditions. During February, March, and October the KZK Station temperatures appear to be approximately equal to the regional station temperatures. Based on these results, it is evident that air temperature in the Project area is highly influenced by local physical factors rather than just by elevation alone.

During May through September, a lapse rate of approximately -6°C per 1,000 m is appropriate based on comparison between Project and regional data, but during October to March, no typical lapse rate is evident, with temperatures often increasing with increasing elevation.

2.5 EVAPORATION AND SUBLIMATION

Regional and site evaporation data is summarized in Appendix A. Climate normal values for Watson Lake A (1981-2010), as provided by ECCC, indicate a mean annual lake evaporation of approximately 345 mm. This value is similar to lake evaporation and potential evapotranspiration (PET) estimates for KZK, based on data collected in 1995 and during 2015 to 2017.

Actual evapotranspiration (AET), which typically occurs between May and September, is a fraction of the PET. The total PET measured in those months in 2016 is 361 mm. A factor of 0.5 [conversion from PET to AET] gives180 mm per year which is within the reasonable range of estimates based on estimates for the region in the 200 mm range (Appendix A). AET may be lower at the site than other regional locations as the shallow soils and minimal vegetation in the Project footprint area mean more rapid runoff generation and less interception. PET to AET ratios of 0.5 to 0.7 are typical and a lower ratio is supported by the site conditions. AEG (2018) estimated sublimation of approximately 21 mm though the 2015 to 2016 winter, but note that it could be higher in larger snowfall years.

Given the avaiable site and regional data, combined annual evaporation and sublimation losses of approximately 200 to 250 mm are expected.

2.6 PRECIPITATION

Precipitation recorded at the KZK Climate Station, snow course survey data and monthly summaries of rain, snow and total precipitation at regional climate stations are provided in Appendix A.

2.6.1 Estimated Long-term Precipitation

In order to develop an estimate of long-term precipitation conditions for the Project, concurrent precipitation records for the KZK Stations and three active regional climate stations with concurrent data were reviewed to assess the suitability of the regional climate stations as predictors of precipitation for the Project area. Data from the Watson Lake, Teslin and Faro stations overlap with the Project site data record and a summary of concurrent monthly and cumulative precipitation from KZK and the regional climate stations are presented on Figure 2.10 and 2.11, respectively. Section 2.2.2. of the 2015-2017 Hydrometeorology Baseline (Appendix A) identifies missing data periods at the KZK precipitation gauge after August 2016. Additionally, review of the station metadata indicates poor gauge accuracy after August 2016. These data issues meant that only September 2015 to August 2016 Project data could reliably be used for this analysis.

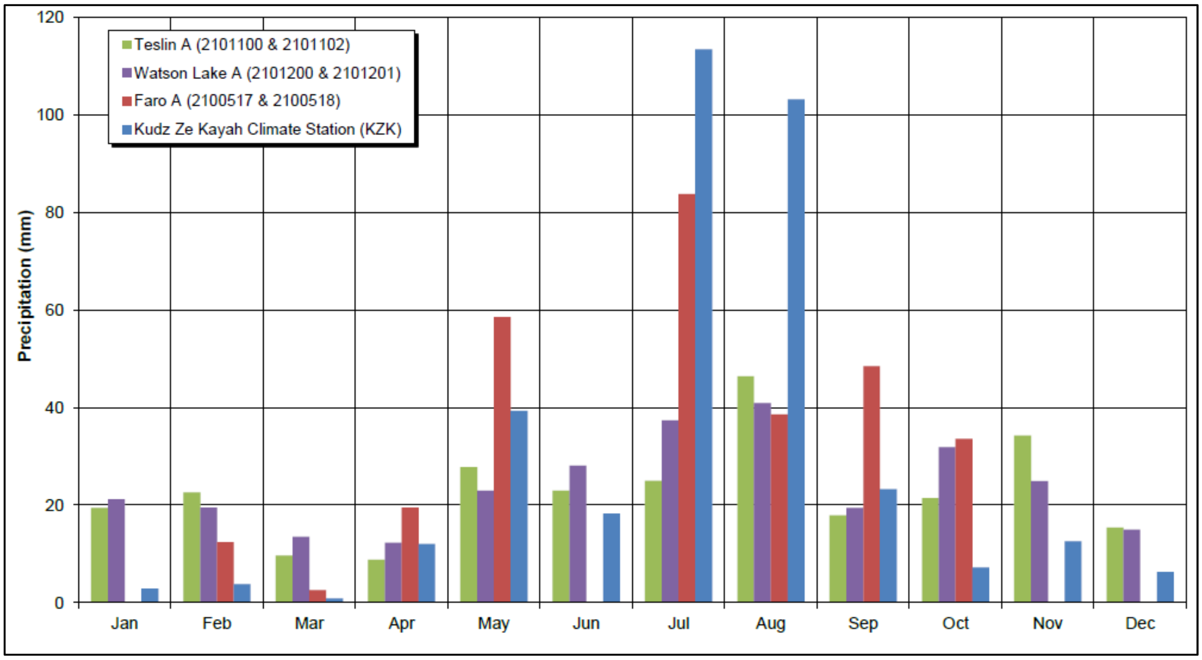


Figure 2.10 Concurrent Monthly Precipitation – September 2015 to August 2016

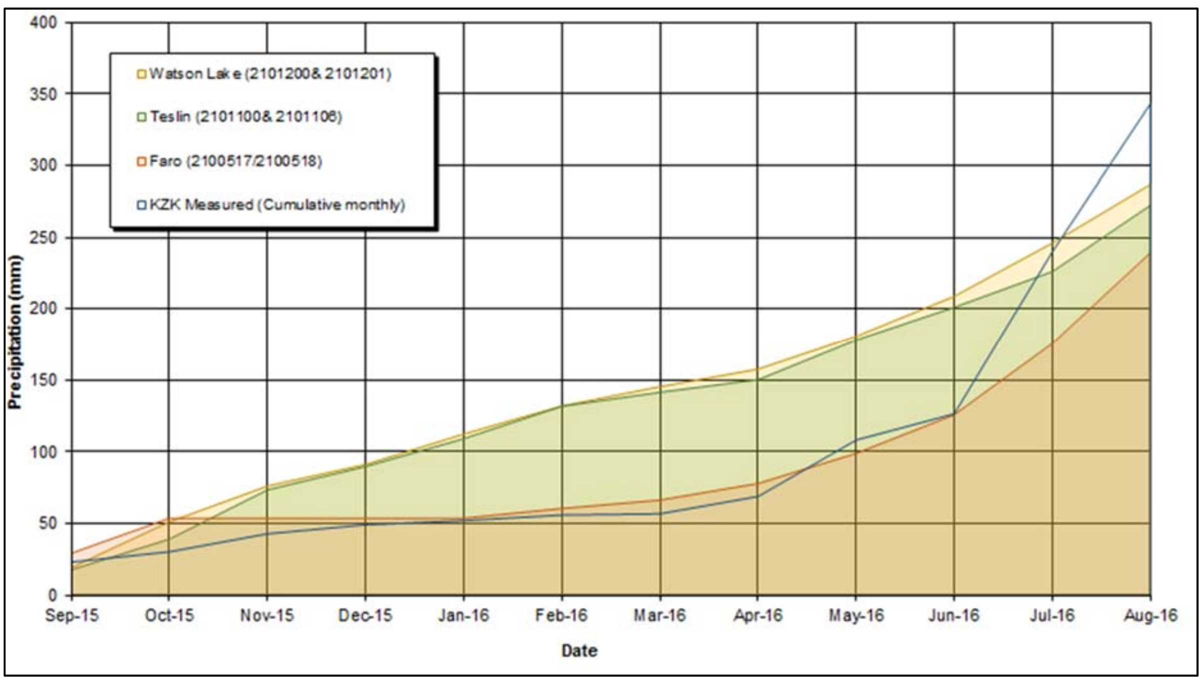


Figure 2.11 Cumulative Precipitation

The Faro Station was chosen as the most suitable climate station for estimating the long-term precipitation for the Project due to its location in a similar geoclimatic zone (Smith et. al., 2004) and based on a comparison of cumulative precipitation. The regression relationship between concurrent cumulative monthly precipitation for Faro and the KZK Station indicates that the KZK Station generally receives more total precipitation than Faro, as presented on Figure 2.12.

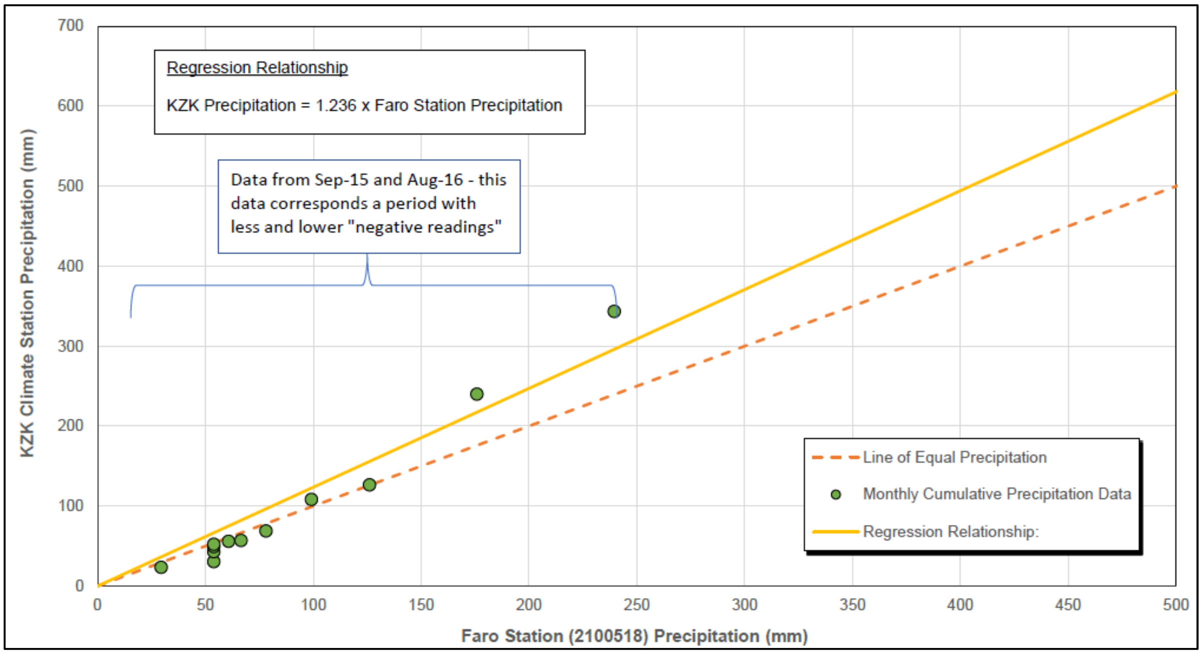


Figure 2.12 Cumulative Total Monthly Precipitation (September 2015 to August 2016) for Faro and KZK

As precipitation gauge undercatch can be significant, the ECCC's second generation adjusted precipitation dataset (Mekis and Vincent, 2011) was reviewed. The corrected dataset accounts for wind undercatch, evaporation, and gauge specific wetting losses. Corrected data were available for Teslin, Ross River and Watson Lake and the corrected datasets were found to be 10% to 15% higher than the uncorrected data published by ECCC. As Faro likely has similar undercatch, and as wind speeds are quite high at the Project site the undercatch at site may be even higher than at Faro.

The Site Wide Water Balance (KP, in progress) was used to ensure consistenency between water inputs (precipitation) and losses (primarily evapotranspiration, sublimation and streamflow). Though this assessment, it was determined that an overall undercatch correction of 32%, which accounts for Faro and KZK station undercatch, was required to balance hydrologic conditions at site.

Precipitation data collection at three Faro stations (IDs: 2100516, 2100517 and 2100518) were combined to produce a 45 year record, although several years have short periods of missing data. Significant data gaps occurred during 1977, 2002 and 2003, and these years were excluded from the record. The derived regression relationship and undercatch factor was applied to the long-term precipitation records for Faro to generate long-term estimates of precipitation for the KZK Station.

The resulting long-term dataset, which is presented in Appendix B2, is summarized in terms of mean monthly and annual values in Table 2.5 and on Figure 2.13. Also provided in the table are the maximum and minimum monthly mean values for the synthetic precipitation series. The mean annual precipitation (MAP) estimate for the KZK Station is 520 mm. Mean monthly precipitation values range from a low of 13 mm in April to 91 mm in July.

Table 2.5 Estimated Long-term Monthly Precipitation (mm) at KZK Climate Station

Station	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
KZK	Min	1	3	2	3	4	18	22	23	9	4	1	6	271
	Mean	**30**	**20**	**22**	**13**	**37**	**66**	**91**	**82**	**59**	**41**	**29**	**29**	520
	Max	121	45	74	48	125	141	198	190	172	90	71	71	722

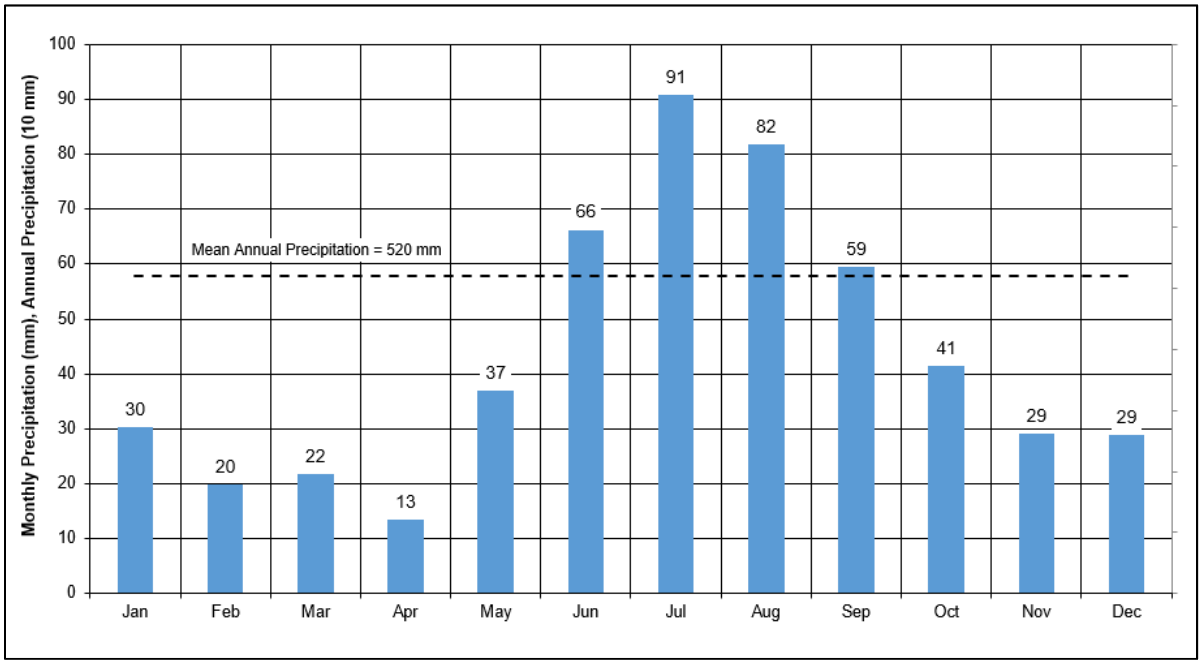


Figure 2.13 Estimated Long-term Mean Monthly Precipitation for KZK

2.6.2 Distribution of Rainfall and Snowfall

The long-term synthetic daily precipitation time series for the KZK Station was converted to corresponding rainfall and snowfall series by assuming that precipitation occurring on days when the mean temperature is above freezing would fall as rain, and that precipitation occurring on days when the mean temperature is below freezing would fall as snow.

The mean monthly rainfall and snowfall values for the KZK Station are presented in Table 2.6. The assessment indicates that approximately 37% of annual precipitation occurs as snowfall.

Table 2.6 Estimated Distribution of Rainfall and Snowfall for KZK

Month	Mean Monthly Rainfall (mm)	Mean Monthly Snowfall (mm)	Ratio of Rainfall (%)	Ratio of Snowfall (%)
January	0	30	0%	100%
February	0	20	1%	99%
March	0	22	0%	100%
April	2	12	12%	88%
May	26	11	71%	29%
June	66	0	100%	0%
July	91	0	100%	0%
August	80	2	98%	2%
September	49	11	82%	18%
October	8	34	18%	82%
November	0	29	1%	99%
December	0	29	0%	100%
Annual	**322**	**198**	**62%**	**38%**

2.6.3 Orographic Effects

Orographic precipitation effects occur as air masses rise over topographic relief, which results in an air mass cooling and losing moisture carrying capacity. Hence, precipitation often increases with increases in elevation. Orographic precipitation increases are most pronounced with frontal weather systems and are less evident in convective rainfall. Consequently, we expect to see increases in precipitation with elevation during the winter, when frontal storms are prevalent, but less so during the summer, when precipitation is often caused by convective storms.

The estimated mean annual precipitation values of 304 mm at Faro (716 masl) and 520 mm at the KZK Station (1,542 masl) indicate an average increase of approximately 5 % per 100 m elevation gain. However, this is an annual average rate, and the change of precipitation with elevation likely varies throughout the year, with much higher percentage increases expected in the winter when all storms are frontal driven.

2.6.4 Extreme Precipitation

Estimates of extreme precipitation are required for a number of design aspects, and are often presented for different storm durations. The most common and useful duration is 24-hours, and accordingly estimates of 24-hour extreme precipitation are provided for various return period events and the probable maximum precipitation (PMP) event.

The maximum recorded 24-hour precipitation events recorded at seven regional meteorological stations during their respective periods of record have been summarized and are presented in Table 2.7. The overall maximum of 47.0 mm of rain was recorded in Watson Lake A on June 22, 1987.

Table 2.7 Maximum 24 hour Precipitation Events at Regional Stations (Period of Record)

Regional Station	Rain		Snow		Precipitation	
	Amount (mm)	Date	Amount (cm)	Date	Amount (mm)	Date
Hour Lake	33.2	Jul 28, 2000	24.8	Mar 25, 2004	33.2	Jul 28, 2000
Tuchitua	36.0	Jun 2, 2001	29.8	Dec 28, 1980	36.0	Jun 02, 2001
Ketza River Mine	32.0	Aug 8, 1991	33.0	Jun 24, 1986	33.0	Jan 24, 1986
Swift River	45.0	Jul 12, 1988	37.0	Dec 24, 1992	45.0	Jul 12, 1988
Ross River	38.9	Jul 13, 1975	15.2	Jan 12, 1973	38.9	Jul 13, 1975
Watson Lake A	47.0	Jun 22, 1987	26.7	Dec 05, 1959	47.0	Jun 22, 1987
Faro A	29.4	May 28, 1993	12.8	Nov 30, 1991	29.4	May 28, 1993

NOTES:
1. SOURCE: AEG (2018).

Extreme 24-hour precipitation values were estimated for the Project using a frequency factor approach, as presented by Hogg and Car (1985) in the Rainfall Frequency Atlas for Canada (RFA). This approach uses estimates of the mean and standard deviation of the annual 24-hour extreme precipitation, to which frequency factors are applied based on the Extreme Value Type I (Gumbel) distribution. Estimates of the mean and standard deviation were derived from the Faro Airport annual maximum daily precipitation record to provide regionally specific estimates of extreme precipitation. These values were converted to equivalent 24-hour precipitation values by multiplying them by a factor of 1.13 (Miller 1963). These values were then translated to the Project site by applying an orographic/location factor of 1.46, which is equal to the ratio of the MAP at the Project climate station and the Faro station. Application of this orographic ratio is based on the finding that the extreme precipitation is highly correlated to annual precipitation (Cathcart, 2001). The resulting mean and standard deviation values are 35 mm and 12 mm, respectively, which were used with the frequency factors to generate return period estimates of 24-hour extreme precipitation for the Project site.

It is generally expected by regulators and the public that climate change is addressed in peak precipitation and flow analyses, and a 15% climate change factor has evolved in engineering practice as a somewhat “de facto” standard to address this concern (APEGBC, 2012). Therefore, a 15% uplift should be applied to return period precipiation values.

The resulting design storm values based on Faro are summarized in Table 2.8. The 24-hour 100 year, 200 year, and PMP values for the Project, including the 15% climate change factor, are estimated to be 89 mm, 95 mm, and 274 mm, respectively.

Table 2.8 Estimated 24-Hour Extreme Precipitation for KZK Climate Station

Return Period (years)	Regional 24-Hour Extreme Event (mm)	Regional 24-Hour Extreme Event Adjusted 15% for Climate Change (mm)
2	33	38
5	45	52
10	37	43
15	57	66
20	61	70
25	63	72
50	70	81
100	77	89
200	82	95
500	92	105
1,000	101	117
PMP	238	274

NOTES:
1. PROBABLE MAXIMUM PRECIPITATION (PMP) EVENT IS BASED ON HERSHFIELD'S EQUATION (HERSHFIELD 1961).
2. RAINFALL INTENSITIES ARE DERIVED FROM COMBINED FARO STATIONS (2100517 / 2100518), YUKON CLIMATE RECORD DATA, ADJUSTED FOR THE PROJECT AREA, AND INFLATED 15% TO ACCOUNT FOR POTENTIAL CLIMATE CHANGE.

2.6.5 Wet and Dry Year Precipitation

Estimates of wet and dry year annual precipitation are required to assess the range of probable precipitation conditions at the site. Wet and dry year annual precipitation totals were calculated based on a normally distributed probability of occurrence. The calculations require mean and standard deviation values for annual precipitation, which were determined from the long-term synthetic climate series for the KZK Station to be 520 mm and 98 mm, respectively. The wet and dry annual precipitation values for various return periods are presented in Table 2.9, which indicates a 1 in 200 year wet annual precipitation of 774 mm and a 1 in 200 year dry annual precipitation of 267 mm.

In the 43 years of synthetic record, the maximum annual precipitation is 722 mm at the KZK Station, which equates to a 1 in 50 year wet event, and the minimum annual precipitation is 271 mm, which equates to between the 1 in 200 and 1 in 100 dry events. This reasonable match between the extremes in the site record and the estimated return period event suggests that the assumption of a normal distribution is appropriate.

Table 2.9 Wet and Dry Year Precipitation

Return Period	Precipitation (mm)
1:200 year dry	267
1:100 year dry	291
1:50 year dry	318
1:20 year dry	358
1:10 year dry	394
Mean Annual	520
1:10 year wet	646
1:20 year wet	682
1:50 year wet	722
1:100 year wet	749
1:200 year wet	774

NOTES:

1. PRECIPITATION VALUES BASED ON THE SYNTHETIC LONG-TERM MEAN MONTHLY KZK RECORD.
2. YEARS WITH ONE OR MORE MONTHS OF MISSING DATA ARE CONSIDERED INCOMPLETE AND ARE NOT INCLUDED IN THIS ANALYSIS.
3. ESTIMATED VALUES ASSUME THAT THE TOTAL ANNUAL PRECIPITATION IS NORMALLY DISTRIBUTED.

3 – HYDROLOGY

3.1 INTRODUCTION

The Project lies in a small (approximately) 26 km^2 watershed called Geona Creek, which is a northern tributary of Finlayson Creek. Finlayson Creek meets the outflow of Finlayson Lake near the Robert Campbell Highway and flows east to eventually join the Frances River and ultimately the Mackenzie River. Annual streamflow in the Yukon Plateau North ecoregion is characterized by a rapid increase in snowmelt discharge that reaches a peak in June, with secondary rainfall-generated peaks throughout the summer. On smaller streams, many of the annual maximum flows are due to intense summer rainstorm events and monthly flows are often high in late summer due to rainfall. The mean annual runoff ranges from approximately 200 mm to 400 mm, based on an assessment of the site and regional datasets. Minimum streamflow generally occurs during February or March, as groundwater stores deplete over the winter when temperatures are low and very little surface runoff or groundwater recharge occurs (Smith et. al., 2004).

3.1.1 Regional Stations

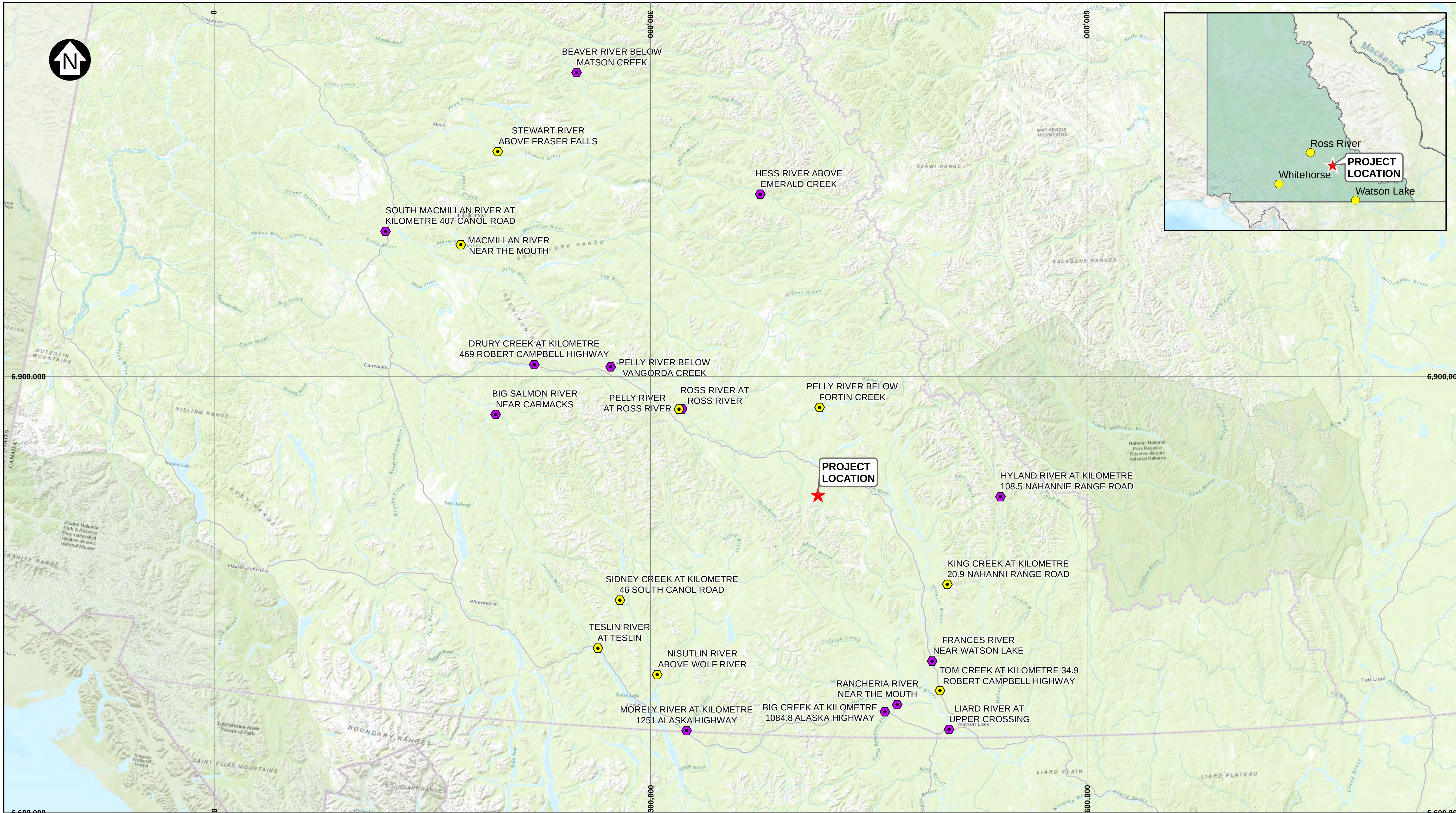
There are several active and discontinued WSC hydrology stations located near the Project area, as summarized in Table 3.1 and shown on Figure 3.1. Most have significantly larger drainage areas than the Project stations and accordingly likely have somewhat different hydrologic patterns and storm response patterns than the Project drainages. Regional hydrologic data are summarised in Appendix A.

Table 3.1 Mean Annual Runoff for Regional Streamflow Stations

Station ID	Name	Area (km^2)	Median Elevation (masl)	Minimum Elevation (masl)	Maximum Elevation (masl)	Date Range	MAR (mm)
10AB003	King Creek	13.7	1,341	935	1,853	1975-1988	289
09AD002	Sidney Creek	372	1,256	730	1,882	1982-1994	365
10AA002	Tom Creek	435	985	724	1,563	1974-1993	216
09AH005	Drury Creek	552	1,225	614	2,050	1995-2009	282
09BB001	South MacMillan River	997	1,380	931	2,536	1974-1996	633
10AA005	Big Creek	1,010	1,176	779	2,006.5	1989-2014	246
10AD002	Hyland River	2,150	1,536	849	2,559	1976-1994	653
09DA001	Hess River	4,840	1,391	782	2,916	1976-1996	500
09BA002	Pelly River below Fortin Creek	5,020	1,214	871	2,105	1986-94, 2013-14	472
10AA004	Rancheria River	5,100	1,231	691	2,248	1986-2014	332
09BA001	Ross River at Ross River	7,310	1,068	679	2,533	1960-2014	287
09AD001	Nisutlin River	8,030	1,204	659	2,188	1979-1995	365
10AB001	Frances River	12,800	1,157	657	2,337	1962-2014	396
09BB002	MacMillan River near the mouth	13,800	1,086	500	2,529	1984-1996	320
09BC002	Pelly River at Ross River	18,400	1,125	649	2,533	1954-1974	310
09BC004	Pelly River below Vangorda Creek	21,900	1,131	626	2,533	1972-2014	289
09AE001	Teslin River at Teslin	30,300	1,159	645	2,174	1944-1994	314
10AA001	Liard River at Upper Crossing	32,600	1,140	609	2,333	1960-2014	366
09DC003	Stewart River above Fraser Falls	30,600	1,164	448	2,916	1980-1996	387

NOTES:

1. MAR = Mean Annual Runoff (mm).



LEGEND:

- PROJECT LOCATION
- ACTIVE HYDROLOGY STATION
- INACTIVE HYDROLOGY STATION

50 25 0 50 100 150 200 250 km

NOTES:

1. BASE MAP: ESRI WORLD TOPOGRAPHIC MAP.
2. COORDINATE GRID IS IN METRES.
COORDINATE SYSTEM: NAD 1983 UTM ZONE 9N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:2,500,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

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REGIONAL HYDROLOGY STATIONS

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P/A NO.	REF NO.
VA101-640/6	4

FIGURE 3.1 REV 0

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3.1.2 Project Stations

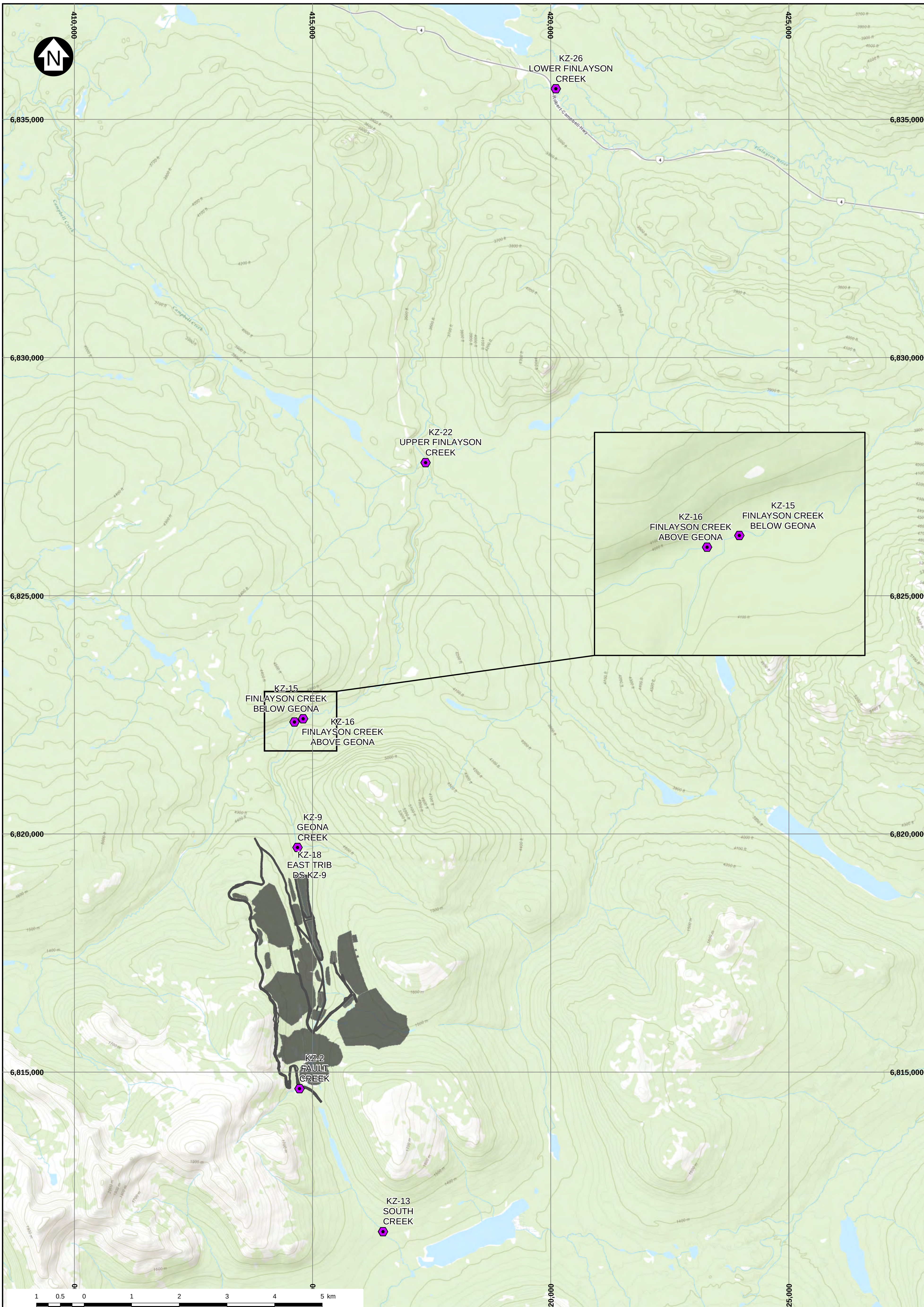
Seven continuously recording hydrology stations have been operated within the KZK Project area since 2015. The locations of these streamflow stations are shown on Figure 3.2 and the station characteristics are summarised in Table 3.2. Details of the gauging program are provided in Appendix A and data processing was completed by KP (2018). Measured monthly discharge and unit discharge are presented in Tables 3.3 and 3.4. Discrete measurements have also been taken at additional hydrology stations (KZ-6, KZ-7, KZ-18, KZ-21, and KZ-37) and derived measurements have been calculated for one additional location (KZ-17). These stations are not presented in this report but can be found in Appendix A.

Table 3.2 Project Streamflow Station Characteristics

Watershed		Location	Station Name	Mean Catchment Elevation (m)	Drainage Area (km²)	Data Collection Type	Active or Inactive	Start Date	End Date[1]
Liard River		South Creek	KZ-13	1,540	7.9	Continuous	Active	Apr 2015	Dec 2017
Liard River	Finlayson Creek	Fault Creek	KZ-2	1,707	1.9	Continuous	Active	Apr 2015	Dec 2017
Liard River	Finlayson Creek	Geona Creek near proposed dam	KZ-9	1,498	16.4	Continuous	Active	May 2015	Dec 2017
Liard River	Finlayson Creek	Finlayson Creek below Geona Creek	KZ-15	1,479	60.9	Continuous	Active	Apr 2015	Dec 2017
Liard River	Finlayson Creek	Finlayson Creek above Geona Creek	KZ-16	1,477	35.0	Continuous	Active	Apr 2015	Dec 2017
Liard River	Finlayson Creek	Finlayson Creek below East Creek	KZ-22	1,354	162.4	Continuous	Active	Apr 2015	Dec 2017
Liard River	Finlayson Creek	Lower Finlayson Creek	KZ-26	1,294	210.7	Continuous	Active	Apr 2015	Dec 2017

NOTES:

1. DATA COLLECTION AT ACTIVE STATION IS ONGOING, HOWEVER THE END DATE INDICATES THE END DATA USED IN THIS REPORT.
2. DRAINAGE AREA AND MEAN CATCHMENT ELEVATION AS PRESENTED IN APPENDIX A.



LEGEND:

- ACTIVE CONTINUOUS HYDROLOGY STATION
- PROPOSED INFRASTRUCTURE

NOTES:

1. BASE MAP: ESRI ONLINE TOPOGRAPHIC MAP.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 9N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:75,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

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PROJECT HYDROLOGY STATIONS

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P/A NO.	REF NO.
VA101-640/6	4

FIGURE 3.2 REV 0

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Table 3.3 Measured Project Discharge Record

Station Name	Station ID.	Drainage Area (km^2)	Year	Monthly Mean Discharge (m^3/s)											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fault Creek	KZ-2	1.9	2015	-	-	-	-	-	0.08	0.04	0.04	0.05	-	-	0.01
			2016	0.01	0.00	0.00	0.00	0.05	0.07	0.04	0.06	0.07	-	-	0.01
			2017	0.00	0.00	0.00	0.01	0.03	0.13	0.12	0.05	0.02	-	0.01	-
Geona Creek near proposed dam	KZ-9	16.4	2015	-	-	-	-	-	0.31	0.24	0.24	0.31	-	-	0.07
			2016	0.05	0.04	0.03	-	0.14	0.16	0.14	0.24	0.41	-	-	0.06
			2017	0.05	0.04	0.03	0.03	-	0.41	0.60	0.40	0.17	-	0.07	0.04
South Creek	KZ-13	7.9	2015	-	-	-	-	-	0.16	0.09	0.11	0.16	0.07	-	-
			2016	-	0.01	-	-	0.11	0.10	0.08	0.13	0.24	0.08	-	-
			2017	0.02	0.02	0.02	0.01	-	0.25	0.38	0.20	0.08	-	0.02	-
Finlayson Creek below Geona Creek	KZ-15	60.9	2015	-	-	-	-	1.65	0.93	0.58	0.66	1.09	-	-	0.27
			2016	0.13	0.09	0.09	-	0.63	0.50	0.53	0.95	1.63	-	-	0.18
			2017	0.15	0.10	0.09	0.10	1.13	1.49	2.10	1.29	0.52	-	0.23	-
Finlayson Creek above Geona Creek	KZ-16	35.0	2015	-	-	-	-	-	0.55	0.39	0.46	0.56	-	-	0.11
			2016	0.06	0.05	0.08	-	-	0.24	0.27	0.53	0.87	-	-	-
			2017	-	-	0.10	0.17	-	0.78	1.19	0.82	0.32	-	0.11	-
Finlayson Creek below East Creek	KZ-22	162.4	2015	-	-	-	-	-	1.78	1.40	1.84	2.83	1.78	-	0.54
			2016	-	-	-	-	1.00	0.80	1.04	1.99	3.19	-	-	0.43
			2017	0.32	0.24	0.21	0.25	2.74	2.99	5.18	2.80	1.10	-	0.37	-
Lower Finlayson Creek	KZ-26	210.7	2015	-	-	-	-	-	2.36	1.72	2.31	2.66	-	-	0.34
			2016	0.37	0.39	0.35	0.55	1.16	0.96	1.34	2.33	3.49	-	-	0.28
			2017	0.47	0.47	0.54	0.49	-	-	-	-	-	-	0.62	-

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TABLE 3.4

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SUMMARY OF MONTHLY UNIT DISCHARGE

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Station Name	Station ID.	Drainage Area (km^2)	Year	Monthly Mean Unit Runoff ($l/s/km^2$)												Annual Mean Unit Runoff [3] ($l/s/km^2$)	Annual Mean Unit Runoff [3] (mm)	Annual Mean Discharge [3] (L/s)
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
Fault Creek	KZ-2	1.9	2015	-	-	-	-	-	41.7	18.8	21.2	24.0	14.5	5.0	4.0	-	-	-
			2016	3.3	2.4	1.8	1.9	27.4	33.7	20.2	28.8	36.0	20.6	5.3	3.9	13.9	439	27
			2017	2.3	2.1	2.1	3.1	13.2	67.6	64.5	25.1	11.6	-	4.7	-	20.5	646	40
Geona Creek near proposed dam	KZ-9	16.4	2015	-	-	-	-	-	18.8	14.5	14.4	18.6	11.8	4.9	4.3	-	-	-
			2016	3.0	2.3	1.8	2.4	8.8	9.5	8.6	14.6	24.7	14.9	5.2	3.9	7.6	238	124
			2017	3.1	2.2	1.8	2.0	23.3	25.1	36.2	24.1	10.5	-	4.5	2.6	13.9	437	228
South Creek	KZ-13	7.9	2015	-	-	-	-	-	20.5	11.6	13.9	20.0	9.0	3.1	2.3	-	-	-
			2016	1.6	1.3	1.0	0.9	13.2	12.7	10.3	16.6	29.7	10.2	3.1	3.1	7.7	242	61
			2017	2.9	2.2	2.4	1.7	28.7	31.0	48.3	25.2	9.9	6.5	3.1	-	15.7	495	125
Finlayson Creek below Geona Creek	KZ-15	60.9	2015	-	-	-	-	27.1	15.2	9.5	10.9	17.9	11.0	5.0	4.5	-	-	-
			2016	2.1	1.5	1.4	1.6	10.4	8.2	8.6	15.5	26.7	15.3	3.9	3.0	7.3	231	445
			2017	2.5	1.7	1.4	1.6	18.6	24.5	34.6	21.3	8.6	-	3.7	-	12.9	408	786
Finlayson Creek above Geona Creek	KZ-16	35.0	2015	-	-	-	-	-	15.6	11.0	13.2	16.1	10.2	4.4	3.1	-	-	-
			2016	1.6	1.5	2.2	2.4	6.4	6.9	7.8	15.0	24.9	15.3	5.7	4.3	6.5	204	226
			2017	1.6	2.3	2.7	4.8	20.8	22.4	33.9	23.4	9.0	-	3.1	1.8	13.5	426	473
Finlayson Creek below East Creek	KZ-22	162.4	2015	-	-	-	-	-	20.6	16.2	21.4	32.8	20.6	4.2	6.2	-	-	-
			2016	2.5	2.8	2.5	2.9	11.5	9.2	12.0	23.0	37.0	13.3	3.5	5.0	10.9	343	1764
			2017	3.7	2.8	2.5	2.8	31.7	34.6	60.0	32.4	12.7	-	4.2	-	19.1	602	3101
Lower Finlayson Creek	KZ-26	210.8	2015	-	-	-	-	-	11.2	8.1	11.0	12.6	7.6	2.5	1.6	-	-	-
			2016	1.8	1.8	1.7	2.6	5.5	4.6	6.4	11.0	16.5	10.5	2.9	1.3	5.0	157	1049
			2017	2.2	2.2	2.6	2.3	4.9	7.9	7.3	11.0	14.6	-	3.0	-	6.0	188	1259

NOTES:

1. MEAN MONTHLY DISCHARGE VALUES ONLY PRESENTED FOR MONTHS WITH DATA FOR MORE THAN 20 DAYS.
2. MEAN MONTHLY DISCHARGE VALUES HIGHLIGHTED IN GREY HAVE BEEN ESTIMATED TO ALLOW DETERMINATION OF ANNUAL MEAN DISCHARGE.
3. MEAN ANNUAL VALUES BASED ON HYDROLOGIC YEAR FROM SETPTEMBER TO AUGUST OF THE FOLLLOWING CALENDAR YEAR.

REV	DATE	DESCRIPTION	PREP'	RVW'D
0	6JUN'18	ISSUED WITH REPORT VA101-640/6-4	EK	TJP

Long-term streamflow estimates for the Project area will be developed using the site wide watershed model, which will incorporate and ensure mass continuity between precipitation, evaporation, sublimation, groundwater and streamflow processes (KP, in progress).

3.2 FLOW STATISTICS AND FREQUENCY ANALYSES

3.2.1 General

Understanding the magnitude and frequency of hydrological events is important to help inform the design and operations of the Project. The following sections describe the results of various statistical analyses performed to generate hydrologic design parameters for the Project.

3.2.2 Wet and Dry Return Period Flows

Wet and dry monthly flow values provide an estimate of streamflow variability for the Project area and are commonly determined for specified recurrence intervals (e.g. 5, 10, 20, and 50 years). Wet and dry return period flows can be estimated from the mean monthly flow, the standard deviation (σ) of monthly flows, and assuming a normal distribution. Variability in regional streamflow datasets was determined and normalized by the mean (μ) to calculate the coefficient of variation (Cv = σ/μ).

Available monthly runoff data from regional hydrology stations were plotted against station drainage area in order to determine monthly correlations. In general, it is expected that the coefficient of variation decreases with increasing drainage area (Cathcart, 2001). Monthly equations were developed to represent the relationship between drainage area (*A,* in km^2) and coefficient of variation (Cv), $Cv(A) = Am + b$, with the equation coefficients summarized below in Table 3.5. Monthly Cv values for any drainage area at the Project can be estimated based on these equations.

Table 3.5 Coefficient of Variation

Month	Slope, m	Intercept, b
January	-0.00010	0.4403
February	-0.00020	0.4857
March	-0.00010	0.4420
April	-0.00009	0.4675
May	0.00002	0.4019
June	-0.00010	0.4327
July	-0.00010	0.4906
August	-0.00009	0.4066
September	-0.00003	0.4140
October	-0.00010	0.4924
November	-0.00009	0.4187
December	-0.00020	0.6010

NOTES:

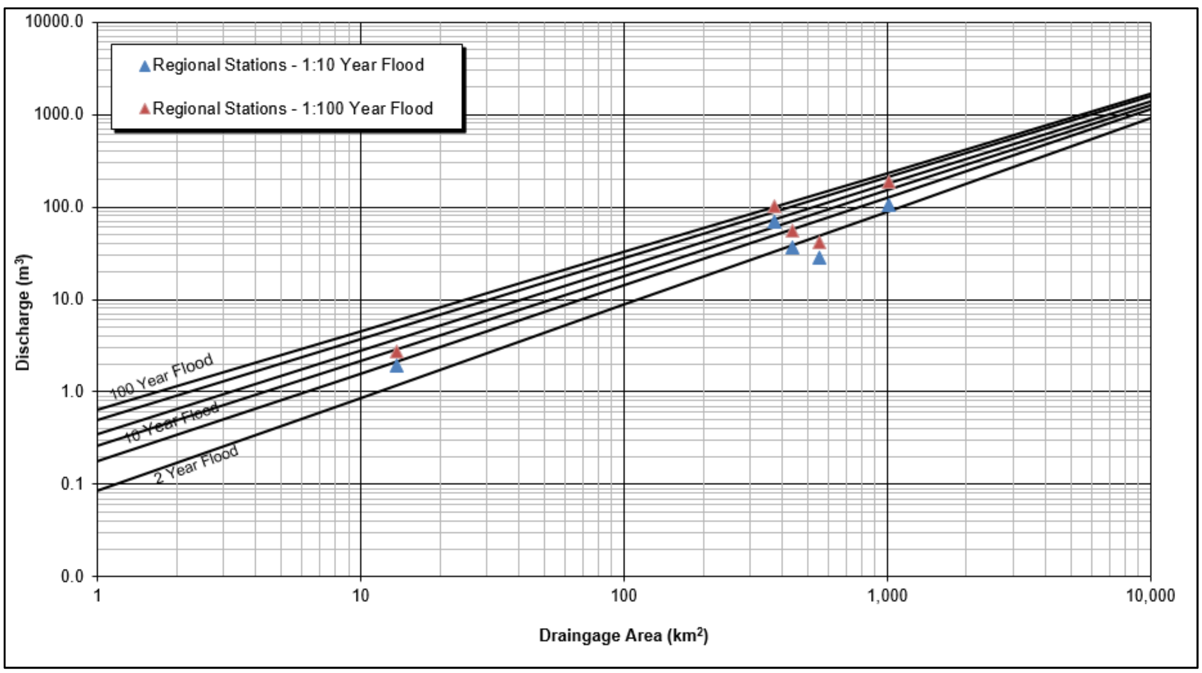
1. MONTHLY RUNOFF COEFFICIENT OF VARIATION FOR THE PROJECT AREA BASED ON THE FOLLOWING EQUATION: C.V. = m * DRAINAGE AREA (km2) + b.
2. COEFFICEINT OF VARIATION (Cv) = STANDARD DEVIATION / MEAN.

Long-term streamflow records generated from the site wide watershed model will be compared to these values to ensure that the synthetic record suitably represents the hydrologic variability expected at the Project site.

3.2.3 Peak Flow

Janowicz (1986) provides a methodology for estimating flood flows using a two parameter lognormal theoretical probability distribution, which is believed to be most appropriate for sparse data regions. Linear regression relationships were developed between maximum annual instantaneous discharge and drainage area for two hydrologic regions. The stream channel slope determines which hydrologic zone the scaling relationship is based within, either interior or mountain. The mountain hydrologic zone represents watersheds with stream channel slopes greater than 4.5% and has been deemed appropriate for the Project area. A regional scaling plot for the 2, 5, 10, 20, 50, and 100 year return period floods, including the 1 in 10 year and 1 in 100 year flood values calculated for five regional stations, based on recent records, is provided on Figure 3.3.

The regional stations all fall below the relevant regional envelope curves, except the 1 in 10 year flow for Sidney Creek, as shown in Figure 3.3. Based on the Project drainage areas, which are all less than approximately 200 km^2, the regional envelop curves are positioned well above the regional station values within this range of drainage area. They may therefore overestimate the flood potential in the Project area; however, there is uncertainty surrounding peak flood estimations and the curves allow for a conservative approach.



NOTES:

1. DESIGN FLOOD REGIONAL RELATIONS FOR ESTIMATING PEAK FLOWS FOR 2, 5, 10, 20, 50, AND 100 YEAR RETURN PERIODS BASED ON JANOWICZ (1989).
2. DESIGN FLOODS ARE BASED ON MOUNTAIN HYDROLOGIC ZONE WITH TYPICAL STREAM CHANNEL SLOPES GREATER THAN 4.5%.

Figure 3.3 Regional Design Floods for Select Return Periods – Mountain Hydrologic Zone

It is considered prudent, for design purposes, to err on the side of caution, and therefore, the envelope curves presented on Figure 3.3 are recommended as the basis for generating Project design flows for drainage areas greater than approximately 10 km^2. The curves should be used to estimate the various return period design peak flows, using the curve equations provided in Table 3.6.

Table 3.6 Design Flood Estimate Equations

Return Period	Regression Constant, a	Regression Coefficient, b
2 Yr	0.085	1.007
5 Yr	0.176	0.952
10 Yr	0.257	0.923
20 Yr	0.352	0.899
50 Yr	0.500	0.873
100 Yr	0.631	0.855

NOTES:

1. DESIGN FLOOD ESTIMATES FOR THE PROJECT ARE BASED ON THE FOLLOWING EQUATION: DESIGN FLOOD DISCHARGE = a*(DRAINAGE AREA)^b, WHERE DISCHARGE HAS UNITS OF m^3/s AND DRAINAGE AREA HAS UNITS OF km^2.
2. DESIGN FLOODS ARE BASED ON JANOWICZ (1989) METHODOLOGY USING THE MOUNTAIN HYDROLOGIC ZONE.

For drainage areas smaller than approximately 10 km^2, peak design flow values should be calculated using an appropriate rainfall-runoff modelling approach. Return period 24-hour design rainfall events should be taken from Table 2.8.

The 24-hour precipitation values can be distributed over 24 hours according to a USDA Soil Conservation Service (SCS) Type 1 rainfall distribution (USDA, 1986). Storm runoff depth can be calculated using the Soil Conservation Service (SCS) curve number (CN) values for catchment areas contributing to the water management structures, considering an assessment of Project area rainfall and runoff patterns. CN values can be obtained from standard tables published in USDA documents, such as TR-55 (USDA, 1986).

The storm runoff can be distributed into a storm hydrograph using the SCS dimensionless unit hydrograph, with the time of concentration determined based on the SCS CN/lag time equation (USDA, 2010), as shown below. The recommended procedure for calculating T_c is using the CN/lag equation as follows:

$$Tc = \frac{0.57L^{0.8}[\left(\frac{1000}{CN}\right) - 9]^{0.7}}{\sqrt{S}\, x100}$$

Where, T_c = time of concentration (hours)

L = flow travel length (km)

CN = curve number

S = average travel slope (rise/run)

The time of concentration (T_c) is used to describe the length of time required for runoff to travel from the hydrologically furthest part of a catchment to the facility being designed (collection or conveyance infrastructure). This involves defining the hydraulic length and average slope of the contributing catchment.

A climate change adjustment factor will be applied to the peak flow estimates to account for the uncertainty, and potential greater volatility, of future climatic conditions, given that the flood estimates are based on historic events. The APEGBC guidelines (APEGBC 2012) indicate that if no climate change trend is detectable when analyzing historic streamflow trends, a 10% upward adjustment factor should be used to account for cliamtechange. An analysis of regional climate trends within the Project area is presented in Section 4 of this report and indicates that due to the strong scatter in the data, no strong conclusions can be derived on potential climate change at this time. It is generally expected by regulators and the public that climate change is addressed in peak flow analyses, and a 15% climate change factor has evolved in engineering practice as a somewhat “de facto” standard to address this concern.

To conclude, it is recommended that peak instantaneous design flows for the Project be determined using the curve relationships based on Figure 3.3 and presented in Table 3.6, or rainfall runoff modelling, depending on the catchment area in question. A 15% climate change adjustment factor will be added to these estimates.

Example:

1 in 100 year design flow for a diversion ditch with a projected design life of 20 years that collects runoff from a 20 km^2 drainage area:

From Table 3.6: $Q_{100} = 0.631*(20\ km^2)^{0.855} = 8.2\ m^3/s$

Climate change factor (+15%): $\mathbf{Q_{100}} = 8.2\ m^3/s \times 1.15 =$ **9.4 m^3/s**

4 – CLIMATE CHANGE

4.1 REGIONAL RECORDS

4.1.1 General

A review of changes in climate normal temperature and precipitation values were undertaken as a simple means of assessing climate trends. The data periods considered were 1960 to 2010, and the data values generally indicate increasing temperatures and constant precipitation, with increasing proportions of rain versus snow. It should be noted, however, that these changes, though consistent with general climate change predictions for the Yukon, may be due to the effects of climate cycles, as much as climate change, and it is recommended that a more thorough and comprehensive assessment be completed before strong conclusions about climate change are made.

4.1.2 Temperature

Temperature trends were analyzed for six regional stations (Hour Lake, Tuchitua, Swift River, Ross River A/YTG, Watson Lake A, and Faro A) with all of the stations displaying an increasing trend over the data collection period for average minimum, average maximum and mean monthly temperatures (Appendix A). However, correlations were very weak in all cases.

Monthly climate normals for average, minimum and maximum temperatures were also compared for the Watson Lake A climate station for the periods of 1961 to 1990, 1971 to 2000 and 1981 to 2010. The temperatures were higher during the most recent period for every month except for August and October, with the greatest differences occurring during the winter months and for the minimum temperature (Appendix A).

A similar analysis was performed for the Faro A climate station, with results showing annual and winter temperature normals generally higher during the most recent period (1981 to 2010) than during the 1971 to 2000 period, which is consistent with the generally accepted condition of a warming trend (Appendix A).

4.1.3 Precipitation

Total precipitation trends were also analyzed for the same six regional stations as noted above. There was no clear pattern for total rain, snow, and precipitation, with some stations indicating a decreasing trend over the period of record, others an increasing trend, and others remaining constant (Appendix A). The proportion of total precipitation falling as rain showed an increasing trend, consistent with the rising trends observed in air temperature, and although the correlation was weak, a similar trend was generally observed for all stations, with a rate of increase of approximately 0.1% to 0.3% per year (Appendix A).

Monthly climate normals for total rainfall, total snowfall, and MAP were also compared for the Watson Lake A climate station for the periods of 1961 to 1990, 1971 to 2000, and 1981 to 2010. There was observed a 2.1% increase in total rainfall, a 10.4% decrease in total snowfall, and a 0.6% increase in MAP (Appendix A).

A similar analysis was performed for the Faro A climate station, with total rainfall, total snowfall, and MAP showing an increasing trend between the two climate normals periods (1971 to 2000 and 1981 to 2010) of 1.9%, 2.2%, and 1.2% respectively (Appendix A).

4.2 CLIMATE CHANGE SCENARIOS

An assessment was also conducted using predicted climate change patterns for the Yukon. There is a general consensus in the scientific community that the global atmosphere is warming and that worldwide climate patterns are changing as a result. There is some concern about whether or not historical flow and climate records reasonably represent conditions that might be expected over the next 30 years through Project operations, or even longer time scales through Project closure and post-closure.

According to the ClimateWNA model (Wang et. al., 2016), mean temperatures in the Project area are expected to increase by approximately 3.5°C by the 2050s. Winter precipitation is predicted to increase by 13% with summer precipitation expected to increase by 12%, winter snowfall predicted to increase by 12%, and the fall and spring snowfall is predicted to decrease by 6% and 4% respectively. The estimated values, as summarized in Table 4.1, represent potential changes for the 2050s (2055) relative to 1981-2010 baseline conditions, based on a series of Global Climate Model (GCM) projections.

Table 4.1 Climate Change Predictions for the Project Area in the 2050s (ClimateWNA)

Climate Variable	Season	Mean	Range
Mean Temperature (°C)	Annual	+3.5	+2.8 to +6.2
	Summer	+2.6	+1.4 to +3.2
	Winter	+1.6	+0.8 to +2.5
Precipitation (%)	Annual	+13%	+10% to +18%
	Winter	+13%	+9% to +23%
	Spring	+24%	+13% to +38%
	Summer	+12%	+7% to +14%
	Fall	+19%	+4% to +19%
Snowfall (%)	Annual	-1%	-4% to +4%
	Fall	-6%	-12% to 0%
	Winter	+12%	+5% to +21%
	Spring	-4%	-23% to +6%

NOTES:

1. THE ABOVE VARIABLES REPRESENT THE PROJECTED CHANGE FROM THE 1981-2010 BASELINE.
2. WINTER = DEC, JAN, FEB; SPRING = MAR, APR, MAY; SUMMER = JUN, JUL, AUG; FALL = SEP, OCT, NOV.
3. DATA SOURCE: CLIMATEWNA, 2018.

These predictions were obtained from the ClimateWNA website (Wang et. al., 2016), which is commonly used for estimating possible future climate conditions. This site provides a range of climate change estimates based on several GCMs and CO_2 emission scenarios. Three GCMs (CanESM2, CNSR-CM5, and HadGEM2- ES) and two CO_2 emission scenarios (RCP 2.6 and RCP 8.5) were selected to provide and ensemble of results. All scenarios predict warmer temperatures and higher precipitation on an annual basis and the predicted range is generally similar to the results found from the regional data.

It is not possible to make strong conclusions about future climate conditions based on the measured climate and flow data available. There appears to be a general trend towards slightly warmer temperatures, however, it is less clear if precipitation is increasing or decreasing. Modelled climate values presented in Table 4.1 indicate that all GCM models and CO_2 emission scenarios considered lead to the prediction of generally warmer temperatures and increased annual precipitation in the Project area, albeit with a range of potential seasonal changes.

It is generally expected by regulators and the public that climate change is addressed in peak flow analyses, and a 15% climate change factor has evolved in engineering practice as a somewhat “de facto” standard to address this concern. Therefore, a 15% uplift should be applied to the peak design flow values for the design of structures. Accordingly, if return period precipitation values are used for the design flow determination, the precipitation values should be increased by 15%, as appropriate. Similarly, water management planning should consider that future precipitation is expected to increase and that the timing of water availability may alter from historic conditions.

5 – CONCLUSIONS

This report presents the climate and hydrology characterization for the Kudz Ze Kayah Project. The analysis presented in this report is suitable for Project development and advancement, including permit applications and engineering design.

The assessment of the long-term meteorological conditions in the Project study area is based on site specific climate and snow course data, as well as regional climate records spanning several decades. Long-term synthetic precipitation and temperature series were developed for the Project by correlating the site specific data with the regional data. The long-term average and statistical variability of meteorological values were assessed based on these synthetic data sets. The meteorological values provided in this report are believed to reasonably represent the magnitude and variability of actual conditions in the Project area.

The assessment of streamflow/runoff conditions in the Project study area is based on site-specific streamflow data collected at seven continuous hydrology stations for a period of approximately 2.5 years, and on regional streamflow records spanning several decades. Long-term streamflow records for the Project will be developed using a site wide watershed model, which is currently in progress. The long-term statistical variability of hydrological conditions were assessed based on regional data sets.

Potential future climate change in the Project area was assessed through a review of regional climate and streamflow trends using long-term historical records. There appears to be a general trend towards slightly warmer temperatures, as well as an increasing proportion of annual precipitation occurring as rain; however, these trends were not entirely compelling. The predicted future climate change effects for the Project area were also assessed through a review of modelled climate values generated with various GCM models and CO_2 emission scenarios. These values generally suggest that both temperatures and annual precipitation will increase in the Project area. Design of structures and water management planning should consider the potential for hydrometeorological conditions that deviate to some degree from historical conditions.

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7 – CERTIFICATION

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APPENDIX A

2015-2017 HYDROMETEOROLOGY BASELINE REPORT (AEG, 2018)

(Pages A-1 to A-261)

2015-2017 HYDROMETEOROLOGY BASELINE REPORT

KUDZ ZE KAYAH PROJECT

BMC-17-02-1105_004_Hydrometeorology Baseline Report_Rev1_180604

June 2018

Prepared for:

BMC MINERALS (NO.1) LTD.

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EXECUTIVE SUMMARY

BMC Minerals (No.1) Ltd. (BMC) is proposing to develop the Kudz Ze Kayah (KZK) Project (the Project), which is located approximately 110 km southeast of Ross River, Yukon territory. BMC's Project Proposal for the Project and is currently undergoing a Screening Assessment by the Yukon Environmental and Socio-economic Assessment Board's (YESAB) Executive Committee, under the *Yukon Environmental and Socio-economic Assessment Act (YESAA).* During the Adequacy stage of the Assessment, YESAB requested that BMC submit a number of updated water related reports, prior to YESAB preparing the draft Screening Report. Subsequently, this 2015-2017 Hydrometeorology Baseline Report is an update to the 2015-2016 Hydrometeorology Baseline Report (AEG, 2016) that was submitted as Appendix D-2 of the Project Proposal (BMC, 2017).

The Project lies in a small (approximately) 26 km^2 watershed called Geona Creek which is a north flowing and north facing tributary of Finlayson Creek. Finlayson Creek meets the outflow of Finlayson Lake below the Robert Campbell Highway and flows east to eventually join the Frances River and ultimately the Mackenzie River. One of the highest elevation tributaries within Geona Creek has been named Fault Creek which has a median elevation of 1,707 metres above sea level (masl) and an area of 2 km^2. Fault Creek is characterized by steep slopes and small trees and shrubs in the creek valley but otherwise is an alpine environment. Geona Creek has a median elevation of 1,482 masl with vegetation spaning from alpine to some sparsely forested areas at lower elevations. The Finlayson Creek catchment area is approximately 41 km^2 above the confluence with Geona Creek and grows to 215 km^2 where it flows under the Robert Campbell Highway shortly before it joins the outflow of Finlayson Lake. The watershed divide of Geona Creek is characterized by several small lakes.

The hydrometeorological character of the KZK property is described using regional data available through Environment and Climate Change Canada (ECCC) and Environment Yukon and meteorological and hydrological data collected at site in 1995, and from 2015 to present. Two meteorological stations were established in the Project area during 1995, one high and one low elevation station. A Campbell Scientific meteorological station was installed and commissioned at the Project site on August 25, 2015, for the measurement of air temperature, relative humidity, wind speed and direction, barometric pressure, solar radiation and total precipitation. An evaporation pan was also installed and daily manual measurements were taken during the open water seasons of 2016 and 2017. Manual snow surveys were conducted in 1995 and monthly (January, February, March and April) in 2016 and 2017.

Hydrometric data were collected on site in 1995. Seven continuous monitoring stations were installed in May 2015 and discrete monthly discharge data were gathered to facilitate the development of a continuous record. The current monitoring network consists of 12 active stations (one station was discontinued in March 2017). Hydrometric stations were designed to conform with British Columbia standard criteria for the collection of Grade A data (or Grade B when channel conditions prevent Grade A (MOE, 2009)).

The mean annual temperatures at regional stations range from -4.7°C at Ross River to -2.2°C at Ketza River Mine, and extreme annual temperatures range from -59.4°C at Ross River in December to 35.4°C at Watson Lake in July. Long term records indicate an increasing trend for average minimum, average maximum and mean monthly temperatures at the six regional stations studied. The mean annual temperature recorded at Kudz Ze Kayah for 2016 was -0.80°C and -2.67°C for 2017 while extremes ranged from -26.3°C to 19.9°C. When comparing to both long term regional averages and to regional data for the same period, the 2015-2017 record at KZK generally shows warmer winter temperatures (October to April), cooler summer temperatures (May to September), and reduced diurnal range.

Mean annual precipitation at regional stations ranges from 210 mm at Ross River to 710 mm at Ketza River Mine; the proportion of total annual precipitation falling as rain ranges from 39% at Ketza River Mine up to 70% at Ross River and Faro. The greatest amount of precipitation generally falls between June and September for all regional stations. Long term records do not show clear trends when looking at total precipitation over time; however, the proportion of total precipitation falling as rain has displayed an increasing trend at all stations, consistent with the rising trends observed in air temperature. Total measured precipitation at Kudz Ze Kayah for 2016 was 333.4 mm and 314.6 mm for 2017. Note however that 2017 has missing data due to wildlife interaction with station and the annual total is therefore underestimated.

The 2016 and 2017 snow survey data at five regional stations indicate that both years were below average snow years. Snow Water Equivalent (SWE) values in April 2017 ranged from 70% to 88% of long term average with a mean of 79% whereas the May 2017 SWE values ranged from 74% to 109% of normal with a mean of 90%. Snow surveys conducted in 2016 and 2017 generally showed lower snow water equivalent values than at regional stations, although sampling was not carried out at the exact same time of year. The 2016 and 2017 Project snow survey data also generally showed a lower snow year when compared to the 1995 Project data, although 2017 data are closer to 1995 values.

Winds at the Kudz Ze Kayah site blow predominantly from the northwest to northeast with average and maximum wind speeds being relatively high. Relative humidity and barometric pressure at KZK are generally consistent with regional patterns, and solar radiation peaks in June and is at a minimum in December. Pan evaporation measurements and evapotranspiration calculations at KZK for the 2015-2017 period are generally consistent with 1995 measurements and estimates.

Rating curves, hydrographs, and unit runoff comparisons were calculated by Knight Piesold Ltd. (KP) using baseline data presented in this report. This analysis found that site discharge hydrographs are typically characterised by high spring snowmelt-driven flows, lower summer flows sustained by groundwater inflows and periodic rainfall events, followed by large autumn rainfall events. Winter flow is very low as a result of cold temperatures, freezing conditions, and the gradual depletion of groundwater storage.

LIST OF ACRONYMS

°C	degrees Celsius
%	Percentage
AEG	Alexco Environmental Group Inc.
AET	Actual Evapotranspiration
ASCE	American Society of Civil Engineers
DIAND	Department of Indian Affairs and Northern Development
E	Easting
ECCC	Environment and Climate Change Canada
ET	Evapotranspiration
IEE	Initial Environmental Evaluation
INAC	Indigenous and Northern Affairs Canada
hPa	hectopascal
KP	Knight Piesold Ltd.
KZK	Kudz Ze Kayah
m	Metre
mm	Millimetre
m/s	Metres per second
MAP	Mean Annual Precipitation
MAR	Mean Annual Runoff
masl	Meters Above Sea Level
MOE	Ministry of Environment
N	Northing
NAD83	North American Datum of 1983
PET	Potential Evapotranspiration
QA/QC	Quality Assurance/Quality Control
RPD	Relative Percent Difference
SWE	Snow Water Equivalent
UTM	Universal Transverse Mercator coordinate system
VA	Velocity-Area
W/m^2	Watt per square meter
WSC	Water Survey of Canada, Department of Environment and Climate Change Canada
YESAA	Yukon Environmental and Socio-economic Assessment Act
YESAB	Yukon Environmental and Socio-economic Assessment Board
YG	Yukon Government

GLOSSARY

Evapotranspiration: the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

Hectopascal: a metric measurement unit of pressure commonly used to measure atmospheric pressure.

Initial Environmental Evaluation: document produced by Cominco in 1996 that summarises baseline studies at the Kudz Ze Kayah property, describes the Mine plan, waste material characterization, closure plan, environmental management, potential impacts and associated mitigation measures, and socio-economic impacts associated with the Project as it was defined in 1996.

Mean Annual Runoff: the average value of all annual runoff amounts usually estimated from the period of record or during a specified base period from a specified area.

Penman-Monteith Equation: approximates net evapotranspiration, requiring input data including daily mean temperature, wind speed, relative humidity and solar radiation.

Quality Assurance: the process or set of processes used to measure and assure the quality of a product.

Quality Control: the process of ensuring products and services meet consumer expectations.

Relative Percent Difference: used to compare two quantities while taking into account the "sizes" of the things being compared.

Salt Dilution Gauging: refers to a known mass of salt deployed, typically in a stream, all at once in order to measure discharge through principles of dilution gauging.

Snow Water Equivalent: the amount of water contained within the snowpack.

Velocity-Area: a method of measuring discharge in a channel cross section by dividing it into imaginary vertical panels of known area and measuring and assigning a mean velocity to each panel which cumulatively can be used to compute total discharge.

Yukon Environmental and Socio-economic Assessment Board: an independent body, responsible for implementation of the assessment responsibilities under the *Yukon Environmental and Socio-economic Assessment Act*.

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1 INTRODUCTION

BMC Minerals (No.1) Ltd. (BMC) is proposing to develop the Kudz Ze Kayah (KZK) Project (the Project), which is located approximately 110 km southeast of Ross River, Yukon territory. BMC's Project Proposal for the Project and is currently undergoing a Screening Assessment by the Yukon Environmental and Socio-economic Assessment Board's (YESAB) Executive Committee, under the *Yukon Environmental and Socio-economic Assessment Act (YESAA).* During the Adequacy stage of the Assessment, YESAB requested that BMC submit a number of updated water related reports, prior to YESAB preparing the draft Screening Report. Subsequently, this 2015-2017 Hydrometeorology Baseline Report is an update to the 2015-2016 Hydrometeorology Baseline Report (AEG, 2016) that was submitted as Appendix D-2 of the Project Proposal (BMC, 2017).

This report summarizes local and regional baseline hydrometeorological information in support of Project design and development planning. It is a compilation of monitoring data and observations collected from: the Initial Environmental Evaluation (IEE) by Cominco Ltd. (1996); and site data (2015 to 2017).

From this baseline data, Knight Piesold Ltd. (KP) produced measured discharge records for the Project study area, including stage-discharge curves, hydrographs, and unit-runoff estimates.

1.1 REGIONAL SETTING

The Project is located in the northern foothills of the Pelly Mountains on the Yukon Plateau, on the east side of the divide between the Pelly River and Liard River drainage basins. The Project area is located in the Finlayson Creek/River drainage, which forms part of the Liard Basin. Elevations in the area range from approximately 1,300 meters above sea level (masl) to 2,000 masl. The area has a typical northern interior climate. Summers are cool and short, whereas winters are long and very cold. The frost-free period is generally 40 to 60 days (some valley bottom stations report 70 to 90 days), although frost can occur in any month. Mean annual temperatures range from approximately 0 to -5°C. The study area is within the Extensive Discontinuous Permafrost Zone (Bonnaventure and Lewkowicz, 2013). Permafrost is commonly encountered under the organic layers that cover the Geona and upper Finlayson valleys. Permafrost is typically located under poorly drained areas, cool aspects (north to west facing slopes), and upper elevations. Permafrost related ground movement or solifluction is apparent on upper to middle elevation slopes.

Precipitation estimates range from 250 mm to 500 mm per year, with June, July, and August being the wettest months (Canadian Wildlife Service, 1989); to 500 mm to 600 mm with evapotranspiration under 200 mm (Fisheries and Environment Canada, 1978). Assuming a 500 mm to 600 mm annual average, this gives a rough mean annual runoff (MAR) estimate approximately 300 mm to 400 mm which is appropriate when compared to discharge measured at the Water Survey of Canada (WSC) stations in the region.

1.2 OBJECTIVES

Baseline studies were initiated in 2015 to build on previous work completed in 1995. These programs were designed to meet the requirements of the YESAB and the Yukon Water Board for a Water Use Licence application. This report summarizes the historical data collected for the Project, the current data collected and the available regional hydrometeorological data.

2 CLIMATE AND METEOROLOGICAL DATA

The following section presents regional and site-specific climatic and meteorological data. Regional data are available through Environment and Climate Change Canada (ECCC) and Environment Yukon. Meteorological data were collected on site in 1995, and a new meteorological station for the Project was commissioned in late August 2015.

2.1 METHODS

2.1.1 Regional Data

Climatic normals and long-term trends were evaluated by reviewing long-term records from stations in the region (regional analysis). ECCC meteorological stations used for regional temperature and precipitation summary and trend analysis, selected based on location/proximity and data availability, are presented in Table 2-1 below. The table also indicates which stations were included in each analysis, while rationale on station selection are provided in the respective sections. Figure 2-1 shows the location of these stations.

Of the stations listed, only Watson Lake A and Faro A have a long enough and complete enough data record for the compilation of climate normals, which were available for the periods 1961-1990, 1971-2000 and 1981-2010 for Watson Lake A, and 1971-2000 and 1981-2010 for Faro A.

The Wolverine Mine is located approximately 28 km to the east of the Project and ran an automated HOBO® Onset Weather Station located on the southwest side of the airstrip, at an approximate elevation of 1,320 masl. This station collected temperature, relative humidity, rain, solar radiation wind speed and direction, and barometric pressure data (Yukon Zinc Corporation, 2011). Results obtained at the Wolverine Mine were used for comparison where practicable, but were not used in the regional analysis because the level of quality assurance/quality control (QA/QC) conducted on the data is not known and may not meet the same standards as those by ECCC. For example, there were some data gaps in the Wolverine Mine record, some of which were filled by the installation of a second station at a different location (above the tailings facility) (Yukon Zinc Corporation, 2011).

Table 2-1: Regional Environment and Climate Change Canada Meteorological Stations

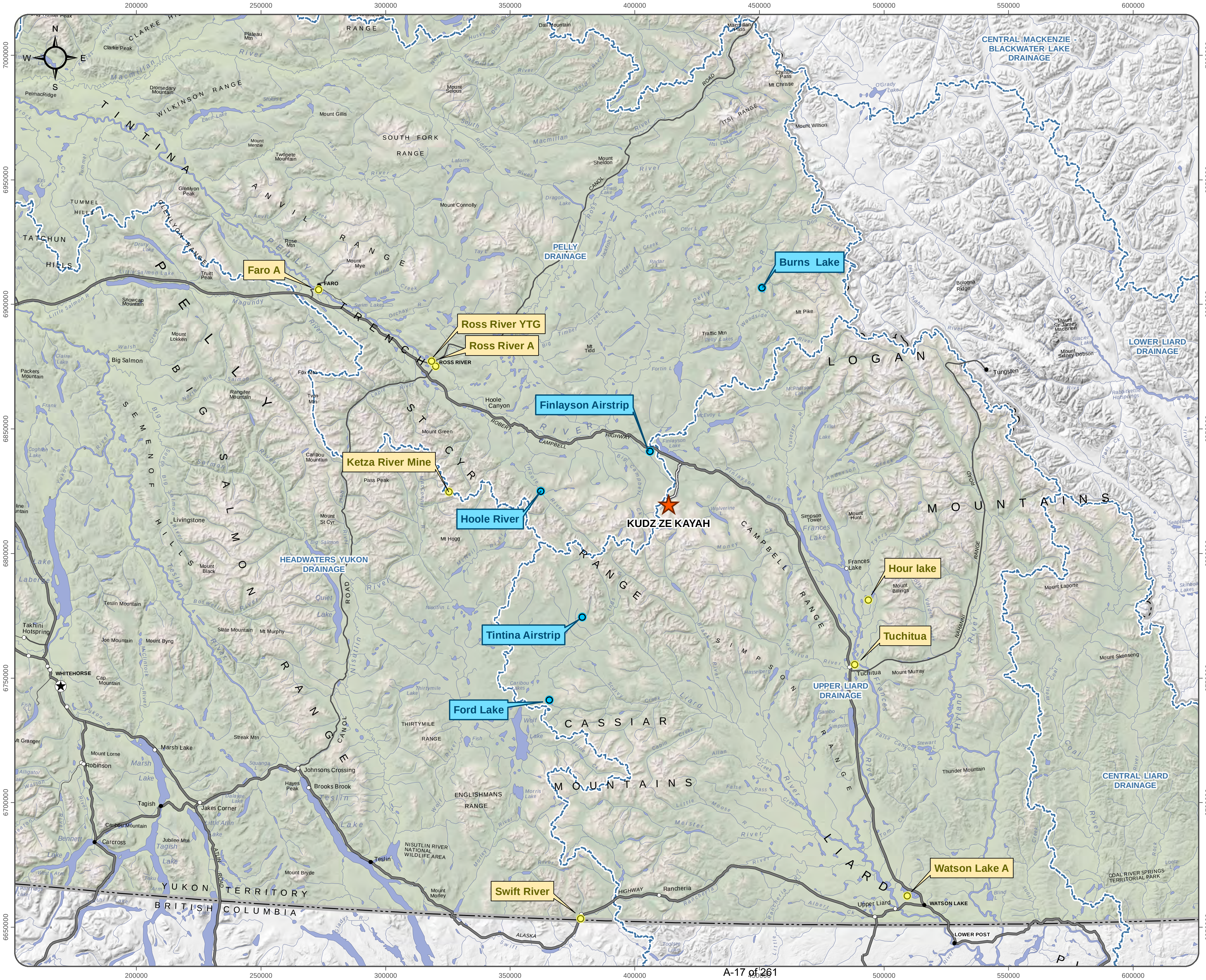
Station Name	Station ID	Latitude	Longitude	Elevation (masl)	Distance from KZK (km)	Years of data	Temperature		Precipitation		
							Summary Statistics	Trend Analysis	Summary Statistics	Elevation Relationships	Trend Analysis
Hour Lake	2100FCG	61°10'54"	-129°07'54"	890	86	1982-2014	✓	✓	✓	✓	✓
Tuchitua	2101135	60°56'00"	-129°13'00"	724	97	1967-2014	✓	✓	✓	✓	✓
Ketza River Mine	210FPP	61°31'00"	-132°16'00"	1,380	87	1985-1995	✓		✓	✓	
Swift River	2101081	60°00'00"	-131°11'00"	891	167	1966-2008	✓	✓	✓	✓	✓
Ross River A	2100940	61°58'00"	-132°26'00"	705	111	1964-1994	✓	✓	✓	✓	✓
Ross River YTG	2100941	61°59'00"	-132°27'00"	698	111	1993-2008	✓		✓		
Watson Lake A	2101200	60°06'59"	-128°49'20"	687	181	1953-2014	✓	✓	✓	✓	✓
	2101201	60°06'59"	-128°49'21"			2014-2018					
Faro A	2100517	62°12'25"	-133°22'24"	716	167	1978-2018	✓	✓	✓	✓	✓

BMC MINERALS

KUDZ ZE KAYAH PROJECT
HYDROMETEOROLOGY BASELINE REPORT

FIGURE 2 - 1
REGIONAL METEOROLOGICAL AND SNOW MONITORING STATIONS

OCTOBER 2016



- Kudz Ze Kayah Project
- Meteorological and Snow Monitoring Station
- Snow Monitoring Station

ALEXCO ENVIRONMENTAL GROUP

Digital elevation model created by the Yukon Department of the Environment interpolated from the digital 1:50,000 Canadian National Topographic Database (NTDB Edition 2) contour and watercourse layers. Obtained from Geomatics Yukon.

Canvec compiled by Natural Resources Canada at a scale of 1:10,000 - 1:50,000. Reproduced under license from Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada. All rights reserved.
Drainage areas obtained from National Hydrology Network 2011

Datum: NAD 83; Projection UTM Zone 9N

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1:1,500,000 when printed on 11 x 17 inch paper

0 20 40 60 80
Kilometers

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2.1.2 Site Data

Site meteorological data consists of historical datasets collected in 1995, and of ongoing monitoring initiated in late August 2015.

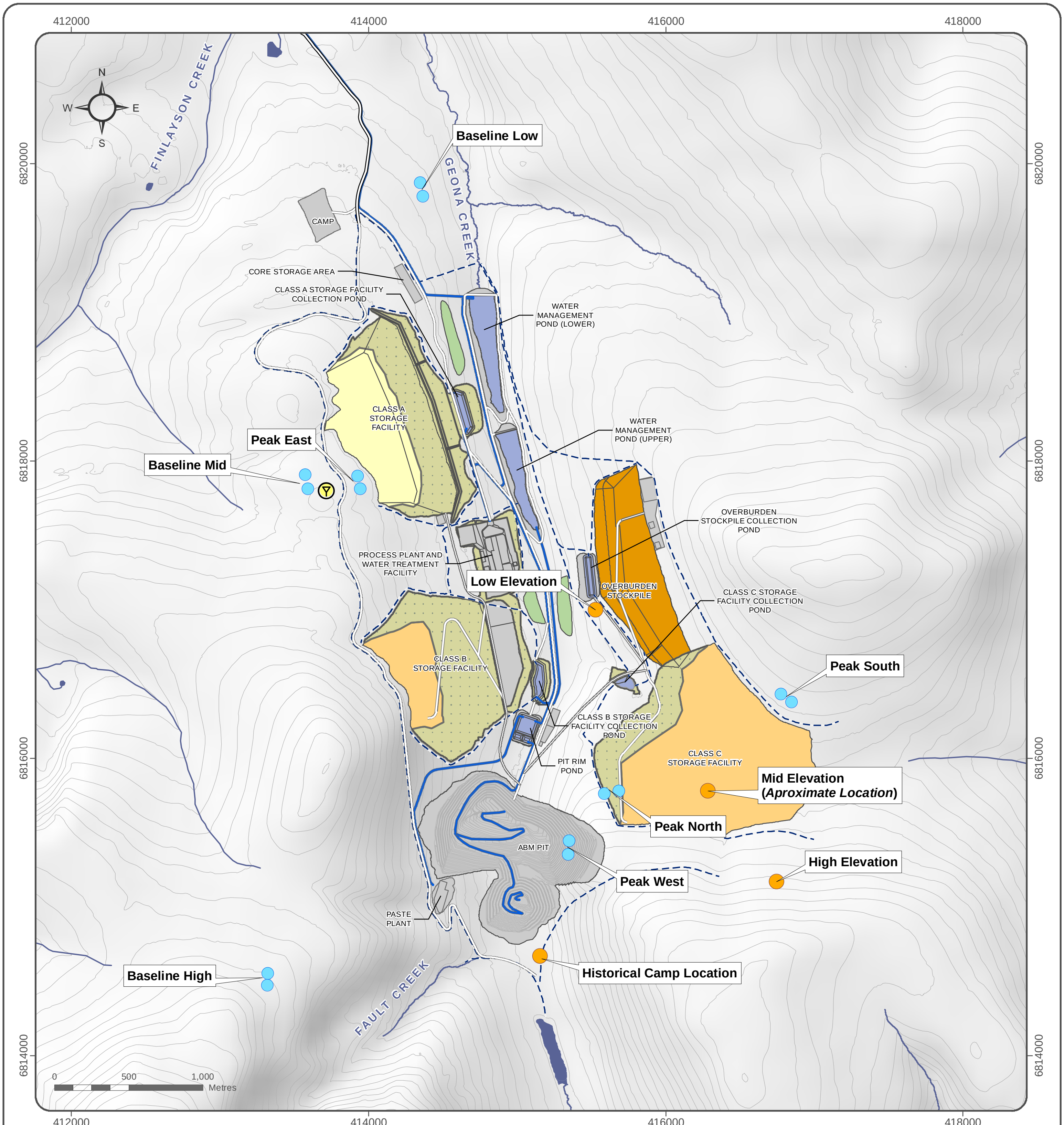
2.1.2.1 Historical Data

Two meteorological stations were established in the Project area during 1995, as shown in Figure 2-2. A low elevation station was located just east of Geona Creek adjacent to the then proposed location of the tailings impoundment, and was in full operation between April 13 and September 3, 1995. A high elevation station was initially installed (April 12, 1995) at the Project exploration camp at the head of Geona Creek before being moved to its high elevation location on May 8, 1995. The station was also in full operation until September 3, 1995. Data collected included temperature, wind speed, and direction and precipitation. Additional data collected at the low elevation site included evaporation, solar radiation, and relative humidity. These data were sampled at 15 second intervals and averaged and recorded every 30 minutes. The results are summarized in Table 2-2 below (details can be found in Cominco Ltd., 1996).

Table 2-2: Monthly Summary of Climatic Parameters, KZK Climate Stations, 1995

	Wind Speed (m/s)		Air temperature (°C)			Solar Radiation (W/m^2)		Relative Humidity (%)		Precipitation (mm)
	Avg	Max	Avg	Max	Min	Avg	Max	Avg	Max	Total
Low Elevation Station										
April	5.7	15.4	0.4	11.6	-9.3	-	-	-	-	-
May	6.8	14.4	6.7	8.8	-5.5	319.9	869.6	-	-	-
June	6.0	21.0	10.5	25.1	-2.9	340.4	947.8	60.2	94.9	54
July	5.6	16.9	10.0	19.2	2.1	282.0	920.0	77.0	100.0	59
Aug- 4 Sept	5.9	22.3	7.1	16.9	-1.2	267.5	854.0	77.9	100.0	47*
Camp Station										
Apr 12 – May 8	4.7	15.8	0.7	11.5	-11.4	-	-	-	-	-
High Elevation Station										
May 8 – 25	12.7	29.7	5.2	16.0	-2.8	-	-	-	-	-
June 8 – 30	9.6	27.2	11.2	22.6	0.1	-	-	-	-	142*
July	10.1	27.3	8.7	17.0	2.4	-	-	-	-	52
Aug – 4 Sept	10.0	27.7	6.2	14.7	-0.6	-	-	-	-	54*

** Monthly total rather than specified interval*
Source: Cominco Ltd., 1996 (Table 3-2)



Current Meteorological Station

Historical Meteorological/Snow Monitoring Station

Snow Sampling Location

Proposed Site Infrastructure

- Class A Storage Facility
- Class B and C Storage Facility
- Overburden Stockpile
- Topsoil Stockpile
- Progressive Reclamation
- Pond/Water

- Pipeline
- Diversion Ditch
- Tote Road/Proposed Access Road
- Proposed Mine Road

KUDZ ZE KAYAH PROJECT HYDROMETEOROLOGY BASELINE REPORT

FIGURE 2-2

HISTORICAL AND CURRENT METEOROLOGICAL AND SNOW SURVEY STATIONS LOCATIONS

DECEMBER 2016

Datum: NAD 83; Projection: UTM Zone 9N

AEG

BMC MINERALS

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2.1.2.2 Current Data Collection

A Campbell Scientific meteorological station was installed at the Project site at the following UTM NAD83 coordinates: 09V 413,710 Easting (E) 6,817,805 Northing (N), elev. 1,542 masl (Figure 2-2) and commissioned on August 25, 2015. The station consists of a 10 m tower, datalogger, and sensors to collect the following measurements:

- Air Temperature (°C);
- Relative Humidity (%);
- Wind Speed (m/s) and Direction (degrees);
- Barometric Pressure (hPa);
- Solar Radiation (W/m^2); and
- Precipitation (mm).

A detailed list of components and photos are presented in Appendix A. The station was programmed to take readings at 10 second intervals and to log hourly values of the above parameters, including average and maximum wind speed. The station was equipped with satellite communication and was set up for weekly data transfers. The station's program also incorporates an evapotranspiration (ET) instruction that provided an estimate of ET values based on measured meteorological parameters, using the American Society of Civil Engineers (ASCE) Penman-Monteith Standardized reference evapotranspiration equation.

A Class A evaporation pan was installed at the weather station site; however, no pan evaporation data could be collected in 2015 due to water freezing in the pan at the time of commissioning (late August). In 2016, daily measurements were taken between May 21 and September 5, and in 2017 from June 25 to September 11, as conditions allowed.

2.1.2.3 QA/QC

Data collected at the Campbell Scientific meteorological station were validated weekly by searching for outliers or any unrealistic values, and comparing with data from regional stations as required. Diagnostic values were also consulted to help determine whether or not data needed to be invalidated and, as the case may be, determine the cause. ET calculations were also verified using REF-ET, a reference evapotranspiration calculator developed by the University of Idaho (Allen, 2015). When suspicious values were noted during the weekly validation, appropriate maintenance or troubleshooting actions were incorporated into the next site visit. In addition, the station was visually inspected and maintained monthly, including the following steps:

- Ensuring that the solar panel was free of frost, snow and/or debris;
- Ensuring that the solar radiation sensor was free of frost, snow and/or debris. The sensor was wiped free of dust, using a soft cloth dampened with water or alcohol. Condensation within the dome was also checked for;
- Ensuring that the precipitation gauge opening was not obstructed by debris or snow. If clearing was necessary, note the date and time clearing was completed;
- Ensuring that all the wires were properly connected to the datalogger inside the enclosure;
- Replacing desiccant in enclosure; and
- Observing any sign of damage to the station by animals, wind, etc. paying particular attention to sensor cables and guy wires; guy wires were tightened if necessary.

As part of the QA/QC program, the Geonor T-200B total precipitation gauge was returned to Campbell Scientific for testing and recalibration and a SBS500 tipping bucket was temporarily installed at site to prevent data loss from May 17 to September 12, 2017.

As part of the regular inspections, the alter screen height was noted to be low relative to the Geonor opening and adjusted in August 2016. Some wind screen panels were also found to have fallen on the ground on a few occasions during the winters of 2016 and 2017 and were put back in place during the monthly visits.

The station was down between August 30, 2017 and September 12, 2017 due to damage to the power cable caused by porcupines.

2.2 RESULTS

The following sections summarize regional data, where available, and site data collected between September 2015 and December 2017. A complete daily table of data collected at the Project site is available in Appendix B, while monthly summaries are discussed in the sections below.

2.2.1 Temperature

2.2.1.1 Regional Data

Extreme and average minimum and maximum, as well as mean monthly and annual temperatures were calculated for the entire period of record for each regional station (Table 2-3). The mean annual temperatures ranged from -4.7°C at Ross River to -2.2°C at Ketza River Mine, and extreme annual temperatures ranged from -59.4°C at Ross River in December to 35.4°C at Watson Lake in July.

Table 2-3: Regional Monthly and Annual Temperatures (°C)

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Extreme Monthly Minimum Temperature (period of record) in °C													
Hour Lake	-51.0	-48.0	-45.0	-35.0	-24.0	-4.5	-2.5	-4.5	-20.0	-36.0	-47.0	-51.0	-51.0
Tuchitua	-54.4	-55.6	-45.6	-33.3	-22.5	-8.0	-2.2	-6.1	-19.5	-29.5	-45.6	-54.4	-55.6
Ketza River Mine	-40.0	-40.0	-27.0	-19.0	-12.0	-2.5	1.0	-5.0	-10.0	-24.0	-40.0	-40.0	-40.0
Swift River	-52.2	-54.0	-43.9	-33.3	-17.0	-6.7	-4.0	-5.6	-16.7	-28.9	-41.7	-52.2	-54.0
Ross River A	-59.4	-59.4	-50.0	-32.2	-10.6	-6.7	-3.3	-5.6	-18.5	-38.0	-51.0	-59.4	-59.4
Ross River YTG	-57.0	-52.0	-45.0	-32.0	-17.0	-3.5	-1.0	-4.5	-12.0	-31.5	-45.0	-57.0	-57.0
Watson Lake A	-58.9	-56.1	-46.7	-32.8	-16.0	-3.3	0.6	-6.7	-13.9	-36.6	-47.5	-58.9	-58.9
Faro A	-51.0	-51.0	-44.0	-30.5	-8.0	-2.5	0.6	-4.5	-15.5	-34.0	-46.0	-51.0	-51.0
Monthly Mean Minimum Temperature (period of record)													
Hour Lake	-26.1	-22.8	-19.0	-9.1	-1.5	4.2	6.2	4.4	0.3	-5.9	-19.5	-24.4	-9.4
Tuchitua	-29.2	-25.5	-20.7	-9.1	-1.3	4.2	6.1	3.6	-1.0	-7.0	-19.5	-27.3	-10.6
Ketza River Mine	-16.1	-16.8	-10.9	-7.2	0.1	4.9	7.3	5.4	0.6	-7.1	-16.4	-16.3	-6.0
Swift River	-24.6	-21.0	-17.1	-9.3	-1.9	2.7	5.0	3.3	-0.2	-5.6	-16.7	-23.4	-9.0
Ross River A	-34.2	-27.2	-20.1	-8.7	-1.4	3.5	6.1	3.3	-1.8	-8.7	-23.3	-30.5	-11.9
Ross River YTG	-31.6	-26.1	-22.0	-9.3	-1.1	4.6	6.6	3.5	-1.5	-8.0	-21.1	-27.2	-11.1
Watson Lake A	-28.8	-24.4	-18.2	-6.8	1.0	6.7	8.9	6.9	2.3	-4.3	-18.8	-26.8	-8.5
Faro A	-24.5	-20.9	-15.4	-5.5	1.3	6.9	9.0	6.5	1.5	-5.3	-18.3	-23.6	-7.4
Mean Monthly Temperature (period of record)													
Hour Lake	-19.9	-16.2	-10.9	-1.7	5.7	11.7	13.5	11.6	5.8	-1.9	-14.7	-18.7	-3.0
Tuchitua	-23.7	-18.2	-11.4	-0.9	6.3	11.8	13.5	11.2	5.4	-1.9	-14.5	-21.9	-3.7
Ketza River Mine	-12.3	-12.6	-7.2	-3.0	4.0	9.5	11.9	9.5	3.8	-4.4	-12.9	-12.4	-2.2
Swift River	-19.1	-14.0	-9.4	-2.0	5.0	10.1	11.9	10.5	5.6	-1.1	-11.6	-18.1	-2.7
Ross River A	-27.7	-19.2	-10.7	-1.0	6.1	11.6	13.7	11.0	5.1	-3.1	-17.5	-24.1	-4.7
Ross River YTG	-24.3	-17.2	-11.5	-0.9	6.5	12.5	14.2	11.5	5.4	-2.5	-15.9	-20.1	-3.5
Watson Lake A	-23.6	-17.8	-10.4	-0.2	7.5	13.1	15.1	13.1	7.7	0.0	-14.2	-22.0	-2.6
Faro A	-20.1	-15.6	-8.9	0.7	7.8	13.2	15.0	12.6	6.8	-1.6	-14.4	-19.3	-2.0
Monthly Mean Maximum Temperature (period of record)													
Hour Lake	-14.4	-9.6	-2.7	5.8	12.8	19.1	20.8	18.5	11.2	2.3	-9.9	-13.4	3.4
Tuchitua	-18.0	-10.9	-2.0	7.1	13.8	19.4	21.0	18.8	12.0	3.3	-9.4	-16.2	3.2
Ketza River Mine	-8.4	-8.4	-3.4	1.2	7.8	14.1	16.4	13.6	7.0	-1.7	-9.4	-8.6	1.7
Swift River	-13.5	-7.1	-1.6	5.4	11.9	17.4	19.2	17.6	11.4	3.5	-6.4	-12.5	3.8
Ross River A	-21.2	-11.3	-1.3	6.5	13.6	19.6	21.4	18.9	12.0	2.6	-11.7	-18.4	2.6
Ross River YTG	-18.0	-9.0	-1.5	7.3	14.1	20.7	22.0	19.6	12.4	3.0	-10.7	-14.3	3.8
Watson Lake A	-18.3	-11.1	-2.5	6.4	13.9	19.4	21.2	19.2	13.0	4.2	-9.6	-17.2	3.2

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual
Extreme Monthly Minimum Temperature (period of record) in °C													
Faro A	-15.8	-10.4	-2.4	6.9	14.2	19.5	20.9	18.5	11.9	2.1	-10.5	-15.1	3.3
Extreme Monthly Maximum Temperature (period of record)													
Hour Lake	11.0	10.0	15.0	19.5	31.0	32.5	33.0	32.5	24.0	18.0	18.0	11.0	33.0
Tuchitua	4.0	11.0	17.0	21.7	33.0	32.8	34.0	33.0	26.7	20.6	10.0	4.0	34.0
Ketza River Mine	1.0	6.0	4.0	9.5	19.5	24.0	25.0	26.5	21.0	6.0	3.0	1.0	26.5
Swift River	9.0	16.0	16.0	24.0	31.0	31.1	31.0	31.0	27.2	29.0	11.0	9.0	31.1
Ross River A	5.0	11.7	13.0	21.1	31.0	33.3	31.5	31.1	27.8	18.9	11.7	5.0	33.3
Ross River YTG	5.0	7.0	14.0	21.0	32.5	35.0	31.0	32.0	25.0	19.0	10.0	5.0	35.0
Watson Lake A	8.9	12.2	16.6	20.1	34.2	33.9	35.4	32.8	28.9	21.7	12.2	8.9	35.4
Faro A	10.6	12.1	15.5	21.5	32.0	33.8	33.2	33.9	25.5	18.5	12.5	10.6	33.9

Source: ECCC, 2018

The mean annual temperature observed at the nearby Wolverine Mine is comparable to that of the ECCC regional stations, ranging from -5.7°C to 0.4°C between 2010 and 2015 and in 2017. The warmest month has typically been June or July and the coldest being December or January, with extremes extending from -41.3°C to 25.2°C (Yukon Zinc Corporation, 2011a, 2012, 2013, 2014, 2015, 2016, 2018).

