Volume 2, Section 6 Snake Lake Reservoir Expansion Project Environmental Impact Assessment Hydrogeology

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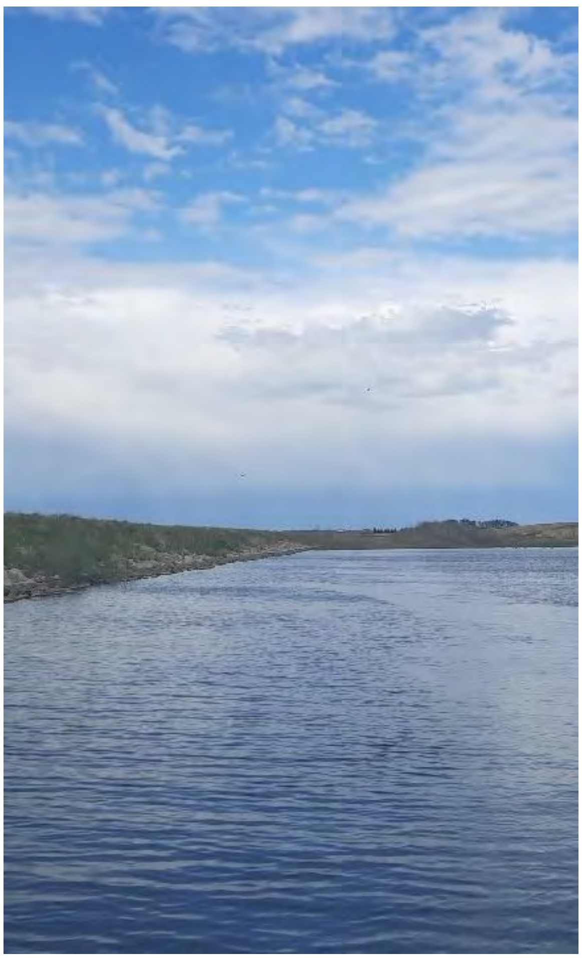

On Behalf of:

Eastern Irrigation District
Brooks, Alberta

With support from:

AAR Environmental Services
Calgary, Alberta

March 28, 2025
AARES Project #: 21-127

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Executive Summary

The Eastern Irrigation District (EID) is applying for approval under the *Environmental Protection and Enhancement Act* (EPEA) and the Alberta *Water Act* to construct the proposed Snake Lake Reservoir (SLR) Expansion Project (the Project). The baseline assessment provides details and rationale for the selected hydrogeological resources study area. The impact assessment is based on requirements provided in the Final Terms of Reference (FTOR; Volume 2, Appendix A) for the Project issued by Alberta Environment and Protected Areas (Alberta EPA), and following the Guide to Preparing Environmental Impact Assessments in Alberta (GOA, 2013). This section of the Environmental Impact Assessment (EIA) describes the results of a base line hydrogeological study, identified issues to support the EIA process and provides an assessment of indicators and potential impacts on groundwater resources with respect to the environment and groundwater users.

The EID is proposing to expand the existing SLR located approximately 18 km southeast of Bassano and 23 km northwest of Brooks, Alberta. The existing reservoir is contained by two earth-fill dams. The existing reservoir is an off-stream irrigation storage facility originally constructed from 1995 to 1997 and is owned and operated by the EID. The current storage capacity is 15,600-ac ft (19.25 million m^3) of water with full supply level (FSL) at a geodetic elevation of 781.7 m. Outflow from the existing reservoir is through the East Dam Low Level Outlet Structure, located near the north end of the East Dam which supports approximately 50,000 ac (20,000 ha) of irrigated agriculture.

The planned reservoir expansion will include the area to the east of the existing SLR and East Dam. The Project will cover a total area of 920.7 ha and water in the expanded reservoir will be impounded by east, north, and south embankments. The East Branch Canal located to the south of SLR and East Dam will form the boundary of the newly expanded reservoir in the southwestern portion of the expanded reservoir. Earthworks will include the construction of approximately 8 km of earthen banks up to 20 m in height. The project will attempt to excavate the material within the footprint of the dam and will create over 55,000 ac ft (67.8 million m^3) of new storage. Removal of all or a portion of the East Dam will connect the existing reservoir with the reservoir expansion. Total storage in the expanded reservoir is estimated to be 70,900 ac ft (87.4 million m^3). The FSL of the reservoir will be raised to 782 m.

Table 6-14 presents key findings based on the baseline data collected as part of the hydrogeological baseline study and the results of groundwater flow simulations completed to support the hydrogeological baseline study.

Table of Contents

Figures

Tables

Appendix

Abbreviations

AB	Alberta
AER	Alberta Energy Regulator
AESRD	Alberta Environment and Sustainable resource Development
AGS	Alberta Geological Survey
BH	Borehole
BM	Benchmark
BOD	Biochemical Oxygen Demand
BTEX	Benzene, Toluene, Ethylbenzene, Xylenes
CCME	Canadian Council of Ministers of the Environment
CGVD2013	Canadian Geodetic Vertical Datum of 2013
CH	Core hole
CHF	Conceptual Hydro-stratigraphic Framework
COD	Chemical Oxygen Demand
CPT	Cone Penetration Testing
CSRS	Canadian Spatial Reference System
DEM	Digital Elevation Model
EIA	Environmental Impact Assessment
EID	Eastern Irrigation District
EPEA	Environmental Protection and Enhancement Act
F1	Petroleum Hydrocarbon Fraction 1 [Carbon number (C) 6 to C10]
F2-F4	Petroleum Hydrocarbon Fractions 2 to 4 (>C6 to C50)
FSL	Full Supply Level
FTOR	Final Terms of Reference
GOA	Government of Alberta
GIS	Geographic Information System
GNSS	Global Navigation Satellite System
GPS	Global positioning system
GSC	Geological Survey of Canada
HDPE	High-Density Polyethylene
masl	Metres above mean sea level
mbgs	Metres below ground surface
MMY	Maximum Mining Yield
MPE	MPE Engineering
MSY	Maximum Sustained Yield
mtop	Metres below top of the pipe
MW	Monitoring Well
NAD83	North American Datum 1983
NC	Not Calculated
NR Canada	Natural Resource Canada
NTU	Nephelometric Turbidity Unit
pH	Power of hydrogen; Quantitative Measure of Acidity or Basicity of Aqueous Solution
PMY	Permissive Mining Yield
PVC	Polyvinyl Chloride
PSY	Permissive Sustained Yield
QA/QC	Quality Assurance/Quality Control
RMS	Root Mean Square
RQD	Rock Quality Designation
SLR	Snake Lake Reservoir
SPT	Standard Penetration Test
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
TOR	Terms of Reference
USCS	Unified Soil Classification System

Glossary

Terms	Definitions
EIA TOR	Refers to the Final Terms of Reference (FTOR) for the Environmental Impact Assessment prepared per Section 1(b) of the *Alberta Environmental Protection and Enhancement Act* (GOA, 2000a).
Apparent Hydraulic Conductivity	Hydraulic conductivity calculated from predetermined depth interval within a borehole during a packer test. The value represents the sum of transmissivities of fractures within the tested interval divided by the length (m) of the testing interval, and it therefore provides an average hydraulic conductivity for the interval rather than the hydraulic conductivity of individual fractures.
Aquifer	A geologic unit which contains sufficient saturated permeable material to yield quantities of water to wells and springs.
Aquitard	A geologic unit that has the less-permeable bed in a stratigraphic sequence and is unable to transmit water in significant quantities.
Areal Recharge	Water infiltrating into the groundwater system mainly from precipitation is referred to as areal recharge.
Buried Valley	An ancient river or stream valley that has been filled with glacial or loosely arranged sediment.
Borehole	A narrow shaft vertically and horizontally bored in the ground.
Boundary Conditions	The physical conditions at the boundaries of a system. Examples are model bottom and no-flow boundaries at the lateral aquifer terminus, constant head or specified head boundaries representing a fixed inflow or outflow of water across that boundary cell. A mathematical representation of boundary conditions must be specified in a numerical groundwater flow model.
Calibration Parameters	The parameters or input factors in the groundwater flow model are estimated during the calibration process.
Calibration Residual Criterion	The acceptable difference between the measured hydraulic head at a well location and the modelled hydraulic head interpolated from the finite-element grid to the well location below which the model calibration or fit is considered acceptable.

Terms	Definitions
Calibration Residuals	The difference between the measured hydraulic head at a well location and the computer-modelled hydraulic head interpolated from the finite-element grid to the well location.
Confined Aquifer	A type of aquifer in which the groundwater is isolated from the atmosphere by impermeable geologic formations. In a confined aquifer, the fluid pressure is greater than atmospheric pressure and the water level in wells rises to some static level above the upper stratigraphic boundary of the aquifer.
Core Hole	A narrow shaft vertically and horizontally bored in rock material.
Darcy's Law	The equation that describes the flow or fluid through a porous medium.
Drain Boundary	The release of water or removal of water from an aquifer that occurs when an excavation intercepts the groundwater table. This is simulated using the drain boundary condition.
Drawdown	Lowering of the water table of an unconfined aquifer or the piezometric surface of a confined aquifer caused by withdrawal of groundwater (e.g., through pumping wells or construction dewatering).
Effective Porosity	The percent ratio of the volume of interconnected voids in a rock or sediment to the total volume of the rock or sediment. The effective porosity in the rock or sediment may be equal or be less than the total porosity and it includes interconnected pore spaces that are available to conduct groundwater flow.
Evapotranspiration	A term used to describe the sum of evaporation and plant transpiration from the earth's surface to the atmosphere.
Finite-Element Grid	The spatial discretization of the modelled domain into a grid of cells. In the vertical direction, the domain is discretized into layers. In the horizontal direction, the domain is discretized into a grid consisting of triangular elements with each triangle having three nodes and sides.
Fluid Conductance	The rate at which a unit of material with a defined area and thickness can transmit fluids.

Terms	**Definitions**
Gaining Stream	A body of surface water which is gaining water from the inflow of groundwater.
Geometric Mean	The n^{th} root of the product of n numbers.
Groundwater	All water below the ground surface is distinct from surface water, specifically within the saturated zone of a defined aquifer.
Groundwater Sink or Source	In agricultural drain or gaining stream) that draws water from a groundwater source (i.e., aquifer in the physical system or aquifer boundary condition in a numerical model).
Hydraulic Conductivity	Hydraulic conductivity is a measure of the capacity of a porous medium to transmit water. It is dependent on the texture, porosity, and the interconnection of pores of materials that make up the medium.
Hydraulic Head	Level to which water would rise above a fixed reference point in a monitoring well.
Initial Conditions	The hydraulic head distribution everywhere in the model domain at the beginning of the model simulation.
Interface Aquifer	Combination of hydraulically connected hydrostratigraphic units including the fractured bedrock and clay till immediately above the fractured bedrock. These units are often grouped and considered as a single hydrostratigraphic unit due to the hydraulic connectivity and similarity in hydraulic properties.
Laminar Flow	Fluid flow which travels smoothly or in a regular path.
Leakance	A supply of water flowing into the Interface Aquifer from the shallow aquifer system.
Lugeon Test (Packer Test)	An in-situ testing method to estimate the average hydraulic conductivity of rock mass performed by measuring the flow rate of water injected in a section of test hole isolated with packers when the interval is pressurized at preset different pressure values.
Lugeon Value	The loss of water per minute per metre of borehole.
Model	See “numerical groundwater flow model”.

Terms	Definitions
Model Calibration	The process of adjusting the parameters in the groundwater flow model until an acceptable agreement is achieved between the simulated hydraulic head values and the measured hydraulic head values at specific well locations.
Model Cell	A 3-dimensional volume used in a numerical model to represent a discretized portion of a physical system.
Model Domain	The volume defined by the horizontal and vertical study area boundaries in which groundwater flow is simulated.
Numerical Groundwater Flow Model	A computer program that solves by approximation, algebraic equations describing groundwater flow, the boundary conditions, and the initial conditions that form the mathematical model.
Numerical Models	Calculate the flows in and out of each model cell balancing with the flows of the surrounding model cells. The numerical model calculates the potentiometric head or water level at the centre of each model cell at the end of each model stress period.
Particle Tracking	Tracking the journey of a chemically inert and dimensionless particle over time in the groundwater system using modelling software.
Percent Discrepancy	The difference, in percentage, between the total simulated inflows and outflows (i.e., volumetric water budget) for the aquifer simulated using the FEFLOW. In addition to serving as a check on the accuracy of model results, the percent discrepancy identifies errors when designing the model.
Percent Discrepancy Error	The percent difference between the total simulated inflows and outflows in the volumetric water budget.
Perched Water	The saturated soil zone that exists within an unsaturated zone, which typically sits on top of an aquitard. A perched zone is typically unconfined and at a higher elevation than the shallow aquifer system. Unsaturated conditions exist below a perched unit.
Piezometric Elevation	The elevation above a datum plus the pressure head due to the pressure that exists in a confined aquifer.

Terms	Definitions
Porchet Method (Inverse Auger-hole Method)	An in-situ percolation test to estimate the percolation rate by measuring the rate of fall of a given level of water within a borehole drilled to a specific depth.
Porosity	The percent ratio of the volume of voids in a rock or sediment to the total volume of the rock or sediment. The voids in the rock or sediment include all pore spaces that are liquid or air-filled and not available to conduct flow because of discontinuities.
Potentiometric Head	The hypothetical surface that indicates the level to which water will rise and match the hydraulic head in a monitoring well. In the scientific literature, the terms hydraulic head and potentiometric head are often used interchangeably although they have slightly different meanings.
Potentiometric Surface	An imaginary surface representing the elevation of the hydrostatic head throughout the confined aquifer. In unconfined situations, the potentiometric surface is the elevation of the water table.
Recharge	The addition of water from any source into the groundwater system. For the Project Baseline, recharge occurs mainly through infiltration of water resulting from precipitation.
Root Mean Square Error	The Root Mean Square (RMS) error is essentially a standard deviation calculated as the average of the squared differences between the measured and the simulated hydraulic heads. If the ratio of the RMS error to the total head differential over the model area is small, then the errors are only a small part of the overall hydraulic response of the model.
Saturated Thickness	The aquifer thickness, which is generally inferred from published background information or borehole records.
Saturated Zone	The zone of a porous medium (e.g., fractured bedrock, sand, silt, clay, and gravel) in which all the voids are filled with water (e.g., no effective porosity).
Slug Test	An in-situ test performed to estimate the hydraulic properties of aquifers and aquitards.
Specific Yield	The volume of water that an unconfined aquifer releases from storage per unit surface area of the aquifer per unit decline in the water table.

Terms	Definitions
Standard Penetration Test (SPT)	A geotechnical testing procedure to determine the relative density and angle of shearing resistance of cohesionless soils and also the strength of stiff cohesive soils.
Steady-State Groundwater Flow Model	A groundwater flow model in which the hydraulic head distribution and aquifer stresses are independent of time.
Storativity (Coefficient of Storage)	A dimensionless coefficient defined as the volume of water that a permeable unit will release from storage per unit surface area per unit change in the hydraulic head.
Stream Gauge	A station established to measure depth or flow in a river or stream.
Till	Non-sorted, non-stratified sediment deposited by a glacier.
Transmissivity	The rate at which water can be transmitted through a vertical strip of aquifer one unit wide, extending the full saturated thickness of the aquifer, under a unit of hydraulic gradient.
Unconfined Aquifer	An aquifer in which there is no overlying aquitard and groundwater is exposed to the atmosphere. The top of the water surface is defined by the water table.
Unsaturated Zone	The zone between the land surface and the water surface elevation or water table. The soil pore spaces contain water at less than atmospheric pressure, as well as air and other gases. Saturated zones, such as perched groundwater, may exist in the unsaturated zone.
Water Level	The water surface elevation (also known as water table) in an unconfined aquifer or hydraulic head in a confined aquifer, is usually measured relative to the existing ground surface or above mean sea level.

6.1 INTRODUCTION

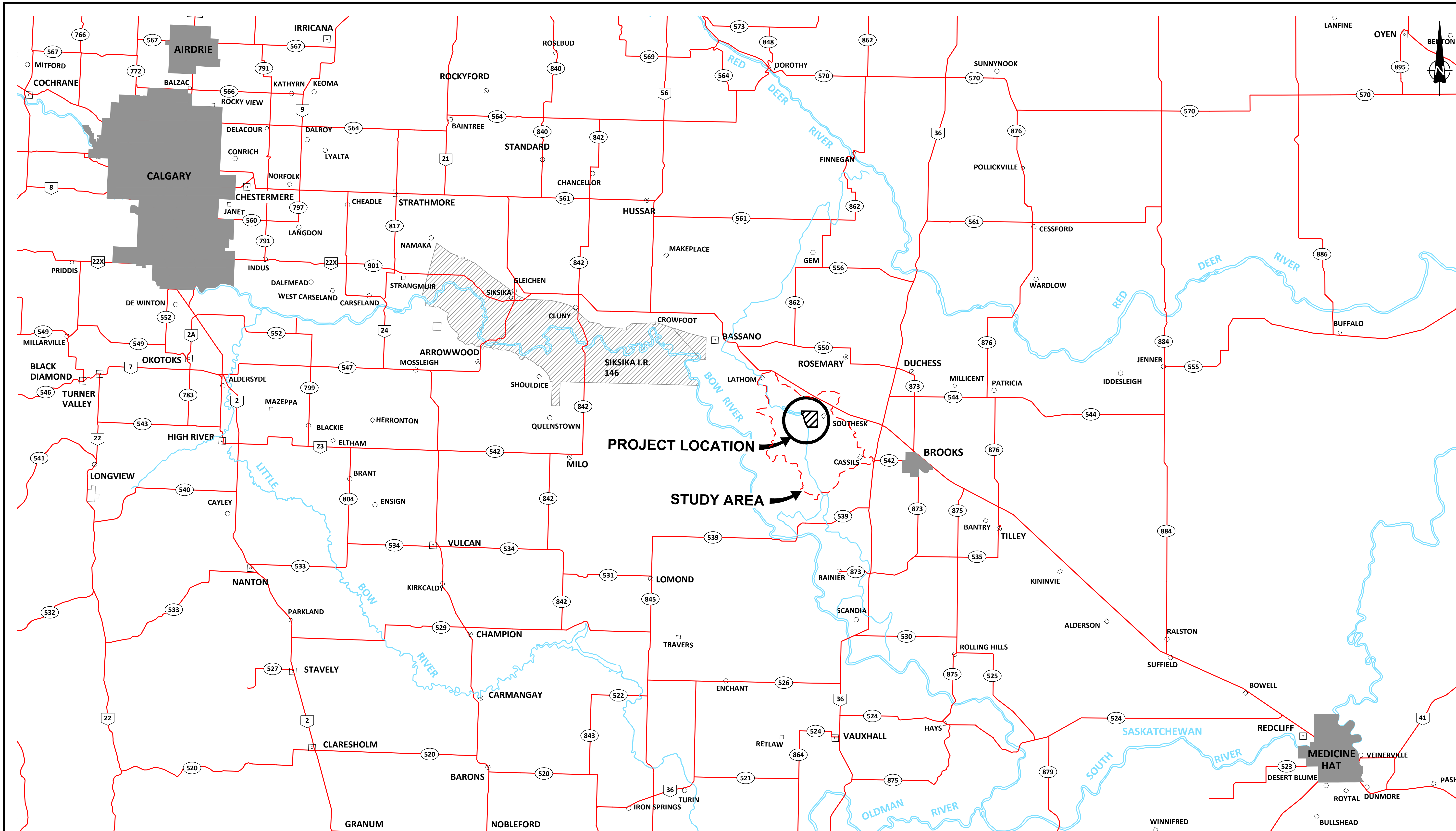
The Eastern Irrigation District is proposing to expand the existing Snake Lake Reservoir (SLR) located approximately 18 km southeast of Bassano and 23 km northwest of Brooks, Alberta (refer to Figure 6-1). The existing reservoir is an off-stream irrigation storage facility originally constructed from 1995 to 1997 and is owned and operated by the Eastern Irrigation District (EID). The current storage capacity is 15,600-ac ft (19.25 million m^3) of water with full supply level (FSL) at a geodetic elevation of 781.7 m. Water is diverted into the reservoir from the East Branch Canal via a gated inlet chute in combination with an online check structure. Outflow from the existing reservoir is through the East Dam Low Level Outlet Structure, located near the north end of the East Dam which supports approximately 50,000 ac (20,000 ha) of irrigated agriculture.

The EID is proposing to expand the size and capacity of the existing SLR (the Project). Most irrigation water within the EID is sourced from Rocky Mountain runoff via the Bow River. However, if there is little snow accumulation in the Rocky Mountains in any given year, there is reduced water available for agricultural uses. Excess spring water collected in reservoirs during the spring freshet is available to users later in the summer without additional diversion from the Bow River. Therefore, an expanded reservoir would help offset the direct use of water from the Bow River when it tends to run lower in the summer. In future years, this should help alleviate impacts of climate change, while maintaining flows and supporting aquatic biodiversity in the Bow River.

The planned reservoir expansion will include the area to the east of the existing SLR and East Dam. The Project will cover a total area of 920.7 ha and water in the expanded reservoir will be impounded by east, north, and south embankments. The East Branch Canal located to the south of SLR and East Dam will form the boundary of the newly expanded reservoir in the southwestern portion of the expanded reservoir. Earthworks will include the construction of approximately 8 km of earthen banks up to 20 m in height. Total earthworks are estimated to require 7,000,000 m^3 of material. The project will attempt to excavate the material within the footprint of the dam and will create over 55,000 ac ft (67.8 million m^3) of new storage. Removal of all or a portion of the East Dam will connect the existing reservoir with the reservoir expansion. Total storage in the expanded reservoir is estimated to be 70,900 ac ft (87.4 million m^3). The FSL of the reservoir will be raised to 782 m. A new low-level outlet structure will be constructed at the north end of the Project to deliver water into the existing Springhill Canal System.

This Technical Data Report (the Report) describes the results of a baseline hydrogeological study prepared by Englobe Corp. ("Englobe") and MPE a division of Englobe (MPE) to support the Environmental Impact Assessment (EIA) process for this Project. This Report is subject to the statement of limitations included in Section 6.5.

A map showing the location of the proposed SLR expansion is provided in Figure 6-1.



EID / englobe	EASTERN IRRIGATION DISTRICT
	SNAKE LAKE RESERVOIR EXPANSION LOCATION PLAN

SCALE: NOT TO SCALE	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 1

6.1.1 The Environmental Impact Assessment Process and this Report

The Report is a component of a larger EIA report describing various natural environment components (e.g., air quality and noise, hydrogeology, hydrology, etc.) prepared under the *Environmental Protection and Enhancement Act* (EPEA) for the Project. This report was prepared in accordance with the Final Terms of Reference (FTOR) dated July 4, 2024.

6.1.2 Purpose for this Report

This Report presents the factual results of the hydrogeological baseline study that supports the environmental impact assessment for the Snake Lake Reservoir (SLR) Expansion project (the Project). This Report also describes the model inputs and parameters used in the groundwater flow modelling of various construction and post-construction scenarios implemented to evaluate the impacts on the groundwater flow regime (refer to Appendix D7). The report was completed in accordance with the FTOR for the EID's Proposed SLR Expansion Project (EID, 2023) and the Guide to Preparing Environmental Impact Assessment Reports in Alberta (GOA, 2013). All work has been completed following the practice standards for hydrogeological data collection and reporting. This technical data Report includes the following pertinent hydrogeological information that supports the environmental impact assessment for the Project:

- Identifies the Project-specific data sources (e.g., Alberta Geological Survey maps) used to develop the conceptual hydrogeological framework of the Study Area.
- Describes the surficial and bedrock geology of the Study Area based on the review of available literature and field investigation.
- Describes the hydraulic properties of the strata intercepted in the field investigations.
- Defines and describes the hydro-stratigraphy of the Study Area based on the geological and hydraulic properties of the strata.
- Describes the numerical groundwater flow model developed based on the conceptual hydrogeological framework to simulate the groundwater flow regime.
- Identifies and describes methods applied to evaluate the field data and assess the potential effects of the Project on the groundwater flow regime.

6.1.3 Supporting Documents

The following EIA-related documents were reviewed and referenced in support of the preparation of this Report:

- *Proposed Terms of Reference. Environmental Impact Assessment Report for Eastern Irrigation District's Proposed Snake Lake Reservoir Expansion Project. Dated October 20, 2023.*
- *Final Terms of Reference. Environmental Impact Assessment Report for Eastern Irrigation District's Proposed Snake Lake Reservoir Expansion Project. Dated July 4, 2024.*
- Project Summary Table prepared by the EID.

6.1.4 Study Area

The Study Area was defined based on the watershed boundaries identified as part of hydrological studies completed for the Project, refer to Figure 6-1 depicting the Study Area boundaries.

6.1.5 Regulatory Context

Table 6-1 below provides an overview of Acts and regulations pertaining to groundwater use and protection.

Table 6-1: Regulatory Context – Acts and regulations pertaining to groundwater resources

Regulation or Guideline	Context
Alberta Environmental Protection and Enhancement Act	Provides control and prevention of the release of substances that may cause an adverse effect on water resources. It also requires proper reclamation or remediation of contaminated groundwater sites and environmental impact assessments to determine the effects that any major development will have on water resources (GOA, 2000a).
Public Lands Act	All permanent and naturally occurring bodies of water are Crown lands in Alberta (GOA, 2000b). This includes only deep permanent natural waterbodies or flowing watercourses.
Water Act and Water Act Ministerial Regulations	Supports and promotes the conservation and management of water, through the use and allocation of water in Alberta. It requires the establishment of a water management framework and sets out requirements for the preparation of water management plans. Any impacts to water must first be approved under this *Act* (GOA, 2000c; GOA, 1998).
Alberta Soil and Groundwater Remediation Guidelines	Guidelines for the protection of soil and groundwater quality in Alberta. Alberta's framework for the management of contaminated sites aims at pollution prevention, health protection, and productive use through three management options including Tier 1, Tier 2, and Exposure Control. Groundwater guidelines are protective of receptors including potable groundwater users and aquatic life. These guidelines may be applied to assess groundwater quality and assess impacts of the project on groundwater quality (GOA, 2024a; GOA, 2024b).
Standards and guidelines for municipal waterworks, wastewater and storm drainage systems	Alberta Environment and Sustainable Resource Development (AESRD) is responsible for the Drinking Water and Wastewater Programs for large public systems in Alberta. The Guidelines address source water protection, groundwater source requirements, groundwater under the direct influence of surface water sources, water quality as well as source selection criteria (GOA, 2021).
Water wells and ground source heat exchange systems directive	The directive outlines requirements for drilling, construction and reclamation of water wells completed above Alberta' base of groundwater protection (the depth at which groundwater is estimated to transition from non-saline to saline). The requirements in the Directive are deemed enforceable by reference in the Water (Ministerial) Regulation.

6.2 ISSUE SCOPING

Per the requirements in the FTOR and the regulatory guidance, and given an understanding of the Project area, the following issues have been scoped for inclusion in the EIA for Hydrogeology. Scoping for this EIA is a process that includes:

- developing a list of resources or indicators for hydrogeology;
- identifying Project activities that may alter hydrogeology/groundwater resources;
- identifying the risks, issues, or concerns regarding these resources or indicators;
- determining what assessments to include (ones where effects are likely), and which to exclude (effects are likely to be negligible or trivial); and
- screening based on data/information available for the assessment to help determine if the issue can be assessed locally and or regionally.

Table 6-2 is a summary of issue scoping for hydrogeological resources impacted by the Project. Based on the screening, the following indicators were selected for the impact assessment of hydrogeological resources:

- Groundwater Quantity
    - The area of increased groundwater levels (during reservoir operations) was selected to assess the impacts from groundwater seepage from the expanded reservoir
    - The area of reduced groundwater during borrow pit and dam construction dewatering was selected to assess impacts related to groundwater drawdown during construction where effects on shallow wetlands may occur
- Groundwater Quality
    - Routine chemistry of groundwater and reservoir water was selected to assess the effects of water seepage from the reservoir into the underlying geological formations potentially affecting groundwater quality

Table 6-2: Hydrogeological Scoping for the Impact Assessment

Project Activities and Risks	Resources	Potential Issues	Indicators or Measures	Screening[1]	Applicability
Removal of surface waterbodies in expansion area Altered water drainage patterns Increased seepage due to hydraulic head of reservoir water pressurizing aquifers Encountering groundwater during stripping and excavation activities	Groundwater quantity	Impact on aquifers/ groundwater depletion	Aquifer recharge rates	Aquifer potential of the overburden is low given the predominant fine-grained nature of overburden and water levels often found in bedrock. Upper Bearpaw formation can be described as an aquitard.	Baseline characterization only
		Groundwater seepage from the expanded reservoir	Area of increased groundwater levels (during reservoir operations)	There is low potential for groundwater infiltration/seepage beneath the base of the reservoir basin and through the berms based on the low permeability of the clay till and bedrock aquitards.	Baseline characterization and impact assessment
		Groundwater drawdown during construction where effects on shallow wetlands may occur	Area of reduced groundwater during borrow pit and dam construction dewatering	During borrow pit and dam footprint excavation, groundwater infiltration will need to be pumped off, which could draw down shallow groundwater. This may affect wetlands in the radius of influence of dewatering.	Baseline characterization and impact assessment
		Conflicts with other groundwater users	Interaction with water wells in the Project area	Effects on water wells in the surrounding area would be related to increased area of groundwater effects due to groundwater level increases during operations, and reduced area during construction due to drawdown. However, there are no registered water wells in the study area.	Baseline Characterization only

Project Activities and Risks	Resources	Potential Issues	Indicators or Measures	Screening[1]	Applicability
	Groundwater quality	Contamination of groundwater from surface sources focusing on chemicals used for agricultural operation which could infiltrate into groundwater	Nutrient and pesticide groundwater chemistry	Nutrient and pesticide use will not change due to the project, as the project is not adding new irrigated lands.	Baseline Characterization only
		Conflicts with other groundwater users related to infiltration of contaminated surface water into groundwater	Contaminant chemistry of groundwater	Effects on surrounding area wells would be related to increased surface water infiltration that may occur during operations (increase in groundwater levels, but there is an absence of water wells in the study area.	Baseline Characterization only
		Seepage from the reservoir into groundwater may affect groundwater quality for area users	Routine chemistry of groundwater and reservoir water	There is low potential for groundwater infiltration/seepage beneath the base of the reservoir basin and through the berms that could have minor effects on groundwater chemistry.	Baseline characterization and impact assessment

[1] Determine if the issue is unlikely to occur, or if relevant data is not sufficient for assessment.

6.3 METHODOLOGY

This Section presents the methods used in the development of the Report.

6.3.1 Data Compilation

The construction of a conceptual hydro-stratigraphic framework of the Study Area from the available data sources is necessary. This conceptual hydro-stratigraphic framework can be transformed into a numerical groundwater flow model to evaluate the various hypothetical post-construction scenarios associated with the Project. Data was compiled to understand the baseline or pre-construction hydrogeological conditions of the Study Area and assess potential implications to the regional groundwater flow regime during the post-construction stage of the Project.

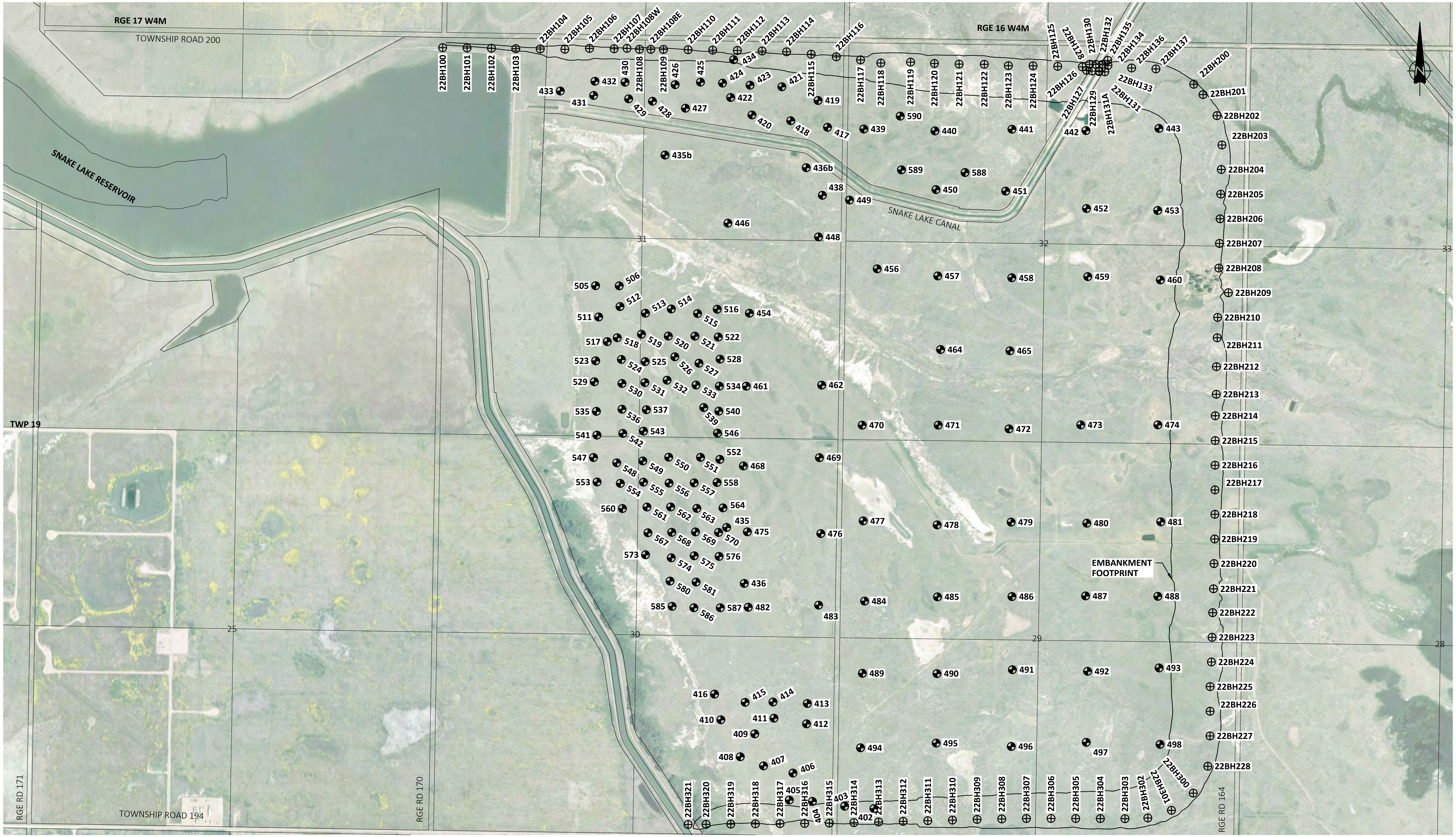
The data requirements to develop a conceptual understanding of the hydrogeology of the Study Area required extensive literature review and data collection. It was necessary to collate and analyze the available data to develop an understanding of the important aspects of the physical system and the hydrological processes that control or impact the groundwater flow system. The process of data compilation involved data collected from the field investigations completed by MPE and Englobe. MPE and Englobe then used professional judgment to analyze publicly available data sources for the development of the Study Area's conceptual hydro-stratigraphic framework.

6.3.2 Borehole and Monitoring Well Installation

A TOR document was provided by Thurber dated December 8, 2021. The TOR specified the technical requirements for the investigation from the dam designer's (Thurber) perspective. MPE coordinated with Thurber throughout the preliminary investigation. MPE identified that the ground conditions were rough and movement around the proposed reservoir site (hereinafter "the Site") would be difficult for the drilling rigs. MPE worked with the EID to construct a path along the proposed dam centerline to improve access for the drilling program.

The investigation program was carried out from March 3, 2022, to September 14, 2022, using drill rigs contracted from Chilako Drilling Services Limited (Ltd.). of Coaldale, Alberta (AB), ConeTec Investigations Ltd. of Edmonton, AB, and Val's Drilling Ltd. of Calgary, AB. The drilling was done with either solid stem, hollow stem continuous-flight augers, Cone Penetration Testing (CPT) advancement, or rock coring drilling methods. The soil and rock core samples were classified and logged by MPE's field representatives. A total of 264 boreholes were completed ranging from 0.6 m below the ground surface (mbgs) to 15.6 mbgs with a total meterage of 1,670.1 m. Boreholes were grouped into 100, 200, and 300 series boreholes depending on their locations in the dam alignment of the Site. Standard Penetration Tests (SPT) were completed in selected boreholes using calibrated auto-hammers. Boreholes that did not contain any instrumentation were backfilled after the collection of soil samples using environmentally safe bentonite chips.

A total of 19 boreholes were instrumented as 25 mm diameter polyvinyl chloride (PVC) standpipes and 47 boreholes were completed as 50 mm PVC monitoring wells. Figure 6-2 shows the borehole locations. Figure 6-3 shows borehole locations instrumented with well screens for groundwater monitoring.



NOTES

* BOREHOLES 400 & 500 SERIES NAME WAS SHORTEN IN PLAN VIEW TO AVOID TEXT OVERLAPPING (22BH402 TO 402)

LEGEND

EMBANKMENT FOOTPRINT
FOUNDATION BOREHOLES
BORROW INVESTIGATIONS BOREHOLES

SCALE 1:15 000
0 300 600 900m

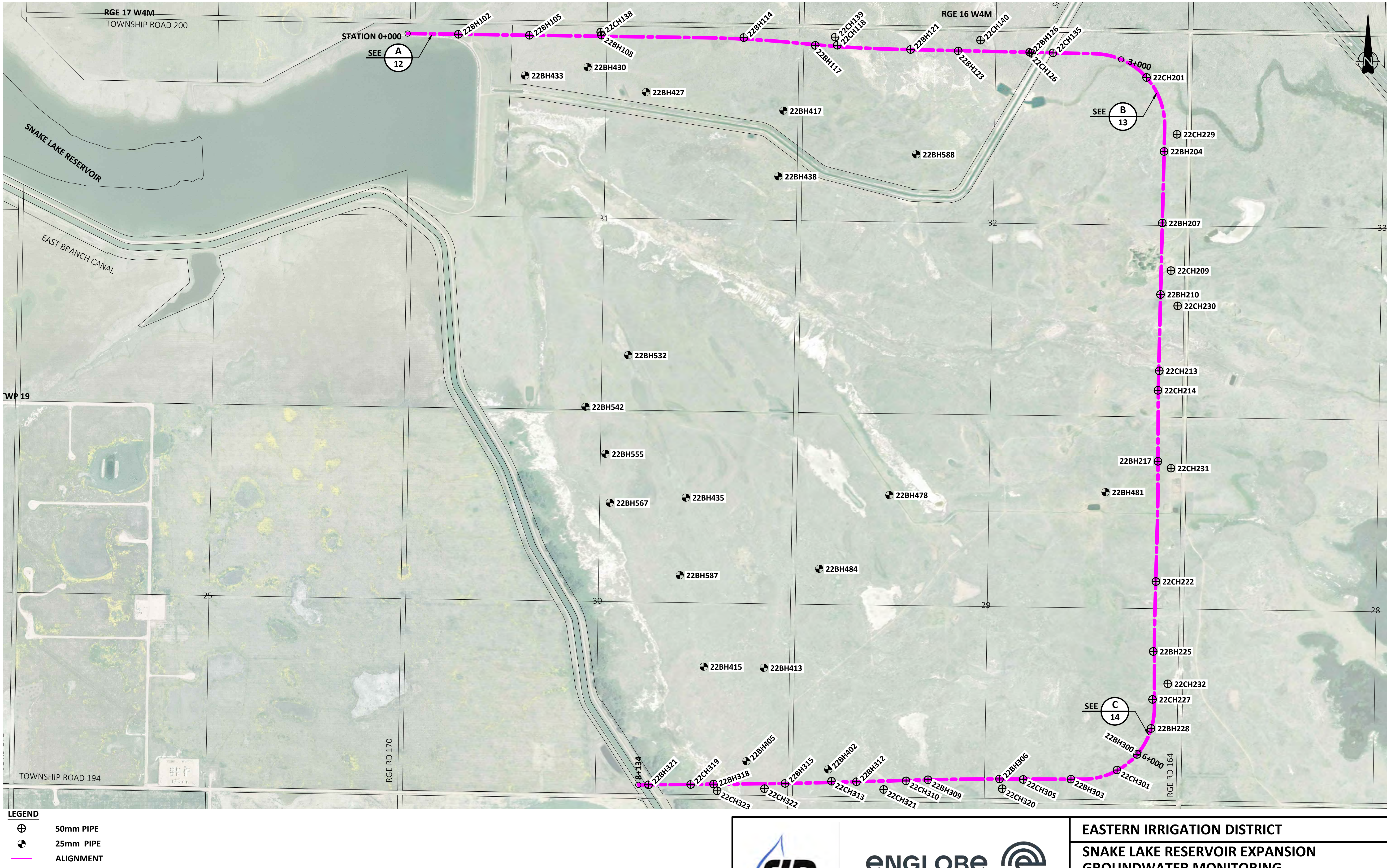
EID

englobe

EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION
BOREHOLE LOCATIONS

SCALE: 1:15 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 2



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EASTERN IRRIGATION DISTRICT			
SNAKE LAKE RESERVOIR EXPANSION GROUNDWATER MONITORING 50 mm AND 25 mm PIPES			
SCALE: 1:15 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 3

6.3.3 Hydraulic Conductivity Testing

In-situ hydraulic conductivity tests or slug tests were performed at 14 monitoring well locations during MPE's 2022 field investigation (Table 6-3) to obtain horizontal hydraulic conductivity values of the stratigraphic units intercepted in the select borehole locations. These borehole locations are located along the planned dam alignment. In-situ permeability tests involve inducing increased (Falling Head Test) or decreased (Rising Head Test) water level in the monitoring wells and monitoring the water level recovery to its initial level. The time to reach the initial level depends on the hydraulic conductivity, thickness of the aquifer where the screen and sand pack are installed, and the monitoring well geometry. The variation in water levels can be monitored through manual measurements and/or electronic water level loggers.

Before the initiation of the slug tests, static groundwater levels in each monitoring well location were recorded in addition to the monitoring well depths. Following the acquisition of static groundwater level and well depth data, a pressure transducer (electronic water level logger) was installed in the monitoring well below the planned depth of the solid slug when inserted. The pressure transducer recorded water levels during the slug test at a pre-determined frequency, in addition to recording manually with a water level probe. These in-situ hydraulic conductivity tests were performed by inserting a solid slug [1-inch (25 mm) diameter, and 36 inches (0.91 m) long, constructed of solid PVC] into each 2-inch (50 mm) diameter well, which induced the water level to increase. The water level was monitored and recorded once it returned to static water level or 90% of the static water level (Falling Head Test). The solid slug was then removed, which induced the level to decrease, and the water level was recorded as it recovered to static water level of 90% of the static water level (Rising Head Test).

Slug tests should be continued until at least 85-90% of the initial pre-test static water level (U.S. Environmental Protection Agency, 1986). The last 10% of test response is generally considered to be less reliable than the foregoing 90% of the test, since this late-time response is more strongly affected by observational errors (Hvorslev, 1951).

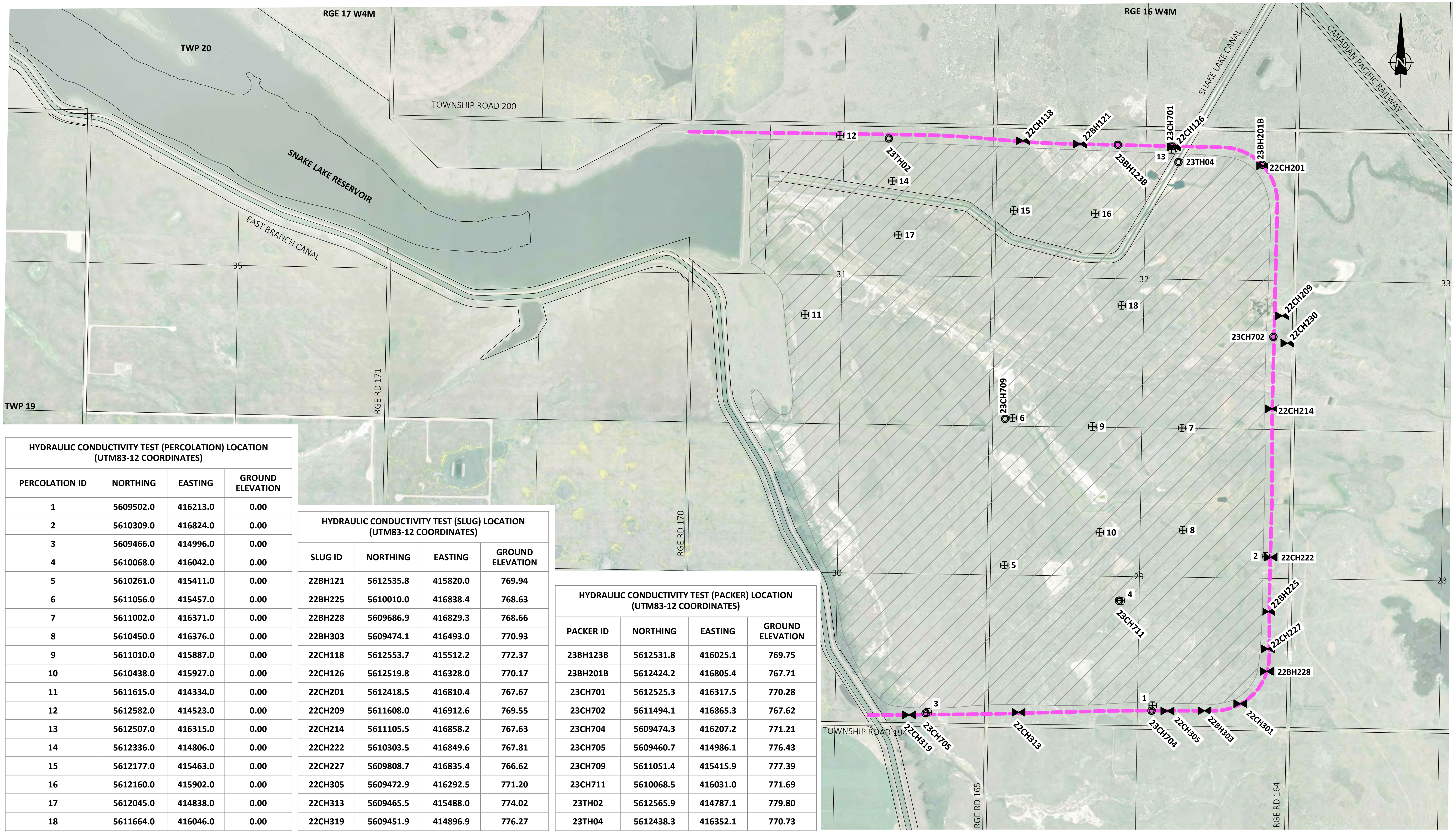
The in-situ hydraulic conductivity tests were performed between August 29, 2022, and March 17, 2023, and the test data were analyzed by using AquiferTest Pro Software Version 10.0 (Waterloo Hydrogeologic, Inc., 2020). Results were interpreted using the Bouwer-Rice solution (Bouwer & Rice, 1976) for the unconfined aquifers.

Refer to Section 6.3 and Appendix D2 of this Report for the test results.

Figure 6-4 shows the hydraulic conductivity test locations.

Table 6-3: Hydraulic Conductivity Test Locations

Monitoring Well Location	Stratigraphic Unit Tested
22CH118	Weathered Shale / Bentonite
22BH121	Weathered Shale
22CH126	Siltstone
22CH201	Shale
22CH209	Fractured Shale
22CH214	Fractured Shale
22CH222	Shale
22CH225	Sand
22CH227	Shale
22BH228	Weathered Shale
22BH303	Weathered Shale
22CH305	Shale / Bentonite
22CH313	Siltstone
22CH319	Siltstone



HYDRAULIC CONDUCTIVITY TEST (PERCOLATION) LOCATION (UTM83-12 COORDINATES)

PERCOLATION ID	NORTHING	EASTING	GROUND ELEVATION
1	5609502.0	416213.0	0.00
2	5610309.0	416824.0	0.00
3	5609466.0	414996.0	0.00
4	5610068.0	416042.0	0.00
5	5610261.0	415411.0	0.00
6	5611056.0	415457.0	0.00
7	5611002.0	416371.0	0.00
8	5610450.0	416376.0	0.00
9	5611010.0	415887.0	0.00
10	5610438.0	415927.0	0.00
11	5611615.0	414334.0	0.00
12	5612582.0	414523.0	0.00
13	5612507.0	416315.0	0.00
14	5612336.0	414806.0	0.00
15	5612177.0	415463.0	0.00
16	5612160.0	415902.0	0.00
17	5612045.0	414838.0	0.00
18	5611664.0	416046.0	0.00

HYDRAULIC CONDUCTIVITY TEST (SLUG) LOCATION (UTM83-12 COORDINATES)

SLUG ID	NORTHING	EASTING	GROUND ELEVATION
22BH121	5612535.8	415820.0	769.94
22BH225	5610010.0	416838.4	768.63
22BH228	5609686.9	416829.3	768.66
22BH303	5609474.1	416493.0	770.93
22CH118	5612553.7	415512.2	772.37
22CH126	5612519.8	416328.0	770.17
22CH201	5612418.5	416810.4	767.67
22CH209	5611608.0	416912.6	769.55
22CH214	5611105.5	416858.2	767.63
22CH222	5610303.5	416849.6	767.81
22CH227	5609808.7	416835.4	766.62
22CH305	5609472.9	416292.5	771.20
22CH313	5609465.5	415488.0	774.02
22CH319	5609451.9	414896.9	776.27

HYDRAULIC CONDUCTIVITY TEST (PACKER) LOCATION (UTM83-12 COORDINATES)

PACKER ID	NORTHING	EASTING	GROUND ELEVATION
23BH123B	5612531.8	416025.1	769.75
23BH201B	5612424.2	416805.4	767.71
23CH701	5612525.3	416317.5	770.28
23CH702	5611494.1	416865.3	767.62
23CH704	5609474.3	416207.2	771.21
23CH705	5609460.7	414986.1	776.43
23CH709	5611051.4	415415.9	777.39
23CH711	5610068.5	416031.0	771.69
23TH02	5612565.9	414787.1	779.80
23TH04	5612438.3	416352.1	770.73

LEGEND

- PROPOSED TOP OF DAM
- SLUG TEST
- PACKER TEST
- PERCOLATION TEST
- EXPANSION AREA

SCALE 1:20 000
0 400 800 1200m

ENGLOBE

EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION HYDRAULIC CONDUCTIVITY, PACKER AND PERCOLATION TEST LOCATIONS

SCALE: 1:20 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 4

6.3.4 Short Duration Constant Rate Pumping Tests

The short-duration constant rate pumping tests were conducted at the two monitoring wells (23CH700B and 23CH709B) located within the Study Area to obtain the hydraulic properties of the tested stratigraphic units. Before initiating the pumping tests, MPE obtained static groundwater levels and identified discharge locations to ensure that groundwater discharge during the test did not result in recharge. A maximum pumping rate of 5 L/min was selected based on the review of the results of slug tests and data obtained during the well development. The pumping phase of the test lasted approximately 60 minutes and the groundwater level recovery phase of the test lasted several days since groundwater level recovery to the static groundwater level is slow.

Immediately following the pumping test, water level recovery was monitored in each tested well until approximately 90% recovery. The last 10% of test response is generally considered to be less reliable than the foregoing 90% of the test, since this late-time response is more strongly affected by observational errors (Hvorslev, 1951). In addition to monitoring groundwater level changes over time, barometric pressure was monitored using a Solinst™ baro-logger. Section 6.3 of this Report presents the hydraulic parameters estimated from the short duration constant rate pumping tests and the data collected during these pumping tests is presented in Appendix D2.

6.3.5 Packer Testing and Estimates of Apparent Permeability of Bedrock

A total of 10 boreholes were tested by MPE in 2023 to obtain apparent permeability of the bedrock in the tested zone. Packer tests, also referred to as Lugeon tests, were completed at multiple pressure steps using a double obstructor setup and an injection zone of about 2 m. The selection of the packer testing intervals focused on intervals where the highest potential density of bedrock fractures was observed in each borehole, as indicated on borehole logs by lower rock quality designation (RQD) values and notes describing the presence of fractures, shear zones, and/or faults in the lithological logs where RQD data was not available.

Lugeon tests are completed with five pressure steps. The Lugeon unit corresponds to the flow rate absorbed in litres per minute per linear metre of the borehole (L/min/m) at a net pressure of injection of 1000 kPa (10 bars). The lugeon value at other pressures is calculated by linear extrapolation using the following formula:

Lugeon Value = (A x 1000 kPa)/(Actual pressure of injection in kPa)

Where “A” corresponds to the water absorption in L/min/m.

An approximate estimate of equivalent hydraulic conductivity can be determined using the typical correlation established by Houlsby (1976) of 1 Lugeon = 1.3 x 10^{-7} m/s or 1 Lugeon = 1.3 x 10^{-5} centimetres per second (cm/s).

The permeability of rock with low effective porosity being essentially fracture controlled, the flow regime is generally turbulent therefore it falls outside of the parameters where Darcy’s Law applies. As a consequence, the Lugeon Test, which is conducted under high pressure, is considered a qualitative permeability test rather than a measurement of hydraulic conductivity.

Due to the nature of the test, under normal circumstances, the uppermost 1.0 to 1.5 m section of bedrock that is in contact with overburden cannot be tested with this method. This constraint is due to the obstructor placement above and below the targeted test interval. This portion of bedrock is often more fractured and weathered and therefore more permeable. To test this interval of bedrock, observation wells screened in this interval were used. Figure 6-4 presents the borehole and monitoring well locations where packer tests were conducted.

Section 6.3 of this Report presents the apparent permeability rates estimated from the packer tests and the data collected during the packer tests is presented in Appendix D3.

6.3.6 Percolation Testing

In-situ percolation tests were carried out at 18 locations within the reservoir basin floor to obtain the length of time required for a quantity of water to infiltrate into the soil. It should be noted that the percolation rate is related to, but not equivalent to, the infiltration rate. While an infiltration rate is a measure of the speed at which water progresses downward into the soil, the percolation rate measures not only the downward progression but the lateral progression through the soil as well. This reflects that the surface area for infiltration testing would include only the horizontal surface. In contrast, the percolation test includes both the bottom surface area and the sidewalls of the test hole. However, a relationship exists between the percolation test and infiltration rate. Based on the inverse auger-hole method (also referred as Porchet Method) (Hoorn, 1979), the following equation was used to convert percolation rates to the tested infiltration rate:

$$I_t = \frac{\Delta H\ \pi r^2 60}{\Delta t(\pi r^2 + 2\pi r H_{avg})} = \frac{\Delta H\ 60\ r}{\Delta t(r + 2H_{avg})}$$

Where:

I_t = tested infiltration rate, inches/hour

ΔH = change in head over the time interval, cm

Δt = time interval, minutes

r = effective radius of test hole

H_{avg} = average head over the time interval, cm

Figure 6-4 shows the percolation test locations and Section 6.3 of this Report presents percolation rates. The percolation test results are presented in Appendix D4.

6.3.7 Groundwater Quality – Groundwater Sampling

Groundwater samples were retrieved from the boreholes instrumented as the monitoring wells 23CH700, 23CH702, and 23CH704 on July 10, 2024. Before groundwater sample collection, boreholes instrumented as monitoring wells were purged using low-flow techniques with a peristaltic pump to lessen sediment disturbance.

The groundwater samples were collected on July 10, 2024, and sent to the Bureau Veritas Laboratory located in Calgary, Alberta where they were received on July 12, 2024. The temperature of samples at reception was below 10 °C and met sample storage requirements. The groundwater samples were submitted for analysis of alkalinity, biochemical oxygen demand (BOD), Canadian Council of Ministers of the Environment (CCME) hydrocarbons, benzene, toluene, ethylbenzene, xylenes (BTEX), chemical oxygen demand (COD), total and dissolved metals, fecal coliforms, conductivity, hardness, total mercury, methyl mercury, major ions, nitrate and nitrite, pH, phenols, total dissolved solids (TDS), Total Kjeldahl nitrogen; nitrogen, total organic carbon (TOC), and total phosphorus. Analytical methods used for the analyses are listed on the laboratory certificates of analyses.

Groundwater sampling results are discussed in Section 6.3 of this Report and associated laboratory certificates of analysis are presented in Appendix D5.

6.3.8 Development of a Conceptual Hydro-Stratigraphic Framework

The conceptual Hydro-Stratigraphic Framework (hereinafter “conceptual framework”) is a simplified idealization of real conditions that summarizes the hydrogeology, including how the groundwater flow system works. The conceptual framework development comprised a collection of the physical and hydrogeological framework data components, data analysis and synthesis, and visualization of the conceptual framework in maps and cross-sections. The conceptual framework was later transformed into a three-dimensional conceptual Hydro-Stratigraphic Framework using the interface for the fine element modelling software FEFLOW™ for implementation as a three-dimensional groundwater flow model. The groundwater flow model construction details are provided in Appendix D7.

The data required for the development of the conceptual framework can be broadly classified into the physical framework data and hydrogeological framework data. The following sections detail the process and steps involved in the development of the conceptual framework.

6.3.8.1 Data Collection

Physical Framework Data

Topography, Surface Drainage, and Hydrological Features

The physical framework used in the conceptual framework included elements such as the regional and local topography, and surface drainage. Information on regional topography was obtained from a number of sources but consisted primarily of topographic contours from Natural Resources Canada (NR Canada) and the Digital Elevation Model (DEM) for the existing reservoir and planned reservoir expansion area. These datasets were reviewed and combined to generate the regional topography and surface drainage for the Study Area.

The data sources reviewed included the following:

- Geological Survey Canada surface elevation and topographic data.
- MPE. Inflow Design Flood Estimate, Snake Lake Expansion, dated August 2023 (MPE, 2023).

Geology, Lithology, and Stratigraphy

Records of stratigraphic details of the Study Area are quite extensive. Alberta Geological Survey (AGS) maps contained stratigraphic interval information and spatial occurrences of various lithologies relating to the Mesozoic bedrock formations within the Study Area.

Private water well records from the Alberta Water Well Information Database contained lithologic and stratigraphic information relating to the overburden and shallow bedrock formations within the Study Area. In addition, extensive overburden lithology and stratigraphy information were available in the geotechnical investigation reports completed for the proposed reservoir area, and the data from the borehole records in the geotechnical investigation reports were reviewed in conjunction with publicly available quaternary and surficial geology maps. The data sources reviewed included the following:

- Alberta Geological Survey (AGS) and Alberta Energy Regulator: Alberta Table of Formations (AGS, 2015).
- Alberta Environment Water Well Information Database, refer to Appendix D6 for the reviewed water well records (GOA, 2024c).
- Bedrock Geology of Alberta (Map 600) (Prior et al., 2013).
- Bedrock Geology of Southeastern Alberta (Maps 567, 568, 569, and 570) (AGS, 2014).
- Bedrock Topography of Alberta (Map 602) (MacCormack et al., 2015).
- MPE. Geotechnical Investigation Report, Revision 1., Snake Reservoir Expansion, November 22, 2022 (MPE, 2022).
- Thickness and distribution of Quaternary and Neogene sediment in Alberta; Energy Resources Conservation Board, ERCB/AGS Map 551 (Atkinson & Lyster, 2012).
- Quaternary Geology of Southern Alberta (Map 207) (Shetsen, 1987).
- Stratigraphic Framework of the Uppermost Cretaceous to Paleocene Strata of the Alberta Basin (Jerzykiewicz, 1997).
- Field investigation results discussed in this Report.

Hydrogeological Framework Data

The hydrostratigraphic definition of the subsurface strata was determined by identifying the bedrock formations or overburden units having similar groundwater flow characteristics. Delineation of these units or formations resulted in the subdivision of the physical framework into portions characterized by permeability (e.g., more permeable to less permeable portions). The delineation and definition of hydro-stratigraphy of the Study Area involved the application of:

- Sequence stratigraphic concepts to the Study Area deposits to derive an overall conceptual framework of the strata where appropriate.
- In-situ hydraulic testing of bedrock units (short-duration constant rate pumping tests, packer tests, hydraulic conductivity tests).
- Field examination and laboratory testing of soil samples to identify soil texture and classify soils comprising the overburden units using the Unified Soil Classification System (USCS).
- Laboratory determination of plasticity in fine-textured soil materials and the determination of the soil permeability through the plasticity index and soil permeability relationship.
- Publicly accessible information of geologic history of the Study Area.
- The results from previous investigations and historical reports.

- The data sources reviewed included the following:
- Hydrogeological Regions of Alberta (Map 009), (AGS, 2021).
- MPE. Geotechnical Investigation Report, Revision 1., Snake Reservoir Expansion, November 22, 2022 (MPE, 2022).

- Field investigation results discussed in this Report.

6.3.8.2 Data Analysis and Synthesis

The physical and hydrogeological framework source data included boring logs, water levels, published papers and other documents in various computer file formats (e.g., .PDF,.MDB,.SHP). The source data contained well/borehole locations, water levels, boring identifiers, lithologies, and interpreted stratigraphic unit designations. The physical and hydrogeologic framework source data files were converted into Geographic Information System (GIS) and mapping software formats for use in the subsequent analysis and preparation of data input files for the visualization of the physical and hydrogeological framework data in cross-sections and maps.

6.3.8.3 Conceptual Hydro-Stratigraphic Framework

A conceptual hydro-stratigraphic framework (CHF) is an idealization of real conditions that summarize the hydrogeology, including the description of the groundwater flow system in the Study Area. Baseline data are presented in Section 6.3 of this report. The CHF is discussed in Section 6.3 and presented in cross-sections and maps in Section 6.3.

6.3.9 Development of the Groundwater Flow Model

The CHF was implemented as a simplified three-dimensional groundwater flow model of the Study Area using the modelling tool FEFLOW™ Version 7.3 (Appendix D7).

6.4 RESULTS

6.4.1 Topography, Surface Drainage, and Hydrological Features

In general, the Study Area slopes from west to east. Topography for the site includes a steep drop from the canal and extent reservoir related glacial and fluvial geomorphology (Figure 6-5). A prominent facture is a paleo channel which supports a wetland and drains water to the east. The ground surface elevation varies approximately from 840 m above mean sea level (masl) in the southwestern portion of the Study Area to 758 masl in the northeast portion of the Study Area. The ground surface elevation varies approximately from 784 to 765 masl along the proposed reservoir alignment. Within the proposed reservoir basin, the ground surface elevation varies approximately from 782 to 768 masl. The SLR is located immediately to the west of the proposed reservoir expansion area at an approximate elevation of 792 to 772 masl.

The area to the southeast of the existing reservoir is characterized by the presence of several lakes, the largest water body within the Study Area is San Francisco Lake. The Province of Alberta has identified San Francisco Lake as a provincially significant environmental area (Alberta Community Development, Parks and Protected Area Division, 2001).

The existing SLR is another major hydrological feature in the Study Area. It is located within the One Tree Creek subwatershed of the Red Deer River sub-basin, however, the existing reservoir receives surface water from the Bow River via the East Branch Canal. The maximum water depth recorded in the spring was 14.3 m and 12.8 m in the fall. The SLR stores about 15,600 ac ft (19.25 million m^3) of water at FSL (781.7 m).

The surface drainage is generally poor to imperfect drainage conditions within the Study Area even accounting for weathering and fracturing of upper soil horizons comprised of fine-textured soil materials, which has the effect of reducing the net infiltration to groundwater.

