REPORT

Coldwater River Groundwater / Surface Water Interaction Study - Phase 1

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19131378-001-R-Rev0

23 March 2020

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Executive Summary

Golder Associates Ltd. (Golder) was retained by the Fraser Basin Council (FBC), in partnership with the British Columbia Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD), to conduct this Phase 1 Study of groundwater-surface water interaction along the Coldwater River in southcentral British Columbia. This Study was conducted to support FLNRORD'S research which is to improve the scientific understanding of surface water and groundwater interactions along the Coldwater River. The Study Area comprises the 38 km stretch of the Coldwater River from Brookmere to Merritt, BC.

This Phase 1 Study was primarily a desk-top study which consisted of the compilation and analysis of available data and the review of available reports. This Study was successful in providing a baseline understanding of groundwater-surface water interaction along the Coldwater River based on currently available information. The primary findings of this Study are the identification of:

- Two potential or known losing reaches.
- One potential gaining reach.
- Two potential high vulnerability reaches with respect to the adverse effects of groundwater extraction.
- Five potential low vulnerability reaches with respect to the adverse effects of groundwater extraction .

In addition, the Coldwater River between Brookmere and Merritt was found to be a net gaining river (0.51 m^3/s) on an annual average basis, with lowest 7-day flows typically occurring during the third week of September. However, it is anticipated that several gaining and losing reaches exist along this 35 km stretch of river. According to McCleary (2019), critical environmental flow thresholds (CEFT) range from 0.43 m^3/s to 0.84 m^3/s, depending on the species of fish. Mean monthly flow do not typically fall below the CEFT. However, historical daily flow rates as low as 1.3 m^3/s and 0.43 m^3/s have been recorded at the Brookmere and Merritt hydrometric stations respectively during the summer low-flow period.

Several data gaps have been identified as part of this Study. These data as evidence of potential gaining or losing conditions include:

- The absence of geodetic groundwater and nearby surface water level elevations to examine hydraulic gradients between the river and connected aquifers and the associated direction of water movement.
- The absence of incremental river flow measurements between the two active hydrometric stations on the Coldwater River, to identify gaining and losing sections and to quantify the gains and losses on a localized or reach scale.
- Geochemical data from shallow groundwater upstream of Merritt, to compare similarities or dissimilarities to the Coldwater River water quality.

In addition, water demand estimates for the Study Area should be updated since this was last done in 2006.

This Study included recommendations for a field program as part of the next phase of the Study to address the data gaps that could provide evidence of potential gaining or losing conditions. The recommendations include the measurement of incremental river flows along the 35 km stretch of the Coldwater River within the Study Area as part of a snap-shot monitoring event during the low flow season (mid-September) when tributary inflow and surface water runoff is minimized. The field program would also include installing mini-piezometers along the length of the river to allow a direct comparison of groundwater and surface water level elevations and to allow the collection of shallow groundwater samples. Both groundwater and surface water samples would be analysed for major anions and cations as well as stable isotopes for the purpose of conducting a geochemical analysis. The groundwater and surface water level comparisons and the geochemical analysis of the water samples would be used to support the analysis of flow differentials for the purpose of identifying and quantifying gaining and losing stream reaches.

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1.0 INTRODUCTION

Golder Associates Ltd. (Golder) was retained by the Fraser Basin Council (FBC), in partnership with the British Columbia Ministry of Forests, Lands, Natural Resource Operations & Rural Development (FLNRORD), to conduct Phase 1 of a study on groundwater-surface water interaction along the Coldwater River in south central British Columbia. This study was conducted to support FLNRORD'S research which is to improve the scientific understanding of surface water and groundwater interactions along the Coldwater River. The scope of work for this study followed Golder's proposal to FBC dated 20 November 2019.

The study area, shown in Figure 1, comprises the 38 km stretch of the Coldwater River from Brookmere to Merritt, BC.

2.0 BACKGROUND

This study on groundwater-surface water interaction along the Coldwater River (referred to herein as 'the Study') is an initiative of FLNRORD. According to FLNRORD (email from FBC/FLNRORD dated 23 October 2020), there is considerable interest in the Coldwater River valley and Merritt areas regarding these interactions, particularly on how river flows contribute to the aquifers in these areas and how groundwater withdrawals from wells may impact river flow. FLNRORD indicates that recent research and water budget projects have raised questions of aquifer-river connectivity and of aquifer sustainability. This has prompted the need for a better understanding of these interactions to assist with water management decision making and water-use planning to preserve environmental flow needs[1] in the river during critical periods.

The objective of FLNRORD's initiative is to better understand surface water and groundwater interactions along the Coldwater River. The results of this study may be used by stakeholders to:

- support groundwater use planning by the City of Merritt and other local water purveyors
- inform FLNRORD's surface water and groundwater allocation decisions, drought response activities and development of area-based policy or regulations
- conduct environmental flow needs determinations
- develop the groundwater components of the Nicola Basin Fish Water Management Tool
- plan fisheries enhancement activities
- support scientific research by faculty and students at academic institutions that could be used to inform future policy or regulations

Golder proposed to conduct this Study using a phased approach which was detailed in Golder's proposal dated 20 November 2019. This approach is conducive to completing the work in stages as data, results, and funding become available, it allows the field program to be conducted during the optimal period for data quality (i.e., during low-flow conditions to minimize the influence of rainfall/surface runoff), and allows FBC and FLNRORD the

[1] the volume and timing of water flow required for proper functioning of the aquatic ecosystem.

option to expand or limit the phased scopes of work, with phased deliverables allowing for exit points and greater financial certainty in the overall project. The proposed approach is intended to be flexible such that the project can be responsive to ongoing generation of results and the needs of the relevant stakeholders.

The overall approach comprises three main phases, with a fourth phase consisting of optional studies that may be added on if desired. These phases are summarized below:

- **Phase 1** (Report Review, Data Compilation and Analysis): Phase 1 (this Study) is primarily a desk-top study which consisted of the compilation and analysis of available data and the review of available reports. The primary purpose of Phase 1 is to obtain a baseline understanding of what is known and what remains a data gap on locations of groundwater interaction with surface water in the Coldwater River.
- **Phase 2** (Summer Field Program): Based on our current understanding, this field program would be conducted so that it can capture the lowest flow period for the Coldwater River for data quality purposes (to minimize the influence of rainfall/surface runoff in the measurements) and for safety purposes (the river flows can be hazardous during freshet and at other times of high flow). The key objectives for this program would be to map and quantify gaining and losing stream reaches over the summer monitoring period and provide recommendations for any future field program to confirm or more accurately delineate and quantify the gaining and losing portions of the creek, if required.
- **Phase 3** (Numerical Flow Model Development): This phase is anticipated to comprise the development of an integrated groundwater-surface water flow model of the Study area using HydroGeoSphere (HGS). The input parameters and calibration targets for the model will be based on the data compiled during Phase 1 and Phase 2 and from previous hydrology studies for the Coldwater River. The scope of work for this phase and later phases, if any, will be dependent on the quantity and quality of available data as well as the results of the preceding phases. The calibrated model will be used to evaluate the impact to the river for specific groundwater and/or surface water withdrawal scenarios which would be developed with input from FBC and FLNRORD.
- **Phase 4** (Additional Optional Studies): Additional field programs and/or the continuation of monitoring of groundwater and surface water at monitoring points established as part of Phase 2 may be required to obtain the necessary temporal data to calibrate the numerical model for transient conditions (to enable predictions that could be affected by seasonality), refine key areas of interest and/or address remaining data gaps.

This report presents the key findings of the Phase 1 Study and outlines a recommended field program for the next phase (Phase 2) of this study.

3.0 OBJECTIVES AND SCOPE OF WORK

Phase 1 is primarily a desk-top study the primary purpose of which is to obtain a baseline understanding of what is known and what remains a data gap with respect to groundwater-surface water interaction along the Coldwater River. The objectives of Phase 1 were to:

- Identify known and suspected gaining and losing stream reaches.
- Provide preliminary estimates of rates of river gain or river loss where sufficient information is available.
- Provide a baseline for future data collection.
- Identify data gaps.
- Provide a plan for the next phase (Phase 2) of the Study.

An outline of the scope of work is provided below.

- Task 1- Report Review: This includes the compilation and review of available professional reports relevant to this Study provided by FLNRORD. The information from these reports will be synthesized and key findings with respect to the mapping and quantification of gaining and losing reaches of the Coldwater River will be outlined.
- Task 2- Data Analysis: The compilation and analysis of currently available data (surface water flows and water levels, water quality, water well data; water licensing information) from Environment Canada, FBC, FLNRORD, the BC Ministry of Environment and Climate Change Strategy (ENV), the BC Ministry of Agriculture and the City of Merritt that supports the assessment of gaining and losing stream reaches, with specific focus on the area where the Coldwater River enters the Merritt Basin.
- Task 3 - Site Visit: Conduct a site visit to verify key findings from the report review and data analysis and/or to assess possible future field investigation/monitoring locations to support the work plan development described as Task 4 below. (Deferred to the next phase of study)
- Task 4 - Work Plan for Summer Field Program: Develop a work plan for the next phase (Phase 2) of the Study. This plan will focus on the lowest-flow period and will identify the monitoring locations, monitoring frequency and type of field data collection. The key objective of the program would be to obtain field measurements to confirm or more accurately delineate and quantify the gaining and losing portions of the creek.
- Task 5 - Reporting: A draft report to be prepared summarizing the findings of Phase 1 and presentation of the findings to FBC and FLNRORD.

4.0 DATA SOURCES

The following data and information sources were utilized in this Phase 1 Study:

Table 1: Data Sources

Data Type	Source
Historical Reports	Reports identified by FLNRORD in an email dated 19 November 2019 and were provided by FLNRORD or were publicly available (downloaded from the internet). These reports are listed in the reference section (Section 14.0).
Topography	Canadian Digital Elevation Model (CDEM) for map sheets 092I/14 and 092I/11 downloaded from Natural Resources Canada Geogratis website in April 2018 (http://ftp.geogratis.gc.ca/pub/nrcan_rncan/elevation/cdem_mnec/).
Orthophoto (georeferenced)	Imagery copyright © 2011-2015 Esri and its licensors. Source: DigitalGlobe,Vivid Canada WV02. Used under license, all rights reserved.
Surficial Geology	Map 1393A (1974). Surficial Geology Merritt, BC. Geological Survey of Canada: R.J. Fulton (1960-62). Scale 1:126,720.
Bedrock Geology	Map 886A (1961). Nicola. Kamloops and Yale Districts, BC. Geological Survey of Canada: W.E. Cockfield (1939-43). Scale 1:253,440.
Registered Water Well Data	Extracted from WELLS Database from BC Ministry of Environment and Climate Change Strategy (ENV) website on 15 Oct 2020.
Groundwater Licencing Dataset	Data file from FLNRORD received by email 5 Feb 2020 (File Name: GW_WW_WRBC_10U.csv).
Surface Water Licencing Data	Licence Demand Report from FLNRORD received 29 May 2018. Location of licenced points of diversion extracted from DataBC's Water License Points of Diversion layer from the BC Water Resource Atlas (https://maps.gov.bc.ca/ess/hm/wrbc/) in May 2018.
Hydrometric Station Data for Coldwater River (flows and stage)	Extracted from the Environment and Climate Change Canada Historical Hydrometric Data web site (https://wateroffice.ec.gc.ca/mainmenu/historical_data_index_e.html) on 4 Feb 2020.
Hydrometric Station Geodetic Elevations	File from FLNRORD received by email 16 Jan 2020 (File Name: Nicola Watershed Geodetic Elevations_June 2019.xlsx)
Water Quality Dataset (isotopes and general inorganic chemistry	Files from FLNRORD received by email 19 Nov 2019 (File Names: 2016 Isotope_GenChem.xlsx; Nicola Coldwater Isotopes.kmz)
Map Files: roads, land use boundaries, lakes, rivers, streams, hydrometric station locations; water diversion locations; quaternary geology,	Extracted from Data BC - iMapBC Web-based Mapping Application (https://maps.gov.bc.ca/ess/hm/imap4m/) in May 2018.
Aquifer Mapping	Extracted from Golder's previously developed geologic (Leapfrog) model described in Gorski et al. (2018) with updated mapping described in Golder (2019).

5.0 REPORT REVIEW

Golder conducted a review of 20 historical reports identified by FLNRORD as well as 1 additional report that was obtained as part of another ongoing study in the region by Golder (Phase 3 Nicola Project). These reports are included in the reference section (Section 14.0). Based on this review, the relevant information from each of these reports is outlined in APPENDIX A, and the key findings from the report review is summarized below. Some of the points of interest identified as part of this review are shown on Figure 2. This figure also shows the Coldwater River divided into 11 reach lengths to aide in the description of river characteristics for this study. The reach lengths were selected in consideration of physiographic regions, tributary location, administrative land boundaries and mapped aquifers, and have been labelled Reach A to Reach K in the upstream direction starting at it's confluence with the Nicola River in Merritt. The reaches vary in length from about 1.5 km to 4.0 km, depending on location.

Merritt Area

- Several studies indicate that the stretch of the Coldwater River that flows through the Merritt Basin (largest depositional basin in the region and underlies the Merritt Area) is likely a losing reach (i.e. the river recharges the underlying unconfined aquifer along this reach) (EBA 2002; BC Groundwater Consulting Services 2006 and 2011; MOE 2009, Golder 2018). The location of this reach, identified herein as Reach A, is shown on Figure 2. This was based on several lines of evidence including: comparison of surface water to shallow groundwater level elevations, comparison of surface water to shallow groundwater chemistry and temperatures, observed water level responses during pumping tests in the Merritt (now known as the Upper Merritt) Aquifer[2], and local/snapshot flow monitoring results in August/September 2005, with measured river flow loss of 0.15 m^3/s (approximately 40% of flow) (MOE 2009). These flow results were obtained for a 5 km stretch of river, from the Mountain Music Festival site to the WSC hydrometric station at Voght Park, shown on Figure 2.
- A water budget analysis indicated that this losing reach (Reach A) is a primary source of recharge to the (Upper) Merritt Aquifer under both pre-development (pre-1965; inferred to be natural conditions) and pumping conditions with respect to the City of Merritt production wells (MOE 2009).
- Hydrographs suggest the Coldwater River loses water in Reach A throughout the year, and this is supported by the observed disconnection of the water table from the river (i.e. unsaturated zone below the river) throughout the year (BC Groundwater Consulting Services 2006 and 2011).
- The shallow unconfined aquifer underlying Reach A is the Upper Merritt Aquifer (Aquifer No. 74) based on mapping in Gorski et al (2018). This unconfined shallow aquifer was considered to provide some recharge to underlying confined aquifer(s) because the underlying aquitard was found to be leaky (BC Groundwater Consulting Services 2011). Estimated groundwater withdrawal rates from the Upper Merritt Aquifer are approximately 90% of total withdrawal by the City of Merritt according to Western Water Associates Ltd., (2012).

[2] EBA (2002) reviewed historical pumping test data for five City of Merritt wells and inferred that the wells completed in the (Upper Merritt) unconfined aquifer responded as "leaky-confined aquifer". The water levels in these wells did not stabilize during the pumping tests. EBA (2002) concluded that the unconfined aquifer was recharged by precipitation and leakage from surface water bodies such as the Coldwater River and Nicola River.

Kingsvale Area

- The deep unmapped confined aquifer near Kingsvale (Piteau 2018) was found to not be hydraulically connected to the Coldwater River based on the water level responses observed during a pumping test on the licensed well WTN 103997.

Environmental Flow Needs

- The main fish species in the Coldwater River are Chinook (*Oncorhynchus tshawtscha*) and Coho salmon (*O. gorbuscha*), Steelhead trout (*Salmo gairdneri*), Dolly Varden char (*Salvelinus malma*), and Mountain Whitefish (*Prosopium williamsoni*) (Kosakoski and Hamilton, 1982; Swales et al., 1986). According to Kosakoski and Hamilton (1982), the minimum, maintenance and optimal river flow requirements for fish habitat are 0.85 m^3/s, 1.4 m^3/s and 3.4 m^3/s respectively. According to McCleary (2019), the critical environmental flow thresholds (CEFT) is 0.43 m^3/s or 0.84 m^3/s, depending on the species of fish. Flow rates below the minimum requirement or below the CEFT are expected to impact spawning.
- Based on the Coldwater River hydrographs in Golder (2018) for the Brookmere (period of record 1965 to 2018) and Merritt (period of record 1911-2018) stations, mean monthly flow rates are typically below the optimal flow requirement for fish (3.4 m^3/s) from August to October and are typically close to the optimal flow requirement between December and March, with remaining months exceeded this requirement. The mean monthly flow rates are typically close to the maintenance flow requirement (1.4 m^3/s) in September and do not typically fall below the minimum requirement (0.85 m^3/s) or the CEFT (0.84 or 0.43 m^3/s, depending on fish species). However, historical flow rates as low as 1.3 m^3/s and 0.43 m^3/s have been recorded at the Brookmere and Merritt stations respectively during the summer low-flow period (MOE 2009). In addition, according to MOE (2009), daytime surface water temperatures in August in the lower Coldwater River (portion of the river in the Merritt Area) are exceeding the lethal limit for salmon, trout and char (24°C).

River Bed Characteristics

- According to McPhail (1980), surficial riverbed material consists of gravel to cobble-sized sediment. However, fine-grained glacial or glacio-lacustrine sediments may occur beneath the riverbed. McPhail (1980) specifies that "*the valley walls of the Coldwater River near the Coldwater Bridge south of Kingsvale contain lacustrine sediments. This indicates that* (for this location) *lacustrine sediments may be lying underneath the fluvial sediments in the valley bottom*".

Water Use and Water Demand

- According to Summit (2007), the estimated 2006 total annual water extraction and water demand (does not account for water losses from total extractions) in the Coldwater Basin (includes irrigated lands in the Coldwater Valley bottom, the Coldwater River and its tributaries, and the southern half of the City of Merritt) was estimated to be 7.76M m^3/yr and 6.03 M m^3/yr respectively for the following water users: agricultural (mostly irrigation; 49%), domestic water supply (34%), resorts/recreational (11%), institutional (4%), industrial/commercial (2%). The annual licensed quantity of surface water was reported to be 10.02 M m^3/yr, which indicates a potential shortfall of 2.23 M m^3/yr. Of the estimated total water extraction or demand, 56% is estimated to be sourced from groundwater and 44% from surface water.
- Surface water and groundwater extraction for irrigation water supply is greatest during the growing season which is between June and August (Summit, 2007).

6.0 PHYSICAL SETTING

The Study Area comprises the 38 km section of the Coldwater River from Brookmere to Merritt, BC, and lies within the larger Nicola watershed. The Study Area includes the Coldwater River valley bottom and the portion of the Merritt Basin that is incised by the Coldwater River.