2.2.1.1.1 Long-Term Trends

Temperature trends were analyzed for six regional stations (the two Ross River stations were combined, and Ketza River Mine was removed because the record was too short for trend analysis). All stations displayed an increasing trend over the data collection period for average minimum, average maximum and mean monthly temperatures. The greatest rate of increase was observed at Hour Lake (0.0174°C per year for the mean and maximum temperatures) and the lowest was observed at Watson Lake A (0.0018°C per year for maximum temperature). However, correlations were very weak in all cases (Appendix C).

When comparing climate normals at Watson Lake A for the period 1961 to 1990 with the most recent normal period 1981 to 2010, average, minimum and maximum temperatures were higher during the most recent period for every month except for August and October. The difference was greatest during the winter months and for the minimum temperature, which is consistent with trends observed in northern latitudes worldwide (IPCC, 2013; NOAA, 2014). Table 2-4 presents Watson Lake A climate normals data for the three periods.

Table 2-4: Temperature Normals for Watson Lake A

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1981-2010													
Daily Average (°C)	-22.5	-17	-9.6	0.1	7.6	13.2	15.3	13	7.5	-0.5	-14.7	-20.8	-2.4
Daily Maximum (°C)	-17.5	-10.4	-1.8	7	14	19.6	21.5	19.1	12.8	3.7	-10	-16	3.5
Daily Minimum (°C)	-27.5	-23.5	-17.3	-6.8	1.3	6.8	9	6.9	2.2	-4.7	-19.3	-25.6	-8.2
1971-2000													

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Daily Average (°C)	-24.2	-17.9	-10	0	7.4	12.8	15.1	13	7.5	-0.5	-15	-22.4	-2.9
Daily Maximum (°C)	-18.9	-11.3	-2	6.7	13.7	19.1	21.2	19.1	12.9	3.8	-10.3	-17.4	3.1
Daily Minimum (°C)	-29.4	-24.5	-17.9	-6.8	1	6.3	8.9	6.8	2	-4.8	-19.7	-27.4	-8.8
1961-1990													
Daily Average (°C)	-24.6	-18.4	-10.5	-0.4	6.9	12.5	14.9	13	7.4	-0.1	-15.3	-22.9	-3.1
Daily Maximum (°C)	-19.4	-11.8	-2.7	6.1	13.3	18.9	21.1	19.2	12.8	4.3	-10.5	-18	2.8
Daily Minimum (°C)	-30	-25.1	-18.6	-7.1	0.5	6.1	8.7	6.8	1.9	-4.5	-20.2	-28	-9.1

**Source: ECCC, 2016*

Similarly, at Faro A, annual and winter temperature normals were generally higher during the most recent period (1981 to 2010) than during 1971 to 2000, consistent with a warming trend (Table 2-5).

Table 2-5: Temperature Normals for Faro A

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
1981 to 2010													
Daily Average (°C)	-20.1	-15.5	-8.6	0.6	7.5	13.2	15	12.4	6.4	-2	-14.8	-17.9	-2
Daily Maximum (°C)	-16	-10.3	-2.1	6.8	13.8	19.6	21	18.4	11.5	1.7	-11.1	-13.8	3.3
Daily Minimum (°C)	-24.6	-20.7	-15	-5.5	1.2	6.8	8.9	6.3	1.3	-5.7	-18.5	-22.3	-7.3
1971 to 2000													
Daily Average (°C)	-21.5	-16	-8.2	0.5	7.5	13	15	12.3	6.5	-1.7	-14.1	-19.9	-2.2
Daily Maximum (°C)	-17.3	-10.8	-1.8	6.8	13.7	19.3	20.9	18.3	11.6	2.1	-10.4	-15.8	3.1
Daily Minimum (°C)	-26	-21.3	-14.5	-5.7	1.2	6.6	9	6.2	1.3	-5.4	-17.9	-24.3	-7.6

**Source: ECCC, 2016*

2.2.1.2 Site Data

Monthly average minimum, maximum, mean and extreme temperatures were compiled from the hourly data collected at the Project's Campbell Scientific station since time of commissioning (Table 2-6). The mean annual temperature for 2016 was -0.80°C and -2.61°C for 2017, and extremes ranged from -31.33°C to 22.86°C.

Table 2-6: Monthly Air Temperature (°C), KZK, 2015-2017

Month	Extreme Minimum Temperature (°C)	Average Minimum Temperature (°C)	Mean Temperature (°C)	Average Maximum Temperature (°C)	Extreme Maximum Temperature (°C)
Sep 2015	-8.28	-0.66	1.42	3.65	8.94
Oct 2015	-11.05	-3.08	-1.12	0.89	6.01
Nov 2015	-26.28	-11.08	-8.57	-5.93	2.00
Dec 2015	-21.89	-13.28	-11.08	-9.23	0.23
Jan 2016	-17.04	-8.87	-6.97	-5.41	-0.94
Feb 2016	-21.58	-10.08	-8.02	-6.11	-0.75

Month	Extreme Minimum Temperature (˚C)	Average Minimum Temperature (˚C)	Mean Temperature (˚C)	Average Maximum Temperature (˚C)	Extreme Maximum Temperature (˚C)
Mar 2016	-16.21	-8.01	-6.14	-4.28	7.69
Apr 2016	-5.53	-2.61	-0.16	2.26	9.39
May 2016	-3.05	1.94	5.12	8.31	17.48
Jun 2016	1.45	6.39	9.81	13.29	19.42
Jul 2016	1.52	7.71	10.75	13.91	19.89
Aug 2016	0.33	6.71	9.29	12.31	18.93
Sep 2016	-6.27	0.78	3.23	5.95	10.68
Oct 2016	-13.62	-6.96	-4.99	-2.88	4.42
Nov 2016	-17.82	-9.35	-7.46	-5.74	0.26
Dec 2016	-26.38	-16.12	-14.10	-12.23	-4.05
Jan 2017	-27.40	-13.09	-10.55	-8.29	-1.64
Feb 2017	-18.93	-13.57	-11.60	-9.43	3.20
Mar 2017	-31.33	-17.61	-15.44	-13.15	-1.12
Apr 2017	-16.42	-5.72	-3.35	-0.83	3.92
May 2017	-5.13	0.77	3.73	6.68	16.80
Jun 2017	-0.65	4.58	7.91	11.40	20.31
Jul 2017	2.30	7.34	10.14	13.31	21.38
Aug 2017	0.81	7.03	10.18	13.36	22.86
Sep 2017*	*-3.81*	*2.36*	*4.85*	*7.45*	*13.40*
Oct 2017	-9.30	-4.95	-2.96	-1.00	10.37
Nov 2017	-29.27	-18.25	-15.75	-13.44	-5.27
Dec 2017	-25.56	-10.66	-8.52	-6.17	2.52
2016	**-26.38**	**-3.21**	**-0.80**	**1.62**	**19.89**
2017	**-31.33**	**-5.15**	**-2.61**	**-0.01**	**22.86**
2016-2017	**-31.33**	**-4.18**	**-1.71**	**0.80**	**22.86**

Grey italics indicate partial data

** September 2017 is missing 11 days of data due to porcupines chewing on station's power cable*

Monthly average temperatures recorded at the Project site in 2016 and 2017 were generally comparable to those recorded during the summer months of 1995 (at both the low and high elevation stations) (Table 2-2).

Figure 2-3 presents a comparison of monthly averages of all the regional stations in Table 2-3 to the September 2015 – December 2017 with the corresponding Kudz Ze Kayah monthly averages. Note: the 2016 and 2017 temperature data collected at the Project site generally had warmer winter temperatures (November to February) and cooler summer temperatures (May to September) than at regional stations, with 2016 being overall warmer than 2017.

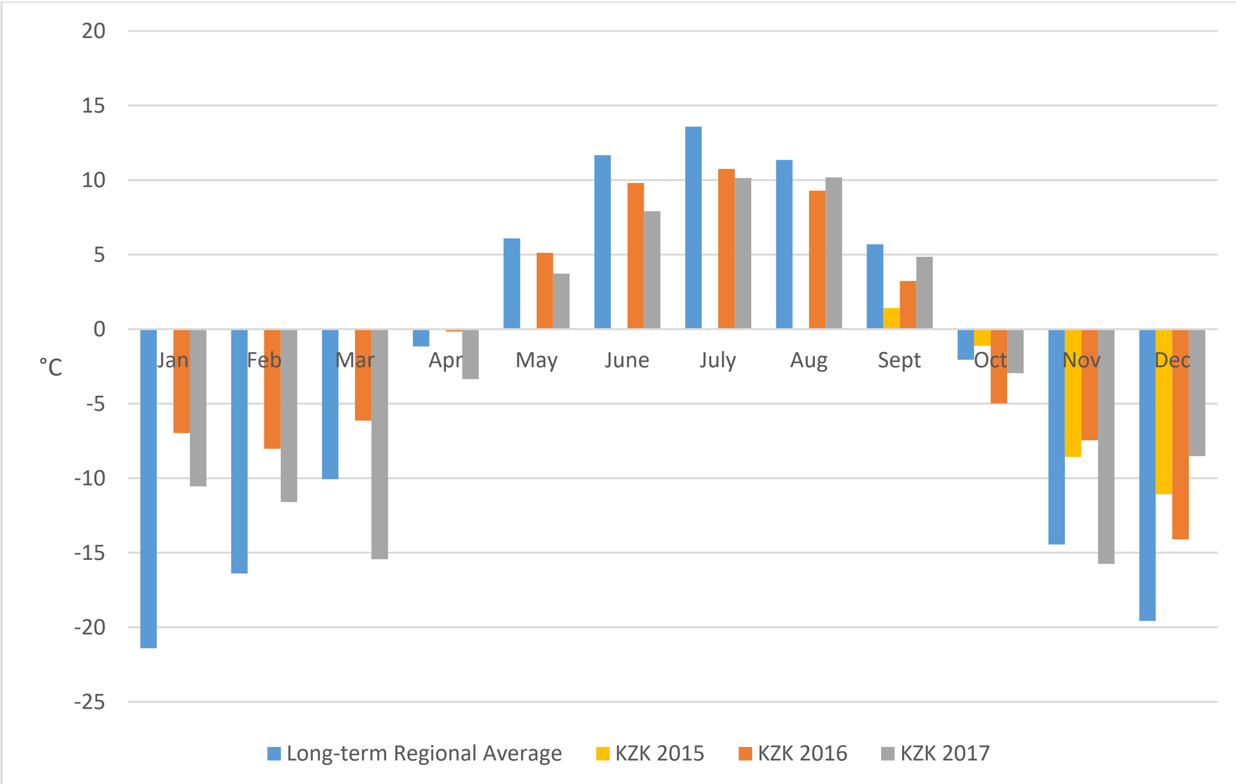


Figure 2-3: Long-term Regional Monthly Average Temperatures and Sept 2015 to Dec 2017 Monthly Averages at KZK

Only two of the regional stations were active during the period September 2015 to December 2017; namely Watson Lake A (station ID 2101201) and Faro A (station ID 2100527). Figure 2-4 presents a comparison of the hourly temperature record for that period between those two regional stations and the Project site. There was correlation between all three sites, with Kudz Ze Kayah temperatures generally warmer in the winter and cooler in the summer, which is consistent with observations described above. The diurnal temperature range was also smaller at the Project site compared to Watson Lake A and Faro A, particularly during summer months. The mean annual temperature for 2016 was -0.43°C at Watson Lake and 0.22°C at Faro, in comparison to -0.80°C at the Project site. For 2017, mean annual temperatures were -1.62°C, -1.72°C and -2.61°C in Watson Lake, Faro and KZK respectively.

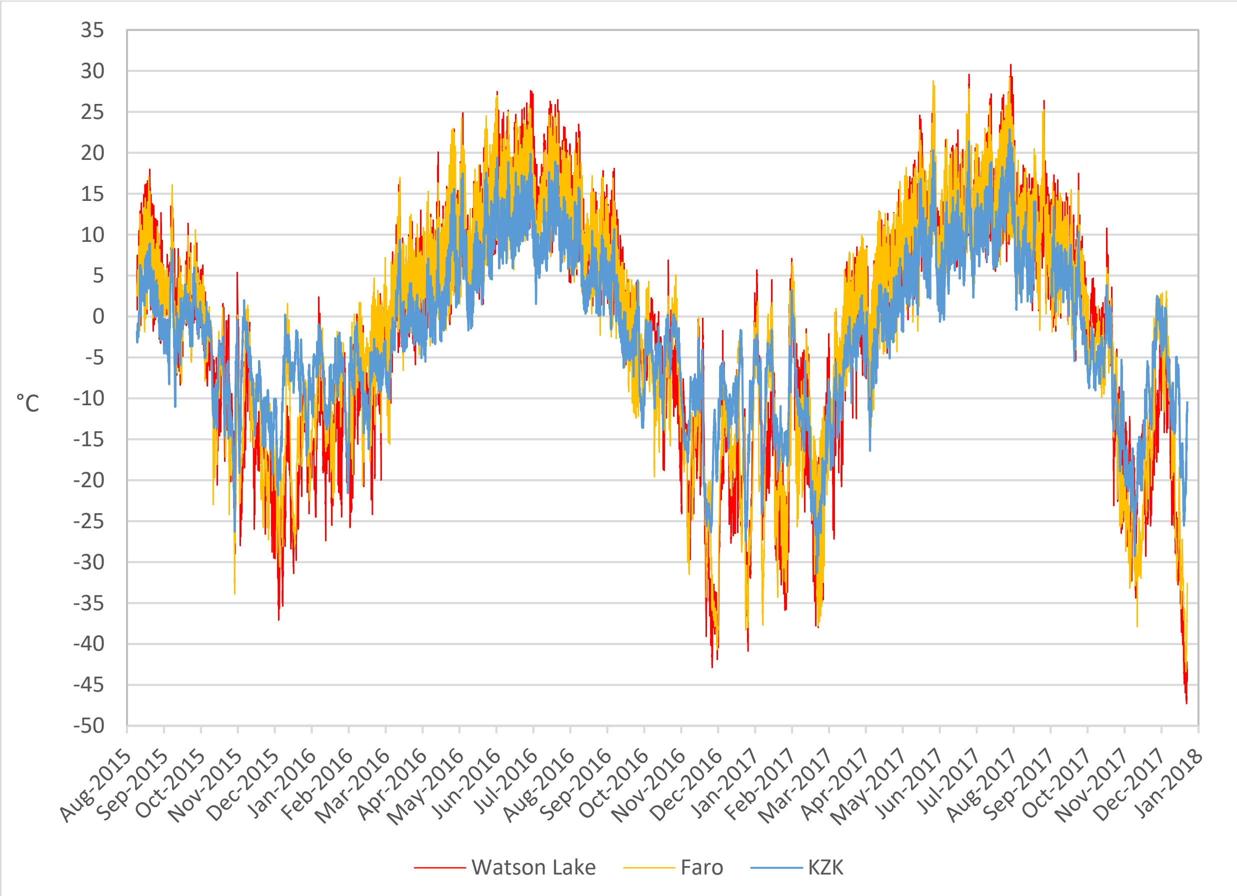


Figure 2-4: Watson Lake A, Faro A, and KZK Hourly Temperature, Sept 2015 to Dec 2017

2.2.2 Precipitation

2.2.2.1 Regional Data

Mean monthly rain, snow and total precipitations were calculated for the entire period of record for each station listed in Table 2-1. The proportion of total annual precipitation falling as rain ranged from 39% at Ketza River Mine to up to 70% at Ross River and Faro (Table 2-7). The greatest amount of precipitation generally fell between June and September for all stations.

Table 2-7: Regional Monthly and Annual Rain, Snow and Total Precipitation

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual*
Mean Monthly Rain (mm) - period of record													
Hour Lake	0.0	0.2	0.2	5.1	29.5	61.9	69.6	68.9	49.5	14.6	0.3	0.0	299.8
Tuchitua	0.0	0.0	0.0	5.9	31.0	52.6	68.9	49.6	45.3	15.3	0.7	0.1	269.4
Ketza River Mine	0.3	0.5	0.0	0.0	14.1	52.5	51.8	77.3	63.9	12.6	0.0	0.0	272.9

	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Annual*
Swift River	0.1	0.0	0.3	2.3	27.1	40.7	61.9	54.7	69.4	23.7	3.2	0.0	283.5
Ross River A	0.0	0.0	0.0	3.1	16.1	30.4	49.2	34.4	24.7	5.7	0.2	0.0	163.8
Ross River YTG	0.0	0.0	0.0	2.0	19.7	28.8	36.8	31.4	23.4	4.7	0.0	0.0	146.8
Watson Lake A	0.2	0.0	0.4	3.9	26.6	51.4	55.0	43.7	39.9	16.2	1.5	0.3	238.9
Faro A	0.0	0.0	0.1	2.2	22.9	32.7	51.2	41.0	32.6	8.7	0.1	0.1	191.6
Mean Monthly Snow (cm) - period of record													
Hour Lake	40.9	28.8	25.8	14.2	6.6	0.0	0.1	0.1	4.1	30.7	44.9	44.7	240.9
Tuchitua	39.9	28.3	20.8	11.8	3.2	0.0	0.0	0.0	1.9	21.8	37.8	43.1	208.6
Ketza River Mine	62.3	51.7	48.1	25.0	16.5	0.6	0.0	1.0	22.4	55.0	90.7	66.0	439.1
Swift River	45.0	36.1	35.9	19.7	3.9	0.1	0.0	0.1	3.7	36.1	51.9	47.6	280.1
Ross River A	17.1	12.4	10.6	4.4	0.3	0.0	0.0	0.4	1.9	12.8	18.9	15.4	94.3
Ross River YTG	11.4	7.7	5.0	2.2	0.4	0.0	0.0	0.0	0.6	9.2	12.9	12.1	61.4
Watson Lake A	38.2	27.4	21.5	12.8	4.0	0.0	0.0	0.1	2.3	19.9	35.6	40.4	202.1
Faro A	14.3	12.9	11.6	5.8	0.5	0.0	0.0	0.5	2.3	17.0	19.1	16.3	100.3
Mean Monthly Precipitation (mm) - period of record													
Hour Lake	40.9	29.0	26.0	19.3	36.4	61.9	69.7	69.1	53.5	45.3	45.3	44.7	541.0
Tuchitua	39.9	28.3	20.8	18.0	34.2	52.6	68.9	49.6	47.2	37.1	38.5	43.2	478.3
Ketza River Mine	62.5	52.2	48.1	25.0	28.2	53.1	51.8	78.3	86.3	67.5	90.7	66.0	709.8
Swift River	45.2	36.1	36.3	21.4	31.0	40.8	61.9	54.8	73.2	59.0	54.9	47.6	562.0
Ross River A	17.1	12.4	10.6	7.5	16.8	30.4	49.2	34.8	26.6	18.4	19.1	15.4	258.5
Ross River YTG	11.4	7.7	5.0	4.1	21.9	28.8	36.8	31.4	24.0	14.4	12.9	12.1	210.4
Watson Lake A	32.2	22.2	18.6	15.5	31.8	52.8	57.7	45.1	43.0	34.7	31.9	34.0	419.7
Faro A	13.9	10.4	10.9	7.9	21.8	40.3	57.1	50.3	36.9	23.8	15.9	14.3	303.5
% of Total Precipitation Falling as Rain – period of record													
Hour Lake	0.1	0.7	0.6	26.5	81.3	100.0	99.8	99.8	92.4	32.2	0.7	0.1	55.4
Tuchitua	0.0	0.1	0.0	32.6	90.8	100.0	100.0	99.9	96.0	41.2	1.8	0.2	56.3
Ketza River Mine	0.4	1.0	0.0	0.0	49.9	98.8	100.0	98.7	74.1	18.6	0.0	0.0	38.5
Swift River	0.3	0.0	0.9	10.5	87.5	99.8	100.0	99.9	94.9	40.3	5.9	0.0	50.4
Ross River A	0.0	0.0	0.0	41.2	96.2	100.0	100.0	98.7	92.7	30.8	1.1	0.0	63.4
Ross River YTG	0.0	0.0	0.0	47.1	90.1	100.0	100.0	100.0	97.5	32.8	0.0	0.0	69.7
Watson Lake A	0.5	0.2	1.9	25.2	83.7	97.3	95.2	96.7	92.6	46.7	4.8	0.9	56.9
Faro A	0.0	0.1	0.9	27.1	100.0	81.2	100.0	81.5	88.4	36.5	0.8	0.7	63.1

**Annual indicates total for rain, snow and precipitation, and average for % of total precipitation falling as rain*

Source: ECCC, 2017

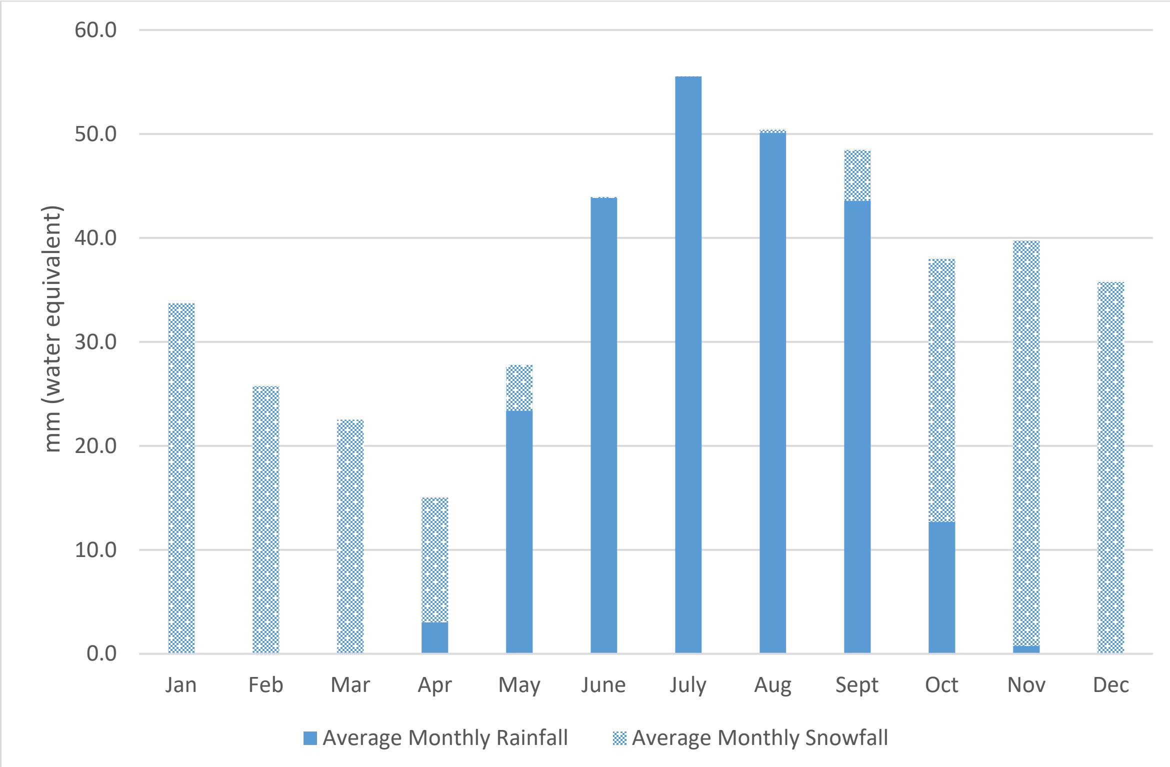


Figure 2-5 presents the average monthly distribution of rain and snow across all regional stations.

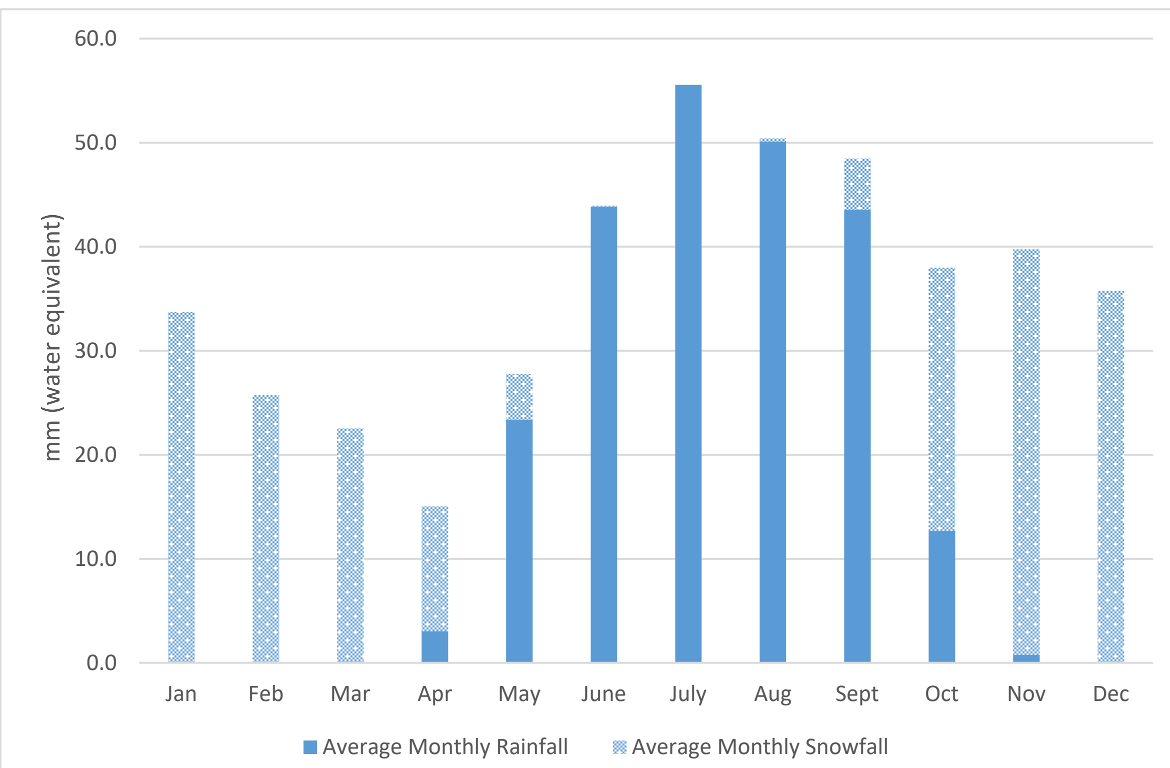


Figure 2-5: Monthly Distribution of Rain and Snow across Eight Regional Stations for the Period of Record

2.2.2.1.1 Long-Term Trends

Total precipitation trends for the same six stations were analyzed for temperature tendencies. The two Ross River stations were combined and Ketza River Mine's record was too short for trend analysis. No clear pattern emerged, as some stations showed a decreasing trend over the period of record, others an increasing trend, and others remained constant. Correlations are weak in all cases, with R^2 values ranging from 1.0e-05 to 0.50 (see Appendix D for total rain, snow and precipitation trend graphs).

The proportion of total precipitation falling as rain showed an increasing trend at all stations, consistent with the rising trends observed in air temperature. Although the correlation was weak, a similar trend was generally observed for all stations, with a rate of increase of approximately 0.1% to 0.3% per year, except for Hour Lake, which shows a much steeper slope (1.0% per year). The trend for Hour Lake is based on a shorter data record and could easily be biased by a few observations (Figure 2-6).

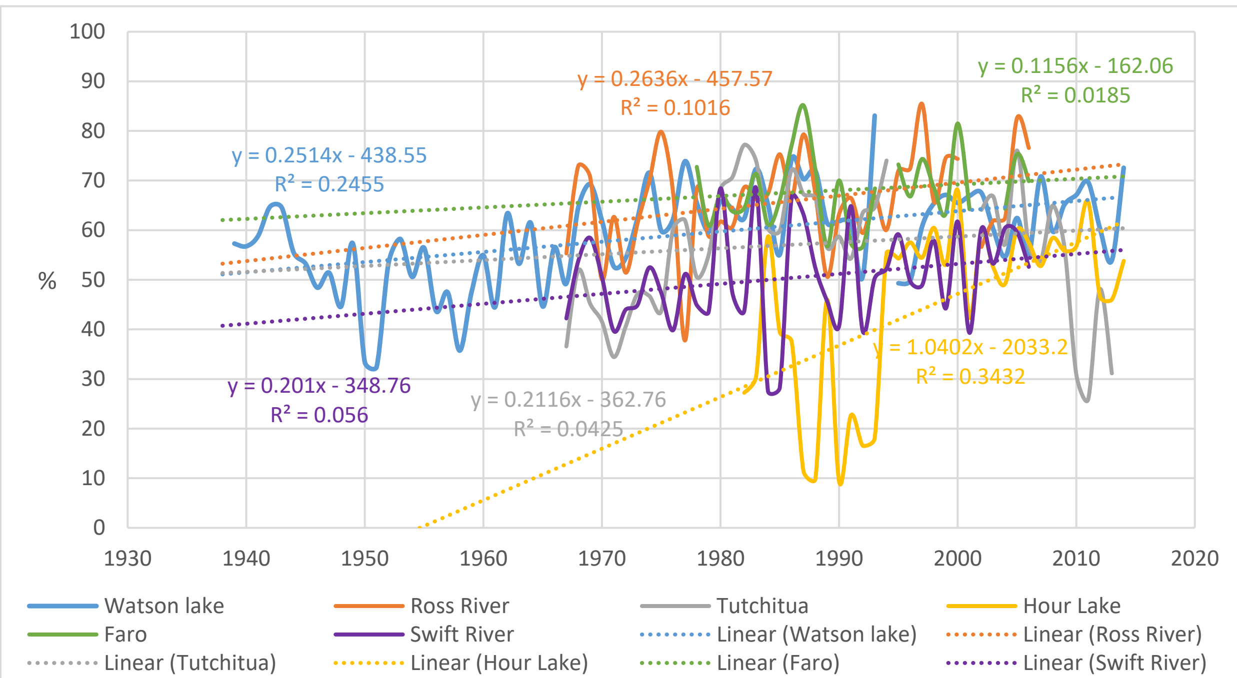


Figure 2-6: Trends in Proportion of Total Annual Precipitation Falling as Rain for Six Regional Stations

When comparing precipitation normals for Watson Lake A between the periods 1961 to 1990 and 1981 to 2010, a 5.3 mm or 2.1% increase in total rainfall, and a 22.8 cm or 10.4% decrease in total snowfall was observed, even with a negligible change in MAP (2.6 mm or 0.6% increase) (Table 2-8) At Faro A, total precipitation, rainfall and snowfall showed an increasing trend between the two climate normals periods of 1.2%, 1.9% and 2.2% respectively, although this comparison was made over a shorter time span than for Watson Lake A (Table 2-9).

Table 2-8: Precipitation Normals, Watson Lake A

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981 to 2010													
Rainfall (mm)	0.1	0	0.1	4.6	33.6	54.9	59.5	47.4	41.1	19.5	0.6	0.5	262
Snowfall (cm)	40.6	28.5	19.6	11.4	3.7	0	0	0.3	1.7	20.8	34.2	35.3	196.1
Precipitation (mm)	30.9	20.4	15.3	14.1	37.4	54.9	59.5	47.6	42.6	37.7	27.9	27.9	416.4
1971 to 2000													
Rainfall (mm)	0.3	0	0.2	4.1	35.2	52.4	59.9	44	39.7	18.8	0.3	0.2	255.2
Snowfall (cm)	35.7	29.5	19.8	11.5	4.6	0	0	0.3	2.1	21.4	33.9	37.6	196.5
Precipitation (mm)	26.1	20.9	14.6	13.9	39.9	52.4	59.9	44.2	41.8	36.8	25.6	28.4	404.4
1961 to 1990													
Rainfall (mm)	0.3	0	0.2	3.1	32.3	54.1	60	44.2	43	18	1.1	0.3	256.7
Snowfall (cm)	41.4	32.9	24.5	13.7	5.6	0	0	0.2	2.2	20.4	36.3	41.5	218.9
Precipitation (mm)	30	21.9	17.2	14.3	37.5	54.1	60.1	44.3	45.1	34.1	26.1	29.1	413.8

**Source: ECCC, 2016*

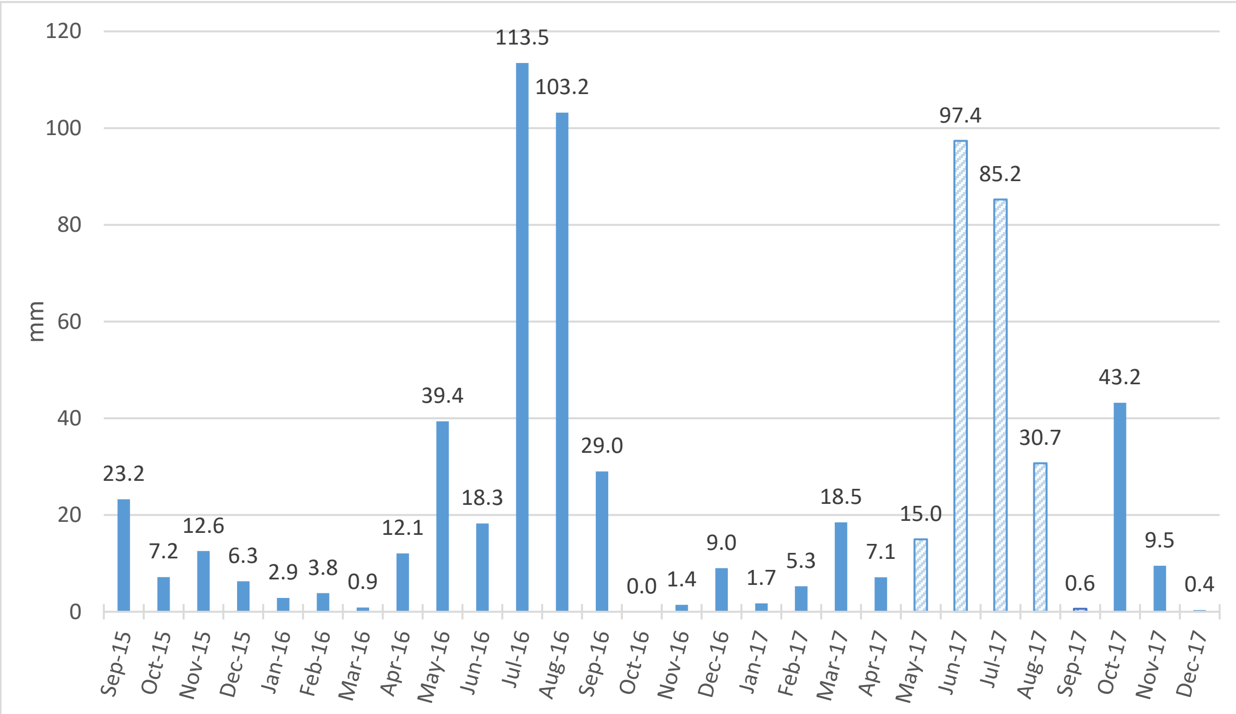
Table 2-9: Precipitation Normals, Faro A

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1981 to 2010													
Rainfall (mm)	0	0	0.1	2.6	27.3	36.7	56.1	47.5	38.4	9.4	0.2	0.1	218.4
Snowfall (cm)	16.7	14.6	13.1	6.3	0.6	0	0	0.7	2.4	20.4	21.7	17.6	114
Precipitation (mm)	14.6	12.3	12.3	8.7	27.9	36.7	56.1	48.2	41	27.3	19.4	15.2	319.7
1971 to 2000													
Rainfall (mm)	0	0	0	2.2	23.7	36.1	58.8	47.6	36	9.7	0.2	0.1	214.4
Snowfall (cm)	16	15	12.2	6	0.3	0	0	0.7	2.6	19.4	21.1	18.3	111.6
Precipitation (mm)	14.8	13.3	11.6	8	24	36.1	58.8	48.3	38.9	26.5	19.4	16.4	316

**Source: ECCC, 2016*

2.2.2.2 Site Data

Monthly total precipitation measured at the Geonor total precipitation gauge was obtained by subtracting the average cumulative depth at the beginning of the month from the average cumulative depth at the end of the month, in order to minimize noise effect. With the SBS500 tipping bucket (which was in operation between May 17 and September 12, 2017 – see section 2.1.1.3), recorded tips (equivalent to 0.202 mm of rain) were summed for each month. The annual total for 2016 period was 333.4 mm and 314.6 mm for 2017. The year 2017 however has missing precipitation data (4 days in May, 4 days in June, 16 days in July, 8 days in August and 12 days in September 2017) due to repeated damage to the cable caused by porcupines. Therefore, the true annual total for 2017 has been underestimated. The Geonor total precipitation sensor is equipped with armoured cable such that it is not susceptible to damage by animals. Should a replacement sensor be needed again in the future, armoured cable will be used on the replacement sensor as well to prevent potential data loss associated with such damage. Monthly totals for the period of record are shown in Figure 2-7.



***Note**: Months with crosshatched fill indicate partial data (May-17: 4 days missing, Jun-17: 4 days missing, Jul-17: 16 days missing, Aug-17: 8 days missing, Sep-17: 12 days missing).*

Figure 2-7: Project Monthly Total Precipitation, September 2015 to December 2017

Project data for the month of June was drier in 2016 than 1995, while the months of July and August 2016 were wetter (Table 2-2 and Figure 2-7). In 2017, partial totals do not allow for accurate comparisons, but June was generally wetter than in 2016 and than in 1995 at the low elevation station. July 2017 could be comparable to 2016 and wetter than in 1995, while August 2017 was probably drier than 2016 and comparable to 1995.

The 2015 to 2017 Project data generally had lower monthly precipitation than at most of the regional stations, except for Ross River YTG and Faro A, which had lower long-term averages (Table 2-7).

Total precipitation gauges typically have a reduced catch efficiency for solid precipitation that varies as a function of wind speed as well as height and profile of the gauge; therefore, the amount of snowfall measured at the Project could underestimate the actual snowfall amount (Smith, 2007). Most EC stations use similar types of instruments to that used at the Project site and undercatch is well documented (Mekis and Vincent, 2011). In addition, the Project meteorological station experiences very high wind speed which would further contribute to undercatch. Table 2-10 presents the monthly precipitation totals for the Project, and the two regional stations (Watson Lake A and Faro A) that were active for the period

September 2015 to December 2017. Total annual precipitation was higher on average at KZK than at regional stations, with considerable month to month variations, which is expected considering the often very localized nature of precipitation in Yukon.

Table 2-10: Monthly Total Precipitation (mm), Watson Lake A, Faro A and Kudz Ze Kayah

Month	KZK (mm)	Watson Lake A (mm)	Faro A (mm)
Sep 2015	23.25	19.4	29.4
Oct 2015	7.18	31.9	24.4
Nov 2015	12.56	24.9	0
Dec 2015	6.30	15	0
Jan 2016	2.88	21.2	0
Feb 2016	3.84	19.5	6.8
Mar 2016	0.88	13.5	5.8
Apr 2016	12.06	12.3	11.6
May 2016	39.38	23	21
Jun 2016	18.26	28.1	27
Jul 2016	113.46	37.4	49.8
Aug 2016	103.22	40.9	63.6
Sep 2016	29.01	44.5	19.0
Oct 2016	0.00	10.0	2.2
Nov 2016	1.45	9.9	4.8
Dec 2016	9.01	15.0	0.0
Jan 2017	1.73	7.8	1.0
Feb 2017	5.27	6.4	7.2
Mar 2017	18.49	32.0	11.6
Apr 2017	7.14	2.3	4.6
May 2017	*14.97*	28.1	4.4
Jun 2017	*97.36*	54.6	86.2
Jul 2017	*85.24*	77.5	121.2
Aug 2017	*30.70*	18.4	60
Sep 2017	*0.62*	15.1	22
Oct 2017	43.23	23.6	29.6
Nov 2017	9.50	32.9	0
Dec 2017	0.36	12.9	0
2016	**333.44**	**275.3**	**211.6**
2017	*314.62*	**311.6**	**347.8**
Average of 2016 and 2017	**324.03**	**293.5**	**279.7**

***Note**: Values in grey italics indicate partial totals.*

2.2.2.3 Extreme 24-Hour Precipitation

Table 2-11 presents the maximum 24-hour precipitation events recorded at all regional meteorological stations (the two Ross River stations were combined) during their respective period of record. An overall maximum of 47.0 mm of rain was recorded at Watson Lake A on June 22, 1987.

Table 2-11: Maximum 24-hour Precipitation Events at Seven Regional Stations (Period of Record)

	Rain		Snow		Precipitation	
	Amount (mm)	**Date**	**Amount (cm)**	**Date**	**Amount (mm)**	**Date**
Hour Lake	33.2	Jul 28, 2000	24.8	Mar 25, 2004	33.2	Jul 28, 2000
Tuchitua	36.0	Jun 2, 2001	29.8	Dec 28, 1980	36.0	Jun 02, 2001
Ketza River Mine	32.0	Aug 8, 1991	33.0	Jun 24, 1986	33.0	Jan 24, 1986
Swift River	45.0	Jul 12, 1988	37.0	Dec 24, 1992	45.0	Jul 12, 1988
Ross River	38.9	Jul 13, 1975	15.2	Jan 12, 1973	38.9	Jul 13, 1975
Watson Lake A	47.0	Jun 22, 1987	26.7	Dec 05, 1959	47.0	Jun 22, 1987
Faro A	37.2	Aug 23, 2017	12.8	Nov 30, 1991	37.2	Aug 23, 2017

The maximum 24-hour precipitation event recorded for the Project, since commissioning of the meteorological station was 43.0 mm on August 26, 2016.

2.2.3 Snowpack

2.2.3.1 Regional Data

Environment Yukon conducts regular snow surveys across the territory, on or around March 1, April 1, and May 1 of each year. Average snow water equivalent (SWE) values for the stations located in the Project region are summarized in Table 2-12 (see Figure 2-1 for station locations).

Table 2-12: Regional Average Snow Water Equivalent (mm) provided by Environment Yukon

Station Name	Hoole River	Burns Lake	Finlayson Airstrip	Tintina Airstrip	Ford Lake
Station ID	09BA-SC03	09BA-SC04	09BA-SC05	10AA-SC02	10AA-SC04
Latitude	61°32'4"	62°17'21"	61°41'27"	61°5'9"	60°47'1"
Longitude	-131°35'28"	-129°56'41"	-130°46'36"	-131°14'43"	-131°28'4"
Elevation (masl)	1,036	1,112	988	1,067	1,110
Distance from KZK (km)	52	96	24	55	90
Years of data	1977-2017	1986-2017	1987-2017	1977-2017	1987-2017
March 2016 SWE (mm)	n/a	n/a	87	n/a	n/a
April 2016 SWE (mm)	88	209	74	184	149
May 2016 SWE (mm)	0	201	0	130	109
March 2017 SWE (mm)	n/a	n/a	52	n/a	n/a
April 2017 SWE (mm)	123	197	76	158	135
May 2017 SWE (mm)	90	198	60	145	129
March Average SWE (mm)*	121	198	93	186	171
April Average SWE (mm)*	140	225	106	208	194
May Average SWE (mm)*	93	219	55	185	175

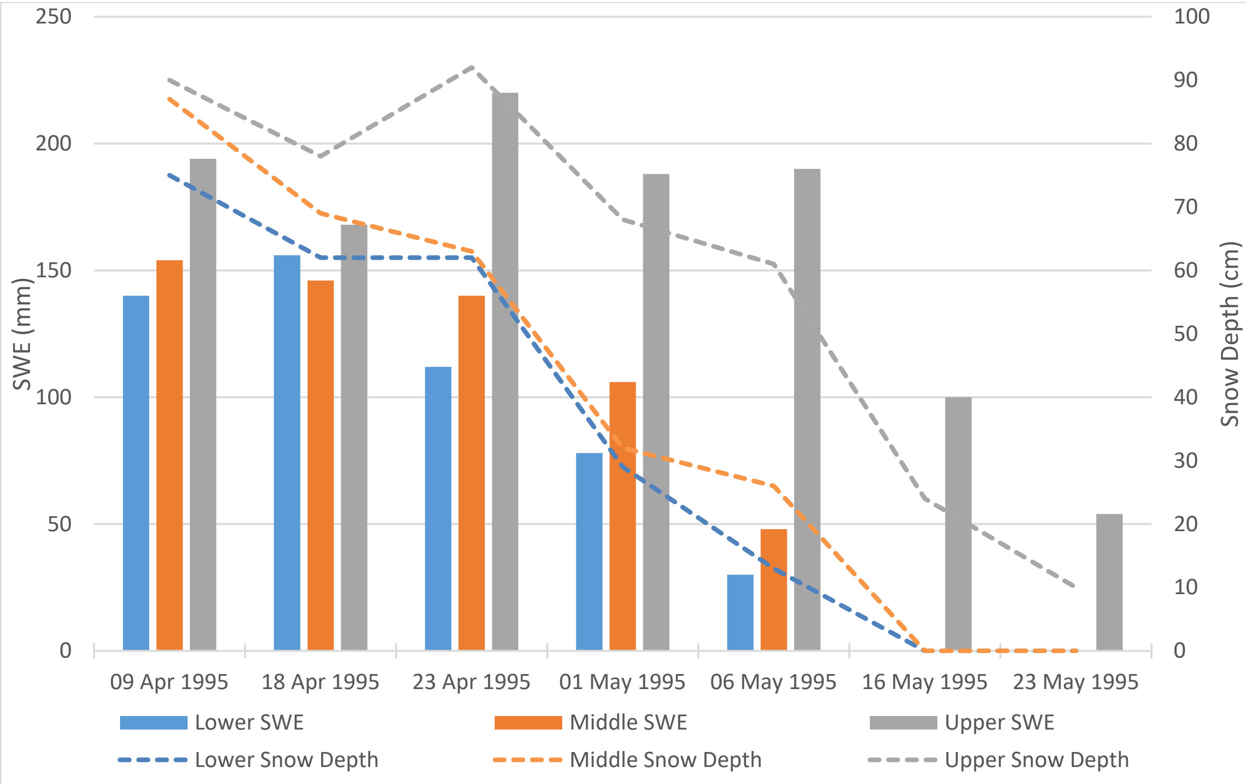
Source: Environment Yukon, 2017
**Over the period of record*

2016 was below average snow years (Table 2-12). SWE values in April 2016 ranged from 62% to 93% of normal with a mean of 78% whereas the May 2016 SWE values ranged from 0% to 91% of normal with a mean of 44%. SWE values in April 2017 ranged from 70% to 88% of normal with a mean of 79% whereas the May 2017 SWE values ranged from 74% to 109% of normal with a mean of 90%.

The Wolverine Mine, located approximately 28 km to the east of the Project, reported average SWE values ranging from 199 mm to 279 mm for the period 2010 to 2014 (Yukon Zinc Corporation, 2015). Annual average values are generally based on two to seven surveys, sampled in March or April of each year. The aspect and elevation of these stations were not specified. The estimated average snowfall at Wolverine Mine is 253 mm (as SWE) (Yukon Zinc Corporation, 2011), which is higher than at other regional stations.

2.2.3.2 Site Data

During the 1995 baseline characterization, three snow survey stations were established and sampled in April and May for snow depth and snow water equivalent. Stations were located at both the low and high elevation climate stations, and a third station was located at a median elevation between the high and low sites (Figure 2-2). Although elevations were not specified in the 1996 IEE, they were estimated from the map to be approximately 1,400 masl, 1,500 masl and 1,600 masl for the lower, middle and upper station, respectively (Figure 2-8). The regional snow course stations demonstrated below normal snowpacks for 1995 and extrapolated SWE and snow depth values measured at the Project that year correspond to lower than average values.



** Measurements at the lower station were collected on April 7, 1995 rather than April 9.*

Figure 2-8: Snow Course Measurements, KZK, 1995

Baseline snow surveys were completed monthly (January, February, March and April) in 2016 and 2017, at three stations located on east facing slopes at low (1,445 masl), mid (1,519 masl) and high (1,819 masl) elevations (Figure 2-2). All surveys consisted of ten-point transects that were averaged (Table 2-13 and Figure 2-9 and Figure 2-10). Four additional stations (at mid-elevations ranging from 1,487 masl to 1,551 masl) were also sampled in March of both years, to better characterize peak snowpack variability based on slope aspect (Table 2-13). No samples were taken in April 2016 as there was little or no snowpack left at the survey sites.

Table 2-13: Snow Survey Data, KZK, 2016-2017

Station	Average Snow Depth (cm)				SWE (mm)			
2016								
	Jan 21-22	Feb 8-10	Mar 19-21	-	Jan 21-22	Feb 8-10	Mar 19-21	-
Baseline Low Elevation	35.4	35.0	41.0	-	37	39	42	-
Baseline Mid- Elevation	30.2	38.5	36.6	-	51	34	62	-
Baseline High Elevation	n/a	15.4	23.1	-	n/a	39	36	-
Mid-Elevation Peak North Aspect	-	-	53.1	-	-	-	47	-
Mid-Elevation Peak East Aspect	-	-	47.3	-	-	-	67	-
Mid-Elevation Peak South Aspect	-	-	56.7	-	-	-	47	-
Mid-Elevation Peak West Aspect	-	-	45.4	-	-	-	44	-
2017								
	Jan 15-17	Feb 22-23	Mar 20-22	Apr 28-29	Jan 15-17	Feb 22-23	Mar 20-22	Apr 28-29
Baseline Low Elevation	47.2	54.8	65.2	50.8	76	71	82.1	118
Baseline Mid- Elevation	32.8	38.5	51.4	33.6	65	78	90	70
Baseline High Elevation	27.9	17.3	33.6	22.7	80	29	68	69
Mid-Elevation Peak North Aspect	-	-	91.6	-	-	-	226	-
Mid-Elevation Peak East Aspect	-	-	74.5	-	-	-	163	-
Mid-Elevation Peak South Aspect	-	-	88.7	-	-	-	161	-
Mid-Elevation Peak West Aspect	-	-	30.3	-	-	-	56	-

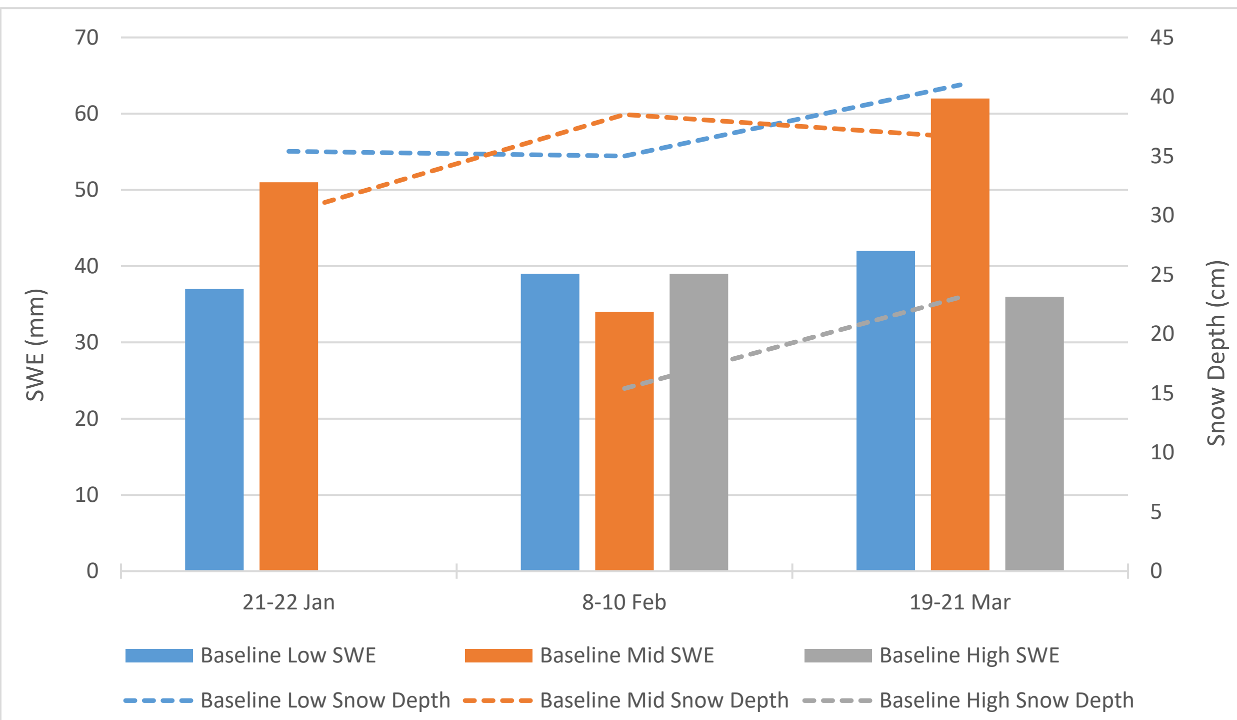


Figure 2-9: Baseline Snow Survey Results, KZK, 2016

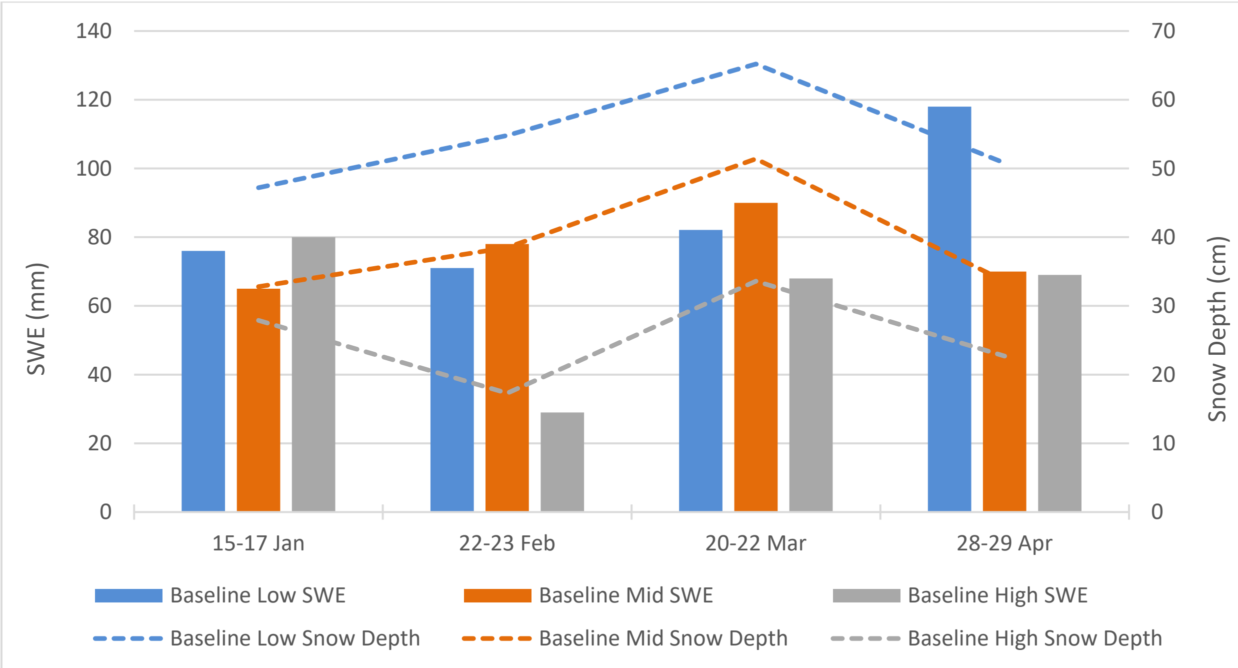


Figure 2-10: Baseline Snow Survey Results, KZK, 2017

Snow surveys conducted in 2016 and 2017 generally showed lower snow water equivalent values than at regional stations, although sampling was not carried out at the exact same time of year. The 2016 and 2017 Project snow survey data also generally showed a lower snow year when compared to the 1995 Project data, although 2017 data are closer to 1995 values.

2.2.4 Wind Speed and Direction

Wind speed and direction are measured at a height of 10 m at the Campbell Scientific meteorological station. Wind data collected between September 1, 2015 and December 31, 2017 are presented in Figure 2-11. The wind sensor experienced occasional icing during the winter months and periods of zero wind speed were invalidated. In addition, the winter wind speeds may have been occasionally underestimated due to the presence of ice on the sensor; however, these occurrences cannot be detected in the data record. The prevailing winds blow from the northwest and northeast and the highest average wind speeds originating from the northeast. Summary statistics are presented in Table 2-14.

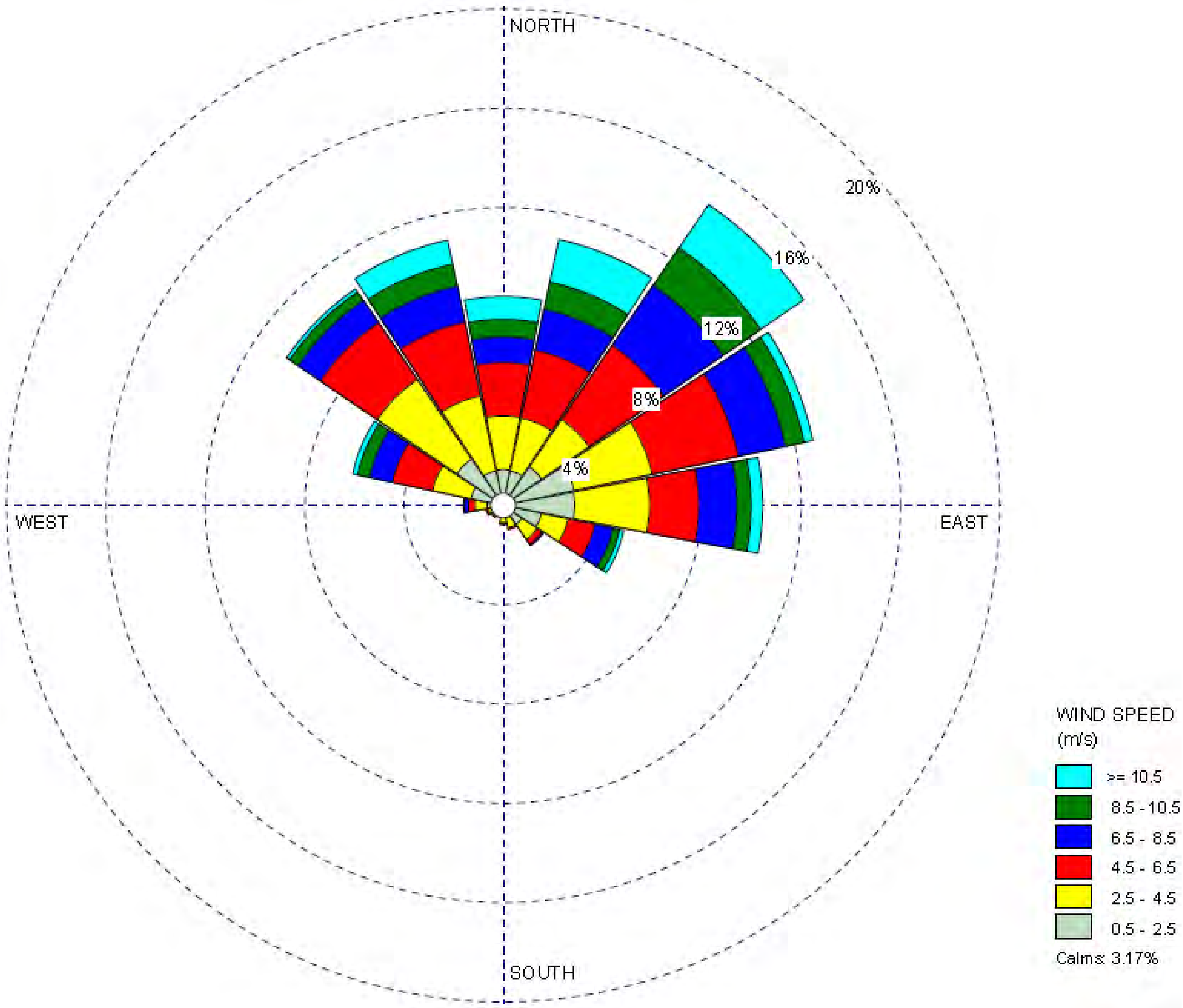


Figure 2-11: Wind Rose, KZK, September 2015 to December 2017

Table 2-14: Wind Rose Summary Statistics

Total Number of Hours	20,474
Average Wind Speed	5.00 m/s
Calm Records	649
Calm Winds Frequency	3.2 %
Data Availability	98.0 %
Incomplete/Missing Records	406
Total Records Used	20,068

The strongest winds were observed during the month of February 2017 for the period of record (Table 2-15). Monthly average and maximum wind speeds were generally comparable to results obtained at the low elevation station in 1995 (Table 2-2). Because wind is highly influenced by local topographical features, comparison with data from regional stations is not meaningful.

Table 2-15: Monthly Average and Maximum Wind Speed, KZK, 2015-2017

Month	Average Wind Speed (m/s)	Maximum Wind Speed (m/s)
Sep 2015	5.78	25.42
Oct 2015	4.71	19.17
Nov 2015	6.37	28.52
Dec 2015	3.47	23.62
Jan 2016	4.91	25.99
Feb 2016	4.97	20.93
Mar 2016	4.91	19.56
Apr 2016	6.10	24.87
May 2016	4.87	21.09
Jun 2016	4.84	16.90
Jul 2016	4.44	18.93
Aug 2016	4.70	17.29
Sep 2016	4.89	22.62
Oct 2016	2.93	16.50
Nov 2016	*5.31*	*25.11*
Dec 2016	4.96	24.21
Jan 2017	7.61	29.11
Feb 2017	5.15	34.61
Mar 2017	4.55	20.68
Apr 2017	5.10	21.44
May 2017	6.00	25.28
Jun 2017	4.59	15.33
Jul 2017	4.02	15.82
Aug 2017	4.74	18.05
Sep 2017	*4.37*	*19.13*
Oct 2017	5.77	26.28
Nov 2017	*2.87*	*20.93*
Dec 2017	6.73	26.40

Grey italics indicate partial data

2.2.5 Relative Humidity

Monthly minimum, maximum, and mean relative humidity were compiled from the hourly data collected at the Project Campbell Scientific station since time of commissioning (Table 2-16).

Table 2-16: Monthly Average, Maximum and Minimum Relative Humidity (%), KZK, 2015-2017

Month	Average RH	Maximum RH	Minimum RH
Sep 2015	76.4	96.6	57.7
Oct 2015	73.0	96.1	39.9
Nov 2015	73.1	89.1	34.1
Dec 2015	78.8	88.6	49.0
Jan 2016	72.4	88.3	31.7
Feb 2016	75.5	90.1	53.1
Mar 2016	74.9	86.9	47.1
Apr 2016	66.1	89.7	43.3
May 2016	61.7	87.4	26.3
Jun 2016	57.2	78.2	36.1
Jul 2016	69.9	86.7	49.9
Aug 2016	71.0	93.2	45.6
Sep 2016	72.6	91.1	36.9
Oct 2016	73.5	93.2	37.1
Nov 2016	77.8	88.9	63.7
Dec 2016	73.4	86.8	47.5
Jan 2017	70.5	84.0	33.8
Feb 2017	71.6	87.5	45.9
Mar 2017	71.7	83.5	44.8
Apr 2017	59.9	88.8	45.6
May 2017	57.2	95.7	24.8
Jun 2017	68.2	92.8	42.7
Jul 2017	73.9	94.7	39.3
Aug 2017	62.5	89.0	35.4
Sep 2017	*67.9*	*86.9*	*43.9*
Oct 2017	77.7	96.5	46.8
Nov 2017	76.3	87.5	30.7
Dec 2017	62.2	84.6	10.2

Grey italics indicate partial data

Relative humidity values measured at the low elevation station during the summer months of 1995 were on average slightly higher than in 2016 and 2017, except for the month of June 2017 which was higher than historical. Maximum values were also higher in 1995.

Although long-term relative humidity data were not readily available from the ECCC regional meteorological stations, hourly relative humidity data for the period September 2015 to December 2017 for Watson Lake and Faro are plotted and compared to Project data (Figure 2-12). Overall, similar patterns are observed between the three stations; however, the Project station displays greater variability and lower values during the winter months.

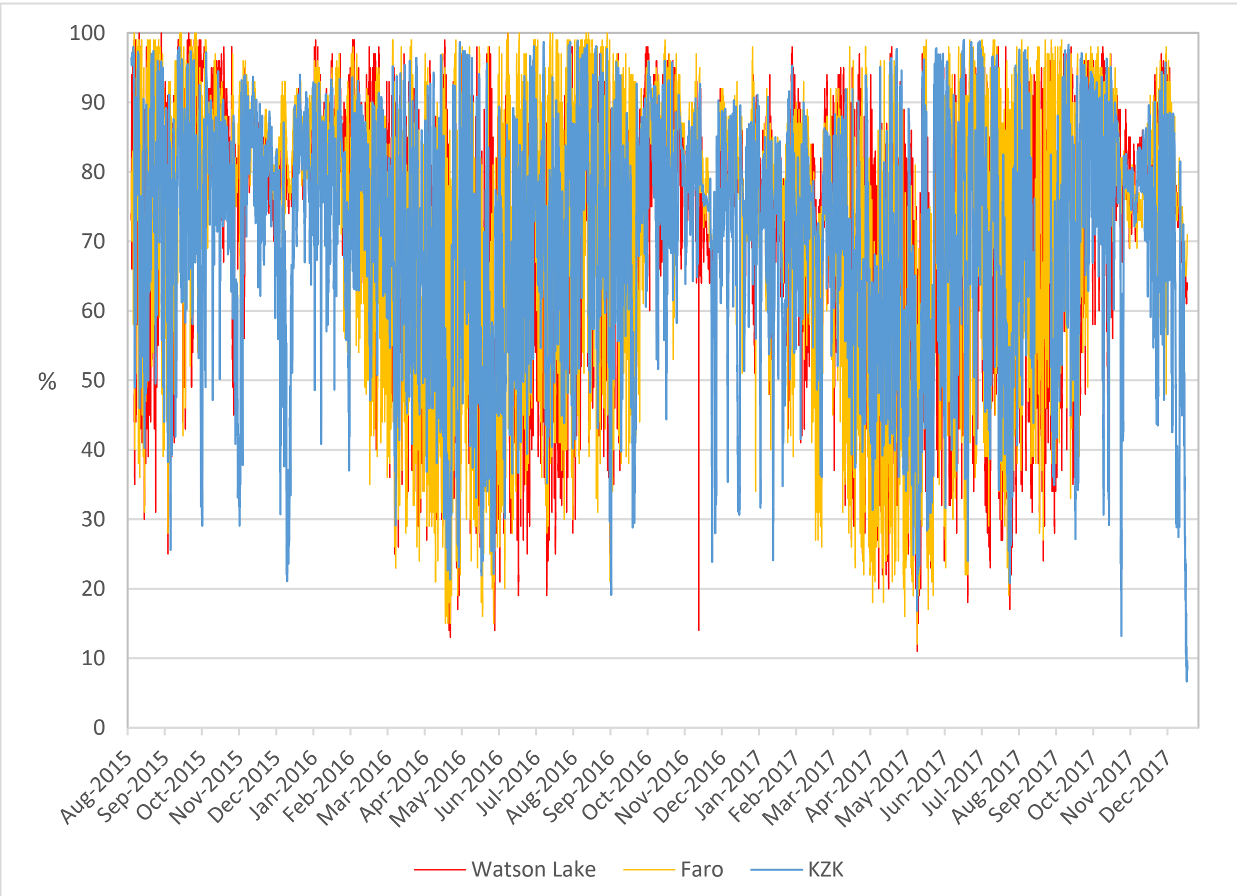


Figure 2-12: Watson Lake A, Faro A and KZK Hourly Relative Humidity, September 2015 to December 2017

2.2.6 Solar Radiation

Monthly solar radiation averages were compiled from the hourly data collected at the Project Campbell Scientific station since time of commissioning (Table 2-17).

Table 2-17: Monthly average solar radiation (W/m²), KZK, 2015-2017

Month	Average Solar Radiation
Sep 2015	105.85
Oct 2015	50.31
Nov 2015	18.25
Dec 2015	5.59
Jan 2016	12.82
Feb 2016	44.84
Mar 2016	120.06
Apr 2016	176.36
May 2016	225.47
Jun 2016	256.27
Jul 2016	196.60
Aug 2016	153.18
Sep 2016	153.18
Oct 2016	106.56
Nov 2016	54.05
Dec 2016	17.88
Jan 2017	5.58
Feb 2017	11.63
Mar 2017	43.37
Apr 2017	114.02
May 2017	219.94
Jun 2017	260.47
Jul 2017	219.42
Aug 2017	185.78
Sep 2017	*88.41*
Oct 2017	50.67
Nov 2017	21.28
Dec 2017	4.79

Grey italics indicate partial data (Station was down between August 30, 2017 and September 12, 2017 due to damage to the power cable caused by porcupines)

Solar radiation measured at the low elevation station during the summer months of 1995 was on average slightly higher than in 2016 or 2017, which could be the result of using different instrumentation or higher frequency of overcast skies in 2016 and 2017. However, the same pattern is observed, with the highest values measured in June. Solar radiation is not typically reported for the ECCC regional stations.

2.2.7 Barometric Pressure

Barometric pressure is corrected to sea-level equivalent within the Campbell Scientific datalogger program. Monthly averages were compiled from the hourly data collected at the Project meteorological station since time of commissioning (Table 2-18).

Table 2-18: Monthly Average Barometric Pressure (hPa), KZK, 2015-2017

Month	Average Barometric Pressure
Sep 2015	1,006.8
Oct 2015	1,006.8
Nov 2015	1,000.6
Dec 2015	997.9
Jan 2016	1,002.0
Feb 2016	1,003.8
Mar 2016	1,003.9
Apr 2016	1,008.6
May 2016	1,014.4
Jun 2016	1,013.3
Jul 2016	1,014.7
Aug 2016	1,017.3
Sep 2016	1,011.3
Oct 2016	1,008.4
Nov 2016	999.6
Dec 2016	1,004.7
Jan 2017	1,004.1
Feb 2017	1,003.0
Mar 2017	1,003.7
Apr 2017	1,008.6
May 2017	1,010.9
Jun 2017	1,011.3
Jul 2017	1,014.6
Aug 2017	1,013.1
Sep 2017	*1,011.3*
Oct 2017	1,006.4
Nov 2017	1,003.7
Dec 2017	1,010.9

Grey italics indicate partial data (Station was down between August 30, 2017 and September 12, 2017 due to damage to the power cable caused by porcupines)

A seasonal pattern emerged with the lowest average values in late fall (November/December) and the highest in summer (July/August). No barometric pressure measurements were conducted for the Project in 1995.

Although long-term barometric pressure data are not readily available for the EC regional meteorological stations, hourly pressure data for the period September 2015 to December 2017 for Watson Lake A and Faro A are reported at the station elevation. The same correction used in the Project datalogger program can be applied to the regional hourly data to obtain the sea-level equivalent pressure and enable comparisons with the Project data. The equation is as follows:

$$BP_{sl} = BP_E + 1013.25\left(1-\left(1-\frac{E}{44307.69231}\right)^{5.25328}\right)$$

Where BP_{sl} = sea-level equivalent barometric pressure in hPa

BP_E = barometric pressure at station elevation in hPa

E = station elevation in meters (m)

Figure 2-13 shows that the sea-level equivalent barometric pressure of the two regional stations and of the Project station correlate well for the period September 2015 to December 2017, with typically greater variability during the winter months and less during the summer.

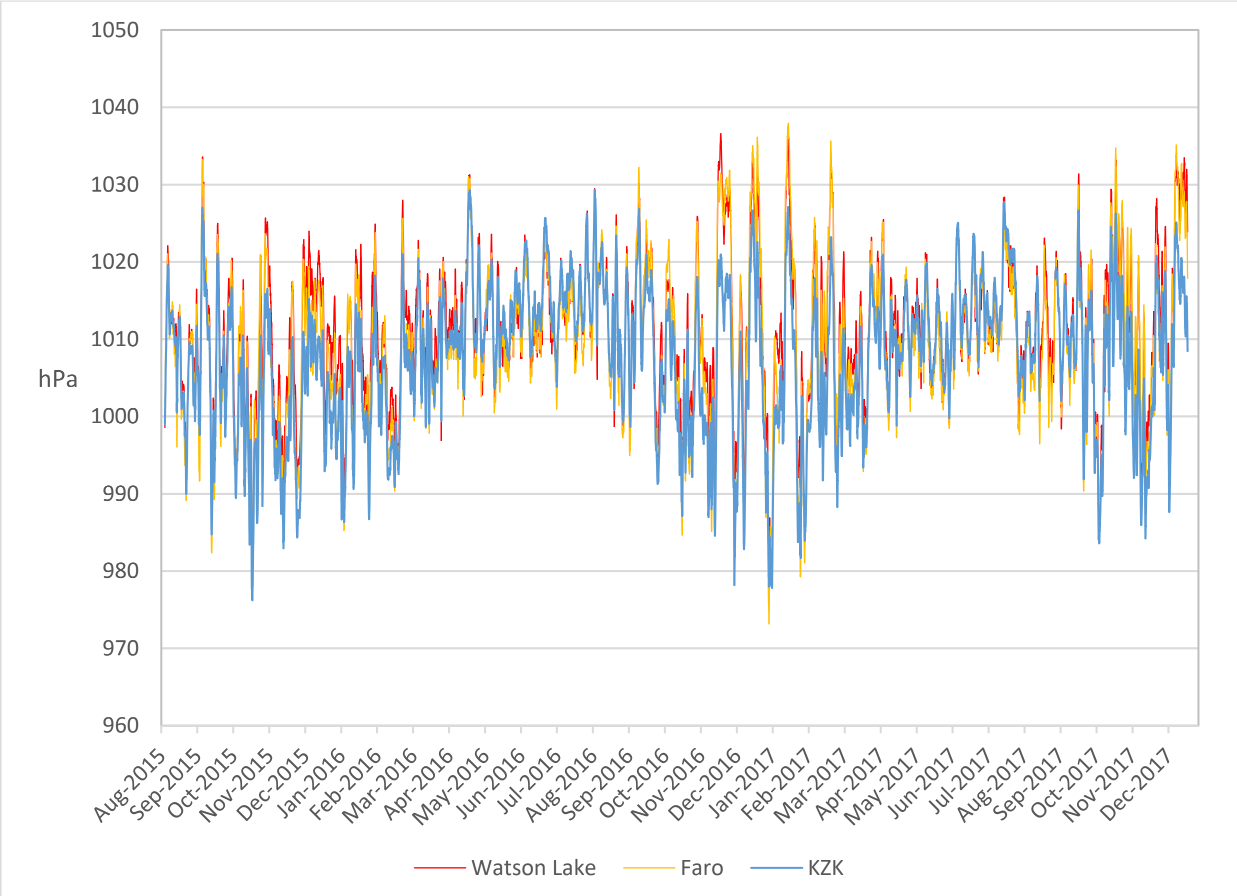


Figure 2-13: Watson Lake A, Faro A and KZK Sea-level Equivalent Hourly Barometric Pressure, September 2015 to December 2017

2.2.8 Evaporation and Evapotranspiration

Pan evaporation measurements were carried out at the low elevation climate station during baseline characterization in 1995 (Table 2-19). Estimated reservoir evaporation values were obtained assuming a conversion factor of 0.7 (Cominco Ltd., 1996).

Table 2-19: Measured Pan Evaporation and Estimated Reservoir Evaporation, KZK, 1995

Period	Measured Pan Evaporation Average (mm/day)	Measured Pan Evaporation Maximum (mm/day)	Estimated Reservoir Evaporation Average (mm/day)	Estimated Reservoir Evaporation Maximum (mm/day)
25 May 16:30 - 28 May 13:00	5.3	6.0	3.7	4.2
7 June 19:30 – 13 June 15:30	4.5	5.0	3.2	3.5
21 June 14:00 – 28 June 10:30*	4.2	5.5	3.0	3.9
7 Aug 14:00 - 10 Aug 17:30	2.1	3.0	1.5	2.1

11Aug 08:00 – 16 Aug 15:00*	2.9	6.0	2.0	4.2

** evaporation records adjusted for rainfall collated in evaporation pan*
Source: Cominco Ltd., 1996 (Table 3.1.4)

Cominco Ltd. then extrapolated the above data and compared them to Watson Lake 1981 to 1990 lake evaporation values to obtain the monthly and annual evaporation estimates presented in Table 2-20 below.

Table 2-20: Mean Monthly Lake Evaporation Values, KZK

Month	Evaporation (mm)
Jan	-
Feb	-
Mar	-
Apr	-
May	45
Jun	100
Jul	100
Aug	55
Sep	30
Oct	-
Nov	-
Dec	-
Year	330

Source: Cominco Ltd., 1996

Pan evaporation measurements could not be conducted at the Project in 2015 due to freeze-up happening at time of deployment (late August). In 2016, daily measurements were taken between May 21 and September 5, and in 2017 from June 25 to September 11, as conditions allowed. Monthly totals, after adjustments for rainfall, are shown in Table 2-21. For months with missing precipitation data (July and August 2017), pan evaporation is presented as partial totals for days where precipitation data are available.

The Campbell Scientific datalogger program incorporates an instruction for the calculation of potential evapotranspiration (PET) using the ASCE standardized reference evapotranspiration equation (Penman-Monteith).

Table 2-21: Monthly Pan Evaporation and Potential Evapotranspiration (mm), KZK, 2015-2017

Month	Pan Evaporation (mm)	Total PET (mm)
Sep 2015	-	34.0
Oct 2015	-	14.1
Nov 2015	-	5.0
Dec 2015	-	-1.0

Jan 2016	-	2.2
Feb 2016	-	7.4
Mar 2016	-	25.0
Apr 2016	-	51.3
May 2016	-	84.5
Jun 2016	138.5	106.2
Jul 2016	111.5	76.5
Aug 2016	80.2	59.5
Sep 2016	-	33.63
Oct 2016	-	6.77
Nov 2016	-	3.50
Dec 2016	-	1.42
Jan 2017	-	7.27
Feb 2017	-	5.56
Mar 2017	-	13.37
Apr 2017	-	51.09
May 2017	-	89.71
Jun 2017	-	80.40
Jul 2017	*65.4 **	67.69
Aug 2017	*72.7 ***	79.47
Sep 2017	-	*18.26*
Oct 2017	-	12.36
Nov 2017	-	0.29
Dec 2017	-	7.29
Sep 2015 – Aug 2016	*330.39*	**464.67**
Sep 2016 – Aug 2017	*138.1*	**439.86**
Average	**-**	**452.26**

** For period from June 25 to July 15, 2017*
*** For period from August 8 to August 30, 2017*

The pan evaporation (E_{pan}) is related to the reference evapotranspiration (ET_o) by an empirically derived pan coefficient (FAO, 1998):

$$ET_o = K_p\, E_{pan}$$

Where Kp = pan coefficient

The pan coefficient is determined by the mean relative humidity and wind speed as well as by the pan siting. In the case of the Project Class A pan, this coefficient was estimated to be 0.75 based on a windward side distance of dry ground surface of between 1 m and 10 m, a mean relative humidity between 40% and 70%, and average wind speeds between 2 m/s and 5 m/s. Applying this coefficient to the 2016 evaporation pan measurements taken at the Project site yields ET_o results that are very similar to the ET_o values obtained with the Penman-Monteith equation, with 103.9 mm, 83.6 mm and 60.2 mm for June, July and August, respectively. Because 2017 results are incomplete, this comparison wasn't made.

The pan evaporation values measured in 2016 are similar to the average values measured in 1995 (when the average monthly rates in Table 2-21 are applied to the entire month) for June and August while the measured amount in July 2016 was higher than in July 1995.

Using the same conversion factor of 0.7 used by Cominco Ltd. in 1995 to convert pan evaporation values to reservoir/lake evaporation values, estimated reservoir/lake evaporation values of 97.0 mm, 78.1 mm and 56.1 mm were obtained for June, July and August 2016, respectively. These values are very similar to the mean monthly lake evaporation values presented in Table 2-20 for June and August, while estimated lake evaporation from the July 2016 pan evaporation measurements yielded a lower value.

Actual evapotranspiration (AET) is some fraction of PET and occurs between May and September. The total PET measured in those months in 2016 is 361 mm (Table 2-21). A factor of 0.5 gives 180 mm per year which is within the reasonable range of estimates based on estimates for the region in the 200 mm range. AET may be lower at the site than other regional locations as the shallow soils and more minimal vegetation in the Project footprint area mean more rapid runoff generation and less interception.

Sublimation occurs whenever there is snow present, and that includes October through April. Sublimation is dependent mostly on wind speed, availability and vegetation. It is estimated that sublimation comprised only 28% of the winter 2015 to 2016 snowfall (~21 mm); however, it could be much higher in higher snowfall years. Sublimation is typically more significant in the north than in more temperate climates (Liston and Sturm, 2004).

2.3 Discussion

Data collected at the Project site in 1995 and 2015 to 2017 indicate that average temperatures were comparable to those of regional stations for the same period. The diurnal and annual temperature range at the Project site appears to be smaller than at regional stations.

Total annual precipitation recorded at the Project site in 2015 to 2016 was greater than at regional stations (Watson Lake and Faro), but not when accounting for the elevation difference between the sites. In 2017, the site total is comparable or less than at regional stations but includes partial data for summer months. Overall, 1995, 2016 and 2017 appear to have been drier years than average (less precipitation and lower snowpack) when compared to the long-term regional record. Based on the local data available to date, it is difficult to determine at this point whether the Project site is part of a drier microclimate compared to the surrounding region, or if the period of record at site coinciding with a drier regional trend. Continued monitoring at the Project site will allow for better characterization of local versus regional patterns.

Winds at the Project site blow predominantly from the northwest to northeast, with average and maximum wind speeds being relatively high. Relative humidity and barometric pressure at the Project site are generally consistent with regional patterns. Solar radiation peaks in July and is at a minimum in December. Pan evaporation measurements and evapotranspiration calculations at Kudz Ze Kayah for the 2015 to 2016 period correlate relatively well with 1995 measurements and estimates.

3 SURFACE WATER HYDROLOGY

The following sections describe the hydrometric (discharge) data available both regionally from government sources and for the Project. Regional data is available through the WSC. Hydrology data were collected on site in 1995 and more recently during the baseline monitoring program that began in April 2015 and which is ongoing.

3.1 METHODS

3.2 REGIONAL DATA

WSC stations offer long-term data sets within the Project region and are therefore the best source from which to estimate longer term statistics such as high and low flows. The IEE (Cominco Ltd., 1996) included a regional analysis of 16 WSC stations and two Indigenous and Northern Affairs Canada (INAC, formerly DIAND) stations with seasonal records. For the purposes of this assessment it was determined that the regional stations would need to have at least 10 years of data for them to be included. Of the 16 WSC stations, 13 had the prerequisite 10 years of data to be used in the regional flood frequency analysis. These data were included in Appendix 3.2 to the IEE report and are included here as Appendix E.

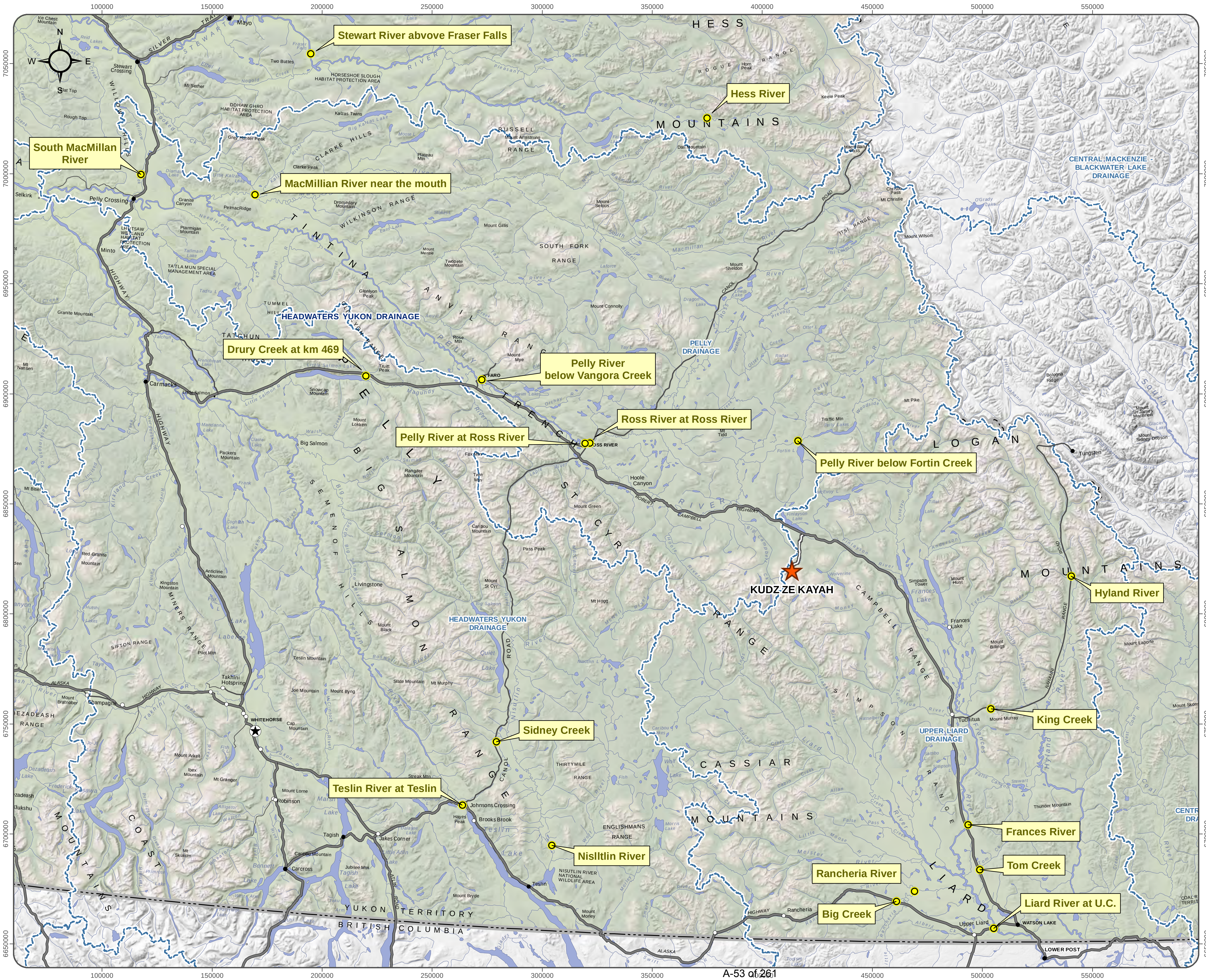
At the time of the initial evaluation, approximately 14 of the 16 WSC stations were active or current. Presently, six of those 14 active stations have continuous active data since that time; the other eight were discontinued in 1994 to 1996 or have large data gaps. At the time of the previous analysis, data was available up to 1994. In order to update the regional analysis, it was deemed prudent to test for any significant change in runoff at these six active sites. The pre and post 1994 total annual runoff populations were tested for a significant difference using 95% confidence limits. The populations were first tested for normality and the appropriate T-test was selected. No significant difference was found in the pre and post 1994 populations of mean annual flow at all six sites with post 1994 data. As such, 15 of 16 stations from the original analysis with greater than 10 years of data were considered appropriate for analysis. Rose Creek was the only station that did not qualify as it was only in operation for approximately 4 years.

In addition, four other regional stations, not included in the original analysis, were also added for a total of 19 stations. The INAC stations were not included in the analysis as the data sets were incomplete. Figure 3-1 shows the location of all regional hydrometric stations used in the analysis and they are listed in Table 3-1 with metadata.

Table 3-1: Regional Mean Annual Runoff (mm) and Metadata at WSC Stations

Station ID	Name	Area (km^2)	Median Elevation (masl)	Minimum Elevation (masl)	Maximum Elevation (masl)	Date Range	MAR (mm)*
10AB003	King Creek	13.7	1,341	935	1,853	1975-1988	289
09AD002	Sidney Creek	372	1,256	730	1,882	1982-1994	365
10AA002	Tom Creek	435	985	724	1,563	1974-1993	216
09AH005	Drury Creek	552	1,225	614	2,050	1995-2009	282
09BB001	South MacMillan River	997	1,380	931	2,536	1974-1996	633
10AA005	Big Creek	1,010	1,176	779	2,006.5	1989-2014	246
10AD002	Hyland River	2,150	1,536	849	2,559	1976-1994	653
09DA001	Hess River	4,840	1,391	782	2,916	1976-1996	500
09BA002	Pelly River below Fortin Creek	5,020	1,214	871	2,105	1986-94, 2013-14	472
10AA004	Rancheria River	5,100	1,231	691	2,248	1986-2014	332
09BA001	Ross River at Ross River	7,310	1,068	679	2,533	1960-2014	287
09AD001	Nisutlin River	8,030	1,204	659	2,188	1979-1995	365
10AB001	Frances River	12,800	1,157	657	2,337	1962-2014	396
09BB002	MacMillan River near the mouth	13,800	1,086	500	2,529	1984-1996	320
09BC002	Pelly River at Ross River	18,400	1,125	649	2,533	1954-1974	310
09BC004	Pelly River below Vangorda Creek	21,900	1,131	626	2,533	1972-2014	289
09AE001	Teslin River at Teslin	30,300	1,159	645	2,174	1944-1994	314
10AA001	Liard River at Upper Crossing	32,600	1,140	609	2,333	1960-2014	366
09DC003	Stewart River above Fraser Falls	30,600	1,164	448	2,916	1980-1996	387
Mean	*All Stations*		1,209	-	-	-	370
Mean	*Station <1500 km^2, excl. 09BB001*		1,197	-	-	-	280

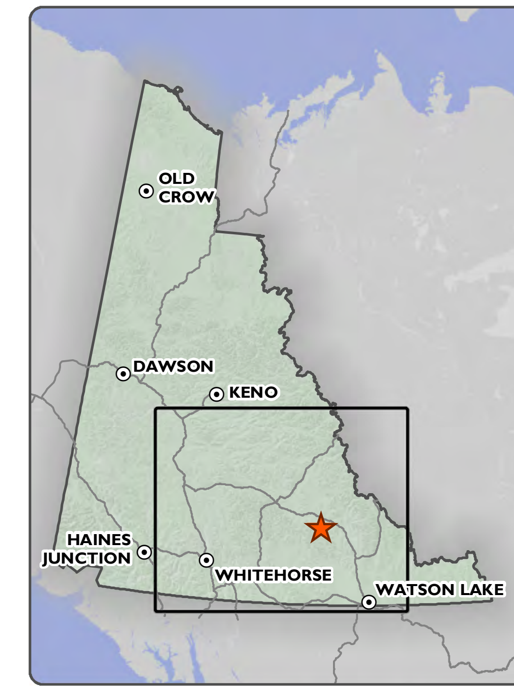
**MAR = Mean Annual Runoff*



KUDZ ZE KAYAH PROJECT
HYDROMETEOROLOGY BASELINE REPORT

FIGURE 3 - 1
REGIONAL HYDROMETRIC STATION LOCATIONS

OCTOBER 2016



- Kudz Ze Kayah Project
- Regional Hydrometric Station

Digital elevation model created by the Yukon Department of the Environment interpolated from the digital 1:50,000 Canadian National Topographic Database (NTDB Edition 2) contour and watercourse layers. Obtained from Geomatics Yukon.

Canvec compiled by Natural Resources Canada at a scale of 1:10,000 - 1:50,000. Reproduced under license from Her Majesty the Queen in Right of Canada, as represented by the Minister of Natural Resources Canada. All rights reserved.
Drainage areas obtained from National Hydrology Network 2011

Datum: NAD 83; Projection UTM Zone 9N

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Kilometers

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(*Last edited* Name REDACTED */31/2016/11:47 AM*)

3.2.1 Site Data and Monitoring Network

The Project lies in a small (approximately) 26 km^2 watershed called Geona Creek which is a north flowing and north facing tributary of Finlayson Creek. Finlayson Creek meets the outflow of Finlayson Lake below the Robert Campbell Highway and flows east to eventually join the Frances River and ultimately the Mackenzie River. One of the highest elevation tributaries within Geona Creek has been named Fault Creek which has a median elevation of 1,707 masl and an area of 2 km^2. Fault Creek is characterized by steep slopes and small trees and shrubs in the creek valley but otherwise is an alpine environment. Geona Creek has a median elevation of 1,482 masl with vegetation spaning from alpine to some sparsely forested areas at lower elevations. The Finlayson Creek catchment area is approximately 41 km^2 above the confluence with Geona Creek and grows to 215 km^2 where it flows under the Robert Campbell Highway shortly before it joins the outflow of Finlayson Lake. The watershed divide of Geona Creek is characterized by several small lakes. Figure 3-2 shows the local catchment areas in the vicinity of the Project.

Four seasons of hydrometric monitoring have taken place at the Project; the first during the 1995 open water season, and three during the current baseline program initiated in April 2015. The current network builds on the original in both spatial and temporal coverage.

Hydrometric monitoring in 1995 utilized six stations. All stations were equipped with staff gauges, and two were also equipped with automated water level recorders. All data were available for the manual stations; however, the continuous data from Geona Creek and Lower Finlayson Creek were not recovered from Cominco Ltd. Active stations in 1995 are indicated in Table 3-2 in the right-hand column. The full extent of the 1995 data can be found in Appendix E (Appendix 3.2a of Cominco Ltd., 1996).

In 2015 a hydrometric monitoring program was initiated in support of the new development plans. The re-initiation began with an evaluation of the previous monitoring network compared with water balance and water quality modelling requirements. Based on this review, the new network includes the original locations (in part for data consistency) and the addition of four new sites. Table 3-2 lists the current monitoring network and indicates which sites were present in 1995. The current monitoring network was established in early May of 2015 (Figure 3-3) and some stations were added or removed later to address gaps or changes that arose during development planning.