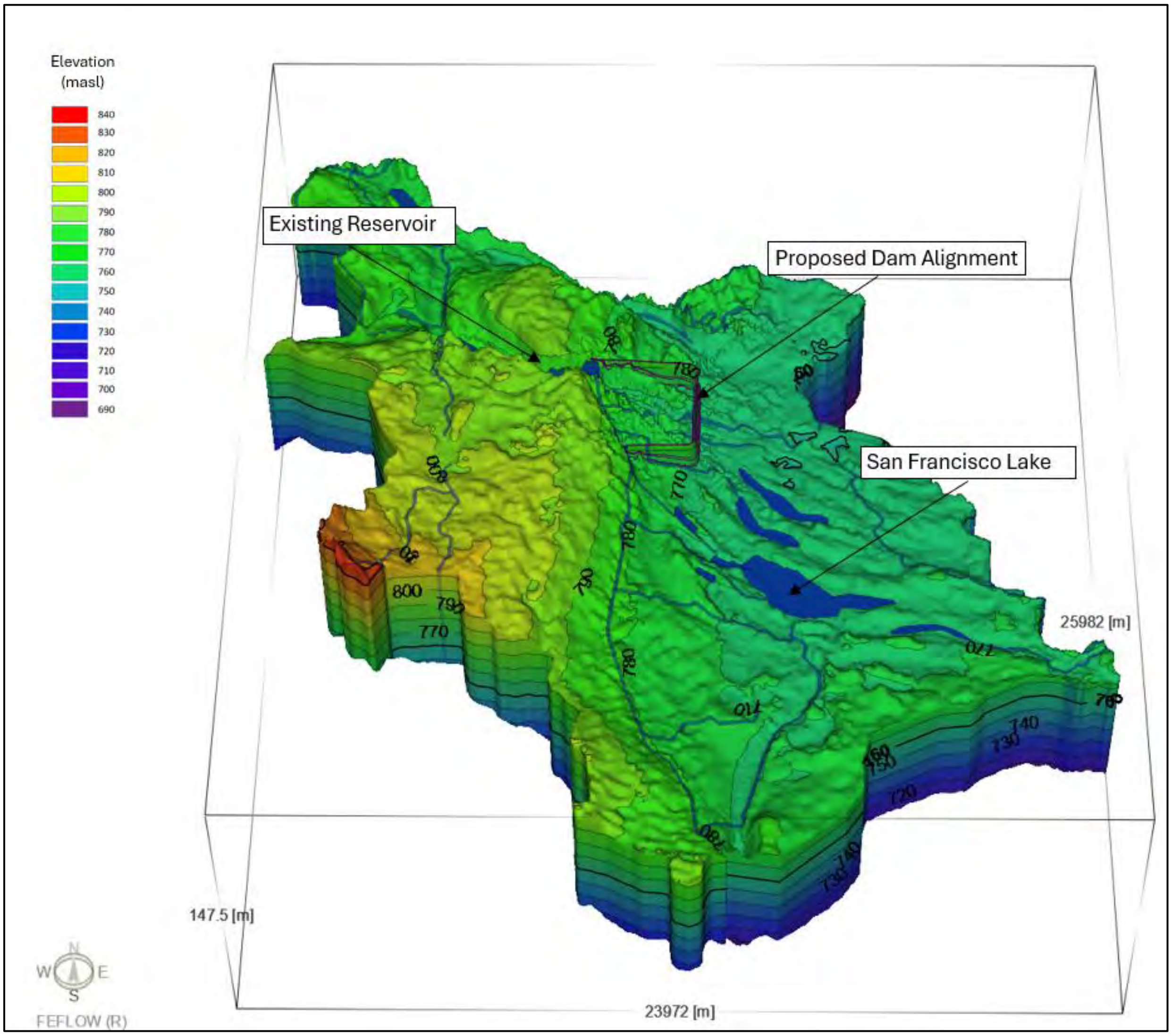


Figure 6-5: Conceptual Representation of the Study Area Topography and Surface Drainage

6.4.2 Unconsolidated Surficial Deposits and Groundwater Flow Regimes

The surficial geology of the Study Area is dominated by glacial deposits with minor colluvial, eolian, and fluvial deposits. The area near the reservoir expansion is mapped as a mixture of unsorted sediments consisting of a mixture of clay, silt, sand and gravel to the north and west, fluvial gravel, sand, silt and clay to the north and east, and glaciolacustrine deposits of gravel, sand, silt and clay towards the south. A deposit of clay till with low to high plasticity was noted to be underlain by unsorted sediments comprising both coarse and fine textured soil materials.

The surficial geology in the area of San Francisco Lake is characterized by the presence of ice-contact lacustrine and fluvial deposits comprised of undivided gravel, sand, silt, and clay up to 25 m in thickness. The surficial geology in the northeastern portion of the Study Area is characterized by the presence of wind-modified coarse sediments (sand and silt) or fine sediments (silt and clay). The general stratigraphy in the area of the reservoir expansion consists of surficial soils extending to a maximum depth of 6.9 mbgs, underlain by weathered bedrock.

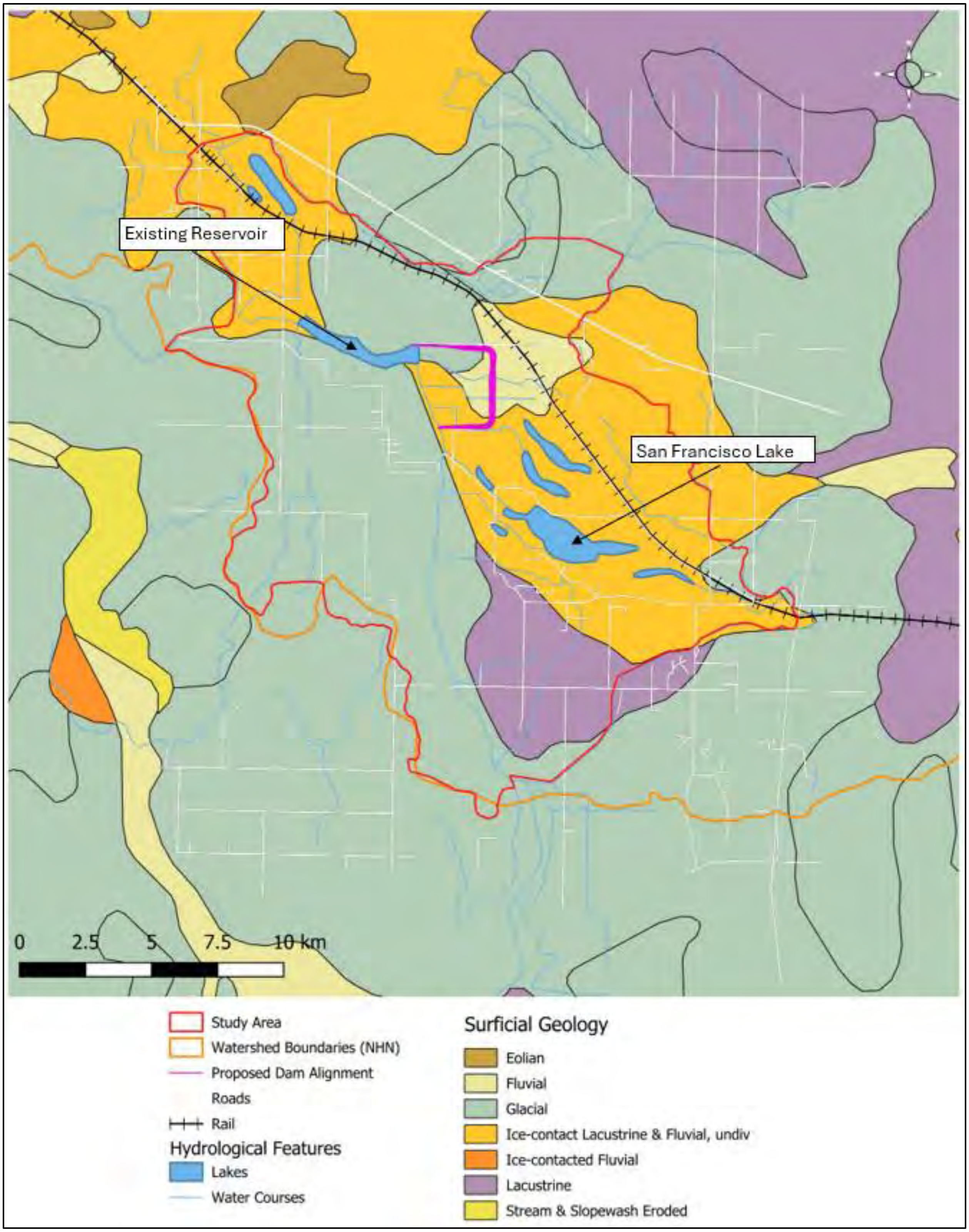


Figure 6-6: Surficial Geology of the Study Area (Modified after Fenton et al., 2013)

The surficial geology of the Project area is characterized by extensive clay till overlying the weathered shale underlain by competent unweathered shale bedrock. The clay till is typically medium to high plasticity, loose to compact, and comprised of trace silt, sand, and areas of high gravel and cobble contents. Several minor isolated occurrences of a sand layer overlying the weathered clay till layer were noted in less than 10 of 251 boreholes completed within the Site by MPE in 2022. Figure 6-7 shows the location of stratigraphic profiles along the north and east dam alignment sections. Figures 6-7A and 6-7B depict the stratigraphic profile encountered in the boreholes along the north and east dam alignments.

The clay till field samples had estimated plasticity index value from 10.5% to 66.5% (MPE, 2022). The hydraulic conductivity of clays decreases with an increase in plasticity. Thus, the plasticity index values are an indirect measure of the capacity of soils to pass fluids. These measures were supported by in situ field hydraulic conductivity testing. Plasticity index values were derived through laboratory tests known as the Atterberg Limits (ASTM D4318-10e1, 2010). During the Atterberg Limits testing, the soil samples require mixing air-dried samples with distilled water to form a test sample. However, the use of ion-free distilled water in this test may over-estimate the plasticity index values of clay till, thus, MPE completed Atterberg Limits testing of select soil samples using both distilled water and groundwater (Table 6-4).

Table 6-4: Plasticity Index Values of Select Clay Till Samples – Groundwater vs. Distilled Water (MPE, 2022)

Test Hole	Sample Depth (m)	Water Type	Liquid Limit (%) [1]	Plastic Limit (%) [2]	Plasticity Index (%)
22CH122	5.1	Distilled	87.9	18.4	69.5
		Groundwater	73.7	16.9	56.8
22CH215	22.0	Distilled	65.8	15.4	50.4
		Groundwater	64.2	17.6	46.6
22CH312	5.2	Distilled	61.3	16.9	44.4
		Groundwater	70.6	15.4	55.2
22CH319	8.6	Distilled	93.7	17.4	76.3
		Groundwater	85.7	18.9	66.8
22BH409	2.1	Distilled	79.0	22.9	56.1
		Groundwater	71.9	19.6	52.3
22BH498	1.2	Distilled	72.4	22.3	50.1
		Groundwater	58.8	16.2	42.6
22BH558	1.0	Distilled	61.1	17.6	43.5
		Groundwater	49.9	16.8	33.1

[1] Liquid Limit is the water content, in percent, of a soil at the arbitrarily defined boundary between the semi-liquid and plastic states in cohesive soils (ASTM D4318-10e1, 2010).

[2] Plastic Limit is the water content, in percent, of a soil at the boundary between the plastic and semi-solid states in cohesive soils (ASTM D4318-10e1, 2010).

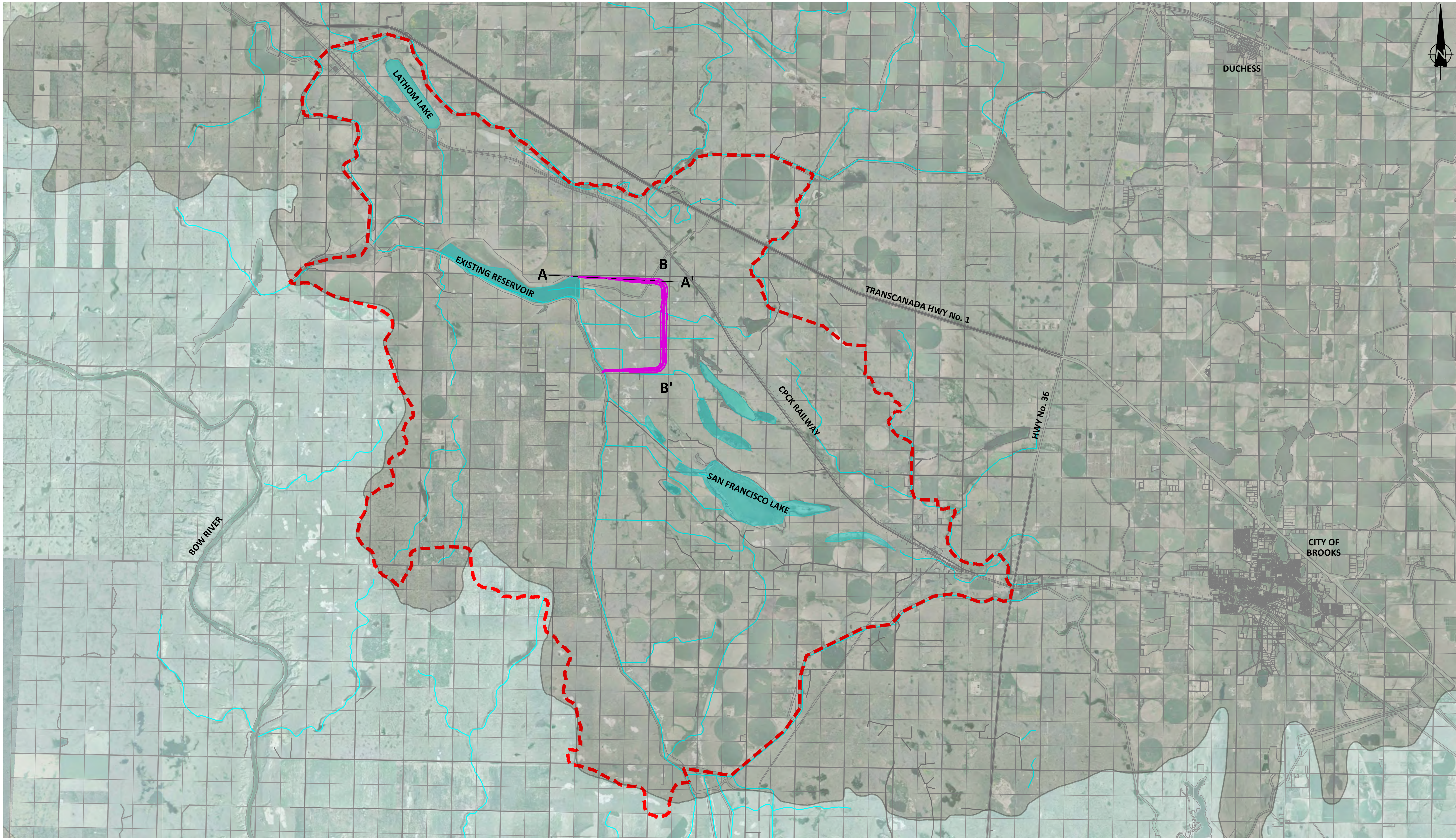
As expected, the plasticity index values were generally elevated when using distilled water. Thus, groundwater chemistry plays a role in the plasticity of the clay till. Table 6-4 shows this occurred in 6 of the test holes.

Percolation testing was conducted between May 22 and June 7, 2024, at 18 locations distributed across the basin floor area of the proposed reservoir expansion area to obtain an estimate of the percolation rate. Figure 6-4 shows the 18 locations where percolation testing was conducted. The obtained percolation rates ranged from approximately 2 min/cm to 35 min/cm, with an average of

9.3 min/cm. These values typically correspond to sandy silt, as opposed to values expected for silty clay documented at the Site. In effect, values in the range of the result obtained in P-08 would be more typical of the soils observed within the reservoir footprint. These percolation rates might be attributable to the very dry soil conditions observed at the time of testing and representative of transient conditions, which would be representative of conditions when the basin is filled initially. It is possible that a prolonged test duration would have provided more results resembling the value obtained in P-08 by allowing the clay soils to swell and reduce the percolation rates, which would be more representative of long-term saturated conditions prevailing after the reservoir is filled and the underlying silty clay deposit is saturated for an extended period of time. A summary of percolation test results is presented in Table 6-5 below.

Table 6-5: Percolation Test Results

Test Location	Test Date	Percolation Rate (min/cm)
P-01	June 7, 2024	18.1
P-02	June 7, 2024	2.0
P-04	June 7, 2024	9.0
P-05	June 7, 2024	5,0
P-06	May 22, 2024	3.1
P-07	May 22, 2024	5.2
P-08	June 7, 2024	34.9
P-09	May 22, 2024	3.8
P-10	May 22, 2024	4.0
P-11	May 22, 2024	6.2
P-12	May 22, 2024	9.3
P-13	May 22, 2024	13.6
P-14	May 22, 2024	8.5
P-15	May 22, 2024	7.9
P-16	May 22, 2024	8.8



LEGEND

- STUDY AREA
- RESERVOIR
- ROADS
- RAIL LINES
- WATERCOURSES
- CROSS-SECTIONS
- LAKES
- WATERSHED BOUNDARIES

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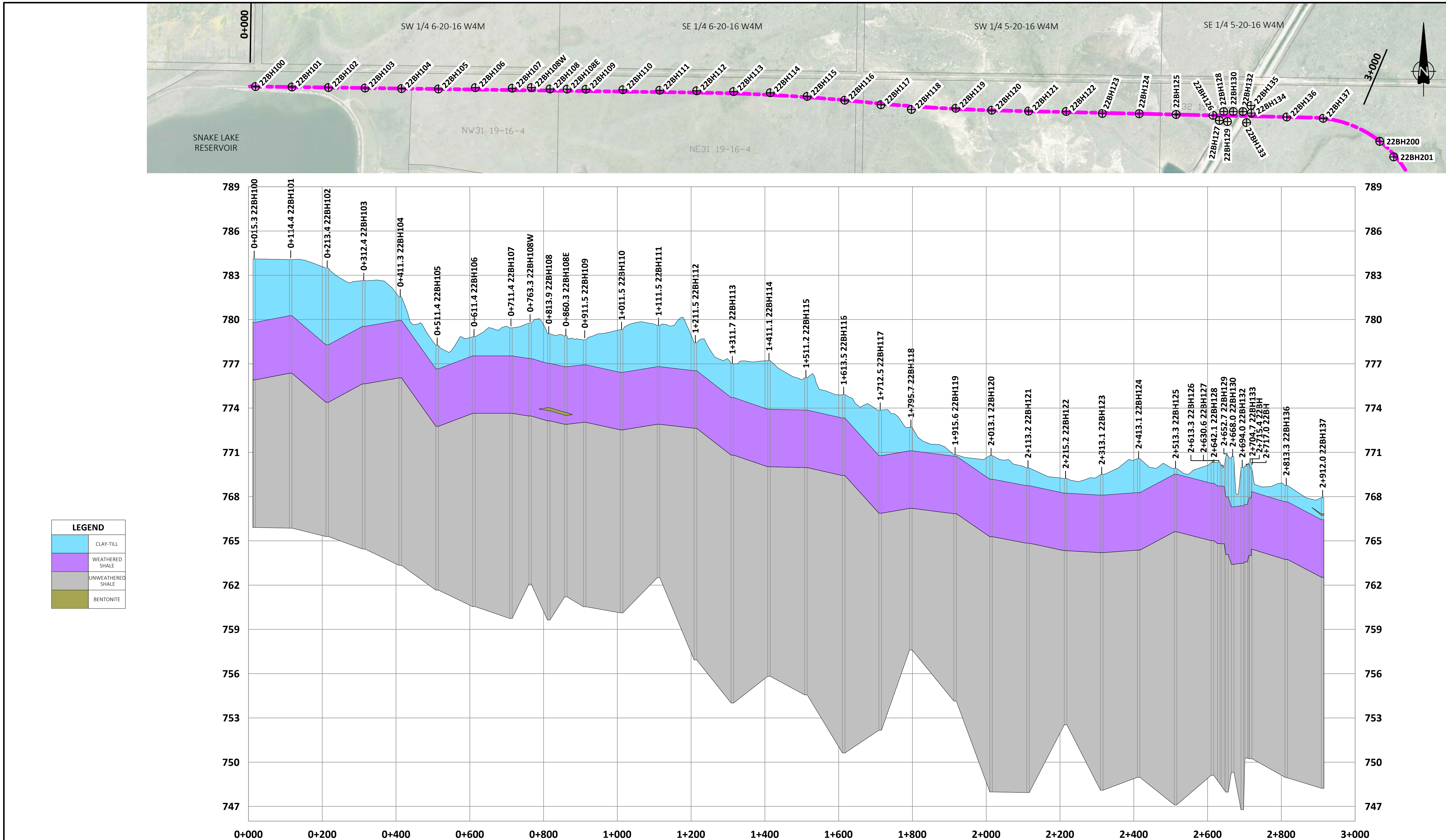
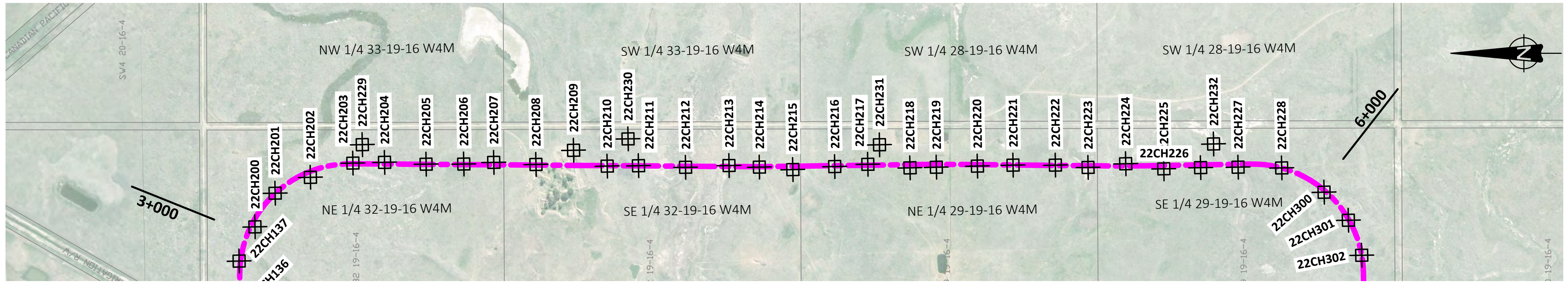
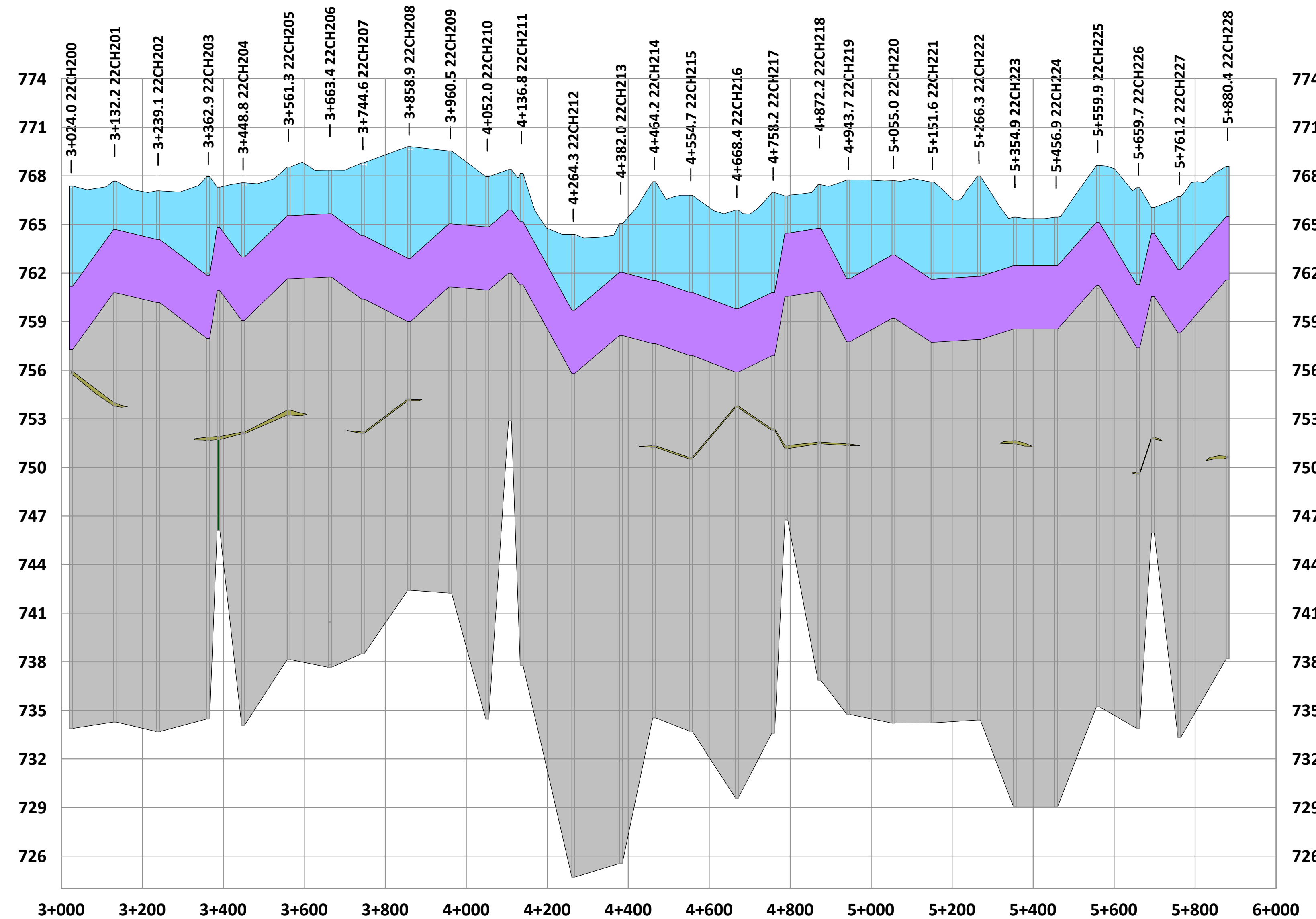
SNAKE LAKE RESERVOIR EXPANSION
HYRDOSTRATIGRAPHIC CROSS-SECTION
LOCATION

SCALE: NOT TO SCALE	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 7



EASTERN IRRIGATION DISTRICT			
SNAKE LAKE RESERVOIR EXPANSION CROSS SECTION STRATIGRAPHY BOREHOLE 100 SERIES			
SCALE: H 1:10 000 V 1:250	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 7A





LEGEND

	CLAY-TILL
	WEATHERED SHALE
	UNWEATHERED SHALE
	BENTONITE

LEGEND

⌖ COREHOLE LOCATIONS

SCALE 1:15 000

0 300 600 900m

EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION
CROSS SECTION STRATIGRAPHY
COREHOLE 200 SERIES

EID

englobe

SCALE:H 1:15 000 V 1:375	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 7B

6.4.2.1 Groundwater Levels and Groundwater Flow Regimes – Surficial Deposits

The clay till deposits in the Project area varied from 0.10 m to 7.60 m deep and had increasing moisture content with depth. Groundwater was encountered in some boreholes. Well screens were used to sample groundwater at the two following interface zones of the Bearpaw Formation:

- Between the weathered clay till and weathered shale bedrock; or,
- Between the unweathered clay till and shale or siltstone bedrock.

Observed groundwater levels ranged from 1.53 to 5.33 mbgs. A summary of the observed groundwater levels is presented in Table 6-6 below.

Table 6-6: Groundwater Levels in the Interface Zone

Bore Hole ID	Ground Elevation (m)	Top of Pipe (m)	2022-08-10		2022-09-15		2022-10-12		2023-01-25		2023-04-27		2023-09-27	
			WL	WE	WL	WE	WL	WE	WL	WE	WL	WE	WL	WE
22BH102	783.49	0.77	3.71	780.55	3.78	780.48	4.16	780.10	3.89	780.37	4.65	779.61	4.57	779.70
22BH207	769.12	0.86	4.22	765.76	4.27	765.71	4.32	765.66	4.38	765.60	4.19	765.79	4.30	765.68
22BH210	767.69	0.78	1.53	766.94	2.00	766.48	2.22	766.25	2.41	766.06	2.56	765.91	2.65	765.82
22BH217	767.06	0.94	3.12	764.88	3.20	764.80	3.21	764.79	3.19	764.81	3.01	764.99	3.15	764.85
22BH225	768.63	1.10	-[1]	-[1]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[3]	-[3]	-[3]	-[3]
22BH417	775.36	0.85	5.33	770.88	5.27	770.94	5.26	770.95	5.25	770.96	5.31	770.9	5.28	770.93
22BH478	775.09	0.28	2.95	772.42	-[2]	-[2]	2.76	772.61	3.61	771.76	3.83	771.54	3.98	771.40
22BH481	769.00	0.31	2.88	766.43	2.88	766.44	2.90	766.41	3.01	766.30	2.99	766.32	3.03	766.29

Notes: WL = Water level, WE = Water elevation (masl)

[1] Groundwater level and elevation not obtained due to slug test being performed.

[2] Groundwater level and elevation not obtained during data collection.

[3] Dry conditions observed in borehole during data collection.

As detailed in the preceding table, groundwater is confined to the thin and discrete interface zone comprising a weathered portion of clay till or a weathered portion of bedrock and directly overlying the bedrock interface, these small discrete units do not typically provide significant groundwater yield.

6.4.2.2 The Potential for Hosting Aquifers – Surficial Deposits

Areas containing thick deposits of surficial unconsolidated sediments, such as buried valleys in Alberta, may host aquifers that yield sufficient quantities of groundwater for potable and other uses. Most buried valleys in Alberta were eroded by eastward-flowing pre-glacial river systems, these valleys were subsequently modified by glacial and fluvial processes that occurred after their initial formation (Cummings et al., 2012). The surficial deposits with sufficient thickness of highly permeable sand and gravel deposits could hold aquifers capable of yielding groundwater for potable and non-potable purposes. In Alberta, aquifer-hosting surficial deposits can be classified according to their physiographic position on the bedrock surface; those within the buried bedrock valleys, and those on the surrounding bedrock plains and uplands. Hartman et al., (2023) mapped aquifer-hosting sediments in Alberta and noted that sediment thickness of 15 m or greater is corroboratory evidence of aquifer-hosting sediments. Hartman et al., (2023) noted that sand and gravel deposits occupying buried valleys represent significant aquifer systems in Alberta.

A review of AGS Map 47-1960 titled *Buried Valleys in Central and Southern Alberta* (Stalker, 1961), in conjunction with the more up-to-date Map 611 titled *Sediment Thickness of Alberta, Version 2* (Atkinson et al., 2020) was completed to identify the potential presence or absence of Buried Valleys within the Study Area. Based on both maps, it appears no buried valleys exist in the Study Area except within the northwestern portion. Map 47-1960 indicates that the buried “Preglacial Bow Valley” is located some 10 km to the north, and another unnamed buried valley some 20 km to the southeast. Map 611 presents a range of sediment thickness of 0 – 5 m or 5 – 10 m for the site of proposed reservoir expansion.

Figure 6-8 shows the distribution of buried valleys in the Study Area, which confirms that there are no buried valleys with significant thicknesses (>15 m) of permeable sediments.

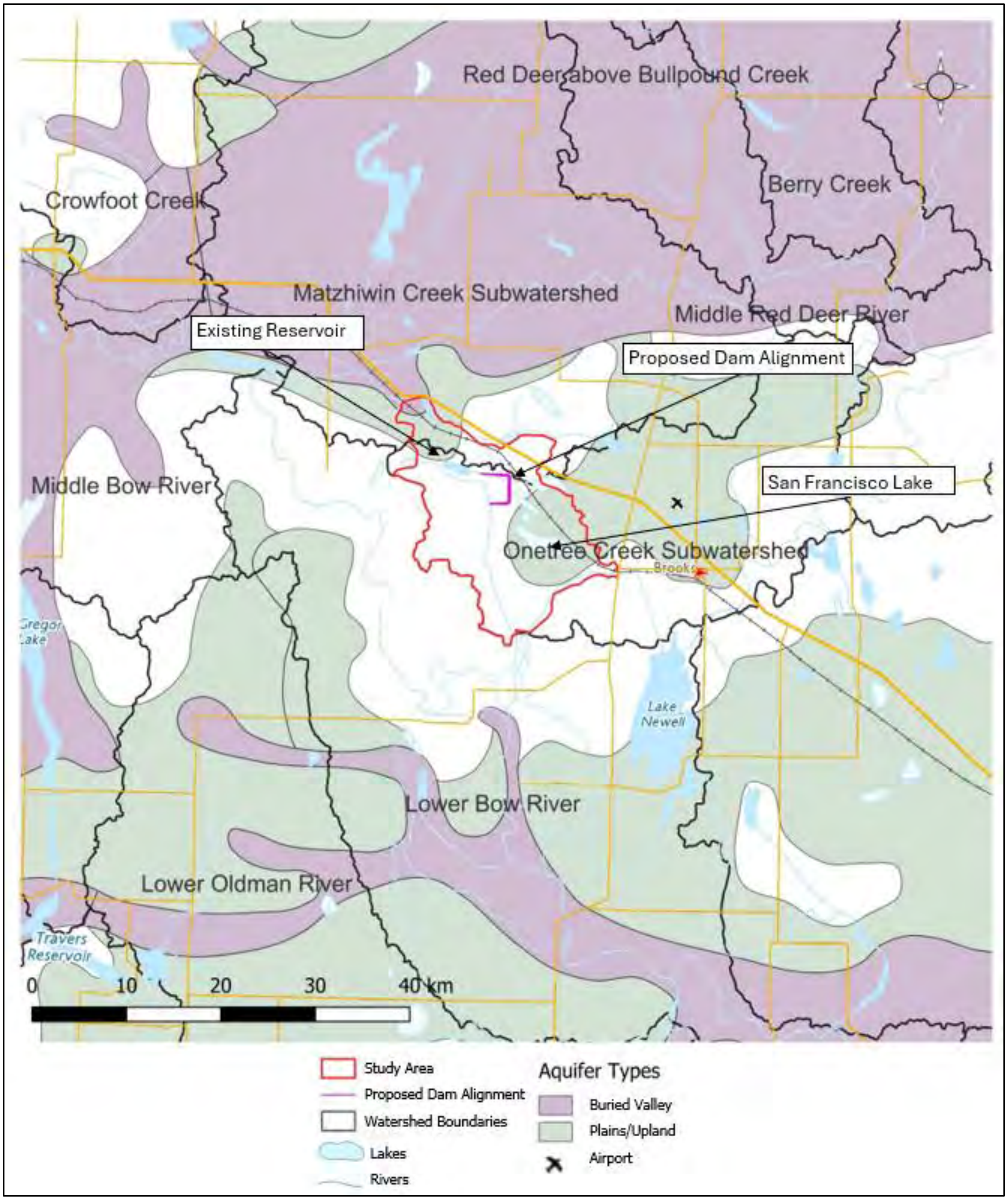


Figure 6-8: Buried Valleys in the Proximity of the Study Area (Modified after Hartman et al., 2023)

While the distribution of aquifer systems in the buried valleys can be deduced from the bedrock topography, the distribution of aquifers on the bedrock plains and uplands of the Study Area is less predictable. Atkinson et al., (2017) noted that across much of Southern Alberta which includes the Study Area, permeable sediments are typically localized and aquifers (if present) are thin, discrete, and directly overlying the bedrock interface as observed in this assessment. During the field investigations, there was some free water that was observed in the test pits within the sand and gravel layers along the east alignment of the planned reservoir expansion area. Locally, these types of sand and gravel layers do not provide sufficient yield to serve as aquifer for water supply purposes. Geotechnical investigations conducted in the area of reservoir expansion did not encounter free water or seepage in the surficial deposits primarily comprised of clay till further reflected in the poor density of drilled water well records in the Study Area. Thus, the potential for aquifer hosting sediments in the Study Area is low.

6.4.2.3 Groundwater Recharge and Discharge – Surficial Deposits

Snowmelt-driven depression focussed recharge is a key mechanism for recharge in the Canadian Prairies (Hayashi et al., 2003). With a moisture deficit occurring during the summer months, groundwater recharge occurs primarily during the spring, early summer, and sometimes fall months when snowmelt occurs and available water can exceed evaporation (Klassen et al., 2018). During the winter months, the soil freezes and pore networks become limited, thereby reducing the infiltration capacity of the soil. Surface runoff is generated during spring snowmelt because the ground has not completely thawed and runoff is directed into small topographic depressions that are characteristic of this Southern Alberta landscape (Klassen et al., 2018).

The Study Area is primarily located in the One Tree Creek subwatershed of the Red Deer River sub-basin, Klassen et al., (2018) estimated about 4 mm/year to 5 mm/year as groundwater recharge for the One Tree Creek subwatershed accounting for grassland evapotranspiration and low vertical permeability of the fine-textured surficial deposits overlying the bedrock. Low recharge coupled with low permeability of surficial deposits within the Study Area limits their capacity to host aquifers.

The upward flow of groundwater (discharge) from the aquifer into the shallow depressions of the landscape often results in the formation of wetlands. Marshes are known to form in a landscape characterized by slow-moving water rich in nutrients and are known to be inundated frequently by standing water. A review of the Wetland Atlas of Alberta indicates that several areas of marsh are present primarily surrounding the series of irrigation canal-fed lakes found in the southeastern portion of the Study Area which includes San Francisco Lake.

Springs are often expressions of upward groundwater discharge to the ground surface, springs at the land surface can occur at cliff faces, hillsides, riverbanks, or along road cuts, and underwater springs occur beneath a lake or river. The springs can be classified as bedrock contact springs, thermal springs, karst springs, and bedrock springs. Springs supported by surficial sediment deposits are very rare. A review of the Alberta Geological Survey inventory of known springs did not indicate any springs originating within the surficial deposits of the Study Area (refer to Figure 6-19). However, field evidence shows several areas of water accumulation in the Project area along the sides of the meltwater channel. The attached clip from google earth shows evidence of their presence. The white areas along the meltwater channel south side are all evidence of water accumulation. These sloped areas have salt crusts left behind and there was field evidence of water upwelling in some areas. These areas are interpreted as wetlands accumulated after rainfall events.

As discussed in Section 6.3.2.1, the surficial deposits primarily act as an aquitard with poor potential for groundwater discharge.

6.4.2.4 The Potential for Hydraulic Interconnection between the Surficial Geologic Units

The surficial geology of the Study Area primarily comprised of two surfaces stratigraphic units: weathered clay till and unweathered clay till. Neither are sufficiently permeable to be hydraulically interconnected since the permeability acts as a proxy determining the hydraulic connection between these stratigraphic units. Further, these stratigraphic units do not host aquifers capable of yielding sufficient quantities of water or potable water.

6.4.2.5 Bedrock (Upper Bearpaw Formation) and Groundwater Flow Regimes

The surficial sediments in the proposed Project are underlain by the bedrock of the Upper Cretaceous age of the Bearpaw Formation. Figure 6-9 depicts the stratigraphic profile of the southern Alberta Plains where the SLR and planned reservoir expansion area are located.

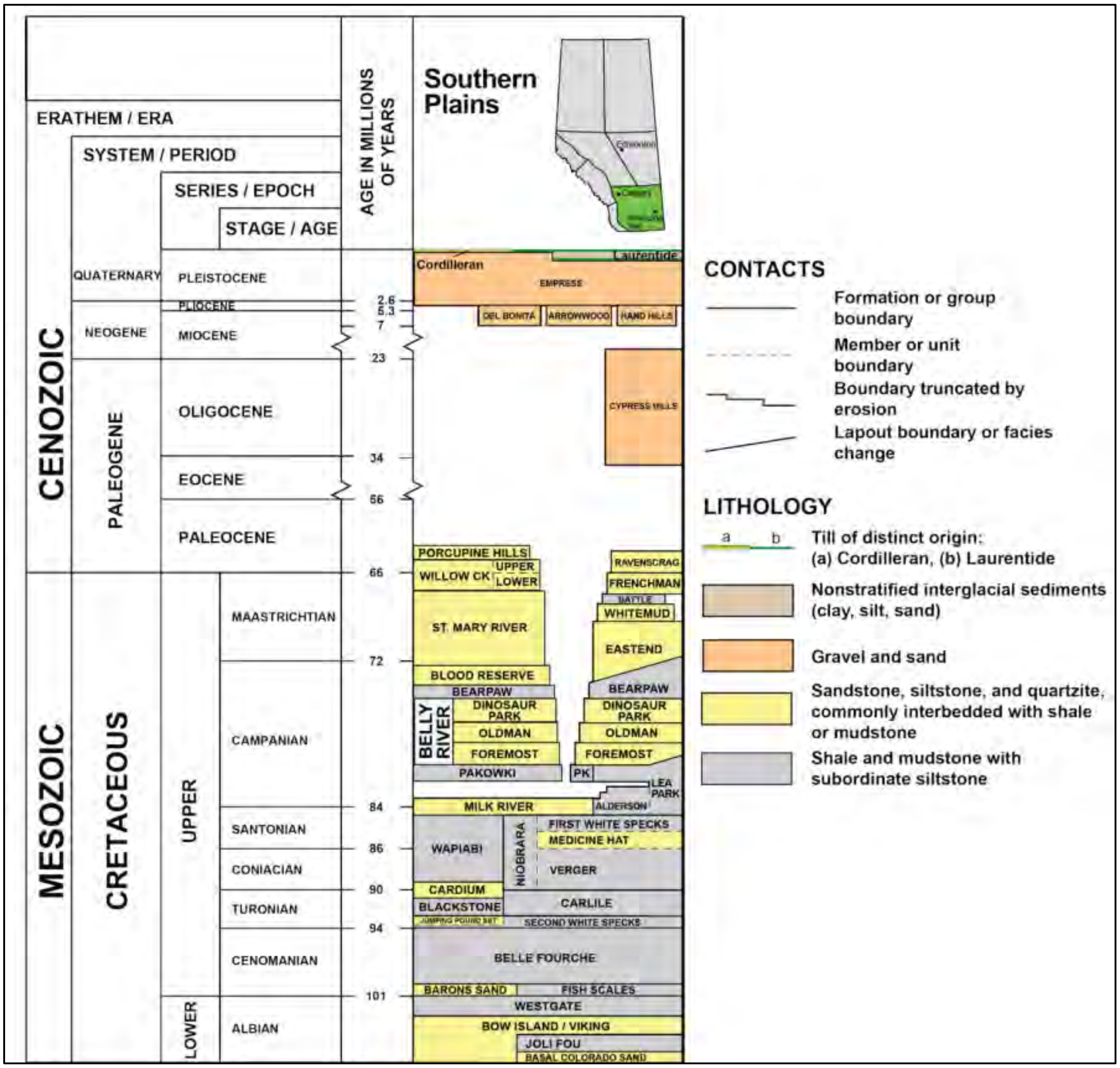


Figure 6-9: Stratigraphic Profile of Southern Plains of Alberta (Modified from Atkinson et al., 2017)

According to the Lexicon of Canadian Stratigraphy Volume 4 (Caldwell & Hawes, 2009), the Bearpaw Formation (Figure 6-10) mostly consists of dark grey clays, claystones, silty claystones, shales, silts and siltstones, with subordinate brownish-grey silty sands, sands and sandstones. It also contains numerous concretionary beds and thin beds of bentonite. Bentonite, primarily comprised of the clay mineral montmorillonite formed by the alteration of volcanic glass, is common in the Cretaceous bedrock underlying the Alberta Plains. The thickness of the Bearpaw Formation was documented to average 30 m between Calgary and Drumheller in southern Alberta, but it can reach a thickness of 300 metres at the Alberta-Saskatchewan border. The Bearpaw Formation is underlain by the Dinosaur Park Formation of the Belly River Group, which primarily consists of organic-rich mudstones and bentonite in its upper part and fine- to medium-grained sandstone in its lower portion.

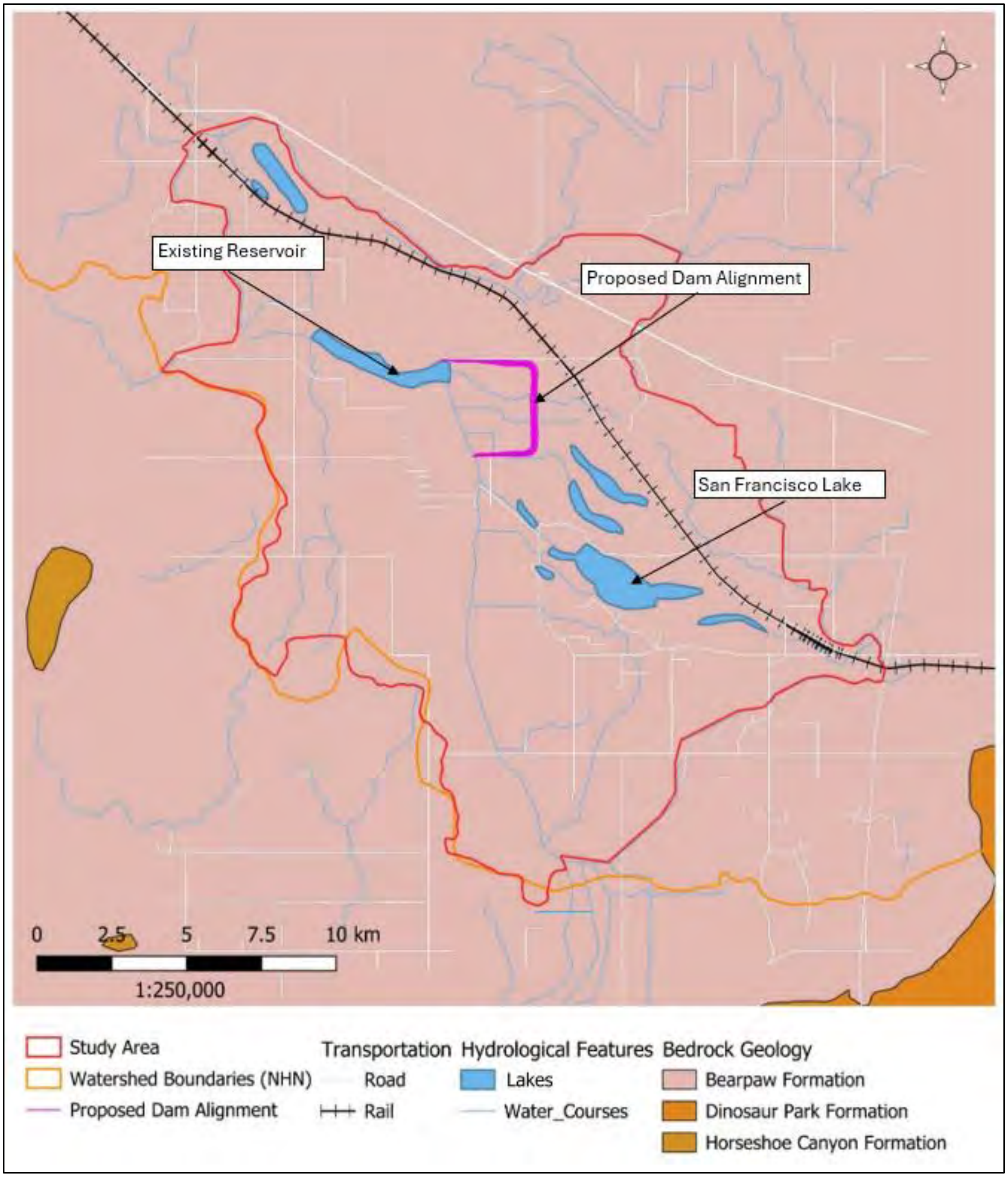


Figure 6-10: Bedrock Geology of the Study Area (Modified after Prior et al., 2013)

In total, 441 boreholes, core holes, and vibrating wire piezometers were drilled within the proposed reservoir expansion area and logged as part of the geotechnical investigations. The lithological descriptions in the borehole logs indicated that the bedrock was generally composed of shale with some smaller intervals of siltstone and sandstone and some thin layers of bentonite within the shale unit. The marine shales constituting most of the Bearpaw Formation within the Project area are typically grey to brownish-grey, soft, with a distinct flaky appearance on the weathered outcrop face. The unweathered shale has a blocky habit. The sandstone layers noted in the boreholes are characteristically fine-grained, poorly indurated, and argillaceous. Bentonite beds, ranging in thickness from a <1 cm to several centimetres.

The contact between the overlying clay till and the weathered bedrock was generally >1 m below the ground surface. The weathered shale layer varies in thickness from 0.5 m up to 27.4 m in some boreholes but it was less than 8 m thick in more than 90% of the boreholes and core holes drilled.

The rock quality, which is based on Rock Quality Designation (RQD) values, was highly variable ranging from very poor to excellent, corresponding to RQD values of less than 25% to greater than 90%. In general, the shallow bedrock had lower quality than the deeper bedrock unit with the first 2-3 m. 70% of the intervals with inferior RQD values are located within the first three rock core samples (runs that are typically 1.52 m in length each) in the bedrock. However, they represent less than 10% of the overall bedrock quality distribution with depth observed within the Site. Some exceptions included very poor quality bedrock up to 30 m deep and surface bedrock with excellent RQD values. The in-situ hydraulic conductivity in permeable bedrock such as sandstone is strongly related to the frequency and distribution of fractures within the rock mass and is often quantified by the relationship between the hydraulic conductivity and RQD values. Typically increasing RQD values are positively correlated with the decreasing hydraulic conductivity. However, the hydrogeological complexity of clay-rich shale formations such as the Bearpaw Formation is often difficult to assess as the hydraulic conductivity varies by orders of magnitude depending on the presence or absence of interconnected permeable features. Groundwater flow within the Bearpaw Formation depends on the presence of hydraulically active fractures, permeable sandstone layers and the thickness of the weathered upper bedrock.

6.4.2.6 Groundwater Levels

Following the completion of the geotechnical investigation completed by MPE, groundwater data was collected on six separate occasions between the dates of August 10, 2022, and September 27, 2023. The water levels are presented in Table 6-7 below.

Table 6-7: Groundwater Levels in the Upper Bearpaw Formation

Bore Hole ID	Ground Elevation (m)	Top of Pipe (m)	2022-08-10		2022-09-15		2022-10-12		2023-01-25		2023-04-27		2023-09-27	
			WL	WE	WL	WE	WL	WE	WL	WE	WL	WE	WL	WE
22BH105	778.26	0.73	2.95	776.04	2.78	776.22	2.84	776.15	3.35	775.64	3.53	775.46	3.12	775.87
22BH108	779.03	0.59	5.68	773.94	5.70	773.92	5.57	774.05	5.50	774.13	5.47	774.15	5.32	774.30
22BH114	777.22	0.86	7.49	770.59	7.27	770.81	7.15	770.93	6.97	771.11	6.88	771.2	6.95	771.14
22BH117	773.86	0.83	4.37	770.32	4.13	770.56	4.09	770.60	4.12	770.57	4.07	770.62	4.05	770.64
22BH121	769.94	0.72	3.11	767.55	3.03	767.63	3.07	767.59	3.17	767.49	3.21	767.45	2.80	767.86
22BH123	769.50	1.02	3.63	766.89	3.55	766.98	3.53	766.99	3.76	766.76	3.8	766.72	3.31	767.22
22BH126	770.31	0.93	4.31	766.93	4.27	766.97	4.29	766.95	4.47	766.76	4.49	766.74	4.09	767.15
22BH204	767.48	1.01	3.25	765.24	2.80	765.70	2.84	765.65	3.19	765.30	3.7	764.79	3.21	765.29
22BH228	768.66	1.07	3.66	766.07	3.56	766.18	3.63	766.10	3.94	765.79	4.04	765.69	3.57	766.16
22BH300	768.40	0.61	3.09	765.92	2.99	766.03	3.03	765.98	3.26	765.75	3.35	765.66	2.95	766.06
22BH303	771.03	0.72	8.10	763.65	-[1]	-[1]	6.89	764.86	5.22	766.53	5.93	765.82	5.93	765.82
22BH306	771.34	0.83	4.23	767.94	4.18	768.00	4.20	767.98	4.09	768.08	4.17	768	4.06	768.11
22BH309	773.99	0.82	5.19	769.62	5.13	769.68	5.12	769.69	5.23	769.58	5.29	769.52	5.10	769.71
22BH312	774.15	0.88	3.57	771.46	3.53	771.50	3.60	771.43	3.85	771.18	3.84	771.19	3.59	771.45
22BH315	775.17	1.01	2.45	773.73	2.63	773.55	2.78	773.40	3.04	773.14	2.71	773.46	3.00	773.18
22BH318	776.48	0.87	2.72	774.63	3.15	774.20	3.21	774.14	3.01	774.34	2.45	774.9	3.53	773.82
22BH321	784.90	0.83	4.13	781.60	4.50	781.24	3.49	782.24	-[]	-[2]	-[2]	779.77	4.49	781.24
22BH402	774.63	0.12	1.90	772.85	-[4]	-[4]	1.76	773.00	2.10	772.65	2.4	772.35	-[2]	-[2]
22BH405	778.15	0.28	4.08	774.35	4.26	774.17	4.42	774.01	4.51	773.92	4.3	774.13	4.60	773.83
22BH413	776.15	0.20	2.31	774.04	2.33	774.02	2.42	773.93	2.70	773.65	2.72	773.63	2.56	773.80
22BH415	778.29	0.11	3.62	774.78	3.44	774.96	3.41	774.99	3.42	774.98	3.71	774.69	3.51	774.89
22BH427	775.58	0.82	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	6.44	769.96	6.48	769.92
22BH430	776.05	0.80	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	3.59	773.26	3.59	773.26
22BH433	775.06	0.77	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[3]	-[3]	-[3]	-[3]

Bore Hole ID	Ground Elevation (m)	Top of Pipe (m)	2022-08-10		2022-09-15		2022-10-12		2023-01-25		2023-04-27		2023-09-27	
			WL	WE	WL	WE	WL	WE	WL	WE	WL	WE	WL	WE
22BH435	779.04	0.20	4.65	774.59	-[4]	-[4]	4.44	774.80	4.58	774.66	4.7	774.54	4.57	774.67
22BH438	768.34	0.47	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[2]	-[3]	-[3]	-[3]	-[3]
22BH484	774.88	0.60	5.72	769.76	4.56	770.92	4.09	771.39	3.54	771.94	3.83	771.65	3.85	771.63
22BH532	778.63	0.30	3.86	775.07	-[2]	-[2]	3.85	775.09	3.95	774.98	4.05	774.88	4.00	774.93
22BH542	781.06	0.40	5.81	775.65	-[4]	-[4]	4.10	777.36	3.98	777.48	4.13	777.33	4.11	777.35
22BH555	780.31	0.33	3.43	777.21	-[2]	-[2]	3.49	777.16	3.72	776.92	3.75	776.89	3.64	777.01
22BH567	779.85	0.25	3.02	777.08	-[2]	-[2]	3.20	776.90	3.43	776.67	3.36	776.74	3.34	776.76
22BH587	777.67	0.26	3.05	774.88	2.91	775.02	2.91	775.02	2.86	775.08	3.07	774.86	2.99	774.94
22BH588	774.42	0.46	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]
22CH118	772.37	1.00	3.46	769.91	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	2.65	770.72	2.8	770.57
22CH126	770.17	0.81	6.62	764.36	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	7.36	763.62	7.08	763.90
22CH135	770.05	0.84	3.80	767.09	3.75	767.14	3.68	767.21	3.76	767.13	3.79	767.1	3.66	767.23
22CH138	779.13	0.94	-[2]	-[2]	5.79	774.28	5.82	774.25	5.80	774.27	5.77	774.3	5.80	774.28
22CH139	772.12	0.96	-[2]	-[2]	2.83	770.25	2.97	770.11	2.93	770.15	3.12	769.96	3.28	769.80
22CH140	769.89	0.89	-[2]	-[2]	3.68	767.10	3.67	767.11	-[2]	-[2]	3.95	766.83	3.47	767.31
22CH201	767.67	1.02	3.11	765.58	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	2.89	765.8	3.05	765.64
22CH209	769.53	0.83	2.38	767.98	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	4.94	765.42	4.38	765.98
22CH213	765.04	0.89	2.07	763.86	1.71	764.22	1.72	764.22	1.55	764.38	-[4]	-[4]	1.66	764.28
22CH214	767.63	1.01	3.62	765.02	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	5.35	763.29	5.45	763.20
22CH222	767.99	0.93	2.00	766.92	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	2.75	766.17	3.05	765.88
22CH227	766.71	1.02	2.73	765.00	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	3.90	763.83	4.00	763.73
22CH229	767.30	0.93	-[2]	-[2]	2.80	765.43	2.97	765.26	2.71	765.52	3.22	765.00	3.28	764.95
22CH230	768.39	0.85	-[2]	-[2]	3.34	765.90	3.41	765.83	-[1]	-[1]	4.72	764.52	4.72	764.53
22CH231	766.75	0.85	-[2]	-[2]	2.78	764.82	2.83	764.78	2.94	764.66	3.12	764.48	3.28	764.33
22CH232	766.04	0.68	-[2]	-[2]	1.46	765.26	1.35	765.37	1.88	764.84	1.93	764.79	1.47	765.25

Bore Hole ID	Ground Elevation (m)	Top of Pipe (m)	2022-08-10		2022-09-15		2022-10-12		2023-01-25		2023-04-27		2023-09-27	
			WL	WE	WL	WE	WL	WE	WL	WE	WL	WE	WL	WE
22CH301	769.34	1.02	4.09	766.27	4.114	766.25	4.09	766.27	-[1]	-[1]	4.58	765.78	4.65	765.71
22CH305	771.35	1.05	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]	-[3]
22CH310	772.77	1.07	3.22	770.62	3.18	770.66	3.14	770.70	3.18	770.66	3.31	770.53	3.15	770.69
22CH313	774.02	1.01	3.33	771.70	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	2.82	772.21	2.65	772.38
22CH319	776.27	1.03	2.09	775.21	-[1]	-[1]	-[1]	-[1]	-[1]	-[1]	2.11	775.19	2.47	774.84
22CH320	771.49	0.76	-[2]	-[2]	4.39	767.86	2.53	769.72	4.26	767.99	4.37	767.88	4.37	767.89
22CH321	773.03	0.88	-[2]	-[2]	2.96	770.95	3.02	770.90	3.27	770.64	3.31	770.60	2.96	770.95
22CH322	778.92	0.85	-[2]	-[2]	6.13	773.64	6.24	773.53	6.34	773.44	6.22	773.55	6.51	773.26
22CH323	776.12	0.82	-[2]	-[2]	2.81	774.13	2.85	774.10	2.66	774.28	2.16	774.78	3.20	773.75

Notes: WL = Water level, WE = Water elevation (masl)

[1] Groundwater level and elevation not obtained due to slug test being performed.

[2] Groundwater level and elevation not obtained during data collection.

[3] Dry conditions observed in borehole during data collection.

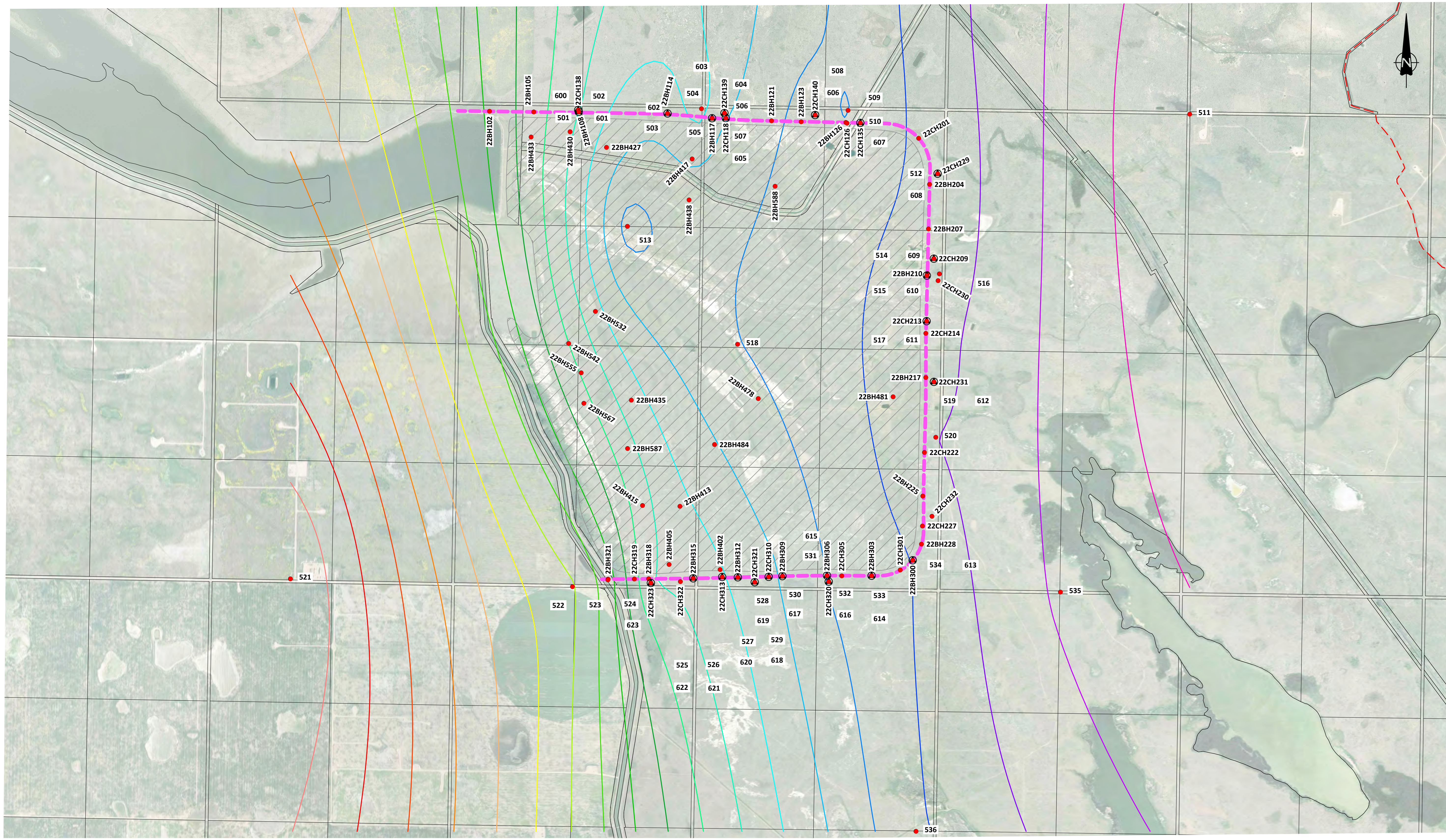
[4] Groundwater level and elevation not obtained due to inaccessible conditions.

Groundwater flows in the upper Bearpaw Formation from SLR and the EID East Branch Canal toward the east. Figure 6-11 depicts the bedrock groundwater flow contour map of the Study Area utilizing groundwater levels collected on August 10, 2022. Figures 6-12, 6-13, and 6-14 depict the groundwater elevations along the dam alignment.

Select boreholes (i.e., 22BH102, 22BH117, 22BH123) were monitored over 12 months to evaluate groundwater response to seasonal variations in precipitation. Figure 6-15 depicts temporal variations in groundwater levels at the borehole 22BH102 screened in clay, clay till, and weathered till. At 22BH102 lowest water levels were recorded in the winter and early spring months and an increasing trend (up to +1 m) in water levels was noted in the late spring and early summer months. A declining trend in water levels coincides with peak and late summer months.

