SPRINGBANK OFF-STREAM RESERVOIR PROJECT
Groundwater Monitoring Plan

Prepared for:
Alberta Transportation

Prepared by:
Stantec Consulting Ltd.

December 2021

Table of Contents

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Abbreviations

3D CSM	3D Conceptual Site Model
ACO	Aboriginal Consultation Office
AEP	Alberta Environment and Parks
AGS	above ground surface
AWWID	Alberta Water Well Information Database
BGP	base of groundwater protection
BTEX	benzene, toluene, ethylbenzene and xylene
CALA	Canadian Association for Laboratory Accreditation
DEM	digital elevation model
DFO	Fisheries and Oceans Canada
DO	dissolved oxygen
DOC	dissolved organic carbon
EC	electrical conductivity
ECO Plan	Environmental Construction Operation Plan
GWMP	groundwater monitoring plan
LAA	local assessment area
m ASL	metres above sea level
m BGL	metres below ground level
ORP	oxidation-reduction potential
PDA	Project development area
PS1	Parameter Suite 1
PS2	Parameter Suite 2
PS3	Parameter Suite 3

QA/QC	quality assurance / quality control
RAA	regional assessment area
TDR	technical data report
TDS	total dissolved solids
the Project	Springbank Off-stream Reservoir Project
TLRU	traditional land and resource use
TUS	Traditional Use Study
UCL	upper confidence limit
US EPA	United States Environmental Protection Agency

1.0 INTRODUCTION

This document describes the Groundwater Monitoring Plan (GWMP) for construction and operation of the Springbank Off-stream Reservoir Project (SR1; the Project). Based on the EIA conclusions, and associated regulatory and legislative requirements, mitigation and monitoring of groundwater will be undertaken. The GWMP is current as of December 2021 and is subject to change.

Alberta Transportation developed a draft Groundwater Monitoring Plan which provides a summary of the project, the hydrogeological framework, and the potential groundwater issues and mitigation measures identified to provide context for the GMP. An overview of the regulatory structure is provided to introduce the various agencies and stakeholders involved and the guidelines and reporting requirements that will be followed.

The GWMP was developed using a tiered approach to consider that the potential project interactions that could lead to effects on groundwater resources vary depending upon the specific location and the project phase. The timing and level of comprehensiveness involved varies accordingly. Monitoring results will be compared to guidelines or control limits and temporal trend analyses to identify potential project effects.

Should the GWMP results exceed groundwater quantity or quality triggers, a conceptual groundwater response plan is also included in this report that describes the actions that would be taken.

1.1 PLAN OBJECTIVES

The goals and objectives of the GWMP have been developed to align with approval conditions (see Section 2.0, Table 1) related to groundwater including specific requirements for a follow-up program.

The objectives of the GWMP are to:

- collect groundwater data to support long term, ongoing management of groundwater conditions in the LAA and RAA
- support the management of construction-related effects
- confirm that Project effects during operations are consistent with EIA conclusions and can be managed with planned and implemented mitigation measures
- provide a means for detecting unexpected changes to groundwater quantity or quality such that the need to implement additional mitigation measures is identified
- demonstrate appropriate due diligence and compliance with regulatory requirements

2.0 REGULATIONS, APPROVALS AND GUIDELINES

The Project was subject to approval under various provincial and federal regulations and regulations relevant to groundwater are provided in Appendix A. Alberta Transportation has prepared this GWMP to meet NRCB approval condition 10 as described in approval NR 2021-01. The approval conditions as defined by IAAC and NRCB are provided in Table 2.1. Project approval conditions that have been received at the time of preparation the GWMP include:

- NRCB Hearing commitment for one-time baseline sampling (pre-construction) of domestic wells adjacent to the Project development area (PDA) and within the local assessment area (LAA), north of the Elbow River.
- NRCB project approval condition 7, to monitor water levels in domestic water wells located west of the diversion channel to the boundary of the local assessment area that may be impacted by dewatering for a minimum of five years or until it can be demonstrated that permanent lowering of the water level does not significantly impact yields from the water wells

It is anticipated that some components of the Project may require additional short-term approvals/licenses for activities related to construction (e.g., dewatering activities) and these requirements will be considered during the applicable timeframe.