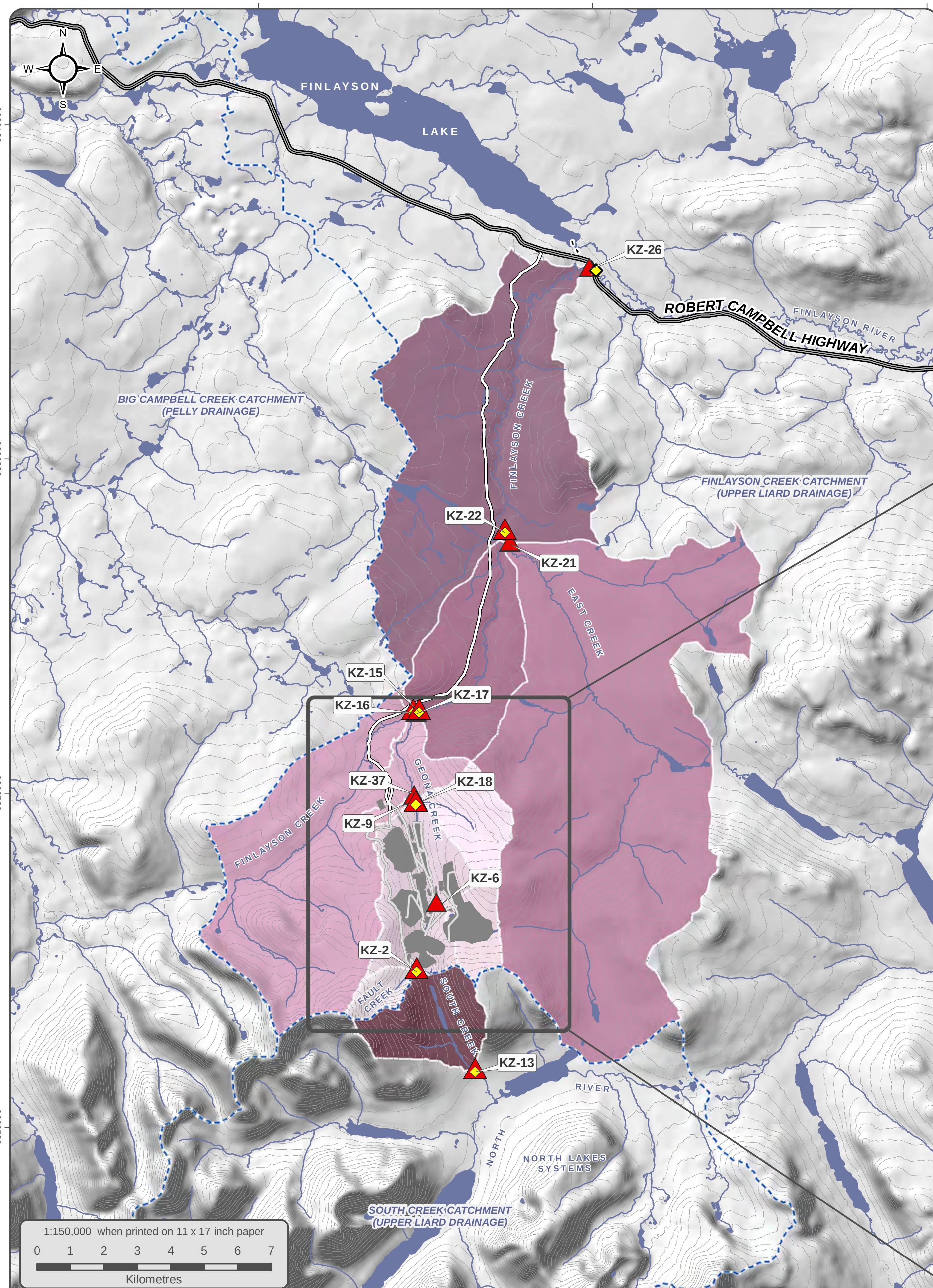
BMC MINERALS

KUDZ ZE KAYAH PROJECT HYDROMETEOROLOGY REPORT

FIGURE 3-2

SURFACE WATER QUALITY AND HYDROMETRIC MONITORING CATCHMENTS

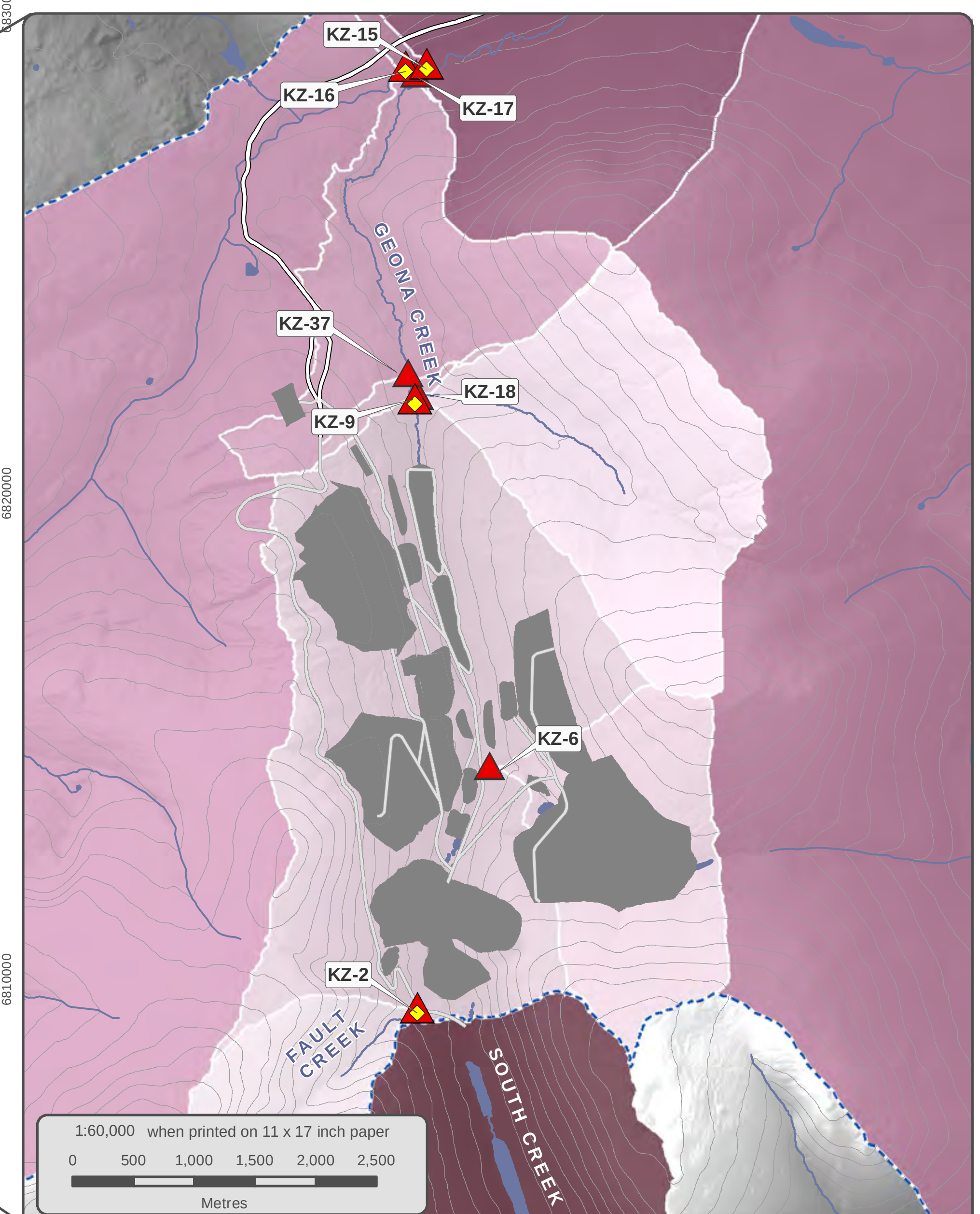
MAY 2018



CATCHMENT INFORMATION

Current Station ID	Location	Drainage Area (sq.km)
KZ-26	Finlayson Creek at Robert Campbell Highway	210.69
KZ-22	Finlayson Creek 100 m downstream East Creek	162.36
KZ-21	East Creek at mouth	86.40
KZ-15	Finlayson Creek 100 m downstream confluence with Geona Creek	6.85
KZ-16	Finlayson Creek upstream confluence with Geona Creek	35.00
KZ-17	Geona Creek at mouth	25.69
KZ-18	East Tributary to Geona Creek	5.31
KZ-9	Lower Geona Creek	16.44
KZ-37	Geona Creek above East Tributary	21.97
KZ-6	Unnamed east-side trib. of Geona Creek d/s of ore	3.55
KZ-2	Fault Creek	1.93
KZ-13	South Creek near mouth	7.94

KZ-26, KZ-13, KZ-22, KZ-21, KZ-15, KZ-16, KZ-17, KZ-37, KZ-9, KZ-6, KZ-2, KZ-18



- Hydrometric Station
- Water Quality and Hydrometric Station
- Water Quality Sampling Location
- Location of Proposed Mine Infrastructure
- Major Drainages
- Tote Road/Proposed Access Road
- Proposed Mine Road
- Contour (40 m interval)
- Watercourse
- Waterbody

ALEXCO ENVIRONMENTAL GROUP

Catchments delineated using ArcGIS Spatial Analyst Watershed Tools, using 2014 LiDAR data and/or 2005 orthorectified aerial imagery and/or 16m DEM data obtained from geogratis.gc.ca, depending on extent.

Datum: NAD 83; Projection UTM Zone 9N

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(Name REDACTED 07/05/2018/13:50 PM)

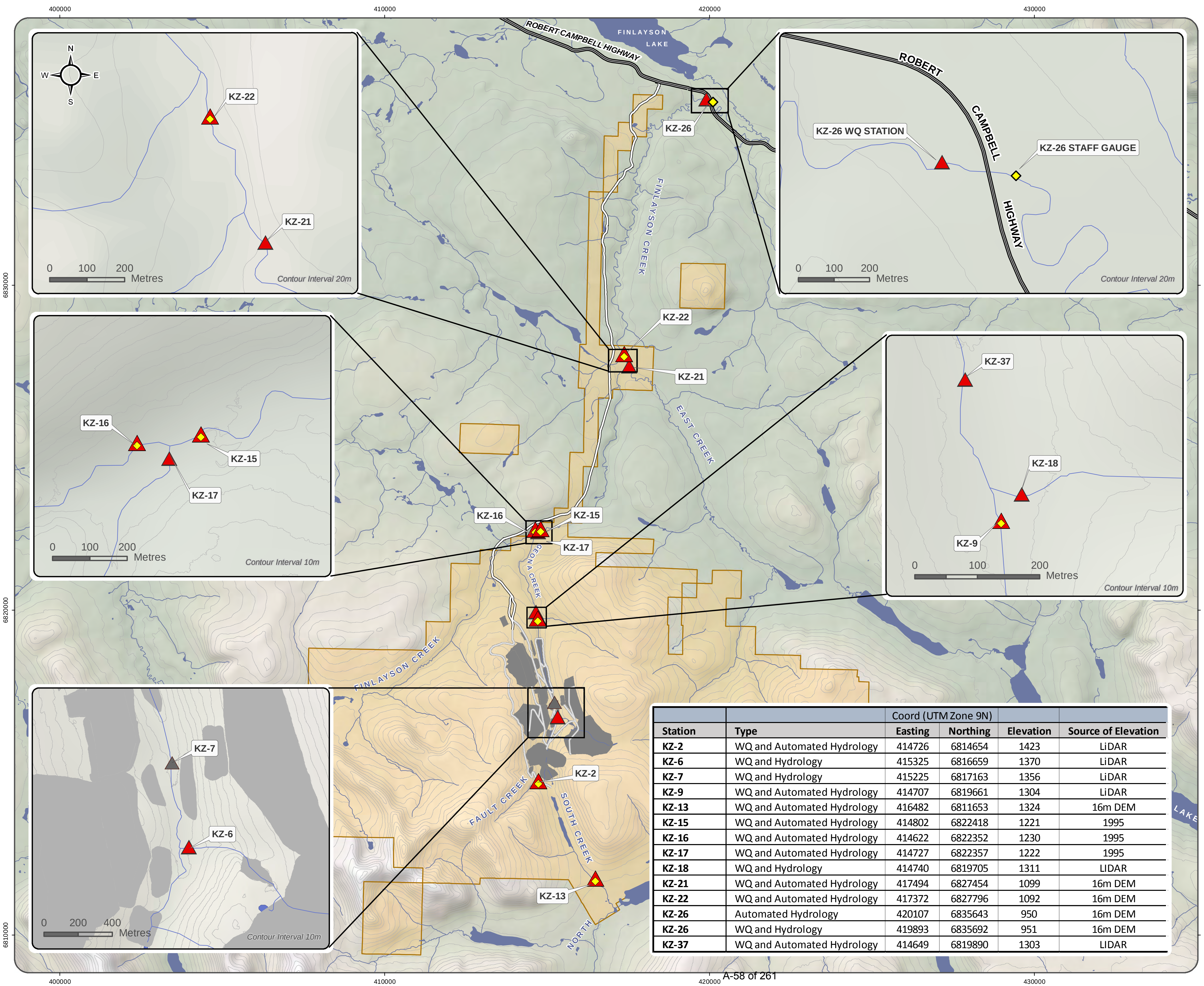
The hydrometric stations, referred to as continuous in Table 3-2, consist of a steel angle iron post driven into the stream bed supported with a steel cross piece and guy wire to which the staff gauge is bolted and the stilling well is attached (Photo 3-1). Staff gauges are WSC issue with 2 mm graduations and stilling wells are black 2" ABS pipe. A Solinst Edge M1.5 Levelogger water level recorder is placed in the stilling well affixed to a direct read cable such that the logger is not disturbed during download. Solinst Leveloggers are paired with Solinst Barologgers to provide barometrically compensated pressure data as height of water. Barologgers are located at KZ-26, KZ-15 and KZ-2. Solinst recommends Barologgers be located within 300 m of elevation of the Levelogger being compensated. All sites comply with this recommendation.

Table 3-2: Surface Water Hydrometric Monitoring Network at KZK

Catchment/Description	Current Station ID	Drainage Area (km^2)	Median Catchment Elev. (masl)	Current Hydrometric Data Collection Type	Description of 1995 Data Collection Type *	Station Status
Fault Creek	KZ-2	1.93	1,707	Continuous	Manual	Active
Unnamed tributary to Geona Creek	KZ-6	3.55	1,557	Discrete Measurements	None	Active
Upper Geona Creek	KZ-7	10.28	1,541	Discrete Measurements	None	Discontinued
Geona Creek near proposed dam	KZ-9	16.44	1,498	Continuous	None	Active
South Creek	KZ-13	7.94	1,540	Continuous	Manual	Active
Finlayson Creek below Geona	KZ-15	60.85	1,479	Continuous	None	Active
Finlayson Creek above Geona	KZ-16	35.00	1,477	Continuous	None	Active
Geona Creek at the mouth	KZ-17	25.69	1,482	Derived/Calculated	Automated	Active
Unnamed tributary to Geona Creek	KZ-18	5.31	1,499	Discrete Measurements	None	Active
East Creek	KZ-21	86.40	1,282	Discrete Measurements	Manual	Active
Upper Finlayson Creek	KZ-22	162.36	1,354	Continuous	Manual	Active
Lower Finlayson Creek	KZ-26	210.69	1,294	Continuous	Automated	Active
Geona Creek	KZ-37	21.97	1,498	Discrete Measurements	None	Active

***Notes**: * Manual: Includes staff gauge, discrete measurements and periods of daily stage observation, data May-Sept/Oct. Automated: Discrete measurements, staff gauge and automated water level recorder, data May-Sept/Oct.*

Photo 3-1: KZ-15 Hydrometric Shown as Example of Hydrometric Stations Installed at the Project



		Coord (UTM Zone 9N)			
Station	**Type**	**Easting**	**Northing**	**Elevation**	**Source of Elevation**
KZ-2	WQ and Automated Hydrology	414726	6814654	1423	LiDAR
KZ-6	WQ and Hydrology	415325	6816659	1370	LiDAR
KZ-7	WQ and Hydrology	415225	6817163	1356	LiDAR
KZ-9	WQ and Automated Hydrology	414707	6819661	1304	LiDAR
KZ-13	WQ and Automated Hydrology	416482	6811653	1324	16m DEM
KZ-15	WQ and Automated Hydrology	414802	6822418	1221	1995
KZ-16	WQ and Automated Hydrology	414622	6822352	1230	1995
KZ-17	WQ and Automated Hydrology	414727	6822357	1222	1995
KZ-18	WQ and Hydrology	414740	6819705	1311	LiDAR
KZ-21	WQ and Automated Hydrology	417494	6827454	1099	16m DEM
KZ-22	WQ and Automated Hydrology	417372	6827796	1092	16m DEM
KZ-26	Automated Hydrology	420107	6835643	950	16m DEM
KZ-26	WQ and Hydrology	419893	6835692	951	16m DEM
KZ-37	WQ and Automated Hydrology	414649	6819890	1303	LIDAR

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KUDZ ZE KAYAH PROJECT

FIGURE 3-3

HYDROMETRIC STATION LOCATION

MAY 2018

- Hydrometric Station
- Water Quality and Hydrometric Station
- Water Quality Sampling Location
- Water Quality Sampling Location, Discontinued
- Tote Road/Proposed Access
- Proposed Mine Road
- Contour (40 m interval)
- Watercourse
- Waterbody
- Location of Proposed Infrastructure
- BMC Minerals (No.1) Ltd. Mineral Claim Areas

ALEXCO ENVIRONMENTAL GROUP

Digital elevation model created by the Yukon Department of the Environment interpolated from the digital 1:50,000 Canadian National Topographic Database (NTDB Edition 2) contour and watercourse layers. Obtained from Geomatics Yukon.

Datum: NAD 83; Projection UTM Zone 9N

1:115,000 when printed on 11 x 17 inch paper

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3.2.1.1 Finlayson Creek

Finlayson Creek flows through a medium size valley with moderate gradient and gravel/rocky substrate for most of its course. Finlayson Creek is monitored at four locations, near the Robert Campbell Highway (KZ-26), midway between the Highway and Geona Creek (KZ-22), immediately below the confluence with Geona Creek (KZ-15), and above the confluence with Geona Creek (KZ-16).

KZ-15 - Finlayson Creek below Geona

Station KZ-15 is located on Finlayson Creek downstream of the Geona Creek confluence and is a location where preliminary water quality objectives have been established. This site was established 9 May 2015 and is characterized by a straight channel, with relatively uniform stream bed, which provides an ideal spot for velocity-area discharge measurements. Discharge measurements are conducted approximately 2 m from where the hydrometric station is located. Some undercut banks have been noted in this section of the creek. In the winters of 2015 and 2016, this section of the creek would stay open, allowing for velocity-area discharge measurements year-round (Photo 3-2). In 2017, however, prolonged cold temperatures in this area did not allow for velocity-area discharge measurements and therefore the salt-dilution method was employed. The hydrometric station at KZ-15 is located on the left-hand side of the creek, if looking downstream (Photo 3-3). A summary of the instrumentation and maintenance record is provided in Table 3-3.

Table 3-3: KZ-15 Maintenance and Instrumentation

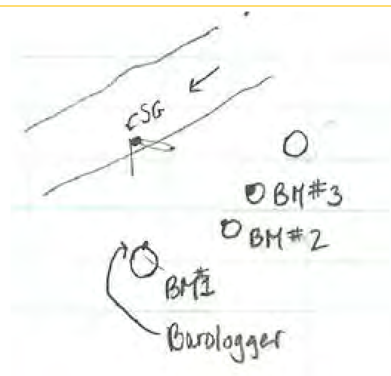
Site	KZ-15
Date Established	May 9th, 2015
Benchmarks	 BM1 used as "100 m" for all surveys from May 2015 to October 2017.
Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation	Site contains a stilling well, levelogger, barologger and staff gauge. Manual measurements conducted monthly.

Photo 3-2: Finlayson Creek at Station KZ-15, Looking Upstream, February 2016

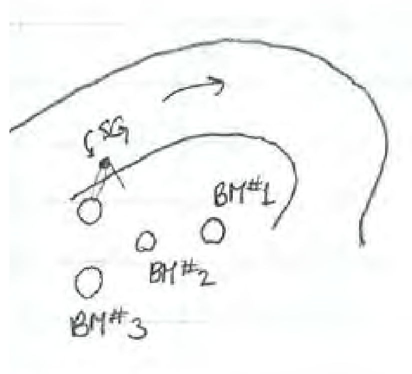
Photo 3-3: Finlayson Creek at Station KZ-15, Looking Upstream, June 2016

KZ-16 - Finlayson Creek above Geona

Station KZ-16 is located on Finlayson Creek upstream of the Geona Creek confluence, and was added to the monitoring network to characterize background water quality in Finlayson Creek prior to the confluence with Geona Creek. The KZ-16 channel is a more irregular than KZ-15. This site was established 10 May 2015 and was run for five months, before the station was relocated approximately 25 meters upstream of the original station on 9 September 2015. The station was moved as the initial location was determined to be inadequate, and the new location would have more suitable conditions for rating curve development. A summary of the instrumentation and maintenance record is provided in Table 3-4.

Discharge measurements are conducted approximately two meters below where the current hydrometric station was installed. The current station is located in a deep pool on the left-hand side of the creek looking downstream (Photo 3-4). Ice development is significant with overflow running over the banks and into the trees surrounding the creek (Photo 3-5). These conditions make it challenging to collect accurate discharge measurements in the winter, such that the discharge measurement location is moved approximately 100 m upstream or until a point where flowing water can be found. Salt dilution gauging is utilized in the winter months at this site, as ice development does not allow for velocity-area measurements.

Table 3-4: KZ-16 Maintenance and Instrumentation

Site	KZ-16
Date Established	May 10th, 2015
Date moved (if applicable)	September 9th, 2015, stations were run in tandem until November 2016.
Benchmarks (Original location)	 BM1 used as “100 m” for all surveys from May 2015 to October 2017.

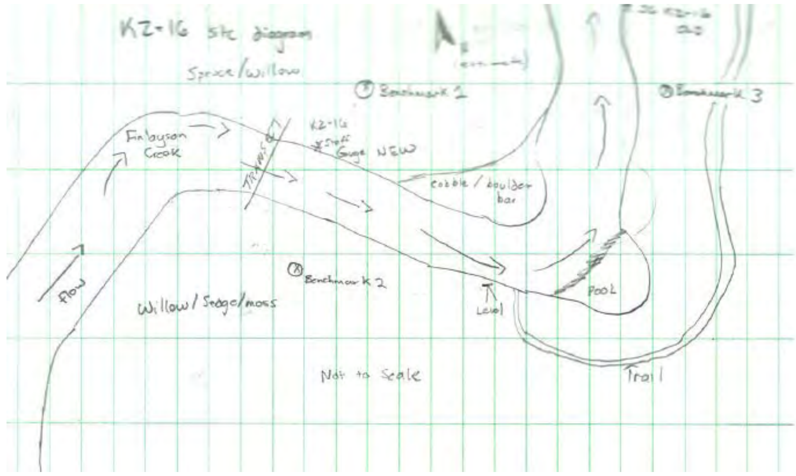
Benchmarks (new location)	 BM1 used as "100 m" for all surveys from September 2015 to October 2017.
Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation Present	New staff gauge site contains a stilling well, levelogger and staff gauge. Manual measurements conducted monthly. The Old staff gauge site only contains a staff gauge, and no levelogger.

Photo 3-4: Finlayson Creek at Current Hydrometric Station at KZ-16, Looking Downstream, August 2016

Photo 3-5: Finlayson Creek at Old Staff Gauge Location at KZ-16, Looking Upstream, March 2016

KZ-22 - Finlayson Creek midway between Geona and the Highway

Station KZ-22 is located on Finlayson Creek midway between the Robert Campbell Highway and Geona Creek, just downstream of East Creek confluence. This section of Finlayson Creek is characterized by wider banks and a more open landscape. This site is confined by small cliffs on the right bank (looking downstream). The station is located in a deep pool, and is on the left-hand side of the creek, looking downstream (Photo 3-6). Discharge measurements are typically conducted approximately 2-3 m above the hydrometric station. However, when creek flows are too high to safely gauge, the transect is typically moved about 10-15 m above the station or to a point that is safe for field personnel. Salt dilution gauging is utilized in the winter months at this site, as ice development does not allow for velocity-area measurements (Photo 3-7). A summary of the instrumentation and maintenance record is provided in Table 3-5.

Table 3-5: KZ-22 Maintenance and Instrumentation

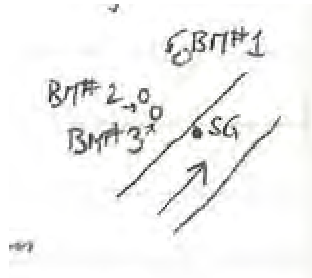
Site	KZ-22
Date Established	May 10th, 2015
Benchmarks	 BM1 used as "100 m" for all surveys from May 2015 to October 2017.
Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation Present	Site contains a stilling well, levelogger, and staff gauge. Manual measurements conducted monthly.

Photo 3-6: Finlayson Creek at Station KZ-22, Looking Upstream, July 2017

Photo 3-7: Finlayson Creek at Station KZ-22, Looking Downstream, March 2016

KZ-26 - Finlayson Creek below the Robert Campbell Highway

Station KZ-26 is located on Finlayson Creek near the Robert Campbell Highway. This section of Finlayson Creek is confined by large old growth forest, and is located in a section that has a straight channel with a relatively uniform stream bed, providing an ideal area for velocity-area discharge measurements (Photo 3-8). Discharge measurements are typically conducted in the summer approximately 1-2 meters above the hydrometric station. KZ-26 does experience significant ice development, especially downstream of the Highway where the culverts are located (Photo 3-9). In the winter to find flowing water for discharge measurements, the discharge location is moved upstream, above the Highway. Salt dilution gauging is utilized in the winter months at this site, as ice development does not allow for velocity-area measurements. A summary of the instrumentation and maintenance record is provided in Table 3-6.

Table 3-6: KZ-26 Maintenance and Instrumentation

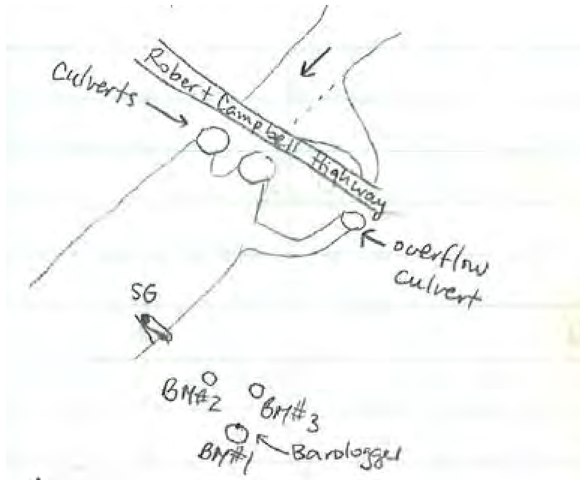
Site	KZ-26
Date Established	May 14th, 2015
Benchmarks	 BM1 used as "100 m" for all surveys from May 2015 to October 2017.
Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • A new Staff Gauge was installed at KZ-26 on June 5th, 2017. It was installed in the same location to replace the staff gauge that was destroyed by ice the previous winter. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation Present	Site contains a stilling well, levelogger, barologger and staff gauge. Manual measurements conducted monthly.

Photo 3-8: Finlayson Creek at Station KZ-26, Looking Upstream Towards Robert Campbell Highway, September 2016

Photo 3-9: Finlayson Creek at Station KZ-26, Looking Downstream, February 2016

3.2.1.2 East Creek

East Creek flows through a medium size valley with moderate gradient for most of its course with a gravel/rocky substrate. Part of East Creek's headwaters are in the Project area, but most of the creek is located outside the Project area. One water quality station is located on East Creek: KZ-21.

KZ-21 – East Creek upstream of Finlayson Creek

Station KZ-21 is located on East Creak upstream of the confluence with Finlayson Creek and is generally characterised by an open forested area with mostly shrubs surrounding the station (Photo 3-10). KZ-21 is a background site, which provides reference water quality and hydrology information and is one of the major tributaries to Finlayson Creek south of the Highway. This is a discrete monitoring station, which means it is metered monthly concurrent with the collection of water quality samples. KZ-21 previously had a staff gauge (in 1995) and was initially planned to be a continuous monitoring station; however, the site did not provide a suitable location for development of a stage-discharge relationship. Additionally, since it is a background site, it is considered appropriate to derive an estimate of the discharge at this site based on comparison of the discrete measurements from other sites and utilizing the continuous record at those other sites, particularly KZ-22. Salt dilution gauging is utilized in the winter months at this site, as ice development does not allow for velocity-area measurements (Photo 3-11). A summary of the instrumentation and maintenance record is provided in Table 3-7.

Table 3-7: KZ-21 Maintenance and Instrumentation

Site	**KZ-22**
Date Established	May 10th, 2015
Benchmarks	n/a
Maintenance	• Only maintenance conducted at this site is during the summer when rocks or debris needs to be moved to conduct manual discharge measurements.
Instrumentation Present	Manual measurements conducted monthly.

Photo 3-10: East Creek at Station KZ-21, Looking Downstream, July 2016

Photo 3-11: East Creek at Station KZ-21, Looking Upstream, February 2017

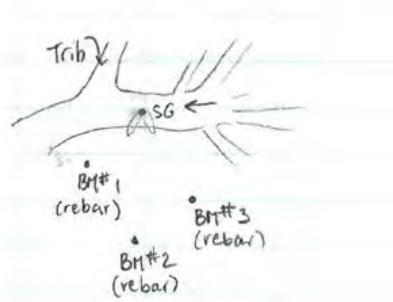
3.2.1.3 Geona Creek

Geona Creek's headwaters are made up of braided channels and three main ponds, and it receives additional water from its headwater Fault Creek. Two small unnamed creeks enter Geona Creek before flowing into Finlayson Creek. Geona Creek meanders through a marshy shrub dominated valley. Geona Creek has a lower gradient than Finlayson and East Creek, with more sediments mixed in with gravel and small boulders as substrate. Three water quality stations are located on Geona Creek: KZ-9, KZ-17 and KZ-37. A fourth station, KZ-7, located in upper Geona Creek, was present from April 2015 to March 2017. The station included water quality, and discrete discharge measurements but had no continuous data infrastructure. The station was decommissioned after two years as it was determined that the water quality between KZ-7 and KZ-9 was similar enough to discontinue sampling. Additionally, the stream substrate at KZ-7 was less than ideal for velocity-area discharge measurements due to large matts of instream moss that would significantly decrease the accuracy of the meter readings.

KZ-9 – Geona Creek upstream of Finlayson Creek

Station KZ-9 is located on Geona Creek upstream of the confluence with Finlayson Creek and is generally characterised by deeply incised banks, with slight meandering as it makes its way down to Finlayson Creek. The station is located 2 meters above the confluence with the small unnamed tributary that station KZ-18 falls on. The hydrometric station is located in a deep pool, on the left-hand side of the creek if you are looking downstream (Photo 3-12). Due to the physical nature of Geona Creek at this location (deeply incised undercut banks), salt dilution gauging is utilized year-round. KZ-9 experiences significant ice development during the winter months, with ice being present for approximately 10 meters on either side of the banks of Geona Creek (Photo 3-13). A summary of the instrumentation and maintenance record is provided in Table 3-8.

Table 3-8: KZ-9 Maintenance and Instrumentation

Site	KZ-9
Date Established	May 10th, 2015
Date moved (if applicable)	n/a
Benchmarks	 BM1 used as "100 m" for all surveys from May 2015 to October 2017.

Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation Present	Site contains a stilling well, levelogger, and staff gauge. Manual measurements conducted monthly.

Photo 3-12: Geona Creek at Station KZ-9, Looking Downstream, July 2017

Photo 3-13: Geona Creek at Station KZ-9, Looking Downstream, February 2017

KZ-17 – Geona Creek upstream of confluence with Finlayson Creek

KZ-17 is located at the mouth of Geona Creek where the initial objective was to install a hydrometric station. However, a large beaver dam has been constructed immediately above the confluence and two dominant channels drain from the dam into Finlayson Creek. The channels are turbulent. As such, the decision was made to establish a hydrometric station on Finlayson Creek above the confluence with Geona Creek (KZ-16) so that discharge at KZ-17 could be calculated by the subtraction of KZ-16 from KZ-15 (Finlayson Creek below Geona Creek confluence). Therefore, no manual or continuous discharge measurements are taken at this site. Substrate in the two main channels is dominated by fines and Geona Creek typically stays open year-round at this location. A summary of the instrumentation and maintenance record is provided in Table 3-9.

Table 3-9: KZ-17 Maintenance and Instrumentation

Site	KZ-7
Date Established	May 11th, 2015
Date moved (if applicable)	n/a
Benchmarks	n/a
Maintenance	• As derived flows are utilized for this site, no monthly maintenance is required.
Instrumentation Present	n/a

Photo 3-14: Geona Creek at Station KZ-17, Looking Upstream, August 2017

Photo 3-15: Geona Creek at Station KZ-17, Looking Upstream, February 2016

KZ-37 – Geona Creek below the confluence of unnamed tributary

Station KZ-37 is located approximately 100 meters below the confluence of the unnamed tributary (KZ-18) on Geona Creek. This station was established in February of 2017 to characterize where water quality modeling predictions are made and to refine water quality objectives established upstream at KZ-9. There is no continuous data capture set up at this site and only discrete discharge measurements are conducted (Photo 3-16). Salt dilution gauging is utilized in the winter months at this site, as ice development does not allow for velocity-area measurements. Obtaining discharge measurements at both KZ-9 and KZ-37 in the winter is typically quite successful, as the flow underneath the ice is still present (Photo 3-17). A summary of the instrumentation and maintenance record is provided in Table 3-10.

Table 3-10: KZ-37 Maintenance and Instrumentation

Site	KZ-37
Date Established	February 23rd, 2017
Date moved (if applicable)	n/a
Benchmarks	n/a
Maintenance	• Only maintenance conducted at this site is during the summer when rocks or debris needs to be moved to conduct manual discharge measurements.
Instrumentation Present	Manual measurements conducted monthly.

Photo 3-16: Geona Creek at Station KZ-37, Looking Downstream, July 2017

Photo 3-17: Geona Creek at Station KZ-37, Looking Downstream, March 2017

3.2.1.4 Fault Creek

Fault Creek is a short mountainous creek with a steep gradient serving as the headwaters for Geona Creek. One water quality station is located on Fault Creek; KZ-2.

KZ-2 – Fault Creek above the confluence of Geona Creek

KZ-2 is located on Fault creek before it flows into Geona Creek. This station is characterized by a steep gradient, cascading and confined stream channel. It is in a narrow valley and has a gravel/rocky substrate with shrubs surrounding the creek on its edge and subalpine fir on the higher banks. Fault Creek flows under a small road a few meters before its confluence with Geona Creek. A thick layer of glacier overflow usually forms at this location during the winter. The hydrometric station at KZ-2, is located in a pool just below a cascade. It's located on the left-hand side of the creek looking downstream (Photo 3-18). Due to the physical nature of Fault Creek at this location, salt dilution gauging is utilized year-round. Ice cover on Fault Creek is limited due to the heavy snow that accumulates in the gully where Fault Creek lies (Photo 3-19). Discharge measurements at this site can occur year-round. A summary of the instrumentation and maintenance record is provided in Table 3-11.

Table 3-11: KZ-2 Maintenance and Instrumentation

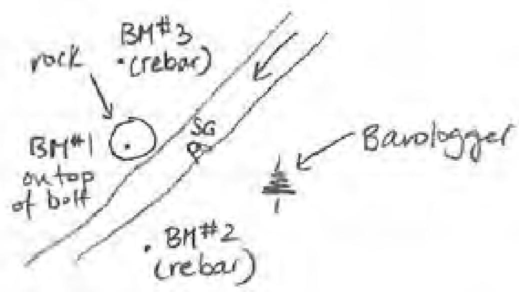
Site	KZ-2
Date Established	May 12th, 2015
Date moved (if applicable)	n/a
Benchmarks	 BM1 used as "100 m" for all surveys from May 2015 to October 2017.
Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation Present	Site contains a stilling well, levelogger, barologger and staff gauge. Manual measurements conducted monthly.

Photo 3-18: Fault Creek at Station KZ-2, Looking Upstream, June 2016

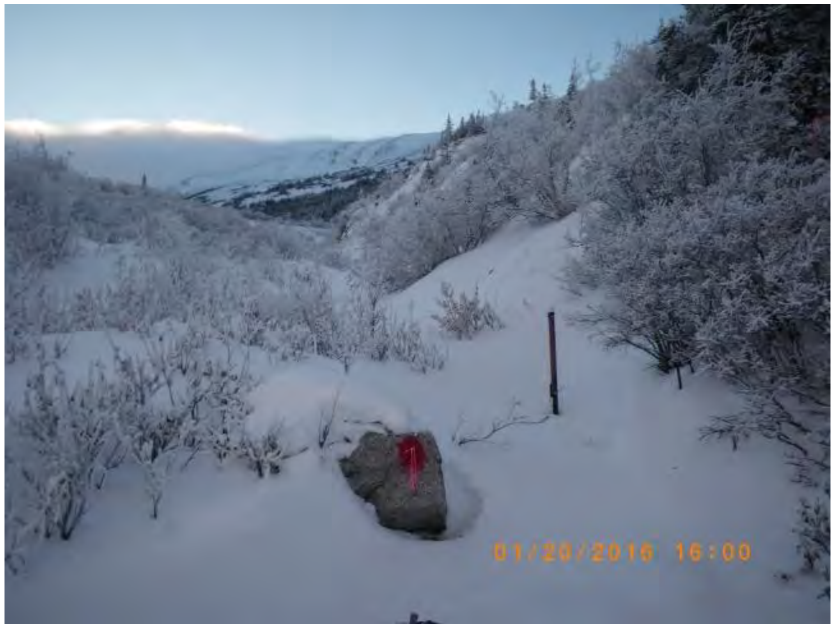


Photo 3-19: Fault Creek at Station KZ-2, Looking Upstream, January 2016

3.2.1.5 South Creek

South Creek originates in two small lakes and flows downhill before its confluence with the North River system to the South. South creek is in a separate catchment from all of the other stations, as it drains into the North River, rather than the Finlayson River.

South creek flows through a wide marshy valley dominated by deciduous shrubs, and has a low gradient with a substrate consisting of fine sand/mud and small boulders. Only one site is located on South Creek; KZ-13.

KZ-13 – South Creek

KZ-13 is similar to KZ-9, with deeply incised banks and slight meandering. The hydrometric station is located upstream of an inactive beaver dam, as beavers have been using the area extensively over the last few years, building dams along the creek. The station is installed in a deep pool on the left side of the creek (looking downstream), and is not affected by the beaver pond (Photo 3-20). The water at site tends to freeze in different layers, creating overflow and different channels spreading in the shrubs along the bank during winter months (Photo 3-21). Salt dilution gauging is utilized year-round. A summary of the instrumentation and maintenance record is provided in Table 3-12.

Table 3-12: KZ-13 Maintenance and Instrumentation

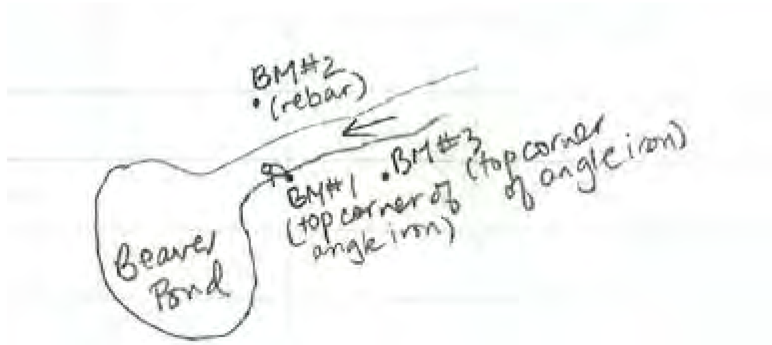
Site	KZ-13
Date Established	May 13th, 2015
Date moved (if applicable)	n/a
Benchmarks	 BM1 used as “100 m” for all surveys from May 2015 to October 2017.
Maintenance	• September 2015, staff gauge surveyed, winterized for 2015/16 winter. • June 2016, staff gauge surveyed, de-winterized for 2016 summer. • September 2016, staff gauge surveyed, winterized for 2016/17 winter. • June 2017, staff gauge surveyed, de-winterized for 2017 summer. • October 2017, staff gauge surveyed, winterized for 2017/2018 winter.
Instrumentation Present	Site contains a stilling well, levelogger, and staff gauge. Manual measurements conducted monthly.

Photo 3-20: South Creek at Station KZ-13, Looking Downstream, September 2016

Photo 3-21: South Creek at Station KZ-13, Looking Downstream, March 2016

3.2.1.6 Unnamed Tributaries of Geona Creek

There are two stations, KZ-18 and KZ-6, located on small unnamed creeks within the Geona Creek catchment, both flowing from the East side.

KZ-18 – Unnamed tributary above Geona Creek at KZ-37

KZ-18 is located on a small very narrow unnamed creek flowing west into Geona Creek between KZ-37 and KZ-9. The water quality station is located a few meters upstream from its confluence with Geona Creek. The creek is short and less than a meter wide, meandering in a small valley through thick deciduous shrubs with a gravel substrate (Photo 3-22). This small creek usually keeps flowing under a thin layer of ice all throughout the winter (Photo 3-23). Due to the physical nature of this creek at this location, salt dilution gauging is utilized year-round. A summary of the instrumentation and maintenance record is provided in Table 3-13.

Table 3-13: KZ-18 Maintenance and Instrumentation

Site	KZ-18
Date Established	August 27th, 2016
Date moved (if applicable)	n/a
Benchmarks	n/a
Maintenance	• Only maintenance conducted at this site is during the summer when rocks or debris needs to be moved to conduct manual discharge measurements.
Instrumentation Present	Manual measurements conducted monthly.

Photo 3-22: Unnamed Creek at Station KZ-18, Looking Upstream, August 2017

Photo 3-23: Unnamed Creek at Station KZ-18, Looking Upstream, February 2017

KZ-6 – Unnamed tributary above KZ-9 on Geona Creek

KZ-6 is located on a small narrow unnamed creek flowing west into Geona Creek below the headwater ponds. The creek meanders down a small valley with medium gradient, through thick deciduous shrub habitat. The substrate of this creek is mostly gravel (Photo 3-24). The water quality station is located a few meters upstream of the confluence with Geona Creek. This creek usually creates thick layers of glacial overflow throughout its course during the winter months (Photo 3-25). Due to the physical nature of this creek at this location, salt dilution gauging is utilized year-round. A summary of the instrumentation and maintenance record is provided in Table 3-14.

Table 3-14: KZ-6 Maintenance and Instrumentation

Site	KZ-6
Date Established	December 2nd, 2015
Date moved (if applicable)	n/a
Benchmarks	n/a
Maintenance	• Only maintenance conducted at this site is during the summer when rocks or debris needs to be moved to conduct manual discharge measurements.
Instrumentation Present	Manual measurements conducted monthly.

Photo 3-24: Unnamed Creek at Station KZ-6, Looking Downstream, July 2017

Photo 3-25: Unnamed Creek at Station KZ-6, Looking Downstream, March 2017

3.2.2 Data Acquisition

The 2015 to 2017 monitoring program consisted of discrete discharge observations on a monthly basis concurrent with water quality sampling from April 2015 to December 2017. Hydrometric stations are designed to conform with British Columbia standard criteria for the collection of Grade A data (or Grade B when channel conditions prevent Grade A (MOE, 2009)). Sampling was carried out according to AEG's *Standard Operating Protocol, Surface Water Hydrology, Data Collection and Management* (Appendix F). The protocol recommends that two discharge measurements are collected at each site so the repeatability of the measurement can be calculated. The repeatability is calculated as the difference between the two measurements divided by their mean and expressed as a percent. Measurements are collected either using the velocity-area method with an electromagnetic flow meter, or using salt dilution gauging. Calibrations for the salt concentration–electrical conductivity relationship are conducted on site for each measurement; weather permitting. Field technicians then enter their data upon return and the staff hydrologist confirms the calculations.

Leveloggers and Barologgers log half-hourly observations and are downloaded monthly; as long as weather permits. Continuous data was provided to KP for data analysis and is presented in Appendix G.

3.2.3 Data Quality

Data quality assurance starts with AEG's Standard Operating Protocol (Appendix F) which aims to ensure compliance with Grade A or B data as defined in the British Columbia Hydrometric Standards (MOE, 2009). The following discussion presents those data gathered during the 2015 to 2017 baseline monitoring program and examines the quality and confidence in those data. The data quality of Environment and Climate Change Canada is not discussed as the British Columbia standards are based on WSC data which is only released once the data have been reviewed and approved. The regional data is very high quality, suitable for international distribution and only long and complete records were used for analysis for high confidence results.

While the goal is Grade A compliance for data collected at site, this is extremely difficult and often impossible in small mountain streams, especially those which are too turbulent and narrow for velocity-area measurements, or where the dominant morphology may be step pools, such as at KZ-2. The British Columbia standards criteria assumes the use of the velocity-area method for discharge and requires 20 or more panels, which is not possible at sites such as KZ-2, 9 and 13. Because of their morphology, the sites must be defined as data grade U for "Undefined." However, other than dilution gauging it is the channel morphology itself that precludes a higher grade. The channel should be a stable straight reach, free of boulders and vegetation. While the sites chosen for these stations are quite stable and relatively straight, they are not sufficient for velocity-area measurements. KZ-15, 16 and 26 are considered Grade A data. KZ-22 would be Grade A and it meets all criteria except the channel has some very large boulders and is somewhat turbulent which lowers it to Grade B.

The mean repeatability (RPD) is for all measurements; however, the uncertainty was assumed to be 10% for the rating measurements. The rating accuracy is the mean of the percent deviation of each rating measurement from the rating curve. Grade A data must be 7% or less (MOE, 2009).

Prior to developing rating curves, hydrographs and unit runoff comparisons for the Project, KP has reviewed the hydrometric data collected in general accordance with the "Standard Process for Review of Hydrometric Data", as detailed in the Manual of BC Hydrometric Standards (RISC, 2009), and judged the Project hydrometric datasets to be of good quality, predominantly Grade A (see Appendix G).

3.3 RESULTS

The rating curves, hydrographs, and unit runoff comparisons were all calculated by KP using baseline data presented in this report. Their analysis and results are provided as Appendix G, with key findings summarized below.

Rating curves were developed for each continuous flow station, by manually fitting 'visual-best-fit' lines to the calibration data, with the objective of minimizing the difference between the rating curve predicted discharges and the measured discharges, and extrapolated over the entire range of recorded stage. Rating curves were then applied to the 30-minute record to develop hydrographs.

Overall, "discharge hydrographs are typically characterised by high spring snowmelt-driven flows, lower summer flows sustained by groundwater inflows and periodic rainfall events, followed by large autumn rainfall events. Winter flow is very low as a result of cold temperatures, freezing conditions, and the gradual depletion of groundwater storage." (KP, 2018).

"The discharge hydrographs for each station […] were converted to unit runoff and compared to identify site trends. Overall, all streamflow measured within the Project study area show consistent relationships and trends. Based on sites with three years of record, 2017 was the highest flow year while 2015 was the lowest. All years have a roughly bimodal shape, with one distinct peak in late May or June and another peak in September and early October. Many hydrographs also show rainfall-induced peaks in mid-summer, particularly in July. Consistent with typical hydrologic patterns, those stations with higher elevations and smaller catchments tend to experience higher unit runoff during the freshet and lower unit runoff during the summer." (KP, 2018).

4 CONCLUSION

Data collected in 1995 and in 2015 to 2017 indicate that average temperatures at Kudz Ze Kayah were comparable to those of regional stations for the same period, but were warmer than long-term averages at regional stations. The diurnal and annual temperature range at Kudz Ze Kayah appears to be smaller than at regional stations.

Total annual precipitation recorded at Kudz Ze Kayah in 2016 and 2017 was greater than at regional stations (Watson Lake A and Faro A), but not as much as expected when accounting for the elevation difference between the sites. Overall, both 1995 and 2015 to 2017 appear to have been drier years than average (less precipitation and lower snowpack) when compared to the long term regional record.

Winds at the Kudz Ze Kayah site blow predominantly from the northwest to northeast with average and maximum wind speeds being relatively high. Relative humidity and barometric pressure at Kudz Ze Kayah are generally consistent with regional patterns and solar radiation peaks in July and is at a minimum in December. Pan evaporation measurements and evapotranspiration calculations at Kudz Ze Kayah for the 2015 to 2017 period correlate relatively well with 1995 measurements and estimates. Actual evapotranspiration is estimated to be 180 mm while sublimation will range depending on snowfall but may be approximately 30 percent of total snowfall.

Hydrometric data were collected on site in 1995 and at present beginning in April 2015. Seven continuous monitoring stations were installed in May 2015 and discrete monthly discharge were gathered to facilitate the development of continuous derived record. The current monitoring network consists of 12 active stations (one station was discontinued in March 2017).

Rating curves, hydrographs, and unit runoff comparisons were all calculated by Knight Piesold Ltd. (KP) using baseline data presented in this report. Their analysis and results are provided as Appendix G. Overall, KP found that “discharge hydrographs are typically characterised by high spring snowmelt-driven flows, lower summer flows sustained by groundwater inflows and periodic rainfall events, followed by large autumn rainfall events. Winter flow is very low as a result of cold temperatures, freezing conditions, and the gradual depletion of groundwater storage.” (Appendix G).

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APPENDIX A

CAMPBELL SCIENTIFIC METEOROLOGICAL STATION COMPONENTS AND PHOTO

Project Campbell Scientific Meteorological Station Component List

Component	Model	Serial Number
Air Temperature and Relative Humidity Sensor	HC-S3-XT-L	61431525
Total Precipitation Gauge	Geonor T-200B (3 sensors)	T1: 44415 T2: 44515 T3: 44615
Wind Speed and Direction Sensor	RM Young 05103AP-10-L	WM139088
Barometric Pressure Sensor	Vaisala CS106	L1250653
Pyranometer	Kipp & Zonen CMP3-L	151852
Solar Panel	MSX50R	n/a
Datalogger	CR1000-XT	72240
Battery	BP100	C1237
Iridium Modem	9522B	300025010847390
Iridium Modem Interface	COM9522B	1141

Project Campbell Scientific Meteorological Station Photograph

APPENDIX B

KUDZ ZE KAYAH DAILY METEOROLOGICAL DATA 2015-2017

APPENDIX B

KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2015-08-26	11.36	7.956333	3.866	58.68375	-0.6555	5.874167	14.54	211.272	3.05	1015.279
2015-08-27	6.452	4.486833	2.366	86.55	1.3842	5.546667	11.94	82.12394	0.96	1003.54
2015-08-28	6.44	3.460417	0.933	83.25542	0.5046	3.533	9.04	160.0375	1.61	1000.959
2015-08-29	7.382	5.493792	2.962	89.30125	2.9131	5.167792	12.17	92.8868	0.99	996.5188
2015-08-30	5.343	2.939417	0.257	91.53375	8.6815	2.487875	11.25	107.9539	1.03	988.2197
2015-08-31	0.505	-0.54663	-1.856	96.0625	1.0637	4.170333	9.45	82.64978	0.51	993.664
2015-09-01	-0.825	-2.09125	-3.184	96.14583	1.3814	7.184583	11.56	83.01933	0.45	1004.265
2015-09-02	0.62	-0.88179	-2.52	96.59583	0.4978	3.562542	8.39	104.4129	0.68	1013.765
2015-09-03	6.324	2.402125	0.167	73.57583	0.4443	3.851333	12.03	197.8148	2.01	1018.578
2015-09-04	5.79	2.666083	0.126	73.94458	0.0539	5.733542	13.35	116.5882	1.47	1013.541
2015-09-05	4.931	3.34025	1.943	84.71958	1.4328	3.00475	9.47	77.7621	0.88	1012.086
2015-09-06	3.458	2.562167	1.819	93.62917	4.8233	1.916542	7.076	56.35264	0.41	1012.843
2015-09-07	7.045	4.390667	1.339	64.77833	-0.1212	1.427917	4.841	177.5624	1.92	1012.989
2015-09-08	7.473	5.225583	2.945	58.6	-0.1461	3.162208	7.193	137.5229	1.88	1011.33
2015-09-09	7.926	5.718375	3.218	63.52542	-0.6585	6.345417	14.84	155.8508	2.17	1009.57
2015-09-10	7.392	5.524417	3.422	78.01375	1.2943	9.032417	23.83	68.57936	1.18	1007.678
2015-09-11	8.94	7.177458	4.495	57.66583	-0.2813	11.69108	24.93	159.6764	2.73	1005.709
2015-09-12	5.949	3.391583	1.506	64.34083	-0.5066	5.820958	14.41	117.4135	1.49	1011.444
2015-09-13	4.463	2.2055	0.809	76.84208	0.4018	5.02875	11.21	99.34892	1.07	1012.167
2015-09-14	5.58	2.506792	0.508	63.6975	-0.1589	6.083625	12.68	145.5951	1.65	1004.372
2015-09-15	3.802	1.368417	0.081	73.15208	0.2202	5.159125	11.33	111.0954	1.12	1002.101
2015-09-16	4.336	1.734083	-0.11	77.81083	-0.266	4.440625	10.78	108.6246	1.07	1002.657
2015-09-17	3.816	1.698417	0.152	87.06125	0.7799	6.581917	15.31	123.364	0.89	998.8072
2015-09-18	2.008	0.428583	-0.881	91.45	3.8581	4.8785	13.9	43.28993	0.4	993.499
2015-09-19	-0.004	-1.12996	-2.438	76.79333	0.0028	9.02575	15.56	101.2661	1.01	996.0493
2015-09-20	1.319	-0.73542	-2.89	65.45208	-0.0857	3.0675	7.546	92.29425	0.95	1005.183
2015-09-21	1.4	-0.615	-2.814	72.855	0.3015	3.553375	7.958	110.8959	0.96	1008.86
2015-09-22	-0.561	-2.22679	-3.903	90.31917	1.3222	4.349042	8.88	93.46146	0.48	1008.507
2015-09-23	-0.273	-2.67483	-4.538	87.17042	1.2426	1.430917	5.312	49.59805	0.31	1008.735
2015-09-24	-2.078	-2.62075	-3.425	89.5	0.5752	4.38525	9.39	41.53602	0.36	1004.818
2015-09-25	-0.374	-2.25288	-4.579	76.42167	0.0422	6.79575	15.68	112.8142	1.03	1002.783
2015-09-26	-0.98	-4.09483	-7.16	74.39583	2.3704	10.25075	22.17	97.37449	0.76	1003.183
2015-09-27	0.193	-3.53396	-8.28	69.28083	-0.0664	3.857708	10.96	125.2647	0.92	1010.459
2015-09-28	6.226	4.4635	1.392	82.14833	-0.1963	7.64375	16.56	101.5188	0.95	1005.838
2015-09-29	8.17	6.722625	4.32	73.44458	-0.4593	12.1495	25.42	49.87144	1.14	1000.546
2015-09-30	7.344	1.9105	-1.323	59.13208	3.2039	12.04	23.58	115.7272	1.7	1002.579
2015-10-01	-1.505	-5.07954	-10.1	73.48542	-0.4437	6.5795	17.82	64.18088	0.53	1017.888
2015-10-02	-2.41	-6.39829	-11.05	57.48667	-0.3322	2.693667	10.47	105.259	0.77	1025.598
2015-10-03	0.439	-2.33788	-5.76	53.94708	-0.1748	3.205625	8.92	69.03147	0.86	1021.704
2015-10-04	-0.31	-2.17713	-3.822	72.86833	0.2437	6.53525	14.13	50.22676	0.68	1016.006
2015-10-05	-2.816	-3.92646	-4.945	79.705	0.2625	2.675833	7.115	38.29094	0.37	1015.961
2015-10-06	2.241	-2.30021	-5.931	62.17417	-0.195	1.911542	5.606	114.1523	1.03	1011.45
2015-10-07	1.67	0.1505	-1.926	61.93	-0.1779	1.446375	6.527	33.65666	0.32	1010.78
2015-10-08	1.875	0.083292	-1.576	88.36125	0.0484	5.066833	12.76	27.18518	0.31	1006.757
2015-10-09	2.552	0.75275	-0.94	96.14583	0.8982	5.140292	13.19	25.42561	0.2	992.2392
2015-10-10	3.919	2.540542	1.224	77.77583	1.1515	6.121083	14.8	70.63089	0.87	989.3457
2015-10-11	2.651	0.769833	-0.697	72.6525	-0.3991	6.234625	14.5	74.6906	0.79	997.4657
2015-10-12	2.75	0.82475	-0.969	71.93292	0.2676	10.02658	19.17	52.34698	0.87	994.4841
2015-10-13	-0.075	-0.93175	-2.265	73.88458	-1.4199	8.940167	19.07	53.43865	0.73	1003.158
2015-10-14	1.698	-1.31379	-3.68	72.24958	-0.0568	5.51325	11.11	82.34131	0.77	1017.557
2015-10-15	-0.197	-2.11267	-3.648	72.84042	0.7506	2.595875	8.43	57.08766	0.34	1018.07
2015-10-16	5.244	0.647042	-3.624	88.005	0.4471	6.633333	16.52	39.18592	0.44	1008.863

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KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2015-10-17	6.014	3.492333	1.422	77.91958	-0.263	6.946667	15.43	46.33685	0.68	1001.02
2015-10-18	4.041	2.096708	-0.018	80.59167	-1.7174	6.009125	14.23	57.74897	0.54	1004.318
2015-10-19	1.043	-0.05113	-1.506	80.02375	-0.4737	6.234875	12.9	47.17913	0.43	1006.512
2015-10-20	0.934	-1.14421	-2.555	74.51292	0.0828	3.708917	9.07	54.09208	0.41	1007.174
2015-10-21	0.514	-1.12942	-2.726	88.8975	3.6727	5.730292	16.91	18.01968	0.03	998.8974
2015-10-22	1.803	0.426583	-0.484	75.02417	0.6738	8.030292	16.64	65.26243	0.65	1004.155
2015-10-23	0.29	-0.39008	-1.16	74.99833	-0.1022	6.3345	15.35	46.22805	0.42	1010.418
2015-10-24	-1.392	-2.37367	-3.327	71.73292	0.2234	4.342833	12.09	38.38612	0.26	1013.175
2015-10-25	-1.028	-2.619	-4.805	67.72958	0.0884	2.62425	10.54	36.3369	0.12	1011.861
2015-10-26	-2.001	-4.15521	-5.077	79.92417	0.2595	2.349083	7.703	40.44534	0.05	1015.646
2015-10-27	1.783	-0.83421	-2.503	39.8575	-0.2495	1.2025	8.88	48.39675	0.23	1010.546
2015-10-28	0.408	-0.88617	-2.329	52.07	-0.0334	2.381083	9.21	35.89101	0.25	999.7499
2015-10-29	0.253	-0.82417	-2.577	77.22208	0.0763	5.262917	13.92	31.46304	0.25	993.3351
2015-10-30	-0.568	-1.47625	-2.203	59.05292	-0.004	1.896417	5.625	24.6883	0.08	991.3881
2015-10-31	-2.338	-4.10221	-5.814	87.6375	3.2817	*1.736947*	*6.899*	11.97878	-0.22	995.5183
2015-11-01	-5.903	-9.844	-12.1	89.075	2.4365	*0.000222*	*0.157*	12.97928	-0.32	1003.021
2015-11-02	-8.81	-11.6338	-13.61	85.34375	0.1323	*2.990727*	*10.45*	30.1598	-0.08	1005.091
2015-11-03	-8.97	-11.0546	-13.21	83.8425	0.2337	3.206167	10.49	20.06073	-0.06	1003.705
2015-11-04	-8.27	-11.4079	-13.22	87.62917	0.9256	4.22125	11.35	14.06473	-0.07	1003.423
2015-11-05	-7.069	-9.97633	-13.72	68.4	-0.1252	3.60025	14.54	51.66045	0.29	1007.186
2015-11-06	-2.91	-4.89092	-8.8	76.21875	2.6455	11.40025	22.21	22.87425	0.3	992.3509
2015-11-07	-3.482	-4.01938	-4.948	76.47625	-0.8714	7.478833	17.35	22.77212	0.21	997.5761
2015-11-08	-3.546	-4.75738	-5.899	80.17917	0.4057	3.363708	15.27	21.61174	0.04	1004.547
2015-11-09	-2.444	-4.16838	-5.652	75.26042	0.4881	8.174708	18.54	16.42283	0.23	996.532
2015-11-10	-3.562	-8.29142	-11.89	87.16083	4.8518	5.301417	15.21	7.499425	-0.07	987.6017
2015-11-11	-10.47	-12.42	-14.71	70.23333	-0.3698	4.328292	13.92	26.51915	0.13	994.8506
2015-11-12	-6.073	-8.4225	-10.33	79.73667	-0.3709	11.72333	20.46	15.328	0.22	981.0925
2015-11-13	-5.437	-6.23646	-7.557	77.7325	-0.659	7.68875	15.35	20.93261	0.19	981.7001
2015-11-14	-5.833	-11.6203	-14.92	84.55583	0.7145	2.055917	8.68	17.43014	-0.07	993.7728
2015-11-15	-8.22	-10.2054	-12.31	81.94625	0.1009	4.525708	10.21	22.74728	0.05	996.4957
2015-11-16	-11.54	-12.7833	-14.58	77.79375	-0.1891	6.747	15.64	24.55255	0.11	991.3982
2015-11-17	-12.76	-13.9654	-16.76	82.22833	0.6234	2.706917	8.06	14.36279	-0.08	990.3604
2015-11-18	-15.97	-18.9588	-21.99	76.35833	0.4384	1.466625	8.98	14.68368	-0.02	1001.3
2015-11-19	-12.08	-21.5675	-26.28	75.71958	-0.3187	1.964458	9.21	37.53367	0.03	1008.699
2015-11-20	-3.351	-5.79808	-9.92	71.03458	1.0649	12.24908	26.64	9.837638	0.27	1002.832
2015-11-21	-0.402	-2.94629	-5.909	71.70333	0.5	14.56708	28.52	12.41792	0.35	992.6907
2015-11-22	-6.501	-11.1783	-16.25	80.98542	-0.7423	8.684792	19.95	12.91444	0.09	1004.876
2015-11-23	-14.27	-16.6125	-19.13	59.04417	-0.1159	5.540458	14.29	19.48815	0.15	1013.907
2015-11-24	-5.751	-9.62033	-14.23	57.62083	-0.3116	2.496208	9.39	13.67208	0.07	1014.449
2015-11-25	-1.873	-4.842	-7.353	53.92	-0.0905	5.460042	18.44	12.3359	0.32	1015.305
2015-11-26	0.112	-0.81158	-1.961	38.49458	2.1739	14.11758	27.44	11.78829	0.91	1010.577
2015-11-27	1.998	-0.35729	-1.675	34.10083	-0.0524	11.54538	24.3	15.75932	0.99	1012.009
2015-11-28	-0.622	-1.88213	-3.966	65.6775	0.3062	7.719375	22.89	12.49136	0.35	1008.313
2015-11-29	-0.701	-1.90892	-3.422	70.55292	0.8515	9.003625	17.93	7.261728	0.3	1003.301
2015-11-30	-3.272	-4.78754	-6.027	73.81375	-0.4398	6.859292	18.93	5.295698	0.14	999.6018
2015-12-01	-3.713	-4.64925	-5.897	84.09375	-0.0567	8.362625	18.5	8.053379	0.1	994.8695
2015-12-02	-4.779	-6.09804	-7.851	83.76875	0.7509	3.144875	11.49	5.872964	-0.09	993.9057
2015-12-03	-6.824	-8.18363	-9.6	82.695	0.2801	3.357333	10.82	6.287341	-0.03	993.267
2015-12-04	-7.589	-9.21658	-11.59	85.72917	0.4772	1.892708	7.252	5.906797	-0.16	995.1036
2015-12-05	-11.61	-12.4446	-14.57	83.88458	0.1741	1.567083	5.488	6.024075	-0.09	998.4215
2015-12-06	-8.84	-11.0696	-13.11	87.6375	0.1374	3.349917	11.05	5.347121	-0.08	991.2364
2015-12-07	-7.134	-8.36633	-10.19	87.275	0.1311	1.059833	8.35	5.628005	-0.2	989.3651

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Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2015-12-08	-7.041	-8.06596	-10.35	88.58667	0.0487	3.645917	12.84	4.544099	-0.05	986.9268
2015-12-09	-5.43	-7.16325	-9.18	79.4075	-0.0218	5.205667	11.68	12.27712	0.05	987.2611
2015-12-10	-7.269	-8.72654	-10.69	80.2675	-0.0207	2.411458	12.56	4.162771	-0.14	993.3662
2015-12-11	-10.21	-11.9008	-14.27	84.97083	0.3483	1.963208	7.526	3.99017	-0.14	996.6383
2015-12-12	-10.28	-12.2729	-15.79	73.20625	0.0386	0.956292	5.821	7.549008	-0.14	995.155
2015-12-13	-9.93	-12.2288	-16.02	80.3225	0.0251	0.815167	4.116	4.720236	-0.19	999.1429
2015-12-14	-9.85	-11.9617	-15.8	76.32375	0.3821	5.609	16.05	3.356335	0.05	998.9689
2015-12-15	-10.41	-11.6892	-12.89	83.0175	0.0407	4.118667	10.09	4.882357	0	1006.195
2015-12-16	-8.97	-10.3154	-12.48	73.52583	0.0766	3.901833	10.07	6.402291	-0.02	1009.624
2015-12-17	-11.68	-12.8917	-14.36	75.40375	0.068	8.790875	15.84	6.259875	0.12	1001.216
2015-12-18	-13.42	-14.8283	-16.25	80.39	0.0926	5.420167	12.78	7.38394	0	995.2725
2015-12-19	-11.69	-14.8308	-17.51	81.81792	0.052	3.958542	11.76	3.08429	-0.04	990.152
2015-12-20	-13.11	-15.7617	-19.38	82.94083	0.3245	0.4715	3.254	3.257301	-0.22	985.3678
2015-12-21	-10.05	-11.4933	-13.84	87.175	0.1339	1.329833	7.154	3.091017	-0.16	987.4318
2015-12-22	-10.03	-10.9921	-12.4	79.59917	0.6062	3.498167	10	6.472766	-0.03	987.9616
2015-12-23	-10.95	-15.4529	-20.37	81.67292	0.5596	1.403	8.11	4.636813	-0.14	994.1403
2015-12-24	-18.84	-20.2242	-21.89	78.36917	0.0645	1.962125	6.35	3.542224	0	1004.568
2015-12-25	-17.46	-18.7525	-19.66	76.49125	0.0211	0.662417	2.47	7.735133	-0.1	1010.068
2015-12-26	-15.99	-17.6163	-20.02	75.35333	0.4597	1.248917	8.66	4.372104	-0.12	1005.235
2015-12-27	-10.7	-14.3579	-16.44	79.79708	0.0626	1.237375	3.998	4.212656	-0.12	1006.101
2015-12-28	-5.748	-9.32846	-11.68	66.29542	0.371	6.130417	20.58	6.045077	0.14	1006.178
2015-12-29	-4.638	-6.49196	-8.42	70.21542	-1.5976	6.144	23.62	4.920395	0.11	1008.63
2015-12-30	0.228	-2.53358	-4.341	49.03708	0.5388	6.841958	21.89	7.179622	0.38	1012.884
2015-12-31	-2.222	-3.57288	-4.944	63.42708	-0.3082	7.103417	22.29	6.190838	0.31	1010.124
2016-01-01	-3.266	-4.42321	-5.612	72.6475	-0.7974	7.541458	20.5	5.242361	0.21	1011.206
2016-01-02	-2.229	-3.64583	-4.824	56.47833	1.0273	8.187417	17.48	7.461607	0.44	1007.951
2016-01-03	-4.147	-6.49858	-7.916	57.6025	-0.0464	5.131167	18.29	4.855988	0.12	1010.569
2016-01-04	-5.829	-6.77858	-7.894	31.66667	0.9165	2.01825	10.35	6.95859	0.14	1009.144
2016-01-05	-5.578	-6.28208	-6.994	31.99542	-0.0292	1.329792	6.056	4.473309	0.01	1005.348
2016-01-06	-6.018	-7.61313	-9.32	32.10583	-0.7281	1.89825	9.49	5.03099	0.06	1008.735
2016-01-07	-4.283	-5.28813	-6.638	47.59542	-0.068	0.780083	4.194	5.159391	-0.17	1010.055
2016-01-08	-1.682	-3.07475	-4.221	59.64958	-0.1377	1.590083	7.468	5.439578	-0.07	1007.974
2016-01-09	-1.902	-3.59708	-5.918	68.13333	1.8155	6.656	18.56	5.109785	0.12	1005.379
2016-01-10	-5.296	-7.5435	-8.97	78.04875	-0.2662	4.1025	19.82	8.516013	0.02	1009.875
2016-01-11	-6.807	-9.23146	-11.64	85.79958	1.9772	4.470042	12.5	4.982398	-0.02	1002.11
2016-01-12	-2.805	-4.38179	-7.093	74.03958	-1.0272	8.349542	25.99	7.257769	0.19	994.6542
2016-01-13	-5.704	-6.49675	-7.877	83.41375	0.8068	2.744667	11.7	7.311181	-0.09	996.4245
2016-01-14	-7.183	-8.49225	-9.72	85.13958	0.1879	2.150417	11.05	12.44889	-0.1	1004.479
2016-01-15	-8.7	-9.66542	-11.57	88.34167	0.721	1.138375	9.78	9.415195	-0.18	1004.42
2016-01-16	-11.66	-13.7129	-17.04	84.20833	0.3369	5.915958	12.35	8.620165	-0.02	1000.473
2016-01-17	-13.93	-15.0154	-16.16	83.92917	0.1047	0.704208	4.861	33.1227	-0.11	998.3729
2016-01-18	-5.872	-9.6115	-15.59	81.17125	-0.4585	2.373583	12.41	13.48117	-0.06	999.0619
2016-01-19	-6.771	-8.62225	-9.73	79.3275	0.043	2.115458	7.781	16.95452	-0.1	1000.567
2016-01-20	-7.504	-9.26392	-10.34	86.78333	0.2375	1.76675	8.49	27.58168	-0.07	1004.484
2016-01-21	-9.43	-10.5042	-11.86	88.19167	-0.6995	4.066042	11.35	11.47077	-0.03	997.8729
2016-01-22	-4.591	-6.25208	-12.27	79.79458	0.8332	7.086458	15.09	15.39872	0.1	996.178
2016-01-23	-5.141	-5.50046	-5.819	73.16625	0.2314	9.402583	17.33	20.99222	0.3	998.6418
2016-01-24	-4.854	-5.72804	-7.423	73.5425	1.143	7.734833	16.84	22.82155	0.27	1002.544
2016-01-25	-3.082	-5.4595	-6.69	83.58417	-0.3671	5.29025	14.88	12.97929	0.05	1000.464
2016-01-26	-0.939	-3.41292	-7.081	78.17667	0.7692	13.76508	24.74	17.36578	0.29	992.0921
2016-01-27	-2.571	-4.2025	-5.756	76.23958	-1.9795	9.476833	20.85	11.90755	0.22	995.1186
2016-01-28	-1.689	-2.99354	-4.128	73.83125	1.0171	9.847125	19.33	28.08729	0.41	987.8379

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-01-29	-4.16	-5.27383	-7.408	74.74125	-1.0569	6.19675	20.05	28.76213	0.24	992.1361
2016-01-30	-5.718	-6.85338	-8.54	88.2525	0.097	4.469292	10.21	9.001156	0	1000.684
2016-01-31	-8.52	-10.6088	-12.9	86.43542	0.4846	3.84325	8.45	19.25733	0.01	1008.156
2016-02-01	-10.75	-12.0792	-13.57	64.88167	0.2957	1.40825	6.899	37.50977	0.07	1005.051
2016-02-02	-11.53	-12.4704	-13.82	81.57583	0.2962	1.320292	5.429	21.38997	-0.11	1007.674
2016-02-03	-10.85	-11.9621	-12.62	84.85833	0.0922	3.935167	8.96	19.795	-0.02	1003.316
2016-02-04	-6.146	-9.32929	-13.45	80.39208	0.0737	7.345458	18.21	29.71881	0.18	996.6021
2016-02-05	-5.865	-7.75792	-10.21	77.36417	-0.1531	5.25075	11.11	39.96457	0.22	992.0035
2016-02-06	-7.778	-8.83729	-9.44	69.075	0.602	8.151542	13.78	41.3992	0.43	1004.962
2016-02-07	-5.899	-9.20008	-10.65	71.98	-0.3883	5.094958	17.86	22.18516	0.13	1012.725
2016-02-08	-5.189	-6.50292	-7.591	76.81375	0.852	5.123542	14.86	22.1385	0.13	1010.887
2016-02-09	-2.67	-5.91533	-8.21	87.61417	0.2831	4.80575	17.6	25.1726	0.01	1010.686
2016-02-10	-6.084	-7.09367	-8.58	86.83458	0.8404	7.003458	14.74	16.57897	0.03	1007.247
2016-02-11	-2.362	-5.30808	-9.85	74.62375	-0.2541	7.438917	16.17	48.38803	0.43	1010.709
2016-02-12	-1.961	-4.90838	-7.341	71.99458	1.0316	6.709583	18.4	43.83426	0.38	1003.038
2016-02-13	-3.162	-4.16625	-5.143	68.53542	-0.5873	9.090792	17.8	54.65291	0.53	999.7548
2016-02-14	-4.629	-5.73946	-6.834	77.04625	-0.1738	3.364833	10.7	39.12247	0.15	997.9452
2016-02-15	-5.037	-6.424	-7.403	80.67	0.4386	3.326833	9.21	33.80064	0.09	999.6223
2016-02-16	-6.972	-8.09983	-10.32	90.0875	0.4177	1.823333	6.801	23.39101	-0.11	998.6513
2016-02-17	-10.81	-12.4892	-14.75	86.42083	0.4267	0.897917	4.508	24.54417	-0.14	994.9659
2016-02-18	-14.98	-16.22	-18.18	82.30833	0.4291	*1.149632*	*4.41*	21.49149	-0.12	989.06
2016-02-19	-17.68	-19.5129	-21.58	74.91208	0.4833	3.155833	11.6	56.82103	0.13	998.129
2016-02-20	-5.709	-10.7577	-18.5	71.12292	-0.4305	6.074	20.29	69.16822	0.43	1005.401
2016-02-21	-2.533	-5.16525	-7.775	63.82625	-1.7442	4.375958	11.09	67.71772	0.59	1008.656
2016-02-22	-3.628	-6.26038	-8.36	65.80042	0.814	7.519417	15.15	63.69499	0.6	1012.474
2016-02-23	-5.94	-7.67592	-9.6	53.08667	-0.0362	3.694125	10.6	79.01089	0.6	1016.533
2016-02-24	-2.744	-6.18867	-9.48	63.93792	-0.5675	5.751417	20.93	58.05798	0.5	1008.651
2016-02-25	-1.209	-2.17488	-3.609	76.37292	-0.0073	7.784	19.54	58.2436	0.42	1005.935
2016-02-26	-0.746	-2.67471	-4.302	78.17583	1.4098	7.147958	17.07	41.72	0.37	1000.658
2016-02-27	-3.315	-4.7225	-6.094	69.04917	-0.7362	6.259375	14.88	87.34032	0.71	1002.874
2016-02-28	-5.818	-6.558	-7.842	83.15792	0.4644	5.544375	15.56	59.23162	0.25	999.5152
2016-02-29	-5.065	-6.43058	-7.309	77.11667	-0.1975	3.621208	8.74	94.41066	0.53	1005.417
2016-03-01	-6.599	-7.84508	-9.27	86.91583	0.2157	3.166083	7.977	56.25987	0.24	1006.945
2016-03-02	-6.782	-9.5005	-11.87	82.25417	0.0949	1.526542	4.312	110.3752	0.53	1006.89
2016-03-03	-9.54	-11.9454	-14.27	85.27917	0.2727	2.504542	7.84	55.39353	0.19	1001.678
2016-03-04	-9.17	-11.1192	-13.13	83.685	0.7035	5.805167	12.33	80.44116	0.33	994.8501
2016-03-05	-9.59	-10.9875	-12.55	84.1625	-0.3311	6.825708	11.92	91.34573	0.34	992.5946
2016-03-06	-10.78	-12.4296	-14.06	82.62833	0.9037	7.256417	16.39	78.95642	0.27	992.9638
2016-03-07	-11.53	-13.9533	-16.21	76.7575	0.0209	4.159917	14.19	107.6058	0.37	995.4859
2016-03-08	-4.423	-7.78783	-12.53	79.10917	-0.9102	3.098833	9.72	116.7392	0.58	996.9138
2016-03-09	-4.329	-6.5805	-7.992	74.7625	-0.0821	3.856708	8.02	99.28365	0.59	996.2173
2016-03-10	-4.595	-5.90608	-7.442	74.67	-0.9209	4.261417	9.88	107.1379	0.62	991.8907
2016-03-11	-2.735	-4.95175	-6.07	60.96375	-0.3828	6.940458	16.25	129.1177	1.1	997.3225
2016-03-12	-3.839	-5.50775	-6.751	55.02375	0.0247	4.046542	8.04	127.5376	0.98	995.8015
2016-03-13	-5.011	-6.01696	-7.102	78.46583	0.0383	5.675792	12.82	75.35854	0.5	993.7184
2016-03-14	-4.13	-6.54654	-7.894	78.92417	0.316	4.011708	11.39	140.3425	0.95	995.8181
2016-03-15	-4.699	-6.99217	-9.04	76.45958	0.004	4.588	10.74	95.92536	0.63	1003.052
2016-03-16	-4.865	-5.90446	-7.307	74.1625	0.4571	4.48	10.11	102.4027	0.6	1015.015
2016-03-17	-4.491	-7.00463	-9.07	63.35208	0.1561	5.473167	10.37	132.325	0.91	1019.664
2016-03-18	-5.798	-7.04958	-8.38	81.04833	0.2435	4.683292	7.918	88.7575	0.53	1010.261
2016-03-19	-3.27	-4.67438	-6.99	81.49917	0.2441	5.074833	14.72	81.14624	0.51	1007.953
2016-03-20	-2.913	-4.411	-6.119	81.10792	-0.9841	6.167042	15.01	160.9893	0.92	1009.628

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Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-03-21	-5.746	-7.58954	-8.77	82.33375	0.2093	5.163958	10.54	144.3496	0.68	1006.364
2016-03-22	-6.799	-7.84496	-9.25	72.40458	-0.002	2.365708	4.92	106.476	0.61	1007.607
2016-03-23	-7.248	-8.91179	-9.93	78.67708	0.1437	3.139625	8.6	135.2085	0.65	1005.257
2016-03-24	-5.342	-7.40546	-10.1	74.69667	-0.1638	2.644583	7.35	178.2324	0.96	1004.651
2016-03-25	-1.643	-3.70488	-6.637	67.85458	-0.4912	4.268625	10.15	155.2613	1.1	1007.371
2016-03-26	-0.139	-2.31821	-4.452	68.3625	-0.545	5.941875	16.15	151.5225	1.26	1002.511
2016-03-27	-1.782	-2.46025	-3.469	68.01583	2.7377	6.744417	16.7	144.1095	1.21	1003.828
2016-03-28	-0.565	-2.14613	-4.128	71.49542	-0.369	8.491167	17.78	155.9059	1.17	1010.321
2016-03-29	3.177	1.559208	-0.675	75.4125	-0.7463	8.951292	19.56	151.7247	1.39	1014.07
2016-03-30	4.947	2.335667	0.067	75.39542	0.1816	5.168792	11.41	166.8091	1.58	1019.001
2016-03-31	7.689	5.406042	2.953	47.0525	-0.3428	5.654292	11.19	194.8127	2.74	1016.75
2016-04-01	9.39	6.807458	3.013	43.30833	3.2068	11.84025	24.87	191.1539	3.61	1007.856
2016-04-02	2.409	-0.22004	-2.444	70.79708	0.946	9.841375	21.76	134.4925	1.34	1005.209
2016-04-03	1.658	-1.36142	-3.493	57.61417	0.1803	3.190042	8.58	189.4126	1.71	1010.099
2016-04-04	1.855	-1.39288	-4.246	61.78667	0.0506	3.53525	9.78	158.7994	1.49	1006.132
2016-04-05	-0.79	-2.37617	-4.258	84.60125	0.5581	5.242083	14.13	100.9981	0.71	1000.983
2016-04-06	0.147	-2.36342	-3.913	65.67083	-1.1604	9.273458	17.17	166.7174	1.45	1010.444
2016-04-07	-0.238	-1.93833	-3.694	72.13458	0.0835	7.276333	16.93	95.47062	0.94	1011.036
2016-04-08	2.752	0.355125	-1.472	77.19083	0.6104	6.685458	15.27	143.6935	1.46	1001.625
2016-04-09	4.066	1.036	-1.903	66.1525	-0.1257	4.7415	9.27	185.9145	1.83	1011.145
2016-04-10	4.047	1.621125	-1.204	54.99167	-0.1308	5.408917	12.98	211.8728	2.2	1007.469
2016-04-11	2.296	0.252	-1.765	62.91292	0.3238	6.782333	13.35	212.2725	1.94	1004.62
2016-04-12	1.842	-0.57454	-2.278	67.80083	0.1711	3.819042	8.09	147.9667	1.39	1002.514
2016-04-13	0.472	-1.34079	-3.484	71.68125	-0.1302	6.245167	12.03	166.9965	1.43	1004.951
2016-04-14	1.868	-0.58296	-2.725	55.24375	-0.1189	5.69575	12.82	247.2425	2.31	1005.457
2016-04-15	2.673	-0.73633	-2.954	73.73083	-0.0096	5.248917	11.45	168.668	1.56	1005.942
2016-04-16	1.012	-1.36371	-3.078	65.34625	0.0915	7.644583	16.42	233.5415	1.96	1011.398
2016-04-17	0.699	-0.89471	-3.434	73.17042	1.0464	6.7385	12.96	170.3984	1.38	1013.746
2016-04-18	-1.028	-1.95196	-3.802	89.66917	5.4431	6.362292	18.42	47.14983	0.36	1004.531
2016-04-19	0.369	-2.15738	-5.094	66.96875	0.4469	8.149667	16.99	195.8985	1.62	1014.423
2016-04-20	1.935	-0.91683	-3.047	55.65708	0.0791	4.397583	8.27	181.7553	1.81	1015.91
2016-04-21	-0.314	-2.13833	-4.728	68.12917	0.0139	8.089	14.09	236.7986	1.71	1013.821
2016-04-22	0.027	-2.6085	-5.527	75.62083	-0.1645	6.823333	16.62	94.30467	0.92	1009.642
2016-04-23	6.346	2.341208	-2.789	58.89542	0.0674	5.123875	13.01	231.7253	2.55	1008.492
2016-04-24	7.087	4.631	3.065	58.125	0.3497	2.509167	8.8	158.6479	1.88	1009.389
2016-04-25	3.264	1.389542	-1.281	69.96167	-0.4859	4.348792	11.54	134.3578	1.38	1010.301
2016-04-26	4.951	1.335667	-2.49	50.82917	-0.0403	4.2275	10.29	277.6733	2.85	1009.741
2016-04-27	3.554	1.069125	-1.63	68.03375	0.0486	5.078375	12.33	232.2692	2	1010.459
2016-04-28	2.466	-0.12133	-3.19	62.24458	-0.1805	4.909083	11.74	237.8808	2.18	1009.524
2016-04-29	1.178	-0.19054	-1.122	76.37083	1.0415	5.277292	13.68	110.6247	1.04	1010.201
2016-04-30	1.805	-0.36921	-3.379	57.99625	0.7731	8.568125	17.97	226.0237	2.26	1011.846
2016-05-01	5.638	2.371542	0.364	67.95292	-0.7649	8.187208	18.09	217.5957	2.28	1011.059
2016-05-02	10.75	6.262667	2.666	70.4825	0.248	7.041125	18.09	219.8981	2.78	1009.352
2016-05-03	3.885	2.510417	0.624	69.44792	0.0027	4.141958	11.62	142.8912	1.58	1009.11
2016-05-04	2.364	-0.29058	-2.901	54.50875	0.8037	7.663542	14.25	274.2244	2.68	1008.888
2016-05-05	3.014	-0.14267	-3.052	59.58417	-1.0293	6.165458	12.88	264.9846	2.49	1013.134
2016-05-06	2.742	1.054583	-0.704	76.87958	3.5671	9.582542	21.09	155.4411	1.41	1007.121
2016-05-07	3.638	0.499792	-1.722	60.05792	0.2693	6.78525	18.93	228.7094	2.41	1003.546
2016-05-08	4.682	0.897417	-1.432	80.24833	1.2601	7.757125	14.8	187.0455	1.66	1011.949
2016-05-09	7.166	4.253958	0.146	56.05333	-0.0224	4.370458	11.54	176.9598	2.41	1017.763
2016-05-10	8.14	4.88775	1.72	55.90292	0.1119	2.896417	13.9	194.3563	2.63	1022.166
2016-05-11	8.81	5.210375	1.338	46.145	-0.0022	2.756667	8.7	237.3581	2.95	1028.366

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Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-05-12	12.45	8.651583	4.303	33.87333	0.6991	2.682375	8.06	308.3001	4.2	1028.099
2016-05-13	14.93	11.07029	7.857	29.815	0.5631	2.798208	10.19	328.838	4.85	1026.173
2016-05-14	15.05	11.67083	8.05	30.84292	-0.9277	5.792125	13.92	327.7326	5.59	1020.368
2016-05-15	15.59	12.62792	8.56	26.3	-0.111	4.310125	9.74	286.9127	5.17	1011.967
2016-05-16	12.32	8.250125	3.888	45.62208	-0.288	7.319917	14.27	279.4721	4.37	1009.66
2016-05-17	8.06	4.17825	1.097	62.93833	2.5654	5.996667	14.7	218.8492	2.74	1009.212
2016-05-18	5.06	3.154292	1.508	82.25417	6.1162	2.293083	6.742	148.2	1.103	1012.4
2016-05-19	7.173	4.05075	1.668	81.595	5.7084	1.768167	9.11	157.7875	1.112	1020.599
2016-05-20	12.24	8.727667	3.852	50.73042	0.2387	4.764333	9.66	307.3799	4.189	1018.762
2016-05-21	16.84	12.58404	7.322	33.52	-0.2452	5.427958	10.92	342.1185	5.673	1010.477
2016-05-22	17.48	13.74008	6.868	36.72625	0.0863	6.110833	11.17	302.8701	5.709	1007.823
2016-05-23	9.99	6.624625	4.588	84.59875	8.4773	3.968792	12.82	133.278	1.027	1008.878
2016-05-24	10.6	8.096625	5.658	67.71125	0.2807	3.418417	9.74	224.5693	2.429	1010.796
2016-05-25	9.84	6.0415	2.14	71.98917	0.5113	5.26825	11.23	260.3135	2.867	1012.532
2016-05-26	4.108	1.341833	-0.807	87.41042	4.9383	6.43125	14.68	182.2792	1.247	1013.414
2016-05-27	3.734	0.922792	-1.705	86.55208	2.4854	2.933125	8.45	158.9409	0.973	1016.46
2016-05-28	3.826	2.000667	-0.209	73.27083	0.0652	2.746792	6.958	133.3528	0.917	1016.759
2016-05-29	3.082	0.609583	-1.472	83.84292	1.5299	3.896292	8.94	135.074	0.833	1016.206
2016-05-30	5.649	1.621125	-1.211	82.98167	2.0849	2.033125	8.49	200.9535	1.508	1019.46
2016-05-31	8.85	5.187292	1.292	63.83833	-0.0666	3.595917	8.74	252.9337	2.718	1014.266
2016-06-01	10.12	7.204083	3.876	57.61958	0.3289	5.651833	12.41	253.6427	3.322	1005.647
2016-06-02	11.58	7.239375	3.204	64.38458	-0.2187	3.851083	11.86	292.4044	3.429	1004.639
2016-06-03	10.2	6.49675	2.914	58.45583	-0.2138	5.548625	12.7	296.9373	3.591	1008.523
2016-06-04	9.3	6.04925	2.893	60.74917	-0.1619	9.512583	16.9	335.7261	3.872	1016.341
2016-06-05	8.7	5.828833	3.677	60.3825	0.4528	6.8955	15.27	187.3917	2.404	1013.87
2016-06-06	8.86	5.838042	3.577	67.74875	2.5761	7.231875	15.92	293.3083	3.014	1007.222
2016-06-07	6.166	3.610792	1.454	73.21292	1.7566	5.727458	11.66	251.5869	2.304	1010.591
2016-06-08	10.71	6.629833	2.457	67.88583	-0.3393	2.764083	10.88	248.5296	2.676	1011.461
2016-06-09	16.68	11.88658	6.978	38.79542	-0.2448	2.9105	10.62	331.5238	4.696	1013.616
2016-06-10	17.57	13.91083	10.1	38.78625	-0.5818	6.88225	12.66	330.8666	6.035	1011.494
2016-06-11	16.13	12.13967	7.314	45.06167	0.0808	5.930167	11.86	232.8518	4.317	1010.41
2016-06-12	12.26	9.056875	6.205	50.42417	0.1348	3.877292	9.29	236.0368	3.197	1008.568
2016-06-13	10.01	6.891583	4.9	73.4325	1.1499	3.935042	8.49	177.9827	1.857	1007.793
2016-06-14	14.1	8.454375	4.603	72.95292	3.5474	3.162833	16.46	242.2258	2.875	1009.863
2016-06-15	13.18	9.184458	4.529	58.14708	0.2708	4.050417	15.7	252.7272	3.392	1014.062
2016-06-16	13.76	10.90158	7.729	48.75417	-0.328	3.796208	11.39	254.4272	3.644	1013.776
2016-06-17	15.77	12.41667	8.2	39.63042	0.1189	7.597375	16.07	308.3312	5.544	1011.299
2016-06-18	18.04	13.66958	9.57	47.09583	1.452	5.980417	14.13	277.6569	4.824	1014.853
2016-06-19	19.42	16.32125	12.15	36.10042	-0.5959	5.631875	13.68	375.1611	6.922	1018.239
2016-06-20	14.61	11.11042	7.35	39.54292	0.2141	6.69225	15.48	323.1804	5.356	1016.614
2016-06-21	11.5	8.506875	5.864	67.19792	0.0652	2.270375	6.39	157.8851	1.597	1015.064
2016-06-22	14.13	10.937	7.165	60.41625	-0.0276	3.1905	8.88	193.5406	2.538	1016.642
2016-06-23	14.46	11.0855	7.772	58.92708	0.5143	3.188708	11.31	237.8777	3.084	1013.294
2016-06-24	11.83	9.265125	6.436	78.22417	0.2279	2.439667	9.64	166.6817	1.542	1011.415
2016-06-25	14.3	10.63875	8.51	65.33833	1.1095	4.099375	10.33	213.148	2.709	1014.746
2016-06-26	13.19	10.46833	8.03	55.56292	-0.196	6.434167	13.31	286.1536	4.144	1019.497
2016-06-27	15.4	11.31088	6.507	49.10583	-0.1607	4.560042	11.19	297.4754	4.335	1022.053
2016-06-28	18.86	14.7225	9.86	42.5875	-0.6555	4.526958	14.74	327.0943	5.555	1022.156
2016-06-29	16.09	12.42458	9.34	64.53875	4.6171	3.108708	8.53	166.1083	2.015	1019.807
2016-06-30	11.72	10.2425	8.4	75.38333	1.0857	3.623792	10.23	139.6207	1.368	1014.95
2016-07-01	12.03	9.792458	7.118	69.58167	0.2234	4.577833	12.66	223.8693	2.698	1009.888
2016-07-02	12.72	9.086542	5.895	62.45542	-0.0306	4.011208	9.64	241.5276	3.036	1008.376

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Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-07-03	14.59	10.98879	7.004	54.82917	-0.0963	3.43375	7.507	210.3251	2.892	1010.561
2016-07-04	17.59	13.22604	7.409	49.90542	-0.0785	4.116833	8.86	295.6085	4.51	1013.811
2016-07-05	15.17	12.0475	8.95	65.59625	14.4086	2.46575	8.57	155.1164	1.831	1014.435
2016-07-06	15.9	12.15375	8.57	69.90875	4.6593	2.392542	9.23	201.7729	2.35	1012.146
2016-07-07	14.11	11.67867	7.958	62.43917	0.2247	3.03925	10.11	223.0306	2.857	1011.797
2016-07-08	15.01	11.88792	8.79	70.21292	0.1215	2.234875	7.703	179.5276	2.03	1013.973
2016-07-09	17.26	13.8975	9.89	54.03458	-0.0948	3.531375	12.23	252.7425	3.815	1013.429
2016-07-10	16.16	12.0875	9.19	67.18708	5.534	3.878	14.07	230.7691	3.02	1011.901
2016-07-11	17.13	13.5225	9.95	59.20792	4.207	2.198833	12.33	264.7022	3.505	1014.392
2016-07-12	15.96	12.60167	10.3	71.85958	3.526	4.215333	10.94	236.1933	2.943	1019.11
2016-07-13	16.54	13.12042	9.86	65.76167	1.978	2.346583	10.43	198.6073	2.488	1023.997
2016-07-14	13.73	11.3	9.35	84.44333	16.379	2.421958	8.15	118.8655	0.925	1025.101
2016-07-15	17.54	13.58125	10.64	72.21542	0.114	2.417583	7.017	198.4937	2.435	1023.072
2016-07-16	19.89	15.11583	11.57	60.88458	0.78	3.094792	11.54	259.7727	3.865	1021.692
2016-07-17	17.41	14.27625	12.03	66.89125	-0.14	4.399708	13.31	256.6092	3.668	1019.599
2016-07-18	14.32	11.71458	8.74	71.80875	0.131	5.33875	13.05	134.4114	1.958	1016.069
2016-07-19	12.99	9.544458	7.031	75.74708	1.579	7.579	16.54	193.8425	2.568	1012.367
2016-07-20	11.19	7.460417	2.577	73.60875	7.77	6.790417	18.93	169.1544	2.083	1012.048
2016-07-21	9.84	5.957375	1.522	80.92167	5.686	4.290375	9.55	162.7729	1.505	1012.696
2016-07-22	10.12	7.482958	5.249	86.68458	13.612	4.682625	13.05	126.4871	1.087	1008.516
2016-07-23	8.76	6.79125	4.7	83.14708	4.929	5.968042	14.52	92.04637	0.807	1006.142
2016-07-24	9.7	7.508375	5.195	75.5625	-0.577	6.852458	15.11	179.8886	1.987	1008.71
2016-07-25	10.23	8.326167	7.071	71.84292	-0.553	8.172833	15.48	236.8155	2.762	1013.6
2016-07-26	10.13	8.354583	6.476	71.46292	0.227	6.073125	10.64	207.9332	2.438	1016.594
2016-07-27	14.34	10.11213	6.975	69.90083	-0.083	6.013667	12.8	198.5298	2.688	1019.396
2016-07-28	12.8	9.709958	7.214	74.53125	3.725	5.805542	14.95	150.0069	1.855	1017.162
2016-07-29	7.752	6.514542	5.571	83.87583	6.039	6.634792	12.5	104.6256	0.918	1014.288
2016-07-30	12.72	9.8865	7.006	82.58417	1.002	5.280833	11.25	157.8008	1.503	1015.637
2016-07-31	17.66	13.65458	9.24	58.79625	-0.182	3.502375	9.41	232.6232	3.492	1014.746
2016-08-01	15.35	12.00208	8.01	54.95208	-0.031	5.06825	15.6	280.697	3.908	1017.559
2016-08-02	16.62	14.18917	11.11	45.62417	-0.049	1.954917	8.98	184.1687	2.517	1017.534
2016-08-03	15.85	13.10292	9.37	59.48542	5.998	2.39325	10.29	141.8243	1.726	1017.648
2016-08-04	16.39	12.63292	9.18	67.32875	-0.139	2.739542	8.57	196.5987	2.498	1020.781
2016-08-05	18.93	15.09667	10.99	57.30583	-0.108	3.743875	9.9	255.4579	4.011	1019.349
2016-08-06	15.54	12.6175	10.08	79.98125	0.383	2.865583	9.43	108.6244	1.088	1018.13
2016-08-07	18.45	14.42417	11.67	69.40417	-0.128	3.314083	8.58	155.9872	2.098	1013.597
2016-08-08	14.57	12.26833	9.03	63.10083	0.181	4.591958	10.76	130.6588	2.115	1010.374
2016-08-09	13.24	9.824958	7.072	74.70083	0.096	4.866875	11.47	166.0511	2.006	1010.685
2016-08-10	11.21	8.348458	5.518	72.07125	2.753	5.349125	12.21	154.6894	1.912	1012.796
2016-08-11	12.83	9.5535	6.583	73.07958	0.331	4.350625	10.23	172.8539	1.969	1017.192
2016-08-12	14.6	10.93792	8.44	67.61667	-0.422	6.456083	13.56	181.296	2.574	1018.431
2016-08-13	14.09	10.93321	7.578	63.53875	0.112	5.106667	10.58	207.34	3.023	1014.367
2016-08-14	12.35	10.24	8.5	65.53708	0.802	7.009042	17.29	156.0862	2.442	1011.797
2016-08-15	12.45	9.633375	7.867	59.17917	0.321	7.252083	15.95	179.2762	2.813	1012.72
2016-08-16	11.81	7.643917	5.812	69.5325	1.066	6.701208	12.27	182.2084	2.32	1017.662
2016-08-17	11.44	8.601708	6.27	69.75	0.038	4.852458	11.74	145.5577	1.775	1024.694
2016-08-18	12.08	9.190292	7.377	68.28958	1.121	4.840417	13.6	115.6174	1.538	1022.505
2016-08-19	7.441	6.217917	5.131	92.32083	9.088	4.125875	10.66	59.624	0.137	1017.629
2016-08-20	9.32	6.424375	5.009	92.52875	17.184	4.249417	8.29	104.9601	0.58	1013.596
2016-08-21	13.99	9.606917	5.781	67.615	-0.558	4.091333	14.11	211.4858	2.701	1012.5
2016-08-22	13.53	9.942333	6.118	61.60292	0.063	5.469042	13.52	210.6066	3.073	1013.757
2016-08-23	12.7	9.508583	7.117	67.16208	2.14	6.650917	13.39	173.7295	2.533	1021.114