The Coldwater River headwaters originate near Zupjok Peak in the steep mountainous terrain of the Cascade Mountains of southern British Columbia, approximately 1,372 m above sea level. The river flows northeast for approximately 94 km to its confluence with the Nicola River in the town of Merritt, BC, approximately 579 m above sea level. The Coldwater River is a tributary of the Nicola River, and the Nicola River is a tributary of the Thompson River, which drains into the Fraser River at Lytton, BC. The Coquihalla highway runs along side the Coldwater River until it diverges east from the river just south of Merritt, BC.

7.0 GEOLOGICAL SETTING

The geology of the northern section of the Study Area (BCGS index 092I/02) has been mapped and is described in the Geological Survey of Canada Memoir 380 – Quaternary Geology and Geomorphology, Nicola- Vernon Area, British Columbia, by Robert. J. Fulton (1975). However, the southern section of the Study Area along the Coldwater River has not been mapped (BCGS index 092H/15).

The upper reaches of the Coldwater River upstream (south) of the Study Area, is a region of high relief where the eastern slopes of the Cascade Mountains drain into the Coldwater River. The Cascades are formed primarily of igneous rocks (granodiorite, quartz diorite, and granite) with volcanic intrusions, while sedimentary rocks occur locally (conglomerates, sandstones and shales) (McPhail, J.D., 1980; GSC Map 1069A). The section of the Coldwater River in the Study Area is situated within the Thompson Plateau, which is a region defined by gently rolling upland separated by steep walled, flat floored valleys (McPhail, J.D., 1980). Fulton described the area as "an area of rolling rocky upland, only thinly-veneered with Quaternary deposits, and broad deep valleys containing lakes and thick Quaternary sediments". The total thickness of unconsolidated valley bottom sediments is not documented; however, Golder (2018) estimated the thickness of the unconsolidated valley bottom deposits in the Coldwater River valley to range from about 30 m (upriver) to 110 m (downriver) based on water well records and a rough extrapolation of the valley base from the valley side slopes.

The Coldwater River valley developed along the regional Coldwater Fault, characterized by narrow valley walls constrained by unconsolidated valley deposits (Fulton, 1975). The valley walls are commonly lined by varying thicknesses of undifferentiated glacial tills and morainal deposits. During late Fraser Glaciation, the Nicola Basin was occupied by three successive glacial lakes: glacial Lake Quilchena which drained south, followed by glacial Lake Hamilton which drained east, ending with glacial Lake Merritt which drained north (Fulton 1969). Glaciolacustrine deposits are inferred to extend from the Merritt Basin into the northern reaches of the Coldwater Valley to approximately the location of the Coldwater Indian Band Reserve No.1 based on the Fulton's depiction of glacial lake extent and glacial retreat (1969). Fulton (1969) inferred that glaciolacustrine deposition was minor outside of the basin as the ice was thought to be relatively clean, but that large quantities of silt were carried into the Merritt area from wasting ice in the Guichon Creek valley - a major meltwater channel north of Merritt. Glacial lake deposits are typically bound by fan and near-shore deposits (WMC, 2008b). Following the draining of the glacial lakes in the Merritt Basin, meltwater from glaciers in the upper reaches (south portion) of the Coldwater River eroded a channel sub-parallel to the current course of the Coldwater River and glacial outwash sands and gravel deposits formed (WMC, 2008b). The Merritt Aquifer complex was formed through the spreading of these sand and gravel deposits over areas not previously eroded.

Surficial Geology

Most of the surficial geology in the Study Area is a result of the Fraser Glaciation. Primary deposits along the valley slopes are comprised of morainal deposits and glacial drift or till, while the valley bottom quaternary geology and geomorphology formed as a result of glacial retreat with stagnant ice and meltwater. However, post-glacial fan deposits consisting of poorly sorted gravel, sand and silt are also present in the Coldwater valley with modern alluvium and fan deposits forming shallow connected aquifers alongside the Coldwater River (Golder, 2018). Post-glacial alluvium was mapped in the Coldwater Valley by Fulton (1975) from Merritt to approximately the location of the Coldwater Indian Band Reserve No.1 and is inferred extend throughout the Coldwater valley (Golder 2018).

Bedrock Geology

Bedrock within the Study Area is primarily volcanic (based on IMAP bedrock geology layer). The Coldwater Fault that runs along the valley bottom separates the Nicola Group to the east from the Princeton and Spences Groups to the west. The principal rock groups are described below.

- Nicola Group of the Upper Triassic, primary consisting of extrusive rock comprised of greenstone, andesite, basalt, agglomerate and tuff. The Nicola Group forms a wide band extending north from Merritt to Kamloops. The Nicola Group is considered to be highly fractured (secondary permeability) with fracture-flow being the source of groundwater to wells drilled in bedrock.
- Coldwater Beds of the Princeton Group are present south of Merritt and lie along the west side of the valley bottom fault. The Coldwater beds consist of sedimentary rock comprised of conglomerate, sandstone, shale and coal. The Princeton Group is present south of Merritt and lie along the west side of the valley bottom fault. Two distinct bed groups of the Princeton Group are present along this section: the Coldwater beds consist of sedimentary rock comprised of conglomerate, sandstone, shale and coal. An additional group of beds from the Princeton group (an unnamed rock) are present only in a localized area on the west of the Coldwater River just south of Merritt. This consists of intermediate, locally mafic and felsic, flows and volcaniclastic rocks
- Spences Bridge Group – Spius Creek Formation and Pimaninus Formations of the Lower Cretaceous also west of the Coldwater River (Coldwater Fault) but south of Princeton Group. These two formations are volcanic rock consisting of rhyolite, andesite, basalt, tuffs and breccias.

8.0 HYDROGEOLOGICAL SETTING

Unconsolidated valley bottom deposits in the Coldwater River valley consisting of poorly sorted gravel, sand and silts form the major hydrostratigraphic units in the Study Area. The Study Area also includes the Merritt Basin, which is the largest depositional basin in the region and is characterized by consistent and continuous stratigraphy with thick extensive glaciolacustrine and sand and gravel deposits (Gorski *et al.* 2018).

A total of eight (8) known aquifers and one additional inferred aquifer (i.e. Intermediate Aquifer; Golder 2019) occur within the Study Area. The aquifers are located in or near to three subregions: Merritt Basin, Paul's Basin and the Kingsvale area. The locations and lateral extents of these aquifers are shown on Figure 3, and a summary of their characteristics is provided in Table 2. Only two known aquifers within the Study area are shallow and unconfined or partially confined, namely the Upper Merritt Aquifer (No. 74) and the Upper Joeyaska

Aquifer (No. 1169). The remaining aquifers are confined by several meters of lower permeability material and only one of these confined aquifers are in bedrock. Of the two unconfined shallow aquifers in the Study Area, only the Upper Merritt Aquifer (saturated and/or unsaturated zone) is in direct contact with the Coldwater River. This contact area generally coincides with the previously identified losing reach of the Coldwater River (see Section 5.0 and Reach A in Figure 2).

Table 2: Summary of Aquifers and their Characteristics within the Study Area

Name	Coldwater Valley Aquifer	Inter-mediate Valley Aquifer	Kwinshatin Intertill Aquifer	Joeyaska Deep Aquifer	Joeyaska Shallow Aquifer	Lower Merritt Aquifer	Middle Merritt Aquifer	Upper Merritt Aquifer	Kingsvale Aquifer
Aquifer No.	1164	NA	1173	75	1169	1167	1168	74	1165
Descriptive Location	Coldwater Valley south of Paul's Basin	Coldwater Valley between Brookmere and Paul's Basin	Coldwater River at Kwinshatin Creek	South-east side of Merritt Basin	South-east side of Merritt Basin	Merritt Basin	Merritt Basin	Merritt Basin	Coldwater Valley near Kingsvale
Confinement	Confined	Confined	Confined	Confined	Partially Confined	Confined	Confined	Un-confined	Confined/ Partially Confined
Vulnerability	B	A	C	C	B	C	C	A	C
Level of Development	III	I	II	II	II	II	II	I	II
Subtype	4b	4b	4b	4b/5a	4a/4b	4b	4b	1c	6b
Materials	Glacio-fluvial sand and gravel	Glacio-fluvial sand and gravel	glaciofluvial sand and gravel	Glacio-fluvial sand and gravel /Shallow sedimentary bedrock	Glacio-fluvial sand and gravel	Glacio-fluvial sand and gravel	Glacio-fluvial sand and gravel	fluvial or glacio-fluvial	fractured crystalline rock (bedrock)
Flowing Artesian Conditions Noted						Y			
Area (km^2)	0.8	4.7	1.8	2.7	1.9	6.8	13	7	7.4
Estimated Avg. Elev. Top of Aquifer (masl)	757	736	676	557	666	506	548	607	890
Estimated Avg. Elev. Bottom of Aquifer (masl)	751	720	669	548	655	458	520	592	N/A
Estimated Avg. Thickness of Aquifer (m)	6	16	7	9	11	81	28	13	N/A
Estimated Avg. Thickness of Confining Material (m)	8	18	61	72	14	21	50	N/A	28
Water Type (no. of Samples)*	NA	NA	NA	NA	NA	$CaSO_4$	NA	$CaHCO_3$	NA

'*Based on results in Figure 4.

There is not much specific information on the hydrogeology of the quaternary deposits beyond the mapped aquifers. Based on Gorski et. al (2018), review of the water well records to determine the location of permeable (aquifer) versus non-permeable (aquitard) quaternary deposits for aquifer mapping purposes, non permeable unit soil descriptions ranged from silt (sandy silt to clayey silt), clay (including silty clay), and till, and were assigned as potential aquitard deposits. Based on the depositional history described by Fulton (1975), the majority of the quaternary deposits are inferred to be of glacial origin, with deposits surrounding the mapped aquifers inferred to be mostly glacial lacustrine or glacial till.

9.0 DATA ANALYSIS

Currently available data for the Study Area that was considered relevant to the assessment of groundwater-surface water interaction was compiled and analysed. This included:

- Hydrometric data (flows and stage) from the two WSC stations on the Coldwater River.
- Surface water and groundwater quality and stable isotope data.
- Lithologic information, pumping rates and water levels from the water well records.
- Surface water and Groundwater licencing information.

The results of the data analysis are described in the following sections.

9.1 Hydrometric Data

Within the Study Area there are two active hydrometric stations along the Coldwater River and five main tributaries that drain into this river, as shown on Figure 2. All water courses within the Study Area are considered to be snow-melt driven systems, with freshet peak flows typically occurring in May or June. The low flow periods for these water features is typically August and September; the low flow periods do not typically coincide with the lowest precipitation months (typically March and April).

As part of a previous study (Golder 2018), a hydrological analysis was conducted of the Coldwater River and its contributing tributaries, between the Water Survey of Canada (WSC) hydrometric station near Brookmere (upstream station) and the station in Merritt (downstream station). The hydrograph for the Coldwater River, based on monthly flow records from these two WSC stations is shown on Figure 4. The hydrograph indicates a mean annual flow rate of 2.55 m^3/s upstream and 3.06 m^3/s downstream, excluding freshet flows. This indicates an annual average net baseflow (i.e., net gaining) rate of about 0.51 m^3/s for this 35 km stretch of river, although it is anticipated that several incremental gaining and losing reaches exist along this stretch of river. The net baseflow estimate infers an overall groundwater discharge rate to the river of about 0.0146 m^3/s per km of river.

Based on an analysis of daily flows for the hydrometric station in Merritt from 2005 to 2016, the lowest 7-day flow occurs in the third week of September on average. Overall, the lowest flow typically occurs from the end of August to the end of September.

9.2 Comparison of Groundwater and Surface Water Levels

Shallow Groundwater

A comparison between river levels and shallow groundwater levels within the Study Area was conducted to evaluate whether there were reaches, such as Reach A, where there is potentially a downward hydraulic gradient or where the water table is potentially disconnected and below the base of the river (i.e. where an unsaturated zone exists below the river) or where. If such areas could be identified, these would be considered potential losing reaches.

Stage data from the two active hydrometric stations along the Coldwater River, the upstream hydrometric station near Brookmere and the downstream station in Merritt, was compiled and analysed to determine the average water level elevation at each station. Between these two stations, approximate surface water level elevations along the river were roughly estimated using the CDEM and by linearly interpolating between bounding topographic points where local topographic elevation data did not indicate a downward slope along the river because of its coarse resolution (20 m resolution). In addition, groundwater level information from the water well records (water levels recorded at the time of drilling) was compiled and reduced for shallow wells (wells less than 30 m depth below ground surface) and wells known to be completed in unconfined aquifers within the Coldwater valley bottom or within Merritt Basin. The well water level depths were converted to approximate groundwater level elevations by using the topographic dataset (CDEM) as the top-of-well elevations.

The resulting water level elevations, both known and approximated, are shown on Figure 5 and the shallow wells are listed in APPENDIX B. There is a high degree of uncertainty in the approximated water level elevations in this figure. The approximated groundwater levels were obtained from different years, may not reflect static levels, and the wells were not surveyed. The approximated surface water levels were not measured but were based on topography and a consideration of the water level elevations at the two hydrometric stations spaced 35 km apart. However, in consideration of this uncertainty, potential losing reaches were identified at 2 locations, as shown in Figure 5. These locations had surface water level elevations that were above the groundwater level elevation in the nearest shallow wells. One of these locations is Reach A which was previously identified as a losing reach (see Section 4.0). The other location, Reach H (north of Kingsvale), is uninvestigated. It is recommended that this location be targeted for investigation in the next phase of the Study (Phase 2 – summer field program) to confirm or refute these conditions.

Deeper Groundwater

Information from the water well records was compiled and reduced to identify deeper water wells within or near the Coldwater valley bottom or within Merritt Basin that are known to be completed in confined aquifers and/or are known to be flowing artesian wells. These well locations are shown on Figure 6 and listed in APPENDIX B together with the well depths and the inferred aquifers that the wells are completed in. These water well locations are considered to represent groundwater zones that are likely hydraulically unconnected to the river; therefore the river reaches where shallow water wells and mapped unconfined aquifers are not known to exist (based on Figure 3 and Figure 5) and where there is a confining aquitard below river (based on Figure 3 and Figure 6) are considered to be relatively less vulnerable to the adverse effects of groundwater extraction. Furthermore, potentially gaining reaches can be identified where the water wells are flowing artesian. This is because the shallow groundwater zone in these areas is anticipated to have upward hydraulic gradients towards the river.

Potentially less vulnerable reaches, with respect to the adverse effects of groundwater pumping, were identified at five locations (Reach D, E, G, I and K). One of the reaches is potentially also a gaining reach because of flowing artesian conditions in the confined aquifer (Reach E) (see Figure 6).

9.3 Geochemical Analysis of Water Samples

Golder reviewed water chemistry data that was provided by FLNRORD for this Study. The data included results for 10 groundwater sampling locations and 2 surface water sampling locations within the Study Area. The samples were mostly collected in November/December 2016, mostly from the Merritt Area, and were analysed for the following parameters:

- field parameters (dissolved oxygen (DO), electrical conductivity (EC), Eh, pH, temperature)
- general parameters (turbidity, total dissolved solids (TDS), hardness)
- anions (alkalinity, ammonia, chloride, fluoride, nitrate, nitrite, dissolved organic nitrogen (DON) dissolved kjeldahl nitrogen (DKN), total nitrogen, sulphate
- total and dissolved metals (includes major cations and trace metals)
- stable isotopes of oxygen and hydrogen

The sampling locations are shown on Figure 7 and include:

- Two (2) surface water locations from the Coldwater River: one upstream near Kingsvale and one downstream in Merritt.
- Four (4) wells completed in the shallow unconfined Upper Merritt Aquifer in Merritt: OBS Well 296, WTN 24157 (Voght Park #1), WTN 114668 (Voght Park #2; only sampled for stable isotopes), WTN 38902 (Fairley Park).
- Two (2) artesian water wells completed in confined aquifers: WTN 71419 and WTN 83868 (Mt Music).
- One (1) deep well was completed in a confined aquifer: (WTN 97218; Kengard well).
- Three (3) water wells completed in bedrock: two deep wells near Kingsvale (WTN 59434 and WTN 76421), and one shallow well (WTN 83959) near or within Merritt.

Because the majority of the sampling dates were in November and December 2016 (the only exceptions being one river sample and one well (WTN 14668) were sampled October 2015, and another well (WTN 56918/OBS WELL 296) was sampled in February 2017) the effect of seasonality on water quality could not be assessed.

9.3.1 Major Ion Chemistry Analysis

The major ion chemistry of the water samples is represented graphically on the Piper diagram in Figure 8. The regions of different water types are also shown on the piper diagram as calcium-sulphate type (Ca-SO4), calcium-carbonate type (Ca-HCO3), sodium-bicarbonate type (Na-HCO3) and sodium-chloride type (NaCl). Groundwater is typically found to chemically evolve from bicarbonate- to sulphate- to chloride-type waters with increasing flow paths and increasing groundwater age (Freeze and Cherry 1979).

The data presented in Figure 8 illustrates that:

- The upstream and downstream surface water samples from the Coldwater River are geochemically consistent. This suggests that any influence of surface water infiltration in groundwater (i.e. river losing) will appear as the same geochemical signature at all locations along the river. The surface water samples present as calcium bicarbonate-type waters on the Piper plot.
- The wells completed in the unconfined shallow Upper Merritt Aquifer within Merritt Basin (WTN 38902-Fairly Park, WTN 24159-Voght Park #1, WTN 56918-OBW 296) also have calcium bicarbonate-type waters, which suggests the influence of surface water infiltration from the Coldwater River.
- The wells completed in confined aquifers and confined bedrock aquifers are either calcium sulphate-type (WTN 97218-Kengard well and WTN 71419), calcium-bicarbonate-chloride (WTN 76421) or sodium-bicarbonate-chloride type (WTN 59434), indicating older groundwater that has not been influenced by surface water infiltration.
- The shallow bedrock well south of Merritt (WTN 83959) and the artesian well completed in the deep unmapped confined aquifer south of Merritt (WTN 83868-Mt Music well) have similar major ion percentages but substantially higher ion concentrations (TDS is 423 mg/L and 361 mg/L for these wells respectively) relative to surface water in the Coldwater River (TDS of 50-70 mg/L). WTN 83959 is located significantly upslope from the Coldwater river and is screened in shallow bedrock that is likely unconfined and directly recharged by the infiltration of precipitation; therefore, groundwater at this location is expected to be relatively young (short travel time in the subsurface). This well is screened approximately 150 m above the elevation of the Coldwater River; therefore, it is unlikely to have any direct hydraulic connectivity with the river. WTN 83868-Mt Music well is located directly adjacent to the Coldwater River just upstream of the Merritt Basin, though it is a deep (122 m), confined, flowing artesian well. Therefore, it is unlikely to be hydraulically connected to the Coldwater River.