Figure 6-16 depicts temporal variations in groundwater levels at the borehole 22BH117 screened in weathered shale, siltstone, and shale. At 22BH117, a stable trend in groundwater levels was noted for the monitoring period of 12 months. A medium to high plastic clay unit overlies the weathered shale, siltstone, and shale units intercepted in the screened portion of the borehole and it is possible that the surficial shale retards infiltration and promotes runoff in response to precipitation (i.e., water pools at the surface of the bedrock).

Figure 6-17 variations in groundwater levels at the borehole 22BH123 screened in weathered shale. The groundwater level response to the seasonal variations is similar to the trends noted at 22BH102, however, groundwater response to seasonal variations is rather muted when compared to the groundwater response noted at 22BH102.



LEGEND

PROPOSED TOP OF DAM

STUDY AREA

WATER LEVEL OBSERVATION

GROUNDWATER CONTOURS

EXPANSION AREA

WATER LEVEL CONTOURS

796.00	778.00
794.00	776.00
792.00	774.00
790.00	772.00
788.00	770.00
786.00	768.00
784.00	766.00
782.00	764.00
780.00	762.00
	760.00

SCALE 1:25 000

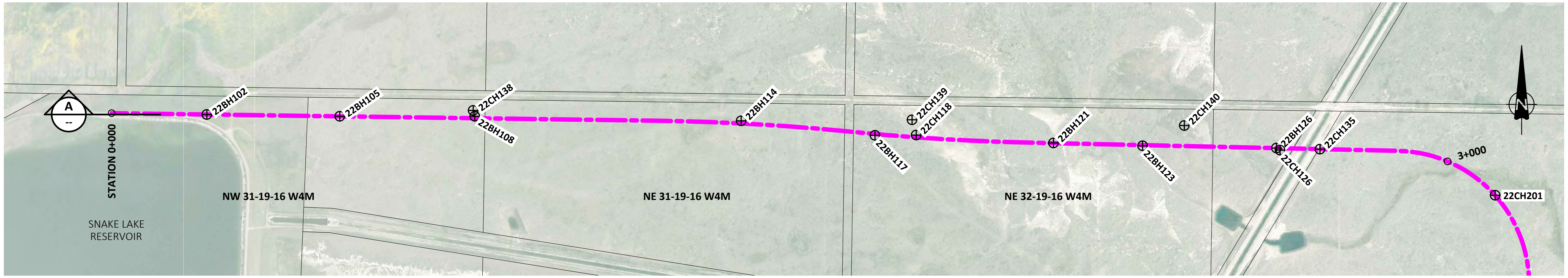
0 500 1000 1500m

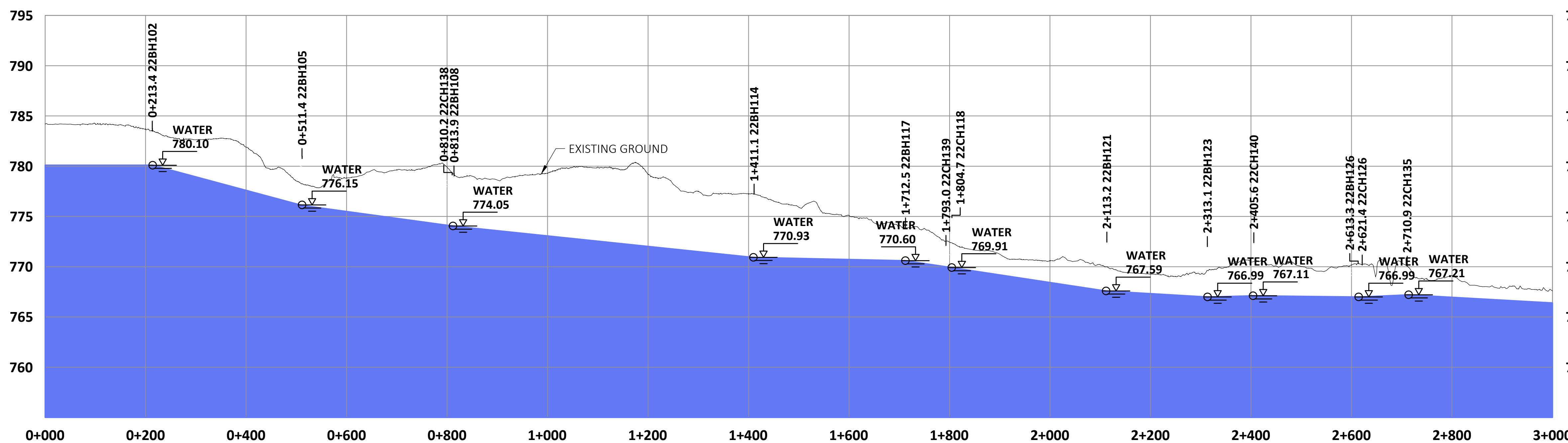
EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION
GROUNDWATER FLOW CONTOURS -BEDROCK

AUGUST 10, 2022

SCALE: 1:25 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 11A





CROSS SECTION A --

LEGEND

- ⊕ 50mm PIPE
- 25mm PIPE
- ALIGNMENT
- WATER LEVEL

*WATER LEVEL MEASUREMENTS TAKEN ON AUGUST 10, 2022

CH COREHOLE
BH BOREHOLE

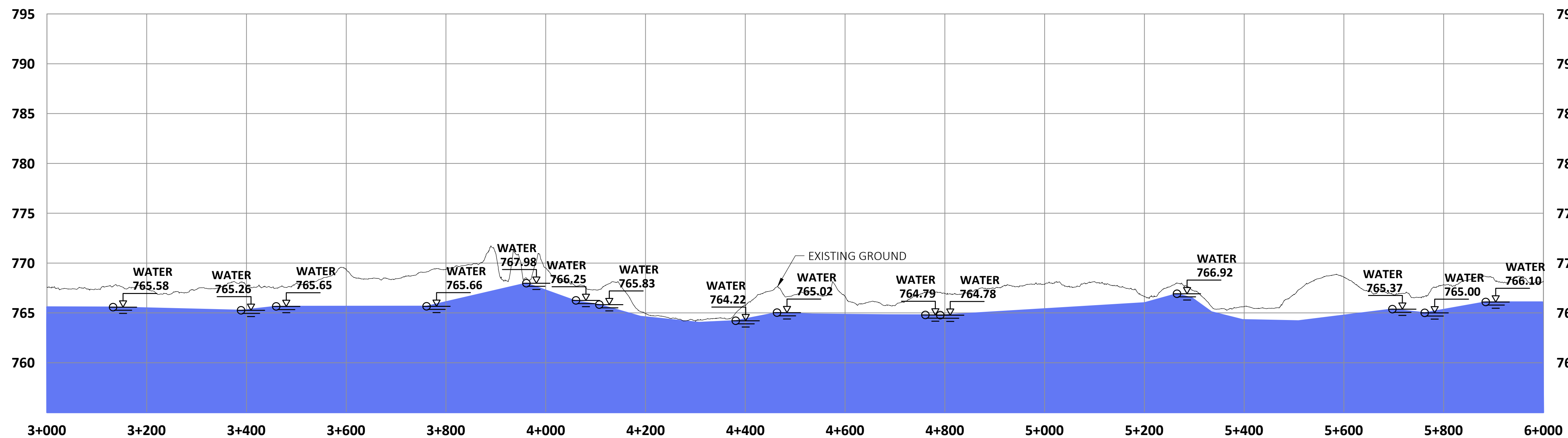
SCALE 1:10 000
0 200 400 600m

EID englobe

EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION
GROUND WATER MONITORING
BOREHOLES AND COREHOLES 0+000 TO 3+000

SCALE: 1:10 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 12



CROSS SECTION

B

--

LEGEND

⊕	50mm PIPE
◕	25mm PIPE
—	ALIGNMENT
■	WATER LEVEL
	*WATER LEVEL MEASUREMENTS TAKEN ON AUGUST 10, 2022
CH	COREHOLE
BH	BOREHOLE

SCALE 1:10 000

0 200 400 600m

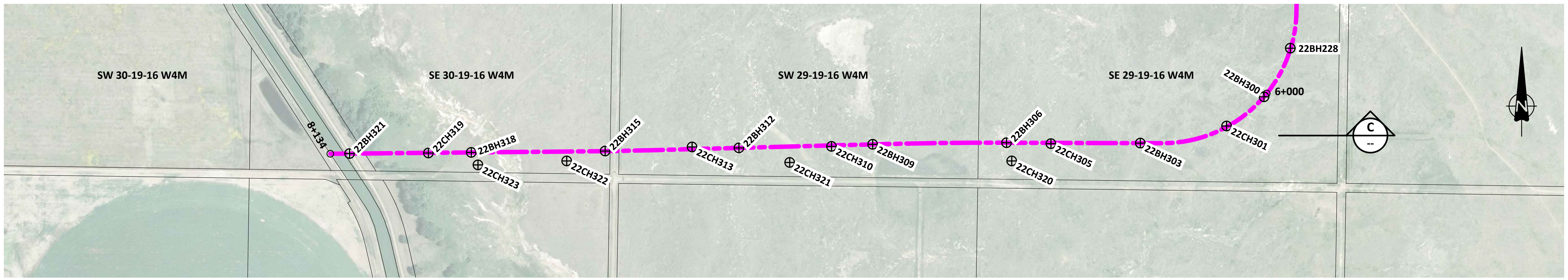
EID

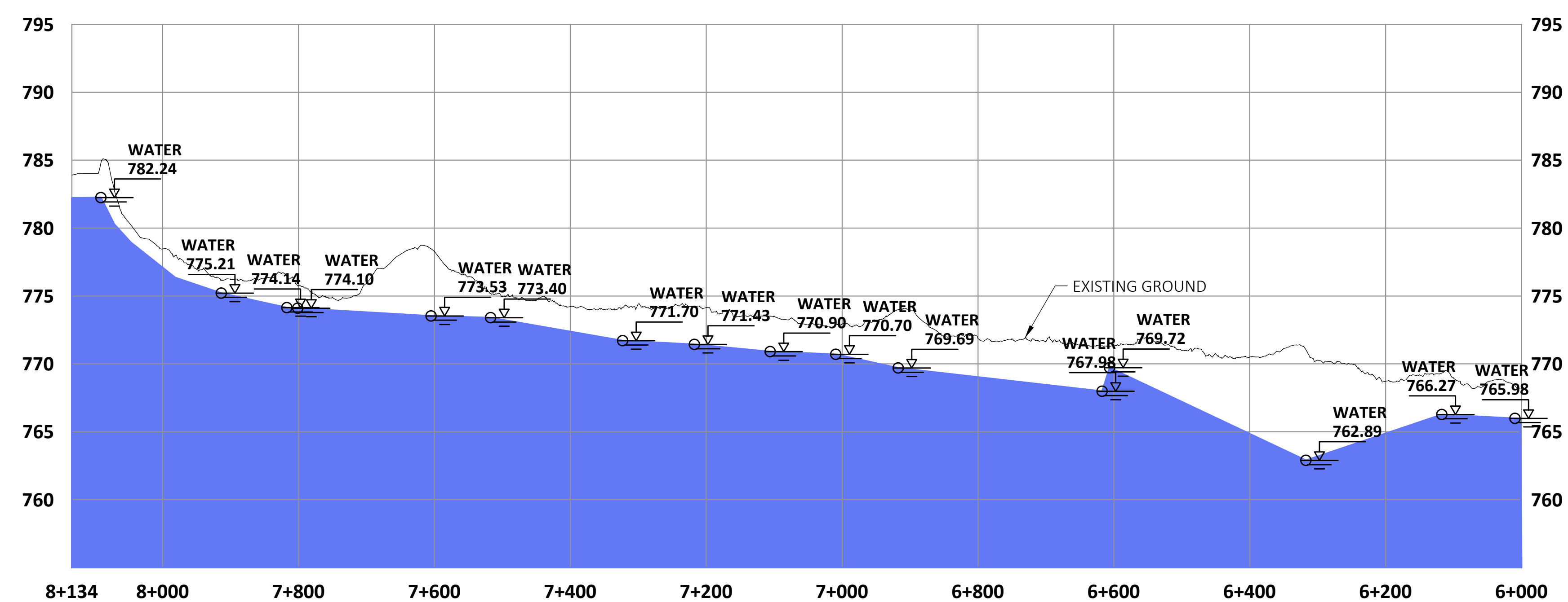
eNGLOBe

EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION
GROUND WATER MONITORING
BOREHOLES AND COREHOLES 3+000 TO 6+000

SCALE: 1:10 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 13





CROSS SECTION

C

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LEGEND

⊕	50mm PIPE
◕	25mm PIPE
—	ALIGNMENT
■	WATER LEVEL
	*WATER LEVEL MEASUREMENTS TAKEN ON AUGUST 10, 2022
CH	COREHOLE
BH	BOREHOLE

SCALE 1:10 000

0 200 400 600m

EID

englobe

EASTERN IRRIGATION DISTRICT

SNAKE LAKE RESERVOIR EXPANSION
GROUND WATER MONITORING
BOREHOLES AND COREHOLES 6+000 TO 8+134

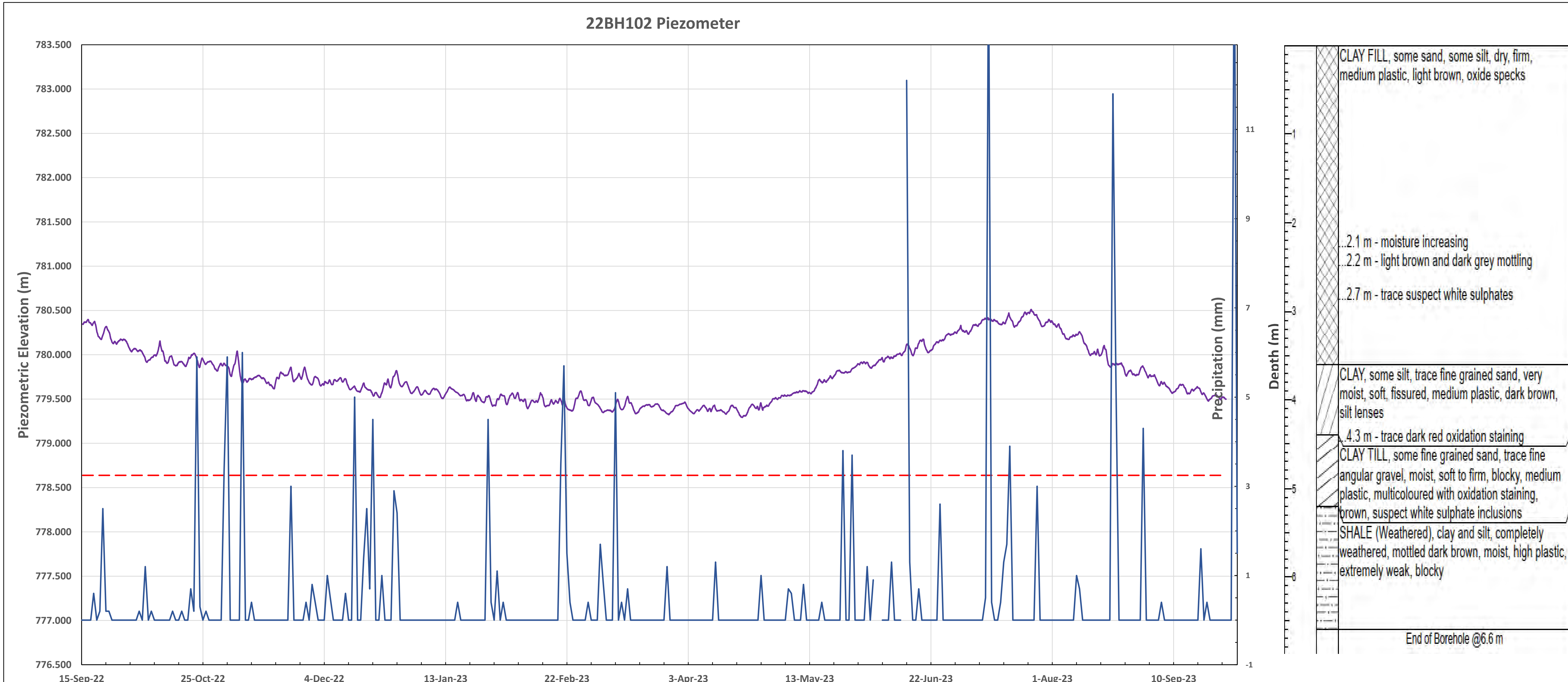
SCALE: 1:10 000	DATE: FEBRUARY 2024	JOB: 2301113.000	FIGURE: 14

MPE Engineering Ltd.
1, 3320 18 Avenue North
Lethbridge, Alberta T1H 5J3
Tel: (403)892-6036

GROUNDWATER PLOT

Project: Snake Lake Reservoir Expansion **Project No.:** 1560-193-00 **Location ID:** 22BH102 **Client:** EID

Ground Elevation: 783.31 **Levelogger Elevation:** 778.64 **Depth / Elevation of Last Reading:** 779.50 **Date of Last Reading:** 27-Sep-23



*Environment and Climate Change Canada. (n.d.). *Historical Climate Data for Bassano AGCM (Station ID)*. Government of Canada. Retrieved from https://climate.weather.gc.ca/historical_data

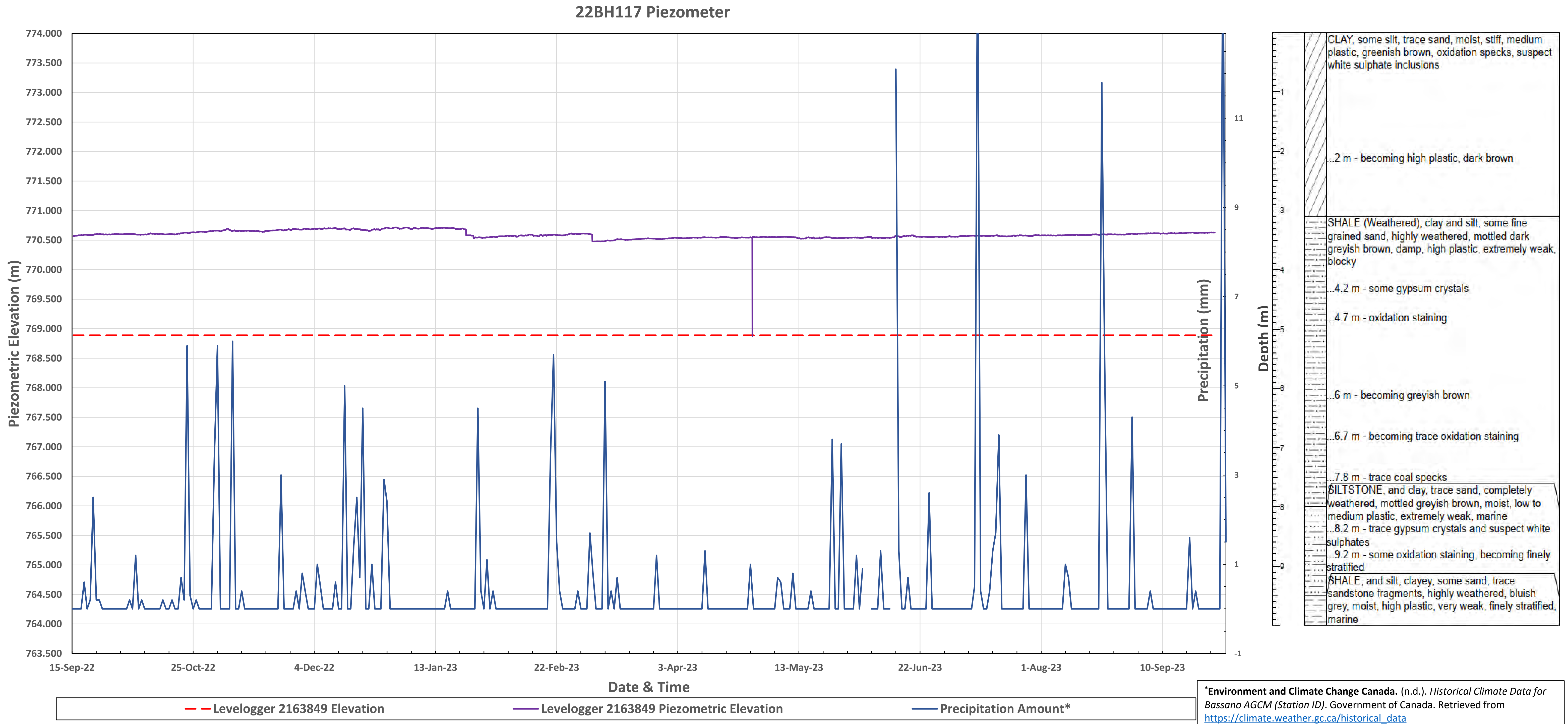
ENGLOBE

MPE Engineering Ltd.
1, 3320 18 Avenue North
Lethbridge, Alberta T1H 5J3
Tel: (403)892-6036

GROUNDWATER PLOT

Project: Snake Lake Reservoir Expansion **Project No.:** 1560-193-00 **Location ID:** 22BH117 **Client:** EID

Ground Elevation: 773.87 **Levelogger Elevation:** 768.89 **Depth / Elevation of Last Reading:** 770.63 **Date of Last Reading:** 27-Sep-23



*Environment and Climate Change Canada. (n.d.). *Historical Climate Data for Bassano AGCM (Station ID)*. Government of Canada. Retrieved from https://climate.weather.gc.ca/historical_data

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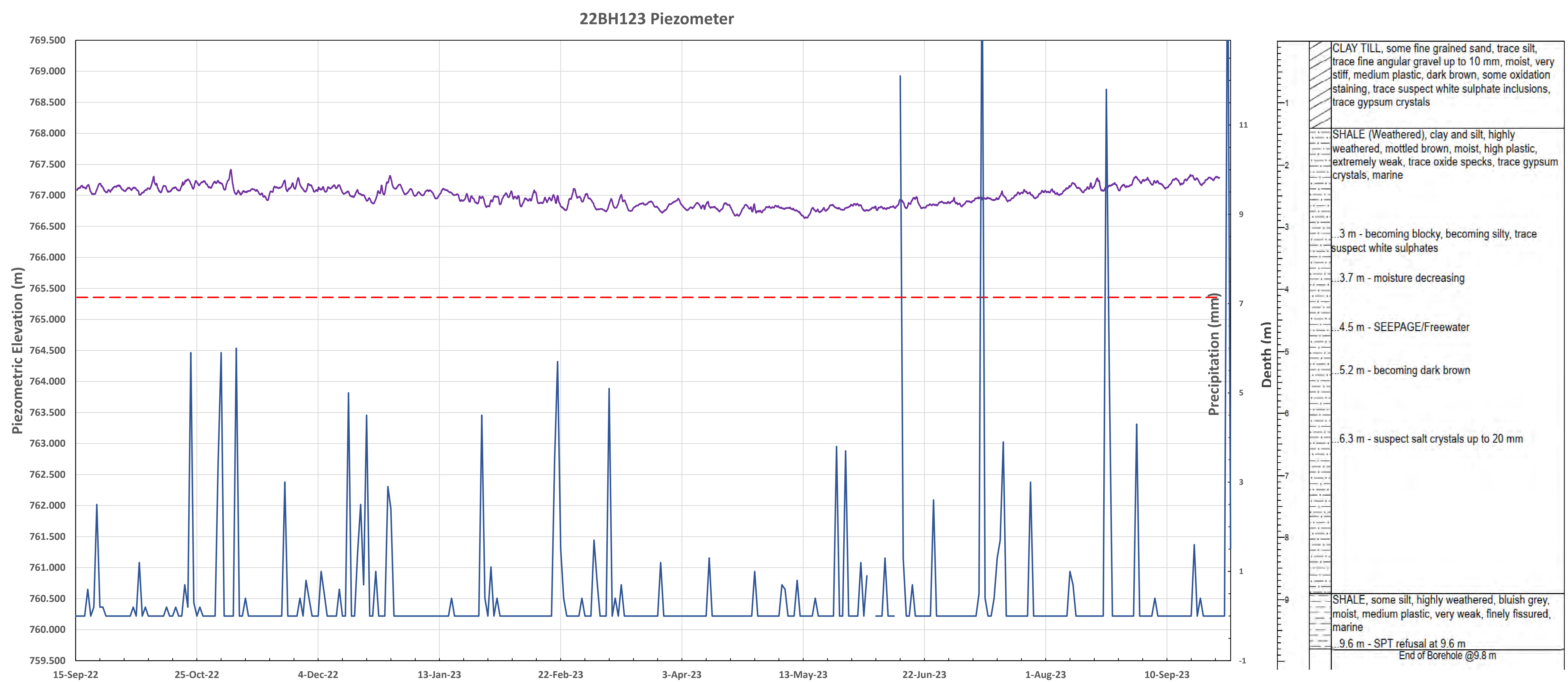
MPE Engineering Ltd.
1, 3320 18 Avenue North
Lethbridge, Alberta T1H 5J3
Tel: (403)892-6036

GROUNDWATER PLOT

Project: Snake Lake Reservoir Expansion **Project No.:** 1560-193-00 **Location ID:** 22BH123 **Client:** EID

Ground Elevation: 769.61 **Levelogger Elevation:** 765.36 **Depth / Elevation of Last Reading:** 767.28 **Date of Last Reading:** 27-Sep-23



*Environment and Climate Change Canada. (n.d.). *Historical Climate Data for Bassano AGCM (Station ID)*. Government of Canada. Retrieved from https://climate.weather.gc.ca/historical_data

6.4.2.7 Hydraulic Properties – Upper Bearpaw Formation

Hydraulic Conductivity – In Situ Hydraulic Conductivity Tests

Table 6-8 presents the estimated hydraulic conductivity values from the in-situ hydraulic conductivity tests conducted in select boreholes within the reservoir expansion area. Hydraulic conductivity value of 6.99E-11 m/s was recorded at borehole 22CH118. This borehole was screened in the weathered shale with a 50 mm highly plastic bentonite layer. The highest estimated hydraulic conductivity values were from the borehole 22BH228 screened in the completely weathered shale in the range of 1.08E-06 to 1.86E-06 m/s. The geometric mean hydraulic conductivity of the data from the in-situ hydraulic conductivity tests is 2.6E-08 m/s.

Appendix D2 presents the data analysis sheets associated with in-situ hydraulic conductivity tests.

Table 6-8: Calculated Hydraulic Conductivity Estimates - Upper Bearpaw Formation

Monitoring Well ID	Unit	Calculated Hydraulic Conductivity Estimates (m/s)
22CH118	Weather Shale / Bentonite	6.99E-11
22BH121	Weathered Shale	1.40E-06
22CH126	Siltstone	4.14E-09
22CH201	Shale	6.21E-10
22CH201	Shale	3.52E-10
22CH214	Shale	6.78E-10
22BH228	Weathered Shale	1.08E-06
22BH228	Weathered Shale	1.86E-06
22BH228	Weathered Shale	1.72E-06
22CH313	Siltstone	2.69E-08
22CH319	Siltstone	1.59E-09
Geometric Mean Hydraulic Conductivity (m/s)		**2.6E-08**

Hydraulic Conductivity – Packer Tests

Packer tests to determine the apparent hydraulic conductivity of specific fractured bedrock zones in the select boreholes were completed. It should be noted that the packer tests are short duration and can only influence a modest volume of bedrock around the tested zone and estimated hydraulic conductivity values are only representative of the zone tested. MPE conducted packer tests in 23 boreholes, however, no useable data was collected in 13 boreholes. The apparent hydraulic conductivity data estimated from the packer tests conducted at the remaining 10 boreholes are presented in Table 6-8. The geometric mean of the apparent hydraulic conductivity values estimated from the packer tests is 1.00E-05 m/s. The packer test results and data are included in Appendix D3. The results obtained during the packer tests show apparent hydraulic conductivity estimates that are greater than results obtained during in situ hydraulic conductivity testing by approximately three orders of magnitude. This difference is interpreted to be mostly attributable to the bedrock quality within the tested depth intervals. Packer testing focuses on bedrock intervals of lowest quality showing a high level of fracturing in tested boreholes whereas in situ hydraulic conductivity testing results are typically more representative of bulk bedrock hydrogeological characteristics. Given that the hydraulic conductivity linked to the primary porosity in shale is very low, the presence of open fractures in some depth intervals results in significant contrasts in hydraulic conductivity. In effect, the hydraulic conductivity linked to the secondary porosity (fractures) is largely superior to that of the bedrock matrix in shale bedrock. This difference in hydraulic conductivity is also noted in the hydraulic conductivity estimates presented in Table 6-8 where results from monitoring wells completed in weathered shale (22BH121 and 22BH228) are in the same order of magnitude as some of the packer test results while values obtained in shale and siltstone or weathered shale with bentonite are two to five orders or magnitude lower than results obtained in weathered shale. Additional development linked to the injection of water in packer tests may also have, to a lesser extent, contributed to the higher apparent hydraulic conductivity results shown in Table 6-9.

Table 6-9: Apparent Hydraulic Conductivity from the Packer Tests – Upper Bearpaw Formation

Monitoring Well ID	Tested Zone Top (m)	Tested Zone Bottom (m)	Apparent Hydraulic Conductivity (m/s)
23BH123B	3.5	5.52	2.00E-05
23BH201B	2.5	4.52	3.00E-05
23CH701	5	7.02	4.00E-05
23CH702	3.5	5.52	9.00E-06
23CH704	7	9.01	3.00E-06
23CH705	7	15.26	1.00E-05
23CH709	6	8.02	3.00E-06
23CH711	7.5	10.8	4.00E-06
23TH02	6	8.02	4.00E-06
23TH04	6	8.02	4.00E-05
Geometric Mean of the Apparent Hydraulic Conductivity (m/s)			**1.00E-05**

Hydraulic Conductivity – Short Duration Pumping Tests

On April 18 and 26, 2024, short-duration pumping and recovery tests were undertaken in monitoring wells 23CH700B and 23CH709B. During the pumping tests, water well measurements were recorded manually using a water level probe and electronically using pressure transducer to monitor the drawdown of the water level in the test wells in response to pumping. The water levels were recorded manually to record real time data and determine when water levels returned to static levels. The water level was recorded electronically using a pressure transducer to provide more resolution in the dataset and facilitate the data analysis by recording pressures every second for the duration of the test. Results in Table 6-10 below reflect water levels determined from the pressure transducer data that was confirmed periodically by manual measurements. Monitoring well 23CH700B was pumped for 75 minutes at 4.5 L/min, and the resulting drawdown was 14.35 m. The water level did not stabilize during the pumping phase of the test and no response was observed in nearby monitoring wells. The recovery was monitored for a period of ten days after the end of pumping. Based on the recovery data, the groundwater level in well 23CH700B recovered approximately 90% of the initial static groundwater level (6.13 m bgs) 5,280 minutes (3.67 days) after the end of pumping, indicating low permeability (90% recovery taking longer than a day). The recovery data was analyzed and the curve depicting the groundwater recovery is provided in Appendix D2.

A similar pumping and recovery test was conducted in 23CH709B. Monitoring well 23CH709B was pumped for 60 minutes at a rate averaging 3.9 L/min and the resulting total drawdown was approximately 16.79 m. The water level did not stabilize during the pumping phase of the test and no response was observed in nearby monitoring wells. The recovery was monitored for multiple days after the end of pumping. Based on the recovery data, the groundwater level in well 23CH709B recovered 90% of the initial static groundwater level (6.91 mbgs) 570 minutes (0.59 days) after the end of pumping, indicating moderate to low permeability (90% recovery taking longer than 1 hour but less than a day). The recovery data was analyzed and the curve depicting the groundwater recovery is provided in Appendix D2. Table 6-10 provides a summary of pumping test results.

Table 6-10: Pumping and Recovery Test Results

Pumping Well	Test Date	Pumping Rate (L/min)	Pumping Duration (min)	Recovery Duration (min)	Static Water Level (mbgs)	Approximate Maximum Drawdown (m)	Time to reach 90% recovery (min)
23CH700B	2024/04/12	4.5	75	11,400	6.13	14.35	5,280
23CH709B	2024/04/26	3.9	60	6,200	6.91	16.79	570

The objective of the pumping and recovery tests was to estimate the aquifer properties such as the transmissivity of the aquifer. The transmissivity is the rate at which water is transmitted through a unit width of an aquifer under a unit hydraulic gradient. In contrast to hydraulic conductivity, the coefficient of transmissivity shows the transmission of groundwater for the entire thickness of the aquifer. In a bedrock environment, it is not uncommon for permeability to decrease with increasing depth. Table 6-11 presents estimates of aquifer transmissivity based on the recovery tests. The estimates of aquifer transmissivity were conducted by applying the method of Theis (1935) recovery and based on the following assumptions:

- the aquifer is assumed to be confined and has an infinite areal extent;
- flow is laminar;
- the aquifer is homogeneous, isotropic, and of uniform thickness;
- water is released from storage instantaneously with a decline in the head.

Although not all assumptions are met based on available information, the analysis using the Theis Recovery solution provides a reasonable estimate of the hydraulic conductivities in monitoring wells 23CH700B and 23CH709B. The results are therefore suitable to be used for the creation of a numerical flow model to represent the groundwater flow regime in the study area. The aquifer test analysis results are provided in Table 6-11.

Table 6-11: Estimate of Aquifer Properties

Well ID	Stratigraphic Unit	Transmissivity (m^2/s)	Hydraulic Conductivity (m/s)	Data Analysis Method
23CH700B	Shale	1.47E-07	6.58E-09	Theis recovery
23CH709B	Shale	1.96E-07	9.34E-09	Theis recovery

6.4.2.8 Groundwater Flow and Hydraulic Gradients

As previously stated, groundwater flows in the upper Bearpaw Formation from the existing reservoir and the EID east branch canal towards the east (refer to Figure 6-11). The horizontal hydraulic gradient during the majority of the monitoring period ranged from roughly 0.004 to 0.005 m/m toward the East Northeast, except on September 15, 2022, when the horizontal hydraulic gradients were steeper near the western canal and reached 0.01 m/m before returning to the average horizontal hydraulic gradient of 0.004 m/m towards the east.

6.4.2.9 The Potential for Hosting Aquifers – Upper Bearpaw Formation

The geometric mean value of hydraulic conductivity values was 3.50E-07 m/s, which suggests that the upper Bearpaw Formation has a low permeability and transmits water at slow rates. The lower capacity of the Upper Bearpaw Formation to transmit water within the proposed reservoir expansion area is reflected in the transmissivity values from the pumping test. Thus, the Upper Bearpaw Formation can be described as an aquitard. Freeze and Cherry (1979) describe an aquitard as the less-permeable bed in a stratigraphic sequence. These beds may be permeable enough to transmit water in quantities that are significant in the study of regional groundwater flow, but their permeability is not sufficient to allow for the sufficient production of groundwater via wells for potable, industrial or agricultural uses. A review of publicly available geological and hydrogeological information for Southern Alberta indicates that the Bearpaw Formation acts as an aquitard and the upper confining layer to the Upper Belly River Aquifer (Figure 6-18). Therefore, the potential of the Upper Bearpaw Formation for hosting aquifers is low.

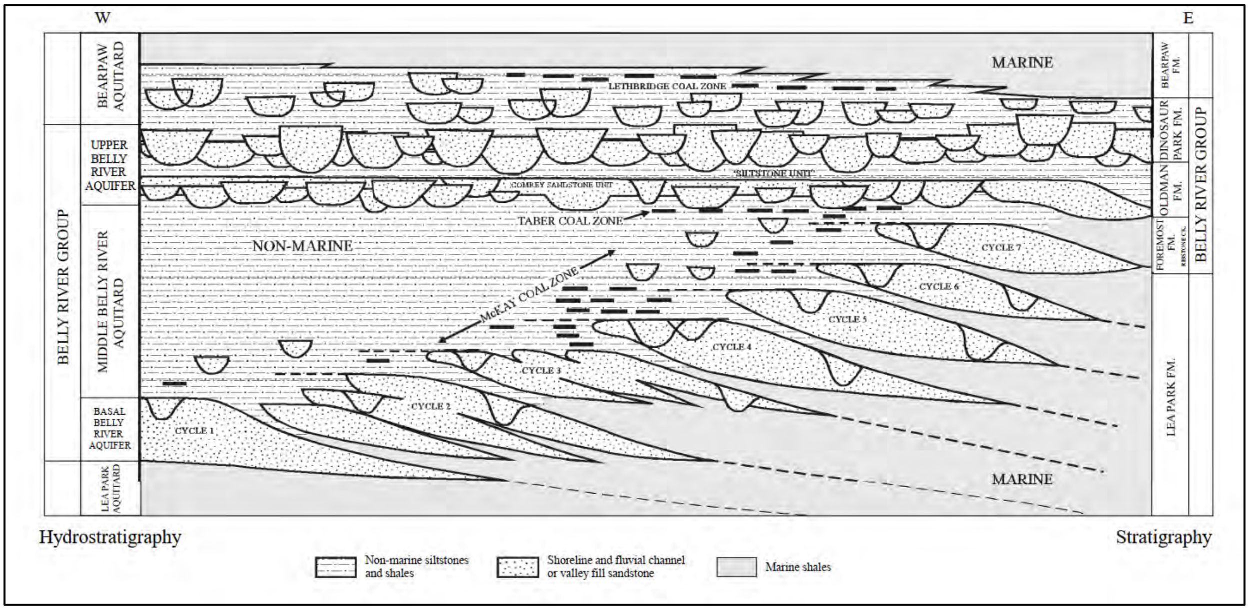


Figure 6-18: Diagrammatic Cross-Section across Bearpaw Formation and Belly Group of Formations in Southern Alberta (Modified after Hamblin, 1997)

6.4.2.10 Groundwater Recharge and Discharge – Upper Bearpaw Formation

Figures 6-16 and 6-17 (above) depict temporal groundwater level variations in boreholes 22BH117 and 22BH123 screened entirely in the Upper Bearpaw Formation. Groundwater level response to the seasonal variations in precipitation in boreholes 22BH117 and 22BH123 is negligible or subdued indicating low potential for groundwater recharge. Field reconnaissance and investigations did not identify the presence of springs or other groundwater discharge areas. A review of the Alberta Geological Survey inventory of known springs did not indicate any springs originating within the Bearpaw Formation of the Study Area (refer to Figure 6-19). As discussed in Section 6.3.2.9, the Bearpaw Formation primarily acts as an aquitard with poor potential for groundwater discharge or recharge.

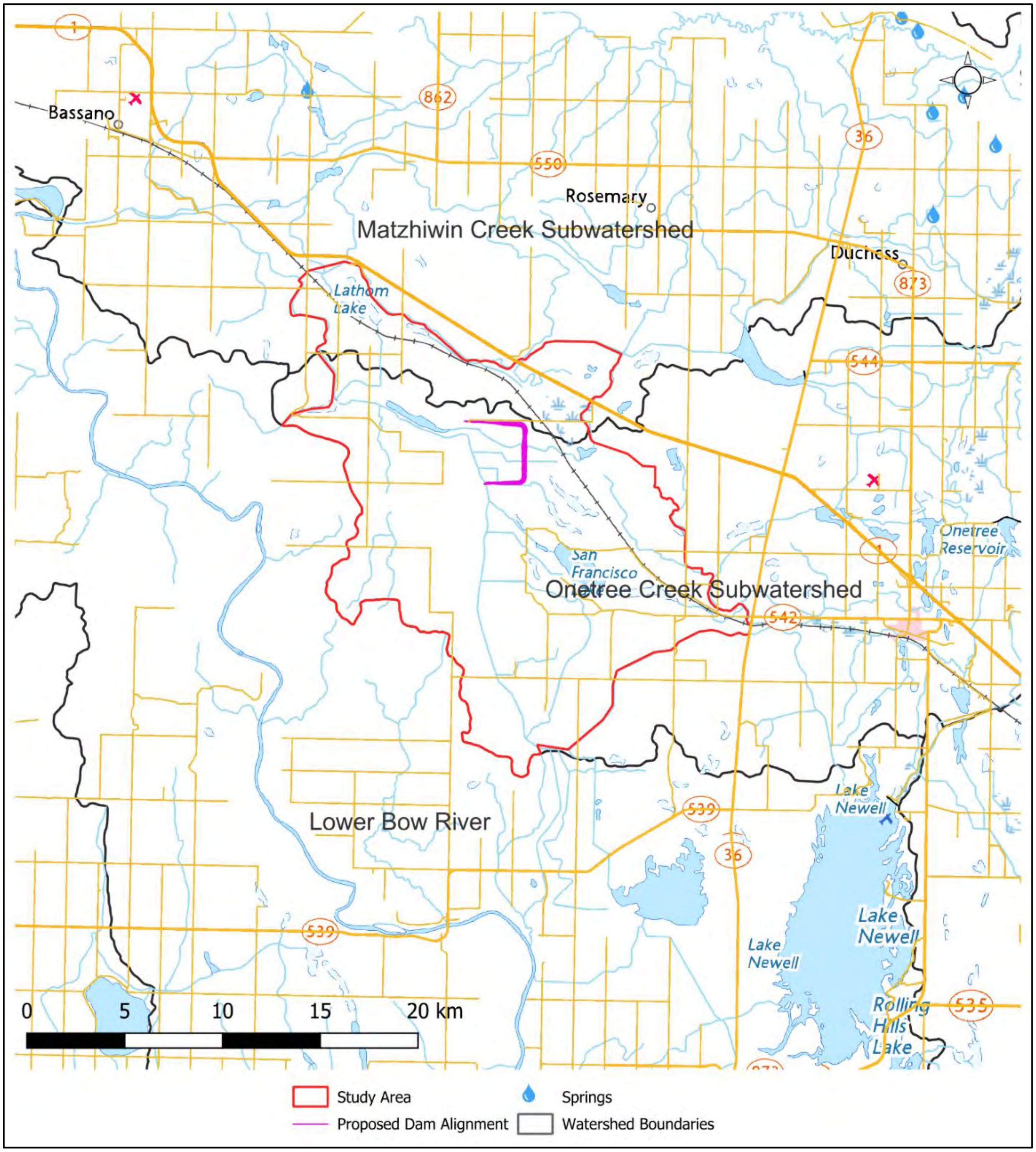


Figure 6-19: The Location of Springs in the Study Area (Modified after Hamblin, 1997)

6.4.2.11 The Potential for Hydraulic Interconnection

Some vertical leakage from the underlying aquifer into the overlying aquitard is possible, however, this type of diffusive exchange is expected to be limited and unlikely to modify the overall hydrostratigraphic designation of the upper Bearpaw Formation as the aquitard. Thus, the potential for hydraulic connection between bedrock units (Bearpaw Formation and underlying Belly River Group) is deemed low. Groundwater was encountered in select boreholes (refer to Table 6-7) with well screens intercepting the interface zone comprised of weathered clay till and weathered shale bedrock or unweathered clay till and or shale or siltstone bedrock of the Bearpaw Formation indicating the potential for hydraulic connection, however, such interface zones are expected to be localized in the areas where the weathering of the bedrock and clay till is extensive.

6.4.3 Conceptual Hydrostratigraphic Framework of the Study Area

Based on the results presented in the preceding sections, a conceptual hydrostratigraphic framework was developed for implementation as a numerical groundwater flow model and simulated hypothetical scenarios involving the proposed reservoir expansion (Table 6-12). The hydrostratigraphic conceptual framework serves as a good foundation for the numerical modeling as it summarizes, based on site-specific information, the occurrence and properties of the main layers comprised within the numerical groundwater flow model. As a result, the level of confidence regarding the numerical groundwater flow model output is considered acceptable. In effect, key factors susceptible of influencing the groundwater flow regime were taken into consideration and applied to each layer and model boundary during the construction of the numerical flow model.

Table 6-12: Hydrostratigraphic Conceptual Framework

<table>
<tr><th>Major Soil or Bedrock Classification Group</th><th>Geological Description</th><th>USCS Symbols</th><th>Conceptual Geological Units</th><th>Conceptual Hydrostratigraphic Units</th><th>Hydrogeological Setting</th></tr>
<tr><td>Overburden – Clay Till</td><td>Glacial Till</td><td>CH</td><td>Overburden – Till</td><td colspan="2">Clay Till</td></tr>
<tr><td>Primarily Weathered Shale</td><td rowspan="2">Shale of the Bearpaw Formation</td><td>Not applicable (NA)</td><td>Weathered Bedrock (RQD[1] values <75)</td><td>Shallow weathered bedrock aquifer/aquitard</td><td>Flow regime with significant heterogeneities</td></tr>
<tr><td>Unweathered Shale[2]</td><td>NA</td><td>Bedrock (RQD[1] values ≥75)</td><td>aquitard</td><td>Simpler, slower flow regime</td></tr>
</table>

Notes:
[1] RQD: Rock Quality Designation
[2] Since permeability at depth is lower, it is expected that groundwater flow will be limited in this zone. Only a small proportion of recharge influences this depth and migrates within the shale bedrock.

For more details on the implementation of the conceptual hydrostratigraphic framework as the numerical groundwater flow model, refer to Appendix D7 of this Report.

6.4.4 Groundwater Use

Water well records were compiled from the provincial Access database extracted from the Alberta Government's Alberta Water Well Information Database (GOA, 2024c). A total of 32 unique water well records were identified within the Study Area. This database includes some abandoned wells including the nearest well to the reservoir which was drilled to a depth of 243 m (approximately 797 feet) and subsequently decommissioned.

Well records are concentrated in the southeast region of the Study Area and are primarily shallow wells that reach a depth of 11 m (approximately 35 feet) or less. The majority of the well records do not have any yields reported, and the greatest recommended pumping rate for the wells within the Study Area, is 2.5 imperial gallons per minute in a 43 m (approximately 140 feet) deep bedrock well. The proposed use of the wells associated with the well records were:

- 20 domestic wells;
- 3 Domestic and Stock wells;
- 2 Stock wells; and
- 7 Unknown.

Water well depth ranges from 3 to 243 mbgs. Figure 6-20 presents a histogram of the total depth recorded on the drilling records. Most of the shown well records indicate a well depth exceeding 50 m and do not provide well yields.

Klassen et al. (2018) presented aquifer yield mapping results for the various classes of yield estimates. To summarize, the classes of yield are defined as follows:

- Permissive sustained yield (PSY): can be quantified as any value between non-use and maximum sustained yield. Use of groundwater resources is limited, permitting discharge to surface water bodies albeit at a reduced rate. This type of yield is a social and environmental boundary rather than a physical system boundary.
- Maximum sustained yield (MSY): pumping is balanced by the maximum amount of capture (water input to the aquifer from various sources) which includes induced recharge of streamflow and zero groundwater discharge. Pumping above the maximum sustained yield means water is continuously removed from storage and has significant impacts to the hydrogeological system will occur.
- Permissive mining yield (PMY): includes the maximum amount of capture plus partial mining of the aquifer, without fully depleting the theoretically recoverable volume of stored water over a planned time horizon. The amount of aquifer mining permitted is governed as a social boundary.
- Maximum Mining Yield (MMY): represents the maximum amount of capture plus all theoretically available water stored within the aquifer over a planned time horizon. It is unlikely that this yield would ever be reached as not all water in an aquifer is technically recoverable and would result in significant alterations to the hydrogeological system.

The "MSY" yield class is most appropriate for assessing the yield potential of the upper Bearpaw Formation aquitard. Figure 6-21 depicts that yield potential in the Study Area Bearpaw Formation is low. Based on the maximum sustained yield, the potential yield from groundwater in the Project area is low (Figure 6-21).

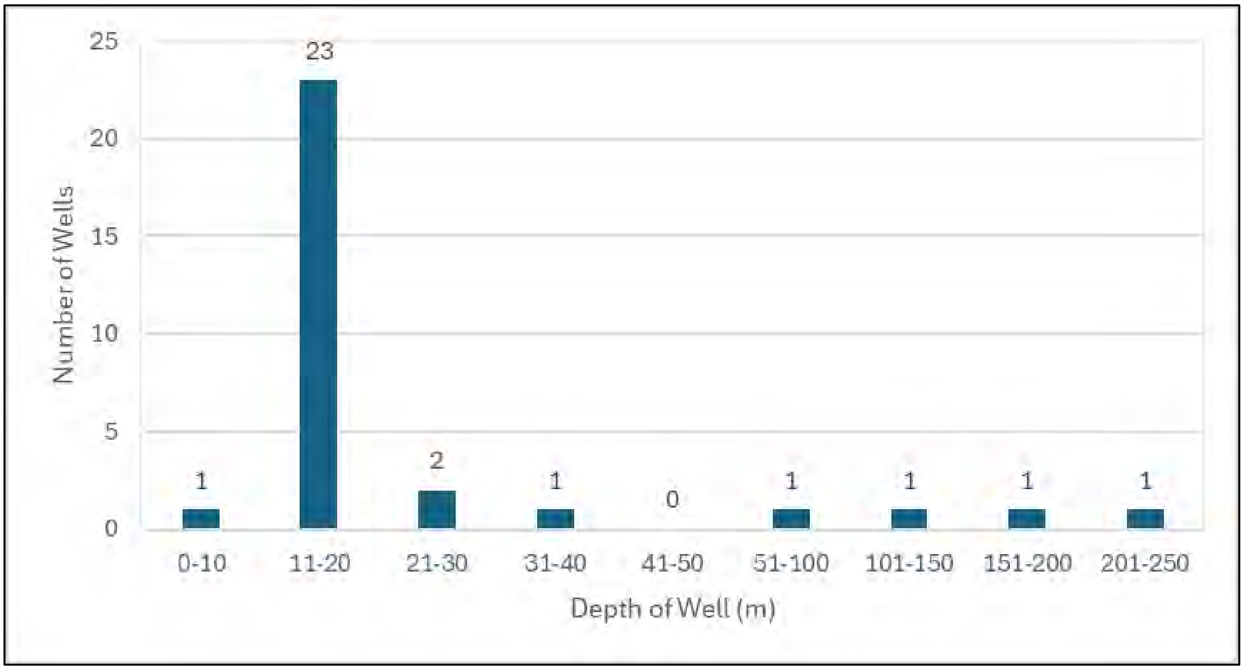


Figure 6-20: Distribution of Alberta Environment Water Well Records by Depth (Modified based on Alberta Water Well Information Database)

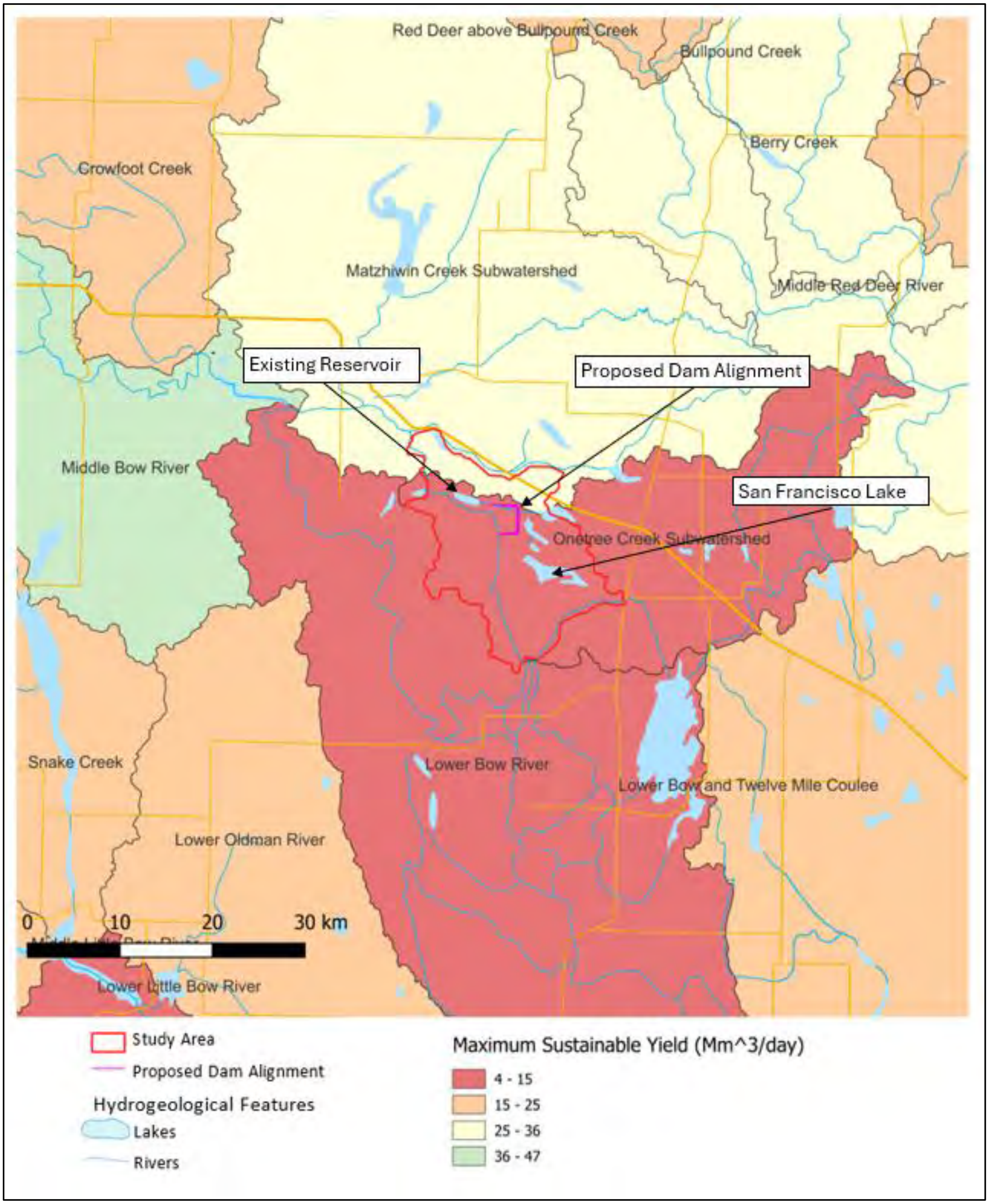


Figure 6-21: Maximum Sustained Yield of Water Wells (Modified after Klassen et al., 2018)

6.4.5 Groundwater Chemistry

In southern Alberta, groundwater quality is linked to the nature of unconsolidated sediments as well as the underlying bedrock. The hydraulic properties of geological units tend to control the quality and chemistry of groundwater encountered in these units. The low permeability clay till and underlaying Bearpaw Formation are the predominant geological units within the Study Area, the low permeability of these geological units results in longer water residence time and contact time between the water and minerals comprised of the rock or soil matrix. The longer water residence time and contact time between water and minerals in the rock and soil matrix results in higher values of constituents such as sulphate, this is evident in the groundwater samples collected from the boreholes 23CH700, 23CH700B, 23CH702, 23CH702B, and 23CH704B screened in the upper Bearpaw Formation shale.

Table 6-13 presents the laboratory analytical results and Figure 6-22 presents a Piper diagram (Piper, 1944) of the major ion chemistry of the groundwater samples collected from the boreholes within the reservoir expansion area. A Piper diagram is a graphical procedure to segregate relevant analytical data to understand the dissolved constituents in the natural waters. In this procedure, most natural waters contain cations and anions in chemical equilibrium. It is also assumed that the most abundant cations are two “alkaline earths” calcium (Ca^{2+}) and magnesium (Mg^{2+}) and one “Alkali” sodium (Na^{+}). The most common anions are one “weak acid” bicarbonate (HCO_3^-) and two “strong acids” sulphate (SO_4^{2-}) and chloride (Cl^-). The water sampled within each of the wells is generally considered to be chloride sodium and potassium or sulphate sodium type groundwater except for the groundwater sample from borehole 23CH702 which is bicarbonate sodium and potassium water type. The purpose of groundwater sampling is to obtain the baseline groundwater chemistry data and identify the dominant cations and anion groups in the natural groundwater.

Table 6-13: Laboratory Analytical Results

Parameter	Units	23CH700 Shallow	23CH700B Deep	23CH702 Shallow	23CH702B Deep	23CH704B Deep
Regulated Metals - Total						
Total Cadmium (Cd)	µg/L	6.6	0.20	0.21	0.67	0.27
Total Aluminum (Al)	mg/L	510	15	10	110	27
Total Antimony (Sb)	mg/L	<0.024	0.0013	0.00084	<0.012	<0.00060
Total Arsenic (As)	mg/L	0.58	0.016	0.016	0.067	0.027
Total Barium (Ba)	mg/L	2.6	0.47	0.22	1.8	0.80
Total Beryllium (Be)	mg/L	0.048	0.0013	<0.0010	<0.020	0.0021
Total Boron (B)	mg/L	1.1	2.2	0.58	0.80	0.82
Total Calcium (Ca)	mg/L	720	380	5.2	75	150
Total Chromium (Cr)	mg/L	0.62	0.019	0.010	0.13	0.034
Total Cobalt (Co)	mg/L	0.56	0.019	0.0083	0.081	0.026
Total Copper (Cu)	mg/L	1.1	0.028	0.032	0.21	0.052
Total Iron (Fe)	mg/L	1300	30	12	190	54
Total Lead (Pb)	mg/L	1.0	0.023	0.019	0.13	0.042
Total Lithium (Li)	mg/L	1.4	2.8	0.086	<0.40	0.73
Total Magnesium (Mg)	mg/L	300	210	2.6	44	40
Total Manganese (Mn)	mg/L	28	1.3	0.14	2.2	1.1

Parameter	Units	23CH700 Shallow	23CH700B Deep	23CH702 Shallow	23CH702B Deep	23CH704B Deep
Total Molybdenum (Mo)	mg/L	0.021	0.014	0.031	0.021	0.0075
Total Nickel (Ni)	mg/L	1.3	0.043	0.022	0.20	0.064
Total Phosphorus (P)	mg/L	41	<2.0	0.69	3.0	1.0
Total Potassium (K)	mg/L	83	16	3.1	20	11
Total Selenium (Se)	mg/L	0.016	0.0023	0.0013	<0.0040	0.0016
Total Silicon (Si)	mg/L	190	31	20	180	52
Total Silver (Ag)	mg/L	0.0056	0.00014	0.00014	<0.0020	0.00029
Total Sodium (Na)	mg/L	1600	4600	270	690	2000
Total Strontium (Sr)	mg/L	6.2	8.1	0.098	1.0	2.5
Total Sulphur (S)	mg/L	790	3500	51	180	1200
Total Thallium (Tl)	mg/L	0.0090	<0.00020	<0.00020	<0.0040	<0.00020
Total Tin (Sn)	mg/L	<0.040	0.0012	0.0021	<0.020	0.0014
Total Titanium (Ti)	mg/L	0.98	0.17	0.11	0.38	0.19
Total Uranium (U)	mg/L	0.14	0.0046	0.0069	0.026	0.015
Total Vanadium (V)	mg/L	0.75	0.034	0.025	0.22	0.060
Total Zinc (Zn)	mg/L	8.9	0.16	0.084	1.3	0.24
Anions						
Alkalinity (PP as $CaCO_3$)	mg/L	<1.0	<1.0	19	19	2.6
Alkalinity (Total as $CaCO_3$)	mg/L	560	830	430	560	490
Bicarbonate (HCO_3)	mg/L	680	1000	480	640	590
Carbonate (CO_3)	mg/L	<1.0	<1.0	23	23	3.1
Hydroxide (OH)	mg/L	<1.0	<1.0	<1.0	<1.0	<1.0
Chloride (Cl)	mg/L	99	200	18	250	470
Sulphate (SO_4)	mg/L	1700	9900	160	370	3300
Nutrients						
Nitrite (N)	mg/L	0.029	0.29	<0.010	0.030	0.067
Nitrate plus Nitrite (N)	mg/L	0.051	0.64	0.93	0.10	0.19
Total Kjeldahl Nitrogen (Calc)	mg/L	29.2	9.93	0.55	4.8	5.22
Total Nitrogen (N)	mg/L	29	11	1.5	4.9	5.4
Total Phosphorus (P)	mg/L	150	0.50	0.65	3.0	1.3
Misc. Inorganics						
Specific Conductivity	µS/cm	4600	17000	1200	2600	8100
pH	pH	8.09	8.23	8.82	8.69	8.32
Calculated Parameters						
Anion Sum	meq/L	50	230	13	26	92
Cation Sum	meq/L	53	230	14	28	99
Hardness ($CaCO_3$)	mg/L	150	1700	24	39	460
Ion Balance (% Difference)	%	2.8	0.29	5.4	4.2	3.7
Nitrate (N)	mg/L	0.022	0.35	0.93	0.073	0.13
Nitrate (NO_3)	mg/L	0.098	1.6	4.1	0.32	0.56
Nitrite (NO_2)	mg/L	0.094	0.96	<0.033	0.10	0.22
Calculated Total Dissolved Solids	mg/L	3400	16000	770	1600	6300
Mercury by Cold Vapour						
Total Methyl Mercury	ng/L	0.42	<0.050	<0.050	<0.050	0.071

Parameter	Units	23CH700 Shallow	23CH700B Deep	23CH702 Shallow	23CH702B Deep	23CH704B Deep
Total Mercury (Hg)	µg/L	0.408	0.0401	0.00505	0.0944	0.0362
Pet. Hydrocarbons and BTEX						
F2 (C10-C16 Hydrocarbons)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10
F3 (C16-C34 Hydrocarbons)	mg/L	<0.10	<0.10	<0.10	<0.10	<0.10
F4 (C34-C50 Hydrocarbons)	mg/L	<0.20	<0.20	<0.20	<0.20	<0.20
Benzene	µg/L	<0.40	<0.40	<0.40	<0.40	0.43
Toluene	µg/L	0.53	0.40	1.4	0.58	0.66
Ethylbenzene	µg/L	<0.40	<0.40	<0.40	<0.40	<0.40
m & p-Xylene	µg/L	<0.80	<0.80	<0.80	<0.80	<0.80
o-Xylene	µg/L	<0.40	<0.40	<0.40	<0.40	<0.40
Xylenes (Total)	µg/L	<0.89	<0.89	<0.89	<0.89	<0.89
F1 (C6-C10) - BTEX	µg/L	<100	<100	<100	<100	<100
F1 (C6-C10)	µg/L	<100	<100	<100	<100	<100
Misc. Organics						
Phenols	mg/L	<0.0015	<0.0015	<0.0015	<0.0015	<0.0015
Demand Parameters						
Biochemical Oxygen Demand	mg/L	43	8.1	18	32	14
Chemical Oxygen Demand	mg/L	132	95	114	494	182
Misc Organic						
Total Organic Carbon (C)	mg/L	10	7.3	5.2	10	11
Microbiological Parameters						
Fecal Coliforms	MPN/100mL	<100	<5.0	<5.0	<100	<10

Methylmercury concentrations were below detection limits in all but one sample. Concentrations of petroleum hydrocarbon fractions and benzene, ethylbenzene and xylenes were below detection limits while toluene was detected at concentrations below 1.4 µg/L in all samples showing little evidence of organic chemicals contamination.

Total organic carbon ranged from 5.2 to 11 mg/L. The total dissolved solids ranged widely from borehole to borehole with the lowest values encountered in borehole 23CH702 (770 mg/L) and the highest value encountered in borehole 23CH700B (16,000 mg/L). The ionic balances reported by the laboratory (Bureau Veritas) varied between 0.29 and 5.4%. These ionic balances are within the acceptable range of <10%. The lab duplicates for the volatiles were within the appropriate range.

Fecal coliforms were not detected in any samples, although the detection limits were raised to <100 MPN/100 mL in 23CH700 Shallow and 23CH402B Deep due to matrix interference, and holding times were exceeded for these samples. Nevertheless, the groundwater does not appear significantly contaminated by fecal coliform bacteria.