APPENDIX B
KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-08-24	15.74	10.923	6.664	64.40333	-0.105	4.971625	8.53	204.9282	2.934	1028.215
2016-08-25	15.45	11.63125	9.4	72.76542	1.449	4.406125	9.76	122.5829	1.652	1022.868
2016-08-26	9.71	7.4315	5.551	93.2375	43.001	5.207292	13.74	35.72594	-0.17	1013.054
2016-08-27	8.64	5.802875	3.666	65.10792	2.622	2.670083	8.21	179.3056	1.825	1018.164
2016-08-28	4.978	3.04	1.523	86.95042	12.094	2.809042	8.53	74.83461	0.289	1017.864
2016-08-29	4.376	2.091375	0.813	80.97958	-2.574	6.944292	14.07	110.5145	0.921	1019.955
2016-08-30	2.854	1.64525	0.326	91.50833	-0.16	5.723542	12.13	63.14731	0.185	1021.974
2016-08-31	5.112	2.547042	0.583	85.77792	1.126	4.921583	9.11	82.07196	0.522	1018.135
2016-09-01	4.81	3.113917	1.277	91.06667	0.132	3.61625	7.468	77.54855	0.309	1014.923
2016-09-02	5.632	3.762875	2.073	90.42917	4.149	1.771958	5.214	85.40009	0.304	1016.021
2016-09-03	6.791	4.566125	2.795	87.74625	5.17	2.396375	6.448	78.47011	0.352	1017.509
2016-09-04	10.45	6.414417	4.036	67.285	0.013	3.021083	7.252	147.803	1.616	1012.986
2016-09-05	8.52	6.169583	3.641	62.21042	-0.055	4.948083	10.07	147.481	1.887	1008.011
2016-09-06	8.35	5.900083	3.891	72.28542	0.845	4.080292	10.96	135.4378	1.415	1005.696
2016-09-07	8.31	4.95575	1.866	77.03167	*-2.323*	6.006417	12.62	126.8718	1.381	1006.488
2016-09-08	6.671	2.7245	0.433	81.48542	n/a	3.861875	12.29	100.0123	0.756	1013.712
2016-09-09	3.485	1.826417	0.131	89.3525	*0.1618*	4.657792	12.62	41.31384	0.037	1005.527
2016-09-10	5.49	1.784208	0.081	84.06958	8.2109	3.828375	10.37	77.43274	0.438	1012.022
2016-09-11	7.538	3.659667	0.114	57.29625	-0.8692	4.985083	9.78	164.2038	2.015	1021.774
2016-09-12	9.89	7.598167	5.227	62.93375	-20.0958	9.675458	22.62	123.5833	2.007	1013.182
2016-09-13	9.4	6.694792	0.157	74.79167	15.7923	8.861417	22.32	139.6117	1.761	1006.039
2016-09-14	6.806	3.974083	0.868	76.38917	-0.0122	4.894625	12	110.9157	1.084	1009.754
2016-09-15	8.36	5.307667	2.601	82.60208	1.4117	4.785	13.52	93.89687	0.808	1007.357
2016-09-16	6.817	5.196458	3.941	72.61625	0.9415	7.076542	17.4	88.03254	1.1	1001.55
2016-09-17	5.87	3.801333	2.185	67.10375	1.7834	2.980167	8.08	72.40593	0.624	1000.345
2016-09-18	6.662	3.443167	0.922	78.45417	4.0519	3.403083	9.07	94.50885	0.754	1007.222
2016-09-19	4.555	1.710167	-0.993	82.59958	-2.9065	5.1695	11.41	114.3812	0.904	1016.229
2016-09-20	7.499	3.590667	-1.596	60.50042	1.7762	3.710333	11.05	133.936	1.568	1018.258
2016-09-21	9.28	6.163167	4.352	43.82042	-0.8651	5.711583	16.37	137.3934	2.416	1012.937
2016-09-22	10.68	7.271583	3.912	36.92958	-1.1929	9.088542	17.54	137.2129	3.632	1002.431
2016-09-23	4.667	3.159	1.667	70.47708	3.4477	5.423625	15.52	90.34752	1.047	1001.144
2016-09-24	5.066	2.0825	-0.595	62.74292	-5.1752	5.58475	11.84	126.2553	1.4	1011.045
2016-09-25	4.153	1.739917	0.073	70.48583	-3.1072	4.42175	12.6	125.0755	1.117	1011.124
2016-09-26	1.734	-0.02063	-1.89	79.275	7.4424	3.27625	10.43	68.45646	0.314	1005.455
2016-09-27	1.624	-1.11021	-2.56	76.51917	1.4423	6.523625	12.37	92.84675	0.805	1013.305
2016-09-28	-0.425	-2.22163	-4.16	77.265	-4.65	3.787167	9.53	74.50091	0.409	1019.512
2016-09-29	-0.808	-2.92425	-4.881	73.6925	-1.2611	6.613	13.05	70.5197	0.611	1021.751
2016-09-30	0.564	-3.50921	-6.27	68.77542	3.0133	2.403917	6.958	121.0778	0.757	1025.483
2016-10-01	0.503	-2.87513	-5.065	57.61917	-0.5487	3.681833	9.37	120.9289	1.052	1017.287
2016-10-02	-2.309	-3.61533	-5.411	73.77958	6.9631	3.383833	11.66	57.77121	0.255	1007.127
2016-10-03	-1.736	-3.16542	-4.272	71.305	-9.1756	1.228708	4.39	53.39361	0.048	1009.524
2016-10-04	-3.104	-3.90483	-5.16	68.99792	0.2873	3.694875	8.19	51.58258	0.339	1013.947
2016-10-05	-3.312	-4.41583	-5.381	82.86542	-3.1681	1.0445	4.743	35.60648	-0.177	1016.092
2016-10-06	-2.819	-4.101	-5.02	69.87833	11.776	0.737625	3.508	43.53401	-0.114	1020.006
2016-10-07	-1.508	-3.51746	-5.189	69.6275	-7.8103	1.318792	5.508	67.21427	0.202	1017.147
2016-10-08	-0.995	-4.30025	-7.362	66.1825	-1.8533	2.261667	7.507	97.6316	0.62	1015.986
2016-10-09	0.124	-2.75429	-4.877	50.52	2.4344	2.819625	7.624	95.49425	0.91	1015.876
2016-10-10	0.756	-1.75108	-4.657	42.68375	-4.1863	3.514583	7.84	85.92045	1.024	1018.035
2016-10-11	4.417	1.087333	-0.73	37.06333	-7.5991	0.724375	3.802	88.47504	0.476	1015.352
2016-10-12	1.184	-0.86696	-5.374	51.06292	0.0085	2.801583	8.74	87.37184	0.71	1009.748
2016-10-13	-5.748	-9.13046	-10	86.61625	0.3462	5.551583	9.74	26.42328	0.029	1002.844
2016-10-14	-9.85	-10.8558	-11.98	76.1275	0.1763	8.077125	15.52	57.13606	0.322	996.4643

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-10-15	-11.44	-12.7696	-13.58	78.43917	-0.3084	4.606083	13.74	46.93206	0.17	993.3186
2016-10-16	-8.84	-11.1588	-13.62	82.88542	-3.1749	4.455292	9.78	50.73488	0.156	992.2867
2016-10-17	-3.418	-7.66554	-10.86	81.44417	0.7791	5.322708	14.39	82.78808	0.403	997.1155
2016-10-18	-0.44	-1.68613	-3.81	78.79333	-0.3351	6.316083	16.5	48.22321	0.357	1004.183
2016-10-19	-0.874	-2.42058	-4.738	81.69833	1.6082	4.550167	10.53	46.16673	0.255	1005.908
2016-10-20	-0.839	-2.401	-4.202	74.28	-7.1719	2.28175	6.39	35.10672	0.06	1002.109
2016-10-21	-0.558	-2.76104	-4.393	72.59625	-5.671	3.941708	8.13	45.95481	0.304	1001.744
2016-10-22	-0.869	-2.85158	-4.089	88.01417	-5.1223	2.745667	7.585	31.06441	-0.071	1006.22
2016-10-23	-4.128	-4.85425	-5.545	93.18333	1.9572	0.381833	5.704	20.54815	-0.393	1013.167
2016-10-24	-5.334	-6.77921	-8.67	91.475	-1.6169	2.012417	6.292	23.9589	-0.184	1013.288
2016-10-25	-6.227	-9.30021	-11.25	88.46667	6.5779	0.961071	2.47	15.18671	-0.326	1014.54
2016-10-26	-3.4	-5.28217	-6.338	83.77375	-10.5167	1.520167	6.723	34.95612	-0.108	1009.087
2016-10-27	-3.33	-5.48417	-7.57	83.83167	1.625	3.037792	10.98	31.61572	-0.003	1006.201
2016-10-28	-1.249	-3.96863	-5.987	80.695	4.2082	2.110292	7.174	50.72645	0.11	1011.268
2016-10-29	-3.699	-5.21013	-9.83	66.1275	1.1527	1.045375	5.155	47.99643	0.069	1010.022
2016-10-30	-3.274	-6.73708	-9.15	67.64417	0.7366	1.374875	5.37	49.68722	0.129	1005.391
2016-10-31	-7.118	-9.08946	-11.52	80.19208	-3.3544	3.2455	9.17	45.35453	0.148	1000.25
2016-11-01	-8.66	-11.3533	-13.84	81.33292	3.5348	0.9645	4.841	42.36516	-0.036	999.2002
2016-11-02	-2.392	-4.89808	-8.58	78.76083	-0.2291	3.245875	14.21	45.67056	0.16	999.7634
2016-11-03	-0.318	-3.16367	-6.081	82.51375	1.8208	7.655583	17.84	21.81665	0.211	994.0955
2016-11-04	0.156	-1.62733	-2.903	76.73792	-1.8654	9.068042	19.93	27.93686	0.436	994.5648
2016-11-05	0.231	-1.46346	-4.842	73.60667	-3.9876	9.833583	20.33	23.73391	0.465	989.7873
2016-11-06	-3.267	-4.29629	-5.514	63.73958	-4.8106	4.013583	14.33	27.42139	0.25	998.827
2016-11-07	-3.45	-5.13875	-7.098	82.36792	6.0936	7.256417	19.85	14.97929	0.142	999.1264
2016-11-08	-0.673	-1.93654	-4.429	76.77167	3.0453	9.048292	19.5	17.06538	0.395	996.1457
2016-11-09	0.258	-0.67338	-1.92	71.9	0.4621	8.523667	17.78	34.10039	0.566	1005.833
2016-11-10	0.249	-1.14554	-2.47	81.24792	-2.609	11.08104	20.31	12.92881	0.305	1003.067
2016-11-11	-0.549	-1.00058	-1.588	68.61292	-3.4706	12.88167	25.11	18.70865	0.719	995.8311
2016-11-12	-1.498	-2.77592	-4.245	72.13042	0.9593	8.095	15.56	22.36926	0.462	999.1267
2016-11-13	-1.411	-3.6365	-5.44	79.29875	0.8531	6.078667	16.5	15.44601	0.144	995.7802
2016-11-14	-1.456	-4.30163	-5.746	68.77167	-1.5246	6.44075	19.07	19.56784	0.267	998.1785
2016-11-15	-6.008	-7.78792	-9.68	76.04625	0.7656	4.102417	9.86	16.91667	0.046	1002.665
2016-11-16	-9.22	-10.3375	-11.26	88.8625	-9.4433	2.490083	5.351	10.51993	-0.147	1011.088
2016-11-17	-11.43	-12.2588	-13.76	86.46667	-2.4518	*0.605889*	*1.372*	6.009547	*-0.376*	1016.525
2016-11-18	-14.24	-15.1617	-16.28	83.15417	-0.0977	*0.706*	*2.097*	9.174755	*-0.265*	1015.536
2016-11-19	-14.26	-15.3413	-16.28	81.03417	-3.2979	2.415208	6.762	8.20968	-0.079	1006.058
2016-11-20	-15.44	-16.0563	-17.15	80.77875	-0.4483	*0.229882*	*2.215*	8.013735	*-0.263*	1000.741
2016-11-21	-15.03	-16.6763	-17.82	69.61833	1.0807	0.312458	2.097	30.32935	-0.097	1002.233
2016-11-22	-12.7	-13.7546	-15.13	75.55208	2.6467	2.3805	8.33	10.19984	-0.042	1000.219
2016-11-23	-7.362	-9.36646	-12.38	81.66125	-4.0031	1.480125	7.33	15.55444	-0.134	997.8092
2016-11-24	-8.14	-8.75042	-9.82	81.57833	-2.4547	3.715208	9.41	11.49655	-0.031	999.4603
2016-11-25	-8	-9.96042	-11.41	76.88167	-6.5093	3.985583	10.33	10.6332	0.049	998.0802
2016-11-26	-7.591	-8.62604	-10.58	78.82875	-2.3224	5.350458	16.39	16.11281	0.065	996.7961
2016-11-27	-7.051	-9.16229	-12.19	74.64708	3.9841	4.9245	16.95	14.71817	-0.012	988.5498
2016-11-28	-7.656	-9.23192	-10.69	82.50375	7.2872	3.79325	13.17	8.27662	-0.065	996.5791
2016-11-29	-2.749	-8.08363	-11.39	85.22042	-4.1169	8.445625	21.44	4.573959	0.051	992.9079
2016-11-30	-2.62	-5.88463	-9.91	73.73542	0.543	10.21075	20.99	11.50426	0.313	994.5966
2016-12-01	-7.324	-9.07729	-11.7	73.97167	-0.9888	7.988333	19.93	10.78891	0.169	1000.233
2016-12-02	-6.081	-8.42638	-9.88	86.74917	5.8958	4.890792	14.35	7.739695	-0.035	987.8057
2016-12-03	-4.046	-8.72696	-16.26	86.84417	-5.2671	3.251292	10.02	4.229163	-0.16	994.0818
2016-12-04	-16.98	-20.2646	-22.03	78.60125	2.3526	3.643125	8.49	4.462927	-0.025	1009.77
2016-12-05	-20.42	-21.8729	-24.17	77.23208	1.1809	2.123042	9.94	6.681167	-0.067	1019.119

APPENDIX B

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Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2016-12-06	-22.31	-24.1733	-25.6	75.73125	1.398	3.470375	11.62	11.39839	0.005	1017.632
2016-12-07	-22.82	-23.9233	-24.7	75.87167	0.4953	1.276875	6.39	4.920793	-0.067	1020.066
2016-12-08	-22.95	-23.5333	-24.11	76.12542	0.1988	0.8075	4.822	4.198304	-0.108	1018.257
2016-12-09	-24.13	-25.1742	-26.13	75.09875	-0.278	1.387292	5.331	3.705798	-0.076	1014.295
2016-12-10	-23.83	-25.3	-26.38	75.00167	0.5507	4.356167	6.86	5.983252	0.023	1012.64
2016-12-11	-16.56	-19.8942	-23.32	76.64875	1.9874	6.805625	12.54	5.883658	0.063	1016.356
2016-12-12	-11.77	-13.9558	-16.39	59.91792	1.0558	7.485708	12.78	4.973497	0.252	1017.906
2016-12-13	-11.37	-13.5796	-15.78	48.91667	0.4984	6.353375	12.07	5.007167	0.302	1016.442
2016-12-14	-16	-18.7413	-20.14	70.06542	0.0843	4.703208	11.68	3.710943	0.058	1016.756
2016-12-15	-15.32	-17.4771	-19.94	47.49292	4.621	5.17175	9	3.872215	0.259	1015.907
2016-12-16	-10.06	-13.1029	-15.83	52.1075	1.963	2.480708	10.88	5.927173	-0.015	1007.69
2016-12-17	-6.139	-9.24879	-12.25	75.51667	1.9464	5.208917	17.46	5.400529	0.063	999.7175
2016-12-18	-5.996	-8.42879	-10.12	79.74208	-1.936	7.184792	18.03	2.861816	0.074	987.9525
2016-12-19	-5.669	-6.63829	-7.787	68.64042	0.362	12.9575	24.21	6.232447	0.439	984.561
2016-12-20	-5.425	-6.80171	-8.26	69.14333	-2.0756	10.74321	18.93	7.94036	0.377	989.7428
2016-12-21	-7.907	-8.96654	-10.18	79.63083	0.2135	3.849917	14.23	3.641398	-0.064	990.8331
2016-12-22	-8.39	-9.4925	-10.82	75.47708	-11.4326	1.340583	6.056	3.680173	-0.208	999.5031
2016-12-23	-10.03	-11.295	-12.56	83.66542	-0.8811	1.465292	4.586	4.840521	-0.188	1007.93
2016-12-24	-12.71	-14.4029	-16.16	77.98167	1.3072	1.298333	9.13	6.482338	-0.145	1008.637
2016-12-25	-9.49	-10.845	-13.19	54.69375	0.6991	4.737458	14.54	5.513225	0.192	1000.15
2016-12-26	-10.03	-11.5629	-13.2	72.19708	-6.6139	4.197958	13.17	8.499898	0.044	987.9676
2016-12-27	-10.44	-11.4846	-12.18	84.4325	11.2129	1.941708	9.37	6.730616	-0.159	986.5682
2016-12-28	-8.15	-8.735	-9.7	76.48667	3.8643	6.820292	13.17	4.635088	0.137	998.6071
2016-12-29	-8.54	-9.89125	-12.98	77.18292	-1.8541	6.537542	12.39	5.897109	0.101	1003.969
2016-12-30	-7.281	-9.04438	-12.67	80.07375	4.6493	7.04325	15.6	3.601837	0.093	1002.416
2016-12-31	-10.86	-13.0496	-15.28	85.69167	-0.7597	12.25208	21.13	3.537102	0.083	1013.243
2017-01-01	-6.919	-8.45725	-10.53	80.23542	0.3311	10.03246	15.97	7.007908	0.227	1020.269
2017-01-02	-3.14	-5.22858	-6.699	51.95917	6.0784	6.169042	11.09	4.389225	0.504	1024.686
2017-01-03	-1.643	-2.68638	-4.194	33.75833	-1.7989	5.556458	12.39	6.888664	0.829	1025.783
2017-01-04	-3.746	-6.67092	-11.61	51.11417	-6.4148	5.873542	12.74	4.822935	0.491	1020.976
2017-01-05	-11.88	-14.7517	-18.67	83.83625	2.1372	3.041875	7.624	4.509868	-0.077	1013.948
2017-01-06	-18.4	-20.6625	-24.32	77.96667	0.8447	3.196792	6.468	4.872513	-0.016	1015.909
2017-01-07	-22.78	-25.5413	-27.4	72.97125	3.224	3.5225	11.23	12.37315	0.015	1019.765
2017-01-08	-19.37	-23.4133	-25.7	61.44458	2.7251	5.690042	12.62	7.529889	0.09	1015.731
2017-01-09	-14.44	-17.0313	-19.44	78.10542	-0.2471	6.932375	15.99	8.364362	0.079	1009.064
2017-01-10	-7.832	-12.2904	-17.53	80.2125	0.1694	8.607708	15.43	9.109727	0.112	1009.212
2017-01-11	-7.923	-9.79138	-12.5	72.2825	-5.2279	4.143875	11.19	8.368314	0.01	1003.28
2017-01-12	-11.25	-12.6054	-13.8	83.20375	-3.8846	3.203458	10.21	5.49544	-0.093	998.4965
2017-01-13	-4.49	-7.97225	-10.45	79.02875	-1.011	8.432958	16.46	4.910874	0.155	996.2145
2017-01-14	-2.813	-3.40188	-4.455	78.73833	0.6756	13.72625	29.11	7.85807	0.325	991.2942
2017-01-15	-3.519	-4.29367	-5.919	73.53833	-2.7614	10.04158	28.36	9.254784	0.351	993.2644
2017-01-16	-2.224	-2.79621	-4.1	79.59708	2.5768	12.93417	26.36	6.271038	0.3	980.8187
2017-01-17	-3.305	-6.33013	-8.14	67.05417	-5.4792	7.543167	20.74	12.87616	0.308	982.0859
2017-01-18	-5.699	-6.95104	-8.37	81.93542	-1.6538	4.855	15.88	8.291299	-0.057	980.1843
2017-01-19	-5.104	-8.48038	-15.1	84.01917	-0.4951	7.785417	14.92	11.35333	0.066	980.8171
2017-01-20	-17.11	-21.9946	-24.08	65.88083	-0.1084	6.818375	12.84	18.02464	0.118	992.8815
2017-01-21	-16.65	-18.7592	-22.07	52.61042	-1.7528	5.040417	14.09	18.79438	0.157	999.8881
2017-01-22	-13.28	-15.4933	-18.12	75.37917	-1.024	5.867417	16.39	18.02642	0.074	1000.742
2017-01-23	-6.31	-9.31208	-13.74	79.15958	0.7123	5.461042	14.39	16.64055	0.123	1000.41
2017-01-24	-4.503	-6.77046	-9.49	78.48292	-0.8219	8.348792	17.93	17.57421	0.254	999.7012
2017-01-25	-3.226	-4.14142	-4.727	71.34	7.2174	14.64633	27.09	8.6487	0.558	1001.063
2017-01-26	-4.25	-5.08067	-5.845	70.0975	1.5642	12.07467	22.6	16.95126	0.417	1005.145

APPENDIX B

KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-01-27	-3.394	-4.87213	-6.702	69.24792	1.3952	11.48	25.05	15.70864	0.485	1003.315
2017-01-28	-1.641	-4.22667	-6.549	68.16167	0.8512	10.58304	25.83	18.20743	0.479	999.0399
2017-01-29	-5.477	-8.59608	-13.02	64.56833	-0.91	10.10633	19.56	22.43885	0.463	1002.943
2017-01-30	-12.77	-14.8388	-16.13	76.50833	-3.0017	9.738208	19.74	16.70653	0.156	1017.319
2017-01-31	-11.99	-13.7133	-16.31	43.22	1.7271	4.494083	9.09	28.40695	0.367	1021.967
2017-02-01	-12.41	-13.6067	-15.37	65.49583	0.6043	4.793375	8.9	25.03057	0.204	1026.079
2017-02-02	-13.3	-16.28	-18.93	79.67667	-1.278	6.032375	11.07	45.55959	0.129	1023.985
2017-02-03	-15.02	-16.9158	-18.27	80.61208	1.7362	5.707208	11.27	35.83865	0.098	1019.108
2017-02-04	-10.94	-13.495	-14.99	68.15292	-1.9253	5.889	11.49	40.35233	0.304	1015.458
2017-02-05	-13.62	-14.7521	-16.07	77.72083	-1.2021	3.911792	6.958	32.32853	0.089	1011.301
2017-02-06	-16.34	-17.0092	-17.77	78.81208	7.276	2.219792	4.626	68.40928	0.154	1010.36
2017-02-07	-15.03	-16.4517	-17.14	60.66083	10.0914	2.268917	5.37	42.28584	0.104	1008.508
2017-02-08	-14.17	-14.9554	-16.23	45.8975	3.6733	1.597292	5.41	39.58819	0.116	1000.958
2017-02-09	-13.94	-15.4492	-17.07	56.77583	2.7359	2.333292	13.05	37.58347	0.073	989.2253
2017-02-10	-13.08	-16.6708	-18.25	62.03792	0.9463	2.971125	14.21	31.96165	0.045	984.3543
2017-02-11	-4.271	-8.98813	-13.13	74.59875	-2.3403	13.30083	34.61	26.93318	0.325	985.7095
2017-02-12	-3.627	-5.49863	-9.28	82.2375	3.0232	11.36575	28.99	26.54111	0.273	990.4319
2017-02-13	3.198	-1.31604	-5.872	74.01417	-0.9165	11.585	31.5	33.23524	0.61	1000.343
2017-02-14	1.856	-0.14388	-1.129	65.99	1.6095	9.607167	21.64	25.33866	0.67	993.788
2017-02-15	-0.194	-1.57954	-2.629	81.09625	2.0873	5.153583	14.88	24.60425	0.119	985.732
2017-02-16	-2.496	-6.18067	-8.66	76.43292	-2.0668	4.281	12.39	49.50913	0.267	987.3705
2017-02-17	-6.451	-9.09688	-9.94	71.58458	-4.2699	1.72225	5.9	48.78317	0.093	996.1749
2017-02-18	-9.2	-10.585	-11.85	63.57333	4.1533	1.313292	4.292	43.44645	0.051	999.1531
2017-02-19	-10.12	-11.6896	-13.32	66.88375	-1.5771	2.064542	7.37	47.3996	0.107	998.3566
2017-02-20	-10.65	-11.775	-13.41	74.53833	7.2324	1.97175	6.017	42.69253	0.049	999.3497
2017-02-21	-11.3	-12.0904	-12.65	69.99	-0.6185	1.677	5.762	39.92718	0.037	1004.194
2017-02-22	-11.51	-13.3267	-14.92	59.34458	0.762637	3.74125	8.94	64.62007	0.319	1011.67
2017-02-23	-12.34	-14.8604	-16.44	72.76375	0.559707	6.67525	13.13	54.61102	0.234	1015.687
2017-02-24	-5.407	-10.1236	-16.46	74.5925	2.193076	4.351583	9.37	58.58335	0.272	1013.486
2017-02-25	-8.45	-10.9363	-12.22	87.46667	4.212567	7.747917	14.05	52.34238	0.151	1011.55
2017-02-26	-9.98	-11.8763	-13.9	79.51167	-0.79728	9.055	18.11	48.59842	0.246	1006.326
2017-02-27	-11.79	-13.1713	-15.58	79.48958	-0.28994	8.591292	15.62	53.87003	0.225	999.2145
2017-02-28	-13.38	-15.9296	-18.48	74.4	1.804144	2.34625	6.468	74.36324	0.195	997.3937
2017-03-01	-19.29	-22.1954	-23.84	75.61667	2.983598	4.856667	10.27	98.28418	0.18	1006.362
2017-03-02	-20.12	-22.6788	-24.05	76.51042	7.592642	1.761875	11.45	42.09456	0.02	997.413
2017-03-03	-21.98	-22.7204	-23.65	76.44417	-1.50936	4.317667	9.17	66.08813	0.107	1000.223
2017-03-04	-21.36	-23.7967	-25.74	69.39875	-1.47642	3.102458	8.35	109.2788	0.248	1002.881
2017-03-05	-24.61	-25.7175	-26.74	74.53542	-0.39383	3.874833	8.29	77.10214	0.128	998.6741
2017-03-06	-27	-28.8663	-31.33	71.645	0.117606	3.304625	6.135	122.5211	0.161	1005.308
2017-03-07	-24	-26.5438	-29.24	59.95792	2.232319	4.443625	9.66	133.272	0.243	1010.933
2017-03-08	-22.5	-24.7288	-26.26	56.3625	-0.50979	6.750542	11.13	90.06662	0.259	1014.758
2017-03-09	-21.67	-23.77	-26.45	60.7525	-1.40632	4.34525	7.86	118.0686	0.281	1021.676
2017-03-10	-17.31	-20.4283	-22.82	48.9075	-8.90528	0.994875	4.782	119.1215	0.323	1019.19
2017-03-11	-17.66	-19.6408	-21.27	44.75625	3.901902	5.299583	15.52	126.1578	0.465	1014.475
2017-03-12	-18.72	-20.5683	-23.03	71.39292	2.332211	6.502583	16.37	101.4331	0.264	1002.592
2017-03-13	-12.76	-16.0125	-19.05	80.11083	-4.69148	1.451125	6.586	51.72977	0.018	994.1582
2017-03-14	-10.75	-14.9313	-17.9	83.45417	10.08663	1.179708	5.958	41.35252	-0.038	992.2017
2017-03-15	-7.791	-11.1892	-14.43	77.58708	0.398928	2.940708	8.02	62.80683	0.205	995.7655
2017-03-16	-9.16	-11.1433	-14.44	78.05375	-3.48808	5.786625	16.66	103.03	0.401	1002.376
2017-03-17	-13.22	-15.7021	-18.76	79.25042	10.65949	2.1125	8.8	108.4599	0.274	1002.43
2017-03-18	-14.43	-15.8083	-17.1	77.55917	-5.34659	1.89	6.801	104.0754	0.199	996.4606
2017-03-19	-11.61	-15.2475	-18.24	67.13583	3.136187	1.884375	12.39	176.1445	0.646	1006.741

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Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-03-20	-7.466	-8.73838	-10.73	67.8625	0.872552	11.85888	19.7	94.19988	0.684	1009.525
2017-03-21	-5.621	-8.11046	-9.58	72.34667	-5.97712	3.247167	10.47	124.2513	0.659	1005.074
2017-03-22	-8.73	-10.39	-13.41	79.9675	-3.86108	6.102833	14.66	125.5465	0.351	1000.022
2017-03-23	-12.53	-13.6775	-14.86	77.77042	2.4143	2.9225	7.703	94.27158	0.258	1000.053
2017-03-24	-7.07	-10.5766	-13.41	66.56333	-1.4902	2.392708	9.19	145.5227	0.735	1001.262
2017-03-25	-7.438	-9.77267	-11.18	78.84958	-3.0048	6.010833	10.43	156.0624	0.704	997.9427
2017-03-26	-7.914	-10.0223	-12.53	69.5975	0.0191	5.4295	11.05	164.1133	0.825	1002.259
2017-03-27	-5.288	-8.05717	-10.35	78.85	-1.6826	6.870583	13.99	169.1519	0.798	1001.518
2017-03-28	-3.51	-5.05771	-6.855	77.30917	0.795	7.387708	14.33	175.1565	1.082	1002.081
2017-03-29	-2.252	-4.63608	-6.347	78.14708	3.991	4.619208	9.33	162.8748	0.986	1004.012
2017-03-30	-2.677	-4.35833	-6.211	68.97375	4.6289	7.699708	17.37	157.1979	1.119	1006.153
2017-03-31	-1.117	-3.63367	-6.035	78.23083	1.4214	9.838917	20.68	115.1553	0.785	999.7903
2017-04-01	-0.042	-2.00858	-3.391	66.53333	0.0154	8.181458	17.5	192.7862	1.549	1001.237
2017-04-02	-2.508	-4.99638	-7.474	65.45833	-1.5896	7.605458	16.82	184.5254	1.226	1006.979
2017-04-03	-3.621	-6.66988	-10.58	62.825	1.8882	5.61625	13.48	206.5581	1.404	1010.296
2017-04-04	-1.57	-3.62838	-5.647	53.7075	-1.0826	8.632583	17.09	169.5558	1.594	1004.487
2017-04-05	-0.898	-3.17388	-4.951	68.99958	1.9451	7.394458	18.78	94.56882	0.77	994.8861
2017-04-06	-2.59	-3.80229	-4.878	63.40833	-1.2856	9.426375	21.44	209.5288	1.542	997.7461
2017-04-07	-0.183	-3.41725	-6.596	50.58792	-0.2049	5.682583	13.37	217.0393	1.951	997.6271
2017-04-08	-0.822	-2.73575	-4.877	65.32083	0.7617	7.406583	14.13	175.7243	1.344	998.5879
2017-04-09	0.717	-1.57871	-3.07	75.865	-4.5952	2.304583	8.19	160.693	1.11	1006.798
2017-04-10	2.175	-0.70788	-2.45	74.54625	6.3072	2.212042	8.17	152.812	1.071	1012.012
2017-04-11	2.563	0.19125	-2.016	59.39042	-2.3919	2.723167	7.722	229.9791	2.017	1017.732
2017-04-12	0.478	-0.83433	-2.659	51.27667	1.9194	4.238292	9.47	237.0605	2.078	1018.631
2017-04-13	-1.631	-3.48238	-5.395	52.99	-1.7408	8.251583	16.64	230.7723	1.95	1015.343
2017-04-14	-0.974	-4.31104	-7.308	57.68625	-2.051	3.676792	10.62	238.9996	1.738	1013.766
2017-04-15	0.564	-1.69325	-4.005	51.07583	-2.1096	4.161417	9.8	204.8594	1.865	1010.327
2017-04-16	-2.77	-5.33788	-7.987	88.76167	0.4612	2.369708	5.018	149.827	0.601	1011.185
2017-04-17	-8.61	-10.8175	-12.76	78.56375	5.2131	4.124167	9.27	200.1011	0.714	1013.318
2017-04-18	-10.61	-13.1113	-16.42	62.10208	4.9328	4.567542	9.96	250.6689	1.111	1009.043
2017-04-19	-5.524	-8.81746	-12.25	53.03333	-2.7137	2.904708	5.821	260.6026	1.631	1007.884
2017-04-20	-3.304	-5.92925	-8.79	49.31125	0.7907	2.2465	7.154	255.3646	1.766	1014.139
2017-04-21	-1.514	-5.28988	-8.72	45.6125	3.8009	3.294417	8.47	244.528	1.763	1019.763
2017-04-22	-2.973	-4.81567	-6.428	50.49208	1.6563	5.415458	10.05	278.0141	1.975	1016.765
2017-04-23	-1.605	-5.43021	-8.16	55.15917	-0.3284	3.428083	9.49	280.7992	1.99	1007.603
2017-04-24	1.216	-2.63875	-6.29	53.74125	-0.2116	5.302667	12.15	276.9625	2.461	1006.266
2017-04-25	3.808	1.092208	-1.432	59.77208	0.6865	7.175208	13.45	259.9549	2.495	1003.82
2017-04-26	3.924	2.212042	1.302	56.9575	0.8696	4.925708	9.64	178.586	1.92	1001.069
2017-04-27	3.719	1.230917	-0.655	65.67917	0.1657	5.035958	13.72	196.3952	1.688	1005.404
2017-04-28	1.656	-1.03379	-3.051	59.67625	-0.5459	8.079917	14.17	297.5507	2.431	1013.661
2017-04-29	2.749	0.044542	-3.036	51.89958	-7.0952	2.491833	7.624	290.9719	2.612	1011.077
2017-04-30	3.38	1.055375	-1.568	47.67875	0.2909	4.124875	11.9	272.3299	2.719	1010.188
2017-05-01	0.154	-1.52542	-2.92	66.81333	1.3277	7.509667	13.99	255.2801	1.97	1009.72
2017-05-02	2.86	-0.291	-3.795	55.14292	-1.5391	6.999792	14.09	284.8438	2.602	1009.001
2017-05-03	1.026	-0.45033	-3.214	67.28875	4.7079	11.067	21.36	262.9189	2.026	1002.551
2017-05-04	1.141	-2.29908	-5.134	55.6925	-3.2032	7.235375	20.4	277.4553	2.28	1008.417
2017-05-05	2.081	-0.64779	-2.786	55.48333	-0.3642	3.590833	10.27	187.9173	1.765	1007.303
2017-05-06	-0.404	-1.67525	-2.77	95.7375	5.2262	4.648625	10.66	159.7075	0.608	1007.325
2017-05-07	4.72	0.745	-3.161	66.01083	6.0137	5.077083	10.49	318.0217	2.888	1007.823
2017-05-08	2.181	0.19275	-1.989	67.99958	2.4364	5.363292	11.35	187.2158	1.609	1008.692
2017-05-09	4.974	1.394958	-1.799	56.39625	-4.6851	4.865792	12.74	302.2259	2.857	1013.037
2017-05-10	2.833	1.287125	0.214	75.00125	1.0755	3.412083	9.96	158.5439	1.022	1016.392

APPENDIX B

KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-05-11	5.99	2.803542	-0.049	77.16625	2.0431	7.645792	16.09	206.446	1.809	1017.171
2017-05-12	7.106	4.569417	2.433	47.82333	0.4751	8.623833	16.33	299.5662	3.676	1013.302
2017-05-13	3.564	2.076458	0.261	68.66167	0.7459	6.61775	14.17	187.5585	1.737	1009.677
2017-05-14	1.833	-0.08492	-1.758	83.18042	0.4281	5.494292	10.66	197.3495	1.279	1003.984
2017-05-15	5.544	2.267917	-1.881	65.445	0.5359	3.501958	7.546	262.6707	2.436	1008.453
2017-05-16	8.66	5.646625	2.556	44.12167	6.6383	3.627292	11.25	341.292	3.842	1012.704
2017-05-17	9.55	6.035792	2.407	47.84417	-432.097	6.176042	11.13	301.9598	3.914	1011.98
2017-05-18	8.68	5.213042	1.56	43.63417	0	6.258083	12.27	338.3707	4.25	1011.189
2017-05-19	7.691	4.718	2.151	49.69583	0	6.012542	12.98	311.4554	3.659	1012.804
2017-05-20	7.663	3.827917	1.215	60.4125	0.404	6.290042	13.5	247.6528	2.813	1014.301
2017-05-21	7.333	4.899708	2.388	77.28875	1.01	7.725583	20.5	194.5516	1.748	1011.407
2017-05-22	6.615	4.799792	3.064	59.9075	0	11.0735	25.28	321.3755	3.432	1009.246
2017-05-23	7.972	4.8155	1.426	53.37958	0	4.731333	13.94	201.4633	2.452	1007.852
2017-05-24	10.88	6.5815	2.519	45.77167	0.202	6.918625	15.01	287.3319	3.959	1012.367
2017-05-25	10.72	7.628208	4.312	46.20667	0	5.907333	16.99	330.1575	4.324	1009.497
2017-05-26	5.018	3.200292	0.607	50.74792	0	7.674833	21.32	210.9753	2.591	1011.923
2017-05-27	11.17	5.946333	0.204	30.76792	*0.404*	3.696167	9.96	332.5463	4.374	1018.672
2017-05-28	16.31	11.60575	6.244	24.81333	n/a	4.368	12.29	332.3563	5.396	1018.858
2017-05-29	16.8	12.88667	8.76	33.00375	n/a	5.849417	12.62	289.6673	5.487	1014.212
2017-05-30	13.12	10.33517	7.371	40.63417	n/a	4.698458	13.64	276.2536	4.272	1010.722
2017-05-31	13.27	9.168625	5.578	61.39833	n/a	3.2065	8.47	209.3642	2.63	1006.906
2017-06-01	11.64	7.626208	4.611	75.71375	n/a	3.942667	10.07	200.5932	2.177	1004.929
2017-06-02	12.01	7.661292	4.546	70.59667	n/a	3.518667	15.33	279.3799	3.168	1005.876
2017-06-03	8.73	5.694083	3.477	71.90542	n/a	4.129125	10.54	212.3912	2.193	1007.069
2017-06-04	9.89	6.125792	2.321	53.46042	n/a	4.821417	9.82	233.5577	2.973	1009.16
2017-06-05	10.91	7.610208	3.801	42.70333	*0*	5.7735	12.88	323.5682	4.533	1013.151
2017-06-06	13.61	8.675292	2.183	49.11667	0	4.233083	8.8	355.2029	4.708	1015.776
2017-06-07	16.87	12.52471	7.297	43.6225	0	6.035167	12.82	312.9861	5.276	1014.534
2017-06-08	20.31	15.82583	10.62	43.74875	0	8.041958	14.74	300.4007	6.255	1011.773
2017-06-09	18.8	15.09625	10.44	48.8325	0	5.093417	12.35	283.6394	4.775	1010.054
2017-06-10	15.06	11.63213	7.054	77.38375	11.11	4.324167	11.54	93.47057	1.015	1006.139
2017-06-11	6.817	5.572	3.841	92.82917	26.664	2.53725	8.21	58.25944	-0.069	1004.227
2017-06-12	5.785	3.195875	1.447	86.26375	9.898	6.967417	14.25	209.8416	1.525	1004.08
2017-06-13	5.098	2.225708	0.634	77.63458	1.01	4.905583	11.25	224.9595	1.863	1008.792
2017-06-14	6.325	2.399875	-0.645	83.08542	0.202	3.422208	11.45	156.3903	1.132	1010.788
2017-06-15	9.06	4.499042	0.339	72.92333	0.808	5.343458	12.31	273.0437	2.897	1004.552
2017-06-16	8.11	3.812042	0.654	77.05083	1.212	6.157958	13.09	235.6602	2.279	1002.252
2017-06-17	5.29	1.428458	-0.409	89.22458	11.514	4.432083	11.52	108.1532	0.494	1008.027
2017-06-18	12.69	9.57825	4.842	55.33417	0	3.938583	9.39	260.0172	3.347	1014.584
2017-06-19	14	10.84679	7.587	48.32292	0	5.858542	13.6	265.0159	4.359	1010.73
2017-06-20	7.543	5.3205	3.199	87.66917	8.888	3.09075	8.84	100.0558	0.372	1008.06
2017-06-21	11.27	6.311417	2.763	84.57625	3.636	4.314542	10.8	174.7047	1.625	1016.302
2017-06-22	11.13	7.926792	6.078	79.23625	4.242	3.541708	10.56	174.4874	1.726	1023.182
2017-06-23	12.5	9.0545	6.368	74.28417	5.252	2.305208	8.15	199.6852	2.033	1024.215
2017-06-24	14.57	10.92017	7.764	57.00583	0	5.667167	12.86	228.105	3.608	1019.826
2017-06-25	10.93	8.215375	6.54	76.32875	8.686	2.408708	10.21	207.2694	1.96	1013.382
2017-06-26	12.78	9.203125	5.598	67.13833	1.818	6.765042	14.31	295.8615	3.789	1009.691
2017-06-27	13.71	10.37354	6.805	61.36833	1.414	5.280167	12.23	225.0698	3.099	1013.279
2017-06-28	15.39	11.58429	7.083	55.01	0	3.686125	9.6	285.6416	4.041	1015.009
2017-06-29	12.17	9.605542	5.849	64.46375	0	3.753458	9.53	153.1895	1.912	1015.586
2017-06-30	8.97	6.773167	4.632	77.9875	1.01	3.482583	8.96	151.9025	1.333	1014.12
2017-07-01	12.62	9.399583	7.251	75.83958	4.646	3.62775	7.722	133.7389	1.399	1010.408

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-07-02	10.46	7.897167	6.185	77.29292	0.606	3.289458	10.72	166.0951	1.616	1008.493
2017-07-03	6.052	4.614167	3.793	94.45417	38.784	7.22425	13.07	57.63327	0.06	1009.202
2017-07-04	10.25	7.35825	5.5	93.12292	7.676	3.775083	7.958	99.45473	0.459	1013.643
2017-07-05	15.66	11.90917	8.17	58.39958	0	2.765542	8.17	305.2293	4.011	1019.864
2017-07-06	17.66	14.02583	9.71	54.36458	0	3.359833	8.98	302.3371	4.408	1023.089
2017-07-07	21.38	17.78917	12.42	39.34167	0	3.084375	9.62	337.3417	5.684	1020.728
2017-07-08	16.24	11.72333	8.34	71.53167	2.02	4.32275	13.05	138.3065	1.726	1017.047
2017-07-09	13.21	9.461083	7.023	78.96667	2.424	3.570292	9.37	153.2281	1.512	1012.024
2017-07-10	8.35	5.966375	3.812	94.67083	28.078	5.172042	11.9	90.49264	0.345	1007.96
2017-07-11	7.953	4.978583	2.302	79.59917	0.606	3.852	8.96	248.407	2.195	1013.101
2017-07-12	12.85	9.244792	5.134	62.00292	0.202	2.097375	7.762	280.776	3.157	1017.975
2017-07-13	13.24	10.74792	8.85	65.61875	0	2.3145	9.56	215.4701	2.431	1019.191
2017-07-14	15	11.13579	7.593	60.11083	0	3.357667	8.06	265.0444	3.477	1019.231
2017-07-15	10.11	8.258833	6.108	81.97167	*0.202*	2.431542	7.428	92.87525	0.423	1012.677
2017-07-16	13.37	9.627833	6.336	85.81417	n/a	5.420958	11.66	142.2462	1.399	1012.277
2017-07-17	13.78	10.65625	8.58	84.5575	n/a	6.812583	14.48	132.1294	1.364	1015.375
2017-07-18	12.93	9.987083	8.25	89.33958	n/a	3.640333	12.82	111.8024	0.796	1013.515
2017-07-19	12.36	9.4025	7.89	90.95625	n/a	3.361125	8.11	117.7345	0.768	1012.168
2017-07-20	15.43	11.57833	8.62	74.41167	n/a	2.831125	8.82	244.6309	3.007	1012.435
2017-07-21	15.87	12.33842	7.752	61.02375	n/a	5.02025	10.31	298.4957	4.389	1011.346
2017-07-22	14.15	10.17821	6.824	70.28833	n/a	3.813	11.45	204.115	2.475	1012.515
2017-07-23	15.91	12.56396	7.715	58.77333	n/a	6.92525	13.66	255.2377	4.169	1016.706
2017-07-24	18.62	15.05083	11.46	56.07333	n/a	4.916167	11.35	208.4801	3.574	1016.459
2017-07-25	18.87	15.41958	12.01	53.69583	n/a	2.942667	7.291	212.0809	3.26	1014.475
2017-07-26	15.71	11.93667	8.44	66.72708	n/a	3.428125	10.7	189.77	2.487	1011.582
2017-07-27	7.936	6.571	5.768	89.34583	n/a	7.744042	15.82	57.77196	0.377	1010.056
2017-07-28	10.72	7.7445	5.906	85.53542	n/a	4.952167	11.11	179.9914	1.656	1012.694
2017-07-29	12.8	9.440875	6.878	70.80417	n/a	2.884708	8.86	193.4174	2.148	1013.278
2017-07-30	9.97	7.704917	6.084	86.78958	n/a	3.189375	10.8	135.4638	0.967	1017.172
2017-07-31	13.1	9.7425	6.766	80.25625	n/a	2.44225	6.546	189.3238	1.946	1026.31
2017-08-01	15.49	12.1375	8.14	57.56333	n/a	4.600333	9.68	262.0521	3.935	1026.015
2017-08-02	16.92	12.76042	8.65	55.12958	n/a	4.01225	8.68	269.1097	4.081	1023.852
2017-08-03	18.28	14.57292	10.99	53.58083	n/a	3.742	9.6	253.2097	4.062	1023.772
2017-08-04	17.1	14.97833	12	56.26333	n/a	2.027583	9.09	165.9852	2.208	1022.968
2017-08-05	15.69	13.08708	10.43	64.53333	n/a	2.825625	8.25	203.003	2.662	1020.561
2017-08-06	17.87	13.72875	10.3	57.93167	n/a	3.098	7.84	270.4818	3.819	1021.027
2017-08-07	19.37	16.25042	12.85	51.33458	n/a	3.080292	10.53	223.5389	3.597	1021.009
2017-08-08	21.02	16.91792	12.69	44.21292	*0*	3.057333	8.94	250.1466	4.116	1021.272
2017-08-09	22.86	19.21542	16.13	35.5825	0	3.04875	8.25	272.133	4.91	1020.519
2017-08-10	21.21	17.82083	14.83	35.38	0	5.556208	11.52	230.4186	5.349	1016.872
2017-08-11	20.64	16.42	12.34	35.45625	0	4.231833	9.04	236.9343	4.653	1012.246
2017-08-12	18.76	14.85875	11.3	45.02333	0	4.3	9.45	245.2884	4.291	1006.382
2017-08-13	14.01	11.24013	7.253	67.06792	3.03	5.407083	15.35	127.5954	1.913	1003.597
2017-08-14	7.654	5.79275	1.935	69.59625	1.414	5.086833	16.31	166.1264	1.82	1005.731
2017-08-15	8.45	4.90825	0.809	74.08792	5.454	3.44075	8.7	182.3009	1.641	1006.84
2017-08-16	12.15	8.486542	5.437	58.32833	0	3.56875	11.11	224.7978	2.717	1006.253
2017-08-17	9.17	6.566583	3.913	72.70417	0.404	5.56175	14.76	128.9417	1.528	1005.382
2017-08-18	6.176	3.939833	2.547	88.52292	5.858	5.348083	13.15	148.1095	0.948	1005.4
2017-08-19	8.38	5.066083	1.711	66.68542	0	6.50075	13.09	202.2949	2.303	1010.651
2017-08-20	10.48	6.754125	3.392	65.82875	0.404	5.055833	12.66	199.294	2.373	1012.554
2017-08-21	11.06	8.227042	6.147	75.66208	0	4.702083	12.07	127.8494	1.404	1012.955
2017-08-22	12.74	9.621083	7.516	83.70708	2.424	4.745083	11.31	157.5777	1.608	1010.686

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-08-23	8.93	6.942542	4.284	72.95542	2.222	7.694042	18.05	216.5879	2.332	1006.375
2017-08-24	5.862	4.016417	1.842	89.02083	3.838	3.918292	11.72	73.84335	0.304	1006.865
2017-08-25	8.94	5.926917	2.7	73.13667	0	5.097792	11.9	172.6566	1.866	1007.846
2017-08-26	8.19	5.254792	2.843	76.10292	5.252	6.216125	17.46	95.9645	0.944	1008.037
2017-08-27	7.159	3.879792	1.699	68.43708	0.202	7.138583	16.66	180.9462	1.96	1013.651
2017-08-28	8	5.096542	2.357	63.21917	0	5.435917	11.47	202.0725	2.303	1017.284
2017-08-29	14.05	9.477625	4.052	57.0875	0	6.483458	14.76	154.2384	2.63	1012.068
2017-08-30	*14.04*	*11.48615*	*9.92*	*61.29769*	*0.202*	*7.235615*	*13.88*	*115.0695*	*1.188*	*1004.037*
2017-08-31	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-01	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-02	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-03	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-04	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-05	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-06	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-07	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-08	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-09	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-10	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-11	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a
2017-09-12	*5.851*	*3.343889*	*2.483*	*71.13778*	n/a	*4.106556*	*7.585*	*32.79026*	*-0.001*	*1018.354*
2017-09-13	9.64	5.801875	2.361	55.54625	*-1.5585*	3.847	7.017	155.964	1.793	1018.763
2017-09-14	13.4	9.093375	6.04	43.925	-1.6535	2.368167	12.8	146.0172	1.911	1017.239
2017-09-15	6.434	4.988	1.025	52.10292	-0.2252	4.638583	10.11	73.51193	1.27	1013.829
2017-09-16	8.37	4.47025	0.559	57.955	0.6467	3.296167	8.98	147.9727	1.677	1009.11
2017-09-17	9.01	5.5935	2.958	60.29042	-0.8229	4.805875	10.86	103.1464	1.6	1003.032
2017-09-18	7.061	5.106583	3.23	72.22333	-0.8173	4.645083	10.72	67.9893	0.756	1006.207
2017-09-19	8.61	5.974083	3.855	58.15333	-0.2562	2.923375	8.02	87.8608	0.994	1010.765
2017-09-20	8.73	5.600125	3.396	65.36708	-0.1617	3.230042	8.49	103.8492	1.141	1016.624
2017-09-21	7.836	5.303917	3.803	66.80167	-0.2791	3.872458	8.31	95.29136	1.083	1014.813
2017-09-22	5.27	3.748458	1.719	83.75792	0.7127	3.611625	11.09	62.05157	0.282	1010.085
2017-09-23	8.23	5.158333	3.244	81.24292	1.6773	2.989833	9.29	92.60808	0.696	1009.531
2017-09-24	7.857	5.447375	3.898	85.59208	-2.203	4.25125	12.8	82.78181	0.583	1006.191
2017-09-25	6.192	3.8335	2.185	70.15167	-0.1427	5.540958	13.07	88.8759	0.979	1009.254
2017-09-26	4.291	2.113542	0.019	80.63708	1.5772	3.712208	9.74	32.62001	0.111	1011.073
2017-09-27	8.36	6.502917	3.767	86.97	-0.4032	7.012875	15.86	33.18226	0.222	1012.214
2017-09-28	8.76	6.49975	2.078	69.04667	0.5275	7.410917	19.13	91.56178	1.391	1007.933
2017-09-29	6.095	3.779833	2.092	57.69375	0.1951	1.985833	6.507	102.2563	0.848	1007.22
2017-09-30	1.613	-0.23467	-3.806	71.54	0.1663	8.75225	15.46	79.46992	0.926	1011.77
2017-10-01	-1.218	-3.43063	-5.449	71.80167	-0.3523	5.792667	13.27	81.55477	0.616	1023.373
2017-10-02	5.986	1.864625	-2.786	48.32125	2.0905	5.319833	20.89	75.47593	1.331	1020.954
2017-10-03	5.371	3.04025	0.829	73.27292	6.7482	4.404167	19.76	52.85953	0.414	1017.661
2017-10-04	10.37	7.025167	3.519	56.26125	0.6389	5.950833	19.42	105.0641	1.941	1015.161
2017-10-05	5.423	3.055875	1.147	61.76042	2.2438	8.481542	19.76	79.2675	1.329	1004.245
2017-10-06	2.144	-0.02688	-1.454	85.25292	2.3509	4.711208	12.41	60.98823	0.307	994.345
2017-10-07	-0.203	-1.07258	-2.168	96.50417	3.8807	4.165167	7.781	41.53385	-0.067	1006.712
2017-10-08	-0.023	-1.43592	-3.406	85.15042	-1.1117	8.437958	20.29	44.49571	0.259	1003.319
2017-10-09	-0.693	-2.22367	-4.163	87.93583	0.4726	7.344042	15.17	49.31681	0.219	1005.926
2017-10-10	-2.312	-4.58921	-5.81	82.98292	-0.05	3.759167	10.7	95.7538	0.456	1014.01
2017-10-11	-4.155	-5.30239	-6.669	91.25833	2.6163	5.291292	11.21	35.16101	0.004	1011.974
2017-10-12	-6.551	-7.27021	-8.21	84.61375	1.1885	3.986792	8.66	59.02048	0.13	1015.131
2017-10-13	-6.356	-7.38783	-8.77	77.67708	2.9326	5.4085	14.9	37.73596	0.228	1007.659

APPENDIX B

KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-10-14	-3.04	-4.75871	-6.434	89.5625	2.4702	3.028708	7.683	46.86263	0.044	1004.837
2017-10-15	-1.211	-3.63158	-4.98	88.33	9.4886	4.056792	14.29	55.41044	0.192	994.8672
2017-10-16	-2.142	-4.31692	-6.826	82.27625	2.5995	3.38575	10.09	77.2184	0.381	995.8722
2017-10-17	-6.083	-7.30217	-8.74	84.14458	0.7127	3.28275	11.86	54.56508	0.141	995.9143
2017-10-18	-5.719	-6.86542	-9.03	83.3425	1.0579	7.223833	16.29	44.36543	0.228	988.2771
2017-10-19	-4.302	-5.79938	-7.123	85.95917	0.3739	4.278458	10.8	33.64949	0.069	984.9271
2017-10-20	-3.558	-4.98371	-5.736	83.08542	-1.0798	6.658708	14.82	66.98025	0.352	990.3937
2017-10-21	-5.574	-7.31996	-8.22	79.60208	-0.2731	6.837042	13.58	50.32231	0.292	992.849
2017-10-22	-3.407	-5.6015	-8.22	81.45667	0.1379	4.020333	10.56	55.97197	0.252	997.3061
2017-10-23	-2.522	-3.77421	-5.447	79.03625	2.146	5.264458	16.31	29.02267	0.175	1007.847
2017-10-24	-3.933	-5.392	-7.345	76.65333	0.1228	3.355042	11.96	48.24903	0.22	1011.573
2017-10-25	-3.131	-5.02083	-7.467	50.84208	-1.1762	7.022708	16.76	36.85181	0.77	1011.248
2017-10-26	0.28	-2.65796	-3.326	78.825	2.2139	6.765042	16.74	23.27822	0.203	1011.277
2017-10-27	3.809	2.16175	-1.23	78.90833	0.3868	13.75208	26.28	21.46941	0.693	1005.157
2017-10-28	-0.77	-1.76613	-3.134	71.05167	0.3545	8.788833	16.52	42.55578	0.621	1019.695
2017-10-29	1.36	-1.25229	-3.819	46.76583	1.8866	3.031917	11.52	36.91936	0.524	1021.638
2017-10-30	1.05	-0.94096	-3.732	74.41208	-0.6929	6.3925	18.13	11.93371	0.049	1013.058
2017-10-31	0	-4.65796	-9.3	90.90208	2.1338	8.773417	17.25	16.95799	-0.01	1010.887
2017-11-01	-9.72	-11.9158	-14.03	84.64667	0.2193	4.492083	10.76	40.34178	0.087	1021.646
2017-11-02	-7.661	-10.533	-13.93	71.47	-0.1315	3.961375	8.82	35.52152	0.216	1022.668
2017-11-03	-7.125	-8.92888	-10.47	84.62083	1.4519	5.666167	12.45	15.63716	0.034	1014.089
2017-11-04	-10.54	-11.31	-13.69	87.45417	0.4618	4.404208	8.62	15.03346	-0.039	1017.287
2017-11-05	-10.81	-12.475	-14.33	83.69625	-0.294	1.780167	6.507	42.46463	0.037	1011.69
2017-11-06	-13.39	-14.7629	-17.17	83.66667	0.6511	5.23675	9.78	21.60846	0.047	1012.419
2017-11-07	-15.55	-17.5358	-18.92	78.08208	-0.1166	2.368458	5.586	66.88161	0.165	1017.375
2017-11-08	-5.274	-9.25404	-15.86	30.74333	-0.7026	2.814292	10.49	27.55637	0.461	1010.645
2017-11-09	-9.16	-13.3967	-16.17	54.56833	-1.2018	4.571792	13.11	26.71832	0.235	1003.797
2017-11-10	-9.5	-14.7521	-18.59	65.2925	0.5158	2.839667	10.13	19.67359	0.062	1000.559
2017-11-11	-18.08	-19.5575	-20.72	78.73417	1.0445	2.618208	5.39	21.54428	0.009	1011.335
2017-11-12	-15.79	-18.0779	-20.63	79.96583	-0.1623	0.722167	2.724	51.32843	0.03	1007.581
2017-11-13	-17.34	-19.2308	-21.01	78.9175	0.1522	2.320542	5.076	50.95144	0.075	1005.316
2017-11-14	-18.17	-19.5288	-21.36	78.59667	0.027	*0.545286*	*1.646*	14.36997	*-0.132*	1012.099
2017-11-15	-17.75	-18.9429	-19.95	78.82375	0.1518	*0.787688*	*2.176*	32.68882	*-0.07*	1007.291
2017-11-16	-18.52	-21.0213	-23.89	77.05708	-0.023	*1.498316*	*4.567*	29.3382	*-0.048*	996.1999
2017-11-17	-16.09	-17.9742	-20.23	79.75208	0.708	*0.434688*	*2.744*	19.26018	*-0.17*	994.7562
2017-11-18	-21.09	-23.4217	-26.3	75.65958	0.6515	2.349667	4.802	9.479945	-0.025	1001.206
2017-11-19	-23.16	-25.5988	-29.27	74.10833	-0.0529	*0.785333*	*2.078*	19.89975	*-0.082*	994.6835
2017-11-20	-21.79	-22.6188	-23.51	75.01958	0.1595	*0.862063*	*4.018*	5.065027	*-0.139*	1004.12
2017-11-21	-15.5	-18.8267	-22.6	78.77583	-0.1962	0.631042	3.45	6.41818	-0.175	1005.119
2017-11-22	-14.71	-17.4575	-20.44	80.87458	0.3269	0.96625	6.311	4.550032	-0.173	994.9321
2017-11-23	-14.7	-16.105	-18.09	82.10833	0.276	*0.373*	*2.117*	4.124345	*-0.248*	987.4247
2017-11-24	-15.05	-19.4592	-21.26	78.67583	2.4374	*1.241682*	*3.469*	2.763849	*-0.138*	993.7492
2017-11-25	-15.31	-17.7767	-21.25	80.27333	-0.0746	*0.810389*	*4.41*	6.429889	*-0.178*	1003.355
2017-11-26	-12.68	-14.4513	-16.29	83.25333	0.4042	5.066208	20.21	3.546861	-0.062	991.0676
2017-11-27	-8.91	-13.1971	-17.32	77.07667	1.2593	5.506667	15.27	16.90283	0.071	989.4573
2017-11-28	-8.28	-10.3613	-12.45	79.62125	-0.111	2.485417	8.49	8.495017	-0.1	991.5692
2017-11-29	-5.451	-6.58646	-8.5	73.05833	-1.4762	10.81746	20.93	13.33466	0.338	992.7754
2017-11-30	-6.03	-7.50075	-9.31	74.48208	-4.7282	7.069083	18.64	6.389905	0.201	995.216
2017-12-01	-9.13	-10.7504	-12.87	80.28375	-1.1668	4.8735	12.78	6.435071	0.01	999.1031
2017-12-02	-11.74	-12.6213	-13.78	69.02292	0.7588	6.1315	12.17	8.242386	0.161	1000.657
2017-12-03	-3.303	-8.50533	-12.93	73.90042	3.2516	6.799792	22.07	5.466394	0.146	1003.969
2017-12-04	-3.049	-3.76625	-4.92	69.40542	4.2106	13.37583	26.4	5.6979	0.561	1003.682

APPENDIX B

KZK Daily Meteorological Data 2015-2017

Date	Daily Max Temp	Daily Mean Temp	Daily Min Temp	Daily RH Avg	Daily Precip Total *	Daily Avg Wind Sp	Daily Max Wind Sp	Daily Avg Solar	Daily Total ET	Daily BP Avg
2017-12-05	-1.381	-4.53492	-6.272	69.30292	-6.3845	9.161833	17.31	4.082199	0.295	1017.814
2017-12-06	0.861	-2.00058	-4.044	63.35667	0.9766	9.133125	18.27	5.777857	0.514	1018.724
2017-12-07	2.518	1.355958	0.603	52.57625	1.0153	9.085417	20.13	7.0313	0.926	1015.962
2017-12-08	2.116	1.080125	-0.438	56.97083	1.9885	9.557375	18.15	5.423671	0.845	1010.398
2017-12-09	2.003	0.384083	-1.572	79.54417	-2.5696	7.921583	22.78	4.482016	0.102	1007.872
2017-12-10	0.879	-2.33792	-4.892	67.45875	0.9322	10.16217	23.23	3.199305	0.51	1012.582
2017-12-11	1.269	-1.06913	-3.734	78.49042	-0.0925	10.55708	25.95	7.15799	0.313	1007.91
2017-12-12	-0.236	-2.16675	-4.198	74.04208	-0.0588	6.905208	15.27	4.136901	0.188	1012.544
2017-12-13	1.085	-1.93458	-3.352	69.2825	-2.9227	5.89375	16.78	5.938594	0.153	1016.553
2017-12-14	0.86	-0.60317	-3.68	81.58375	-6.2437	10.92621	24.09	3.76201	0.252	1002.672
2017-12-15	-3.958	-5.84608	-6.831	75.53417	-3.3281	9.508292	22.89	4.667381	0.235	1001.578
2017-12-16	-4.944	-6.38613	-7.91	73.28042	-0.7739	10.55646	22.17	5.912066	0.312	992.2593
2017-12-17	-5.49	-7.58275	-9.28	77.05625	-0.436	8.6585	16.68	4.486601	0.203	993.9638
2017-12-18	-8.85	-10.6875	-12.48	84.55292	0.718	6.848917	12.7	6.213312	0.032	1005.675
2017-12-19	-9.62	-12.0242	-13.83	56.88708	0.4007	4.976375	9.86	5.603841	0.201	1009.831
2017-12-20	-8.08	-10.79	-13.58	74.89	0.8866	6.802917	17.93	5.198775	0.01	1009.934
2017-12-21	-12.62	-13.5863	-14.31	81.27083	0.8921	8.2735	15.62	3.703599	0.061	1021.704
2017-12-22	-4.909	-10.5613	-13.86	54.16583	-0.797	6.82975	12.54	3.44283	0.362	1024.363
2017-12-23	-4.939	-6.94504	-8.42	35.03625	0.4513	2.8515	6.468	3.162617	0.292	1022.025
2017-12-24	-5.867	-7.0905	-8.67	32.55125	-0.0671	1.981583	6.39	3.109975	0.081	1018.557
2017-12-25	-7.904	-11.2277	-16.1	40.34667	0.2933	1.973708	7.428	3.317802	-0.015	1015.409
2017-12-26	-16.4	-18.5567	-19.69	67.18417	-1.1481	3.69625	7.703	4.845945	0.042	1018.629
2017-12-27	-15.47	-16.3904	-18.03	50.4675	0.2032	4.123833	10.39	3.777908	0.179	1017.847
2017-12-28	-15.96	-20.2042	-23.85	62.36042	0.2521	4.630708	11.52	3.587722	0.079	1016.863
2017-12-29	-22.22	-24.11	-25.56	47.74792	0.1232	2.916125	8.19	3.589017	0.047	1014.964
2017-12-30	-17.75	-20.7346	-22.24	20.73625	-0.1142	1.828042	5.174	3.369976	0.077	1012.195
2017-12-31	-9.09	-13.9088	-19.75	10.15483	-0.6506	1.69325	7.311	3.803388	0.117	1012.521

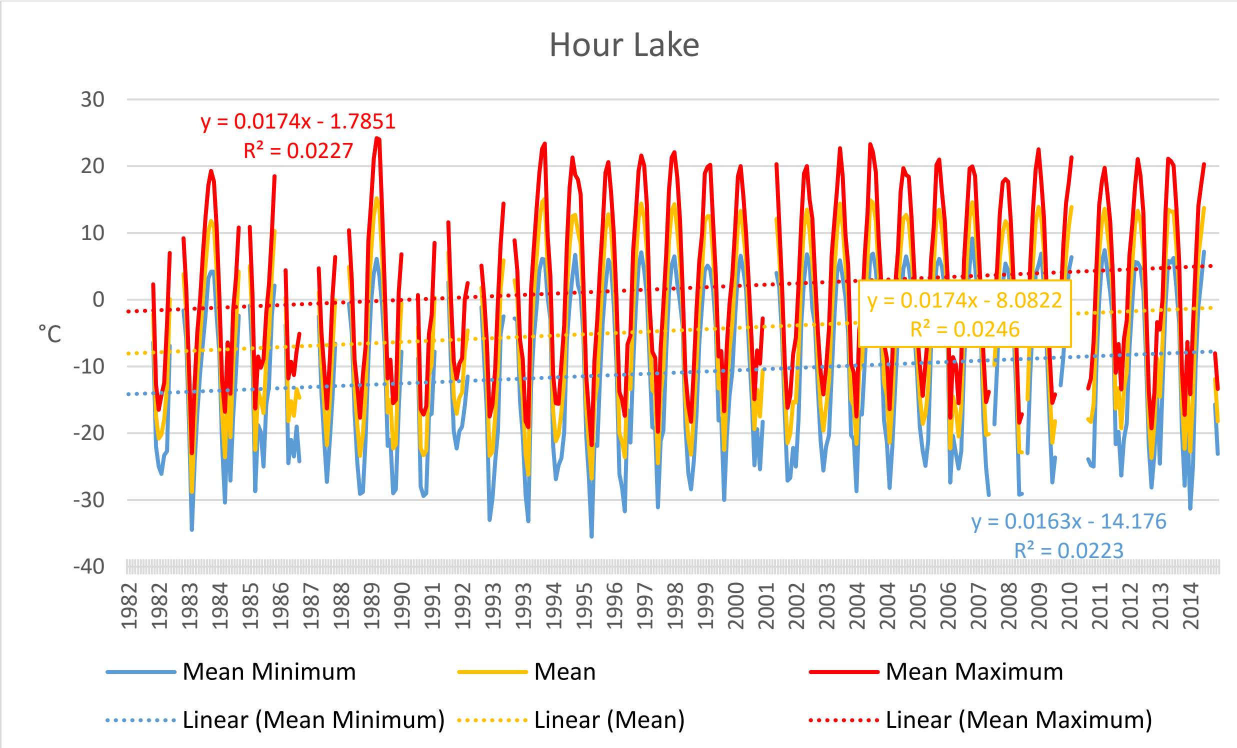
**daily total precip is calculated from average depth of 3 Geonor sensors at the end of the day minus the average depth at the start of the da*y

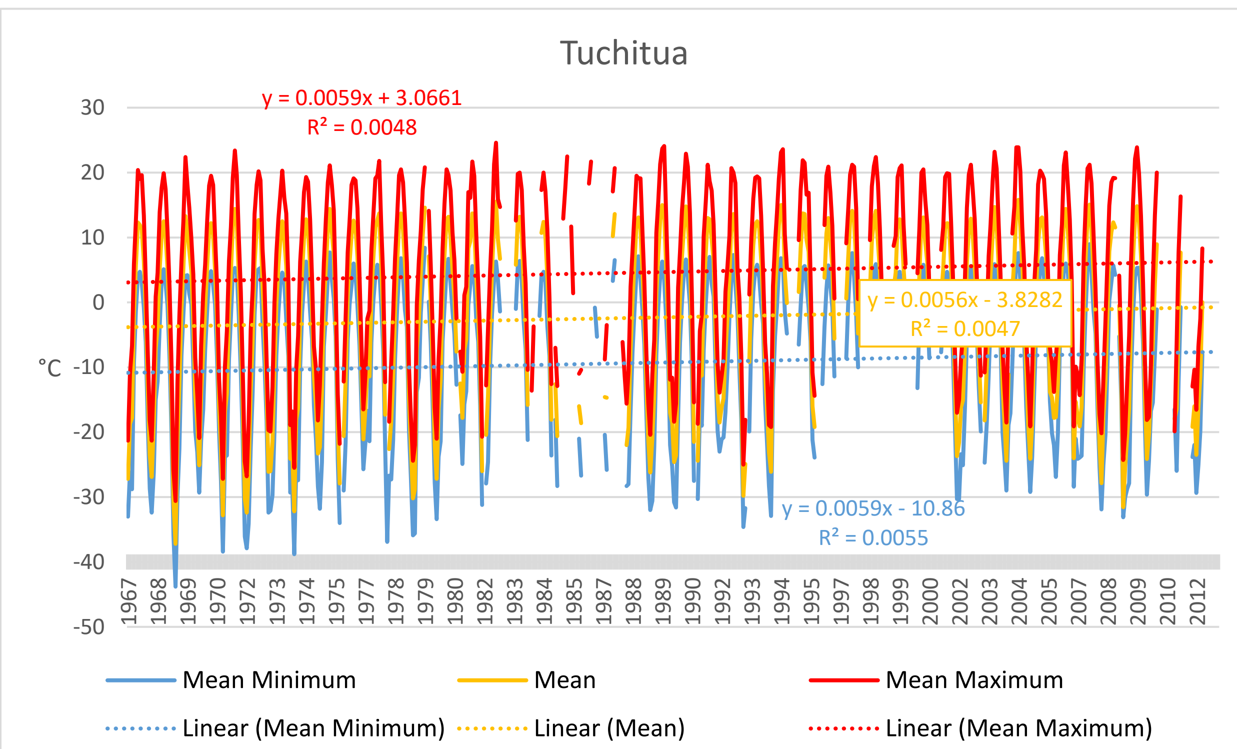
negative values could be due to vibrating wire sensor noise

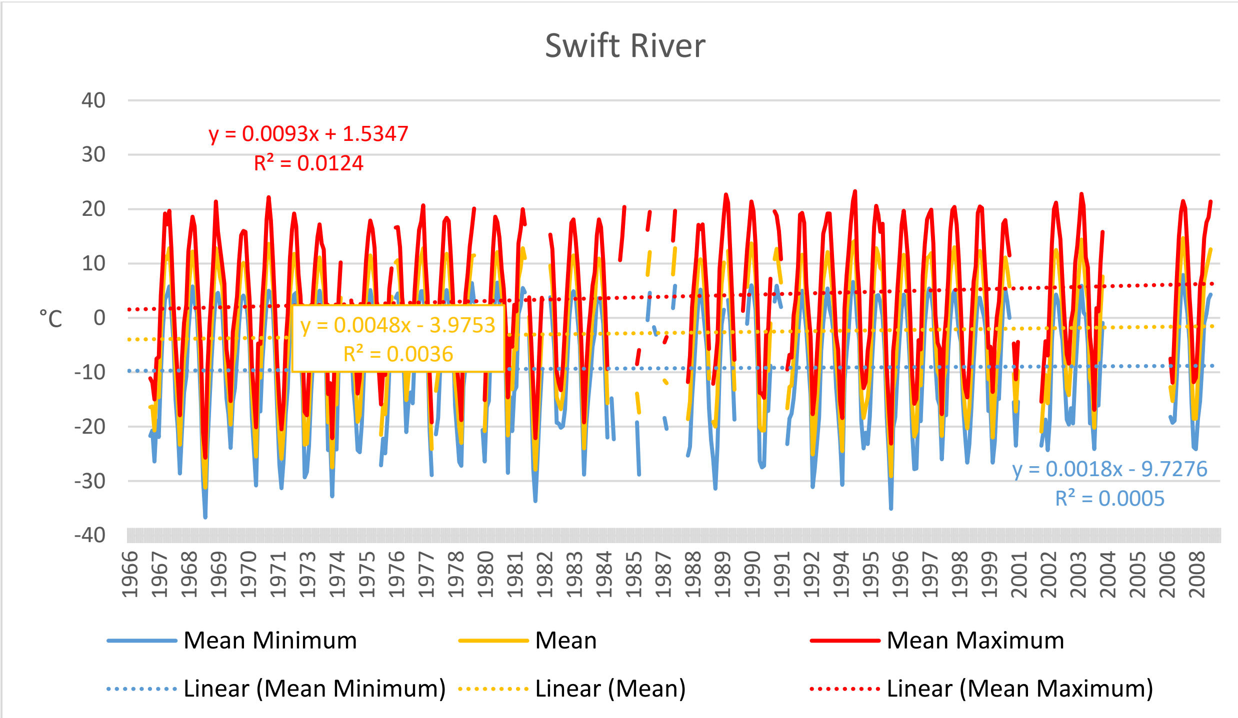
grey italics indicate partial data

APPENDIX C

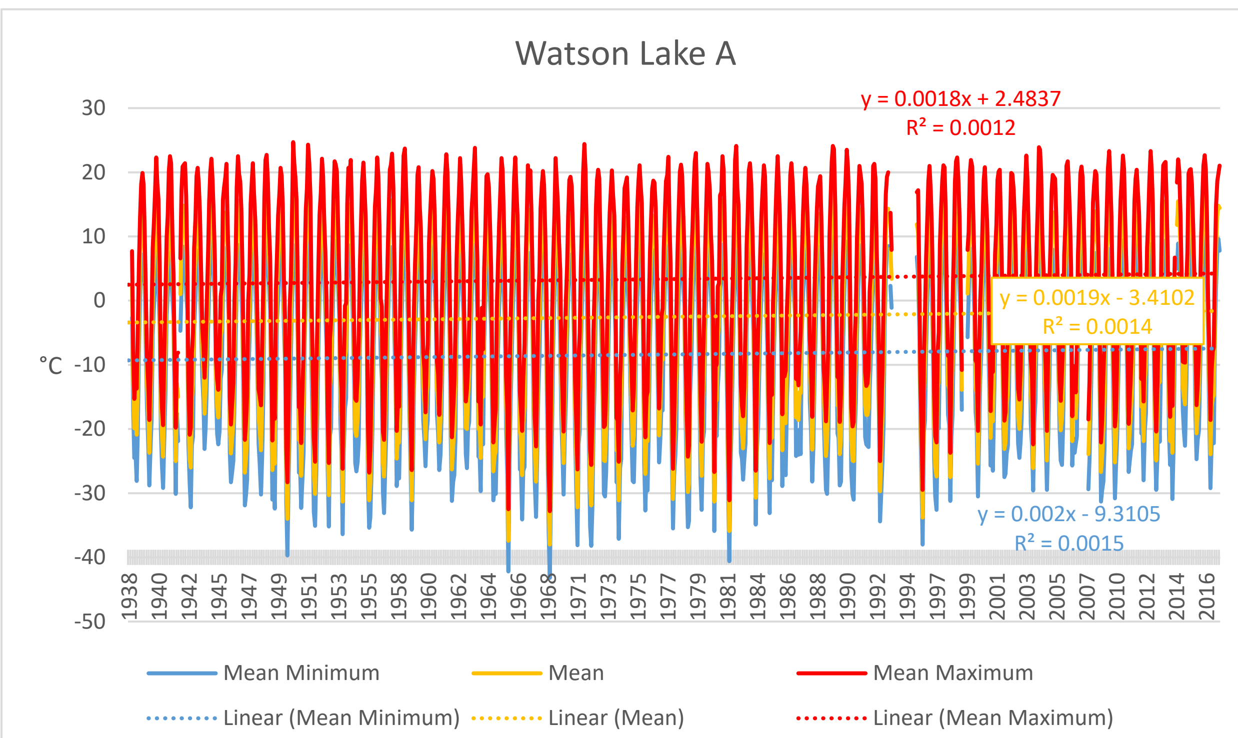
REGIONAL TEMPERATURE TRENDS


Hour Lake
y = 0.0174x - 1.7851
R² = 0.0227
y = 0.0174x - 8.0822
R² = 0.0246
y = 0.0163x - 14.176
R² = 0.0223
°C
30
20
10
0
-10
-20
-30
-40
1982 1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Mean Minimum
Mean
Mean Maximum
Linear (Mean Minimum)
Linear (Mean)
Linear (Mean Maximum)

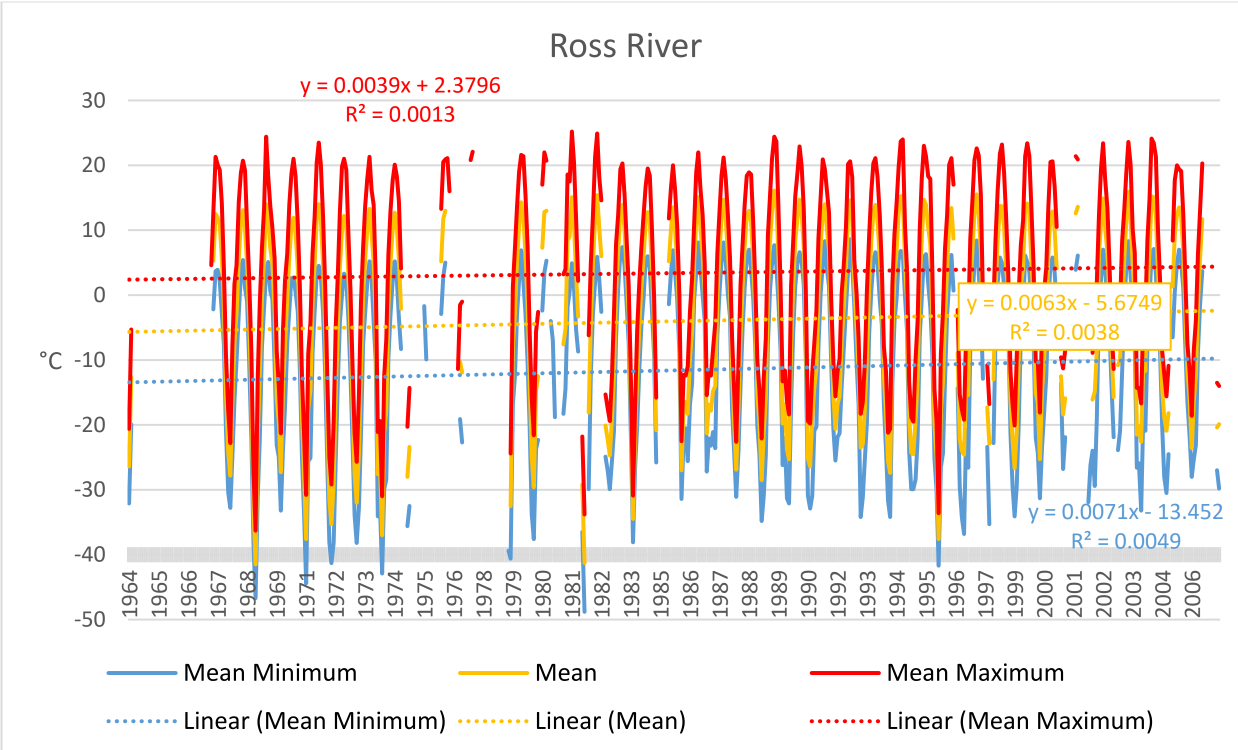

Tuchitua
y = 0.0059x + 3.0661
R² = 0.0048
y = 0.0056x - 3.8282
R² = 0.0047
y = 0.0059x - 10.86
R² = 0.0055
°C
30
20
10
0
-10
-20
-30
-40
-50
1967 1968 1969 1970 1972 1973 1974 1975 1977 1978 1979 1980 1982 1983 1984 1985 1987 1988 1989 1990 1992 1993 1994 1995 1997 1998 1999 2000 2002 2003 2004 2005 2007 2008 2009 2010 2012
Mean Minimum
Mean
Mean Maximum
Linear (Mean Minimum)
Linear (Mean)
Linear (Mean Maximum)

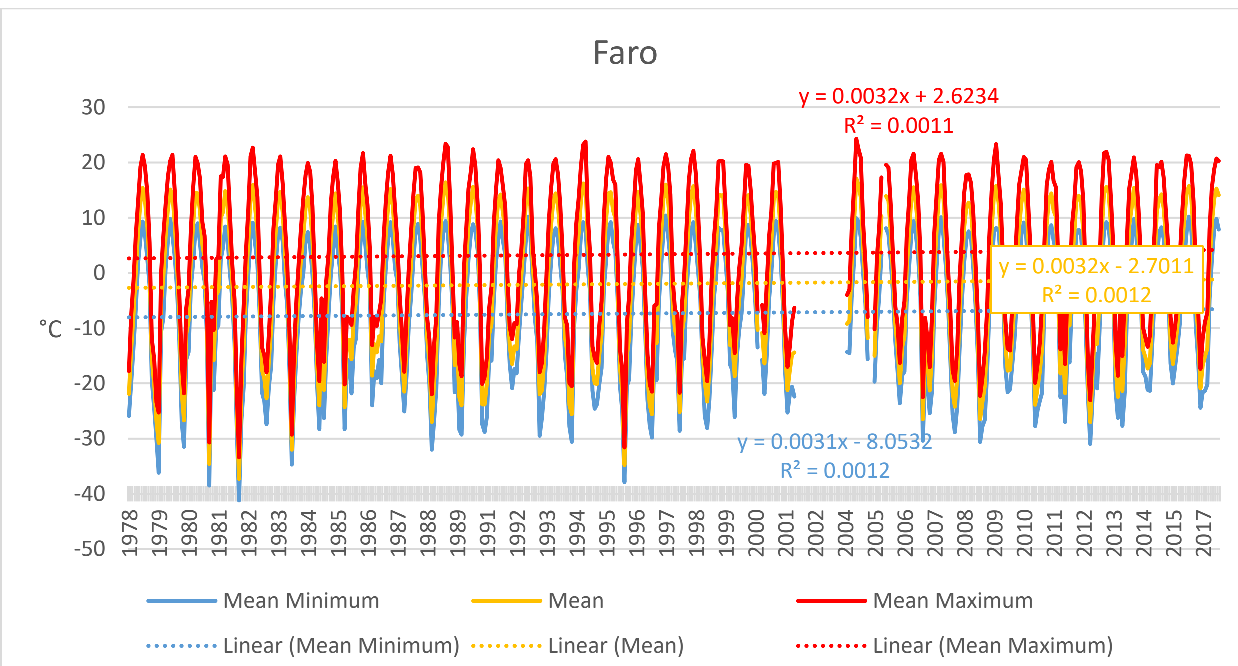


Swift River
40
30
20
10
°C 0
-10
-20
-30
-40
y = 0.0093x + 1.5347
R² = 0.0124
y = 0.0048x - 3.9753
R² = 0.0036
y = 0.0018x - 9.7276
R² = 0.0005
1966 1967 1968 1969 1970 1971 1973 1974 1975 1976 1977 1978 1980 1981 1982 1983 1984 1985 1987 1988 1989 1990 1991 1992 1994 1995 1996 1997 1998 1999 2001 2002 2003 2004 2005 2006 2008
Mean Minimum
Mean
Mean Maximum
Linear (Mean Minimum)
Linear (Mean)
Linear (Mean Maximum)



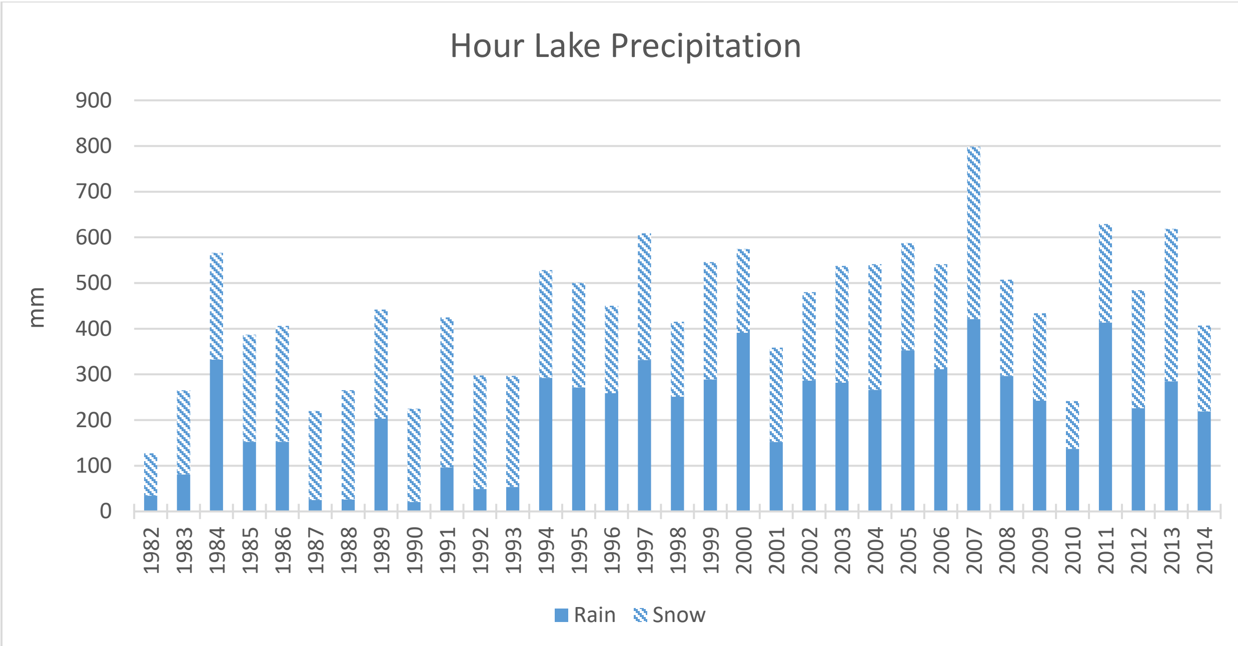
Watson Lake A
30
20
10
0
°C -10
-20
-30
-40
-50
y = 0.0018x + 2.4837
R² = 0.0012
y = 0.0019x - 3.4102
R² = 0.0014
y = 0.002x - 9.3105
R² = 0.0015
1938 1940 1942 1945 1947 1949 1951 1953 1955 1958 1960 1962 1964 1966 1968 1971 1973 1975 1977 1979 1981 1984 1986 1988 1990 1992 1994 1997 1999 2001 2003 2005 2007 2010 2012 2014 2016
Mean Minimum
Mean
Mean Maximum
Linear (Mean Minimum)
Linear (Mean)
Linear (Mean Maximum)


Ross River
y = 0.0039x + 2.3796
R² = 0.0013
y = 0.0063x - 5.6749
R² = 0.0038
y = 0.0071x - 13.452
R² = 0.0049
°C
Mean Minimum
Mean
Mean Maximum
Linear (Mean Minimum)
Linear (Mean)
Linear (Mean Maximum)

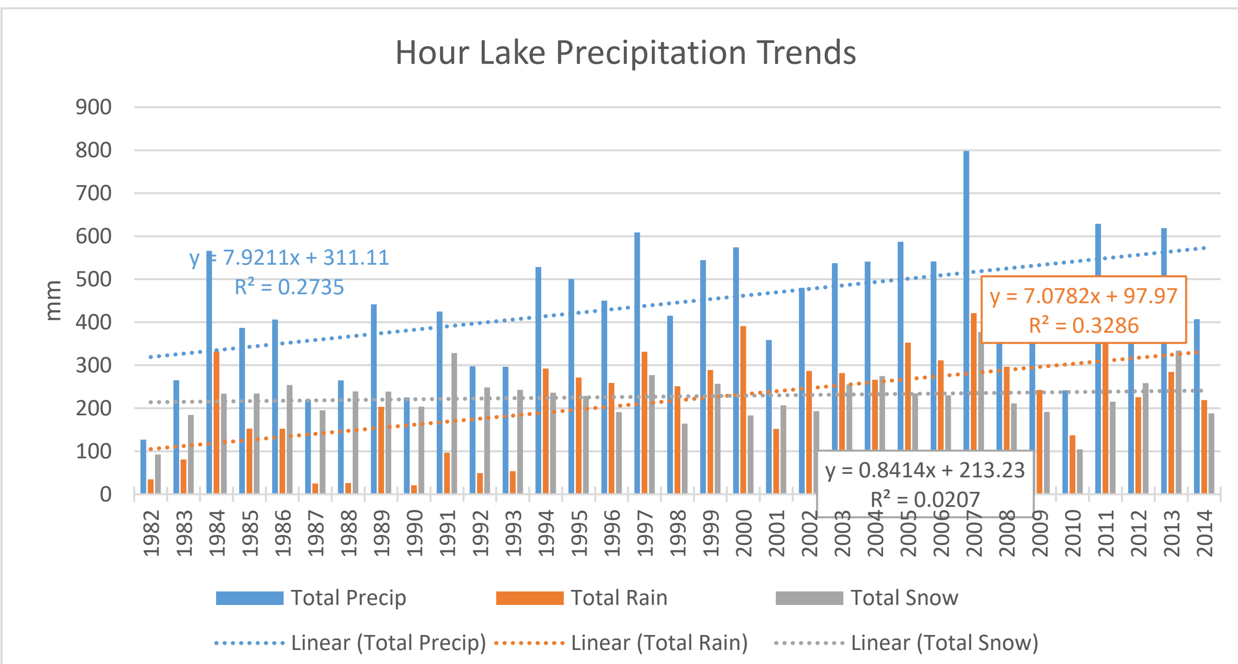

Faro
y = 0.0032x + 2.6234
R² = 0.0011
y = 0.0032x - 2.7011
R² = 0.0012
y = 0.0031x - 8.0532
R² = 0.0012
°C
Mean Minimum
Mean
Mean Maximum
Linear (Mean Minimum)
Linear (Mean)
Linear (Mean Maximum)

APPENDIX D

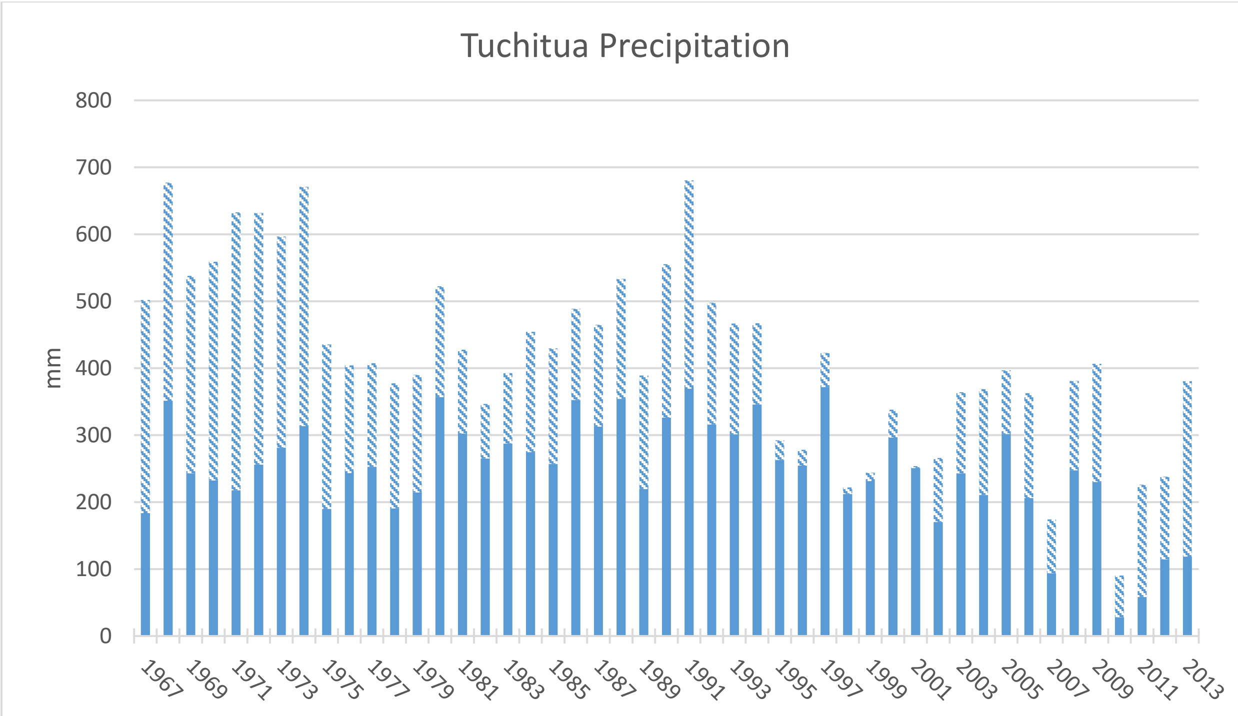
REGIONAL PRECIPITATION TRENDS



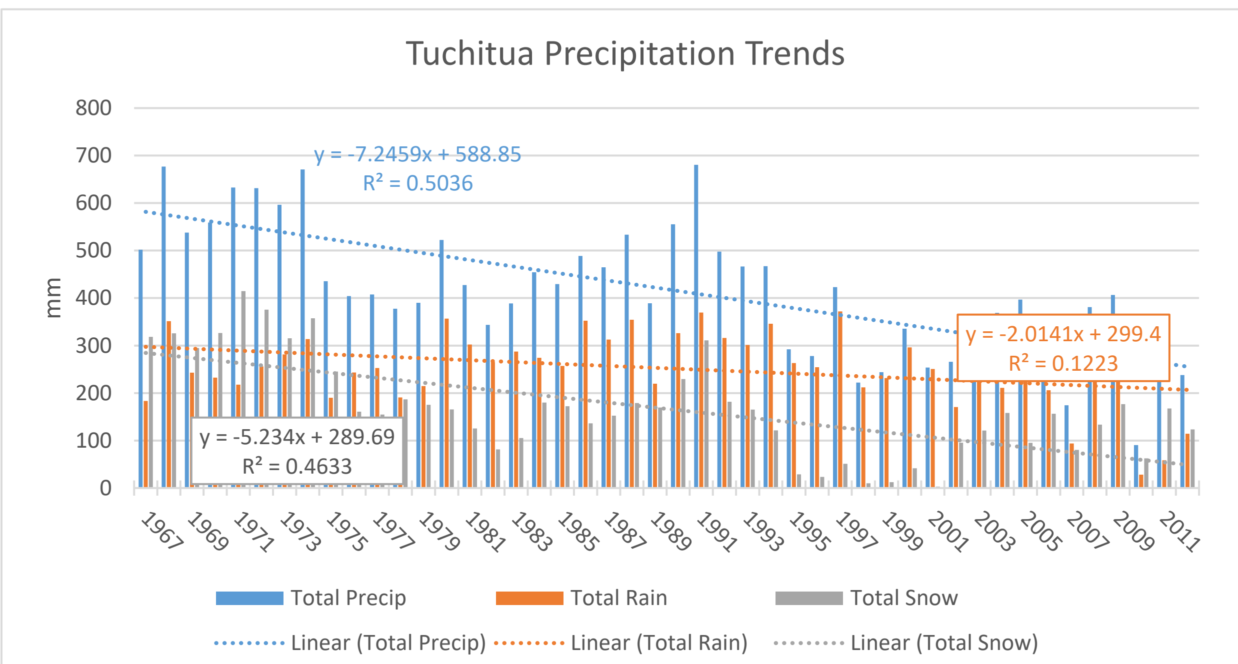
Hour Lake Precipitation
mm
900
800
700
600
500
400
300
200
100
0
1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Rain
Snow



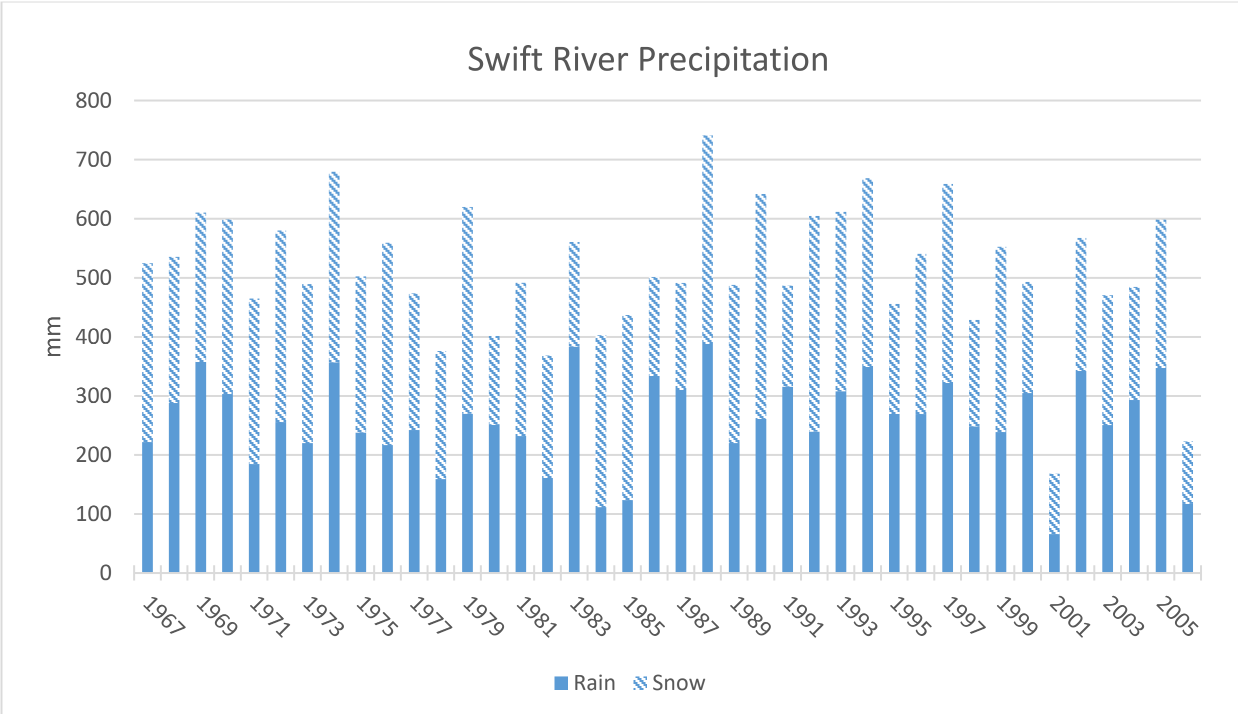
Hour Lake Precipitation Trends
mm
900
800
700
600
500
400
300
200
100
0
y = 7.9211x + 311.11
R² = 0.2735
y = 7.0782x + 97.97
R² = 0.3286
y = 0.8414x + 213.23
R² = 0.0207
1982 1983 1984 1985 1986 1987 1988 1989 1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014
Total Precip
Total Rain
Total Snow
Linear (Total Precip)
Linear (Total Rain)
Linear (Total Snow)