9.3.2 Isotope Analysis

Golder reviewed isotopic data provided by FLNRORD for the same groundwater and surface water sampling locations as described above. The samples were mostly collected over November/December 2016, mostly from the Merritt Area, although two samples were collected in differing years (2015 and 2017). The samples were analysed for the stable isotopes of oxygen and hydrogen.

Within the water molecule, there are two stable isotopes of hydrogen: ^{2}H and ^{1}H, and three stable isotopes of oxygen: ^{16}O, ^{17}O and ^{18}O. These stable isotopes are conservative groundwater tracers and often carry a signature that indicates the source of groundwater recharge and relative residence times of groundwater in the subsurface.

The stable isotopes of hydrogen and oxygen are measured as the ratio of the two most abundant isotopes of a given element (for oxygen, these are ^{16}O and ^{18}O) (Clark and Fritz 1997). Water isotope results are reported relative to Vienna Standard Mean Ocean Water (VSMOW)-Standard Light Antarctic Precipitation (SLAP), and expressed in the δ(‰) ("del") notation (Clark and Fritz 1997), as follows for $\delta^{18}O$:

$$\partial^{18}O = \left(\frac{(^{18}O/^{16}O)_{sample} - (^{18}O/^{16}O)_{smow}}{(^{18}O/^{16}O)_{smow}} \right) x1000$$

where:

$(^{18}O/^{16}O)_{sample}$ is the light to heavy isotope ratio for the oxygen in the sample

$(^{18}O/^{16}O)_{smow}$ is the light to heavy isotope ratio for the oxygen in a standard.

Similarly, the value of δD is calculated by replacing the ratio of $^{18}O/^{16}O$ with $^{2}H/^{1}H$ in the above equation.

The stable isotope results for the water samples is presented on the $\delta^{2}H$ / $\delta^{18}O$ cross plot in Figure 9. Sample results are shown in relation to the linear trend of the sampled data and the Global Meteoric Water Line (GMWL; Craig 1961). The GMWL is based on unevaporated precipitation data from locations around the globe and shows the linear relationship between $\delta^{2}H$ and $\delta^{18}O$ values of precipitation. The GWML has an equation of $\delta^{2}H = 8\ \delta^{18}O + 10$ (linear slope of 8). Although the slope is nearly constant globally, both the slope and the intercept can vary considerably, reflecting local meteorological, topographic and seasonal conditions and resulting in local meteoric water lines.

In general, natural groundwaters that are recharged by the infiltration of precipitation originating at higher elevations and colder temperatures (i.e., snow and/or early spring or late fall rains), where little to no evaporation of the precipitation occurs prior to infiltration into the ground, will have a more-depleted isotopic signature (i.e., more negative $\delta^{2}H$ and $\delta^{18}O$ values) and will plot at the bottom left hand corner of a $\delta^{2}H$ $\delta^{18}O$ plot. Groundwaters with a more-enriched isotopic signature (i.e., more positive $\delta^{2}H$ and $\delta^{18}O$ values) are generally indicative of a source of recharge that is either different or lower in elevation; that has been altered through evaporation; and/or that mixing of different sources of water has occurred.

- The surface water samples from the Coldwater River plot towards the top right corner, indicating that these are amongst the most $\delta^{2}H$ and $\delta^{18}O$ enriched samples, likely due to the high rates of evaporation in surface water. The isotopic signature of the Coldwater River is generally consistent between the upstream (Gillis Rd bridge in Kingsvale) and downstream (Collette bridge in Merritt) sampling locations.
- Samples from shallow wells within the Upper Merritt Aquifer exhibit $\delta^{2}H$ and $\delta^{18}O$ values very similar to those of the Coldwater River. This is consistent with the major ion chemistry results and suggests the influence of surface water infiltration from the Coldwater River.
- The remaining groundwater samples exhibit much more depleted isotopic signatures. These samples are from deep wells completed in confined aquifers (either overburden or bedrock aquifers), with the exception of one well completed in shallow bedrock upslope and disconnected from the Coldwater River. The depleted isotopic signatures in these wells suggest recharge of groundwater from precipitation from higher elevations rather than recharge from river water.

9.3.3 Geochemical Conclusions

The geochemical analysis of both major ions and stable isotopes generally supports the understanding that Reach A in Figure 2 is a losing reach, with surface water infiltrating into the underlying unconfined aquifer. This analysis also suggests that groundwater from confined aquifers are not directly hydraulically connected to the Coldwater River. This supports the identification of potentially less vulnerable reaches described in Section 9.2 where shallow water wells or mapped unconfined aquifer are not known to exist and where confined aquifers are known or inferred based on the water well records. With the current dataset, limited interpretation can be made regarding the more upstream reaches of the Coldwater River. This is because of the absence of shallow groundwater samples from the unconfined aquifers within the Coldwater valley, upstream (south) of Merritt Basin.

9.4 Water Use Data

Based on currently available licencing information (provided in APPENDIX C), total licensed surface water withdrawal from the Coldwater River amounts to 6.49 M m^3/yr (0.21 m^3/s), while 2.68 M m^3/yr (0.085 m^3/sec) is reserved for water conservation (2018 data). The total licensed groundwater withdrawals amount to 7.51M m^3/yr of which 5.21 M m^3/yr (~70%) is estimated to be sourced from shallow unconfined aquifers that could be in hydraulic connection to the Coldwater River. The current total surface water licencing amount (6.49 M m^3/yr) is less than the 2006 estimate by Summit (2007) for the Coldwater Basin (10.02 M m^3/yr; discussed in Section 4.0). This discrepancy is likely because the 2006 estimate includes surface water licenses from tributaries of the Coldwater River. A direct comparison of these two amounts to assess the potential increase in surface water withdrawal since 2006 is not possible with the available dataset.

The locations of licenced surface water withdrawals (points of diversion) and groundwater withdrawals are shown on Figure 10 and Figure 11 respectively. The surface water locations are relatively evenly distributed along the Coldwater River, suggesting that there is no specific location on the river more vulnerable to surface water over-withdrawal issues. Most surface water licenses are for irrigation, with City of Merritt waterworks being the next largest license holder; however, the City of Merritt is licensed with the largest allocation amount of 4.00 M m^3/yr representing approximately 44% of the total licensed surface water use. Irrigation use amounts to 2.49 M m^3/yr or 27% of the total licensed surface water use. This suggests a higher stress on surface water during the growing season of June to August.

There are only five licensed shallow groundwater extraction wells in the vicinity of the river, with three located in the Merritt Area (used by the City of Merritt waterworks; 5.05 M m^3/yr or 2537 gpm) and completed in the unconfined Upper Merritt Aquifer. The remaining two are in the Coldwater valley: one near Paul's Basin and used for livestock water supply (537,081 m^3/yr or 2.7 gpm), and the other is near Kingsvale and used for irrigation (161,955 m^3/yr or 81.4 gpm). The total unlicensed annual groundwater extraction from the unconfined aquifer(s) near to and potentially hydraulically connected to the river is currently unknown. Based on this limited information, the two river areas which are nearest to licensed groundwater extraction wells completed in shallow unconfined aquifers and have high groundwater extraction rates are considered the most vulnerable to the adverse effects of groundwater extraction. One of these locations is Reach A which was previously identified as a losing reach (see Section 4.0). The other location, named herein as Reach J located south of Kingsvale, is uninvestigated. It is recommended that this location be included for investigation in the next phase of the Study (Phase 2).

10.0 SUMMARY AND CONCLUSIONS

This Phase 1 Study was successful in providing a baseline understanding of groundwater-surface water interaction along the Coldwater River based on currently available information. The primary findings of this Study are outlined below. The reach locations discussed below are shown on Figure 12.

Location of Potential or Known Losing Reaches

- The stretch of the Coldwater River that flows through the Merritt Basin (Reach A) is likely a losing reach. This is based on multiple lines of evidence from several historical studies, and also based on the results of the groundwater-surface water level elevation comparison and the geochemical analysis conducted as part of this Phase 1 Study. Flow monitoring results in August/September 2005 indicated a river flow loss of 0.15 m^3/s (approximately 40% of flow) over this 3.5 km stretch of river between the Mountain Music Festival site and Claybanks Park (MOE 2009). This reach is inferred to be a losing reach throughout the year and is considered to be a primary source of recharge to the Upper Merritt Aquifer under both pre-pumping and pumping conditions with respect to the City of Merritt production wells.
- A potential losing reach (Reach H, north of Kingsvale) was identified based on a comparison of approximate surface water and shallow groundwater level elevations, although there is a high level of uncertainty in this finding. This is because actual water level measurements were not available. This reach location has not been previously investigated. It is recommended that this location be targeted for investigation in the next phase of the study (Phase 2).

Location of Potential or Known Gaining Reaches

- A potential gaining reach (Reach E, north of Paul's Basin) was identified based on the analysis of water well records for wells within or near the valley bottom that are known to be completed in confined aquifers and/or are artesian, and where shallow water wells or unconfined aquifers are not known to exist.

River Flow Conditions

- Based on the mean monthly flow analysis for the two active hydrometric stations on the Coldwater River, a net annual average baseflow (i.e., net gaining) rate of about 0.51 m^3/s was estimated, although it is anticipated that several gaining and losing reaches exist along this 35 km stretch of river.
- Based on an analysis of daily flows for the hydrometric station in Merritt, the lowest 7-day flow occurs in the third week of September on average. Overall, the lowest flow typically occurs from end of August to end of September.
- The critical environmental flow thresholds (CEFT) are 0.43 m^3/s or 0.84 m^3/s, depending on the species of fish (McCleary 2019). Mean monthly flow do not typically fall below the CEFT. However, historical daily flow rates as low as 1.3 m^3/s and 0.43 m^3/s have been recorded at the Brookmere and Merritt stations respectively during the summer low-flow period. In addition, according to MOE (2009) daytime surface water temperatures in August in the lower Coldwater River (portion of the river in the Merritt Area) exceeded the lethal limit for salmon, trout and char (24°C)

Groundwater Conditions and Potentially Less Vulnerable Reaches

- Surficial riverbed material consists of gravel to cobble-sized sediment. However, fine-grained glacial or glacio-lacustrine sediments may occur beneath the riverbed, such as in the Kingsvale area.

- Only two known aquifers within the Study area are shallow and unconfined or partially confined, namely the Upper Merritt Aquifer (No. 74) and the Upper Joeyaska Aquifer (No. 1169). The remaining aquifers are confined by several meters of lower permeability material and only one of these confined aquifers are in bedrock. Of the two unconfined shallow aquifers in the Study Area, only the Upper Merritt Aquifer is in direct contact with the Coldwater River.
- Potentially less vulnerable reaches with respect to the adverse effects of groundwater extraction were identified at five locations (Reach D, E, G, I and K). These are river reaches where shallow water wells and mapped unconfined aquifers are not known to exist and where there is a confining aquitard below the river (based on the presence of mapped confined aquifers or water wells known to be completed in confined aquifers). This is supported by several lines of evidence, including the geochemical analysis conducted as part of this Phase 1 Study which indicated that the confined aquifers in the Study Area are not likely to be in direct hydraulic connection with the Coldwater River.

Licensed Water Uses and Potentially More Vulnerable Reaches

- Points of diversion related to surface water licenses are relatively evenly distributed along the Coldwater River, suggesting that there is no specific location on the river that is more vulnerable to surface water over-withdrawal issues. Most surface water licenses are for irrigation, with City of Merritt waterworks being the next largest license holder; however the City of Merritt is licensed with the largest allocation amount of 4.00 M m^3/yr representing approximately 44% of the total licensed surface water use. Irrigation use amounts to 2.49 M m^3/yr or 27% of the total licensed surface water use. This suggests a higher demand on surface water from the Coldwater River during the growing season (June to August).
- There are only five licensed shallow groundwater extraction wells in the vicinity of the river, with three located in the Merritt Area and completed in the Upper Merritt Aquifer and two located in the Coldwater Valley. The total unlicensed annual groundwater extraction from shallow unconfined aquifer(s) near to and potentially hydraulically connected to the river is currently unknown. The two reach areas which are nearest to licensed high groundwater extraction rates from shallow unconfined aquifers are considered the most vulnerable to the adverse effects of groundwater extraction. One of these locations is Reach A (Merritt Area) which was previously identified as a losing reach. The other location (Reach J, south of Kingsvale) is uninvestigated. It is recommended that this location be targeted for investigation in the next phase of the study (Phase 2).

11.0 DATA GAPS

Based on the results of this Phase 1 Study, the primary data gaps and uncertainties with respect to the identification and quantification of gaining and losing reaches along the Coldwater River, from Brookmere to Merritt, are as follows:

- There are no measured (and surveyed) surface water and nearby shallow groundwater level elevations in the Study Area between the WSC station near Brookmere and the WSC station in Merritt, although geodetic water level elevations are available at the stations themselves.

- There is an absence of geochemical data for shallow groundwater from the unconfined aquifers within the Coldwater valley upstream (south) of Merritt Basin to Brookmere; and there is an absence of geochemical data to assess the effect of seasonality.
- There is an absence of incremental river flow measurements between the upstream station near Brookmere and the downstream station in Merritt. It is recently understood that there may be some limited data (from 2016-2017) from two previously active provincial (BC Hydro) hydrometric stations on the Coldwater River; these data should be evaluated as part of the next phase of the Study.
- The total unlicensed annual groundwater extraction from the unconfined aquifer(s) near to and potentially hydraulically connected to the river is currently unknown.
- There are no water use or water demand estimates for the Study Area more recent than 2006, as documented in Summit (2007).
- There is an absence of riverbed data (e.g., thickness and grain-size of the hyporheic zone).
- There is an absence of surficial geology mapping upstream of the Coldwater Indian Reserve No. 1.

Resolution of these data gaps could be beneficial for assessing the connectivity and interaction between the Coldwater River upstream of Merritt and the underlying shallow groundwater, and for confirming the rate of river flow loss over the reach within Merritt Basin.

12.0 RECOMMENDATIONS FOR PHASE 2 (FIELD PROGRAM)

This Phase 1 Study allowed for the identification of potentially vulnerable reaches as a result of groundwater extraction, potentially losing and gaining reaches, and data gaps. These locations and data gaps allow for the subsequent planning of future field work and the targeting of these specific areas for Phase 2 of the Study.

Data collection and field work as part of Phase 2 has been recommended in a way that is least invasive (no drilling of new observation wells and no disruption of the current landscape). The field program is recommended to take place in mid-September when the flow in the Coldwater River is at an annual low and tributary inflow and surface water runoff is minimized. In addition, this is a time of year when a high contrast between the groundwater and surface water temperatures is anticipated (typically occurs in late summer or mid-winter). The data collected during the field program will provide a snapshot of conditions that is representative of the monitoring period associated with the field program. The reach locations identified in this Study as being potentially losing (Reach H) or potentially having a higher vulnerability to the influence of groundwater extraction (Reach J) are targeted for investigation in this next phase of the Study.

The following is recommended for Phase 2 of this Study. The approximate locations of proposed investigation/measurement points associated with Phase 2 are shown on Figure 12. These locations are partly based on the reach divisions assigned to the Coldwater River. It should be noted that some of the planned investigation locations may not produce useful data for this Study because of local conditions (e.g., flows too low for sufficient accuracy in flow measurements, riverbed material too coarse and thick for mini-piezometer installations). Therefore, the number of investigation locations outlined in the field program below are slightly more than what is anticipated to be needed for this Phase 2 Study.

Field Program

- Measure incremental river flows using a handheld flowmeter at up to 15 locations distributed relatively evenly along the river as part of a 5-day snap-shot monitoring event. The anticipated locations are shown on Figure 12; however, actual locations may vary based on access and to enable better accuracy in the flow measurements. If tributaries are observed, measurement of tributary flow near the mouth of the tributaries will be attempted.
- Install stainless steel mini-piezometers at up to 15 locations distributed relatively evenly along the river's edge and in-between flow measurement points. The mini-piezometers will be driven-in using a slide hammer, hammer drill or similar type of manually operated mobile equipment. The screens will be installed at least 1.5 m below the river base in an attempt to contact groundwater below the hyporheic zone. The mini-piezometers will be developed immediately following installation. The anticipated mini-piezometer locations are shown on Figure 12; however, actual locations may vary for accessibility and safety reasons. It should be noted that completion of the installations to the target depth may not be achievable if riverbed material is very thick and comprised predominantly of gravels and cobbles.
- Survey all measurement points associated with the field program, including the elevation of the top-of-pipe of each mini-piezometer. The top-of-pipe locations will serve as geodetic reference points. The elevation survey should also consider including, if accessible, the stage reference points for the two inactive provincial hydrometric stations (08LG0003 and 08LG0004) on the Coldwater River.
- As part of a snap-shot monitoring event, measure and record surface water and shallow groundwater levels at each mini-piezometer using the surveyed top-of-pipe as the reference point for these measurements. In addition, record the surface water height above the riverbed at each mini-piezometer location.
- Conduct one water sampling event. Sample surface water directly downstream of the mini-piezometers, and then purge and sample groundwater from the mini-piezometers for field parameters (temperature, EC, pH, Eh, DO). Collect samples of groundwater (15 GW samples plus one duplicate for QAQC purposes) from each mini-piezometer and collect samples of surface water from every three mini-piezometer locations (4 SW samples plus one duplicate for QAQC purposes) for laboratory analysis of the following parameters:
  - stable isotopes of oxygen and hydrogen
  - alkalinity
  - anions scan (includes major anions: chloride, fluoride, nitrate, sulphate)
  - total metals (includes major cations: calcium, magnesium, sodium and potassium) for surface water samples,
  - dissolved metals (includes the major cations listed above) for groundwater samples (requires field-filtration).
- Conduct a drone survey of the Coldwater River as pilot study using thermal-imaging and visible light instruments to complete broad scale mapping of temperature variations along the river. This will attempt to locate thermal refugia, groundwater discharge locations, and locations of surface water mixing. This work is recommended as a pilot study because it is unknown whether this will be a useful tool for this type of assessment.

Data Reduction and Analysis

- Compile and reduce the field data. Download flow measurements from the two active hydrometric stations along the Coldwater River (08LG048 and 08LG010) for the monitoring period associated with the field program.
- Calculate change in flow between station and flow measurement locations and the approximate uncertainty in the values.
- Assess historical flow data and stage levels (if available) from the two inactive provincial hydrometric stations (08LG0003 and 08LG0004) and compare with hydrometric data of the same monitoring period from the active stations (08LG048 and 08LG010). Historical baseflow estimates from these data may be used to cross-check the baseflow results from the field program.
- Graphically plot change in flow and groundwater and surface level elevations relative to distance along the river from the Brookmere hydrometric station to evaluate whether gaining or losing reaches can be delineated and whether flow exchanges can be quantified.
- Graphically plot major ion chemistry and stable isotope results for all the water samples on a Piper diagram and cross-plot respectively. Include previous geochemical results from the Phase 1 Study presented in Figure 8 and Figure 9 for comparison purposes. Data from the geochemical analysis may provide evidence to support or refute the evaluation of gaining and losing reaches.