Total metals concentrations are highly variable (>10 times difference) among sampled sites. In general, differences in concentrations appear linked with the nature and depth of the screened geological units. Some metals are found at lower concentrations in shallow wells than deep wells and vice versa. These changes are likely linked with chemical properties of overburden and weathered bedrock differing from those of unaltered bedrock, resulting in metals dissolving at different concentrations. Loading or dilution by water infiltrating from the ground surface may also affect concentrations in shallow groundwater the most. These changes are also indirectly reflected by the generally higher total dissolved solids concentrations in deep groundwater compared to shallow groundwater results.

In addition to variations with depth, concentrations also appear to vary by locations. For example, calcium ranged from 5.2mg/L in 23CH7027 to 20 mg/L in 23CH700. In fact, total metals concentrations in 23CH700 appear consistently higher than those is 23CH702. Concentrations in other monitoring wells appear between concentrations found at these two locations for most metals.

Concentrations of anions were highest in 23CH700B and 23CH704B and lowest in 23CH702. Electrical conductivity ranged from 1200 µS/cm (moderately brackish) to 17,000 µS/cm (saline). Laboratory measurements of pH were, however, relatively similar among samples. Nutrients concentrations were generally low, as expected in an area with low cultivation and fertilization. Nitrate and nitrite concentrations (expressed as nitrogen) were detected in all wells, but concentrations were all below 1 mg/L.

The Piper diagram indicates major cations in groundwater at the site primarily consist of sodium and potassium. Sample 23CH700A also contains calcium and magnesium, although sodium and potassium still represent more than 50% of cations in that sample.

Anions, on the other hand, show that samples 23CH700A, 23CH700B and 23CH704B are enriched in sulfate while sample 23CH702A is enriched in bicarbonate and sample 23CH702B features a mixture of bicarbonate, chloride, nitrate and sulfate.

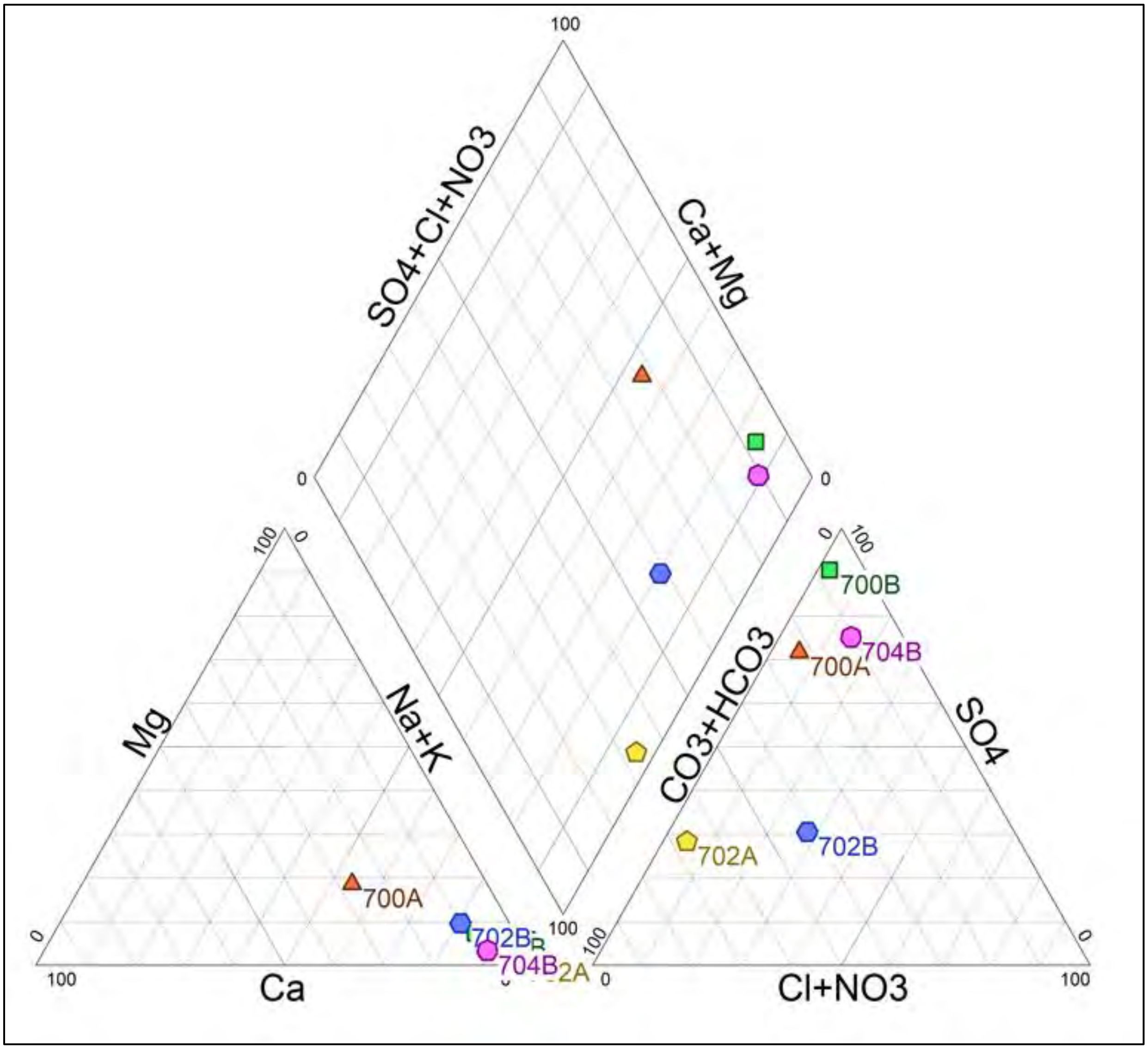


Figure 6-22: Piper Diagram depicting Groundwater Chemistry

6.5 SUMMARY OF KEY FINDINGS

Table 6-14 presents key findings based on the baseline data collected as part of the hydrogeological baseline study and the results of groundwater flow simulations completed to support the hydrogeological baseline study.

Table 6-14: Summary of Key Findings

EIA TOR Reference No:	Potential Environmental Effect	Potential Effect Pathway - Interactions between the Project and Groundwater can include:	Key Findings from the Study
3.2.1	Provide and overview of the existing geologic and hydrogeologic setting.	Not applicable	Refer to Section 6.3 of this Report. Section 6.3 of this Report describes the baseline data obtained through the hydrogeological and geotechnical investigations and the conceptual hydrostratigraphic framework developed based on the baseline data. The conceptual hydrostratigraphic framework developed based on the baseline data was implemented as a numerical groundwater flow model to simulate hypothetical scenarios about the project components of the proposed reservoir expansion.
3.2.2.1	Describe the project components and activities that could affect groundwater resource quality and quantity.	Not applicable	The project components that could affect the groundwater resource quantity and quality include: 1. Construction stage groundwater dewatering in the dam footprint, and potentially in borrow pits. 2. Lowering of the SLR while initially filling the combined reservoir 3. Storage of surface water in the planned expanded reservoir. The impact assessment results associated with these project components are described in Appendix D7 of this Report and the remainder of this table.
3.2.2.2	Identify areas that may experience seepage from the reservoir and predicted interactions with aquifers or surface water bodies	Groundwater seepage from the planned reservoir.	The potential for groundwater infiltration/seepage beneath the base of the reservoir basin and through the berms is very limited based on the low permeability of the clay till and bedrock aquitards, as demonstrated by the FEFLOW and SEEP/W model simulations of the simplified conceptual hydrogeological models. The clay till in the planned reservoir expansion area is underlain by the Bearpaw Formation shale, which acts as an aquitard. The Bearpaw Formation is underlain by the Upper Belly River aquifer. The regional groundwater flow regime in the upper Bearpaw Formation is not expected to be significantly altered by the reservoir expansion due to the limited capacity of the Bearpaw Formation for the regional-scale transmission of groundwater, therefore, no significant interactions between the Project and the Upper Belly River aquifer is anticipated. Refer to the responses to

EIA TOR Reference No:	Potential Environmental Effect	Potential Effect Pathway - Interactions between the Project and Groundwater can include:	Key Findings from the Study
			EIA TOR No: 3.2.2.3 A and 3.2,2.3 B for the findings related to the predicted interactions with aquifers.
3.2.2.3 A 3.2.2.3 B	Inter-relationship between surface water and groundwater in terms of surface water quality and quantity Implications for wildlife and aquatic resources, terrestrial vegetation and wetlands outside of the SLR footprint	Groundwater level/quantity changes during the construction and post-construction can affect the surface water features within the vicinity of the planned reservoir expansion area in terms of surface water quantity and quality.	Based on the limited radius of influence of construction-related temporary groundwater dewatering, significant water bodies such as San Francisco Lake are not likely to be influenced by the temporary construction activities. Wetlands in the footprint will be removed under Water Act approval. Thus, the only other wetland effects would be on surrounding wetlands, which should be limited as they are recharge / discharge system typically dry except after large rains. The calculated radius of influence in both modelled scenarios (the assumed maximum capacity over 3 months and the assumed average capacity over 2 years) does not extend beyond roughly the midway point of the dam alignment, the reservoir expansion and associated reservoir fill levels are not anticipated to significantly impact the local groundwater flow regime. There could be some minor decrease in groundwater levels downstream from the reservoir expansion, generally less than 1 m. However, the San Francisco Lake and associated natural resources such as the wetlands located downstream from the reservoir expansion are sustained by the existing EID canal system, and therefore the maintenance of this existing EID canal system should mitigate any potential decrease in groundwater baseflow resulting from the reservoir expansion and any impacts to wildlife and aquatic resources, terrestrial or riparian vegetation including wetlands. However, it should be noted that the components contributing to the water balance of the San Francisco Lake are not fully known, it is understood that a canal system is the primary contributor of the San Francisco Lake. Thus, the canal system will be maintained to ensure no change.
3.2.2.3.C 3.2.2.3.D 3.2.2.3.E	Changes in groundwater resource quantity or quality	Changes in groundwater quantity - Groundwater levels or yield changes in water supply wells of the groundwater users of the Study Area. Conflicts with other groundwater users Groundwater protection including	Water supply wells are located outside of the radius of influence of construction dewatering as well as outside of the radius of influence of the reservoir filled at the assumed average capacity (FSL) for two years (this is considered conservative). No significant impacts on groundwater users or conflicts with groundwater users are anticipated. There are no groundwater users or water supply wells within the planned reservoir expansion area, therefore, the protection of wells before the construction of the project is not required. Further,

EIA TOR Reference No:	Potential Environmental Effect	Potential Effect Pathway - Interactions between the Project and Groundwater can include:	Key Findings from the Study
		reclaiming wells in the project area	Water supply wells are located outside of the radius of influence of construction dewatering.
		Changes in groundwater quantity and flow - Groundwater level/quantity changes during the construction and post-construction of the project can affect existing infrastructure (railroad located to the northeast of the project site).	Groundwater infiltration beneath the base of the basin and through the berms is very limited based on the low permeability of the clay till and bedrock aquitards, as demonstrated by the FEFLOW and SEEP/W model simulations. The calculated radius of influence ranged for both scenarios (the assumed maximum capacity over 3 months and the assumed average capacity over 2 years) is limited to the reservoir footprint and changes to the groundwater levels are not anticipated to significantly impact the local groundwater flow regime and the existing infrastructure such as the railroad located to the northeast of the project site.
		Changes in groundwater quality	Water supply wells are located outside of the radius of influence of construction dewatering as well as outside of the radius of influence of the reservoir filled at the assumed average capacity (FSL) for two years (this is considered conservative), therefore, no significant impacts on groundwater quality are anticipated.
3.2.2.3.G		Groundwater withdrawal for project operations is expected to involve groundwater extraction during the construction dewatering.	Construction dewatering scenarios were run and the dewatering rates for a dewatering period of 90 days were estimated at 915 m^3/day with a factor of safety of 3. The radius of influence after 90 days of dewatering is small and is limited to an area within roughly 25 m of the excavation limits. There are no receptors within that radius therefore, temporary construction-related groundwater dewatering is not expected to affect groundwater users or San Francisco Lake (which is identified as one of the sensitive ecological receptors).
		Groundwater seepage into the open excavations during construction.	Given the dry conditions at the planned reservoir expansion area, the groundwater water levels were found a few metres below the ground surface and the low hydraulic conductivity of the clay till and bedrock aquitard (Upper Bearpaw Formation shale), groundwater seepage into open excavations during construction is estimated at 915 m^3/day (based on the excavation dimensions available at the time of the EIA).

EIA TOR Reference No:	Potential Environmental Effect	Potential Effect Pathway - Interactions between the Project and Groundwater can include:	Key Findings from the Study
3.2.2.3.H		Groundwater vulnerability below the proposed reservoir, specifically groundwater seepage through the berms and bottom surface of the reservoir basin.	Groundwater infiltration beneath the base of the reservoir basin and through the berms is very limited based on the low permeability of the clay till and bedrock aquitards, as demonstrated by the FEFLOW and SEEP/W model simulations of the simplified conceptual hydrogeological models. The regional groundwater flow regime in the upper Bearpaw Formation is not expected to be significantly altered by the reservoir expansion due to the limited capacity of the Bearpaw Formation for the regional-scale transmission of groundwater.
		Groundwater vulnerability below the proposed reservoir and hydraulic connection between bedrock units	The clay till in the planned reservoir expansion area is underlain by the Bearpaw Formation shale, which acts as an aquitard. The Bearpaw Formation is underlain by the Upper Belly River aquifer. Some vertical leakage from the Upper Belly River aquifer into the overlying aquitard such as the Bearpaw Formation is possible However, this type of diffusive exchange between the aquifer such as the Upper Belly River aquifer is expected to be limited and unlikely to modify the overall hydrostratigraphic designation of the Bearpaw Formation as the aquitard. Thus, the potential for hydraulic connection between the bedrock units (Bearpaw Formation and underlying Belly River Group) and associated groundwater vulnerability below the proposed reservoir is deemed low.
		Groundwater vulnerability below the proposed reservoir specifically groundwater seepage into the reservoir basin when dry.	Given the dry conditions in the study area and the groundwater levels that are typically 2 m or more below the ground surface, no significant seepage into the reservoir is anticipated when the reservoir basin is dry.
3.2.2.4	Contribution to cumulative effects on regional groundwater	Changes in regional groundwater levels/quantity Conflicts with regional groundwater users	Based on the impact assessment results presented in this table and Appendix D7 of this Report, it is not expected that the groundwater level variations caused by the reservoir expansion will overlap with changes caused by the other projects (recently completed projects, recently disclosed projects, and projects reasonably foreseeable to 2050), therefore, no significant contributions to cumulative effects on regional groundwater flow regime is anticipated. Further, no conflicts with regional groundwater users are expected.

6.6 RESIDUAL IMPACT ASSESSMENT

The residual impacts assessment (Table 6-15) characterized the following potential effects on groundwater resources:

- Groundwater Quantity: Increases – There are no anticipated increases in groundwater levels as seepage into groundwater from the reservoir will be unlikely to occur due to the low connectivity of water from the surface, through the clay till layer, and into the deeper ground layers and Bearpaw formation bedrock. The impact rating was assessed as neutral.
- Groundwater Quantity: Decreases – Water drawdown will need to occur during the construction of borrow pits and excavations into the footprint, whenever there is seepage of water into the excavations. The effect is negative in direction as the water drawdown is expected to reduce water levels in areas immediately beyond the excavation, but the effect will not occur beyond the footprint. The effects are short-term in duration as they will only occur during construction. Confidence is high as the results come from a tested and calibrated water flow model. Overall, the impact rating is assessed as Low.
- Groundwater Quality – Groundwater quality is not expected to change from baseline levels. Surface water quality of the expanded reservoir is expected to remain high, as this water will be sourced from the Bow River with very little additional water entering as surface runoff, as the only new source of runoff will be on the raised berms themselves. The residual effect is rated as neutral

Table 6-15: Residual impacts on hydrogeological resources from the Project

Impact description	Direction	Key Criteria			Modifiers		Residual Impact Rating
		Magnitude	Geographical Extent	Duration	Confidence	Ecological and Social Context	
Groundwater seepage from the reservoir resulting in increased area of groundwater during expanded reservoir operations	Neutral						Neutral
Groundwater drawdown during construction resulting in increased area of reduced groundwater during borrow pit and dam construction dewatering	Negative	Low	Footprint	Short-term	High	N/A	Low Negative
Seepage of reservoir water into groundwater resulting in decreased water quality of groundwater during reservoir operations	Neutral						Neutral

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The assessment should not be considered a comprehensive audit that covers and eliminates all present, past and future risks. The information presented in this Report is based on data collected during the completion of the monitoring conducted. The overall site/building/subsurface/groundwater conditions were extrapolated based on information collected at specific sampling locations. Professional judgement was exercised in gathering and analyzing data; however, no monitoring method can completely eliminate the possibility of obtaining partially imprecise or incomplete information; it can only reduce the possibility to an acceptable level. Consequently, the actual site/building/subsurface/groundwater conditions between the sampling points may vary. In addition, analysis has been carried out only for the chemical and physical parameters identified, and it should not be inferred that other chemical species or physical conditions are not present.

It is recommended practice that the Company be retained during subsequent phases of the project, to confirm that the conditions throughout the site do not deviate materially from those encountered throughout the sampling program.

Any description of the site and its physical setting documented in this Report is presented for informational purposes only, to provide the reader a better understanding of the site and scope of work. Any topographic benchmarks and elevations are primarily to establish relative elevation differences between sampling locations and should not be used for other purposes such as grading, excavation, planning, development, or similar purposes.

Any results from the laboratory or other subcontractors reported herein have been carried out by others, and the Company cannot warrant their accuracy.

6.8 CLOSURE

We trust that the above meets your present requirements. Should you have any questions or concerns regarding this report, please feel free to contact the undersigned at your convenience.

Sincerely,

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Appendix D

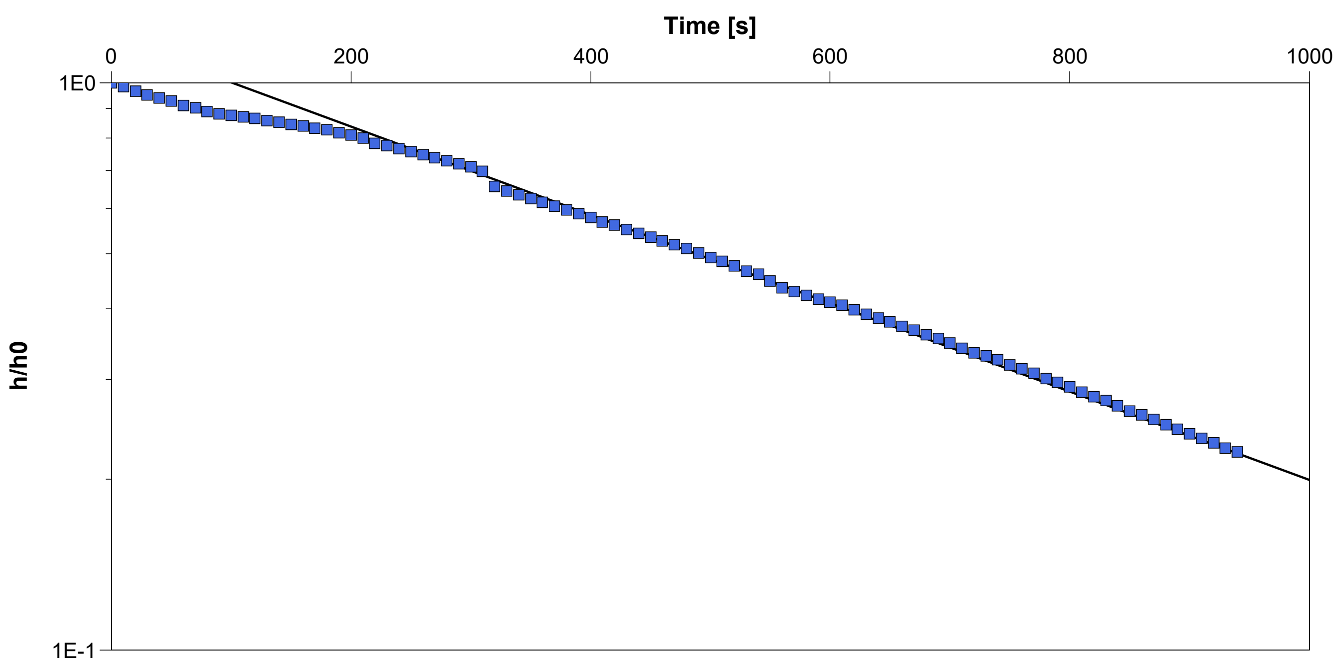
Appendix

Appendix D1: Borehole Logs

Note: This document is provided as a digital copy only [See Annex]

Appendix D2: Hydraulic Conductivity Tests

	Slug Test Analysis Report	
	Project: Snake Lake Reservoir Expansion	
	Number: 1560-193-00	
	Client: EID	
Location: Snake Lake Reservoir	Slug Test: 22BH121 Slug Test	Test Well: MW 22BH121
Test Conducted by: Josh Boyd		Test Date: 2022-12-05
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-01-18
Aquifer Thickness: 2.85 m		

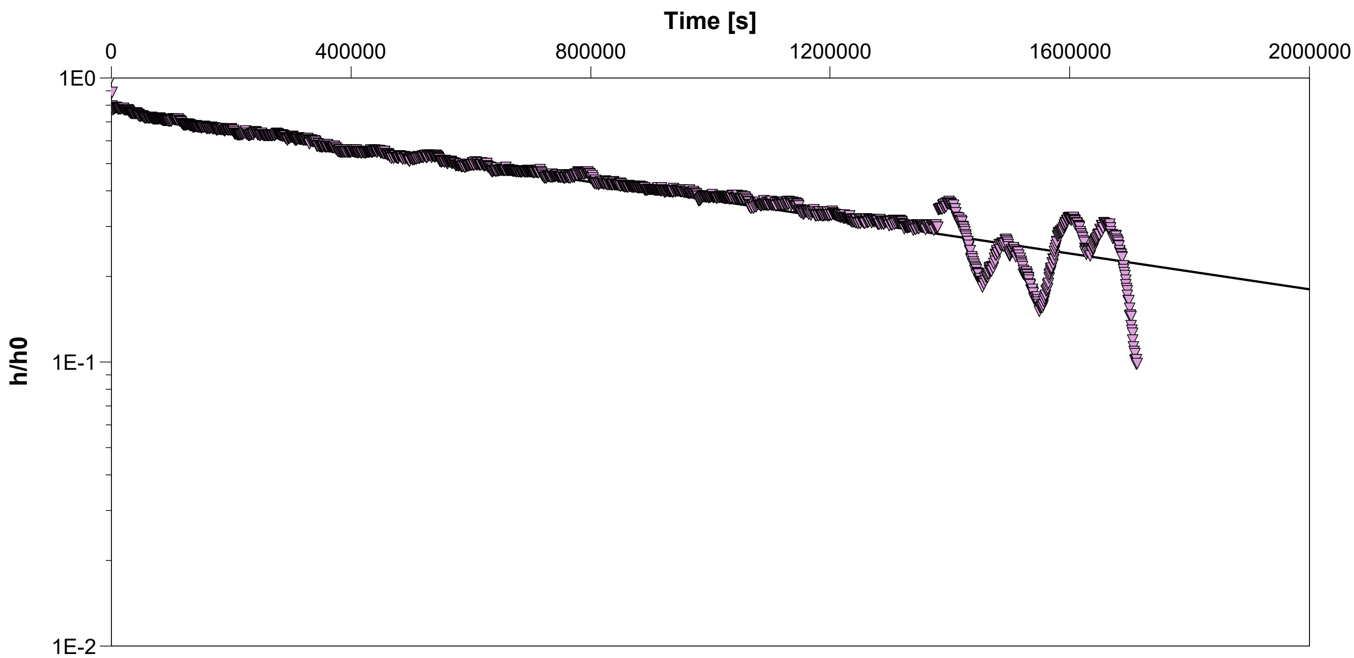


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22BH121	1.18×10^{-6}	

Slug Test Analysis Report	
Project:	Snake Lake Reservoir Expansion
Number:	1560-193-00
Client:	EID

Location: Snake Lake Reservoir	Slug Test: 22CH201 Slug Test One	Test Well: MW 22CH201
Test Conducted by: Josh Boyd		Test Date: 2022-08-29
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-01-18
Aquifer Thickness: 11.40 m		



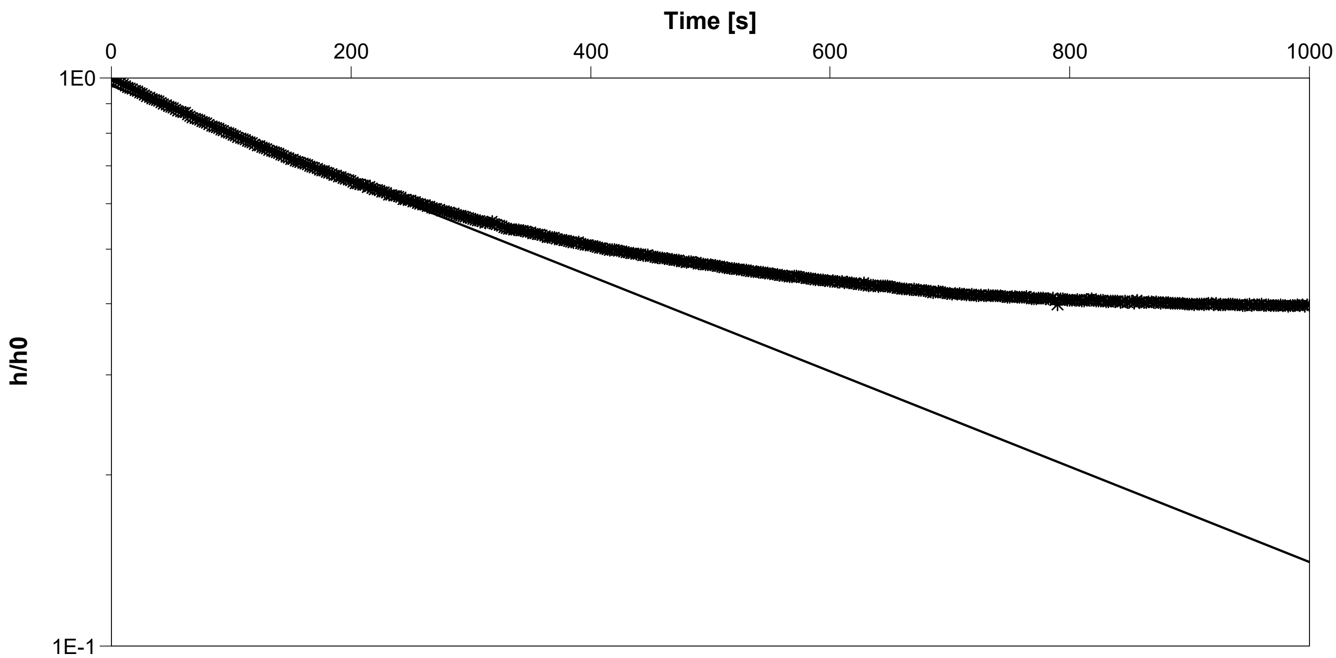
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH201	4.76×10^{-10}	

Odd data points seen in the later portion of the test. 22CH201 Slug Test Two contains better data points.

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22BH228 Slug Test One	Test Well: MW 22BH228
Test Conducted by: Josh Boyd		Test Date: 2022-09-15
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-01-18
Aquifer Thickness: 5.00 m		



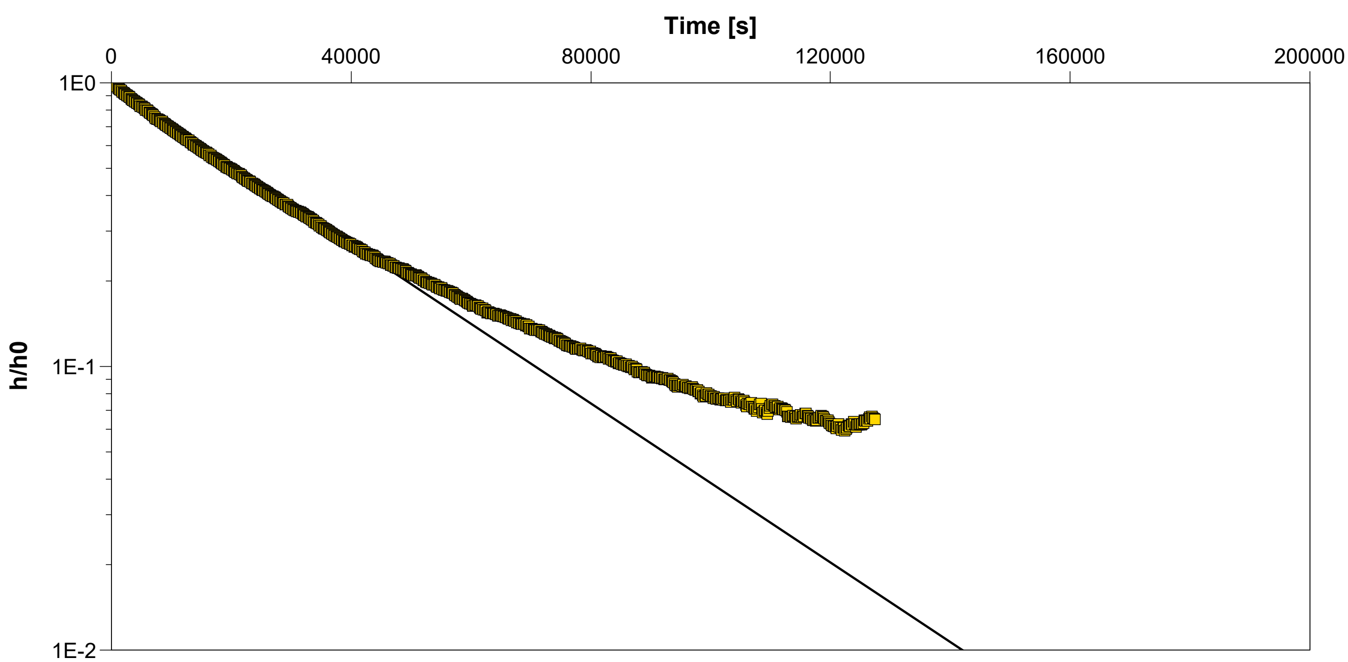
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22BH228	7.49×10^{-7}	

Discrepency is noted between the measured water level and recorded data which presents as 60% recovery seen in the test.

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22CH313 Slug Test	Test Well: MW 22CH313
Test Conducted by: Josh Boyd		Test Date: 2022-10-13
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-01-18
Aquifer Thickness: 8.14 m		

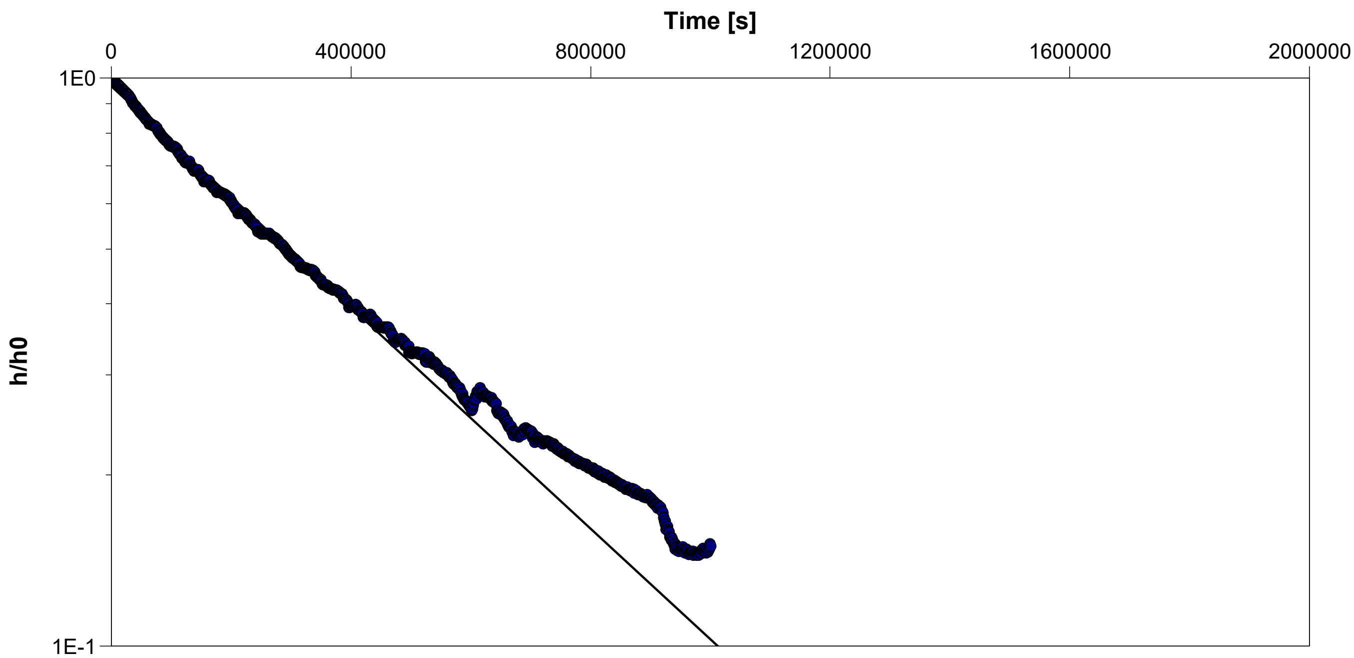


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH313	2.13×10^{-8}	

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22CH319 Slug Test	Test Well: MW 22CH319
Test Conducted by: Josh Boyd		Test Date: 2022-10-13
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-01-19
Aquifer Thickness: 13.08 m		

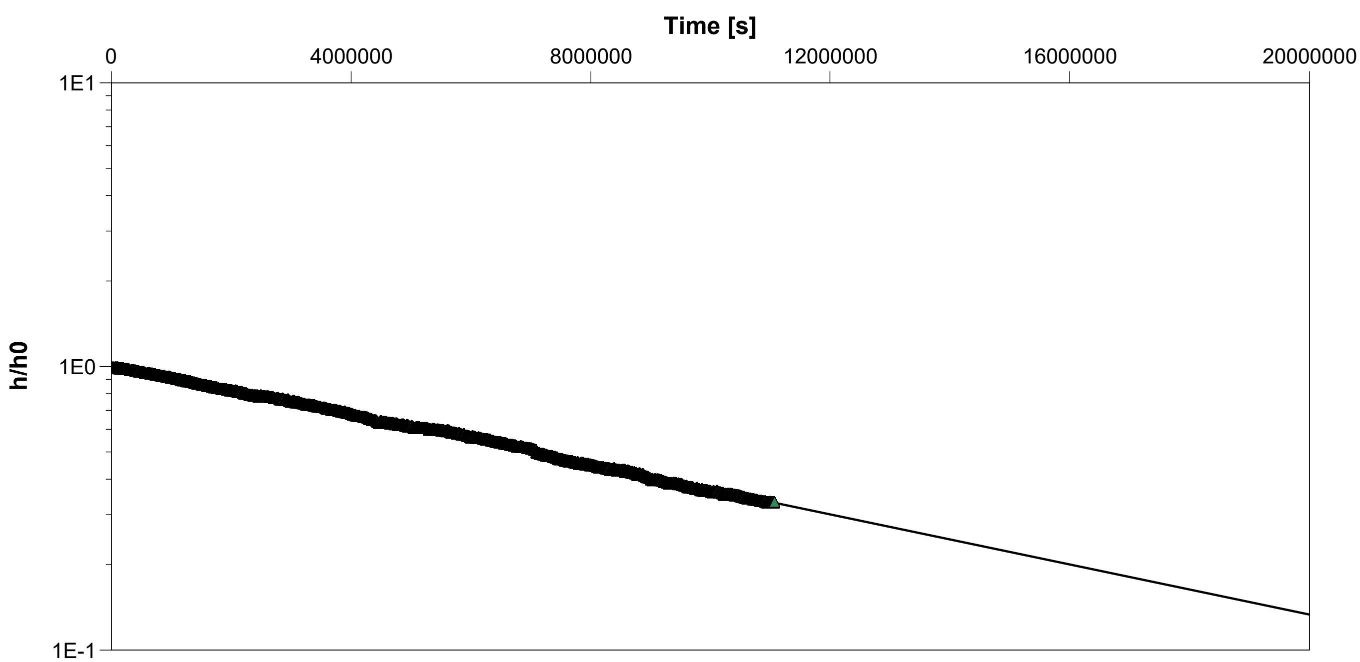


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH319	1.48×10^{-9}	

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22CH118 Slug Test	Test Well: MW 22CH118
Test Conducted by: Josh Boyd		Test Date: 2022-08-29
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-01-23
Aquifer Thickness: 6.61 m		

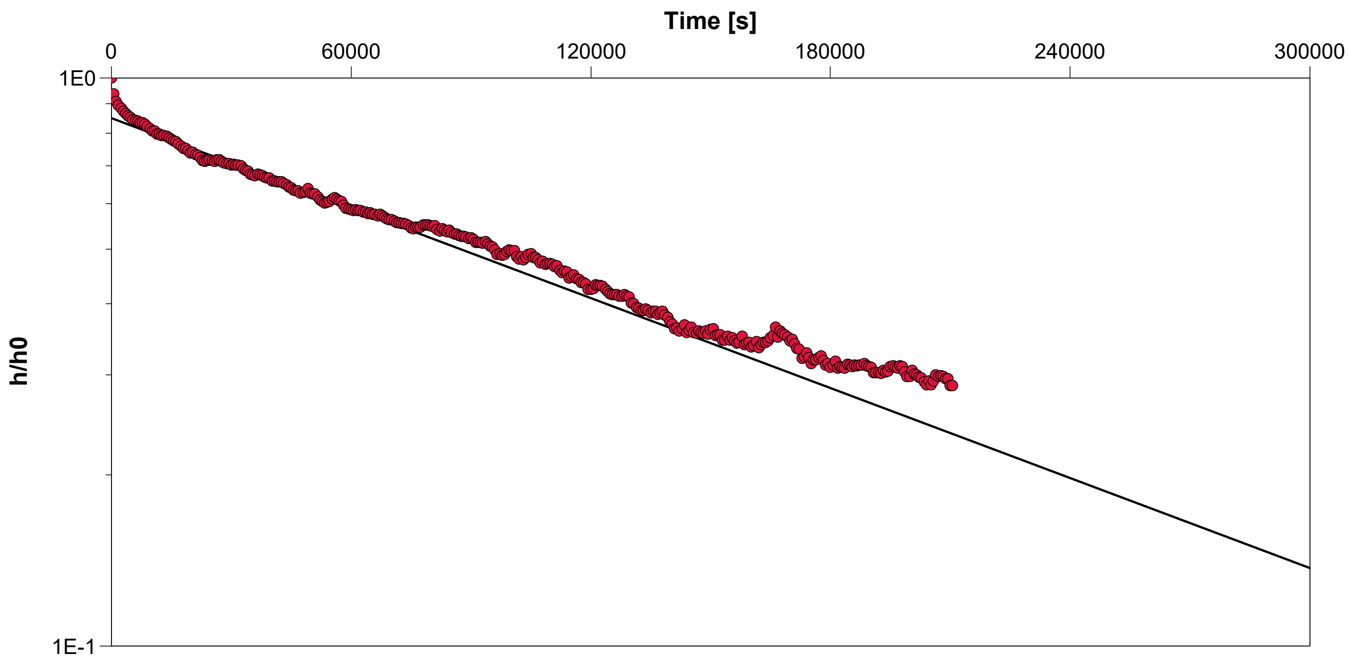


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH118	5.37×10^{-11}	

Analysis was completed with most recent data and with monitoring well recovery of approximately 80%.

	Slug Test Analysis Report	
	Project: Snake Lake Reservoir Expansion	
	Number: 1560-193-00	
	Client: EID	
Location: Snake Lake Reservoir	Slug Test: 22CH126 Slug Test Two	Test Well: MW 22CH126
Test Conducted by: Josh Boyd		Test Date: 2023-01-20
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-02-01
Aquifer Thickness: 12.17 m		



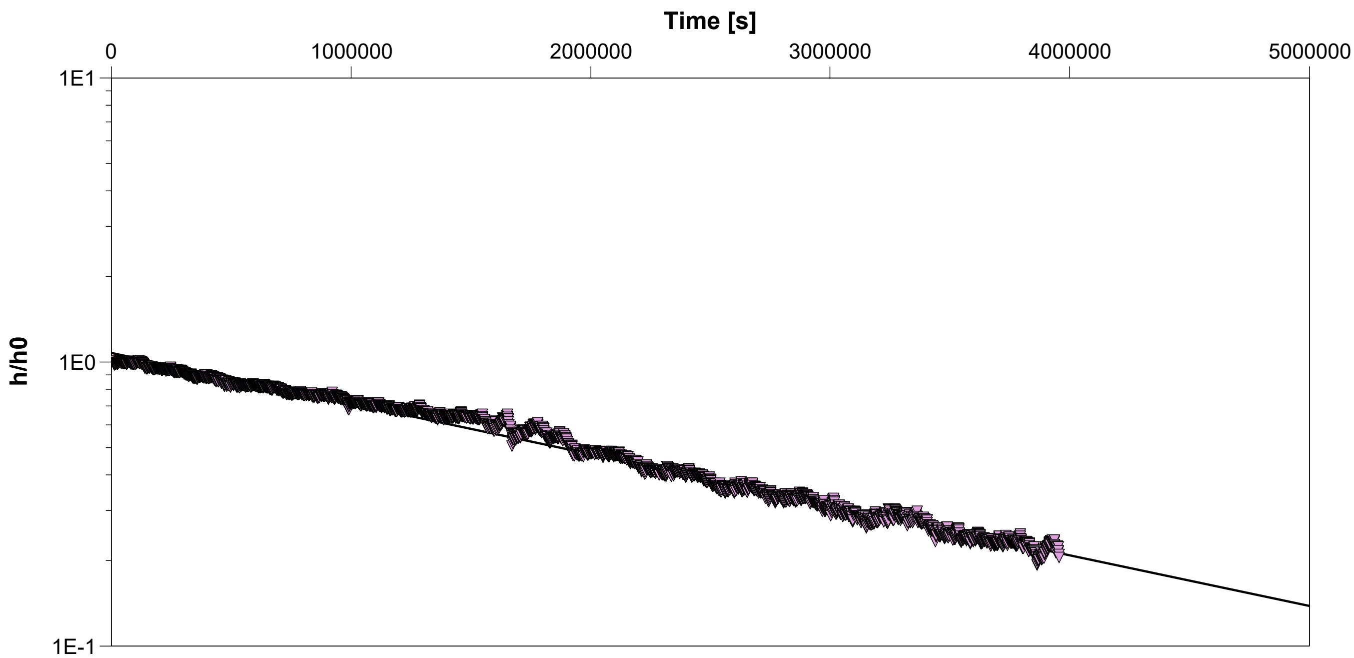
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH126	3.64×10^{-9}	

Analysis was completed with most recent data and with monitoring well recovery of approximately 80%.

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22CH201 Slug Test Two	Test Well: MW 22CH201
Test Conducted by: Josh Boyd		Test Date: 2022-12-05
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-02-02
Aquifer Thickness: 10.00 m		



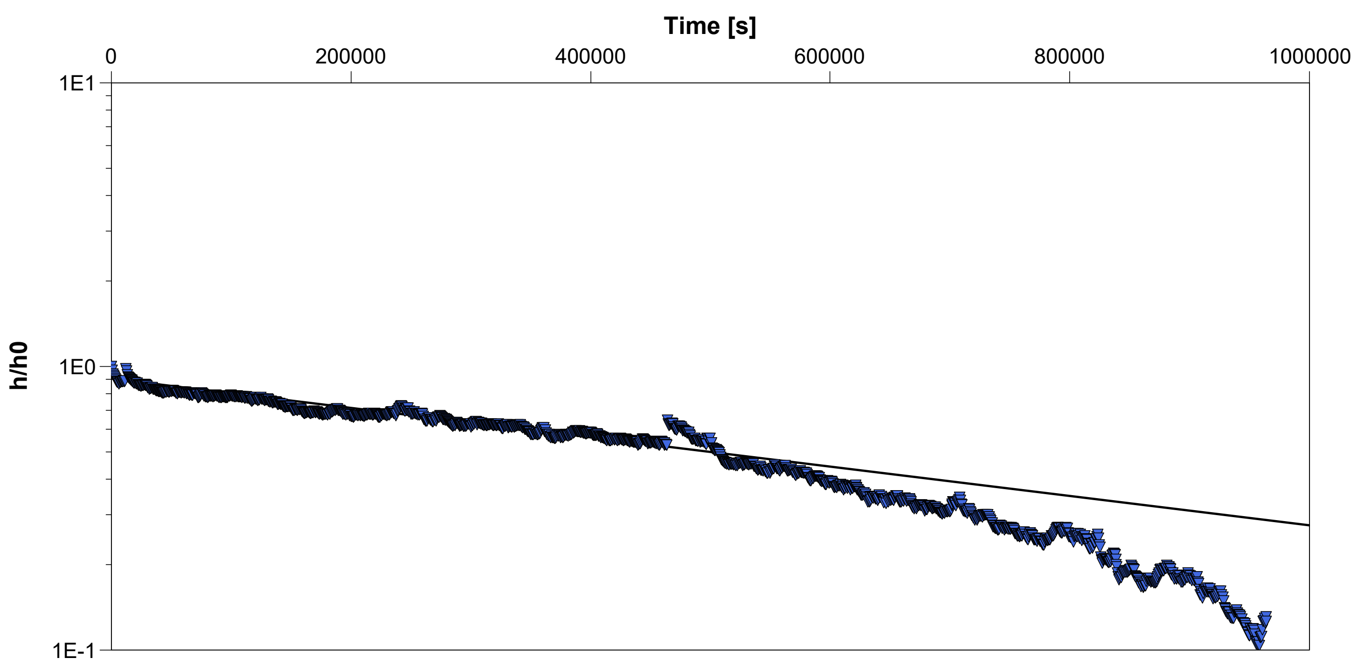
Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH201	2.70×10^{-10}	

Analysis was completed with most recent data and with monitoring well recovery of approximately 80%.

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22CH214 Slug Test One	Test Well: MW 22CH214
Test Conducted by: Josh Boyd		Test Date: 2022-08-29
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-02-02
Aquifer Thickness: 7.86 m		

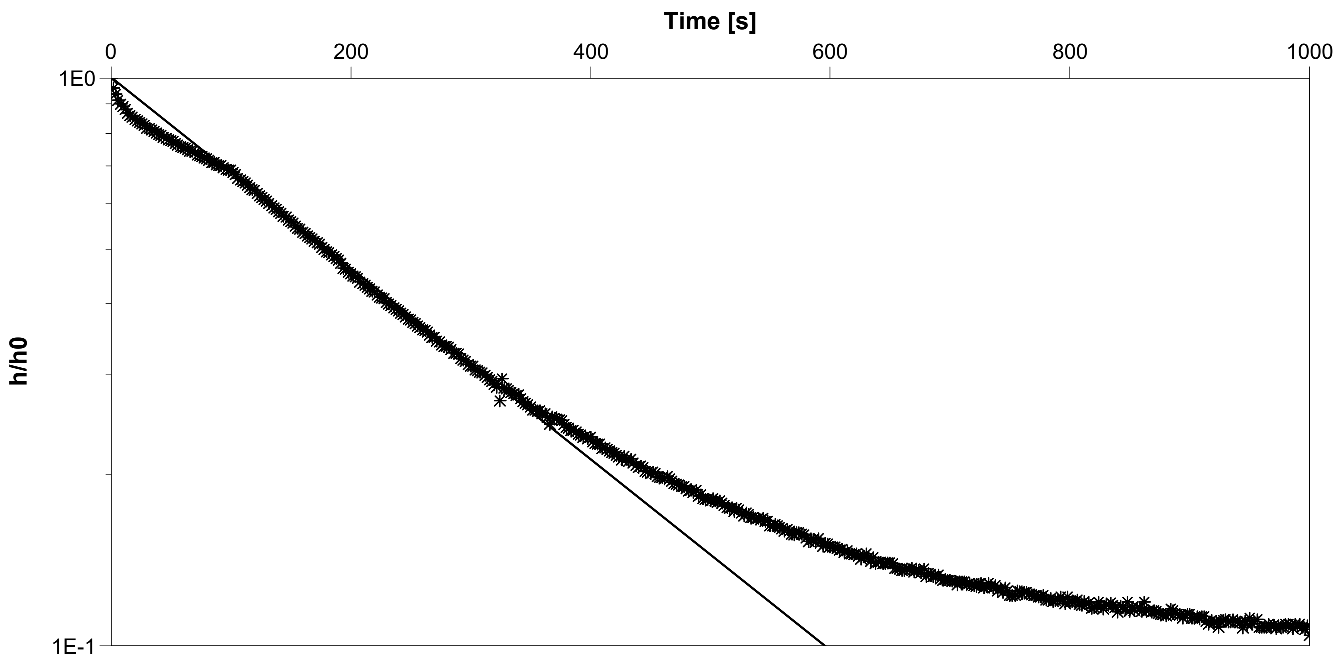


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH214	5.68×10^{-10}	

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22BH228 Slug Test Two	Test Well: MW 22BH228
Test Conducted by: Josh Boyd		Test Date: 2023-03-17
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-03-17
Aquifer Thickness: 3.91 m		

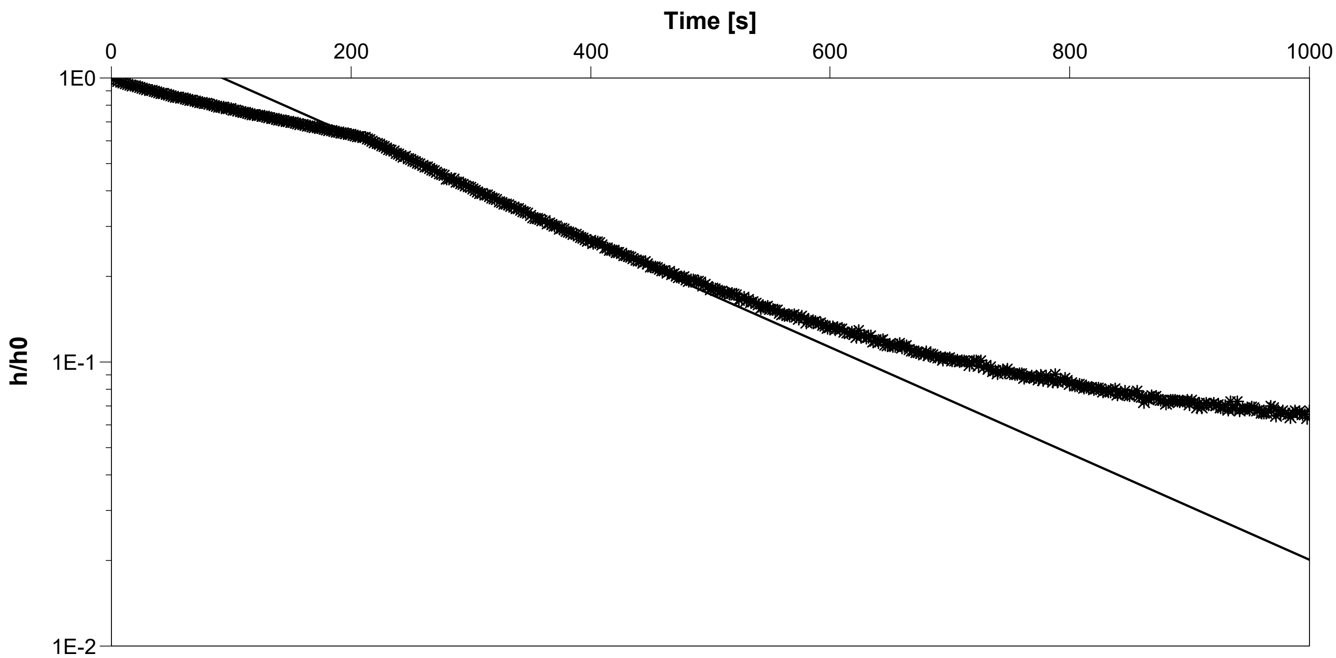


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22BH228	1.50×10^{-6}	

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22BH228 Slug Test Three	Test Well: MW 22BH228
Test Conducted by: Josh Boyd		Test Date: 2023-03-17
Analysis Performed by: MP	Bouwer & Rice	Analysis Date: 2023-03-17
Aquifer Thickness: 3.91 m		

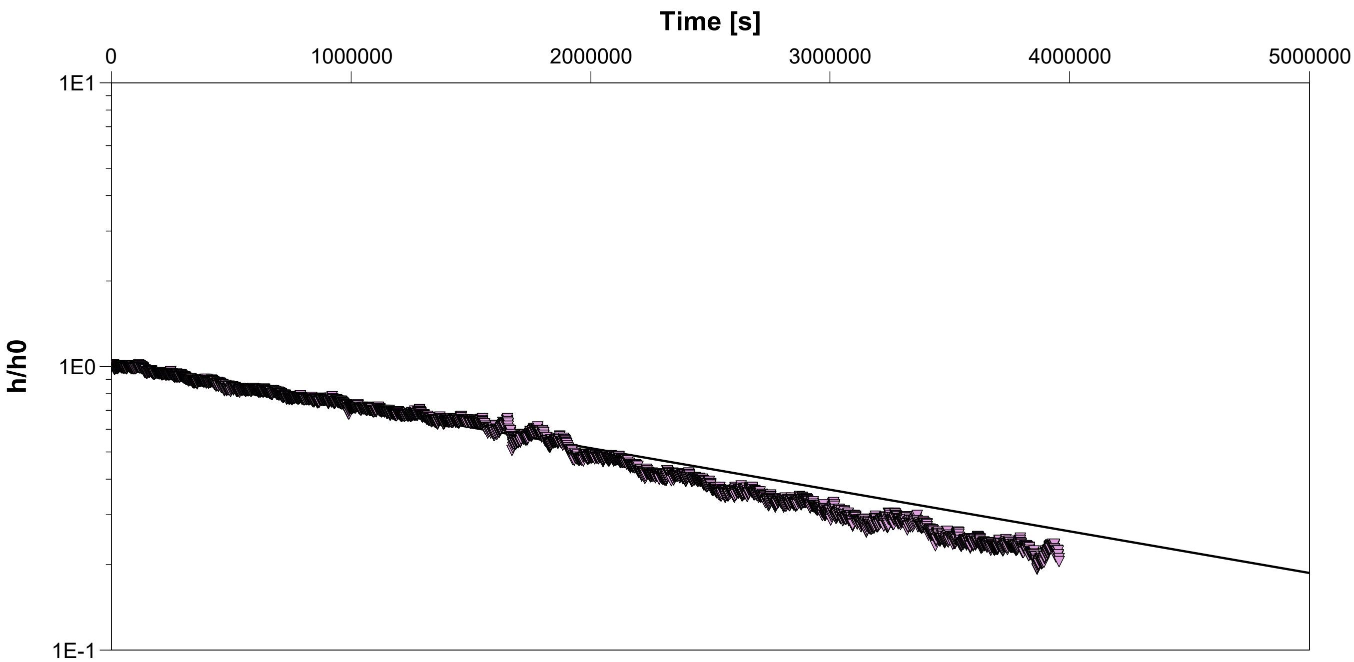


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22BH228	1.67×10^{-6}	

	Slug Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 1560-193-00
	Client: EID

Location: Snake Lake Reservoir	Slug Test: 22CH201 Slug Test Two	Test Well: MW 22CH201
Test Conducted by:		Test Date: 2024-07-19
Analysis Performed by:	New analysis 1	Analysis Date: 2024-07-19
Aquifer Thickness: 11.40 m		

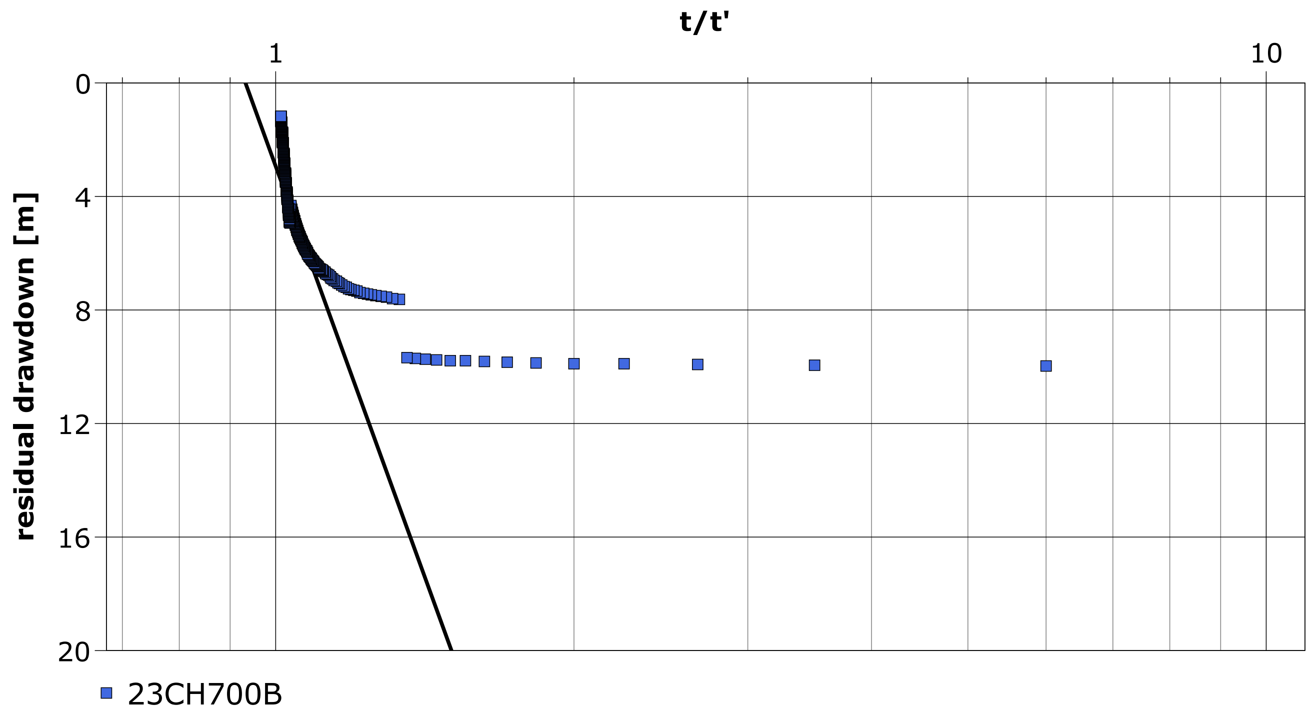


Calculation using Bouwer & Rice

Observation Well	Hydraulic Conductivity [m/s]	
MW 22CH201	2.22×10^{-10}	

	Pumping Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 2301113.000
	Client: MPE

Location: Snake Lake	Pumping Test: 23CH700B	Pumping Well: 23CH700B
Test Conducted by: MPE		Test Date: 2024-07-18
Analysis Performed by: Marc P	New analysis 1	Analysis Date: 2024-07-18
Aquifer Thickness: 22.40 m	Discharge: variable. average rate 0.077444 [l/s]	

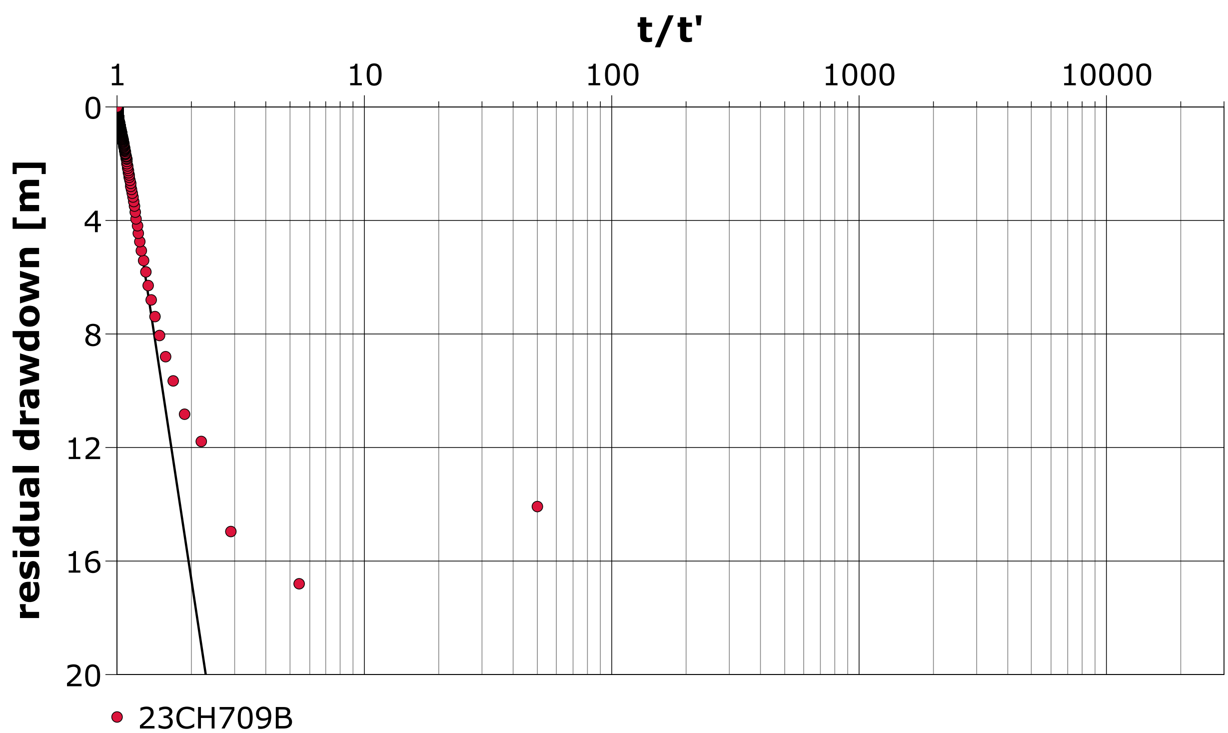


Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]	
23CH700B	1.47×10^{-7}	6.58×10^{-9}	0.05	

	Pumping Test Analysis Report
	Project: Snake Lake Reservoir Expansion
	Number: 2301113.000
	Client: MPE

Location: Snake Lake	Pumping Test: 23CH709B	Pumping Well: 23CH709B
Test Conducted by: MPE		Test Date: 2024-07-19
Analysis Performed by: Marc P	New analysis 1	Analysis Date: 2024-07-19
Aquifer Thickness: 21.00 m	Discharge: variable. average rate 0.061565 [l/s]	



Calculation using THEIS & JACOB

Observation Well	Transmissivity [m²/s]	Hydraulic Conductivity [m/s]	Radial Distance to PW [m]	
23CH709B	1.96×10^{-7}	9.34×10^{-9}	0.05	