Applicable regulatory guidelines for groundwater quality include:

- Guidelines for Canadian Drinking Water Quality (Health Canada 2020)
- Alberta Tier 1 Soil and Groundwater Remediation Guidelines (AEP 2019)

Groundwater monitoring results collected during construction and operation phases of the project will be compared to these guidelines and, where relevant, to the baseline groundwater quality data.

Table 2.1 Summary of Approval Conditions for Groundwater

Project Phase	Reference	Approval Condition
Construction and Operations	NRCB Condition 7	The Operator shall: • monitor water levels in domestic water wells west of the diversion channel to the boundary of the local assessment area that may be impacted by dewatering during the Project construction. During flood and dryland operation, monitoring of the wells should be continued by the Operator for a minimum of five years or until it can be demonstrated that permanent lowering of the water level does not significantly impact yields from the water wells, and • take mitigative action if significant yield reductions attributable to the Project are observed at water wells referred to in Condition 7(a), to the satisfaction of Alberta Environment and Parks.
Construction and Operations	IAAC Condition 7.9	The Proponent shall develop prior to operation, and implement, in consultation with Indigenous groups and relevant authorities, a follow-up program to verify the accuracy of the environmental assessment and the effectiveness of the mitigation measures as it pertains to drinking water quality. As part of the follow-up program, the Proponent shall: • monitor groundwater level, major ions, dissolved metals, nutrients, benzene, toluene, ethylbenzene, xylenes (BTEX), F1 to F2 fraction hydrocarbons, and bacteriological parameters at locations selected from existing domestic wells and finalized monitoring locations similar to those identified in Figure 7-1 of Appendix IR15-1 submitted in the Response to Information Request Round 1 package 3 (Canadian Impact Assessment Registry Reference Number 80123, Document Number 1260) between the project development area and Tsuut'ina Nation 145 Reserve during dry operation and at the start of post-flood operation according to the tiered monitoring approach; • report the results of monitoring referred to in condition 7.9.1 to Tsuut'ina Nation 145 Reserve; • if the results of the monitoring referred to in condition 7.9.1 demonstrate any exceedance of thresholds for parameters identified in Health Canada Guidelines for Canadian Drinking Water Quality, the Proponent shall determine, in consultation with the parties involved in the development of the follow-up program, if the source of exceedance is attributable to the Designated Project and develop and implement modified or additional mitigation measures for any such exceedance.

3.0 RESPONSIBILITIES AND REPORTING REQUIREMENTS

Alberta Transportation will be responsible for final development of the GWMP and implementation during the construction phase and for a period of three years post-construction during the dry operations phase of the Project. After that period, AEP will implement the GWMP during dry operations. AEP will be responsible for implementing the GWMP during both flood and post-flood operation phases of the Project.

In compliance with IAAC approval condition 2.11, Alberta Transportation and AEP will prepare an annual report summarizing the monitoring results (connected to IAAC approval 7.9; groundwater during operations), which will be provided to IAAC and the First Nation Land Use Advisory Committee by October 31 of the reporting year to which the annual report applies. IAAC has defined the reporting year as July 1 of the calendar year to June 30 of the subsequent calendar year (definition 1.32). The annual report, including a plain language executive summary in both official languages will be made publicly available to Indigenous groups and public stakeholders no later than October 31 following the reporting year to which the annual report applies (IAAC approval condition 2.13). Indigenous groups, the First Nation Land Use Advisory Committee and the Agency will be notified of the annual reports within 48 hours of their publications (IAAC approval condition 2.14). The annual reports will be available for 15 years following their publication (IAAC approval condition 2.14).

In compliance with NRCB approval condition 10, Alberta Transportations will make the GWMP easily accessible to the public, subject to privacy protection requirements and to the satisfaction of AEP.