Reporting

- Prepare a report of the Phase 2 Study which documents of the methods and findings of this study.
- Develop a map which shows the actual investigation locations and delineates the gaining and losing reaches identified as part of Phase 2. The associated estimated groundwater-surface water exchange rates and the uncertainty in these values for the monitoring period will also be summarized graphically on the map.

13.0 CLOSURE

We trust that this report meets your requirements at this time. Should you have any questions, please do not hesitate to contact the undersigned.

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https://golderassociates.sharepoint.com/sites/117784/project files/6 deliverables/issued to client_wp/19131378-001-r-rev0/19131378-001-r-rev0-coldwater gw_sw interactions 23mar_20.docx

14.0 REFERENCES

Active Earth Engineering Ltd., 2009. Letter re: *Groundwater Supply Evaluation Results for Coldwater Estates Development*, Covert Place, Merritt, BC., 13 October 2009.

BC Groundwater Consulting Services Ltd., 2006. Surface Water / Groundwater Interaction Study: Stage 1. For City of Merritt. 27 March 2006.

BC Groundwater Consulting Services Ltd., 2009. *City of Merritt Deep Aquifer Development Program*: Initial Interpretations from March 2009 Kengard Deep Well Pumping Test and Recommendation to Retest the Aquifer. For City of Merritt. 24 April 2009.

BC Groundwater Consulting Services Ltd., 2011. D*eep Aquifer Development Program - Kengard Production Well Summary Report* 2004-2010. For City of Merritt. 11 April 2011.

BC. Ministry of Agriculture, 2013. Agricultural Water Demand Model - Report for the Nicola Watershed. October 2013.

BC. Ministry of Agriculture, 2013. Agricultural Water Demand Model. Irrigation Scheduling Factsheet. Order No. 500.320-2. Revised September 2015.

British Columbia Ministry of Environment and Climate Change Strategy (ENV, 2019a). Groundwater Wells and Aquifers (GWELLS) Database; Accessed January 2020. https://www2.gov.bc.ca/gov/content/environment/air-land-water/water/groundwater-wells-aquifers/groundwater-observation-well-network. Available data obtained using interactive tool: https://governmentofbc.maps.arcgis.com/apps/webappviewer/index.html?id=b53cb0bf3f6848e79d66ffd09b74f00d

British Columbia Ministry of Environment and Climate Change Strategy. Groundwater Wells and Aquifers (GWELLS) Database; Aquifer 1081 Summary (ENV, 2019b). Accessed January 2020. https://apps.nrs.gov.bc.ca/gwells/aquifers/1081.

Clark, I., & Fritz, P. (1997). The environmental isotopes. Environmental isotopes in hydrogeology, 2-34.

Craig, H. (1961). Isotopic variations in meteoric waters. Science, 133(3465), 1702-1703.

Data BC. 2019. iMapBC Web-based Mapping Application. Accessed January 2020. https://www2.gov.bc.ca/gov/content/data/geographic-data-services/web-based-mapping/imapbc.

EBA Engineering Consultants Ltd. (EBA), 2002. *Aquifer Protection Plan*. December 2002.

Enkon Environmental Ltd., 2008. *Environmental Protection Plan (EPP) for proposed City of Merritt pump test discharge to the Nicola River*. December 2008.

Freeze , R. A., Cherry, J.A., 1979. Groundwater. Prentice-Hall, Inc., Englewood Cliffs,

N.J. Gorski, N.G., R.K., Willis, J.A. Sacre and K.A. Bennett, 2018. *Nicola Watershed Aquifer Classification and Mapping*. Water Science Series (WSS), WSS2018-XX. Prov. BC., Victoria, BC.

Golder, 2018. Report re: *Nicola River Project*. Data Compilation Plan to Support Numerical Flow Modelling Strategy. 28 June 2018.

Golder, 2019. Technical Memorandum re: Part 1 of Nicola Valley Groundwater Flow Modelling Project. 21 March 2019.

Geological Survey of Canada, "A" Series Map 1069A, 1959, 1 sheet, https://doi.org/10.4095/107021 (Open Access)

Kosakoski, G.T., Hamilton, R.E., 1982. *Water Requirements for the Fisheries Resource of the Nicola River, B.C*. Dept. of Fisheries and Oceans. September 1982.

McCleary, R., 2019. *Critical Environmental Flow Thresholds for the Coldwater River*. 12 August 2019.

McPhail, J.D., 1980. *Coldwater River Study*.

MOE 2009. *Review of Groundwater/Surface Water Interactions Within the City of Merritt*. June 2009.

Natural Resources Canada. Canadian Digital Elevation Model (CDEM). https://open.canada.ca/data/en/dataset/7f245e4d-76c2-4caa-951a-45d1d2051333.

Piteau Associates Engineering Ltd. 2018. Technical Memorandum: Hydraulic Connection Between Irrigation Well at 2321 Peterson Road with the Coldwater River, near Merritt, BC. July 2018.

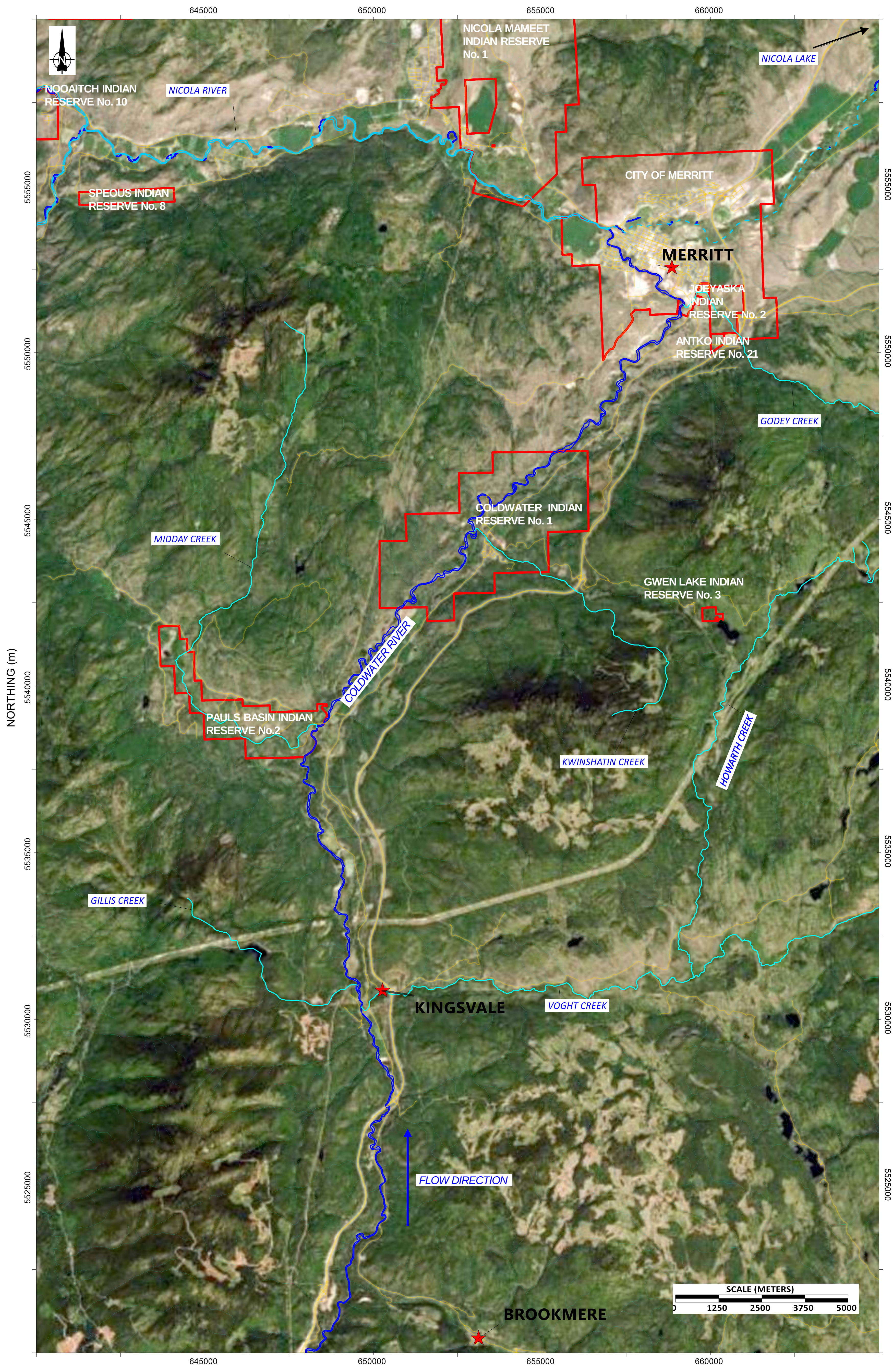
Summit Environmental Consultants Ltd., 2007. *Nicola River Watershed Present and Future Water Demand Study*. June 2007.

Water Management Consultants (WMC), 2008a. *Nicola Watershed Water Budget Analysis*. 8 October 2008.

Water Management Consultants (WMC), 2008b. *Surface and Groundwater Supply and Interaction Study - Phase 1 and 2*. 31 March 2008.

Western Water Associates Ltd. (WWA), 2012. *Well Assessment and Asset Evaluation, City of Merritt, BC*., December 2012.

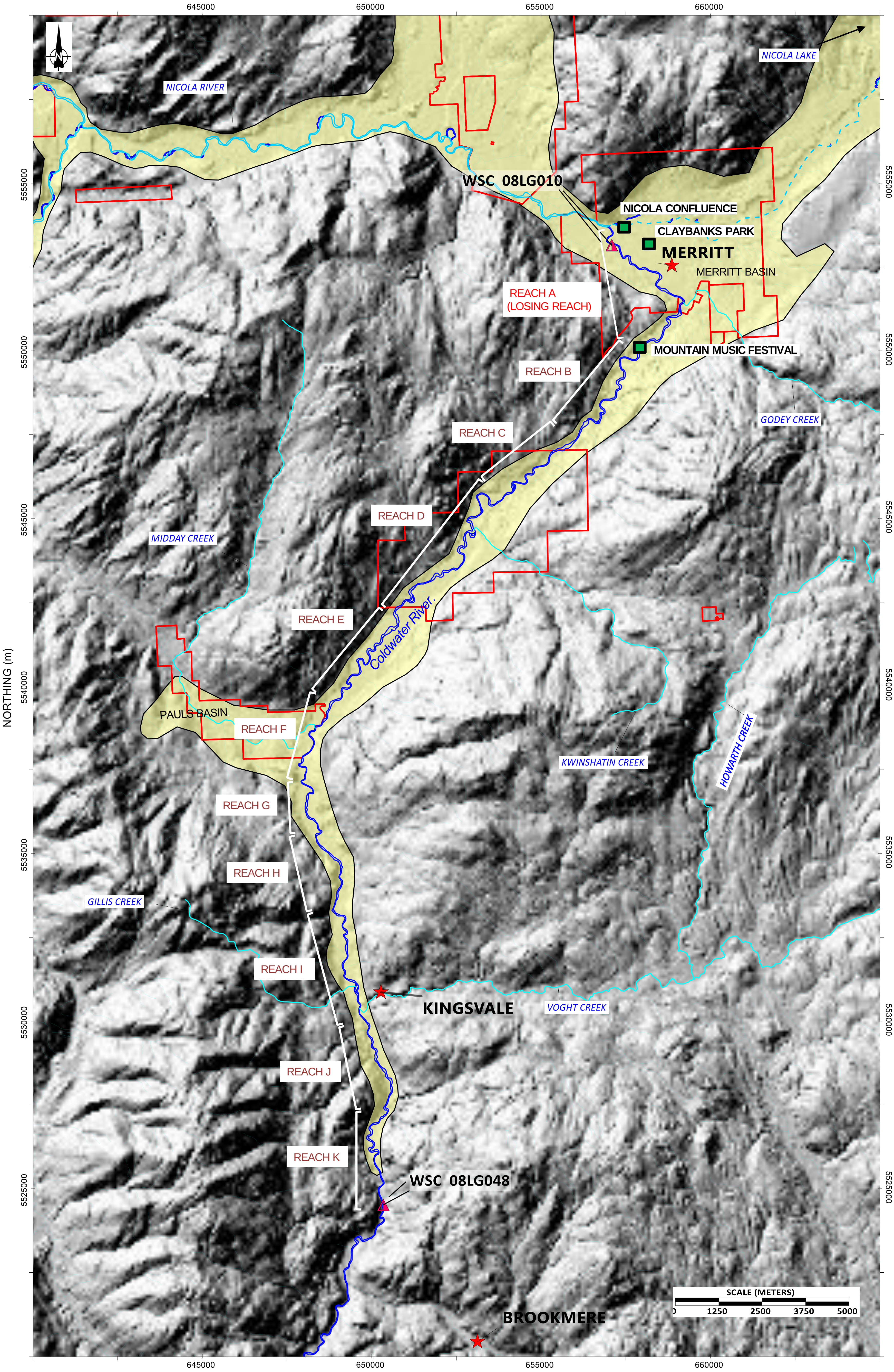
S. Swales, R. B. Lauzier, C. D. Levings. 1986. Winter habitat preferences of juvenile salmonids in two interior rivers in British Columbia. *Canadian Journal of Zoology*, 1986, 64:1506-1514, https://doi.org/10.1139/z86-225



LEGEND

- ADMINISTRATIVE BOUNDARIES
- COLDWATER RIVER
- NICOLA RIVER
- MAJOR TRIBUTARIES
- ROADWAYS

CLIENT	FRASER BASIN COUNCIL	PROJECT	COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY
CONSULTANT	GOLDER	TITLE	STUDY AREA
YYYY-MM-DD	2020-03-01	PROJECT NO.	19131378
PREPARED	JD	PHASE	1000
DESIGNED	JD	REV.	A
REVIEWED	CR	FIGURE	1
APPROVED	CR		



LEGEND

- ADMINISTRATIVE BOUNDARIES
- COLDWATER RIVER
- NICOLA RIVER
- MAJOR TRIBUTARIES
- HYDROMETRIC STATIONS (WSC)

CLIENT
FRASER BASIN COUNCIL

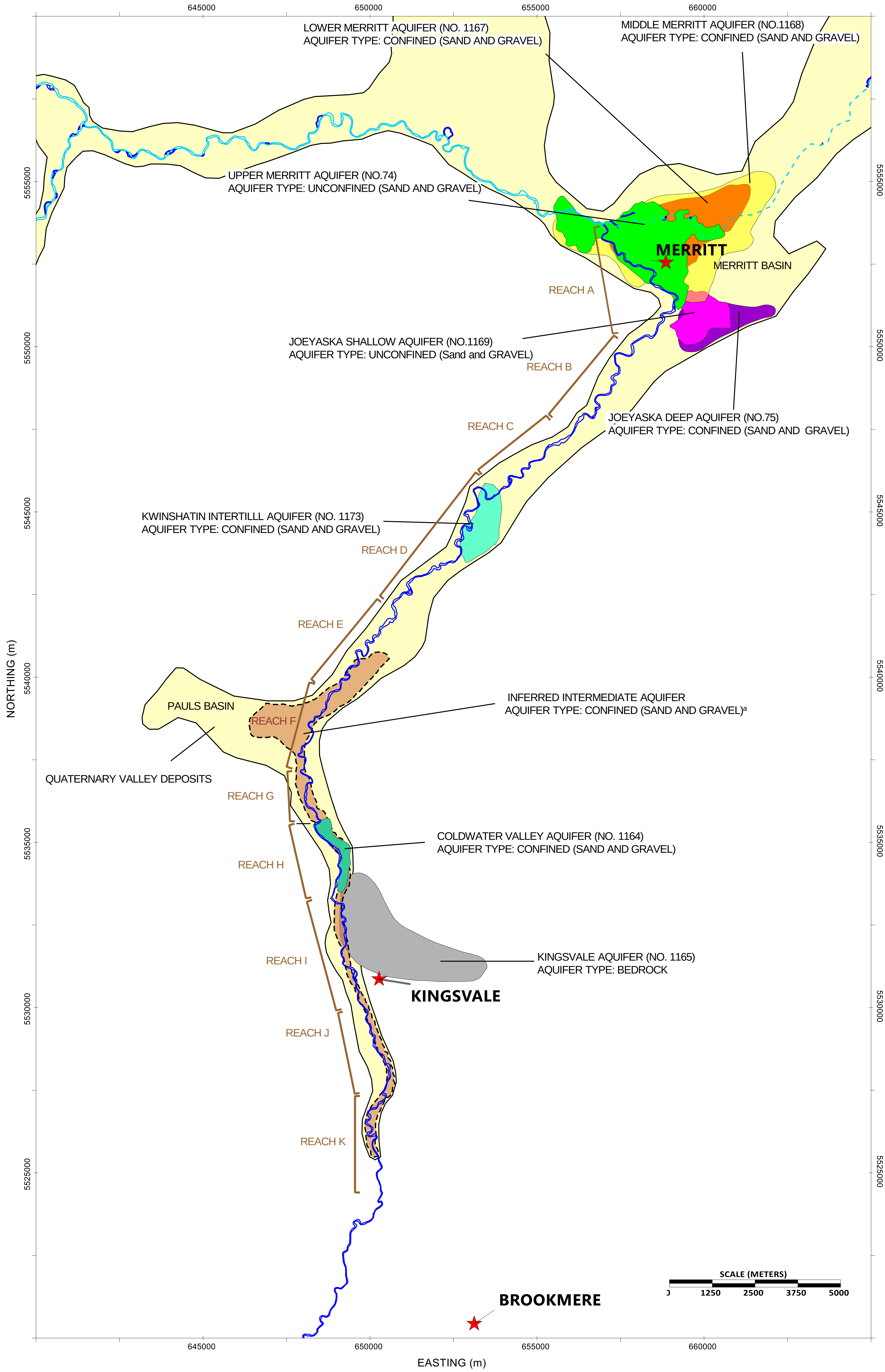
CONSULTANT
GOLDER

YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY

TITLE
GAINING AND LOSING REACHES OF THE COLDWATER RIVER BASED ON EXISTING STUDIES

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	2



NOTES

a. INFERRED AQUIFER EXTENT BASED ON MAPPING IN GOLDER, (2019).