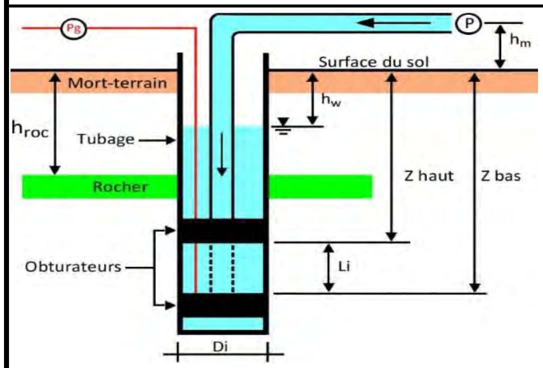
Appendix D3: Packer Test Results

MULTI STEP PRESSURIZED PERMEABILITY TEST

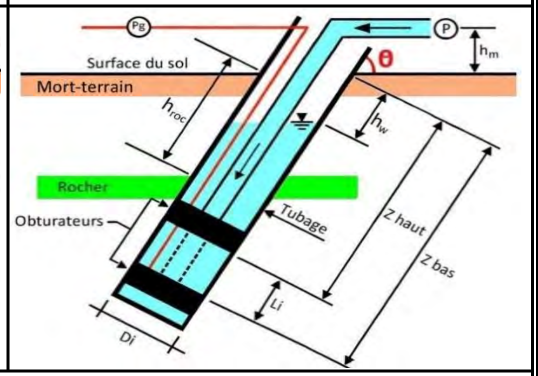
MPE an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23BH123B	Borehole no :	23BH123B
Depth :	3.50 to 5.52 m Dip (θ): 90° Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	◯ BQ ◯ NQ ◉ HQ	Packers :	◯ Single ◉ Double
Depth of borehole :	6.10 m	Depth of bedrock (h_{roc}) :	2.00 m
Z top : 3.50 m	Z bot : 5.52 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	6.10 m
Flowmeter used? :	◉ Yes ◯ No	Date and time of measuremen	08/08/2023 17:09
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	93 kPa

Max Pressure : $$P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right] \sin\theta$$

Net pressure of injection : P_{nette} = $$P_m + 9,81\,(h_m + h_w \sin\theta)$$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\ A}{P_{net}}$

Step # 1 — P = 0.33 P_{max}

Pressure of the manometer P m (kPa): 37

Net pressure of injection (kPa): 107

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.7	0.4
2	0.0	2.9		
3	2.9	0.0		
4	2.9	0.0		
5	2.9			

LUGEON VALUE: 3.4

Step # 2 — P = 0.66 P_{max}

Pressure of the manometer P m (kPa): 74

Net pressure of injection (kPa): 144

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			

LUGEON VALUE: 0.0

Step # 3 — P = P_{max}

Pressure of the manometer P m (kPa): 111

Net pressure of injection (kPa): 181

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	27.3	47.8	54.4	26.9
2	75.1	50.0		
3	125.1	58.2		
4	183.3	61.7		
5	245.0			

LUGEON VALUE: 149.1

Step # 4 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 74

Net pressure of injection (kPa): 144

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	49.1	49.2	50.4	25.0
2	98.3	49.9		
3	148.2	50.7		
4	198.9	51.9		
5	250.8			

VALEUR LUGEON: 173.8

Step # 5 — P = 0.33 Pmax

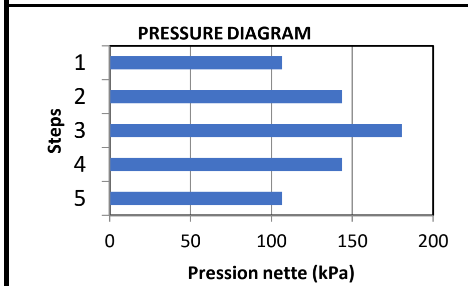
Pressure of the manometer P m (kPa): 37

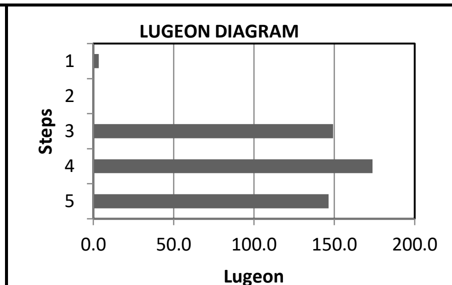
Net pressure of injection (kPa): 107

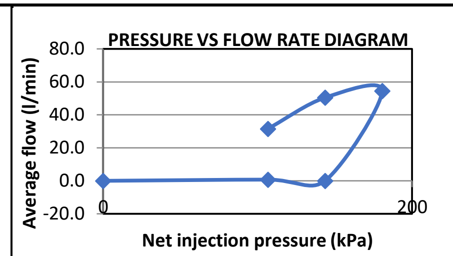
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	31.1	31.3	31.6	15.6
2	62.4	31.4		
3	93.8	32.0		
4	125.8	31.5		
5	157.3			

VALEUR LUGEON: 146.4

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	149.1	Lu
ABSORPTION :	26.9	L/min/m
PERMEABILITY :	2.E-03	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Completed by :	C. Tams	Date :	08/08/2023
Calculated by :	C. Braun	Date :	17/08/2023
Verified by :	M. Patenaude	Date :	31/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

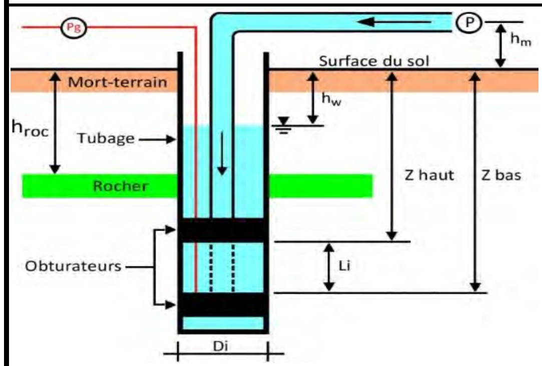
Flow Pattern : ◯ Laminar ◯ Turbulent ◯ Dilatation ◯ Washout ◯ Void Fill ◉ Undertermined ◯ No Flow

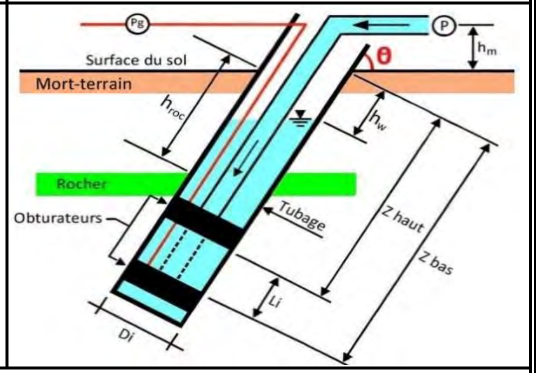
MULTI STEP PRESSURIZED PERMEABILITY TEST

MPE an Englobe company

Project	Snake Lake Reservoir Expansion			Project No. :	1560-193-00
Location :	23BH201B			Borehole no :	23BH201B
Depth :	2.50 to 4.52 m	Dip (θ): 90°	Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*	SCHEMATIC OF THE TEST- INCLINED BOREHOLE*





* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	○ BQ ○ NQ ◉ HQ	Packers :	○ Single ◉ Double
Depth of borehole :	10.00 m	Depth of bedrock (h_{roc}) :	2.20 m
Z top : 2.50 m	Z bot : 4.52 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	6.10 m
Flowmeter used? :	◉ Yes ○ No	Date and time of measuremen	11/08/2023 07:42
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	66 kPa

Max Pressure : $$P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right] \sin\theta$$

Net pressure of injection : P_{nette} = $$P_m + 9{,}81\,(h_m + h_w \sin\theta)$$

Absorption "A" = $\frac{Q}{\text{Ztop - Zbot}}$ Lugeon = $\frac{1000\text{ A}}{P_{net}}$

Step # 1 — P = 0.33 P_{max}

Pressure of the manometer P m (kPa): 33

Net pressure of injection (kPa): 103

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			

LUGEON VALUE: 0.0

Step # 2 — P = 0.66 P_{max}

Pressure of the manometer P m (kPa): 66

Net pressure of injection (kPa): 136

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	1.0	17.8	8.8
2	1.0	5.7		
3	6.7	26.1		
4	32.8	38.4		
5	71.2			

LUGEON VALUE: 65.0

Step # 3 — P = P_{max}

Pressure of the manometer P m (kPa): 99

Net pressure of injection (kPa): 169

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	68.6	68.5	70.3	34.8
2	137.1	70.7		
3	207.8	70.7		
4	278.5	71.2		
5	349.7			

LUGEON VALUE: 206.3

Step # 4 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 66

Net pressure of injection (kPa): 136

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	59.0	59.3	59.7	29.5
2	118.3	59.5		
3	177.8	59.8		
4	237.6	60.1		
5	297.7			

VALEUR LUGEON: 217.8

Step # 5 — P = 0.33 Pmax

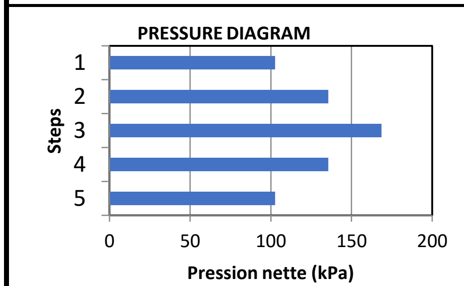
Pressure of the manometer P m (kPa): 33

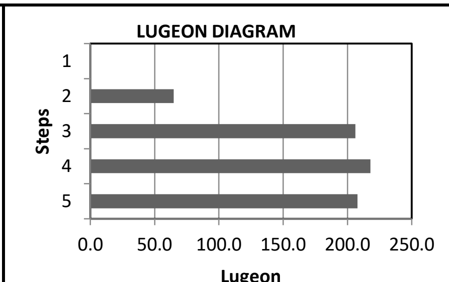
Net pressure of injection (kPa): 103

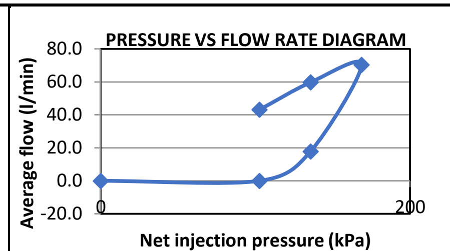
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	43.0	43.0	43.1	21.3
2	86.0	52.0		
3	138.0	34.2		
4	172.2	43.2		
5	215.4			

VALEUR LUGEON: 207.9

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	207.9	Lu
ABSORPTION :	34.8	L/min/m
PERMEABILITY :	3.E-03	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Used 245 Gallons

Completed by :	C. Tams	Date :	11/08/2023
Calculated by :	C. Braun	Date :	17/08/2023
Verified by :	M. Patenaude	Date :	31/08/2023

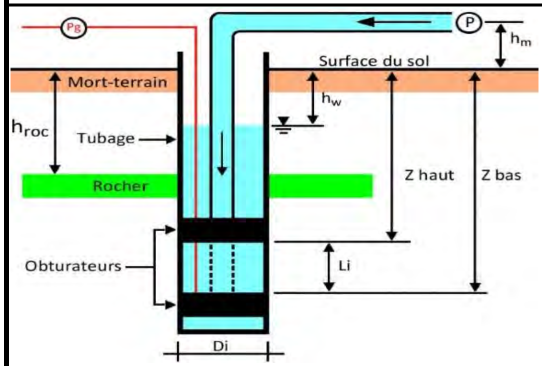
Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

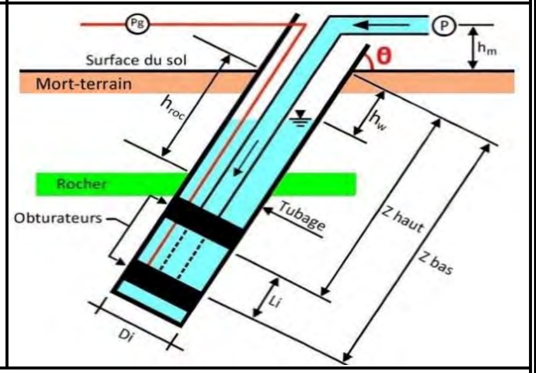
Flow Pattern : ○ Laminar ○ Turbulent ○ Dilatation ○ Washout ◉ Void Fill ○ Undertermined ○ No Flow

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23CH701	Borehole no :	23CH701
Depth :	5.00 to 7.02 m	Dip (θ): 90°	Azimuth : NA
		Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter : ○ BQ ○ NQ ◉ HQ		Packers : ○ Single ◉ Double	
Depth of borehole :	7.02 m	Depth of bedrock (h_{roc}) :	1.40 m
Z top : 5.00 m	Z bot : 7.02 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	4.50 m
Flowmeter used? : ◉ Yes ○ No		Date and time of measuremen	09/08/2023 12:55
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	136 kPa

Max Pressure : $$P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right]\ \sin\theta$$

Net pressure of injection : P_{nette} = $$P_m + 9{,}81\,(h_m + h_w \sin\theta)$$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\ A}{P_{net}}$

Step # 1 — P = 0.33 P_{max}

Pressure of the manometer P m (kPa): 38
Net pressure of injection (kPa): 92

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	27.8	28.7		
2	56.4	29.8		
3	86.2	31.0	30.3	15.0
4	117.2	31.6		
5	148.8			

LUGEON VALUE: 162.9

Step # 2 — P = 0.66 P_{max}

Pressure of the manometer P m (kPa): 76
Net pressure of injection (kPa): 130

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	41.9	42.9		
2	84.8	45.2		
3	130.0	46.1	45.3	22.4
4	176.1	46.8		
5	222.9			

LUGEON VALUE: 172.4

Step # 3 — P = P_{max}

Pressure of the manometer P m (kPa): 114
Net pressure of injection (kPa): 168

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	59.8	60.4		
2	120.2	66.4		
3	186.6	68.3	66.4	32.9
4	254.9	70.4		
5	325.3			

LUGEON VALUE: 195.6

Step # 4 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 76
Net pressure of injection (kPa): 130

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	59.1	61.3		
2	120.4	62.8		
3	183.2	63.1	62.7	31.0
4	246.3	63.4		
5	309.7			

VALEUR LUGEON: 238.7

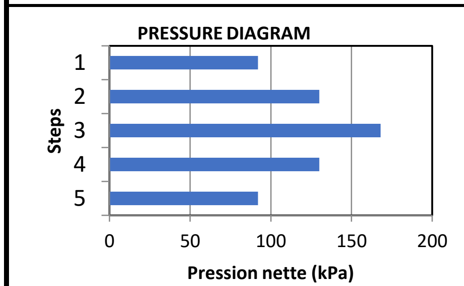
Step # 5 — P = 0.33 Pmax

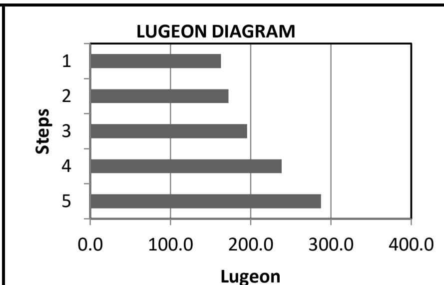
Pressure of the manometer P m (kPa): 38
Net pressure of injection (kPa): 92

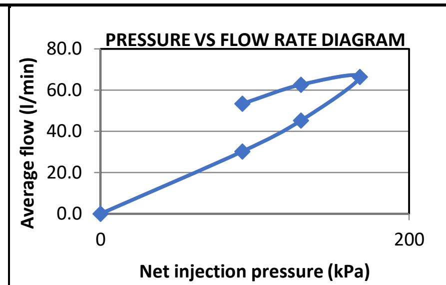
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	52.7	52.9		
2	105.6	54.3		
3	159.9	52.5	53.4	26.4
4	212.4	53.9		
5	266.3			

VALEUR LUGEON: 287.5

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	287.5	Lu
ABSORPTION :	32.9	L/min/m
PERMEABILITY :	4.E-03	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

337 gallons used

Completed by :	C. Tams	Date :	09/08/2023
Calculated by :	C. Braun	Date :	17/08/2023
Verified by :	M. Patenaude	Date :	30/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

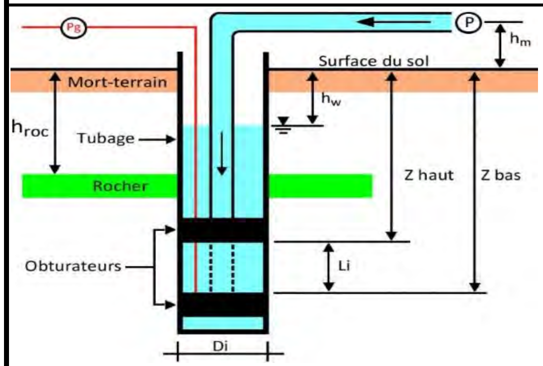
Flow Pattern : ○ Laminar ○ Turbulent ○ Dilatation ◉ Washout ○ Void Fill ○ Undertermined ○ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

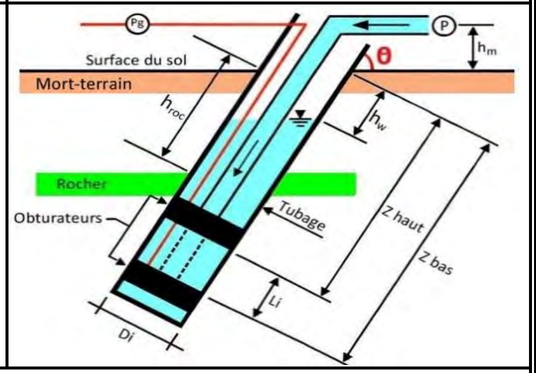
an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23CH702	Borehole no :	23CH702
Depth :	3.50 to 5.52 m Dip (θ): 90° Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	◯ BQ ◯ NQ ◉ HQ	Packers :	◯ Single ◉ Double
Depth of borehole :	5.52 m	Depth of bedrock (h_{roc}) :	1.40 m
Z top : 3.50 m	Z bot : 5.52 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	1.78 m
Flowmeter used? :	◉ Yes ◯ No	Date and time of measuremen	11/08/2023 17:07
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	99 kPa

Max Pressure : $$P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right] \sin\theta$$

Net pressure of injection : P_{nette} = $$P_m + 9{,}81\,(h_m + h_w \sin\theta)$$

Absorption "A" = $\dfrac{Q}{Ztop - Zbot}$ Lugeon = $\dfrac{1000\ A}{P_{net}}$

Step # 1	$P = 0.33\ P_{max}$			
Pressure of the manometer P m (kPa): 21				
Net pressure of injection (kPa): 48				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.2	0.0	0.0	0.0
2	0.2	0.0		
3	0.2	0.0		
4	0.2	0.0		
5	0.2			
LUGEON VALUE:			0.0	

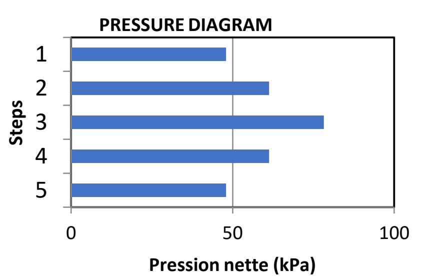
Step # 2	$P = 0.66\ P_{max}$			
Pressure of the manometer P m (kPa): 34				
Net pressure of injection (kPa): 61				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			
LUGEON VALUE:			0.0	

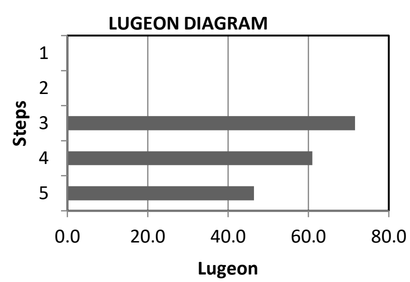
Step # 3	$P = P_{max}$			
Pressure of the manometer P m (kPa): 51				
Net pressure of injection (kPa): 78				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	9.9	11.0	11.3	5.6
2	20.9	11.4		
3	32.3	11.5		
4	43.8	11.4		
5	55.2			
LUGEON VALUE:			71.6	

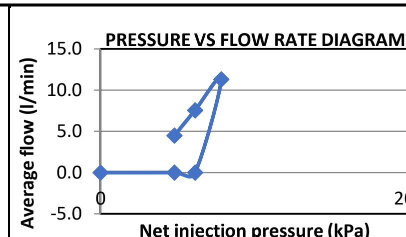
Step # 4	P = 0.66 Pmax			
Pressure of the manometer P m (kPa): 34				
Net pressure of injection (kPa): 61				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	8.2	7.5	7.6	3.7
2	15.7	7.5		
3	23.2	7.5		
4	30.7	7.7		
5	38.4			
VALEUR LUGEON:			61.0	

Step # 5	P = 0.33 Pmax			
Pressure of the manometer P m (kPa): 21				
Net pressure of injection (kPa): 48				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	6.9	4.3	4.5	2.2
2	11.2	4.5		
3	15.7	4.6		
4	20.3	4.6		
5	24.9			
VALEUR LUGEON:			46.4	

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	71.6	Lu
ABSORPTION :	5.6	L/min/m
PERMEABILITY :	9.E-04	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Used 33 gallons, water visible on surface/leaking up.

Completed by :	C. Tams	Date :	11/08/2023
Calculated by :	C. Braun	Date :	18/08/2023
Verified by :	M. Patenaude	Date :	30/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

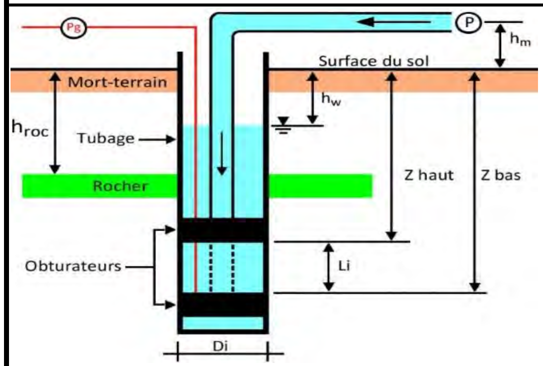
Flow Pattern : ◯ Laminar ◯ Turbulent ◯ Dilatation ◉ Washout ◯ Void Fill ◯ Undetermined ◯ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

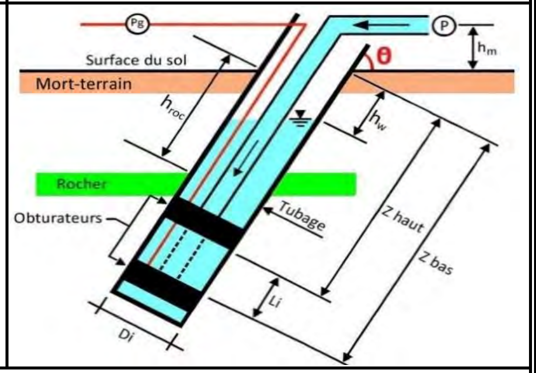
an Englobe company

Project	Snake Lake Reservoir Expansion			Project No. :	1560-193-00
Location :	23CH704			Borehole no :	23CH704
Depth :	7.00 to 9.01 m	Dip (θ): 90°	Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter : ○ BQ ○ NQ ◉ HQ		Packers : ○ Single ◉ Double	
Depth of borehole :	9.01 m	Depth of bedrock (h_{roc}) :	0.30 m
Z top : 7.00 m	Z bot : 9.01 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.01 m	Depth of water (h_w) :	1.50 m
Flowmeter used? : ◉ Yes ○ No		Date and time of measuremen	15/06/2023 09:04
Height - manometer wrt to ground (h_m) :	0.90 m	Maximum pressure (Pmax) :	197 kPa

Max Pressure : $$P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\,h_{roc}\right]\sin\theta$$

Net pressure of injection : P_{nette} = $$P_m + 9,81\,(h_m + h_w \sin\theta)$$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\,A}{P_{net}}$

Step # 1 — P = 0.33 Pmax

Pressure of the manometer P m (kPa): 37
Net pressure of injection (kPa): 61

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			

LUGEON VALUE: 0.0

Step # 2 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 74
Net pressure of injection (kPa): 98

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	1.6	0.8
2	0.0	0.0		
3	0.0	0.0		
4	0.0	6.5		
5	6.5			

LUGEON VALUE: 8.3

Step # 3 — P = P_{max}

Pressure of the manometer P m (kPa): 110
Net pressure of injection (kPa): 134

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	4.7	5.7	6.0	3.0
2	10.4	5.9		
3	16.3	6.0		
4	22.3	6.2		
5	28.5			

LUGEON VALUE: 22.2

Step # 4 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 74
Net pressure of injection (kPa): 98

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	4.2	0.0	0.0	0.0
2	4.2	0.0		
3	4.2	0.0		
4	4.2	0.0		
5	4.2			

VALEUR LUGEON: 0.0

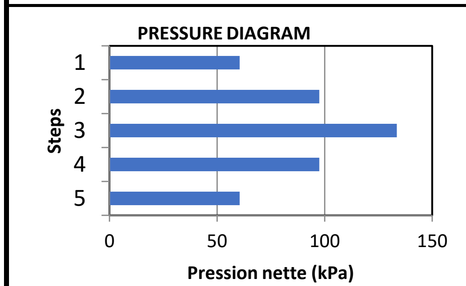
Step # 5 — P = 0.33 Pmax

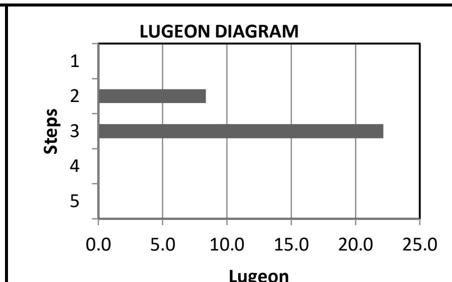
Pressure of the manometer P m (kPa): 37
Net pressure of injection (kPa): 61

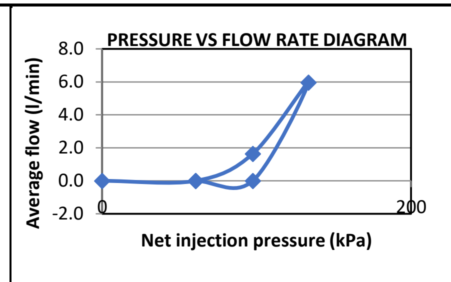
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			

VALEUR LUGEON: 0.0

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	22.2	Lu
ABSORPTION :	3.0	L/min/m
PERMEABILITY :	3.E-04	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Used 11.57 gallons

Completed by :	C. Tams	Date :	15/06/2023
Calculated by :	C. Braun	Date :	18/07/2023
Verified by :	M. Patenaude	Date :	31/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

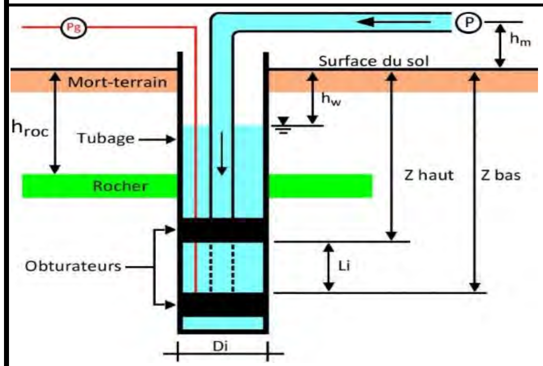
Flow Pattern : ○ Laminar ○ Turbulent ○ Dilatation ○ Washout ○ Void Fill ◉ Undertermined ○ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

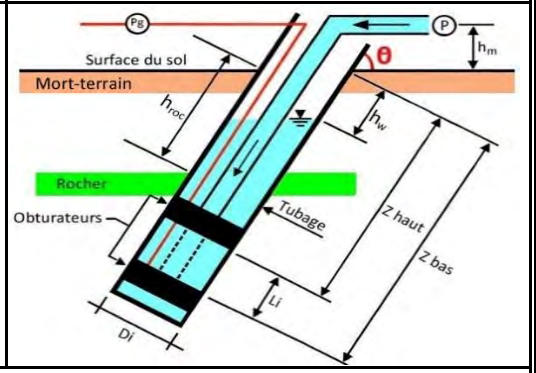
MPE an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23CH705	Borehole no :	23CH705
Depth :	7.00 to 15.26 m	Dip (θ): 90° Azimuth : NA	Test no : 1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	○ BQ ○ NQ ◉ HQ	Packers :	◉ Single ○ Double
Depth of borehole :	15.26 m	Depth of bedrock (h_{roc}) :	1.10 m
Z top : 7.00 m	Z bot : 15.26 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	8.26 m	Depth of water (h_w) :	1.77 m
Flowmeter used? :	◉ Yes ○ No	Date and time of measuremen	12/06/2023 16:50
Height - manometer wrt to ground (h_m) :	0.90 m	Maximum pressure (Pmax) :	267 kPa

Max Pressure : $P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right] \sin\theta$

Net pressure of injection : $P_{nette} = P_m + 9,81\,(h_m + h_w \sin\theta)$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\,A}{P_{net}}$

Step # 1	P = 0.33 P_{max}			
Pressure of the manometer P m (kPa): 50				
Net pressure of injection (kPa): 76				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	58.7	59.6	61.2	7.4
2	118.3	60.2		
3	178.5	60.4		
4	238.9	64.6		
5	303.5			
LUGEON VALUE:	97.2			

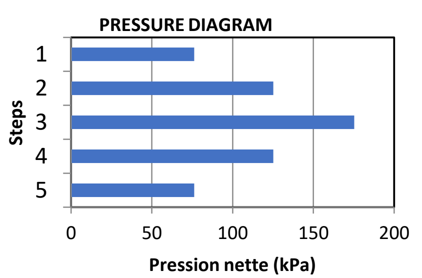
Step # 2	P = 0.66 P_{max}			
Pressure of the manometer P m (kPa): 99				
Net pressure of injection (kPa): 125				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	93.4	94.5	95.5	11.6
2	187.9	95.4		
3	283.3	96.0		
4	379.3	96.0		
5	475.3			
LUGEON VALUE:	92.3			

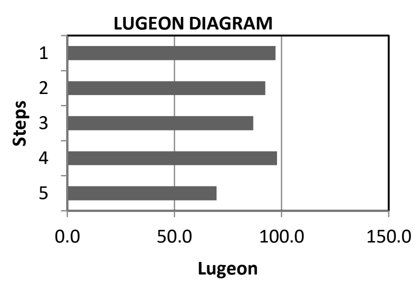
Step # 3	P = P_{max}			
Pressure of the manometer P m (kPa): 149				
Net pressure of injection (kPa): 175				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	125.2	125.7	125.5	15.2
2	250.9	125.5		
3	376.4	125.7		
4	502.1	125.1		
5	627.2			
LUGEON VALUE:	86.7			

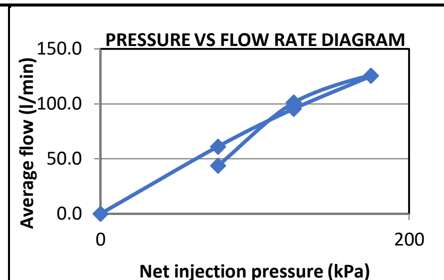
Step # 4	P = 0.66 Pmax			
Pressure of the manometer P m (kPa): 99				
Net pressure of injection (kPa): 125				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	103.4	100.8	101.2	12.2
2	204.2	100.3		
3	304.5	98.4		
4	402.9	105.1		
5	508.0			
VALEUR LUGEON:	97.8			

Step # 5	P = 0.33 Pmax			
Pressure of the manometer P m (kPa): 50				
Net pressure of injection (kPa): 76				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	51.4	50.4	43.8	5.3
2	101.8	48.8		
3	150.6	35.4		
4	186.0	40.6		
5	226.6			
VALEUR LUGEON:	69.6			

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	88.7	Lu
ABSORPTION :	15.2	L/min/m
PERMEABILITY :	1.E-03	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Completed by :	C. Tams	Date :	12/06/2023
Calculated by :	C. Braun	Date :	16/08/2023
Verified by :	M. Patenaude	Date :	30/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

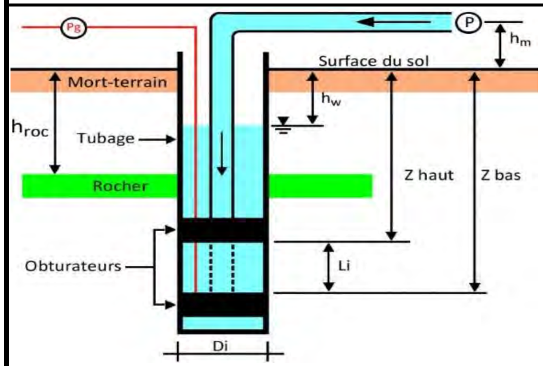
Flow Pattern : ◉ Laminar ○ Turbulent ○ Dilatation ○ Washout ○ Void Fill ○ Undertermined ○ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

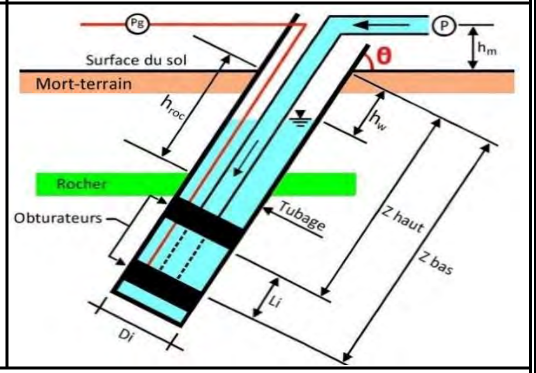
MPE an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23CH709	Borehole no :	23CH709
Depth :	6.00 to 8.02 m	Dip (θ): 90° Azimuth : NA	Test no : 1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	◯ BQ ◯ NQ ◉ HQ	Packers :	◯ Single ◉ Double
Depth of borehole :	8.02 m	Depth of bedrock (h_{roc}) :	4.00 m
Z top : 6.00 m	Z bot : 8.02 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	9.00 m
Flowmeter used? :	◉ Yes ◯ No	Date and time of measuremen	26/06/2023 16:00
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	135 kPa

Max Pressure : $P_{max} = \left[25\left(\frac{z_{bas}+z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right] \sin\theta$

Net pressure of injection : $P_{nette} = P_m + 9{,}81\,(h_m + h_w \sin\theta)$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\,A}{P_{net}}$

Step # 1 — P = 0.33 P_{max}

Pressure of the manometer P m (kPa): 26

Net pressure of injection (kPa): 124

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			

LUGEON VALUE: 0.0

Step # 2 — P = 0.66 P_{max}

Pressure of the manometer P m (kPa): 51

Net pressure of injection (kPa): 149

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	2.0	1.9	2.4	1.2
2	3.9	2.2		
3	6.1	2.0		
4	8.1	3.3		
5	11.4			

LUGEON VALUE: 7.8

Step # 3 — P = P_{max}

Pressure of the manometer P m (kPa): 77

Net pressure of injection (kPa): 175

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	4.8	4.8	5.1	2.5
2	9.5	5.1		
3	14.6	5.2		
4	19.8	5.3		
5	25.1			

LUGEON VALUE: 14.4

Step # 4 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 51

Net pressure of injection (kPa): 149

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	4.4	4.8	5.4	2.7
2	9.2	5.3		
3	14.5	5.5		
4	20.0	6.0		
5	26.0			

VALEUR LUGEON: 17.9

Step # 5 — P = 0.33 Pmax

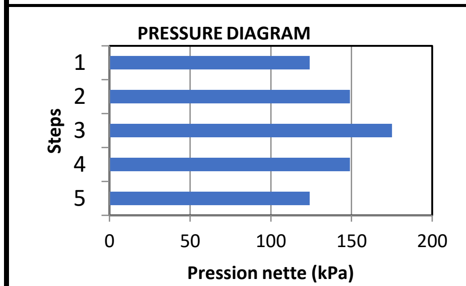
Pressure of the manometer P m (kPa): 26

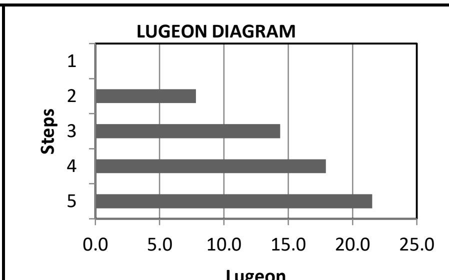
Net pressure of injection (kPa): 124

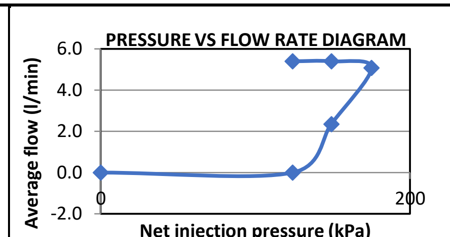
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	5.3	5.1	5.4	2.7
2	10.4	6.3		
3	16.7	4.5		
4	21.2	5.7		
5	26.9			

VALEUR LUGEON: 21.5

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	21.5	Lu
ABSORPTION :	2.5	L/min/m
PERMEABILITY :	3.E-04	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Total of 23.38 gallons used

Completed by :	C. Tams	Date :	26/06/2023
Calculated by :	C. Braun	Date :	16/08/2023
Verified by :	M. Patenaude	Date :	30/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

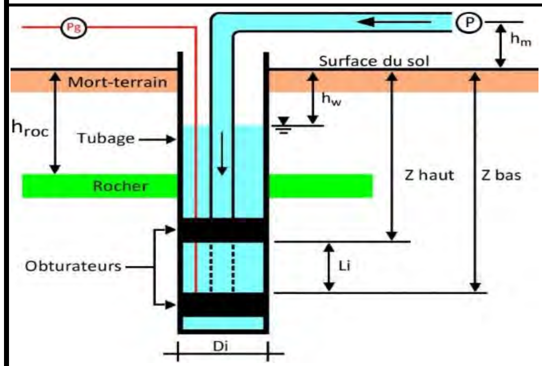
Flow Pattern : ◯ Laminar ◯ Turbulent ◯ Dilatation ◉ Washout ◯ Void Fill ◯ Undertermined ◯ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

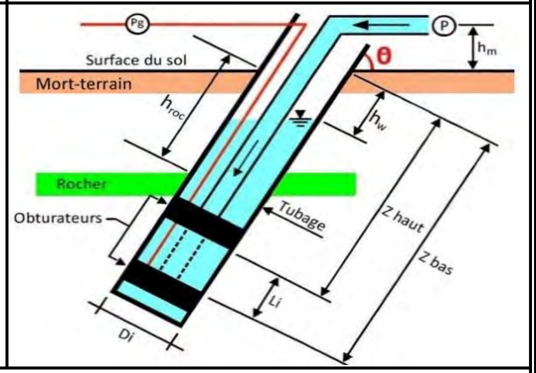
MPE an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23CH711	Borehole no :	23CH711
Depth :	7.50 to 10.80 m Dip (θ): 90° Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	◯ BQ ◯ NQ ◉ HQ	Packers :	◉ Single ◯ Double
Depth of borehole :	10.80 m	Depth of bedrock (h_{roc}) :	2.30 m
Z top : 7.50 m	Z bot : 10.80 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	3.30 m	Depth of water (h_w) :	3.98 m
Flowmeter used? :	◉ Yes ◯ No	Date and time of measuremen	13/06/2023 11:30
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	206 kPa

Max Pressure : $$P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\,h_{roc}\right]\sin\theta$$

Net pressure of injection : P_{nette} = $$P_m + 9,81\,(h_m + h_w \sin\theta)$$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\ A}{P_{net}}$

Step # 1	P = 0.33 P_{max}			
Pressure of the manometer P m (kPa): 48				
Net pressure of injection (kPa): 97				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	2.0	5.6	5.6	1.7
2	7.6	5.6		
3	13.2	5.7		
4	18.9	5.6		
5	24.4			
LUGEON VALUE:	17.6			

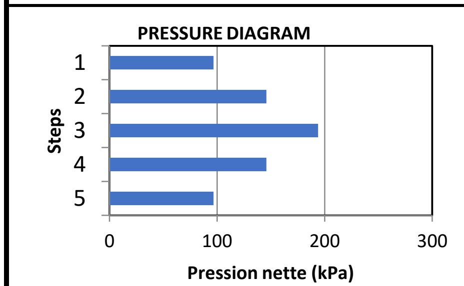
Step # 2	P = 0.66 P_{max}			
Pressure of the manometer P m (kPa): 97				
Net pressure of injection (kPa): 146				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	11.4	10.3	10.5	3.2
2	21.8	10.4		
3	32.1	10.5		
4	42.7	10.7		
5	53.4			
LUGEON VALUE:	21.8			

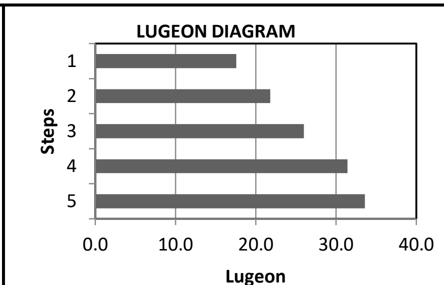
Step # 3	P = P_{max}			
Pressure of the manometer P m (kPa): 145				
Net pressure of injection (kPa): 194				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	15.2	15.3	16.6	5.0
2	30.5	16.1		
3	46.5	15.9		
4	62.4	19.3		
5	81.7			
LUGEON VALUE:	26.0			

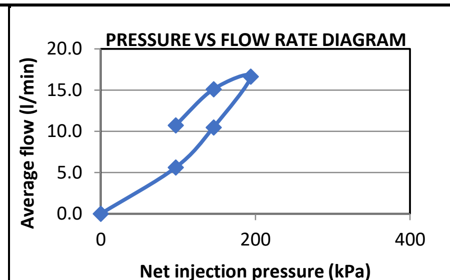
Step # 4	P = 0.66 Pmax			
Pressure of the manometer P m (kPa): 97				
Net pressure of injection (kPa): 146				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	13.4	14.9	15.1	4.6
2	28.3	15.1		
3	43.3	15.2		
4	58.6	15.3		
5	73.8			
VALEUR LUGEON:	31.4			

Step # 5	P = 0.33 Pmax			
Pressure of the manometer P m (kPa): 48				
Net pressure of injection (kPa): 97				
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
5	8.6	10.9	10.7	3.3
6	19.5	10.6		
7	30.1	10.7		
8	40.7	10.8		
9	51.5			
10				
VALEUR LUGEON:	33.6			

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	33.6	Lu
ABSORPTION :	5.0	L/min/m
PERMEABILITY :	4.E-04	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Completed by :	C. Tams	Date :	13/06/2023
Calculated by :	C. Braun	Date :	18/07/2023
Verified by :	M. Patenaude	Date :	31/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

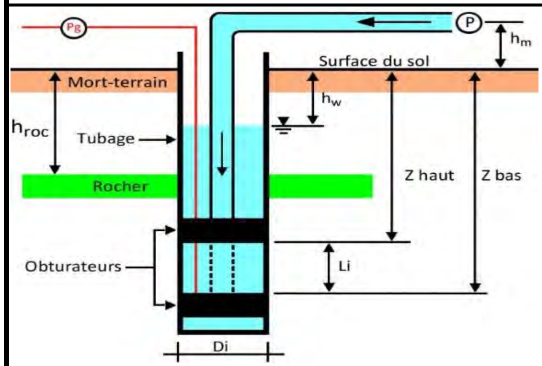
Flow Pattern : ◯ Laminar ◯ Turbulent ◯ Dilatation ◉ Washout ◯ Void Fill ◯ Undertermined ◯ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

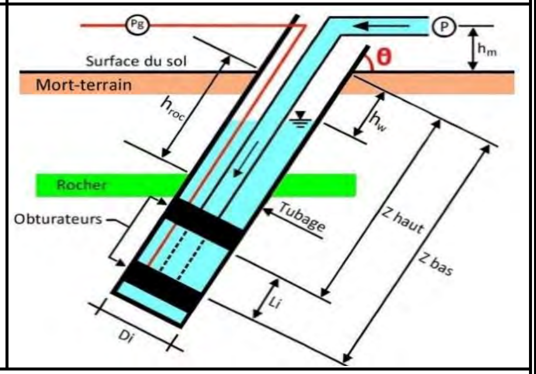
MPE an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23TH02	Borehole no :	23TH02
Depth :	6.00 to 8.02 m Dip (θ): 90° Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter : ◯ BQ ◯ NQ ◉ HQ — Packers : ◯ Single ◉ Double

Depth of borehole :	8.02 m	Depth of bedrock (h_{roc}) :	3.90 m
Z top : 6.00 m	Z bot : 8.02 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	3.70 m
Flowmeter used? : ◉ Yes ◯ No		Date and time of measuremen	08/08/2023 14:56
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	136 kPa

Max Pressure : $P_{max} = \left[25\left(\frac{z_{bas}+z_{haut}}{2} - h_{roc}\right) + 15\,h_{roc}\right]\ \sin\theta$

Net pressure of injection : $P_{nette} = P_m + 9{,}81\,(h_m + h_w \sin\theta)$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\ A}{P_{net}}$

Step # 1 — P = 0.33 P_{max}

Pressure of the manometer P m (kPa): 38
Net pressure of injection (kPa): 84

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	0.0	0.0
2	0.0	0.0		
3	0.0	0.0		
4	0.0	0.0		
5	0.0			

LUGEON VALUE: 0.0

Step # 2 — P = 0.66 P_{max}

Pressure of the manometer P m (kPa): 75
Net pressure of injection (kPa): 121

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	0.0	0.0	1.1	0.6
2	0.0	0.0		
3	0.0	0.1		
4	0.1	4.5		
5	4.5			

LUGEON VALUE: 4.6

Step # 3 — P = P_{max}

Pressure of the manometer P m (kPa): 113
Net pressure of injection (kPa): 159

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	5.6	5.8	6.2	3.1
2	11.4	6.2		
3	17.6	6.3		
4	23.9	6.6		
5	30.5			

LUGEON VALUE: 19.4

Step # 4 — P = 0.66 Pmax

Pressure of the manometer P m (kPa): 75
Net pressure of injection (kPa): 121

Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	5.4	5.6	5.8	2.9
2	11.0	5.7		
3	16.7	5.9		
4	22.6	5.9		
5	28.5			

VALEUR LUGEON: 23.6

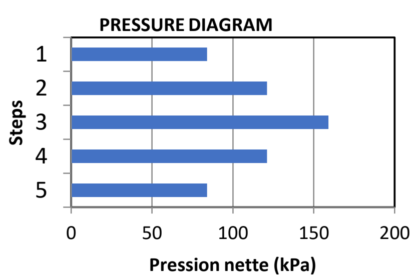
Step # 5 — P = 0.33 Pmax

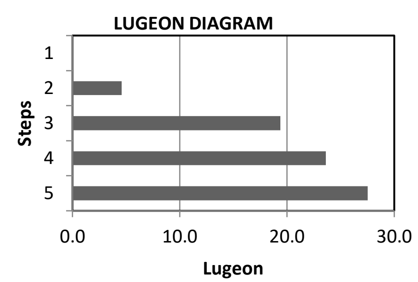
Pressure of the manometer P m (kPa): 38
Net pressure of injection (kPa): 84

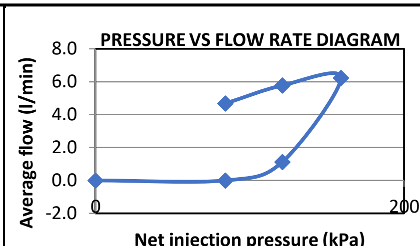
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	4.1	4.5	4.7	2.3
2	8.6	4.6		
3	13.2	4.7		
4	17.9	4.9		
5	22.8			

VALEUR LUGEON: 27.5

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	27.5	Lu
ABSORPTION :	3.1	L/min/m
PERMEABILITY :	4.E-04	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

Used 22.69 gallons

Completed by :	C. Tams	Date :	08/08/2023
Calculated by :	C. Braun	Date :	17/08/2023
Verified by :	M. Patenaude	Date :	30/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

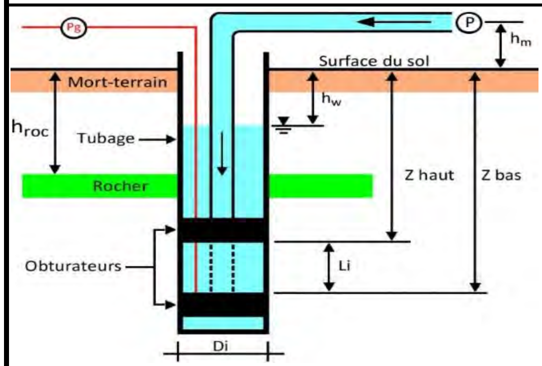
Flow Pattern : ◯ Laminar ◯ Turbulent ◯ Dilatation ◉ Washout ◯ Void Fill ◯ Undertermined ◯ No Flow

MULTI STEP PRESSURIZED PERMEABILITY TEST

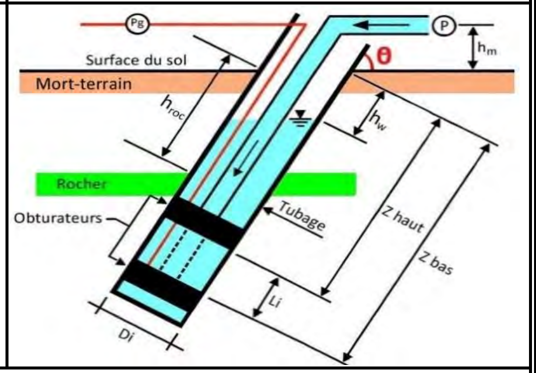
MPE an Englobe company

Project	Snake Lake Reservoir Expansion	Project No. :	1560-193-00
Location :	23TH04	Borehole no :	23TH04
Depth :	6.00 to 8.02 m — Dip (θ): 90° — Azimuth : NA	Test no :	1

SCHEMATIC OF THE TEST - VERTICAL BOREHOLE*



SCHEMATIC OF THE TEST- INCLINED BOREHOLE*



* All depths are measured along the axis of the borehole.

Test parameters

Borehole Diameter :	◯ BQ ◯ NQ ◉ HQ	Packers :	◯ Single ◉ Double
Depth of borehole :	8.02 m	Depth of bedrock (h_{roc}) :	1.50 m
Z top : 6.00 m	Z bot : 8.02 m	Diameter of well (Di) :	9.6 cm
Length of the injection zone (Li) :	2.02 m	Depth of water (h_w) :	3.70 m
Flowmeter used? :	◉ Yes ◯ No	Date and time of measuremen	10/08/2023 13:40
Height - manometer wrt to ground (h_m) :	1.00 m	Maximum pressure (Pmax) :	160 kPa

Max Pressure : $P_{max} = \left[25\left(\frac{Z_{bas}+Z_{haut}}{2} - h_{roc}\right) + 15\, h_{roc}\right] \sin\theta$

Net pressure of injection : $P_{nette} = P_m + 9{,}81\,(h_m + h_w \sin\theta)$

Absorption "A" = $\frac{Q}{Ztop - Zbot}$ Lugeon = $\frac{1000\ A}{P_{net}}$

Step # 1	P = 0.33 P_{max}			
Pressure of the manometer P m (kPa):	39			
Net pressure of injection (kPa):	85			
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	28.2	28.9	32.7	16.2
2	57.1	33.1		
3	90.2	33.3		
4	123.5	35.6		
5	159.1			
LUGEON VALUE:	190.4			

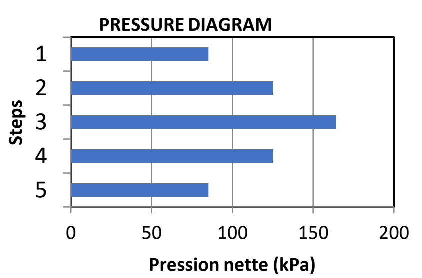
Step # 2	P = 0.66 P_{max}			
Pressure of the manometer P m (kPa):	79			
Net pressure of injection (kPa):	125			
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	49.1	49.2	51.7	25.6
2	98.3	51.9		
3	150.2	52.0		
4	202.2	53.8		
5	256.0			
LUGEON VALUE:	204.7			

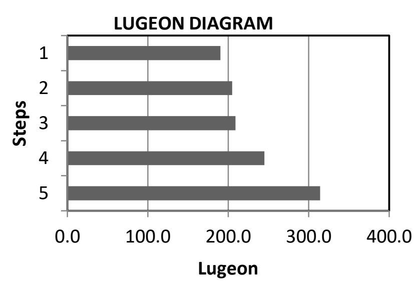
Step # 3	P = P_{max}			
Pressure of the manometer P m (kPa):	118			
Net pressure of injection (kPa):	164			
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	65.8	67.6	69.3	34.3
2	133.4	67.6		
3	201.0	70.5		
4	271.5	71.6		
5	343.1			
LUGEON VALUE:	209.1			

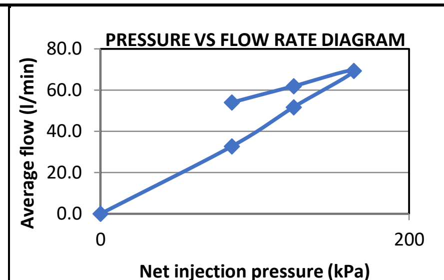
Step # 4	P = 0.66 Pmax			
Pressure of the manometer P m (kPa):	79			
Net pressure of injection (kPa):	125			
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	61.8	61.8	61.9	30.7
2	123.6	62.0		
3	185.6	61.9		
4	247.5	62.0		
5	309.5			
VALEUR LUGEON:	245.0			

Step # 5	P = 0.33 Pmax			
Pressure of the manometer P m (kPa):	39			
Net pressure of injection (kPa):	85			
Time (min)	Counter (L)	Flow-rate (L/min)	Avg. Flow (L/min)	A L/min/m
1	52.8	52.8	54.0	26.7
2	105.6	54.4		
3	160.0	54.5		
4	214.5	54.4		
5	268.9			
VALEUR LUGEON:	314.3			

GRAPHICS







RESULTS OF THE TEST

LUGEON VALUE:	314.3	Lu
ABSORPTION :	34.3	L/min/m
PERMEABILITY :	4.E-03	cm/s

Notes: 1 Lugeon ≈ 1,3 x 10^{-5} cm/s

355 gallons used

Completed by :	C. Tams	Date :	10/08/2023
Calculated by :	C. Braun	Date :	17/08/2023
Verified by :	M. Patenaude	Date :	31/08/2023

Interpretation of the Lugeon test (Interpretation based on Houlsby, 1976 and Quinones-Rozo, 2010)

When the pattern is "undetermined", the Lugeon value presented in the results section corresponds to the value calculated for the test at the highest pressure

Flow Pattern : ◯ Laminar ◯ Turbulent ◯ Dilatation ◉ Washout ◯ Void Fill ◯ Undertermined ◯ No Flow

Appendix D4: Percolation Test Results

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: June 7, 2024
Test Location: P-01

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	18	17	0.0	7.8	7.8	4.9
2	17	16	7.8	17.6	9.8	4.2
3	16	15	17.6	29.1	11.5	3.7
4	15	14	29.1	42.0	12.9	3.5
5	14	13	42.0	57.3	15.3	3.2
6	13	12	57.3	75.4	18.1	2.9

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: June 7, 2024
Test Location: P-02

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	16	15	0.0	1.0	1.0	43.0
2	15	14	1.0	1.9	0.9	50.7
3	14	13	1.9	2.9	1.0	48.5
4	13	12	2.9	3.9	1.0	51.7
5	12	11	3.9	5.0	1.1	50.3
6	11	10	5.0	6.1	1.1	54.0
7	10	9	6.1	7.5	1.4	45.7
8	9	8	7.5	8.7	1.2	57.7
9	8	7	8.7	10.0	1.3	57.9
10	7	6	10.0	11.5	1.5	55.0
11	6	5	11.5	13.0	1.5	60.7
12	5	4	13.0	14.5	1.5	67.6
13	4	3	14.5	16.1	1.6	71.5
14	3	2	16.1	17.8	1.7	77.3
15	2	1	17.8	19.6	1.8	86.8
16	1	0	19.6	21.6	2.0	102.1

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: June 7, 2024
Test Location: P-04

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	20	19	0.0	3.2	3.2	10.9
2	19	18	3.2	8.9	5.7	6.4
3	18	17	8.9	15.1	6.2	6.2
4	17	16	15.1	21.4	6.3	6.5
5	16	15	21.4	28.6	7.2	6.0
6	15	14	28.6	36.6	8.0	5.7
7	14	13	36.6	45.6	9.0	5.4

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: June 7, 2024
Test Location: P-05

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	15	14	0.0	2.5	2.5	18.3
2	14	13	2.5	6.1	3.6	13.5
3	13	12	6.1	9.6	3.5	14.8
4	12	11	9.6	12.6	3.0	18.4
5	11	10	12.6	16.9	4.3	13.8
6	10	9	16.9	21.4	4.5	14.2
7	9	8	21.4	25.9	4.5	15.4
8	8	7	25.9	30.6	4.7	16.0
9	7	6	30.6	35.5	4.9	16.8
10	6	5	35.5	40.5	5.0	18.2

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Location: P-06

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	19	18	0.0	0.9	0.9	40.7
2	18	17	0.9	1.8	0.9	42.8
3	17	16	1.8	2.8	1.0	40.7
4	16	15	2.8	3.9	1.1	39.1
5	15	14	3.9	5.4	1.5	30.4
6	14	13	5.4	7.1	1.7	28.5
7	13	12	7.1	8.6	1.5	34.5
8	12	11	8.6	10.5	1.9	29.1
9	11	10	10.5	12.6	2.1	28.3
10	10	9	12.6	14.7	2.1	30.5
11	9	8	14.7	16.6	1.9	36.4
12	8	7	16.6	18.8	2.2	34.2
13	7	6	18.8	21.2	2.4	34.4
14	6	5	21.2	23.8	2.6	35.0
15	5	4	23.8	26.7	2.9	35.0
16	4	3	26.7	29.8	3.1	36.9

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Location: P-07

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	15	14	0.0	2.5	2.5	18.3
2	14	13	2.5	4.9	2.4	20.2
3	13	12	4.9	7.4	2.5	20.7
4	12	11	7.4	10.5	3.1	17.8
5	11	10	10.5	13.3	2.8	21.2
6	10	9	13.3	16.5	3.2	20.0
7	9	8	16.5	20.0	3.5	19.8
8	8	7	20.0	23.7	3.7	20.4
9	7	6	23.7	27.9	4.2	19.6
10	6	5	27.9	32.3	4.4	20.7
11	5	4	32.3	37.4	5.1	19.9
12	4	3	37.4	42.6	5.2	22.0

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: June 7, 2024
Test Location: P-08

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	20	19	0.0	10.1	10.1	3.4
2	19	18	10.1	32.1	22.0	1.7
3	18	17	32.1	56.4	24.3	1.6
4	17	16	56.4	91.3	34.9	1.2

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Location: P-09

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	19	18	0.0	1.3	1.3	28.2
2	18	17	1.3	3.0	1.7	22.7
3	17	16	3.0	4.8	1.8	22.6
4	16	15	4.8	6.7	1.9	22.7
5	15	14	6.7	8.7	2.0	22.8
6	14	13	8.7	10.7	2.0	24.3
7	13	12	10.7	12.8	2.1	24.6
8	12	11	12.8	15.1	2.3	24.0
9	11	10	15.1	17.5	2.4	24.7
10	10	9	17.5	20.0	2.5	25.6
11	9	8	20.0	22.6	2.6	26.6
12	8	7	22.6	25.6	3.0	25.1
13	7	6	25.6	28.5	2.9	28.4
14	6	5	28.5	31.9	3.4	26.8
15	5	4	31.9	35.5	3.6	28.2
16	4	3	35.5	39.3	3.8	30.1

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Location: P-10

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	15	14	0.0	2.1	2.1	21.7
2	14	13	2.1	4.5	2.4	20.2
3	13	12	4.5	7.1	2.6	19.9
4	12	11	7.1	9.9	2.8	19.7
5	11	10	9.9	12.4	2.5	23.7
6	10	9	12.4	15.4	3.0	21.3
7	9	8	15.4	18.6	3.2	21.6
8	8	7	18.6	22.2	3.6	20.9
9	7	6	22.2	25.9	3.7	22.3
10	6	5	25.9	29.9	4.0	22.8

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Location: P-10

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	15	14	0.0	1.7	1.7	26.8
2	14	13	1.7	4.0	2.3	21.1
3	13	12	4.0	6.9	2.9	17.8
4	12	11	6.9	9.6	2.7	20.5
5	11	10	9.6	12.5	2.9	20.5
6	10	9	12.5	15.9	3.4	18.8
7	9	8	15.9	19.4	3.5	19.8
8	8	7	19.4	23.3	3.9	19.3
9	7	6	23.3	27.5	4.2	19.6
10	6	5	27.5	32.2	4.7	19.4
11	5	4	32.2	37.6	5.4	18.8
12	4	3	37.6	43.2	5.6	20.4
13	3	2	43.2	49.4	6.2	21.2

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: May 22, 2024
Test Location: P-12

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	18	17	0.0	6.1	6.1	6.3
2	17	16	6.1	13.4	7.3	5.6
3	16	15	13.4	20.1	6.7	6.4
4	15	14	20.1	28.3	8.2	5.6
5	14	13	28.3	37.3	9.0	5.4
6	13	12	37.3	46.3	9.0	5.7
7	12	11	46.3	55.8	9.5	5.8
8	11	10	56.8	66.1	9.3	6.4

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: May 22, 2024
Test Location: P-13

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	15	14	0.0	7.2	7.2	6.3
2	14	13	7.2	19.5	12.3	3.9
3	13	12	19.5	32.4	12.9	4.0
4	12	11	32.4	45.7	13.3	4.2
5	11	10	45.7	59.3	13.6	4.4

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: May 22, 2024
Test Location: P-14

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	14	13	0.0	3.8	3.8	12.8
2	13	12	3.8	7.1	3.3	15.7
3	12	11	7.1	12.1	5.0	11.1
4	11	10	12.1	17.2	5.1	11.6
5	10	9	17.2	22.4	5.2	12.3
6	9	8	22.4	28.4	6.0	11.5
7	8	7	28.4	34.2	5.8	13.0

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

a division of Englobe

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: May 22, 2024
Test Location: P-15

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	17	16	0.0	4.1	4.1	9.9
2	16	15	4.1	8.3	4.2	10.2
3	15	14	8.3	12.9	4.6	9.9
4	14	13	12.9	17.8	4.9	9.9
5	13	12	17.8	24.1	6.3	8.2
6	12	11	24.1	30.0	5.9	9.4
7	11	10	30.0	36.5	6.5	9.1
8	10	9	36.5	43.6	7.1	9.0
9	9	8	43.6	50.6	7.0	9.9
10	8	7	50.6	58.5	7.9	9.5

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

MPE a division of Englobe
#40, 1825 Bomford Crescent SW
Medicine Hat, Alberta T1A 5E8
Tel: (403)548- 7773

PERCOLATION TEST

Project: Snake Lake Reservoir Expansion
Project No.: 1560-193-00
Owner: EID
Test Date: May 22, 2024
Test Location: P-16

Borehole radius (cm):	8
Soil class:	Default

Measurement	Start depth of water (cm)	End depth of water (cm)	Start time (*decimal min)	End time (*decimal min)	Perc test result (min/cm)	K_{fs} (mm/hr)
1	15	14	0.0	4.7	4.7	9.7
2	14	13	4.7	10.2	5.5	8.8
3	13	12	10.2	16.8	6.6	7.8
4	12	11	16.8	22.9	6.1	9.1
5	11	10	22.9	29.8	6.9	8.6
6	10	9	29.8	38.8	9.0	7.1
7	9	8	38.8	47.6	8.8	7.9

Seconds	decimal minute
6	0.1
12	0.2
18	0.3
24	0.4
30	0.5
36	0.6
42	0.7
48	0.8
54	0.9

*It will be easiest to take

Appendix D5: Groundwater Monitoring Laboratory Analytical Results

BUREAU VERITAS

Your Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Your C.O.C. #: 1/2

Attention: Cody Braun

MPE ENGINEERING LTD.
SUITE 320
6715 - 8TH STREET NE
CALGARY, AB
CANADA T2E 7H7

Report Date: 2024/08/01
Report #: R3536503
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C452291
Received: 2024/07/12, 08:50

Sample Matrix: Water
Samples Received: 5

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
Alkalinity @25C (pp, total), CO3,HCO3,OH	5	N/A	2024/07/18	AB SOP-00005	SM 24 2320 B m
Biochemical Oxygen Demand	5	2024/07/12	2024/07/17	AB SOP-00017	SM 24 5210B m
BTEX/F1 in Water by HS GC/MS/FID	5	N/A	2024/07/17	AB SOP-00039	CCME CWS/EPA 8260d m
F1-BTEX	1	N/A	2024/07/17		Auto Calc
F1-BTEX	4	N/A	2024/07/18		Auto Calc
Cadmium - low level CCME - Dissolved	5	N/A	2024/07/18		Auto Calc
Cadmium - low level CCME (Total)	5	N/A	2024/07/17		Auto Calc
Chloride/Sulphate by Auto Colourimetry	5	N/A	2024/07/16	AB SOP-00020	SM24-4500-Cl/SO4-E m
COD by Colorimeter	5	N/A	2024/07/16	AB SOP-00016	SM 24 5220D m
Fecal Coliforms (MPN/100mL)	5	2024/07/16	2024/07/17	AB SOP-00089	SM 24 9223 A,B m
Conductivity @25C	5	N/A	2024/07/18	AB SOP-00005	SM 24 2510 B m
CCME Hydrocarbons (F2-F4 in water) (2)	2	2024/07/16	2024/07/16	AB SOP-00037	CCME PHC-CWS m
CCME Hydrocarbons (F2-F4 in water) (2)	3	2024/07/16	2024/07/17	AB SOP-00037	CCME PHC-CWS m
Hardness	4	N/A	2024/07/17		Auto Calc
Hardness	1	N/A	2024/07/18		Auto Calc
Ultra Low Level Mercury - Total (1)	5	2024/07/23	2024/07/23	BBY7SOP-00022	EPA 1631E m
Elements by ICP-Dissolved-Lab Filtered (3)	5	N/A	2024/07/17	AB SOP-00042	EPA 6010d R5 m
Elements by ICP - Total	5	2024/07/16	2024/07/17	AB SOP-00014 / AB SOP-00042	EPA 6010d R5 m
Elements by ICPMS-Dissolved-Lab Filtered (4)	5	N/A	2024/07/17	AB SOP-00043	EPA 6020b R2 m
Elements by ICPMS - Total	5	2024/07/16	2024/07/17	AB SOP-00014 / AB SOP-00043	EPA 6020b R2 m
Ion Balance	5	N/A	2024/07/18		Auto Calc
Sum of cations, anions	4	N/A	2024/07/17		Auto Calc
Sum of cations, anions	1	N/A	2024/07/18		Auto Calc
Methyl Mercury (Total) in Water (1)	4	2024/07/24	2024/07/25	BBY7SOP-00028	EPA 1630 m
Methyl Mercury (Total) in Water (1)	1	2024/07/25	2024/07/26	BBY7SOP-00028	EPA 1630 m
Nitrate and Nitrite	5	N/A	2024/07/17		Auto Calc
NO2 (N); NO2 (N) + NO3 (N) in Water	2	N/A	2024/07/15	AB SOP-00091	SM 24 4500 NO3m
NO2 (N); NO2 (N) + NO3 (N) in Water	3	N/A	2024/07/16	AB SOP-00091	SM 24 4500 NO3m
Nitrate (as N)	5	2024/07/15	2024/07/17		Auto Calc

Your Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Your C.O.C. #: 1/2

Attention: Cody Braun

MPE ENGINEERING LTD.
SUITE 320
6715 - 8TH STREET NE
CALGARY, AB
CANADA T2E 7H7

Report Date: 2024/08/01
Report #: R3536503
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C452291
Received: 2024/07/12, 08:50

Sample Matrix: Water
Samples Received: 5

Analyses	Quantity	Date Extracted	Date Analyzed	Laboratory Method	Analytical Method
pH @25°C (5)	5	N/A	2024/07/18	AB SOP-00005	SM 24 4500-H+B m
Phenols (4-AAP)	5	N/A	2024/07/31	AB SOP-00088	EPA 9066 R0 m
Total Dissolved Solids (Calculated)	5	N/A	2024/07/18		Auto Calc
Total Kjeldahl Nitrogen (Total)	4	N/A	2024/07/17	BBY WI-00033	Auto Calc
Total Kjeldahl Nitrogen (Total)	1	N/A	2024/07/18	BBY WI-00033	Auto Calc
Nitrogen (Total)	2	2024/07/16	2024/07/17	AB SOP-00093	SM 24 4500-N C m
Nitrogen (Total)	3	2024/07/17	2024/07/17	AB SOP-00093	SM 24 4500-N C m
Carbon (Total Organic) (6)	3	N/A	2024/07/19	AB SOP-00087	MMCW 119 1996 m
Carbon (Total Organic) (6)	2	N/A	2024/07/31	AB SOP-00087	MMCW 119 1996 m
Total Phosphorus	5	2024/07/17	2024/07/17	AB SOP-00024	SM 24 4500-P A,B,F m

Remarks:

Bureau Veritas is accredited to ISO/IEC 17025 for specific parameters on scopes of accreditation. Unless otherwise noted, procedures used by Bureau Veritas are based upon recognized Provincial, Federal or US method compendia such as CCME, EPA, APHA or the Quebec Ministry of Environment.