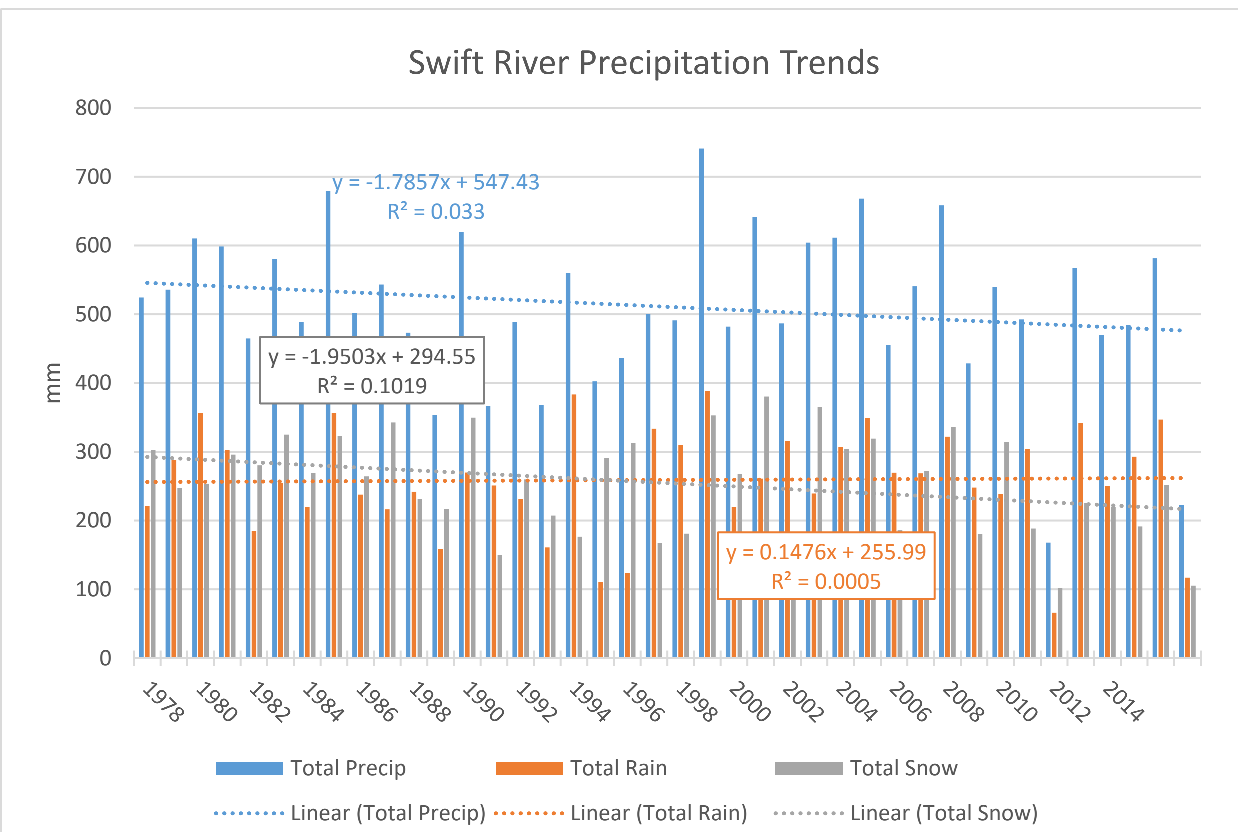


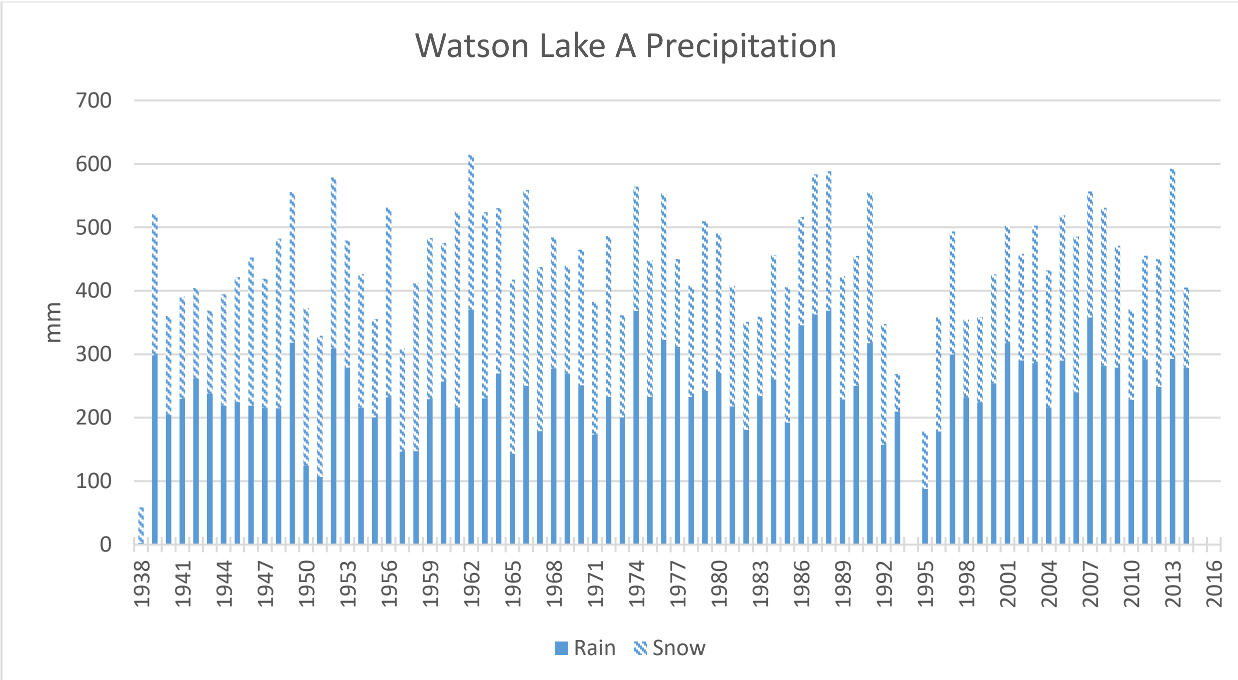
Tuchitua Precipitation
mm
800
700
600
500
400
300
200
100
0
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
2013

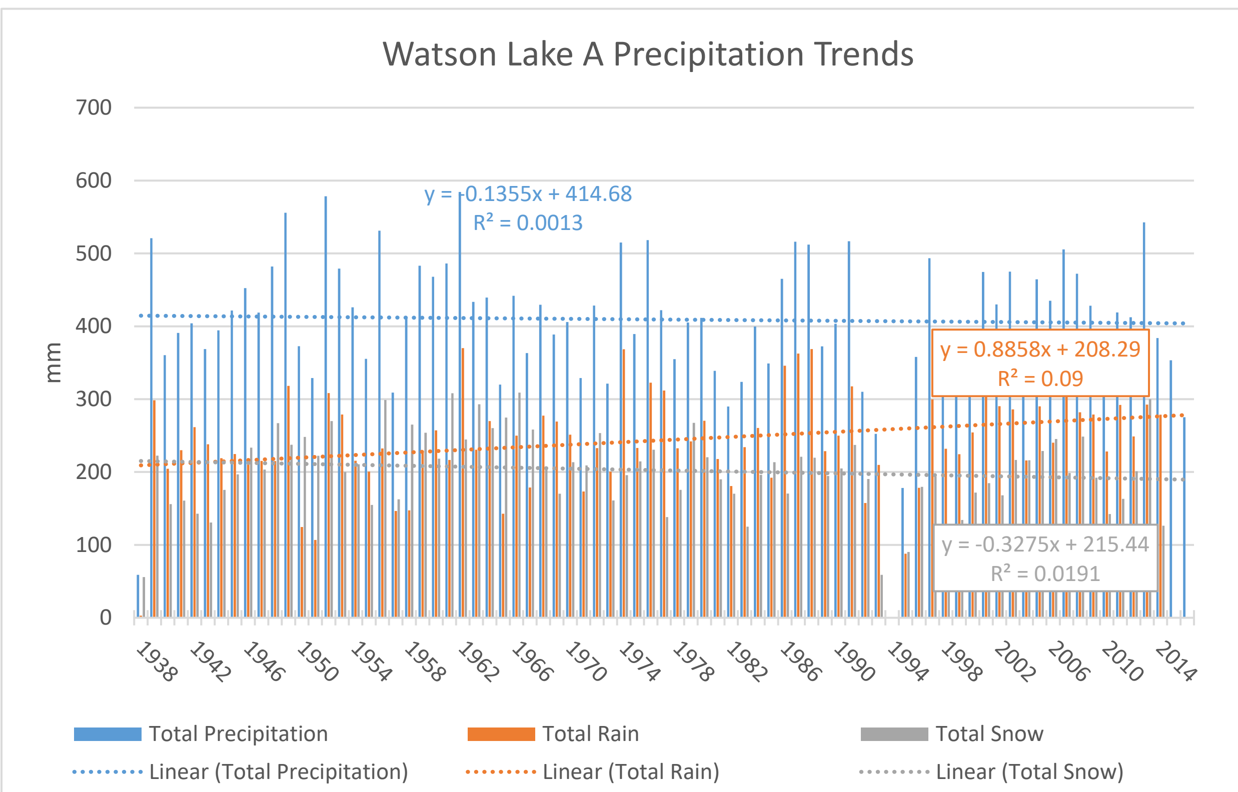


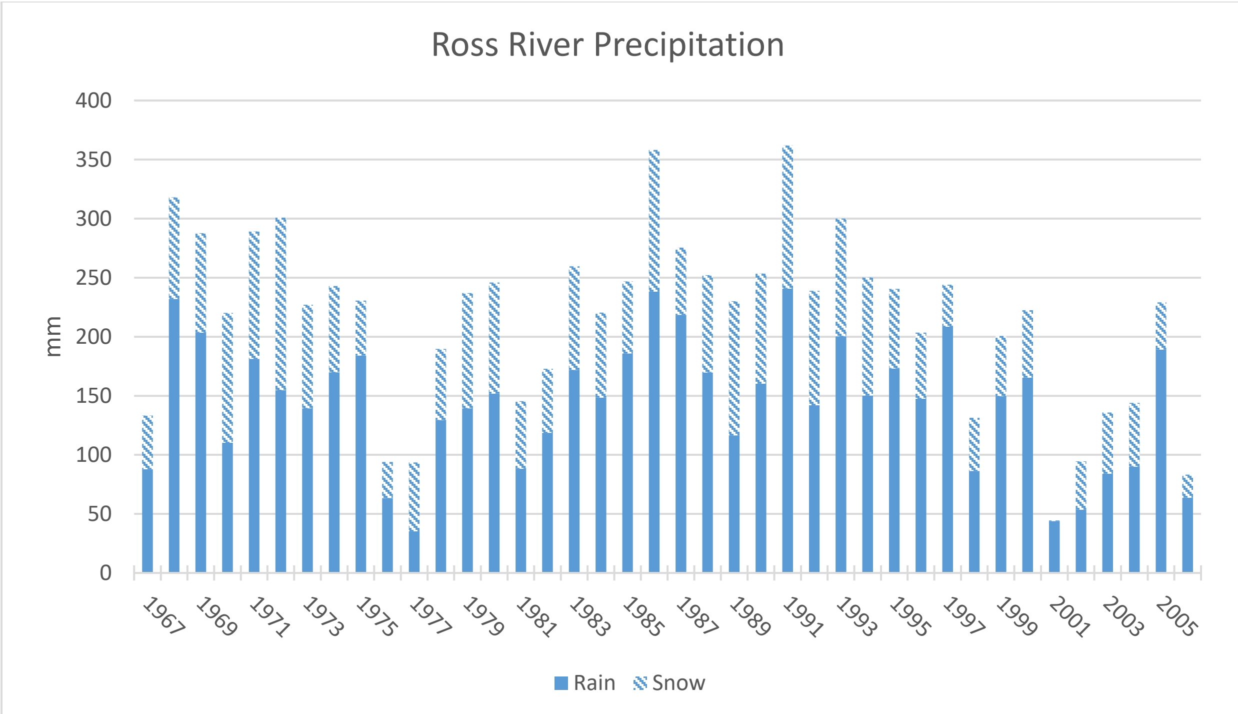
Tuchitua Precipitation Trends
mm
800
700
600
500
400
300
200
100
0
y = -7.2459x + 588.85
R² = 0.5036
y = -2.0141x + 299.4
R² = 0.1223
y = -5.234x + 289.69
R² = 0.4633
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
2007
2009
2011
Total Precip
Total Rain
Total Snow
Linear (Total Precip)
Linear (Total Rain)
Linear (Total Snow)

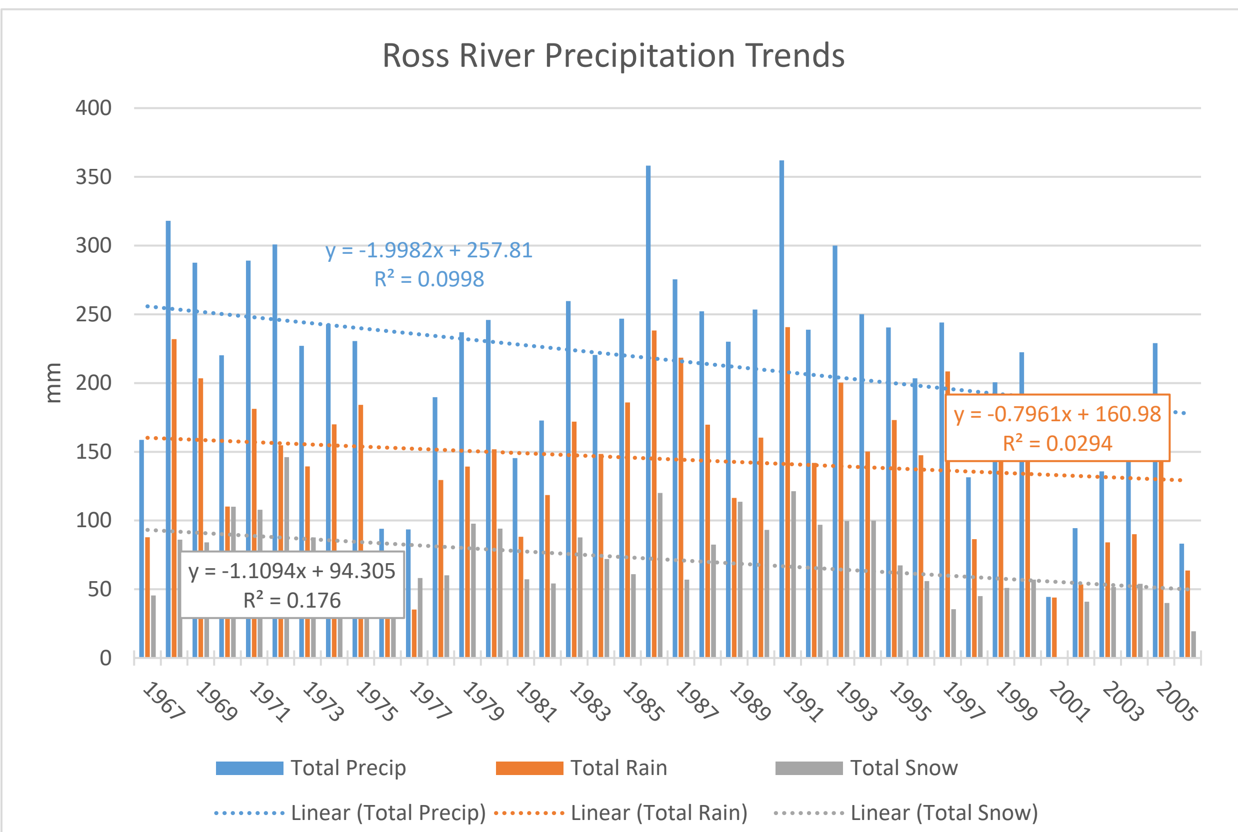

Swift River Precipitation
800
700
600
500
400
300
200
100
0
mm
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Rain
Snow

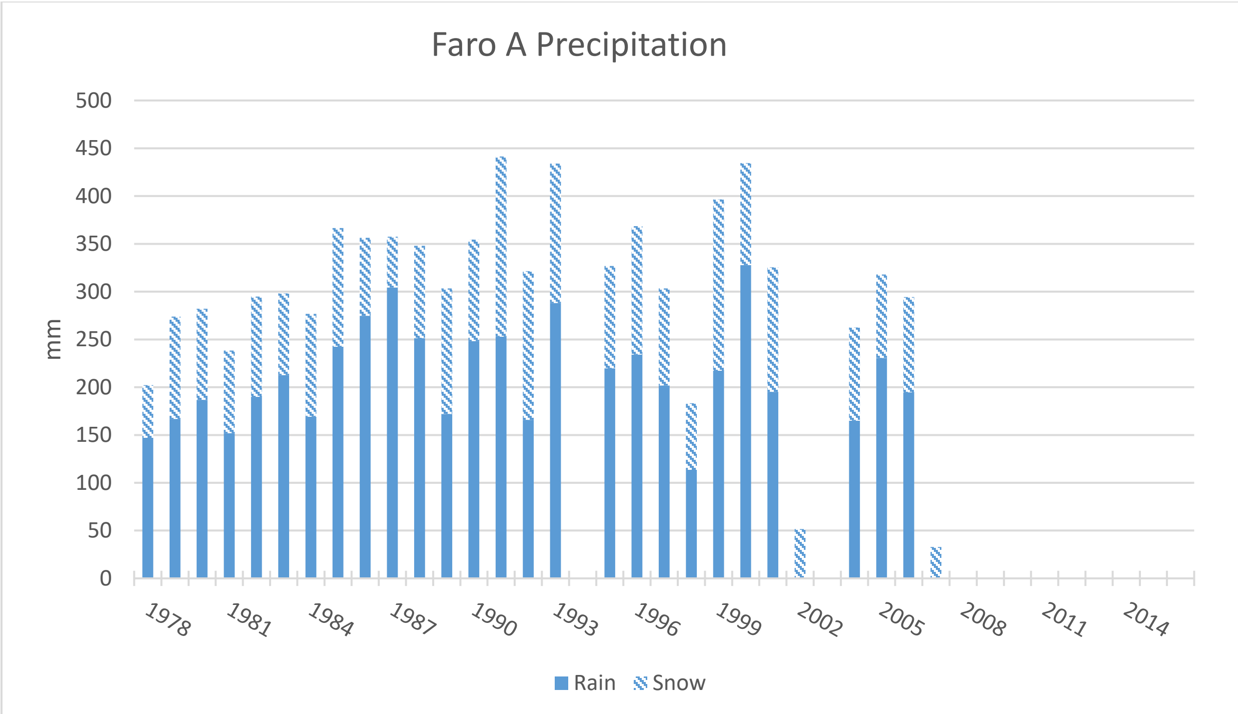

Swift River Precipitation Trends
800
700
600
500
400
300
200
100
0
mm
y = -1.7857x + 547.43
R² = 0.033
y = -1.9503x + 294.55
R² = 0.1019
y = 0.1476x + 255.99
R² = 0.0005
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
Total Precip
Total Rain
Total Snow
Linear (Total Precip)
Linear (Total Rain)
Linear (Total Snow)

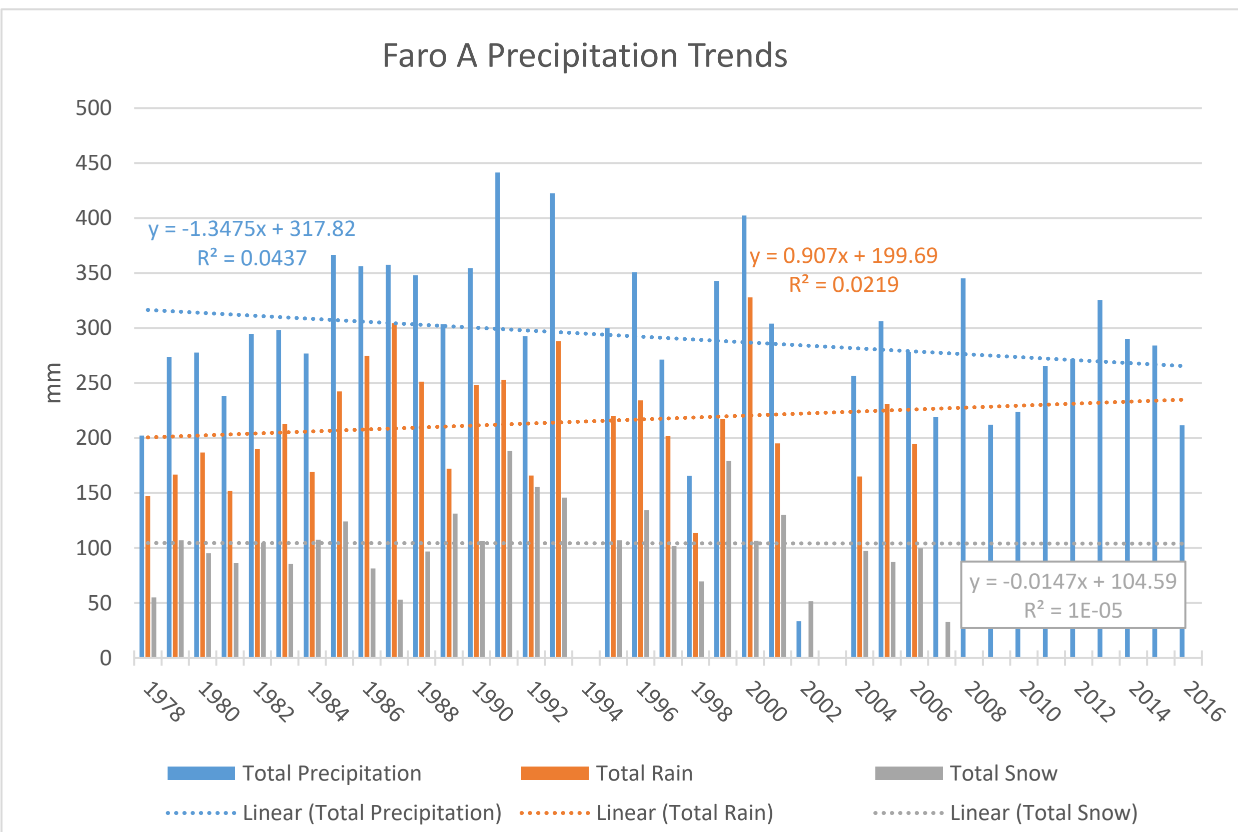

Watson Lake A Precipitation
mm
700
600
500
400
300
200
100
0
1938 1941 1944 1947 1950 1953 1956 1959 1962 1965 1968 1971 1974 1977 1980 1983 1986 1989 1992 1995 1998 2001 2004 2007 2010 2013 2016
Rain
Snow


Watson Lake A Precipitation Trends
mm
700
600
500
400
300
200
100
0
y = -0.1355x + 414.68
R² = 0.0013
y = 0.8858x + 208.29
R² = 0.09
y = -0.3275x + 215.44
R² = 0.0191
1938 1942 1946 1950 1954 1958 1962 1966 1970 1974 1978 1982 1986 1990 1994 1998 2002 2006 2010 2014
Total Precipitation
Total Rain
Total Snow
Linear (Total Precipitation)
Linear (Total Rain)
Linear (Total Snow)


Ross River Precipitation
400
350
300
250
200
150
100
50
0
mm
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Rain
Snow


Ross River Precipitation Trends
400
350
300
250
200
150
100
50
0
mm
y = -1.9982x + 257.81
R² = 0.0998
y = -0.7961x + 160.98
R² = 0.0294
y = -1.1094x + 94.305
R² = 0.176
1967
1969
1971
1973
1975
1977
1979
1981
1983
1985
1987
1989
1991
1993
1995
1997
1999
2001
2003
2005
Total Precip
Total Rain
Total Snow
Linear (Total Precip)
Linear (Total Rain)
Linear (Total Snow)


Faro A Precipitation
500
450
400
350
300
250
200
150
100
50
0
mm
1978
1981
1984
1987
1990
1993
1996
1999
2002
2005
2008
2011
2014
Rain
Snow


Faro A Precipitation Trends
y = -1.3475x + 317.82
R² = 0.0437
y = 0.907x + 199.69
R² = 0.0219
y = -0.0147x + 104.59
R² = 1E-05
500
450
400
350
300
250
200
150
100
50
0
mm
1978
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Total Precipitation
Total Rain
Total Snow
Linear (Total Precipitation)
Linear (Total Rain)
Linear (Total Snow)

Appendix E

Appendix 3.2, Initial Environmental Evaluation (Cominco Ltd., 1996)

APPENDIX 3.2a

RUNOFF CHARACTERIZATION

APPENDIX 3.2a

RUNOFF CHARACTERIZATION

1. Regional Analysis

The runoff in the project area was determined from a regional analysis which utilized hydrometric station records as shown on Figure 3.2.1. This analysis was based on Water Survey of Canada station records within a geographical block defined by: Latitudes 60° to 63°N and Longitudes 128° to 134°W (Kudz Ze Kayah is near 61°30'N, 130°35'W). The HYDAT software package was utilized for this analysis, with data from CD-ROM Version 4.93. A total of 16 WSC stations were included in the analysis. In addition, data collected by DIAND was also included, though this consisted of only two stations which had seasonal records only. The average monthly flow distribution from the WSC stations was used to extend the seasonal DIAND records in order to obtain annual runoff totals. In each case, the mean monthly flow for each station was translated into mean monthly runoff depth in mm. Results are listed in Table 3.2A.1.

The available hydrometric records were reviewed and a number of the smaller catchments were selected for defining the mean runoff in the project area. Also chosen were two of the larger catchments near the project site. While the Frances River catchment is much larger than any of the others, it was included as the project area is tributary to this watercourse. The mean annual total runoff at Kudz Ze Kayah was assumed to be equal to the average runoff derived from these stations, namely 414 mm, see Table 3.2A.2. An attempt was made to correlate the mean annual runoff from these stations with the median basin elevation, however, this failed to produce a meaningful correlation. The R^2 from a linear regression analysis was determined to be only 0.225 indicating an exceedingly weak relationship. It is likely that local conditions with respect to basin location and aspect play a far more important role than basin elevation in defining runoff. This would be especially true for the very small catchments which can have high or low runoff depending on which side of a mountain they are located on.

The monthly runoff distribution was derived by averaging the runoff distributions obtained from the three smallest catchments for which complete annual records were available. These included King Creek, Rose Creek and Sidney Creek. Elevation ranges and median elevation for each of these catchments are listed below:

Basin	Drainage area km^2	Annual runoff mm	Elevation range m	Median basin elevation m
King Creek	13.7	290	930 - 1860	1340
Rose Creek	208	358	1040 - 1980	1420
Sidney Creek	372	355	750 - 1890	1260

In comparison, the catchment above the tailings dam has an elevation range of 1370 to 2040 m with a median elevation of 1505 m. While the mean runoff distribution derived from the above catchments would be sufficient to represent the natural drainage below the tailings impoundment, it was concluded that some adjustment would be necessary to reflect the higher elevations above the impoundment. Rose Creek is the highest of the three natural catchments and examination of the mean monthly flows for this station (Table 3.2A.1) revealed considerably lower flow than the other stations during the winter months. It was concluded that the runoff for this upper catchment should be modified as follows:

- January to April: reduce flows by one-half
- May to September: increase flows by 8.4%
- October to December: reduce flows by one-third

The above adjustments retard winter flows and concentrate more of the runoff into the freshet. Results of this analysis, including the estimated runoff distribution at the Kudz Ze Kayah site, are given in Table 3.2A.3.

The mean annual precipitation at Kudz Ze Kayah is estimated to be 655 mm so 414 mm of runoff is 63.2% of total precipitation. This is in agreement with data obtained from the Hydrological Atlas of Canada.

2. Estimated Runoff From Mine Sub-catchment Areas

The mean monthly runoff for the project area was then used to obtain corresponding catchment runoff from each of the subcatchment areas surrounding the mine and tailings impoundment. This analysis was conducted using the Quattro Pro Ver 5.0 spreadsheet program. Results are given in a spreadsheet table (see Addendum following tables) which includes mean monthly flows in m^3/s for the individual sub-catchments as well as for the cumulative catchment area at various monitoring points.

3. Annual Runoff - Frequency Analysis

The variation in annual runoff was estimated based on an analysis of the long-term streamflow records in the project area. The best long-term records consist of Ross River at Ross River (09BA001) and Liard River at Upper Crossing (10AA001), with 30 and 33 years of annual means, respectively. Frequency analysis of the annual mean flows for these stations was conducted using Environment Canada's Consolidated Frequency Analysis (CFA) software, Version 3.1. The ratio of the frequency estimates to the mean annual flow was calculated, as listed in Table 3.2A.4. The average of the two ratios was adopted for use at the Kudz Ze Kayah site.

In terms of low flows, Table 3.2A.4 is inadequate as the tabulated values of return period are limited and do not correspond with required values. To overcome this problem, the frequency estimates corresponding to the average Kudz Ze Kayah runoff ratios were plotted on probability paper and the required return periods were read off the graph. Results are listed in Table 3.2A.5.

The flow ratios listed in Table 3.2A.5 were then used to obtain estimates of runoff from the project catchment areas by modifying the spreadsheet table (see Addendum). Results are included for 1 in 10-year high and low runoff years as well as 1 in 100-year high and low runoff years.

Drainage areas listed in the spreadsheet tables assume the diversion of some minor creeks in the mine site catchment (see Appendix 3.1, Figure 3.1.3). Fault Creek and the adjacent tributary to the north, are assumed to be diverted into South Creek and, thus, away from the mine pit. Likewise, an area on the uphill side of the northwest dump was assumed to be diverted and spilled at the tailings dam thereby reducing the area draining into the northwest dump which will require treatment. In addition, the area above the access road between the tailings dam and the mill site was also assumed to be diverted and spilled at the tailings dam, reducing the catchment into the tailings impoundment. The diversions toward the tailings dam were assumed to be only 50% effective as seepage would bypass the diversion channel.

4. Low Flow Analysis

4.1 Low Monthly Flow Analysis

A frequency analysis of low monthly flows was conducted in order to estimate the 25-year low monthly flow during the operational period of the tailings impoundment releases, which covers the May to October period. It was determined that the minimum monthly runoff would occur in October. An analysis was therefore conducted, using records from several stations in the area, to determine the relationship between the 25-year low flow for October and the mean flow. Results of this monthly frequency analysis are listed in Table 3.2A.6. It is evident from these tabulated results, that the ratio between the 25-year low monthly flow and the mean monthly flow, for October, is relatively constant, though a slight increase in the ratio with drainage area is likely. Adopted values used for the project area are as follows:

- Drainage Area = 16 km^2
  October 25-year low flow = 0.49 x October mean flow

- Drainage Area = 187 km^2

October 25-year low flow = 0.51 x October mean flow

The 25-year low monthly flow, during the operational period of May to October, can be used as an approximation of the 10-year seven day low flow (Down Valley Tailings Impoundment Decommissioning Plan, Faro, Yukon. 1991. Curragh Resources).

4.2 Normal Variations in Monthly Flows

An analysis was carried out to determine the normal variations in monthly flows for the winter months of February, March and April. Flow data for King Creek (1976-1988), Rose Creek (1968-1969) and Sidney Creek (1982-1993) was analyzed to determine the average ratio between the lowest flow in a month and the mean flow in that month. Results are summarized below:

Stream	Average Ratio of Minimum Daily to Mean Monthly Flow		
	February	March	April
King Creek	0.876	0.845	0.836
Rose Creek*	0.979	0.993	0.844
Sidney Creek	0.904	0.915	0.817
Average (omit *)	0.890	0.880	0.827

The Rose Creek results were subsequently dropped from the analysis as being too short. Expressed as a percentage, the minimum daily flows for February, March and April are, on average, equal to 89%, 88% and 83% of the monthly flows, respectively.

4.3 Annual 10-Year 7-Day Low Flows

An analysis of annual 7-day low flows was conducted for four streams which had 10 or more years of data which is the accepted minimum requirement for frequency analysis. The Consolidated Frequency Analysis computer program (Version 3.1) was utilized in the analysis. The frequency estimates derived from this program were plotted on probability graph paper in order to interpolate the 10-year return period low flow estimates. Results are given below.

Stream	Drainage Area		Record	10-year 7-day Low Flow
	km^2	years	m^3/s	$l/s/km^2$
King Creek	13.7	13	0.008	0.58
Sidney Creek	372	12	0.43	1.16
Tom Creek	435	19	0.19	0.44
South MacMillan River	997	19	0.55	0.55

The 10-year 7-day low flows were relatively constant, on a unit runoff basis, except for the result for Sidney Creek which appeared to be excessively high and was therefore omitted. The average 10-year 7-day low flow for the other three streams is 0.52 $l/s/km^2$ on a unit runoff basis.

4.4 10-Year 7-Day Low Flows for May, June, July, August and September

The daily flow records for the four streams listed in Section 4.3 were exported from the HYDAT CD-ROM in Lotus format and imported into Quattro Pro for analysis. Monthly 7-day low flows were extracted from the data and subsequently entered into the CFA program for frequency analysis. These estimates were subsequently plotted on probability paper in order to interpolate the 10-year 7-day low flows. Results of this analysis are listed below.

Stream	Drainage Area	Month	10-year 7-day Low Flow	
	km^2		m^3/s	$l/s/km^2$
King Creek	13.7	May	0.015	1.10
		June	0.166	12.1
		July	0.093	6.79
		Aug	0.068	4.96
		Sep	0.054	3.94
Sidney Creek	372	May	0.600	1.61
		June	6.40	17.2
		July	2.38	6.40
		Aug	1.69	4.54
		Sep	2.08	5.59
Tom Creek	435	May	0.800	1.84
		June	2.30	5.29
		July	1.56	3.59
		Aug	1.12	2.57
		Sep	1.30	2.99
South MacMillan River	997	May	1.10	1.10
		June	44.0	44.1
		July	25.8	25.9
		Aug	13.8	13.8
		Sep	9.55	9.58

Monthly estimates of 10-year 7-day low flows were determined by averaging the above results as listed below:

- 10-year 7-day low flow for May = 1.41 $l/s/km^2$
- 10-year 7-day low flow for June = 19.7 $l/s/km^2$
- 10-year 7-day low flow for July = 10.7 $l/s/km^2$
- 10-year 7-day low flow for Aug = 6.47 $l/s/km^2$
- 10-year 7-day low flow for Sep = 5.53 $l/s/km^2$

The above low flow unit runoff estimates may be factored by drainage area to obtain low flow estimates in the mine area.

5. Site Data - Hydrometric Station Installations

Evaluation of the runoff characteristics for Kudz Ze Kayah also included the collection and analysis of site specific hydrologic data. Installation of these hydrometric stations was conducted by Via-Sat Data Systems. The following equipment was installed:

- Two automated stage recorders: pressure transducers and data loggers were employed to collect a continuous record of stage. Stage was recorded every 15 minutes, and upon completion of a stage-discharge curve, a continuous record of discharge was produced. The locations of these stations were Geona Creek and Lower Finlayson Creek.

- Four staff gauge sites: staff gauges were installed at Fault Creek, South Creek, East Creek and Upper Finlayson Creek. Stage was read manually from the staff gauge on a regular basis, and upon completion of a stage-discharge curve, a discharge value was calculated for each stage reading collected.

The locations of these data collection sites are shown in Appendix 3.1 on Figure 3.1.3. Sites were chosen on the basis of preliminary information with respect to the location of potential tailings storage areas. Drainage areas are listed below for each hydrometric station shown on the above figure.

Catchment	**Drainage Area km^2**
South Creek	9.82
Fault Creek	1.94
Geona Creek	26.2
East Creek	73.4
Upper Finlayson Creek	153
Lower Finlayson Creek	191

6. Site Data - Hydrometric Station Operation

Installation of the hydrologic monitoring equipment was initiated in early April, however, some sites were still frozen. Some of the staff gauges were installed between April 10 and 12. Reliable data was collected a few weeks later when the water surface had thawed sufficiently. In early April, the only creek which had thawed enough to allow discharge measurements to be made was Geona Creek. All other discharge measurements for the hydrologic monitoring stations were collected between May 3 and 10, on June 28, between July 1 and 18, between August 4 and 7, on August 20, and between August 28 and September 3. Each station had between 5 and 7 simultaneous stage and discharge measurements. The stage-discharge relationship was re-evaluated to produce a revised rating curve for each station following each set of additional flow measurements. The best fit was obtained for the recording gauge on Geona Creek which had an R^2 of 0.987 corresponding to a coefficient of variation of 8.2%. The poorest fit was determined for the rating curve on South Creek which had an R^2 of 0.762 corresponding to a coefficient of variation of 30.4%.

The rating curve initially developed for Fault Creek was not considered reliable due to the bouldery channel bed, however, data collected subsequent to May 7 has resulted in an acceptable stage-discharge curve which provides a reasonable fit to the data. Stage-discharge rating curves for all six sites are listed in Table 3.2A.7 and plotted on Figures 3.2A.1 to 3.2A.3.

7. Site Data - Recording Gauges

For the two automated sites, data collection began in late April. On Geona Creek, ice breakup was observed to begin on approximately April 27. An initial maximum of 0.72 m^3/s was recorded on April 28, after which flows fluctuated for a few weeks. A second, higher peak flow of 0.98 m^3/s then occurred on May 14, Figure 3.2A.4. Maximum discharges in Geona Creek following the rainstorm of June 4-6 were just slightly less than those recorded during ice breakup and snowmelt: a discharge of 0.96 m^3/s was recorded on June 6 at 01:30. Following recession of the stormflow, discharge remained below 0.6 m^3/s until September 2. As a comparison, the minimum flow recorded on Geona Creek during the period of observation was 0.14 m^3/s.

The ice breakup on Lower Finlayson Creek began in early May. The associated peak discharges occurred between May 12 and 14: there was a small peak on May 12 of 3.69 m^3/s, and a slightly larger maximum of 3.89 m^3/s on May 14. These snowmelt maxima were exceeded by the discharges produced by the rainstorm of June 4-6. The stage began to rise on June 5, and the peak discharge of 5.92 m^3/s occurred at 18:00 on June 6. Following recession of the stormflow, discharge remained below 3.0 m^3/s until September 2. As a comparison, the minimum flow recorded at this station during the period of observation was 0.22 m^3/s.

8. Site Data - Manual Gauges

For the manually read staff gauge stations, installations were completed in early May, and daily stage readings were initiated on May 3 for South and Fault Creeks, and May 6 for Upper Finlayson and East Creeks. On all four creeks, the peak flows associated with snowmelt and ice breakup occurred between May 11 and 13. Measurement of the discharge on East Creek is complicated by the presence of some large boulders. A discharge estimate for East Creek was obtained by subtracting the measured discharge on Finlayson Creek, upstream of the East Creek confluence, from the measured discharge on Finlayson Creek, downstream of the confluence. This discharge estimate was then compared to the East Creek staff gauge reading to obtain the rating curve.

Peak flow (freshet) measurements at the various gauge locations are as follows:

- Fault Creek = 0.09 m^3/s on May 13
- South Creek = 0.29 m^3/s on May 13
- East Creek = 1.65 m^3/s on May 12
- Upper Finlayson Creek = 2.60 m^3/s on May 11

The peak discharges associated with the storm event of June 4-6 exceeded the freshet discharges for both Upper Finlayson and East Creek and almost equalled the freshet discharge for South and Fault Creeks:

- Fault Creek = 0.08 m^3/s
- South Creek = 0.27 m^3/s
- East Creek = 2.37 m^3/s
- Upper Finlayson Creek = 3.93 m^3/s

The above peak discharges occurred on June 5 and 6. Following recession of the storm flows, discharges remained relatively low for the remainder of the summer. Maximum and minimum flows during this latter period were as follows:

- Fault Creek = 0.04 to 0.01 m^3/s
- South Creek = 0.15 to 0.05 m^3/s
- East Creek = 0.71 m^3/s
- Upper Finlayson Creek = 1.33 to 0.29 m^3/s

The lowest flows recorded on each creek during the data collection period occurred in late July. The minimum value determined for East Creek, determined by subtraction of flows, was not considered reliable and has therefore been omitted.

Discharge measurements for each of the gauges are listed in Table 3.2A.8. Daily flow records for the manual gauges are listed in Tables 3.2A.9 to 3.2A.12. Correlation with regional station records was not possible as neither WSC nor DIAND were able to supply 1995 data in time to be incorporated into this study. An examination of the snowpack at regional snow course stations, Appendix 3.1 - Section 5.5, revealed the April 1, 1995 snowpack to be significantly below normal (66 to 92 percent of normal). Streamflow in the Kudz Ze Kayah area would therefore be expected to be below average for the 1995 freshet.

Table 3.2A.1

Mean Monthly Runoff Depth (mm) from Streamflow Records

Sta. No.	Name	D.A. km²	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Annual Total mm
DIAND															
29AE003	Partridge C.	63.7	-	-	-	-	108.5	181.1	82.3	47.1	53.7	-	-	-	E 573
29BA002	180 Mile C.	83.1	-	-	-	-	109.3	123.8	58.0	40.3	37.7	24.5	-	-	E 443
WSC															
10AB003	King C.	13.7	5.28	4.24	3.91	3.97	48.1	88.4	53.6	25.8	19.9	18.2	10.4	6.65	290
09BC003	Rose C.	208	3.67	2.45	2.65	3.03	42.4	89.5	43.4	38.8	34.9	15.7	9.47	6.89	358
09AD002	Sidney C.	372	7.70	5.66	5.49	6.87	65.9	115.0	53.3	26.7	26.0	23.3	12.3	9.94	355
10AA002	Tom C.	435	3.48	2.59	2.70	4.77	54.6	53.1	36.4	16.4	15.0	14.9	7.75	4.90	217
10AA005	Big C.	607	13.6	10.6	11.2	14.8	62.7	91.4	49.4	28.9	32.6	28.6	18.3	16.0	378
09BB001	S. MacMillan R.	997	5.99	3.69	3.52	4.13	77.6	210	138	78.7	56.7	34.9	15.1	9.00	639
10AD002	Hyland R.	2150	7.96	6.00	5.73	5.88	60.3	206	154	81.8	55.3	36.3	16.9	11.4	648
09BA002	Pelly R. below F.C.	5020	5.34	3.51	3.26	4.00	94.4	147	79.0	48.2	47.6	34.0	12.7	8.91	488
10AA004	Rancheria R.	5100	8.19	5.98	5.67	5.95	39.0	94.5	64.6	29.9	25.9	24.6	14.3	10.6	327
09BA001	Ross R. at R. R.	7250	3.36	2.38	2.36	2.86	61.7	91.2	46.2	29.8	25.5	18.7	7.08	5.02	294
09AD001	Nisutlin R.	8030	6.84	4.82	4.97	6.68	57.4	110.4	61.0	30.0	27.0	27.3	15.4	10.0	362
10AB001	Frances R.	12800	6.95	5.03	4.90	5.20	38.5	115	81.4	46.7	35.4	29.3	15.6	9.92	394
09BC002	Pelly R. at R. R.	18400	3.36	2.45	2.47	2.73	51.7	101	51.4	33.8	27.8	18.8	7.80	5.30	321
09BC004	Pelly R. below V.C.	22100	3.70	2.66	2.57	3.14	54.7	84.8	48.2	30.7	26.6	20.1	8.48	5.37	293
09AE001	Teslin R. at Teslin	30300	8.82	6.79	6.92	6.36	22.3	76.0	64.3	36.9	28.0	27.2	18.0	11.9	316
10AA001	Liard R. at U.C.	33400	7.75	5.68	5.57	6.43	44.4	105	66.8	37.0	30.8	26.3	13.7	10.3	360
Average	*All Stations*		*6.37*	*4.66*	*4.62*	*5.43*	*60.8*	*115.7*	*68.4*	*39.3*	*33.7*	*24.9*	*12.7*	*8.88*	*385*
Average	*Stations <1000 km²*		*6.62*	*4.87*	*4.91*	*6.26*	*71.1*	*119*	*64.3*	*37.8*	*34.6*	*22.9*	*12.2*	*8.90*	*393*

E = Estimated

Table 3.2A.2

Annual Runoff Depth - mm

Stream	**Drainage Area - km²**	**Annual Runoff - mm**
Partridge C.	63.7 km^2	573 E
180 Mile C.	83.1 km^2	443 E
King C.	13.7 km^2	290
Rose C.	208 km^2	358
Sidney C.	372 km^2	355
Pelly R. below F.C.	5020 km^2	488
Frances R.	12800 km^2	394
Average		414

Table 3.2A.3

Mean Monthly Runoff Depth - mm

Month	**Average of 3 small catchments mm**	**Monthly Distribution %**	**KZK Monthly Unit Runoff mm**	**KZK Monthly Unit Runoff mm (above dam*)**
January	5.55	1.77	**7.3**	**3.7**
February	4.12	1.32	**5.5**	**2.7**
March	4.02	1.28	**5.3**	**2.7**
April	4.62	1.48	**6.1**	**3.1**
May	52.1	16.6	68.9	**74.7**
June	97.6	31.2	129.0	**140**
July	50.1	16.0	66.2	**71.8**
August	30.4	9.71	40.2	**43.6**
September	26.9	8.59	35.6	**38.6**
October	19.1	6.10	25.3	**16.9**
November	10.7	3.42	14.1	**9.4**
December	7.83	2.50	10.4	**6.9**
Annual	313.16	100	414	**414**

* winter flows reduced upstream of tailings dam

Table 3.2A.4
Frequency Analysis of Annual Runoff

Return Period years	Exceedance Probability	Ratio to Mean Ross River	Ratio to Mean Liard River	KZK Average Runoff Ratio
1.003	0.997	0.550	0.607	0.579
1.05	0.952	0.723	0.751	0.737
1.25	0.800	0.862	0.870	0.866
2	0.500	1.004	0.996	1.000
5	0.200	1.140	1.127	1.134
10	0.100	1.208	1.198	1.203
20	0.050	1.262	1.258	1.260
50	0.020	1.319	1.327	1.323
100	0.010	1.355	1.374	1.365
200	0.005	1.386	1.419	1.403
500	0.002	1.421	1.471	1.446

Table 3.2A.5

Runoff Frequency Estimates - mm

Return Period	Exceedance Probability	Ratio to Mean	KZK Annual Runoff mm
1 in 500 year low flow	0.998	0.560	231
1 in 200 year low flow	0.995	0.602	249
1 in 100 year low flow	0.990	0.639	264
1 in 50 year low flow	0.980	0.679	281
1 in 20 year low flow	0.950	0.741	306
1 in 10 year low flow	0.900	0.799	330
1 in 5 year low flow	0.800	0.866	358
1 in 2 year flow (mean)	0.500	1.000	413.2
1 in 5 year high flow	0.200	1.134	469
1 in 10 year high flow	0.100	1.203	497
1 in 20 year high flow	0.050	1.260	521
1 in 50 year high flow	0.020	1.323	547
1 in 100 year high flow	0.010	1.365	564
1 in 200 year high flow	0.005	1.403	580
1 in 500 year high flow	0.002	1.446	597

Table 3.2A.6

25-Year Low Monthly Flow Analysis

Stream	Drainage Area km^2	October 25-Yr Low Flow m^3/s	October Mean Monthly Flow m^3/s	Ratio 25-Yr low flow to Mean flow
Ross River	7250	26.6	50.6	0.526
South MacMillan River	997	6.6	13.0	0.508
Tom Creek	435	1.25	2.42	0.517
Sidney Creek	372	1.66	3.23	0.514
King Creek	13.7	0.041	0.093	0.441

Table 3.2A.7
Stage-Discharge Rating Curves

Site	Stage-discharge equation	Sample size	R Sqr.	Coefficient of Variation
Lower Finlayson Creek	Q= 9.969 (S) -3.752	5	0.976	11.7%
Geona Creek	Q= 1.307 (S) -0.288	7	0.987	8.2%
South Creek	Q= 1.066 (S) -0.180	6	0.762	30.4%
East Creek	Q= 10.384 (S) -0.683	5	0.956	21.6%
Upper Finlayson Creek	Q= 8.074 (S) -1.517	6	0.987	8.3%
Fault Creek	Q= 0.680 (S) -0.014	5	0.892	

Table 3.2A.8
Discharge Measurements

STATION	DATE	DISCHARGE m^3/s	STAGE m
Fault Creek	May 7	0.005	0.065*
	May 10	0.027	0.102*
	June 28	0.021	0.056
	July 1	0.024	0.062
	July 11	0.015	0.044
	July 18	0.012	0.035
	Sep 3	0.039	0.072
South Creek	May 4	0.067	0.245
	May 8	0.188	0.311
	July 1	0.061	0.214
	July 11	0.054	0.208
	Aug 7	0.072	0.260
	Aug 28	0.109	0.294
Upper Finlayson Creek (below East Creek)	May 4	2.38	0.490
	May 9	2.27	0.455
	July 13	0.523	0.244
	Aug 4	0.650	0.286
	Aug 20	0.623	0.258
	Sep 2	1.29	0.352
East Creek	May 4	1.78	0.225
	May 9	1.47	0.210
	July 13	0.187	0.066
	Aug 4	0.222	0.095
	Sep 2	0.509	0.134

Geona Creek (datalogger)	Apr 10	0.038	0.240
	May 4	0.334	0.465
	May 10	0.477	0.585
	July 1	0.150	0.362
	July 15	0.138	0.324
	Aug 5	0.160	0.340
	Sep 2	0.253	0.412
Lower Finlayson Creek (datalogger)	May 3	2.86	0.645
	May 10	2.18	0.612
	July 13	0.645	0.430
	Aug 4	1.04	0.494
	Aug 20	0.765	0.452

TABLE 3.2A.9
FAULT CREEK- ESTIMATED FLOWS 1995

Date	Time	Stage (m)	Discharge (m3/s)	Remarks
3-May	1930	0.070	0.033	relocated to a better location
4-May	1855	0.074	0.036	
5-May	1900	0.076	0.037	
6-May	1850	0.086	0.044	
7-May	1900	0.065	0.030	
8-May	1910	0.082	0.041	
9-May	1845	0.086	0.044	
10-May	1845	0.102	0.055	
11-May	1900	0.128	0.073	
12-May	1910	0.144	0.084	turbidity level has increased
13-May	1850	0.165	0.098	high sediment load, warm weather
14-May	1905	0.122	0.069	cooler temperatures, precipitation (some snow)
15-May	1850	0.102	0.055	turbidity has decreased
16-May	1845	0.086	0.044	
17-May	1905	0.072	0.035	
18-May	1925	0.065	0.030	cool temperatures (10cm snow)
19-May	1900	0.060	0.026	
20-May	1915	0.059	0.026	
21-May	1900	0.065	0.030	
22-May	1905	0.078	0.039	precipitation
23-May	1905	0.079	0.039	
24-May	1900	0.102	0.055	warm temperatures
25-May	1920	0.140	0.081	
26-May	1910	0.130	0.074	
27-May	1829	0.125	0.071	
28-May	1940	0.106	0.058	
29-May	2000	0.090	0.047	
30-May	1915	0.081	0.041	
31-May	1905	0.080	0.040	
1-Jun	1900	0.078	0.039	
2-Jun	1905	0.081	0.041	
3-Jun	1910	0.075	0.037	
4-Jun	1900	0.085	0.043	precipitation
5-Jun	1955	0.155	0.091	precipitation
6-Jun	1600	0.132	0.075	precipitation ending in the morning
6-Jun	1905	0.137	0.079	
7-Jun	1905	0.132	0.075	
8-Jun	1915	0.128	0.073	
9-Jun	1910	0.128	0.073	
10-Jun	1915	0.125	0.071	
11-Jun	1945	0.120	0.067	
12-Jun	1955	0.110	0.060	
13-Jun	1945	0.118	0.066	
14-Jun	1945	0.118	0.066	
15-Jun	1245	0.112	0.062	
16-Jun				
17-Jun				
18-Jun				
19-Jun	1922	0.090	0.047	

TABLE 3.2A.9
FAULT CREEK- ESTIMATED FLOWS 1995

20-Jun	1915	0.085	0.043					
21-Jun	1900	0.082	0.041					
22-Jun	1910	0.084	0.043					
23-Jun	1910	0.075	0.037					
24-Jun	1920	0.066	0.030					
25-Jun	1905	0.064	0.029					
26-Jun	1855	0.058	0.025					
27-Jun	2000	0.054	0.022					
28-Jun	1930	0.054	0.022					
29-Jun	1840	0.050	0.020					
30-Jun	1910	0.048	0.018					
1-Jul	1830	0.062	0.028					
2-Jul	1900	0.048	0.018					
3-Jul	1930	0.058	0.025					
4-Jul	1930	0.062	0.028					
5-Jul	1920	0.058	0.025					
6-Jul	1905	0.056	0.024					
7-Jul	1915	0.056	0.024					
8-Jul	1915	0.062	0.028					
9-Jul	1845	0.050	0.020					
10-Jul	1945	0.046	0.017					
11-Jul	1920	0.045	0.016					
12-Jul								
13-Jul								
14-Jul								
15-Jul								
16-Jul								
17-Jul								
18-Jul								
19-Jul								
20-Jul								
21-Jul	1915	0.032	0.007					
22-Jul								
23-Jul								
24-Jul	1948	0.034	0.009					
25-Jul								
26-Jul				heavy precipitation				
27-Jul	1610	0.034	0.009	precipitation				
28-Jul								
29-Jul								
30-Jul	1800	0.056	0.024	precipitation				
31-Jul								
1-Aug								
2-Aug	1900	0.056	0.024					
3-Aug	1915	0.056	0.024					
4-Aug	1900	0.056	0.024					
5-Aug	1935	0.056	0.024					
6-Aug	1855	0.056	0.024					
7-Aug	1930	0.054	0.022					
8-Aug	1900	0.052	0.021					
9-Aug	1915	0.050	0.020					

TABLE 3.2A.9

FAULT CREEK- ESTIMATED FLOWS 1995

10-Aug	1920	0.048	0.018					
11-Aug	1935	0.048	0.018					
12-Aug	1910	0.048	0.018					
13-Aug	1925	0.048	0.018					
14-Aug	185	0.046	0.017					
15-Aug	1950	0.046	0.017					
16-Aug	1950	0.045	0.016					
17-Aug	1900	0.042	0.014					
18-Aug	1905	0.042	0.014					
19-Aug	1855	0.042	0.014					
20-Aug	1845	0.042	0.014					
21-Aug	2010	0.055	0.023					
22-Aug	1850	0.048	0.018	heavy precipitation overnight				
23-Aug	1915	0.050	0.020					
24-Aug	1900	0.048	0.018					
25-Aug	1915	0.048	0.018					
26-Aug	1945	0.048	0.018					
27-Aug	1850	0.050	0.020					
28-Aug	1935	0.050	0.020					
29-Aug	1715	0.052	0.021					
30-Aug	1930	0.054	0.022					
31-Aug	1845	0.054	0.022					
1-Sep	1850	0.056	0.024	precipitation				
2-Sep	1945	0.076	0.037	precipitation				
3-Sep	1855	0.070	0.033					
4-Sep	1935	0.064	0.029					

TABLE 3.2A.10
SOUTH CREEK- ESTIMATED FLOWS 1995

Date	Time	Stage (m)	Discharge (m3/s)	Remarks
3-May	1730	0.312	0.152	staff gauge reinforced
6-May	1615	0.310	0.150	
7-May	1624	0.288	0.126	
8-May	1600	0.311	0.151	
9-May	1455	0.308	0.148	
10-May	1729	0.345	0.187	
11-May	1645	0.378	0.222	
12-May	1715	0.394	0.239	
13-May	1641	0.440	0.288	warm weather (up to 20 degrees celcius)
14-May	1700	0.340	0.182	cooler temperatures, precipitation (some snow)
15-May	1705	0.308	0.148	
16-May	1750	0.274	0.112	
17-May	1620	0.245	0.081	
18-May	1744	0.252	0.088	cool temperatures (10 cm snow)
19-May	1540	0.252	0.088	
20-May	1650	0.224	0.058	
21-May	1721	0.214	0.048	
22-May	1628	0.212	0.046	precipitation
23-May	1622	0.236	0.071	
24-May	1740	0.248	0.084	warm temperatures
25-May	1637	0.325	0.166	
26-May	1830	0.308	0.148	
27-May	1655	0.294	0.133	
28-May	1609	0.274	0.112	
29-May	1702	0.252	0.088	
30-May	1715	0.242	0.078	
31-May	1730	0.225	0.059	
1-Jun	1643	0.226	0.061	
2-Jun	1811	0.230	0.065	
3-Jun	1740	0.238	0.073	
4-Jun	1630	0.232	0.067	precipitation
5-Jun	1545	0.270	0.107	precipitation
6-Jun	1710	0.425	0.272	precipitation ending in the morning
7-Jun				
8-Jun	1623	0.328	0.169	
9-Jun				
10-Jun				
11-Jun				
12-Jun	1630	0.296	0.135	
13-Jun				
14-Jun				
15-Jun				
16-Jun				
17-Jun				
18-Jun				
19-Jun				
20-Jun	1629	0.274	0.112	
21-Jun				
22-Jun				

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TABLE 3.2A.10
SOUTH CREEK- ESTIMATED FLOWS 1995

23-Jun	1600	0.245	0.081					
24-Jun								
25-Jun								
26-Jun	1655	0.226	0.061					
27-Jun								
28-Jun								
29-Jun	1628	0.210	0.044					
30-Jun								
1-Jul	930	0.214	0.048	stream gauging				
2-Jul	1723	0.232	0.067	precipitation				
3-Jul								
4-Jul								
5-Jul	1605	0.238	0.073					
6-Jul								
7-Jul								
8-Jul	1815	0.237	0.072					
9-Jul								
10-Jul								
11-Jul	850	0.208	0.041	stream gauging				
12-Jul								
13-Jul								
14-Jul								
15-Jul								
16-Jul								
17-Jul								
18-Jul								
19-Jul								
20-Jul								
21-Jul	1825	0.216	0.050					
22-Jul								
23-Jul								
24-Jul				helicopter unavailable				
25-Jul								
26-Jul				heavy precipitation				
27-Jul	1531	0.272	0.109	precipitation				
28-Jul								
29-Jul								
30-Jul	1720	0.252	0.088	precipitation				
31-Jul								
1-Aug								
2-Aug	1610	0.248	0.084					
3-Aug								
4-Aug								
5-Aug	1520	0.258	0.095					
6-Aug								
7-Aug								
8-Aug	1808	0.254	0.090					
9-Aug								
10-Aug								
11-Aug	1630	0.254	0.090					
12-Aug								

TABLE 3.2A.10
SOUTH CREEK- ESTIMATED FLOWS 1995

13-Aug								
14-Aug								
15-Aug	1405	0.254	0.090	helicopter unavailable				
16-Aug								
17-Aug								
18-Aug	1805	0.252	0.088					
19-Aug								
20-Aug								
21-Aug	1645	0.252	0.088					
22-Aug	1020	0.302	0.141	heavy precipitation				
23-Aug								
24-Aug	1825	0.278	0.116					
25-Aug								
26-Aug								
27-Aug	1650	0.278	0.116					
28-Aug								
29-Aug								
30-Aug								
31-Aug	1630	0.292	0.131					
1-Sep								
2-Sep	1615	0.310	0.150					
3-Sep								
4-Sep								
5-Sep	1350	0.298	0.137					

TABLE 3.2A.11
EAST CREEK- ESTIMATED FLOWS 1995

Date	Time	Stage (m)	Discharge (m3/s)	Remarks
6-May	1600	0.212	1.519	Staff gauge installed
7-May	1636	0.210	1.498	
8-May	1640	0.210	1.498	
9-May	1620	0.210	1.498	
10-May	1717	0.212	1.519	
11-May	1655	0.220	1.602	
12-May	1735	0.225	1.654	
13-May	1650	0.214	1.540	
14-May	1715	0.214	1.540	
15-May	1740	0.185	1.239	water turbidity has decreased
16-May	1705	0.164	1.020	creek was very turbid up to this point
17-May	1655	0.146	0.834	
18-May	1800	0.132	0.688	cool temperatures (10cm snow)
19-May	1626	0.128	0.647	
20-May	1715	0.120	0.564	
21-May	1627	0.112	0.481	
22-May	1615	0.112	0.481	precipitation
23-May	1645	0.118	0.543	
24-May	1651	0.114	0.501	warm temperatures
25-May	1700	0.110	0.460	
26-May	1847	0.105	0.408	
27-May	1716	0.102	0.377	
28-May	1624	0.096	0.314	
29-May	1718	0.092	0.273	
30-May	1656	0.085	0.200	
31-May	1754	0.079	0.138	
1-Jun	1613	0.074	0.086	
2-Jun	1824	0.076	0.107	
3-Jun	1755	0.079	0.138	
4-Jun	1642	0.074	0.086	precipiation
5-Jun	1602	0.092	0.273	precipitation
6-Jun	1155	0.245	1.862	precipitation ending in the morning
6-Jun	1722	0.294	2.370	
7-Jun				
8-Jun	1642	0.202	1.415	
9-Jun				
10-Jun				
11-Jun				
12-Jun	1640	0.122	0.584	
13-Jun				
14-Jun				
15-Jun				
16-Jun				
17-Jun				
18-Jun				
19-Jun				
20-Jun	1644	0.111	0.470	
21-Jun				
22-Jun				

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TABLE 3.2A.11
EAST CREEK- ESTIMATED FLOWS 1995

23-Jun	1615	0.102	0.377					
24-Jun								
25-Jun								
26-Jun	1705	0.092	0.273					
27-Jun								
28-Jun								
29-Jun	1617	0.082	0.169					
30-Jun								
1-Jul				precipitation				
2-Jul	1715	0.094	0.294	precipitation				
3-Jul								
4-Jul								
5-Jul	1550	0.102	0.377					
6-Jul								
7-Jul								
8-Jul	1810	0.088	0.231					
9-Jul								
10-Jul								
11-Jul	1805	0.076	0.107					
12-Jul								
13-Jul								
14-Jul								
15-Jul								
16-Jul								
17-Jul								
18-Jul								
19-Jul								
20-Jul								
21-Jul	2045	0.052	-0.143					
22-Jul								
23-Jul								
24-Jul				helicopter unavailable				
25-Jul								
26-Jul				heavy precipitation				
27-Jul	1548	0.092	0.273	precipitation				
28-Jul								
29-Jul								
30-Jul	1735	0.102	0.377	precipitation				
31-Jul								
1-Aug								
2-Aug	1549	0.102	0.377					
3-Aug								
4-Aug								
5-Aug	1512	0.092	0.273					
6-Aug								
7-Aug								
8-Aug	1715	0.085	0.200					
9-Aug								
10-Aug								
11-Aug	1640	0.096	0.314					
12-Aug								

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TABLE 3.2A.11
EAST CREEK- ESTIMATED FLOWS 1995

13-Aug								
14-Aug				helicopter unavailable				
15-Aug	1445	0.058	-0.080	East Lake continues to rise (beaver dam)				
16-Aug								
17-Aug								
18-Aug	1735	0.070	0.044					
19-Aug								
20-Aug								
21-Aug	1635	0.074	0.086					
22-Aug	1620	0.096	0.314	heavy precipitation overnight				
23-Aug								
24-Aug	1730	0.090	0.252					
25-Aug								
26-Aug								
27-Aug	1625	0.092	0.273					
28-Aug								
29-Aug								
30-Aug				helicopter unavailable				
31-Aug	1630	0.110	0.460					
1-Sep								
2-Sep	1500	0.134	0.709	precipitation				
3-Sep								
4-Sep								
5-Sep	1315	0.125	0.616	East Lake risen approx. 1 m due to beaver dam				

TABLE 3.2A.12
UPPER FINLAYSON CREEK- ESTIMATED FLOWS 1995

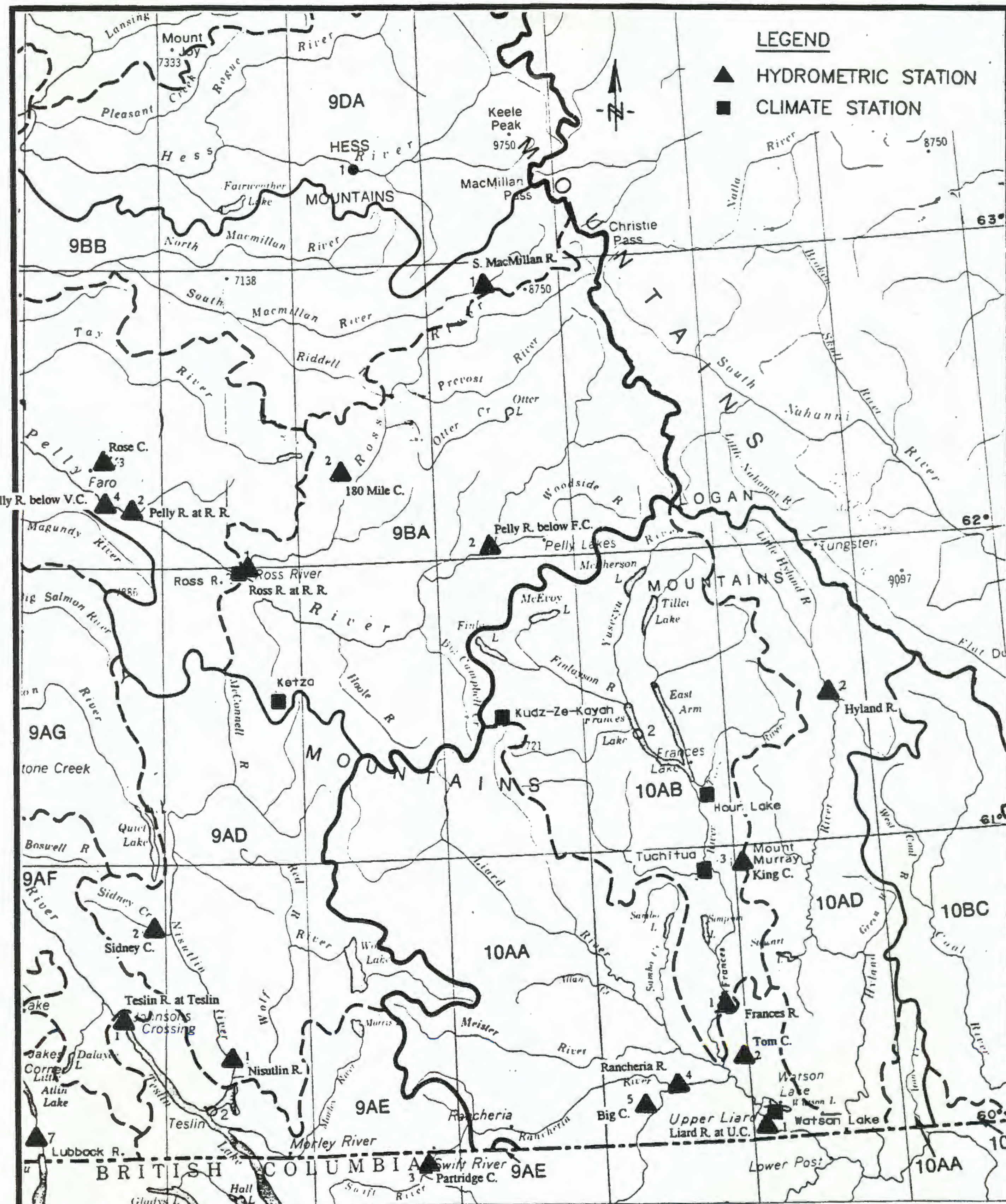
Date	Time	Stage (m)	Temp. Staff	Discharg (m3/s)	Remarks
6-May	1600	0.500	0.550	2.520	Temporary staff gauge installed
7-May	1635	0.486	0.536	2.407	
8-May	1645	0.465	0.515	2.237	installed new staff gauge and removed temp. gauge
9-May	1600	0.455		2.157	(difference of 0.050 m lower)
10-May	1715	0.475		2.318	
11-May	1651	0.510		2.601	
12-May	1730	0.508		2.585	
13-May	1655	0.504		2.552	warm weather, up to 22 degrees Celcius
14-May	1720	0.498		2.504	cooler temperatures, precipitation (some snow)
15-May	1740	0.442		2.052	
16-May	1710	0.390		1.632	
17-May	1645	0.345		1.269	
18-May	1800	0.324		1.099	cool temperatures (10 cm snow)
19-May	1630	0.308		0.970	
20-May	1730	0.302		0.921	
21-May	1624	0.292		0.841	
22-May	1650	0.301		0.913	precipitation
23-May	1653	0.312		1.002	
24-May	1656	0.316		1.034	warm temperatures
25-May	1705	0.365		1.430	
26-May	1850	0.368		1.454	
27-May	1713	0.358		1.373	
28-May	1630	0.338		1.212	
29-May	1720	0.302		0.921	
30-May	1654	0.285		0.784	
31-May	1755	0.275		0.703	
1-Jun	1615	0.262		0.598	
2-Jun	1824	0.266		0.631	
3-Jun	1748	0.261		0.590	
4-Jun	1642	0.262		0.598	precipitation
5-Jun	1600	0.308		0.970	precipitation
6-Jun	1145	0.665		3.852	precipitation ending in the morning
6-Jun	1718	0.675		3.933	
7-Jun					
8-Jun	1645	0.462		2.213	
9-Jun					
10-Jun					
11-Jun					
12-Jun	1645	0.354		1.341	
13-Jun					
14-Jun					
15-Jun					
16-Jun					
17-Jun					
18-Jun					
19-Jun					
20-Jun	1650	0.308		0.970	
21-Jun					
22-Jun					

TABLE 3.2A.12
UPPER FINLAYSON CREEK- ESTIMATED FLOWS 1995

23-Jun	1616	0.298		0.889					
24-Jun									
25-Jun									
26-Jun	1700	0.276		0.711					
27-Jun									
28-Jun									
29-Jun	1615	0.265		0.623					
30-Jun									
1-Jul									
2-Jul	1715	0.274		0.695					
3-Jul									
4-Jul									
5-Jul	1547	0.290		0.824					
6-Jul									
7-Jul									
8-Jul	1805	0.268		0.647					
9-Jul									
10-Jul									
11-Jul	1800	0.250		0.502					
12-Jul									
13-Jul									
14-Jul									
15-Jul									
16-Jul									
17-Jul									
18-Jul									
19-Jul									
20-Jul									
21-Jul	1845	0.224		0.292					
22-Jul									
23-Jul									
24-Jul					helicopter unavailable				
25-Jul									
26-Jul					heavy precipitation				
27-Jul	1545	0.291		0.833	precipitation				
28-Jul									
29-Jul									
30-Jul	1738	0.303		0.929	precipitation				
31-Jul									
1-Aug									
2-Aug	1546	0.292		0.841					
3-Aug									
4-Aug									
5-Aug	1510	0.285		0.784					
6-Aug									
7-Aug									
8-Aug	1710	0.275		0.703					
9-Aug									
10-Aug									
11-Aug	1637	0.280		0.744					
12-Aug									

TABLE 3.2A.12
UPPER FINLAYSON CREEK- ESTIMATED FLOWS 1995

13-Aug									
14-Aug					helicopter unavailable				
15-Aug	1425	0.250		0.502					
16-Aug									
17-Aug									
18-Aug	1740	0.258		0.566					
19-Aug									
20-Aug									
21-Aug	1645	0.258		0.566					
22-Aug	1615	0.296		0.873	heavy precipitation overnight				
23-Aug									
24-Aug	1730	0.282		0.760					
25-Aug									
26-Aug									
27-Aug	1620	0.284		0.776					
28-Aug									
29-Aug									
30-Aug					helicopter unavailable				
31-Aug	1745	0.312		1.002					
1-Sep									
2-Sep	1600	0.352		1.325	precipitation				
3-Sep									
4-Sep									
5-Sep	1320	0.332		1.164					



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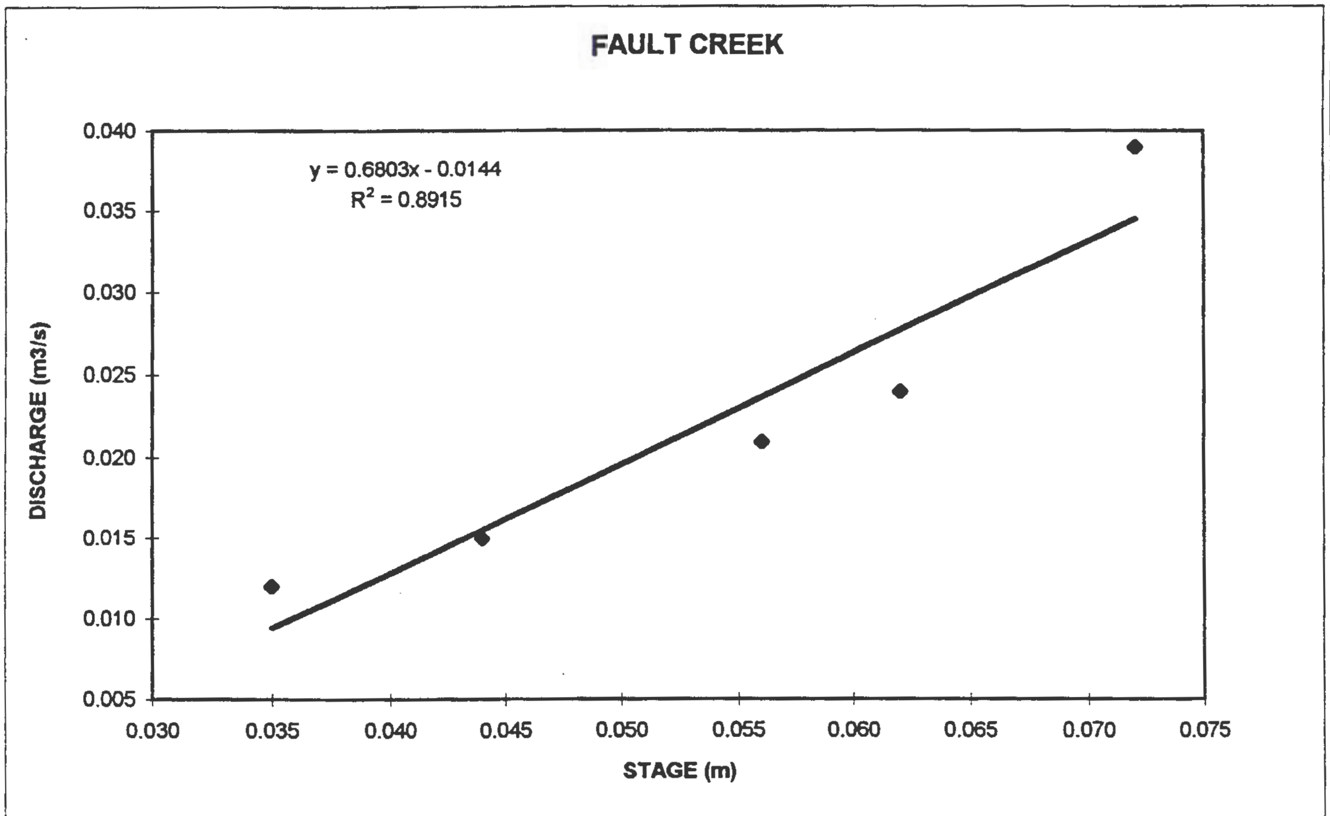
NORECOL, DAMES AND MOORE INC.

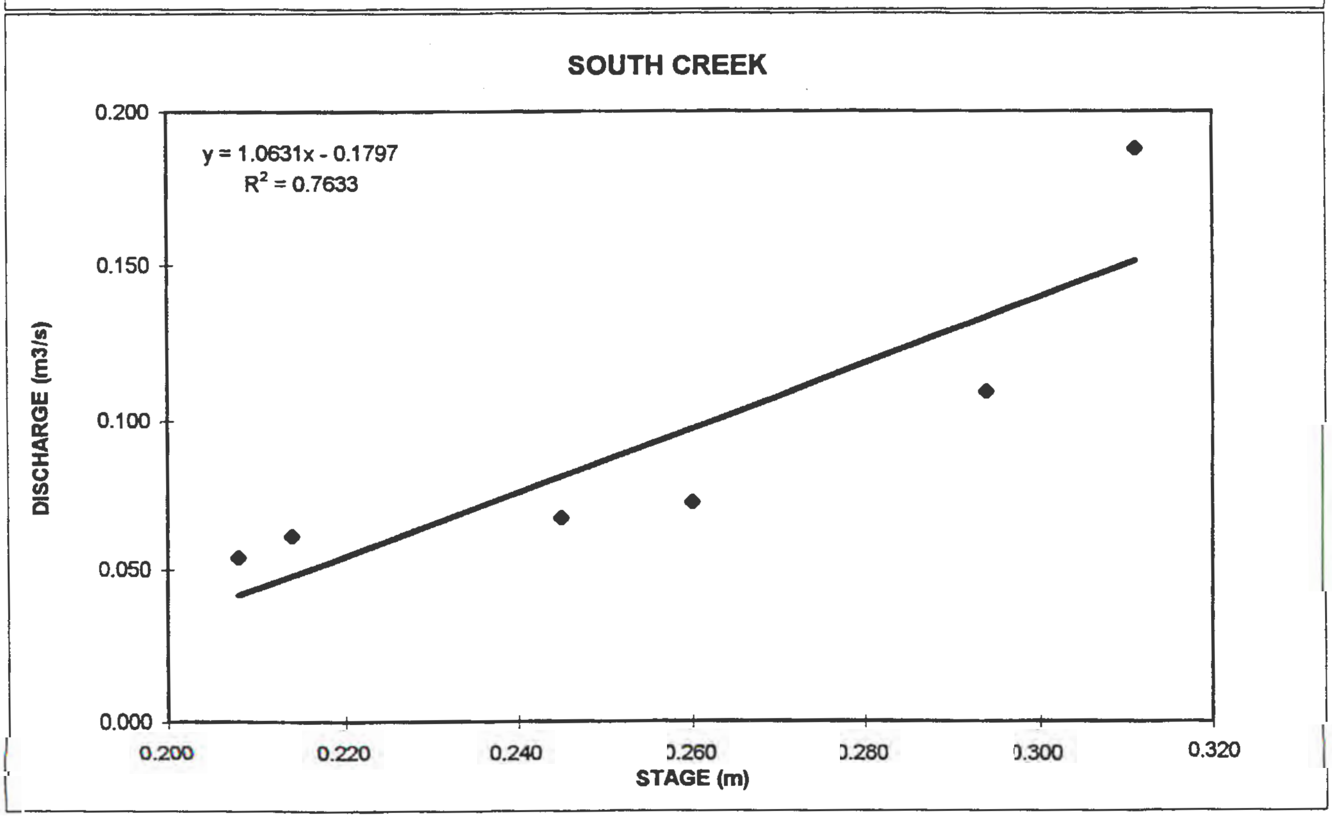
KUDZ – ZE – KAYAH PROJECT
REGIONAL FLOOD ANALYSIS

HYDROMETRIC AND CLIMATE STATIONS

FIG. **3.2.1**

CAD FILE : NDM-001 / NDM001MA.DGN/1995 NOV 08





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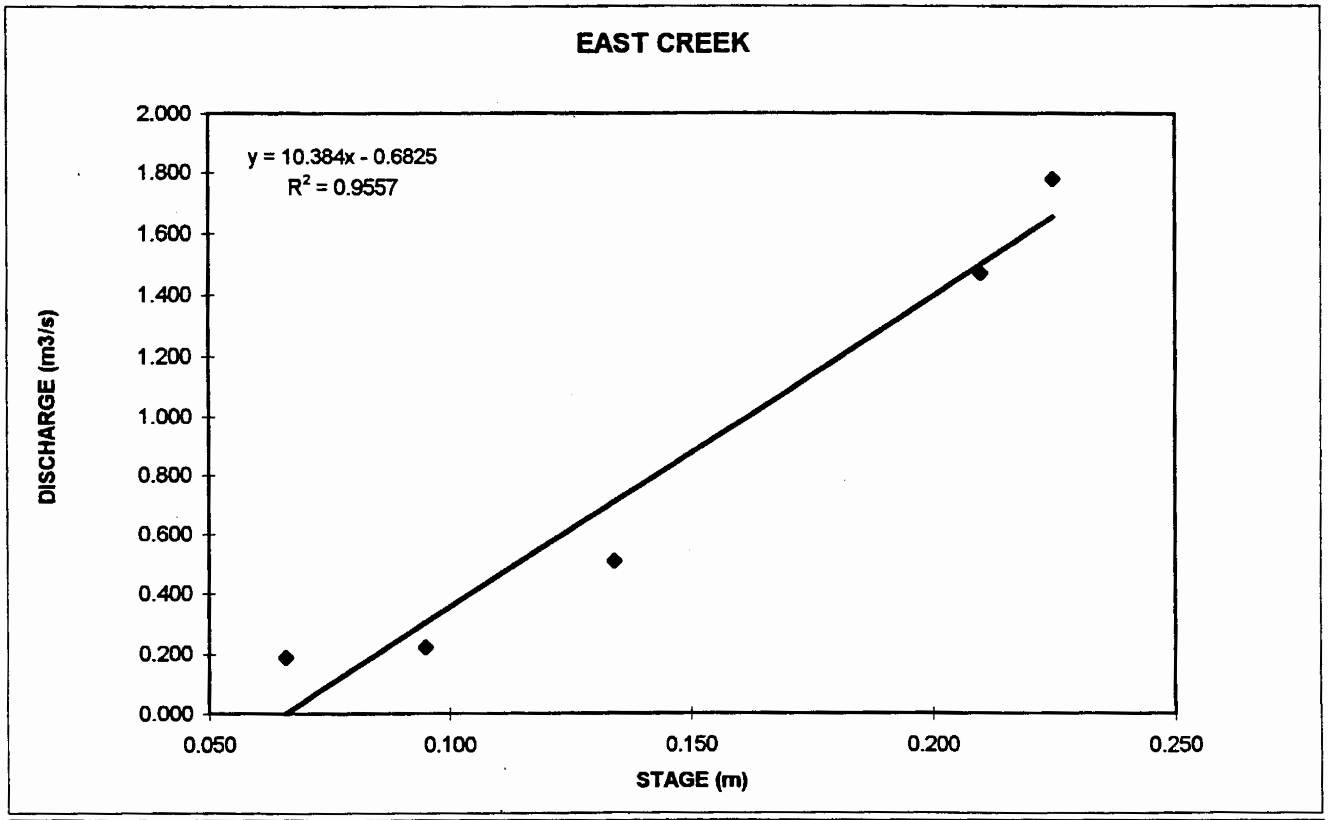
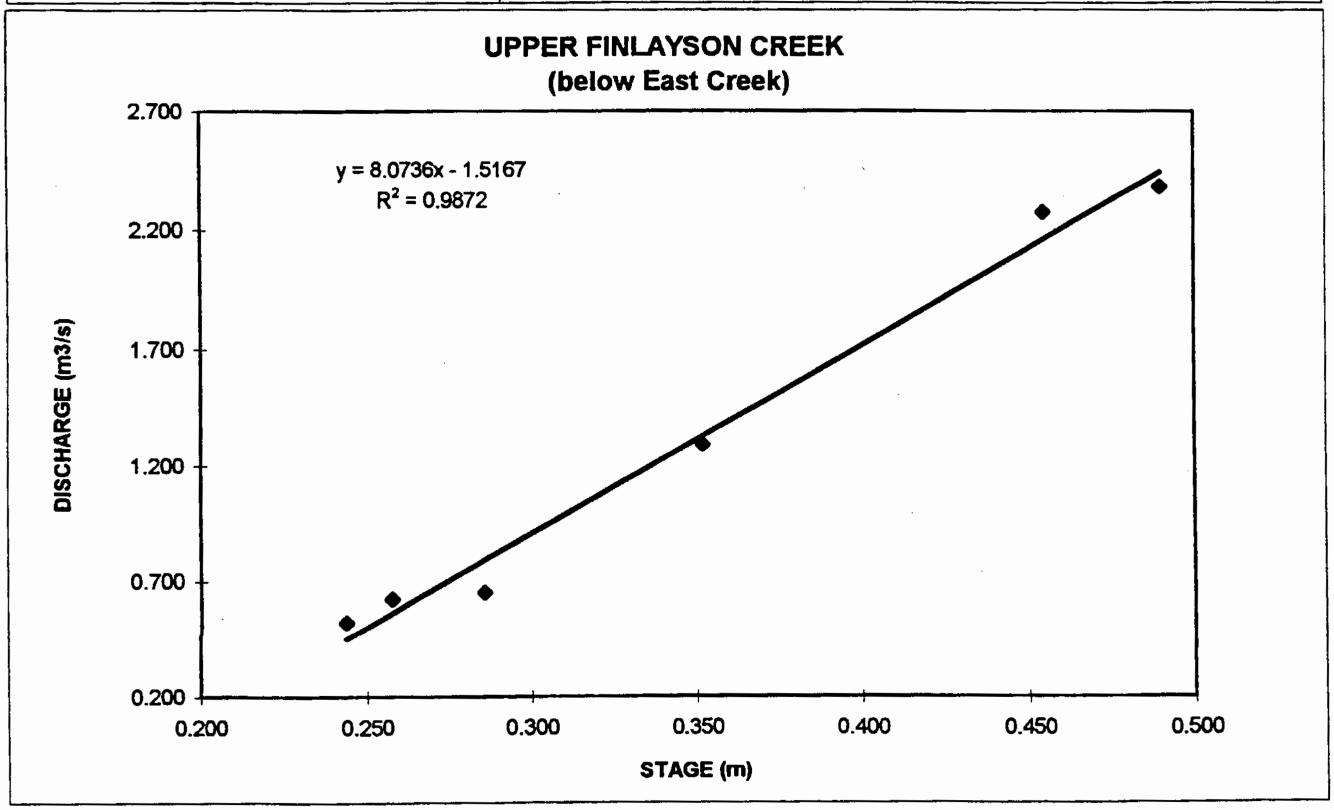
KUDZ-ZE-KAYAH PROJECT
HYDROLOGY: MANUAL GAUGES

FAULT AND SOUTH CREEKS
STAGE-DISCHARGE CURVES

FIG. 3.2A.1





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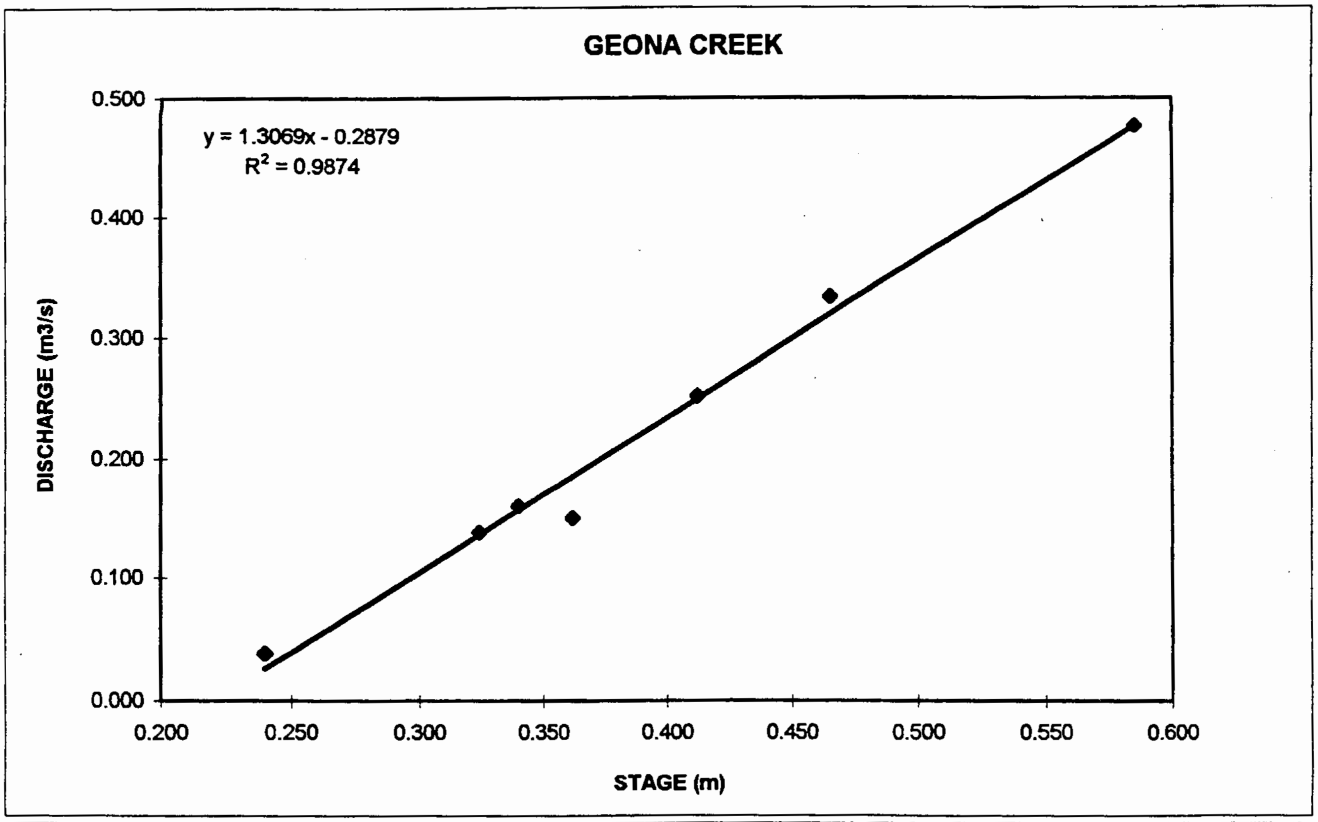
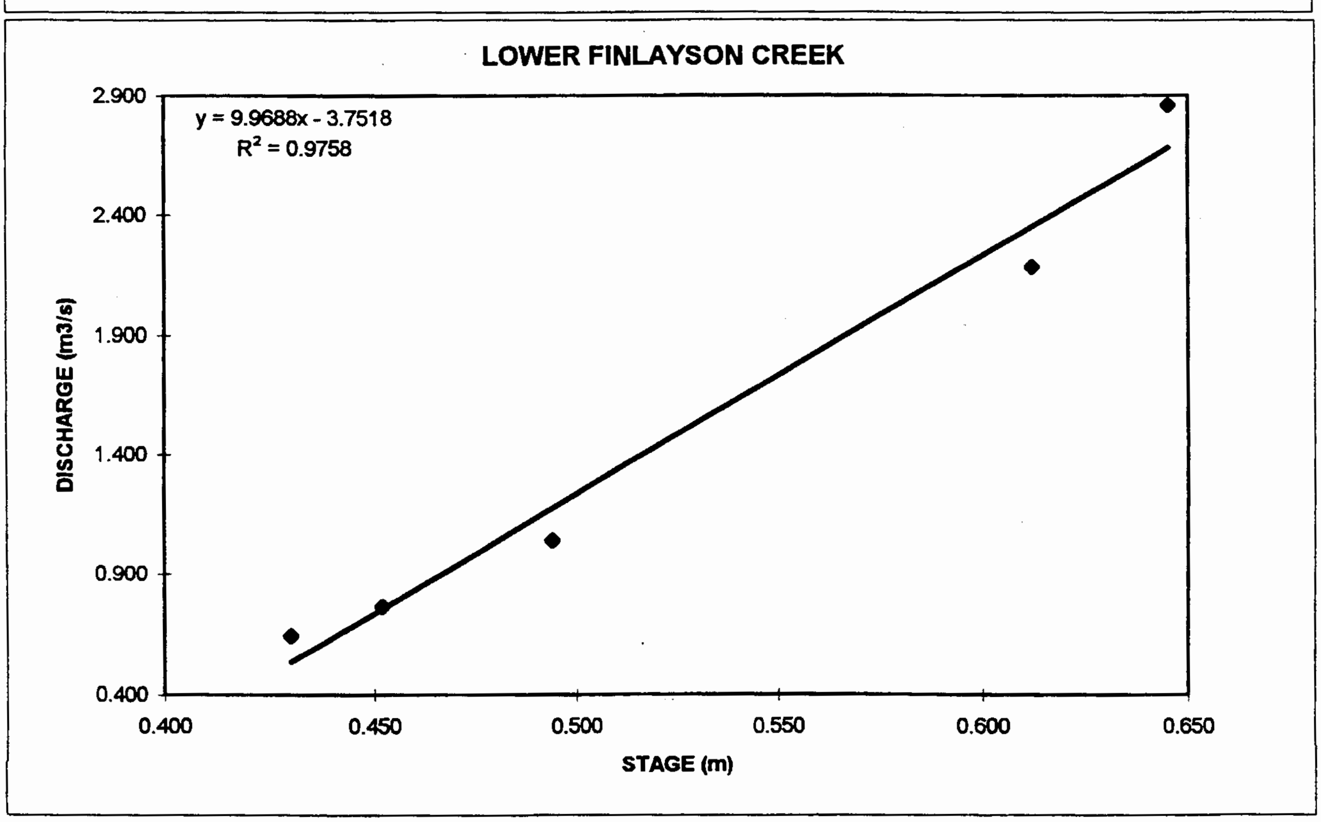
KUDZ-ZE-KAYAH PROJECT
HYDROLOGY: MANUAL GAUGES

EAST AND U.FINLAYSON CREEKS
STAGE-DISCHARGE CURVES

FIG. 3.2A.2





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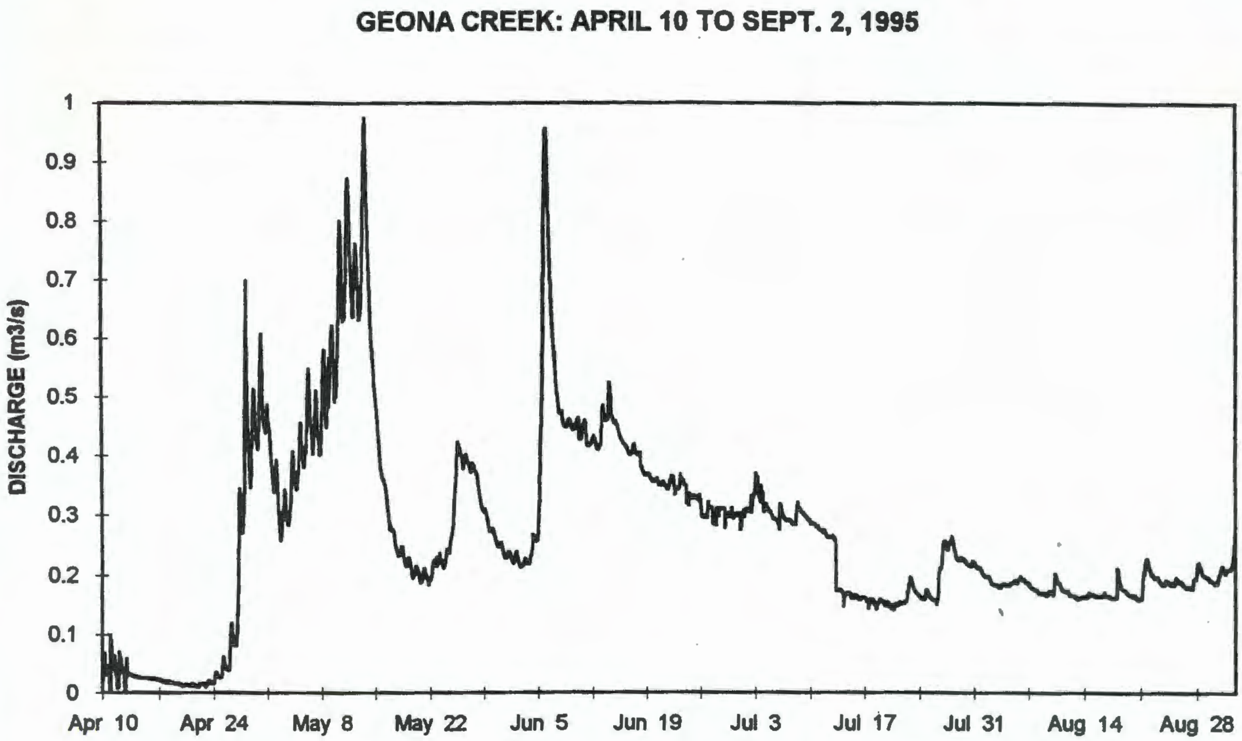
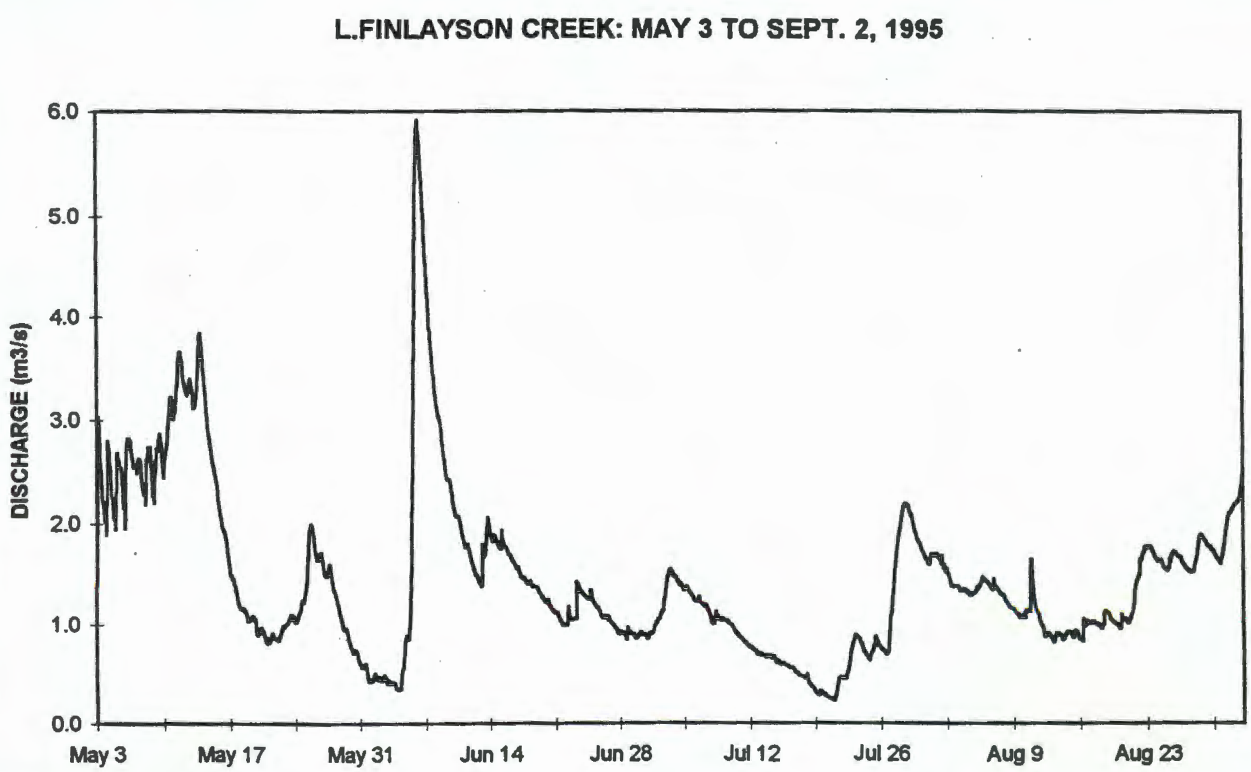
KUDZ-ZE-KAYAH PROJECT
HYDROLOGY: AUTOMATED GAUGES

GEONA AND L.FINLAYSON CREEKS
STAGE-DISCHARGE CURVES

FIG. 3.2A.3





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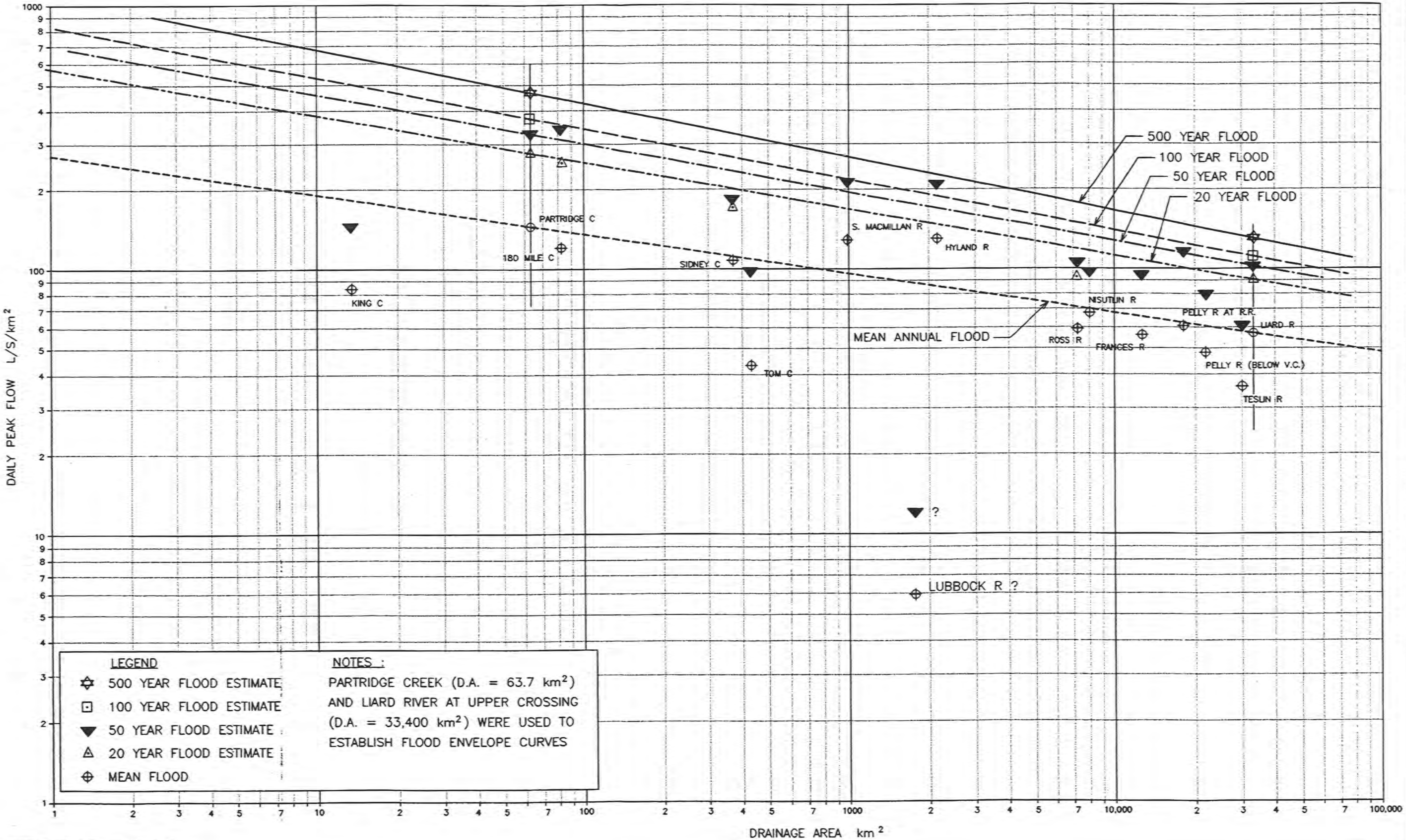
KUDZ-ZE-KAYAH PROJECT
HYDROLOGY: AUTOMATED SITES

GEONA & LOWER FINLAYSON CREEK DISCHARGES

FIG. 3.2A.4



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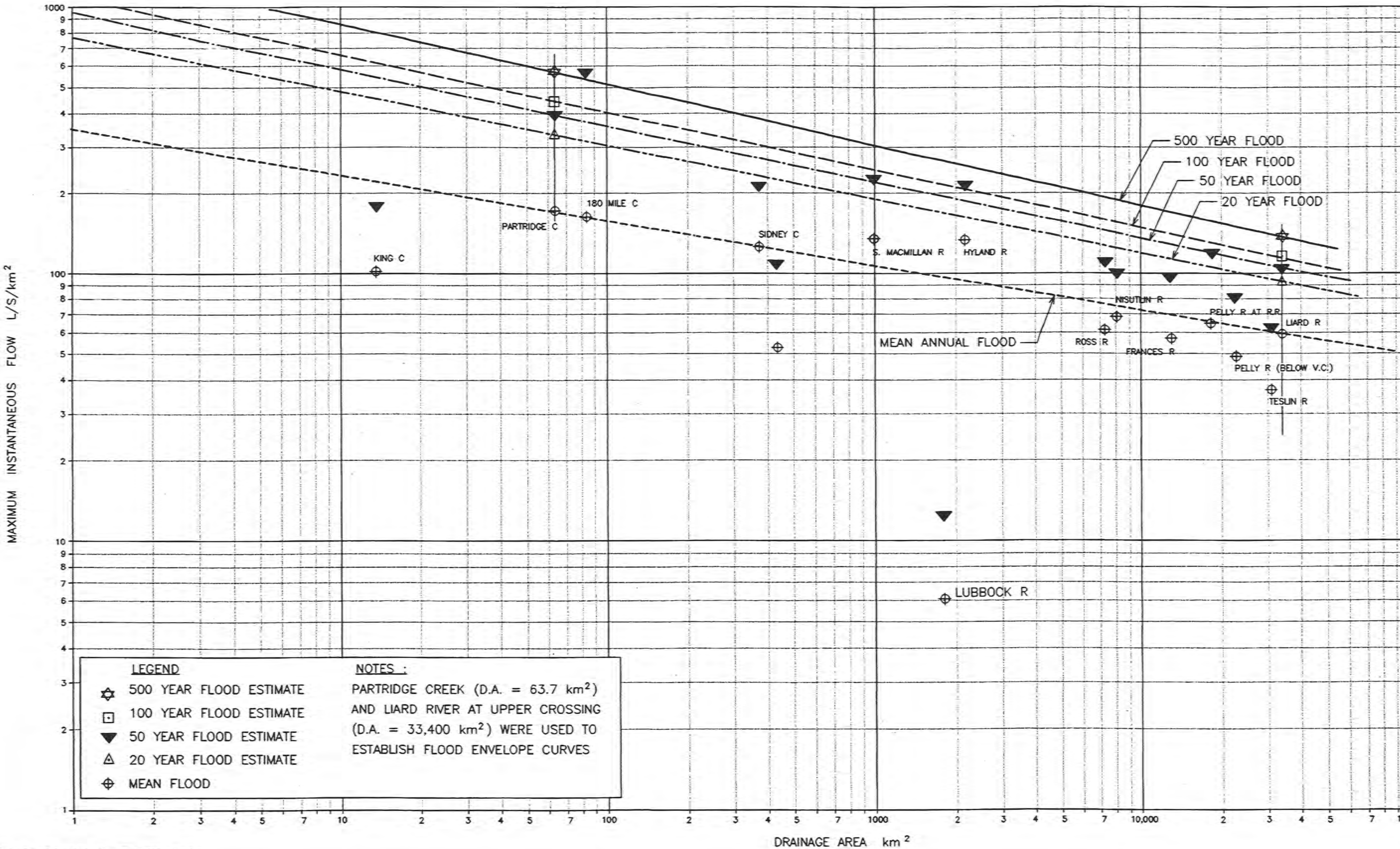
KUDZ – ZE – KAYAH PROJECT REGIONAL FLOOD ANALYSIS

MAXIMUM DAILY FLOODS

FIG. 3.2B.1

CAD FILE : NDM-001 / NDM001MA.DGN/1995 NOV 08



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KUDZ – ZE – KAYAH PROJECT REGIONAL FLOOD ANALYSIS

MAXIMUM INSTANTANEOUS FLOODS

FIG. 3.2B.2

CAD FILE : NDM-001 / NDM001MA.DGN/1995 NOV 08

APPENDIX 3.2b

REGIONAL FLOOD ANALYSIS

APPENDIX 3.2b

REGIONAL FLOOD ANALYSIS

Floods in the vicinity of Kudz Ze Kayah are primarily due to snowmelt though summer rain events can also produce annual flood peaks. Annual hydrographs for several streamflow stations in the region were examined including King Creek, Rose Creek, Sidney Creek, Tom Creek and Ross River at Ross River. Evidence of rain floods was found for each of these catchments with the majority of the events occurring in July. The Ross River catchment has a drainage area of 7250 km^2, yet it also includes annual rain floods such as occurred in July 1969. It should be noted that the regional flood analysis, described below, was based on annual maximum floods, irrespective of the flood generating mechanism. Therefore, the rainfall floods, when they occurred, were incorporated into the regional analysis.

