Appendix 12-A

Surface Hydrology Baseline

HARPER CREEK PROJECT

Application for an Environmental Assessment Certificate / Environmental Impact Statement

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

SURFACE HYDROLOGY BASELINE

PREPARED FOR:

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VA101-458/15-2
Rev 0
August 22, 2014

Knight Piésold
CONSULTING
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HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

SURFACE HYDROLOGY BASELINE
VA101-458/15-2

Rev	Description	Date	Approved
0	Issued in Final	August 22, 2014	KJB

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EXECUTIVE SUMMARY

The Harper Creek Project (the Project) is a proposed open pit copper mine located in south-central British Columbia (BC), approximately 150 km northeast by road from Kamloops. The Project has an estimated 28-year mine life based on a process plant throughput of 70,000 tonnes per day. The Proponent, Harper Creek Mining Corporation (HCMC), is a wholly owned subsidiary of Yellowhead Mining Inc., which is a public BC junior mineral development company trading on the Toronto Stock Exchange.

Knight Piésold Ltd. (KP) was engaged by HCMC to collect baseline surface hydrology data and characterize long-term baseline streamflow conditions at the Harper Creek Project. Field work was initiated during May 2011 and is currently active. This report presents hydrology data collected to April 2014 and provides estimates of a wide range of flow values for numerous locations in the Project area.

The Harper Creek Project is located within the Shuswap Highlands region in the western foothills of the Columbia Mountains. This is a transitional region between the interior plateaus and the eastern mountain ranges. The Project is located on the watershed divide between Harper Creek and the North Thompson River. Regional runoff patterns are characterized by low flows during the winter months when precipitation falls almost exclusively as snow, high flows during the spring and early summer snowmelt freshet period, low flows during the dry late summer months, and moderate flows during the fall months when rainfall increases. A change in runoff patterns and volumes with elevation is also evident in the region, with lower elevation watersheds generally experiencing less precipitation and corresponding lower runoff than higher elevation watersheds, and also experiencing an earlier onset of the spring freshet resulting from warm spring temperatures arriving earlier at lower elevations.

HCMC established six streamflow gauging stations in 2011 and a further three in 2013 within the baseline study area. The locations of these stations were selected to provide broad spatial coverage of the study area and the data collected are believed to generally represent the full range of hydrologic conditions present in the study area. Additionally, the stations were located to collect data at key sites downstream of proposed facilities and infrastructure. The installation and operation of these gauging stations were done in accordance with the requirements of the Manual of British Columbia Hydrometric Standards. Four active Water Survey of Canada streamflow gauging stations, each with more than 30 years of record, are also located within the baseline study area.

Measured data are presented for all nine HCMC streamflow stations. Long-term synthetic daily flow series were developed for four of the key stations, namely Jones Creek, P Creek at Harper Creek, Harper Creek upstream of T-Creek, and T-Creek at Harper Creek, by correlating site and regional flow data. The site stations were selected in areas of interest for fisheries and water quality assessment and where sufficient measured data are available to permit detailed hydrologic analysis. Of these four stations, Jones Creek, which has the lowest elevation watershed, has the lowest unit runoff (discharge per unit area), while T Creek, which has the highest elevation watershed, has the highest unit runoff. The Harper Creek WSC gauge's unit runoff is higher than that of all the HCMC stations, which is somewhat surprising given its intermediary elevation, but this apparent inconsistency is explained by it having a disproportionate amount of its basin to the west, where the climate may be wetter and conditions appear to be more conducive to producing runoff (exposed rock, steep gradient). The mean annual unit runoff in the Project Area ranges from approximately 16 $l/s/km^2$ to 24 $l/s/km^2$.

Low flows in the Project area typically occur during late summer or late winter. A review of measured low flows on site indicated that unit low flows are somewhat correlated to drainage area, although localized drainage conditions confound the pattern, particularly for basins with areas less than approximately 25 km^2. For small watersheds, the mean annual 7-day low flows approach zero.

Peak flows in the Project area occur almost exclusively during the spring and early summer, and result from either snowmelt or rain-on-snow events. Peak flow statistics were generated for the most relevant regional stations operated by WSC and the results were used to establish regional peak flow patterns. Hydrologic and climatic conditions support the idea that the upper headwater areas of the watershed likely experience proportionally greater peak flows than the WSC gauge basin, and estimated flood statistics were selected accordingly.

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GLOSSARY AND ABBREVIATIONS

Application Information Requirements........AIR
Association of Professional Engineers and Geoscientists of British Columbia........APEGBC
British Columbia Environmental Assessment Act........BC EAA
British Columbia........BC
Canadian Environmental Assessment Act........CEAA
Consolidated Frequency Analysis (software package)........CFA
Cubic metre per second........m^3/s
Discharge........Q
Drainage Area........A
Environmental Assessment........EA
Environmental Impact Statement........EIS
Generalized Extreme Value (frequency distribution)........GEV
Harper Creek Mining Corporation........HCMC
Harper Creek Project........the Project
hectare........ha
kilometre........km
Knight Piésold Ltd.........KP
Linear coefficient of skewness........L-Cs
Linear coefficient of variation........L-Cv
Low-Flow Frequency Analysis (software package)........LFA
Mean annual discharge........MAD
Mean annual unit runoff........MAUR
metres above sea level........masl
Potentially acid generating........PAG
Pounds per square inch........psi
Tailings management facility........TMF
Toronto Stock Exchange........TSX
Water Survey of Canada........WSC
Yellowhead Mining Inc.........YMI

1 – INTRODUCTION

1.1 PROJECT DESCRIPTION

Harper Creek Mining Corporation (HCMC) proposes to construct and operate the Harper Creek Project (the Project), an open pit copper mine near Vavenby, British Columbia (BC). The Project has an estimated 28-year mine life based on a process plant throughput of 70,000 tonnes per day (25 million tonnes per year). Ore will be processed on site through a conventional crushing, grinding and flotation process to produce a copper concentrate, with gold and silver by-products, which will be trucked from the Project site along approximately 24 km of existing access roads to a rail load-out facility located at Vavenby. The concentrate will be transported via the existing Canadian National Railway network to the existing Vancouver Wharves storage, handling and loading facilities located at the Port of Vancouver for shipment to overseas smelters.

The Project consists of an open pit mine, on-site processing facility, tailings management facility (TMF) (for tailings solids, subaqueous storage of PAG waste rock, and recycling of water for processing), waste rock stockpiles, low grade and overburden stockpiles, a temporary construction camp, ancillary facilities, mine haul roads, sewage and waste management facilities, a 24 km access road between the Project site and a rail load-out facility located on private land owned by HCMC in Vavenby, and a 12 km power line connecting the Project site to the BC Hydro transmission line corridor in Vavenby. The Project location and infrastructure are shown on Figure 1.1.

This report describes the baseline conditions of surface hydrology (streamflow) for the purposes of the Application for an Environmental Assessment (EA) Certificate under the British Columbia Environmental Assessment Act (BC EAA) and the Environmental Impact Statement (EIS) under the Canadian Environmental Assessment Act (CEAA), in accordance with the Approved Project Application Information Requirements (AIR) issued October 21, 2011.

1.2 PROJECT LOCATION

The Project is located in the Thompson-Nicola area of BC, approximately 150 km northeast of Kamloops along Yellowhead Highway #5, approximately 10 km southwest of the unincorporated municipality of Vavenby, BC. The Project is located within National Topographic System (NTS) map sheets 82M/5 and 82M/12, is geographically centred at 51º30’N latitude and 119º48’W longitude, and is situated at approximately 1800 m above sea level (masl). The mineral claims comprising the Project cover an area of 42,636.48 ha. The Project location is shown on Figure 1.1.

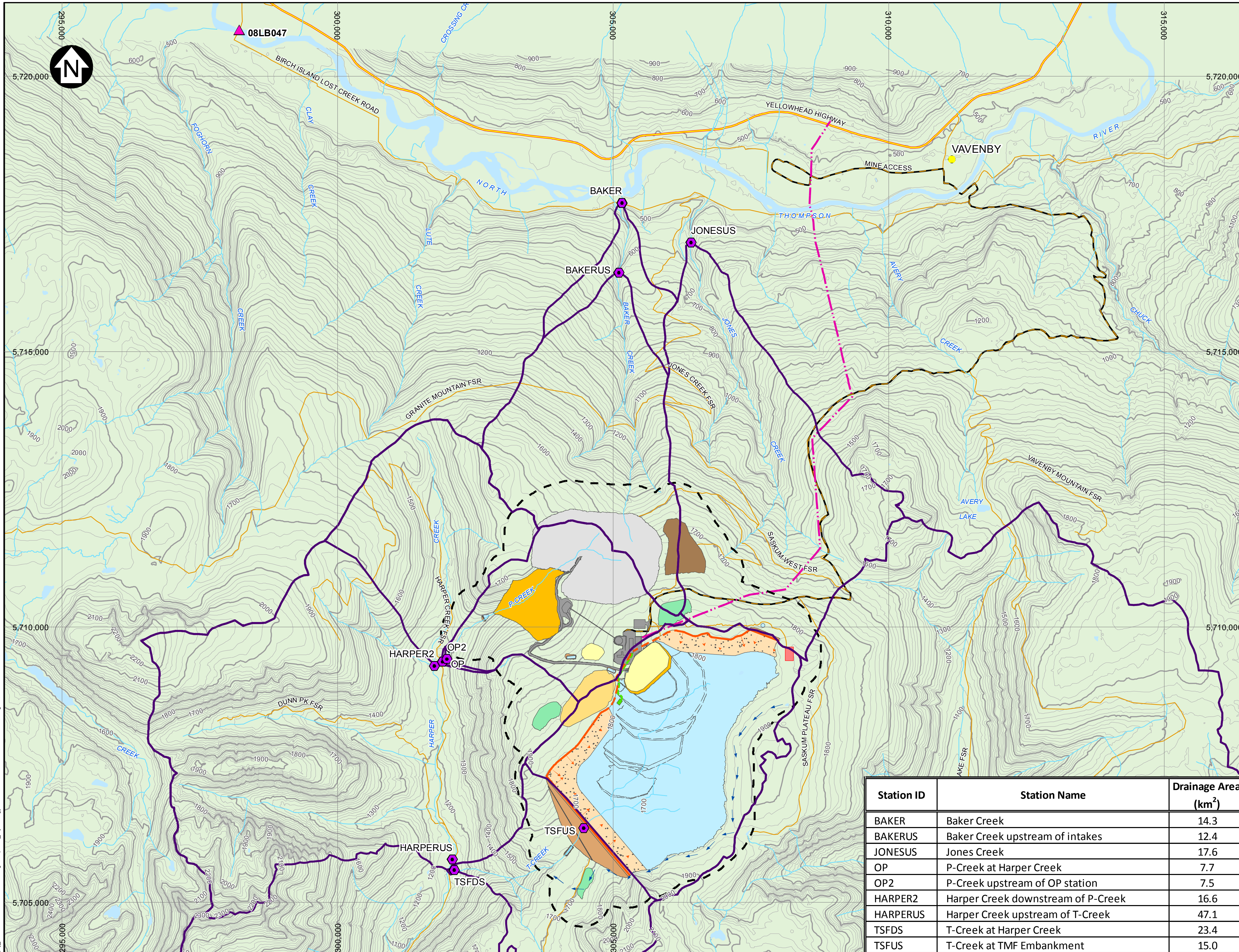
1.3 PROJECT ACCESS

Access to the Project is from Kamloops to Vavenby via Yellowhead Highway # 5, across the North Thompson River and then eastward along the Birch Island - Lost Creek Forestry Service Road (FSR) for approximately 6 km to the Jones Creek FSR, as shown on Figure 1.1.

The proposed main access route to the Project site is from Vavenby via the Vavenby Mountain FSR. This road runs along the western side of Chuck Creek for approximately 6 km before heading west toward Avery Creek and the southeastern part of the Project. This road then meets the Barrière Mountain FSR at approximately 11 km. From there, the Saskum Plateau FSR heads southwest to the eastern and central areas of the Project.

1.4 PROJECT PROPONENT

The Proponent of the Project is HCMC, a wholly owned subsidiary of Yellowhead Mining Inc. (YMI). YMI was formed in 2005 as a private BC company specifically to acquire, explore and, if feasible, develop the Project. YMI is now a publicly owned BC based mineral development company trading on the Toronto Stock Exchange (TSX) in Canada. HCMC's strategy is to engineer, permit, finance, construct, and operate the Project.



Station ID	Station Name	Drainage Area (km^2)
BAKER	Baker Creek	14.3
BAKERUS	Baker Creek upstream of intakes	12.4
JONESUS	Jones Creek	17.6
OP	P-Creek at Harper Creek	7.7
OP2	P-Creek upstream of OP station	7.5
HARPER2	Harper Creek downstream of P-Creek	16.6
HARPERUS	Harper Creek upstream of T-Creek	47.1
TSFDS	T-Creek at Harper Creek	23.4
TSFUS	T-Creek at TMF Embankment	15.0

LEGEND:

GENERAL

- CITY/TOWN
- STREAMFLOW GAUGING STATION - WSC
- STREAMFLOW GAUGING STATION - HCMC
- CONTOUR (20 m)
- RIVER/CREEK
- LAKE
- WATERSHED BOUNDARY
- MINE SITE AREA

PROPOSED MINE SITE FACILITIES

- TRANSMISSION LINE
- TAILINGS DELIVERY PIPELINE
- TAILINGS DISCHARGE PIPELINE
- RECLAIM WATER PIPELINE
- ACCESS ROAD
- HIGHWAY
- SECONDARY ROAD
- NON-PAG LOW GRADE STOCKPILE
- NON-PAG WASTE ROCK STOCKPILE
- PAG LOW GRADE STOCKPILE
- PAG WASTE ROCK STOCKPILE
- OVERBURDEN STOCKPILE
- TOPSOIL STOCKPILE
- OPEN PIT
- EMBANKMENT
- RECLAIM BARGE
- POND
- TAILINGS BEACH
- MINE INFRASTRUCTURE
- EXPLOSIVES STORAGE FACILITY

NOTES:

1. BASE MAP: BC TRIM, ARCGIS ESRI ONLINE BASEMAPS, BC WATERSHED ATLAS.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:70,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. FACILITIES REPRESENT MAXIMUM FOOTPRINT FOR MINE LIFE AND ARE YEAR 24, EXCEPT:
   - OPEN PIT TAILINGS (YEAR 24) ARE REMOVED
   - PIPELINES ARE YEAR 20
   - PAG LOW GRADE STOCKPILE IS YEAR 15
   - NON-PAG LOW GRADE STOCKPILE (WEST OF PLANT SITE) IS YEAR 3.

SCALE 1 0.5 0 1 2 3 km

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MINE SITE OVERVIEW

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE 1.1 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	05AUG14	ISSUED WITH REPORT	CJN	AMD	TJP	KJB

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1.5 STUDY OBJECTIVES

The surface hydrology baseline study was undertaken to characterize pre-Project streamflow conditions in the baseline study area, primarily to support the fisheries and water quality assessments for the Application/EIS.

The specific objectives of the study were to compile long-term daily streamflow records from applicable Water Survey of Canada (WSC) gauging stations, to collect short-term streamflow records at HCMC gauging stations established for the Project, and to use this combined dataset to generate streamflow statistics for locations of interest. Furthermore, the streamflow dataset was used to develop long-term daily flow series for four of the HCMC stations, which were then used to calibrate a watershed model that will be used to predict the effects of the Project on the hydrologic conditions. The watershed model will be described in the Baseline and Life of Mine Watershed Model report (KP, 2014a), which is currently being prepared. It is important to note that in some cases the baseline flows in the watershed model report might differ from baseline flows in this report, for the same gauging station location, due to the resolution of the watershed model calibration. The baseline flows presented in the watershed model report are the flows against which the hydrologic changes due to the Project will be calculated and assessed.

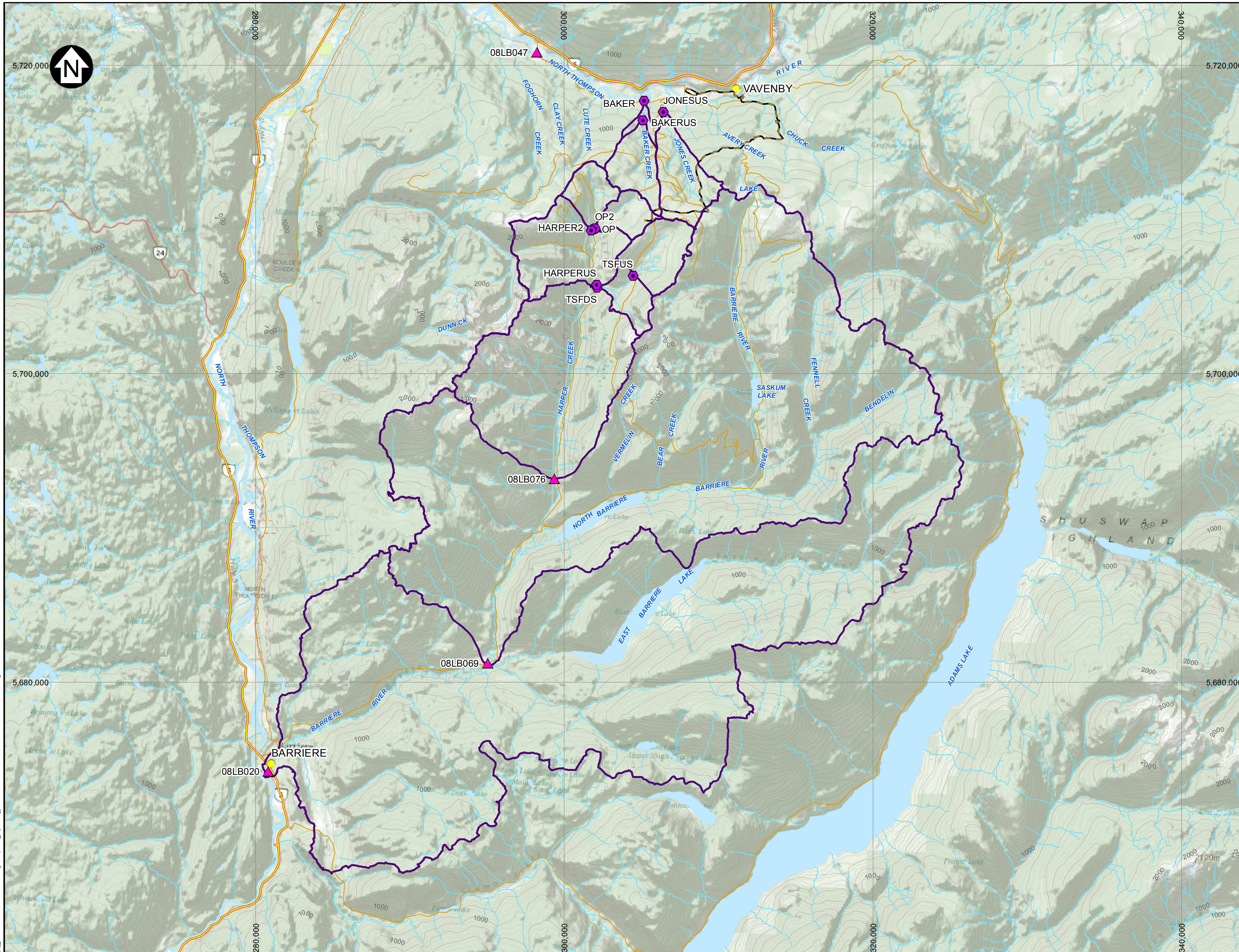
This baseline hydrology report provides long-term flow statistics for the WSC and HCMC streamflow gauging stations. The WSC flow statistics were generated from long-term published records. The HCMC stations have shorter periods of record, so an analysis was undertaken to correlate them with concurrent WSC records to generate long-term synthetic flow series for the HCMC stations. The HCMC station statistics are based on these synthetic flow series, and on other scaling analyses using the WSC records, as described in this report.

1.6 BASELINE STUDY AREA

The Project is located in the North Thompson River watershed on the sub-watershed divide between two small tributaries that flow north directly into the North Thompson River (Baker and Jones Creeks) and Harper Creek that drains south into the Barriere River, which in turn drains into the North Thompson River.

The baseline study area is defined as the Baker Creek, Jones Creek, and Barriere River watersheds. Within the Barriere River watershed, the most intensive data collection efforts were focussed on the upper part of the Harper Creek sub-watershed where mine infrastructure would be located. The watersheds and watercourses in the baseline study area are shown on Figure 1.2. The watersheds and watercourses in the more intensive data collection area in the vicinity of the mine site are shown in more detail on Figure 1.1.

WSC streamflow statistics from a broader surrounding region were used to characterize extreme streamflow statistics within the baseline study area, specifically in the area near the mine infrastructure. Watershed characteristics such as drainage area and physiography play a large role in extreme streamflow statistics, so it is normal practice to consider several watersheds with a similar range of characteristics from the surrounding region when estimating extreme streamflow statistics in a watershed of interest. The regional WSC stations considered in the extreme streamflow analyses are shown on Figure 1.3.



LEGEND:

GENERAL

- CITY/TOWN
- STREAMFLOW GAUGING STATION - WSC
- STREAMFLOW GAUGING STATION - HCMC
- YELLOWHEAD HIGHWAY
- ACCESS ROAD
- SECONDARY ROAD
- CONTOUR (200m)
- RIVER/CREEK
- LAKE
- WATERSHED BOUNDARY

Station ID	Station Name	Drainage Area (km^2)
BAKER	Baker Creek	14.3
BAKERUS	Baker Creek upstream of intakes	12.4
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HARPERUS	Harper Creek upstream of T-Creek	47.1
TSFDS	T-Creek at Harper Creek	23.4
TSFUS	T-Creek at TMF Embankment	15.0
08LB047	North Thompson River At Birch Island	4490
08LB076	Harper Creek Near The Mouth	166
08LB069	Barriere River Below Sprague Creek	624
08LB020	Barriere River At The Mouth	1140

NOTES:

1. BASE MAP: BC TRIM, ARCGIS ESRI ONLINE BASEMAPS, BC WATERSHED ATLAS.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:250,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. CONTOUR INTERVAL IS 200 METRES. DATA SOURCE: NTDB DATA.
5. WATERSHED BOUNDARIES DERIVED FROM BC FRESHWATER ATLAS (FWA_ASS_WS.shp) AND BY KPL AT PROJECT SITE DOWNLOADED FROM GEO BC AND MODIFIED IF REQUIRED, TO DETERMINE PROJECT WATERSHEDS.

SCALE 2 1 0 2 4 6 8 10 KM

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

WATERSHEDS AND WATERCOURSES WITHIN BASELINE STUDY AREA

Knight Piésold CONSULTING

P/A NO. VA101-458/15 REF NO. 2

FIGURE 1.2 REV 0

REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D
0	05AUG'14	ISSUED WITH REPORT	AMD	AMD	TJP	KJB

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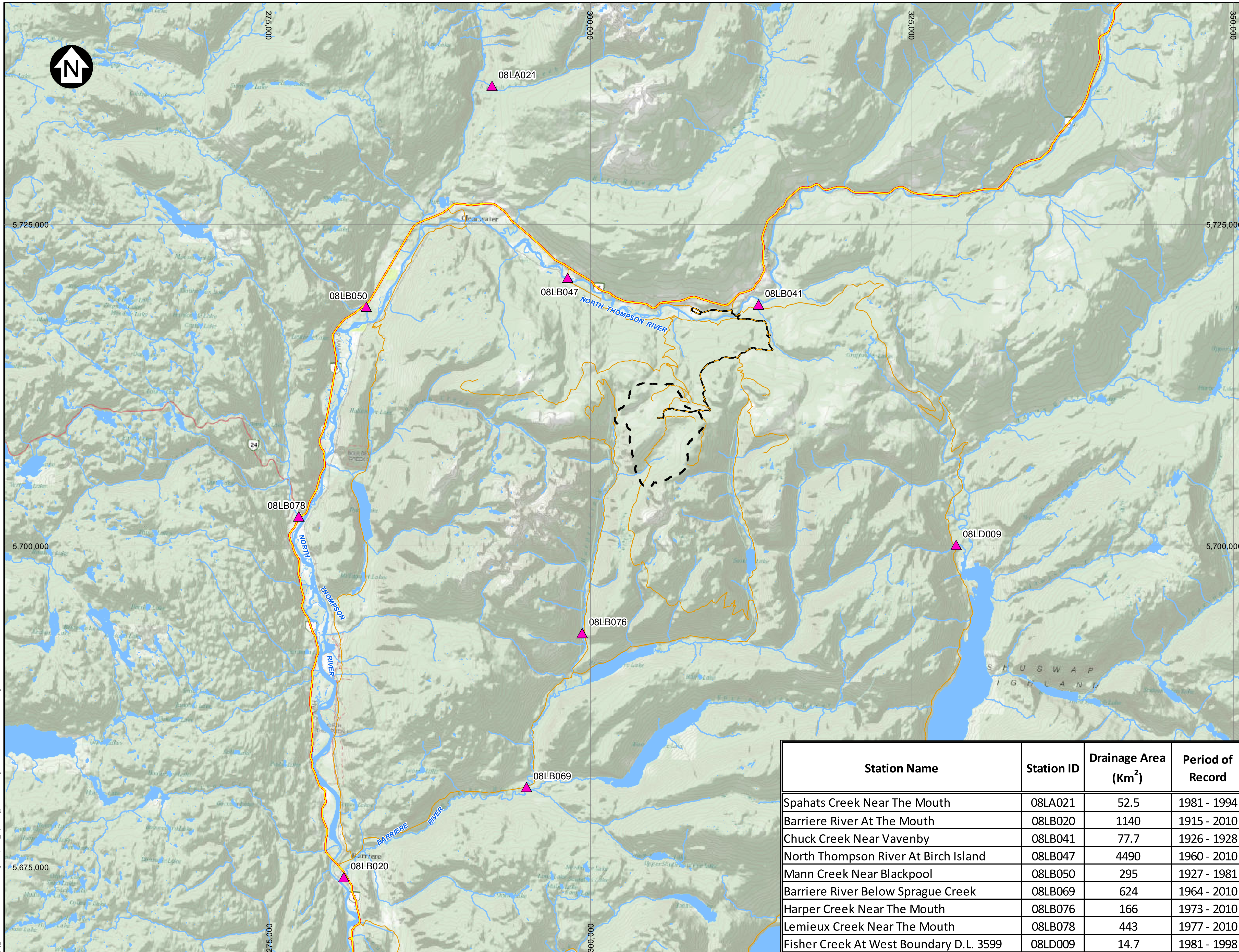

Station Name	Station ID	Drainage Area (Km^2)	Period of Record
Spahats Creek Near The Mouth	08LA021	52.5	1981 - 1994
Barriere River At The Mouth	08LB020	1140	1915 - 2010
Chuck Creek Near Vavenby	08LB041	77.7	1926 - 1928
North Thompson River At Birch Island	08LB047	4490	1960 - 2010
Mann Creek Near Blackpool	08LB050	295	1927 - 1981
Barriere River Below Sprague Creek	08LB069	624	1964 - 2010
Harper Creek Near The Mouth	08LB076	166	1973 - 2010
Lemieux Creek Near The Mouth	08LB078	443	1977 - 2010
Fisher Creek At West Boundary D.L. 3599	08LD009	14.7	1981 - 1998

LEGEND:

GENERAL

- STREAMFLOW GAUGING STATION - WSC
- RIVER/CREEK
- LAKE
- MINE SITE AREA

NOTES:

1. BASE MAP: BC TRIM AND ARCGIS ESRI ONLINE BASEMAPS.
2. COORDINATE GRID IS IN METRES. COORDINATE SYSTEM: NAD 1983 UTM ZONE 11N.
3. THIS FIGURE IS PRODUCED AT A NOMINAL SCALE OF 1:300,000 FOR 11x17 (TABLOID) PAPER. ACTUAL SCALE MAY DIFFER ACCORDING TO CHANGES IN PRINTER SETTINGS OR PRINTED PAPER SIZE.
4. STREAMFLOW STATION DATA OBTAINED FROM ENVIRONMENT CANADA (2012).

SCALE 3 1.5 0 3 6 9 12 15 km

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

REGIONAL STREAMFLOW STATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE 1.3 REV 0

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REV	DATE	DESCRIPTION	DESIGNED	DRAWN	CHK'D	APP'D

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1.7 PROJECT SETTING

The Harper Creek Project is located within the Shuswap Highlands in the western foothills of the Columbia Mountains. This is a transitional region between the interior plateaus and the eastern mountain ranges.

1.7.1 Climate and Runoff Patterns

Weather systems typically track from west to east over the region. Precipitation and runoff generally increase with elevation, as weather systems are forced up and over the Columbia Mountains. Air temperatures in the Project area are cool with a mean annual temperature near 0°C at the Mine site (elevation 1800 masl). Minimum and maximum mean monthly temperatures are approximately -10°C and 10°C, occurring in December and July, respectively. The mean annual precipitation at the proposed mine site is estimated to be in the order of 1050 mm, with 40% falling as rain and 60% falling as snow (KP, 2013).

Regional runoff patterns are characterized by low flows during the winter months when precipitation falls almost exclusively as snow, high flows during the spring and early summer snowmelt (nival) freshet period, low flows during the dry late summer months, and moderate flows during the fall months when rainfall increases. A change in runoff patterns and volumes with elevation is also evident in the region, with lower elevation watersheds generally experiencing less precipitation and corresponding lower runoff than higher elevation watersheds, and also experiencing an earlier onset of the spring freshet resulting from warm spring temperatures arriving earlier at lower elevations. Annual hydrographs in the region typically have a uni-modal shape, with the majority of runoff occurring in May and June during the snowmelt freshet period. Minimum low flows typically occur during late summer or late winter. Peak flows occur primarily during the spring and early summer snowmelt freshet, and may result from either snowmelt or rain-on-snow events, although high flows can also occur in autumn due to intense convective or frontal rainfall.

1.7.2 Watersheds

Baker and Jones Creeks both drain north-facing watersheds and flow approximately 5 km from their headwaters at the mine site to the North Thompson River, as shown on Figure 1.1. Harper Creek flows south from the proposed mine site and discharges into the western end of North Barriere Lake, just upstream of the lake outlet, as shown on Figure 1.2. The Barriere River flows out of the lake and travels in a southwesterly direction for approximately 27 km (valley length) before meeting the North Thompson River at the community of Barriere, 58 km north of Kamloops. The largest tributary to the Barriere River is the East Barriere River, which joins the Barriere River approximately 18 km (valley length) upstream of the North Thompson River confluence.

The proposed mine infrastructure would be mainly located in the upper, eastern part of the Harper Creek watershed, and in the headwaters of Baker and Jones Creeks, at elevations between approximately 1600 masl and 1900 masl (metres above sea level), as shown on Figure 1.1. The Baker, Jones, and Harper Creek watersheds are described below, along with two sub-watersheds of Harper Creek – P Creek and T Creek – which lie within the proposed mine site.

The distributions of elevation within each watershed are plotted in the form of hypsometric curves on Figure 1.4. These curves show that the maximum elevations in Baker, Jones, and P Creeks are similar, at around 1850 to 1900 masl, which is consistent with these watersheds sharing drainage divides within the proposed mine site. Baker and Jones Creeks have lower median elevations than P-Creek because they descend into the lower North Thompson River valley (430 masl), as compared to the Harper Creek valley for P-Creek (1215 masl). Harper Creek has higher maximum elevations than its sub-watersheds, P-Creek and T-Creek, because its watershed contains higher alpine terrain to the west of the proposed mine site.

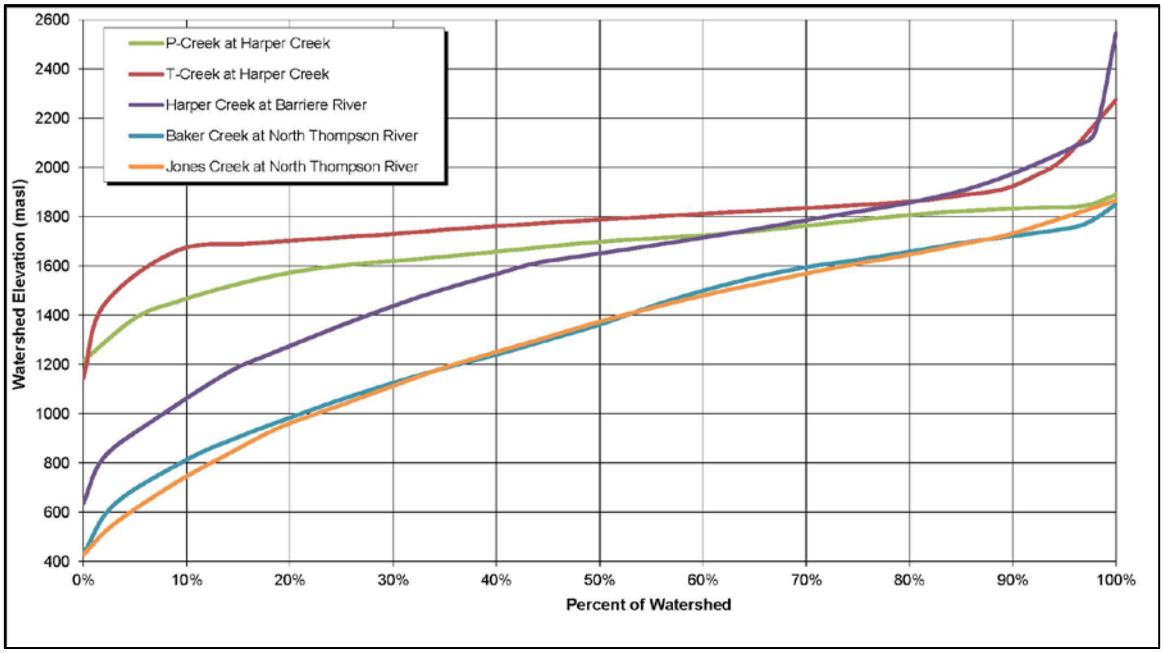

Figure 1.4 Hypsometric Curves

1.7.2.1 Baker Creek Watershed

Baker Creek drains a north-facing watershed with an area of 13.9 km^2. Baker Creek drains steep, high-elevation terrain that transitions to moderate gradient terrain prior to the creek's confluence with the North Thompson River. The average channel gradient of Baker Creek is 16.6% (KP, 2014). The watershed is covered in coniferous forest with some logging activity throughout. Additionally, some farming activity is present in the lower section of the watershed and a few small intakes remove water from lower Baker Creek for irrigation. The watershed elevation ranges from 1850 masl to 430 masl, with a median elevation of 1360 masl. The hypsometric curve for the Baker Creek watershed is presented on Figure 1.4.

The Baker Creek channel is confined by the hillslopes and the dominant stream morphology is step-pool (Montgomery and Buffington 1997). Bed materials consist primarily of cobbles and gravels. The dominant riparian vegetation includes immature and mature trees along mossy banks.

1.7.2.2 Jones Creek Watershed

Jones Creek drains a north-facing watershed with an area of 18.3 km^2. The Jones Creek headwaters drain moderate-gradient, higher-elevation catchments and the mainstem channel continues at a moderate gradient until it confluences with the North Thompson River. The average channel gradient of Jones Creek is 12.9% (KP, 2014). The watershed is covered in coniferous forest with some logging activity throughout. Additionally, some farming activity is present in the lower section of the watershed and a few small intakes remove water from lower Jones Creek for irrigation. The watershed elevation ranges from 1865 to 430 masl, with a median elevation of 1375 masl. The hypsometric curve for the Jones Creek watershed is presented on Figure 1.4.

The Jones Creek channel is confined by hillslopes and the dominant stream morphology is step-pool (Montgomery and Buffington 1997). Bed material consists primarily of cobbles and gravels. Riparian vegetation includes immature and mature trees along mossy banks.

1.7.2.3 Harper Creek Watershed

Harper Creek drains a southerly facing watershed with an area of 186 km^2. The Harper Creek headwaters and tributaries drain steep mountain catchments. The mainstem channel is confined by valley hillslopes throughout much of its length, although the channel meanders slightly in some places through areas where a small valley flat has developed. The creek crosses a low-gradient fan before discharging near the outlet of North Barriere Lake. The catchment is partially covered in coniferous forest with extensive logging on the east side of the watershed. The west side of the watershed consists of higher mountains with alpine terrain and some exposed rock. The average channel gradient of Harper Creek is 3.0% (KP, 2014); however, the creek transitions from moderate gradient sections in the upper watershed to low gradient sections through much of the middle and lower watershed. Elevations in the Harper Creek watershed range from approximately 640 masl near the creek's confluence with North Barriere Lake to over 2600 m at the peak of Granite Mountain. The hypsometric curve for the Harper Creek watershed is presented on Figure 1.4.

The dominant stream morphology in Harper Creek is rapids (Montgomery and Buffington 1997), although intermittent low gradient sections occur where the morphology is riffle-pool and the channel is less confined. Alluvial bed materials consisting primarily of cobbles interspersed with boulders and gravels occur throughout Harper Creek. The dominant riparian vegetation includes overhanging alders with mature trees along mossy banks. The banks are undercut in some sections and can be 0.5 m high.

1.7.2.4 P-Creek Watershed

P-Creek drains a south–southwest facing watershed with an area of 7.7 km^2. The upper portion of this creek overlaps the proposed open pit for the Project. The confluence of P-Creek and Harper Creek is at km 24.4 of Harper Creek (toward the upper end of Harper Creek). The watershed is partially covered in coniferous forest but has undergone extensive logging. The average channel gradient of the lower sections of P-Creek is 9.6% (KP, 2014); the upper portion of the watershed is very steep, and gradually transitions to lower gradients near the Harper Creek confluence. The watershed elevation ranges from 1890 to 1215 masl, with a median elevation of 1700 masl. The hypsometric curve for the P-Creek watershed is presented on Figure 1.4.

The dominant stream morphology in P-Creek is cascade (Montgomery and Buffington, 1997) with bedrock controls. Bed material in P-Creek is primarily coarse materials with the vast majority being classified as angular cobble with some boulders. The dominant riparian vegetation is overhanging alders and mature trees along the mossy creek banks. Some large instream woody debris produces log jam stream features as they are filled with bed material. Below the Harper Creek Forest Service

Road (FSR), the channel flows onto a fan and the Harper valley flat and is less confined by the hillslopes. The channel meanders somewhat and channel avulsions were noted.

1.7.2.5 T-Creek Watershed

T-Creek drains a west-facing watershed with an area of 23.4 km^2. The upper portion of this watershed contains the proposed tailings management facility (TMF) for the Project. The confluence of T-Creek and Harper Creek is at river km 20.3 of Harper Creek (toward the upper end of Harper Creek). The watershed is partially covered in coniferous forest but has undergone extensive logging. The average channel gradient of T-Creek is 7.3% (KP, 2014); however, much of the upper watershed contains a low-gradient hanging valley, which then drops steeply to meet Harper Creek. The watershed elevation ranges from 2275 to 1145 masl, with a median elevation of 1790 masl. The hypsometric curve for the T-Creek watershed is presented on Figure 1.4.

The dominant stream morphology in lower T-Creek is step-pool and cascade (Montgomery and Buffington, 1997). Bed material is primarily coarse materials with the vast majority being classified as boulder and cobbles with some gravels. In contrast, in the upper hanging valley the morphology is pool-riffle and bed material is gravel dominated. The dominant riparian vegetation is overhanging alders and mature trees along the mossy banks. Some large instream woody debris produce log jam stream features as they are filled with bed material. The channel is largely confined by the hillslopes or incised within remnant fan deposits until approximately 100 m upstream of the Harper Creek confluence.

2 – BACKGROUND REVIEW

2.1 LEGISLATION, REGULATIONS AND GUIDELINES

The Project is subject to both provincial and federal EAs under the BC Environmental Assessment Act (2002) and Canadian Environmental Assessment Act 1992 (CEAA; 1992). The EA will undergo a coordinated review in accordance with the 2004 Canada-BC Agreement on Environmental Assessment Cooperation. The requirements for the EA are defined in the AIR for the Project, which was approved by the BC Environmental Assessment Office (EAO) on October 21, 2011. This baseline report has been prepared to support the submission of the Application/EIS.

The surface hydrology baseline study was undertaken to characterize pre-Project streamflow conditions in the baseline study area, primarily to support the fisheries and water quality assessments for the Application/EIS. The legislation, regulations and guidelines pertaining to fisheries and water quality are provided in the respective Baseline reports.

The surface hydrology baseline study was conducted in accordance with two provincial guidelines:

- BC MOE (2009), which provides technical guidance on the collection and processing of streamflow records.
- BC MOE (2012), which provides guidance on baseline hydrology study design for mining projects. This document cites BC MOE (2009) for specific methodology.

3 – METHODOLOGY

3.1 DATA COLLECTION LOCATIONS

Streamflow records have been collected at 13 gauging stations in the baseline study area. Four of these stations are long-term gauging stations operated by the Water Survey of Canada (WSC). The other nine stations were established and operated by Knight Piésold Ltd. (KP) on behalf of HCMC specifically to support the Project. The station locations were selected to represent spatial variability in streamflow throughout the baseline study area, and to characterize streamflow conditions at key sites downstream from proposed Project infrastructure, for the primary purpose of calibrating the watershed model. The gauging stations do not represent every site of interest for fish and water quality studies; those sites are represented by the analysis nodes in the watershed model report. Nor do the gauging stations each have specific individual purposes; rather, they are distributed to collectively represent hydrologic conditions throughout the baseline study area.