All work recorded herein has been done in accordance with procedures and practices ordinarily exercised by professionals in Bureau Veritas' profession using accepted testing methodologies, quality assurance and quality control procedures (except where otherwise agreed by the client and Bureau Veritas in writing). All data is in statistical control and has met quality control and method performance criteria unless otherwise noted. All method blanks are reported; unless indicated otherwise, associated sample data are not blank corrected. Where applicable, unless otherwise noted, Measurement Uncertainty has not been accounted for when stating conformity to the referenced standard.

Bureau Veritas liability is limited to the actual cost of the requested analyses, unless otherwise agreed in writing. There is no other warranty expressed or implied. Bureau Veritas has been retained to provide analysis of samples provided by the Client using the testing methodology referenced in this report. Interpretation and use of test results are the sole responsibility of the Client and are not within the scope of services provided by Bureau Veritas, unless otherwise agreed in writing. Bureau Veritas is not responsible for the accuracy or any data impacts, that result from the information provided by the customer or their agent.

Solid sample results, except biota, are based on dry weight unless otherwise indicated. Organic analyses are not recovery corrected except for isotope dilution methods.
Results relate to samples tested. When sampling is not conducted by Bureau Veritas, results relate to the supplied samples tested.
This Certificate shall not be reproduced except in full, without the written approval of the laboratory.
Reference Method suffix "m" indicates test methods incorporate validated modifications from specific reference methods to improve performance.
* RPDs calculated using raw data. The rounding of final results may result in the apparent difference.
(1) This test was performed by Bureau Veritas Vancouver, 4606 Canada Way , Burnaby, BC, V5G 1K5

Your Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Your C.O.C. #: 1/2

Attention: Cody Braun
MPE ENGINEERING LTD.
SUITE 320
6715 - 8TH STREET NE
CALGARY, AB
CANADA T2E 7H7

Report Date: 2024/08/01
Report #: R3536503
Version: 1 - Final

CERTIFICATE OF ANALYSIS

BUREAU VERITAS JOB #: C452291

Received: 2024/07/12, 08:50

(2) Silica gel clean up employed.
(3) Dissolved > Total Imbalance: When applicable, Dissolved and Total results were reviewed and data quality meets acceptable levels unless otherwise noted.
(4) Samples were filtered and preserved at the lab. Values may not reflect concentrations at the time of sampling. Dissolved > Total Imbalance: When applicable, Dissolved and Total results were reviewed and data quality meets acceptable levels unless otherwise noted.
(5) The CCME method requires pH to be analysed within 15 minutes of sampling and therefore field analysis is required for compliance. All Laboratory pH analyses in this report are reported past the CCME holding time. Bureau Veritas endeavours to analyze samples as soon as possible after receipt.
(6) TOC present in the sample should be considered as non-purgeable TOC.

Encryption Key

AUTHORIZED REPORT
RAPPORT AUTORISÉ

Bureau Veritas
01 Aug 2024 16:10:28

Please direct all questions regarding this Certificate of Analysis to:
Michelle Rivest (Hospedales), B.Sc., Customer Solutions Representative
Email: michelle.rivest@bureauveritas.com
Phone# (403) 291-3077

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This report has been generated and distributed using a secure automated process.
Bureau Veritas has procedures in place to guard against improper use of the electronic signature and have the required "signatories", as per ISO/IEC 17025, signing the reports. For Service Group specific validation, please refer to the Validation Signatures page if included, otherwise available by request. For Department specific Analyst/Supervisor validation names, please refer to the Test Summary section if included, otherwise available by request. This report is authorized by Scott Cantwell, General Manager responsible for Alberta Environmental laboratory operations.

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

AT1 BTEX AND F1-F4 IN WATER (WATER)

Bureau Veritas ID		CRB798	CRB799	CRB800	CRB801	CRB801	CRB802		
Sampling Date		2024/07/10	2024/07/10	2024/07/10	2024/07/10	2024/07/10	2024/07/10		
COC Number		1/2	1/2	1/2	1/2	1/2	1/2		
	UNITS	700A	700B	702A	702B	702B Lab-Dup	704B	RDL	QC Batch
Ext. Pet. Hydrocarbon									
F2 (C10-C16 Hydrocarbons)	mg/L	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0.10	B438325
F3 (C16-C34 Hydrocarbons)	mg/L	<0.10	<0.10	<0.10	<0.10	N/A	<0.10	0.10	B438325
F4 (C34-C50 Hydrocarbons)	mg/L	<0.20	<0.20	<0.20	<0.20	N/A	<0.20	0.20	B438325
Volatiles									
Benzene	ug/L	<0.40	<0.40	<0.40	<0.40	<0.40	0.43	0.40	B440318
Toluene	ug/L	0.53	0.40	1.4	0.58	0.62	0.66	0.40	B440318
Ethylbenzene	ug/L	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	0.40	B440318
m & p-Xylene	ug/L	<0.80	<0.80	<0.80	<0.80	<0.80	<0.80	0.80	B440318
o-Xylene	ug/L	<0.40	<0.40	<0.40	<0.40	<0.40	<0.40	0.40	B440318
Xylenes (Total)	ug/L	<0.89	<0.89	<0.89	<0.89	N/A	<0.89	0.89	B439135
F1 (C6-C10) - BTEX	ug/L	<100	<100	<100	<100	N/A	<100	100	B439135
F1 (C6-C10)	ug/L	<100	<100	<100	<100	<100	<100	100	B440318
Surrogate Recovery (%)									
1,4-Difluorobenzene (sur.)	%	101	99	102	111	112	112	N/A	B440318
4-Bromofluorobenzene (sur.)	%	92	103	103	113	105	102	N/A	B440318
D4-1,2-Dichloroethane (sur.)	%	103	107	107	116	116	117	N/A	B440318
O-TERPHENYL (sur.)	%	96	97	95	97	N/A	97	N/A	B438325

RDL = Reportable Detection Limit
Lab-Dup = Laboratory Initiated Duplicate
N/A = Not Applicable

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

ROUTINE + DISS. REG. METALS – LAB FILT (WATER)

Bureau Veritas ID		CRB798			CRB799			CRB800		
Sampling Date		2024/07/10			2024/07/10			2024/07/10		
COC Number		1/2			1/2			1/2		
	UNITS	700A	RDL	QC Batch	700B	RDL	QC Batch	702A	RDL	QC Batch
Calculated Parameters										
Anion Sum	meq/L	50	N/A	B439329	230	N/A	B439329	13	N/A	B439329
Cation Sum	meq/L	53	N/A	B439329	230	N/A	B439329	14	N/A	B439329
Hardness (CaCO3)	mg/L	150	0.50	B439320	1700	0.50	B439320	24	0.50	B439320
Ion Balance (% Difference)	%	2.8	N/A	B439325	0.29	N/A	B439325	5.4	N/A	B439325
Nitrate (N)	mg/L	0.022	0.010	B439149	0.35	0.010	B439149	0.93	0.010	B439149
Nitrate (NO3)	mg/L	0.098	0.044	B439148	1.6	0.044	B439148	4.1	0.044	B439148
Nitrite (NO2)	mg/L	0.094	0.033	B439148	0.96	0.033	B439148	<0.033	0.033	B439148
Calculated Total Dissolved Solids	mg/L	3400	25	B439348	16000	100	B439348	770	10	B439348
Elements										
Dissolved Cadmium (Cd)	ug/L	<0.020	0.020	B439137	0.029	0.020	B439137	0.050	0.020	B439137
Misc. Inorganics										
Conductivity	uS/cm	4600	2.0	B442617	17000	2.0	B442591	1200	2.0	B442617
pH	pH	8.09	N/A	B442614	8.23	N/A	B442590	8.82	N/A	B442614
Anions										
Alkalinity (PP as CaCO3)	mg/L	<1.0	1.0	B442612	<1.0	1.0	B442586	19	1.0	B442612
Alkalinity (Total as CaCO3)	mg/L	560	1.0	B442612	830	1.0	B442586	430	1.0	B442612
Bicarbonate (HCO3)	mg/L	680	1.0	B442612	1000	1.0	B442586	480	1.0	B442612
Carbonate (CO3)	mg/L	<1.0	1.0	B442612	<1.0	1.0	B442586	23	1.0	B442612
Hydroxide (OH)	mg/L	<1.0	1.0	B442612	<1.0	1.0	B442586	<1.0	1.0	B442612
Chloride (Cl)	mg/L	99	1.0	B441248	200	5.0	B441248	18	1.0	B441248
Sulphate (SO4)	mg/L	1700	25	B441248	9900	100	B441248	160	5.0	B441248
Nutrients										
Nitrite (N)	mg/L	0.029	0.010	B439660	0.29	0.010	B439660	<0.010	0.010	B439660
Nitrate plus Nitrite (N)	mg/L	0.051	0.010	B439660	0.64	0.010	B439660	0.93	0.010	B439660
Lab Filtered Elements										
Dissolved Aluminum (Al)	mg/L	0.048	0.0030	B442324	<0.0030	0.0030	B442324	0.13	0.0030	B442324
Dissolved Antimony (Sb)	mg/L	0.0034	0.00060	B442324	0.0013	0.00060	B442324	0.0013	0.00060	B442324
Dissolved Arsenic (As)	mg/L	0.0029	0.00020	B442324	0.0018	0.00020	B442324	0.012	0.00020	B442324
Dissolved Barium (Ba)	mg/L	0.035	0.010	B441840	0.022	0.010	B441840	<0.10	0.10	B442248
Dissolved Beryllium (Be)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Boron (B)	mg/L	0.75	0.020	B441840	1.7	0.020	B441840	0.73	0.20	B442248
Dissolved Calcium (Ca)	mg/L	44	0.30	B441840	350	0.30	B441840	9.4	3.0	B442248

RDL = Reportable Detection Limit
N/A = Not Applicable

Bureau Veritas Calgary: 2021 - 41st Avenue N.E. T2E 6P2 Telephone (403) 291-3077 Fax (403) 291-9468

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

ROUTINE + DISS. REG. METALS – LAB FILT (WATER)

Bureau Veritas ID		CRB798			CRB799			CRB800		
Sampling Date		2024/07/10			2024/07/10			2024/07/10		
COC Number		1/2			1/2			1/2		
	UNITS	700A	RDL	QC Batch	700B	RDL	QC Batch	702A	RDL	QC Batch
Dissolved Chromium (Cr)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Cobalt (Co)	mg/L	0.00048	0.00030	B442324	0.0079	0.00030	B442324	0.0011	0.00030	B442324
Dissolved Copper (Cu)	mg/L	0.0025	0.0010	B442324	0.0098	0.0010	B442324	0.0052	0.0010	B442324
Dissolved Iron (Fe)	mg/L	<0.060	0.060	B441840	<0.060	0.060	B441840	<0.60	0.60	B442248
Dissolved Lead (Pb)	mg/L	0.00028	0.00020	B442324	<0.00020	0.00020	B442324	0.0021	0.00020	B442324
Dissolved Lithium (Li)	mg/L	0.36	0.020	B441840	2.5	0.020	B441840	<0.20	0.20	B442248
Dissolved Magnesium (Mg)	mg/L	11	0.20	B441840	190	0.20	B441840	<2.0	2.0	B442248
Dissolved Manganese (Mn)	mg/L	<0.0040	0.0040	B441840	0.84	0.0040	B441840	<0.040	0.040	B442248
Dissolved Molybdenum (Mo)	mg/L	0.021	0.00020	B442324	0.014	0.00020	B442324	0.033	0.00020	B442324
Dissolved Nickel (Ni)	mg/L	0.014	0.00050	B442324	0.018	0.00050	B442324	0.0087	0.00050	B442324
Dissolved Phosphorus (P)	mg/L	<0.10	0.10	B441840	<0.10	0.10	B441840	<1.0	1.0	B442248
Dissolved Potassium (K)	mg/L	5.7	0.30	B441840	14	0.30	B441840	<3.0	3.0	B442248
Dissolved Selenium (Se)	mg/L	0.0015	0.00020	B442324	0.0018	0.00080	B442324	0.0010	0.00020	B442324
Dissolved Silicon (Si)	mg/L	2.4	0.50	B441840	3.6	0.50	B441840	<5.0	5.0	B442248
Dissolved Silver (Ag)	mg/L	<0.00010	0.00010	B442324	<0.00010	0.00010	B442324	<0.00010	0.00010	B442324
Dissolved Sodium (Na)	mg/L	1100	2.5	B441840	4400	5.0	B441840	310	5.0	B442248
Dissolved Strontium (Sr)	mg/L	0.62	0.020	B441840	7.6	0.20	B441840	0.43	0.20	B442248
Dissolved Sulphur (S)	mg/L	640	1.0	B441840	3400	2.0	B441840	61	2.0	B442248
Dissolved Thallium (Tl)	mg/L	<0.00020	0.00020	B442324	<0.00020	0.00020	B442324	<0.00020	0.00020	B442324
Dissolved Tin (Sn)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Titanium (Ti)	mg/L	0.0073	0.0010	B442324	<0.0010	0.0010	B442324	0.013	0.0010	B442324
Dissolved Uranium (U)	mg/L	0.0062	0.00010	B442324	0.0016	0.00010	B442324	0.0049	0.00010	B442324
Dissolved Vanadium (V)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324	0.0018	0.0010	B442324
Dissolved Zinc (Zn)	mg/L	<0.0030	0.0030	B442324	0.0057	0.0030	B442324	<0.0030	0.0030	B442324
RDL = Reportable Detection Limit										

Bureau Veritas Calgary: 2021 - 41st Avenue N.E. T2E 6P2 Telephone (403) 291-3077 Fax (403) 291-9468

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

ROUTINE + DISS. REG. METALS – LAB FILT (WATER)

Bureau Veritas ID		CRB801			CRB802		
Sampling Date		2024/07/10			2024/07/10		
COC Number		1/2			1/2		
	UNITS	**702B**	**RDL**	**QC Batch**	**704B**	**RDL**	**QC Batch**
Calculated Parameters							
Anion Sum	meq/L	26	N/A	B439329	92	N/A	B439329
Cation Sum	meq/L	28	N/A	B439329	99	N/A	B439329
Hardness (CaCO3)	mg/L	39	0.50	B439320	460	0.50	B439320
Ion Balance (% Difference)	%	4.2	N/A	B439325	3.7	N/A	B439325
Nitrate (N)	mg/L	0.073	0.010	B439149	0.13	0.010	B439149
Nitrate (NO3)	mg/L	0.32	0.044	B439148	0.56	0.044	B439148
Nitrite (NO2)	mg/L	0.10	0.033	B439148	0.22	0.033	B439148
Calculated Total Dissolved Solids	mg/L	1600	10	B439348	6300	51	B439348
Elements							
Dissolved Cadmium (Cd)	ug/L	<0.020	0.020	B439137	0.025	0.020	B439137
Misc. Inorganics							
Conductivity	uS/cm	2600	2.0	B442617	8100	2.0	B442591
pH	pH	8.69	N/A	B442614	8.32	N/A	B442590
Anions							
Alkalinity (PP as CaCO3)	mg/L	19	1.0	B442612	2.6	1.0	B442586
Alkalinity (Total as CaCO3)	mg/L	560	1.0	B442612	490	1.0	B442586
Bicarbonate (HCO3)	mg/L	640	1.0	B442612	590	1.0	B442586
Carbonate (CO3)	mg/L	23	1.0	B442612	3.1	1.0	B442586
Hydroxide (OH)	mg/L	<1.0	1.0	B442612	<1.0	1.0	B442586
Chloride (Cl)	mg/L	250	5.0	B441248	470	5.0	B441248
Sulphate (SO4)	mg/L	370	5.0	B441248	3300	50	B449635
Nutrients							
Nitrite (N)	mg/L	0.030	0.010	B439660	0.067	0.010	B439660
Nitrate plus Nitrite (N)	mg/L	0.10	0.010	B439660	0.19	0.010	B439660
Lab Filtered Elements							
Dissolved Aluminum (Al)	mg/L	0.23	0.0030	B442324	0.0086	0.0030	B442324
Dissolved Antimony (Sb)	mg/L	0.0011	0.00060	B442324	0.00074	0.00060	B442324
Dissolved Arsenic (As)	mg/L	0.0062	0.00020	B442324	0.0017	0.00020	B442324
Dissolved Barium (Ba)	mg/L	0.097	0.010	B441840	0.073	0.010	B441840
Dissolved Beryllium (Be)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Boron (B)	mg/L	0.60	0.020	B441840	0.66	0.020	B441840
Dissolved Calcium (Ca)	mg/L	11	0.30	B441840	140	0.30	B441840

RDL = Reportable Detection Limit
N/A = Not Applicable

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ROUTINE + DISS. REG. METALS – LAB FILT (WATER)

Bureau Veritas ID		CRB801			CRB802		
Sampling Date		2024/07/10			2024/07/10		
COC Number		1/2			1/2		
	UNITS	702B	RDL	QC Batch	704B	RDL	QC Batch
Dissolved Chromium (Cr)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Cobalt (Co)	mg/L	0.0012	0.00030	B442324	0.0051	0.00030	B442324
Dissolved Copper (Cu)	mg/L	0.0015	0.0010	B442324	0.0035	0.0010	B442324
Dissolved Iron (Fe)	mg/L	0.096	0.060	B441840	<0.060	0.060	B441840
Dissolved Lead (Pb)	mg/L	0.00022	0.00020	B442324	<0.00020	0.00020	B442324
Dissolved Lithium (Li)	mg/L	0.12	0.020	B441840	0.60	0.020	B441840
Dissolved Magnesium (Mg)	mg/L	3.0	0.20	B441840	28	0.20	B441840
Dissolved Manganese (Mn)	mg/L	0.021	0.0040	B441840	0.39	0.0040	B441840
Dissolved Molybdenum (Mo)	mg/L	0.052	0.00020	B448159	0.0091	0.00020	B442324
Dissolved Nickel (Ni)	mg/L	0.0094	0.00050	B442324	0.018	0.00050	B442324
Dissolved Phosphorus (P)	mg/L	<0.10	0.10	B441840	<0.10	0.10	B441840
Dissolved Potassium (K)	mg/L	3.1	0.30	B441840	7.9	0.30	B441840
Dissolved Selenium (Se)	mg/L	0.0013	0.00020	B442324	0.0010	0.00080	B442324
Dissolved Silicon (Si)	mg/L	2.4	0.50	B441840	4.0	0.50	B441840
Dissolved Silver (Ag)	mg/L	<0.00010	0.00010	B442324	0.00013	0.00010	B442324
Dissolved Sodium (Na)	mg/L	630	2.5	B441840	2100	5.0	B441840
Dissolved Strontium (Sr)	mg/L	0.18	0.020	B441840	2.1	0.020	B441840
Dissolved Sulphur (S)	mg/L	150	0.20	B441840	1200	2.0	B441840
Dissolved Thallium (Tl)	mg/L	<0.00020	0.00020	B442324	<0.00020	0.00020	B442324
Dissolved Tin (Sn)	mg/L	<0.0010	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Titanium (Ti)	mg/L	0.018	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Uranium (U)	mg/L	0.013	0.00010	B442324	0.0099	0.00010	B442324
Dissolved Vanadium (V)	mg/L	0.0024	0.0010	B442324	<0.0010	0.0010	B442324
Dissolved Zinc (Zn)	mg/L	<0.0030	0.0030	B442324	<0.0030	0.0030	B442324
RDL = Reportable Detection Limit							

TOTAL KJELDAHL NITROGEN (TOTAL)

Bureau Veritas ID		CRB798			CRB799		CRB800		
Sampling Date		2024/07/10			2024/07/10		2024/07/10		
COC Number		1/2			1/2		1/2		
	UNITS	700A	RDL	QC Batch	700B	QC Batch	702A	RDL	QC Batch
Calculated Parameters									
Total Total Kjeldahl Nitrogen (Calc)	mg/L	29.2	2.0	B438742	9.93	B438742	0.55	0.20	B438742
Nutrients									
Total Nitrogen (N)	mg/L	29 (1)	2.0	B442074	11 (1)	B440959	1.5 (1)	0.20	B442074

RDL = Reportable Detection Limit
(1) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Bureau Veritas ID		CRB801			CRB802		
Sampling Date		2024/07/10			2024/07/10		
COC Number		1/2			1/2		
	UNITS	702B	RDL	QC Batch	704B	RDL	QC Batch
Calculated Parameters							
Total Total Kjeldahl Nitrogen (Calc)	mg/L	4.8	2.0	B438742	5.22	0.20	B438742
Nutrients							
Total Nitrogen (N)	mg/L	4.9 (1)	2.0	B440959	5.4 (1)	0.20	B442069

RDL = Reportable Detection Limit
(1) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

REGULATED METALS (CCME/AT1) - TOTAL

Bureau Veritas ID		CRB798		CRB799		CRB800		CRB801		
Sampling Date		2024/07/10		2024/07/10		2024/07/10		2024/07/10		
COC Number		1/2		1/2		1/2		1/2		
	UNITS	700A	RDL	700B	RDL	702A	RDL	702B	RDL	QC Batch
Elements										
Total Cadmium (Cd)	ug/L	6.6	0.80	0.20	0.020	0.21	0.020	0.67	0.40	B438477
Total Aluminum (Al)	mg/L	510	0.12	15	0.0030	10	0.0030	110	0.060	B440834
Total Antimony (Sb)	mg/L	<0.024	0.024	0.0013	0.00060	0.00084	0.00060	<0.012	0.012	B440834
Total Arsenic (As)	mg/L	0.58	0.0080	0.016	0.00020	0.016	0.00020	0.067	0.0040	B440834
Total Barium (Ba)	mg/L	2.6	0.10	0.47	0.20	0.22	0.010	1.8	0.20	B440842
Total Beryllium (Be)	mg/L	0.048	0.040	0.0013	0.0010	<0.0010	0.0010	<0.020	0.020	B440834
Total Boron (B)	mg/L	1.1	0.20	2.2	0.40	0.58	0.020	0.80	0.40	B440842
Total Calcium (Ca)	mg/L	720	3.0	380	6.0	5.2	0.30	75	6.0	B440842
Total Chromium (Cr)	mg/L	0.62	0.040	0.019	0.0010	0.010	0.0010	0.13	0.020	B440834
Total Cobalt (Co)	mg/L	0.56	0.012	0.019	0.00030	0.0083	0.00030	0.081	0.0060	B440834
Total Copper (Cu)	mg/L	1.1	0.040	0.028	0.0010	0.032	0.0010	0.21	0.020	B440834
Total Iron (Fe)	mg/L	1300	0.60	30	1.2	12	0.060	190	1.2	B440842
Total Lead (Pb)	mg/L	1.0	0.0080	0.023	0.00020	0.019	0.00020	0.13	0.0040	B440834
Total Lithium (Li)	mg/L	1.4	0.20	2.8	0.40	0.086	0.020	<0.40	0.40	B440842
Total Magnesium (Mg)	mg/L	300	2.0	210	4.0	2.6	0.20	44	4.0	B440842
Total Manganese (Mn)	mg/L	28	0.040	1.3	0.080	0.14	0.0040	2.2	0.080	B440842
Total Molybdenum (Mo)	mg/L	0.021	0.0080	0.014	0.00020	0.031	0.00020	0.021	0.0040	B440834
Total Nickel (Ni)	mg/L	1.3	0.020	0.043	0.00050	0.022	0.00050	0.20	0.010	B440834
Total Phosphorus (P)	mg/L	41	1.0	<2.0	2.0	0.69	0.10	3.0	2.0	B440842
Total Potassium (K)	mg/L	83	3.0	16	6.0	3.1	0.30	20	6.0	B440842
Total Selenium (Se)	mg/L	0.016	0.0080	0.0023	0.00080	0.0013	0.00020	<0.0040	0.0040	B440834
Total Silicon (Si)	mg/L	190	5.0	31	10	20	0.50	180	10	B440842
Total Silver (Ag)	mg/L	0.0056	0.0040	0.00014	0.00010	0.00014	0.00010	<0.0020	0.0020	B440834
Total Sodium (Na)	mg/L	1600	5.0	4600	10	270	0.50	690	10	B440842
Total Strontium (Sr)	mg/L	6.2	0.20	8.1	0.40	0.098	0.020	1.0	0.40	B440842
Total Sulphur (S)	mg/L	790	2.0	3500	4.0	51	0.20	180	4.0	B440842
Total Thallium (Tl)	mg/L	0.0090	0.0080	<0.00020	0.00020	<0.00020	0.00020	<0.0040	0.0040	B440834
Total Tin (Sn)	mg/L	<0.040	0.040	0.0012	0.0010	0.0021	0.0010	<0.020	0.020	B440834
Total Titanium (Ti)	mg/L	0.98	0.040	0.17	0.0010	0.11	0.0010	0.38	0.020	B440834
Total Uranium (U)	mg/L	0.14	0.0040	0.0046	0.00010	0.0069	0.00010	0.026	0.0020	B440834
Total Vanadium (V)	mg/L	0.75	0.040	0.034	0.0010	0.025	0.0010	0.22	0.020	B440834
Total Zinc (Zn)	mg/L	8.9	0.12	0.16	0.0030	0.084	0.0030	1.3	0.060	B440834
RDL = Reportable Detection Limit										

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REGULATED METALS (CCME/AT1) - TOTAL

Bureau Veritas ID		CRB802		
Sampling Date		2024/07/10		
COC Number		1/2		
	UNITS	704B	RDL	QC Batch
Elements				
Total Cadmium (Cd)	ug/L	0.27	0.020	B438477
Total Aluminum (Al)	mg/L	27	0.0030	B440834
Total Antimony (Sb)	mg/L	<0.00060	0.00060	B440834
Total Arsenic (As)	mg/L	0.027	0.00020	B440834
Total Barium (Ba)	mg/L	0.80	0.10	B440842
Total Beryllium (Be)	mg/L	0.0021	0.0010	B440834
Total Boron (B)	mg/L	0.82	0.20	B440842
Total Calcium (Ca)	mg/L	150	3.0	B440842
Total Chromium (Cr)	mg/L	0.034	0.0010	B440834
Total Cobalt (Co)	mg/L	0.026	0.00030	B440834
Total Copper (Cu)	mg/L	0.052	0.0010	B440834
Total Iron (Fe)	mg/L	54	0.60	B440842
Total Lead (Pb)	mg/L	0.042	0.00020	B440834
Total Lithium (Li)	mg/L	0.73	0.20	B440842
Total Magnesium (Mg)	mg/L	40	2.0	B440842
Total Manganese (Mn)	mg/L	1.1	0.040	B440842
Total Molybdenum (Mo)	mg/L	0.0075	0.00020	B440834
Total Nickel (Ni)	mg/L	0.064	0.00050	B440834
Total Phosphorus (P)	mg/L	1.0	1.0	B440842
Total Potassium (K)	mg/L	11	3.0	B440842
Total Selenium (Se)	mg/L	0.0016	0.00080	B440834
Total Silicon (Si)	mg/L	52	5.0	B440842
Total Silver (Ag)	mg/L	0.00029	0.00010	B440834
Total Sodium (Na)	mg/L	2000	5.0	B440842
Total Strontium (Sr)	mg/L	2.5	0.20	B440842
Total Sulphur (S)	mg/L	1200	2.0	B440842
Total Thallium (Tl)	mg/L	<0.00020	0.00020	B440834
Total Tin (Sn)	mg/L	0.0014	0.0010	B440834
Total Titanium (Ti)	mg/L	0.19	0.0010	B440834
Total Uranium (U)	mg/L	0.015	0.00010	B440834
Total Vanadium (V)	mg/L	0.060	0.0010	B440834
Total Zinc (Zn)	mg/L	0.24	0.0030	B440834
RDL = Reportable Detection Limit				

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

RESULTS OF CHEMICAL ANALYSES OF WATER

Bureau Veritas ID		CRB798			CRB799	CRB800		
Sampling Date		2024/07/10			2024/07/10	2024/07/10		
COC Number		1/2			1/2	1/2		
	UNITS	**700A**	**RDL**	**QC Batch**	**700B**	**702A**	**RDL**	**QC Batch**
Demand Parameters								
Biochemical Oxygen Demand	mg/L	43 (1)	4.0	B435742	8.1	18	2.0	B435742
Chemical Oxygen Demand	mg/L	132	10	B440137	95	114	10	B440137
Misc. Inorganics								
Total Organic Carbon (C)	mg/L	10	0.50	B444913	7.3	5.2	0.50	B460844
Microbiological Param.								
Fecal Coliforms	MPN/100mL	<100 (2)	100	B440718	<5.0 (2)	<5.0 (2)	5.0	B440718
Nutrients								
Total Phosphorus (P)	mg/L	150	3.0	B442316	0.50 (3)	0.65 (3)	0.030	B442316
Misc. Organics								
Phenols	mg/L	<0.0015	0.0015	B460874	<0.0015	<0.0015	0.0015	B460874

RDL = Reportable Detection Limit
(1) Detection limit raised based on sample volume used for analysis.
(2) Sample was past hold time when received.
Detection limit raised due to matrix interference.
(3) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Bureau Veritas ID		CRB801			CRB802		
Sampling Date		2024/07/10			2024/07/10		
COC Number		1/2			1/2		
	UNITS	**702B**	**RDL**	**QC Batch**	**704B**	**RDL**	**QC Batch**
Demand Parameters							
Biochemical Oxygen Demand	mg/L	32 (1)	4.0	B435742	14	2.0	B435742
Chemical Oxygen Demand	mg/L	494 (2)	50	B440137	182	10	B440137
Misc. Inorganics							
Total Organic Carbon (C)	mg/L	10	0.50	B444913	11	0.50	B444913
Microbiological Param.							
Fecal Coliforms	MPN/100mL	<100 (3)	100	B440718	<10 (3)	10	B440718
Nutrients							
Total Phosphorus (P)	mg/L	3.0 (4)	0.30	B442316	1.3 (4)	0.030	B442316
Misc. Organics							
Phenols	mg/L	<0.0015	0.0015	B460874	<0.0015	0.0015	B461114

RDL = Reportable Detection Limit
(1) Detection limit raised based on sample volume used for analysis.
(2) Detection limits raised due to sample matrix.
(3) Sample was past hold time when received.
Detection limit raised due to matrix interference.
(4) Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

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MERCURY BY COLD VAPOR (WATER)

Bureau Veritas ID		CRB798		CRB799		CRB800		CRB801		
Sampling Date		2024/07/10		2024/07/10		2024/07/10		2024/07/10		
COC Number		1/2		1/2		1/2		1/2		
	UNITS	**700A**	**RDL**	**700B**	**RDL**	**702A**	**RDL**	**702B**	**RDL**	**QC Batch**
Elements										
Total Methyl Mercury	ng/L	0.42	0.050	<0.050	0.050	<0.050	0.050	<0.050	0.050	B452255
Total Mercury (Hg)	ug/L	0.408 (1)	0.010	0.0401 (1)	0.0010	0.00505 (1)	0.00050	0.0944 (1)	0.0050	B448939

RDL = Reportable Detection Limit
(1) Detection limits raised due to matrix interference.

Bureau Veritas ID		CRB802		
Sampling Date		2024/07/10		
COC Number		1/2		
	UNITS	**704B**	**RDL**	**QC Batch**
Elements				
Total Methyl Mercury	ng/L	0.071	0.050	B453401
Total Mercury (Hg)	ug/L	0.0362 (1)	0.0010	B448939

RDL = Reportable Detection Limit
(1) Detection limits raised due to matrix interference.

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

GENERAL COMMENTS

Each temperature is the average of up to three cooler temperatures taken at receipt

Package 1	8.7°C

Sample CRB798 [700A] : Sample was analyzed past method specified hold time for NO2 (N); NO2 (N) + NO3 (N) in Water. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample CRB799 [700B] : NO2 (N); NO2 (N) + NO3 (N) in Water completed within five days of sampling. Data is satisfactory for compliance purposes.

Sample CRB800 [702A] : NO2 (N); NO2 (N) + NO3 (N) in Water completed within five days of sampling. Data is satisfactory for compliance purposes.

Sample CRB801 [702B] : Sample was analyzed past method specified hold time for NO2 (N); NO2 (N) + NO3 (N) in Water. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

Sample CRB802 [704B] : Sample was analyzed past method specified hold time for NO2 (N); NO2 (N) + NO3 (N) in Water. Exceedance of hold time increases the uncertainty of test results but does not necessarily imply that results are compromised.

ROUTINE + DISS. REG. METALS – LAB FILT (WATER) Comments

Sample CRB800 [702A] NO2 (N); NO2 (N) + NO3 (N) in Water: Sample was originally processed within hold time. Data quality required investigation. Re-analysis was completed past recommended hold time.
Sample CRB800 [702A] Elements by ICP-Dissolved-Lab Filtered: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.
Sample CRB801 [702B] NO2 (N); NO2 (N) + NO3 (N) in Water: Sample was originally processed within hold time. Data quality required investigation. Re-analysis was completed past recommended hold time.
Sample CRB802 [704B] NO2 (N); NO2 (N) + NO3 (N) in Water: Sample was originally processed within hold time. Data quality required investigation. Re-analysis was completed past recommended hold time.

REGULATED METALS (CCME/AT1) - TOTAL Comments

Sample CRB798 [700A] Elements by ICPMS - Total: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.
Sample CRB798 [700A] Elements by ICP - Total: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.
Sample CRB799 [700B] Elements by ICP - Total: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.
Sample CRB801 [702B] Elements by ICPMS - Total: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.
Sample CRB801 [702B] Elements by ICP - Total: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.
Sample CRB802 [704B] Elements by ICP - Total: Due to the sample matrix, sample required dilution. Detection limit was adjusted accordingly.

Sample CRB801, Elements by ICPMS-Dissolved-Lab Filtered: Test repeated.
Sample CRB802, Chloride/Sulphate by Auto Colourimetry: Test repeated.

Results relate only to the items tested.

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QUALITY ASSURANCE REPORT

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
B438325	O-TERPHENYL (sur.)	2024/07/16			93	60 - 140	96	%				
B440318	1,4-Difluorobenzene (sur.)	2024/07/17	98	50 - 140	99	50 - 140	103	%				
B440318	4-Bromofluorobenzene (sur.)	2024/07/17	106	50 - 140	105	50 - 140	93	%				
B440318	D4-1,2-Dichloroethane (sur.)	2024/07/17	102	50 - 140	102	50 - 140	103	%				
B435742	Biochemical Oxygen Demand	2024/07/17			91	85 - 115	<2.0	mg/L	3.8	20		
B438325	F2 (C10-C16 Hydrocarbons)	2024/07/16			84	60 - 140	<0.10	mg/L				
B438325	F3 (C16-C34 Hydrocarbons)	2024/07/16			79	60 - 140	<0.10	mg/L				
B438325	F4 (C34-C50 Hydrocarbons)	2024/07/16			82	60 - 140	<0.20	mg/L				
B439660	Nitrate plus Nitrite (N)	2024/07/15	87	80 - 120	108	80 - 120	<0.010	mg/L	NC	20		
B439660	Nitrite (N)	2024/07/15	102	80 - 120	103	80 - 120	<0.010	mg/L	NC	20		
B440137	Chemical Oxygen Demand	2024/07/16	99	80 - 120	100	80 - 120	<10	mg/L	NC	20		
B440318	Benzene	2024/07/17	83	50 - 140	85	60 - 130	<0.40	ug/L	NC	30		
B440318	Ethylbenzene	2024/07/17	90	50 - 140	91	60 - 130	<0.40	ug/L	NC	30		
B440318	F1 (C6-C10)	2024/07/17	85	60 - 140	92	60 - 140	<100	ug/L	NC	30		
B440318	m & p-Xylene	2024/07/17	90	50 - 140	90	60 - 130	<0.80	ug/L	NC	30		
B440318	o-Xylene	2024/07/17	89	50 - 140	89	60 - 130	<0.40	ug/L	NC	30		
B440318	Toluene	2024/07/17	87	50 - 140	81	60 - 130	<0.40	ug/L	6.7	30		
B440718	Fecal Coliforms	2024/07/17					<1.0	MPN/100mL	NC	N/A		
B440834	Total Aluminum (Al)	2024/07/17	108	80 - 120	97	80 - 120	<0.0030	mg/L	2.4	20		
B440834	Total Antimony (Sb)	2024/07/17	107	80 - 120	106	80 - 120	<0.00060	mg/L	4.0	20		
B440834	Total Arsenic (As)	2024/07/17	106	80 - 120	93	80 - 120	<0.00020	mg/L	3.1	20		
B440834	Total Beryllium (Be)	2024/07/17	110	80 - 120	95	80 - 120	<0.0010	mg/L	NC	20		
B440834	Total Chromium (Cr)	2024/07/17	101	80 - 120	93	80 - 120	<0.0010	mg/L	0.67	20		
B440834	Total Cobalt (Co)	2024/07/17	103	80 - 120	94	80 - 120	<0.00030	mg/L	0.95	20		
B440834	Total Copper (Cu)	2024/07/17	100	80 - 120	94	80 - 120	<0.0010	mg/L	0.75	20		
B440834	Total Lead (Pb)	2024/07/17	103	80 - 120	95	80 - 120	<0.00020	mg/L	0.81	20		
B440834	Total Molybdenum (Mo)	2024/07/17	109	80 - 120	102	80 - 120	<0.00020	mg/L	1.7	20		
B440834	Total Nickel (Ni)	2024/07/17	101	80 - 120	94	80 - 120	<0.00050	mg/L	0.94	20		
B440834	Total Selenium (Se)	2024/07/17	102	80 - 120	91	80 - 120	<0.00020	mg/L	1.3	20		
B440834	Total Silver (Ag)	2024/07/17	103	80 - 120	90	80 - 120	<0.00010	mg/L	NC	20		
B440834	Total Thallium (Tl)	2024/07/17	104	80 - 120	93	80 - 120	<0.00020	mg/L	NC	20		

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QUALITY ASSURANCE REPORT(CONT'D)

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
B440834	Total Tin (Sn)	2024/07/17	105	80 - 120	100	80 - 120	<0.0010	mg/L	4.1	20		
B440834	Total Titanium (Ti)	2024/07/17	105	80 - 120	101	80 - 120	<0.0010	mg/L	0	20		
B440834	Total Uranium (U)	2024/07/17	107	80 - 120	95	80 - 120	<0.00010	mg/L	1.4	20		
B440834	Total Vanadium (V)	2024/07/17	106	80 - 120	93	80 - 120	<0.0010	mg/L	0.96	20		
B440834	Total Zinc (Zn)	2024/07/17	99	80 - 120	90	80 - 120	<0.0030	mg/L	18	20		
B440842	Total Barium (Ba)	2024/07/17	95	80 - 120	98	80 - 120	<0.010	mg/L	0.32	20		
B440842	Total Boron (B)	2024/07/17	96	80 - 120	96	80 - 120	<0.020	mg/L	0.17	20		
B440842	Total Calcium (Ca)	2024/07/17	NC	80 - 120	94	80 - 120	<0.30	mg/L	1.4	20		
B440842	Total Iron (Fe)	2024/07/17	NC	80 - 120	106	80 - 120	<0.060	mg/L	0.73	20		
B440842	Total Lithium (Li)	2024/07/17	92	80 - 120	93	80 - 120	<0.020	mg/L	8.1	20		
B440842	Total Magnesium (Mg)	2024/07/17	NC	80 - 120	95	80 - 120	<0.20	mg/L	1.0	20		
B440842	Total Manganese (Mn)	2024/07/17	97	80 - 120	96	80 - 120	<0.0040	mg/L	0.056	20		
B440842	Total Phosphorus (P)	2024/07/17	100	80 - 120	98	80 - 120	<0.10	mg/L	0.44	20		
B440842	Total Potassium (K)	2024/07/17	97	80 - 120	97	80 - 120	<0.30	mg/L	0.40	20		
B440842	Total Silicon (Si)	2024/07/17	92	80 - 120	95	80 - 120	<0.50	mg/L	1.5	20		
B440842	Total Sodium (Na)	2024/07/17	NC	80 - 120	95	80 - 120	<0.50	mg/L	1.1	20		
B440842	Total Strontium (Sr)	2024/07/17	89	80 - 120	94	80 - 120	<0.020	mg/L	0.23	20		
B440842	Total Sulphur (S)	2024/07/17	NC	80 - 120	94	80 - 120	<0.20	mg/L	0.49	20		
B440959	Total Nitrogen (N)	2024/07/17	101	80 - 120	105	80 - 120	<0.020	mg/L	0.28	20	105	80 - 120
B441248	Chloride (Cl)	2024/07/16	101	80 - 120	105	80 - 120	<1.0	mg/L	0.20	20		
B441248	Sulphate (SO4)	2024/07/16	NC	80 - 120	98	80 - 120	<1.0	mg/L	6.1	20		
B441840	Dissolved Barium (Ba)	2024/07/17	103	80 - 120	105	80 - 120	<0.010	mg/L				
B441840	Dissolved Boron (B)	2024/07/17	91	80 - 120	89	80 - 120	<0.020	mg/L				
B441840	Dissolved Calcium (Ca)	2024/07/17	99	80 - 120	103	80 - 120	<0.30	mg/L	0.29	20		
B441840	Dissolved Iron (Fe)	2024/07/17	104	80 - 120	98	80 - 120	<0.060	mg/L	14	20		
B441840	Dissolved Lithium (Li)	2024/07/17	100	80 - 120	99	80 - 120	<0.020	mg/L				
B441840	Dissolved Magnesium (Mg)	2024/07/17	100	80 - 120	102	80 - 120	<0.20	mg/L	0.70	20		
B441840	Dissolved Manganese (Mn)	2024/07/17	98	80 - 120	90	80 - 120	<0.0040	mg/L	11	20		
B441840	Dissolved Phosphorus (P)	2024/07/17	107	80 - 120	98	80 - 120	<0.10	mg/L				
B441840	Dissolved Potassium (K)	2024/07/17	105	80 - 120	103	80 - 120	<0.30	mg/L	1.4	20		
B441840	Dissolved Silicon (Si)	2024/07/17	98	80 - 120	92	80 - 120	<0.50	mg/L				
B441840	Dissolved Sodium (Na)	2024/07/17	94	80 - 120	101	80 - 120	<0.50	mg/L	0.15	20		

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QUALITY ASSURANCE REPORT(CONT'D)

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
B441840	Dissolved Strontium (Sr)	2024/07/17	95	80 - 120	99	80 - 120	<0.020	mg/L				
B441840	Dissolved Sulphur (S)	2024/07/17	NC	80 - 120	94	80 - 120	<0.20	mg/L				
B442069	Total Nitrogen (N)	2024/07/17	98	80 - 120	102	80 - 120	<0.020	mg/L	3.1	20	103	80 - 120
B442074	Total Nitrogen (N)	2024/07/17	103	80 - 120	102	80 - 120	<0.020	mg/L	2.1	20	103	80 - 120
B442248	Dissolved Barium (Ba)	2024/07/17	101	80 - 120	99	80 - 120	<0.010	mg/L				
B442248	Dissolved Boron (B)	2024/07/17	101	80 - 120	96	80 - 120	<0.020	mg/L				
B442248	Dissolved Calcium (Ca)	2024/07/17	100	80 - 120	95	80 - 120	<0.30	mg/L	1.7	20		
B442248	Dissolved Iron (Fe)	2024/07/17	113	80 - 120	107	80 - 120	<0.060	mg/L	NC	20		
B442248	Dissolved Lithium (Li)	2024/07/17	97	80 - 120	94	80 - 120	<0.020	mg/L				
B442248	Dissolved Magnesium (Mg)	2024/07/17	101	80 - 120	96	80 - 120	<0.20	mg/L	5.1	20		
B442248	Dissolved Manganese (Mn)	2024/07/17	102	80 - 120	96	80 - 120	<0.0040	mg/L	NC	20		
B442248	Dissolved Phosphorus (P)	2024/07/17	106	80 - 120	99	80 - 120	<0.10	mg/L				
B442248	Dissolved Potassium (K)	2024/07/17	103	80 - 120	98	80 - 120	<0.30	mg/L	NC	20		
B442248	Dissolved Silicon (Si)	2024/07/17	92	80 - 120	94	80 - 120	<0.50	mg/L				
B442248	Dissolved Sodium (Na)	2024/07/17	99	80 - 120	96	80 - 120	<0.50	mg/L	0.78	20		
B442248	Dissolved Strontium (Sr)	2024/07/17	98	80 - 120	96	80 - 120	<0.020	mg/L				
B442248	Dissolved Sulphur (S)	2024/07/17	105	80 - 120	99	80 - 120	<0.20	mg/L				
B442316	Total Phosphorus (P)	2024/07/17	107	80 - 120	97	80 - 120	<0.0030	mg/L	4.9	20	92	80 - 120
B442324	Dissolved Aluminum (Al)	2024/07/17	109	80 - 120	112	80 - 120	<0.0030	mg/L	1.5	20		
B442324	Dissolved Antimony (Sb)	2024/07/17	104	80 - 120	118	80 - 120	<0.00060	mg/L	9.6	20		
B442324	Dissolved Arsenic (As)	2024/07/17	101	80 - 120	111	80 - 120	<0.00020	mg/L	5.5	20		
B442324	Dissolved Beryllium (Be)	2024/07/17	102	80 - 120	101	80 - 120	<0.0010	mg/L	NC	20		
B442324	Dissolved Chromium (Cr)	2024/07/17	100	80 - 120	104	80 - 120	<0.0010	mg/L	NC	20		
B442324	Dissolved Cobalt (Co)	2024/07/17	99	80 - 120	103	80 - 120	<0.00030	mg/L	NC	20		
B442324	Dissolved Copper (Cu)	2024/07/17	97	80 - 120	104	80 - 120	<0.0010	mg/L	NC	20		
B442324	Dissolved Lead (Pb)	2024/07/17	95	80 - 120	104	80 - 120	<0.00020	mg/L	NC	20		
B442324	Dissolved Molybdenum (Mo)	2024/07/17	NC	80 - 120	106	80 - 120	<0.00020	mg/L	1.6	20		
B442324	Dissolved Nickel (Ni)	2024/07/17	99	80 - 120	105	80 - 120	<0.00050	mg/L	6.8	20		
B442324	Dissolved Selenium (Se)	2024/07/17	93	80 - 120	105	80 - 120	<0.00020	mg/L	12	20		
B442324	Dissolved Silver (Ag)	2024/07/17	94	80 - 120	102	80 - 120	<0.00010	mg/L	NC	20		
B442324	Dissolved Thallium (Tl)	2024/07/17	93	80 - 120	102	80 - 120	<0.00020	mg/L	NC	20		
B442324	Dissolved Tin (Sn)	2024/07/17	103	80 - 120	107	80 - 120	<0.0010	mg/L	NC	20		

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QUALITY ASSURANCE REPORT(CONT'D)

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
B442324	Dissolved Titanium (Ti)	2024/07/17	97	80 - 120	106	80 - 120	<0.0010	mg/L	NC	20		
B442324	Dissolved Uranium (U)	2024/07/17	99	80 - 120	105	80 - 120	<0.00010	mg/L	5.3	20		
B442324	Dissolved Vanadium (V)	2024/07/17	106	80 - 120	108	80 - 120	<0.0010	mg/L	3.6	20		
B442324	Dissolved Zinc (Zn)	2024/07/17	97	80 - 120	106	80 - 120	<0.0030	mg/L	NC	20		
B442586	Alkalinity (PP as CaCO3)	2024/07/18					<1.0	mg/L	NC	20		
B442586	Alkalinity (Total as CaCO3)	2024/07/18			99	80 - 120	<1.0	mg/L	1.5	20		
B442586	Bicarbonate (HCO3)	2024/07/18					<1.0	mg/L	1.5	20		
B442586	Carbonate (CO3)	2024/07/18					<1.0	mg/L	NC	20		
B442586	Hydroxide (OH)	2024/07/18					<1.0	mg/L	NC	20		
B442590	pH	2024/07/18			100	97 - 103			1.9	N/A		
B442591	Conductivity	2024/07/18			100	90 - 110	<2.0	uS/cm	0.10	10		
B442612	Alkalinity (PP as CaCO3)	2024/07/18					<1.0	mg/L	NC	20		
B442612	Alkalinity (Total as CaCO3)	2024/07/18			99	80 - 120	<1.0	mg/L	2.7	20		
B442612	Bicarbonate (HCO3)	2024/07/18					<1.0	mg/L	2.7	20		
B442612	Carbonate (CO3)	2024/07/18					<1.0	mg/L	NC	20		
B442612	Hydroxide (OH)	2024/07/18					<1.0	mg/L	NC	20		
B442614	pH	2024/07/18			100	97 - 103			0.87	N/A		
B442617	Conductivity	2024/07/18			101	90 - 110	<2.0	uS/cm	2.8	10		
B444913	Total Organic Carbon (C)	2024/07/19	NC	80 - 120	100	80 - 120	<0.50	mg/L	5.0	20		
B448159	Dissolved Molybdenum (Mo)	2024/07/22	105	80 - 120	102	80 - 120	<0.00020	mg/L	7.3	20		
B448939	Total Mercury (Hg)	2024/07/23	103	80 - 120	103	80 - 120	<0.00010	ug/L	NC	25		
B449635	Sulphate (SO4)	2024/07/23	100	80 - 120	106	80 - 120	<1.0	mg/L	5.1	20		
B452255	Total Methyl Mercury	2024/07/25	100	80 - 120	117	80 - 120	<0.050	ng/L	6.8	25		
B453401	Total Methyl Mercury	2024/07/26	114	80 - 120	106	80 - 120	<0.050	ng/L	5.6	25		
B460844	Total Organic Carbon (C)	2024/07/31	106	80 - 120	101	80 - 120	<0.50	mg/L	6.1	20		
B460874	Phenols	2024/07/31	90	80 - 120	103	80 - 120	<0.0015	mg/L	NC	20		

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QUALITY ASSURANCE REPORT(CONT'D)

			Matrix Spike		Spiked Blank		Method Blank		RPD		QC Standard	
QC Batch	Parameter	Date	% Recovery	QC Limits	% Recovery	QC Limits	Value	UNITS	Value (%)	QC Limits	% Recovery	QC Limits
B461114	Phenols	2024/07/31	87	80 - 120	100	80 - 120	<0.0015	mg/L	NC	20		

N/A = Not Applicable

Duplicate: Paired analysis of a separate portion of the same sample. Used to evaluate the variance in the measurement.

Matrix Spike: A sample to which a known amount of the analyte of interest has been added. Used to evaluate sample matrix interference.

QC Standard: A sample of known concentration prepared by an external agency under stringent conditions. Used as an independent check of method accuracy.

Spiked Blank: A blank matrix sample to which a known amount of the analyte, usually from a second source, has been added. Used to evaluate method accuracy.

Method Blank: A blank matrix containing all reagents used in the analytical procedure. Used to identify laboratory contamination.

Surrogate: A pure or isotopically labeled compound whose behavior mirrors the analytes of interest. Used to evaluate extraction efficiency.

NC (Matrix Spike): The recovery in the matrix spike was not calculated. The relative difference between the concentration in the parent sample and the spike amount was too small to permit a reliable recovery calculation (matrix spike concentration was less than the native sample concentration)

NC (Duplicate RPD): The duplicate RPD was not calculated. The concentration in the sample and/or duplicate was too low to permit a reliable RPD calculation (absolute difference <= 2x RDL).

Bureau Veritas Calgary: 2021 - 41st Avenue N.E. T2E 6P2 Telephone (403) 291-3077 Fax (403) 291-9468

Bureau Veritas Job #: C452291
Report Date: 2024/08/01

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Location: SNAKE LAKE RESRVOIR
Sampler Initials: CB

VALIDATION SIGNATURE PAGE

The analytical data and all QC contained in this report were reviewed and validated by:

David Huang, M.Sc., P.Chem., QP, Scientific Services Manager

Gita Pokhrel, Laboratory Supervisor

Qiliang (Alex) Wu, Senior Analyst

Sandy Yuan, M.Sc., QP, Scientific Specialist

Suwan (Sze Yeung) Fock, B.Sc., Scientific Specialist

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CHAIN OF CUSTODY RECORD

ENV COC - 00013v5

Page 1 of 2

MCAL-2024-07-918

1/1

Invoice Information	Invoice to (requires report) ☐	Report Information (if differs from invoice)		Project Information	
Company:	MPE a division of Englobe	Company:		Quotation #:	C22038
Contact Name:	Cody Braun	Contact Name:		P.O. #/ AFE#:	
Street Address:	#40, 1825 Bombford Crescent SW	Street Address:		Project #:	1560-193-00
City:	Medicine Hat Prov: AB Postal Code: T1A 5E8	City:	Prov: Postal Code:	Site #:	
Phone:	403-977-3326	Phone:		Site Location:	Snake Lake Reservoir
Email:	cbraun@mpe.ca	Email:		Site Location Province:	AB
Copies:	1	Copies:		Sampled By:	C. Braun

Regulatory Criteria

☐ AT1 ☐ CCME ☐ Drinking Water - Canada ☐ Drinking Water - Manitoba

☐ Saskatchewan ☐ Drinking Water - Alberta ☐ Other ______

SAMPLES MUST BE KEPT COOL (<10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

#	Sample Identification	Date Sampled YY	MM	DD	Time (24hr) HH	MM	Matrix	1 FIELD FILTERED	2 FIELD PRESERVED	3 LAB FILTRATION REQUIRED	4 BTEX F1	5 VOCs	6 BTEX F1-F2	7 BTEX F1-F4	8 Routine water	9 Regulated metals - total	10 Regulated metals - dissolved	11 Mercury - total	12 Mercury - dissolved	13 Salinity 4	14 Sieve (75 micron)	15 Texture (% sand, silt, clay)	16 Basic class II landfill	17 BOD	18	19	20	21 # OF CONTAINERS SUBMITTED	22 HOLD - DO NOT ANALYZE	Comments
1	700A	24	7	10			Water - Ground																	1				1		
2	700B	24	7	10			Water - Ground																	1				1		
3	702A	24	7	10			Water - Ground																	1				1		
4	702B	24	7	10			Water - Ground																	1				1		
5	704B	24	7	10			Water - Ground																	1				1		
6	700A	24	7	10			Water - Ground						1															2		
7	700B	24	7	10			Water - Ground						1															2		
8	702A	24	7	10			Water - Ground						1															2		
9	702B	24	7	10			Water - Ground						1															2		
10	704B	24	7	10			Water - Ground						1															2		
11																														
12																														

Regular Turnaround Time (TAT)	
☐ 5 to 7 Day	☑ 10 Day
Rush Turnaround Time (TAT) Surcharges apply	
☐ Same Day	☐ 1 Day
☐ 2 Day	☐ 3 Day
☐ 4 Day	
Date Required: YY MM DD	

UNLESS OTHERWISE AGREED TO IN WRITING, WORK SUBMITTED ON THIS CHAIN OF CUSTODY IS SUBJECT TO BUREAU VERITAS STANDARD TERMS AND CONDITIONS. SIGNING OF THIS CHAIN OF CUSTODY DOCUMENT IS ACKNOWLEDGMENT AND ACCEPTANCE OF OUR TERMS AND CONDITIONS WHICH ARE AVAILABLE FOR VIEWING AT WWW.BVNA.COM/TERMS-AND-CONDITIONS OR BY CALLING THE LABORATORY LISTED ABOVE TO OBTAIN A COPY.