The floods in the vicinity of the mine can be estimated by means of a regional analysis which utilizes streamflow records from the surrounding area. The region selected for study was identical to that used for the runoff analysis. Only stations with at least 10 years of annual flood records were included in the analysis. A total of 13 WSC stations and 2 DIAND stations were selected for analysis based on the available length of record and on the requirement that flood data include maximum instantaneous as well as maximum daily floods. The Consolidated Frequency Analysis program (CFA Ver 3.1) was used for the flood analysis and the most appropriate flood distribution was selected based on how well it fitted the data. Results of the daily flood analysis are included in Table 3.2B.1. In each case, the flood estimate has been divided by drainage area in order to obtain unit flood estimates in l/s/km^2. The mean annual unit flood estimates were then plotted on log-log graph paper to determine regional trends in the data, Figure 3.2B.1. The mean annual flood data for Partridge Creek, D.A. = 63.7 km^2, and the Liard River at Upper Crossing, D.A. = 33400 km^2, were used to define an upper envelope for the regional data. Data for South MacMillan River and Hyland River were ignored when selecting the regional envelope curve as these stations are located at higher elevations in the Selwyn and Logan Mountains. The mean and 50-year flood estimates for the Partridge Creek and Liard River stations were plotted on probability paper. A straight line extrapolation of these values was then used to obtain estimates for other return periods. Regional envelope curves for 20, 50, 100 and 500 year return periods were added to Figure 3.2B.1, based on these extrapolated values for the above two stations.

A similar analysis was conducted using the maximum instantaneous data and the resulting frequency estimates were examined to ensure that these estimates exceeded the daily estimates for identical return periods. In several cases, the maximum instantaneous flood estimates were less than the daily flood estimates which is impossible. These anomalies are primarily the result of differences in the length of record for the maximum instantaneous and maximum daily floods, the latter being more extensive in all cases where these anomalies were apparent. Differences in record length can introduce variations in the skew parameters incorporated into the frequency distributions and these can have dramatic effects on the estimates at high return periods. In order to overcome these anomalies in the estimates, the daily flood estimates for these streams were multiplied by the ratio of instantaneous to daily floods, as determined by the highest three recorded floods. In this manner, all instantaneous flood estimates exceeded the maximum daily flood estimates by a realistic amount. Maximum instantaneous flood estimates from the regional analysis are listed in Table 3.2B.2. These flood estimates were again divided by drainage area to obtain unit flood estimates in $l/s/km^2$. Once again, the estimates for Partridge Creek and the Liard River were used to develop regional flood trend lines for return periods of 20, 50, 100 and 500 years. These estimates are shown on Figure 3.2B.2 together with estimates for the mean annual flood.

The regional flood graphs can be used to give preliminary estimates of floods in the vicinity of the Kudz Ze Kayah project. The reliability of the estimates naturally decreases as return period increases so caution should be exercised when extracting flood estimates from these graphs.

As an example of the use of the regional flood graphs, preliminary design estimates were developed for two creek diversions in the mine area. The first diversion on the west side of the tailings impoundment involved an area of 2.51 km^2. The second diversion included Fault Creek and the tributary immediately to the north of this creek, with a combined drainage area of 2.65 km^2. Estimates of the 100-year design flows for the diversion ditches were determined from Figure 3.2B.2. Unit flood flows of 900 $l/s/km^2$ and 890 $l/s/km^2$ were determined for the catchment areas of 2.51 km^2 and 2.65 km^2, respectively. Multiplying these unit flood flows by drainage area yields 100-year maximum instantaneous flood estimates of 2.26 m^3/s and 2.36 m^3/s, respectively, for the 2.51 km^2 and 2.65 km^2 catchment areas. These estimates are believed to be conservative, given the relatively small recorded discharges in the mine area, Appendix 3.2a. Attempts were made to confirm these estimates using a runoff model approach, similar to that used to define the Probable Maximum Flood, Appendix 3.2c. The 100-year 24-hour rainfall was determined to be 56.4 mm from the Rainfall Frequency Atlas for Canada. It was found that similar estimates to those reported above would be obtained if a curve number of 77 were assumed, corresponding to a wooded area with slow to very slow infiltration rates (Group C and D soils). Such conditions are believed similar to rain on frozen ground which is a distinct possibility in the project area.

Table 3.2B.1
Maximum Daily Flood Estimates - m^3/s

Sta. No.	Name	D.A. km^2	Mean	10 Year	20 Year	50 Year	100 Year	500 Year
10AB003	King Creek	13.7	1.16 84.7*	1.61 118*	1.78 130*	2.00 146*	2.14 156*	2.45 179*
29AE003	Partridge Creek (DIAND)	63.7	9.25 145*	14.6 229*	17.3 272*	20.9 328*	23.6 370*	29.7 466*
29BA002	180 Mile Creek (DIAND)	83.1	10.0 120*	16.4 197*	20.9 252*	28.6 344*	36.0 433*	61.1 735*
09AD002	Sidney Creek	372	40.0 108*	59.1 159*	63.9 172*	69.0 185*	72.2 194*	78.5 211*
10AA002	Tom Creek	435	18.8 43.2*	32.0 73.6*	36.7 84.4*	42.5 97.7*	46.6 107*	55.8 128*
09BB001	South MacMillan River	997	128 128*	166 167*	186 187*	214 215*	238 239*	298 299*
09AA007	Lubbock River	1770	10.5 5.93*	15.8 8.93*	18.2 10.3*	21.4 12.1*	23.8 13.4*	29.5 16.7*
10AD002	Hyland River	2150	279 130*	348 162*	390 181*	454 211*	511 238*	678 315*
09BA001	Ross River	7250	426 58.8*	603 83.2*	672 92.7*	761 105*	826 114*	973 134*
09AD001	Nisutlin River	8030	541 67.4*	712 88.7*	748 93.2*	780 97.1*	797 99.3*	823 103*
10AB001	Frances River	12800	716 55.9*	966 75.5*	1080 84.4*	1120 95.3*	1330 104*	1600 125*
09BC002	Pelly River at Ross River	18400	1123 61.0*	1620 88.0	1850 101*	2160 117*	2400 130*	2970 161*
09BC004	Pelly River below Vangorda Creek	22100	1062 48.1*	1420 64.3*	1580 71.5*	1780 80.5*	1930 87.3*	2280 103*
09AE001	Teslin River	30300	1094 36.1*	1480 48.8*	1650 54.5*	1870 61.7*	2030 67.0*	2410 79.5*
10AA001	Liard River at Upper Crossing	33400	1913 57.3*	2700 80.8*	3010 90.1*	3400 102*	3680 110*	4320 129*

* $l/s/km^2$

Table 3.2B.2
Maximum Instantaneous Flood Estimates - m^3/s

Sta. No.	Name	D.A. km²	Mean	10 Year	20 Year	50 Year	100 Year	500 Year
10AB003	King Creek	13.7	1.38 101*	1.95 142*	2.17 158*	2.44 178*	2.63 192*	3.03 221*
29AE003	Partridge Creek (DIAND)	63.7	10.8 170*	17.8 279*	21.1 331*	25.1 394*	28.0 440*	34.0 534*
29BA002	180 Mile Creek (DIAND)	83.1	13.8 166*	26.0 313*	34.4 414*	47.6 573*	59.4 715*	94.5 1137*
09AD002	Sidney Creek	372	46.0 124*	67.5 182*	72.9 196*	78.7 212*	82.4 222*	89.6 241*
10AA002	Tom Creek	435	22.6 52.0*	35.2 80.9*	40.5 93.1*	47.3 109*	52.4 121*	64.5 148*
09BB001	South MacMillan River **	997	134 134*	175 176*	196 197*	226 227*	251 252*	315 316*
09AA007	Lubbock River	1770	10.7 6.02*	16.0 9.04*	18.5 10.5*	21.8 12.3*	24.4 13.8*	30.6 17.3*
10AD002	Hyland River	2150	289 134*	357 166*	399 186*	465 216*	525 244*	703 327*
09BA001	Ross River	7250	443 61.1*	612 84.4*	690 95.2*	795 110*	877 121*	1080 149*
09AD001	Nisutlin River	8030	546 68.0*	729 90.8*	767 95.5*	802 99.9*	821 102*	848 106*
10AB001	Frances River	12800	722 56.4*	975 76.2*	1090 85.2*	1230 96.1*	1350 106*	1610 126*
09BC002	Pelly River at Ross River **	18400	1180 64.1*	1646 89.5*	1880 102*	2195 119*	2438 133*	3018 164*
09BC004	Pelly River below Vangorda Creek **	22100	1074 48.6*	1436 65.0*	1597 72.3*	1800 81.4*	1951 88.3*	2305 104*
09AE001	Teslin River **	30300	1101 36.3*	1489 49.1*	1660 54.8*	1881 62.1*	2042 67.4*	2424 80.0*
10AA001	Liard River at Upper Crossing **	33400	1957 58.6*	2762 82.7*	3079 92.2*	3478 104*	3765 113*	4419 132*

* $l/s/km^2$

** Flood estimate derived from maximum daily flood estimate times I/D ratio

APPENDIX 3.2c

PROBABLE MAXIMUM FLOOD ANALYSIS

APPENDIX 3.2c

PROBABLE MAXIMUM FLOOD ANALYSIS

1. Introduction

An estimate of the Probable Maximum Flood (PMF) for the drainage into the proposed tailings impoundment at Kudz Ze Kayah was prepared, representative of conditions at the mine closure stage. This flood estimate is required in order to size the spillway for the tailings dam. The drainage area into the tailings impoundment was determined to be 16.13 km^2, as measured from 1:10,000 mapping for the Kudz Ze Kayah area.

Development of the PMF estimate is based on hydrologic analysis in which the Probable Maximum Precipitation (PMP) is first estimated and then input into an appropriate flood runoff model in order to determine the corresponding inflow PMF to the impoundment.

2. Probable Maximum Precipitation

The 24-hour PMP was estimated for the project area using the Hershfield method. Hershfield developed an empirical relationship to estimate a frequency factor K_M which relates the number of standard deviations which must be added to the mean annual extreme rainfall in order to get the probable maximum rainfall at the location in question. Corresponding values for the frequency factor were developed for return periods of 1, 6, and 24 hours as follows:

$$K_{M1} = 19(10)\exp(-.00492\ _{1})\ (mm)$$
$$K_{M6} = 19(10)\exp(-.00213\ _{6})\ (mm)$$
$$K_{M24} = 19(10)\exp(-.000965\ _{24})\ (mm)$$

These values were subsequently entered into the following equation which relates rainfall frequency estimates to the mean and standard deviation of the rainfall data:

$$X(T) = \quad + K(T)S$$

The mean and standard deviation for the various required durations were determined for the study area from the Rainfall Frequency Atlas for Canada:

1-hour	= 8.3	s = 2.6	mm
6-hour	= 15	s = 5.5	mm
24-hour	= 25	s = 10	mm

The K values were determined to be 17.29, 17.65, and 17.97 for the 1, 6, and 24-hour durations respectively. Corresponding PMP estimates were determined as follows:

1-hour PMP = 53.3 mm
6-hour PMP = 112 mm
24-hour PMP = 205 mm

The 24-hour PMP estimate was found to be in good agreement with similar estimates derived by other consultants for similar studies in Yukon. These estimates are listed in Table 3.2C.1.

The information in Table 3.2C.1 was supplied by Mr. J.R. Janowicz, hydrologist, Water Resources - Northern Affairs Program, Whitehorse.

3. HEC-1 Analysis

The 24-hour PMP estimate of 205 mm was then input into a hydrologic model to determine the runoff hydrograph into the tailings impoundment. The Soil Conservation Service, SCS, Dimensionless Unit Hydrograph method was used in the analysis. This method requires an estimate of the lag time, TLAG, of the basin. This parameter is related to the time of concentration, T_C, of the basin. Several methods were used to estimate the time of concentration of the basin:

- Kirpich T_C = 0.757 hours
- Brandsby-Williams T_C = 2.18 hours
- Watt and Chow T_P = 0.943 hours

The average of the above methods, 1.3 hours, was adopted. The lag time was then determined as follows:

$$TLAG = 0.6\ T_C = 0.78 \text{ hours}$$

The time step for the hydrograph was determined to be 0.167 hours (10 min) and the time to peak, T_{PEAK}, was determined to be 0.86 hours. There would be no loss from the surface of the tailings impoundment which, at El 1370 m, would cover 72 ha. This represents 4.5% of the drainage area and this was treated as impervious in the HEC-1 analysis. Estimation of the appropriate curve number, CN, for use in the model is crucial to the flood estimate. This parameter depends on soil group, land use, antecedent moisture condition and hydrologic condition. At Kudz Ze Kayah, at an elevation range of of 1370 to 2042 m in Yukon, there is a strong possibility of frozen ground conditions at the time of the PMP event. Consequently, a high CN value of 90 was chosen, representing a high potential runoff coefficient for the mine catchment. While snowmelt has not been included, the use of a high runoff coefficient, would, in effect, provide some allowance for snowmelt.

The time distribution of the rainfall was determined from SCS reference literature. A Type I storm was assumed for the 24-hour rainfall distribution as recommended for the interior regions of Alaska. A half hour increment was used in the distribution of rainfall to the model. This rainfall hyetograph had a maximum 1-hour rainfall of 53.5 mm, between hours 8 and 9, in excellent agreement with the estimated 1-hour PMP of 53.3 mm. The maximum 6-hour rainfall was 117.2 mm, between hours 7.5 and 13.5, in good agreement with the 6-hour PMP of 112 mm. When this storm rainfall was analyzed using the SCS dimensionless unit hydrograph, a peak runoff rate of 200 m^3/s was obtained. A plot of the PMF hydrograph is shown in Figure 3.2C.1. The hydrograph is listed in Table 3.2C.2.

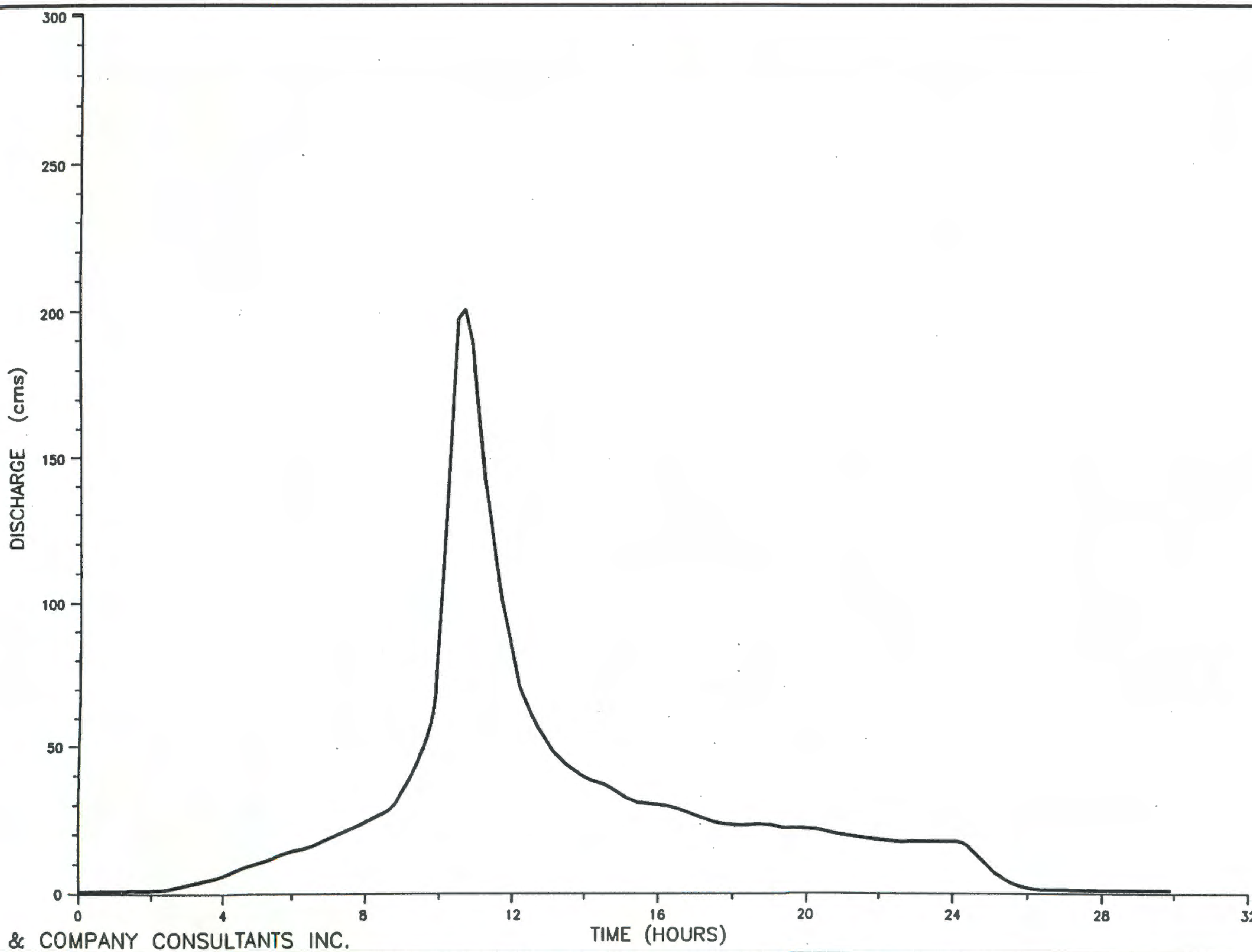
The peak of 200 m^3/s occurred after 10.67 hours. A rational formula approach was used to provide an approximate check on the result obtained from the HEC-1 program. Given a time of concentration of 1.3 hours, the corresponding rainfall intensity was determined to be 61.8 mm/hr, interpolated from the peak 1-hour and 1.5-hour rainfall intensities. It was found that a runoff coefficient of 0.722 would provide the same peak runoff as obtained from the SCS unit hydrograph approach. This runoff coefficient is considered reasonable given the extreme nature of the event.

Table 3.2C.1
Probable Maximum Precipitation Estimates From Previous Studies

Study	Year	Consultant	24-Hour PMP Estimate - mm
Down Valley Tailings Study	1992	Steffen Robertson and Kirsten	184
for Faro	1981	Klohn Leonoff	340
for Anvil	1981	Klohn Leonoff	178
for Ross River	1985	Acres	119
Aishihik Hydro Project	1991	Monenco	225
Average			209

Table 3.2C.2
24-Hour Probable Maximum Flood Hydrograph

Time hours	Discharge m^3/s	Time hours	Discharge m^3/s	Time hours	Discharge m^3/s	Time hours	Discharge m^3/s
0	1	6.5	16	13.0	50	19.5	22
0.5	1	7.0	18	13.5	43	20.0	22
1.0	1	7.5	21	14.0	39	20.5	21
1.5	1	8.0	25	14.5	37	21.0	20
2.0	2	8.5	28	15.0	33	21.5	19
2.5	2	9.0	36	15.5	31	22.0	18
3.0	4	9.5	49	16.0	30	22.5	17
3.5	5	10.0	106	16.5	28	23.0	17
4.0	7	10.5	197	17.0	26	23.5	17
4.5	9	11.0	171	17.5	24	24.0	17
5.0	11	11.5	113	18.0	23	24.5	15
5.5	12	12.0	79	18.5	23	25.0	8
6.0	14	12.5	61	19.0	23	25.5	4



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KUDZ-ZE-KAYAH PROJECT

24 HOUR PROBABLE MAXIMUM FLOOD HYDROGRAPH

FIG. 3.2C.1

CAD FILE : MDN-001 / MDN001MA.DGN/1996 JAN 05

APPENDIX F

AEG'S STANDARD OPERATING PROTOCOL, SURFACE WATER HYDROLOGY, DATA COLLECTION AND MANAGEMENT

ACCESS
CONSULTING GROUP

STANDARD OPERATING PROTOCOL

SURFACE WATER HYDROLOGY

DATA COLLECTION AND MANAGEMENT

April 2013

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1 INTRODUCTION

Hydrology data are critical for a variety of assessment and planning purposes at prospective mine sites. They are used to prepare site water balances, operation plans, loading models, etc. Therefore, sound and consistent data collection practices are key to ensuring hydrology data quality. There are many steps involved in producing an accurate discharge record, and rarely are all steps conducted by the same individual or firm. Therefore, **detailed documentation of conditions and observations during field activities are crucial!**

1.1 DEFINITIONS

Hydrology: The study of water occurrence, distribution, movement and balances in ecosystems

Surface Water Hydrology: Branch of hydrology of the land surface dealing with rainfall–runoff relationships and the general water budget on the surface of the earth.

Hydrometry: The measurement of water on or below the earth's surface.

Stage: The height or elevation of the stream's water surface above a reference elevation.

Staff Gauge: A graduated scale placed in a position so that the stage of a stream may be read directly from it.

Discharge: The volume of water flow which is transported through a given cross-sectional area in a given period of time. Discharge (Q in m^3/s) = Velocity (V in m/s) x Area (A in m^2).

Control: The condition downstream that determines the stage discharge relationship. It may be a boulder control with rapids below or an artificial structure such as a weir. It may also be more subtle such as the convergence with another channel or a narrowing of the stream (constriction). A shifting control may exist where the bed or banks change seasonally.

Laminar Flow: When flow lines are in parallel layers with no disruption, cross currents, eddies or swirls. This occurs in reaches with fine bed sediment and straight banks.

Flowmeter: Meter used to measure streamflow velocity, used with measurements of stream width and depth to calculate discharge at a single point in time.

Central to hydrology data processing is the discharge record (below). This is the graphed relationship of how discharge (Q) varies at a particular location over time. Discharge is typically expressed in L/s or m^3/s. A continuously logged discharge record and actual field discharge measurements plotted together is most often the final product of our hydrology work that is passed to other parties for incorporation into water balances or regional hydrology reviews.

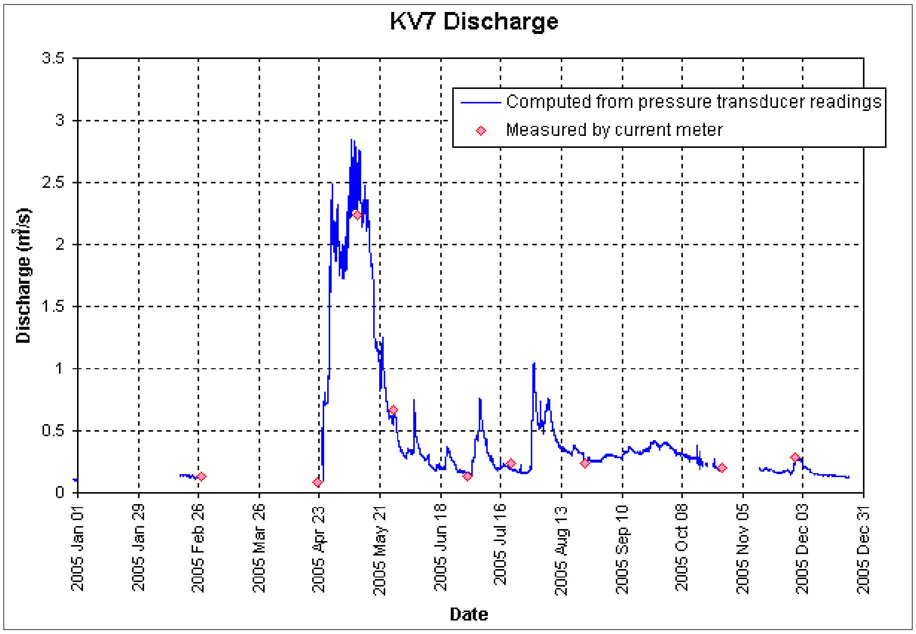


Figure 1-1 Discharge Record

In order to produce an accurate discharge record, a number of steps are required:

1. Field Activities:

    a. Installation of a hydrometric station and datalogging instruments;

    b. Documentation of key conditions during station visits – stage readings from staff gauge (including reading at which zero flow exists), photos of gauge, up and downstream conditions and metering section used, stream conditions (ice present anywhere in channel?) weather conditions including precipitation, time of day, meter used for readings (AA – Rickly or SI, pygmy, Global, YSI (salt slug) etc.);

    c. Collection of a number of accurate field discharge 'spot' measurements with concurrent staff gauge readings, across as great a range of stages as possible (i.e. high, medium and low flows);

    d. Periodic surveying of elevation of staff gauge to track and account for 'drift' or vertical movement of staff gauge if any.

2. Data Management and Processing:

    a. Calculation of discharge value from metering data (varies with meter used);

    b. Prompt and proper management and filing of notes, observations and datalogger files;

c. Processing of data into a site rating curve; and

d. Processing datalogger records into discharge record.

Activities during each of these steps need to be conducted properly, as uncertainty or errors induced by improper methods are compounded in later steps. Proper protocols for conducting each of these steps properly to ensure data integrity are discussed in the following sections.

2 FIELD ACTIVITIES

2.1 HYDROMETRIC STATION INSTALLATION

There are many factors to consider when situating and installing a permanent hydrometric station. This should be completed with the assistance of a senior project manager or hydrologist, but generally speaking a station and its location should meet the following criteria:

- Site is accessible by field staff in a safe fashion, even at high stages and all seasons;
- Site is located in an appropriate reach of the watershed – i.e. data from the station will be valid for planning purposes;
- Located at a point where the stream cross-section is stable (won't shift) and where all but the highest stages will be contained in the channel and not flood over bank;
- Located in or close to a relatively straight reach with shallow slope and ideal conditions for traditional velocity-area stream gauging – i.e. the flow should be as close to laminar as possible with volume distributed as evenly across the channel as possible;
- Ideally, in a location where there is a natural control (narrowing or immobile obstacles) just downstream to 'back' water up where the logger will be, and free draining flow below the control – no obstacles like deadfall;
- The staff gauge and logger should be situated so that at the lowest flows they will still register a stage – i.e. they'll still be within the wetted width of the flow;
- Staff gauge should be installed such that it is plumb and will not move or 'drift' in any direction, either vertically or laterally – usually requiring a cribbing structure anchored to at least two points on the bank;
- Staff gauge can be read accurately and safely at all stages;
- Datalogger is installed as close to the bottom (or gauge zero) of the staff gauge as possible in a non-turbulent area – ideally in a stilling well that is perforated to flood to the same level as surrounding water level;
- Datalogger cord (if applicable) is securely anchored to protect from inadvertent movement (wildlife, personnel) and the connection end is protected from the elements.

The stilling well itself should be constructed using a length of PVC or ABS pipe. Previously, white pipe was often used but now black is seen as advantageous for assisting in warming the pipe and thus helping melt ice in and around the pipe. The well must be perforated for at least the lower 10cm but the perforation may go higher. The pipe must be capped on the bottom and it is also useful to wrap the perforated sections in landscaping fabric, securing it with zip-ties, to prevent sedimentation in the well. Photograph 1 shows a hydrometric station installed with angle iron, one in the stream bed and another bolted and crossing at close to 90 degrees hammered into the bank plus two guy wires anchored to more angle iron and a tree.

Photograph 1: Typical Hydrometric Station

2.2 DOCUMENTATION

Datalogger records and flow readings are of limited value without key supporting information collected from the field. Upon arrival at the metering location, there are a number of items that MUST be noted along with the metering data. It is important to note anything that may affect the discharge measurement, and if the metering location has a staff gauge and/or flow recorder, this information is critical support data for the meter readings. The following is an example of field data collected upon arrival at the metering location; this list is laminated and available to field staff.

Station: ______________________ **Water Course:** ______________________
Date __________ **Time** __________ **Staff Gauge:** ______________________
Personnel: ______________________ **Meter Used:** ______________________
Flow Conditions: ______________________
Weather Conditions: ______________________
Surveyed: Y/N ______________________
Photographs (u/s and d/s conditions, staff gauge, etc.): ______________________
Datalogger downloaded? If so, what is the file name: ______________________
Datalogger installed/ removed (date): ______________________
Datalogger type/ serial number: ______________________
Issues with installation or removal: ______________________

Notes: ______________________

These requirements should be understood and memorized by staff that regularly collects field hydrology data. Anomalies in datalogger records can be corrected or adjusted and errors can be fixed later if, for example, the staff gauge reading is noted, or a photo of the staff gauge is taken, or if a different meter than normal is used, but is noted.

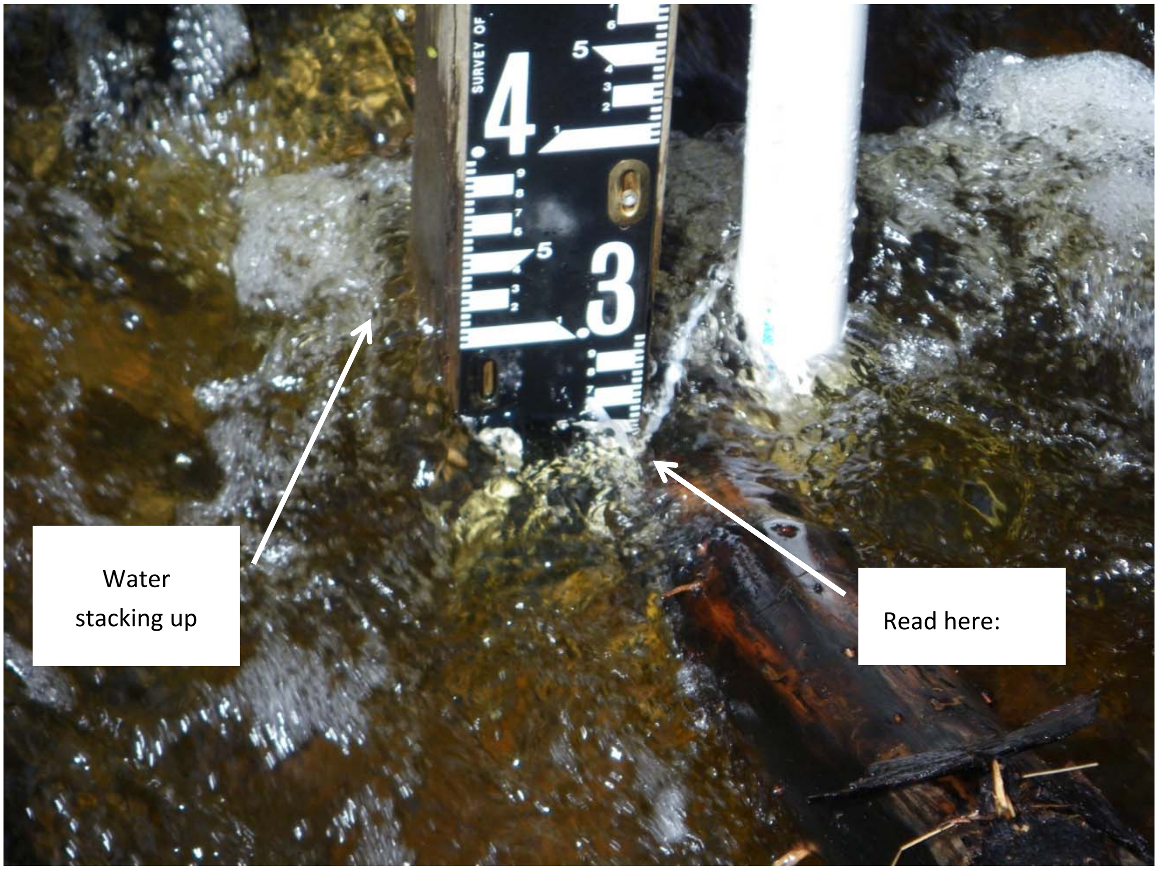
If in doubt, record all the details in the field!!

Staff gauges are used to record the **stage** (water level) of a creek, river, reservoir, etc. The staff gauge is the datum for all the measurements, meaning that all measurements and data records are relative to the staff gauge. It is therefore important to not only read staff gauges carefully, but to make note of anything that would suggest the gauge may have moved or any new debris in the channel that may affect the water level (e.g. fallen tree within the gauge reach or blow out of control feature). Photos and any estimates of direction and magnitude of movement can be very valuable in planning repairs and correcting data records.

Be careful to read and record the gauge correctly in meters, to 3 decimal places. Taking a photograph of the water level on the gauge is useful to cross check staff gauge readings if suspect. **Staff gauge readings should be taken both before and after metering**, as stage of a stream can change over the course of a visit to a station. ALWAYS TAKE A PHOTO!

High flow conditions can result in water ‘stacking up’ against part of the staff gauge structure. In this case, readings should be read at the downstream side of the gauge to minimize error.

Conversely, some stations will have no surface flow when the station is visited. Although tempting to not collect any data, these conditions can be critical to the process of developing accurate discharge records. **Zero is a number!** Zero flow conditions should not only be noted in field records, but photographed as well. Often staff gauges will be located in a pool that may still show a ‘water level’ when there is no discharge. This ‘zero flow reading’ is very important to rating curve development and should be documented.



Photograph 2: Water Stacking on Staff Gauge Structure

2.3 DISCHARGE METERING

Discharge (flow) measurements are usually conducted using a current meter to measure velocity at various points along the width of the stream. Accurate metering is critical to the accuracy of the discharge record. There are many elements to consider when conducting stream discharge measurements and there are many opportunities for error. Adherence to Standard Operating Procedures is critical to data integrity.

If conditions permit, flow measurements should be conducted using a current meter. The manual of operation provided with the meter must be followed and the general current meter use and flow measurement procedure from this protocol should be followed.

"The essential features of conventional current meters are a wheel, which rotates when immersed in flowing water, and a device for determining the number of revolutions of the wheel." (U.S. Department of the Interior 1984.) The relationship between the number of revolutions of the wheel per unit time and velocity will be provided by the manufacture of the device. The instrument is calibrated by the manufacturer prior to its shipment; however, current meters should be re-calibrated every year and be tested periodically by performing a spin test as outlined below.

There are many different types of current meters on the market. Access owns both the Price-type current meter with top setting wading rod and the Marsh McBirney Flow Mate 2000 electromagnetic type. The Price-type current meter and top setting wading rod are commonly used in the Yukon. These meters have the following features: fins to keep the wheel directed upstream to the current, a rod for handling the meter, an electronic device for signalling the number of revolutions, and connections from the current meter to a battery powered headphone.

Before using a current meter, inspect it to be sure the bearing surfaces are in good order. This can be done quite easily:

1. Loosen the bucket wheel raising nut so that the pivot wheel bearing rests on the pivot.

2. Gently rotate the bucket wheel and observe it as it comes to a stop. If the stop is gradual, then the bearing surfaces and the pivot are in satisfactory condition. If the bucket wheel comes to an abrupt halt or the motion is abnormal in any way, the pivot and bearings should be closely inspected. The bucket wheel should spin for at least one minute.

3. Inspect the pivot and bearings if necessary. If there is evidence of wear, the meter should not be used. Have the meter professionally serviced and re-calibrated.

4. If the pivot and bearings are in good order, then go ahead with the discharge measurement.

The March McBirney electromagnetic flow meter uses a digital readout and does not require maintenance. It is also used in conjunction with the top setting wading rod.

2.3.1 Current Meter Procedure

The following general methods should be followed when conducting flow measurements while using a Price-type or Marsh-McBirney Flow-Mate current meter:

- The “sixth-tenths-depth” or “two tenths and eight tenths depth” measurements, in which the velocity at sixth-tenths of the stream depth is assumed to represent the average velocity through the vertical water column, and

- The midsection method, which is a standard discharge measurement technique whereby the depth, revolutions and time are measured for each of a number of verticals along a cross-section.

This procedure has been prepared under the assumption that a person wading across the stream will undertake the flow measurements. For detailed procedures on conducting flow measurements from a boat or bridge refer to the Section D.2.2 of the Manual of Standard Operating Procedures for Hydrometric Surveys, published by the Ministry of Environment (1998).

The flow measurement procedure should consist of the following steps:

1. Locate the monitoring station (the stations should be clearly marked).

2. Assess and mitigate safety risks. It is strongly recommended that two people conduct flow measurements, particularly when streams with high flows are encountered. Debris and slippery substrates are other common hazards. Waders (with wading belt), felt bottomed wading boots, handlines and life vests are available safety items.

3. Identify an appropriate cross-section to meter. The cross section should be:

    a. In a location where metering can be done safely and repeatedly at different stages if required;

    b. In a straight reach, a pool or run if possible – excessive turbulence can impact readings;

    c. Stable – muddy/sandy bottoms and banks make accurate metering difficult;

    d. Free of backwater, eddies, obstacles, etc. if possible.

4. Improving the metering section. Where necessary, take the time to improve the metering section by removing boulders and debris from the metering section and the area immediately above it. Remove significant in-stream vegetation for a distance of about three times the depth from the area upstream and downstream from the section. On smaller watercourses it may be possible to construct small dikes to cut off sections of shallow flows and dead water.

    After the modifications are made, be certain to allow sufficient time for conditions to stabilize before proceeding with the measurement. Note if the modifications have an influence on the gauge reading – ideally they should not, or should be done prior to gauge installation/reading. All improvements to the metering section should be completed before starting the measurement, i.e. do not make changes to the metering section (such as by moving rocks) during the course of the discharge measurement.

5. Use a measuring tape or marked cable (tagline) spread across the channel to outline the locations where depth and velocity measurements will be conducted. Position the tagline correctly. Take the time to ensure that the tagline is placed in a position that is perpendicular to the direction of the current.

6. Record the distance along the tagline of the right bank (facing downstream). The "bank" in this case is the water/land interface (i.e. the bank will be different each time to gauge the site). There will be no depth or velocity readings associated with the two bank distance readings.

7. Collect depth and velocity measurements at intervals (stations) along the tagline. Factors to consider:

    a. **Number and spacing of measurements.** There should be at least 15, but preferably 20-25 flow measurements across the channel. However, the number of measurements can be reduced for narrow channels because the distance between verticals must be greater than the diameter of the current meter bucket wheel. If the cross section is very narrow, use a small meter and space the verticals more closely. Distance between measurements should be spaced such that approximately the same volume of water passes through measured 'panels' per unit of time – i.e. measurement spacing can be increased in shallower areas of slower flow near the banks, but should be tightened together where the channel deepens and the flow rates increase. This will ensure that any error in the measurement is not disproportionately compounded.

b. **Position of the technician.** The field technician's position with respect to the current meter is very important when making a discharge measurement by wading. The technician should stand to the side and downstream from the meter so as not to influence the velocity. Studies show that the following position has the least effect on the operation of the current meter: stand in a comfortable, safe place facing either shore no less than 0.4 m downstream and to the side of the current meter.

c. **Position of the current meter.** Hold the wading rod in a vertical position and the current meter parallel to the direction of flow while measuring velocity. Vertical axis meters - if the axis of the meter is not kept vertical, the meter will tend to under-register. Horizontal axis meters - many propellers are designed to compensate for angular flow. Consequently any deviation from the vertical position of the rod will introduce an error in velocity.

d. **Uneven Channel Bed**. Sounding a channel bed that is extremely soft or strewn with boulders requires a great deal of extra care and attention. Be careful not to over-sound by allowing the bottom of the wading rod to sink into soft channel bed material. If the channel bed is very rough, take time to adjust the observed depths so that they reflect both the tops of the boulders and the depths between them. Sometimes there may be a near-vertical boundary separating zones of different depth or velocity. In this case, position the adjacent measuring verticals equidistant from this boundary, so that the boundary coincides with the common boundary of the partial sections.

e. Record the distance of the reading along the tagline, and measure and record the water depth at each location using the wading rod. The rod is graduated to 0.02 metres with the zero mark at the bottom of the rod. The depth is the point at which the level water surface intersects the rod. Observations should be made to the nearest 0.01 meter.

f. Velocity is to be measured at sixth-tenths (0.6) of the depth from the water surface. Adjust the height of the current meter to sixth-tenths of the depth. ACG utilizes top set wading rods which are calibrated to allow the user to quickly adjust the current meter position by setting the water depth position on the adjustment gauge. For water levels above 0.75m it is preferable to use the two point velocity method of measuring the velocity at two-tenths and eight-tens of the water depth. This can easily be achieved by setting the adjustment gauge to half the water depth (two-tenths) and double the water depth (eight-tenths). If using the Pygmy or Marsh-McBirney meter you may choice to use the point method at depths greater than half a meter.

g. Measure the number of spins per unit time at each location. Either a set of headphones or a digital counter can be used to count the number of revolutions while timing is being conducted. Ensure that the timing is started immediately after the current meter has spun past the point where it records a complete revolution (i.e. a scratch sound using the earphones or number change on the digital reader). Also ensure that the rotations are measured for a minimum of forty (40) seconds. Note: most current meters now available have digital velocity readouts; be sure to record the units.

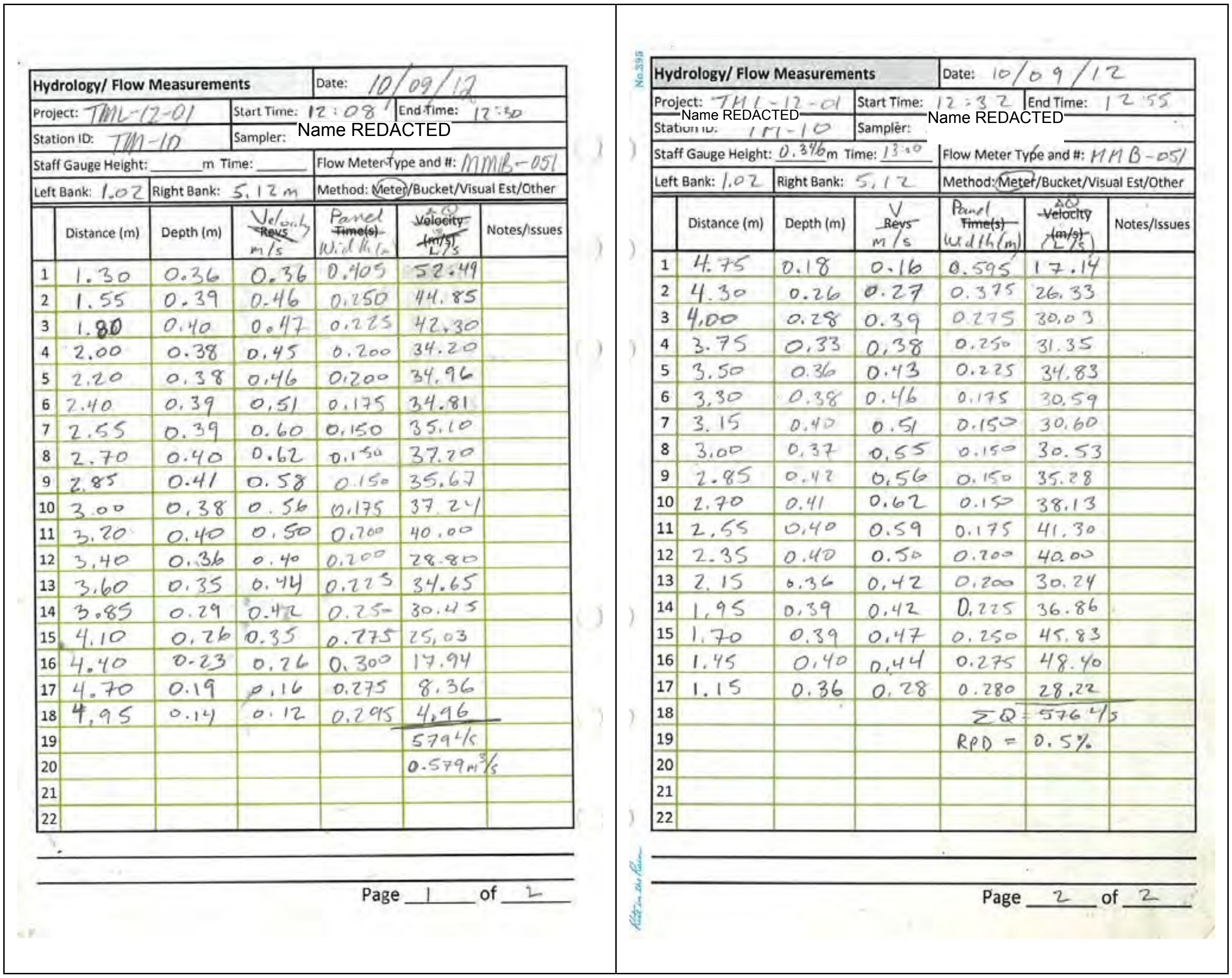
h. Continue the measurements across the stream or river until the left bank is reached. Record the distance on the tagline of the left bank.

Distance or Station along tagline (reading in m from bank), Depth (of water at reading station, in m), Revolutions (of the meter wheel) and Time (in seconds that revolutions were counted) are recorded as shown in an example below.

8. Repeat the discharge measurement. You may use the same tag line or adjust the position within the same reach if conditions permit. It is important to collect your velocity and depth readings at different distances along your tagline to ensure confidence in your measurement.

9. Calculate your uncertainty. Bring a pocket calculator with you in the field. This will allow you to simultaneously calculate discharge while your team member is taking the readings. Calculate your panel width, multiple by height and velocity to get discharge and hit the memory plus button to add this to your cumulative discharge. At the end hit memory recall to get your total discharge and record it. Once you have completed both discharge measurements you can calculate the percent difference between the two using the lower of the two as your base. If the difference between the two measurements is greater than 10% you should conduct a third measurement.

   Where the reach is ideal you will experience a difference of five percent or less. If your error is over 10% it is likely that you have either too few velocity measurements or your conditions are not ideal. Non-ideal conditions are created by turbulence which is the result of too much channel slope and uneven beds, usually from boulders. In some cases, this is unavoidable and a third measurement should be taken.



Hydrology/ Flow Measurements — Date: 10/09/12

Project: TML-12-01 | Start Time: 12:08 | End Time: 12:30
Station ID: TM-10 | Sampler: Name REDACTED
Staff Gauge Height: ______ m Time: ______ | Flow Meter Type and #: MMB-051
Left Bank: 1.02 | Right Bank: 5.12 m | Method: Meter/Bucket/Visual Est/Other

	Distance (m)	Depth (m)	Velocity m/s (~~Revs~~)	Panel Width (m) (~~Time(s)~~)	Q L/s (~~Velocity (m/s)~~)	Notes/Issues
1	1.30	0.36	0.36	0.405	52.49	
2	1.55	0.39	0.46	0.250	44.85	
3	1.80	0.40	0.47	0.225	42.30	
4	2.00	0.38	0.45	0.200	34.20	
5	2.20	0.38	0.46	0.200	34.96	
6	2.40	0.39	0.51	0.175	34.81	
7	2.55	0.39	0.60	0.150	35.10	
8	2.70	0.40	0.62	0.150	37.20	
9	2.85	0.41	0.58	0.150	35.67	
10	3.00	0.38	0.56	0.175	37.24	
11	3.20	0.40	0.50	0.200	40.00	
12	3.40	0.36	0.40	0.200	28.80	
13	3.60	0.35	0.44	0.225	34.65	
14	3.85	0.29	0.42	0.250	30.45	
15	4.10	0.26	0.35	0.275	25.03	
16	4.40	0.23	0.26	0.300	17.94	
17	4.70	0.19	0.16	0.275	8.36	
18	4.95	0.14	0.12	0.295	4.96	
19					579 L/s	
20					0.579 m³/s	
21						
22						

Page 1 of 2

Hydrology/ Flow Measurements — Date: 10/09/12

Project: TML-12-01 | Start Time: 12:32 | End Time: 12:55
Name REDACTED
Station ID: TM-10 | Sampler: Name REDACTED
Staff Gauge Height: 0.346 m Time: 13:10 | Flow Meter Type and #: MMB-051
Left Bank: 1.02 | Right Bank: 5.12 | Method: Meter/Bucket/Visual Est/Other

	Distance (m)	Depth (m)	V m/s (~~Revs~~)	Panel Width (m) (~~Time(s)~~)	ΔQ L/s (~~Velocity (m/s)~~)	Notes/Issues
1	4.75	0.18	0.16	0.595	17.14	
2	4.30	0.26	0.27	0.375	26.33	
3	4.00	0.28	0.39	0.275	30.03	
4	3.75	0.33	0.38	0.250	31.35	
5	3.50	0.36	0.43	0.225	34.83	
6	3.30	0.38	0.46	0.175	30.59	
7	3.15	0.40	0.51	0.150	30.60	
8	3.00	0.37	0.55	0.150	30.53	
9	2.85	0.42	0.56	0.150	35.28	
10	2.70	0.41	0.62	0.150	38.13	
11	2.55	0.40	0.59	0.175	41.30	
12	2.35	0.40	0.50	0.200	40.00	
13	2.15	0.36	0.42	0.200	30.24	
14	1.95	0.39	0.42	0.225	36.86	
15	1.70	0.39	0.47	0.250	45.83	
16	1.45	0.40	0.44	0.275	48.40	
17	1.15	0.36	0.28	0.280	28.22	
18				ΣQ =	576 L/s	
19				RPD =	0.5%	
20						
21						
22						

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Figure 2-1 Recorded Field Data

2.3.2 Dilution Gauging Procedure

Dilution gauging is a convenient and reliable method for gauging channels with irregular morphology that are not suitable for the conventional velocity-area flow metering method described above. There are two methods of dilution gauging, constant rate injection and slug injection; the follow procedure will describe the field methods for salt slug injection. Additionally, dilution gauging may be useful for ice covered streams in some cases.

NOTE: Flow metering by traditional velocity-area method is always preferred to dilution gauging if possible!

The slug injection method deposits a known mass of salt into the stream "instantaneously" and measures the concentration downstream overtime. The measurement period covers the time it takes for the conductivity to respond to the tracer and return to background.

The following preparations should be made prior to a field trip involving dilution gauging:

- Equipment: Large mixing bucket, small calibration bucket, pre-weighed salt, 500 mL and/or 1000mL graduated cylinder, at least 2 syringes, YSI multimeter, and a pair of handheld radios (optional). In winter, an ice chipper and/or auger will be necessary, and a smaller bucket may be useful. **Note: The syringes from water sampling may be reused for this.**

- Salt must be pre-weighed prior to going into the field. It is also helpful to weigh out site specific salt quantities so there is one less decision to make in the field. This can be done by reviewing past flow records and measuring out approximately 15 grams for every L/s of discharge (i.e. if you expect a flow between 20-40 L/s) bring 15X40 = 600 g of salt. There is a precision scale located in the field room for this purpose. Heavy-duty Zip lock bags work well for transporting salt. Alternatively, you may pre-mix solution of known concentration and measure precise quantities to add to your bucket, but the added weight is not very field friendly. For higher background conductivities more salt may be needed.

- Calibration solution must be prepared prior to departing for the field. Mix your stock solution at 10,000 ppm prior to your field trip. That is one gram of salt for every litre of water. Mixing in large quantities such as 5 grams in 5 litres will reduce the error and ensure you have enough stock solution from the same batch for an entire field event. You should use deionized water provided by Maxxam for mixing your stock solution. Volumes must be precise, use graduated cylinders, syringes and pipettes.

The following general steps should be followed when conducting salt dilution type stream gauging:

1. Locate the monitoring station (the stations should be clearly marked).

2. **Assess and mitigate safety risks!** It is strongly recommended that two people conduct flow measurements, particularly when streams with high flows are encountered. One team member should operate the YSI multimeter while the other "injects" the salt slug.

3. The YSI multimeter should be set to log at one second intervals making sure to include the station ID.

4. Mix your salt solution with stream water in the large bucket so that it is completely dissolved. In many cases you will need to pour the salt in slowly while stirring the water, this is the quickest way to dissolve the salt! The ice chisel works well for stirring. Check to see that your team member has started logging with the YSI and dump the salt into the stream. In winter the small bucket may be critical in order to fill your mixing bucket, ice is often thick and making a hole large enough for a 20L bucket can take a long time. Be sure, however, to make the hole large enough to dump the salt mixture quickly without hitting the sides (ice). Use at least 1L for every 200 g. For small salt quantities you can use more water. For example, 200g could be mixed in 5L of water for easier dissolving.

5. When collecting water quality samples be sure to obtain them either prior to the dilution or upstream of the injections site. Doing the injection first will save time as you wait for the salt wave to pass, but only do so if you can collect the sample above the injection site or the current is swift enough to be sure all the salt is carried away immediately.

6. Once the conductivity has returned to base level stop logging, you are finished. Make sure you have recorded the time and quantity of salt used in your field notes in addition to the staff gauge reading at the site. Be sure to photograph the staff gauge, collection site, injection site upstream and downstream photos plus record the time to the minute of the reading.

7. You may perform your calibration before or after your dilution gauging so long as you obtain your background water above your measurement reach following the experiment or dump you calibration solution below your reach if done prior to your measurement. Obtain your calibration by following the steps below:

    a. Take a 1,960 mL sample of water from the creek and measure the specific conductivity. Use a graduated cylinder and syringes to measure your water and place it in a small bucket. Make sure the conductivity is the same as that recorded as the baseline for the salt test;

    b. Add to this 20 mL of stock solution from a syringe. Stir and re-measure the specific conductivity. Record values;

    c. Add another 20 mL of stock solution from the syringe. Stir, re-measure and record details.

    d. You may wish to use 1,940 mL and add three syringes if your background concentration is high since you are aiming to double the specific conductivity.

Note: One photo may capture multiple aspects (i.e. upstream and injection site).

2.4 SURVEYING AND TRACKING STAFF GAUGE DRAFT

Despite attempts to stabilize staff gauges, natural freeze-thaw cycles and ice movement have enormous force that can move staff gauges. Vertical movement of a gauge changes the standard or datum that all other measurements and records at that site are compared to. Stage records can be corrected for this movement or 'drift' is measured regularly.

Periodic surveys are the best way to measure this drift. Completed in the spring and fall, drift can be measured and change can be connected to a specific date and time.

Hydrometric levelling is an integral part of station establishment and its maintenance. The methods described must be strictly adhered to so the data can be properly adjusted at a later date. It is strongly recommended that a levelling test be carried out prior to any level checks, and after any accidental rough usage. The instrument should never be adjusted unless the test indicates the same magnitude of error at least two times. A common procedure known as the 'Two-Peg Test' is usually carried out to test the levelling instrument and determine whether any adjustment is required.

2.4.1 Procedure for Conducting the Two Peg Test

The Two-Peg Test ensures that the level (instrument) is accurately calibrated.

Establish two firm points, A and B, about 60 meters apart. Each part can be marked with a peg or a stake.

1. Set up the instrument midway between points A and B.
2. Stand rod on point A and take reading (a).
3. Stand rod on point B and take reading (b).
4. Record the difference between these two readings (a-b). The correct difference in elevation between points A and B is a-b; this is true even if the level is not sighting a true horizontal line, because the instrument is set up exactly midway.
5. Move and set up the instrument at a point that is 3 – 4 meters away from point A, at a 90° angle from the line created between point A and point B.
6. Take second readings on a rod set on points A (c) and points B (b).
7. The difference in readings found between points A and B in step 4 should be unchanged (ie. a-b=c-d) for the instrument to be in proper adjustment.
8. Should these second readings give a greater or lesser difference of 0.004m than in step 4, the instrument is out of adjustment and must be adjusted until the horizontal cross-hair is equal to the reading of (d)

NOTE: ADJUSTMENT FOR EACH TYPE OF INSTRUMENT VARIES AND THE OPERATOR SHOULD REFER TO THE INSTRUCTION MANUAL FOR THE PROPER PROCEDURE TO ADJUST THE INSTRUMENT.

2.4.2 Levelling Procedures

- Tripod should be set on firm ground
- The placement should ensure secure footing for the person using it
- Accuracy of levelling can be increased by ensuring that all backsights (BS) and all foresights (FS) are **equidistant**, this will eliminate any instrument or physical errors
- The level must first be adjusted so that the cross hairs are in focus for the operator
- The levelling rod must be placed firmly on a repeatable point of a stable object. **Note: Levelling rod should be placed directly on top of the nail head at ACG hydrometric station Bench Marks to ensure this placement repeatability.**

- The telescope can be pointed roughly at the levelling rod and focused
- Levelling rod must be held plumb, both side to side and front to back. **Tip: use a corner level that will allow the holder of the rod to keep the rod plumb, wave the rod slightly back and forth, the lowest number is the correct reading.**
- To verify accuracy of the reading: the surveyor should call out the recorded level height, the rod holder should point to the level height on the rod, and the surveyor should then re-survey verifying the level height that has been recorded
- **Rod readings to 0.002 m are sufficient**

Always place the rod directly on top of the nail head of the bench marks and directly on top of the staff gauge. The rod must be held plumb. (Sid to side - Rod will be parallel to vertical cross hairs; Forward to backward - tip the rod towards the levelling instrument and away from it. At the point of the lowest reading is where the rod will be completely plumb. The corner level will also ensure that the rod remains plumb.

2.4.3 Procedure – Level Circuit to Staff Gauge

The procedure for determining the elevation of a staff gauge in relation to the elevation of a benchmark involves several steps. Access uses three benchmarks (BM) in order to accurately determine the elevation of the staff gauge.

1. Set up levelling instrument in a convenient location roughly equidistant from each Benchmark and the staff gauge. No attempt to stay on the line directly between the two is necessary;
2. Record a backsight (BS) on you primary BM (Your primary BM is typically number #1, but it is whichever benchmark is the most stable over time) and calculate the height of instrument (HOI) by adding the BS to the known elevation of BM#1, use 100.000m;
3. Turn the level on the staff gauge (SG) and record the foresight (FS) reading to the staff gauge and the other two bench marks;
4. Calculate the elevation of the SG and each BM by subtracting the FS readings from the HOI;
5. Check to see that your benchmark elevations have not changed from the known elevations, if they have changed by more than a couple mm, you should move your level and repeat the procedure to check that the change is real and not an error;
6. Move the level to a new location where you can site all benchmarks and the staff gauge;
7. Record the BS to the staff gauge and recalculate your new HOI from the previously measured elevation of the BM;
8. Take a FS reading to all three BMs and calculate the elevation of each. They should match the previously calculate elevations; if they do not you are experiencing closure error, a couple mm is

acceptable, if you are experiencing more than a couple mm, there is an error and you should start the survey again from the beginning.

At most sites it should be possible to set up the level to site to all benchmarks and the staff gauge. If it is not possible to site to some of the benchmarks you should perform a closed circuit of the benchmarks to ensure you are not experiencing any errors. If you have an acceptably low error you may perform the above procedure with one or two benchmarks.

Level Notes

Recording accurate and complete field notes is the most important part of the levelling operation. Notes and sketches constitute a permanent record of the survey, and it should be possible for them to be interpreted with ease by anyone having knowledge of levelling.

When recording notes:

1. Enter the known elevation of the bench mark or staff gauge (or reference mark) on the line in the column headed 'Elevations as Given';
2. The bench mark identification number is entered in the column headed 'Station';
3. On the top line, in the column headed 'BS (backsight)', the reading obtained with the levelling rod on the benchmark or point of known elevation is entered as the backsight;
4. The value for the column 'Ht.Inst.' (height of instrument) is computed by adding the backsight value to the known benchmark elevation;
5. In the column headed 'foresight (FS)', the foresight reading for the point for which an elevation is to be determined is observed and recorded;
6. The elevation of the benchmark is calculated by subtracting the FS value from the Ht.Inst. This value is entered in the 'elevation column' and on the same line as the foresight just observed;
7. When the instrument is moved, the new height of the instrument is determined by a backsight on the turning point (i.e. the last bench mark for which you just determined the elevation). The observation and notes are continued in this manner until the circuit is closed by levelling back to the original starting station;

Figure 2-2 shows the ACG field sheet for performing level surveys. Please remember that is it very important to obtain your benchmark elevations prior to your field visit to check your measurements.

No 393

ACCESS

ACCESS	Stn. ID: Mc-YC-01	Prjct. Code: ACG-01
	Record Name REDACTED	Crew: N.A., A.B
	Date: 16/06/2013	Time: 1030h - 1103h

Staff Gauge Height (m): 0.722 Exact Time: 1034h

Station	BS (m)	Ht. Inst. (m)	FS (m)	Elev. (m)	Elev. as Given (m)
BM 1	1.600	101.600			100.000
Top of S.G.		"	1.400	100.200	
BM2		"	1.700	99.900	
BM3		"	1.550	100.050	
Top of S.G.	1.125	101.325		100.200	
BM1		"	1.325	100.000	
BM2		"	1.425	99.900	
BM3		"	1.275	100.050	

BM #	Est. Elev. (m)	Mean Elev. (m) [this date]	Difference (m)
1	100.000	100.000	0
2	99.900	99.900	0
3	100.050	100.050	0

Comments on Elevation changes: Gauge was 100.190 @ Oct/12 survey, thus gauge has shifted 0.010m up and 10 cm need to be added to correct to previous year.

Gauge Correction (m): +0.010m

Date of Change: Winter 2012-13. (if known)

Computed by: Name REDACTED Date: 16/06/2013.

Checked by: Name REDACTED Date: 23/06/2013.

Notes:

Pg: 4 of: 26

Rite in the Rain

Figure 2-2 Example of Survey Notes

ACCESS

2.5 MAINTENANCE OF METERS AND RATING TABLES

Current meters should be re-calibrated every year and be tested periodically by performing a spin test. As part of the re-calibration process, a relationship between the speed of rotation of the meter and the water velocity is developed. The relationship is called a rating table. The relationship is developed after each calibration and the curve is supplied with the meter as shown in Figure 2-3. The circled area in Figure 2-3 represents the correction factor calculation for the calibrated meter. All meters are unique and offer different correction factor calculations; therefore it is very important that a rating table from another current meter is not used to calculate discharge.

Canada Canada Service National D'Étalonnage

METRIC

METER NUMBER: S00790 VELOCITY IN METRES / SEC = 0.6783 X REVS / SEC + 0.0058
CALIBRATION DATE: March 13, 2008 STANDARD ERROR OF ESTIMATE= 0.0016 METRES / SEC

Revs →	2	5	10	15	20	30	40	50	60	80	100	150	200	[illegible]	← Revs
40.0	0.040	0.091	0.175	0.260	0.345	0.514	0.684	0.854	1.023	[illegible]	1.701	2.549	3.397	[illegible]	40.0
	0.039	0.090	0.173	0.257	0.341	0.508	0.676	0.843	1.011	1.346	[illegible]	[illegible]	3.355	4.193	
41.0	0.039	0.089	0.171	0.254	0.337	0.502	0.668	0.833	0.998	1.329	1.660	2.487	3.314	4.142	41.0
	0.038	0.088	0.169	0.251	0.333	0.496	0.660	0.823	0.986	1.313	1.640	2.457	3.275	4.092	
42.0	0.038	0.087	0.167	0.248	0.329	0.490	0.652	0.813	0.975	1.298	1.621	2.428	3.236	4.043	42.0
	0.038	0.086	0.165	0.245	0.325	0.485	0.644	0.804	0.963	1.283	1.602	2.400	3.198	3.996	
43.0	0.037	0.085	0.164	0.242	0.321	0.479	0.637	0.794	0.952	1.268	1.583	2.372	3.161	3.949	43.0
	0.037	0.084	0.162	0.240	0.318	0.474	0.629	0.785	0.941	1.253	1.565	2.345	3.124	3.904	
44.0	0.037	0.083	0.160	0.237	0.314	0.468	0.622	0.777	0.931	1.239	1.547	2.318	3.089	3.860	44.0
	0.036	0.082	0.158	0.234	0.311	0.463	0.615	0.768	0.920	1.225	1.530	2.292	3.054	3.816	
45.0	0.036	0.081	0.157	0.232	0.307	0.458	0.609	0.759	0.910	1.212	1.513	2.267	3.020	3.774	45.0
	0.036	0.080	0.155	0.229	0.304	0.453	0.602	0.751	0.900	1.198	1.497	2.242	2.987	3.733	
46.0	0.035	0.080	0.153	0.227	0.301	0.448	0.596	0.743	0.891	1.185	1.480	2.218	2.955	3.692	46.0
	0.035	0.079	0.152	0.225	0.298	0.443	0.589	0.735	0.881	1.173	1.464	2.194	2.923	3.652	
47.0	0.035	0.078	0.150	0.222	0.294	0.439	0.583	0.727	0.872	1.160	1.449	2.171	2.892	3.614	47.0
	0.034	0.077	0.149	0.220	0.291	0.434	0.577	0.720	0.863	1.148	1.434	2.148	2.862	3.576	
48.0	0.034	0.076	0.147	0.218	0.288	0.430	0.571	0.712	0.854	1.136	1.419	2.125	2.832	3.539	48.0
	0.034	0.076	0.146	0.216	0.285	0.425	0.565	0.705	0.845	1.125	1.404	2.104	2.803	3.502	
49.0	0.033	0.075	0.144	0.213	0.283	0.421	0.559	0.698	0.836	1.113	1.390	2.082	2.774	3.466	49.0
	0.033	0.074	0.143	0.211	0.280	0.417	0.554	0.691	0.828	1.102	1.376	2.061	2.746	3.431	
50.0	0.033	0.074	0.141	0.209	0.277	0.413	0.548	0.684	0.820	1.091	1.362	2.041	2.719	3.397	50.0
	0.033	0.073	0.140	0.207	0.274	0.409	0.543	0.677	0.812	1.080	1.349	2.020	2.692	3.364	
51.0	0.032	0.072	0.139	0.205	0.272	0.405	0.538	0.671	0.804	1.070	1.336	2.001	2.666	3.331	51.0
	0.032	0.072	0.137	0.203	0.269	0.401	0.533	0.664	0.796	1.059	1.323	1.981	2.640	3.298	
52.0	0.032	0.071	0.136	0.201	0.267	0.397	0.528	0.658	0.788	1.049	1.310	1.962	2.615	3.267	52.0
	0.032	0.070	0.135	0.200	0.264	0.393	0.523	0.652	0.781	1.039	1.298	1.944	2.590	3.236	
53.0	0.031	0.070	0.134	0.198	0.262	0.390	0.518	0.646	0.774	1.030	1.286	1.925	2.565	3.205	53.0
	0.031	0.069	0.133	0.196	0.259	0.386	0.513	0.640	0.766	1.020	1.274	1.908	2.541	3.175	
54.0	0.031	0.069	0.131	0.194	0.257	0.383	0.508	0.634	0.759	1.011	1.262	1.890	2.518	3.146	54.0
	0.031	0.068	0.130	0.192	0.255	0.379	0.504	0.628	0.753	1.001	1.250	1.873	2.495	3.117	

Figure 2-3 Rating Table Example

3 DATA MANAGEMENT AND PROCESSING

3.1 MANAGEMENT AND FILING OF NOTES, OBSERVATIONS AND DATALOGGER FILES

Standardized management of data collected in the field is important in hydrological monitoring programs. Standard protocols and systems make data processing easier and less prone to error. Processing of data often involves returning to the original field notes to cross check suspicious values or to analyze site conditions that might have been responsible for anomalies in the logger records. The following should be undertaken upon return from hydrology field work:

- Field notes scanned and filed digitally in the project files as appropriate; follow established folder and file naming protocols;

- Photos should be saved and labeled (e.g. W1 staff gauge, W1 US, W1 DS), specifically those of gauging stations or flow conditions;

- Hydrology-related observations should be included in the field report, and circulated to project staff and managers;

- Any datalogger files downloaded should be transferred immediately from the field laptop or Leveloader to the server in the appropriate file. Details on the download should be recorded in the project datalogger logbook in the field room – date of download, filename, etc.

- Files should be compensated with the appropriate barometric logger file, if applicable (non-vented loggers like the Solinst M5 need barometric compensation with Barologger data. Vented loggers like the INW PT2X do not require compensation.) Compensation for the Solinst units is straightforward, and is completed in the Data Control tab of the software. Compensated files should be saved to the project file and data should be added to the station master spreadsheet. **Confirm that you are using V.4 of the Solinst Software prior to launch – the compensation feature of V.4 is not compatible with files from loggers launched with V.3.x.**

- Manual stream gauging data should be processed into a discharge value (see below) and reported in the field report and entered into the in-situ spreadsheet for the project for input into EQWin water quality data management software. Data managers should be alerted when this has been completed.

Note: Summary Field Trip Reports (both preliminary and detailed) should be prepared after every field trip. Templates are available from managers and other field staff. Observations and calculations related to hydrology should be included in the detailed reports. These are valuable documents for Quality Control purposes and future investigations into site conditions and observations.

3.2 CALCULATION OF DISCHARGE

3.2.1 Calculating Discharge from Current Meter

The midsection method is most often used to calculate stream discharges. In this method the stream is divided into a number of panels. Each panel extends from half the distance from the previous depth and velocity measurement to half way to the next depth and velocity measurement (see below for reference).

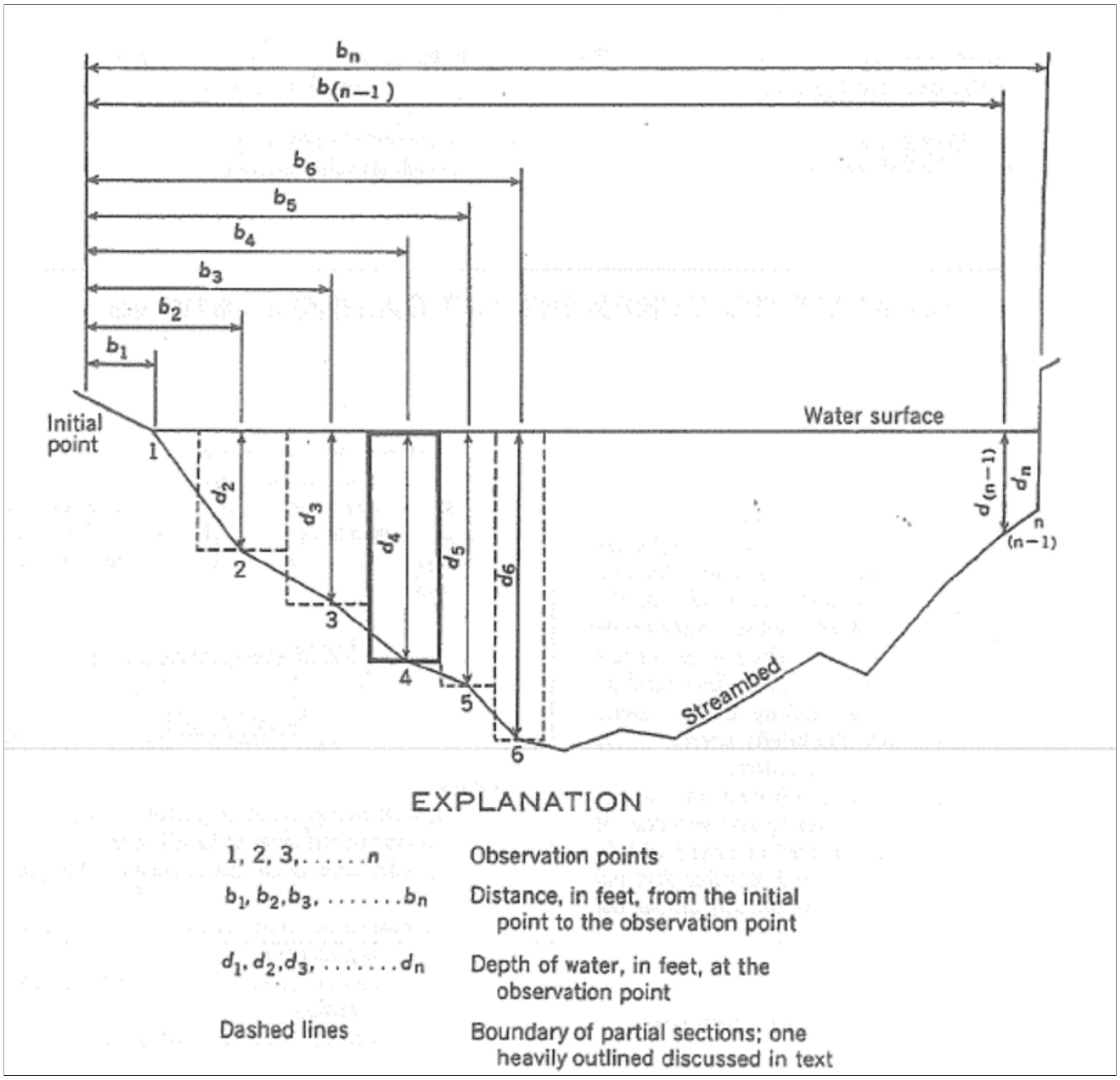


Figure 3-1 Mid-Section Method

The flow (discharge) in each panel is computed by multiplying the mean velocity at the centre of the panel by the corresponding width measured along the surface tape or cord. This width should be taken to be the sum of half the distance to adjacent verticals. The velocity in the two half widths next to the banks can be estimated.

$$Q = d_1 V_1 (b_1/2 + (b_2 - b_1)/2) + d_2 V_2 ((b_2 - b_1)/2 + (b_3 - b_2)/2) + \ldots$$

Where b1, b2, etc. are distances from the initial point (m).

d1, d2, etc. are the water depth at the measurement (m).

V1, V2, etc. are the velocity of the water column at the measurement (m/s) at 0.6 of depth.

Q is the total stream discharge (m3/s).

ACG has spreadsheet templates set up for converting field observations into discharge (Q) values. Project files should have these spreadsheets and templates pre-established. Care should be taken to use the template specific to the meter used, if revolutions were counted and velocity needs to be calculated; meters have specific formulae, which can also vary from year to year with instrument calibration. If velocity values were generated in the field, this is not a concern. An example of a completed calculation is shown below in Table 3-1.

Table 3-1 Discharge Calculation

21-May-09 1200 hrs MN-4.5 Gauge Height = 0.307 S.Keesey

Observations					
Distance from Initial Point	Depth (m)	Width (m)	Area (m)	Velocity (m/sec)	Discharge
0.45	LB				
0.6	0.160	0.125	0.020	1.26	0.025
0.7	0.200	0.1	0.020	1.29	0.026
0.8	0.200	0.1	0.020	1.46	0.029
0.9	0.180	0.1	0.018	1.15	0.021
1	0.170	0.1	0.017	0.90	0.015
1.1	0.190	0.1	0.019	0.72	0.014
1.2	0.160	0.1	0.016	0.75	0.012
1.3	0.200	0.1	0.020	0.78	0.016
1.4	0.240	0.1	0.024	0.26	0.006
1.5	0.220	0.1	0.022	0.78	0.017
1.6	0.200	0.1	0.020	0.74	0.015
1.7	0.160	0.125	0.020	0.76	0.015
1.85	RB				

Total Discharge (Q): m^3/sec 0.211

liters/sec	210.5

3.2.2 Calculating Discharge from Dilution Gauging

The specific conductivity data from the YSI plots a curve similar to a hydrograph. Like a stormflow calculation we can calculate the volume of water passing the measurement point by integrating the area under the curve. By calculating the difference in conductivity over the period of the salt wave and taking the sum we can calculate the discharge:

$$Q = \frac{M_S C_S}{\Delta t \sum (EC_t - EC_b)}$$

Where: Q = discharge

M_S = Mass of salt used

C_S = conductivity constant = ΔECIde(μS cm^{-1})/1 g of NaCl in 1m^3 of solution at 25 °C

Δt = time (s) of sampling interval

EC_t = Electrical conductivity at time t

EC_b = Background electrical conductivity

Like those for the current meter, ACG has spreadsheet templates for imputing data and calculating discharge. This should be done by field staff upon return from or during field excursions.

3.3 PROCESSING OF DATA INTO A SITE RATING CURVE

As discharge readings and corresponding water level readings from staff gauges are collected at a station, they can be plotted as X,Y points. The relationship between these variables is the formula of the line of best fit, and can be used to translate continuous water level records from data loggers into a discharge record, or hydrograph. A minimum of three points are required for a relationship to be developed, but more points across the range of stages are highly desirable. In general, rating curves should be developed by or under the guidance of a hydrologist. However, below is a general outline of how a rating curve is developed.

Steps for developing a rating curve:

- Plot a single series, with stage on the X-axis and corresponding discharge on the Y-axis.
- Chart as a scatter graph

- Add a Power trend line to the data set. A power trend line assumes that zero flow occurs at zero on the staff gauge. Since this is unlikely the staff gauge must be adjusted for the "height of zero flow". This means that if the height of zero flow is at 0.02 m then 0.02 must be subtracted from all staff gauge readings.

An example of a two stage rating curve is shown below. This results from a change in the dominant control such as overtopping the bank.

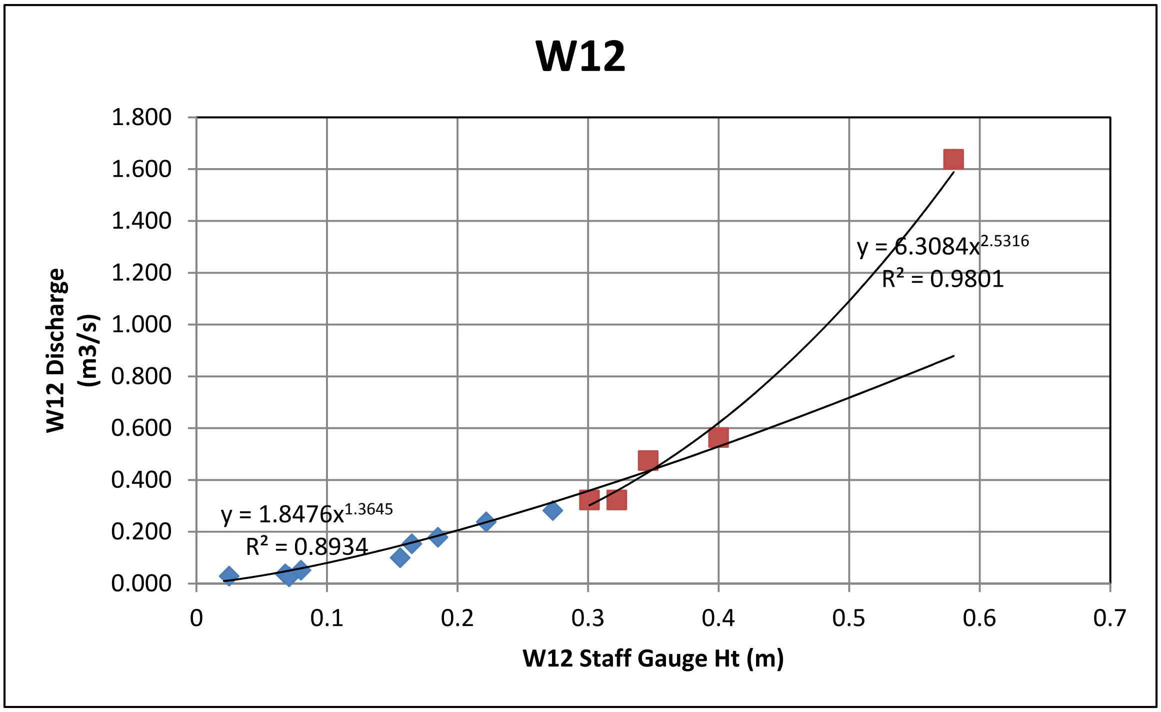


Figure 3-2 Completed Rating Curve

3.4 PROCESSING DATALOGGER RECORDS

Compensated depth of water records from downloaded files are combined into a single 'master' spreadsheet. The following steps are required to convert to an accurate discharge record:

- **Offset:** The water depth from the datalogger at any given point in time will not usually be the same as the staff gauge reading from the same time – the membrane on the datalogger is rarely positioned at exactly 0.000 m on the staff gauge. Therefore, the stage record from the logger will need to be 'adjusted' or 'offset' to line them up. This requires accurate staff gauge readings and time of observation (during the logger collection period). The difference between the logger water depth and staff gauge reading for each point in time can be calculated and the average of all these differences can be applied to the entire data record as a single offset adjustment (this could be a negative or positive difference, care needs to be taken to apply the correction in the proper direction). An example of this is shown below:

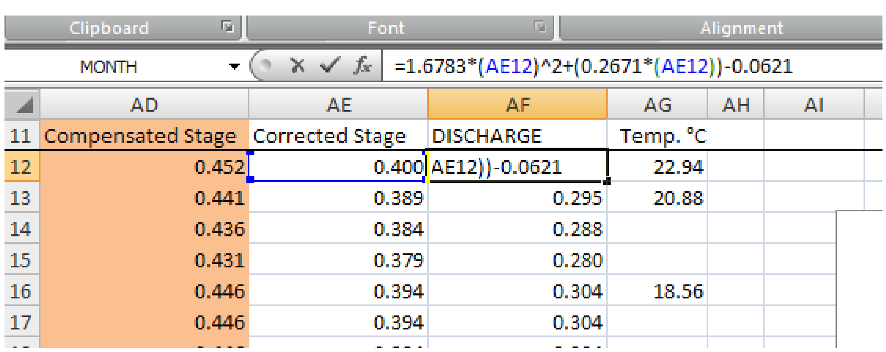
Table 3-2 Stage Record Adjustment

Date	Time	Metered Q	Staff Gauge	Logger Reading	Offset		
3-May-07	1343	0.395	0.400	0.452	0.052		
9-May-07	1400	0.231	0.330	0.431	0.101		
10-May-07	1140	0.27	0.340	0.364	0.024		
14-May-07	1400	0.137	0.261	0.298	0.037		
16-May-07	1330	0.10	0.242	0.286	0.044		
30-May-07	1130	0.02	0.185	0.223	0.038		
31-May-07	1600	0.027	0.13	0.239	0.109		
28-Jun-07	1500	0.013	0.16	0.193	0.033	Average:	0.055

Note: The offset can be determined and programmed into the instrument upon installation, such that the data record is 'adjusted' upon download and export. Notes should indicate if this is conducted or not at installation.

In addition to the offset from the staff gauge, a second offset must be applied to adjust the record relative to the height of zero flow. The height of zero flow may be obtained directly by surveying the height of the section control downstream of the stilling well or indirectly by adjusting the offset until the "best-fit" is found for the observations to a power function with an exponent base in reality (usually 1.5-2.5).

- Apply Rating Formula to Stage Record: The rating curve formula developed for the station is used to convert the stage record to a discharge record. The adjusted stage record values are mapped into the formula as the X variable to determine the discharge for that stage. The formula can then be 'dragged' down the entire data record. See below for example using above rating formula:



Clipboard | Font | Alignment

MONTH =1.6783*(AE12)^2+(0.2671*(AE12))-0.0621

	AD	AE	AF	AG	AH	AI
11	Compensated Stage	Corrected Stage	DISCHARGE	Temp. °C		
12	0.452	0.400	AE12))-0.0621	22.94		
13	0.441	0.389	0.295	20.88		
14	0.436	0.384	0.288			
15	0.431	0.379	0.280			
16	0.446	0.394	0.304	18.56		
17	0.446	0.394	0.304			

Figure 3-3 Rating Formula Example

- **Plot Hydrograph:** the discharge values can then be plotted as Y-axis values against data/time on the X-axis as a discharge record or hydrograph. An example is shown below. Loggers are often launched prior to being placed in the stream, so the data record may need to be 'cropped'. Temperature readings can help to determine if the instrument was in water or air, if field notes are not available or need to be refined for exact time. Erroneous data may be logged due to ice formation, and the temperature record can also help with this determination.

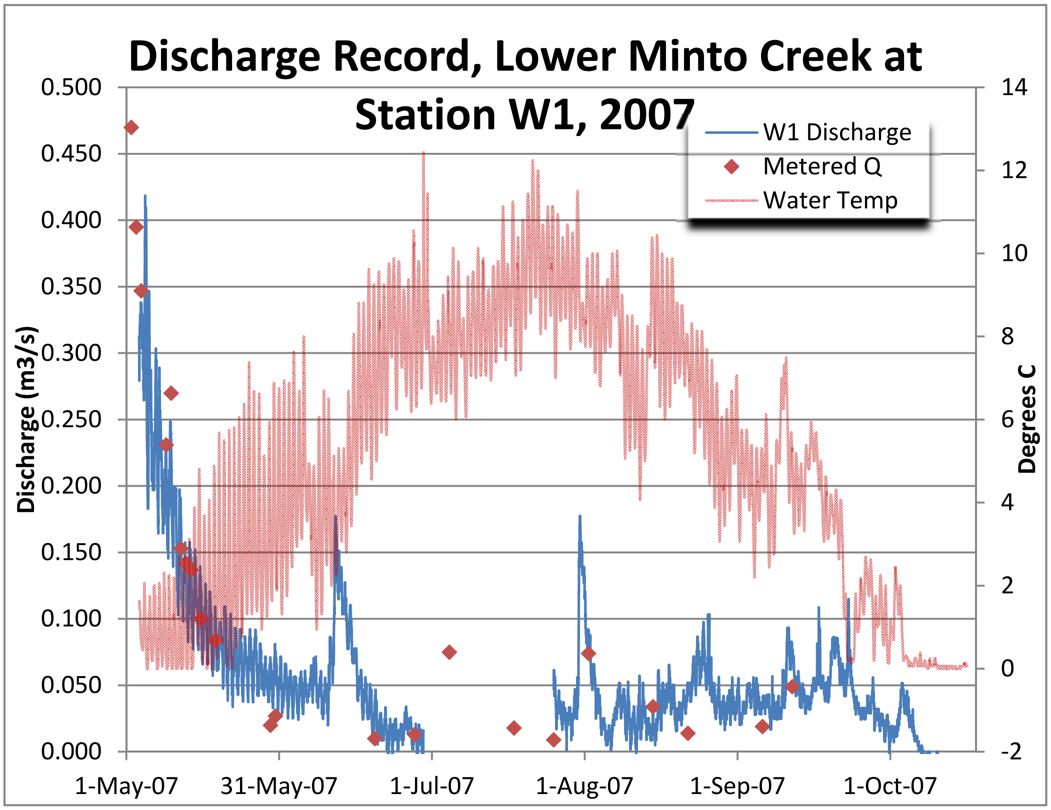


Figure 3-4 Hydrograph Example, Minto Creek 2007

- Dataloggers have shown a tendency to output data with date/time values that do not plot properly in Excel. This problem has consumed excessive time in the data management stage in the past, so the issues and potential resolutions are presented here:

- .csv files are less functional than .xls files. Try saving original data files in .xls format.