The gauging station locations are shown on Figures 1.1 and 1.2, and are described below. The drainage areas at the gauging stations are presented in inset tables on the two figures.

The four WSC gauging stations are located at the following locations:

1. North Thompson River at Birch Island (Station ID: 08LB047): located on the North Thompson River 8 km downstream of the Baker Creek confluence.
2. Harper Creek near the Mouth (Station ID: 08LB076): located on Harper Creek at river km 5.5, measured upstream from the confluence at North Barriere Lake.
3. Barriere River below Sprague Creek (Station ID: 08LB069): located on the Barriere River, immediately upstream of the East Barriere River confluence.
4. Barriere River at the Mouth (Station ID: 08LB020): located on the Barriere River close to the North Thompson River confluence in the community of Barriere.

The nine HCMC gauging stations are located at the following locations:

1. Baker Creek (Station ID: BAKER): located on Baker Creek 0.1 km upstream from the North Thompson River confluence, just upstream the Birch Island – Lost Creek Road crossing.
2. Baker Creek (Station ID: BAKERUS): located on Baker Creek 1.1 km upstream from station BAKER; established to supplement data collection at the latter station.
3. Jones Creek (Station ID: JONESUS): located on Jones Creek 1.5 km upstream from the North Thompson River confluence and 0.9 km upstream from the Birch Island – Lost Creek Road crossing. The station was located upstream of agricultural water withdrawals.
4. P-Creek at Harper Creek (Station ID: OP): located on P-Creek 0.1 km upstream from the Harper Creek confluence and just upstream of the Harper Creek FSR bridge.
5. P-Creek upstream of station OP (Station ID: OP2): located on P-Creek 0.1 km upstream from station OP; established to supplement data collection at the latter station.
6. Harper Creek below P-Creek (Station ID: HARPER2): located on Harper Creek immediately downstream of the P-Creek confluence.
7. Harper Creek upstream of T-Creek (Station ID: HARPERUS): located on Harper Creek immediately upstream of the T-Creek confluence.
8. T-Creek at Harper Creek (Station ID: TSFDS): located on T-Creek 0.1 km upstream from the Harper Creek confluence and just upstream of the Harper Creek FSR bridge.

9. T-Creek at TMF Embankment (Station ID: TSFUS): located on T-Creek 2.9 km upstream from the Harper Creek confluence at the proposed location of the proposed tailings management/storage facility (TMF/TSF) embankment.

3.2 DATA COLLECTION METHODS

3.2.1 WSC Streamflow Gauging Stations

The Water Survey of Canada (WSC) is an independent federal agency that collects streamflow records at a nationwide network of streamflow gauging stations and makes them available to the public online. KP downloaded the available published daily streamflow records for the four WSC stations in the baseline study area from the WSC website (WSC, 2012). Published data were available up to and including 2010 at the Harper Creek station and up to and including 2011 at the other three WSC stations. Provisional data for 2011 to 2013 were provided by WSC (pers. comm.) for the Harper Creek station.

The four WSC gauging stations in the baseline study area are all active and have long-term records greater than 30 years in length. The most recently established station is the one on Harper Creek, which was established in July 1973. In order to avoid biases caused by long-term climate variability, the period of 1974 to 2010 was selected as the standard period for streamflow analyses at all four stations. All four stations have nearly complete records within this period.

3.2.2 HCMC Streamflow Gauging Stations

KP installed six streamflow gauging stations on behalf of HCMC in May and June 2011, and three additional stations at later dates to improve confidence in hydrologic predictions at key locations or to supplement data collection at problematic stations. All the stations are still in operation. Streamflow records collected at these stations up until April 2014 are presented in this report.

Streamflow records were collected at the HCMC stations using methods and procedures outlined in BC MOE (2009), which are in general accordance with the methods and procedures followed by WSC. The streamflow records collected at the WSC and HCMC gauging stations are directly comparable. Any differences in data quality between gauging stations have more to do with site-specific issues than differences in data collection methods. Data collection methods and procedures are described below. Site-specific issues such as physical channel characteristics and equipment performance are discussed in Appendices A through I (one appendix per station).

All data collected at the HCMC gauging stations have been compiled in KP's web-based data management utility, FULCRUM, and are available for review by authorized personnel at any time. These data include date-stamped site photos, field data sheets, flow calculations for both velocity-area and dilution measurements, and stage time series files.

3.2.2.1 Gauging Station Site Selection

Streamflow gauging station sites were selected based on the following criteria:

- Suitable conditions for installing equipment (e.g., accessible at all flow conditions, safe working conditions)
- A stable hydraulic control (i.e. consistent relationship between stage (water level) and discharge (streamflow))

- A hydraulic control that is sensitive to flow changes (i.e. a small flow change produces a measureable stage change)
- A site with minimal turbulence and water surface fluctuations under steady flow conditions
- A site where the stage sensor will remain submerged at low flows, and
- Suitable conditions for accurate instantaneous discharge measurement over a wide range of flow conditions.

The gauging station locations were selected with consideration of the above criteria; however, ideal sites were not found in the baseline study area streams. The gauged streams are typically small and have moderate to steep gradients. Good quality data were collected at most stations, although highly turbulent flow conditions and unstable hydraulic controls have caused data collection challenges at some sites.

3.2.2.2 Gauging Station Installations

Each streamflow gauging station includes instrumentation comprised of a Neon Micrologger datalogger and a KPSI-500 pressure and temperature sensor, which measures and records stream conditions every 15 minutes. The pressure sensors have a range of 0 to 5 psi (pounds per square inch), which is equivalent to a water level (stage) range of 3.514 m.

Each pressure/temperature sensor is housed within a 2 m or 3 m length of aluminum pipe, which protects the sensor and provides some stilling of water level fluctuations. The pipes are attached to bedrock outcrops, large boulders, or angle-iron anchors, which provide stable locations to measure stage. The sensors are surveyed to at least two benchmarks regularly during each field season to ensure that the sensor remains stationary and is functioning correctly, and so that the stage records from successive years can be related to a common elevation datum. Most stations also include a staff gauge or reference mark so that instantaneous stage can be easily measured manually independently of the automated sensor. Where a staff gauge or reference mark could not be installed, water level was surveyed from the benchmarks on most site visits.

The pressure/temperature sensors are installed in the spring, once ice and snow begin to clear and a unique stage-discharge relationship can be applied. They are removed in the autumn once snow and ice begin to accumulate in the channels. Continuous stage records collected during winter conditions are of little value because the presence of ice and snow in the channel changes the relationship between stage and discharge. Examples of station installations are shown on Figures 3.1 and 3.2. Photos of each gauging station are provided in Appendices A through I (one appendix per station).

Figure 3.1 TSFDS Gauging Station looking upstream during low flow conditions ($<0.01\ m^3/s$)

Figure 3.2 JONES Gauging Station looking downstream during low flow conditions ($0.05\ m^3/s$)

The gauging stations were first installed in May and June 2011. The sensors were removed for the winter in November 2011, reinstalled for the open-water season in April 2012, and removed again for the winter in November 2012. The instrumentation was reinstalled in late July 2013. The sensors were winterized with a glycol bladder attached to the transducer in late October and the dataloggers were removed in January 2014.

3.2.2.3 Instantaneous Stage and Discharge Measurement

Each streamflow gauging station was visited approximately monthly in 2011 and 2012 to collect instantaneous discharge measurements. In the months of April through November each year, instantaneous stage measurements were also collected for use in defining stage-discharge relationships. Stage was determined independently of the data logger record either from staff gauge or reference mark observations, or by surveying the water level from the station benchmarks. Stage readings were not collected in the other (winter) months when snow and ice affect the stage-discharge relationships.

Two different techniques were used to collect discharge measurements at the gauging stations: area-velocity and dilution. Discharge measurements were recorded using a current meter (Marsh-McBirney Flo-Mate 2000 or Swoffer 2100, typically) and the area-velocity technique when flow conditions in the channels allowed for safe wading. The dilution technique was employed using Rhodamine WT dye slug injection when flow conditions were too high to allow for safe wading of the channel, or when flow conditions where too turbulent for current meter velocity measurements. Examples of discharge measurement methods are shown on Figures 3.3 and 3.4.

Figure 3.3 Velocity-Area Discharge Measurement at HARPERUS

Figure 3.4 Dye Slug Injection Discharge Measurement at OP

The accuracy of individual area-velocity discharge measurements is typically around +/- 5% under ideal conditions with smooth, streamlined flow in a straight, regular channel with small bed material (Maidment, 1993). Measurements are less accurate in irregular channels with highly turbulent flow and large bed material. The accuracy of dye dilution discharge measurements depends on the characteristics of the mixing reach, but it is typically assumed to be in the +/- 10% to 20% range, based on KP's experience and professional judgement. KP's standard procedure is to collect at least two independent discharge measurements during each site visit. Variables are changed between each measurement; for example, area-velocity measurements are collected using different measurement verticals on the same cross-section, or different cross-section locations are selected if suitable alternatives exist. For dye dilution measurements, the fluorometer is placed in different locations (on opposite sides of the channel or at different downstream locations) between subsequent measurements to confirm complete mixing of the dye tracer. The difference between the two area-velocity or dye dilution measurements helps to quantify the accuracy of the discharge estimate.

3.2.2.4 Stage-Discharge Rating Curve Development

Stage-discharge rating curves were developed for each streamflow gauging station from the instantaneous stage-discharge measurements. Rating curves with the following standard form were fit to the measurement points:

$$Q = C\,(h - A)^{N}$$

Where *Q* is discharge, *C* is a coefficient, *h* is stage, *A* is the stage value at the point of zero flow, and *N* is an exponent. The 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 for the low flow portion of the curve are dependent on the hydraulic characteristics of the control section at the gauging station, which provides a means of checking the validity of the derived equation. Typically, C is in the order of 0.5 to 2.5 times the channel width and *N* is between 1.6 and 3 (Maidment, 1993).

Each rating curve was fit to the measured stage-discharge measurements, with consideration of the physical conditions at each site and with the objective to minimise the difference (or “errors”) between each individual measured discharge value and the corresponding discharge predicted by the rating curve at that water level condition. The error is calculated as rating curve discharge minus measured discharge divided by measured discharge. The curves were developed considering the average of the error values and the standard deviation of the error values (standard error). A positive average error indicates that the rating curve tends to over predict discharge compared to the measured discharges and the standard error describes how much spread there is in the error. A good curve would have an average error of 0% and a standard error of <10%.

It should be noted, however, that many factors affect these statistics; for example, the number of measurements and the spread of the measurements over the range of flows. Further, these statistics are simply a measure of how well the rating curve fits the measured stage-discharge data but may not be indicative of the accuracy of the streamflow record generated from the rating curve. The classic example is where there are only two stage-discharge measurements and the average error and standard error are both 0%. Despite the statistics, such a rating curve likely would not produce accurate discharge values. Conversely, a rating curve that has high average error and standard error statistics may produce very accurate flow records if the variability about the measured stage-discharge data is simply due to uncertainty in the measurements, and the rating curve is representative of the “true” stage-discharge relationship. In summary, care must be taken when interpreting the implication of the average error and standard error on rating curve and hydrograph quality.

3.2.2.5 Stage and Streamflow Records

Stage data recorded at each station were checked against the concurrent manual stage observations collected during site visits (by staff gauge, dipping point or water level survey) to determine the offset required to adjust the stage record to the station datum. At some sites there was a range of differences between the manually measured gauge heights and the simultaneous datalogger readings. Some of the variability was systematic and therefore attributed to movement of the sensor following maintenance or changes in the hydraulic control. Other variability was random and likely due to uncertainty in reading the gauge height or recording water level in very turbulent conditions that occur during moderate to high flows. Uncertainty was typically in the order +/- 1 to 2 cm. The stage records at all stations were adjusted to the station datum, and any periods in which ice or other factors affected the hydraulic control were removed.

The rating curve equation for each station was applied to the final stage record to develop a continuous (15 minute) streamflow record.

3.2.2.6 Winter Streamflow

Instantaneous streamflow measurements were recorded approximately monthly through the winter of 2011/2012 and in February 2014.

3.3 DATA ANALYSIS

Two types of data analysis were undertaken using the streamflow records from the WSC and HCMC gauging stations, as follows:

1. The generation of long-term synthetic series of daily streamflow at the HCMC gauging stations, using seasonal relationships between flows at these gauging stations and flows at the WSC gauging station on Harper Creek.
2. The estimation of streamflows at the WSC and HCMC gauging stations under various extreme conditions, including:
   a. 7-day low flows for return periods ranging from 2 to 200 years;
   b. Instantaneous peak flows for return periods ranging from 2 to 200 years; and

3.3.1 Long-Term Synthetic Flow Series at HCMC Gauging Stations

Long-term synthetic streamflow series were generated for the four HCMC gauging stations that had the most complete records: JONESUS, OP, HARPERUS, and TSFDS. These flow series were generated primarily for use in calibrating the hydrologic watershed model and for fish habitat modelling. They are not intended to specifically replicate the precise chronology of historical streamflows, but rather to represent the magnitude, distribution and variability of daily, monthly and annual flows that would likely be experienced over the project life.

The daily streamflow records from these four gauging stations were compared to the concurrent provisional daily streamflow record from the WSC gauging station on Harper Creek (08LB076). Seasonal correlation relationships were developed between the four HCMC stations and the WSC station using the empirical frequency pairing (EFP) technique (Butt, 2013). The EFP technique compares the frequency distribution of flows at two stations on a seasonal basis and develops scaling relationships between the flows at the two stations, which can then be applied to the long-term record of one station to generate a long-term synthetic flow series for the other station. The EFP technique involves ranking the daily discharge data in the two streamflow records in descending order of magnitude. Each flow value of equal rank in the two datasets has an equal probability of exceedance in its respective dataset since the datasets are of equal length. A comparison of ranked daily flows therefore amounts to a comparison of flow frequency distributions. The EFP technique assumes that the flow frequency relationships developed from the sample (period of concurrent record) is generally representative of the relationships that would exist between concurrent long-term records.

The EFP approach helps address errors common to the chronological pairing approach that result from differences in both the timing and magnitude of runoff events in the flow records of two creeks being correlated. The objective of the EFP technique is not necessarily to reproduce exact historical flow sequences, but rather to generate datasets that provide a representation of the expected future long-term mean annual discharge and the associated year to year, month to month, and day to day variability of flows.

For the Project EFP analysis, two seasons were selected to represent the two main hydrologic mechanisms in the baseline study area: spring/summer (April through July) to represent the snowmelt and rain-on-snow season, and autumn (August through October) to represent the post-snowmelt season that is dominated by groundwater discharge and periodic rainstorm events. EFP analysis was not completed for winter flows because of data limitations, and instead a more simplified scaling approach was adopted.

The seasonal EFP relationships for each of the four HCMC gauging stations were applied to the long-term record at the WSC station on Harper Creek to generate long-term synthetic series of daily streamflow at the HCMC stations for the months of April to October.

During November to March, scaling factors were calculated from the ratios of instantaneous discharge measurements at the HCMC stations to the Harper Creek (08LB076) flows on concurrent dates. A scaling factor for each calendar day was then determined by interpolating between the observed conditions. In this way, the shape of the Harper Creek (08LB076) record was transposed to the HCMC stations, but the flow magnitude was scaled to match the conditions observed.

3.3.2 Wet and Dry Monthly Flow Conditions

The variability of monthly flow conditions is typically specified in terms of return period (e.g. 1 in 20 year event) wet and dry monthly flows. Wet and dry monthly flow conditions are not presented in this report and will be calculated from the long-term monthly flow series generated with the baseline watershed model (KP, 2014a). Values were not computed using the synthetic flow series presented in this report to minimize the potential for confusion that could arise from having two sets of monthly flow estimates.

3.3.3 Low Flow Analysis

Extreme low flows are typically represented by return period values for 7-day low flows. Environment Canada’s Low-Flow Frequency Analysis (LFA) software package was used to estimate 7-day low flow values for various return periods ranging from 2 to 200 years at the four WSC gauging stations in the baseline study area, as well as selected WSC gauging stations in the surrounding region that have similar watershed size and physiography to the smaller streams close to the proposed mine site. The additional selected WSC stations are Lemieux Creek (08LB078), Mann Creek (08LB050), and Fisher Creek (08LD009). The locations of these stations are shown on Figure 1.3. The LFA software uses a Gumbel distribution to model return period low flows. The unit-area flows for the WSC stations were used as a guide to estimate return period low flows at the HCMC gauging stations.

The lowest flows recorded at the WSC gauging station on Harper Creek in each year during the study period were reviewed and found to be approximately equivalent to a 2-year low flow. Low flows at the HCMC gauging stations were assumed to have the same return period as the Harper Creek WSC station. The lowest instantaneous flow measurements collected at the HCMC gauging stations were compared against these return periods estimates generated in the above analysis.

The low flow methodology is more thoroughly explained in the low flow results section (Section 4.4), where the incremental steps involving regional WSC and local HCMC data are laid out.

3.3.3 Peak Flow Analysis

Peak flows are typically represented by return period values for the maximum instantaneous discharge. Environment Canada’s Consolidated Frequency Analysis (CFA) software package was used to compute peak flow statistics for the WSC gauging station on Harper Creek, as well as selected WSC gauging stations in the surrounding region that have similar watershed size and physiography to the smaller streams close to the proposed mine site. The other selected WSC stations are Lemieux Creek (08LB078), Mann Creek (08LB050), and Fisher Creek (08LD009). The locations of these stations are shown on Figure 1.3. Peak flow analysis was not undertaken for the other three WSC gauging stations on larger rivers in the baseline study area (Barriere River and North Thompson River stations). In the CFA analysis, a Generalized Extreme Values (GEV) frequency distribution was applied.

The peak flow statistics that were generated are the mean annual peak flow, the linear coefficient of variation (L-Cv), and the linear coefficient of skewness (L-Cs). Corresponding statistics were estimated for the HCMC gauging stations using drainage area scaling relationships from the WSC station statistics, as described below. Mean annual peak flows were assumed to scale according to a drainage area scaling exponent of 0.75, which was selected based on the hydrometeorological characteristics of the project area and guidance found in studies published by the BC Ministry of Environment, Lands and Parks (Obedkoff 1999) and the University of British Columbia (Wang, 2000; Cathcart, 2001). L-Cv and L-Cs values were selected based on regional values and log-linear scaling relations (per Cathcart, 2001). From these statistics, instantaneous peak flows for return periods ranging from 2 to 200 years were estimated for each of the HCMC gauging stations assuming the annual peak flows fit a Generalized Extreme Value (GEV) distribution. The GEV distribution type is commonly applied to peak flows and has been shown in studies at UBC (Cathcart, 2001) to consistently provide a reasonable, yet conservative fit to measured data.

Peak flows at locations other than the WSC or HCMC gauging stations can also be estimated using the drainage area scaling methods described above. The scaling exponent of 0.75 can be used to translate the instantaneous peak flow for any return period from one of the gauging stations to an ungauged stream location using the drainage area ratio, according the following equation:

$$Q_1 = Q_2 * (A_1/A_2)^{0.75}$$

where:

- A_1 is the drainage area of the location of interest.
- Q_1 is the desired return period peak flow at the location of interest.
- A_2 is the drainage area of the closest gauging station.
- Q_2 is the corresponding return period peak flow at the closest station.

Peak flow analysis is based on long-term streamflow records collected in the past. Peak flow magnitude-frequency relationships are potentially subject to change in the future as the climate changes. A 15% uplift factor was applied to all peak flow values generated in this report to account for possible increases in peak flow intensity under a changing future climate. This uplift value it is consistent with general practices and provincial engineering guidelines (APEGBC, 2012).

3.4 LIMITATIONS AND ASSUMPTIONS

KP installed and operated nine streamflow gauging stations on behalf of HCMC, following methods and procedures outlined in BC MOE (2009), which are in general accordance with the methods and procedures followed by WSC. The streamflow records collected at the WSC and HCMC gauging stations are directly comparable. Any differences in data quality between gauging stations have more to do with site-specific issues than differences in data collection methods. Challenging conditions were encountered at some of the HCMC gauging stations, which affected the quality of the streamflow records collected there. Details are provided in the appendices.

Long-term streamflow estimates were computed for various locations in the project area on the basis of historical flow records that may not be fully representative of future conditions because of climatic variability and limitations due to sample size. These uncertainties and limitations are common to almost all hydrologic analyses.

4 – RESULTS AND DISCUSSION

4.1 MEASURED STREAMFLOW RECORDS AT WSC GAUGING STATIONS

Mean monthly and annual discharge and unit runoff at the four WSC gauging stations in the baseline study area are presented in Table 4.1. It was noted that unit runoff decreases with increasing drainage area at the three gauging stations in the Barriere River watershed: Harper Creek, Barriere River below Sprague Creek, and Barriere River at the mouth. This pattern is attributed to the increasing fraction of low elevation terrain that comprises the basins as one moves downstream in the Barriere River watershed, with corresponding lower precipitation and higher evapotranspiration. The higher unit runoff in Harper Creek, in particular, is attributed to the relatively high runoff that comes off the very high, steep and exposed slopes of Dunn Peak, which approaches 2500 masl in elevation.

The unit runoff of the North Thompson River at Birch Island station is higher than that of any of the stations in the Barriere River watershed, including the Harper Creek station, because the headwaters of the North Thompson River drain the Columbia Mountains and this high elevation, glaciated terrain yields high unit runoff. The glacial signature in the North Thompson River is particularly evident in the high runoff in July to September, when the unit runoff is between 210% and 380% of the Harper Creek unit runoff.

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TABLE 4.1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

MEAN MONTHLY FLOW AND UNIT RUNOFF AT WSC STATIONS WITHIN THE BASELINE STUDY AREA

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WSC Station				Mean Monthly Discharge and Unit Runoff												Mean Annual Discharge and Unit Runoff
Name	ID	Drainage Area (km^2)	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Harper Creek near the Mouth	08LB076	166	m^3/s	0.8	0.7	0.9	3.2	13.1	14.8	6.0	2.1	1.7	1.9	1.6	0.9	4.0
			$l/s/km^2$	4.7	4.4	5.2	19.5	78.9	89.2	36.1	12.4	10.2	11.2	9.7	5.7	24.0
Barriere River below Sprague Creek	08LB069	624	m^3/s	2.5	2.3	2.9	10.5	38.1	42.0	16.2	5.5	4.2	4.6	4.8	3.1	11.4
			$l/s/km^2$	4.0	3.7	4.6	16.8	61.0	67.3	25.9	8.8	6.8	7.4	7.7	5.0	18.3
Barriere River at the Mouth	08LB020	1140	m^3/s	3.6	3.5	4.5	15.5	48.4	50.4	19.7	6.9	5.3	5.6	6.2	4.2	14.5
			$l/s/km^2$	3.2	3.0	4.0	13.6	42.5	44.2	17.3	6.1	4.6	5.0	5.4	3.7	12.7
North Thompson River at Birch Island	08LB047	4490	m^3/s	30.1	28.2	33.9	97.2	296.8	423.0	340.8	214.7	131.4	91.9	65.3	34.8	149.6
			$l/s/km^2$	6.7	6.3	7.5	21.6	66.1	94.2	75.9	47.8	29.3	20.5	14.5	7.7	33.3

M:\1\01\00458\15\A\Data\Task 410 Hydrology Baseline\[Summary of WSC and HCMC Stations.xlsx]Table 4.5

NOTE:

1. MEAN MONTHLY VALUES CALCULATED FROM WSC RECORDS FOR THE PERIOD 1974-2010, EXCLUDING 2001 AND 2002 DUE TO MISSING DATA AT THE HARPER CREEK WSC STATION.

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REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

4.2 MEASURED STREAMFLOW RECORDS AT HCMC GAUGING STATIONS

The three key data collection results for the HCMC gauging stations are as follows:

1. Stage-discharge measurement table
2. Stage-discharge rating curve figure
3. Hydrograph figure of measured daily discharge record, with instantaneous discharge measurements indicated

Instantaneous stage-discharge measurements were collected at all nine gauging stations. However, at some stations these measurements were not sufficient to define stage-discharge rating curves, due to an insufficient number of measurements (stations installed in 2013) or data logging issues. Therefore, streamflow records and hydrographs could not be generated at these stations. Rating curves and streamflow records were successfully generated at the following (6) stations:

- BAKER
- JONESUS
- OP
- HARPERUS
- TSFDS
- TSFUS

At these six stations between 12 and 16 stage-discharge measurements were available for rating curve development. The average error at these stations was less than 6% at all stations except BAKER, where substantial turbulence was experienced during high flow conditions, making stage and discharge measurements difficult. The standard error ranged from 12% to 30% at most stations, except at BAKER where the standard error was 50%. The moderately high standard errors at TSFDS (30%) and TSFUS (24%) are attributed to one or two outlying measurements.

Rating curves and streamflow records were not successfully generated at the following (3) stations:

- BAKERUS
- OP2
- HARPER2

Stations OP2 and HARPER2 were only installed in late July 2013, so an insufficient number of stage-discharge measurements were collected at those two stations to support rating curve development. BAKERUS was installed in 2012 and a good rating curve has been developed for the station; however, data logger malfunction meant that the period of water level time series data recorded at this station is short and intermittent, so a flow series was not developed.

The streamflow records collected at the HCMC gauging stations are summarized in Table 4.2. An example stage-discharge table, stage-discharge rating curve figure, and hydrograph figure are presented for station HARPERUS in Table 4.3, on Figure 4.1, and on Figure 4.2, respectively. Corresponding tables and figures are provided for all nine of the HCMC gauging stations (where applicable, as discussed above) in Appendices A through I (one appendix per station).

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TABLE 4.2

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STREAMFLOW RECORD COLLECTION AT HCMC GAUGING STATIONS

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Stream	Station Name	Station ID	Drainage Area (km^2)	Median Watershed Elevation (masl)	Period of Streamflow Record	Rating Curve No. Points	Rating Curve Average Error	Rating Curve Standard Error	Long-Term Synthetic Flow Series? (Yes/No)	Comments
Baker Creek	Baker Creek	BAKER	14.3	1362	2011: May 16 - Nov 23 (80% complete) 2012: Apr 12 - May 29 (100% complete) 2013: No record	14	17%	50%	No	Site experiences substantial turbulence during high flows making stage measurement challenging and prone to error. Station discontinued as gauge was superseded by BAKERUS
	Baker Creek upstream of Station BAKER	BAKERUS	12.4	1393	2011: No record 2012: May 1 - Nov 6 (25% complete) 2013: Jul 29 - Dec 31 (90% complete)	-	-	-	No	Station experienced substantial issues with the logger's battery in 2012 resulting in many data gaps. A rating curve has not been completed as there are too few stage-discharge measurements for curve development. A synthetic flow series was not developed as a measured record was not developed.
Jones Creek	Jones Creek	JONESUS	17.6	1384	2011: Logger not installed 2012: Apr 11 - Nov 6 (75% complete) 2013: Jul 31 - Dec 31 (100% complete)	13	2%	12%	Yes	No notable issues encountered at this station.
P-Creek	P-Creek at Harper Creek	OP	7.7	1699	2011: Jun 9 - Nov 22 (55% complete) 2012: Apr 12 - Nov 7 (95% complete) 2013: Jul 30 - Dec 3 (30% complete)	13	4%	13%	Yes	Issues with the sensor and logger instrumentation were encountered at this site. Additionally, data gaps exist where the sensor was stranded due to falling water levels in between site visits.
	P-Creek upstream of Station OP	OP2	7.5	1700	2011: No record 2012: No record 2013: Jul 30 - Dec 31 (15% complete)	-	-	-	No	Battery died shortly after installation and no site visits were performed between installation and winterization resulting in very little stage data for this station. A rating curve has not been completed as there are too few stage-discharge measurements for curve development. A synthetic flow series was not developed as a measured record was not developed.
Harper Creek	Harper Creek below P-Creek	HARPER2	16.6	1564	2011: No record 2012: No record 2013: Jul 30 - Dec 31 (100% complete)	-	-	-	No	A rating curve has not been completed as there are too few stage-discharge measurements for curve development. A synthetic flow series was not developed as a measured record was not developed.
	Harper Creek upstream of T-Creek	HARPERUS	47.1	1651	2011: Jun 3 - Nov 22 (100% complete) 2012: Apr 12 - Nov 7 (100% complete) 2013: Jul 30 - Dec 31 (100% complete)	16	6%	17%	Yes	No notable issues encountered at this station.
T-Creek	T-Creek near Harper Creek	TSFDS	23.4	1788	2011: May 21 - Nov 22 (100% complete) 2012: Apr 13 - Nov 7 (100% complete) 2013: Jul 30 - Dec 31 (100% complete)	14	2%	30%	Yes	No notable issues encountered at this station.
	T-Creek at TMF Embankment	TSFUS	15.0	1801	2011: May 10 - Dec 31 (75% complete) 2012: May 21 - Nov 8 (35% complete) 2013: No record	12	-1%	24%	No	Sensor malfunction in mid-August of 2012 and collected erroneous data for the remainder of the year. A synthetic flow series was not developed due to poor rating curve quality and a relativiely short measured streamflow record.

C:\Users\aakkerman\AppData\Local\Microsoft\Windows\Temporary Internet Files\Content.MSO\[Copy of Station Summary.xlsx]VA Table

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
A	20JUN'14	ISSUED WITH REPORT VA101-00458/15-2	ACA	CJN	KJB

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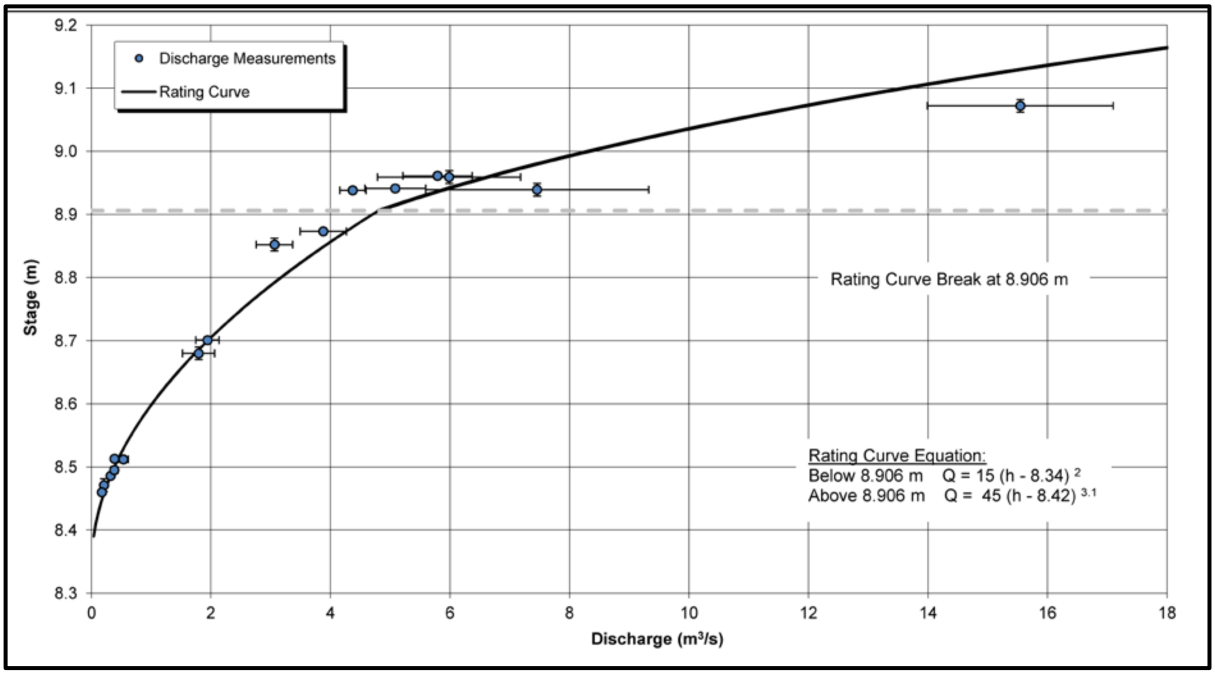
Table 4.3 Stage-Discharge Summary Table, HARPERUS

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
03/06/2011	12:56	RD	8.96	5.99	6.62	11%
13/06/2011	15:04	RD	8.94	7.46	5.89	-21%
20/07/2011	10:25	CM	8.68	1.80	1.73	-3%
18/08/2011	14:05	CM	8.51	0.54	0.44	-17%
14/09/2011	12:11	CM	8.47	0.21	0.26	22%
22/11/2011	15:35	CM	-	0.13	-	-
07/02/2012	13:03	CM	-	0.12	-	-
29/02/2012	12:05	CM	-	0.09	-	-
01/04/2012	12:24	CM	-	0.11	-	-
12/04/2012	16:06	CM	8.46	0.18	0.22	22%
03/05/2012	12:59	CM	8.70	1.94	1.95	1%
16/05/2012	9:16	CM	8.94	4.37	5.86	34%
17/05/2012	13:15	CM	8.87	3.88	4.26	10%
30/05/2012	7:07	CM	8.94	5.08	5.96	17%
06/06/2012	13:07	RD	9.07	15.55	11.95	-23%
19/06/2012	12:44	CM	8.96	5.79	6.70	16%
04/07/2012	13:40	CM	8.85	3.07	3.93	28%
07/11/2012	12:50	CM	8.50	0.39	0.36	-7%
22/08/2012	9:26	CM	8.49	0.32	0.32	0%
21/10/2013	13:10	CM	8.51	0.39	0.45	15%
25/02/2014	12:13	CM	-	0.10	-	-
Average Error (%)						6%
Standard Error (%)						17%

NOTES:

1. METHOD ABBREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE SLUG INJECTION.
2. NO STAGE HEIGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.
3. RATING CURVE ERROR IS THE DIFFERENCE BETWEEN THE RATING CURVE DISCHARGE AND THE MEASURED DISCHARGE, ASSUMING THE MEASURED DISCHARGE IS THE "TRUE" DISCHARGE.



NOTES:

1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011 AND 2012 DATA COLLECTION PROGRAMS.

Figure 4.1 Rating Curve, HARPERUS

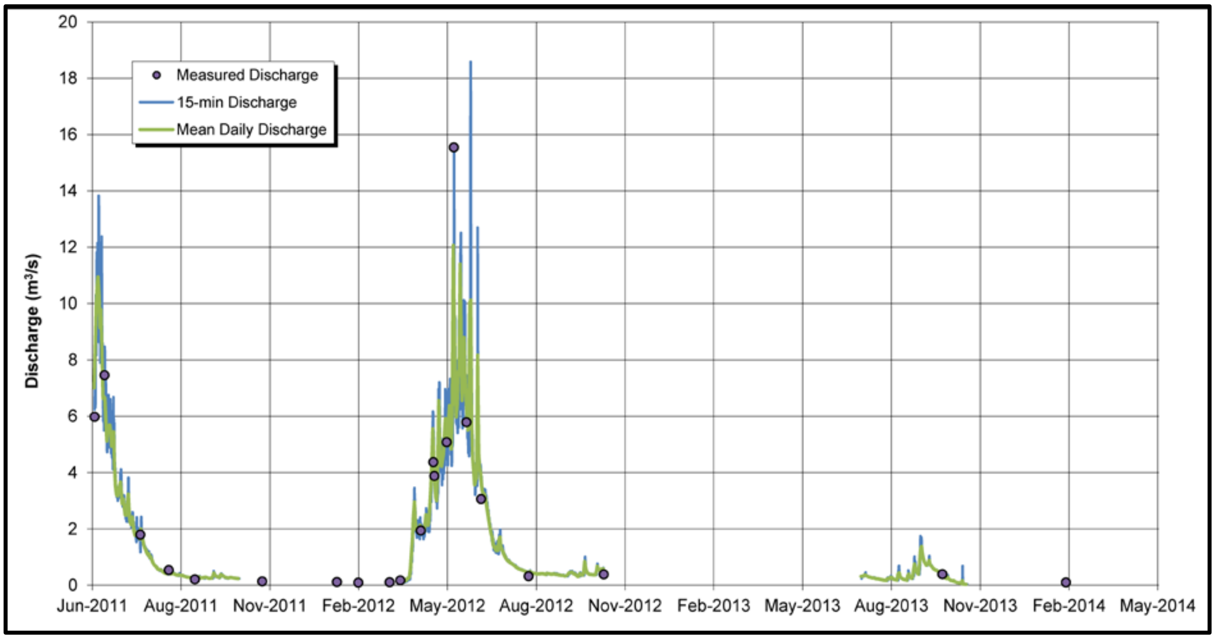


Figure 4.2 Measured streamflow hydrograph, HARPERUS

4.3 LONG-TERM SYNTHETIC STREAMFLOW SERIES AT HCMC GAUGING STATIONS

EFP analyses were undertaken for four HCMC gauging stations, and the key data analysis results are presented in terms of:

1. Seasonal EFP relationship figures (two per station)
2. Hydrograph figure of measured and synthetic daily discharge to illustrate quality of calibration
3. Hydrograph figure of mean monthly discharge for the long-term synthetic flow series
4. Table of monthly and annual flows for the complete long-term synthetic flow series, with summary of mean, maximum, and minimum monthly and annual flows
5. Flow duration figure for the long-term synthetic flow series

Examples of a seasonal EFP relationship figure, a measured and synthetic hydrograph figure, a mean monthly hydrograph figure, a monthly flow table, and a flow duration curve are presented for station HARPERUS on Table 4.4, Figure 4.3, Figure 4.4, Figure 4.5, and Figure 4.6, respectively. Corresponding figures and tables are provided for HCMC stations JONESUS, OP, and TSFDS in Appendices C, D, and H, respectively.

Lines of equal unit runoff are presented on each seasonal EFP plot for reference. In the spring/summer season, HCMC stations HARPERUS and OP have similar unit runoff to the WSC station on Harper Creek, while stations TSFDS and JONESUS have higher and lower unit runoff, respectively. Jones Creek is a lower elevation watershed than Harper Creek and the other HCMC stations, so lower unit runoff in spring/summer is expected. Due to their positions higher in the watershed, stations OP, TSFDS and HARPERUS might all be expected to have higher unit runoff than the WSC station during the spring/summer period. However, upon reviewing the details of the watersheds, it is apparent that the steep westerly slopes of the basin that drain to the WSC station contribute proportionately more runoff than the easterly slopes that feed the HCMC stations. All four HCMC stations have lower unit runoff than the WSC station in the autumn following the dry season, which is consistent with there being proportionally greater groundwater storage capacity in the relatively flat lower regions of the WSC watershed.