4.0 INDIGENOUS AND PUBLIC STAKEHOLDER FEEDBACK

Since completion of the EIA, additional feedback on groundwater was received from Indigenous groups, stakeholders and the public, and through supplemental regulatory information requests and the Project hearing. All input provided to Alberta Transportation related to groundwater was reviewed and responses were provided back to the Indigenous groups. The input was captured in the GWMP.

Additionally, Alberta Transportation has, as committed to during the regulatory phase of the Project, discussed groundwater wells with Tsuut'ina Nation. Alberta Transportation will continue to work with Tsuut'ina Nation to identify appropriate groundwater monitoring for the Tsuut'ina Nation Reserve. As of December 2021, discussion and planning regarding monitoring well locations and monitoring protocols on the Tsuut'ina Nation Reserve is ongoing. As per IAAC approval condition 7.9.2, the results of the GWMP during flood operations will be provided to Tsuut'ina Nation.

This report outlines key mitigations and monitoring commitments during construction, dry and flood operations and was shared with Piikani Nation, Ermineskin Cree Nation, Foothills Ojibway Society, Ktunaxa Nation Council, Métis Nation of Alberta Region 3, Montana First Nation, and Samson Cree Nation on April 20, 2020 for review and feedback. This draft Groundwater Monitoring Plan was also shared with Blood Tribe/Kainai, Siksika Nation, Stoney Nakoda Nations, and Louis Bull Tribe on May 6, 2020 and Tsuut'ina Nation on July 16, 2020. Alberta Transportation offered funding to Indigenous groups to provide written feedback and offered multiple opportunities to provide oral feedback, including group meetings in the fall of September 2020 and individual meetings to discuss. The draft Groundwater Monitoring Plan has been finalized following the NRCB and IAAC decisions and conditions, and has taken into account any feedback received from Indigenous groups.

5.0 PROJECT DESCRIPTION

The Project consists of the construction and operation of an off-stream reservoir to divert and retain a portion of Elbow River flows during a flood. The diverted water will be released back to Elbow River in a controlled manner after the flows in Elbow River decrease sufficiently to accommodate the release of water from the reservoir. The off-stream reservoir will not hold a permanent pool of water. The hydrogeological setting of the Project is presented in Appendix B to provide context for the GWMP.

5.1 PROJECT COMPONENTS

The primary Project components are:

- a diversion structure on the main channel and floodplain of Elbow River
- a diversion channel to transport partially diverted floodwater into the reservoir
- an off-stream dam to temporarily retain the diverted floodwater
- a low-level outlet in the dam to return retained water through the existing unnamed creek and back to the river when AEP staff determines conditions are appropriate.

5.2 PROJECT PHASES

The primary Project components will be constructed and operated under four phases. The groundwater monitoring plan will begin during the construction phase and continue into operational phases.

5.2.1 Construction

The Project is scheduled to be functionally operational (able to accommodate a 1:100-year flood event) for floods after two years of construction and be completely constructed (able to accommodate the design flood) after three years of construction.

5.2.2 Dry Operations

Dry operation refers to post-construction and Project operation between floods. During dry operation, the diversion inlet gates will close, and the service spillway gates will open. The outlet structure will remain open to carry the flow of the unnamed creek over which the dam will be built. The outlet gate system and its operation will be checked according to a routine maintenance schedule to be developed by AEP. Water draining from the base of the dam will flow through unnamed creek and back into Elbow River.

The associated access roads, emergency spillway and reservoir will be inspected at the same time and repaired, if necessary. The maintenance schedule will also include inspections of the diversion structure and the river channel immediately upstream of it, the maintenance building, the floodplain berm, and the auxiliary spillway. Repairs and debris management will be completed as necessary.

5.2.3 Flood Operations

AEP staff will be in communication with the City of Calgary Glenmore Dam operators in advance of and during the flood season each year. The need for flood operations will be determined through this communication, which will be informed by forecasted and measured flows on Elbow River at the diversion structure and upstream. AEP staff, in communication with the City of Calgary Glenmore dam operators, will decide on when to open the diversion gates to commence diversion of flood water flows in excess of 160 m^3/s to the off-stream reservoir.