- Regional settings – US and Canadian regional settings on computers read dates differently. Dataloggers often output dates in the US data format (DD/MM/YY), and if the laptop/PC used to download the files is set to the Canadian regional setting, issues arise that are difficult to correct. All computers should be set to US: Control Panel>Regional Settings and Languages

- Dates need to be in Date/Time format to chart properly. Often outputs are in TEXT format and need to be converted using the DATEVALUE function.

- Date and Time fields are often separated into separate columns, and data is charted in 'blocks' where all data from one day is charted at the same point on the x-axis. In order to create a true 'continuous' record, Date and Time fields will need to be combined. If the original fields are formatted properly (DATEVALUE and TIMEVALUE) then is can be as simple as combining using a formula like: =A1+B1.

- The worst case scenario is that you have to deconstruct a date into its parts and recombine/reformat using functions like: =LEFT(A2,3,1).

- Dataloggers do not automatically adjust for daylight savings time. Typically the area 'synched' with the time of the computer launching it. When data records are being compared with metering for offsets, differences should be accounted for by adjusting the metering time to match the data record – if required.

4 REFERENCES

Resources Information Standards Committee (RISC), 2009. Manual of British Columbia Hydrometric Standards. Province of British Columbia, Ministry of Environment, Science and Information Branch.

APPENDIX G

BASELINE KZK HYDROLOGY REVIEW (KNIGHT PIESOLD LTD.)

May 10, 2018

File No.:VA101-00640/06-A.01
Cont. No.:VA18-00832

Name REDACTED
Mining Engineer
BMC Minerals (No. 1) Ltd.
750 - 789 West Pender Street
Vancouver, British Columbia
Canada, V6C 1H2

Dear Name REDA

Re: Baseline KZK Hydrology Review

1 – INTRODUCTION

BMC Minerals (No. 1) Ltd. (BMC) is currently developing the Kudz Ze Kayah Project (the Project), a proposed lead-zinc mine in the Yukon, Canada. BMC requested that KP provide baseline hydrology data analysis to support the 2018 hydrology and climate baseline report and the 2018 hydrometeorology report.

1.1 SCOPE OF LETTER

This letter report presents KP's hydrology analysis methodology and the resulting measured discharge records for the Project study area. This letter report will be used to support a baseline climate and hydrology report prepared by Alexco Environmental Group Inc. (AEG). As such, information about the data collection sites and procedures, such as station descriptions, instrumentation history, and discharge measurement methodology, are not included in this letter report. The measured streamflow records presented herein will also be used to support estimates of long-term values of hydrologic parameters, which will be provided in a separate hydrometeorology report to be prepared by KP.

2 – INTRODUCTION

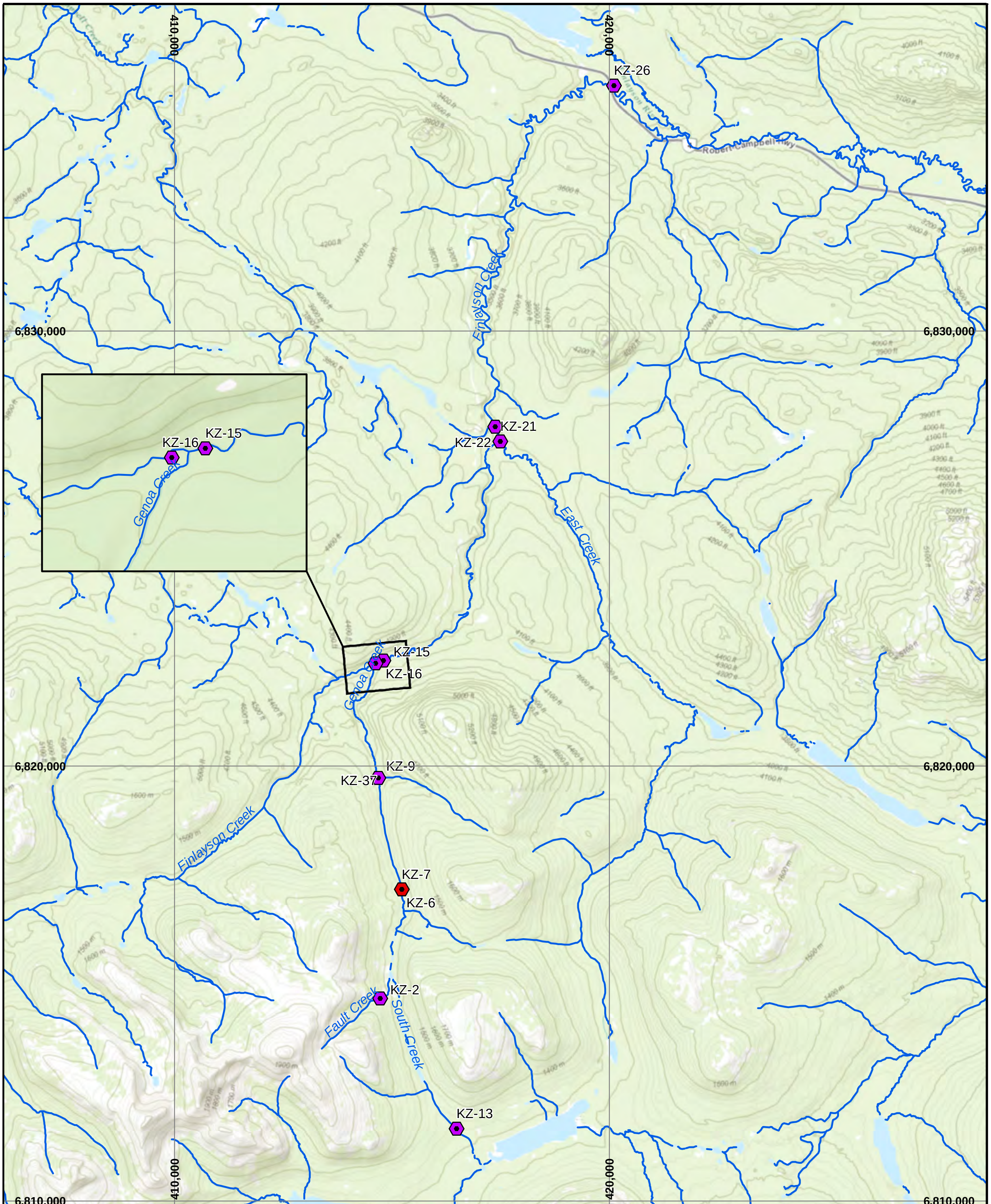
There are a total of nine hydrology stations that have been operating within the KZK Project study area since 2015. The locations of all streamflow stations are shown on Figure 1 and the station characteristics are summarised in Table 1. Continuous streamflow data are available for seven monitoring stations, all of which are still active. The remaining two stations have a discrete discharge measurement record. One discrete measurement station is still active, while measurements at the other have been discontinued. The hydrometric data collected for the Project have been reviewed by a qualified reviewer in general accordance with the "Standard Process for Review of Hydrometric Data", as detailed in the Manual of BC Hydrometric Standards (RISC 2009). AEG has been collecting hydrology data at the Project site and provided KP with site data for this analysis.

AEG has provided KP with the following information:

- 30-minute water level records for seven continuous hydrology stations
- Monthly staff gauge readings during the open water period for seven continuous hydrology stations
- Monthly discharge measurements for nine hydrology stations, and
- Field notes and site photos.

KP understands that these site data were reviewed by AEG so KP has not confirmed:

- The discharge measurement calculations
- The staff gauge readings with site photos
- The appropriateness or validly of discharge methodology, or
- The measurement uncertainty associated with individual stage or discharge measurements.



LEGEND:

- ACTIVE HYDROLOGY STATION
- INACTIVE HYDROLOGY STATION

NOTES:

1. BASE MAP: (C) MICROSOFT BING MAPS.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 9N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:125,000 FOR 8.5x11 (LETTER) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	REVIEWED
0	05APR'18	ISSUED WITH LETTER	DJA	DJA	ACA

BMC MINERALS (NO. 1) LTD

KUDZ ZE KAYAH PROJECT

PROJECT HYDROLOGY STATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-640/06	VA18-00832

FIGURE 1 REV 0

Table 1 Summary of KZK Project Hydrology Stations

Watershed		Location	Station Name	Mean Catchment Elevation (m)	Drainage Area (km²)	Data Collection Type	Active or Inactive	Start Date	End Date[1]
Liard River		South Creek	KZ-13	1540	7.9	Continuous	Active	April 2015	December 2017
Liard River	Finlayson Creek	Fault Creek	KZ-2	1707	1.9	Continuous	Active	April 2015	December 2017
Liard River	Finlayson Creek	Upper Geona Creek	KZ-7	1541	10.3	Discrete	Inactive	April 2016	March 2017
Liard River	Finlayson Creek	Geona Creek near proposed dam	KZ-9	1498	16.4	Continuous	Active	May 2015	December 2017
Liard River	Finlayson Creek	Finlayson Creek below Geona Creek	KZ-15	1479	60.9	Continuous	Active	April 2015	December 2017
Liard River	Finlayson Creek	Finlayson Creek above Geona Creek	KZ-16	1477	35.0	Continuous	Active	April 2015	December 2017
Liard River	Finlayson Creek	East Creek	KZ-21	1282	86.4	Discrete	Active	April 2016	December 2017
Liard River	Finlayson Creek	Finlayson Creek below East Creek	KZ-22	1354	162.4	Continuous	Active	April 2015	December 2017
Liard River	Finlayson Creek	Lower Finlayson Creek	KZ-26	1294	210.7	Continuous	Active	April 2015	December 2017

NOTES:

1. DATA COLLECTION AT ACTIVE STATIONS IS ONGOING, HOWEVER, THE END DATE INDICATES THE END OF DATA USED IN THIS REPORT.
2. MEAN CATCHMENT ELEVATION VALUES ARE AS PRESENTED BY AEG (2016).

3 – METHODOLOGY

3.1 STAGE RECORD REVIEW

For each of the seven continuous water level records, water level to stage corrections were undertaken using Aquarius time series software, which allows for advanced data correction and correction tracking. Periods with erroneous water level data, which may be the result of ice effects, instrumentation malfunction, and/or sensor or clock drift, were reviewed and corrected or removed from the data sets. During winter conditions, the stage-discharge relationship for each station is likely altered by transient effects due to icing of the channel. The timing of ice-affected conditions was assessed on a station by station and year by year basis, using the water level and temperature record as well as site notes and photos. Aside from data likely affected by ice in the channels, most of the data corrections were minor and short-term, covering periods typically less than six hours. There was one exception; the 2017 open water record for KZ-26 diverged from other stations in the project area and was considered invalid. This data anomaly appears to be the result of instrumentation damage, and accordingly it is recommended that the instrument be recalibrated.

The reviewed water level records were then offset to their respective site's datum; the resulting corrected water level data are referred to as stage data. Field notes indicate that one benchmark (BM1) at each station was given an assumed elevation of 100.000 m during biannual station surveys, and this elevation was specified as the universal site datum. The biannual surveys at many stations recorded year to year and intra-year elevation variations for the benchmarks and staff gauges, typically in the order of 1 cm to 2 cm, but sometimes as large as 5 cm. KP assumed that these variations are true elevation variations and therefore average values were used for offset calculations. Offsets were determined by comparing manual staff gauge readings, which are referenced to station datum, to the water level recorded by the instrumentation. The water level records were corrected to the site datum by applying average offsets for an installation period. Instrumentation was moved each fall for sensor winterization and again in each spring to remove icing protection. Instrumentation was also occasionally moved during the open water season for a variety of reasons.

3.2 RATING CURVE DEVELOPMENT

A rating curve describes the relationship between water level (stage) and discharge at a single location in a stream. A rating curve was developed at each continuous monitoring station and was then applied to the respective continuous stage record to derive a continuous streamflow record for the respective station.

In order to develop these rating curves, AEG made a number of site visits to each station to obtain discharge and stage measurements for a range of streamflow conditions. Stage and discharge measurement summaries for each hydrology station are presented in Appendix A. An example of the measurement history for Fault Creek hydrology station KZ-2 is presented in Table 2. During each site visit, the stage was determined independently of the data logger record by reading a staff gauge attach to the instrumentation stilling well. Two different techniques were used to collect discharge measurements at the hydrometric stations: the velocity-area method and the salt dilution method. Typically, two discharge measurements were taken during each site visit by AEG to quantify streamflow.

Rating curves were delineated by manually fitting 'visual-best-fit' lines to the calibration data, with consideration of the physical conditions at each site, including the hydraulic characteristics of the control section, with the objective of minimizing the difference between the rating curve predicted discharges and the measured discharges. The basic form of the rating curve equation is based on general hydraulic theory pertaining to open channel flow, and the values of the coefficient and exponent are dependent on the hydraulic characteristics of the control section at the gauge, thereby providing a means of checking the validity of the derived equation (Maidment, 1993). The stage-discharge rating curves are represented by an equation, or series of equations, of the form:

$$\boldsymbol{Q} = \boldsymbol{C} \times (\boldsymbol{Stage} - \boldsymbol{A})^{\boldsymbol{n}}$$

Where Q is the discharge in cubic meters per second (m^3/s), C is a curve coefficient, $Stage$ is the height of the water surface above an arbitrary site datum, A is an offset (frequently given as the stage of zero flow), and n is a curve exponent.

Rating curves for each continuous flow station were developed and are presented in Appendix B. An example rating curve for Fault Creek hydrology station KZ-2 is presented on Figure 2. Each figure includes a photo of the control section at moderate or low flow. Discharge measurements were given error bars to visualize measurement uncertainty. Measurement uncertainty is typically assigned by the person collecting each measurement, but since the measurements were not collected by KP, measurement uncertainty was simply assumed to be nominal 10%, regardless of measurement methodology or site conditions.

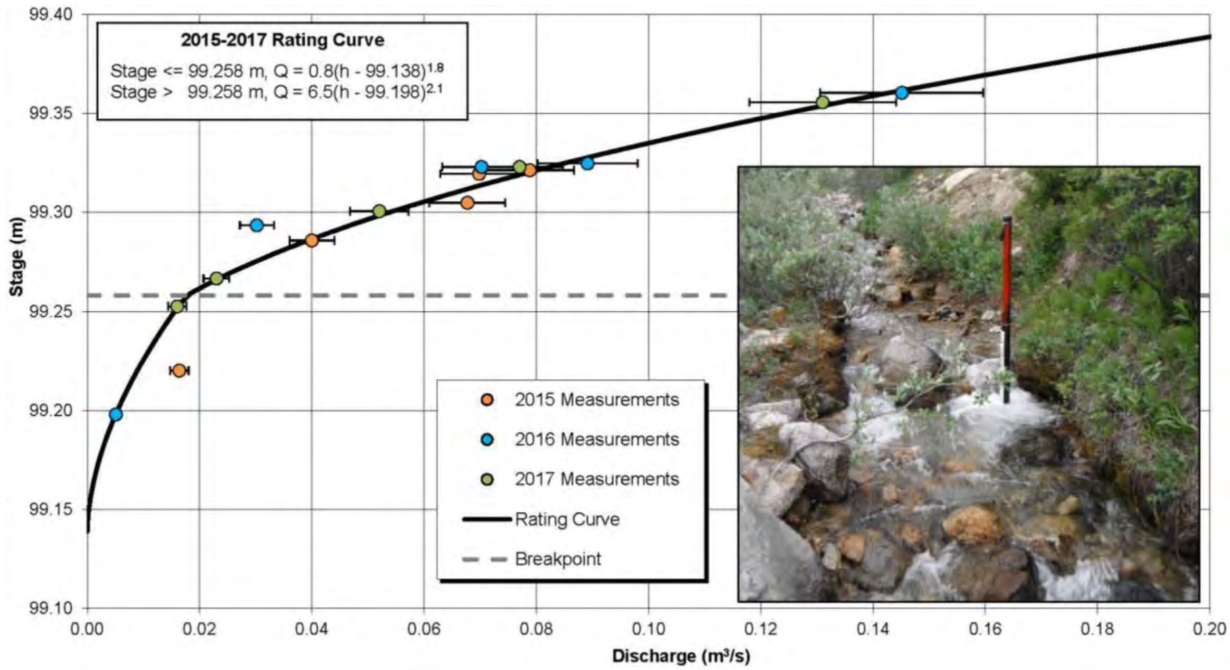
Rating curves extrapolated over the entire range of recorded stage for each station are also presented in Appendix B, and an example of an extrapolated rating curve is shown on Figure 3. Rating curve extrapolation for each station has been done to the maximum measured stage; however, at most stations, the extrapolated flows represent a relatively small proportion of the annual measured flow record, and as such, there is generally good confidence in the quality of the flow records. Caution should, however, be applied when considering extrapolated discharges.

Table 2 **Summary of Stage-Discharge Measurements for Fault Creek Hydrology Station KZ-2**

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
30-Apr-2015	2	Salt Dilution	-	0.005	Channel ice present
12-May-2015	2	Salt Dilution	99.220	0.016	Station installed
22-Jun-2015	2	Salt Dilution	99.321	0.079	-
29-Jul-2015	2	Salt Dilution	99.286	0.040	-
23-Aug-2015	2	Salt Dilution	99.305	0.068	-
11-Sep-2015	2	Salt Dilution	99.319	0.070	-
15-Oct-2015	2	Salt Dilution	-	0.028	Channel ice present
20-Nov-2015	2	Salt Dilution	-	0.011	Channel ice present
3-Dec-2015	2	Salt Dilution	-	0.008	Channel ice present
20-Jan-2016	2	Salt Dilution	-	0.006	Channel ice present
9-Feb-2016	2	Salt Dilution	-	0.005	Channel ice present
20-Mar-2016	2	Salt Dilution	-	0.003	Channel ice present
21-Apr-2016	2	Salt Dilution	-	0.003	Channel ice present
5-May-2016	2	Salt Dilution	99.198	0.005	-
14-Jun-2016	2	Salt Dilution	99.323	0.070	-
28-Jul-2016	2	Salt Dilution	99.293	0.030	-
27-Aug-2016	2	Salt Dilution	99.360	0.145	-
8-Sep-2016	2	Salt Dilution	99.325	0.089	-
4-Oct-2016	2	Salt Dilution	-	0.037	Channel ice present
16-Nov-2016	2	Salt Dilution	-	0.011	Channel ice present
20-Dec-2016	2	Salt Dilution	-	0.007	Channel ice present
16-Jan-2017	2	Salt Dilution	-	0.004	Channel ice present
23-Feb-2017	2	Salt Dilution	-	0.004	Channel ice present
21-Mar-2017	2	Salt Dilution	-	0.004	Channel ice present
29-Apr-2017	2	Salt Dilution	-	0.007	Channel ice present
18-May-2017	2	Salt Dilution	-	0.013	Channel ice present
7-Jun-2017	2	Salt Dilution	99.323	0.077	-
20-Jul-2017	2	Salt Dilution	99.356	0.131	-
10-Aug-2017	2	Salt Dilution	99.301	0.052	-
14-Sep-2017	2	Salt Dilution	99.267	0.023	-
5-Oct-2017	2	Salt Dilution	99.253	0.016	-
2-Nov-2017	2	Salt Dilution	-	0.012	Channel ice present
6-Dec-2017	2	Salt Dilution	-	0.005	Channel ice present

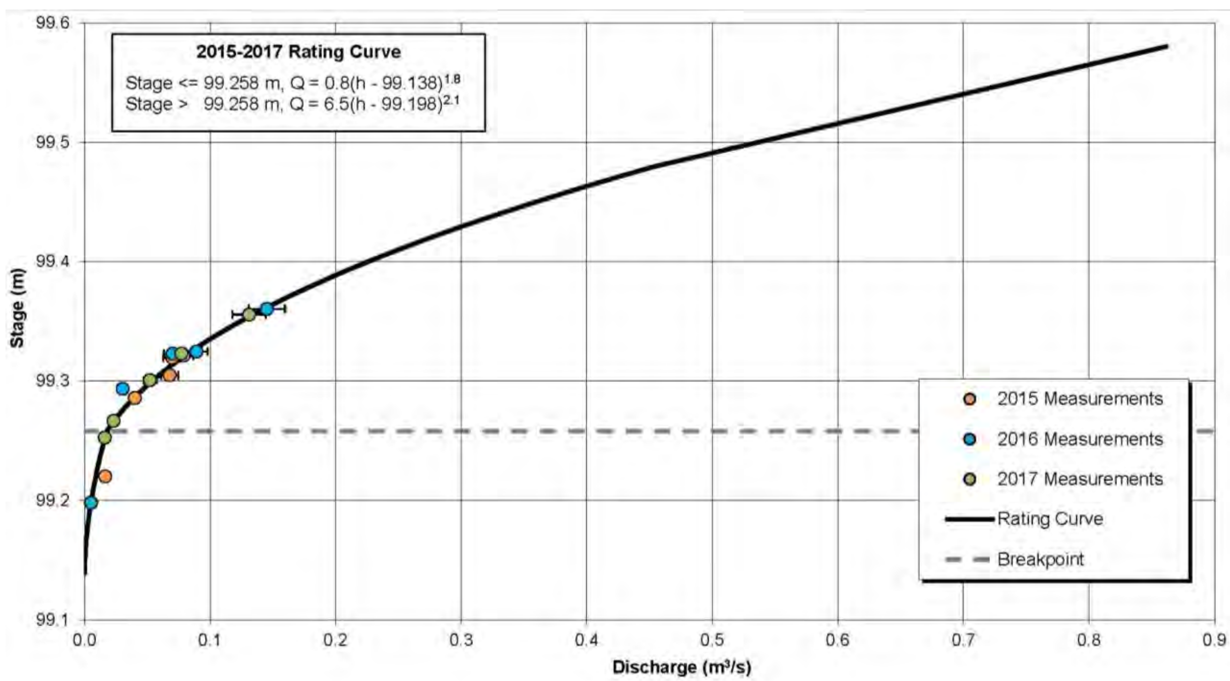
NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.



NOTES:
1. PHOTO OF SITE FROM JUNE 22, 2015.
2. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

Figure 2 Rating Curve for Fault Creek Hydrology Station KZ-2



NOTES:
1. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

Figure 3 Rating Curve for Fault Creek Hydrology Station KZ-2 Extrapolated to Maximum Recorded Stage

3.3 MEASURED RECORD DEVELOPMENT

Measured discharge records were developed for each hydrology station by applying the rating curves to their respective stage records. Average daily discharge values were derived from the 30-minute record to produce daily discharge records for each station. Discharge hydrographs for each station are presented in Appendix C and an example hydrograph for Fault Creek KZ-2 is shown on Figure 4.

Winter measurements were not used for rating curve development due to icing effect errors, but were used to characterise winter streamflow. Estimated daily winter flows were linearly interpolated between winter discharge measurements to infill the gap between individual measurements. These estimated flows were calculated when a sufficient number of measurements were made to estimate streamflow with some certainty. This is a valid approach because all mid-winter flows are provided by groundwater discharge. Typically flows were not estimated during stream freeze-up or thaw since conditions can change rapidly at those times and flows cannot be assumed to be vary consistently. The estimated winter discharge values were added to the discharge records for each station.

The resulting discharge hydrographs are typically characterised by high spring snowmelt-driven flows, lower summer flows sustained by groundwater inflows and periodic rainfall events, followed by large autumn rainfall events. Winter flow is very low as a result of cold temperatures, freezing conditions, and the gradual depletion of groundwater storage.

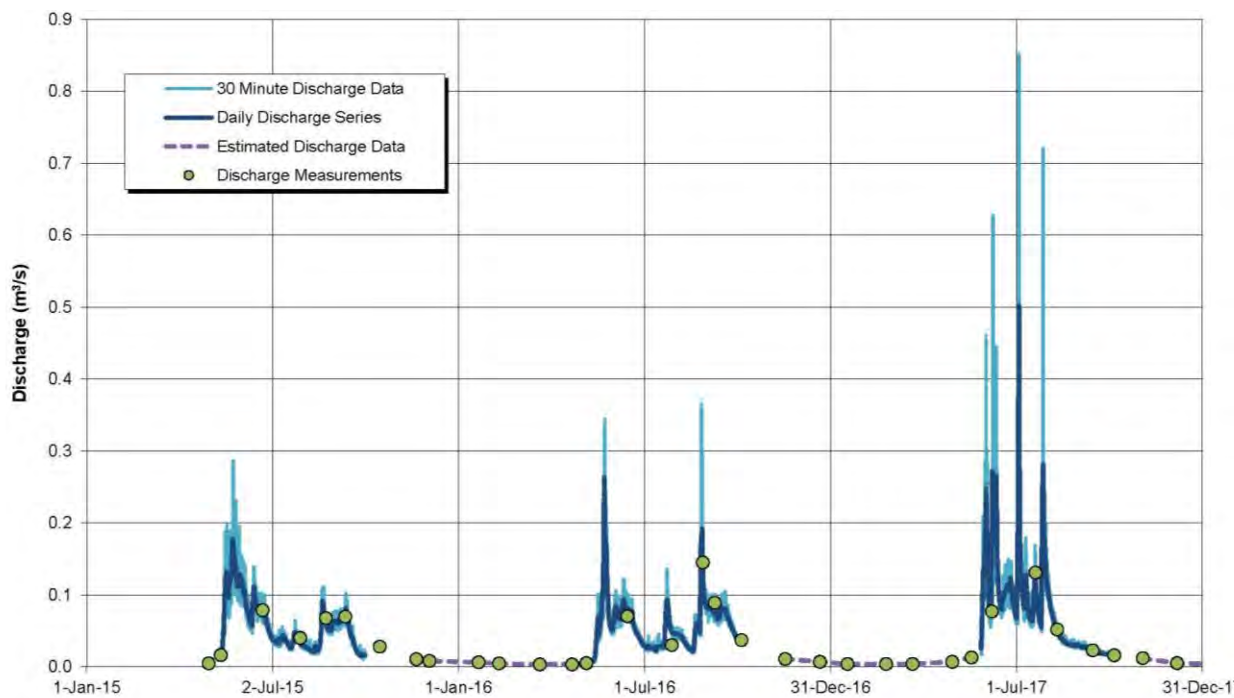


Figure 4 Fault Creek Hydrology Station KZ-2 Hydrograph

3.4 PRORATED RECORD DEVELOPMENT

The KZK hydrometric network has two discrete measurement stations where no instrumentation was installed to collect instantaneous water level records. An estimated daily streamflow record for these two stations, KZ-7 and KZ-21, was developed by prorating the measured record from a nearby continuous station by drainage area. The prorated record was then visually validated by comparing the estimated flows with the instantaneous discharge measurements made at the station. Hydrographs from these stations are presented in Appendix C and an example hydrograph from KZ-7 is presented on Figure 5, along with an inset of the estimated 2016 hydrograph for KZ-9.

The discharge measurements at KZ-7 show a general agreement in scale and timing with the prorated record; however, some 2016 measurements fall above the daily record. The Figure 5 inset shows the KZ-9 hydrograph from 2016 for comparison and some discharge measurements also fall above the measured daily record; however, these measurements agree more closely with the 30-minute record. Overall, it appears that the estimated flows likely reasonably represent the actual flows at these two locations.

Winter streamflow was estimated for discrete stations using the same methodology discussed in Section 3.3.

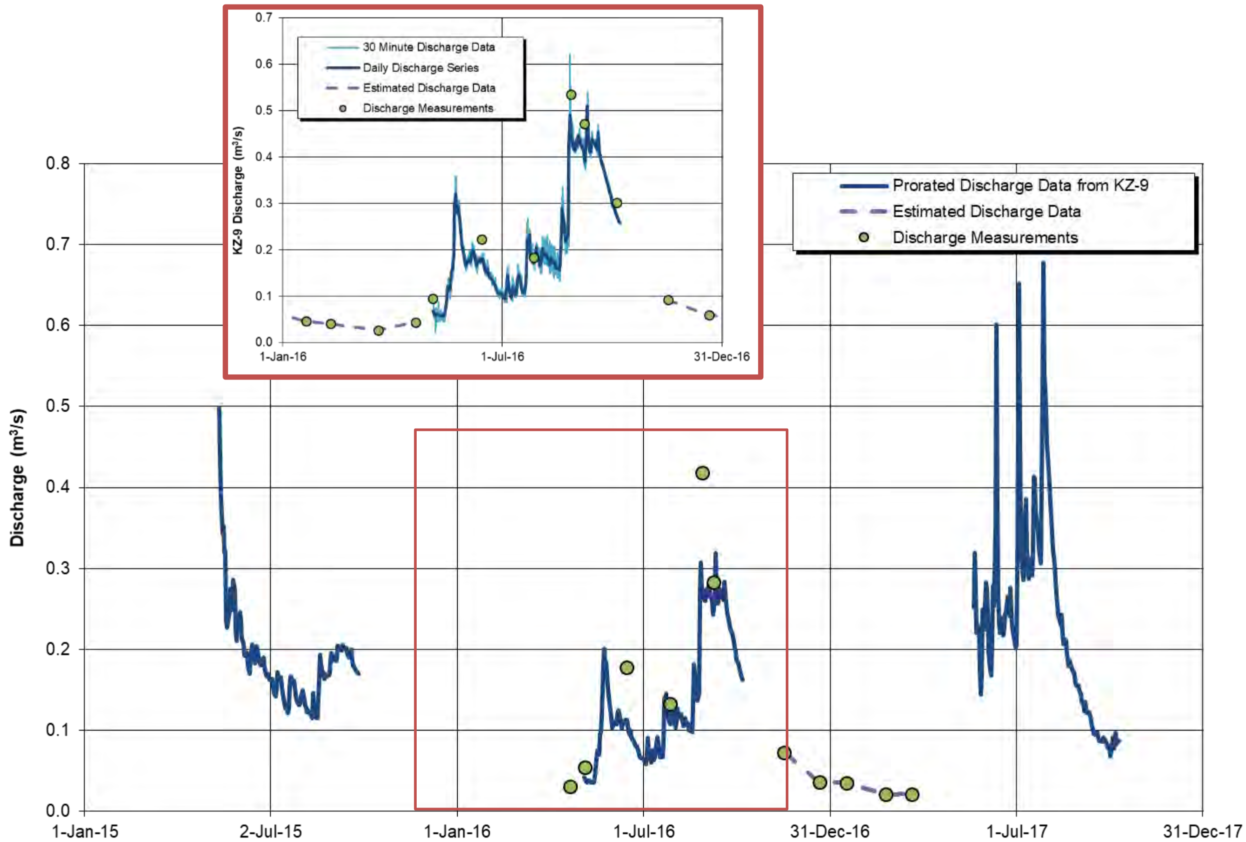


Figure 5 Upper Geona Creek Hydrology Station KZ-7 Estimated Hydrograph with an Inset of the 2016 Hydrograph from Hydrology Station KZ-9

3.5 MEAN MONTHLY DISCHARGE

The monthly discharge for each year of record was calculated for all the hydrology stations, and the results are presented in Table 3. Monthly discharge values are only presented for months with at least 20 days of discharge data. These results show year to year variation in the magnitude and timing of the freshet and fall peaks and the summer low flows. At stations where streamflow from more than one winter was estimated, it appears that the year to year variation of winter flows is minor.

Table 3 Summary Monthly Discharge for Site Stations

Station Name	Station ID.	Drainage Area (km^2)	Year	Mean Monthly Discharge (m^3/s)											
				Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Fault Creek	KZ-2	1.9	2015	-	-	-	-	-	0.08	0.04	0.04	0.05	-	-	0.01
			2016	0.01	0.00	0.00	0.00	0.05	0.07	0.04	0.06	0.07	-	-	0.01
			2017	0.00	0.00	0.00	0.01	0.03	0.13	0.12	0.05	0.02	-	0.01	-
Upper Geona Creek	KZ-7	10.3	2015	-	-	-	-	-	0.19	0.15	0.15	0.19	-	-	-
			2016	-	-	-	-	0.09	0.10	0.09	0.15	0.25	-	0.07	0.04
			2017	0.03	0.02	0.02	-	-	0.26	0.37	0.25	0.11	-	-	-
Geona Creek near proposed dam	KZ-9	16.4	2015	-	-	-	-	-	0.31	0.24	0.24	0.31	-	-	0.07
			2016	0.05	0.04	0.03	-	0.14	0.16	0.14	0.24	0.41	-	-	0.06
			2017	0.05	0.04	0.03	0.03	-	0.41	0.60	0.40	0.17	-	0.07	0.04
South Creek	KZ-13	7.9	2015	-	-	-	-	-	0.16	0.09	0.11	0.16	0.07	-	-
			2016	-	0.01	-	-	0.11	0.10	0.08	0.13	0.24	0.08	-	-
			2017	0.02	0.02	0.02	0.01	-	0.25	0.38	0.20	0.08	-	0.02	-
Finlayson Creek below Geona Creek	KZ-15	60.9	2015	-	-	-	-	1.65	0.93	0.58	0.66	1.09	-	-	0.27
			2016	0.13	0.09	0.09	-	0.63	0.50	0.53	0.95	1.63	-	-	0.18
			2017	0.15	0.10	0.09	0.10	1.13	1.49	2.10	1.29	0.52	-	0.23	-
Finlayson Creek above Geona Creek	KZ-16	35.0	2015	-	-	-	-	-	0.55	0.39	0.46	0.56	-	-	0.11
			2016	0.06	0.05	0.08	-	-	0.24	0.27	0.53	0.87	-	-	-
			2017	-	-	0.10	0.17	-	0.78	1.19	0.82	0.32	-	0.11	-
East Creek	KZ-21	86.4	2015	-	-	-	-	1.85	0.90	0.71	0.93	1.43	0.90	-	-
			2016	-	-	-	-	0.51	0.40	0.53	1.01	1.62	-	-	0.25
			2017	0.20	0.14	0.04	0.10	1.39	1.51	2.63	1.42	0.56	-	0.29	-
Finlayson Creek below East Creek	KZ-22	162.4	2015	-	-	-	-	-	1.78	1.40	1.84	2.83	1.78	-	0.54
			2016	-	-	-	-	1.00	0.80	1.04	1.99	3.19	-	-	0.43
			2017	0.32	0.24	0.21	0.25	2.74	2.99	5.18	2.80	1.10	-	0.37	-
Lower Finlayson Creek	KZ-26	210.7	2015	-	-	-	-	-	2.36	1.72	2.31	2.66	-	-	0.34
			2016	0.37	0.39	0.35	0.55	1.16	0.96	1.34	2.33	3.49	-	-	0.28
			2017	0.47	0.47	0.54	0.49	-	-	-	-	-	-	0.62	-

NOTES:

1. MEAN MONTHLY DISCHARGE VALUES ONLY PRESENTED FOR MONTHS WITH MORE THAN 20 DAYS OF RECORD.

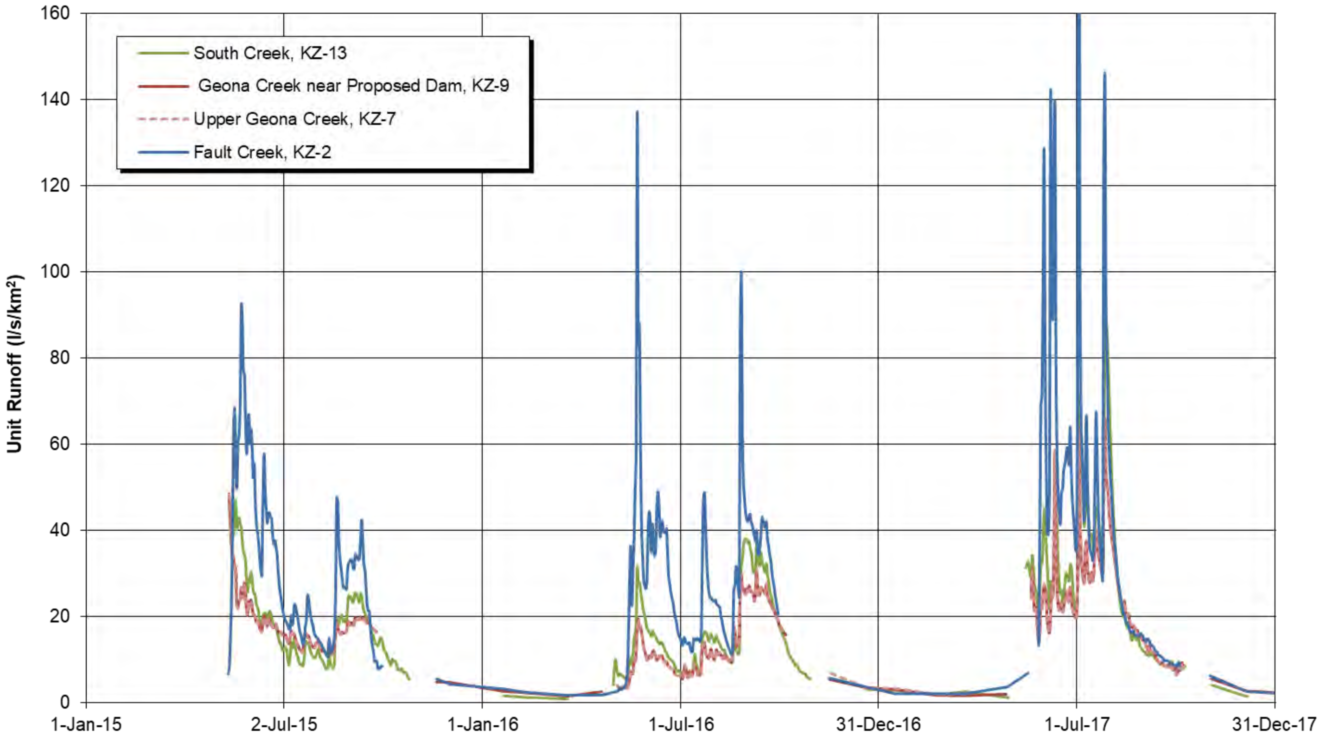
4 – COMPARISON OF UNIT RUNOFF FROM SITE STATIONS

The discharge hydrographs for each station presented in Appendix C were converted to unit runoff and compared to identify site trends. Overall, all streamflow measured within the Project study area show consistent relationships and trends. Based on sites with three years of record, 2017 was the highest flow year while 2015 was the lowest. All years have a roughly bimodal shape, with one distinct peak in late May or June and another peak in September and early October. Many hydrographs also show rainfall-induced peaks in mid-summer, particularly in July. Consistent with typical hydrologic patterns, those stations with higher elevations and smaller catchments tend to experience higher unit runoff during the freshet and lower unit runoff during the summer.

For further discussion, the stations have been separated into two major areas, as follows:

- The proposed mine area, consisting of KZ-2, KZ-7, KZ-9 and KZ-13, and
- Lower Finlayson Creek, consisting of KZ-15, KZ-16, KZ-21, KZ-22, and KZ-26.

The 2015 to 2017 unit runoff comparison for stations in the proposed mine area is presented on Figure 6. Individual figures for each year are presented in Appendix D. Flows at all stations are generally similar in magnitude and shape, with some variation in amplitude. Fault Creek at KZ-2 has the highest freshet and storm-induced runoff. This trend is consistent with its relatively small, high elevation catchment. KZ-2 also has higher runoff through periods of lower flow than other stations in the region, indicating that flows in this catchment may have a relatively large groundwater component. The only station that is not in the Finlayson Creek catchment, KZ-13 on South Creek, is downstream of a long headwater lake (South lakes). Typical lake effects, and in particular attenuated peaks and sustained low flows, are not especially evident from the hydrograph record for KZ-13. The KZ-13 hydrograph is definitely less peaky than the KZ-2 hydrograph, but is arguably more responsive or flashier than the KZ-9 hydrograph. The low flows measured at KZ-13 are similar or lower than at the other stations with a similar median catchment elevation and size. Streamflows at stations in Geona Creek (KZ-7 and KZ-9) have lower unit runoff during the freshet than stations with smaller catchments. Similarly, streamflows in these Geona Creek catchments have a smaller response to storms during the summer. KZ-7 and KZ-9 appear to have the same runoff during the open water season, which is not surprising since the KZ-7 flows were prorated from the KZ-9 flows. Unit winter flows at all stations are quite similar.



NOTES:

1. UNIT RUNOFF FROM KZ-2 PEAKS AT 261 l/s/km^2 ON JULY 4, 2017. THE SCALE OF THE FIGURES HAS BEEN DEFINED FOR PRESENTATION.

Figure 6 Unit Runoff Comparison for Stations near Proposed Mine Area

The 2015 to 2017 unit runoff comparison for lower Finlayson Creek stations is presented on Figure 7. Figures for each year are also presented in Appendix D. Flows at all stations are very similar in magnitude and shape. Streamflows in the relatively higher and smaller catchments (KZ-15 and KZ-16) typically have higher unit runoff during the freshet than stations with larger catchments lower in the watershed, as expected. During periods of low flows, unit runoff in upper and smaller catchments is similar to the lower larger catchment areas indicating groundwater contribution is comparable through the Finlayson Creek system. The station on Finlayson Creek below the Geona Creek confluence (KZ-15) consistently has slightly higher runoff than the station above the confluence (KZ-16), indicating that Geona Creek has higher unit runoff than the headwater area of Finlayson Creek. At the confluence, Geona Creek makes up roughly 40% of the KZ-15 catchment. Streamflows at stations in lower Finlayson Creek (KZ-22 and KZ-26) are quite similar year-round. Finlayson Creek below East Creek KZ-22 and East Creek KZ-21 have the same runoff during the open water season because the KZ-21 flows were prorated from the KZ-22 flows. Unit winter flows at all stations show similar magnitude and variation.

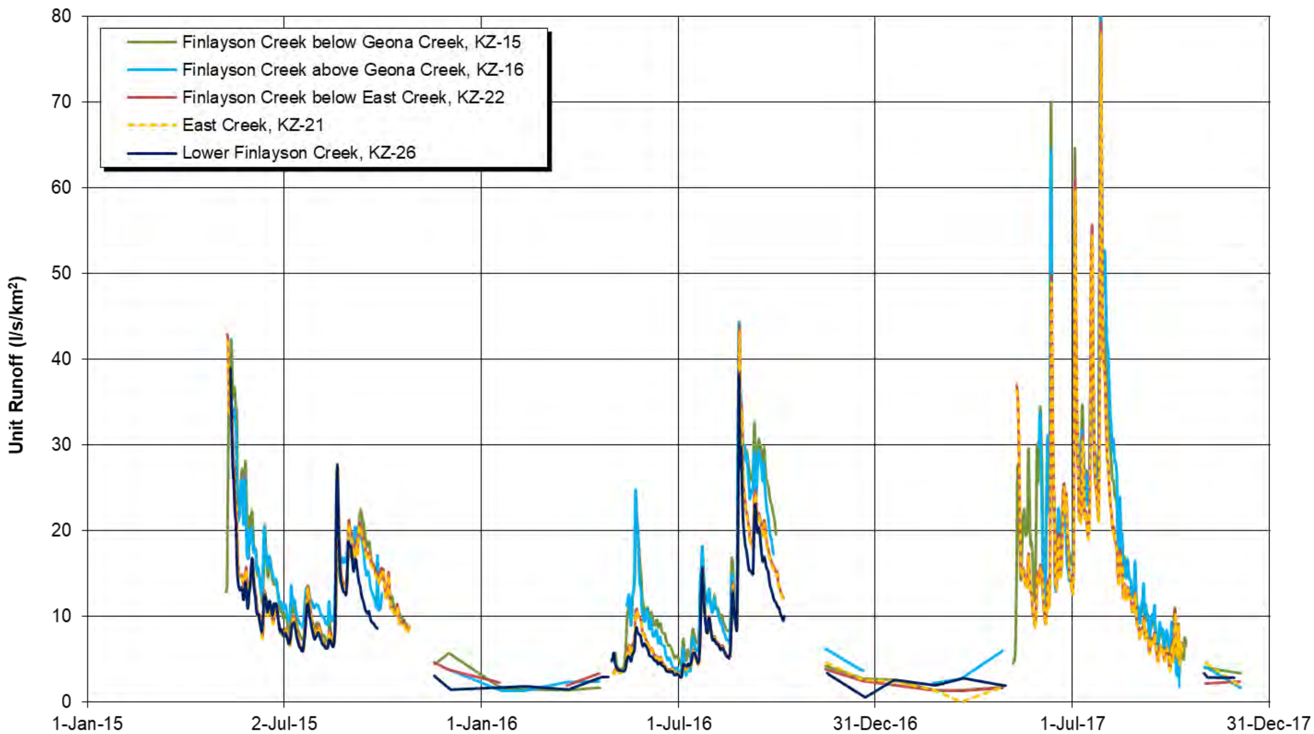


Figure 7 Unit Runoff Comparison for Stations in Lower Finlayson Creek

5 – SUMMARY

The project hydrometric data sets are judged to be of good quality, predominantly Grade A (RISC, 2009), and are considered to provide an appropriate basis for assessing the hydrological characteristics of the Project.

5.1 RECOMMENDATIONS:

Some stations are situated in gauge pools that experience a lot of wave action. KP therefore recommends that AEG confirm that the instruments installed at these locations are set to average multiple readings for a minimum of 5 minutes before logging a value. KP also recommends that AEG field staff estimate staff gauge reading uncertainty each time that a staff gauge level is recorded.

KP further recommends that the instrumentation at KZ-26 be removed for recalibration, and that all instruments be recalibrated on a regular basis (every 2 to 3 years, minimum) since they are particularly prone to malfunction after multiple winters in-situ.

Knight Piésold CONSULTING

Please contact the undersigned if you have any additional questions.

Yours truly,
Knight Piésold Ltd.

Signature REDACTED

PROFESSIONAL

Signature REDACTED

Prepared: Name REDACTED P.Eng.
Project Engineer

Review Name REDACTED ., P.Eng.
Specialist Hydrotechnical Engineer

Signature REDACTED

Approval that this document adheres to Knight Piésold Quality Systems:

Attachments:

Appendix A	Stage-Discharge Measurement Tables
Appendix B	Rating Curves
Appendix C	Hydrographs
Appendix D	Unit Runoff Comparisons

References:

Alexco Environmental Group (AEG), 2016. 2015 Hydrometeorology Baseline Report Kudz Ze Kaya Project. Prepared for BMC Minerals (No. 1) LTD. December 2016.

Maidment, D.R., 1993. Handbook of Hydrology. McGraw-Hill Inc., Washington, DC, USA.

Resources Information Standards Committee (RISC), 2009. Manual of British Columbia Hydrometric Standards. Prepared for the Ministry of Environment. 2009.

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APPENDIX A

STAGE-DISCHARGE MEASUREMENT TABLES

(Tables A-1 to A-10)

Knight Piésold
CONSULTING

TABLE A-1

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-2 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 14:47:25

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
30-Apr-2015	2	Salt Dilution	-	0.005	Channel ice present
12-May-2015	2	Salt Dilution	99.220	0.016	Station installed
22-Jun-2015	2	Salt Dilution	99.321	0.079	-
29-Jul-2015	2	Salt Dilution	99.286	0.040	-
23-Aug-2015	2	Salt Dilution	99.305	0.068	-
11-Sep-2015	2	Salt Dilution	99.319	0.070	-
15-Oct-2015	2	Salt Dilution	-	0.028	Channel ice present
20-Nov-2015	2	Salt Dilution	-	0.011	Channel ice present
3-Dec-2015	2	Salt Dilution	-	0.008	Channel ice present
20-Jan-2016	2	Salt Dilution	-	0.006	Channel ice present
9-Feb-2016	2	Salt Dilution	-	0.005	Channel ice present
20-Mar-2016	2	Salt Dilution	-	0.003	Channel ice present
21-Apr-2016	2	Salt Dilution	-	0.003	Channel ice present
5-May-2016	2	Salt Dilution	99.198	0.005	-
14-Jun-2016	2	Salt Dilution	99.323	0.070	-
28-Jul-2016	2	Salt Dilution	99.293	0.030	-
27-Aug-2016	2	Salt Dilution	99.360	0.145	-
8-Sep-2016	2	Salt Dilution	99.325	0.089	-
4-Oct-2016	2	Salt Dilution	-	0.037	Channel ice present
16-Nov-2016	2	Salt Dilution	-	0.011	Channel ice present
20-Dec-2016	2	Salt Dilution	-	0.007	Channel ice present
16-Jan-2017	2	Salt Dilution	-	0.004	Channel ice present
23-Feb-2017	2	Salt Dilution	-	0.004	Channel ice present
21-Mar-2017	2	Salt Dilution	-	0.004	Channel ice present
29-Apr-2017	2	Salt Dilution	-	0.007	Channel ice present
18-May-2017	2	Salt Dilution	-	0.013	Channel ice present
7-Jun-2017	2	Salt Dilution	99.323	0.077	-
20-Jul-2017	2	Salt Dilution	99.356	0.131	-
10-Aug-2017	2	Salt Dilution	99.301	0.052	-
14-Sep-2017	2	Salt Dilution	99.267	0.023	-
5-Oct-2017	2	Salt Dilution	99.253	0.016	-
2-Nov-2017	2	Salt Dilution	-	0.012	Channel ice present
6-Dec-2017	2	Salt Dilution	-	0.005	Channel ice present

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER VA18-00832	AT	JJM

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TABLE A-2

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-7 HYDROLOGY STATION
SUMMARY OF DISCHARGE MEASUREMENTS

Print May/08/18 14:51:17

Date	Number of Discharge Measurements	Discharge Measurement Method	Discharge (m^3/s)	Comment
20-Apr-2016	2	Salt Dilution	0.03	Ice in chanel.
5-May-2016	2	Salt Dilution	0.05	Some ice remaining in channel.
14-Jun-2016	2	Velocity-Area	0.18	-
27-Jul-2016	2	Velocity-Area	0.13	-
27-Aug-2016	2	Velocity-Area	0.42	-
8-Sep-2016	2	Velocity-Area	0.28	-
16-Nov-2016	2	Salt Dilution	0.07	Ice in channel.
20-Dec-2016	2	Salt Dilution	0.04	Ice in channel.
16-Jan-2017	2	Salt Dilution	0.04	Ice in channel.
23-Feb-2017	2	Salt Dilution	0.02	Ice in channel.
21-Mar-2017	2	Salt Dilution	0.02	Ice in channel.

\\knightpiesold.local\VA-Prj$\1\01\00640\06\A\Data\Task 400 - Water Balance\Task 405 - HydroMet\Hydrology\Data QAQC\[KZ-7 Hydrolo

NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A-3

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-9 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 14:52:40

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
11-May-2015	2	Salt Dilution	-	0.97	Station installed. Channel ice present
13-May-2015	2	Salt Dilution	98.975	0.58	Station moved. Stage effected by bank vegetation
24-Jun-2015	2	Salt Dilution	98.632	0.28	-
29-Jul-2015	2	Salt Dilution	98.572	0.20	-
23-Aug-2015	2	Salt Dilution	98.607	0.24	-
10-Sep-2015	2	Salt Dilution	98.666	0.32	-
15-Oct-2015	2	Salt Dilution	-	0.17	Channel ice present
20-Nov-2015	2	Salt Dilution	-	0.08	Channel ice present
2-Dec-2015	2	Salt Dilution	-	0.08	Channel ice present
20-Jan-2016	2	Salt Dilution	-	0.05	Channel ice present
9-Feb-2016	2	Salt Dilution	-	0.04	Channel ice present
20-Mar-2016	2	Salt Dilution	-	0.03	Channel ice present
20-Apr-2016	2	Salt Dilution	-	0.04	Channel ice present
4-May-2016	2	Salt Dilution	98.517	0.10	-
14-Jun-2016	2	Salt Dilution	98.560	0.22	-
27-Jul-2016	2	Salt Dilution	98.557	0.18	-
27-Aug-2016	2	Salt Dilution	98.806	0.54	-
7-Sep-2016	2	Salt Dilution	98.767	0.47	-
4-Oct-2016	2	Salt Dilution	98.624	0.30	-
16-Nov-2016	2	Salt Dilution	-	0.09	Channel ice present
20-Dec-2016	2	Salt Dilution	-	0.06	Channel ice present
16-Jan-2017	2	Salt Dilution	-	0.05	Channel ice present
23-Feb-2017	2	Salt Dilution	-	0.03	Channel ice present
21-Mar-2017	2	Salt Dilution	-	0.03	Channel ice present
29-Apr-2017	2	Salt Dilution	-	0.03	Channel ice present
17-May-2017	2	Salt Dilution	-	0.36	Channel ice present
7-Jun-2017	2	Salt Dilution	98.601	0.29	-
19-Jul-2017	2	Salt Dilution	98.967	0.78	Stage effected by bank vegetation
10-Aug-2017	2	Salt Dilution	98.765	0.44	-
14-Sep-2017	2	Salt Dilution	98.552	0.15	-
5-Oct-2017	2	Salt Dilution	98.538	0.13	-
3-Nov-2017	2	Salt Dilution	-	0.09	Channel ice present
5-Dec-2017	2	Salt Dilution	-	0.05	Channel ice present

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NOTES:
1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER VA18-00832	AAC	JJM

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TABLE A-4

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-13 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 14:54:14

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
30-Apr-2015	2	Salt Dilution	-	0.010	Channel ice present
13-May-2015	2	Salt Dilution	100.445	0.335	Station installed
24-Jun-2015	2	Salt Dilution	100.292	0.142	-
29-Jul-2015	2	Salt Dilution	100.240	-	-
23-Aug-2015	2	Salt Dilution	100.313	-	-
11-Sep-2015	2	Salt Dilution	100.345	-	-
14-Oct-2015	2	Salt Dilution	100.243	-	-
6-Nov-2015	2	Salt Dilution	-	-	Channel ice present
2-Dec-2015	2	Salt Dilution	-	0.048	Channel ice present
21-Jan-2016	2	Salt Dilution	-	0.013	Channel ice present
8-Feb-2016	2	Salt Dilution	-	0.011	Channel ice present
21-Mar-2016	2	Salt Dilution	-	0.007	Channel ice present
20-Apr-2016	2	Salt Dilution	-	-	Channel ice present
16-May-2016	2	Salt Dilution	100.167	-	-
14-Jun-2016	2	Salt Dilution	100.211	0.105	-
26-Jul-2016	2	Salt Dilution	100.231	0.122	-
28-Aug-2016	2	Salt Dilution	100.341	0.268	-
6-Sep-2016	2	Salt Dilution	100.352	0.327	-
3-Oct-2016	2	Salt Dilution	100.249	0.144	Some ice on banks
16-Nov-2016	2	Salt Dilution	-	0.048	Channel ice present
21-Dec-2016	2	Salt Dilution	-	0.025	Channel ice present
17-Jan-2017	2	Salt Dilution	-	0.023	Channel ice present
22-Feb-2017	2	Salt Dilution	-	0.015	Channel ice present
20-Mar-2017	2	Salt Dilution	-	0.021	Channel ice present
30-Apr-2017	2	Salt Dilution	-	0.010	Channel ice present
17-May-2017	2	Salt Dilution	100.276	0.245	-
6-Jun-2017	2	Salt Dilution	100.219	0.160	-
20-Jul-2017	2	Salt Dilution	100.341	0.345	-
9-Aug-2017	2	Salt Dilution	100.250	0.236	-
14-Sep-2017	2	Salt Dilution	100.116	0.077	-
3-Oct-2017	2	Salt Dilution	100.087	0.058	-
2-Nov-2017	2	Salt Dilution	-	0.033	Channel ice present
6-Dec-2017	2	Salt Dilution	-	0.011	Channel ice present

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A-5

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-15 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 14:55:57

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
29-Apr-2015	2	Velocity-Area	-	0.08	-
9-May-2015	2	Velocity-Area	-	-	Station installed. Ice covered.
11-May-2015	2	Velocity-Area	98.136	1.80	Ice gone from channel banks
12-May-2015	2	Velocity-Area	98.184	2.31	-
13-May-2015	2	Velocity-Area	98.217	2.56	-
22-Jun-2015	2	Velocity-Area	97.942	-	-
23-Jun-2015	2	Velocity-Area	97.943	0.79	-
28-Jul-2015	2	Velocity-Area	97.878	0.63	-
22-Aug-2015	2	Velocity-Area	97.962	0.97	-
9-Sep-2015	2	Velocity-Area	98.064	1.08	-
14-Oct-2015	2	Velocity-Area	97.930	0.70	-
19-Nov-2015	2	Velocity-Area	-	0.27	Ice in channel
2-Dec-2015	2	Salt Dilution	-	0.35	Ice in channel
20-Jan-2016	2	Salt Dilution	-	0.10	Ice covered
9-Feb-2016	2	Salt Dilution	-	0.09	Ice covered
20-Mar-2016	2	Velocity-Area	-	0.08	Ice in channel
20-Apr-2016	2	Velocity-Area	-	0.10	Ice in channel
28-Apr-2016	2	Velocity-Area	-	-	-
4-May-2016	2	Velocity-Area	97.825	0.32	Banks are ice free
13-Jun-2016	2	Velocity-Area	97.865	0.53	-
26-Jul-2016	2	Velocity-Area	97.939	0.81	-
27-Aug-2016	2	Velocity-Area	98.254	2.54	-
7-Sep-2016	2	Velocity-Area	98.089	1.49	-
1-Oct-2016	2	Velocity-Area	-	0.78	Ice in channel margins
15-Nov-2016	2	Salt Dilution	-	0.26	Ice in channel
20-Dec-2016	2	Salt Dilution	-	0.17	Ice in channel
16-Jan-2017	2	Velocity-Area	-	0.16	Ice in channel
27-Feb-2017	2	Velocity-Area	-	0.08	Ice covered
21-Mar-2017	2	Salt Dilution	-	0.09	Ice covered
28-Apr-2017	2	Velocity-Area	-	0.11	Ice on banks
16-May-2017	2	Velocity-Area	97.989	1.23	-
6-Jun-2017	2	Velocity-Area	97.953	0.95	-
19-Jul-2017	2	Velocity-Area	98.189	2.58	-
10-Aug-2017	2	Velocity-Area	98.061	1.64	-
13-Sep-2017	2	Velocity-Area	97.875	0.64	-
5-Oct-2017	2	Velocity-Area	-	0.54	-
2-Nov-2017	2	Salt Dilution	-	0.25	Ice in channel
5-Dec-2017	2	Velocity-Area	-	0.21	Ice in channel

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	JAI	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A-6

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

ORIGINAL KZ-16 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 14:58:05

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
30-Apr-2015	1	Salt Dilution	-	0.07	Channel ice present
11-May-2015	2	Velocity-Area	-	0.95	Channel ice present
12-May-2015	2	Velocity-Area	-	1.12	Channel ice present
13-May-2015	2	Velocity-Area	98.979	1.47	Stilling well moved
22-Jun-2015	2	Velocity-Area	98.833	0.53	-
28-Jul-2015	2	Velocity-Area	98.803	0.41	-
22-Aug-2015	2	Velocity-Area	98.855	0.60	-
10-Sep-2015	2	Velocity-Area	98.862	0.64	Station moved.

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A-7

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

SECOND KZ-16 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 14:58:05

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
9-Sep-2015	2	Velocity-Area	98.818	0.64	Station installed
14-Oct-2015	2	Velocity-Area	-	0.31	Channel ice present
1-Nov-2015	2	Salt Dilution	-	0.16	Channel ice present
2-Dec-2015	2	Salt Dilution	-	0.13	Channel ice present
20-Jan-2016	2	Salt Dilution	-	0.05	Channel ice present
9-Feb-2016	2	Salt Dilution	-	0.05	Channel ice present
20-Mar-2016	2	Salt Dilution	-	0.08	Channel ice present
20-Apr-2016	2	Salt Dilution	-	0.08	Channel ice present
4-May-2016	2	Velocity-Area	-	0.14	Channel ice present
13-Jun-2016	2	Velocity-Area	98.693	0.25	-
26-Jul-2016	2	Velocity-Area	98.769	0.49	-
27-Aug-2016	2	Velocity-Area	98.942	1.46	-
7-Sep-2016	2	Velocity-Area	98.841	0.93	-
1-Oct-2016	2	Velocity-Area	-	0.49	Channel ice present
15-Nov-2016	2	Salt Dilution	-	0.22	Channel ice present
20-Dec-2016	2	Salt Dilution	-	0.13	Channel ice present
16-Jan-2017	2	Salt Dilution	-	0.32	Channel ice present
23-Feb-2017	2	Salt Dilution	-	0.08	Channel ice present
21-Mar-2017	2	Salt Dilution	-	0.10	Channel ice present
28-Apr-2017	2	Salt Dilution	-	0.21	Channel ice present
16-May-2017	2	Velocity-Area	-	0.67	Channel ice present
6-Jun-2017	2	Velocity-Area	98.738	0.40	-
19-Jul-2017	2	Velocity-Area	98.865	1.39	-
10-Aug-2017	2	Velocity-Area	98.821	0.88	-
13-Sep-2017	2	Velocity-Area	98.678	0.34	-
4-Oct-2017	2	Velocity-Area	98.681	0.33	-
2-Nov-2017	2	Salt Dilution	-	0.15	Channel ice present
5-Dec-2017	2	Salt Dilution	-	0.06	Channel ice present

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A-8

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-21 HYDROLOGY STATION
SUMMARY OF DISCHARGE MEASUREMENTS

Print May/08/18 15:00:12

Date	Number of Discharge Measurements	Discharge Measurement Method	Discharge (m^3/s)	Comment
19-Apr-2016	2	Salt Dilution	0.37	Ice in channel.
4-May-2016	2	Velocity-Area	0.43	-
13-Jun-2016	2	Velocity-Area	0.27	-
25-Jul-2016	2	Velocity-Area	1.04	-
26-Aug-2016	2	Velocity-Area	1.95	-
6-Sep-2016	2	Velocity-Area	1.30	-
30-Sep-2016	2	Velocity-Area	1.04	-
15-Nov-2016	2	Salt Dilution	0.40	Ice in channel.
19-Dec-2016	2	Salt Dilution	0.22	Ice in channel.
16-Jan-2017	2	Salt Dilution	0.21	Ice in channel.
22-Feb-2017	2	Salt Dilution	0.13	Ice in channel.
20-Mar-2017	-	Estimation	0.00	No flowing water found. Ice in channel.
28-Apr-2017	1	Salt Dilution	0.16	Ice in channel.
16-May-2017	2	Velocity-Area	1.62	-
6-Jun-2017	2	Velocity-Area	0.87	-
9-Aug-2017	2	Velocity-Area	1.62	-
13-Sep-2017	2	Velocity-Area	0.67	-
4-Oct-2017	2	Velocity-Area	0.64	-
2-Nov-2017	1	Salt Dilution	0.39	Ice in channel.
4-Dec-2017	2	Salt Dilution	0.16	Ice in channel.

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

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TABLE A-9

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-22 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 15:25:26

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
29-Apr-2015	2	Salt Dilution	-	0.34	Station re-established
11-May-2015	2	Salt Dilution	99.601	3.99	-
23-Jun-2015	2	Salt Dilution	99.302	1.77	Sensor moved
28-Jul-2015	2	Velocity Area	99.269	1.52	-
23-Aug-2015	2	Velocity Area	99.376	2.70	-
9-Sep-2015	2	Velocity Area	99.382	2.50	-
14-Oct-2015	2	Salt Dilution	99.290	1.40	No ice in channel
18-Nov-2015	2	Salt Dilution	-	0.75	Ice on staff gauge
1-Dec-2015	2	Salt Dilution	-	0.61	Ice covered
19-Jan-2016	2	Salt Dilution	-	0.36	Ice covered
8-Feb-2016	1	Salt Dilution	-	0.77	Ice covered
20-Mar-2016	2	Salt Dilution	-	0.31	Ice covered
19-Apr-2016	2	Velocity Area	-	0.54	Ice on banks, channel flowing
4-May-2016	2	Velocity Area	99.155	0.61	-
13-Jun-2016	2	Velocity Area	99.181	0.78	-
25-Jul-2016	2	Velocity Area	99.323	2.01	-
26-Aug-2016	2	Velocity Area	99.486	4.18	-
6-Sep-2016	2	Velocity Area	99.402	2.89	-
30-Sep-2016	2	Velocity Area	99.357	2.51	No ice in channel
15-Nov-2016	2	Salt Dilution	-	0.62	Ice covered
19-Dec-2016	2	Salt Dilution	-	0.40	Ice covered
16-Jan-2017	2	Salt Dilution	-	0.32	Ice covered
22-Feb-2017	2	Salt Dilution	-	0.22	Ice covered
20-Mar-2017	2	Salt Dilution	-	0.21	Ice covered
28-Apr-2017	2	Salt Dilution	-	0.27	Ice covered
16-May-2017	2	Velocity Area	99.360	2.70	No ice in channel
5-Jun-2017	2	Velocity Area	99.314	1.80	-
9-Aug-2017	2	Velocity Area	99.431	4.27	-
13-Sep-2017	2	Velocity Area	99.237	1.33	-
4-Oct-2017	2	Velocity Area	99.239	1.30	No ice in channel
2-Nov-2017	2	Salt Dilution	-	0.35	Ice in channel
4-Dec-2017	2	Salt Dilution	-	0.39	Ice covered
7-Jan-2018	2	Salt Dilution	-	0.31	Ice covered

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NOTES:

1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER VA18-00832	AIF	JJM

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TABLE A-10

BMC MINERALS (NO.1) LTD.
KUDZ ZE KAYAH PROJECT

KZ-26 HYDROLOGY STATION
SUMMARY OF STAGE-DISCHARGE MEASUREMENTS

Print May/08/18 15:27:26

Date	Number of Discharge Measurements	Discharge Measurement Method	Stage (m)	Discharge (m^3/s)	Comment
29-Apr-2015	1	Salt Dilution	-	0.35	Ice covered
11-May-2015	2	Velocity Area	-	11.39	-
14-May-2015	2	Velocity Area	98.053	7.61	Station installed
23-Jun-2015	2	Velocity Area	97.806	2.30	-
29-Jul-2015	2	Velocity Area	97.758	1.75	-
22-Aug-2015	2	Velocity Area	97.921	4.76	-
8-Sep-2015	2	Velocity Area	97.857	3.41	-
15-Oct-2015	2	Velocity Area	-	1.54	Ice forming in channel
18-Nov-2015	2	Salt Dilution	-	0.60	Ice covered
1-Dec-2015	2	Salt Dilution	-	0.32	Ice covered
8-Feb-2016	1	Salt Dilution	-	0.40	Ice covered
19-Mar-2016	2	Salt Dilution	-	0.33	Ice covered
19-Apr-2016	2	Velocity Area	-	0.63	Ice on banks and in channel, channel flowing
28-Apr-2016	2	Velocity Area	-	0.63	Ice on banks and in channel, channel flowing
3-May-2016	2	Velocity Area	97.696	0.98	-
13-Jun-2016	2	Velocity Area	97.684	1.02	-
25-Jul-2016	2	Velocity Area	97.836	2.93	-
26-Aug-2016	2	Velocity Area	97.847	2.95	-
6-Sep-2016	2	Velocity Area	97.851	3.67	-
30-Sep-2016	2	Velocity Area	97.797	2.53	No ice in channel
15-Nov-2016	2	Salt Dilution	-	0.70	Ice covered
19-Dec-2016	2	Salt Dilution	-	0.13	Ice covered
15-Jan-2017	2	Salt Dilution	-	0.56	Ice covered
22-Feb-2017	2	Salt Dilution	-	0.43	Ice covered
20-Mar-2017	2	Salt Dilution	-	0.60	Ice covered
28-Apr-2017	2	Salt Dilution	-	0.42	Ice covered
16-May-2017	2	Velocity Area	97.819	2.81	Ice on banks, channel flowing
5-Jun-2017	2	Velocity Area	97.793	2.56	Staff gauge repaired
18-Jul-2017	2	Velocity Area	97.925	5.18	-
10-Aug-2017	2	Velocity Area	97.858	3.82	-
13-Sep-2017	2	Velocity Area	97.709	1.79	-
4-Oct-2017	2	Velocity Area	97.701	1.54	No ice in channel
1-Nov-2017	3	Velocity Area	-	0.62	Ice on banks, channel flowing
4-Dec-2017	4	Salt Dilution	-	0.61	Ice covered

\\knightpiesold.local\VA-Prj$\1\01\00640\06\A\Data\Task 400 - Water Balance\Task 405 - HydroMet\Hydrology\Data QAQC\[KZ-26 Hydrology Review.xlsx]Q Table

NOTES:

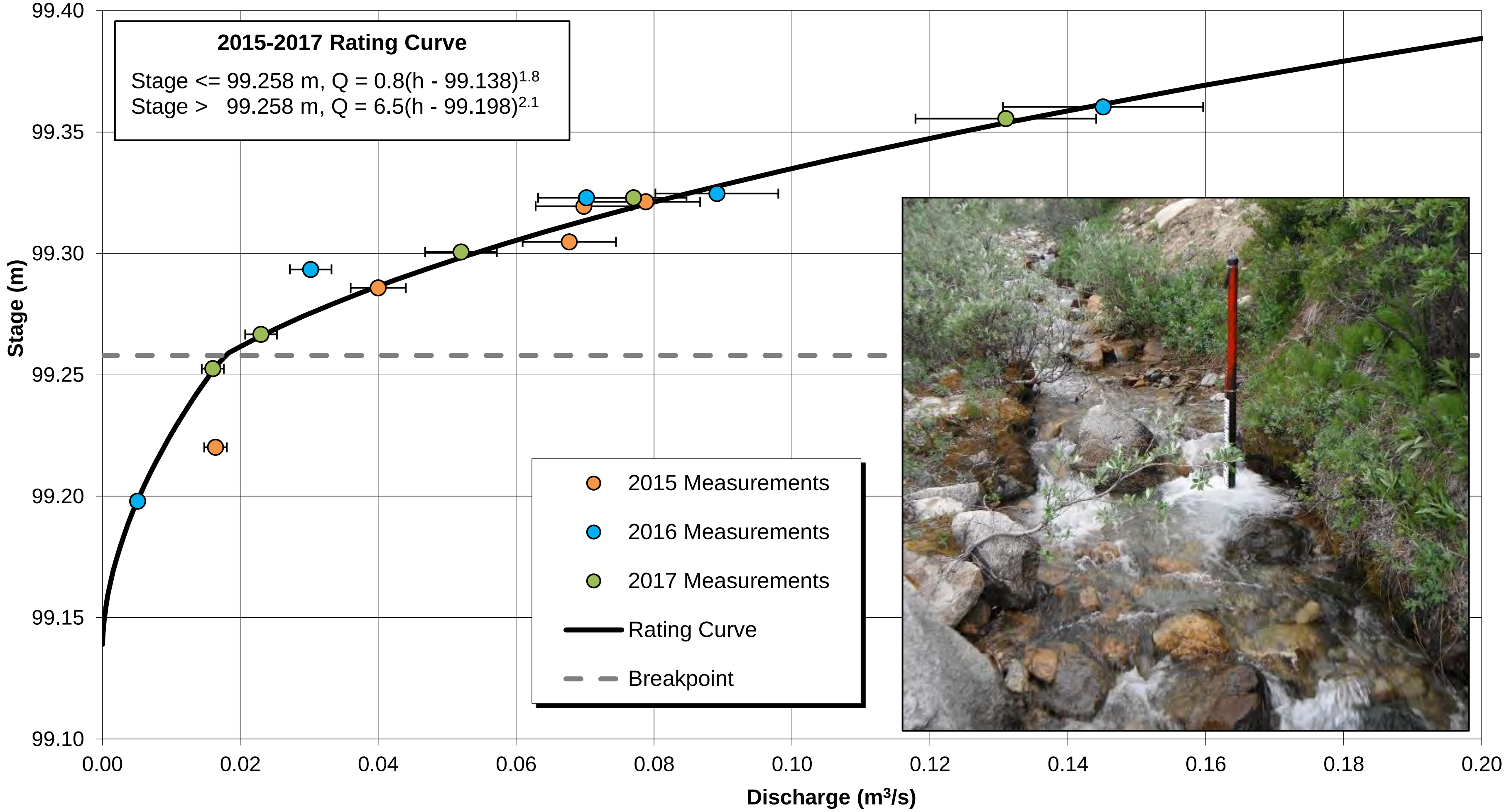
1. NUMBER OF GAUGINGS REFERS TO THE NUMBER OF GAUGINGS AVERAGED TO PRODUCE ONE RATING POINT.

0	08MAY'18	ISSUED WITH LETTER VA18-00832	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

APPENDIX B

RATING CURVES

(Figures B-1 to B-12)



NOTES:

1. PHOTO OF SITE FROM JUNE 22,2015.
2. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINITY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-2 HYDROLOGY STATION RATING CURVE

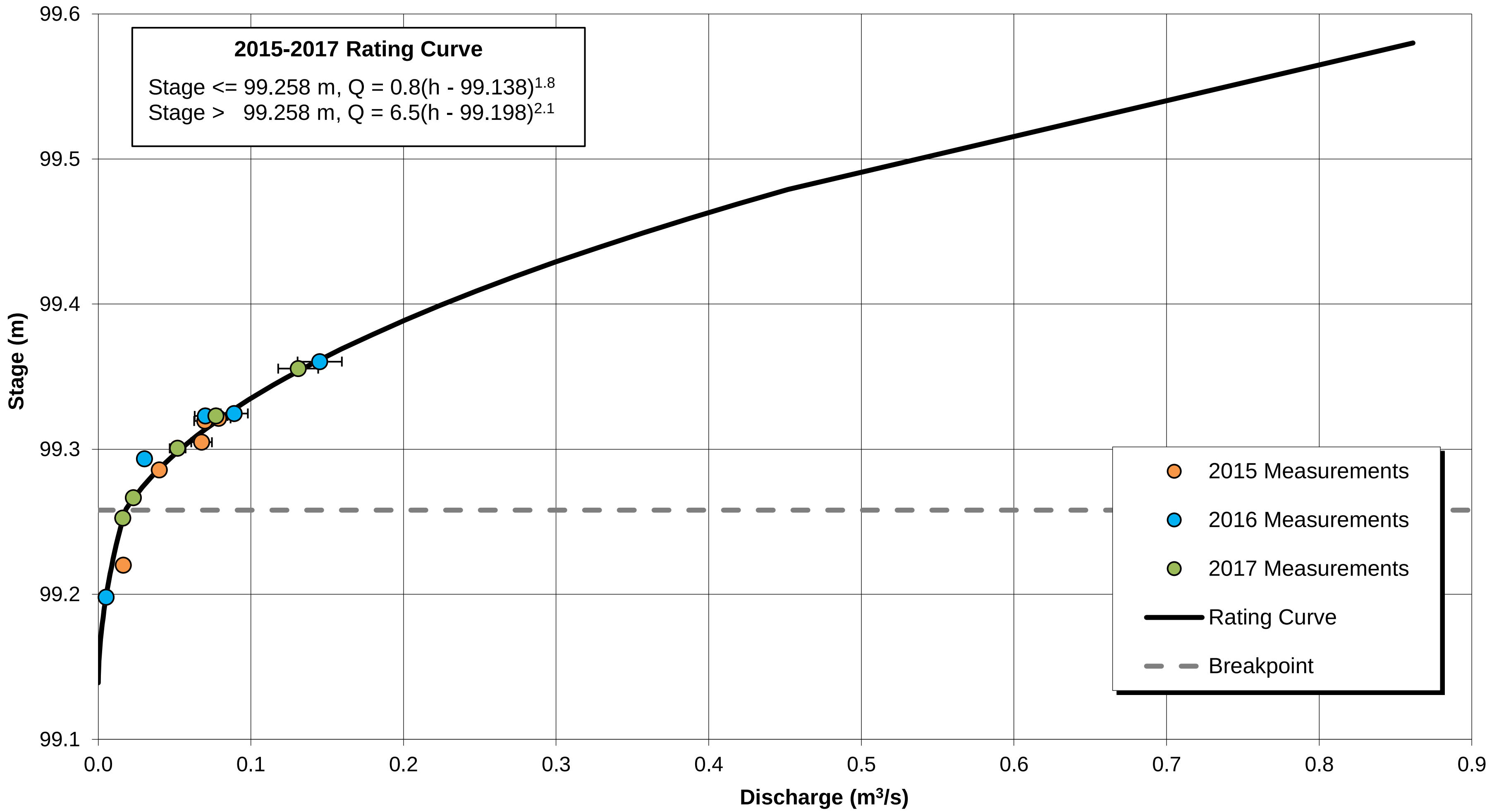
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE B-1

REV 0



NOTES:
1. RATING CURVE EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
2. THERE IS HIGH UNCERTAINTY IN THE UPPER END OF THE RATING CURVE.
3. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

0	08MAY'18	ISSUED WITH LETTER	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-2 HYDROLOGY STATION RATING CURVE - EXTRAPOLATED TO MAXIMUM RECORDED STAGE

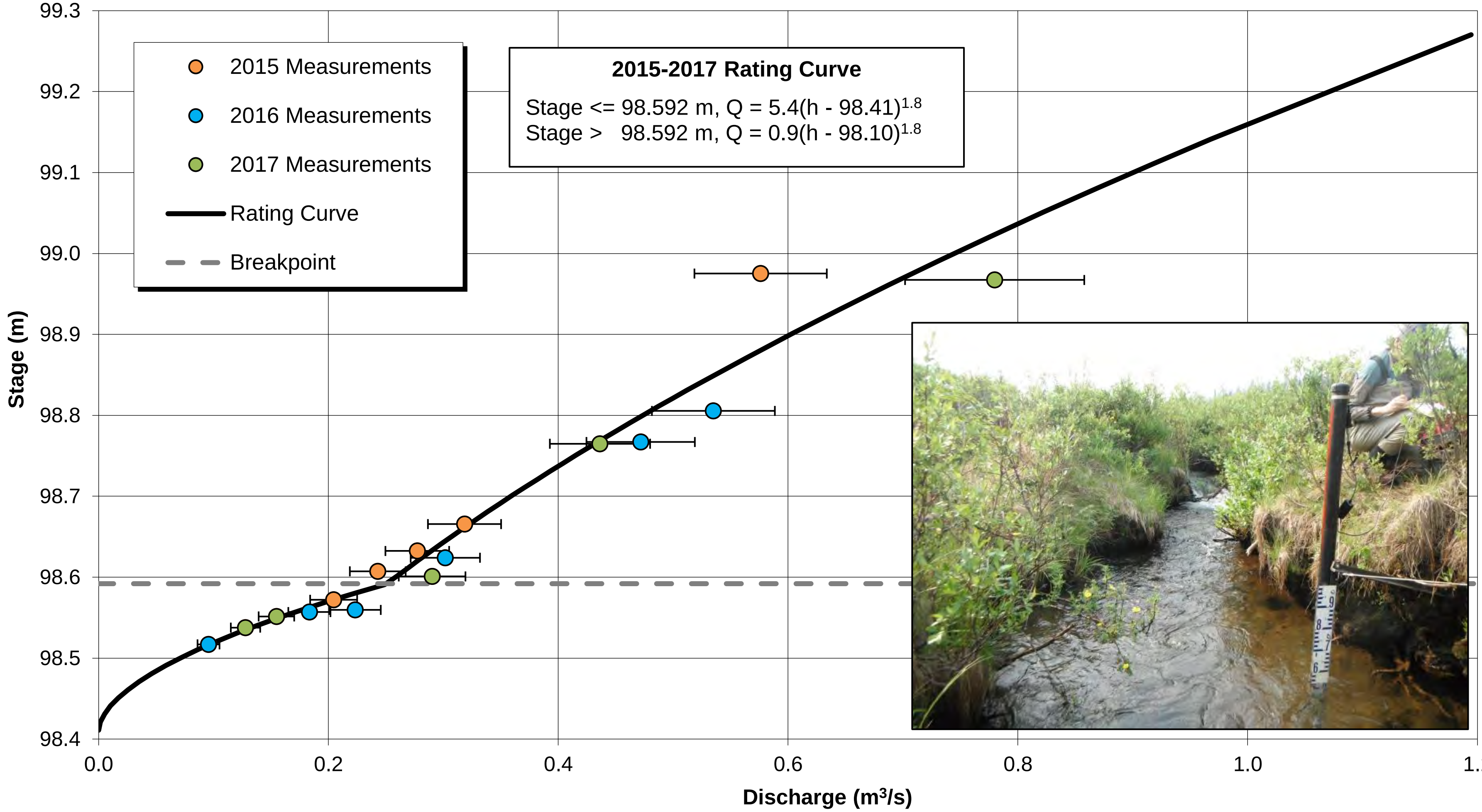
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE B-2

REV 0



NOTES:
1. PHOTO OF SITE FROM JUNE 24, 2015.
2. RATING CURVE EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
3. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINITY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

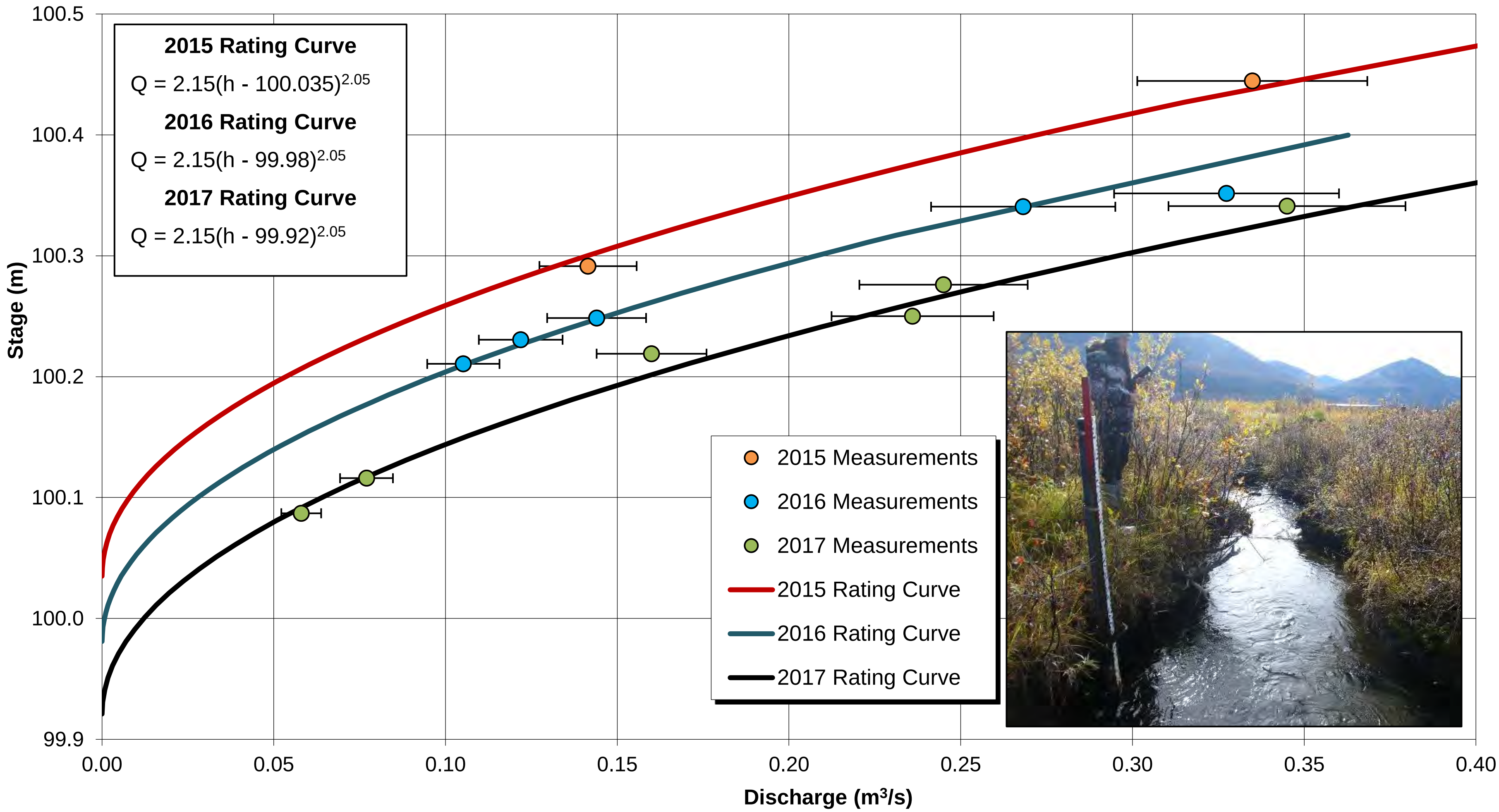
BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-9 HYDROLOGY STATION RATING CURVE

Knight Piésold CONSULTING

P/A NO.	REF. NO.	
VA101-640/6	VA18-00832	
FIGURE B-3		REV 0



NOTES:
1. PHOTO OF SITE FROM SEPTEMBER 14, 2017.
2. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

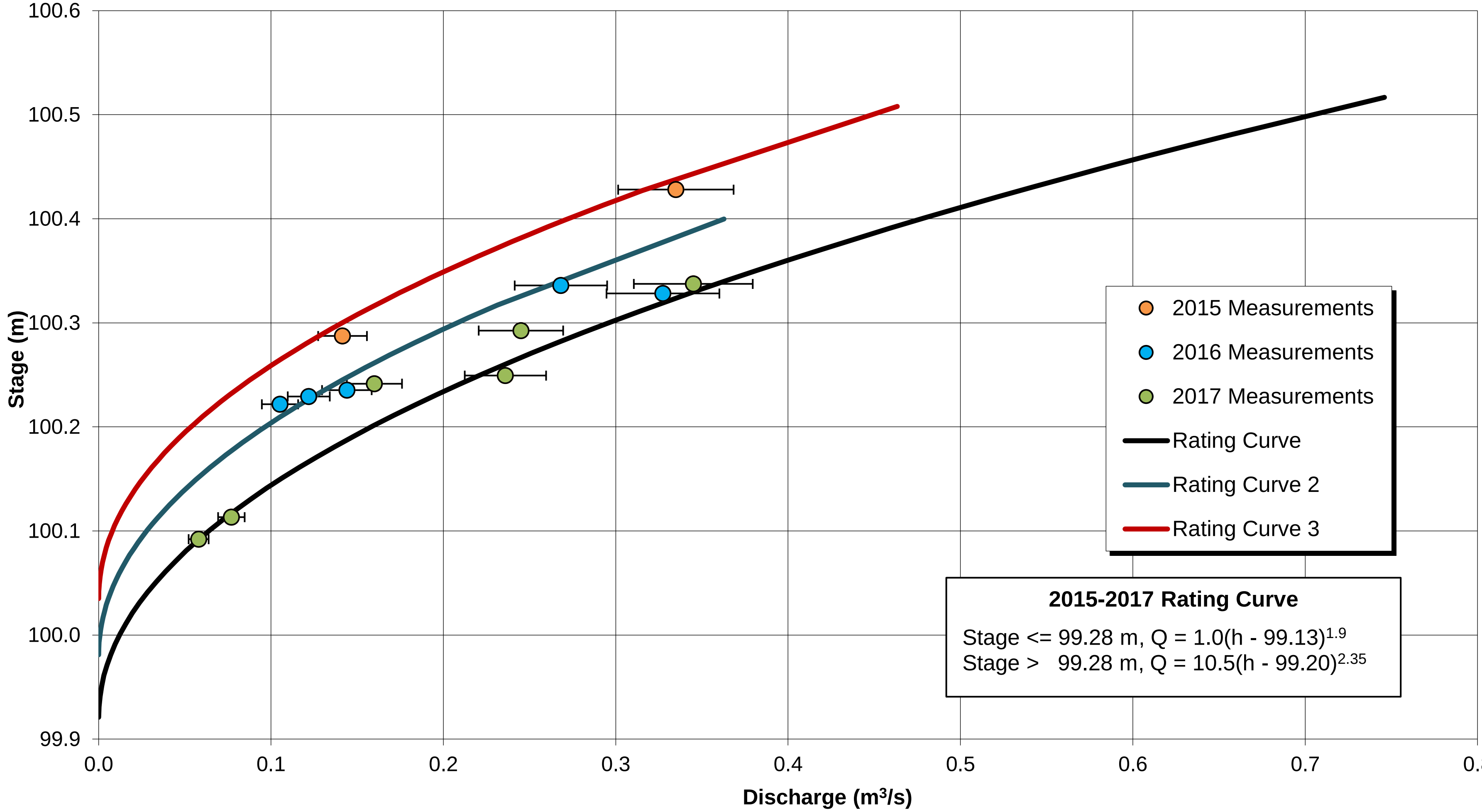
KZ-13 HYDROLOGY STATION RATING CURVE

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE B-4 REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM



NOTES:
1. RATING CURVE EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
2. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

BMC MINERALS (NO.1) LTD.