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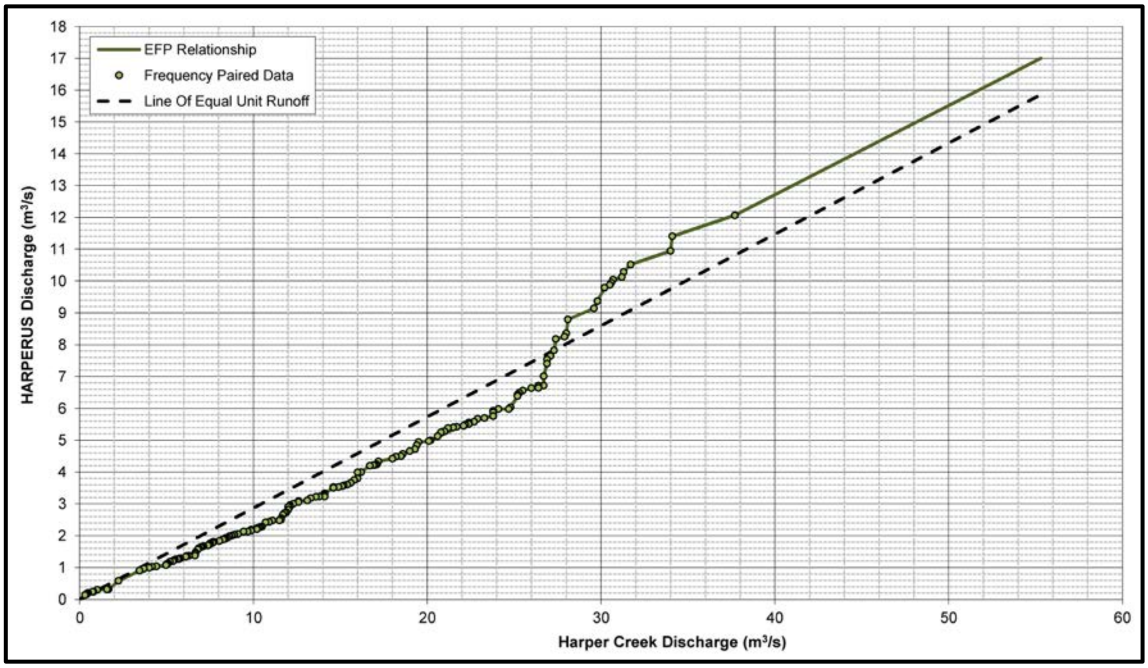
Table 4.4 Monthly Flow Summary, HARPERUS

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	-	-	-	-	-	-	0.93	0.37	0.30	0.43	0.15	0.05	0.36
1974	0.21	0.20	0.20	0.71	2.37	7.61	3.15	0.68	0.39	0.26	0.04	0.01	1.32
1975	0.20	0.18	0.19	0.29	2.14	6.05	2.01	0.54	0.40	0.62	1.01	0.32	1.16
1976	0.29	0.24	0.22	0.48	3.70	3.94	2.77	1.86	0.77	0.45	0.22	0.06	1.25
1977	0.22	0.22	0.24	0.80	1.81	1.92	0.85	0.44	0.58	0.43	0.07	0.05	0.64
1978	0.25	0.21	0.27	0.97	4.57	4.27	1.14	0.48	0.90	0.49	0.23	0.06	1.16
1979	0.22	0.20	0.22	0.40	2.20	2.30	0.70	0.31	0.34	0.36	0.06	0.04	0.61
1980	0.19	0.22	0.21	1.12	3.34	1.52	0.98	0.49	0.55	0.46	0.81	0.23	0.85
1981	0.31	0.30	0.32	0.57	4.03	2.70	1.49	0.46	0.46	1.00	1.35	0.36	1.12
1982	0.26	0.25	0.24	0.34	2.95	6.29	2.56	0.79	0.69	0.80	0.63	0.07	1.32
1983	0.30	0.31	0.42	1.00	4.50	4.06	1.96	0.49	0.50	0.47	1.22	0.13	1.28
1984	0.28	0.27	0.28	0.65	1.71	7.30	3.46	0.57	0.49	0.46	0.10	0.04	1.30
1985	0.21	0.20	0.21	0.62	3.68	3.73	0.98	0.36	0.42	0.46	0.15	0.05	0.93
1986	0.22	0.23	0.25	0.62	3.19	3.72	1.00	0.37	0.33	0.42	0.08	0.05	0.88
1987	0.20	0.20	0.30	1.01	3.78	1.81	0.48	0.35	0.22	0.23	0.04	0.03	0.72
1988	0.17	0.19	0.21	1.15	3.61	2.95	1.29	0.42	0.41	0.52	0.55	0.06	0.96
1989	0.23	0.21	0.22	0.90	3.16	3.34	0.80	0.71	0.48	0.45	0.95	0.25	0.98
1990	0.30	0.25	0.24	1.08	2.66	4.42	1.51	0.40	0.30	0.33	0.46	0.06	1.00
1991	0.22	0.27	0.26	0.84	2.90	3.01	1.34	0.54	0.48	0.27	0.05	0.04	0.85
1992	0.22	0.24	0.50	1.48	3.34	2.20	0.73	0.35	0.37	0.43	0.29	0.06	0.85
1993	0.20	0.19	0.20	0.60	4.08	1.70	0.79	0.51	0.38	0.29	0.05	0.04	0.76
1994	0.22	0.20	0.25	1.58	3.53	2.65	1.06	0.38	0.30	0.26	0.05	0.03	0.88
1995	0.21	0.22	0.23	0.52	3.36	3.08	0.81	0.71	0.39	0.52	0.60	0.22	0.91
1996	0.25	0.24	0.29	1.04	2.36	5.43	2.18	0.54	0.53	0.45	0.79	0.18	1.19
1997	0.25	0.22	0.23	0.55	4.46	4.46	2.03	0.59	0.66	0.92	0.88	0.14	1.29
1998	0.27	0.28	0.31	0.85	4.20	1.61	0.57	0.27	0.22	0.34	0.06	0.06	0.76
1999	0.23	0.23	0.25	0.82	3.02	7.65	4.51	0.98	0.45	0.40	0.98	0.31	1.66
2000	0.29	0.24	0.23	0.72	2.32	4.53	1.82	0.49	0.41	0.41	0.16	0.02	0.97
2001	0.21	0.18	0.21	0.37	2.23	2.74	1.59	0.52	0.32	0.30	0.06	-	0.86
2002	-	-	0.22	0.58	3.03	6.10	1.55	0.41	0.34	0.30	0.06	0.05	1.35
2003	0.22	0.19	0.21	0.72	2.72	3.50	0.59	0.22	0.19	0.51	0.14	0.03	0.77
2004	0.17	0.16	0.20	1.05	2.83	2.27	0.69	0.32	0.63	0.41	0.42	0.22	0.78
2005	0.56	0.60	0.44	1.09	4.28	2.54	1.15	0.40	0.38	0.88	0.69	0.15	1.10
2006	0.35	0.28	0.28	0.72	4.69	2.68	0.52	0.30	0.27	0.24	0.07	0.01	0.87
2007	0.18	0.16	0.19	0.62	2.84	4.34	0.83	0.33	0.31	0.62	0.51	0.13	0.92
2008	0.25	0.26	0.26	0.30	5.04	4.05	1.23	0.41	0.33	0.43	0.68	0.06	1.11
2009	0.23	0.22	0.21	0.34	2.34	3.40	0.79	0.29	0.25	0.29	0.06	0.04	0.71
2010	0.23	0.24	0.27	0.65	2.31	3.72	1.07	0.35	0.45	0.40	0.09	0.06	0.82
2011	0.21	0.19	0.14	0.16	2.56	6.76	2.30	0.54	0.28	0.35	0.05	0.03	1.13
2012	0.12	0.09	0.06	0.62	3.13	6.67	2.14	0.42	0.23	0.29	0.26	0.03	1.17
2013	0.16	0.21	0.23	0.99	4.83	3.89	1.00	0.36	0.53	0.63	0.17	0.03	1.09
Average	**0.24**	**0.23**	**0.25**	**0.75**	**3.24**	**3.92**	**1.45**	**0.50**	**0.42**	**0.45**	**0.37**	**0.10**	**0.99**
Maximum	**0.56**	**0.60**	**0.50**	**1.58**	**5.04**	**7.65**	**4.51**	**1.86**	**0.90**	**1.00**	**1.35**	**0.36**	**1.66**
Minimum	**0.12**	**0.09**	**0.06**	**0.16**	**1.71**	**1.52**	**0.48**	**0.22**	**0.19**	**0.23**	**0.04**	**0.01**	**0.36**

NOTES:

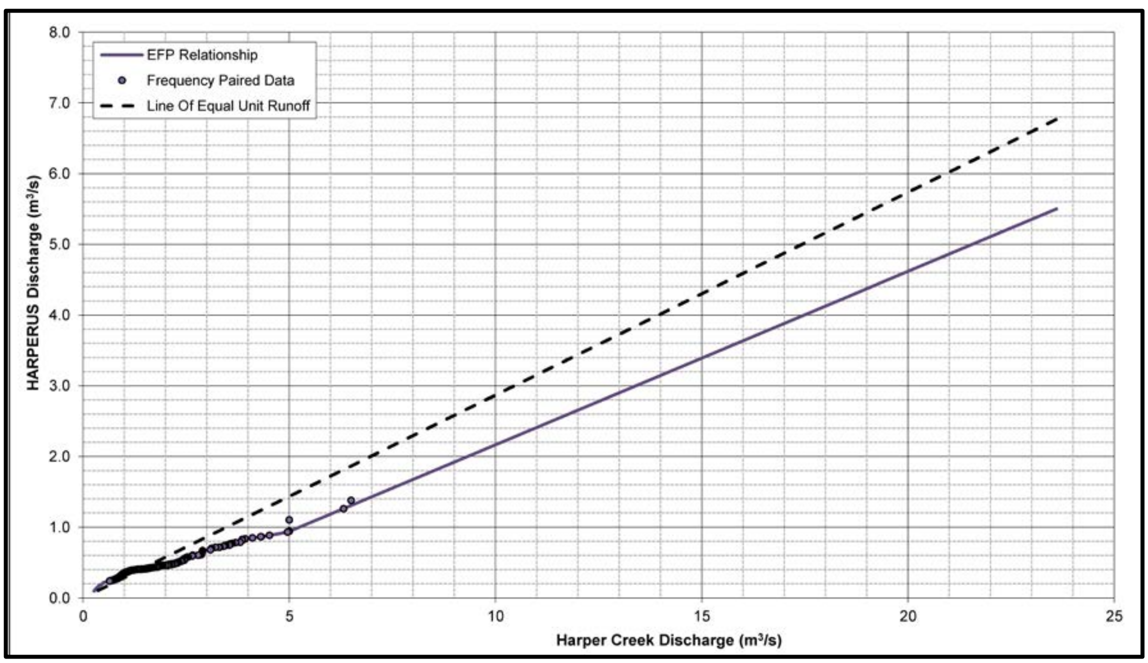
1. MEASURED DAILY FLOWS WERE CORRELATED TO DAILY FLOWS AT WATER SURVEY OF CANADA HYDROMETRIC STATION HARPER CREEK AT THE MOUTH (08LB076) TO GENERATE THE LONG-TERM SYNTHETIC SERIES.



NOTE:

1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST SPRING/SUMMER DISCHARGE IN THE WSC'S HARPER CREEK SERIES

Figure 4.3 Spring/summer EFP relationship, HARPERUS



NOTES:

1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST AUTUMN DISCHARGE IN THE WSC'S HARPER CREEK SERIES

Figure 4.4 Autumn EFP relationship, HARPERUS

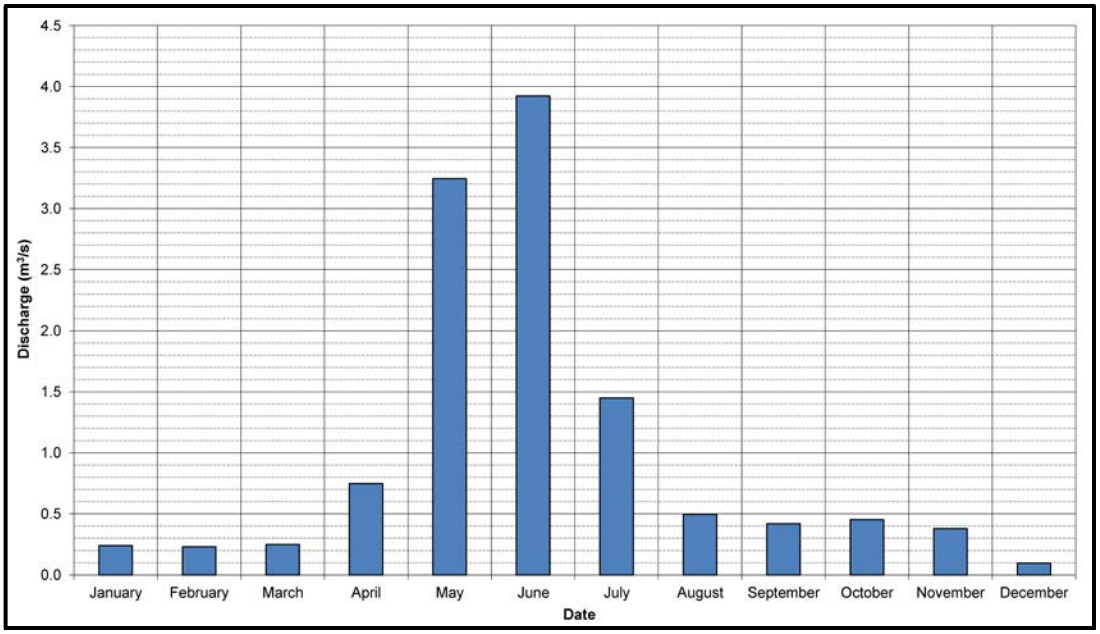


Figure 4.5 Mean Monthly Hydrograph, HARPERUS

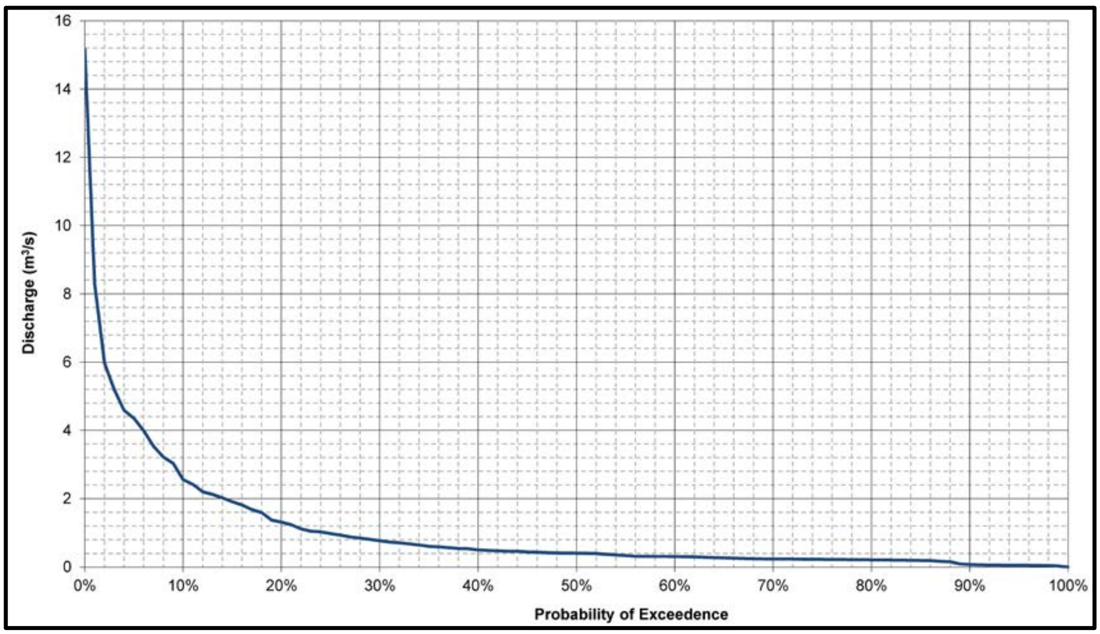


Figure 4.6 Flow Duration Curve, HARPERUS

The mean monthly and mean annual flows, and the corresponding unit runoff values, for the four HCMC gauging stations at which long-term synthetic flow series were generated, are summarized in Table 4.5. Mean annual unit runoff ranges from 16 l/s/km^2 at JONESUS to 21 l/s/km^2 at HARPERUS and TSFDS. These values are lower than the unit runoff value at the WSC gauging station on Harper Creek (24 l/s/km^2), but similar to the unit runoff value at the WSC station on the Barriere River below Sprague Creek (18 l/s/km^2).

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TABLE 4.5

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

LONG-TERM MEAN MONTHLY FLOW AND UNIT RUNOFF AT HCMC STATIONS

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Station				Mean Monthly Discharge and Unit Runoff												Mean Annual Discharge and Unit Runoff
Name	ID	Drainage Area (km^2)	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Jones Creek	JONESUS	17.6	m^3/s	0.03	0.10	0.20	0.34	0.86	1.00	0.49	0.11	0.09	0.10	0.05	0.03	0.28
			$l/s/km^2$	1.6	5.7	11.5	19.2	49.1	57.1	28.0	6.2	4.9	5.5	3.1	1.8	16.1
P-Creek at Harper Creek	OP	7.7	m^3/s	0.01	0.02	0.03	0.09	0.54	0.67	0.19	0.02	0.02	0.02	0.02	0.01	0.14
			$l/s/km^2$	1.8	2.5	4.1	11.6	70.0	86.6	25.0	3.0	2.3	2.6	2.0	1.6	17.6
Harper Creek upstream of T-Creek	HARPERUS	47.0	m^3/s	0.24	0.23	0.25	0.75	3.24	3.92	1.45	0.50	0.42	0.45	0.37	0.10	0.99
			$l/s/km^2$	5.1	4.9	5.3	15.9	69.0	83.5	30.8	10.5	8.9	9.6	7.9	2.1	21.1
T-Creek at Harper Creek	TSFDS	23.4	m^3/s	0.07	0.08	0.12	0.30	1.88	2.31	0.72	0.12	0.08	0.10	0.03	0.04	0.48
			$l/s/km^2$	2.9	3.5	5.0	12.7	80.5	98.7	30.8	5.1	3.4	4.2	1.3	1.8	20.7

M:\1\01\00458\15\A\Data\Task 410 Hydrology Baseline\[Summary of WSC and HCMC Stations.xlsx]Table 4.5

NOTE:

1. MEAN MONTHLY VALUES CALCULATED FROM LONG-TERM SYNTHETIC FLOW SERIES FOR THE PERIOD 1973-2013.

0	20JUN'14	ISSUED WITH REPORT VA101-458/15-2	AA	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

4.4 LOW FLOWS

Minimum 7-day low flows typically occur during late summer or late winter at the regional WSC stations near the Project. For this analysis, low flows were analysed on an annual basis without consideration of season. A summary of return period 7-day low flows and unit-area low flows for Harper Creek (08LB076), Lemieux Creek (08LB078), Mann Creek (08LB050), and Fisher Creek (08LD009) is presented in Table 4.6. The values express the considerable variability in unit-area low flows within the region. The estimated 2-year, 7-day, unit-area low flow in Harper Creek is three to four times greater than corresponding values for the other three stations. Even the 200-year, 7-day, unit-area low flow for Harper Creek (a very rare low flow condition at that station) is approximately double the 2-year values for the other three stations (relatively common low flow conditions at those stations). The unit-area low flows are not well correlated to watershed size. Instead, the low flow regimes are governed by differences in climate and watershed hydrogeological conditions, which determine the storage potential and the amount of water available for groundwater storage and discharge.

Instantaneous discharge measurements collected at the HCMC gauging stations during low flow conditions are summarized in Table 4.7. The values are grouped according to date, with each grouping representing values that were collected during a particular field trip, and which therefore are considered comparable. Included in the table are the concurrent values for the WSC station on Harper Creek (08LB076). The lowest unit flow measurement for each station is highlighted with dark shading. The lowest unit-area low flow value for station 08LB076 is 3.4 l/s/km^2, which occurred in February 2012, which is slightly greater than the estimated 2-year, 7-day, unit-area low flow value for that station, which is 2.9 l/s/km^2, as indicated in Table 4.6. Since the 2 year value has approximately the same probability of occurrence as the mean value, and since the lowest values measured at each station are generally consistent with the February 2012 values, it is reasonable to conclude that the lowest measured flow at each of the HCMC stations is approximately representative of expected mean annual 7-day low flow conditions.

Table 4.6 Regional Unit 7-Day Low Flows

Station	DA (km^2)	Return Period Unit Flows (l/s/km^2)						
		2	5	10	20	50	100	200
Harper Creek	166	2.90	2.30	2.05	1.88	1.73	1.66	1.61
Lemieux Creek	443	0.62	0.26	0.14	0.08	-	-	-
Mann Creek	295	0.86	0.40	0.20	0.04	-	-	-
Fisher Creek	14.7	0.64	0.24	0.13	0.07	-	-	-

NOTES:
1. THE ABOVE VALUES WERE CALCULATED USING ENVIRONMENT CANADAS LFA SOFTWARE.
2. "-" IN THE ABOVE TABLE DENOTES ZERO FLOW IN THE CREEK.

The lowest unit-area low flow value for each HCMC gauging station was plotted against drainage area on Figure 4.7. It is apparent from this plot that unit-area low flows are somewhat correlated to drainage area, although localized drainage conditions confound the pattern, particularly for watersheds with areas less than approximately 25 km2. For such basins, however, it can be seen from the figure that mean annual 7-day low flows approach zero. It should be noted that these flows are getting to be within the precision of gauging and flow measurements, and this may contribute to the scatter in the low flow observations and accuracy of low flow predictions.

The information presented in Table 4.7 and on Figure 4.7 was used to make low flow estimates for the HCMC gauging stations. The estimated return period 7-day low flows and unit-area low flows for each of the HCMC stations are provided in Table 4.8, and the rationale for the estimates is provided below.

- BAKER, BAKERUS, and TSFUS: the estimated 2-year, 7-day, unit-area low flow for these stations is 0.0 l/s/km2. By extension, the low flow values for all longer return periods are also zero.
- JONESUS, TSFDS, OP, and OP2: the estimated 2-year, 7-day, unit-area low flow for these stations is 0.5 l/s/km2. The estimated low flows for return periods of 5 years and longer at these stations is zero.
- HARPERUS: unit-area low flows at this station are notably higher than at the other HCMC stations, but are still substantially lower than at the WSC station on Harper Creek (08LB076). The lowest recorded unit-area flow value of 1.9 l/s/km2 at HARPERUS was selected as representative of the mean annual 7-day low flow for that station. Other return period low flows were calculated assuming the same frequency distribution characteristics as the low flows at the Lemieux Creek WSC station (08LB078). The Lemieux Creek distribution was selected over the Harper Creek distribution because it is believed to represent a more plausible pattern of decreasing low flows for the upper portion of the Harper Creek basin. Hydrogeological studies in the Harper Creek watershed indicate that hydraulic conductivities are generally lower in the upper portions of the watershed, and accordingly that a disproportionate amount of groundwater discharge occurs in the lower reaches of the watershed. As such, low flows would be expected to be maintained more consistently at 08LB076 than at HARPERUS.
- HARPER2: Two sets of concurrent Instantaneous low flow measurements are available for HARPER2 and HARPERUS. In both sets of measurements, the unit discharge at HARPER2 was approximately 0.43 times the unit discharge at HARPERUS. The return period unit-area low flows for HARPERUS were therefore scaled by this ratio to provide unit-area low flows for HARPER2.

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TABLE 4.7

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PROJECT MEASURED LOW FLOWS

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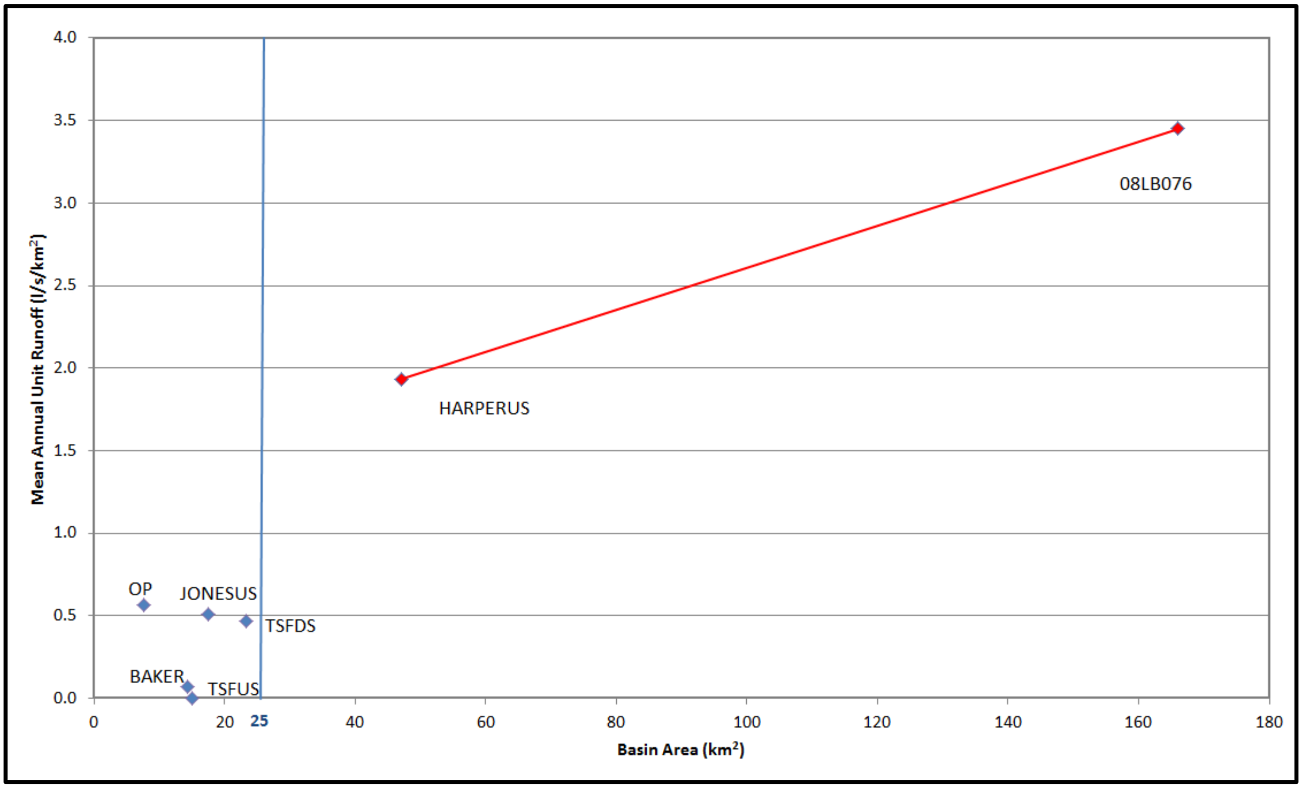
Date	Station																			
	BAKER		BAKERUS		JONESUS		OP		OP2		HARPER2		HARPERUS		TSFDS		TSFUS		08LB076	
	Area (km^2)	14.3	Area (km^2)	12.4	Area (km^2)	17.6	Area (km^2)	7.7	Area (km^2)	7.5	Area (km^2)	16.6	Area (km^2)	47.1	Area (km^2)	23.4	Area (km^2)	15.0	Area (km^2)	166
	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)	Discharge (m^3/s)	Unit Discharge ($l/s/km^2$)
12-Sep-11															0.03	**1.3**			0.72	**4.3**
13-Sep-11	0.03	**2.1**			0.05	**2.8**											0.02	**1.3**	0.72	**4.3**
14-Sep-11							0.01	**1.3**					0.21	**4.5**					0.71	**4.3**
22-Nov-11							0.006	**0.8**					0.134	**2.8**	0.011	**0.5**			0.96	**5.8**
23-Nov-11	0.009	**0.6**			0.023	**1.3**													1.01	**6.1**
26-Jan-12	0.001	**0.1**			0.009	**0.5**													0.59	**3.5**
07-Feb-12							0.004	**0.6**					0.118	**2.5**	0.022	**0.9**			0.57	**3.4**
08-Feb-12	0.003	**0.2**															0	**0.0**	0.58	**3.5**
09-Feb-12					0.026	**1.5**													0.57	**3.5**
27-Feb-12	0.001	**0.1**			0.025	**1.4**													0.85	**5.1**
29-Feb-12							0.005	**0.7**					0.091	**1.9**	0.019	**0.8**	0	**0.0**	0.69	**4.2**
31-Mar-12	0.014	**1.0**			0.033	**1.9**													0.62	**3.7**
01-Apr-12							0.004	**0.6**					0.11	**2.3**	0.023	**1.0**			0.61	**3.7**
11-Apr-12					0.039	**2.2**													0.77	**4.6**
12-Apr-12	0.041	**2.9**					0.014	**1.8**					0.177	**3.8**					0.96	**5.8**
13-Apr-12															0.059	**2.5**			1.10	**6.6**
02-May-12	0.310	**21.6**			0.632	**35.8**											0.633	**42.1**	11.06	**66.6**
03-May-12													1.945	**41.3**					10.17	
04-May-12							0.267	**34.6**											9.71	
05-May-12															0.659	**28.2**			8.84	
20-Oct-13					0.060	**3.4**													2.30	
21-Oct-13							0.023	**3.0**	0.023	**3.1**	0.061	**3.7**	0.390	**8.3**					2.41	
22-Oct-13			0.023	**1.9**											0.163	**7.0**			2.47	
18-Jan-14									0.005	**0.7**	0.017	**1.0**			0.029	**1.2**				
24-Feb-14			0.01	**0.8**	0.015	**0.9**														
25-Feb-14							0.008	**1.0**			0.015	**0.9**	0.102	**2.2**	0.029	**1.2**				
28-Apr-14			0.09	**7.3**	0.129	**7.3**														

M:\1\01\00458\15\A\Data\Task 410 Hydrology Baseline\[Low Flow Summary 20140621.xlsx]Table 4.7 - LOW FLOWS

NOTES:

1. THE DARK SHADING INDICATES THE UNIT DISCHRGE OF THE LOWEST MEASURED FLOWS.

0	12JUN'14	ISSUED WTIH REPORT VA101-458/15-2	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:

1. THE VALUES ARE THE LOWEST DISCHARGES MEASURED DURING THE PERIOD OF JUNE 2011 TO NOVEMBER 2012.

Figure 4.7 Measured Unit Low Flows vs. Drainage Area

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TABLE 4.8

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

RETURN PERIOD BASELINE 7-DAY LOW FLOWS

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Station	DA (km^2)	Return Period Unit Flows ($l/s/km^2$)						
		2	5	10	20	50	100	200
BAKER	14.3	-	-	-	-	-	-	-
BAKERUS	12.4	-	-	-	-	-	-	-
JONESUS	17.6	0.5	-	-	-	-	-	-
OP	7.7	0.5	-	-	-	-	-	-
OP2	7.5	0.5	-	-	-	-	-	-
HARPER2	16.6	0.8	0.3	0.2	0.1	0.0	-	-
HARPERUS	47.1	1.9	0.78	0.43	0.23	0.10	-	-
TSFDS	23.4	0.5	-	-	-	-	-	-
TSFUS	15.0	-	-	-	-	-	-	-
O8LB076	166	2.9	2.3	2.05	1.88	1.73	1.66	1.61
		Return Period Flows (m^3/s)						
BAKER	14.3	**0**	**0**	**0**	**0**	**0**	**0**	**0**
BAKERUS	12.4	**0**	**0**	**0**	**0**	**0**	**0**	**0**
JONESUS	17.6	**0.009**	**0**	**0**	**0**	**0**	**0**	**0**
OP	7.7	**0.004**	**0**	**0**	**0**	**0**	**0**	**0**
OP2	7.5	**0.004**	**0**	**0**	**0**	**0**	**0**	**0**
HARPER2	16.6	**0.014**	**0.01**	**0**	**0**	**0**	**0**	**0**
HARPERUS	47.1	**0.089**	**0.04**	**0.02**	**0.01**	**0**	**0**	**0**
TSFDS	23.4	**0.012**	**0**	**0**	**0**	**0**	**0**	**0**
TSFUS	15.0	**0**	**0**	**0**	**0**	**0**	**0**	**0**
O8LB076	166	**0.481**	**0.38**	**0.34**	**0.31**	**0.29**	**0.28**	**0.27**

M:\1\01\00458\15\A\Data\Task 410 Hydrology Baseline\[Low Flow Summary 20140621.xlsx]Table 4.8

NOTES:

1. "-" IN THE ABOVE TABLE DENOTES ZERO FLOW IN THE CREEK.
2. THE HARPERUS VALUES ARE PRORATED FROM THE 2 YEAR VALUE ACCORDING TO THE PATTERN OF THE REGIONAL LEMIEUX CREEK PATTERN.

0	05AUG'14	ISSUED WITH REPORT VA101-458/15-2	CJN	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

4.5 PEAK FLOWS

A summary of the peak flow statistics for the most relevant regional stations operated by WSC are provided in Table 4.9. These statistics indicate that the year to year variability of peak flows at the WSC gauging station on Harper Creek (08LB076) is much lower than in the other regional creeks, as reflected by the relatively low coefficient of variation (L-Cv) and skewness (L-Cs) values of 0.14 and 0.05. The Harper Creek values are based on 36 years of streamflow record, so the sample size is sufficiently large to reasonably support a flood frequency analysis. The small differences between the shorter and longer return period peak flows at the Harper Creek station are indicative of a system with substantial watershed storage (Cathcart, 2001), which is likely not representative of hydrogeological conditions in the smaller headwater sub-watersheds of Harper Creek where the proposed mine site is located. The upper parts of the Harper Creek watershed have steeper gradients and relatively low hydraulic conductivities and groundwater recharge rates, and corresponding would be expected to have more intense runoff rates during rainfall and snowmelt events. Furthermore, the relatively small drainage areas of the headwater sub-watersheds make them more susceptible to complete (spatial) rainfall coverage during intense convective storm events than in the larger Harper Creek watershed. These conditions support the idea that the upper headwater areas of the watershed likely experience proportionally more intense peak flows than the WSC gauging station on lower Harper Creek.

Estimated flood statistics were selected for the HCMC gauging stations in accordance with the discussion above, as summarized in Table 4.10 and explained below.

- Mean annual peak flow values were scaled from the mean annual value for WSC station 08LB076 (38 m^3/s) using a drainage area scaling exponent of 0.75, which accounts for increased runoff intensity with decreasing watershed size.
- L-Cv and L-Cs values of 0.25 and 0.20 were selected for station TSFUS, the HCMC gauging station with the smallest drainage area.
- L-Cv and L-Cs values for other HCMC gauging stations were scaled linearly between the 08LB076 and TSFUS values.

Estimated return period peak flows for the HCMC gauging stations, based on the peak flow statistics described above, are presented in Table 4.8. The peak flow values in this table have been increased by 15% to account for possible future climate change effects.

Return period peak flow values can be estimated for ungauged stream locations using the results presented in Table 4.8, combined with the following drainage area scaling equation:

$$Q_1 = Q_2 * (A_1/A_2)^{0.75}$$

where:

A_1 is the drainage area of the location of interest.
Q_1 is the desired return period peak flow at the location of interest.
A_2 is the drainage area of the closest gauging station.
Q_2 is the corresponding return period peak flow at the closest station.

For example, if the 100-year peak flow was required for a stream location with a 4.5 km^2 drainage area within the P-Creek watershed, the 100-year peak flow for station OP would be scaled as follows:

$$Q_{100} \text{ for ungauged site} = 12*(4.5/7.71)^{0.75} = 8.0 \text{ m}^3/\text{s}$$

Table 4.9 Peak Flow Statistics

Station		DA (km^2)	Years of Record	Peak Flow Statistics		
Name	WSC Number			Mean (m^3/s)	L-Cv	L-Cs
Harper Creek	08LB076	166	36	38.0	0.14	0.05
Fisher Creek	08LD009	14.7	13	2.58	0.27	0.41
Mann Creek	08LB050	295	19	30.6	0.24	0.19
Lemieux Creek	08LB078	443	20	23.9	0.25	0.20
BAKER	n/a	14.3	n/a	6.1	0.25	0.20
JONESUS	n/a	17.6	n/a	7.1	0.25	0.20
OP	n/a	7.7	n/a	3.8	0.26	0.21
HARPERUS	n/a	47.0	n/a	14.8	0.23	0.17
TSFDS	n/a	23.4	n/a	8.7	0.24	0.19
TSFUS	n/a	15.0	n/a	6.3	0.25	0.20

NOTES:

1. THE SITE STATION VALUES ARE ESTIMATED ON THE BASIS OF THE REGIONAL DATA AND AN UNDERSTANDING OF THE HYDROLOGIC CHARACTERISTICS OF THE PROJECT AREA.
2. THE MEAN VALUES WERE ESTIMATED USING A DRAINAGE AREA SCALING EXPONENT OF 0.75.
3. THE L-Cv VALUES WERE ESTIMATED USING LINEAR SCALING AND ASSUMING VALUES OF 0.25 FOR TSFUS AND 0.14 FOR 08LB076.
4. THE L-Cs VALUES WERE ESTIMATED USING LINEAR SCALING AND ASSUMING VALUES OF 0.20 FOR TSFUS AND 0.05 FOR 08LB076.
5. THE MANN CREEK VALUES ARE FOR ANNUAL DAILY FLOWS. ALL OTHER CREEKS' VALUES ARE PEAK INSTANTANEOUS FLOWS.

Table 4.10 Return Period Instantaneous Peak Flows

Station	DA (km^2)	Return Period Flows (m^3/S)						
		2	5	10	20	50	100	200
BAKER	14.3	6	9	11	13	16	18	20
BAKERUS	12.4	6	8	10	12	14	16	18
JONESUS	17.6	7	11	13	15	18	21	23
OP	7.7	4	6	7	8	10	12	13
OP2	7.5	4	6	7	8	10	11	13
HARPER2	16.6	7	10	12	14	16	18	20
HARPERUS	47.0	16	22	26	31	36	40	44
TSFDS	23.4	9	13	16	18	22	25	27
TSFUS	15.0	7	10	12	14	16	19	21
O8LB076	166	43	53	59	63	68	71	74

NOTES:
1. THE VALUES ARE CALCULATED USING THE STATISTICS IN TABLE 4.7 AND ASSUMING A GEV DISTRIBUTION OR SCALING FROM RETURN PERIOD FLOWS WITHIN THE SAME WATERSHED.
2. ALL VALUES ASSUME A POTENTIAL FUTURE CLIMATE CHANGE FACTOR OF 15%.

The 100 year peak flow per square kilometer for the nine Project streamflow stations ranges from approximately 0.9 to 1.6 $m^3/s/km^2$.

5 – CONCLUSIONS

Baseline streamflow conditions for the Harper Creek Project were assessed on the basis of long-term regional and short-term site specific flow data, and a wide range of flow values were developed for numerous locations. The key findings of this report are:

- Annual hydrographs in the Project area typically have a uni-modal shape, with the majority of runoff occurring in May and June during the snowmelt freshet period. Runoff patterns are characterized by low flows during the winter months when precipitation falls almost exclusively as snow, high flows during the spring and early summer snowmelt (nival) freshet period, low flows during the dry late summer months, and moderate flows during the fall months when rainfall increases.
- Mean annual unit runoff varies substantially in the Project area, ranging from approximately 16 $l/s/km^2$ to 24 $l/s/km^2$, and generally increases with elevation, although it also varies somewhat with location, with the west side of the Harper Creek drainage generally producing greater runoff than the east side.
- Minimum 7-day low flows typically occur during late summer or late winter. Unit low flows appear to be somewhat correlated to drainage area, although localized drainage conditions confound the pattern, particularly for basins with areas less than approximately 25 km^2. For small watersheds, the mean annual 7-day low flows approach zero.
- Peak flows occur almost exclusively during the spring and early summer snowmelt freshet period, and may result from either snowmelt or rain-on-snow events. Hydrologic and climatic conditions support the idea that small upper headwater streams likely experience proportionally greater peak flows than larger lower areas streams, and estimated flood statistics were selected accordingly. 100 year peak instantaneous unit flows for the Project streamflow stations vary from approximately 0.9 $m^3/s/km^2$ to 1.6 $m^3/s/km^2$.
- Long-term synthetic daily flow series were developed for four Project streamflow stations by correlating site and regional flow data. These flow series provided the basis for calibrating a watershed model that will be used to predict the effects of the Project on the hydrologic conditions of the Project area.

6 – REFERENCES

Association of Professional Engineers and Geoscientists of British Columbia (APEGBC), 2012. Professional Practice Guidelines – Legislated Flood Assessments in a Changing Climate in BC. Vancouver, BC.

British Columbia Ministry of Environment (BC MOE), 2009. Manual of British Columbia Hydrometric, Version 1.0. Prepared for the Resources Information Standards Committee (RISC). Victoria, BC.

British Columbia Ministry of Environment (BC MOE), 2012. Water and Air Baseline Monitoring Guidance Document for Mine Proponents and Operators. Victoria, BC.

Butt, C., 2013. Evaluation of the Performance of Frequency and Chronological Pairing Techniques in Synthesizing Long-Term Streamflow. Master's Thesis, Department of Civil Engineering, Faculty of Applied Science, University of British Columbia, Vancouver, BC.

Cathcart, J., 2001. The Effects of Scale and Storm Severity on the Linearity of Watershed Response Revealed Through the Regional L-Moment Analysis of Annual Peak Flows. Ph.D. Thesis, Department of Forest Resources Management, University of British Columbia, Vancouver, BC.

Knight Piésold Ltd. (KP), 2014a. Harper Creek Project –Watershed Modelling. Ref. No. VA101-458/14-1, Rev. 0. Vancouver, BC

Knight Piésold Ltd. (KP), 2014b. Harper Creek Project – Fish and Aquatic Habitat Baseline. Ref. No. VA101-458/15-1, Rev. A. Vancouver, BC.

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

Montgomery, D. R. and J. M. Buffington, 1997. Channel-reach morphology in mountain drainage basins. Geological Society of America Bulletin, Vol 109(5): 596-611.

Obedkoff, W., 1999. Streamflow in the Cariboo Region. BC Ministry of Environment, Lands and Parks, Water Inventory Section, Resources Inventory Branch, Victoria, BC.

Wang, Y., 2000. Development of Methods for Regional Flood Estimates in the Province of British Columbia, Canada. Ph.D Thesis, Institute of Resources and Environment, University of British Columbia, Vancouver, BC.

Water Survey of Canada (WSC), 2013. Archived streamflow records downloaded on 23 July 2012. ww.ec.gc.ca/rhc-wsc

7 – CERTIFICATION

This report was prepared, reviewed and approved by the undersigned.

PROFESSIONAL
PROVINCE OF
T. J. PERKINS
32079
BRITISH COLUMBIA
ENGINEER

22 Aug 2014.

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Approved:

Ken Brouwer, P.Eng.
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APPENDIX A

BAKER CREEK (BAKER)

(Pages A-1 to A-7)

1 – BAKER CREEK (BAKER)

1.1 GAUGING STATION SITE SELECTION

Stream:	Baker Creek
Location:	0.1 km upstream from the North Thompson River confluence, just upstream of the Birch Island – Lost Creek Road Crossing
Channel description:	Small pool created by a cobble step downstream of the gauge
Site conditions:	Stable hydraulic control, sensitive to flow change and, moderate flow measurement conditions
Other key information:	Site experiences substantial turbulence during high flows making stage measurement challenging and prone to error.
Photographs:	Photos A1 to A4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	Yes

1.3 PERIOD OF STAGE RECORD

Installed:	May 16, 2011
Discontinued:	May 29, 2012
2011 record:	May 16 to November 23, 2011 (80% complete)
2012 record:	April 12 to May 29, 2012 (100% complete)
2013 record:	No record

Station was removed in May 2012 as new station was installed on Baker Creek, BAKERUS at a superior gauging site.

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	14 (total), 14 (used for rating curve), see Table A1
Rating curve:	See Figure A1
Rating curve average error:	+17%
Rating curve standard error:	50%

The rating curve for the BAKER gauging station is considered low quality. The large average and standard error is due primarily to high error in the stage measurement at site.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph: Figure A2

1.6 LONG-TERM SYNTHETIC FLOW SERIES

A long-term synthetic flow series wasn't developed for BAKER due to poor rating curve and relatively short measured streamflow record.