5.2.4 Post-Flood Operations

During post-flood operations, the diversion inlet gates are closed, and the service spillway gates are open (lowered to the river bed). The gates of the outlet structure are opened to allow the floodwater retained in the reservoir to drain through the low-level outlet into the unnamed creek and then into Elbow River. The outlet structure gates would remain open after the reservoir has drained.

6.0 MITIGATION

6.1 GROUNDWATER QUANTITY

6.1.1 Construction and Dry Operations

Construction dewatering, if required, would be done locally and according to the terms and conditions of dewatering licences issued by AEP (where applicable and if required) and best management practices. This would be included as part of the ECO Plan (Environmental Construction Operation Plan) prepared by the Contractor. Standard construction dewatering methods will be used, including methods to cut off excessive seepage where trenches extend below the water table in order to mitigate preferential flow paths. Other mitigation measures are as follows:

- Water will be discharged in a manner to avoid erosion using turbidity barriers, containment berms and settling ponds. Construction dewatering, if required, will be in accordance with the terms and conditions of *Water Act* approval and the federal *Fisheries Act* and *Navigable Waters Protection Act*.
- Total suspended solids (TSS) levels will be controlled using silt fences and turbidity barriers. TSS levels will be monitored by carrying out frequent water quality testing.
- Construction dewatering will be limited through construction planning.
- Existing water wells within the off-stream reservoir footprint will be decommissioned and plugged off to prevent groundwater contamination.
- Regional-scale effects on groundwater quantity can be mitigated by allowing seepage in the diversion channel (when it is dry) to infiltrate back into the subsurface, or flow back into Elbow River through surface water drainage pathways.

Effects on groundwater quantity as a result of construction dewatering would not be entirely mitigated at a local scale because dewatering deliberately seeks to temporarily lower the groundwater table in the PDA in order to facilitate construction. The amount of time required for construction dewatering can be minimized through diligent construction planning. Groundwater that is collected during dewatering would be returned to the local watershed to mitigate regional-scale effects on groundwater quantity.

Groundwater that seeps into the diversion channel (when dry) would remain within the watershed, although potentially travelling through a more tortuous route. Regional-scale effects on groundwater quantity can be mitigated by allowing seepage in the diversion channel to infiltrate back into the subsurface, or flow back into Elbow River through surface water drainage pathways.

6.1.2 Flood and Post-Flood Operations

There are no specific mitigation for the temporary changes in groundwater quantity during flood and post-flood operations.

6.2 GROUNDWATER QUALITY

6.2.1 Construction and Dry Operations

As was the case for effects on groundwater quantity, the secondary effects on groundwater quality related to changes in groundwater flow patterns would not be entirely mitigated because dewatering activities deliberately seek to lower the water table (and in turn affect groundwater flowpaths, potentially resulting in changes in groundwater quality). The amount of time required for construction dewatering can be minimized through construction planning which in turn would limit the duration of the residual effects. Other mitigation measures will be completed as follows:

- A care of water plan will be developed to manage dewatering and discharge of water on the construction site.
- At locations where flows from care of water operations are discharged into waterbodies, water quality will be tested at discharge locations and TSS monitored.
- Construction dewatering may be reduced through construction planning.

6.2.2 Flood and Post-Flood Operations

Existing water wells within the off-stream reservoir footprint will be decommissioned and plugged off to prevent groundwater contamination and to prevent flood waters from infiltrating into nearby water wells. Thus, water in the reservoir following floods would not interact with groundwater through open wells (as a vertical conduit), but they would only interact by slower direct infiltration through shallow surficial sediments, which are of low permeability.