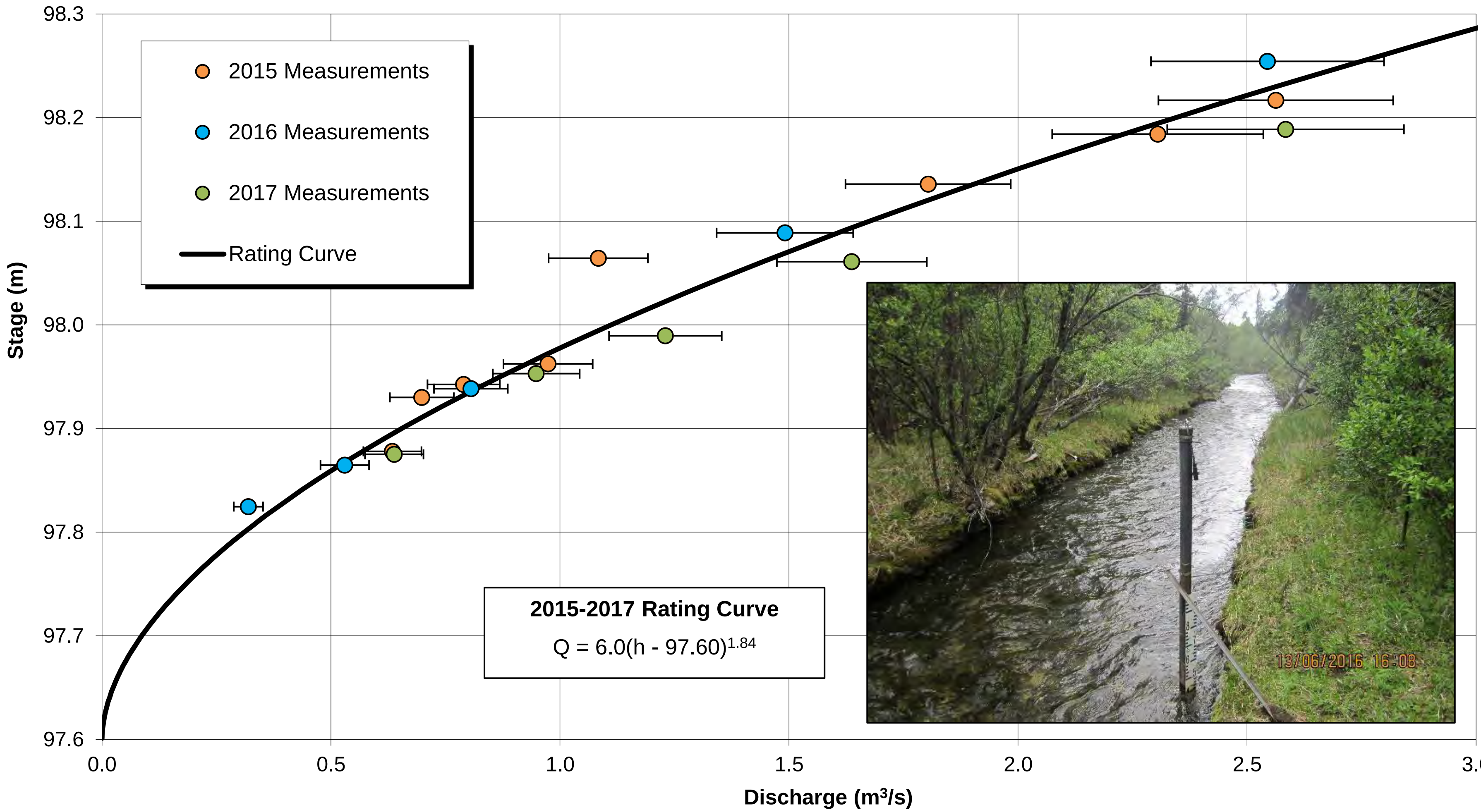
KUDZ ZE KAYAH PROJECT

KZ-13 HYDROLOGY STATION RATING CURVE - EXTRAPOLATED TO MAXIMUM RECORDED STAGE

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE B-5 REV 0



NOTES:
1. PHOTO OF SITE FROM JUNE 13, 2016.
2. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-15 HYDROLOGY STATION RATING CURVE

Knight Piésold CONSULTING

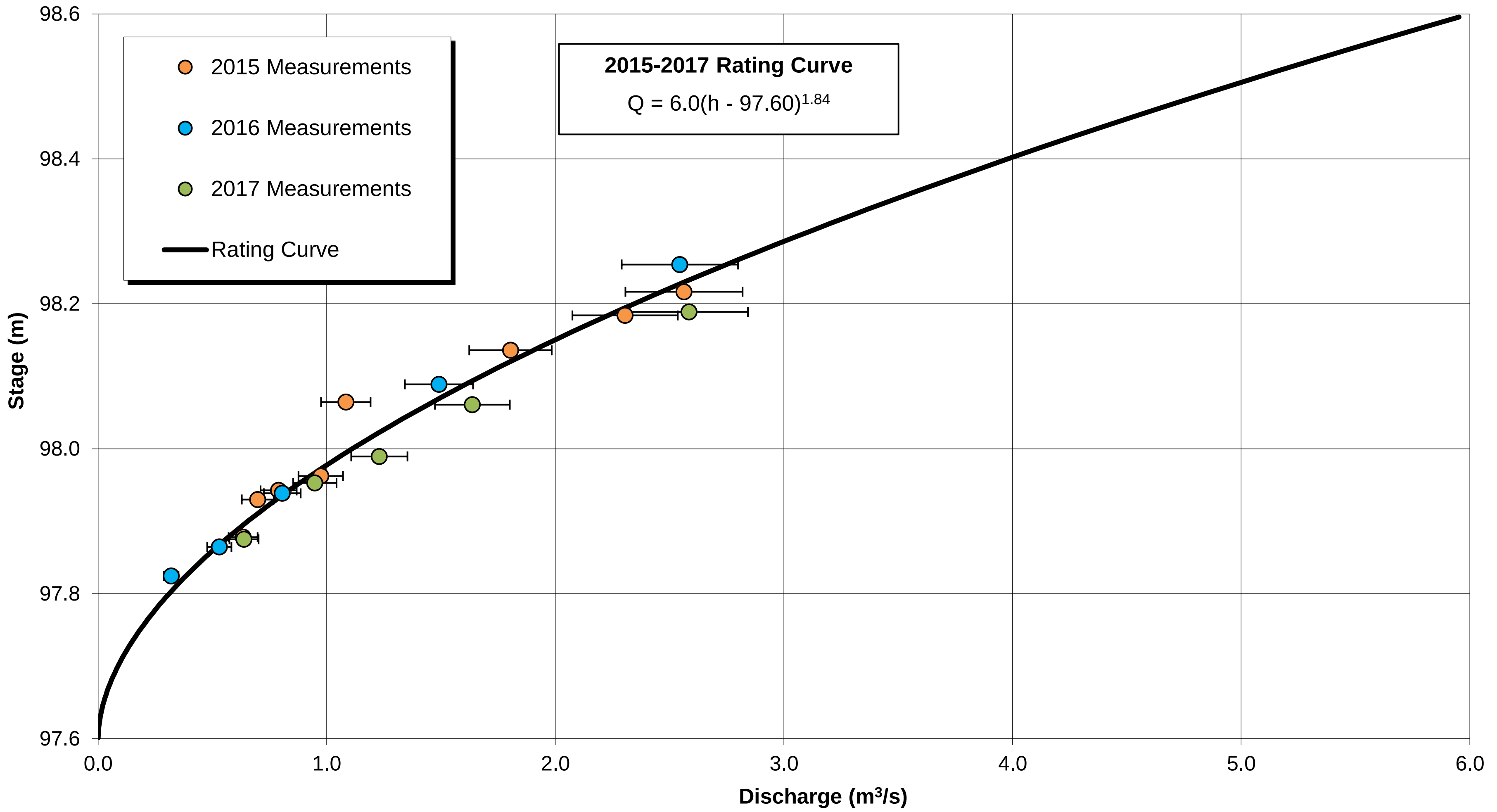
P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE B-6

REV 0

0	08MAY'18	ISSUED WITH LETTER	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D



NOTES:
1. RATING CURVE EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
2. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

0	08MAY'18	ISSUED WITH LETTER	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

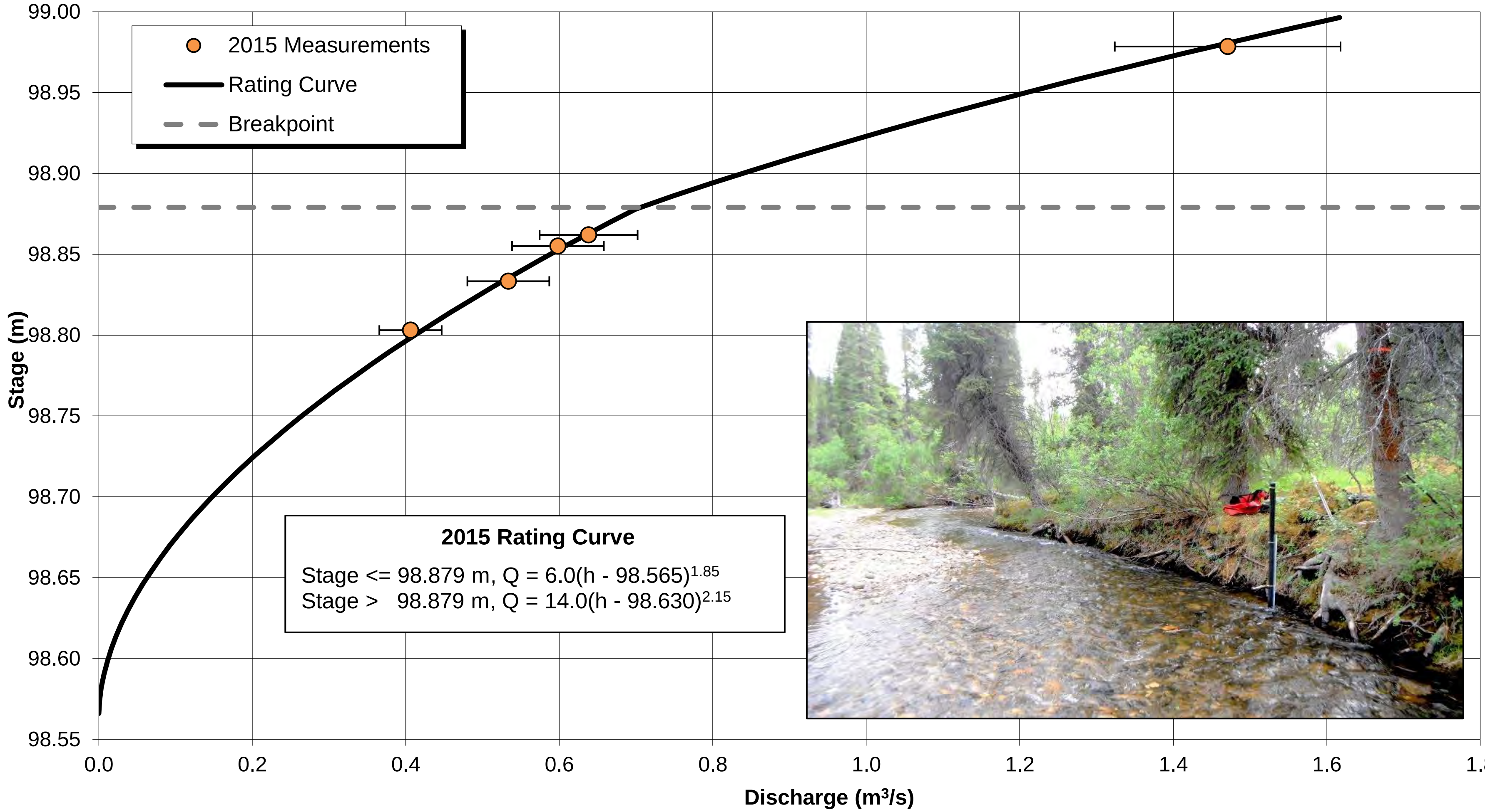
KUDZ ZE KAYAH PROJECT

KZ-15 HYDROLOGY STATION RATING CURVE - EXTRAPOLATED TO MAXIMUM RECORDED STAGE

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE B-7 REV 0



NOTES:
1. PHOTO OF SITE FROM MAY13, 2015.
2. RATING CURVE EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
3. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

ORIGINAL KZ-16 HYDROLOGY STATION RATING CURVE

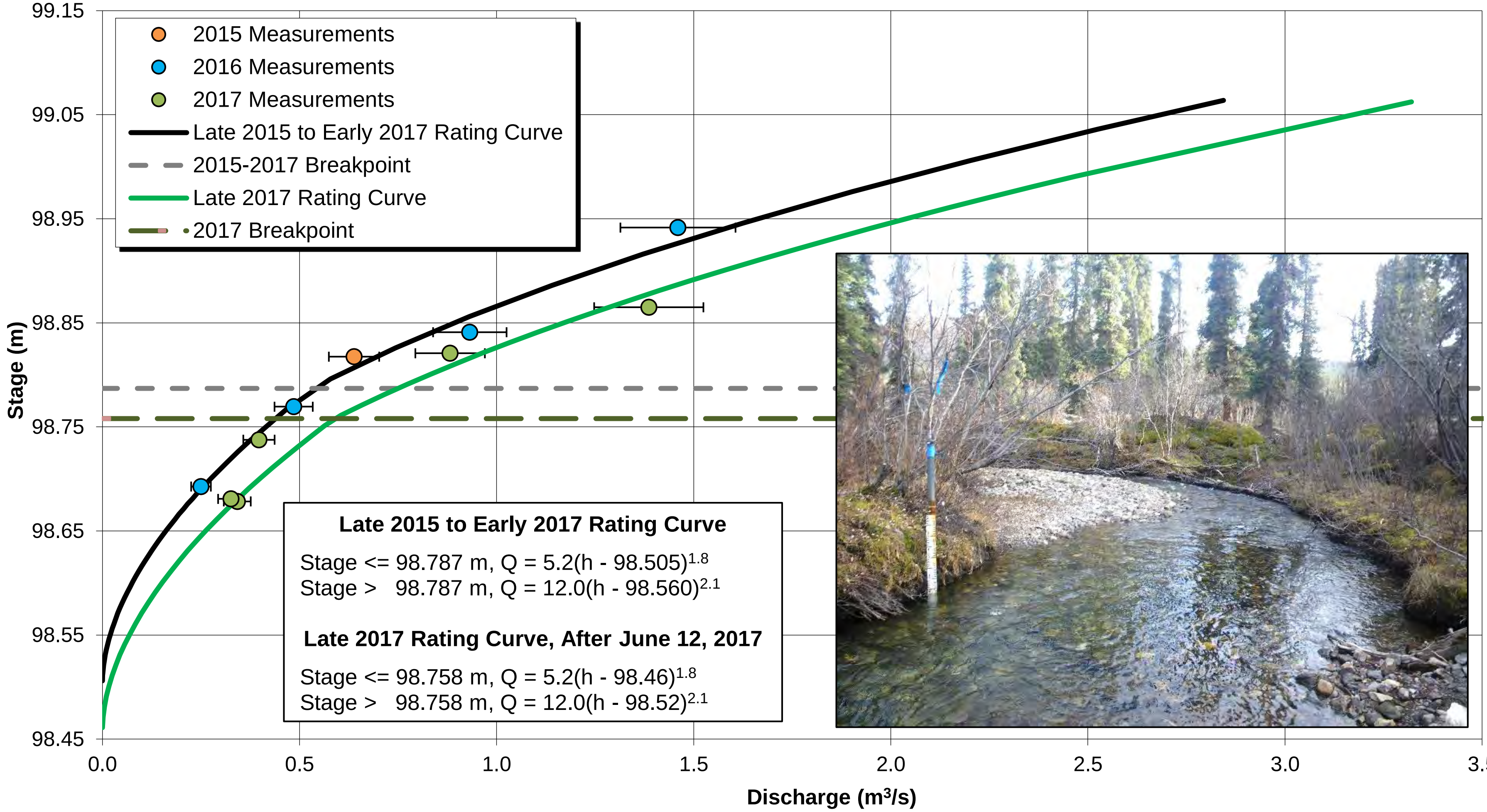
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE B-8

REV 0



NOTES:

1. PHOTO OF SITE FROM OCTOBER 4, 2017.
2. RATING CURVES EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
3. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

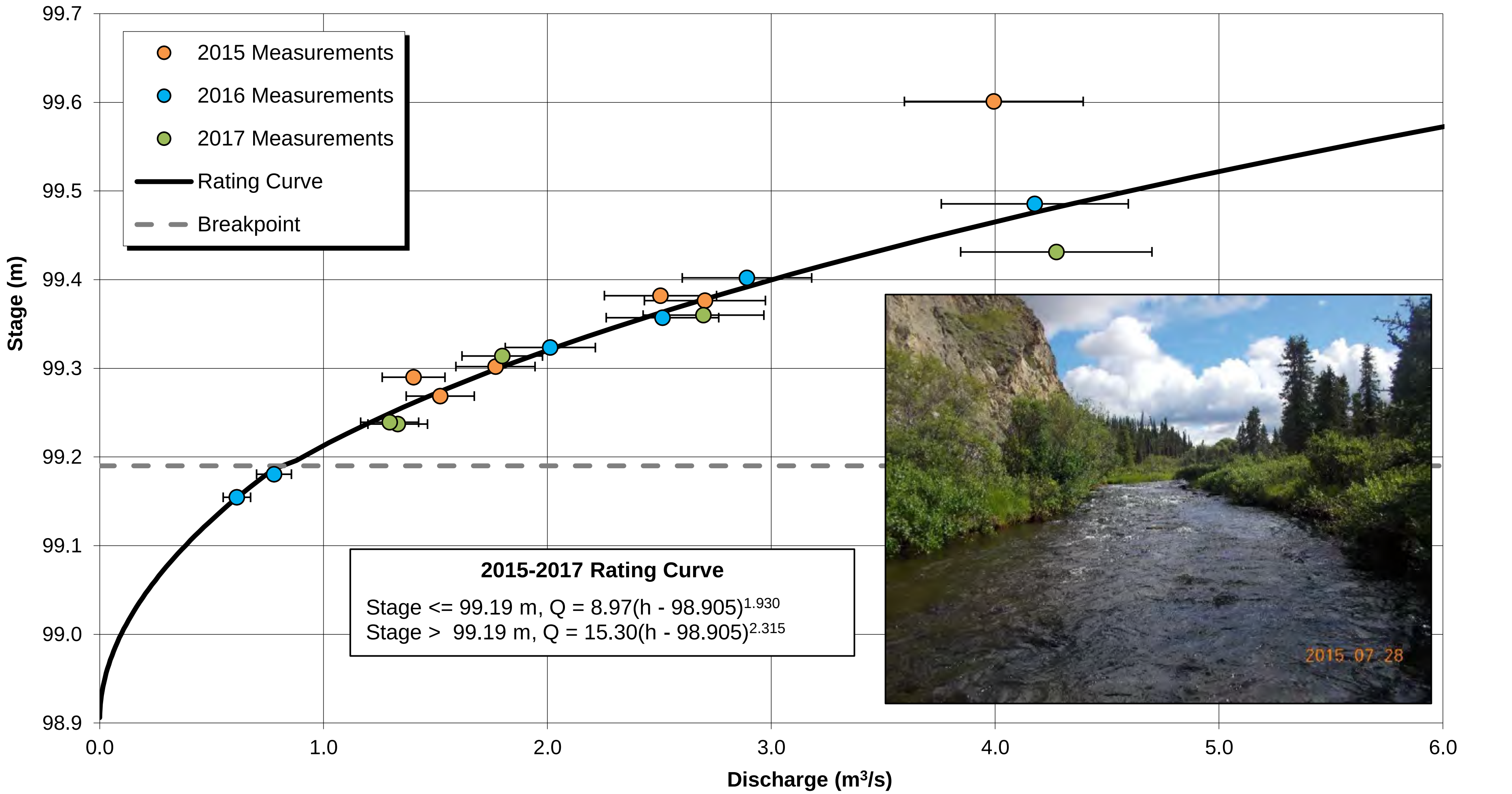
BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

SECOND KZ-16 HYDROLOGY STATION RATING CURVE

Knight Piésold CONSULTING

P/A NO. VA101-640/6	REF. NO. VA18-00832	
FIGURE B-9		REV 0



NOTES:

1. PHOTO OF SITE FROM JULY 28, 2015.
2. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AIF	JJM

BMC MINERALS (NO.1) LTD.

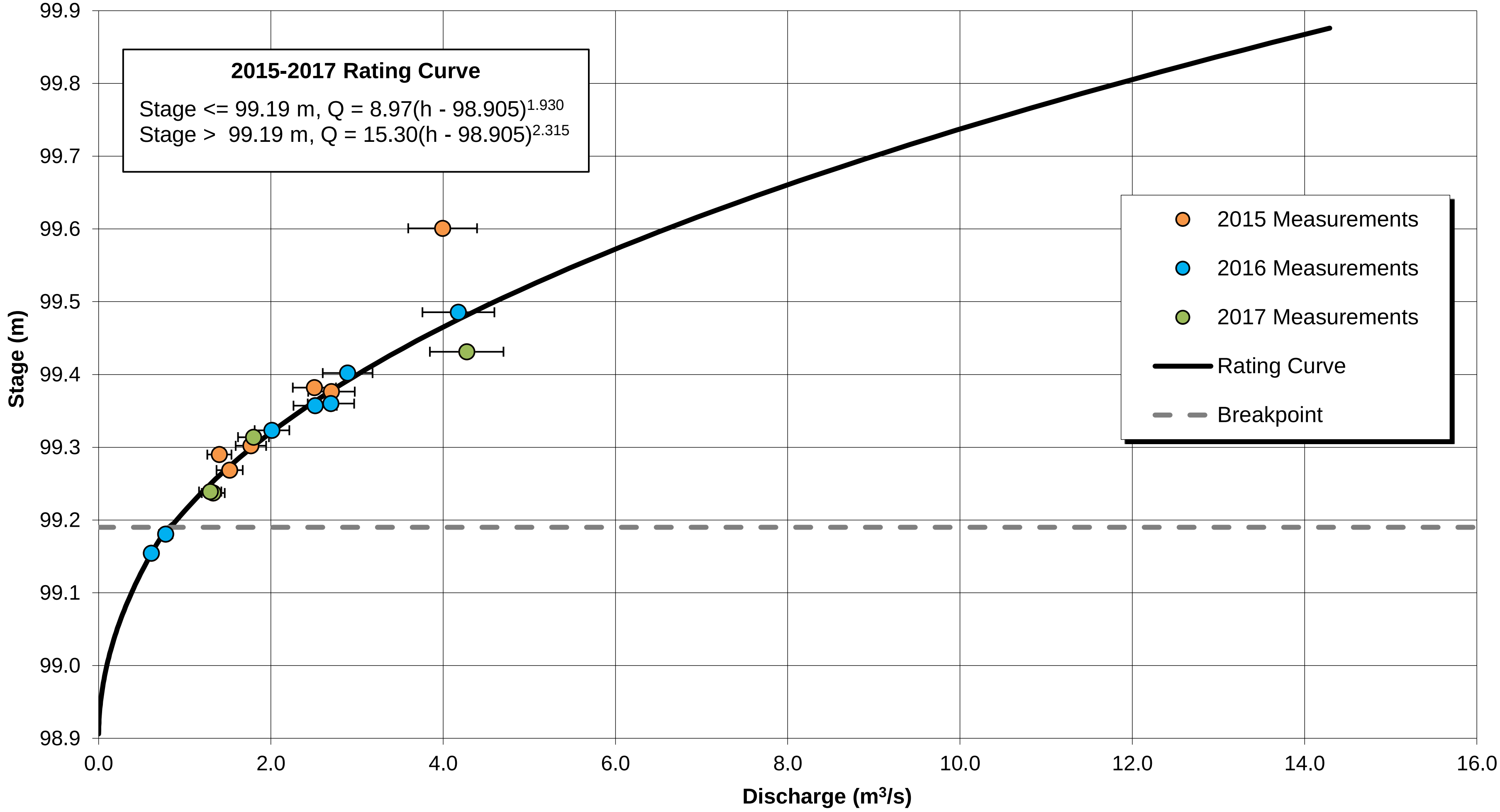
KUDZ ZE KAYAH PROJECT

KZ-22 HYDROLOGY STATION RATING CURVE

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE B-10 REV 0



NOTES:

1. RATING CURVE EXTRAPOLATED TO MAXIMUM RECORDED STAGE.
2. ALL DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AIF	JJM

BMC MINERALS (NO.1) LTD.

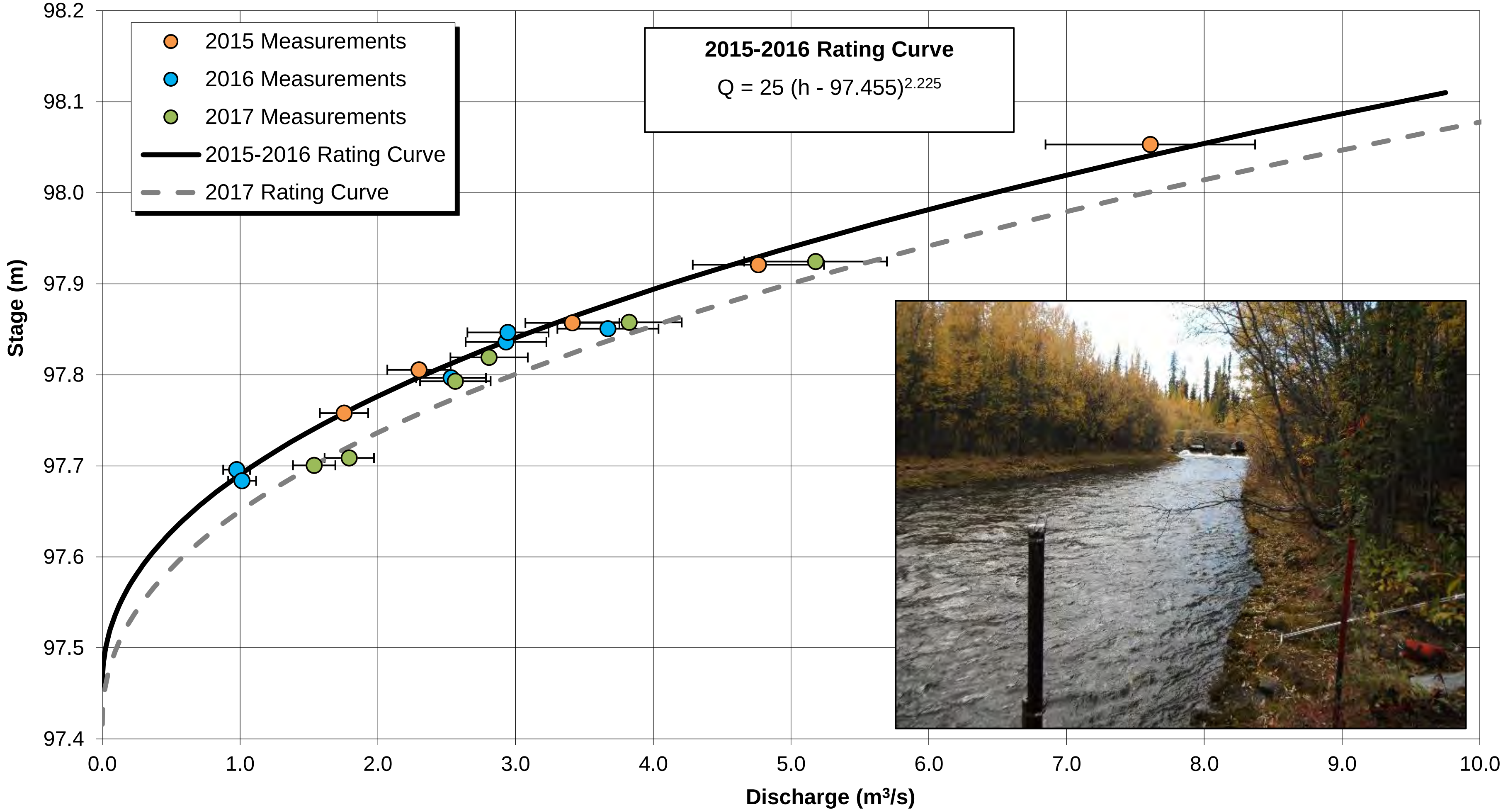
KUDZ ZE KAYAH PROJECT

KZ-22 HYDROLOGY STATION RATING CURVE - EXTRAPOLATED TO MAXIMUM RECORDED STAGE

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE B-11 REV 0



NOTES:
1. PHOTO OF SITE FROM SEPTEMBER 8, 2015.
2. RATING CURVE EXTRAPOLATED TO THE MAXIMUM RECORDED STAGE.
3. DISCHARGE MEASUREMENTS HAVE BEEN ASSIGNED AN ASSUMED UNCERTAINTY OF 10%.
4. THE 2017 MEASUREMENTS SUGGEST A SHIFT IN THE CURVE OCCURED IN EARLY JUNE 2017; HOWEVER, STAGE DATA FROM THE 2017 OPEN WATER SEASON APPEARS ERRONEOUS.

0	08MAY'18	ISSUED WITH LETTER	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

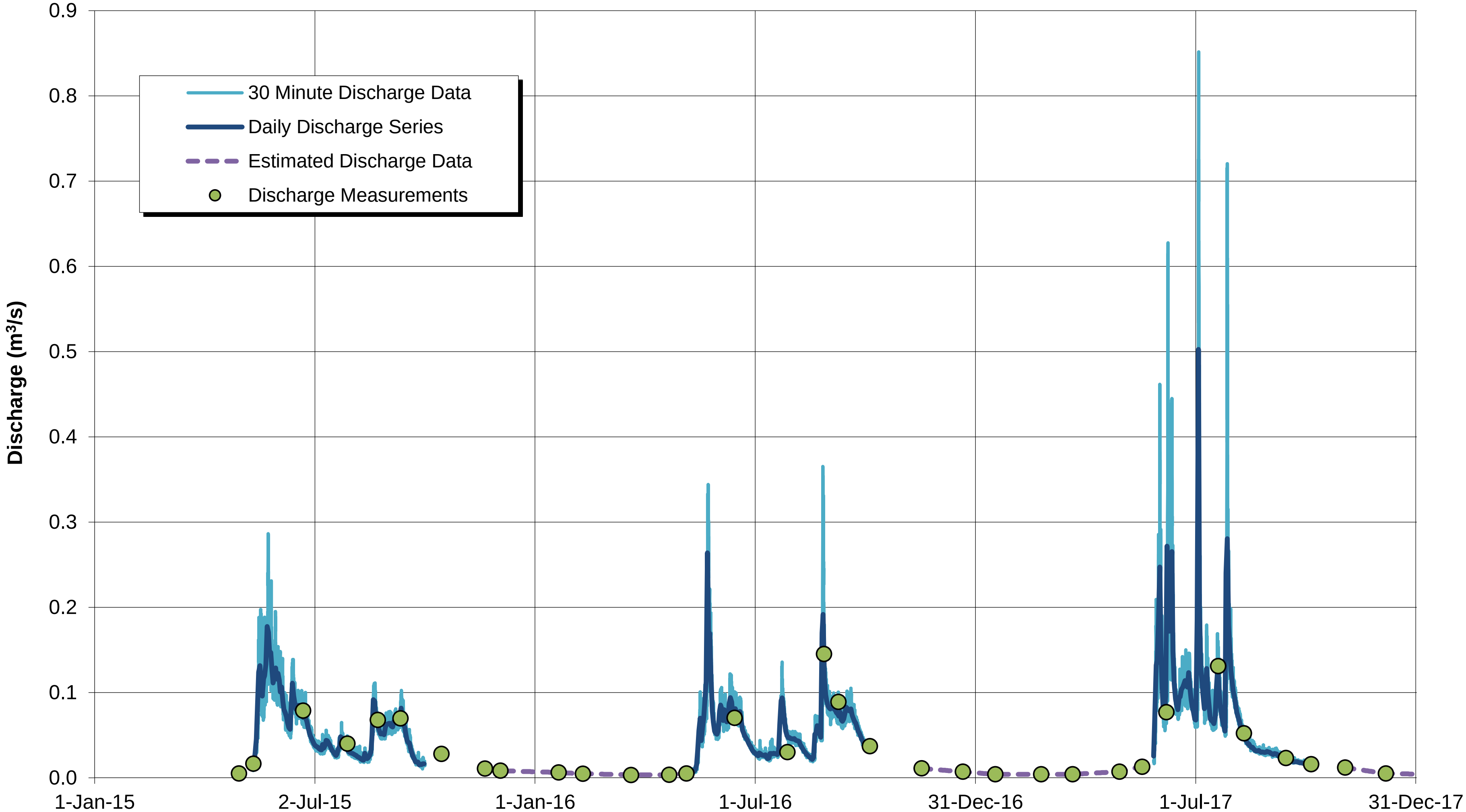
KZ-26 HYDROLOGY STATION RATING CURVE

Knight Piésold CONSULTING	P/A NO. VA101-640/6	REF. NO. VA18-00832
	FIGURE B-12	REV 0

APPENDIX C

HYDROGRAPHS

(Figures C-1 to C-9)



0	08MAY'18	ISSUED WITH LETTER	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

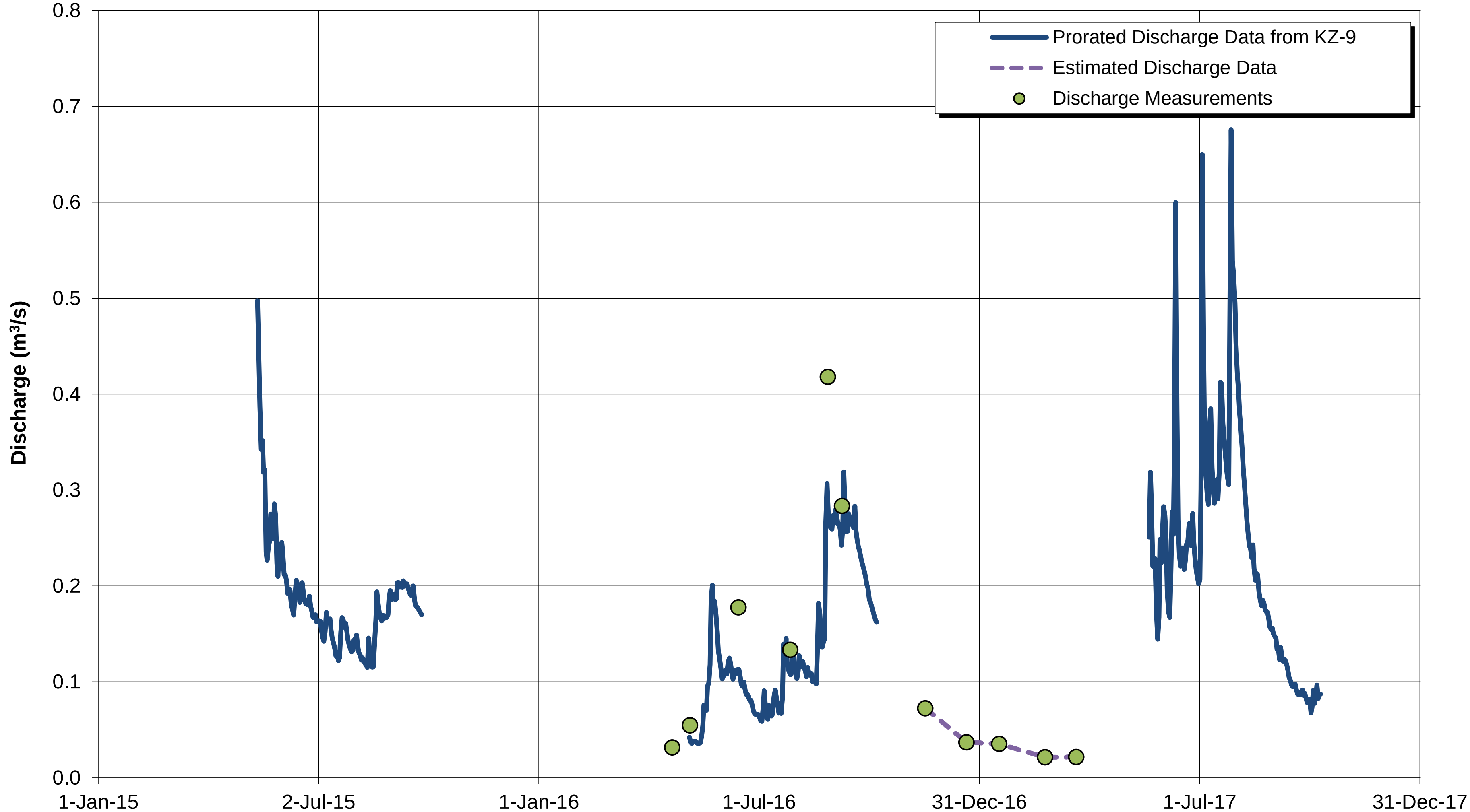
KUDZ ZE KAYAH PROJECT

KZ-2 HYDROLOGY STATION HYDROGRAPH

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE C-1 REV 0



REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-7 HYDROLOGY STATION ESTIMATED HYDROGRAPH

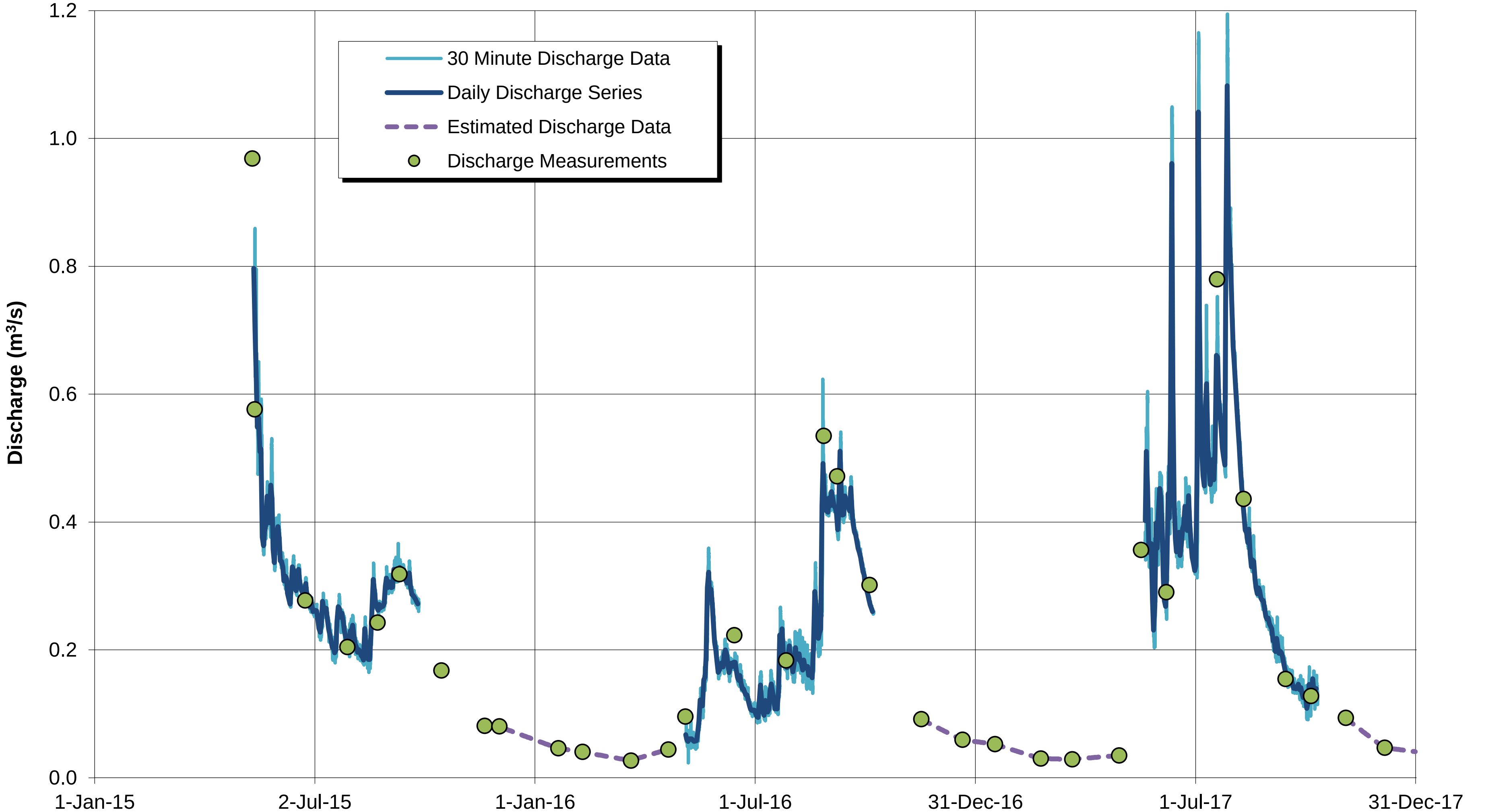
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE C-2

REV 0



BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

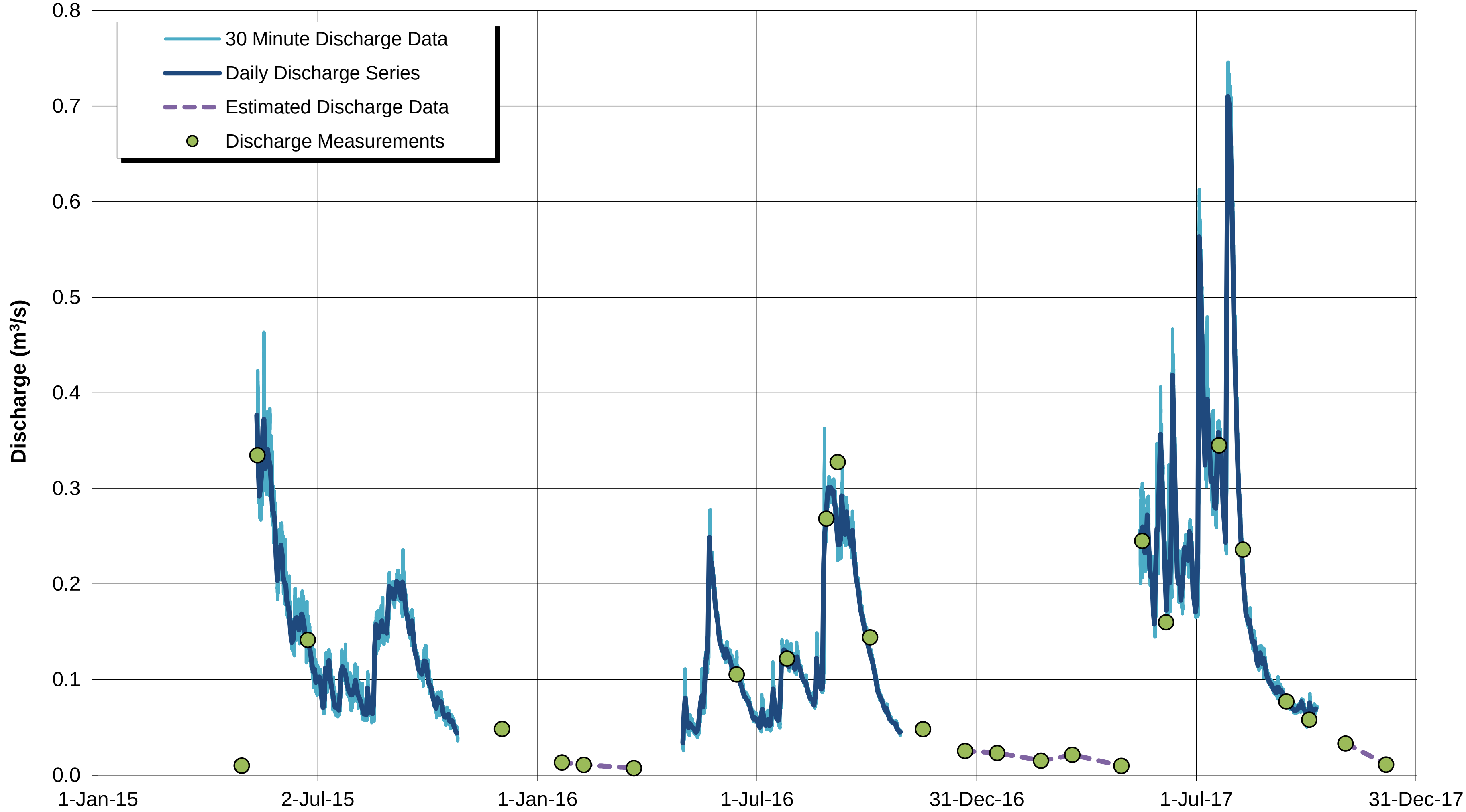
KZ-9 HYDROLOGY STATION HYDROLOGY

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE C-3 REV 0

0	08MAY'18	ISSUED WITH LETTER	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D



BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

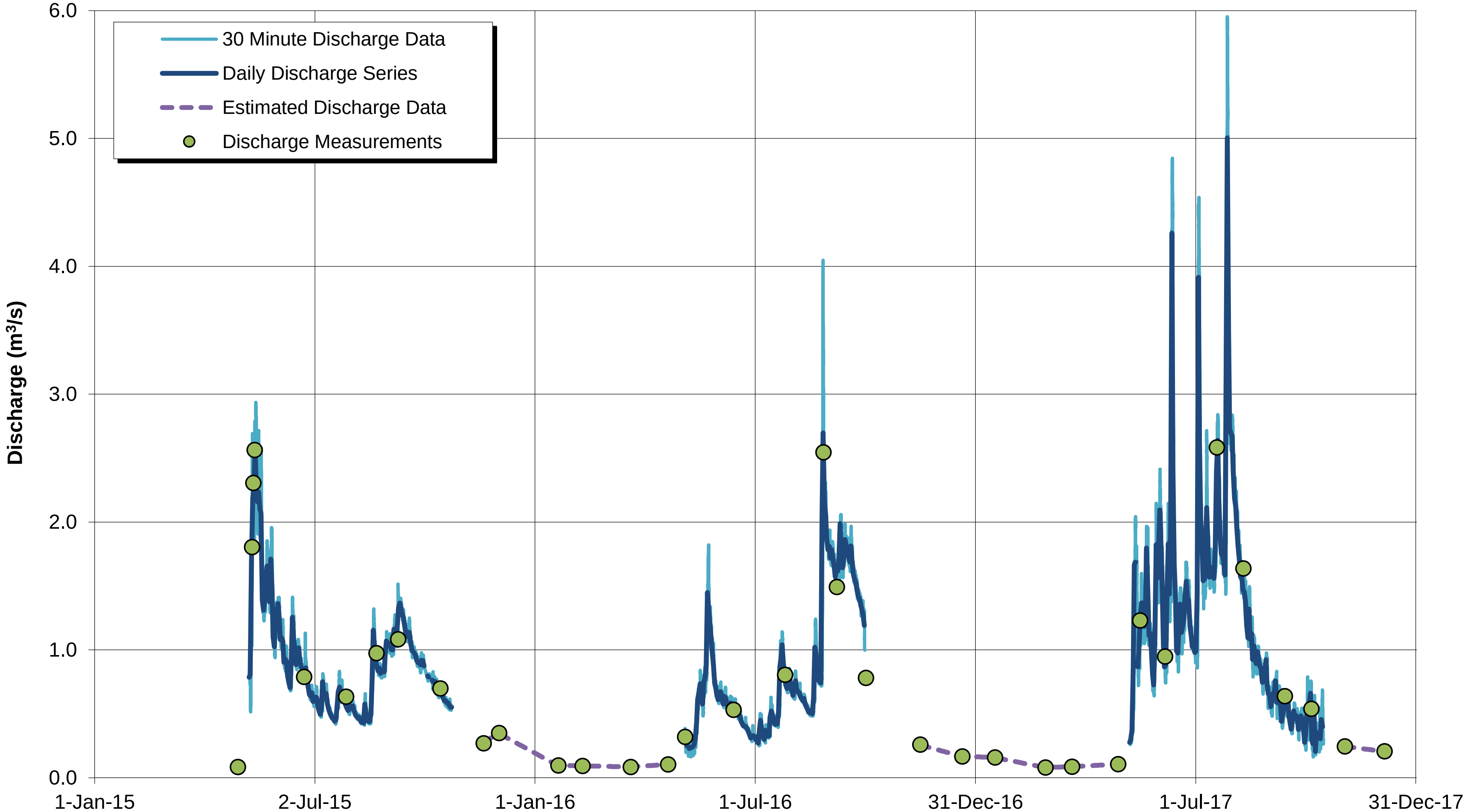
KZ-13 HYDROLOGY STATION HYDROGRAPH

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE C-4 REV 0

0	08MAY'18	ISSUED WITH LETTER	AA	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D



0	08MAY'18	ISSUED WITH LETTER	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-15 HYDROLOGY STATION HYDROGRAPH

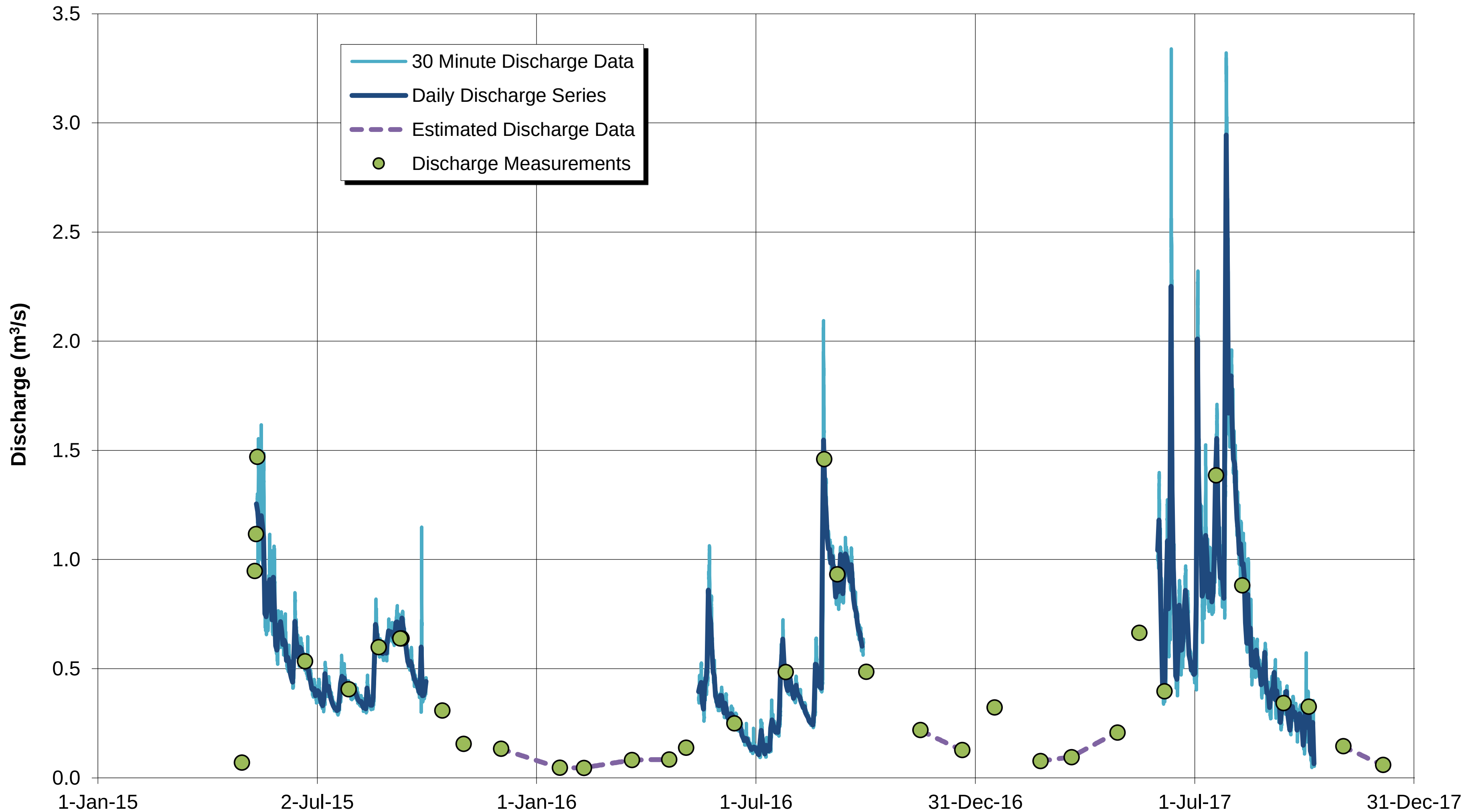
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE C-5

REV 0



BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

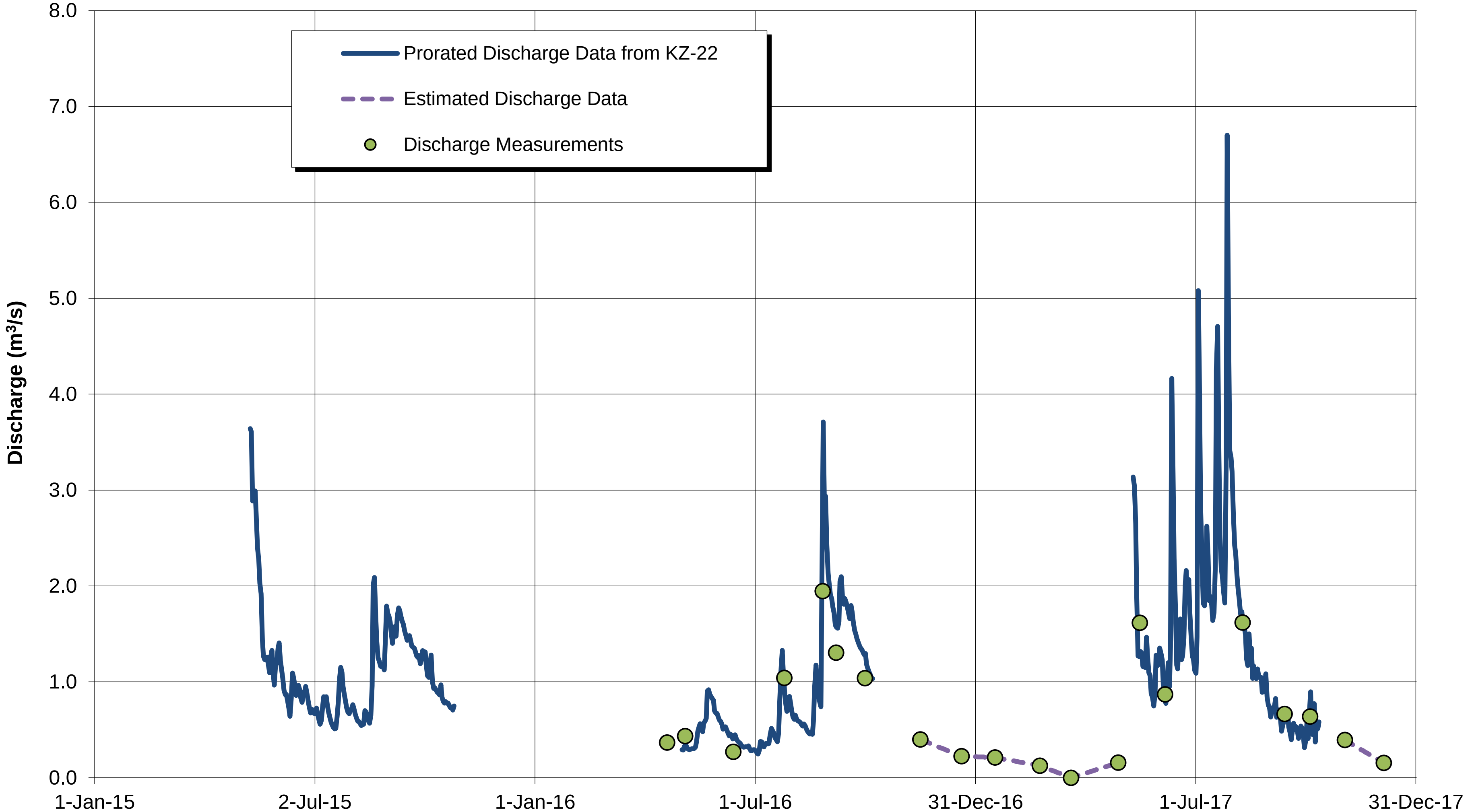
KZ-16 HYDROLOGY STATIONS HYDROGRAPH

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE C-6 REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM



REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	08MAY'18	ISSUED WITH LETTER	AA	JJM

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-21 HYDROLOGY STATION ESTIMATED HYDROGRAPH

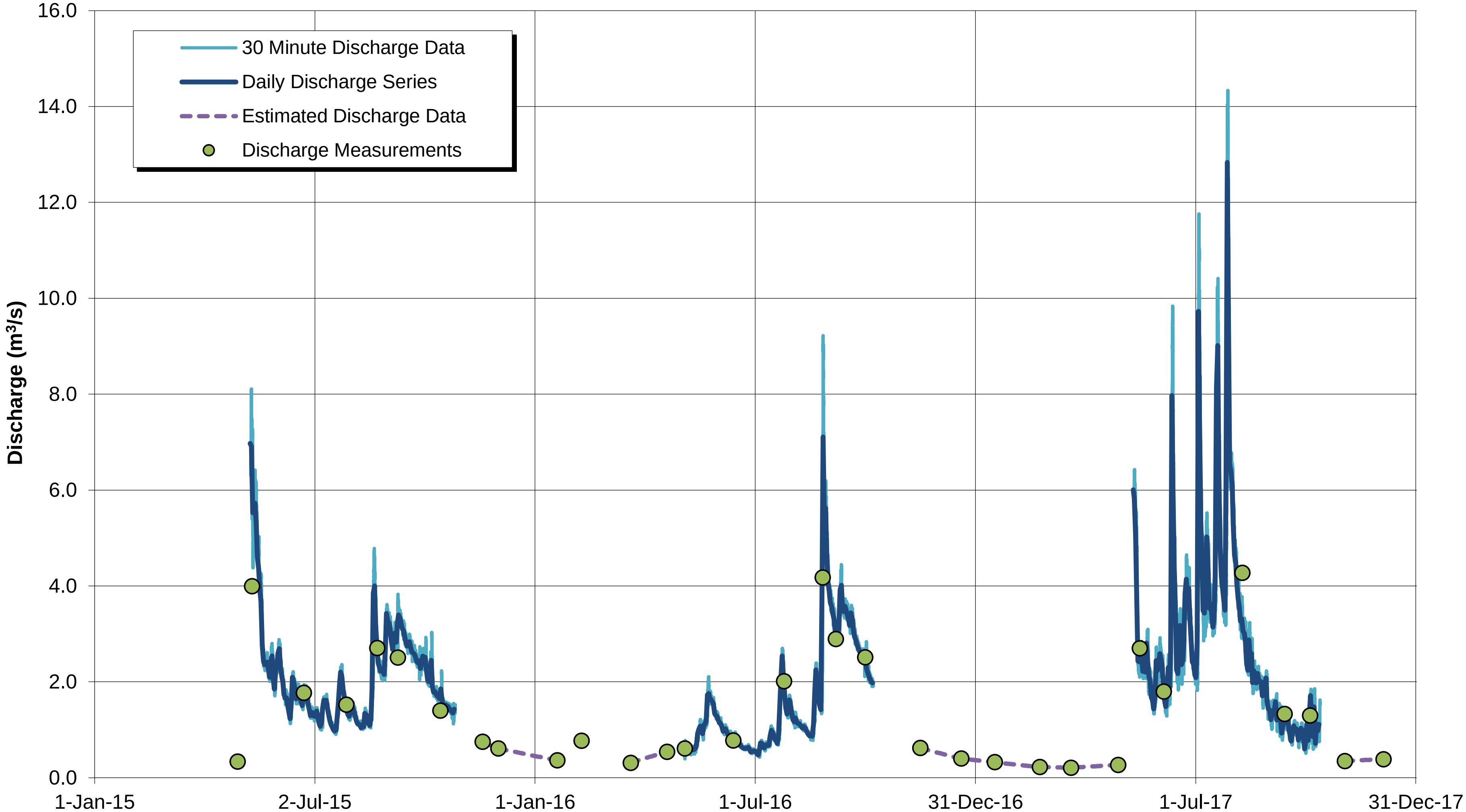
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

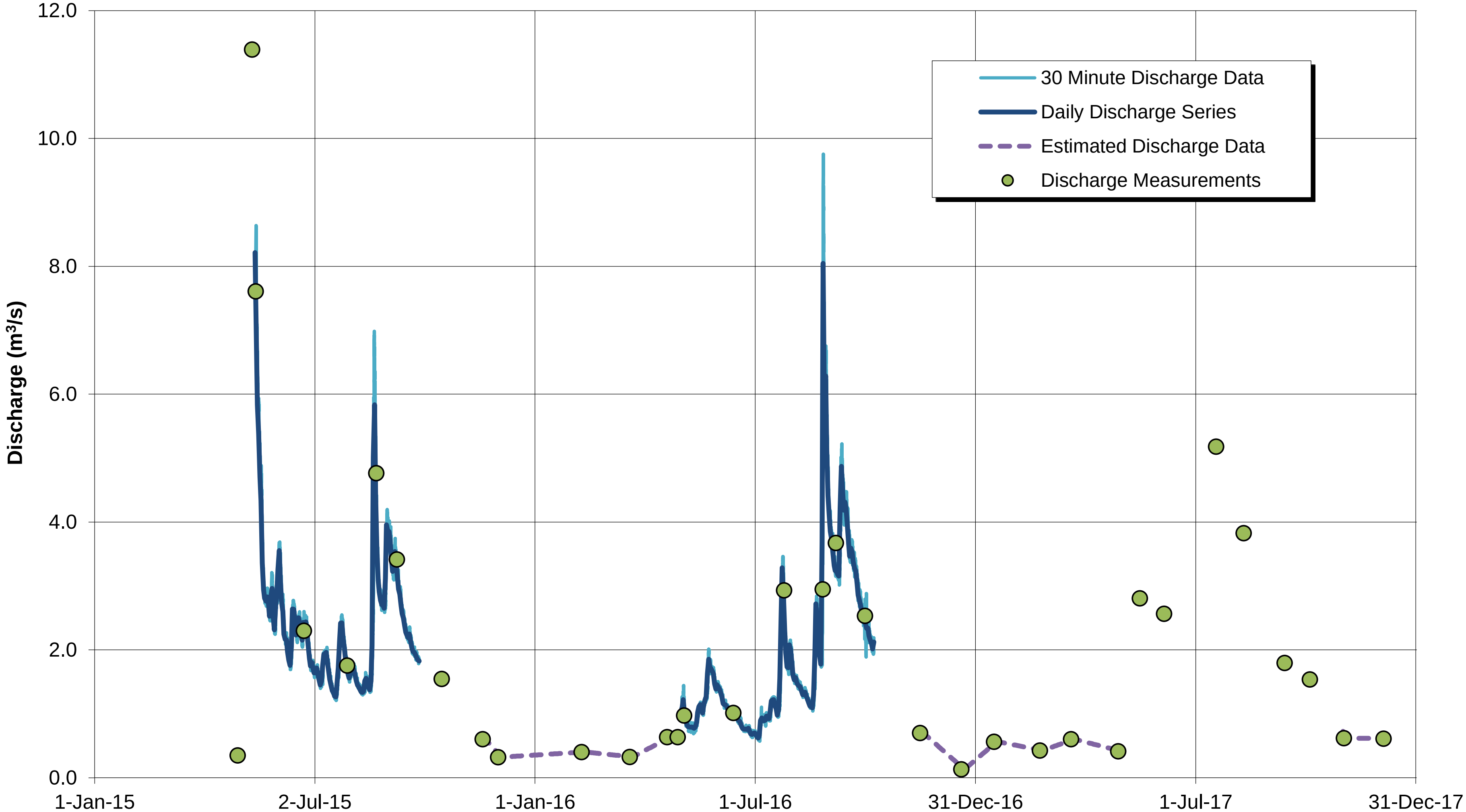
FIGURE C-7

REV 0



BMC MINERALS (NO.1) LTD.		
KUDZ ZE KAYAH PROJECT		
KZ-22 HYDROLOGY STATION HYDROGRAPH		
Knight Piésold CONSULTING	P/A NO. VA101-640/6	REF. NO. VA18-00832
	FIGURE C-8	REV 0

0	08MAY'18	ISSUED WITH LETTER	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D



NOTES:

1. THE STAGE RECORD FROM 2017 SHOWS VARIATION THAT IS INCONSISTANT WITH STREAMFLOW FROM OTHER STATIONS AND MAY BE CAUSED BY INSTRUMENTATION MALFUNCTION.

0	08MAY'18	ISSUED WITH LETTER	AIF	JJM
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

KZ-26 HYDROLOGY STATION HYDROLOGY

Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

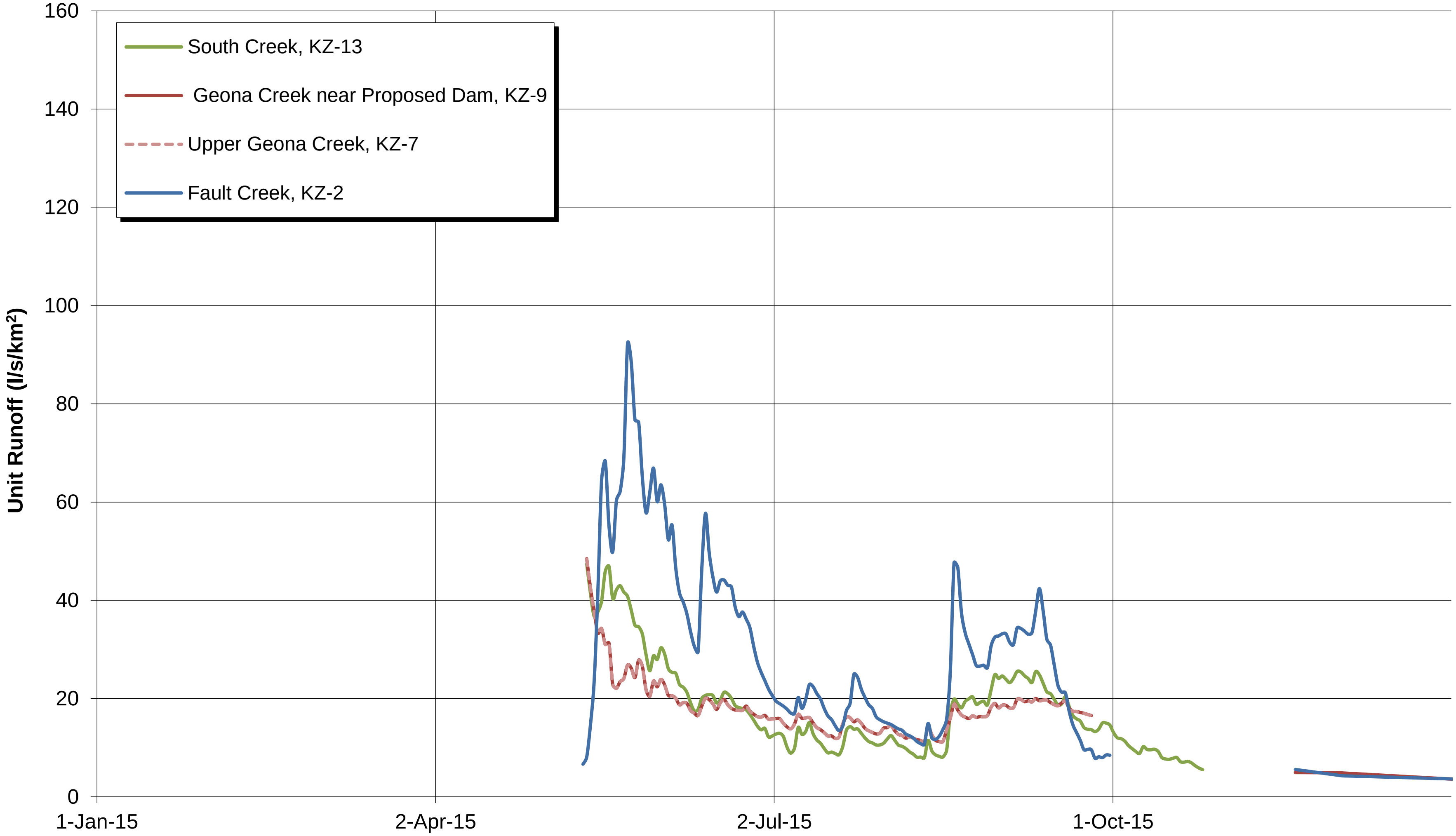
FIGURE C-9

REV 0

APPENDIX D

UNIT RUNOFF COMPARISONS

(Figures D-1 to D-6)



REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	8MAY'18	ISSUED WITH LETTER	AF	AA

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

PROPOSED MINE AREA - UNIT RUNOFF FROM 2015

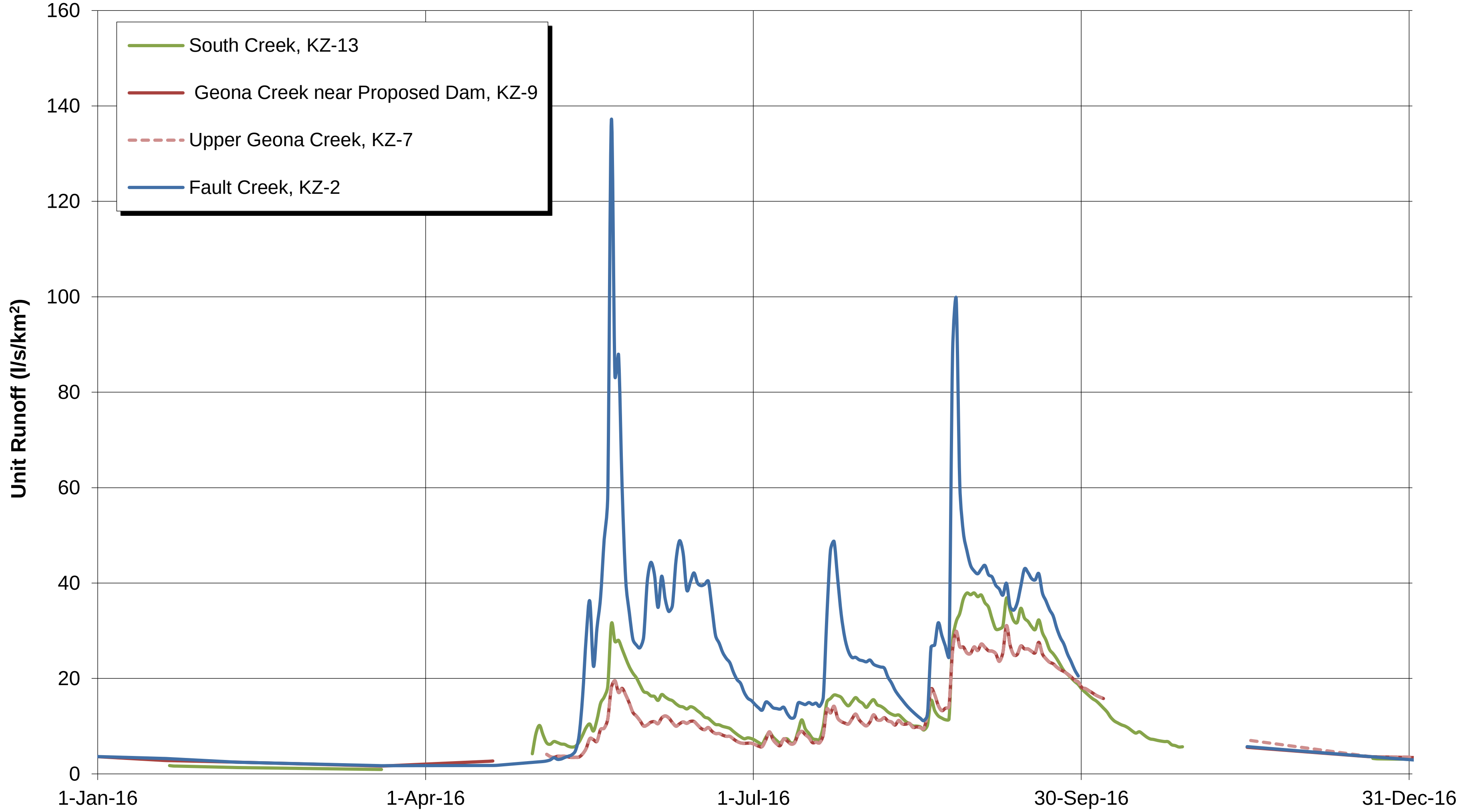
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

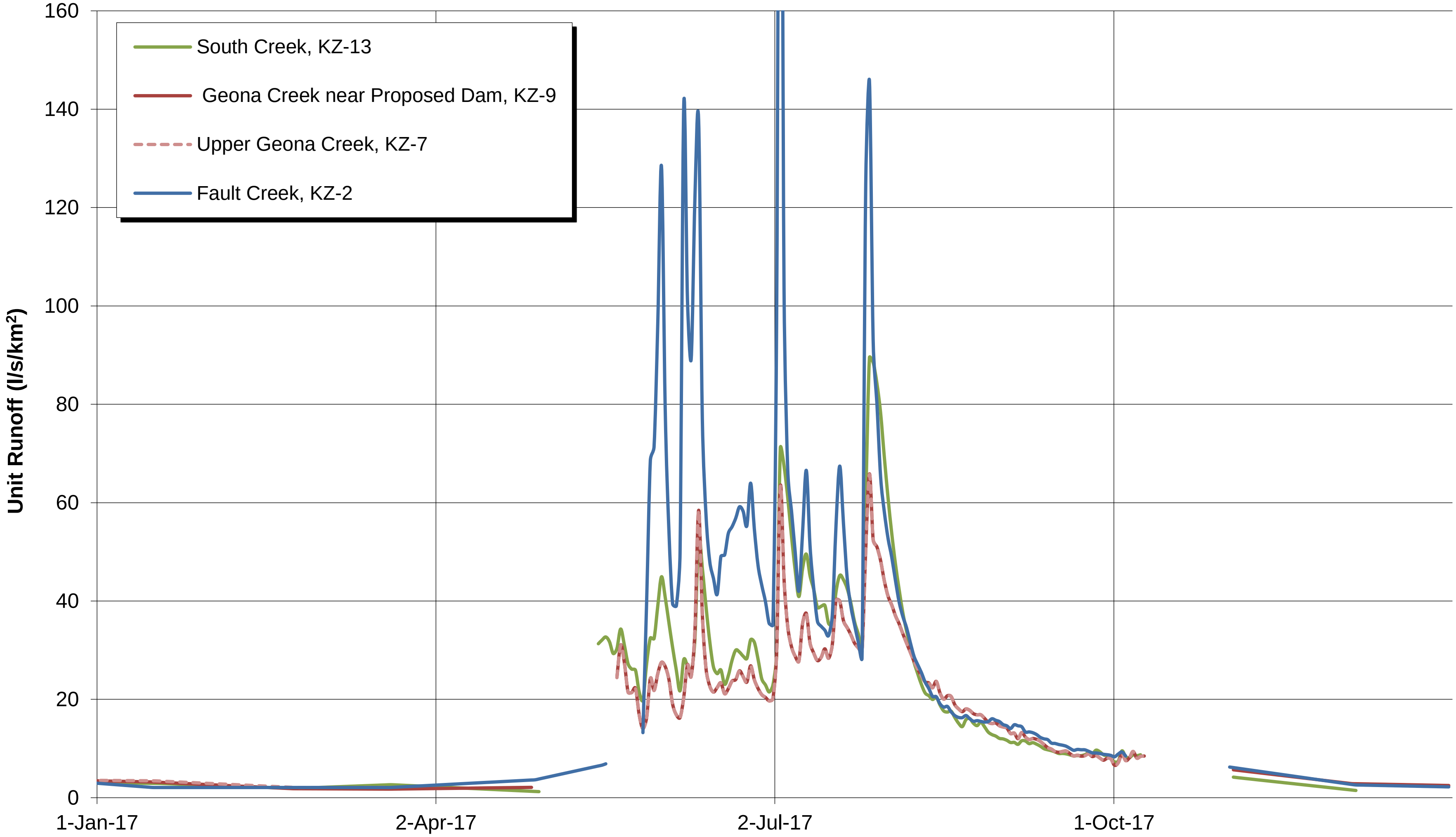
FIGURE D-1

REV 0



BMC MINERALS (NO.1) LTD.		
KUDZ ZE KAYAH PROJECT		
PROPOSED MINE AREA - UNIT RUNOFF FROM 2016		
Knight Piésold CONSULTING	P/A NO. VA101-640/6	REF. NO. VA18-00832
	FIGURE D-2	REV 0

0	8MAY'18	ISSUED WITH LETTER	AF	AA
REV	DATE	DESCRIPTION	PREP'D	RVW'D



NOTES:

1. UNIT RUNOFF FROM KZ-2 PEAKS AT 261 l/s/km^2 ON JULY 4, 2017. THE SCALE OF THE FIGURE HAS BEEN DEFINED FOR PRESENTATION.

0	8MAY'18	ISSUED WITH LETTER	AF	AA
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

PROPOSED MINE AREA - UNIT RUNOFF FROM 2017

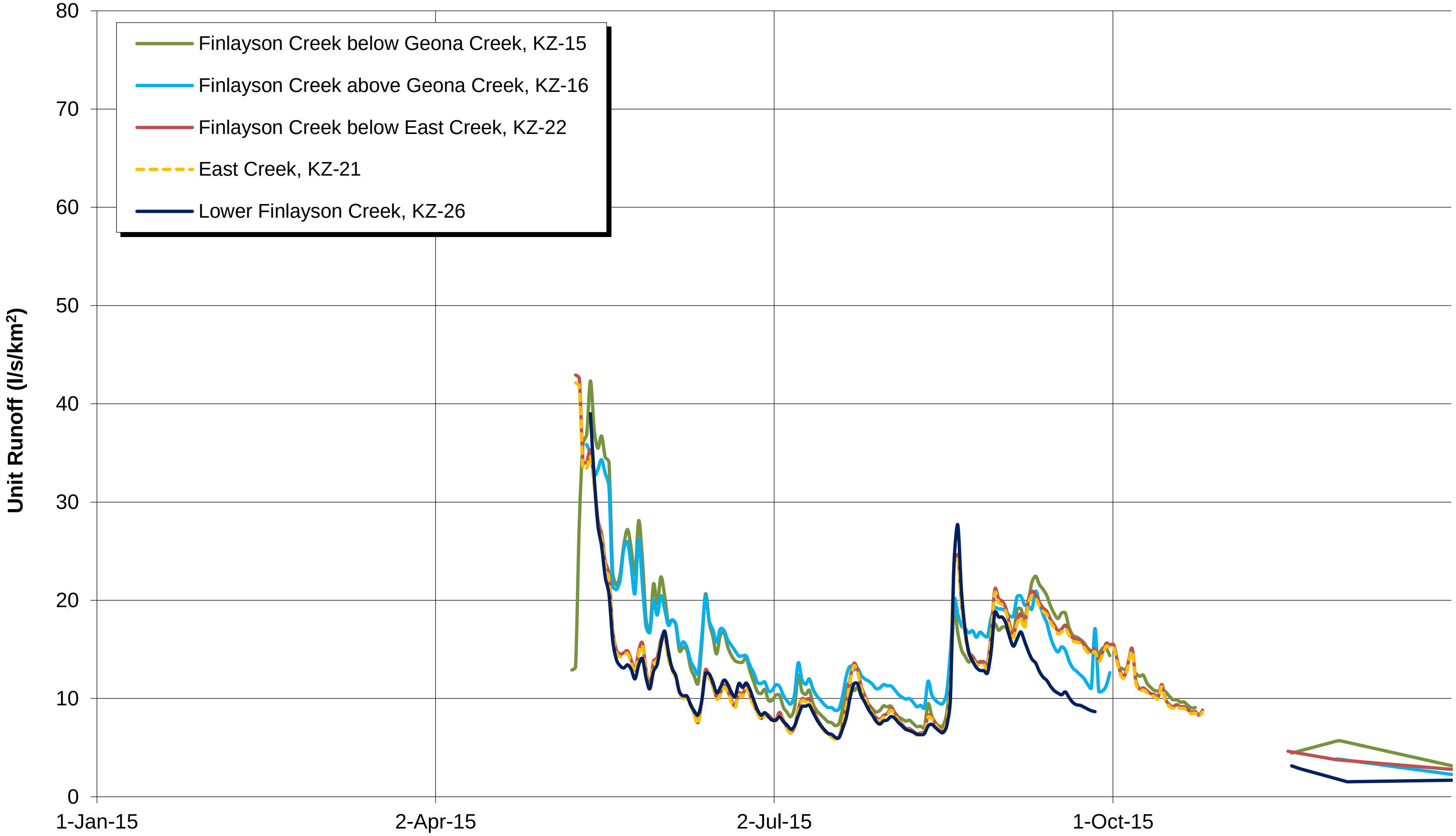
Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE D-3

REV 0



BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

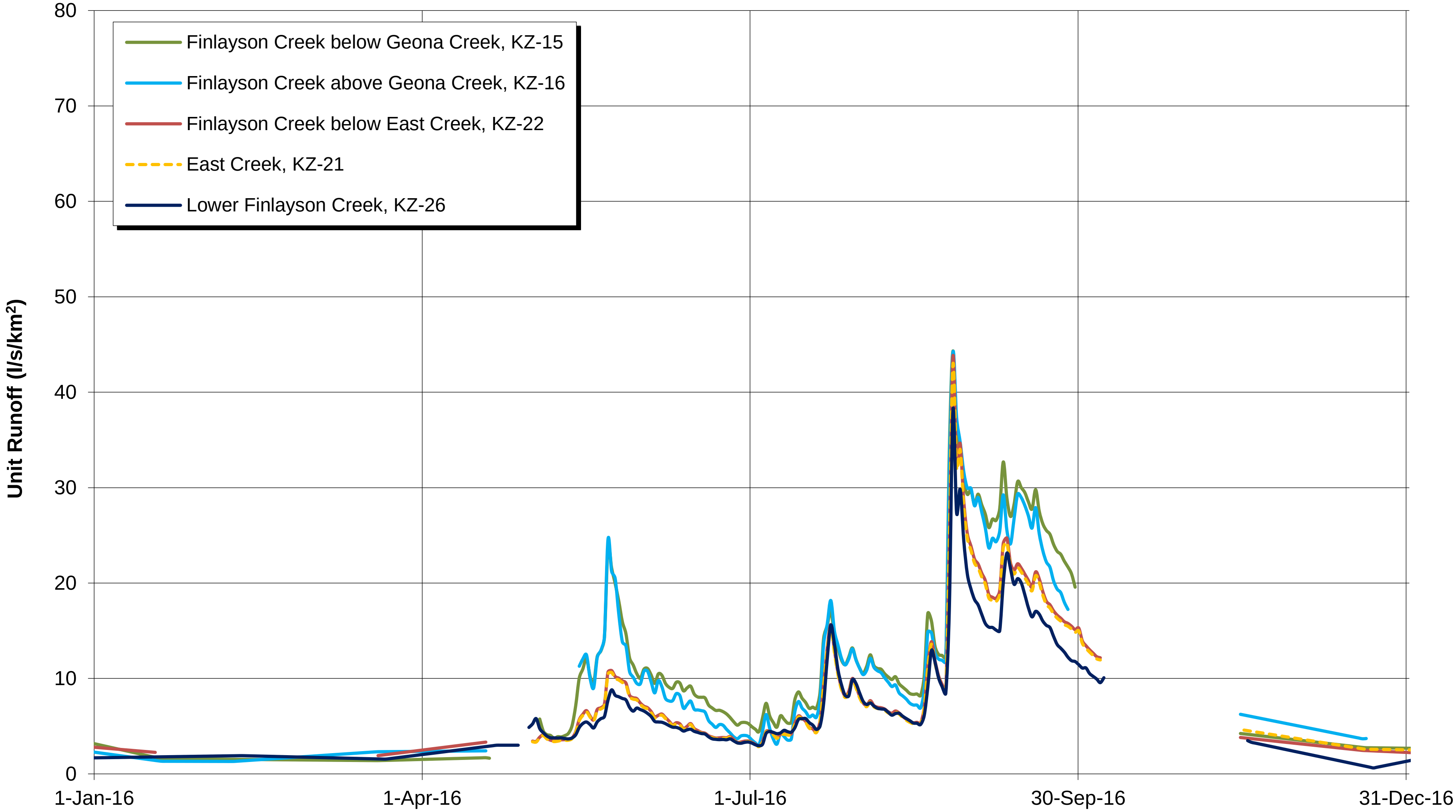
LOWER FINLAYSON CREEK - UNIT RUNOFF FROM 2015

Knight Piésold CONSULTING

P/A NO.	REF. NO.
VA101-640/6	VA18-00832

FIGURE D-4 REV 0

REV	DATE	DESCRIPTION	PREP'D	RVW'D
0	8MAY'18	ISSUED WITH LETTER	AF	AA



BMC MINERALS (NO.1) LTD.

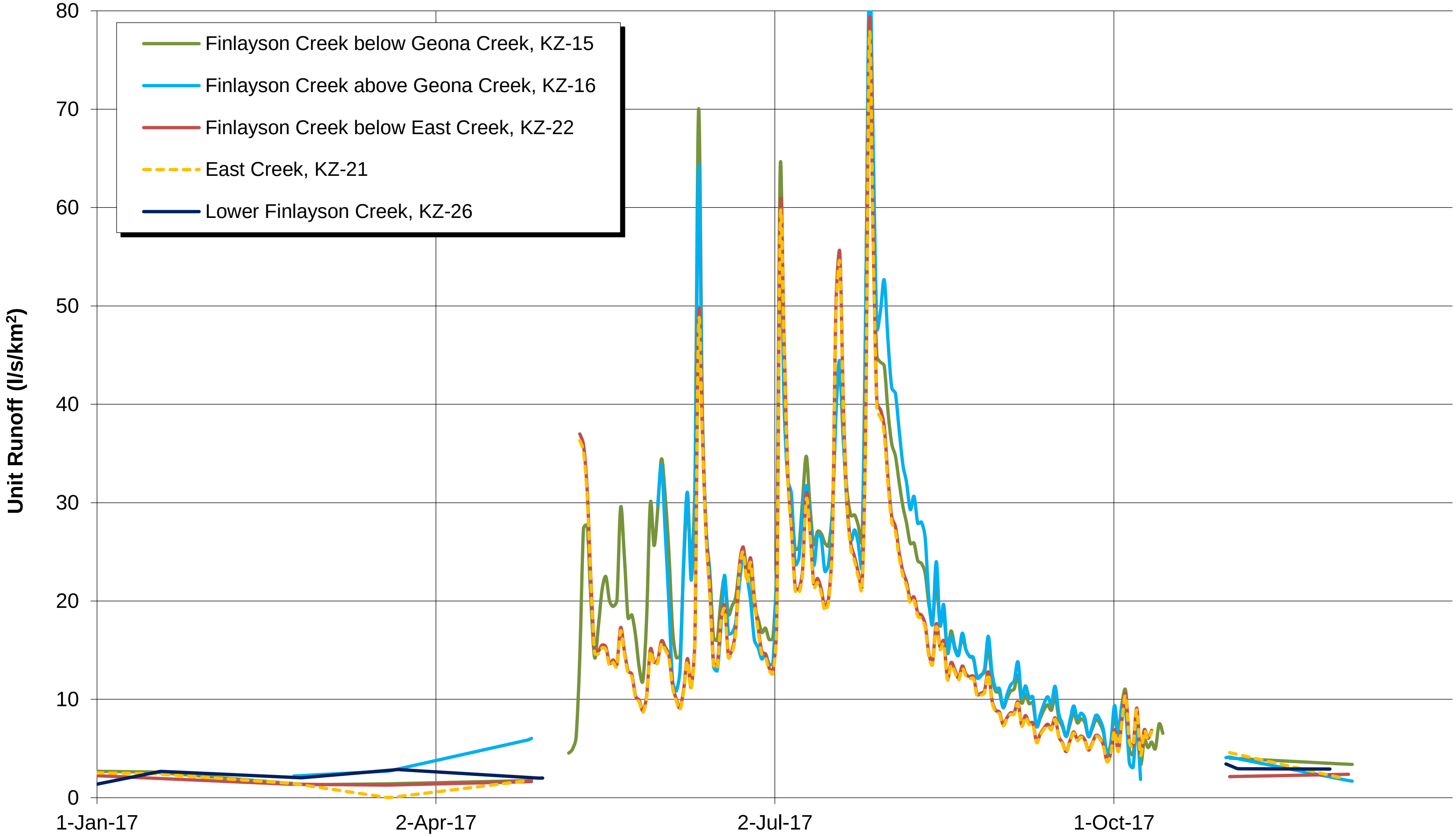
KUDZ ZE KAYAH PROJECT

LOWER FINLAYSON CREEK - UNIT RUNOFF FROM 2016

0	8MAY'18	ISSUED WITH LETTER	AF	AA
REV	DATE	DESCRIPTION	PREP'D	RVW'D

Knight Piésold CONSULTING

P/A NO. VA101-640/6	REF. NO. VA18-00832
FIGURE D-5	REV 0



NOTES:

1. THE KZ-26 STAGE RECORD FROM THE OPEN WATER SEASON IN 2017 SHOWS VARIATION THAT IS INCONSISTANT WITH STREAMFLOW FROM OTHER STATIONS AND MAY BE CAUSED BY INSTRUMENTATION MALFUNCTION.

0	8MAY'18	ISSUED WITH LETTER	AF	AA
REV	DATE	DESCRIPTION	PREP'D	RVW'D

BMC MINERALS (NO.1) LTD.

KUDZ ZE KAYAH PROJECT

LOWER FINLAYSON CREEK - UNIT RUNOFF FROM 2017

Knight Piésold CONSULTING

P/A NO. VA101-640/6

REF. NO. VA18-00832

FIGURE D-6

REV 0

APPENDIX B

LONG-TERM CLIMATE ESTIMATES FOR KZK CLIMATE STATION

APPENDIX B1

ESTIMATED LONG-TERM AIR TEMPERATURE AT KZK CLIMATE STATION

(Table B.1)

Knight Piésold CONSULTING

TABLE B.1

BMC MINERALS (NO. 1) LTD.
KUDZ ZE KAYAH PROJECT

ESTIMATED LONG-TERM AIR TEMPERATURE
AT KZK CLIMATE STATION

Print Jun/06/18 14:30:19

Year	Monthly Temperature (°C)												Annual Average (°C)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1976	-10.0	-13.2	-11.8	-3.2	2.2	8.2	10.7	9.1	3.8	-2.1	-4.7	-12.0	-2.3
1978	-11.4	-10.5	-9.9	-4.6	2.3	7.8	10.3	8.8	4.0	-1.1	-10.5	-13.2	-2.8
1979	-13.3	-18.8	-8.2	-5.6	1.4	6.7	10.0	9.9	4.1	-1.3	-6.1	-13.9	-2.6
1980	-13.3	-9.1	-10.9	-2.4	3.7	9.6	9.3	6.4	0.9	-0.6	-5.8	-19.6	-2.2
1981	-6.4	-11.5	-7.3	-8.1	5.3	5.9	9.7	8.3	1.3	-2.6	-6.4	-15.3	-4.2
1982	-17.4	-14.2	-14.7	-6.8	0.4	8.9	10.9	6.9	3.2	-4.0	-11.6	-12.8	-3.6
1983	-11.7	-11.5	-12.0	-3.5	2.6	8.3	9.5	6.1	-0.2	-3.0	-9.9	-18.4	-2.7
1984	-10.2	-8.4	-6.6	-2.5	1.7	6.7	8.5	6.7	1.6	-3.9	-11.0	-15.0	-3.6
1985	-6.5	-14.2	-10.9	-6.7	1.1	5.5	9.2	5.3	1.6	-4.1	-15.5	-10.0	-3.0
1986	-7.7	-11.4	-10.6	-9.7	0.5	7.3	10.5	5.9	2.1	-1.6	-12.2	-10.2	-2.1
1987	-8.5	-9.3	-14.0	-4.4	2.1	7.1	10.1	7.5	2.1	-1.0	-6.2	-10.9	-1.9
1988	-11.3	-9.6	-7.6	-3.1	3.4	8.3	8.9	7.5	1.7	-2.9	-8.1	-11.5	-2.3
1989	-13.2	-13.2	-15.7	-3.4	4.0	8.7	11.4	10.8	2.8	-3.3	-10.0	-10.3	-2.8
1990	-11.0	-15.5	-8.9	-3.3	3.9	7.8	10.5	9.1	3.7	-3.6	-15.3	-14.6	-2.4
1991	-10.7	-9.2	-11.4	-3.2	3.5	8.3	9.0	6.1	3.2	-4.4	-9.0	-11.7	-2.8
1992	-8.1	-10.5	-8.6	-5.6	-0.3	8.0	10.3	7.4	-2.3	-4.2	-6.5	-14.7	-1.9
1993	-11.3	-11.4	-9.6	-2.1	4.2	8.4	9.3	7.4	2.5	-1.7	-8.1	-10.8	-2.4
1994	-12.2	-16.4	-7.7	-2.0	2.2	8.0	11.2	12.2	1.4	-1.9	-11.6	-13.3	-2.2
1995	-10.7	-11.0	-13.1	-1.5	5.5	9.5	9.7	6.6	5.3	-2.5	-11.4	-13.7	-4.6
1996	-16.3	-11.3	-13.3	-5.8	0.5	7.3	9.9	5.5	1.5	-5.4	-12.4	-15.1	-2.3
1997	-12.9	-9.0	-13.9	-3.7	2.4	8.5	11.0	8.6	3.7	-5.2	-7.5	-9.5	-2.3
1998	-12.8	-9.1	-10.6	-2.5	4.7	9.0	10.7	7.1	2.1	-2.8	-9.9	-14.0	-2.6
1999	-12.4	-12.5	-10.1	-4.1	0.2	8.8	8.5	9.2	2.5	-2.0	-9.0	-10.5	-2.7
2000	-11.8	-8.8	-8.1	-6.3	0.6	8.7	9.2	5.7	0.8	-2.8	-7.3	-12.9	-2.5
2001	-7.3	-11.8	-10.8	-4.3	0.2	8.4	9.4	9.5	2.9	-3.2	-9.6	-13.8	-3.7
2002	-9.9	-11.1	-15.4	-10.1	0.9	7.6	9.7	6.3	1.8	-1.4	-5.7	-11.0	-3.1
2003	-10.2	-10.4	-12.0	-7.4	0.9	7.1	11.4	7.6	1.1	-1.3	-11.4	-12.1	-2.1
2004	-13.6	-8.4	-11.5	-3.8	3.1	12.1	10.7	9.3	0.2	-3.2	-8.5	-12.0	-1.5
2005	-11.7	-11.2	-7.0	-3.1	5.6	8.3	8.6	8.4	2.9	-2.1	-6.8	-10.7	-3.2
2006	-10.8	-10.5	-13.6	-4.5	1.6	8.8	10.2	7.2	3.0	-2.6	-17.2	-10.4	-2.9
2007	-9.2	-14.6	-15.8	-4.6	2.7	9.2	10.8	9.0	1.7	-3.1	-8.0	-14.0	-3.4
2008	-12.3	-13.0	-10.2	-4.7	3.2	6.9	7.5	6.6	1.8	-3.0	-8.0	-16.0	-2.9
2009	-12.0	-13.8	-14.2	-5.3	2.8	9.0	10.7	8.2	3.0	-2.8	-8.9	-12.2	-1.8
2010	-9.8	-9.1	-8.7	-2.5	3.4	7.7	10.0	9.4	2.0	-2.2	-7.5	-14.9	-3.1
2011	-11.0	-12.5	-15.0	-4.6	4.1	8.3	9.3	6.4	3.4	-2.2	-12.0	-10.0	-3.2
2012	-11.4	-8.3	-11.7	-2.8	1.7	8.4	8.8	7.9	3.0	-5.0	-12.6	-16.3	-2.7
2013	-10.0	-8.6	-14.3	-9.7	2.3	9.8	10.3	10.3	3.9	-1.6	-11.0	-14.3	-2.6
2014	-7.2	-14.3	-14.2	-5.0	3.7	6.8	10.3	8.2	2.0	-2.1	-9.4	-11.2	-1.8
2015	-9.7	-11.8	-9.4	-3.4	6.4	8.3	9.1	7.0	1.8	-1.5	-8.4	-11.7	-1.0
2016	-8.1	-8.5	-6.6	-0.2	4.9	9.6	10.7	9.5	2.8	-4.6	-7.5	-13.6	-2.4
2017	-9.4	-11.2	-15.0	-3.3	3.9	8.4	10.2	9.8	4.0	-2.3	-14.0	-11.0	-10.2
Minimum	-17.4	-18.8	-15.8	-10.1	-0.3	5.5	7.5	5.3	-2.3	-5.4	-17.2	-19.6	-10.2
Mean	**-10.8**	**-11.4**	**-11.2**	**-4.5**	**2.7**	**8.2**	**9.9**	**7.9**	**2.3**	**-2.7**	**-9.6**	**-12.9**	**-2.8**
Maximum	-6.4	-8.3	-6.6	-0.2	6.4	12.1	11.4	12.2	5.3	-0.6	-4.7	-9.5	-1.0

\\KPL\VA-Prj$\1\01\00640\06\A\Report\4 - Hydrometerology Report\Rev 0\Appendix B\[Long-Term Synthetic Temperature_20180424_jm.xlsx]Summary Table

0	6JUN'18	ISSUED WITH REPORT VA101-640/6-4	JJM	TJP
REV	DATE	DESCRIPTION	PREP'D	RVW'D

APPENDIX B2

ESTIMATED LONG-TERM MONTHLY PRECIPITATION AT KZK CLIMATE STATION

(Table B.2)

Knight Piésold
CONSULTING

TABLE B.2

BMC MINERALS (NO. 1) LTD.
KUDZ ZE KAYAH PROJECT

ESTIMATED LONG-TERM MONTHLY PRECIPITATION
AT KZK CLIMATE STATION

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Year	Monthly Precipitation (mm)												Annual Precipitation (mm)
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1972	92.2	31.5	36.1	14.1	46.3	52.6	87.3	40.7	75.2	53.3	40.5	35.6	605
1973	33.2	10.1	37.3	3.9	15.5	60.3	26.2	71.9	38.7	28.6	25.5	27.6	379
1974	22.1	45.3	19.0	16.0	58.8	70.3	43.5	107.7	53.3	63.1	12.3	34.8	546
1975	25.8	11.8	23.4	17.5	4.1	77.0	99.7	32.4	68.2	37.4	41.4	21.4	460
1976	25.3	19.9	34.7	17.5	31.7	48.2	61.6	50.8	18.6	23.4	20.1	28.3	380
1978	0.7	19.9	0.0	6.7	19.0	44.1	62.3	68.0	12.7	53.0	33.0	31.1	350
1979	14.5	29.9	33.0	11.0	17.2	111.5	90.6	22.6	21.9	19.0	20.3	56.2	448
1980	32.2	3.9	19.1	20.4	17.2	18.1	155.9	54.3	76.3	29.7	34.8	21.7	484
1981	10.6	37.8	6.5	7.4	12.7	70.0	67.5	36.8	68.5	35.1	27.8	8.8	390
1982	16.7	29.4	15.5	6.7	29.7	23.4	95.3	77.3	77.2	69.1	19.3	22.2	482
1983	58.4	10.8	16.0	3.6	33.7	90.9	80.3	107.6	34.7	26.6	18.6	6.4	487
1984	45.1	39.4	9.6	3.9	60.2	80.1	27.1	106.1	9.0	17.7	17.5	36.8	452
1985	36.8	40.5	3.6	22.6	28.1	45.9	102.3	132.1	75.7	32.7	36.3	42.7	599
1986	13.7	7.7	56.6	21.1	57.4	20.9	133.7	126.5	72.6	37.1	26.0	9.2	582
1987	5.1	22.9	4.6	16.3	65.5	83.0	151.0	103.8	49.4	43.5	29.1	10.1	584
1988	11.4	17.0	28.1	13.4	62.1	61.0	158.9	41.7	71.6	47.4	29.3	27.0	569
1989	32.4	5.9	32.4	3.3	29.3	67.0	84.5	27.6	50.3	75.7	65.1	22.6	496
1990	23.5	42.2	8.2	11.4	38.2	74.2	49.0	105.3	108.2	37.1	41.5	40.5	579
1991	28.1	36.9	27.1	4.6	36.6	49.4	188.6	53.9	78.8	81.1	70.9	65.4	722
1992	37.3	40.2	12.4	25.8	23.5	18.6	111.3	56.2	78.1	22.6	30.7	21.2	478
1993	35.6	24.5	2.6	9.8	125.4	80.1	81.4	90.6	83.0	63.3	66.4	28.1	691
1994	33.0	13.7	18.6	8.2	65.1	39.6	32.0	41.2	74.5	68.0	39.9	13.1	447
1995	13.7	12.7	30.1	8.5	17.8	55.4	120.0	103.6	47.1	19.9	36.5	25.2	491
1996	9.8	14.9	71.9	11.0	21.9	33.2	104.9	115.7	89.4	69.8	13.4	17.3	573
1997	12.7	21.1	2.3	21.9	27.0	62.6	141.2	54.3	29.4	39.7	10.5	20.9	444
1998	11.8	4.6	11.8	8.5	23.5	48.1	31.4	39.6	36.6	30.7	8.5	16.0	271
1999	50.0	17.5	25.2	5.7	72.6	113.8	60.8	61.1	47.1	37.6	20.9	48.1	560
2000	23.2	3.3	0.0	48.1	17.7	64.7	80.6	189.9	172.0	26.5	31.7	29.2	687
2001	12.1	4.9	6.9	23.9	50.3	57.2	95.5	23.2	72.9	89.6	19.6	40.9	497
2004	30.2	18.6	73.6	6.5	30.7	55.6	22.1	62.1	79.3	54.9	16.0	29.2	479
2005	30.2	20.3	4.2	31.9	95.8	66.2	137.0	63.1	59.8	21.2	49.0	18.3	597
2006	17.7	10.1	20.3	17.3	70.3	84.0	45.6	70.6	43.5	24.0	35.0	16.8	455
2007	18.3	16.3	19.9	2.6	36.9	83.0	71.1	81.8	85.2	57.5	13.4	31.5	518
2008	32.9	19.9	8.8	7.8	49.9	115.4	129.1	176.9	62.4	33.8	16.7	41.2	695
2009	54.4	33.5	34.0	11.4	28.8	67.0	32.0	118.7	49.4	41.4	19.0	7.2	497
2010	30.2	9.2	14.7	5.6	24.5	72.9	61.1	46.7	50.3	26.8	42.8	20.9	406
2011	15.5	16.0	0.0	7.2	11.1	121.3	82.2	90.2	44.5	20.3	29.2	51.3	489
2012	27.5	19.9	19.3	20.6	26.2	80.1	103.0	95.1	51.2	41.4	40.5	31.4	556
2013	121.0	19.9	14.1	17.0	10.5	57.5	124.2	124.2	60.5	32.7	22.6	70.6	675
2014	35.3	0.0	12.7	13.4	45.1	75.8	94.2	95.8	66.4	18.6	0.7	0.0	458
2015	0.0	8.5	29.4	17.0	8.5	63.4	103.6	146.1	48.1	39.9	0.0	0.0	465
2016	0.0	11.1	9.5	19.0	34.3	44.1	81.4	104.0	31.1	3.6	7.8	0.0	346
2017	1.6	11.8	19.0	7.5	7.2	140.9	198.1	98.1	36.0	48.4	0.0	0.0	569
Minimum	1	3	2	3	4	18	22	23	9	4	1	6	271
Mean	**30**	**20**	**22**	**13**	**37**	**66**	**91**	**82**	**59**	**41**	**29**	**29**	**520**
Maximum	121	45	74	48	125	141	198	190	172	90	71	71	722

NOTES:

1. THE FOLLOWING YEARS ARE MISSING FROM THE SYNTHETIC PERIOD OF RECORD: 1977, 2002 AND 2003.
2. MONTHS WITH MISSING DATA ARE INFILLED WITH MEAN MONTHLY VALUES AND HIGHLIGHTED IN GREY.

0	6JUN'18	ISSUED WITH REPORT VA101-640/6-4	ELK	TJP
REV	DATE	DESCRIPTION	PREP'D	RVW'D