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TABLE A-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
BAKER CREEK (BAKER)

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Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
09/05/2011	12:26	CM	0.326	0.07	0.07	0%
16/05/2011	8:14	CM	0.385	0.25	0.21	-16%
17/05/2011	7:54	CM	0.403	0.34	0.17	-51%
22/05/2011	9:07	CM	0.415	0.58	0.22	-62%
27/05/2011	9:14	CM	0.492	0.88	0.76	-14%
02/06/2011	9:01	CM	0.442	0.82	0.37	-54%
13/06/2011	11:13	CM	0.485	0.98	0.69	-29%
23/06/2011	9:47	CM	0.461	1.05	0.50	-52%
19/07/2011	10:21	CM	0.395	0.26	0.13	-49%
18/08/2011	8:47	CM	0.3395	0.08	0.09	16%
13/09/2011	12:01	CM	0.274	0.03	0.01	-48%
23/11/2011	8:50	CM	-	0.009	-	-
26/01/2012	12:10	CM	-	0.001	-	-
08/02/2012	15:17	CM	-	0.003	-	-
27/02/2012	13:09	CM	-	0.001	-	-
31/03/2012	13:35	CM	-	0.014	-	-
12/04/2012	8:45	CM	0.321	0.04	0.06	47%
01/05/2012	15:35	CM	0.461	0.38	0.50	33%
02/05/2012	16:44	CM	0.422	0.31	0.26	-17%
Average Error (%)						17%
Standard Error (%)						50%

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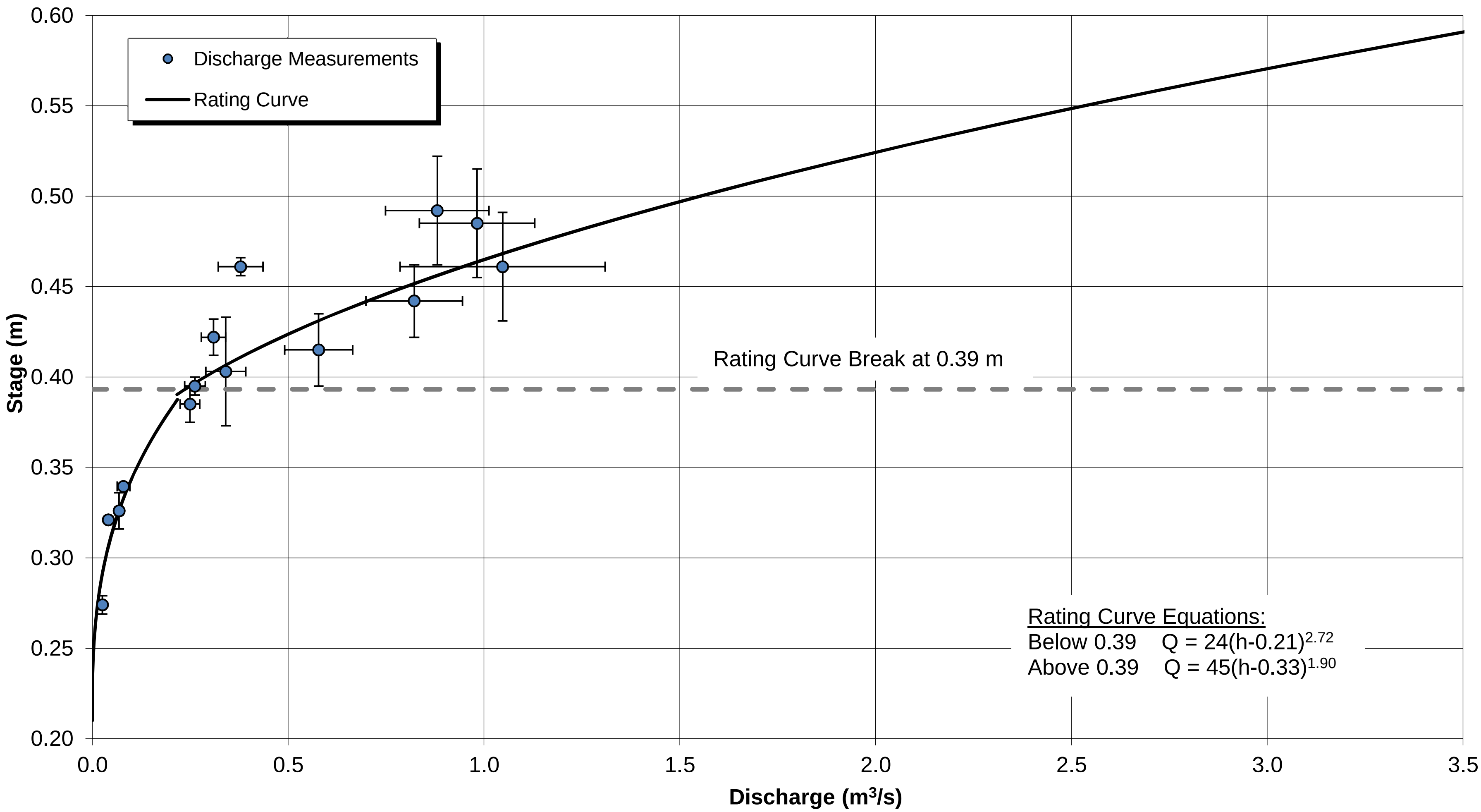
NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE INJECTION.
2. NO STAGE HIEGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:
1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011 AND 2012 DATA COLLECTION PROGRAMS.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	JGC

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

RATING CURVE
BAKER CREEK
(BAKER)

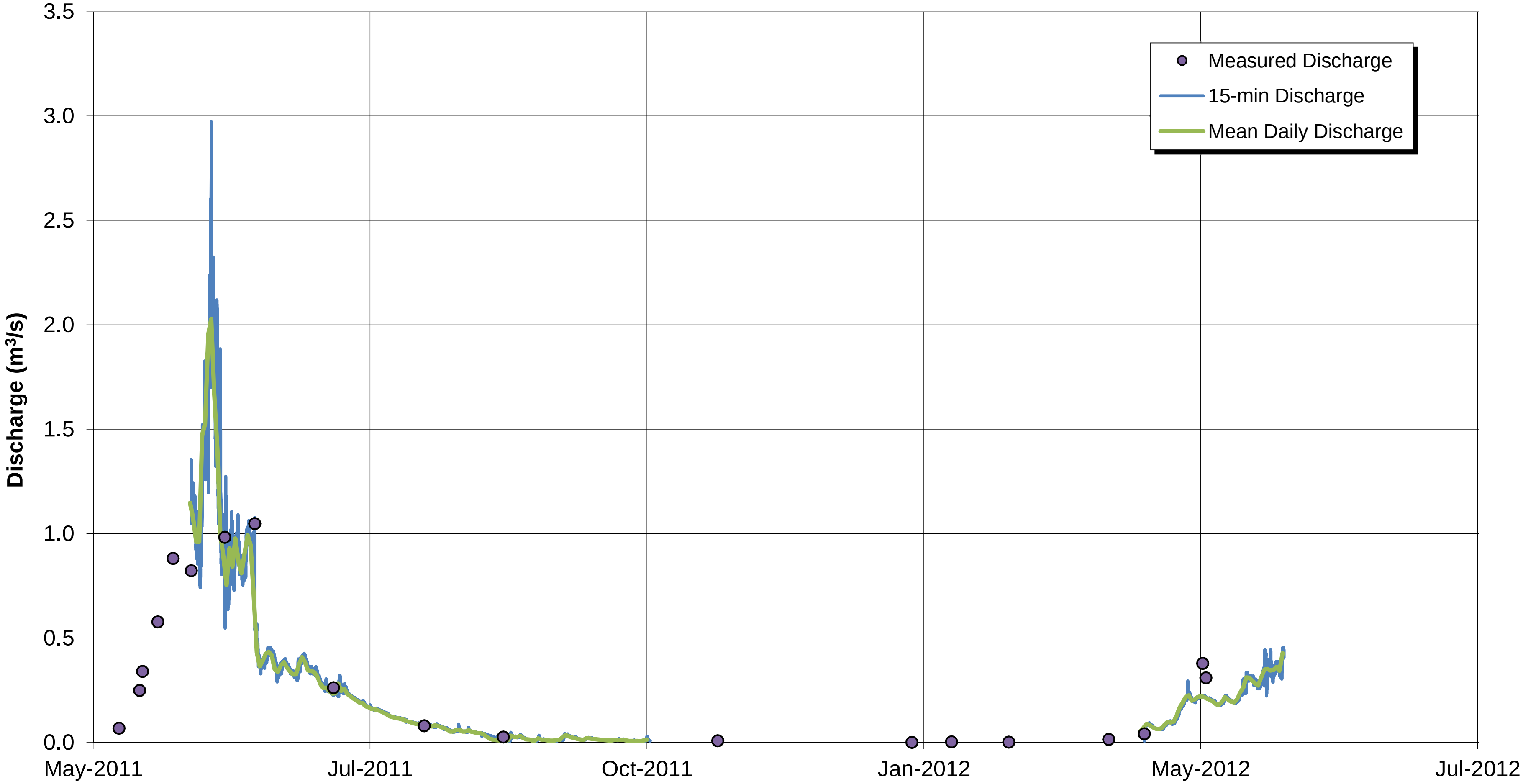
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF. NO. 2

FIGURE A-1

REV 0



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEASURED STREAMFLOW HYDROGRAPH
BAKER CREEK
(BAKER)

Knight Piésold CONSULTING	P/A NO. VA101-458/15	REF. NO. 2			
	FIGURE A-2	REV 0			

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO A1 – Baker Creek hydrology station (BAKER) looking upstream

PHOTO A2 – Baker Creek hydrology station (BAKER), high flows

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO A3 – Baker Creek hydrology station (BAKER), looking downstream

PHOTO A4 – Baker-Creek hydrology station (BAKER), current meter measurement

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX B

BAKER CREEK (BAKERUS)

(Pages B-1 to B-5)

1 – BAKER CREEK (BAKERUS)

1.1 GAUGING STATION SITE SELECTION

Stream:	Baker Creek
Location:	1.1 km upstream of the BAKER station
Channel description:	Small pool created by log across channel which has trapped gravel and cobbles.
Site conditions:	Stable hydraulic control, sensitive to flow change and, reasonably good flow measurement conditions
Other key information:	
Photographs:	Photos B1 to B4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	Yes

Station experienced substantial issues with the logger's battery resulting in many data gaps.

1.3 PERIOD OF STAGE RECORD

Installed:	May 1, 2012
Discontinued:	Currently active
2011 record:	No record
2012 record:	May 1 to November 6, 2012 (25% complete)
2013 record:	July 29 to December 31, 2013 (90% complete)

Station experienced substantial issues with the logger's battery in 2012 resulting in many data gaps. Station winterized in 2013 by placing a glycol bladder over the sensor to prevent it from freezing. .

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	9 (total), see Table A1
Rating curve:	Not completed
Rating curve average error:	-
Rating curve standard error:	-

The rating curve for the BAKERUS gauging station hasn't been completed due to the relatively short measured stage record to apply it to.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph: Not completed

1.6 LONG-TERM SYNTHETIC FLOW SERIES

A long-term synthetic flow series wasn't developed for BAKERUS as a measured streamflow record hasn't been developed.

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TABLE B-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
BAKER CREEK (BAKERUS)

Print Aug/18/14 11:20:06

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
01/05/2012	14:20	CM	0.26	0.38	-	-
15/05/2012	11:10	CM	0.24	0.32	-	-
29/05/2012	7:28	RD	0.30	0.63	-	-
05/06/2012	8:30	RD	0.33	0.93	-	-
19/06/2012	18:10	RD	0.34	0.80	-	-
05/07/2012	9:48	CM	0.25	0.42	-	-
23/08/2012	11:46	CM	0.11	0.04	-	-
31/07/2013	16:25	CM	0.20	0.06	-	-
22/10/2013	14:05	CM	0.18	0.02	-	-
24/02/2014	14:55	CM	-	0.01	-	-
28/04/2014	12:41	CM	-	0.09	-	-
Average Error (%)						-
Standard Error (%)						-

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[StageQ_2014_BAKERUS_20140603.xlsx]B.1DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE INJECTION.
2. NO STAGE HIEGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO B1 – Baker Creek hydrology station (BAKERUS) during high flows

PHOTO B2 – Baker Creek hydrology station (BAKERUS), during low flows

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO B3 – Baker Creek hydrology station (BAKERUS), looking downstream

PHOTO B4 – Baker-Creek hydrology station (BAKERUS), current meter measurement

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX C

JONES CREEK (JONESUS)

(Pages C-1 to C-14)

1 – JONES CREEK (JONESUS)

1.1 GAUGING STATION SITE SELECTION

Stream:	Jones Creek
Location:	1.5 km upstream from the North Thompson River confluence and 0.9 km upstream of the Birch Island – Lost Creek Road crossing
Channel description:	Small pool created by a cobble step and woody debris downstream of the gauge
Site conditions:	Stable hydraulic control, minimal turbulence at most flow conditions, reasonably good flow measurement conditions
Other key information:	Station is located upstream of agricultural water withdrawals
Photographs:	Photos C1 to C4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	Yes

1.3 PERIOD OF STAGE RECORD

Installed:	May 22, 2011
Discontinued:	Currently active
2011 record:	Logger not installed
2012 record:	April 11 to November 6, 2012 (75% complete)
2013 record:	July 31 to December 31, 2013 (100% complete)

Station was winterized over the 2013/2014 winter and instrumentation was not removed.

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	18 (total), 13 (used for rating curve), see Table C1
Rating curve:	See Figure C1
Rating curve average error:	+2%
Rating curve standard error:	12%

The rating curve for the JONEUS gauging station is considered good quality. Five measurements weren't included in rating curve development due to poor measurement quality.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph:	Figure C2

1.6 LONG-TERM SYNTHETIC FLOW SERIES

Seasonal EFP relationships:	Figures C3 and C4
Comparison to Harper Creek (WSC Station 08LB076):	Spring/summer: lower unit runoff than 08LB076 Autumn: lower unit runoff than 08LB0176
Comparison of measured and synthetic streamflow hydrographs:	Open water season: Figure C5 Winter: Figure C6
Long-term mean monthly flow hydrograph (synthetic):	Figure C7
Long-term flow duration curve (synthetic):	Figure C8
Long-term monthly and annual flows (synthetic):	Table C2

Station JONESUS has lower unit runoff than the WSC station on Harper Creek in the spring/summer season and in the autumn. The lower unit runoff in spring/summer is generally attributed to smaller snowpack in lower elevation watershed of JONESUS, while the lower unit runoff in autumn is attributed to the smaller watershed area and smaller groundwater contribution.

It should be noted that the EFP relationship is extrapolated significantly in the autumn season. During the period of measured record at JONESUS, no significant autumn storms were recorded. A relationship parallel to the unit discharge line was selected for extrapolation.

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TABLE C-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
JONES CREEK (JONESUS)

Print Aug/18/14 11:26:39

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
22/05/2011	10:47	CM	3.34	1.51	-	-
27/05/2011	12:10	CM	3.39	1.39	1.39	0%
02/06/2011	11:22	RD	3.36	1.16	1.12	-4%
09/06/2011	7:30	RD	3.35	1.52	-	-
13/06/2011	9:15	CM	3.37	1.49	-	-
19/07/2011	9:10	CM	3.22	0.30	0.32	8%
18/08/2011	7:34	CM	3.14	0.11	0.11	2%
13/09/2011	13:44	CM	3.09	0.05	0.04	-24%
23/11/2011	9:55	CM	-	0.02	-	-
26/01/2012	13:50	CM	-	0.01	-	-
09/02/2012	9:36	CM	-	0.03	-	-
27/02/2012	14:15	CM	-	0.03	-	-
31/03/2012	14:30	CM	-	0.03	-	-
11/04/2012	15:50	CM	3.10	0.04	0.05	18%
02/05/2012	14:46	CM	3.28	0.63	0.57	-9%
15/05/2012	13:15	RD	3.32	0.91	0.85	-6%
27/05/2012	16:37	RD	3.38	1.21	1.39	0%
04/06/2012	16:32	RD	3.42	1.33	1.63	22%
24/06/2012	16:59	RD	3.40	1.37	1.48	8%
05/07/2012	7:42	CM	3.35	0.52	-	-
23/08/2012	9:50	CM	3.15	0.05	-	-
31/07/2013	14:53	CM	3.12	0.07	0.08	2%
20/10/2013	14:15	CM	3.11	0.06	0.06	2%
24/02/2014	13:12	CM	-	0.02	-	-
28/04/2014	11:14	CM	-	0.13	-	-
Average Error (%)						2%
Standard Error (%)						12%

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[PreliminaryRatingCurve_2013_JONESUS_20140602.xlsx]DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE SLUG INJECTION.
2. NO STAGE HEIGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.
3. RATING CURVE ERROR IS THE DIFFERENCE BETWEEN THE RATING CURVE DISCHARGE AND THE MEASURED DISCHARGE, ASSUMING THE MEASURED DISCHARGE IS THE "TRUE" DISCHARGE.

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	SCR	TJP	JGC

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TABLE C-2

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

LONG-TERM SYNTHETIC DISCHARGE AT JONES CREEK (JONESUS) (m^3/s)

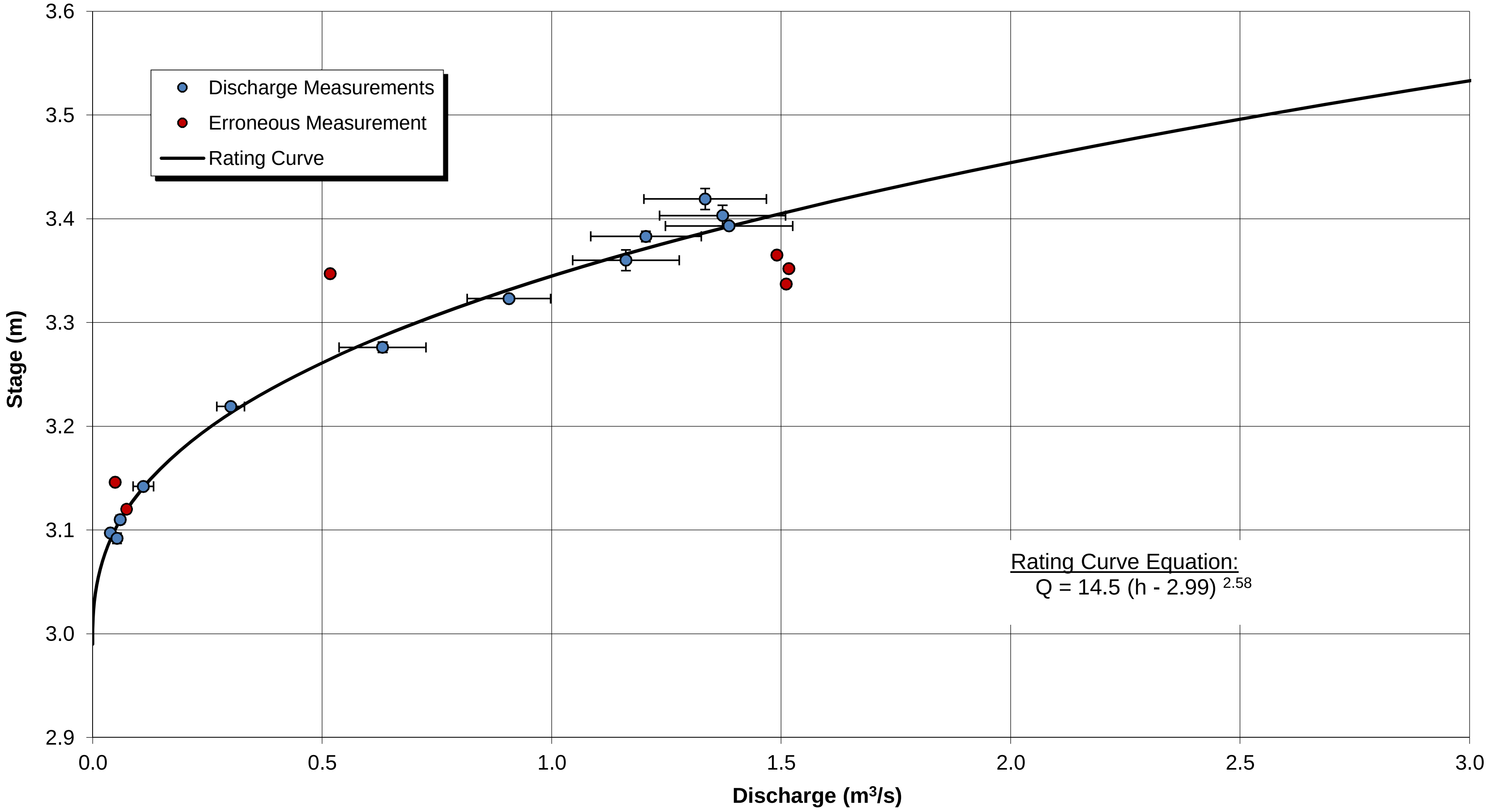
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	-	-	-	-	-	-	0.40	0.07	0.06	0.09	0.04	0.02	0.11
1974	0.02	0.07	0.13	0.33	0.66	1.78	0.84	0.15	0.08	0.05	0.01	0.02	0.35
1975	0.02	0.06	0.11	0.20	0.63	1.46	0.61	0.11	0.08	0.14	0.10	0.06	0.30
1976	0.04	0.10	0.16	0.29	0.95	1.01	0.75	0.58	0.19	0.09	0.05	0.03	0.35
1977	0.02	0.09	0.19	0.36	0.54	0.58	0.38	0.08	0.12	0.08	0.04	0.03	0.21
1978	0.03	0.08	0.21	0.41	1.21	1.07	0.43	0.09	0.22	0.09	0.05	0.03	0.33
1979	0.02	0.07	0.15	0.24	0.63	0.65	0.35	0.06	0.07	0.07	0.03	0.02	0.20
1980	0.02	0.10	0.13	0.40	0.88	0.51	0.41	0.10	0.11	0.09	0.09	0.05	0.24
1981	0.05	0.17	0.34	0.33	1.04	0.73	0.49	0.09	0.09	0.27	0.12	0.06	0.32
1982	0.03	0.12	0.18	0.23	0.83	1.52	0.71	0.19	0.16	0.20	0.08	0.04	0.36
1983	0.05	0.18	0.45	0.40	1.11	1.03	0.58	0.10	0.10	0.10	0.12	0.04	0.35
1984	0.04	0.13	0.27	0.35	0.54	1.68	0.91	0.13	0.10	0.09	0.04	0.02	0.36
1985	0.02	0.07	0.14	0.32	0.94	0.96	0.40	0.07	0.08	0.09	0.04	0.03	0.26
1986	0.02	0.10	0.20	0.33	0.85	0.97	0.41	0.07	0.07	0.08	0.04	0.02	0.26
1987	0.02	0.07	0.28	0.42	0.97	0.56	0.29	0.07	0.04	0.04	0.02	0.02	0.23
1988	0.02	0.07	0.14	0.40	0.94	0.77	0.46	0.08	0.08	0.10	0.07	0.03	0.26
1989	0.03	0.08	0.15	0.35	0.84	0.92	0.36	0.17	0.10	0.09	0.10	0.05	0.27
1990	0.04	0.12	0.18	0.42	0.74	1.16	0.49	0.08	0.06	0.07	0.06	0.03	0.29
1991	0.02	0.14	0.21	0.37	0.78	0.78	0.47	0.11	0.10	0.06	0.03	0.02	0.26
1992	0.02	0.11	0.49	0.50	0.88	0.63	0.36	0.07	0.07	0.08	0.05	0.03	0.28
1993	0.02	0.07	0.13	0.33	1.03	0.54	0.37	0.11	0.08	0.06	0.03	0.02	0.23
1994	0.02	0.07	0.21	0.51	0.93	0.72	0.42	0.07	0.06	0.05	0.02	0.02	0.26
1995	0.02	0.08	0.18	0.32	0.92	0.85	0.38	0.18	0.08	0.11	0.07	0.05	0.27
1996	0.03	0.11	0.29	0.41	0.69	1.33	0.64	0.11	0.11	0.09	0.08	0.04	0.33
1997	0.03	0.09	0.17	0.29	1.13	1.12	0.59	0.13	0.15	0.23	0.09	0.05	0.34
1998	0.03	0.14	0.32	0.38	1.08	0.52	0.32	0.05	0.04	0.07	0.03	0.03	0.25
1999	0.03	0.10	0.21	0.35	0.81	1.79	1.15	0.25	0.09	0.08	0.10	0.05	0.42
2000	0.04	0.11	0.17	0.35	0.65	1.19	0.54	0.10	0.08	0.08	0.04	0.02	0.28
2001	0.02	0.06	0.13	0.23	0.68	0.74	0.53	0.11	0.06	0.06	0.04	-	0.26
2002	-	-	0.18	0.31	0.85	1.49	0.50	0.08	0.07	0.06	0.03	0.03	0.37
2003	0.02	0.07	0.15	0.33	0.77	0.95	0.31	0.04	0.03	0.12	0.04	0.02	0.24
2004	0.02	0.06	0.15	0.42	0.76	0.65	0.35	0.06	0.13	0.08	0.06	0.05	0.23
2005	0.10	0.33	0.47	0.43	1.09	0.68	0.43	0.08	0.07	0.23	0.08	0.04	0.34
2006	0.06	0.14	0.23	0.35	1.11	0.74	0.30	0.06	0.05	0.04	0.03	0.02	0.26
2007	0.02	0.06	0.13	0.32	0.79	1.04	0.37	0.06	0.06	0.13	0.07	0.04	0.26
2008	0.03	0.13	0.21	0.22	1.19	1.01	0.45	0.08	0.06	0.08	0.08	0.03	0.30
2009	0.03	0.08	0.13	0.23	0.68	0.91	0.37	0.06	0.05	0.06	0.03	0.02	0.22
2010	0.03	0.11	0.23	0.32	0.68	0.97	0.41	0.07	0.09	0.08	0.04	0.03	0.25
2011	0.02	0.06	0.08	0.11	0.74	1.60	0.64	0.11	0.06	0.07	0.03	0.01	0.30
2012	0.01	0.03	0.03	0.22	0.85	1.58	0.62	0.08	0.04	0.06	0.05	0.02	0.30
2013	0.02	0.08	0.18	0.42	1.19	1.02	0.41	0.07	0.12	0.14	0.04	0.02	0.31
Average	**0.03**	**0.10**	**0.20**	**0.34**	**0.86**	**1.00**	**0.49**	**0.11**	**0.09**	**0.10**	**0.05**	**0.03**	**0.28**
Maximum	**0.10**	**0.33**	**0.49**	**0.51**	**1.21**	**1.79**	**1.15**	**0.58**	**0.22**	**0.27**	**0.12**	**0.06**	**0.42**
Minimum	**0.01**	**0.03**	**0.03**	**0.11**	**0.54**	**0.51**	**0.29**	**0.04**	**0.03**	**0.04**	**0.01**	**0.01**	**0.11**

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\EFP Regressions\[JONESUS_EFP_20140424.xlsm]Summary Table

NOTE:

1. MEASURED DAILY FLOWS WERE COMPARED TO DAILY FLOWS AT WATER SURVEY OF CANADA HYDROMETRIC STATION HARPER CREEK AT THE MOUTH (08LB076) TO GENERATE THE LONG-TERM SYNTHETIC SERIES.

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:

1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011, 2012 AND 2013 DATA COLLECTION PROGRAMS.

0	22AUG'14	ISSUED WITH REPORT	SCR	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

RATING CURVE
JONES CREEK
(JONESUS)

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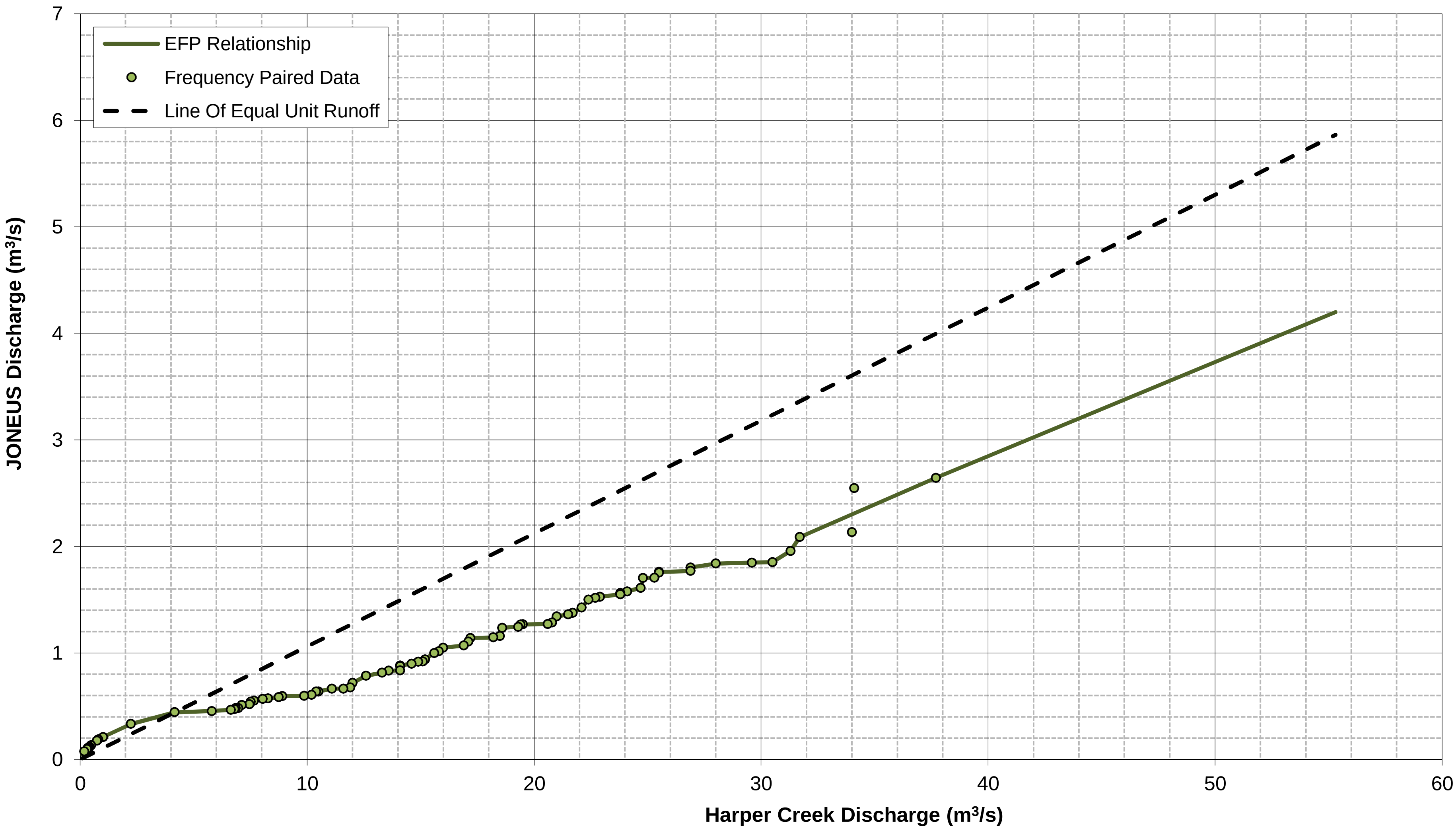
P/A NO.	REF. NO.	
VA101-458/15	2	
FIGURE C-1		REV 0



NOTE:
1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST SPRING/SUMMER DISCHARGE IN THE WSC'S HARPER CREEK SERIES

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

SPRING/SUMMER FREQUENCY PAIRED RELATIONSHIP
JONESUS AND WSC'S HARPER CREEK STATIONS

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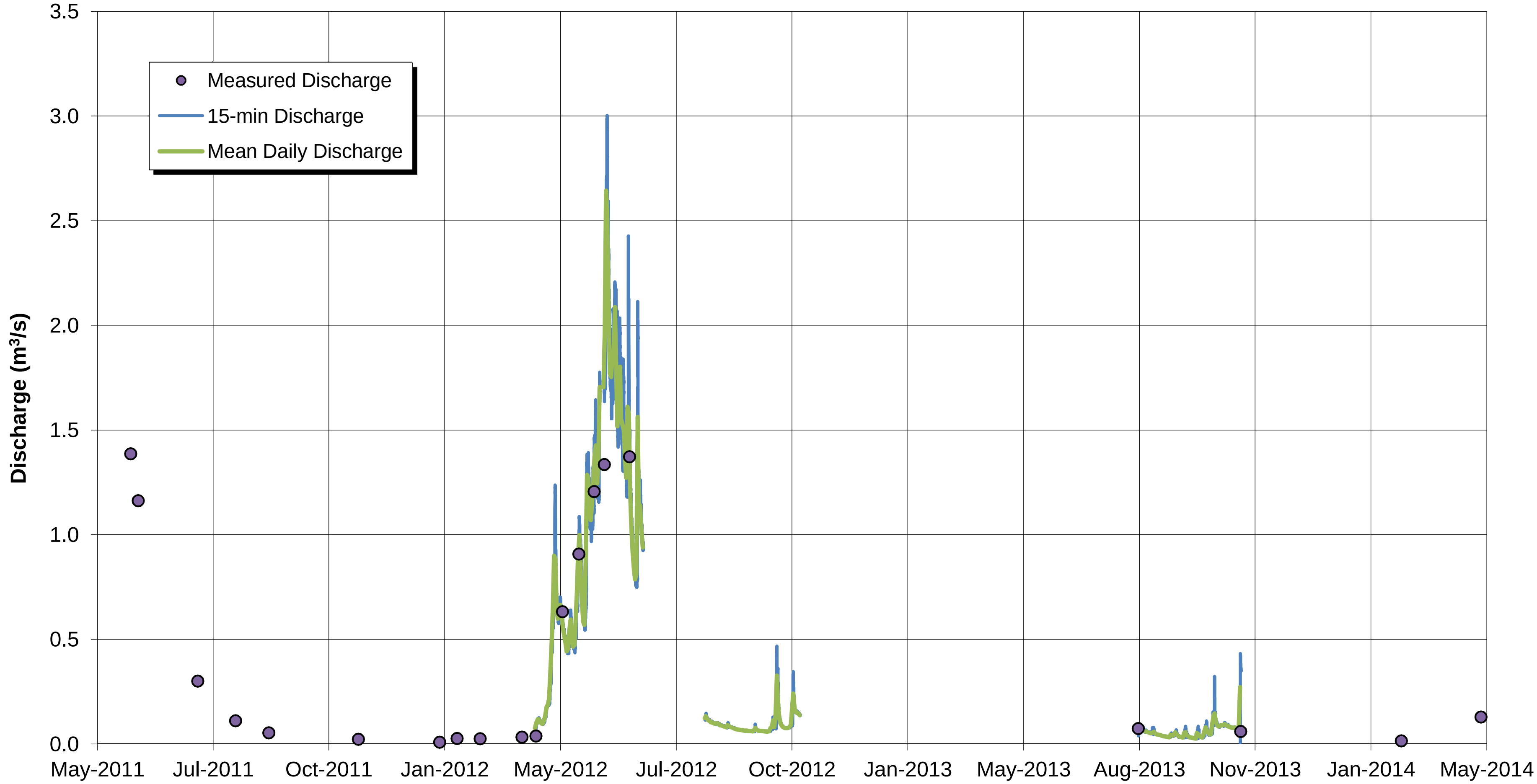
P/A NO. VA101-458/15	REF NO. 2
FIGURE C-3	REV 0

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTE:
1. DATA GAPS (1 JUN TO 4 JUN 2012 AND 5 JUL TO 23 AUG 2012) ARE DUE TO LOGGER MALFUNCTION.