CLIENT
FRASER BASIN COUNCIL

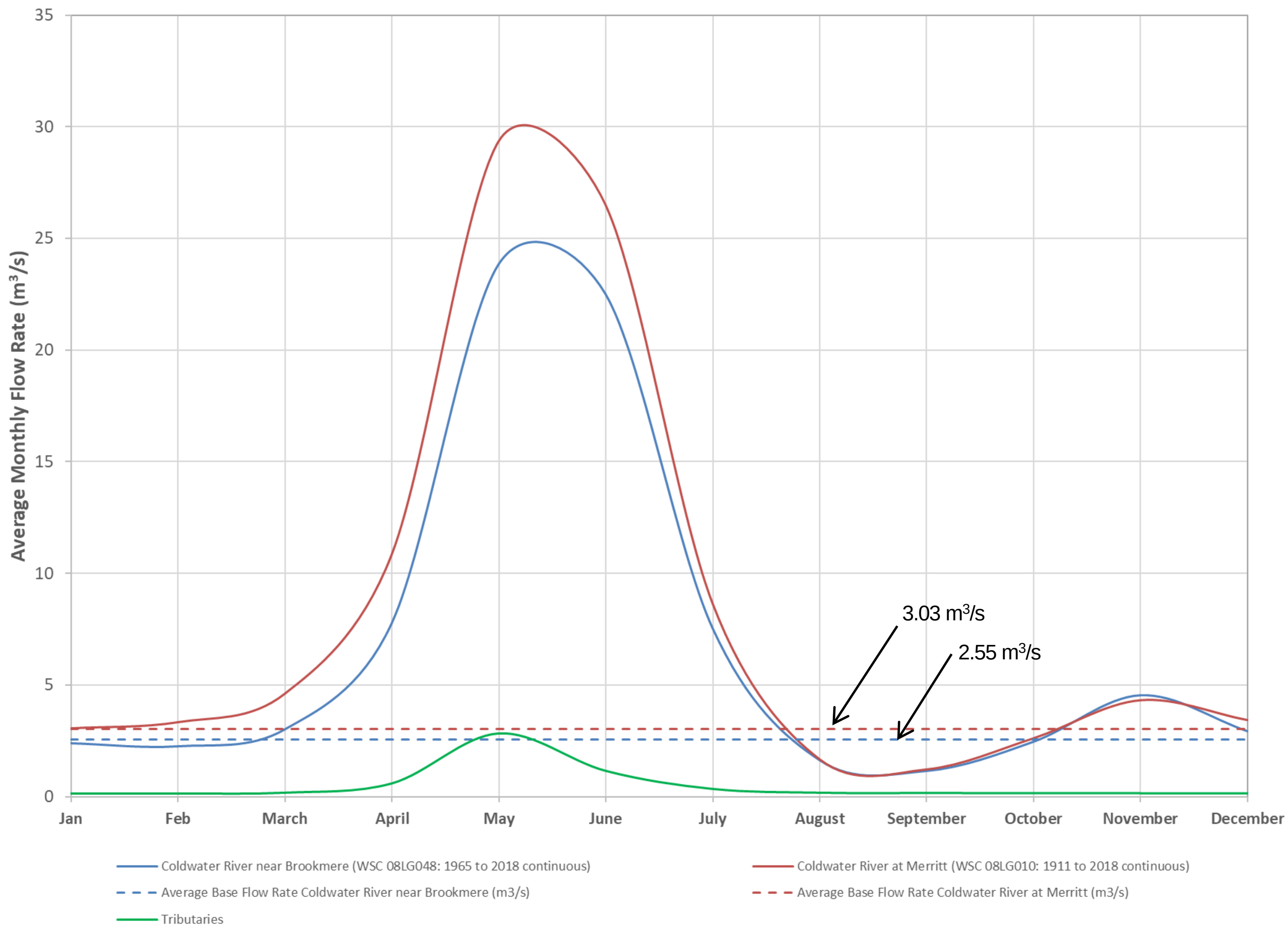
CONSULTANT
GOLDER

YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY

TITLE
AQUIFER LOCATIONS

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	3



CLIENT
FRASER BASIN COUNCIL

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERRACTION STUDY

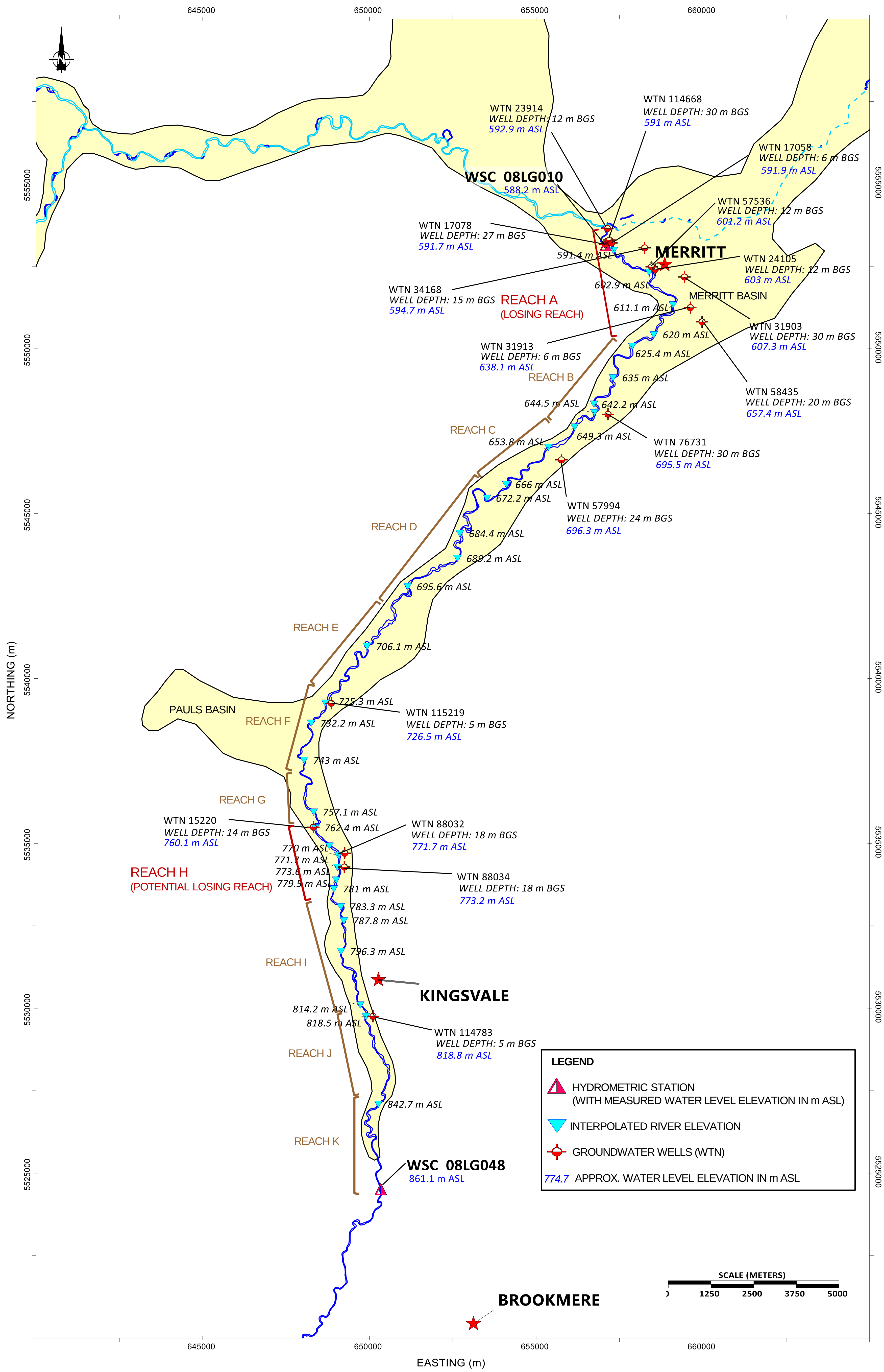
CONSULTANT

GOLDER

YYYY-MM-DD	2020-02-26
PREPARED	SI
DESIGNED	SI
REVIEWED	JD
APPROVED	CR

TITLE
HYDROGRAPH FOR COLDWATER RIVER MEAN MONTHLY FLOWS

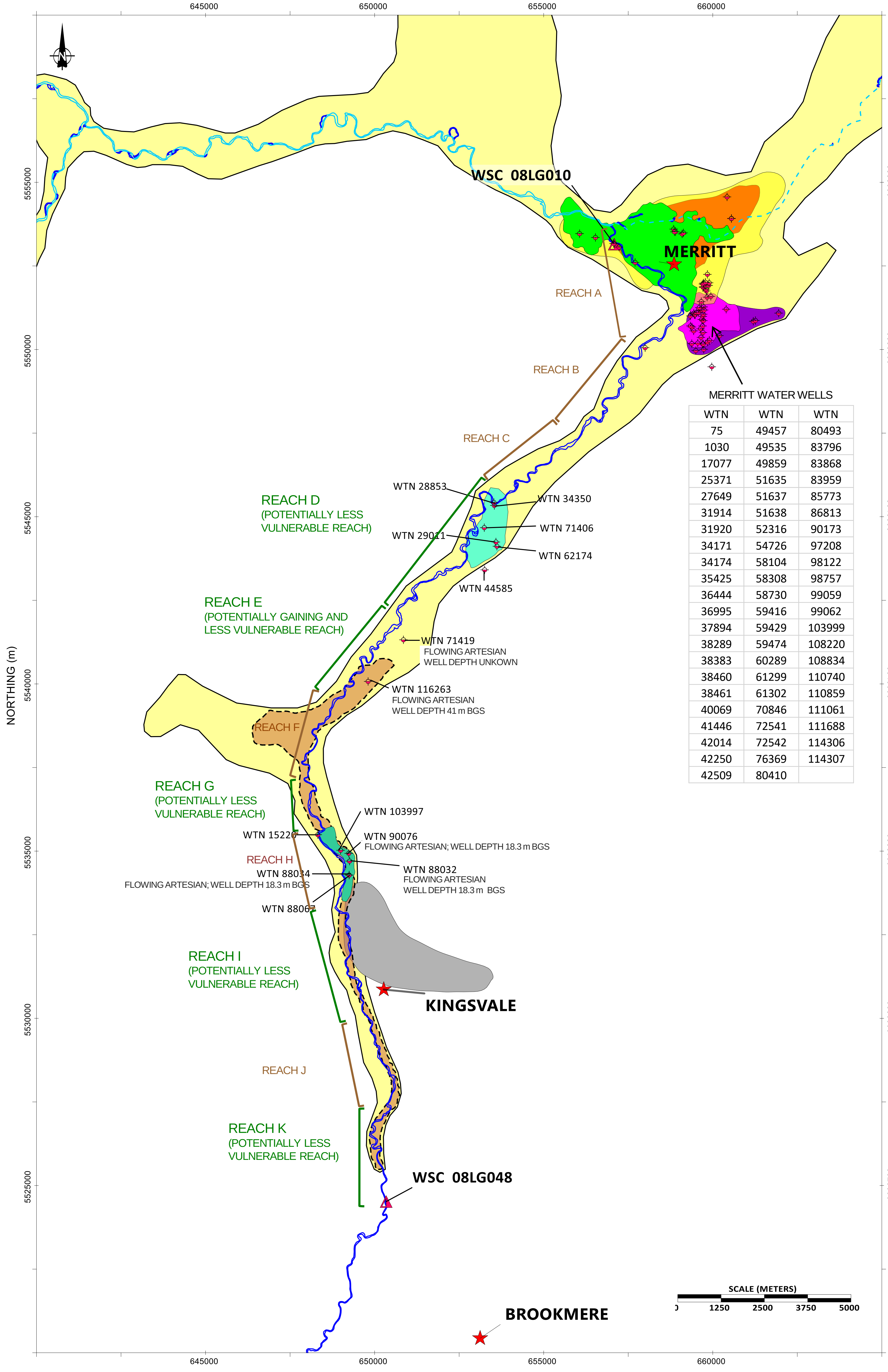
PROJECT NO.	PHASE	REV.	
19131378	1000	A	4



NOTES

1. HYDROMETRIC WATER LEVELS REPRESENT 2019 AVERAGE WATER LEVELS BASED ON STAGE RECORDS AND THE GEODETIC SURVEY RESULTS FOR THE STATIONS PROVIDED BY FLNRORD.
2. ITALICIZED GROUNDWATER LEVELS ARE APPROXIMATE. THEY ARE BASED ON WATER LEVELS REPORTED IN WELL RECORDS MEASURED AT THE TIME OF WELL INSTALLATION AND COMPENSATED USING TOPOGRAPHIC DATASET.
3. ITALICIZED SURFACE WATER LEVELS ARE APPROXIMATE. THEY ARE BASED ON TOPOGRAPHY AND THE WATER LEVEL ELEVATIONS MEASURED AT THE WSC STATIONS .
4. ITALICISED WELL DEPTHS ARE INFERRED AS SOME WELL DEPTHS ARE NOT REPORTED AND ARE ASSUMED TO BE THE SAME AS BOREHOLE DEPTH.
5. m ASL – METERS ABOVE SEA LEVEL
6. m BGS – METERS BELOW GROUND SURFACE

CLIENT	FRASER BASIN COUNCIL
CONSULTANT	GOLDER
YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR
PROJECT	COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY
TITLE	APPROXIMATE SURFACE WATER LEVELS AND NEAREST SHALLOW GROUNDWATER LEVELS
PROJECT NO.	19131378
PHASE	1000
REV.	A
FIGURE	5



WTN	WTN	WTN
75	49457	80493
1030	49535	83796
17077	49859	83868
25371	51635	83959
27649	51637	85773
31914	51638	86813
31920	52316	90173
34171	54726	97208
34174	58104	98122
35425	58308	98757
36444	58730	99059
36995	59416	99062
37894	59429	103999
38289	59474	108220
38383	60289	108834
38460	61299	110740
38461	61302	110859
40069	70846	111061
41446	72541	111688
42014	72542	114306
42250	76369	114307
42509	80410	

LEGEND

GROUNDWATER WELLS (WTN)