7.0 MONITORING PROGRAM

The main factors considered in the GWMP include:

- hydrogeologic setting and use of groundwater in the RAA (presented in Appendix B)
- expected spatial extent of effects on groundwater for both dry and flood operations
- spatial density of monitoring (the number and locations of monitoring wells)
- frequency of monitoring
- monitoring groundwater levels and collection of groundwater samples for assessing water quality
- analytical parameters to be measured
- practical field constraints, including (for example) seasonal access to monitoring wells and instrumentation limitations

7.1 GROUNDWATER MONITORING PROGRAM DESIGN

Since the potential interactions that could lead to effects on groundwater resources vary depending upon the specific location and duration of Project phases, the groundwater monitoring plan has varying levels of comprehensiveness. Some of the potential Project interactions are not applicable during all times; therefore, the details of the GWMP will change over time. For example, construction dewatering leading to changes in groundwater levels is not a potential interaction during dry or flood operations because as all the infrastructure would already be built and construction dewatering would not be required. The following are the potential interactions for each phase:

- During baseline data collection, there will be highly comprehensive baseline monitoring (already ongoing) prior to any Project disturbances. The intent of baseline monitoring is to understand a wide range of hydrochemical parameters and their potential natural variability in location and time. The baseline monitoring program would seek to understand local seasonal variation in water levels and hydrochemistry. This program needs to be robust to establish a point of comparison that could be used to assess changes that could be attributable to the Project.
- During construction, there will be medium comprehensive monitoring, but generally it will be localized around construction activities that could lead to disturbances to the groundwater system (e.g. construction dewatering, deep excavations).

- During dry operations, there will be less comprehensive monitoring to confirm consistency with baseline conditions and to observe potential longer-term regional trends that are not related to Project activities (e.g., effects of long-term precipitation trends).
- During flood and post-flood operations, there will be highly comprehensive monitoring to observe potential effects on groundwater both near and far from Project infrastructure.

7.2 TIERED GROUNDWATER MONITORING LOCATIONS

The density and distribution of groundwater monitoring wells will be based on the need to detect potential changes to groundwater levels and quality that could arise from interactions between the Project and groundwater resources. The siting of monitoring wells will consider the expected extent of effects on groundwater for dry and flood operations.

Simulation results from the numerical groundwater modeling completed as part of the EIA were reviewed to understand the potential areas over which effects on groundwater could be expected. Under dry operations, the simulated extent of potential effects will be limited to areas near the diversion channel, due to drawdown caused by incision of the channel through the water table. Under flood operations, effects on groundwater are expected to be limited to areas near the diversion channel and off-stream reservoir. In the case of both dry and flood operations, potential effects on groundwater will be limited to within the LAA, with the potential exception of the area west of the diversion channel. Thus, monitoring wells sited within the LAA and west of the diversion channel will be able to detect change related to potential Project effects.

Groundwater monitoring well locations are also selected to allow for characterization of "background" water quality in areas anticipated to be unaffected by Project interactions depending on the stage of project. For example, Tier 2 and Tier 3 wells that are far removed from construction activities will continue to provide background data during the construction phase and operation phase up until the first flood event. Monitoring well locations will be selected based on the location of existing users of groundwater, such that some locations are able to provide "early warning" for changes in groundwater prior to those effects reaching existing users. Some existing wells (either Project specific monitoring wells, or previously existing domestic wells) could be retained for incorporation into the monitoring program, depending upon their location, depth, and potential risk of inundation during a flood event.

Three monitoring tiers will be established based loosely around the associated geographic coverage:

- Tier 1 monitoring wells or piezometers will be shallow and located within or immediately adjacent to Project infrastructure (dam, diversion intake and channel). Piezometers or vibrating wire piezometers (for pore pressure monitoring) will be used for geotechnical monitoring within the Project components; however, this data will also be used to support the monitoring of potential effects to groundwater. Shallow monitoring wells will also be installed in this area in consultation with the dam engineering team.
- Tier 2 monitoring wells are shallow and within or very near the wetted perimeter of the off-stream reservoir and diversion channel. They are (or will be) installed in the unconsolidated deposits, augmented with bedrock wells in areas near bedrock outcrops. The Tier 2 wells also include nested pairs completed at different depths to monitor changes in vertical hydraulic gradients. Wells installed in bedrock will only be situated outside of the wetted perimeter to prevent potential vertical pathways for floodwater to enter bedrock aquifers. Nested monitoring well locations are indicated in Figure 7-1. A subset of Tier 2a wells are also included specifically to monitor drawdown near the diversion channel during construction and dry operations to address NRCB approval condition 7.
- Tier 3 monitoring wells are situated beyond the area of predicted project effects at or near some of the closest potential receptors to the project. These monitoring wells are, or will be, installed within unconsolidated or bedrock units depending upon local groundwater use and potential aquifers of interest. The main purpose of these monitoring wells would be to provide early detection of potential effects on groundwater that are propagating outward from the LAA. These monitoring wells would also be potentially used as background monitoring to discriminate between changes to groundwater levels arising from a flood or precipitation event, versus those which can be attributed to operation of the Project.