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEASURED STREAMFLOW HYDROGRAPH
JONES CREEK
(JONESUS)

Knight Piésold CONSULTING

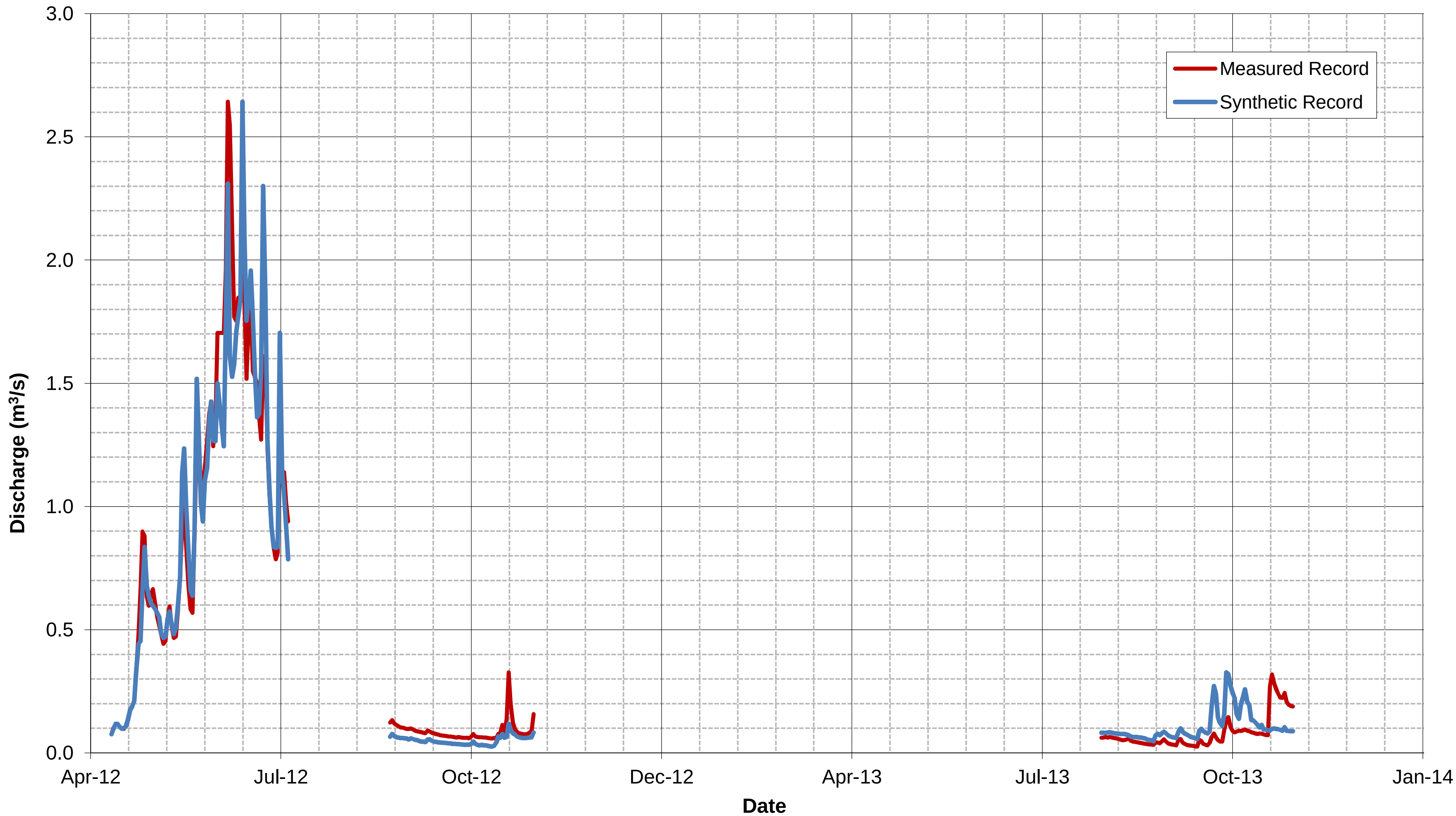
P/A NO. VA101-458/15

REF. NO. 2

FIGURE C-2

REV 0

0	22AUG'14	ISSUED WITH REPORT	SCR	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

COMPARISON OF MEASURED AND SYNTHETIC HYDROGRAPHS
JONES CREEK (JONESUS)

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE C-5 REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
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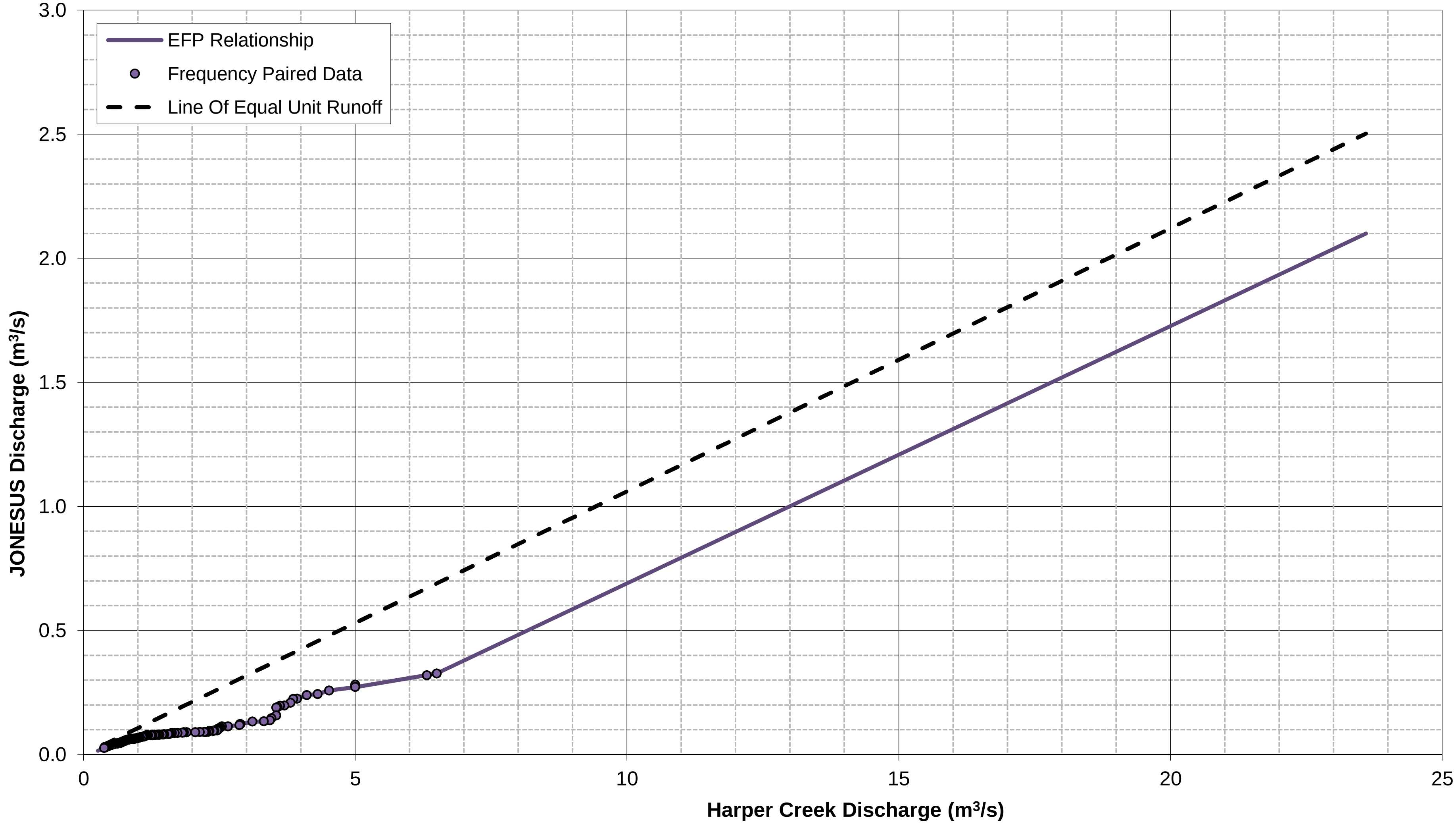


NOTE:
1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST AUTUMN DISCHARGE IN THE WSC'S HARPER CREEK SERIES

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

AUTUMN FREQUENCY PAIRED RELATIONSHIP
JONESUS AND WSC'S HARPER CREEK STATIONS

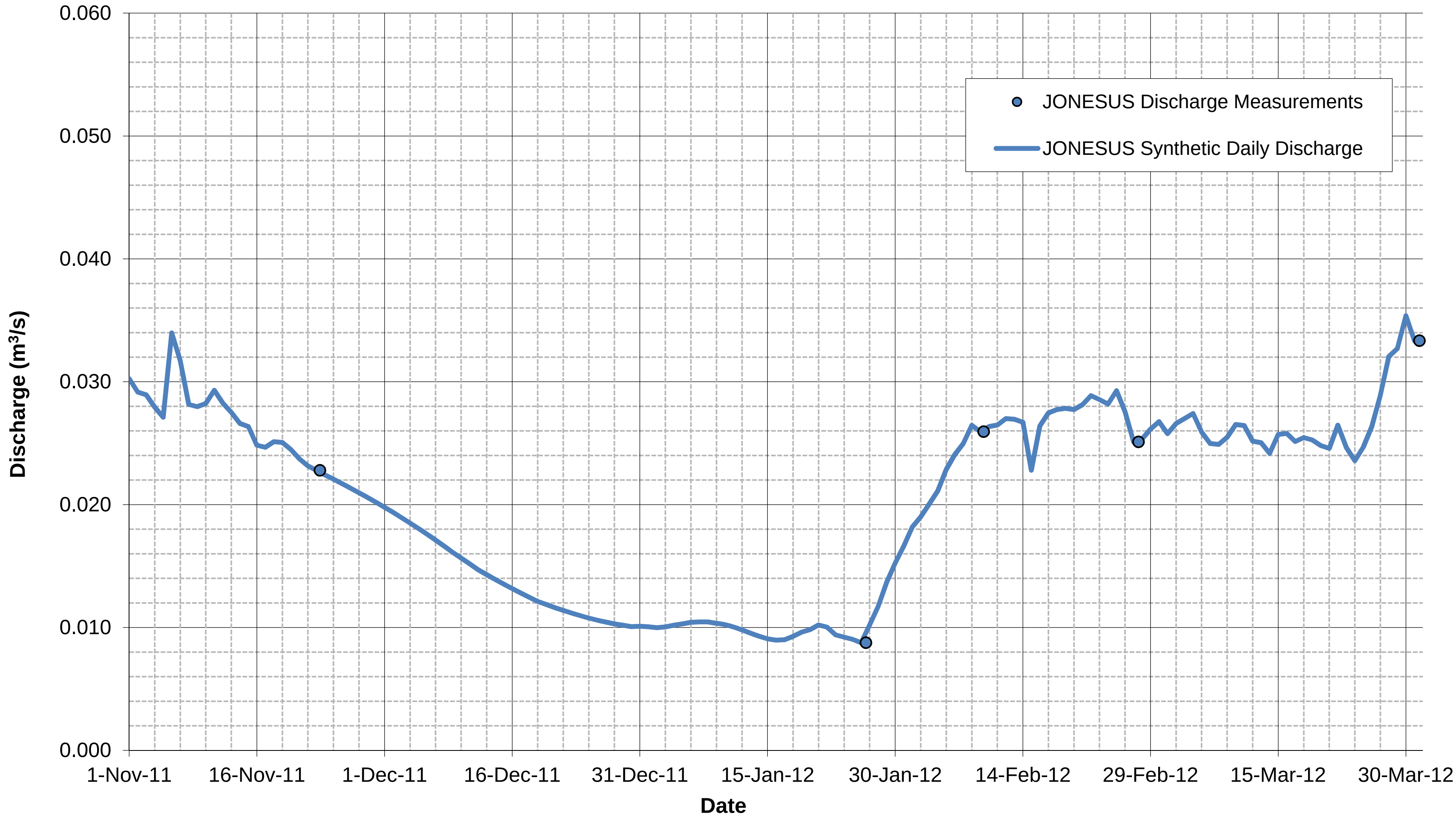
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE C-4

REV 0



0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

WINTER RELATIONSHIP
JONESUS AND WSC'S HARPER CREEK STATIONS

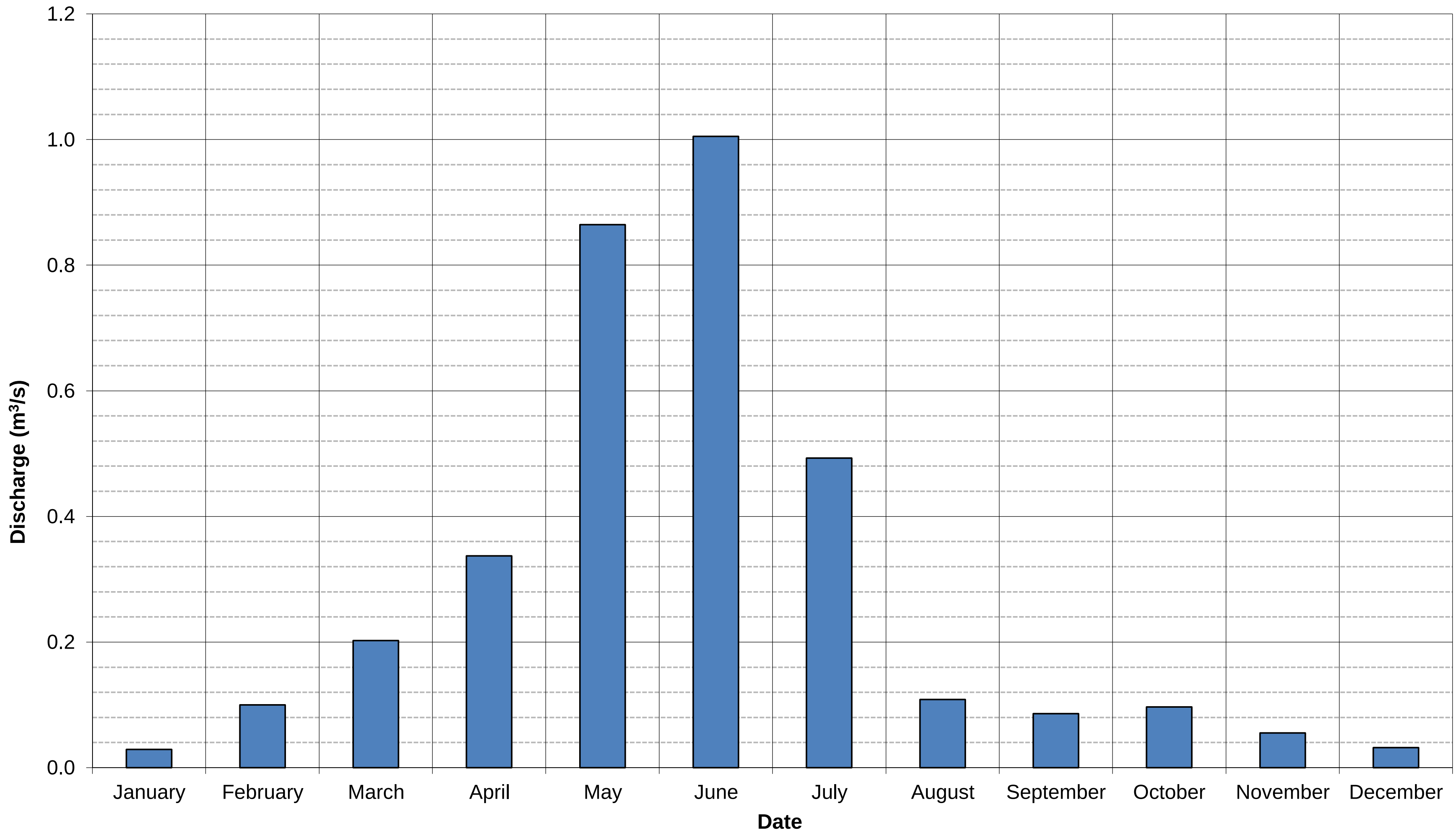
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE C-6

REV 0



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEAN MONTHLY HYDROGRAPH
JONES CREEK (JONESUS)

Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE C-7

REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
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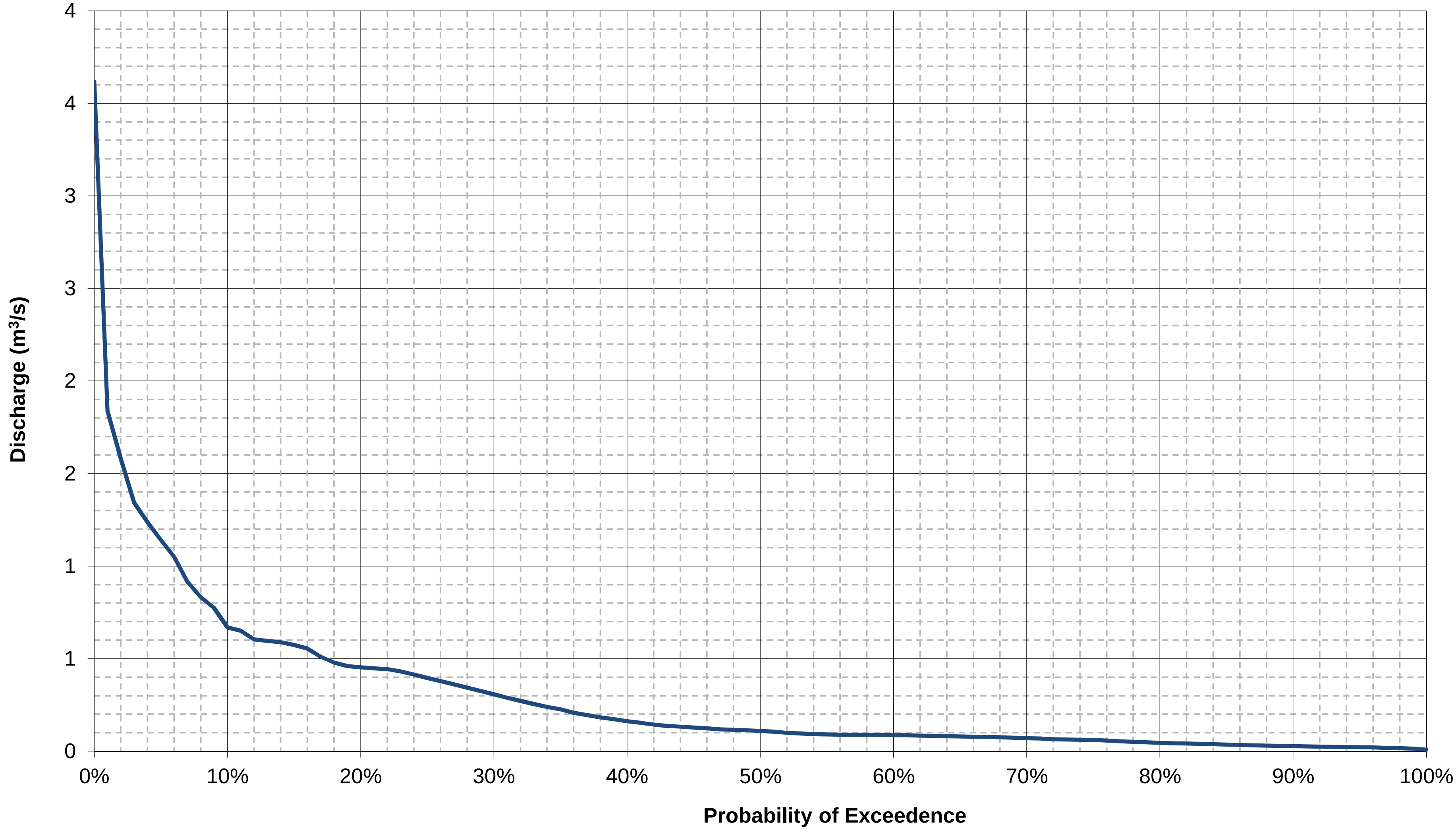

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

LONG TERM FLOW DURATION CURVE
JONES CREEK (JONESUS)

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE C-8 REV 0

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO C1 – Jones Creek hydrology station (JONESUS) during low flows

PHOTO C2 – Jones Creek hydrology station (JONESUS), during high flows

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO C3 – Jones Creek hydrology station (JONESUS), looking downstream

PHOTO C4 – Jones-Creek hydrology station (JONESUS), current meter measurement

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX D

P-CREEK AT HARPER CREEK (OP)

(Pages D-1 to D-14)

1 – P-CREEK AT HARPER CREEK (OP)

1.1 GAUGING STATION SITE SELECTION

Stream:	P-Creek
Location:	0.1 km upstream form the Harper Creek confluence and just upstream of the Harper Creek FSR bridge
Channel description:	Small shallow pool created by a cobble step downstream of the gauge
Site conditions:	Stable hydraulic control, minimal turbulence at most flow conditions, reasonably good flow measurement conditions
Other key information:	The station is located in a small shallow pool on the edge of the creek that goes dry during low flow conditions.
Photographs:	Photos D1 to D4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	Yes

1.3 PERIOD OF STAGE RECORD

Installed:	June 9, 2011
Discontinued:	Currently active
2011 record:	June 9 to November 22, 2011 (55% complete)
2012 record:	April 12 to November 7, 2012 (95% complete)
2013 record:	July 30 to December 3, 2013 (30% complete)

Issues with the sensor/logger instrumentation were encountered at this site. In 2011 the logger appeared to drift, recording incorrect date and time data. In 2013, the sensor recorded significant noise unrelated to turbulence experienced at site. The majority of the open water record for 2013 is considered unreliable and excluded from the dataset. Additionally, data gaps exist where the sensor was stranded due to falling water levels in between site visits.

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	16 (total), 13 (used for rating curve), see Table D1

Rating curve:	See Figure D1
Rating curve average error:	+4%
Rating curve standard error:	13%

The rating curve for the OP gauging station is considered good quality. The average and standard error is due primarily to high error in stage measurement. Rating curve error for flows less than 0.1 m^3/s were excluded from the average and standard error calculation due to the uncertainty associated with measuring such small flows. .

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph:	Figure D2

1.6 LONG-TERM SYNTHETIC FLOW SERIES

Seasonal EFP relationships:	Figures D3 and D4
Comparison to Harper Creek (WSC Station 08LB076):	Spring/summer: similar unit runoff to 08LB076 Autumn: lower unit runoff than 08LB0176
Comparison of measured and synthetic streamflow hydrographs:	Open water season: Figure D5 Winter: Figure D6
Long-term mean monthly flow hydrograph (synthetic):	Figure D7
Long-term flow duration curve (synthetic):	Figure D8
Long-term monthly and annual flows (synthetic):	Table D2

Due to instrumentation malfunctions, only data from 2012 were used to develop the EFP relationships.

Station OP has similar unit runoff to the WSC station on Harper Creek in the spring/summer season and lower unit runoff than the WSC station in the autumn. The similar unit runoff in spring/summer is generally attributed to a similar snowpack in the sub-watershed of OP to the average snowpack across the larger Harper Creek watershed. The lower unit runoff in autumn is attributed to the smaller watershed area and smaller groundwater contribution.

It should be noted that the EFP relationship is extrapolated significantly in the autumn season. During the period of measured record at OP, no significant autumn storms were recorded. A relationship parallel to the unit discharge line was selected for extrapolation.

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TABLE D-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
P-CREEK AT HARPER CREEK (OP)

Print Aug/18/14 11:46:05

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
09/06/2011	13:49	RD		5.27	-	-
14/06/2011	10:55	CM	6.70	1.19	0.99	-17%
22/06/2011	10:20	CM	6.62	0.78	-	-
20/07/2011	12:18	CM	6.56	0.24	-	-
18/08/2011	12:55	CM	6.52	0.05	0.04	-8%
14/09/2011	9:11	CM	6.50	0.01	0.02	168%
22/11/2011	11:45	CM	-	0.006	-	-
07/02/2012	11:24	CM	-	0.004	-	-
29/02/2012	10:20	CM	-	0.005	-	-
01/04/2012	10:37	CM	-	0.004	-	-
12/04/2012	13:27	CM	6.53	0.01	0.94	-3%
04/05/2012	9:16	CM	6.61	0.27	0.31	15%
14/05/2012	13:20	CM	6.66	0.46	0.56	21%
17/05/2012	9:02	RD	6.68	0.71	0.79	12%
28/05/2012	11:57	CM	6.70	0.97	0.94	-3%
05/06/2012	12:43	RD	6.73	1.45	1.33	-8%
19/06/2012	8:31	RD	6.70	0.92	0.96	5%
06/07/2012	6:50	CM	6.63	0.38	0.40	6%
21/08/2012	14:05	CM	6.48	0.02	0.01	-46%
21/10/2013	9:53	CM	6.52	0.02	0.04	86%
25/02/2014	14:21	CM	-	0.01	-	-
Average Error (%)						4%
Standard Error (%)						13%

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[PreliminaryRatingCurve_2013_OP_20140602.xlsx]DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE SLUG INJECTION.
2. NO STAGE HEIGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.
3. RATING CURVE ERROR IS THE DIFFERENCE BETWEEN THE RATING CURVE DISCHARGE AND THE MEASURED DISCHARGE, ASSUMING THE MEASURED DISCHARGE IS THE "TRUE" DISCHARGE.
4. AVERAGE AND STANDARD ERROR ARE BASED ON FLOWS GREATER THAN 0.1 m^3/s.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

TABLE D-2

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

LONG-TERM SYNTHETIC DISCHARGE AT P-CREEK AT HARPER CREEK (OP) (m^3/s)

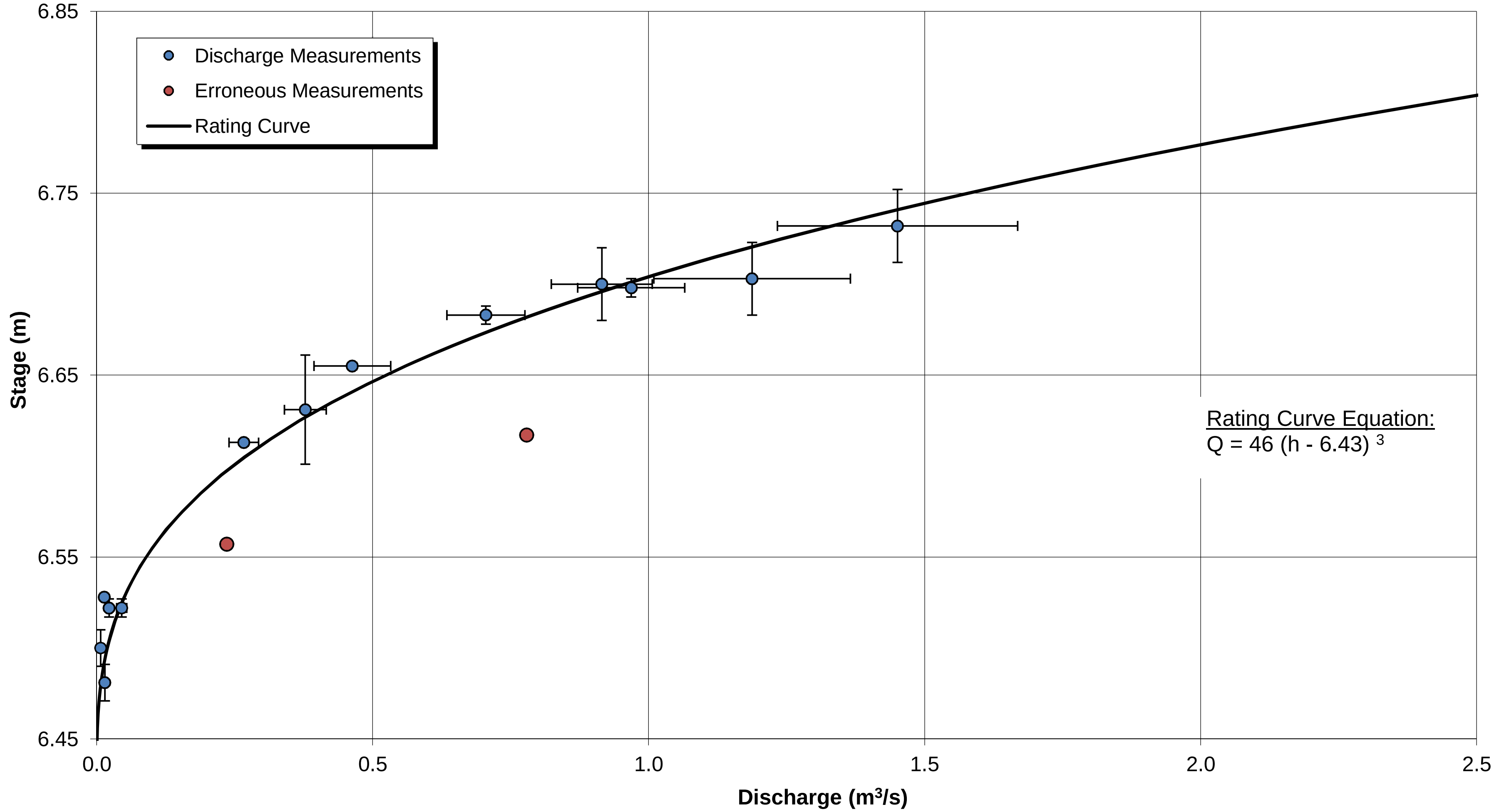
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	-	-	-	-	-	-	0.07	0.01	0.01	0.02	0.01	0.01	0.02
1974	0.01	0.01	0.02	0.08	0.37	1.18	0.56	0.04	0.01	0.01	0.00	0.01	0.19
1975	0.01	0.01	0.02	0.06	0.33	1.05	0.31	0.03	0.01	0.03	0.03	0.02	0.16
1976	0.02	0.02	0.02	0.06	0.67	0.70	0.45	0.14	0.05	0.02	0.01	0.01	0.18
1977	0.01	0.02	0.03	0.11	0.23	0.28	0.06	0.02	0.03	0.02	0.01	0.01	0.07
1978	0.01	0.02	0.03	0.13	0.88	0.74	0.11	0.02	0.06	0.02	0.01	0.01	0.17
1979	0.01	0.01	0.02	0.06	0.33	0.35	0.06	0.01	0.01	0.01	0.01	0.01	0.07
1980	0.01	0.02	0.02	0.18	0.60	0.17	0.07	0.02	0.03	0.02	0.02	0.02	0.10
1981	0.03	0.03	0.05	0.06	0.68	0.47	0.16	0.02	0.02	0.07	0.03	0.02	0.14
1982	0.02	0.02	0.03	0.06	0.52	1.12	0.43	0.05	0.04	0.05	0.02	0.01	0.20
1983	0.02	0.04	0.07	0.14	0.73	0.72	0.28	0.02	0.02	0.02	0.03	0.01	0.18
1984	0.02	0.03	0.04	0.06	0.22	1.18	0.64	0.03	0.02	0.02	0.01	0.01	0.19
1985	0.01	0.01	0.02	0.06	0.57	0.64	0.11	0.01	0.01	0.02	0.01	0.01	0.12
1986	0.01	0.02	0.03	0.06	0.42	0.62	0.07	0.01	0.01	0.01	0.01	0.01	0.11
1987	0.01	0.01	0.04	0.10	0.65	0.25	0.06	0.01	0.01	0.01	0.01	0.01	0.10
1988	0.01	0.01	0.02	0.18	0.61	0.50	0.15	0.01	0.01	0.02	0.02	0.01	0.13
1989	0.01	0.02	0.02	0.10	0.56	0.61	0.08	0.04	0.02	0.02	0.03	0.02	0.13
1990	0.02	0.02	0.03	0.10	0.46	0.86	0.20	0.01	0.01	0.01	0.02	0.01	0.15
1991	0.01	0.03	0.03	0.10	0.47	0.50	0.13	0.03	0.02	0.01	0.01	0.01	0.11
1992	0.01	0.02	0.08	0.16	0.59	0.32	0.06	0.01	0.01	0.02	0.01	0.01	0.11
1993	0.01	0.01	0.02	0.06	0.69	0.21	0.06	0.02	0.01	0.01	0.01	0.01	0.09
1994	0.01	0.01	0.03	0.19	0.65	0.44	0.12	0.01	0.01	0.01	0.01	0.01	0.13
1995	0.01	0.02	0.03	0.06	0.59	0.55	0.06	0.04	0.01	0.02	0.02	0.02	0.12
1996	0.01	0.02	0.05	0.09	0.38	0.98	0.33	0.03	0.03	0.02	0.02	0.02	0.16
1997	0.01	0.02	0.03	0.06	0.73	0.78	0.29	0.03	0.04	0.06	0.03	0.02	0.18
1998	0.02	0.03	0.05	0.09	0.81	0.20	0.06	0.01	0.01	0.01	0.01	0.01	0.11
1999	0.01	0.02	0.03	0.10	0.49	1.25	0.80	0.07	0.02	0.01	0.03	0.02	0.24
2000	0.02	0.02	0.03	0.07	0.34	0.89	0.25	0.02	0.01	0.01	0.01	0.01	0.14
2001	0.01	0.01	0.02	0.06	0.35	0.48	0.19	0.02	0.01	0.01	0.01	-	0.11
2002	-	-	0.03	0.06	0.51	1.10	0.21	0.01	0.01	0.01	0.01	0.01	0.21
2003	0.01	0.01	0.02	0.07	0.42	0.64	0.06	0.01	0.01	0.03	0.01	0.01	0.11
2004	0.01	0.01	0.02	0.10	0.49	0.36	0.06	0.01	0.03	0.01	0.02	0.02	0.10
2005	0.04	0.06	0.08	0.16	0.74	0.43	0.12	0.01	0.01	0.06	0.02	0.02	0.15
2006	0.03	0.03	0.04	0.08	0.73	0.41	0.06	0.01	0.01	0.01	0.01	0.01	0.12
2007	0.01	0.01	0.02	0.06	0.49	0.68	0.07	0.01	0.01	0.03	0.02	0.02	0.12
2008	0.01	0.02	0.03	0.06	0.72	0.69	0.13	0.02	0.01	0.02	0.02	0.01	0.14
2009	0.01	0.02	0.02	0.06	0.36	0.61	0.07	0.01	0.01	0.01	0.01	0.01	0.10
2010	0.01	0.02	0.04	0.07	0.35	0.68	0.09	0.01	0.02	0.01	0.01	0.01	0.11
2011	0.01	0.01	0.01	0.05	0.45	1.17	0.36	0.03	0.01	0.01	0.01	0.01	0.18
2012	0.00	0.00	0.00	0.11	0.56	1.13	0.31	0.02	0.01	0.01	0.01	0.01	0.18
2013	0.01	0.01	0.03	0.07	0.82	0.73	0.10	0.01	0.03	0.04	0.01	0.01	0.16
Average	**0.01**	**0.02**	**0.03**	**0.09**	**0.54**	**0.67**	**0.19**	**0.02**	**0.02**	**0.02**	**0.02**	**0.01**	**0.14**
Maximum	**0.04**	**0.06**	**0.08**	**0.19**	**0.88**	**1.25**	**0.80**	**0.14**	**0.06**	**0.07**	**0.03**	**0.02**	**0.24**
Minimum	**0.00**	**0.00**	**0.00**	**0.05**	**0.22**	**0.17**	**0.06**	**0.01**	**0.01**	**0.01**	**0.00**	**0.01**	**0.02**

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\EFP Regressions\[OP_EFP_2012 Only.xlsm]Summary Table

NOTE:

1. MEASURED DAILY FLOWS WERE COMPARED TO DAILY FLOWS AT WATER SURVEY OF CANADA HYDROMETRIC STATION HARPER CREEK AT THE MOUTH (08LB076) TO GENERATE THE LONG-TERM SYNTHETIC SERIES.

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:
1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011 AND 2012 DATA COLLECTION PROGRAMS.

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

RATING CURVE
P-CREEK AT HARPER CREEK
(OP)

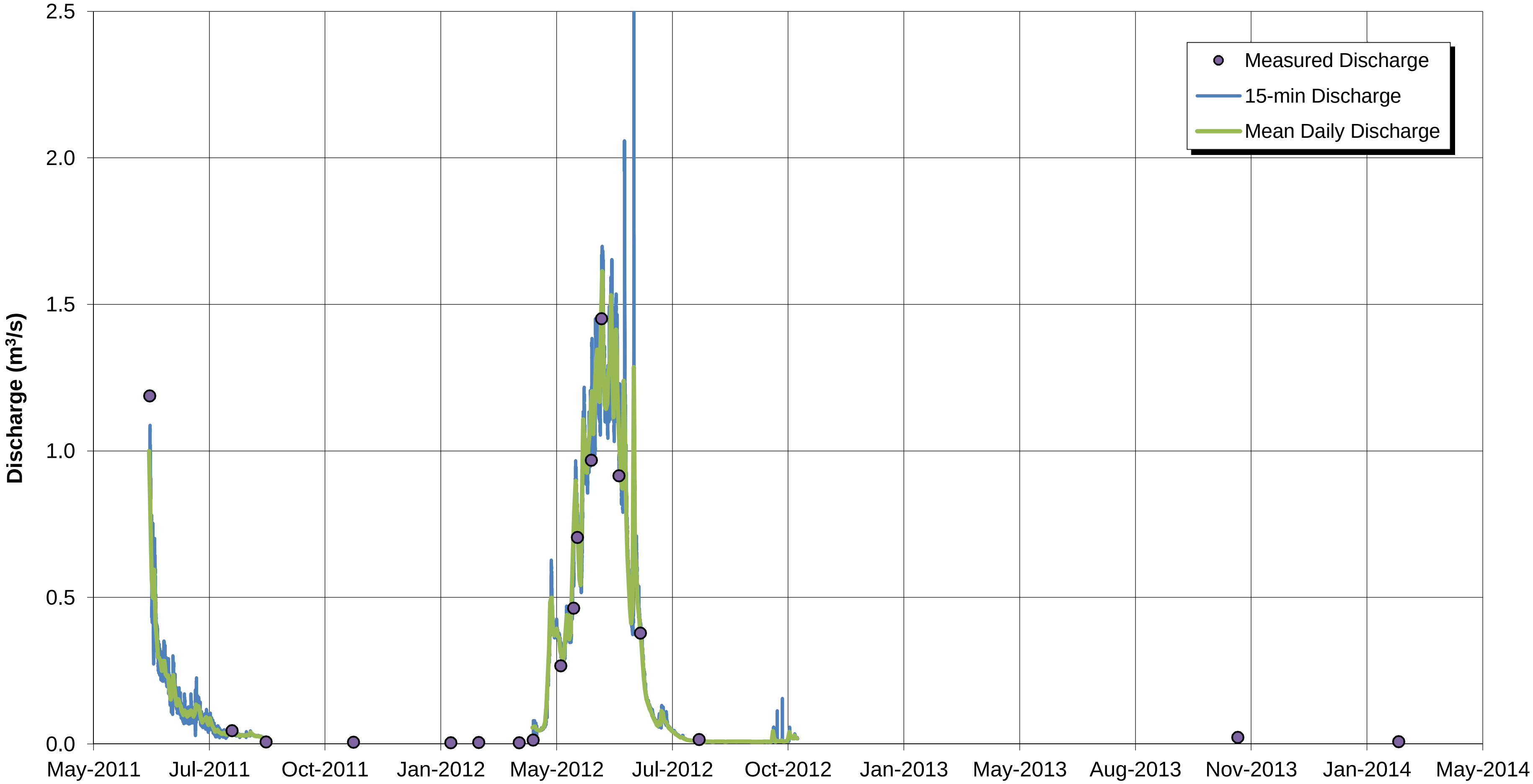
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF. NO. 2

FIGURE D-1

REV 0



NOTE:
1. DATA FROM 2013 WAS REMOVED DUE TO LOGGER MALFUNCTION.

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEASURED STREAMFLOW HYDROGRAPH
P-CREEK AT HARPER CREEK
(OP)

Knight Piésold CONSULTING

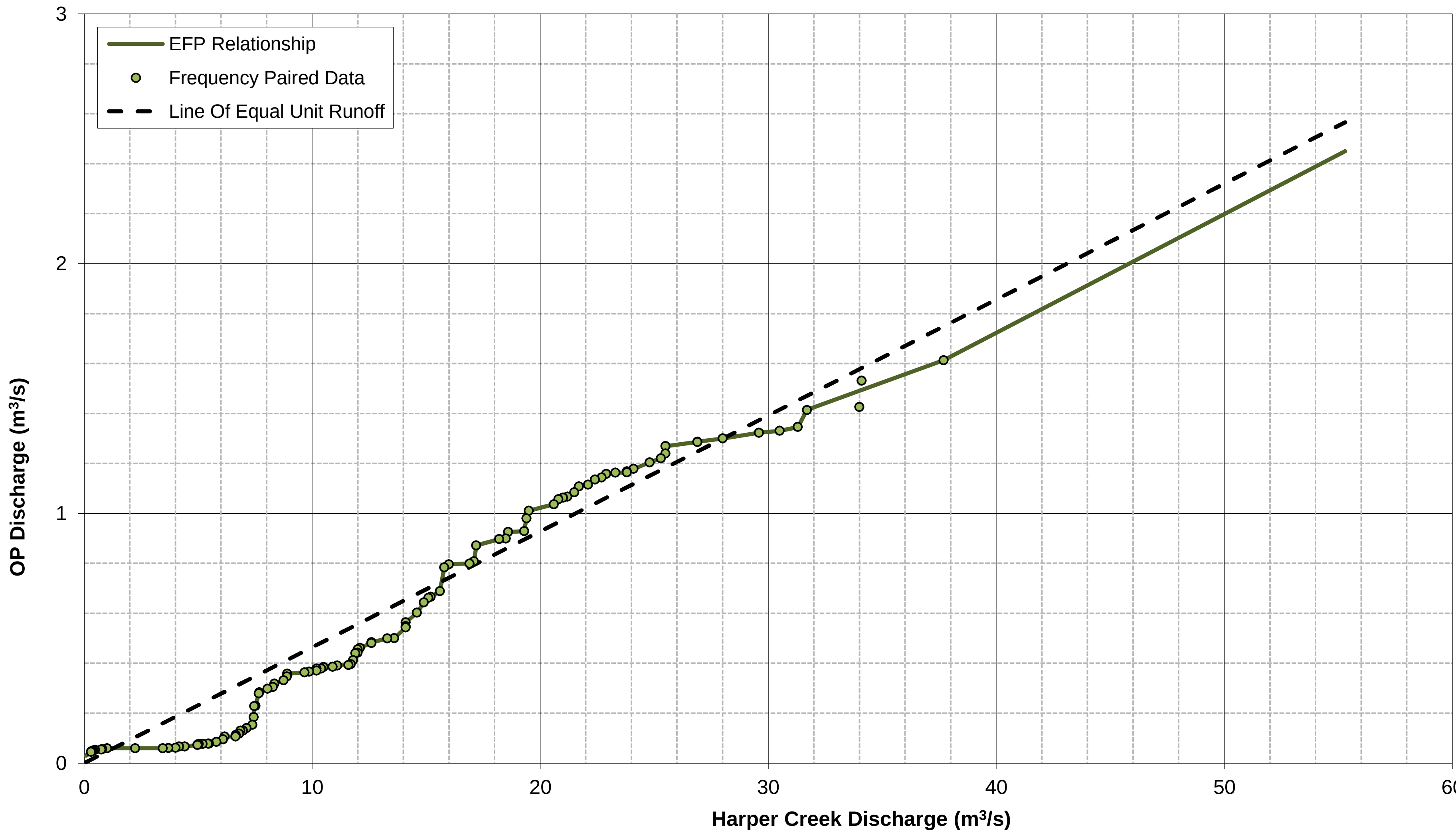
P/A NO. VA101-458/15

REF. NO. 2

FIGURE D-2

REV 0

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTE:
1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST SPRING/SUMMER DISCHARGE IN THE HARPER CREEK SERIES

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

SPRING/SUMMER FREQUENCY PAIRED RELATIONSHIP OP AND WSC'S HARPER CREEK STATIONS

Knight Piésold CONSULTING

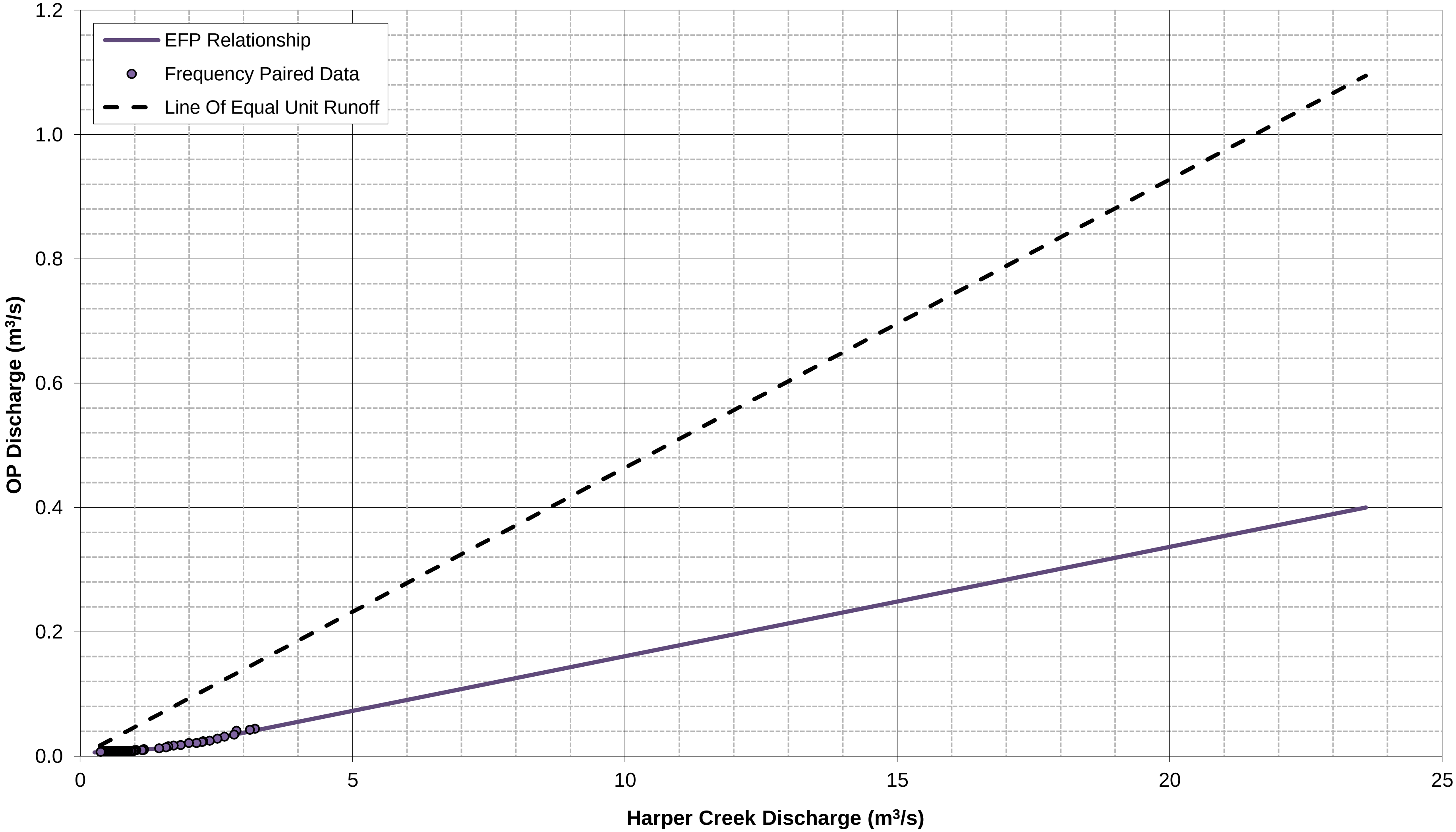
P/A NO. VA101-458/15

REF NO. 2

FIGURE D-3

REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB



NOTE:

1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST AUTUMN DISCHARGE IN THE HARPER CREEK SERIES

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

AUTUMN FREQUENCY PAIRED RELATIONSHIP OP AND WSC'S HARPER CREEK STATIONS

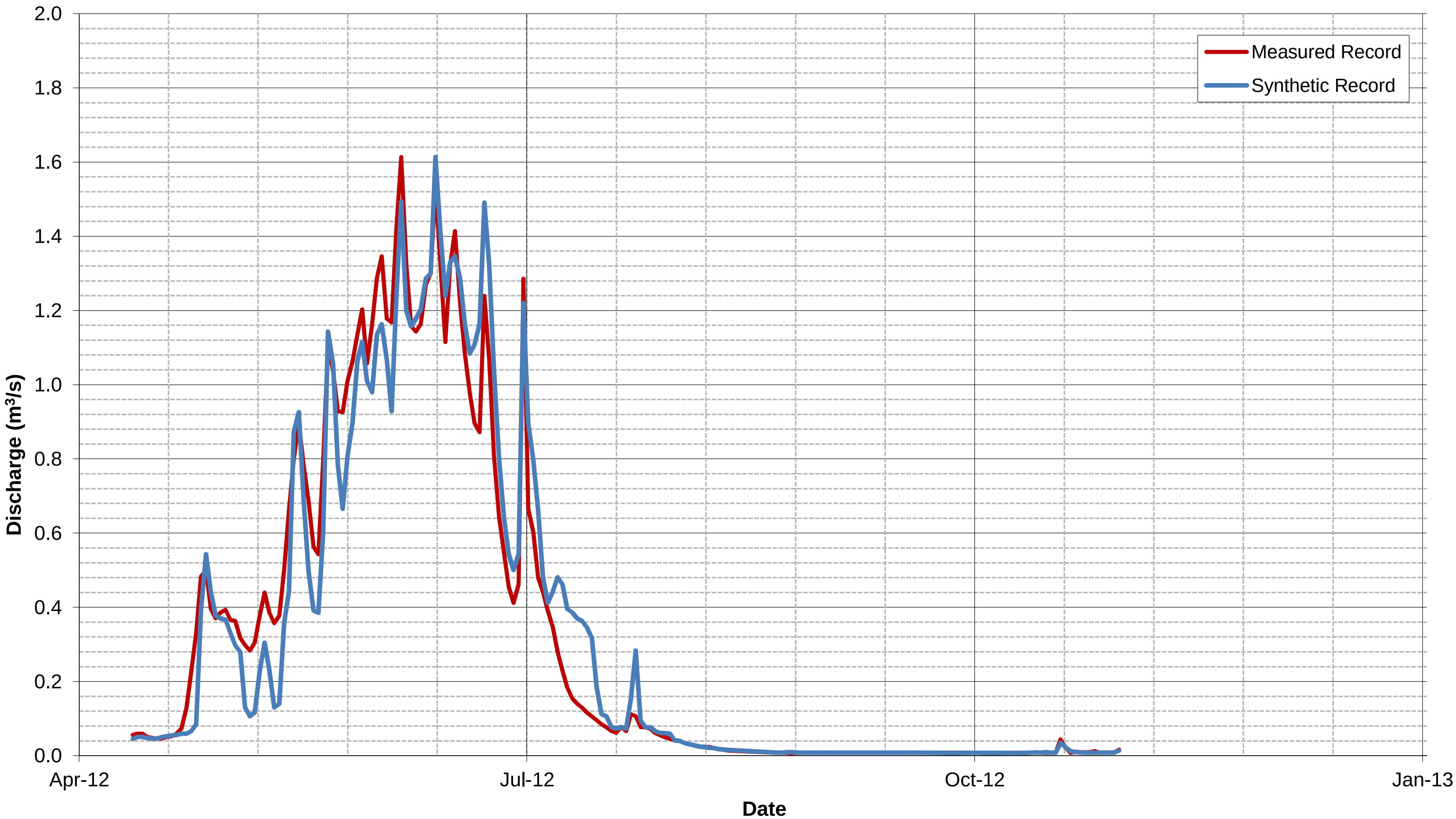
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE D-4

REV 0



NOTE:
1. ONLY 2012 DATA WAS USED TO DEVELOP THE SYNTHETIC RECORD FOR OP.