CLIENT
FRASER BASIN COUNCIL

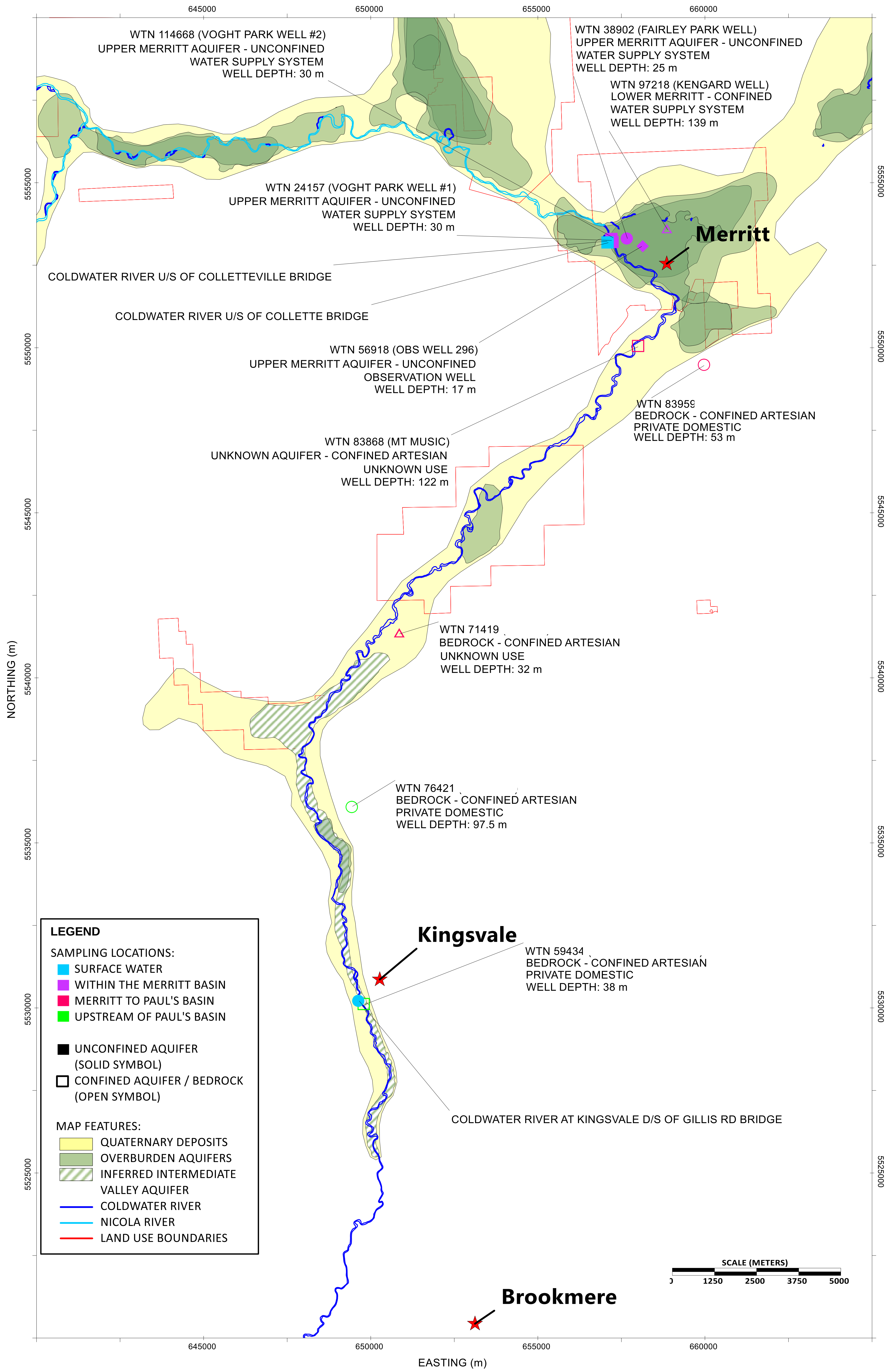
CONSULTANT
GOLDER

YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY

TITLE
LOCATION OF WATER WELLS IN KNOWN CONFINED AQUIFERS

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	6



CLIENT
FRASER BASIN COUNCIL

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERRACTION STUDY

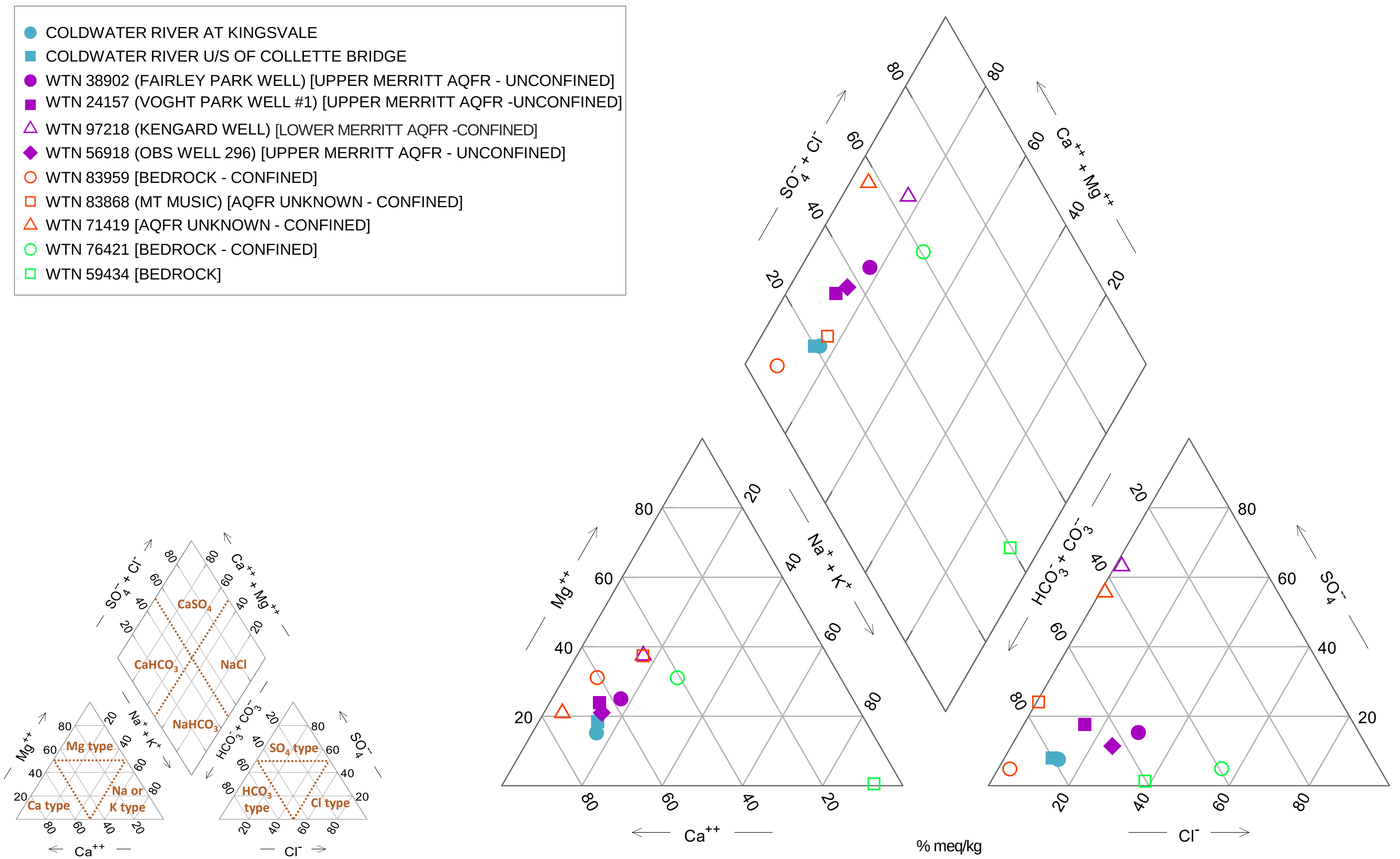
CONSULTANT

GOLDER

YYYY-MM-DD	2020-02-26
PREPARED	SI
DESIGNED	SI
REVIEWED	JD
APPROVED	CR

TITLE
WATER SAMPLE LOCATIONS

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	7



NOTES

- DATA RECEIVED FROM FLNRORD 16 JANUARY 2020
- ALL SAMPLES COLLECTED NOV/DEC 2016 WITH THE EXCEPTION OF "COLDWATER RIVER U/S OF COLLETTE BRIDGE" AND "WTN 114668 (VOGHT PARK WELL #2)" (SAMPLED 28 OCT 2015) AND "WTN 56918 (OBS WELL 296)" (SAMPLED 24 FEB 2017)

CLIENT
FRASER BASIN COUNCIL

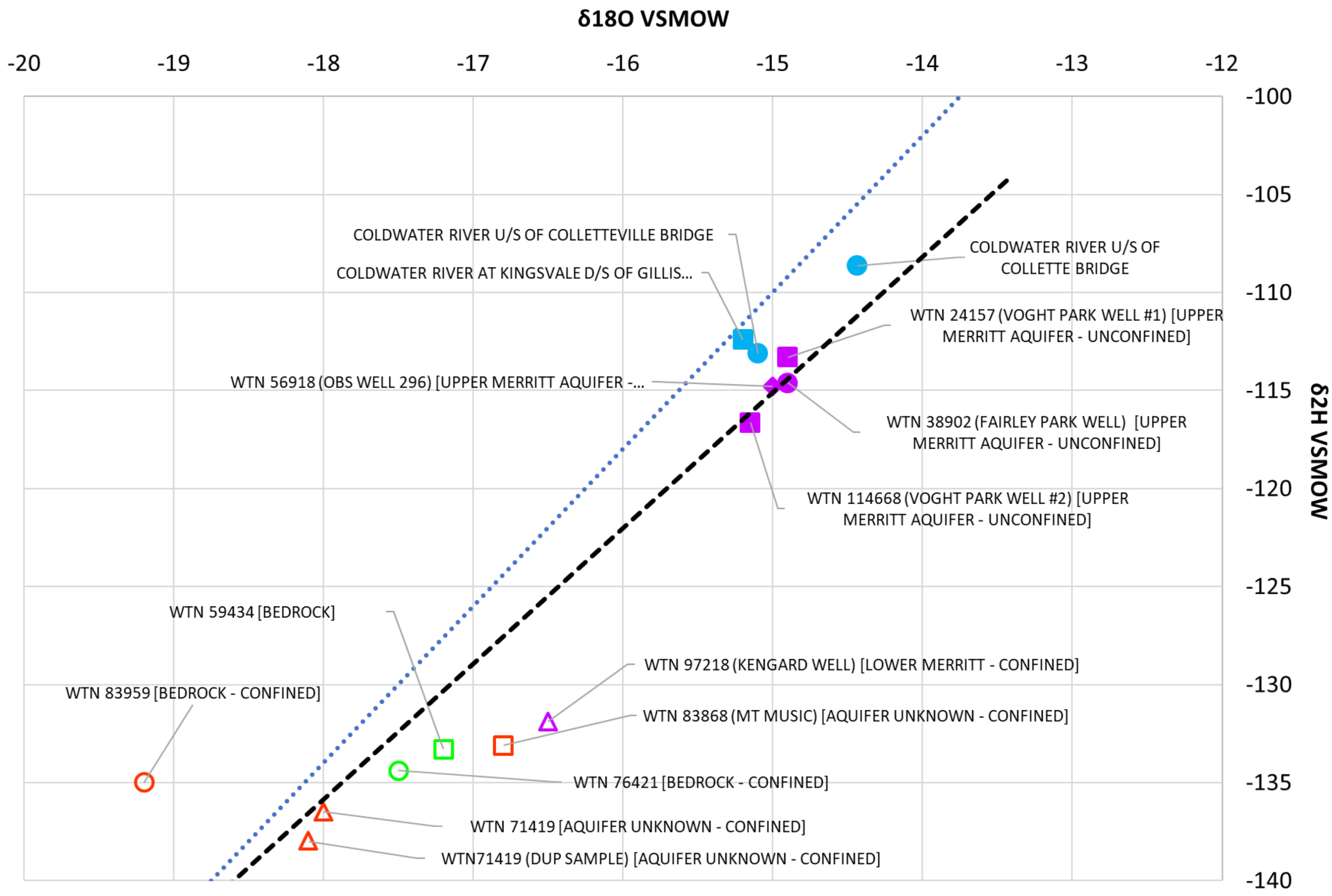
PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERRACTION STUDY

CONSULTANT
GOLDER

YYYY-MM-DD	2020-02-26
PREPARED	SI
DESIGNED	SI
REVIEWED	JD
APPROVED	CR

TITLE
GEOCHEMICAL ANALYSIS – PIPER PLOT

PROJECT NO.	PHASE	REV.	FIGURE
19131378	**1000**	**A**	**8**



LEGEND

- SURFCE WATER
- WITHIN THE MERRITT BASIN
- MERRITT TO PAUL'S BASIN
- UPSTREAM OF PAUL'S BASIN
- UNCONFINED AQUIFER
- COMFINED AQUIFER / BEDROCK
- GLOBAL METEORIC WATER LINE
- TREND LINE (ALL DATA)

NOTES

- DATA RECEIVED FROM FLNRORD 16 JANUARY 2020
- ALL SAMPLES COLLECTED NOV/DEC 2016 WITH THE EXCEPTION OF "COLDWATER RIVER U/S OF COLLETTE BRIDGE" AND "WTN 114668 (VOGHT PARK WELL #2)" (SAMPLED 28 OCT 2015) AND "WTN 56918 (OBS WELL 296)" (SAMPLED 24 FEB 2017)

CLIENT
FRASER BASIN COUNCIL

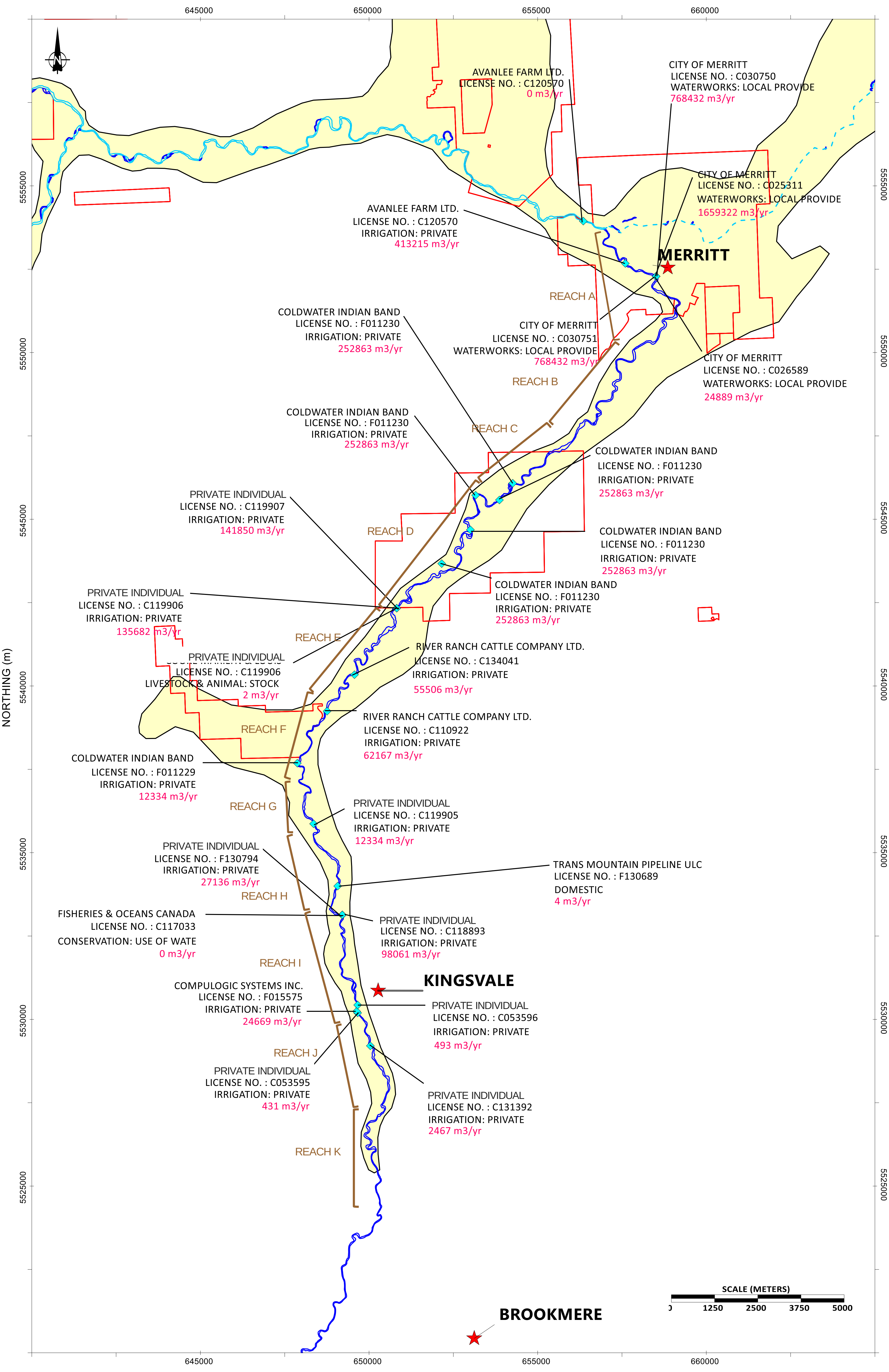
CONSULTANT
GOLDER

YYYY-MM-DD	2020-02-26
PREPARED	SI
DESIGNED	SI
REVIEWED	JD
APPROVED	CR

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERRACTION STUDY

TITLE
GEOCHEMICAL ANALYSIS – OXYGEN (Δ18o) AND HYDROGEN (Δ2h) ISOTOPES

PROJECT NO.	PHASE	REV.	
19131378	1000	A	9



LEGEND

- LICENSED SURFACE WATER POINTS OF DIVERSION
- 982 LICENSED WATER EXTRACTION AMOUNT IN m^3/yr
- ADMINISTRATIVE BOUNDARIES

NOTES

1. SURFACE WATER DEMAND BASED ON MINISTRY OF FLNRORD WATER LICENSE DEMAND REPORT. CREATED ON MAY-28-2018.

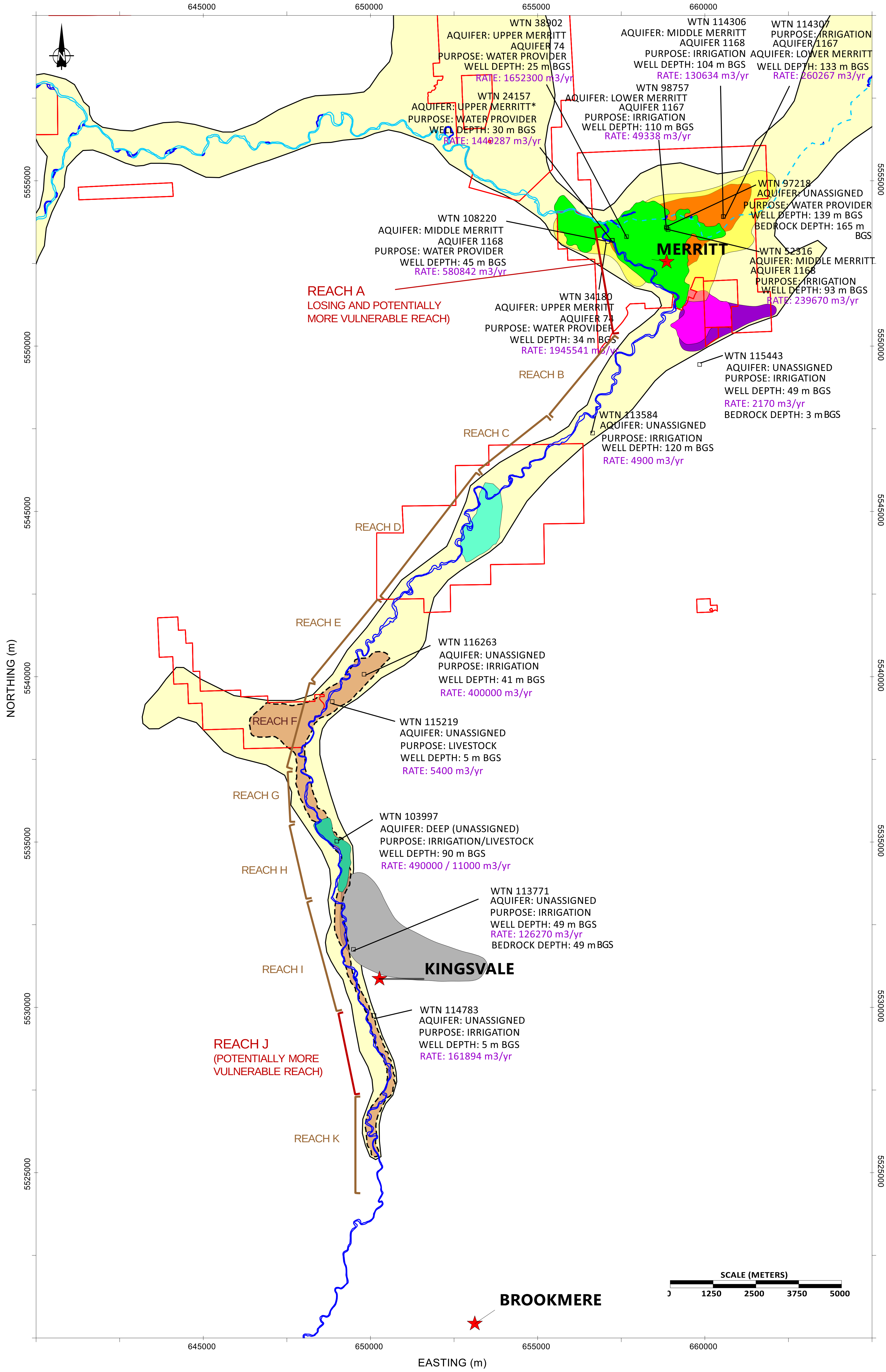
CLIENT	FRASER BASIN COUNCIL
CONSULTANT	GOLDER
YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY

TITLE
LICENSED SURFACE WATER POINTS OF DIVERSION FOR COLDWATER RIVER

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	10

https://golderassociates.sharepoint.com/sites/117784/Project%20Files/Forms/AllItems.aspx?viewid=f352ffaa%2Da8c9%2D4eac%2D9234%2Dcd1d3f8b7101&id=%2Fsites%2F117784%2FProject%20Files%2F5%20Technical%20Work%2FReport%20Figures



IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI B

LEGEND

☐ LICENSED GROUNDWATER SUPPLY WELLS (WTN)

NOTES

1. LICENCED GROUNDWATER EXTRACTION DATA FROM FLNRORD RECEIVED 5 FEB 2020.
2. CITY OF MERRITT WATERWORKS WELLS PUMPING RATE DEFINED BY PERCENTAGE OF TOTAL FROM WWA, 2012.