LAB USE ONLY	Yes	No	°C	1	2	3
Seal present		/		8.9	9.0	8.2
Seal intact		/				
Cooling media present	/					

LAB USE ONLY	Yes	No	°C	1	2	3
Seal present						
Seal intact						
Cooling media present						

LAB USE ONLY	Yes	No	°C	1	2	3	Temperature reading by:
Seal present							
Seal intact							
Cooling media present							

	Relinquished by: (Signature/ Print)	Date YY	MM	DD	Time HH	MM	Received by: (Signature/ Print)	Date YY	MM	DD	Time HH	MM	Special Instructions
1							Ekla Tokl	2024	07	12	08	50	
2													

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- ☐ Winnipeg, MB: D-675 Berry St. R3H 1A7 Toll Free (866) 800-6208

CHAIN OF CUSTODY RECORD

ENV COC - 00013v5

Invoice Information	Invoice to (requires report) ☐	Report Information (if differs from invoice)		Project Information	
Company:	MPE a division of Englobe	Company:		Quotation #:	C22038
Contact Name:	Cody Braun	Contact Name:		P.O. #/ AFE#:	
Street Address:	#40, 1825 Bombford Crescent SW	Street Address:		Project #:	1560-193-00
City: Medicine Hat Prov: AB Postal Code: T1A 5E8		City: Prov: Postal Code:		Site #:	
Phone:	403-977-3326	Phone:		Site Location:	Snake Lake Reservoir
Email:	cbraun@mpe.ca	Email:		Site Location Province:	AB
Copies:	1	Copies:		Sampled By:	C. Braun

C45229 1

LAB USE ONLY - PLACE STICKER HERE

Rush Confirmation #:

Regulatory Criteria

☐ AT1 ☐ CCME ☐ Drinking Water - Canada ☐ Drinking Water - Manitoba

☐ Saskatchewan ☐ Drinking Water - Alberta ☐ Other ______

SAMPLES MUST BE KEPT COOL (<10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

Regular Turnaround Time (TAT): ☐ 5 to 7 Day ☑ 10 Day

Rush Turnaround Time (TAT) Surcharges apply: ☐ Same Day ☐ 1 Day ☐ 2 Day ☐ 3 Day ☐ 4 Day

Date Required: YY MM DD

#	Sample Identification	YY	MM	DD	HH	MM	Matrix	1 FIELD FILTERED	2 FIELD PRESERVED	3 LAB FILTRATION REQUIRED	4 BTEX F1	5 VOCs	6 BTEX F1-F2	7 BTEX F1-F4	8 Routine water	9 Regulated metals - total	10 Regulated metals - dissolved	11 Mercury - total	12 Mercury - dissolved	13 Salinity 4	14 Sieve (75 micron)	15 Texture (% sand, silt, clay)	16 Basic class II landfill	17 FECAL COLIFORMS	18	19	20	21 # OF CONTAINERS SUBMITTED	22 HOLD - DO NOT ANALYZE	Comments
1	700A	24	7	10			Water - Ground																	1				1		
2	700B	24	7	10			Water - Ground																	1				1		
3	702A	24	7	10			Water - Ground																	1				1		
4	702B	24	7	10			Water - Ground																	1				1		
5	704B	24	7	10			Water - Ground																	1				1		
6	700A	24	7	10			Water - Ground											1										3		ULTRA LOW LEVEL MERCURY
7	700B	24	7	10			Water - Ground											1										3		ULTRA LOW LEVEL MERCURY
8	702A	24	7	10			Water - Ground											1										3		ULTRA LOW LEVEL MERCURY
9	702B	24	7	10			Water - Ground											1										3		ULTRA LOW LEVEL MERCURY
10	704B	24	7	10			Water - Ground											1										3		ULTRA LOW LEVEL MERCURY
11																														
12																														

LAB USE ONLY	Yes	No	°C	1	2	3
Seal present						
Seal intact						
Cooling media present						

LAB USE ONLY	Yes	No	°C	1	2	3
Seal present						
Seal intact						
Cooling media present						

LAB USE ONLY	Yes	No	°C	1	2	3	Temperature reading by:
Seal present							
Seal intact							
Cooling media present							

	Relinquished by: (Signature/ Print)	Date YY	Date MM	Date DD	Time HH	Time MM		Received by: (Signature/ Print)	Date YY	Date MM	Date DD	Time HH	Time MM	Special instructions
1							1							
2							2							

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Edmonton, AB: 4326 - 76 Avenue NW, T6B 2T8 Toll Free (800) 386-7247
Winnipeg, MB: D-675 Berry St. R3H 1A7 Toll Free (866) 800-6208

CHAIN OF CUSTODY RECORD

ENV COC - 00013v5

CONTINUED

[PAGE 1 REFERENCE]

Company:	MPE a division of Englobe
Contact Name:	Cody Braun
Project #:	1560-193-00

SAMPLES MUST BE KEPT COOL (<10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

Same as above

	Sample Identification	Date Sampled YY	Date Sampled MM	Date Sampled DD	Time (24hr) HH	Time (24hr) MM	Matrix	1 FIELD FILTERED	2 FIELD PRESERVED	3 LAB FILTRATION REQUIRED	4 BTEX F1	5 VOCs	6 BTEX F1-F2	7 BTEX F1-F4	8 Routine water	9 Regulated metals - total	10 Regulated metals - dissolved	11 Mercury - total	12 Mercury - dissolved	13 Salinity 4	14 Sieve (75 micron)	15 Texture (% sand, silt, clay)	16 Basic class II landfill	17 SULFURIC ACID	18	19	20	21 # OF CONTAINERS SUBMITTED	22 HOLD - DO NOT ANALYZE	Comments
13	700A	24	7	10			Water																	1				1		
14	700B	24	7	10			Water																	1				1		
15	702A	24	7	10			Water																	1				1		
16	702B	24	7	10			Water																	1				1		
17	704B	24	7	10			Water																	1				1		
18																														
19																														
20																														
21																														
22																														
23																														
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CHAIN OF CUSTODY RECORD

ENV COC - 00013v5

CONTINUED

[PAGE 1 REFERENCE]

Company:	MPE a division of Englobe
Contact Name:	Cody Braun
Project #:	1560-193-00

SAMPLES MUST BE KEPT COOL (<10°C) FROM TIME OF SAMPLING UNTIL DELIVERY TO BUREAU VERITAS

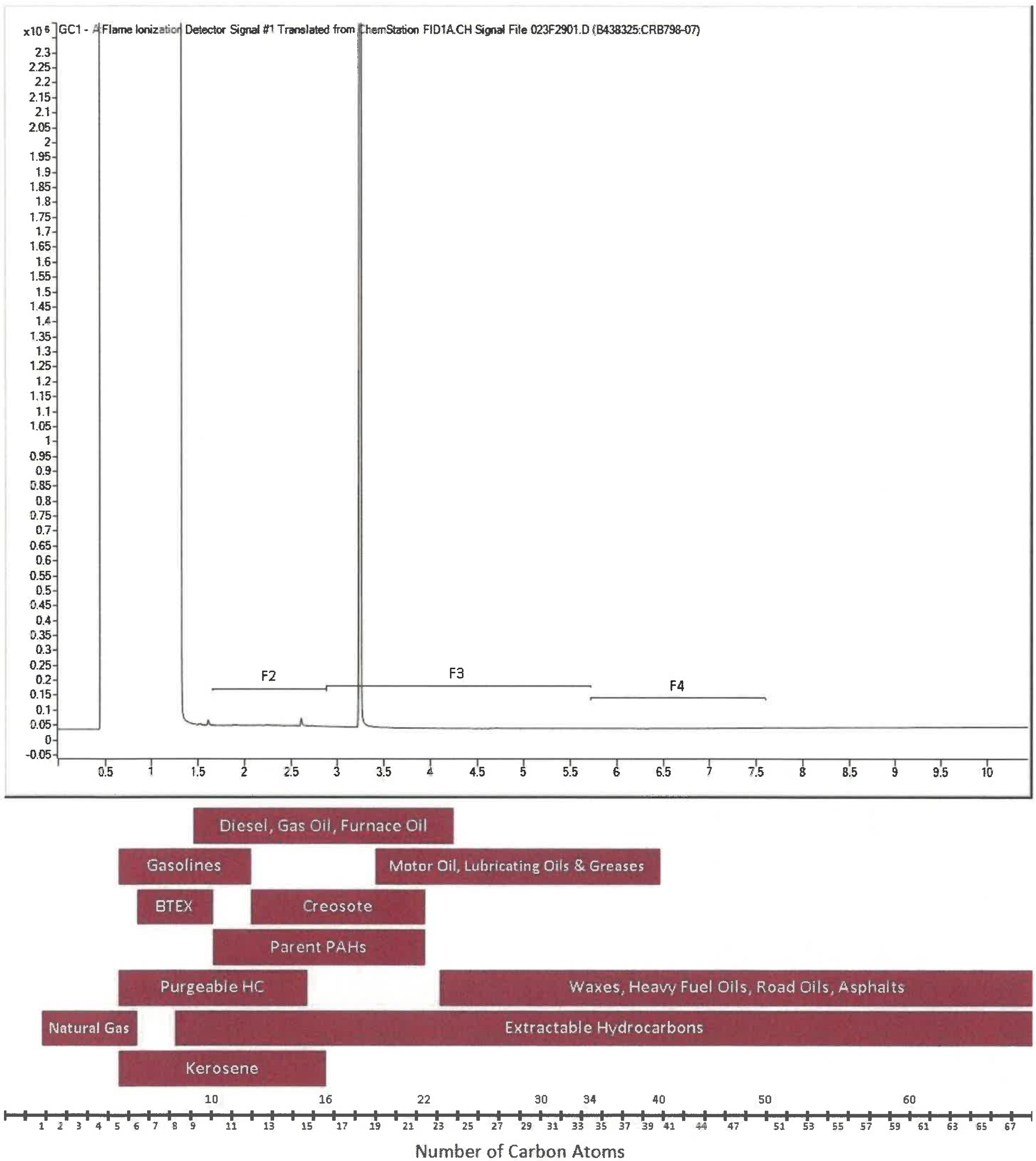
Same as above

	Sample Identification	Date Sampled YY	MM	DD	Time (24hr) HH	MM	Matrix	1 FIELD FILTERED	2 FIELD PRESERVED	3 LAB FILTRATION REQUIRED	4 BTEX F1	5 VOCs	6 BTEX F1-F2	7 BTEX F1-F4	8 Routine water	9 Regulated metals - total	10 Regulated metals - dissolved	11 Mercury - total	12 Mercury - dissolved	13 Salinity 4	14 Sieve (75 micron)	15 Texture (% sand, silt, clay)	16 Basic class II landfill	17	18	19	20	21 # OF CONTAINERS SUBMITTED	22 HOLD - DO NOT ANALYZE	Comments
13	700A	24	7	10			Water - Ground							1														1		
14	700B	24	7	10			Water - Ground							1														1		
15	702A	24	7	10			Water - Ground							1														1		
16	702B	24	7	10			Water - Ground							1														1		
17	704B	24	7	10			Water - Ground							1														1		
18	700A	24	7	10			Water - Ground								1													1		GENERAL 120 ML
19	700B	24	7	10			Water - Ground								1													1		GENERAL 120 ML
20	702A	24	7	10			Water - Ground								1													1		GENERAL 120 ML
21	702B	24	7	10			Water - Ground								1													1		GENERAL 120 ML
22	704B	24	7	10			Water - Ground								1													1		GENERAL 120 ML
23	700A	24	7	10			Water - Ground									1												1		
24	700B	24	7	10			Water - Ground									1												1		
25	702A	24	7	10			Water - Ground									1												1		
26	702B	24	7	10			Water - Ground									1												1		
27	704B	24	7	10			Water - Ground									1												1		
28	700A	24	7	10			Water - Ground										1											1		
29	700B	24	7	10			Water - Ground										1											1		
30	702A	24	7	10			Water - Ground										1											1		
31	702B	24	7	10			Water - Ground										1											1		
32	704B	24	7	10			Water - Ground										1											1		
33	700A	24	7	10			Water - Ground											1										1		METHYL MECURY (TOTAL)
34	700B	24	7	10			Water - Ground											1										1		METHYL MECURY (TOTAL)
35	702A	24	7	10			Water - Ground											1										1		METHYL MECURY (TOTAL)
36	702B	24	7	10			Water - Ground											1										1		METHYL MECURY (TOTAL)
37	704B	24	7	10			Water - Ground											1										1		METHYL MECURY (TOTAL)
38																														
39																														
40																														

Bureau Veritas Job #: C452291
Report Date: 2024/08/01
Bureau Veritas Sample: CRB798

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Reference: SNAKE LAKE RESRVOIR
Client ID: 700A

CCME Hydrocarbons (F2-F4 in water) Chromatogram



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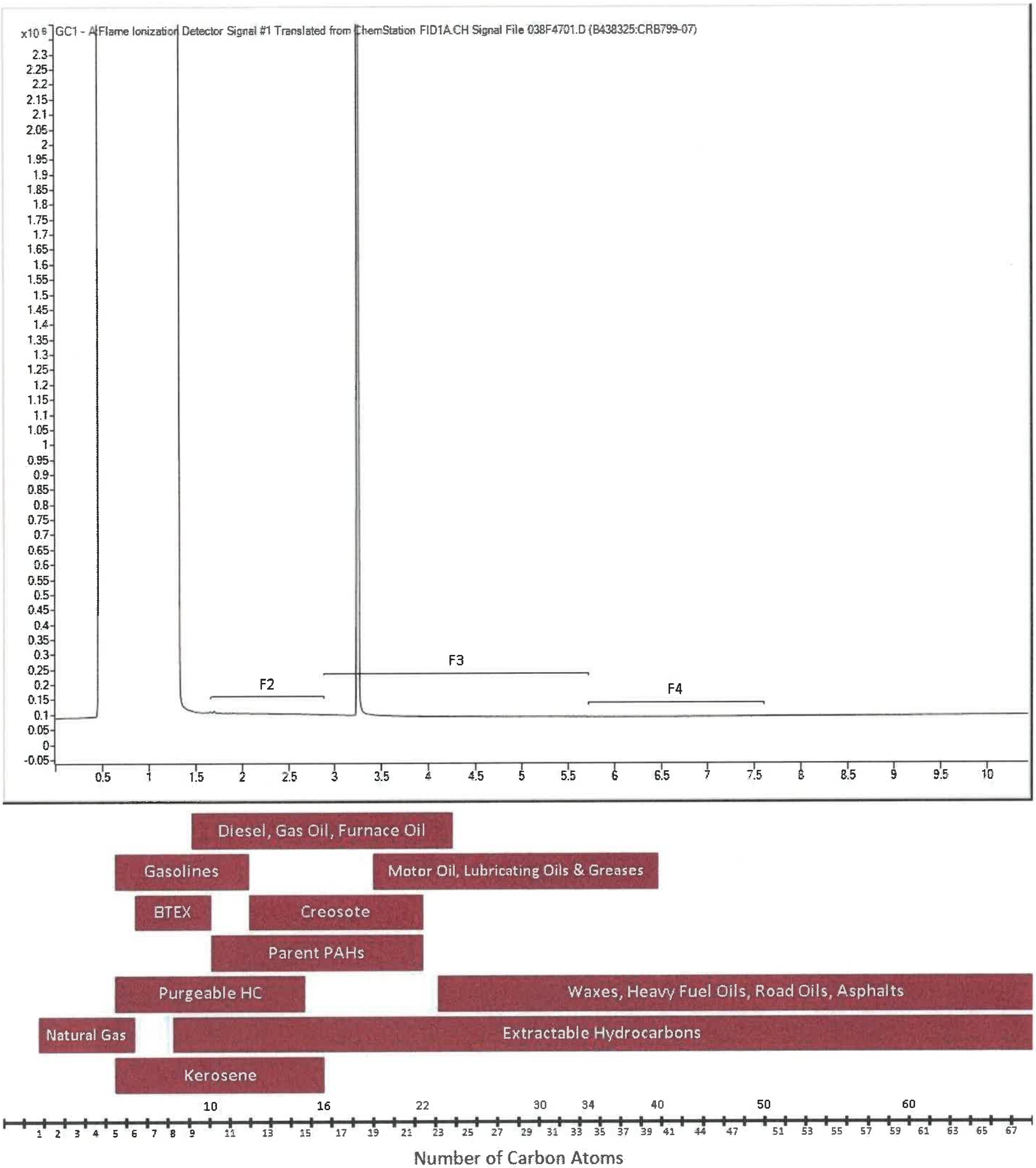
Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Bureau Veritas Job #: C452291
Report Date: 2024/08/01
Bureau Veritas Sample: CRB799

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Reference: SNAKE LAKE RESRVOIR
Client ID: 700B

CCME Hydrocarbons (F2-F4 in water) Chromatogram



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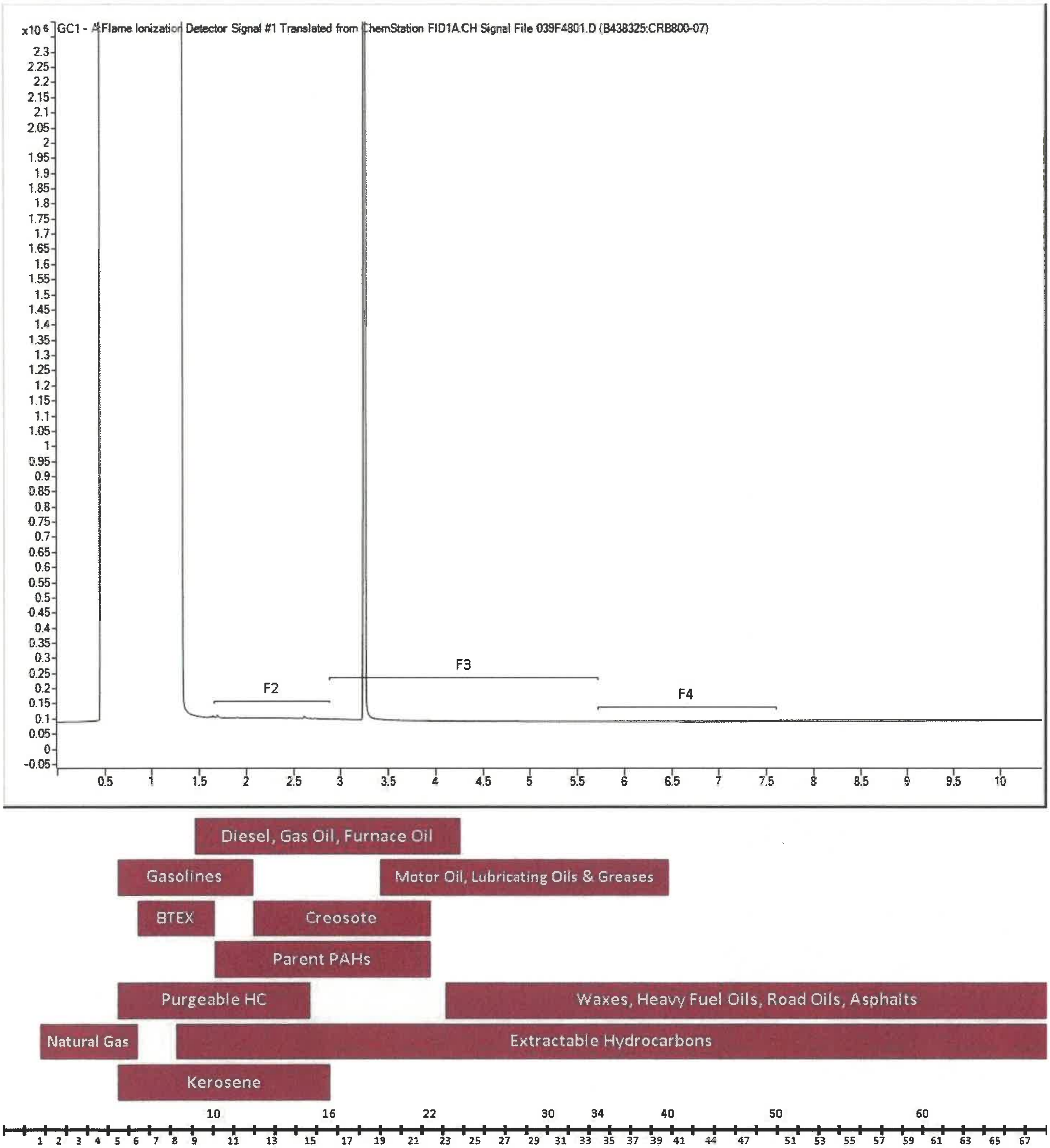
Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Bureau Veritas Job #: C452291
Report Date: 2024/08/01
Bureau Veritas Sample: CRB800

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Reference: SNAKE LAKE RESRVOIR
Client ID: 702A

CCME Hydrocarbons (F2-F4 in water) Chromatogram



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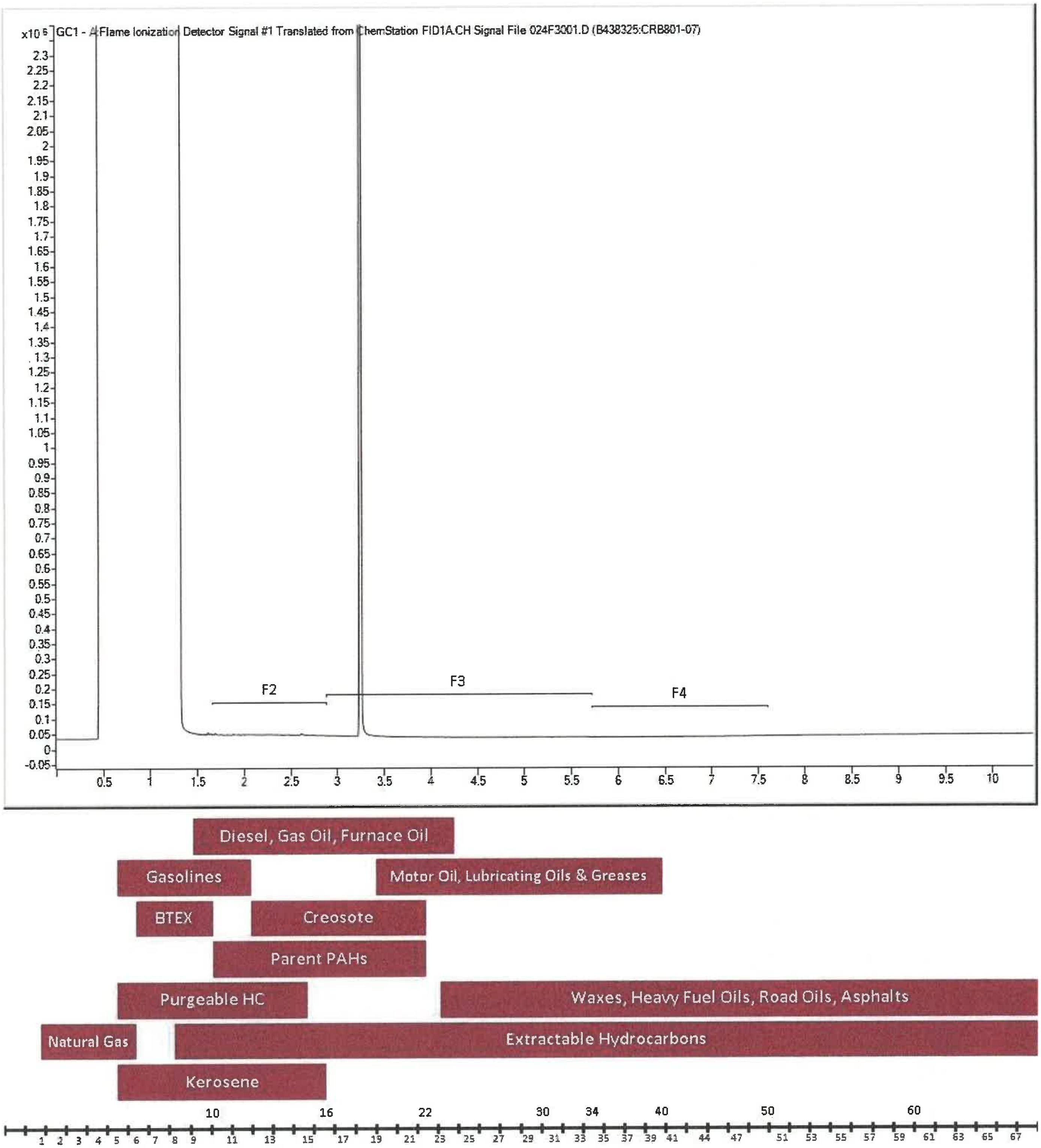
Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Bureau Veritas Job #: C452291
Report Date: 2024/08/01
Bureau Veritas Sample: CRB801

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Reference: SNAKE LAKE RESRVOIR
Client ID: 702B

CCME Hydrocarbons (F2-F4 in water) Chromatogram



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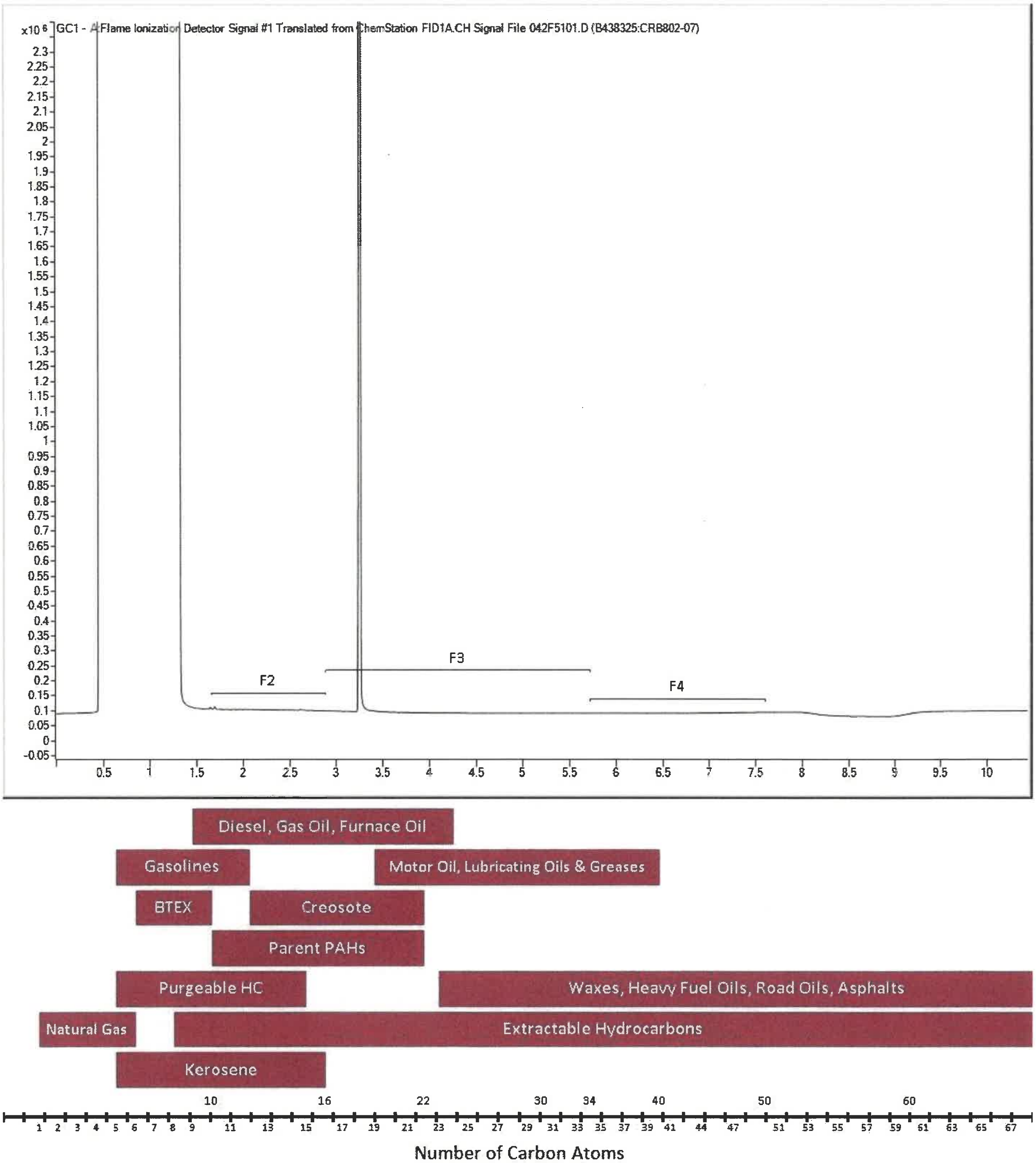
Bureau Veritas Job #: C452291
Report Date: 2024/08/01
Bureau Veritas Sample: CRB802

MPE ENGINEERING LTD.
Client Project #: 1560-193-00
Site Reference: SNAKE LAKE RESRVOIR
Client ID: 704B

CCME Hydrocarbons (F2-F4 in water) Chromatogram



hpchem13\HPchem\1\DATA\2024\07\RUN0716

Note: This information is provided for reference purposes only. Should detailed chemist interpretation or fingerprinting be required, please contact the laboratory.

Appendix D6: Water Well Drilling Records

Reconnaissance Report

View in Metric

Export to Excel

Groundwater Wells

Please click the water Well ID to generate the Water Well Drilling Report.

GIC Well ID	LSD	SEC	TWP	RGE	M	DRILLING COMPANY	DATE COMPLETED	DEPTH (ft)	TYPE OF WORK	USE	CHM	LT	PT	WELL OWNER	LEVEL (ft)	RATE (igpm)	SC_DIA (in)
240789	13	2	20	17	4	M&M DRILLING CO. LTD.	1978-09-19	797.00	New Well-Decommissioned	Stock		54		WARD, GEORGE	0.00	0.25	0.00
240793	NW	3	20	17	4	UNKNOWN DRILLER	1911-01-01	84.00	Well Inventory	Unknown					10.00		0.00
260249	4	15	20	17	4	UNKNOWN DRILLER		12.00	New Well	Stock				MCKINNOR, C.			0.00
285119	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-07-02	55.00	Test Hole-Decommissioned	Irrigation		4		EASTERN IRRIGATION DISTRICT #1			5.56
285120	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-07-03	31.00	Test Hole-Decommissioned	Irrigation		4		EASTERN IRRIGATION DISTRICT #2			5.56
288303	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-28	48.00	New Well	Observation		9		EASTERN IRRIGATION DISTRICT	11.30		5.56
288304	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-09-25	43.00	New Well	Observation		7		EASTERN IRRIGATION DISTRICT	7.00	9.00	5.56
288305	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-09-25	44.00	New Well	Observation		11		EASTERN IRRIGATION DISTRICT	7.00	10.00	5.56
288306	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-09-12	48.00	New Well	Observation		4		EASTERN IRRIGATION DISTRICT	14.20	2.00	5.56
288307	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-09-11	48.00	New Well	Observation		7		EASTERN IRRIGATION DISTRICT	13.00	5.00	5.56
288308	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-09-10	48.00	New Well	Observation		3		EASTERN IRRIGATION DISTRICT	13.30	5.00	5.56
288309	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-23	48.00	New Well	Observation		7		EASTERN IRRIGATION DISTRICT	11.00	10.00	5.56
288310	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-23	48.00	New Well	Observation		9		EASTERN IRRIGATION DISTRICT	12.00	3.00	5.56
288311	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-27	48.00	New Well	Observation		6		EASTERN IRRIGATION DISTRICT	11.50	3.00	5.56
288312	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-28	48.00	New Well	Observation		7		EASTERN IRRIGATION DISTRICT	10.90	7.00	5.56
288313	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-29	48.00	New Well	Observation		10		EASTERN IRRIGATION DISTRICT	12.40	3.00	5.56
288314	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-30	48.00	New Well	Observation		7		EASTERN IRRIGATION DISTRICT	13.00	6.00	5.56
288315	NW	3	20	17	4	M&M DRILLING CO. LTD.	1996-08-30	48.00	New Well	Observation		9		EASTERN IRRIGATION DISTRICT	13.80	4.00	5.56
288316	NW	3	20	17	4	M&M DRILLING CO. LTD. ##	1996-09-03	48.00	New Well	Observation		9		EASTERN IRRIGATION DIST	14.50	4.00	5.56
288317	NW	3	20	17	4	M&S WATERWELL DRILLING LTD. ##	1996-10-21	48.00	New Well	Observation		13		EASTERN IRRIGATION DISTRICT	15.00	18.00	5.56
288318	NW	3	20	17	4	M&M DRILLING CO. LTD. ##	1996-09-04	48.00	New Well	Observation		11		EASTERN IRRIGATION DISTRICT	15.00	6.00	5.56
288319	NW	3	20	17	4	M&M DRILLING CO. LTD. ##	1996-09-06	48.00	New Well	Observation		11		EASTERN IRRIGATION DISTRICT	15.00	10.00	5.50

288320	NW	3	20	17	4	M&M DRILLING CO. LTD.	##	1996-09-06	48.00	New Well	Observation		10		EASTERN IRRIGATION DISTRICT	15.00	10.00	5.56
288321	NW	3	20	17	4	M&M DRILLING CO. LTD.	##	1996-09-09	48.00	New Well	Observation		14		EASTERN IRRIGATION DISTRICT	16.20	2.00	5.56
288322	NW	3	20	17	4	M&M DRILLING CO. LTD.	##	1996-09-16	43.00	New Well	Observation		9		EASTERN IRRIGATION DISTRICT	3.30	6.00	5.56
299810	NW	7	20	17	4	M&M DRILLING CO. LTD.	##	2002-04-25	500.00	Test Hole-Decommissioned	Stock		11		STEINBACK, BEN			0.00
131579	NE	20	18	16	4	M&M DRILLING CO. LTD.		1982-09-23	140.00	New Well	Stock	2	6		JENSEN, BOB	25.00	6.00	0.00
131581	14	22	18	16	4	AMA DRILLING (SASK.) LTD.		1983-07-28	25.00	New Well	Domestic & Stock		4		DUNCAN, W.E.	10.00	5.00	0.00
131583	NE	26	18	16	4	UNKNOWN DRILLER		1912-01-01	160.00	Well Inventory	Domestic					60.00		0.00
131584	1	27	18	16	4	M&M DRILLING CO. LTD.		1989-03-13	177.00	New Well	Stock		15		BUTEAU, RENE	57.00	6.00	0.00
131585	SW	31	18	16	4	UNKNOWN DRILLER		1912-01-01	160.00	Well Inventory	Domestic					120.00		0.00
206292	1	4	19	15	4	UNKNOWN DRILLER			12.00	Well Inventory	Domestic					6.00		30.00
206397	13	33	18	15	4	DOERING DRILLING LTD.		1967-04-06	140.00	New Well	Domestic & Stock	2	6	9	NORTHCOTT, CHAS.	48.00	5.00	5.50
241822	14	31	18	15	:	AQUA BORING LTD.		34606	24.00	New Well	Domestic	4			ANDERSON, MAC	6.00	197.00	0.00
254880	NW	31	18	15	·	AQUA BORING LTD.		34774	35.00	Dry Hole-Decommissioned	Domestic	4			ANDERSON, MAC #1			0.00
254881	NW	31	18	15	·	AQUA BORING LTD.		34774	25.00	Dry Hole-Decommissioned	Domestic	4			ANDERSON, MAC			0.00
1831631	NE	31	18	15	·	AQUA BORING LTD.		39017	30.00	Test Hole-Decommissioned	Unknown	5			JENNINGS, DARRYL			
2094574	SE	5	19	15	4	UNKNOWNDRILLINGCOMP11			174.00	Well Inventory	Unknown	13			CANADIAN PACIFIC RAILWAY			
2095842	SE	5	19	15	4	UNKNOWNDRILLINGCOMP11			16.00	Well Inventory	Domestic	1			SCOTT, RICK			

Appendix D7: Groundwater Flow Modelling Report

Appendix D7
Groundwater Modelling Study Report

Snake Lake Reservoir Expansion

Eastern Irrigation District

MPE Engineering Ltd.
Final Report

Englobe Reference No. 02301113.000
March 28, 2025

Prepared by:

Marc Patenaude, P.Geo. Geo., M.Sc.
Hydrogeologist

Technical Reviewed by:

Jean-Philippe Gobeil, P.Geo. Geo., M.Sc.
Senior Hydrogeologist

Revisions and Publications Log

REVISION No.	DATE	DESCRIPTION
A	August 27, 2024	Draft report for comments and updates
B	November 15, 2024	Final report
C	March 27, 2025	Final report revised

Distribution

1 PDF copy	Cody Braun, P. Eng.

Property and Confidentiality

TABLE OF CONTENTS

List of Figures

List of Tables

1 Introduction

This technical report presents the input, methodology and results of the groundwater flow modelling completed as part of the environmental impact assessment for the Snake Lake Reservoir (SLR) Expansion project (the Project) proposed by the Eastern Irrigation District (EID). Indeed, the Project may have potential hydrogeological impacts during the construction and operation of the expanded reservoir, more specifically during the temporary dewatering of excavations during construction, the operation of the expanded reservoir at maximum capacity and the operation of the expanded reservoir at average capacity. The following is a summary of the data sources that were used to develop the numerical groundwater model (for details on data sources refer to Volume 2, Section 6: Hydrogeology.

- Provincial geological and hydrogeological data (regional overview of hydrogeological data, historical records, private well records, surficial and bedrock geology)
- Borehole and core hole logs used to evaluate the hydrostratigraphic units present within the Study Area
- In-situ hydrogeological testing (packer tests, slug tests, pumping tests, groundwater level monitoring)
- The location of water wells and groundwater use within the assessment area

These data sources were integrated into the hydrostratigraphic conceptual framework that formed the basis of the numerical groundwater flow model that was used to evaluate the potential impacts of the reservoir expansion on groundwater and surface water. The boundaries of the study area were determined from the available hydrological, topographic, hydrogeological, and geological data. These datasets constitute the basis of the numerical groundwater flow model developed to predict the influence of the reservoir expansion on the local groundwater flow regime. The study site has a surface area of approximately 297 km^2.

2 Site Background

2.1 Site Location, Regional Setting, and Current Land Use

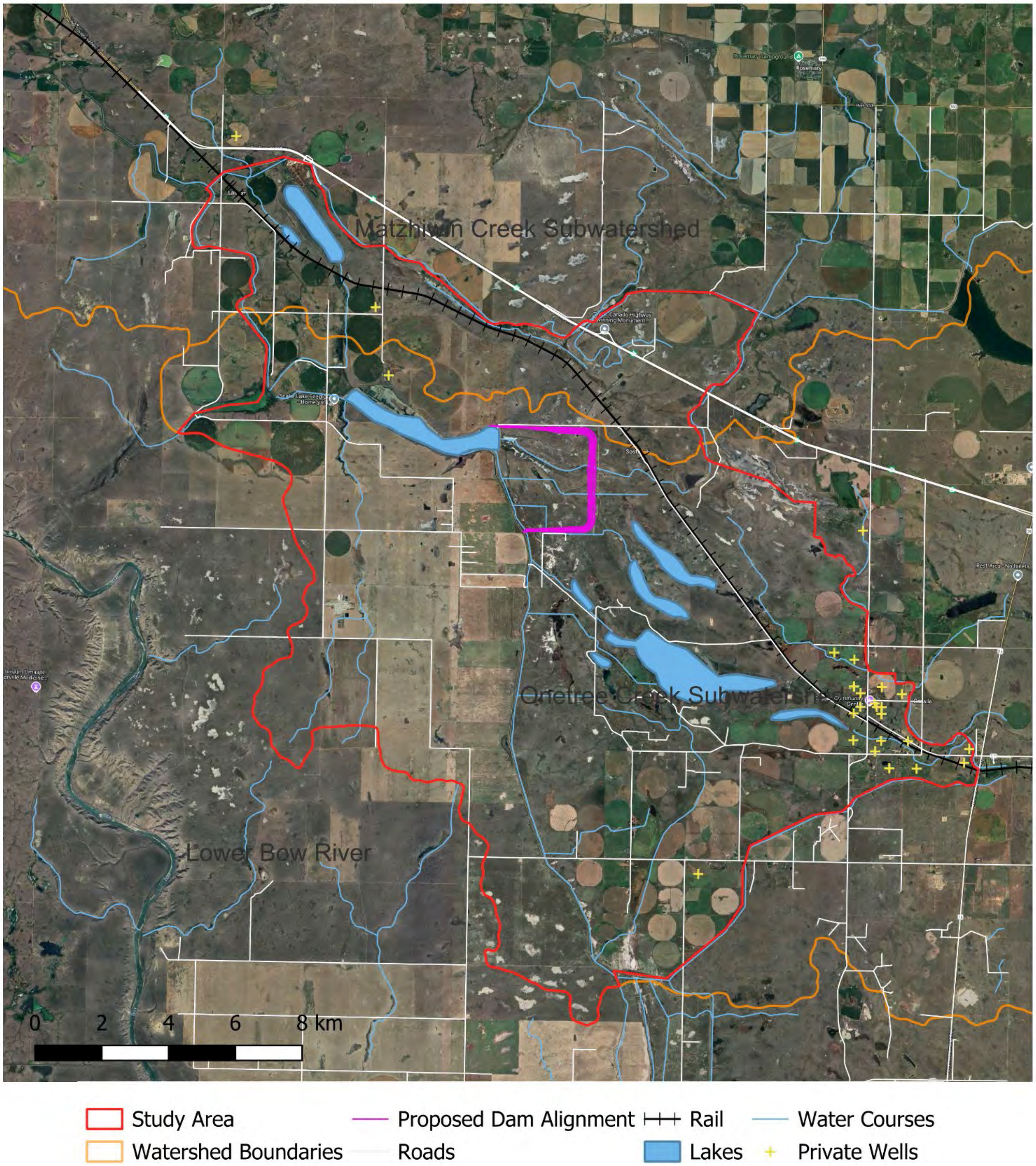
The SLR is located within Townships 19 and 20, Ranges 16 and 17, W4M, approximately 18 km southeast of Bassano and 23 km northwest of Brooks, Alberta. The reservoir is currently contained by two earth-fill dams: the east end (East Dam) located in Section 31-19-16 W4M, and the second along the west end (West Dam) located in Section 3-20-17 W4M. The reservoir is an off-stream irrigation storage facility originally constructed from 1995 to 1997 and operated by the EID.

The reservoir is 299 ha in area and has a current storage volume of 15,600 acre-feet (ac-ft) (19.25 million m^3) at full supply level (FSL) with a geodetic elevation of 781.7 metres above mean sea level (masl). Water is diverted into the reservoir from the EID's East Branch Canal via a gated inlet chute and an inline check structure. Outflow from the reservoir is through the East Dam Low-Level Outlet Structure, located near the north end of the East Dam, which helps support 50,000 acres (20,000 ha) of downstream irrigated agriculture.

The EID proposes to expand the reservoir by constructing an 8 km long earthen berm in Sections 29, 30, 31, and 32 in Township 19, Range 16, W4M, to extend the reservoir approximately 3 km to the South and 3 km to the East. The Project will increase the reservoir area by 764 ha in the expansion area plus an increase of 6 ha in the extant SLR by raising FSL by 0.3 m to 782.0 masl for a total area of 1,069 ha. The total volume of water stored will increase to 87.4 million m^3 and will support downstream users with one year of irrigation water.

The approximate geographic coordinates of the centre of the proposed reservoir expansion are 112° 11' 32.64"W 50° 38' 38.76" N.

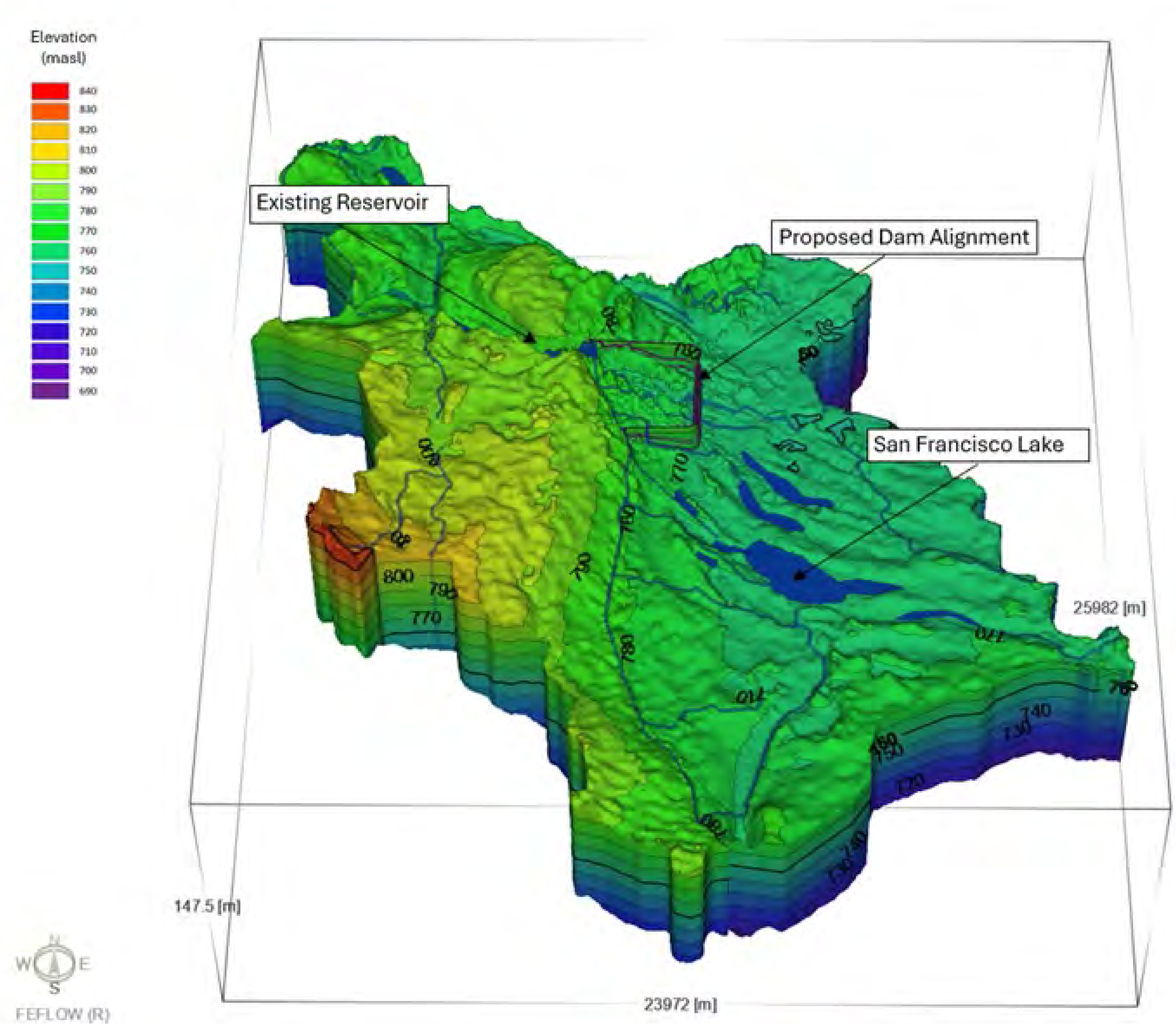
Figure 1: Location of the Snake Lake Reservoir Expansion Project



2.2 Topography

The Project is located between the Bow River and the Red Deer River within the Red Deer River Watershed. The ground surface is depicted in Figure 2 and is based on Light Detection and Ranging (LiDAR) data. Within the Study Area, the topography is highest on the western side and reaches a maximum elevation of 840 m. The lowest elevation of 758 m occurs on the eastern side of the area where some wetlands and waterbodies occur. These localized topographic lows are likely where the majority of groundwater recharge occurs within the Study Area.

Figure 2: Topography of the Study Area and Surface Water Bodies



2.3 Climate

The planned reservoir expansion area is considered dry to very dry with normal annual precipitation from 1971 to 2000 of roughly 348 mm (Environment and Natural Resources, Canadian Climate Normals for Brooks Alberta). The Study Area occurs in the Dry Mixedgrass Natural Subregion, described as semi-arid with cold dry winters with little snowfall and occasional Chinook winds. The area experiences wide diurnal temperature fluctuations due to the arid climate and moderately high elevations ranging between 758 m and 840 m. Low humidity is common year-round with most of the precipitation occurring in late spring and summer. The coldest month is January with a normal temperature of -11.3 °C and the warmest month is July with a normal temperature of 18.3°C. The driest month is February with 12.2 mm of precipitation, and the wettest month is June with a normal of 58.8 mm of precipitation. The maximum daily precipitation reported for the region was 88.9 mm.

2.4 Hydrogeological Setting

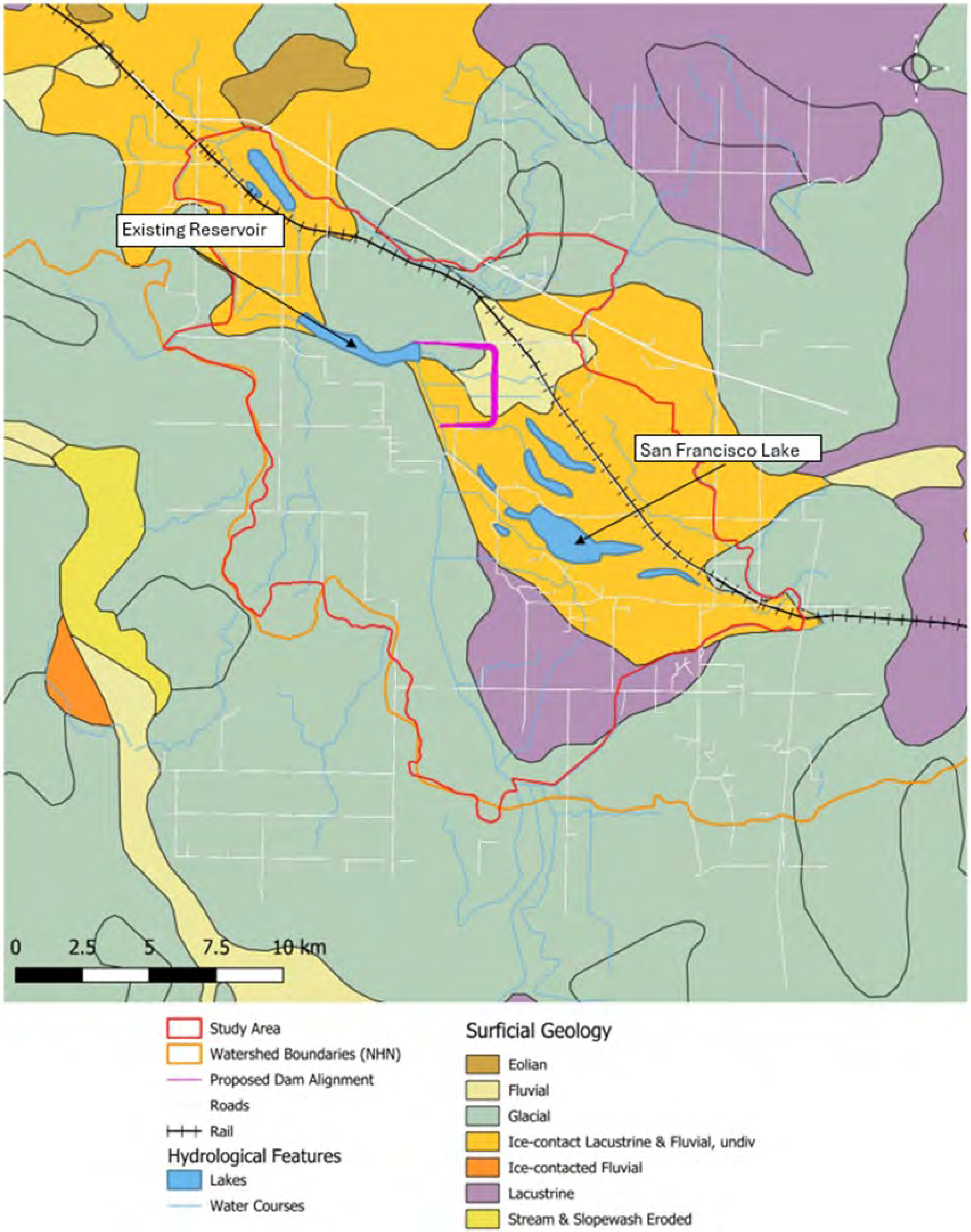
2.4.1 Surficial Geology

The surficial geology of the region is dominated by glacial deposits with minor colluvial, eolian, and fluvial deposits (Figure 3). The area near the reservoir expansion is mapped as a mixture of unsorted till to the north and west, fluvial gravel, to the north and east, and glaciolacustrine towards the south. The most dominant units mapped within the Study Area are the glaciolacustrine deposits towards the east and the till deposits towards the west. Other minor units occur sporadically throughout the Study Area.

Within the boreholes completed in the planned Project area, the thickness of surficial deposits ranges from 0.1 m to 7.5 m; the overburden is mostly as clay till.

Additional details on the surficial geology can be found in the main Hydrogeology Baseline Technical Data Report (Volume 2, Section 6).

Figure 3: Map of Surficial Geology and Hydrological Features in the Area Surrounding the Proposed Reservoir Expansion (Modified after Fenton et al., 2013)



2.4.2 Bedrock Geology

The bedrock underlying the surficial deposits within the Study Area is of Upper Cretaceous age and is composed of shale. The Project area is mapped as Bearpaw Formation (Figure 4). This was confirmed by the borehole and core hole drilling program conducted on the site. Within this area, there are limited bedrock outcrops, and the overburden cover is relatively continuous and primarily composed of clay till.

The contact between the overlying clay till and the weathered bedrock is generally greater than 1 m below ground surface with 90% of boreholes having more than 1 m of overburden. The weathered shale layer varies in thickness from 0.5 m up to 27.4 m in certain boreholes but in general, the weathered layer is less than 8 m thick in over 90% of the boreholes and core holes drilled. The weathered bedrock reaches a maximum depth of 33.5 m with the depth of the weathered bedrock layer generally less than 10 m thick.

Additional details on the bedrock geology can be found in the main Hydrogeology Baseline Technical Data Report (Volume 2, Section 6).

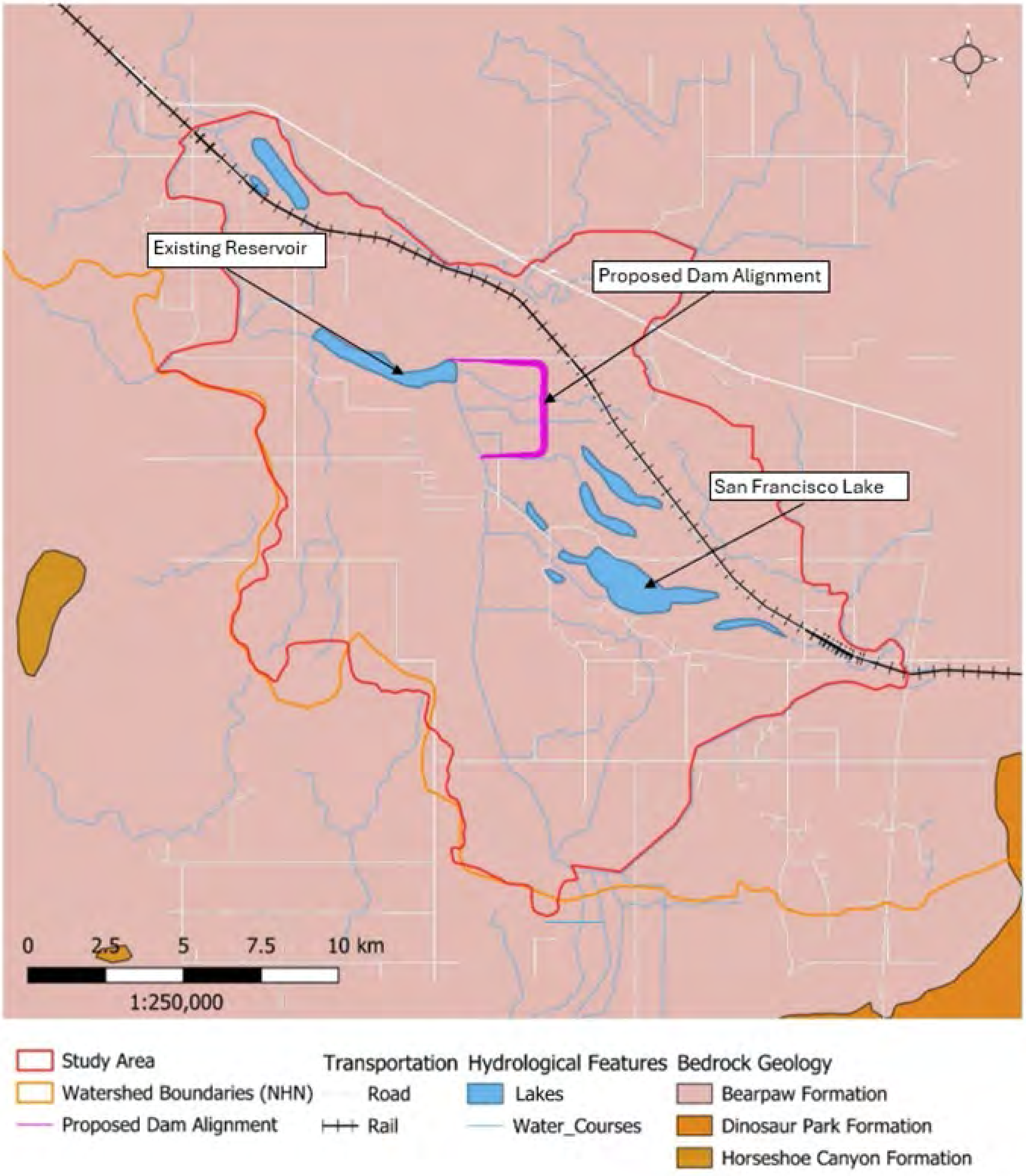
2.5 Hydrogeology

The Study Area is located within the Central Plains Hydrogeological Region (CPHR) of Alberta. In general bedrock within the CPHR consists of alternating layers of sandstone, siltstone, mudstone, and coal. The variations of hydrogeological properties of these units create a wide range of groundwater quality and quantity conditions.

The Study Area is underlain by the Bearpaw Formation (Figure 4) that mostly consists of siltstone and mudstone that also contains bentonite. Generally, the Bearpaw Formation is considered an aquitard.

The regional groundwater flow is not well documented in publicly available data and therefore groundwater flow data are limited. The flow direction and groundwater levels outside of the Project area, where monitoring was conducted, were inferred from topographic and hydrographic data. In general, the groundwater flows from west to east. The nearest mapped watershed boundary is located 6,500 m west of the new reservoir limits and 2,300 m southwest of the western limit of the existing reservoir (Figure 4). This watershed boundary divides flow toward the east into the Red Deer River watershed and toward the west into the Bow River watershed. Both of these rivers flow into the Saskatchewan River and ultimately into the Nelson River which eventually empties into Hudson’s Bay.

Figure 4: Map of the Bedrock Geology in the Area Surrounding the Proposed Reservoir Expansion (Modified after Prior et al., 2013)



2.6 3-Dimensional Groundwater Flow Model Construction

2.6.1 Hydrostratigraphic Conceptual Framework of the Study Area

The hydrostratigraphic conceptual framework was developed using available information including the provincial water well database (Government of Alberta, 2024), geotechnical drilling, monitoring well construction, and regional bedrock and surficial mapping (Figure 5). Refer to Sections 2 and 3 of the hydrogeology baseline report for more details on the development of the hydrostratigraphic conceptual framework of the Study Area. The hydrostratigraphic conceptual framework forms the basis of the numerical groundwater flow model that was developed to predict the influence of the Project, during the construction and operational phases, on the local groundwater flow regime. Through the development of the hydrostratigraphic conceptual framework, three distinct groundwater zones were identified, including surficial clay till deposits, weathered shale, and unweathered shale. There is additionally some localized alluvium within the Study Area, however, this material will be removed from the area within the dam footprint and was excluded from the hydrostratigraphic conceptual framework.

Based on the geology and stratigraphy observed in boreholes and coreholes, the hydrostratigraphic conceptual framework was separated into three distinct hydrostratigraphic units described below and in Table 1.

Within the Project area, three units were observed directly using various methods. Beyond the planned reservoir expansion area, data was limited to regional scale mapping and available literature.

- Overburden – Clay Till

  The overburden thickness near the Project area decreases in the topographic highs and reaches its maximum thickness in the lower elevation areas along watercourses and towards the low-lying areas east of the planned reservoir expansion area. These low-lying areas consist primarily of areas where water accumulates during the wetter periods of the year. Intermittent water bodies and watercourses generally drain east towards the various natural and man-made water bodies within the Study Area.

  The clay till deposit was encountered in the majority of the boreholes, core holes and test pits throughout the Project area. The clay till deposits ranged in thickness from 0.1 m up to 7.5 m at vibrating wire piezometer location 22VWP-04 with the greatest thickness of silt observed in the lowland area east and northeast of the planned reservoir expansion area.

  The hydraulic conductivities calculated in the clay till interval based on plasticity index was on the order of 10^{-9} m/s.

  The groundwater flow direction in both the overburden and the bedrock was similar and hydraulic gradients were also similar. The flow direction is controlled by the topography recharge of the aquifer concentrated in the low-lying areas where water accumulates.

- Weathered Shale

  The near-surface bedrock was generally more fractured and weathered in the geological logs. This zone ranges greatly in thickness based on the description in the geotechnical logs but generally comprises the first 3 to 4 m of bedrock. This portion of the bedrock was screened in the monitoring wells installed as part of the hydrogeological study and slug tested and packer tested to estimate the hydraulic conductivities of this unit. The hydraulic conductivity from the slug testing of this section of bedrock was slightly higher than those observed during the packer tests ranging from 1.1×10^{-6} to 4.0×10^{-5} m/s. These values correspond to the values from literature. A single outlier of 6.9×10^{-11} m/s from monitoring well 22CH118, but this result was excluded from the model. Although the depth interval tested in 22CH118 was described as weathered, the low hydraulic conductivity obtained appears to indicate the level of fracturing and/or the interconnectivity of fractures in the vicinity of 22CH118 were lower than the levels observed within weathered shale in intervals tested in other boreholes and coreholes.

- Unweathered Shale

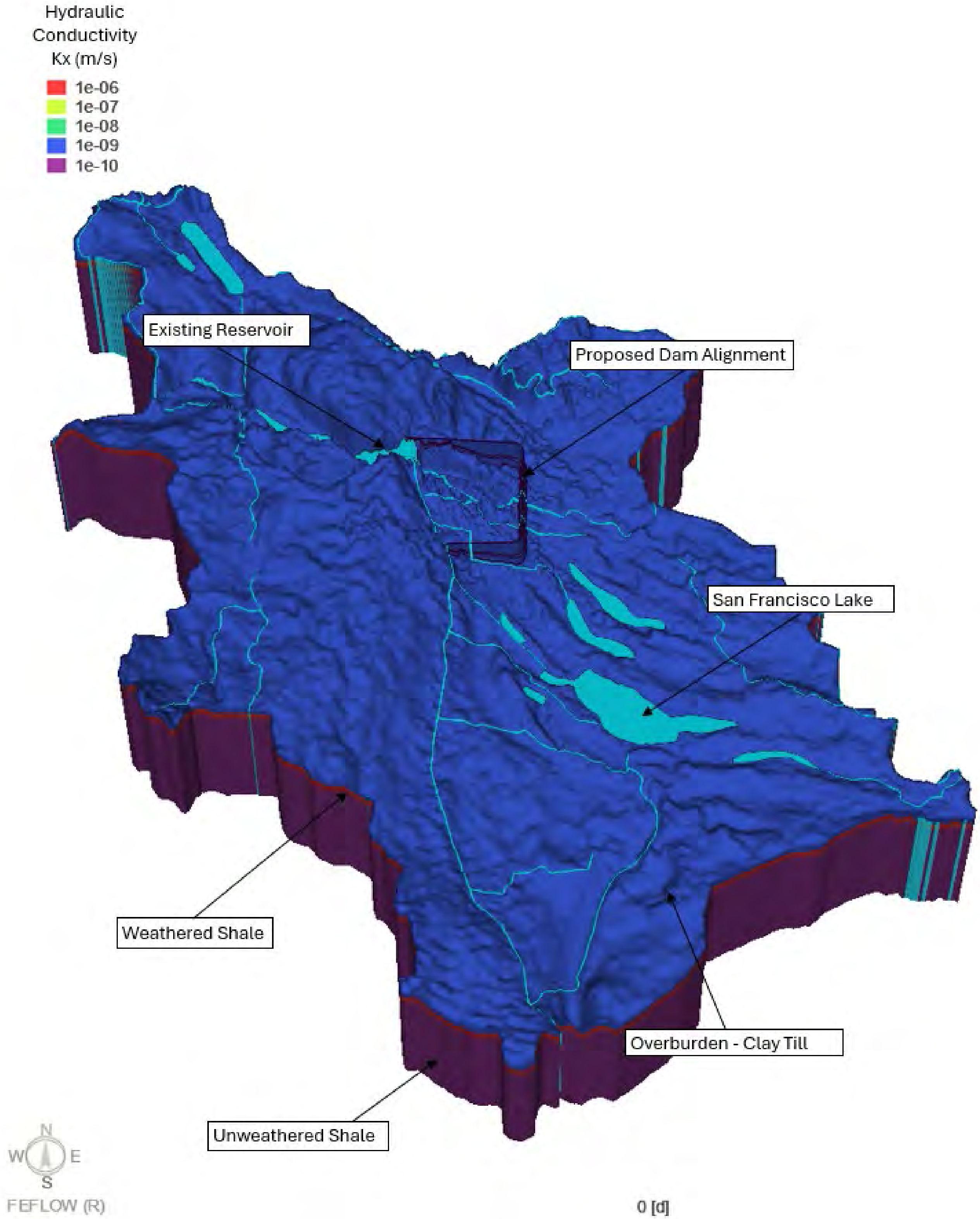
Below the near-surface weathered zone, the bedrock becomes more competent, and the fracture density decreases. Groundwater flow in this unit is largely controlled by bedding, fractures, and joints. This portion of the bedrock unit generally was of good [≥75-90% Rock Quality Designation (RQD)] to excellent (≥90-100% RQD) quality. The zones evaluated using packer testing and slug testing had similar hydraulic conductivities ranging from 3.5×10^{-10} to 2.7×10^{-8} m/s. The results obtained during the packer tests show apparent hydraulic conductivity estimates that are greater than results obtained during in situ hydraulic conductivity testing by more than two orders of magnitude. This difference is interpreted to be mostly attributable to the bedrock quality within the tested depth intervals. Packer testing focuses on bedrock intervals of lowest quality showing a high level of fracturing in tested boreholes whereas in situ hydraulic conductivity testing results are typically more representative of bulk bedrock hydrogeological characteristics. Given that the hydraulic conductivity linked to the primary porosity in shale is very low, the presence of open fractures in some depth intervals results in significant contrasts in hydraulic conductivity. In effect, the hydraulic conductivity linked to the secondary porosity (fractures) is largely superior to that of the bedrock matrix in shale bedrock. The unweathered shale was considered a single hydrostratigraphic unit for the conceptual model and the various lithologies encountered at depth were combined.