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

COMPARISON OF MEASURED AND SYNTHETIC HYDROGRAPHS
P-CREEK AT HARPER CREEK (OP)

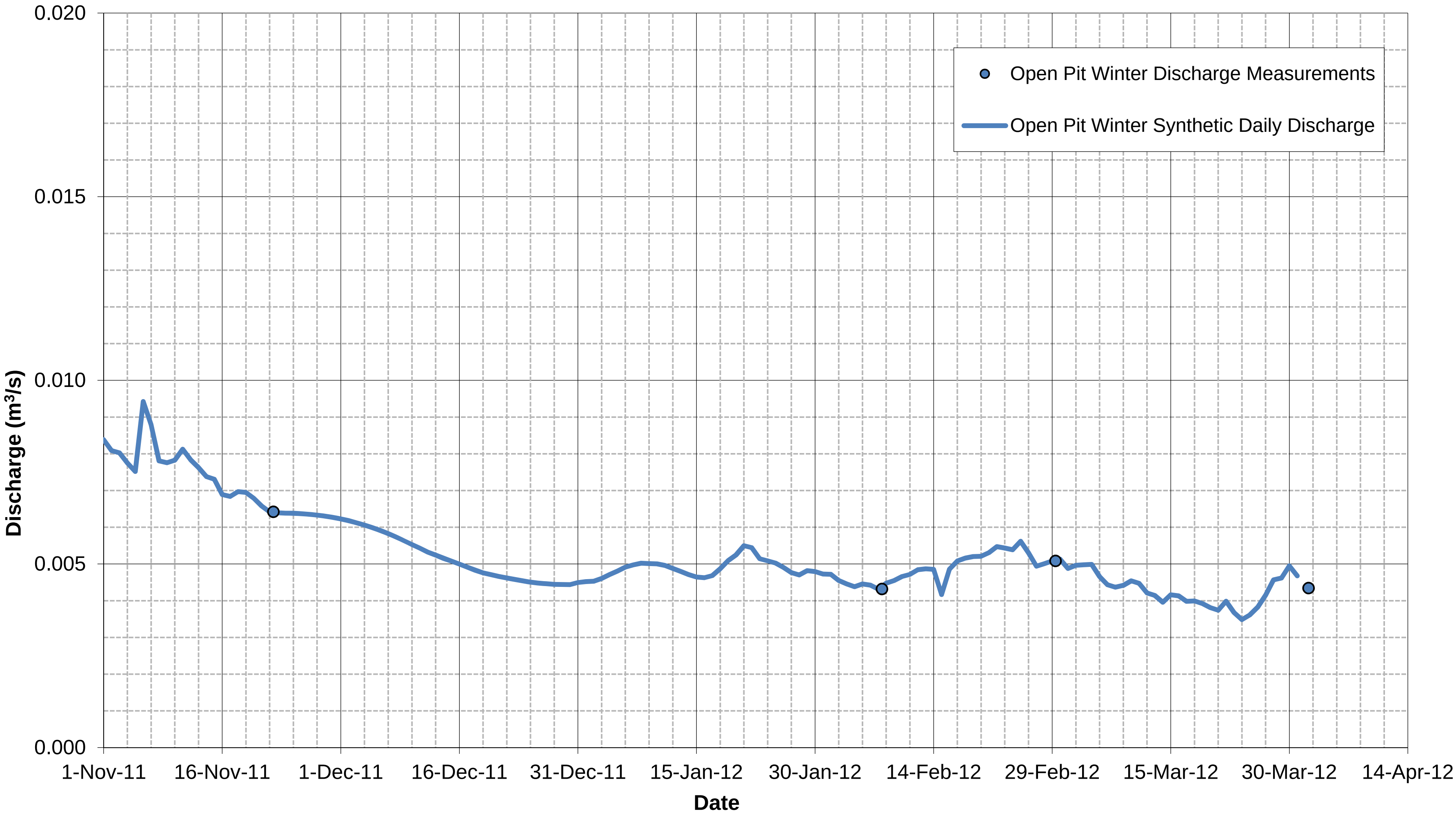
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE D-5

REV 0



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

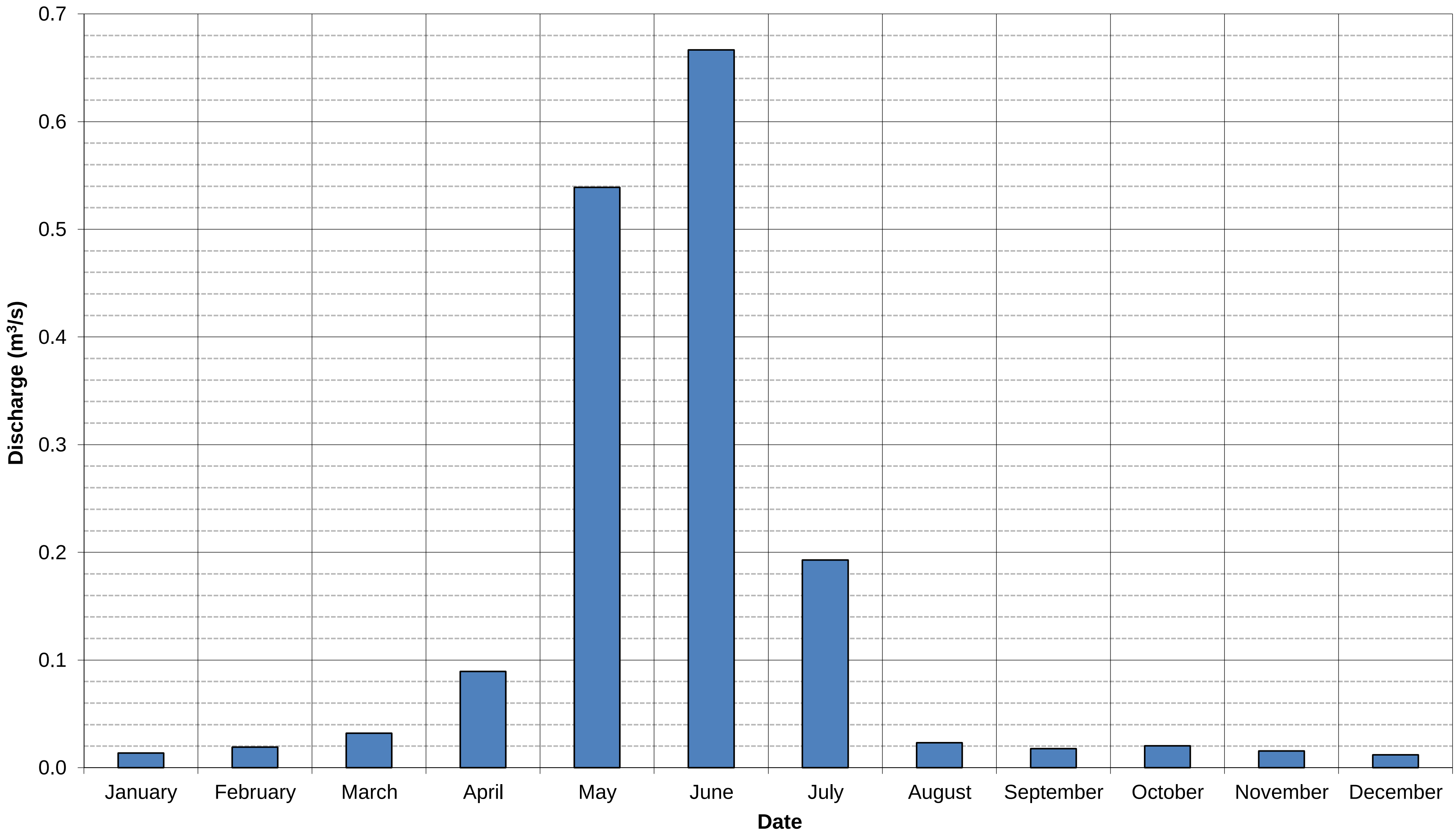
WINTER RELATIONSHIP
OP AND WSC'S HARPER CREEK STATIONS

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE D-6 REV A

A	24APR'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEAN MONTHLY HYDROGRAPH
P-CREEK AT HARPER CREEK (OP)

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2
FIGURE D-7	REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
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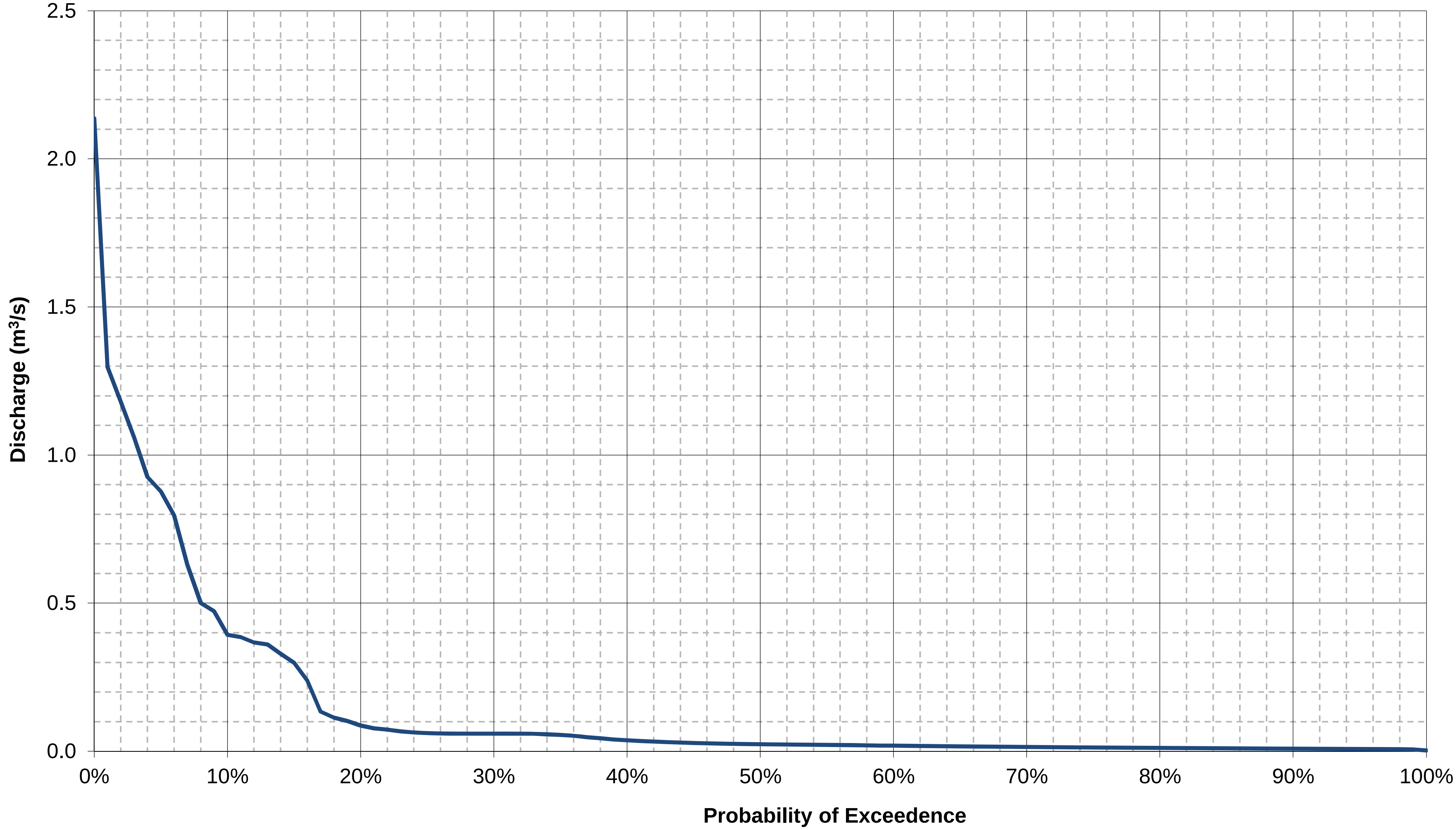

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

LONG TERM FLOW DURATION CURVE
P-CREEK AT HARPER CREEK (OP)

Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE D-8

REV 0

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO D1 – P-Creek hydrology station (OP) during low flows

PHOTO D2 – P-Creek hydrology station (OP), during high flows

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO D3 – P-Creek hydrology station (OP), looking downstream

PHOTO D4 – P-Creek hydrology station (OP), current meter measurement

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX E

P-CREEK UPSTREAM OF STATION OP (OP2)

(Pages E-1 to E-5)

1 – P-CREEK UPSTREAM OF STATION OP (OP2)

1.1 GAUGING STATION SITE SELECTION

Stream:	P-Creek
Location:	0.1 km upstream from station OP
Channel description:	Small pool created by a cobble strep downstream of the gauge.
Site conditions:	Stable hydraulic control, sensitive to flow change and, reasonably good flow measurement conditions
Other key information:	
Photographs:	Photos E1 to E4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	No

1.3 PERIOD OF STAGE RECORD

Installed:	July 30, 2013
Discontinued:	Currently active
2011 record:	No record
2012 record:	No record
2013 record:	July 30 to December 31, 2013 (15% complete)

Battery died a week after installation. As no site visits were made between installation and winterization in 2013, very little stage data exists for 2013. Station winterized in 2013 by placing a glycol bladder over the sensor to prevent it from freezing. .

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	2 (total), see Table E1
Rating curve:	Not completed
Rating curve average error:	-
Rating curve standard error:	-

The rating curve for the OP2 gauging station hasn't been completed as there are too few stage-discharge measurements for curve development.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph: Not completed

1.6 LONG-TERM SYNTHETIC FLOW SERIES

A long-term synthetic flow series wasn't developed for OP2.

Knight Piésold CONSULTING

TABLE E-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
P-CREEK UPSTREAM OF OP (OP2)

Print Aug/18/14 11:52:34

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
31/07/2013	9:41	CM	3.71	0.02	-	-
21/10/2013	8:19	CM	3.72	0.02	-	-
18/01/2014	10:33	CM	-	0.01	-	-
Average Error (%)						-
Standard Error (%)						-

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[StageQ_2014_OP2_20140603.xlsx]DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER.
2. NO STAGE HIEGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO E1 – P-Creek hydrology station (OP2), looking upstream

PHOTO E2 – P-Creek hydrology station (OP2), looking downstream

PHOTO E3 – P-Creek hydrology station (OP2), looking at the right bank

PHOTO E4 – P-Creek hydrology station (OP2), looking at the left bank

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX F

HARPER CREEK BELOW P-CREEK (HARPER2)

(Pages F-1 to F-5)

1 – HARPER CREEK BELOW P-CREEK (HARPER2)

1.1 GAUGING STATION SITE SELECTION

Stream:	Harper Creek
Location:	Immediately downstream of the P-Creek confluence
Channel description:	Small pool created by a cobble strep downstream of the gauge. Installed on footing of washed out bridge.
Site conditions:	Stable hydraulic control, minimal turbulence under a range of flow conditions, sensitive to flow change and, reasonably good flow measurement conditions
Other key information:	
Photographs:	Photos F1 to F4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	No

1.3 PERIOD OF STAGE RECORD

Installed:	July 30, 2013
Discontinued:	Currently active
2011 record:	No record
2012 record:	No record
2013 record:	July 30 to December 31, 2013 (100% complete)

Station winterized in 2013 by placing a glycol bladder over the sensor to prevent it from freezing. .

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	2 (total), see Table F1
Rating curve:	Not completed
Rating curve average error:	-
Rating curve standard error:	-

The rating curve for the HARPER2 gauging station hasn't been completed as there are too few stage-discharge measurements for curve development.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph: Not completed

1.6 LONG-TERM SYNTHETIC FLOW SERIES

A long-term synthetic flow series wasn't developed for HARPER2.

Knight Piésold
CONSULTING

TABLE F-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
HARPER CREEK DOWNSTREAM OF P-CREEK (HARPER2)

Print Aug/18/14 11:56:12

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
31/07/2013	8:50	CM	4.16	0.06	-	-
21/10/2013	11:56	CM	4.17	0.06	-	-
18/01/2014	11:43	CM	-	0.02	-	-
25/02/2014	16:11	CM	-	0.01	-	-
Average Error (%)						-
Standard Error (%)						-

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[StageQ_2014_HARPER2_20140603.xlsx]DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER.
2. NO STAGE HIEGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO F1 – Harper Creek hydrology station (HARPER2), during low flows

PHOTO F2 – Harper Creek hydrology station (HARPER2), looking downstream

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO F3 – Harper Creek hydrology station (HARPER2), looking upstream

PHOTO F4 – Harper-Creek hydrology station (HARPER2), current meter measurement

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX G

HARPER CREEK UPSTREAM OF T-CREEK (HARPERUS)

(Pages G-1 to G-14)

1 – HARPER CREEK UPSTREAM OF T-CREEK (HARPERUS)

1.1 GAUGING STATION SITE SELECTION

Stream:	Harper Creek
Location:	Immediately upstream of the T-Creek confluence
Channel description:	Cobble and gravel low gradient channel bed creates control for gauging station
Site conditions:	Stable hydraulic control, minimal turbulence at most flow conditions, reasonably good flow measurement conditions at lower flows
Other key information:	Difficult to accurately measure high flows
Photographs:	Photos G1 to G4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	No

1.3 PERIOD OF STAGE RECORD

Installed:	June 3, 2011
Discontinued:	Currently active
2011 record:	June 3 to November 22, 2011 (100% complete)
2012 record:	April 12 to November 7, 2012 (100% complete)
2013 record:	July 30 to December 31, 2013 (100% complete)

Station was winterized over the 2013/2014 winter and instrumentation was not removed.

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	16 (total), 16 (used for rating curve), see Table G1
Rating curve:	See Figure G1
Rating curve average error:	+6%
Rating curve standard error:	17%

The rating curve for the HARPERUS gauging station is considered good quality in the low and mid flow range. The upper portion of the curve is poorly defined due to challenging site condition for measuring high flows.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph:	Figure G2

1.6 LONG-TERM SYNTHETIC FLOW SERIES

Seasonal EFP relationships:	Figures G3 and G4
Comparison to Harper Creek (WSC Station 08LB076):	Spring/summer: slightly lower unit runoff to 08LB076 Autumn: lower unit runoff than 08LB0176
Comparison of measured and synthetic streamflow hydrographs:	Open water season: Figure G5 Winter: Figure G6
Long-term mean monthly flow hydrograph (synthetic):	Figure G7
Long-term flow duration curve (synthetic):	Figure G8
Long-term monthly and annual flows (synthetic):	Table G2

Station HARPERUS has lower unit runoff than the WSC station on Harper Creek in the spring/summer season and in the autumn. The slightly lower unit runoff in spring/summer is generally attributed to smaller snowpack in watershed of HARPERUS, while the lower unit runoff in autumn is attributed to the smaller watershed area and smaller groundwater contribution.

It should be noted that the EFP relationship is extrapolated significantly in the autumn season. During the period of measured record at HARPERUS, no significant autumn storms were recorded. A relationship parallel to the unit discharge line was selected for extrapolation.

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TABLE G-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
HARPER CREEK UPSTREAM OF T-CREEK (HARPERUS)

Print Aug/18/14 12:07:12

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
03/06/2011	12:56	RD	8.96	5.99	6.62	11%
13/06/2011	15:04	RD	8.94	7.46	5.89	-21%
20/07/2011	10:25	CM	8.68	1.80	1.73	-3%
18/08/2011	14:05	CM	8.51	0.54	0.44	-17%
14/09/2011	12:11	CM	8.47	0.21	0.26	22%
22/11/2011	15:35	CM	-	0.13	-	-
07/02/2012	13:03	CM	-	0.12	-	-
29/02/2012	12:05	CM	-	0.09	-	-
01/04/2012	12:24	CM	-	0.11	-	-
12/04/2012	16:06	CM	8.46	0.18	0.22	22%
03/05/2012	12:59	CM	8.70	1.94	1.95	1%
16/05/2012	9:16	CM	8.94	4.37	5.86	34%
17/05/2012	13:15	CM	8.87	3.88	4.26	10%
30/05/2012	7:07	CM	8.94	5.08	5.96	17%
06/06/2012	13:07	RD	9.07	15.55	11.95	-23%
19/06/2012	12:44	CM	8.96	5.79	6.70	16%
04/07/2012	13:40	CM	8.85	3.07	3.93	28%
07/11/2012	12:50	CM	8.50	0.39	0.36	-7%
22/08/2012	9:26	CM	8.49	0.32	0.32	0%
21/10/2013	13:10	CM	8.51	0.39	0.45	15%
25/02/2014	12:13	CM	-	0.10	-	-
Average Error (%)						6%
Standard Error (%)						17%

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[PreliminaryRatingCurve_2013_HARPERUS_20140602.xlsx]DischargeSummaryTa

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE SLUG INJECTION.
2. NO STAGE HEIGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.
3. RATING CURVE ERROR IS THE DIFFERENCE BETWEEN THE RATING CURVE DISCHARGE AND THE MEASURED DISCHARGE, ASSUMING THE MEASURED DISCHARGE IS THE "TRUE" DISCHARGE.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

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TABLE G-2

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

LONG-TERM SYNTHETIC DISCHARGE AT HARPER CREEK UPSTREAM OF T-CREEK (HARPERUS) (m^3/s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	-	-	-	-	-	-	0.93	0.37	0.30	0.43	0.15	0.05	0.36
1974	0.21	0.20	0.20	0.71	2.37	7.61	3.15	0.68	0.39	0.26	0.04	0.01	1.32
1975	0.20	0.18	0.19	0.29	2.14	6.05	2.01	0.54	0.40	0.62	1.01	0.32	1.16
1976	0.29	0.24	0.22	0.48	3.70	3.94	2.77	1.86	0.77	0.45	0.22	0.06	1.25
1977	0.22	0.22	0.24	0.80	1.81	1.92	0.85	0.44	0.58	0.43	0.07	0.05	0.64
1978	0.25	0.21	0.27	0.97	4.57	4.27	1.14	0.48	0.90	0.49	0.23	0.06	1.16
1979	0.22	0.20	0.22	0.40	2.20	2.30	0.70	0.31	0.34	0.36	0.06	0.04	0.61
1980	0.19	0.22	0.21	1.12	3.34	1.52	0.98	0.49	0.55	0.46	0.81	0.23	0.85
1981	0.31	0.30	0.32	0.57	4.03	2.70	1.49	0.46	0.46	1.00	1.35	0.36	1.12
1982	0.26	0.25	0.24	0.34	2.95	6.29	2.56	0.79	0.69	0.80	0.63	0.07	1.32
1983	0.30	0.31	0.42	1.00	4.50	4.06	1.96	0.49	0.50	0.47	1.22	0.13	1.28
1984	0.28	0.27	0.28	0.65	1.71	7.30	3.46	0.57	0.49	0.46	0.10	0.04	1.30
1985	0.21	0.20	0.21	0.62	3.68	3.73	0.98	0.36	0.42	0.46	0.15	0.05	0.93
1986	0.22	0.23	0.25	0.62	3.19	3.72	1.00	0.37	0.33	0.42	0.08	0.05	0.88
1987	0.20	0.20	0.30	1.01	3.78	1.81	0.48	0.35	0.22	0.23	0.04	0.03	0.72
1988	0.17	0.19	0.21	1.15	3.61	2.95	1.29	0.42	0.41	0.52	0.55	0.06	0.96
1989	0.23	0.21	0.22	0.90	3.16	3.34	0.80	0.71	0.48	0.45	0.95	0.25	0.98
1990	0.30	0.25	0.24	1.08	2.66	4.42	1.51	0.40	0.30	0.33	0.46	0.06	1.00
1991	0.22	0.27	0.26	0.84	2.90	3.01	1.34	0.54	0.48	0.27	0.05	0.04	0.85
1992	0.22	0.24	0.50	1.48	3.34	2.20	0.73	0.35	0.37	0.43	0.29	0.06	0.85
1993	0.20	0.19	0.20	0.60	4.08	1.70	0.79	0.51	0.38	0.29	0.05	0.04	0.76
1994	0.22	0.20	0.25	1.58	3.53	2.65	1.06	0.38	0.30	0.26	0.05	0.03	0.88
1995	0.21	0.22	0.23	0.52	3.36	3.08	0.81	0.71	0.39	0.52	0.60	0.22	0.91
1996	0.25	0.24	0.29	1.04	2.36	5.43	2.18	0.54	0.53	0.45	0.79	0.18	1.19
1997	0.25	0.22	0.23	0.55	4.46	4.46	2.03	0.59	0.66	0.92	0.88	0.14	1.29
1998	0.27	0.28	0.31	0.85	4.20	1.61	0.57	0.27	0.22	0.34	0.06	0.06	0.76
1999	0.23	0.23	0.25	0.82	3.02	7.65	4.51	0.98	0.45	0.40	0.98	0.31	1.66
2000	0.29	0.24	0.23	0.72	2.32	4.53	1.82	0.49	0.41	0.41	0.16	0.02	0.97
2001	0.21	0.18	0.21	0.37	2.23	2.74	1.59	0.52	0.32	0.30	0.06	-	0.86
2002	-	-	0.22	0.58	3.03	6.10	1.55	0.41	0.34	0.30	0.06	0.05	1.35
2003	0.22	0.19	0.21	0.72	2.72	3.50	0.59	0.22	0.19	0.51	0.14	0.03	0.77
2004	0.17	0.16	0.20	1.05	2.83	2.27	0.69	0.32	0.63	0.41	0.42	0.22	0.78
2005	0.56	0.60	0.44	1.09	4.28	2.54	1.15	0.40	0.38	0.88	0.69	0.15	1.10
2006	0.35	0.28	0.28	0.72	4.69	2.68	0.52	0.30	0.27	0.24	0.07	0.01	0.87
2007	0.18	0.16	0.19	0.62	2.84	4.34	0.83	0.33	0.31	0.62	0.51	0.13	0.92
2008	0.25	0.26	0.26	0.30	5.04	4.05	1.23	0.41	0.33	0.43	0.68	0.06	1.11
2009	0.23	0.22	0.21	0.34	2.34	3.40	0.79	0.29	0.25	0.29	0.06	0.04	0.71
2010	0.23	0.24	0.27	0.65	2.31	3.72	1.07	0.35	0.45	0.40	0.09	0.06	0.82
2011	0.21	0.19	0.14	0.16	2.56	6.76	2.30	0.54	0.28	0.35	0.05	0.03	1.13
2012	0.12	0.09	0.06	0.62	3.13	6.67	2.14	0.42	0.23	0.29	0.26	0.03	1.17
2013	0.16	0.21	0.23	0.99	4.83	3.89	1.00	0.36	0.53	0.63	0.17	0.03	1.09
Average	**0.24**	**0.23**	**0.25**	**0.75**	**3.24**	**3.92**	**1.45**	**0.50**	**0.42**	**0.45**	**0.37**	**0.10**	**0.99**
Maximum	**0.56**	**0.60**	**0.50**	**1.58**	**5.04**	**7.65**	**4.51**	**1.86**	**0.90**	**1.00**	**1.35**	**0.36**	**1.66**
Minimum	**0.12**	**0.09**	**0.06**	**0.16**	**1.71**	**1.52**	**0.48**	**0.22**	**0.19**	**0.23**	**0.04**	**0.01**	**0.36**

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\EFP Regressions\[HARPERUS (Alternate).xlsm]Summary Table

NOTE:

1. MEASURED DAILY FLOWS WERE COMPARED TO DAILY FLOWS AT WATER SURVEY OF CANADA HYDROMETRIC STATION HARPER CREEK AT THE MOUTH (08LB076) TO GENERATE THE LONG-TERM SYNTHETIC SERIES.

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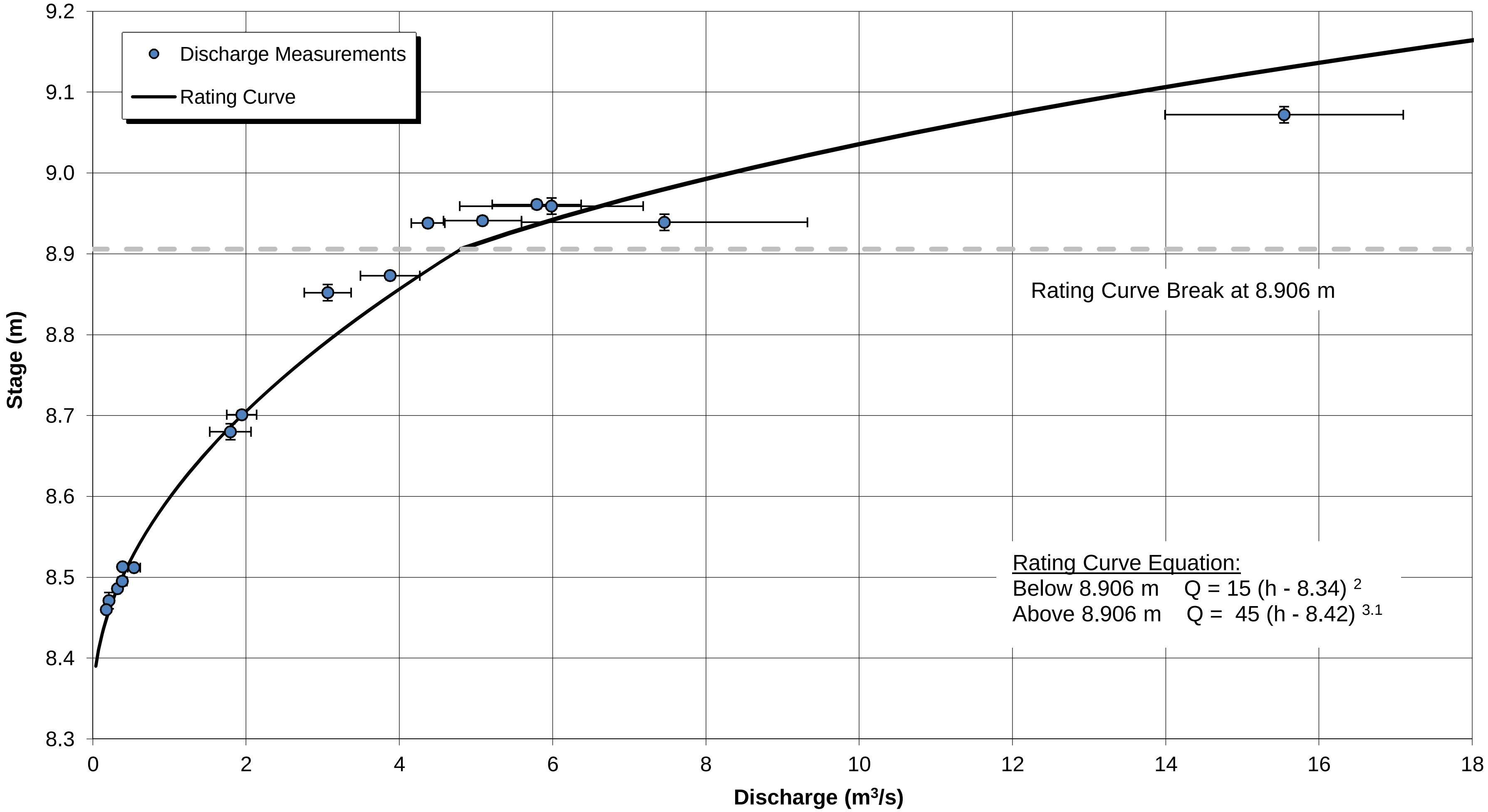
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:

1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011 AND 2012 DATA COLLECTION PROGRAMS.