CLIENT
FRASER BASIN COUNCIL

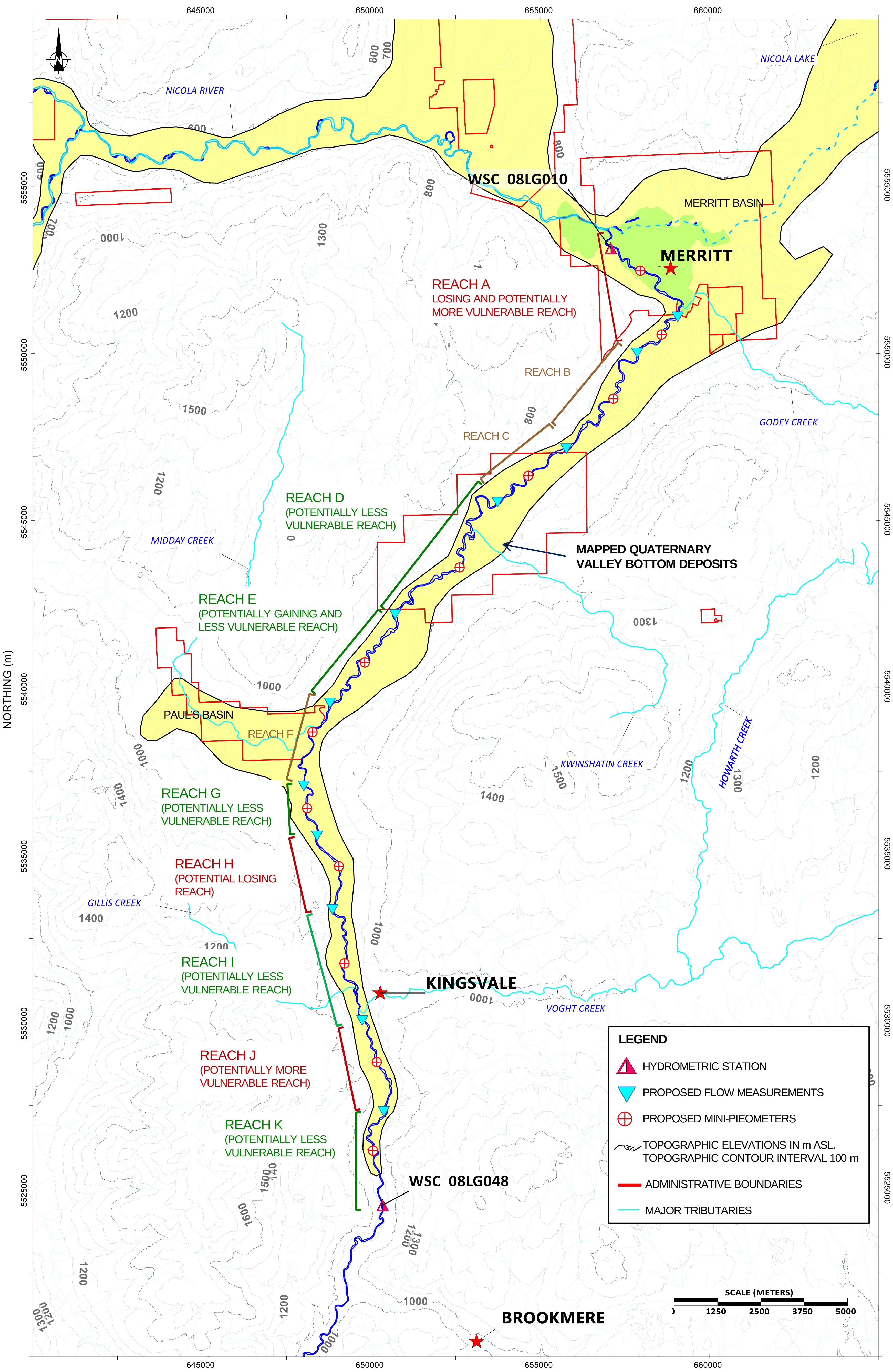
CONSULTANT
GOLDER

YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY

TITLE
LICENSED GROUNDWATER SUPPLY WELLS

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	11



NOTES

1. m ASL – METERS ABOVE SEA LEVEL

CLIENT
FRASER BASIN COUNCIL

PROJECT
COLDWATER RIVER GROUNDWATER – SURFACE WATER INTERACTION STUDY

CONSULTANT

GOLDER

YYYY-MM-DD	2020-03-01
PREPARED	JD
DESIGNED	JD
REVIEWED	CR
APPROVED	CR

TITLE
POTENTIAL GAINING / LOSING AND HIGH / LOW VULNERABILITY REACHES AND PROPOSED PHASE 2 INVESTIGATION POINTS

PROJECT NO.	PHASE	REV.	FIGURE
19131378	1000	A	12

APPENDIX A

Report Review Summary

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
1	Active Earth Engineering Ltd., 2009. Letter re: Groundwater Supply Evaluation Results for Coldwater Estates Development, Covert Place, Merritt, BC., 13 October 2009.	20 km south of Merritt and 8 km from the Coldwater River.	Data provided in this report is site-specific and not related to the Coldwater River due to its distance.
2	BC Groundwater Consulting Services Ltd., 2006. Surface Water / Groundwater Interaction Study: Stage 1. For City of Merritt. 27 March 2006.	Merritt BC – study area includes production wells within 200 m of both Nicola and Coldwater rivers.	Report identified losing reach at MW04-2 based on hydrographs of surface water and groundwater monitoring wells along the river. The Coldwater River may be disconnected from the water table at MW04-1 and MW04-3. However, water chemistry data suggests that mixing of groundwater and surface water occurs within the upper 15 m of the surficial aquifer at MW04-1 through to MW04-3 and ME 296. Water chemistry trends on a piper plot suggest groundwater evolution, or “mixing” is occurring with end members being identified as MW04-01 (surface water sourced) and MW04-02 (groundwater influenced). Additionally, each of the five (5) production wells completed in the surficial unconfined aquifer have similar water chemistry composition to the Coldwater River. - *City of Merritt (CoM) uses five (5) GW supply wells for city water.* - *Surface water from the Nicola River and Coldwater River may be depleted from the pumping of city wells located approximately 20 m from Coldwater River and 200 m from the Nicola River.* - *Maximum total pumping from groundwater is approx. 250L/s – occurring in July and August from shallow unconfined and deeper confined aquifers.* - *Hydrographs suggest that the Coldwater river loses water throughout the year to the surficial aquifer in Merritt.* - *Coldwater river water type is Ca-HCO3.* - *Shallow aquifer wells have generally the same water type Ca-HCO3 throughout the year.* *Provincial data bases show two shallow aquifers (BC Aquifer 74 and 75) although there are likely several more unmapped aquifers in the area.*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
3	BC Groundwater Consulting Services Ltd., 2009. City of Merritt Deep Aquifer Development Program: Initial Interpretations from March 2009 Kengard Deep Well Pumping Test and Recommendation to Retest the Aquifer. For City of Merritt. 24 April 2009.	Merritt BC. Located along the left bank of the Nicola River, approximately 4.5 km upstream from the confluence with the Coldwater River.	The connection between the Coldwater River and the Kengard well completed in the confined deep aquifer is uncertain and unlikely. - *Deep aquifer is described as confined under pressure with a high yield.* *Surficial Shallow aquifer recharges the deeper aquifer via aquitard leakage.*
4*	BC Groundwater Consulting Services Ltd., 2011. Deep Aquifer Development Program – Kengard Production Well Summary Report 2004-2010. For City of Merritt. 11 April 2011.	Merritt BC. Located along the left bank of the Nicola River, approximately 4.5 km upstream from the confluence with the Coldwater River.	Survey results for the water table within the surficial unconfined aquifer confirms that the Coldwater River is disconnected from the water table throughout the year (within Merritt). Therefore, it is expected that the Coldwater River continually “leaks” or “recharges” the surficial (shallow) aquifer. *-Surficial shallow aquifers and deep aquifers are confirmed to be hydraulically connected. Deep aquifer groundwater levels rise and fall abruptly over the freshet period.* *-Surficial aquifer is typically about 10 m (30ft) thick within the valley.*
5	BC. Ministry of Agriculture, 2013. Agriculture Water Demand Model – Report for the Nicola Watershed. October 2013.	Nicola Watershed	Review of predicted water demand for future agricultural use (2100). Compiled data on 2003 water demand by purveyor for the Coldwater region *-The 2003 water demand analysis identified that within the Coldwater Sub-basin surface water irrigation demand was 223,132 m^3, while there was no data listed for groundwater irrigation demand.*
6	BC. Ministry of Agriculture, 2013. Agriculture Water Demand Model – Irrigation Scheduling Factsheet. Order No. 500. 320-2. Revised September 2015.	Nicola Watershed	As above: Review of crop water demand in the Okanagan basin for 2003.
7	EBA Engineering Consultants Ltd. (EBA), 2002. Aquifer Protection Plan City of Merritt, BC. December 2002.	Merritt, BC. (City production wells located within the city limits)	Interpretation of pumping test data from the May Street, Colletteville and Voght Park wells screened in the shallow unconfined Merritt Aquifer supports the concept of a losing reach of the Coldwater River in Merritt. *-Groundwater extraction by the CoM wells greatly exceeds the rate of aquifer recharge from precipitation.* *-Capture zone analysis of a conservative scenario with current pumping rates illustrates that for a moderately leaky-confined aquifer with moderate Coldwater leakage, the 1-year capture zone extends to a small portion of the Coldwater river.*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
8	Enkon Environmental Ltd., 2008. Environmental Protection Plan (EPP) proposed for City of Merritt pump test discharge to the Nicola River. December 2008.	Merritt BC. Located along the left bank of the Nicola River, approximately 4.5 km upstream from the confluence with the Coldwater River.	Report summarized environmental monitoring for the duration of the Kengard well pump test. Report information not relevant.
9	Gorski, N.G., R.K., Willis, J.A. Sacre and K.A. Bennet, 2018. Nicola Watershed Aquifer Classification and Mapping. Water Science Series (WSS), WSS2018-XX. Prov. BC., Victoria, BC.	Coldwater River Valley Area (among other local areas)	Identifies aquifers and their extent within the Coldwater valley and associated geology. *-Kwinshatin Intertill Aquifer (type 4b) – located near the Coldwater river confluence with the Kwinshatin Creek and is comprised of sand and gravel within glacial till and undifferentiated morainal deposits.* *-Coldwater Valley Aquifer (Type 4b) -located just north of Kingsvale, the aquifer is characterized as a confined glaciofluvial sand and gravel aquifer.* *-Paul's Basin Aquifer (Type 6b)-located in a sparsely populated area in the Midday Creek Valley, the aquifer is characterized as a bedrock aquifer* *-Kingsvale Aquifer (Type 6b) -Located near the community of Kingsvale, the aquifer is characterized as a bedrock aquifer.* *-All boundaries are based on existing well records and morphological expressions; therefore, aquifer extents are not well known.*
10	Golder, 2018. Report re: Nicola River Project. Data Compilation Plan to Support Numerical Flow Modelling Strategy. 28 June 2018.	-Nicola Watershed, including the Coldwater Valley region.	Provides insight into the Coldwater River flow using flow data collected from WSC hydrometric stations at Merritt and Brookmere, along with estimated tributary contribution to flow. Report findings based on surface water-groundwater water budget results supports losing reach of the Coldwater River in Merritt. Provides a generalized assessment that identifies the Coldwater River upstream of Merritt as a net gaining reach from December through July. August through October groundwater recharge is net zero whereby localized gaining reaches may be offset by losing reaches between Brookmere and Merritt. *Additionally:* *-Coldwater valley deposits consist of unconsolidated deposits and are estimated to*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
			be between 30m (upriver) and 110 m thick (downriver) *-Freshet surface runoff was estimated to be negligible source of valley floor recharge.* *-plot of mean monthly flow rates in Coldwater River shows a sharp increase in river flow rates between April and July from approximately 2-3 m^3/sec to 25-30 m^3/sec at Brookmere and Merritt, respectively.* *-Bedrock inflow estimates to the Coldwater catchment (unconsolidated deposits) vary from 3,000 to 30,000 m^3/day.* *-Irrigation demand estimates for surface water from the Coldwater river are approximately 3,338,000 m^3/year and 997,000 m^3/year from groundwater* *-Groundwater flow direction inferred to be aligned with valley axis. Average hydraulic gradient of 8.5m/km.*
11	Kosakoski, G.T., Hamilton, R.E., 1982. Water Requirements for the Fisheries Resource of the Nicola River, B.C. Dept. of Fisheries and Oceans. September 1982.	Coldwater river and the Nicola River	Report identifies primary fish species inhabiting the Coldwater River and optimal (3.4 m^3/s) and minimum flow conditions required for fish habitat (0.85 m^3/s). *-fish species inhabiting the Coldwater River include chinook (Oncorhynchus tshawtyscha), coho (O. kisutch), pink salmon (O. gorbuscha), and steelhead trout (Salmo gairdneri)).* *- Flow requirements outlined as the Fisheries Resource Maintenance Flow is determined to be 50 ft^3/sec (1.41 m^3/sec). Below 30 ft^3/sec (0.85 m^3/sec) impact spawning. Optimum flow for spawning conditions occurs at 120 ft^3/sec (3.40 m^3/sec)*
12	McCleary, R., 2019. Critical Environmental Flow Thresholds for the Coldwater River. 12 August 2019.	Coldwater River	Report estimates the long term mean annual discharge (LT MAD) of the Coldwater River based on runoff estimates and provides estimates for Critical Environmental Flow Thresholds (CEFT). *- Naturalized LT MAD for flow for Coldwater River at Merritt is 8.35 m^3/s.* *-CEFT for Steelhead, Chinook, and Coho Juveniles is 0.43 m^3/s, and CEFT for Chinook spawning is 0.84 m^3/s.*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
13	McPhail, J.D., 1980. Coldwater River Study.	Coldwater Valley (from Hope to Merritt highway)	Report provides a comprehensive analysis of the geology, geomorphic, hydrology and aquatic biology of the Coldwater River valley for engineering considerations for the construction of a highway between Hope and Merritt, BC, (presently known as the Coquihalla Highway). *-Southward extent of the sediments within the Coldwater drainage has not yet been mapped.* *- Runoff contribution is greater near Brookmere than just north of Merritt.* *-Maximum annual discharges of the Coldwater River occur at two distinct times 1) September to February (during the wet season), and 2) March to August (during spring freshet)* *-Minimum annual discharge of the Coldwater river near Merritt have flows at or near 0 cfs (0 m^3/s), and stations near the eastern slopes of the Cascades have larger minimum flows around 0.04 to 0.1 cfs/mile^2 (0.001 to 0.003m^3/s/ mile^2), while within the Cascades, minimum discharges are greater yet at 0.3 cfs/mile^2 (0.008m^3/s/mile^2). These low flows are sufficiently small to comprise a significant threat to fisheries resources during these times.* *-Summer minimum discharges are more severe than winter minimum discharge in the Coldwater river.* *-Summer minimum discharges are smaller at Merritt than at Brookmere, possibly reflecting ET losses and water withdrawal for agricultural and domestic purposes.* ***Fluvial Setting:*** *-Surface samples of the surface "armor" of the Coldwater riverbed was sampled, however, samples deep under the surface armor were not taken. Surficial samples show that the Coldwater river can be described as a degrading, gravel to cobble bedded* ***-** Occasionally, the river is confined by the valley walls or terraces (at varying heights) made of till overlying bedrock.* *-Riverbank composition varies with the origin of the material. Where the river impinges on the valley wall, bedrock, lacustrine, glacial and glacio-fluvial sediments may be exposed.* *-Sub-bed materials were not sampled but are expected to be generally composed of sandy*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
			gravels and gravelly cobbles and boulders. However, fine grained glacial or glacio-lacustrine sediments may occur beneath the present riverbed. In isolated locations bedrock may be found immediately below the riverbed. *-The valley walls of the Coldwater River near the Coldwater Bridge south of Kingsvale contain lacustrine sediments. This indicates that lacustrine sediments may be lying underneath the fluvial sediments in the valley bottom.*
14	MOE 2009. Review of Groundwater/Surface Water Interactions Within the City of Merritt. June 2009.	Coldwater River	Report supports losing reach of the Coldwater River in Merritt, specifically between the Mountain Musical Festival site and Claybanks Park based on Aug/Sept 2005 flow measurements from the Merritt Mountain Music festival site and at Claybanks Park. Additionally, the report identifies seasonal low flows as % of mean annual flows (MAF). - *Measured stream flow in the Coldwater River at the Merritt Mountain Music Festival and at Claybanks Park suggests that section is a losing stream. River flow measurements from August to September 2005 indicate that surface water losses up to 0.147 m^3/sec or 40% of flow, were occurring in the Coldwater River in Merritt, between the Mountain festival site and Claybanks Park. Groundwater and river elevation data confirm the loss of stream water to groundwater (river elevations higher than groundwater elevations) in Merritt, specifically May Street, Claybanks and Voght Park, through April 2007 to April 2008. The greatest downward gradients exist at May Street and Voght Park (location of a production well).* - *Naturalized (no withdrawals) mean annual flow (MAF) for the Coldwater River at Merritt has been calculated by the Ministry of Environment (MOE) to be approximately 8.5 m^3/sec.* - *At the Coldwater Brookmere station, historical data demonstrates that during summer low-flow conditions an in-stream flow of 1.3 m^3/sec (~15%) MAF) occurs; whereas at the Coldwater-Merritt location in-stream flow is frequently less than*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
			0.43m^3/sec (5% MAF) during the same period. - *Daytime surface water temperatures in August in the lower Coldwater River are exceeding the lethal limit for salmon, trout and char (24 degrees C). Data collected by MOE and DFO show the Lower Coldwater River is now usually warmer than the Nicola River, suggesting that the Coldwater River is not benefiting from periods of groundwater influx which can reduce in-stream temperatures.* - *Temperature data illustrate the strong influence of surface water on groundwater temperatures in the Merritt Aquifer, with groundwater temperatures at deep and shallow monitoring points following the seasonal temperature pattern of the Coldwater River. However, at Claybanks park, the groundwater temperature was very stable indicating minimal surface flow into the silt formation below the river was minimal. (note: Groundwater temperature is generally close to the average annual temperature ~6.7 C).* *The water budget suggest that river losses are the primary source of recharge to the Merritt aquifer under both the pre-development and post-development pumping conditions (pumping from COM production wells).*
15	Summit Environmental Consultants Ltd., 2007. Nicola River Watershed Present and Future Water Demand Study. June 2007.	Nicola basin (including specifics on the Coldwater sub-basin)	Report identifies the agricultural demands of 2006, compares water demands with licensed quantities, develops future projections of water demand taking into consideration expected growth and climate change. *-The annual quantity of water licensed in the Coldwater sub-basin for agricultural purposes totals 6,637,436 m^3, with irrigation water accounting for 99%. Summit suggests that some of the licensed quantity may not be used based on their prediction of actual demand required for irrigation in the region. Summit estimates that a total of 10 wells support the irrigation in the Coldwater sub-basin, and that 23% of irrigation water is sourced from groundwater and 77% from surface water.* *- There are four (4) industrial companies identified as being key water users in*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
			Coldwater sub-basin. The estimated demand for industrial water use is 79,601 m^3 per year. *-There are about 250 businesses in the Coldwater basin with an estimated combined demand of approximately 83,000 m^3 per year.* *-There is an estimated population of 7,364 in the Coldwater sub-basin. 82,546 m^3 is licensed for individual domestic users. An additional 3,294,852 m^3 of water is licensed from surface water (Coldwater River) for waterworks. The total estimated actual domestic water demand is 2,068,485 m^3/year.* *-Municipal institutional water demand is estimated to be 213,472 m^3/year and the estimated water demand for recreation and resort activities in the Coldwater sub-basin is 636,560 m^3/year.* *- 56% of annual water demand or use is sourced from groundwater while the remaining 44% is sourced from surface water.* *- By 2020, total annual water demand in the Nicola Watershed is expected to be 4% higher than it currently is (in 2006) if "low "growth and no climate change are assumed. If Climate change is accounted for, total water demand is expected to increase by 10%. If climate change and "high" growth were experienced, water demand is projected to increase by 43%.*
16	Water Management Consultants (WCC), 2008. Nicola Watershed Water Budget Analysis. 8 October 2008.	Nicola Watershed	Report calculates water budget estimates for the Coldwater sub-basin for the Coldwater River.
17	Water Management Consultants (WMC), 2008. Surface and Groundwater Supply and Interaction Study- Phase 1 and 2. 31 March 2008.	Nicola Watershed, and the Coldwater sub-basin.	Provides an in-depth discussion on the geomorphology, geology and hydrology of the Coldwater River valley. Supports previous reporting on the Coldwater Valley geology and deposition history of the region and includes aquifer and groundwater characterization. Report also conducted a watershed model and determined that the Coldwater sub-basin was resilient to extreme drought. The model concluded that the 1 in 50-year drought for the minimum annual weekly flow is 87% of the 15-year drought. *-The Coldwater Aquifer is a major aquifer in the Nicola watershed and is comprised of sand and gravel.*