Table 1 Hydrostratigraphic Conceptual Framework and Numerical Model Layers

Major Soil or Bedrock Classification Group	Geological Description	USCS Symbols	Conceptual Geological Units	Conceptual Hydrostratigraphic Units	Hydrogeological Setting	Numerical Model Layer
Overburden - Clay Till	Glacial Till	CH	Overburden - Till	Clay Till		1
Primarily Weathered Shale	Shale of the Bearpaw Formation	Not applicable	Weathered Bedrock (RQD[1] values <75)	Shallow weathered bedrock aquifer/aquitard	Flow regime with significant heterogeneities	2
Unweathered Shale[2]		NA (NA)	Bedrock (RQD[1] values ≥75)	aquitard	Simpler, slower flow regime	3

Notes:
1- RQD: Rock Quality Designation
2- Since permeability at depth is lower, it is expected that groundwater flow will be limited in this zone. Only a small proportion of recharge influences this depth and migrates within the shale bedrock.

Figure 5 : Conceptual Hydrostratigraphic Framework of the Study Area



2.6.2 Development of a Numerical Groundwater Flow Model

A three-dimensional groundwater flow model was used to implement the hydrostratigraphic conceptual framework described in the preceding section. The model was used to predict the potential impacts of the reservoir expansion on regional groundwater levels, the environment, and other groundwater users. The model was based on the available information from the investigations completed to date and pertinent information from the literature to fill gaps in data that could not be directly measured in the field. The finite element modelling software FEFLOW Version 7.3 was used to create the numerical model. Groundwater flow simulations in steady-state conditions were completed using the initial convergence criteria. The calculations were completed using the standard iterative solver, which is a numerical method used to solve large, sparse system of linear equations when solving for groundwater flow. In steady-state groundwater flow conditions, the termination criterion is 10^{-10} (unitless).

2.7 Groundwater Flow Model Construction

The numerical model used to simulate the potential impacts of the reservoir expansion on regional groundwater levels, the environment, and groundwater users was developed based on the hydrostratigraphic conceptual framework. The hydrostratigraphic conceptual framework was developed using available and pertinent information from literature to complete the information that could not be directly measured in the field. The elevation of the layers is based mainly on the stratigraphic boundary elevations identified in boreholes drilled in the planned reservoir expansion area with additional information derived from the private well logs available in the provincial water well database. The logs for monitoring wells constructed during this project are presented in Appendix D2 of the Hydrogeological Baseline Technical Data Report.

2.7.1 Model Domain

The model limits include one-tree creek sub-watershed to the southwest and surface water features (rivers, wetlands, and canals) for the remainder of the model domain. The northern limit of the model is 2.7 km north of the Project area. The eastern model limits consist of surface water features including canals and wetlands, 3.5 to 11.5 km east of the planned reservoir expansion area. The western limit of the model is located 6.25 km away and consists of the watershed boundary between the Bow River and the Red Deer River. The southern limit consists of the watershed boundary and canals and is 13.5 km south of the reservoir expansion.

2.7.2 Hydrological Features

The project is located in a relatively flat area of Alberta with high topography areas located on the western side of the Study area. Throughout the Study Area, numerous wetlands, natural watercourses and manmade canals are present. The watercourses located within the limits of the model were not gauged and estimates of inflow to the reservoir are based on the results of the Inflow Design Flood Estimate report prepared by MPE Engineering Ltd. (MPE), prepared for EID, dated August 22, 2023, Project No. 1560-193-00 and File No.: N:\1560-193-00\R04-1.0 (Volume 1, Section 6, Attachment 6C). The most important hydrologic feature is located southwest of the planned reservoir expansion area: San Francisco Lake represents a topographic low within the model domain, and it is surrounded by wetlands. The most prominent hydrologic feature within the Study area is the canal just south of the existing reservoir and west of the planned reservoir expansion area.

2.7.3 Planned Reservoir Expansion

The planned project involves the expansion of the existing reservoir, which currently covers a 299 ha area and has a storage capacity of 15,600 ac-ft (19.25 million m^3) at full supply level (FSL) to a total area of approximately 1069 ha and a storage capacity of 87.4 million m^3 to support downstream users with up to one year of irrigation water. The planned project will not increase the volume of water diverted by the EID and will not increase the maximum diversion rate at Bassano Dam. The project will also provide an opportunity to divert water to fill the reservoir when flows are abundant in the Bow River and reduce diversions from the river during periods of low flow.

2.7.4 Model Layers

The model was separated into 3 layers representing the 3 hydrostratigraphic units (See Section 2.6.1).

The following summarizes the hydrostratigraphic conceptual framework implemented as part of the numerical model starting from the overburden to the deep bedrock:

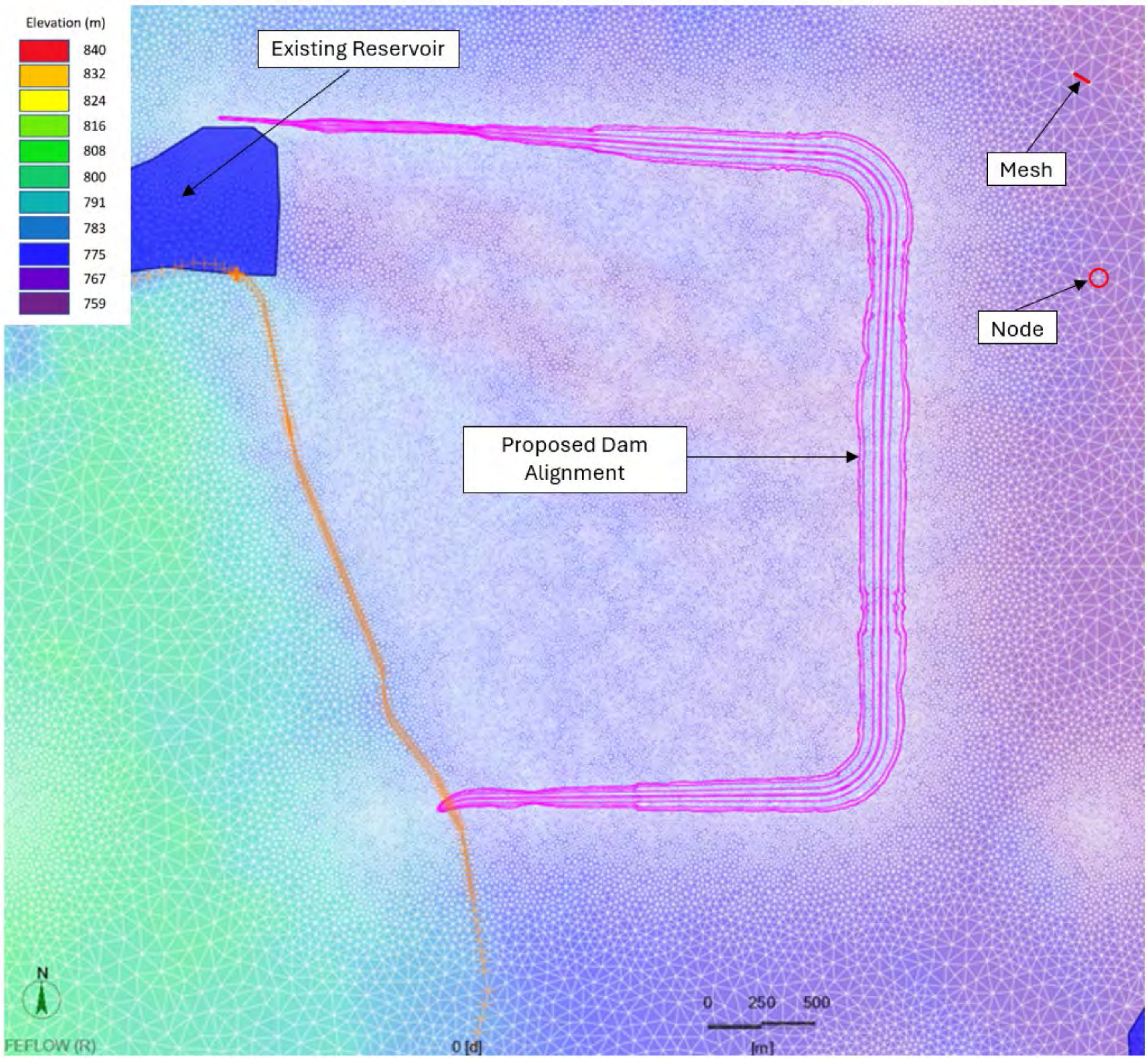
- 1: Overburden - Clay Till (maximum thickness of 22.7 m and average thickness of 2 m at the reservoir)
- 2: Weathered shale (maximum thickness of 10.0 m and average thickness of 4 m at the reservoir))
- 3: Unweathered shale (maximum thickness of 60.4 m and average thickness of 60 m)

The model domain was initially discretized by generating a triangular mesh with a maximum mesh size of 140 m located more distally from the planned reservoir expansion area and to allow for a reasonable calculation time for the groundwater flow simulations. The meshing was refined along water courses, the model limits, and the reservoir expansion limits to achieve a mesh length of roughly 12 m to allow for better convergence around these elements and to better illustrate the more pronounced variations in groundwater flow created by the reservoir expansion. The final model consisted of 750,603 total elements (250,201 elements per layer) and 503,496 nodes (125,874 nodes per layer)

The elevation of the layers was defined based on the borehole logs in the area of the reservoir expansion where data was collected directly. The layer elevations are based on LIDAR values as well as the average layer thicknesses measured during the various field works. The borehole data was used to calculate the thickness of the various layers, which were then fixed to the digital elevation model (DEM) surface. The layer thicknesses beyond the planned reservoir expansion area were set at an average thickness for the corresponding unit based on the drilling data. It should be noted that most of the available data is concentrated in a small region near the planned reservoir expansion area and the information beyond this zone was extrapolated based on regional geological mapping and topographic data.

The mesh distribution around the proposed dam alignment is shown in Figure 6.

Figure 6 : Mesh Distribution in the Area Surrounding the Proposed Dam Alignment



2.7.5 Boundary Conditions

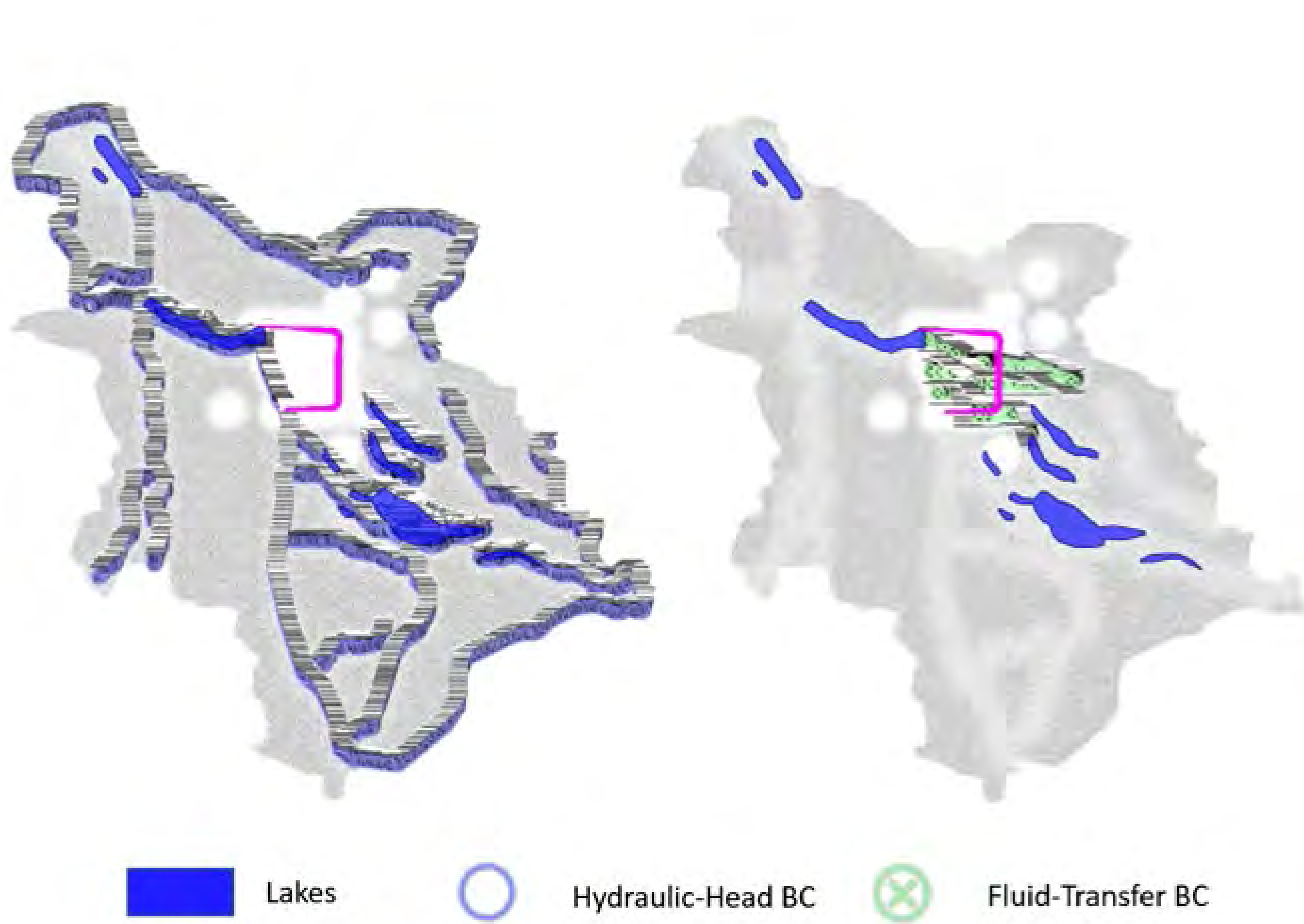
In order for FEFLOW to generate hydraulic heads within different layers, constant head boundary conditions were applied at the southern, eastern, and northern limits of the model domain. These constant head boundaries were applied to the upper two (2) layers of the model.

No flow limits corresponding to watershed boundaries (based on the National Hydrographic Network) were applied at the western limits of the model domain.

Constant head boundaries were used to represent the watercourses, waterbodies and canals located outside of the reservoir boundaries. The values for each of these head boundaries were assigned based on topographic data and interpolated along the water courses. Within the limits of the proposed reservoir basin, fluid transfer boundary conditions were used to represent the water courses. This type of boundary condition allows for assigning inflow and outflow limits to a water course. The inflow and outflow constraints were set based on the results of the hydrological study entitled Inflow Design Flood Estimate prepared by MPE (Ref. No.: N:\1560-193-00\R04-1.0; (Volume 1, Section 6, Attachment 6C) and manually adjusted based on the calibration results. The available information does not allow for precise quantification of the connection between watercourses and the bedrock units and the proportion of total surface water flow related to runoff.

Since data collection was concentrated within the area close to the reservoir expansion, the level of uncertainty pertaining to the boundary conditions where no direct observations were made remain high. Given that the area of interest with respect to potential impacts related to the reservoir expansion is primarily concentrated in the vicinity of the reservoir, the uncertainty pertaining to the boundary conditions is not expected to significantly affect modeling results in the area where potential impacts may occur and where site data is available. The model should therefore provide an accurate representation of predicted potential impacts near the reservoir.

Figure 7 : Constant Head Boundaries (Left) and Fluid Transfer Boundaries (Right) Applied to the Model Domain of the Study Area



2.7.6 Model Input Parameters

2.7.6.1 Hydraulic conductivity

The hydraulic conductivities integrated into the model are based on data collected in the field, and theoretical values from literature to fill in knowledge gaps. The minimum thickness for the various units was set at 1 m. The horizontal hydraulic conductivities applied to the various hydrostratigraphic units do not distinguish between the hydraulic conductivities in different horizontal directions (i.e., K_x and K_y). Figure 8 depicts the assigned horizontal hydraulic conductivities in the model layers. The vertical component (i.e., K_z). was fixed at a rate of 10% of the horizontal component based on values provided in Todd (1980), which reports values of K_z/K_r ranging between 0.1 and 0.5 for alluvium and possibly as low as 0.01 when clay layers are present.

Figure 8: Distribution of Horizontal Hydraulic Conductivities in Model Layers 1, 2, and 3.

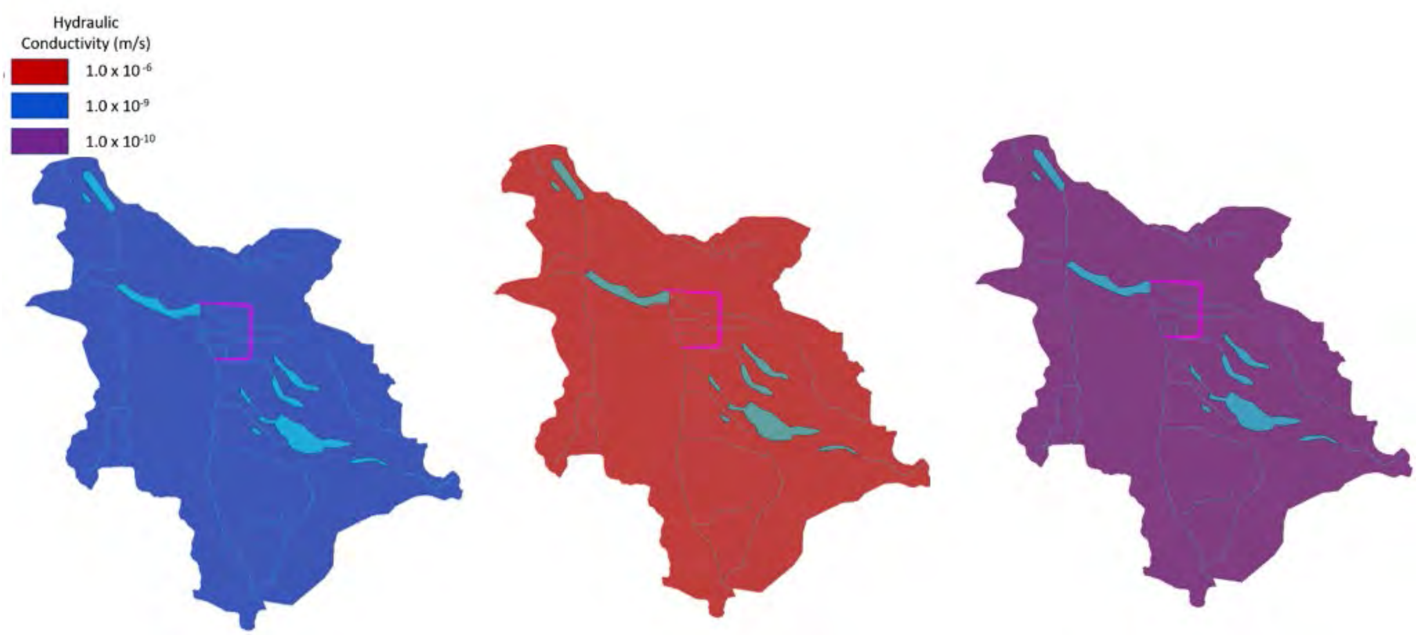


Table 2: Summary of Hydraulic Conductivities Applied to Hydrostratigraphic Units.

Hydrostratigraphic Unit	Applied Hydraulic Conductivity Values (m/s)
Layer 1 – Clay Till	1.0×10^{-9}
Layer 2 – Weathered Shale	1.0×10^{-6}
Layer 3 – Unweathered Shale	1.0×10^{-10}

2.7.6.2 Areal Recharge

As indicated in the Section 2.7.4, the clay till unit is present at the surface throughout the entire model domain. Since clay is impermeable, a large part of the water from precipitation will run off and therefore will not infiltrate into the soil.

An evaluation of the recharge rate was done using the Thornthwaite equation as a starting point and modified based on past modelling experience and the results of the model calibration process. The recharge for the entire model domain was fixed at 0.2 mm per year. This should be considered an average recharge rate for the entire model domain, and the actual recharge is expected to vary with a lower recharge in the areas with finer-grained materials and in the higher topographic areas and higher in the low-lying areas where runoff accumulates and where coarse-grained materials are present.

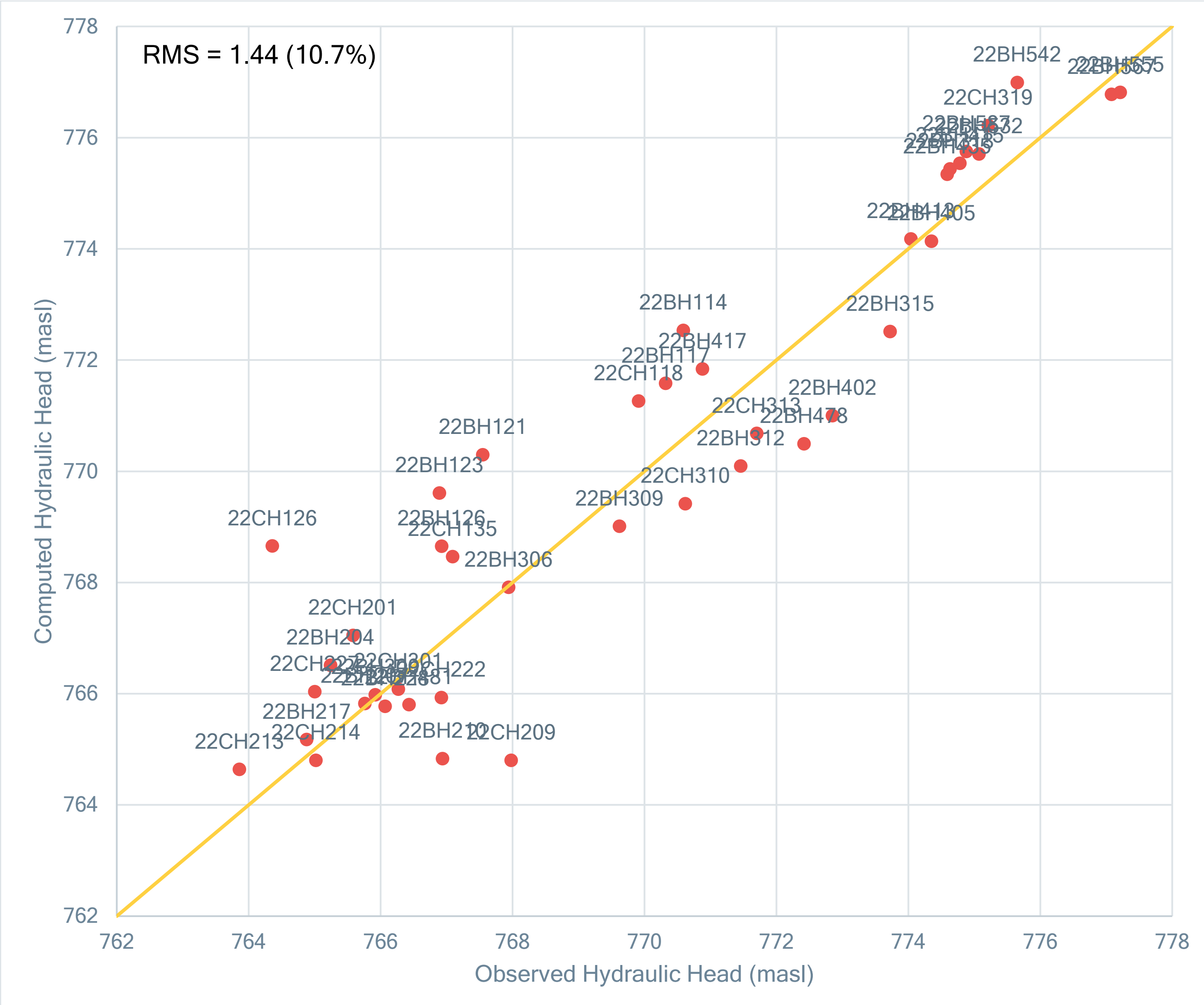
2.7.7 Model Calibration and Baseline Case

There are two important types of model implementations. Models can be implemented in an interpretive sense to gain insight into the system dynamics or regional hydrogeological setting or be implemented to predict contaminant migration or groundwater flow conditions. The interpretive models do not necessarily require calibration (Anderson, Mary P., and W.W. Woessner, 1991). However, predictive models generally require calibration.

The steady-state calibration of the model has the objective of demonstrating the concordance between simulated and observed groundwater flow. A good concordance between the simulated and observed groundwater flow indicates that the model should be an approximate representation of realistic flow conditions. If there is a significant difference between the simulated and observed values, some parameters must be adjusted to better approximate realistic conditions. For this project, the model was calibrated under steady-state conditions using water levels observed on August 10th, 2022. The main parameters that were varied to allow for calibration were the hydraulic conductivity of the various hydrostratigraphic units, the recharge, and the hydraulic head values assigned to rivers, canals and lakes. No dynamic calibration was conducted as pumping data was limited and no response was observed in nearby observation wells during the tests.

Figure 9 shows the model calibration results. The yellow line on the graph in Figure 9 represents a theoretical line that represents perfect concordance between simulated and measured water levels.

Figure 9: Observed Hydraulic Head vs. Simulated Hydraulic Head



In Figure 9, data points located above the line indicate that the calculated water levels are higher than the observed water levels, whereas data points located below the line indicate the opposite. The data projected on the graph shows a good agreement between the observed and simulated water levels and the maximum difference between the calculated and observed values is 4.3 m. To quantitatively evaluate the concordance between the simulated and observed water levels, the root-mean-squared (RMS) error value for the model is generally used. This value corresponds to the quadratic mean of the difference between the calculated and observed water levels. This value can be expressed as a percentage by dividing the quadratic mean by the difference between the highest and lowest observed values. The RMS of the model was 10.7%, the typical target is below 10%, however, there are a large number of wells within a small area, with a relatively small difference in the hydraulic head, which leads to small variations in water levels having more impact on the best fit. The results are therefore considered acceptable in this type of hydrogeological study.

Table 3 presents a comparison of the total simulated inflows and outflows (i.e., volumetric water budget) for the groundwater model at the regional scale shows the percent discrepancy in the water budget for this application of the model to be 0.000002%. Errors of the order of less than 1% are considered to be acceptable (Anderson Mary P. and Woessner W.W., 1991).

Table 3 : Summary of Inflows (+) and Outflows (-) from the Boundary Conditions Applied to the Model

Groundwater Source or Sink	Flowrate out of the model domain (m^3/day)	Flowrate into the model domain (m^3/day)
Contribution of streams, lakes and reservoir (constant head boundaries)	-138.08	-
Contribution of c in reservoir footprint (fluid transfer boundaries)	-29.45	5.24
Areal Recharge		162.29
Percent discrepancy: 0.000002%		

Table 4 below presents the percent differences between the calculated and observed values of hydraulic heads from the steady-state calibration results.

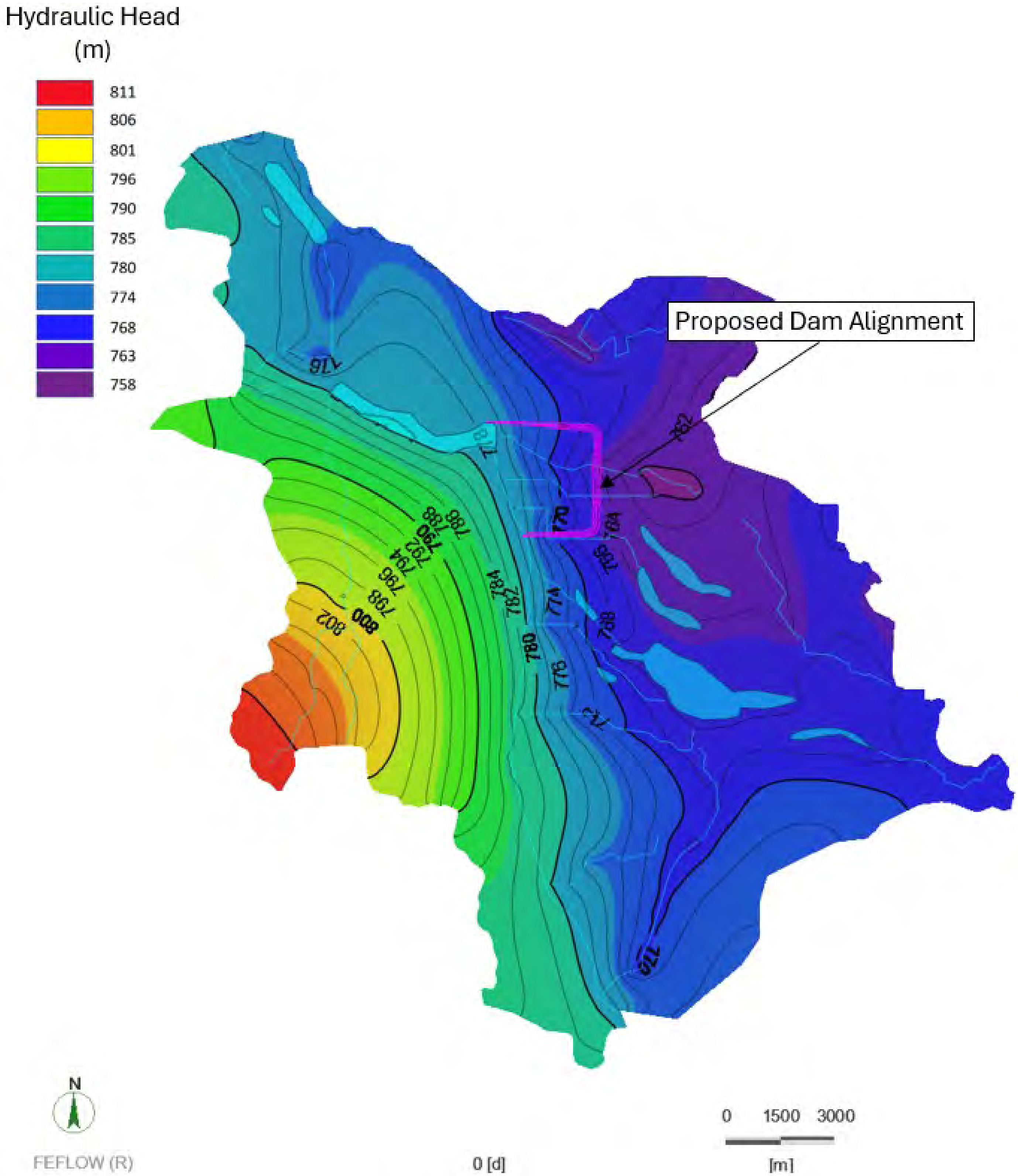
Table 4: Observed vs. Simulated Hydraulic Head during Calibration

Borehole ID	Observed Head	Simulated Head	Difference (m)	% Difference
22CH213	763.86	764.64	-0.78	0.10%
22CH126	764.36	768.66	-4.30	0.56%
22BH217	764.88	765.18	-0.30	0.04%
22CH227	765.00	766.04	-1.04	0.14%
22CH214	765.02	764.80	0.22	0.03%
22BH204	765.24	766.51	-1.27	0.17%
22CH201	765.58	767.05	-1.47	0.19%
22BH207	765.76	765.82	-0.06	0.01%
22BH300	765.92	765.98	-0.06	0.01%
22BH228	766.07	765.77	0.30	0.04%
22CH301	766.27	766.08	0.19	0.02%
22BH481	766.43	765.80	0.63	0.08%
22BH123	766.89	769.61	-2.72	0.35%
22CH222	766.92	765.93	0.99	0.13%
22BH126	766.93	768.65	-1.72	0.22%
22BH210	766.94	764.83	2.11	0.28%
22CH135	767.09	768.46	-1.37	0.18%

Borehole ID	Observed Head	Simulated Head	Difference (m)	% Difference
22BH121	767.55	770.29	-2.74	0.36%
22BH306	767.94	767.91	0.03	0.00%
22CH209	767.98	764.80	3.18	0.41%
22BH309	769.62	769.01	0.61	0.08%
22CH118	769.91	771.26	-1.35	0.18%
22BH117	770.32	771.58	-1.26	0.16%
22BH114	770.59	772.53	-1.94	0.25%
22CH310	770.62	769.42	1.20	0.16%
22BH417	770.88	771.84	-0.96	0.12%
22BH312	771.46	770.10	1.36	0.18%
22CH313	771.70	770.68	1.02	0.13%
22BH478	772.42	770.49	1.93	0.25%
22BH402	772.85	771.00	1.85	0.24%
22BH315	773.73	772.51	1.21	0.16%
22BH413	774.04	774.18	-0.14	0.02%
22BH405	774.35	774.14	0.21	0.03%
22BH435	774.59	775.34	-0.75	0.10%
22BH318	774.63	775.44	-0.81	0.10%
22BH415	774.78	775.54	-0.76	0.10%
22BH587	774.88	775.75	-0.87	0.11%
22BH532	775.07	775.71	-0.64	0.08%
22CH319	775.21	776.22	-1.01	0.13%
22BH542	775.65	776.99	-1.34	0.17%
22BH567	777.08	776.78	0.30	0.04%
22BH555	777.21	776.81	0.40	0.05%
Average	**769.86**	**770.15**	**-0.28**	**0.04%**

Generally, within the area where data was collected near the planned reservoir expansion, groundwater flows towards the lowland areas east and southeast of the reservoir expansion. Groundwater flows in the west-to-east direction with a hydraulic gradient that ranges from 0.004 m/m to 0.01 m/m depending on the period when measurements were taken. The simulated gradient in the steady-state model scenario was 0.005 m/m in the same direction, which is similar to the natural flow conditions. The measured and simulated gradients and the flow directions are similar. Figure 10 depicts the simulated groundwater levels under the steady-state and pre-reservoir conditions.

Figure 10 : Simulated Groundwater Levels under Steady-State, Pre-Construction Conditions



3 Application Cases: 3-Dimensional Groundwater Flow Model Simulations and Potential Impacts of the Construction Dewatering and Reservoir Expansion

This section presents the application case comprising an evaluation of potential hydrogeological impacts related to three (3) major steps in the completion of the construction project and operation of the expanded reservoir, namely the temporary dewatering of excavations during construction, the operation of the expanded reservoir at maximum capacity and the operation of the expanded reservoir at average capacity.

3.1 Estimate of seepage rate into the excavations during construction

Once the calibration was deemed satisfactory, the seepage rate and the area of influence of the temporary groundwater dewatering activities during construction were estimated. The seepage rate evaluation was completed using transient flow conditions.

Each simulation was run for a 12-month period (365 days) with additional monthly time steps. The excavation work is expected to last roughly three (3) months (90 days) in the worst case locations where alluvial deposits are excavated beneath the future eastern dam and the estimate of seepage rates into the excavation was calculated using this time step. The bottom of the excavation is anticipated to reach an elevation of 759 m in the southern excavation and 761 m in the northern excavation approximately 6 m below ground surface. The seepage rates represent the groundwater dewatering rate for the entire excavation footprint provided by MPE. If the rate of excavation of the open pit is accelerated or slowed, the seepage rates may vary accordingly.

To simulate seepage rates, drain boundary conditions were applied at the elevation of the excavation floor.

3.1.1 Simulated Seepage Rates

The simulated seepage rate for the excavation after three months and 1 year (excluding surface water runoff and precipitation) are summarized in Table 5 below:

Table 5: Summary of Simulated Seepage Rates

Simulation time (days)	Seepage rate	Seepage rates with safety factor of 3)
90	305 m^3/day	915 m^3/day
365	140 m^3/day	420 m^3/day

The drainage flow rate decreases over time because the distance to constant head increases as the transient radius of influence of dewatering increases toward steady state conditions, and because water levels in the area stabilize, which results in a reduction of the groundwater removal rates from storage as time elapses since the beginning of pumping. In effect, the initial flow rates combining advection flow and water removal from storage in the pore spaces are expected to be significantly higher than long term flow rates under conditions approaching steady state conditions in which removal of water from storage becomes negligible and flow rates essentially consist of advection flow from distant constant head boundaries.

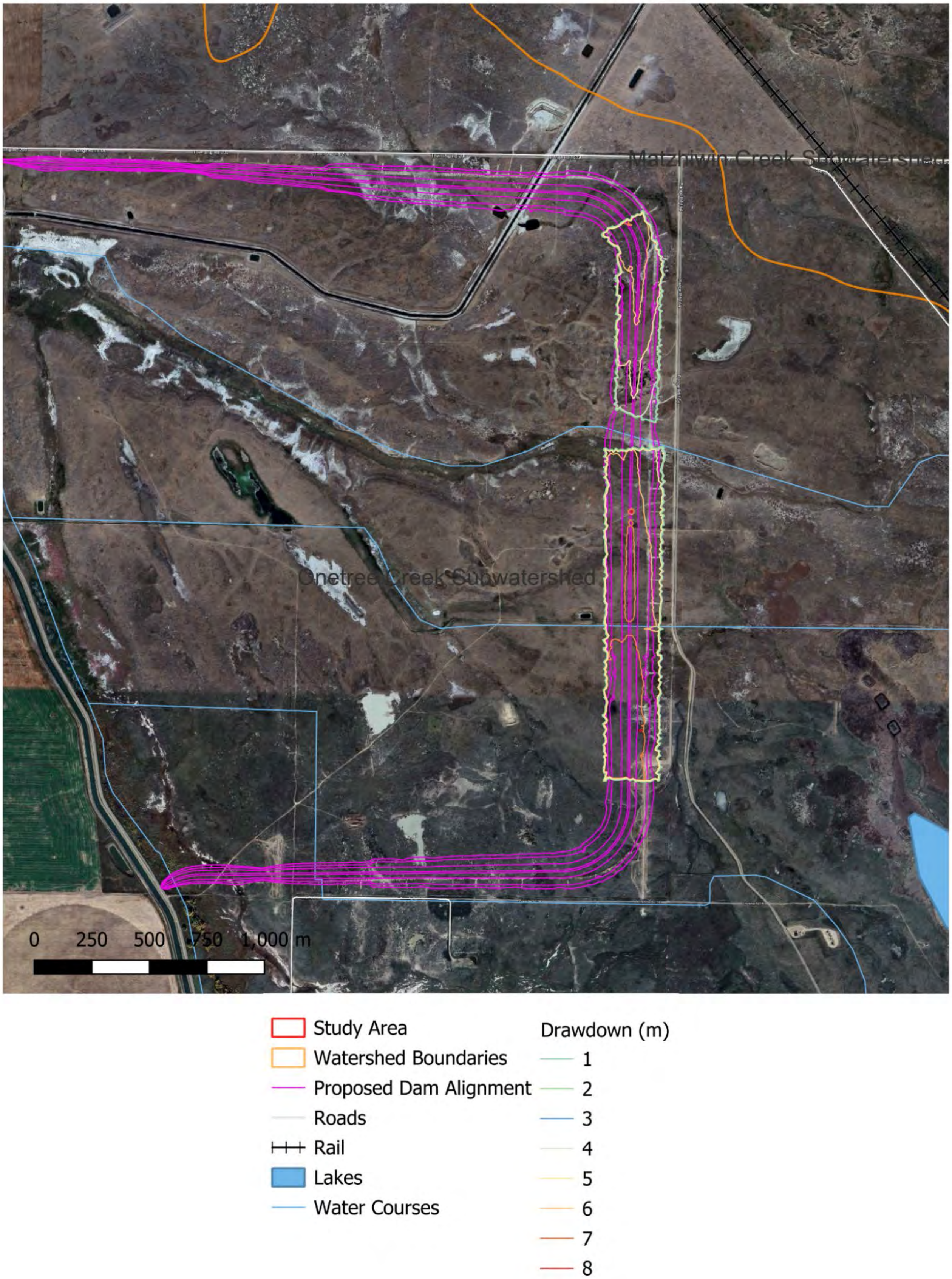
A factor of safety of three was applied to the results to account for heterogeneity within the subsurface as well as the potential contribution of the alluvial deposits along the water courses located within the planned reservoir expansion area that was not integrated into the conceptual model as it will be removed in the area of the proposed dam alignment before dam construction. This unit will remain in place during excavation and could contribute more groundwater to the excavation than the surrounding clay till unit.

3.1.2 Radius of Influence of Temporary Construction-Related Groundwater Dewatering

The results of the modelling indicate that the effect of groundwater drawdown is most pronounced within the footprint of the excavations and decreases rapidly with distance from the edge of the excavation.

The radius of influence of the dewatering activities was considered the area where drawdown was 0.5 m or greater in bedrock. Groundwater drawdown in layers 1 and 2 was used for determining the radius of influence since these layers are where the majority of the seepage in excavations and groundwater flow will occur based on their higher hydraulic conductivities. The impact of the groundwater dewatering during construction over the 90-day and 365-day periods is limited to the area immediately surrounding the excavation and does not extend beyond about 25 m of the excavation footprint. Figure 11 presents the simulated drawdown in the bedrock induced by the excavation dewatering for a period of 90 days.

Figure 11: Simulated Drawdown During Construction Dewatering (90 Days)



3.1.3 Impacts of the Dewatering Activities on Groundwater Users and the Environment

The potential impact of the excavation is limited to the area immediately surrounding the excavation and does not extend beyond about 25 m of the excavation footprint. The modelled scenario considers that the entire excavation will be open at the same time, when the actual work is expected to progress sequentially, and the entire excavation will not be open at the same time. Nonetheless, the modelled scenario does not indicate any significant impact on groundwater users, or the environment. Therefore, the simulated effects represent the worst case and still show no effect beyond 25 m of excavation.

3.2 Model Simulations of the Potential Influence of the Reservoir Expansion

Once the calibration was deemed satisfactory, the area of influence of the reservoir expansion was estimated using transient flow conditions. To simulate average and full capacity conditions in the reservoir expansion, constant head boundary conditions were applied to the area covering the planned reservoir expansion.

The calibrated hydrogeological model was used to simulate the potential influence of the reservoir expansion under two separate scenarios representing the following reservoir levels:

- Maximum capacity of the reservoir for a period of 3 months (Elevation of 782.0 masl; proposed FSL raise with the new dam)
- Average capacity of the reservoir for a period of 2 years (779.5 masl)

The numerical groundwater model of the maximum capacity is based on the design criteria and the average capacity scenario is based on water levels in the existing reservoir over the monitoring period. The water level for the maximum capacity scenario is higher than the maximum water level of the existing reservoir.

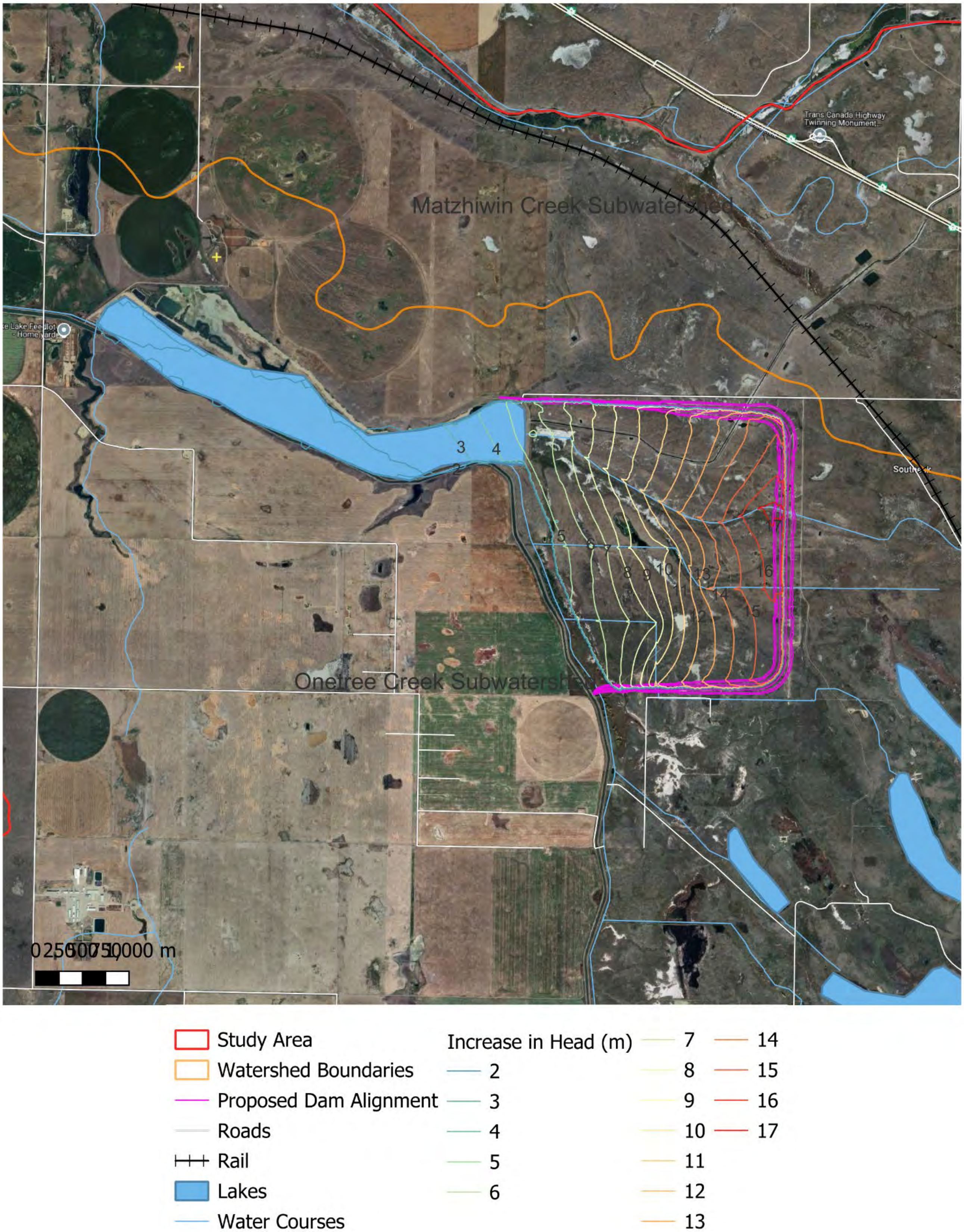
3.2.1 Groundwater Elevation Changes and Radius of Influence of the Reservoir Expansion (Maximum Capacity)

The radius of influence of the reservoir expansion was considered the area where the simulated head increased by 0.5 m or more in bedrock. The radius corresponding to an increase in the water level of 0.5 m was chosen because this increase is significant, particularly in relation to seasonal variations. Increases in the hydraulic head in layers 1 and 2 of the model were used to determine the radius of influence of the reservoir expansion activities since these layers are where the majority of the infiltration and groundwater flow will occur based on their higher hydraulic conductivities.

As the reservoir is not expected to be at maximum capacity (782 masl) for prolonged periods, the maximum capacity simulation was completed for a period of 90 days, which would exceed the actual period that the reservoir would be maintained at maximum capacity and is therefore a conservative estimate. The area of the influence of the reservoir expansion is limited to an area within the dam footprint. The hydraulic head dissipates over a short distance and does not extend beyond the midpoint of the dam footprint (Figure 12).

This dissipation over a short distance reflects the low hydraulic conductivity used in the modelled scenario. Outside of the reservoir and dam area, on the downstream side, there is a slight decrease in the hydraulic head that is generally less than 1 m. This decrease is the result of the obstruction of existing streams by the future dam, which will cut the flow to those streams downstream of the dam.

Figure 12: Impact of the Reservoir Expansion at Maximum Capacity Over 90 Days



3.2.2 Groundwater Elevation Changes and Radius of Influence of the Reservoir Expansion (Average Conditions)

The average water level conditions (779.5 masl) were simulated for a longer period (2 years) as it was anticipated that this would exceed the maximum time that the reservoir would be maintained at this level, and once again be a conservative estimate of the impacts of the reservoir expansion. Under these conditions, the area of influence of the reservoir expansion is limited to the area within the dam footprint. The hydraulic head dissipates over a short distance and does not extend beyond roughly the midpoint of the dam footprint (refer to Figure 13).

This dissipation over a short distance reflects the low hydraulic conductivity used in the modelled scenario and the associated elevated hydraulic gradients. As a result, the majority of the change in hydraulic head is concentrated within proximity of the proposed dam alignment. Outside of the reservoir and dam area, on the downstream side, there is a slight decrease in head that is generally less than 1 m was observed.

Figure 13: Impact of the Reservoir Expansion at Average Capacity over 2 Years

3.2.3 Impacts of the Reservoir Expansion on Groundwater Users and the Environment

The potential impacts of the reservoir expansion at both maximum capacity over three months and average conditions over two years are limited to an area that generally reaches the midpoint of the dam footprint, and no significant changes to the surface water features, groundwater regime, and groundwater users are expected.

A slight decrease in hydraulic head generally less than 1 m in the area downgradient from the dam could occur. The decrease in groundwater flow towards the downgradient area could have some impacts if the flow from the canal system that is currently used to help maintain the wetlands is interrupted. The reservoir, under actual operating conditions, would not be maintained at the average levels for two years. Nonetheless, some minor decreases in groundwater flow towards the low-lying areas surrounding the reservoir expansion could be anticipated with the introduction of the reservoir expansion.

Impacts of the reservoir expansion on the groundwater quality are not expected unless water quality within the reservoir is poor. If water quality within the reservoir is poor, migration of contaminants towards groundwater and surface water could occur, however, it is not possible to quantify to what extent at this stage. It can be expected however that if impaired water quality occurs, there will not be an impact on nearby groundwater users since the nearest wells are located at a distance that exceeds 7 km from the planned reservoir expansion area limits and the groundwater flow through the dam floor and unweathered shale is limited. However, the quality of the water is anticipated to be relatively good since the water storage in the reservoir is intended for irrigation purposes therefore no major risk of groundwater quality degradation is anticipated. Water monitoring data provided in Volume 2, Section 7, summarizing EID monitoring data of the river water and a site downstream of the reservoir also demonstrate that the water quality is generally very good.

3.3 Sensitivity Analysis

A sensitivity analysis was conducted to evaluate the uncertainty of the model parameters on model calibration.

3.3.1 Potential Changes of Hydraulic Conductivity in the Weathered Shale

To evaluate the impact of increasing and decreasing the hydraulic conductivity of the various units on the model results, the hydraulic conductivity of the weathered shale unit (layer 2) where most of the groundwater flow occurs was increased and decreased by two orders of magnitude.

When increasing the hydraulic conductivities by two orders of magnitude to 10^{-4} m/s compared to the calibrated model, the hydraulic heads throughout the model domain decrease and the RMS increases to roughly 67% showing consistently lower hydraulic heads throughout the model. Increased recharge rates would be required to compensate for this increased hydraulic conductivity during the model calibration.

When decreasing the hydraulic conductivity by one order of magnitude to 10^{-7} m/s, the hydraulic head increases, especially in locations located farther from the constant head boundaries, and the RMS increases to roughly 64 %. Decreased recharge would be required to compensate for the decreased hydraulic conductivity during calibration.

3.3.2 Increase and Decrease of Areal Recharge

To evaluate the impact of the uncertainty of recharge on the model, the recharge applied to the model decreased by half and doubled on the entire model domain.

When decreasing the recharge throughout the model domain to half of the calibrated value, the water levels decrease, especially more distally from the constant head boundaries applied to the model. The impact of these changes is less pronounced than those of the modifications to the hydraulic conductivities and only leads to changes of a few percent in the RMS.

When increasing the recharge throughout the model domain by twice the calibrated value, water levels increase, especially farther from the constant head boundaries applied to the model. The impact of these changes is less pronounced than those of the modifications made to the hydraulic conductivities and leads to a near doubling of the RMS compared to the calibrated model.

3.3.3 Increase and Decrease of Constant Head Boundaries

Increasing and decreasing the hydraulic head boundary conditions by 1 m does not significantly impact model calibration for the majority of the wells. Most of the wells are located at a sufficient distance from the boundary conditions that the impact of these changes is minimal. The impact is most pronounced at the wells near the boundary conditions.

3.3.4 Overall Sensitivity

The uncertainty on the hydraulic conductivity has the highest potential impact on the results of the modelling including seepage rates into the excavations and the area of influence of the reservoir expansion. A conservative approach that does not integrate any mitigation measures was used and this uncertainty should not alter the overall results significantly. If bulk hydraulic conductivities used in the simulation are underestimated, the seepage rates through the fractured bedrock would also be underestimated. A factor of safety of 3 could be used to compensate for this uncertainty when reporting the radius of influence of the reservoir expansion the construction dewatering and the seepage rate into the excavation during construction which would provide an appropriate margin to account for uncertainty of the bulk hydraulic conductivities.

3.4 SEEP/W Model Simulations

As a method of supplementing the results of the 3-D numerical modelling produced in FEFLOW, a two-dimensional model was developed to evaluate the potential change in hydraulic heads associated with the reservoir expansion. SEEP/W software (GEO-SLOPE International Ltd, 2015) was used for the 2-D numerical modelling. This software can represent 2-D groundwater flow and also allows for the integration of constant head boundaries and geomaterial properties into the numerical flow model. SEEP modeling was used in addition to FEFLOW modeling because it is simpler to implement and allows for an estimate of the order of magnitude of the anticipated results. Indeed, since this modeling considers fewer parameters, it allows for confirmation of the results of the FEFLOW model.

This model was developed based on the same hydrostratigraphic conceptual framework as the 3-D groundwater flow model and is summarized in the section **Error! Reference source not found.**. This model uses simplified stratigraphy similar to the 3-D groundwater flow model.

The ground elevation was set at a fixed arbitrary elevation of 6 m. The dam was set at a height of 25.5 m and a width at its base of roughly 200 m. The entire modelled cross section extends out 2,400 m towards the west and 2,000 m towards the east of the dam.

3.4.1 Model Construction

The model is subdivided into two layers to represent the two uppermost geological units (clay till and fractured bedrock). The layers and their maximum thickness are :

1: Clay Till (thickness of 2.0 m)

2: Fractured bedrock (thickness of 4.0 m)

The 2-D model was generated using rectangular meshing with a length of 1.0 m to allow for an adequate representation of the more distal parts of the model and to permit reasonable calculation times. The meshing was subsequently refined in the zone close to the reservoir and excavation zones to allow for better convergence of the model.

The elevation of the layers was defined based on an idealized cross-section through the expansion reservoir and dam area.

3.4.2 Boundary Conditions Applied to the Model

For the SEEP/W model to be able to calculate the hydraulic head for the various layers, constant heads were applied to the eastern and western extremities of the model domain for the steady-state pre-reservoir simulation.

The groundwater levels in the model were set at an elevation of 3.0 m, which is roughly 3.0 m below the ground surface for the pre-reservoir conditions. The reservoir was simulated for the same two scenarios outlined in the 3-D modelling section, namely full capacity for 3 months and average capacity for 2 years.

An additional simulation of the dewatering of the excavation zone during construction was also conducted with a depth of 6 m below the ground surface.

The simulations consider the initial water level that corresponds to a depth of 3 m below the ground surface. This simulation does not represent a worst-case scenario but represents what is considered a reasonable representation of the reservoir expansion. If the conditions within the Study Area are different from those used in the simulation, differences in the flow paths and head changes can be expected.

3.4.3 Hydraulic Conductivity

The hydraulic conductivity applied to each model layer corresponds to the values used in the 3-D model, which is based on field observations. The hydraulic conductivity of the clay-till layer was defined based on plasticity index results and the hydraulic conductivity of the weathered shale unit is based on *in situ* testing (slug testing and packer testing). The retention curve used for the approximation of unsaturated flow conditions is based on the lithologies encountered. The unweathered shale unit was not included in this model scenario as it has a very low hydraulic conductivity and contributes very little to the flow regime within the reservoir area.

The table below summarizes the hydraulic conductivity applied to the model layers.

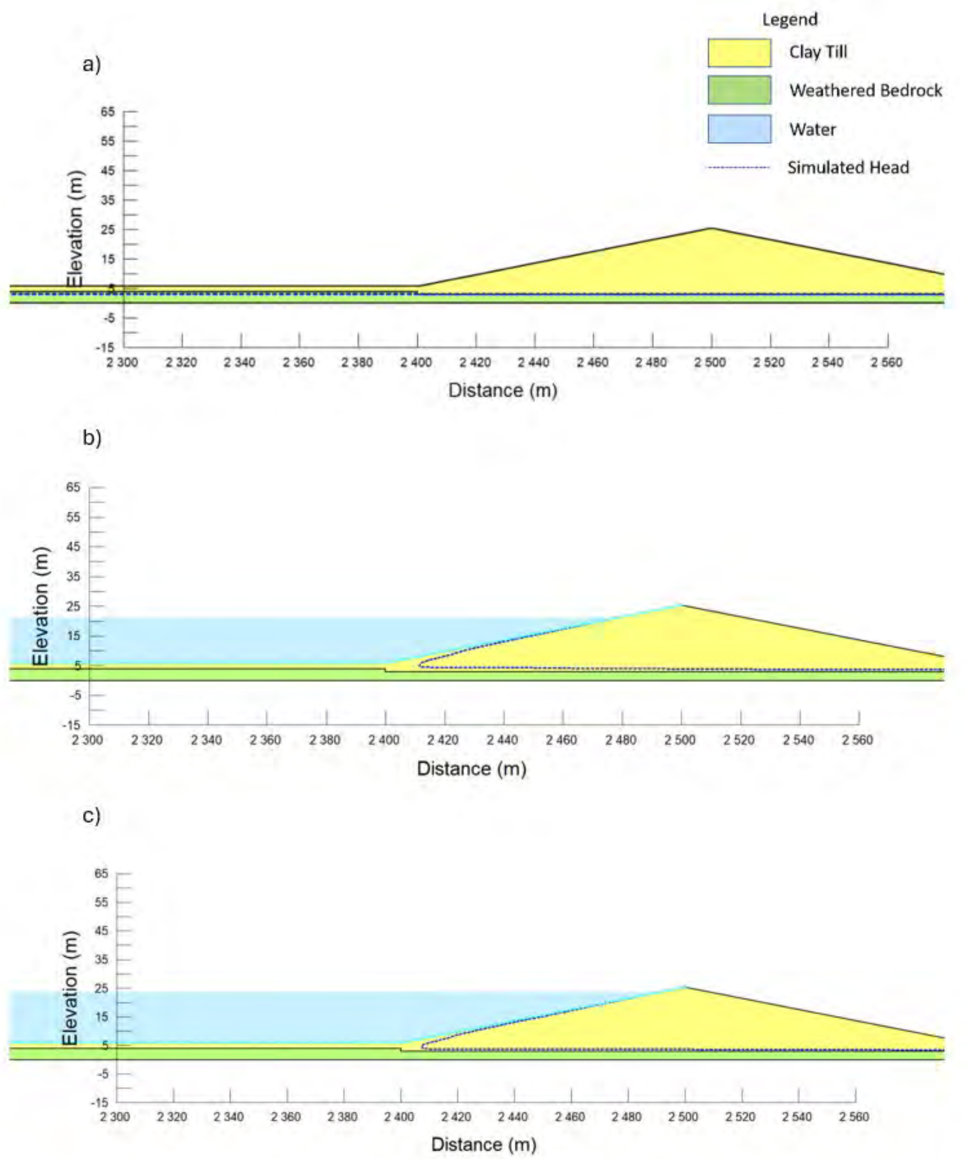
Table 6: Saturated Hydraulic Conductivity of the Model Layers

Model Layer (Material)	Assigned Hydraulic Conductivity (m/s)
Layer 1 (Clay-Till)	1×10^{-9}
Layer 2 (Weathered Shale)	1×10^{-6}

3.4.4 Potential Impact of the Reservoir Expansion on the Environment and Groundwater Users

The results of the 2-D SEEP/W indicate that the potential impact of the reservoir expansion is limited, and no significant impacts on nearby groundwater users and the environment are expected (refer to Figure 14). The simulated head changes using SEEP/W dissipate rapidly within the dam and do not increase outside of the reservoir. If the conditions of the dam and the basin of the reservoir differ from those used for model construction, the impacts could be greater than those simulated. For example, if gaps in the clay till are present, and allow infiltration directly to the weathered shale unit, the flow through this layer could increase and create some zones where the potential impacts are greater.

Figure 14 : Cross Section of the SEEP/W Model showing the Two Model Layers and the Simulated Head Value in the Reservoir and Dam Area. A) Pre-Expansion Groundwater Levels; B) Average Reservoir Capacity over 2 Years; C) Maximum Capacity over 3 Months.



4 Cumulative Effects Assessment (Planned Development Case)

Cumulative effects are changes to the environment that are caused by an action(s) of a project in combination with past, present, and future projects and human activities. The combined effects of several unrelated projects or activities can result in aggregate effects that may be different in nature or extent from project-derived effects.

The Alberta Environment and Protected Areas (EPA) Terms of Reference for the Snake Lake Project requires that the environmental and social impact assessment (ESIA) address the potential for cumulative effects. Although multiple projects were recently completed, were disclosed or are reasonably foreseeable to 2050 as per the list of projects provided in Table 7 below, no significant cumulative effects are anticipated from a hydrogeological point of view. In effect, given the limited radius of influence presented in the Application Case, it is not expected that the groundwater level variations caused by the reservoir expansion will overlap with changes caused by the projects listed in Table 7 and affect valued components (VCs). As a result, no additional model simulations were run to illustrate cumulative effects given that results are not anticipated to differ significantly from the Application Case simulation results.

Table 7: List of Projects Included in the Cumulative Effects Assessment

Feature Type	Activity and Disturbance Classes
Past Activities and Disturbances	
Eastern Irrigation District (EID) Canals	12 Springhill Canal, C Springhill Canal, 01C Springhill Pipeline
Roads and Rail	TransCanada Highway, CPKC Rail line, Other Roads
Pipelines and other Temporary Disturbances	Abandoned railway, Pipelines, Water pipelines, Reclaimed berms
Anthropogenic Waterbodies (Reservoirs, Dugouts)	Existing SLR
Residential / Urban Development	Acreages
Cultivated Lands	Cultivated and Irrigated Cultivated
Pasture / Grazing Lands	Grazing Lands
Project Activities	
Project	Snake Lake Reservoir Expansion
Future Activities and Disturbances	
EID Canals	Snake Lake Canal Upgrade, 16 Spring Hill Pipeline, 03 East Branch Pipeline, Main Bantry Canal Bank Lift
Pipelines and other Temporary Disturbances	Powerlines and Pipelines
Residential / Urban Development	Cassils Growth, County of Newell: Future Residential/Business developments
Solar	Lathom Solar Project, Luna Solar Project Phase 1 & 2 Brooks Solar Farm
Cultivated Lands	Increased Irrigation Land (Reasonably Foreseeable)
Pasture / Grazing Lands	Increased Cropland Conversion

5 Summary and Conclusions

The numerical groundwater flow model was used to simulate the potential impacts of the construction dewatering and the reservoir expansion on the groundwater, and surface water features. The groundwater seepage rates into the excavation during construction are estimated at 915 m^3/day after 90 days and 420 m^3/day after 365 days with a factor of safety of 3. The simulated radius of influence of the groundwater dewatering activities is limited to the area within roughly 25 m of the excavation limits.

No seepage into the reservoir under dry conditions is anticipated as the water levels measured are naturally below ground surface and the locations screened at multiple depths generally show a downward hydraulic gradient.

Overall, the potential impacts of both modelled scenarios (maximum water levels over 3 months and average conditions over 2 years) were limited to the area within the footprint of the dam and increased hydraulic head does not generally extend beyond roughly the midpoint of the dam footprint. A minor decrease in hydraulic head (<1 m) on the downgradient side of the reservoir expansion was predicted by the 3-D model. Impacts to the surface water bodies within the Study Area are not expected aside from some potential for decreased baseflow to the surface water bodies in the downgradient area, which could mean decreased groundwater supply to nearby lakes and wetlands. Water levels in these features are already managed using the existing canal system, and therefore this existing measure (water management through the canal system) should mitigate any potential decrease in baseflow resulting from the reservoir expansion.

Based on the results of both of the groundwater modelling scenarios (maximum water levels over 3 months and average conditions over 2 years), there are no significant expected impacts to nearby groundwater users as the nearest private well is located over 7 km away from the planned reservoir expansion.

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