0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

RATING CURVE
HARPER CREEK UPSTREAM OF T-CREEK
(HARPERUS)

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P/A NO. VA101-458/15

REF. NO. 2

FIGURE G-1

REV 0

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[PreliminaryRatingCurve_2013_HARPERUS_20140602.xls]HYDROGRAPH
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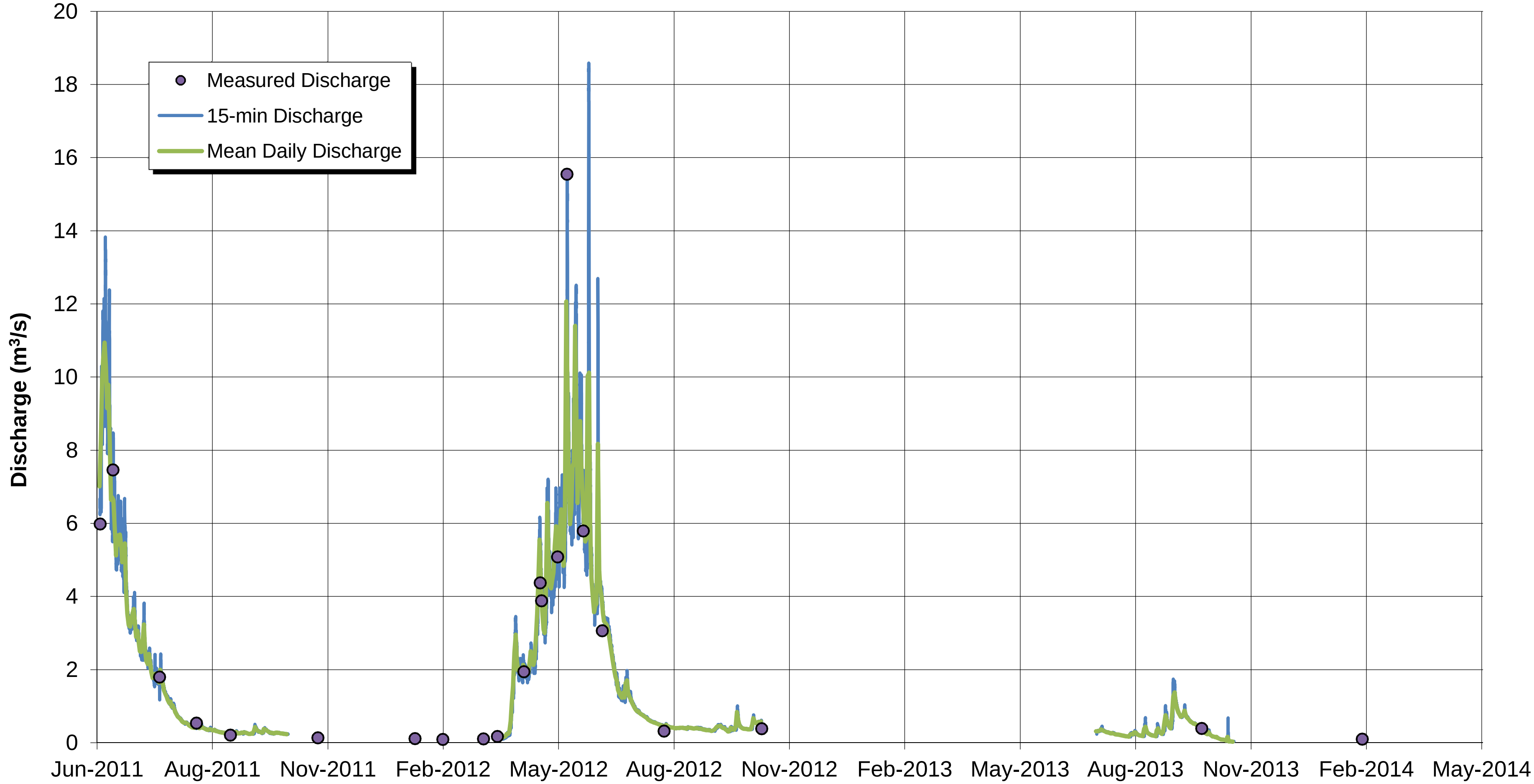


0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEASURED STREAMFLOW HYDROGRAPH
HARPER CREEK UPSTREAM OF T-CREEK
(HARPERUS)

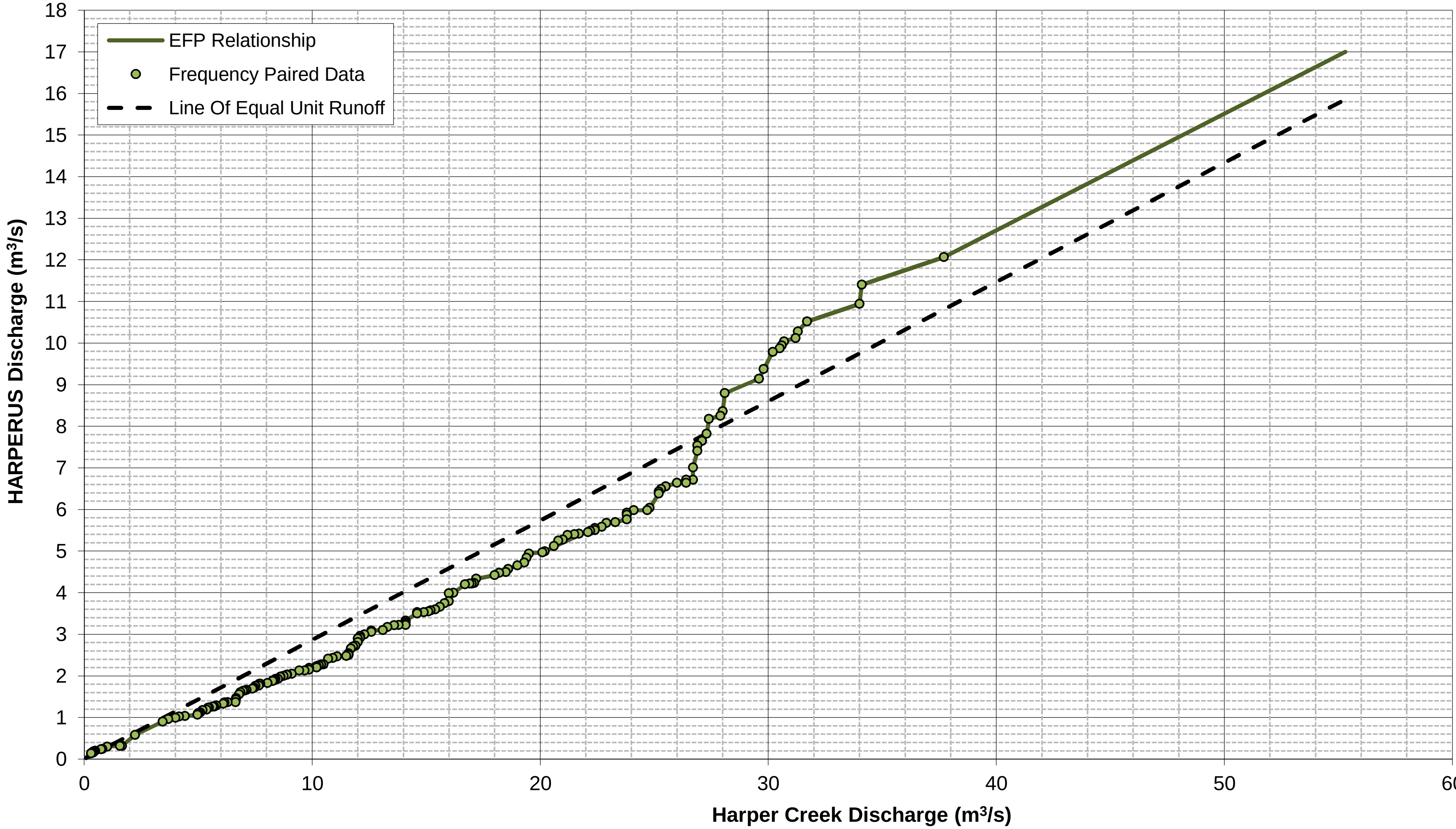
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF. NO. 2

FIGURE G-2

REV 0



NOTE:
1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST SPRING/SUMMER DISCHARGE IN THE WSC'S HARPER CREEK SERIES

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

SPRING/SUMMER FREQUENCY PAIRED RELATIONSHIP HARPERUS AND WSC'S HARPER CREEK STATIONS

Knight Piésold CONSULTING

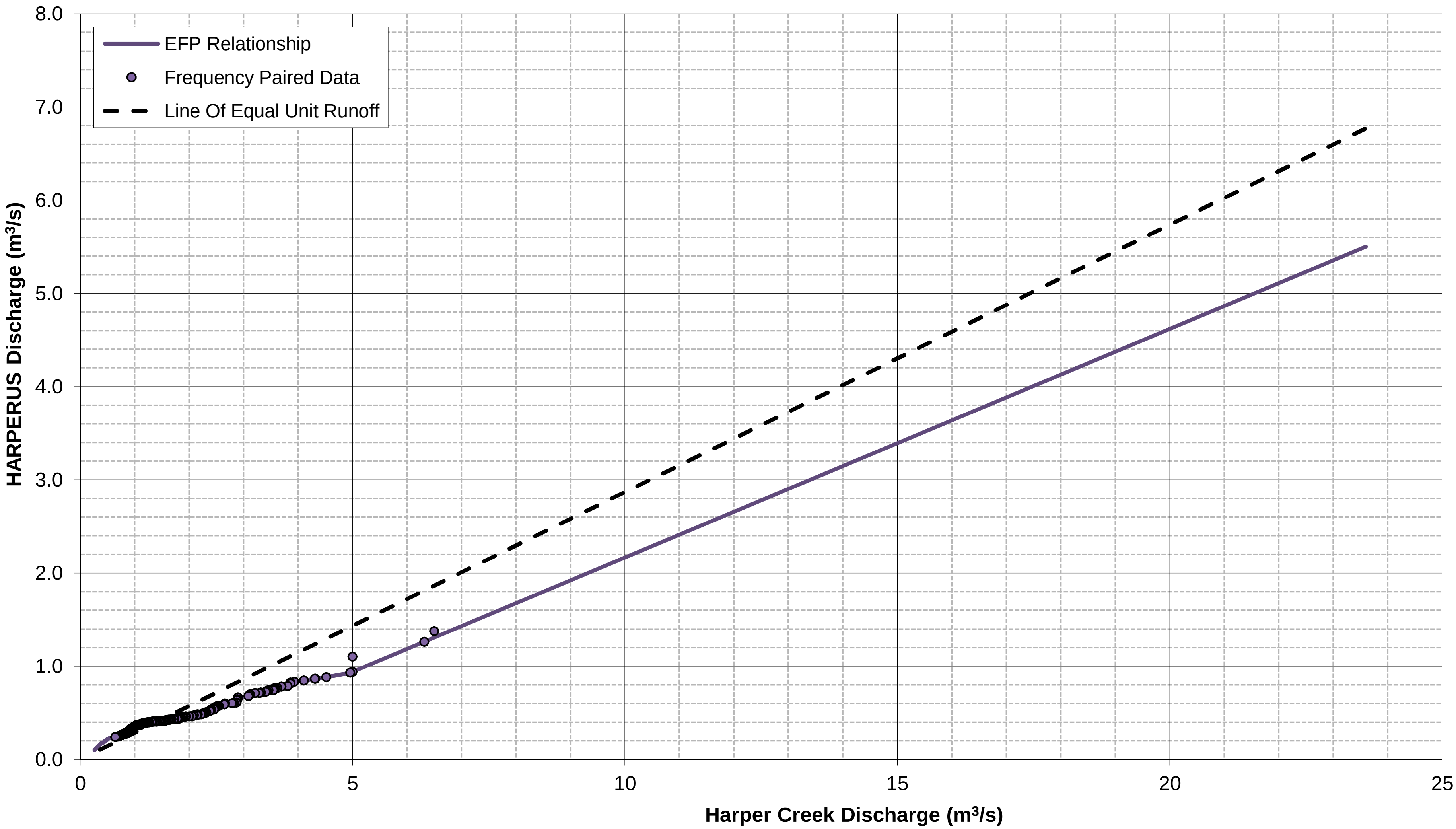
P/A NO. VA101-458/15

REF NO. 2

FIGURE G-3

REV 0

0	22AUG'14	ISSUED WITH REPORT	SCR	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTE:

1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST AUTUMN DISCHARGE IN THE WSC'S HARPER CREEK SERIES

0	22AUG'14	ISSUED WITH REPORT	SCR	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

AUTUMN FREQUENCY PAIRED RELATIONSHIP HARPERUS AND WSC'S HARPER CREEK STATIONS

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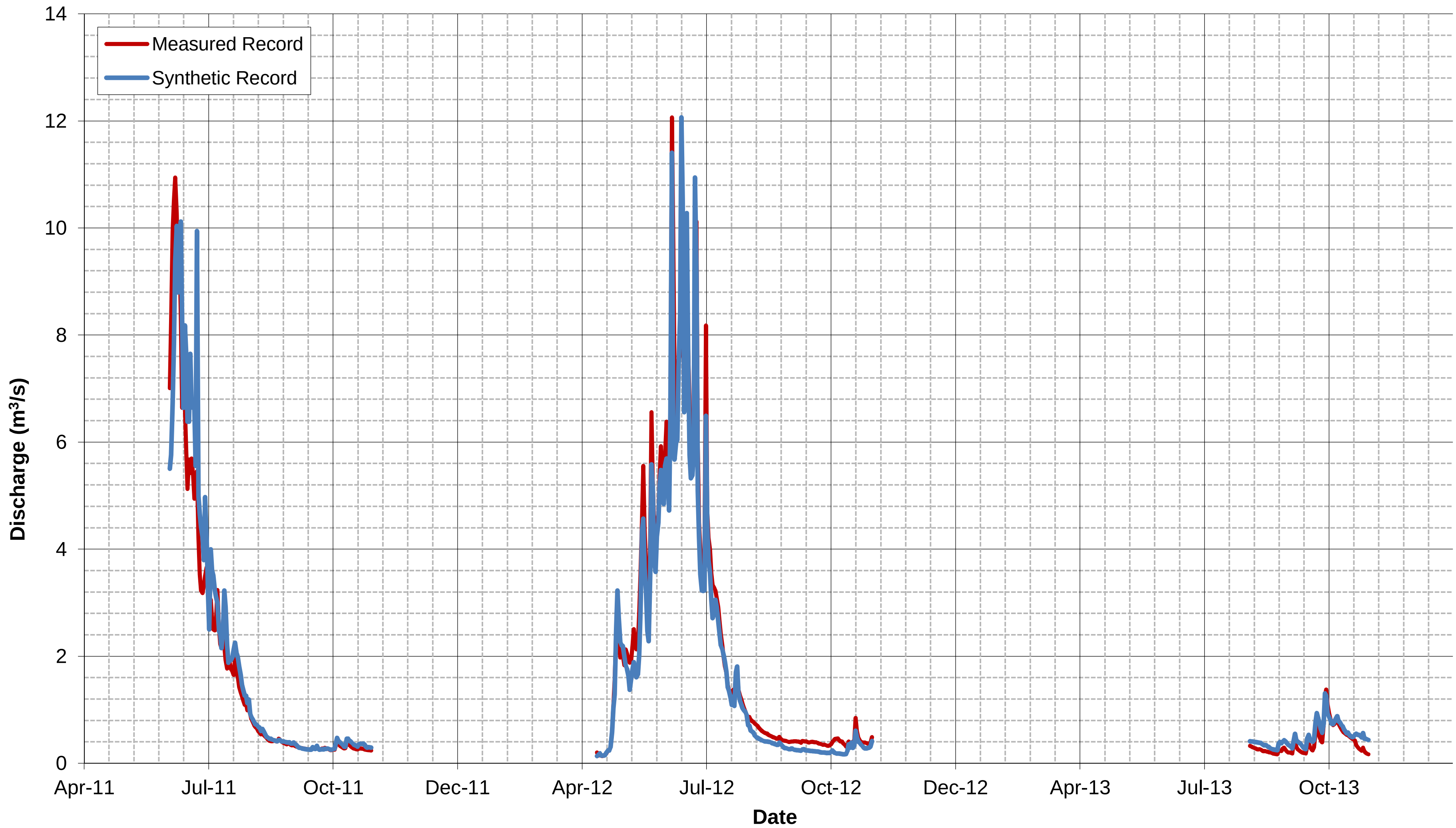
P/A NO. VA101-458/15

REF NO. 2

FIGURE G-4

REV 0



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

COMPARISON OF MEASURED AND SYNTHETIC HYDROGRAPHS
HARPER CREEK UPSTREAM OF T-CREEK (HARPERUS)

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P/A NO.	REF NO.
VA101-458/15	2

FIGURE G-5 REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
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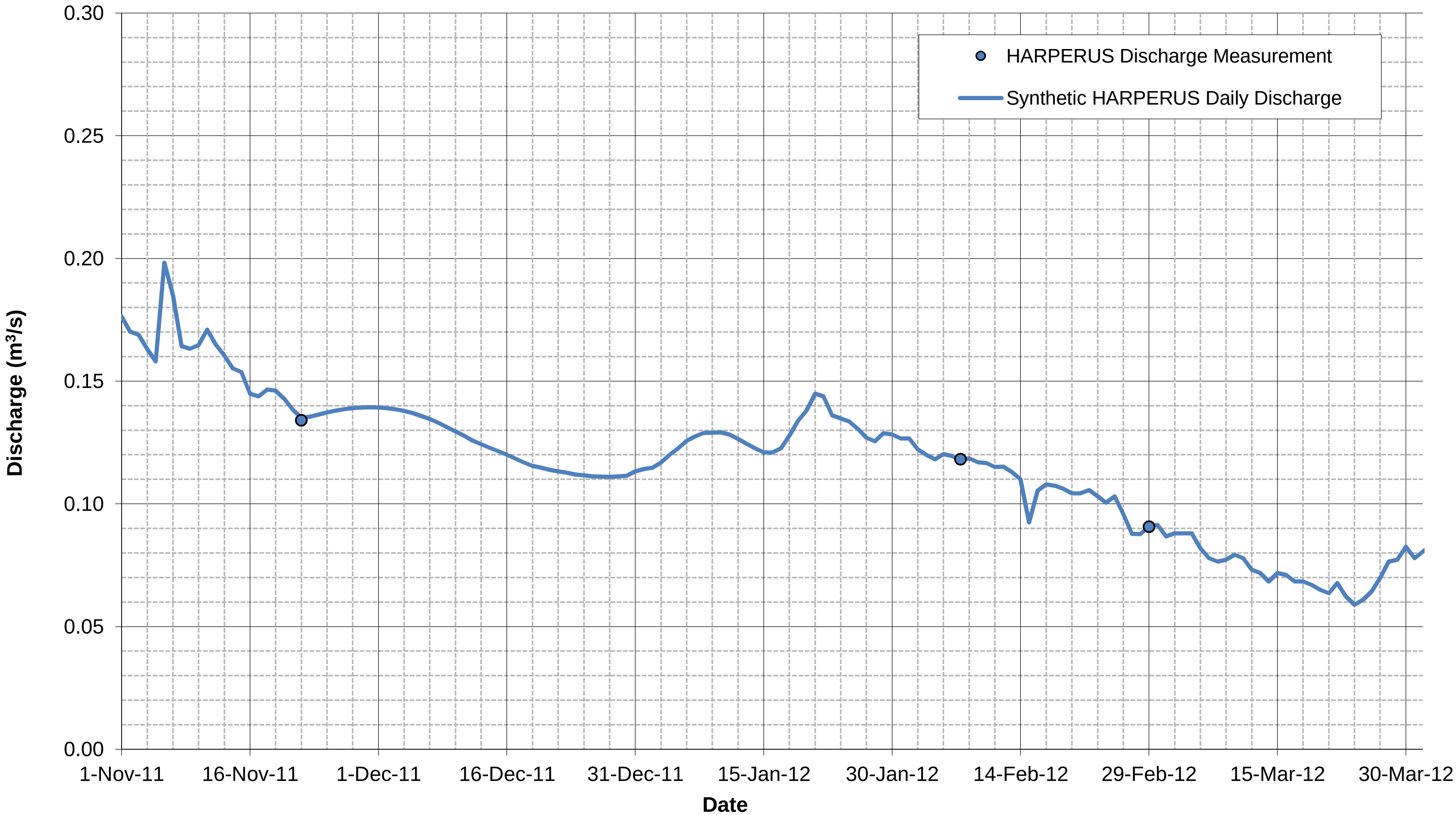

0	03JUN'14	ISSUED WITH REPORT	ACA	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

WINTER RELATIONSHIP
HARPERUS AND WSC'S HARPER CREEK STATIONS

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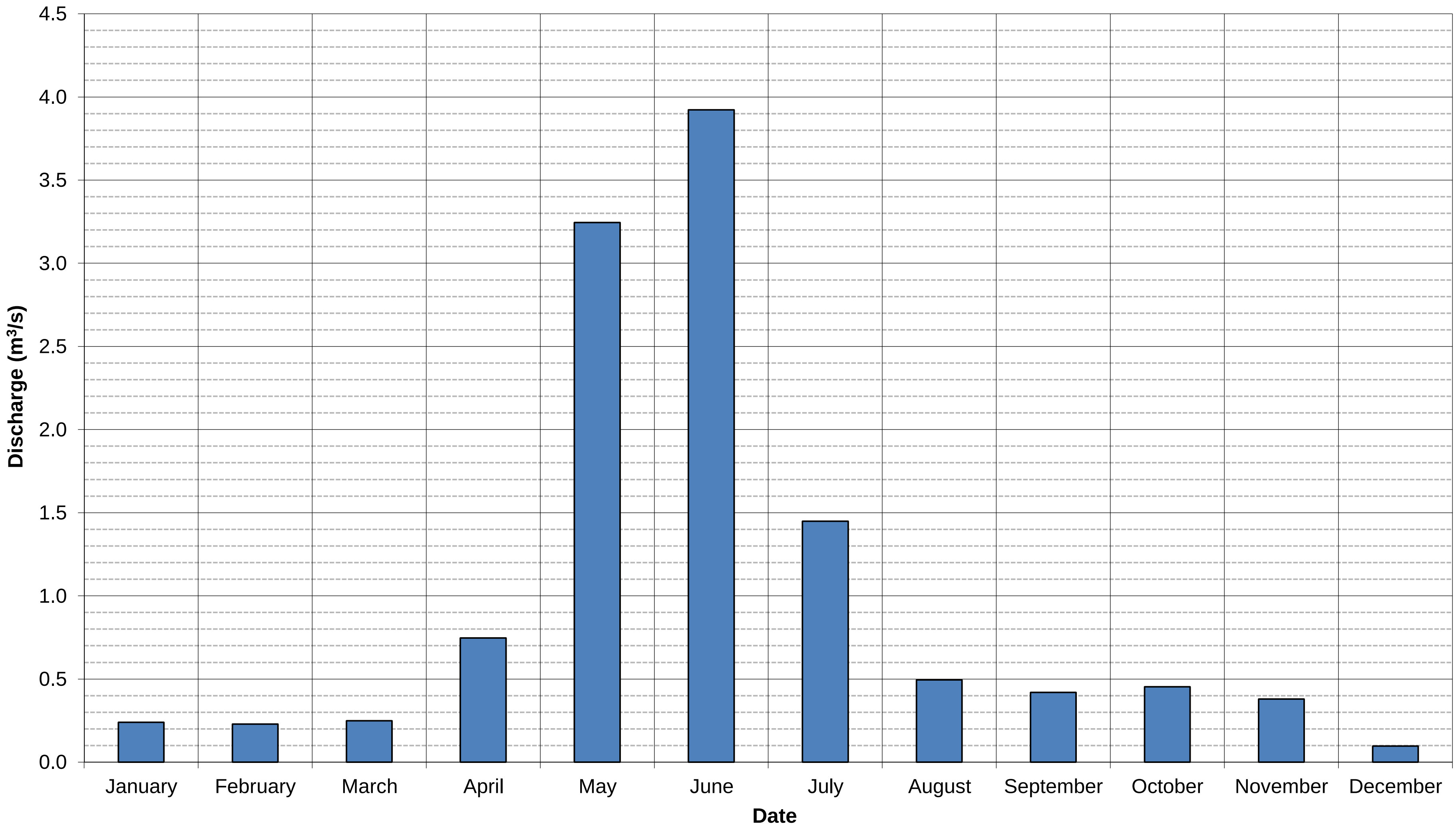
P/A NO. VA101-458/15

REF NO. 2

FIGURE G-6

REV A



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

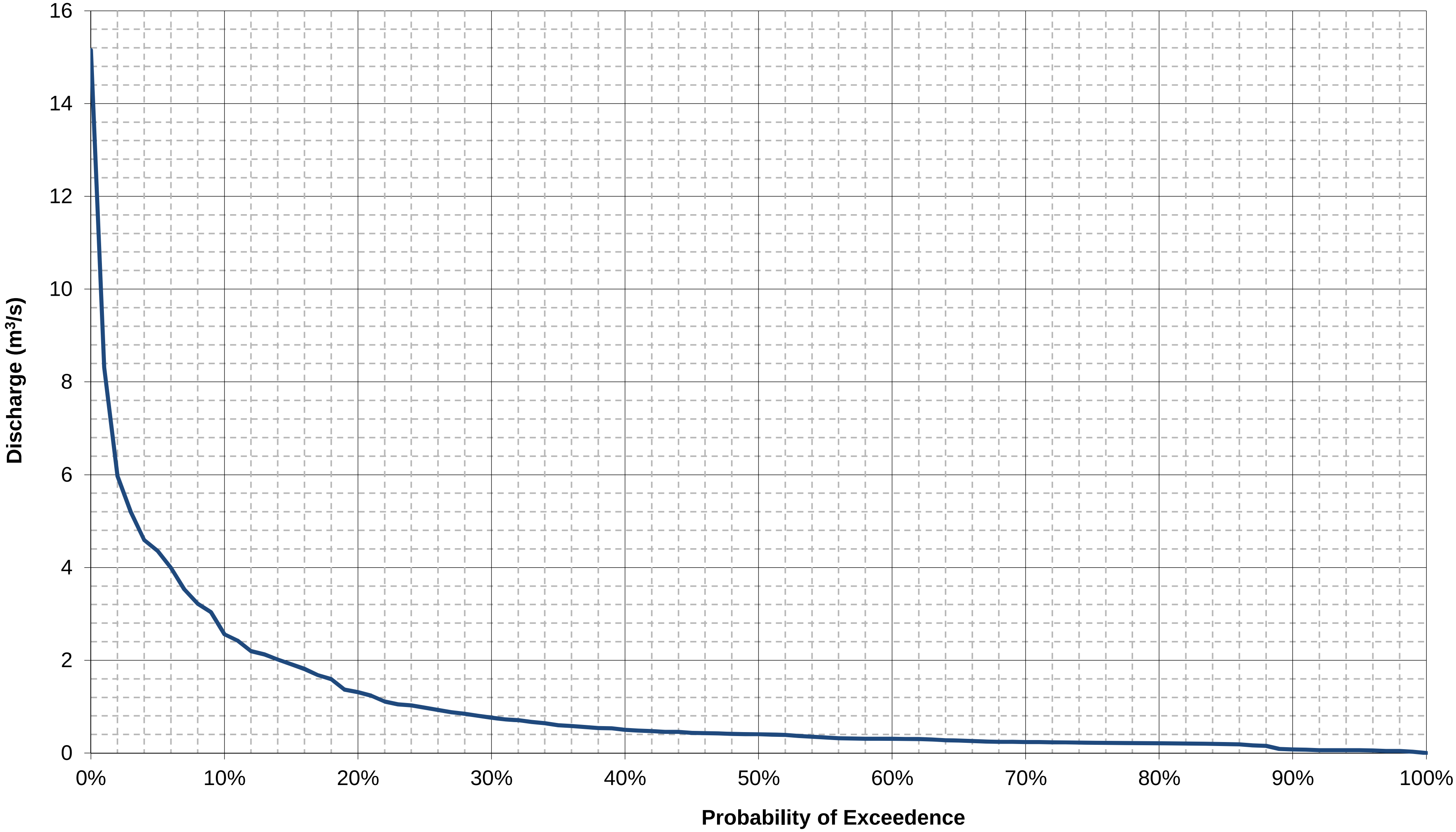
SYNTHETIC MEAN MONTHLY HYDROGRAPH
HARPER CREEK UPSTREAM OF T-CREEK (HARPERUS)

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE G-7 REV 0

0	22AUG'14	ISSUED WITH REPORT	SCR	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

LONG TERM FLOW DURATION CURVE
HARPER CREEK UPSTREAM OF T-CREEK
(HAREPERUS)

Knight Piésold CONSULTING

P/A NO.	REF NO.
VA101-458/15	2

FIGURE G-8 REV 0

0	22AUG'14	ISSUED WITH REPORT	SCR	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO G1 – Harper Creek hydrology station (HARPERUS)

PHOTO G2 – Harper Creek hydrology station (HARPER2), looking upstream

PHOTO G3 – Harper Creek hydrology station (HARPERUS), looking downstream during low flows

PHOTO G4 – Harper-Creek hydrology station (HARPERUS), looking downstream during high flows

APPENDIX H

T-CREEK NEAR HARPER CREEK (TSFDS)

(Pages H-1 to H-14)

1 – T-CREEK NEAR HARPER CREEK (TSFDS)

1.1 GAUGING STATION SITE SELECTION

Stream:	T-Creek
Location:	Just upstream of the Harper Creek Forest Service Road (FSR) bridge
Channel description:	Small pool created by a cobble step downstream of the gauge
Site conditions:	Stable hydraulic control, minimal turbulence at low and average flow conditions, reasonably good flow measurement conditions
Other key information:	There is a small distributary that splits off the left bank approximately 50 m upstream of the gauging site. Flow in this distributary was measured to calculate the total flow although it represented a small portion of the total flow (typically less than 5%).
Photographs:	Photos H1 to H4.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	Yes

1.3 PERIOD OF STAGE RECORD

Installed:	May 21, 2011
Discontinued:	Currently active
2011 record:	May 21 to November 22, 2011 (100% complete)
2012 record:	April 13 to November 7, 2012 (100% complete)
2013 record:	July 30 to December 31, 2013 (100% complete)

Station was winterized over the 2013/2014 winter and instrumentation was not removed.

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	14 (total), 14 (used for rating curve), see Table H1
Rating curve:	See Figure H1
Rating curve average error:	+2%

Rating curve standard error: 30%

The rating curve for the TSFDS gauging station is considered good quality. The large standard error is due primarily to high error in the last measurement collected.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph: Figure H2

1.6 LONG-TERM SYNTHETIC FLOW SERIES

Seasonal EFP relationships:	Figures H3 and H4
Comparison to Harper Creek (WSC Station 08LB076):	Spring/summer: higher unit runoff than 08LB076 Autumn: lower unit runoff than 08LB0176
Comparison of measured and synthetic streamflow hydrographs:	Open water season: Figure H5 Winter: Figure H6
Long-term mean monthly flow hydrograph (synthetic):	Figure H7
Long-term flow duration curve (synthetic):	Figure H8
Long-term monthly and annual flows (synthetic):	Table H2

Station TSFDS has higher unit runoff than the WSC station on Harper Creek in the spring/summer season and lower unit runoff than the WSC station in the autumn. The higher unit runoff in spring/summer is generally attributed to larger snowpack in higher elevation sub-watershed of TSFDS, while the lower unit runoff in autumn is attributed to the smaller watershed area and smaller groundwater contribution.

It should be noted that the EFP relationship is extrapolated significantly in the autumn season. During the period of measured record at TSFDS, no significant autumn storms were recorded. A relationship parallel to the unit discharge line was selected for extrapolation.

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TABLE H-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
T-CREEK AT HARPER CREEK (TSFDS)

Print Aug/18/14 12:12:22

Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
13/06/2011	13:47	RD	0.80	5.13	4.49	-13%
20/07/2011	8:48	CM	0.59	1.44	1.59	10%
18/08/2011	14:49	CM	0.30	0.11	0.11	2%
12/09/2011	15:07	CM	0.20	0.03	0.01	-53%
22/11/2011	14:00	CM	-	0.01	-	-
25/01/2012	13:45	CM	-	0.03	-	-
07/02/2012	12:30	CM	-	0.02	-	-
29/02/2012	13:09	CM	-	0.02	-	-
01/04/2012	12:55	CM	-	0.02	-	-
13/04/2012	9:40	CM	0.26	0.06	0.06	-3%
05/05/2012	10:49	CM	0.47	0.66	0.67	1%
16/05/2012	11:23	RD	0.66	2.71	2.32	-14%
17/05/2012	11:01	RD	0.62	2.01	1.84	-9%
28/05/2012	15:01	RD	0.76	3.39	3.79	12%
06/06/2012	9:37	RD	0.85	5.79	5.43	-6%
19/06/2012	10:57	RD	0.69	2.91	2.71	-7%
06/07/2012	9:32	CM	0.59	1.22	1.52	24%
22/08/2012	12:50	CM	0.24	0.04	0.04	0%
22/10/2013	9:39	CM	0.38	0.16	0.31	89%
18/01/2014	13:53	CM	-	0.03	-	-
25/02/2014	10:10	CM	-	0.03	-	-
Average Error (%)						2%
Standard Error (%)						30%

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[PreliminaryRatingCurve_2013_TSFDS_20140602.xlsx]DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE SLUG INJECTION.
2. NO STAGE HEIGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.
3. RATING CURVE ERROR IS THE DIFFERENCE BETWEEN THE RATING CURVE DISCHARGE AND THE MEASURED DISCHARGE, ASSUMING THE MEASURED DISCHARGE IS THE "TRUE" DISCHARGE.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

Knight Piésold CONSULTING

TABLE H-2

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

LONG-TERM SYNTHETIC DISCHARGE AT T-CREEK AT HARPER CREEK (TSFDS) (m^3/s)

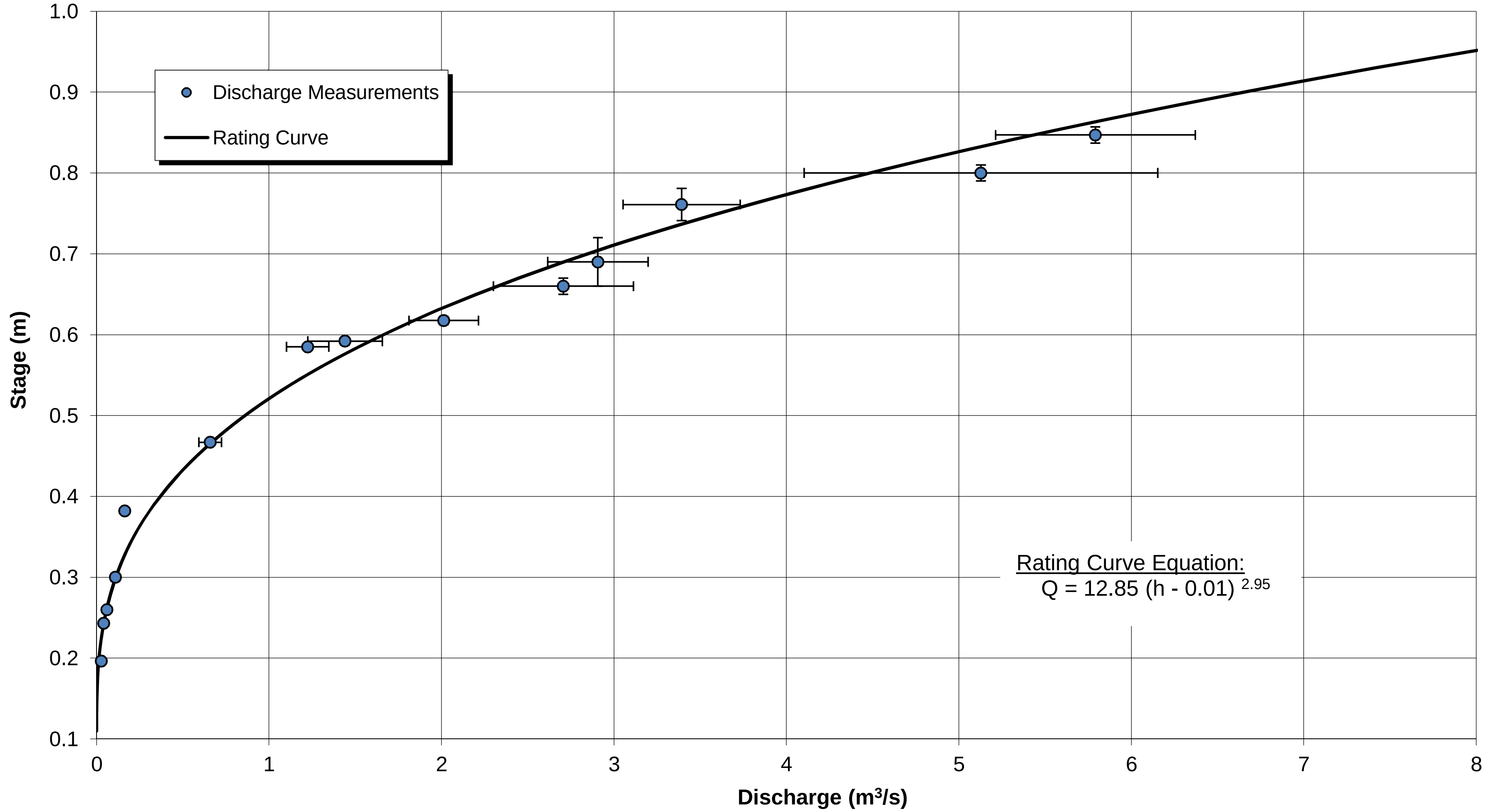
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1973	-	-	-	-	-	-	0.36	0.05	0.02	0.08	0.02	0.03	0.09
1974	0.05	0.06	0.07	0.27	1.35	4.14	1.90	0.22	0.06	0.01	0.01	0.02	0.68
1975	0.04	0.05	0.06	0.06	1.19	3.57	1.10	0.13	0.06	0.19	0.05	0.07	0.55
1976	0.09	0.09	0.09	0.14	2.28	2.35	1.62	0.93	0.27	0.09	0.03	0.05	0.67
1977	0.05	0.07	0.11	0.35	0.96	1.03	0.28	0.08	0.15	0.08	0.02	0.04	0.27
1978	0.07	0.07	0.12	0.44	2.87	2.58	0.50	0.10	0.34	0.11	0.02	0.04	0.61
1979	0.05	0.06	0.09	0.11	1.22	1.30	0.23	0.03	0.04	0.05	0.02	0.03	0.27
1980	0.04	0.08	0.08	0.57	2.03	0.73	0.37	0.11	0.13	0.09	0.05	0.07	0.36
1981	0.13	0.14	0.20	0.18	2.38	1.62	0.73	0.09	0.09	0.40	0.07	0.08	0.51
1982	0.08	0.10	0.11	0.08	1.75	3.77	1.51	0.28	0.21	0.27	0.04	0.05	0.69
1983	0.11	0.15	0.26	0.48	2.58	2.48	1.05	0.11	0.11	0.10	0.06	0.05	0.63
1984	0.09	0.11	0.16	0.20	0.87	4.17	2.15	0.15	0.11	0.09	0.02	0.03	0.68
1985	0.05	0.06	0.08	0.19	2.10	2.24	0.41	0.04	0.07	0.09	0.02	0.04	0.45
1986	0.06	0.08	0.11	0.19	1.56	2.15	0.37	0.05	0.03	0.07	0.02	0.03	0.39
1987	0.04	0.06	0.16	0.41	2.24	0.97	0.13	0.04	0.00	0.00	0.01	0.03	0.34
1988	0.04	0.05	0.08	0.58	2.12	1.78	0.60	0.08	0.06	0.12	0.04	0.04	0.47
1989	0.06	0.07	0.09	0.39	1.93	2.02	0.30	0.23	0.10	0.09	0.05	0.07	0.45
1990	0.09	0.10	0.10	0.44	1.60	2.81	0.77	0.06	0.02	0.03	0.03	0.04	0.51
1991	0.06	0.11	0.13	0.34	1.68	1.79	0.62	0.14	0.11	0.01	0.01	0.03	0.42
1992	0.05	0.09	0.28	0.71	1.98	1.22	0.23	0.04	0.05	0.08	0.03	0.04	0.40
1993	0.05	0.05	0.07	0.19	2.40	0.88	0.25	0.12	0.05	0.02	0.01	0.03	0.35
1994	0.05	0.06	0.12	0.78	2.19	1.56	0.46	0.05	0.02	0.01	0.01	0.03	0.45
1995	0.05	0.07	0.10	0.15	2.03	1.88	0.28	0.24	0.06	0.12	0.04	0.06	0.43
1996	0.07	0.09	0.16	0.45	1.36	3.30	1.22	0.13	0.13	0.09	0.04	0.06	0.59
1997	0.07	0.08	0.10	0.18	2.56	2.61	1.11	0.16	0.20	0.37	0.05	0.06	0.63
1998	0.08	0.11	0.18	0.34	2.67	0.84	0.17	0.01	0.00	0.04	0.02	0.04	0.38
1999	0.06	0.08	0.12	0.34	1.72	4.35	2.73	0.40	0.09	0.06	0.05	0.07	0.84
2000	0.09	0.09	0.10	0.26	1.30	2.86	0.98	0.10	0.07	0.07	0.02	0.03	0.50
2001	0.05	0.05	0.08	0.10	1.24	1.64	0.78	0.12	0.03	0.02	0.02	-	0.40
2002	-	-	0.09	0.18	1.77	3.70	0.78	0.06	0.04	0.02	0.02	0.04	0.72
2003	0.05	0.06	0.09	0.27	1.54	2.13	0.18	0.00	0.00	0.15	0.02	0.03	0.38
2004	0.04	0.05	0.08	0.44	1.71	1.26	0.22	0.03	0.17	0.07	0.03	0.07	0.35
2005	0.22	0.29	0.27	0.52	2.52	1.52	0.50	0.06	0.05	0.34	0.04	0.06	0.53
2006	0.15	0.12	0.13	0.25	2.59	1.53	0.14	0.02	0.01	0.00	0.02	0.02	0.42
2007	0.04	0.05	0.08	0.19	1.66	2.44	0.31	0.03	0.02	0.17	0.04	0.06	0.42
2008	0.07	0.10	0.12	0.05	2.66	2.40	0.56	0.07	0.03	0.08	0.04	0.04	0.52
2009	0.06	0.07	0.08	0.08	1.32	2.05	0.29	0.02	0.01	0.02	0.02	0.03	0.34
2010	0.06	0.09	0.13	0.23	1.26	2.28	0.44	0.04	0.09	0.06	0.02	0.04	0.39
2011	0.05	0.05	0.04	0.04	1.52	4.05	1.31	0.13	0.02	0.04	0.01	0.02	0.61
2012	0.02	0.02	0.02	0.32	1.89	3.91	1.18	0.07	0.00	0.03	0.03	0.03	0.62
2013	0.04	0.06	0.10	0.38	2.80	2.44	0.41	0.05	0.14	0.18	0.02	0.03	0.56
Average	**0.07**	**0.08**	**0.12**	**0.30**	**1.88**	**2.31**	**0.72**	**0.12**	**0.08**	**0.10**	**0.03**	**0.04**	**0.48**
Maximum	**0.22**	**0.29**	**0.28**	**0.78**	**2.87**	**4.35**	**2.73**	**0.93**	**0.34**	**0.40**	**0.07**	**0.08**	**0.84**
Minimum	**0.02**	**0.02**	**0.02**	**0.04**	**0.87**	**0.73**	**0.13**	**0.00**	**0.00**	**0.00**	**0.01**	**0.02**	**0.09**

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\EFP Regressions\[TSFDS (Alternate).xlsm]Summary Table

NOTE:

1. MEASURED DAILY FLOWS WERE COMPARED TO DAILY FLOWS AT WATER SURVEY OF CANADA HYDROMETRIC STATION HARPER CREEK AT THE MOUTH (08LB076) TO GENERATE THE LONG-TERM SYNTHETIC SERIES.

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:

1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011 AND 2012 DATA COLLECTION PROGRAMS.