Report No.	Report Name	Location Relative to the Coldwater River	Relevant Information
			-Coarse sand and gravel deposits are continuous along the Coldwater River floodplain. The upper valley deposits are expected to be outwash deposits and some glacial lake deposits, as meltwater from glaciers at the higher elevations were the dominant force in shaping this section of the valley. As a result, aquifers in this region are likely local moderate to good aquifers. *- Naturally elevated Iron and Manganese are typical water quality concerns for groundwater in the Nicola Valley. Arsenic concerns are typically only found in bedrock wells. Arsenic may exceed DW standards near Kingsvale, depending on seasonal conditions.* *-Watershed model (for 39 years of generated data) results found that the Coldwater sub-basin was resilient to extreme drought. (Annual low flows in extreme drought years are high compared to other sub basins). This is because of the larger precipitation and snowpack melt contribution to the Coldwater River.*
18	Western Water Associates Ltd. (WWA), 2012. Well Assessment and Asset Evaluation, City of Merrritt, BC., December 2012.	City of Merritt. (Production pumping wells)	Report presents a review of historical information, with a focus on assessing the current efficiency (specific capacity) of each CoM well. Report identifies that the three wells responsible for approximately 90% of the water supplied comes from both Voght park wells and the Fairley Park Well.

APPENDIX B

Selected Water Wells

Table B1: Shallow Water Wells and Approximate Groundwater Levels

WTN	Estimated Top of Casing Elevation (m ASL) *	Well Depth** (m)	Recorded Water Level (m) measured below reference point	Hydraulic Head (m ASL)***
15220	762.6	*14*	2.44	760.1
17058	594.0	*5*	2.13	591.9
17078	594.7	*27*	3.05	591.7
23914	595.6	*12*	2.74	592.9
24105	606.0	*12*	3.05	603
31903	613.4	*30*	6.10	607
31913	639.3	*6*	1.22	638.1
34168	599.0	*15*	4.27	594.7
57536	607.0	*12*	5.79	601.2
57994	711.5	*24*	15.24	696.3
58435	658.0	*20*	0.61	657.4
76731	713.1	*30*	17.68	695.5
88032	772.6	*18*	0.91	771.7
88034	774.2	*18*	0.91	773.2
114668	594.0	*30*	3.05	591
114783	819.4	5	0.61	818.8
115219	727.9	5	1.43	726.5

Notes:
* Estimated elevation based on DEM.

** Italicized well depths are inferred from drilling depth or known aquifer base depth.

*** Hydraulic heads are approximate. Water levels recorded at time of well completion and may not be representative of static conditions.

Table B2: Deeper Water Wells Completed in Known Aquifers

Location	WTN	Aquifer No. *	Aquifer Name*	Flowing Artesian	Well Depth (m)	Finished Borehole Depth (m)
Outside Merritt Area	71419	N/A	N/A	YES	N/A	NA
	88032	1164	Coldwater	YES	18.3	18.3
	88034	1164	Coldwater	YES	18.3	18.3
	90076	1164	Coldwater	YES	18.3	18.3
	116263	N/A	N/A	YES	41.0	41.1
	15220	1164	Coldwater		13.9	13.7
	28853	1173	Kwinshatin Intertill		65.2	68.3
	29011	1173	Kwinshatin Intertill		93.0	93.0
	34350	1173	Kwinshatin Intertill		119.8	119.8
	44585	*1173*	Kwinshatin Intertill		61.0	61.0
	62174	1173	Kwinshatin Intertill		56.4	56.4
	71406	1173	Kwinshatin Intertill		*91.4*	91.4
	88067	1164	Coldwater		24.4	24.4
	103997	N/A	*Intermediate Valley*		90.0	89.9
Merritt Area	75	1168	Middle Merritt		57.9	57.9
	1030	1168	Middle Merritt		70.1	70.1
	17077	1168	Middle Merritt		46.3	46.3
	25371	1168	Middle Merritt		63.4	80.8
	27649	75	Deep Joeyaska		32.0	32.0
	31914	75	Deep Joeyaska		64.0	64.0
	31920	75	Deep Joeyaska		96.0	96.0
	34171	75	Joeyaska Deep		33.5	33.5
	34174	75	Deep Joeyaska		33.5	33.5
	35425	75	Deep Joeyaska		120.1	120.1
	36444	75	Deep Joeyaska		72.8	72.8
	36995	75	Deep Joeyaska		128.0	128.0
	37894	75	Deep Joeyaska		60.4	60.4
	38289	1168	Middle Merritt		46.6	61.0
	38383	1168	Middle Merritt		65.5	65.5
	38460	75	Deep Joeyaska		61.0	61.0
	38461	75	Deep Joeyaska		115.8	115.8
	40069	1168	Middle Merritt		49.1	49.1
	41446	1168	Middle Merritt		48.8	48.8
	42014	1168	Middle Merritt		49.4	53.3
	42250	75	Deep Joeyaska		51.8	51.8
	42509	1168	Middle Merritt		48.8	48.8
	49457	1168	Middle Merritt		53.9	54.3
	49535	75	Deep Joeyaska		128.0	128.0
	49859	75	Deep Joeyaska		85.3	85.3
	51635	1168	Middle Merritt		70.1	70.1
	51637	1168	Middle Merritt		68.6	68.6
	51638	1167	Lower Merritt		93.0	93.0
	52316	1168	Middle Merritt	YES	93.0	87.5
	54726	1168	Middle Merritt		51.8	51.8
	58104	75	Deep Joeyaska		30.5	78.9
	58308	75	Deep Joeyaska		82.9	82.9
	58730	75	Deep Joeyaska		68.0	68.0
	59416	1168	Middle Merritt		59.7	59.7
	59429	75	Deep Joeyaska		114.6	114.6
	59474	1168	Middle Merritt		56.0	55.5
	60289	1168	Middle Merritt		66.4	66.4
	61299	75	Deep Joeyaska		196.6	196.6
	61302	75	Deep Joeyaska		129.5	158.5
	70846	75	Deep Joeyaska		85.3	86.0
	72541	75	Deep Joeyaska		105.2	105.2
	72542	75	Deep Joeyaska		115.8	115.8
	76369	75	Deep Joeyaska		118.9	118.9
	80410	1168	Middle Merritt		51.8	51.8
	80493	*75*	Deep Joeyaska		54.9	54.9
	83796	1168	Middle Merritt		59.4	59.4
	83868	N/A	N/A	YES	121.9	121.9
	83959	N/A	N/A	YES	49.7	49.7
	85773	1168	Middle Merritt		79.2	79.2
	86813	75	Deep Joeyaska		97.5	97.5
	90173	75	Deep Joeyaska		87.2	87.2
	97208	1167	Lower Merritt		172.2	172.2
	98122	75	Deep Joeyaska		102.7	102.7
	98757	1167	Lower Merritt		110.0	109.7
	99059	75	Deep Joeyaska		135.9	135.9
	99062	75	Deep Joeyaska		124.4	124.4
	103999	75	Deep Joeyaska		64.6	64.6
	108220	1168	Middle Merritt		45.0	45.1
	108834	1168	Middle Merritt		44.2	44.2
	110740	75	Deep Joeyaska		153.9	153.9
	110859	75	Deep Joeyaska		102.7	102.7
	111061	75	Deep Joeyaska		121.0	121.0
	111688	75	Deep Joeyaska		102.4	102.4
	114306	1168	Middle Merritt		104.0	NA
	114307	1167	Lower Merritt		133.0	NA

Note:
* Italicized aquifer names and numbers are inferred based on well depth and aquifer depths.

APPENDIX C

Surface Water and Groundwater Licences – Coldwater River Area

Ministry of FLNRORD
Water Licensing
LICENCE DEMAND REPORT

Created By: KDeRose
Created: May-28-2018

SELECTION CRITERIA:

TRIBUTARIES: No **DIRECTION:** Downstream **TYPE:** Surface Water
START POINT: PD53611
END POINT: PD53219
INCLUDE: Licences and Short Term Use Approvals only
DEMAND ON DATE: Jul-01-2018
All Purpose/Uses will be displayed

Licence/ Job No	File No.	Status	Purpose/Use	Term Start	Term End	Quantity	Units	Qty Flag	Sto. Flag	Source Name	Points Code	AVERAGE DEMAND m3/s
C030751	263044	Current	00A - Waterworks: Local Provider	Jan 01	Dec 31	768,432.41184	m3/year	T	N	Coldwater River	PD53283	0.02443
			TOTAL QUANTITY:			**768432.41184**				**TOTAL DEMAND:**		**0.02443**
C030750	127528	Current	00A - Waterworks: Local Provider	Apr 01	Sep 30	768,432.41184	m3/year	T	N	Coldwater River	PD53283	0.04887
			TOTAL QUANTITY:			**768432.41184**				**TOTAL DEMAND:**		**0.04887**
C025311	225282	Current	00A - Waterworks: Local Provider	Jan 01	Dec 31	1,659,322.85000	m3/year	T	N	Coldwater River	PD53283	0.05276
C026589	237469	Current	00A - Waterworks: Local Provider	Jan 01	Dec 31	24,889.84275	m3/year	T	N	Coldwater River	PD53283	0.00079
			TOTAL QUANTITY:			**1684212.69275**				**TOTAL DEMAND:**		**0.05355**
F130689	215610	Current	01A - Domestic	Jan 01	Dec 31	4.54609	m3/day	T	N	Coldwater River	PD53531	0.00005
			TOTAL QUANTITY:			**4.54609**				**TOTAL DEMAND:**		**0.00005**
C119906	3004329	Current	02I31 - Livestock & Animal: Stockw	Jan 01	Dec 31	2.27305	m3/day	T	N	Coldwater River	PD78671	0.00003
			TOTAL QUANTITY:			**2.27305**				**TOTAL DEMAND:**		**0.00003**
C053595	346697	Current	03B - Irrigation: Private	Apr 01	Sep 30	431.71800	m3/year	T	N	Coldwater River	PD53538	0.00003
C053596	346696	Current	03B - Irrigation: Private	Apr 01	Sep 30	493.39200	m3/year	T	N	Coldwater River	PD53533	0.00003
C110922	222323	Current	03B - Irrigation: Private	Apr 01	Sep 30	62,167.39200	m3/year	T	N	Coldwater River	PD72014	0.00395
C118893	87294	Current	03B - Irrigation: Private	Apr 01	Sep 30	98,061.66000	m3/year	T	N	Coldwater River	PD53532	0.00624
C119905	270617	Current	03B - Irrigation: Private	Apr 01	Sep 30	12,334.80000	m3/year	T	N	Coldwater River	PD53368	0.00078
C119906	3004329	Current	03B - Irrigation: Private	Apr 01	Sep 30	135,682.80000	m3/year	T	N	Coldwater River	PD78671	0.00863
C119907	128300	Current	03B - Irrigation: Private	Apr 01	Sep 30	141,850.20000	m3/year	T	N	Coldwater River	PD78671	0.00902
C120570	142858	Current	03B - Irrigation: Private	Apr 01	Sep 30	413,215.80000	m3/year	T	N	Coldwater River	PD53219	0.02628
C131392	152726	Current	03B - Irrigation: Private	Apr 01	Sep 30	2,467.00000	m3/year	T	N	Coldwater River	PD186207	0.00016
C134041	346220	Current	03B - Irrigation: Private	Apr 01	Sep 30	55,506.60000	m3/year	T	N	Coldwater River	PD72015	0.00353
F011229	127907	Current	03B - Irrigation: Private	Apr 01	Sep 30	12,334.80000	m3/year	T	N	Coldwater River	PD53366	0.00078

Ministry of FLNRORD
Water Licensing
LICENCE DEMAND REPORT

Created By: KDeRose
Created: May-28-2018

Licence/ Job No	File No.	Status	Purpose/Use	Term Start	Term End	Quantity	Units	Qty Flag	Sto. Flag	Source Name	Points Code	AVERAGE DEMAND m3/s
F011230	241033	Current	03B - Irrigation: Private	Apr 01	Sep 30	252,863.40000	m3/year	M	N	Coldwater River	PD53311	
F011230	241033	Current	03B - Irrigation: Private	Apr 01	Sep 30	252,863.40000	m3/year	M	N	Coldwater River	PD53310	
F011230	241033	Current	03B - Irrigation: Private	Apr 01	Sep 30	252,863.40000	m3/year	M	N	Coldwater River	PD53309	
F011230	241033	Current	03B - Irrigation: Private	Apr 01	Sep 30	252,863.40000	m3/year	M	N	Coldwater River	PD53307	
F011230	241033	Current	03B - Irrigation: Private	Apr 01	Sep 30	252,863.40000	m3/year	M	N	Coldwater River	PD53312	0.01608
F015575	170300	Current	03B - Irrigation: Private	Apr 01	Sep 30	24,669.60000	m3/year	T	N	Coldwater River	PD53536	0.00157
F130794	86682	Current	03B - Irrigation: Private	Apr 01	Sep 30	27,136.60048	m3/year	T	N	Coldwater River	PD53532	0.00173
			TOTAL QUANTITY:			**2250669.36248**				**TOTAL DEMAND:**		**0.07881**
C117033	3003910	Current	11B - Conservation: Use of Water	Jan 01	Dec 31	0.08495	m3/sec	T	N	Coldwater River	PD53532	0.08495
			TOTAL QUANTITY:			**0.08495**				**TOTAL DEMAND:**		**0.08495**
										TOTAL DEMAND FOR DEMAND DATE:		**0.29069**

License No.	Well Tag Number (WTN)	Name	Easting (m)	Northing (m)	Well Depth (m)	Aquifer ID	Aquifer Name	Inferred Aquifer Type	Purpose	Quantity (m^3/year)	Quantity (US gpm)
500785	114783	Private	650107	5529757	5	N/A	Unassigned	Unconfined	Irrigation	161894	81
TBD	113771	Private	649490	5531754	49	N/A	Unassigned	Confined	Irrigation	126270	64
TBD	103997	Private	648994	5535026	90	N/A	*Deep Unassigned**	Confined	Irrigation / Livestock	490,000 / 11,000	N/A
500505	115219	River Ranch Cattle Co.	648855	5539250	5	N/A	Unassigned	Unconfined	Livestock	5400	3
TBD	116263	River Ranch Cattle Co.	649808	5540075	41	N/A	Unassigned	Confined	Irrigation	400000	201
500332	113584	Private	656642	5547370	120	N/A	Unassigned	Confined	Irrigation	4900	3
501687	115443	Private	659845	5549444	49	N/A	Unassigned	Confined	Irrigation	2170	1
500267	52316	River Ranch - Kengard	658899	5553521	93	1168	Lower Merritt	Confined	Irrigation	239670	121
500554	114307	River Ranch - Kengard	660552	5553915	133	1167	Lower Merritt	Confined	Irrigation	260267	131
500406	114306	River Ranch - Airport #2	660554	5553921	104	1168	Middle Merritt	Confined	Irrigation	130634	66
500097	98757	Private	658845	5553602	110	1167	Lower Merritt	Confined	Irrigation	49338	25
TBD	38902	City of Merritt - Well #2	657660	5553310	25	74	Upper Merritt	Unconfined	Water Provider	1,652,300**	N/A
TBD	24157	City of Merritt - Well #5	657236	5553203	30	N/A	Upper Merritt	Unconfined	Water Provider	1,449,287**	N/A
TBD	108220	City of Merritt - Well #1	657089	5553163	45	1168	Middle Merritt	Confined	Water Provider	580,842**	N/A
TBD	34180	City of Merritt - Well #3	657228	5553197	34	74	Upper Merritt	Unconfined	Water Provider	1,945,541**	N/A
TBD	97218	City of Merritt - Well #4	658860	5553563	139	N/A	*Lower Merritt**	*Confined**	Water Provider	-**	N/A

Notes:
1. Aquifer type was inferred based on well location, information of mapped aquifers, and depth of well. Generally, if a well is located in an area with no mapped aquifers and it is a deep well (>30 m) it was considered to be installed in a confined aquifer.
* Indicates that the aquifer name has been inferred based on well depth and locally mapped or inferred aquifers.
**The total pumping for City of Merritt waterworks is 5,639,250 m^3/year. The distribution of the total water pumped from each well is based on the 2011 dataset of groundwater use by well from Western Water Associates Ltd. (2012). This report states that approximately 29.6% of total pumping is supplied by the Fairly Park well (WTN 38902), 34.5% supplied by Voght Park GE well (WTN 34180), 25.7% supplied by the Voght Park VFD well (WTN 24157) and 10.3% supplied by the Collettville well (WTN 108220).