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

RATING CURVE
T-CREEK AT HARPER CREEK
(TSFDS)

Knight Piésold CONSULTING

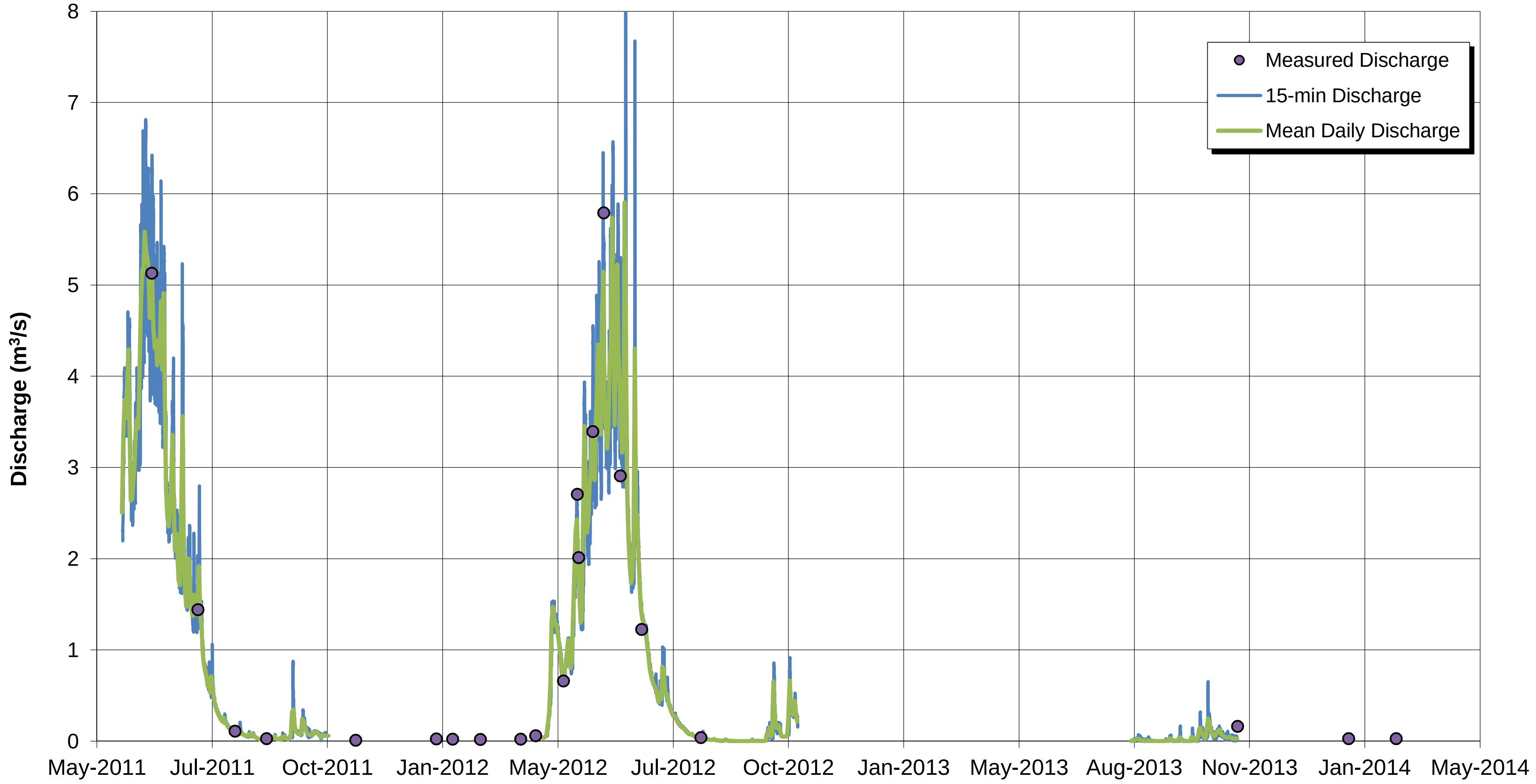
P/A NO. VA101-458/15

REF. NO. 2

FIGURE H-1

REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	JGC



0	22AUG'14	ISSUED WITH REPORT	JOL	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEASURED STREAMFLOW HYDROGRAPH
T-CREEK AT HARPER CREEK
(TSFDS)

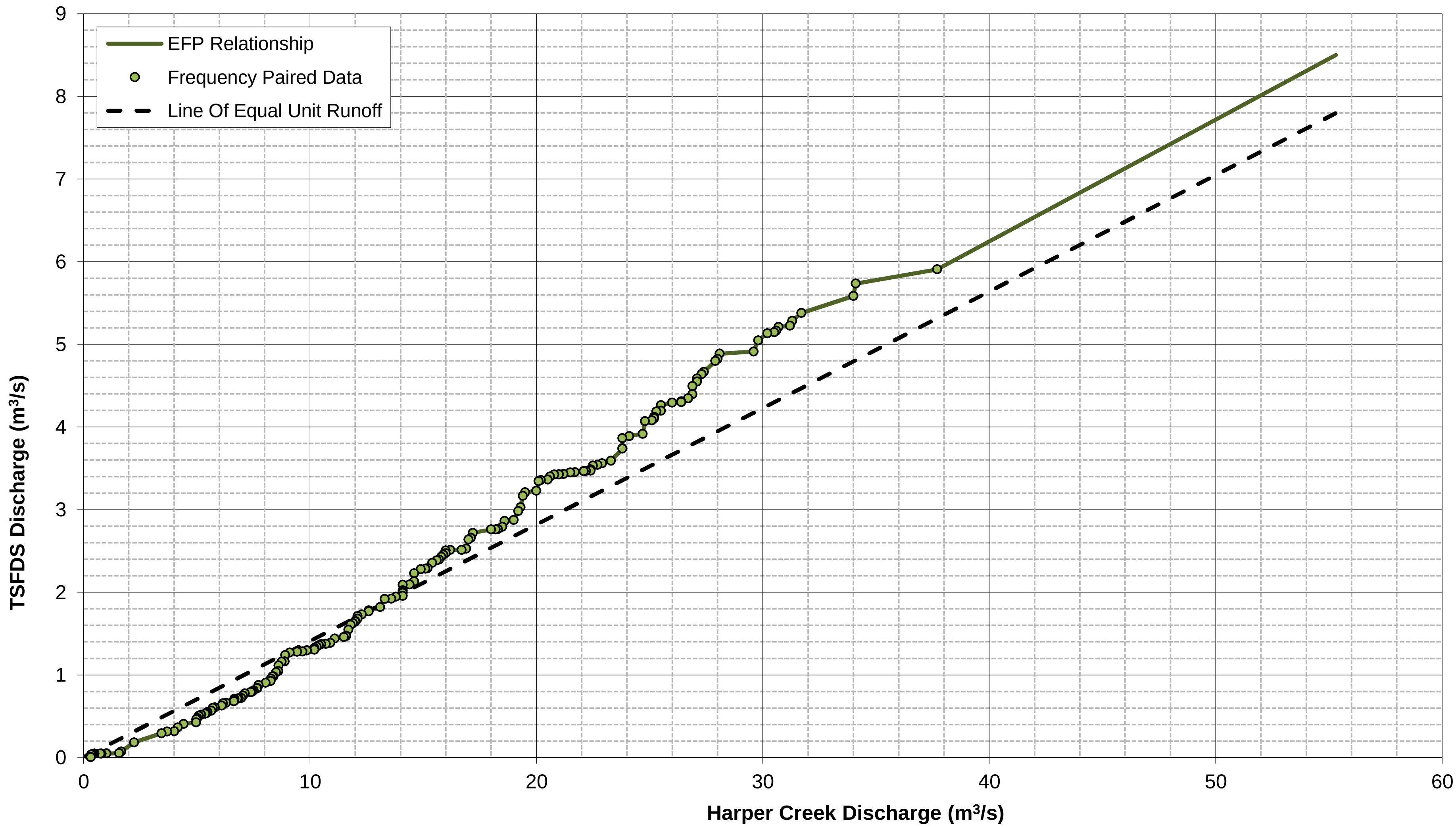
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF. NO. 2

FIGURE H-2

REV 0



NOTE:
1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST SPRING/SUMMER DISCHARGE IN THE WSC'S HARPER CREEK SERIES

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

SPRING/SUMMER FREQUENCY PAIRED RELATIONSHIP TSFDS AND WSC'S HARPER CREEK STATIONS

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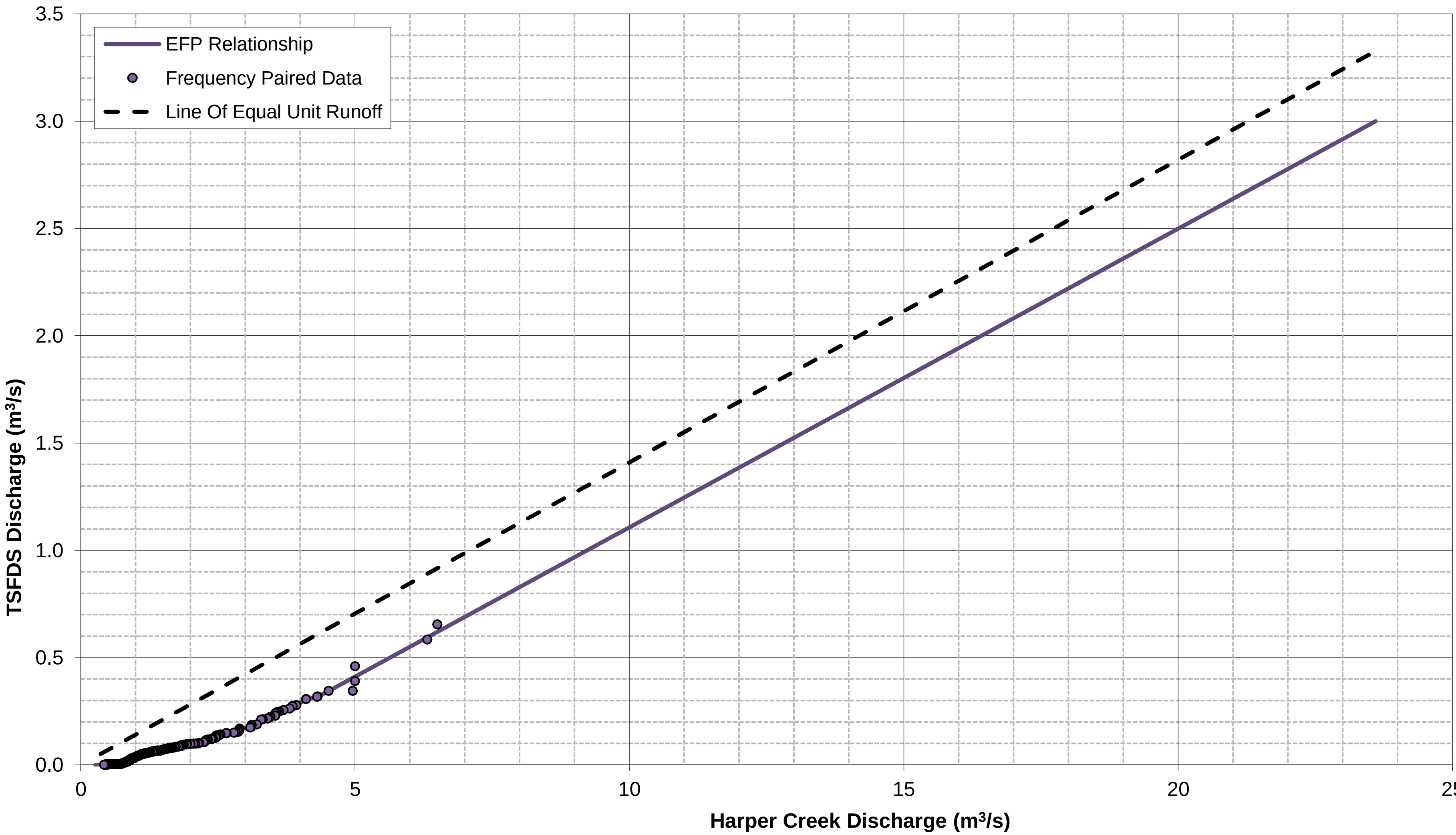
P/A NO. VA101-458/15

REF NO. 2

FIGURE H-3

REV 0

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB



NOTE:

1. THE EFP RELATIONSHIP IS EXTRAPOLATED TO THE HIGHEST AUTUMN DISCHARGE IN THE WSC'S HARPER CREEK SERIES

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

AUTUMN FREQUENCY PAIRED RELATIONSHIP TSFDS AND WSC'S HARPER CREEK STATIONS

Knight Piésold CONSULTING

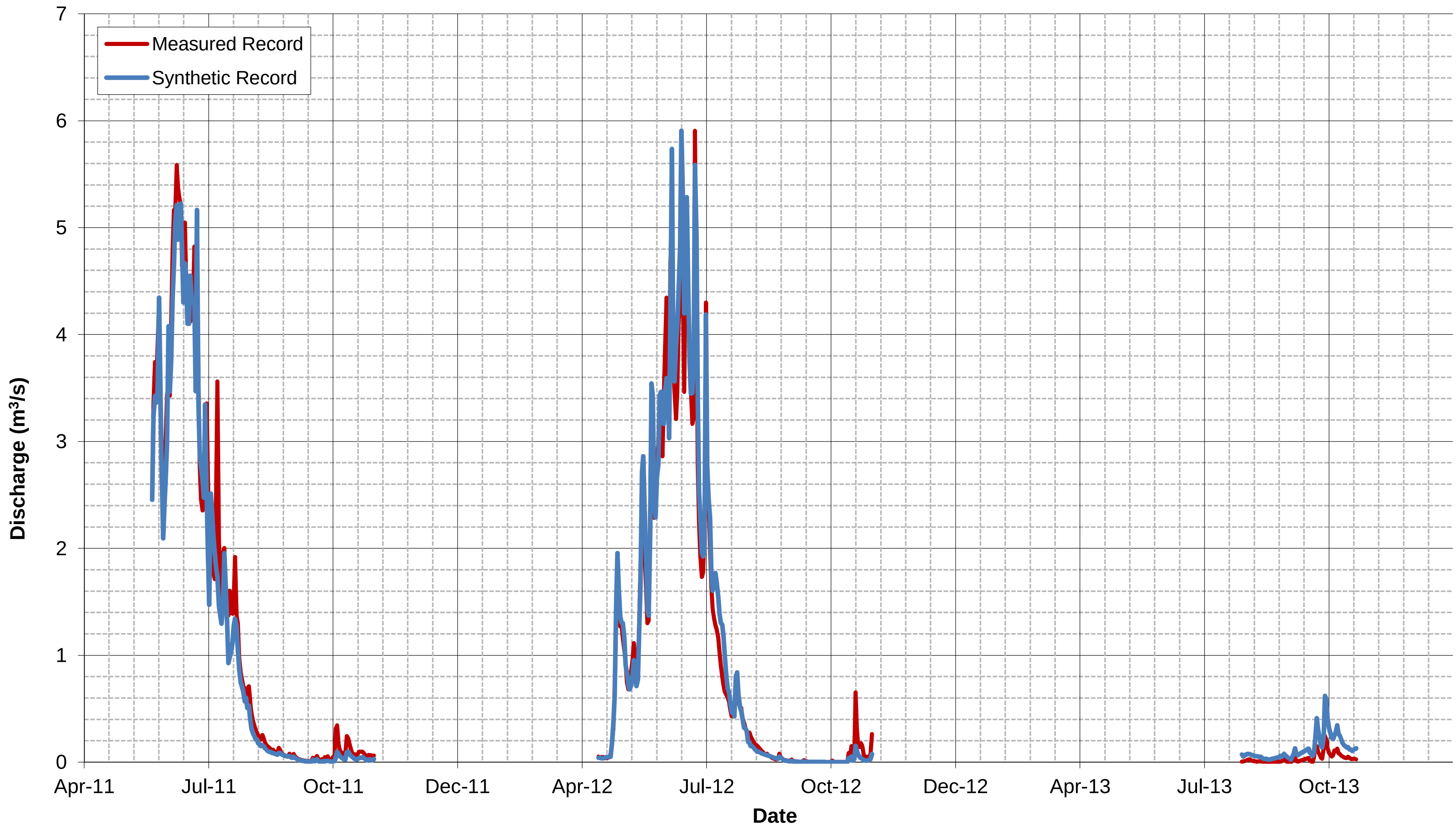
P/A NO. VA101-458/15

REF NO. 2

FIGURE H-4

REV 0

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

COMPARISON OF MEASURED AND SYNTHETIC HYDROGRAPHS T-CREEK AT HARPER CREEK (TSFDS)

REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB

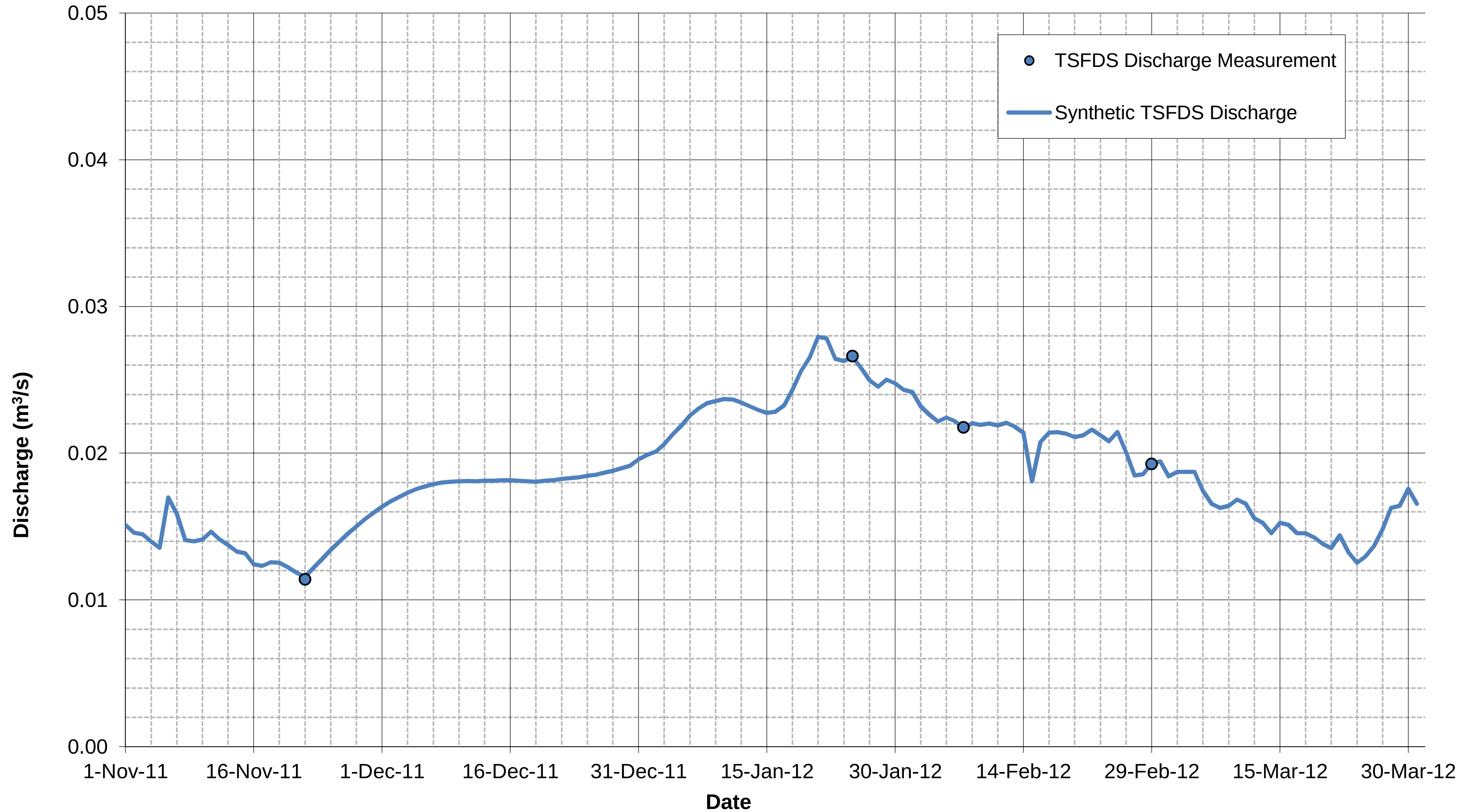
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE H-5

REV 0



REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D
0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

WINTER RELATIONSHIP
TSFDS AND WSC'S HARPER CREEK STATIONS

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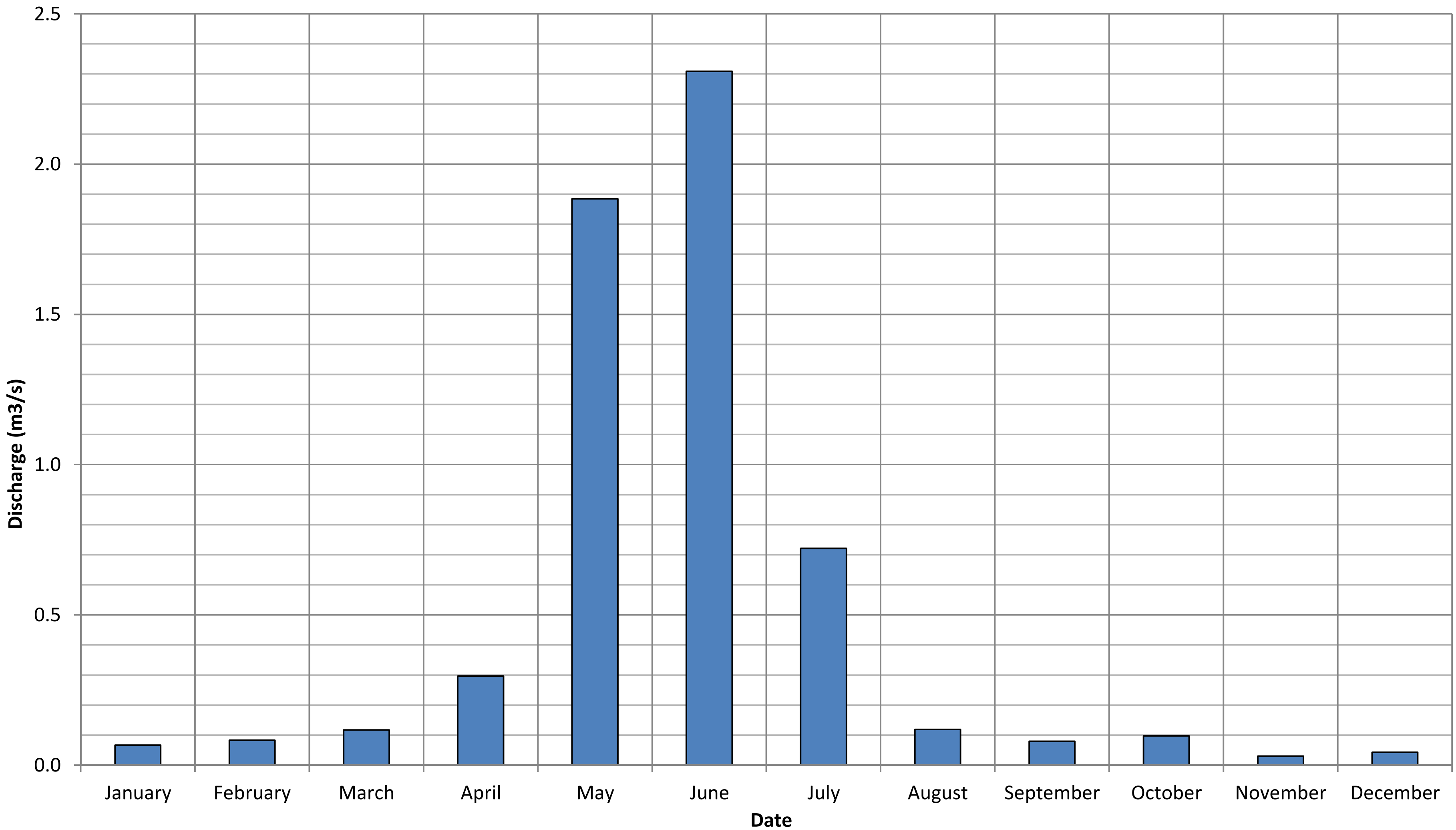
P/A NO. VA101-458/15

REF NO. 2

FIGURE H-6

REV 0



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEAN MONTHLY HYDROGRAPH
T-CREEK AT HARPER CREEK (TSFDS)

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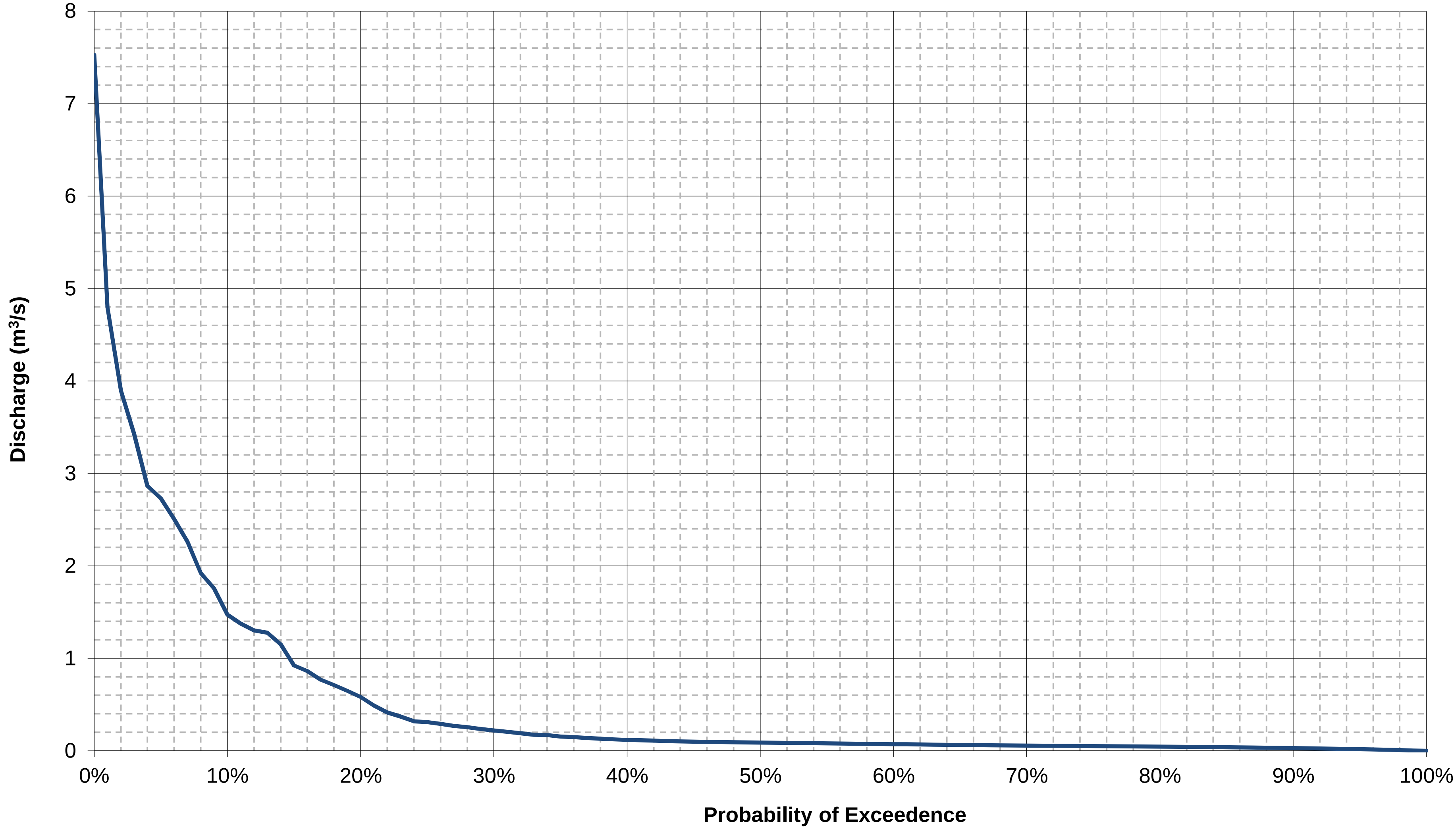
P/A NO. VA101-458/15

REF NO. 2

FIGURE H-7

REV 0

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

LONG TERM FLOW DURATION CURVE
T-CREEK AT HARPER CREEK (TSFDS)

Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF NO. 2

FIGURE H-8

REV 0

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	KJB
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

PHOTO H1 – T-Creek hydrology station (TSFDS) during low flows

PHOTO H2 – T-Creek hydrology station (TSFDS), during high flows

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO H3 – T-Creek hydrology station (TSFDS), gauge pool

PHOTO H4 – T-Creek hydrology station (TSFDS), current meter measurement, looking upstream

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

APPENDIX I

T-CREEK AT TMF EMBANKMENT (TSFUS)

(Pages I-1 to I-8)

1 – T-CREEK AT TMF EMBANKMENT (TSFUS)

1.1 GAUGING STATION SITE SELECTION

Stream:	T-Creek
Location:	2.9 km upstream of the Harper Creek confluence at the proposed location of the proposed TMF/TSF embankment
Channel description:	Cobble and gravel low gradient channel bed creates control for gauging station
Site conditions:	Stable hydraulic control, minimal turbulence at variable flow conditions, reasonably good flow measurement conditions
Other key information:	Site is difficult to access in the winter due to heavy snowfall. Station is downstream of road culvert which was blocked in the spring of 2012 and the culvert was blown out on June 23, 2012 causing disruption to the discharge record.
Photographs:	Photos I1 to I6.

1.2 GAUGING STATION EQUIPMENT

Data logger:	Neon Micrologger
Pressure/temperature sensor:	KPSI-500, 0 to 5 PSI (0 to 3.514 m)
Sampling interval:	15 mins
Benchmarks:	3
Staff gauge/reference mark:	No

1.3 PERIOD OF STAGE RECORD

Installed:	May 10, 2011
Discontinued:	Currently active
2011 record:	May 10 to December 31, 2011 (75% complete)
2012 record:	May 2 to November 8, 2012 (35% complete)
2013 record:	No record

Station was left in over 2011/2012 winter due to lack of access and instrumentation was not removed. Sensor malfunctioned in mid-August in 2012 and collected erroneous data for the remainder of the year.

1.4 STAGE-DISCHARGE RATING CURVE DEVELOPMENT

Number of stage-discharge measurements:	12 (total), 12 (used for rating curve), see Table H1

Rating curve: See Figure I1

Rating curve average error: -1%

Rating curve standard error: 24%

The rating curve for the TSFUS gauging station is considered good quality. The large standard error is due primarily to high error in the low flow measurements collected.

1.5 MEASURED STREAMFLOW RECORD

Daily discharge hydrograph: Figure I2

1.6 LONG-TERM SYNTHETIC FLOW SERIES

A long-term synthetic flow series wasn't developed for TSFUS due to poor rating curve and relatively short measured streamflow record.

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TABLE I-1

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

STAGE - DISCHARGE SUMMARY TABLE
T-CREEK AT TMF EMBANKMENT (TSFUS)

Print Aug/18/14 11:58:51

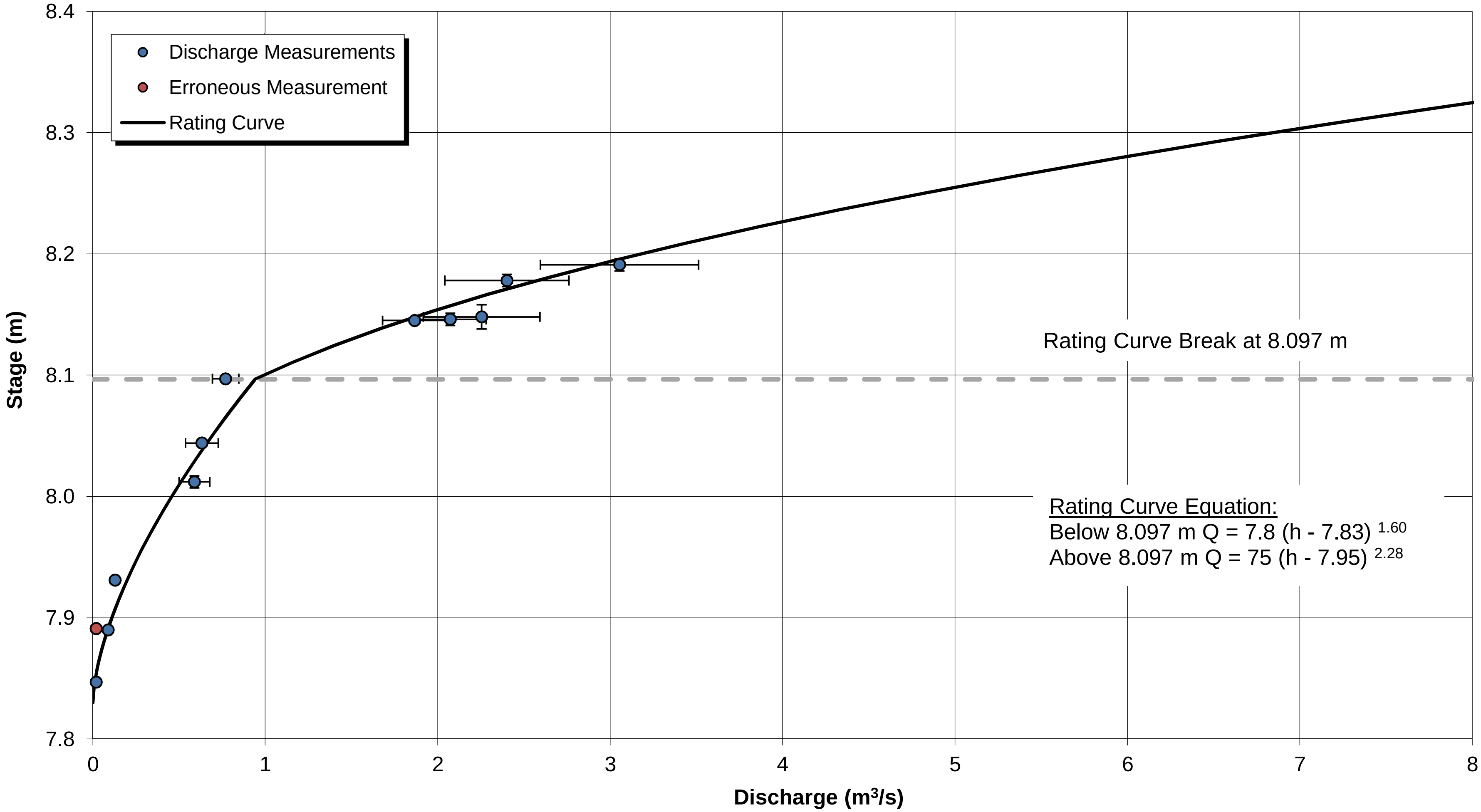
Date	Time	Method	Recorded Stage (m)	Measured Discharge (m^3/s)	Rating Curve Discharge (m^3/s)	Rating Curve Error (%)
10/05/2011	13:54	CM	7.93	0.13	0.20	54%
02/06/2011	17:44	CM	8.15	2.26	1.87	-17%
08/06/2011	10:40	CM	8.18	2.40	2.58	7%
14/06/2011	13:16	CM	8.19	3.05	2.92	-4%
18/07/2011	9:48	CM	8.01	0.59	0.51	-13%
17/08/2011	14:18	CM	7.89	0.09	0.09	-3%
13/09/2011	10:29	CM	7.85	0.02	0.01	-43%
02/05/2012	10:31	CM	8.04	0.63	0.66	5%
29/05/2012	12:54	CM	8.15	1.87	1.80	-3%
07/06/2012	11:37	CM	8.15	2.07	1.83	-12%
05/07/2012	12:47	CM	8.10	0.77	0.95	23%
23/08/2012	13:55	CM	7.89	0.02	-	-
Average Error (%)						-1%
Standard Error (%)						24%

M:\1\01\00458\15\A\Data\Task 500 Information Sharing\Hydrology data and files\Measured Data\[PreliminaryRatingCurve_2012_TSFUS_20140603.xlsx]DischargeSummaryTable

NOTES:

1. METHOD ABREVIATION LEGEND: CM - CURRENT METER, RD - RHODAMINE DYE SLUG INJECTION.
2. NO STAGE HEIGHTS ARE RECORDED DURING THE WINTER MONTHS DUE TO ICE EFFECTS.
3. RATING CURVE ERROR IS THE DIFFERENCE BETWEEN THE RATING CURVE DISCHARGE AND THE MEASURED DISCHARGE, ASSUMING THE MEASURED DISCHARGE IS THE "TRUE" DISCHARGE.

0	22AUG'14	ISSUED WITH REPORT VA101-458/15-2	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D



NOTES:

1. ERROR BARS REPRESENT THE BEST ESTIMATE OF STAGE AND DISCHARGE MEASUREMENT ERROR.
2. RATING CURVE IS BASED ON DATA COLLECTED DURING THE 2011 AND 2012 DATA COLLECTION PROGRAMS.

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

RATING CURVE
T CREEK AT TMF EMBANKMENT
(TSFUS)

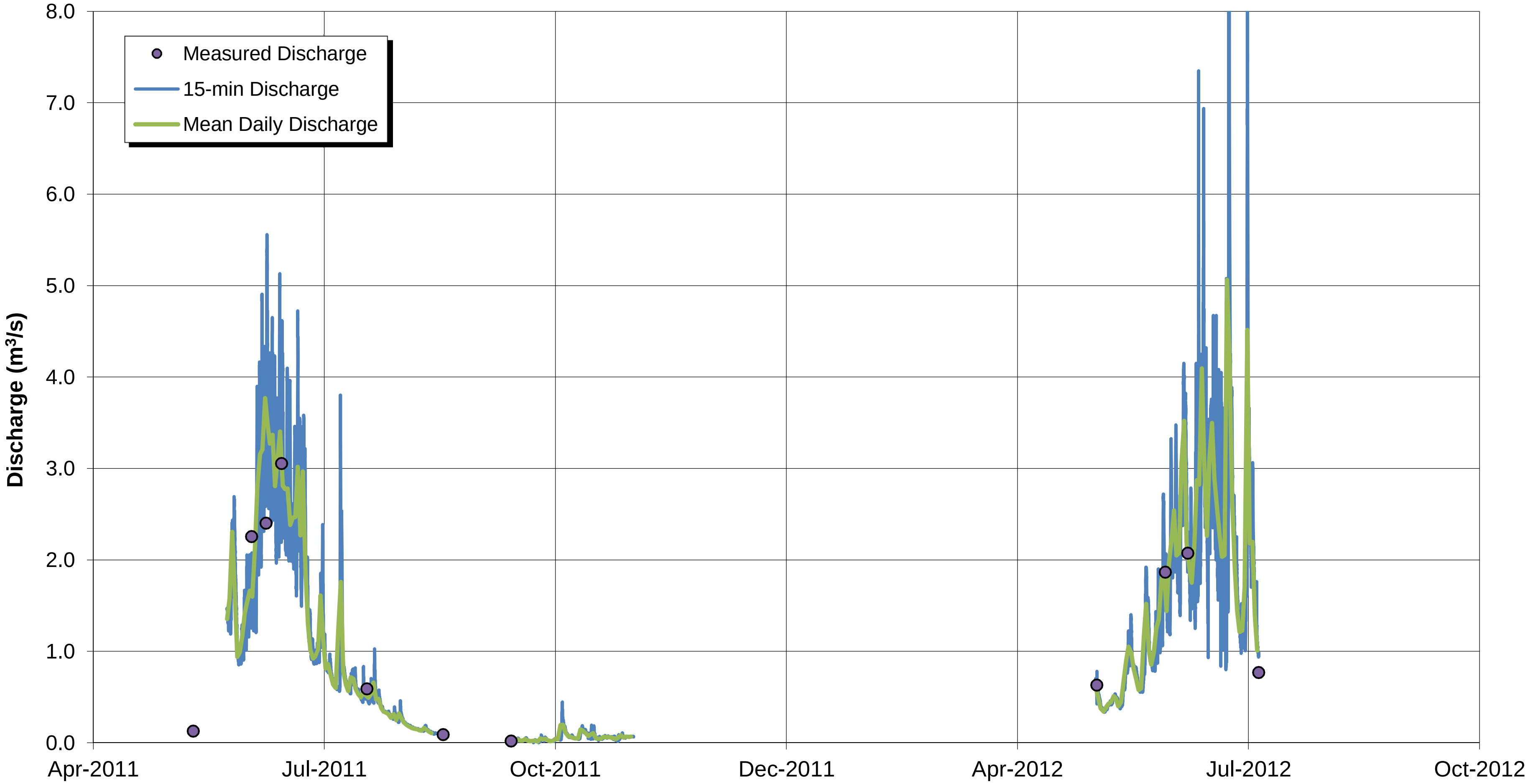
Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF. NO. 2

FIGURE I-1

REV 0



NOTES:

1. STAGE DATA PRIOR TO 24 MAY 2011 WERE REMOVED DUE TO ICE AFFECTING THE STAGE DISCHARGE RELATIONSHIP.
2. STAGE DATA BETWEEN 10 OCT 2011 TO 8 JUN 2012 REMOVED DUE TO ICE AFFECTING THE STAGE-DISCHARGE RELATIONSHIP.

0	22AUG'14	ISSUED WITH REPORT	ACA	TJP	JGC
REV	DATE	DESCRIPTION	PREP'D	CHK'D	APP'D

HARPER CREEK MINING CORP.

HARPER CREEK PROJECT

MEASURED STREAMFLOW HYDROGRAPH
T-CREEK AT TMF EMBANKMENT
(TSFUS)

Knight Piésold CONSULTING

P/A NO. VA101-458/15

REF. NO. 2

FIGURE I-2

REV 0

PHOTO I1 – T-Creek hydrology station (TSFUS) during low flows

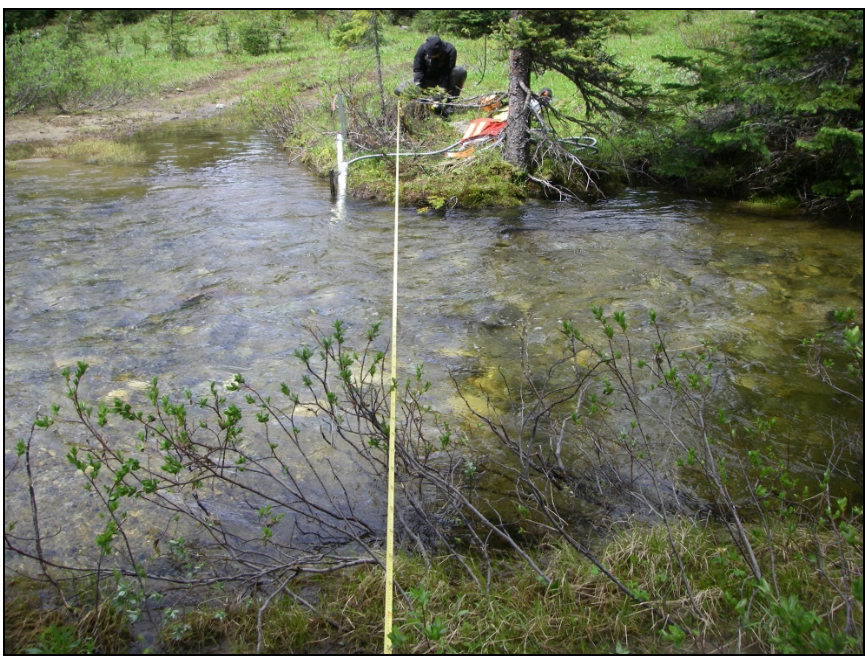


PHOTO I2 – T-Creek hydrology station (TSFUS), during high flows

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO I3 – T-Creek hydrology station (TSFUS), gauge pool

PHOTO I4 – T-Creek hydrology station (TSFUS), looking upstream

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT

PHOTO I5 – T-Creek hydrology station (TSFUS), winter conditions

PHOTO I6 – T-Creek hydrology station (TSFUS), upstream road and culvert washed up

HARPER CREEK MINING CORP.
HARPER CREEK PROJECT