Figure 7.1 presents the preliminary layout of a groundwater monitoring network comprising monitoring wells assigned to each tier. Tier 2 monitoring well locations have been finalized (pending land access in some cases) and the network is nearing completion. Land access is pending for, Tier 2a and Tier 3 monitoring well locations. Tier 1 locations will be finalized toward the end of the construction phase once the Project infrastructure is built. In addition to the proposed network, the locations of monitoring wells used in the EIA that will not be part of the long-term network are also presented. These monitoring wells have been decommissioned, or will be decommissioned prior to construction or operation, due to their location relative to the construction footprint or their completion relative to flooding of the reservoir. Previously collected data from these decommissioned monitoring wells will also be included in the baseline dataset.

In Figure 7.1, the Tier 1 monitoring wells are shown within the dam structure. These wells would be expected to fall within an area where Project effects are expected (during dry and flood operations). Additional Tier 1 monitoring wells may be included near the diversion inlet and along the diversion channel. The locations will be finalized based on geotechnical and dam safety requirements.

In Figure 7.1, the Tier 2 monitoring wells are shown across much of the LAA, including some wells within the wetted area of the reservoir (i.e., the area of the reservoir that would be inundated during a design flood). These wells would be expected to fall within or very near to areas where Project effects are expected (during dry and flood operations). Previous wells installed to support the EIA that were completed in bedrock within the wetted perimeter will be decommissioned prior to dry operations. The remaining Tier 2 wells within the wetted perimeter are shallow and completed in the unconsolidated deposits and will remain in place during flood operations to monitor effects. Wells near the wetted perimeter (i.e., the edge of the area inundated during a design flood) of the off-stream reservoir will also be left in place during dry operations and flood operations because these locations are unlikely to be inundated with surface water.

Tier 2a wells are shown in Figure 7.1 based on AWWID record locations. The Tier 2a locations fall within the potential construction and dry operations drawdown area near the diversion channel. Monitoring of the Tier 2a wells will be voluntary and the final locations will be dependent on landowner participation, land access, and field verification of the well locations and condition.

In Figure 7.1, the Tier 3 monitoring wells are shown both north and south of Elbow River. These wells are situated in areas outside of the expected areas where Project effects could occur (however they could still detect effects from a flood or precipitation). Wells closest to Elbow River would be situated within the alluvial deposits and thus are directly connected to Elbow River, and they would be expected to experience changes in levels or quality during and after a flood. Changes in these wells would be associated with natural effects of a flood and could be used to help differentiate flood-related effects from those attributable to the Project. Other wells south of the Project would be situated in upland areas outside the alluvial deposits, and they would not be in direct communication with Elbow River. The goal is to use as many existing domestic wells as possible for Tier 3, however, because they require appropriate construction and are dependent on long-term access agreements, there may be a need to drill and install additional wells. Alberta Transportation is currently in the process of securing access agreements with private landowners in targeted Tier 3 locations. Tier 3 wells will provide the ability to detect changes that could potentially propagate outward from the LAA in the direction of domestic and agricultural well users.

Existing domestic water wells for inclusion as Tier 3 monitoring wells will be evaluated to verify that they are in appropriate locations, are screened at appropriate depths, are in good condition and have good surface seal integrity. Ideally these wells would not be in use or near other wells in use such that water levels are not influenced by pumping, however, that is unlikely to be the case, but data logging pressure transducers will be installed in the Tier 3 wells to monitor water level variation due to pumping as well as potential interference from the project.

7.3 ANALYTICAL PARAMETER SUITES

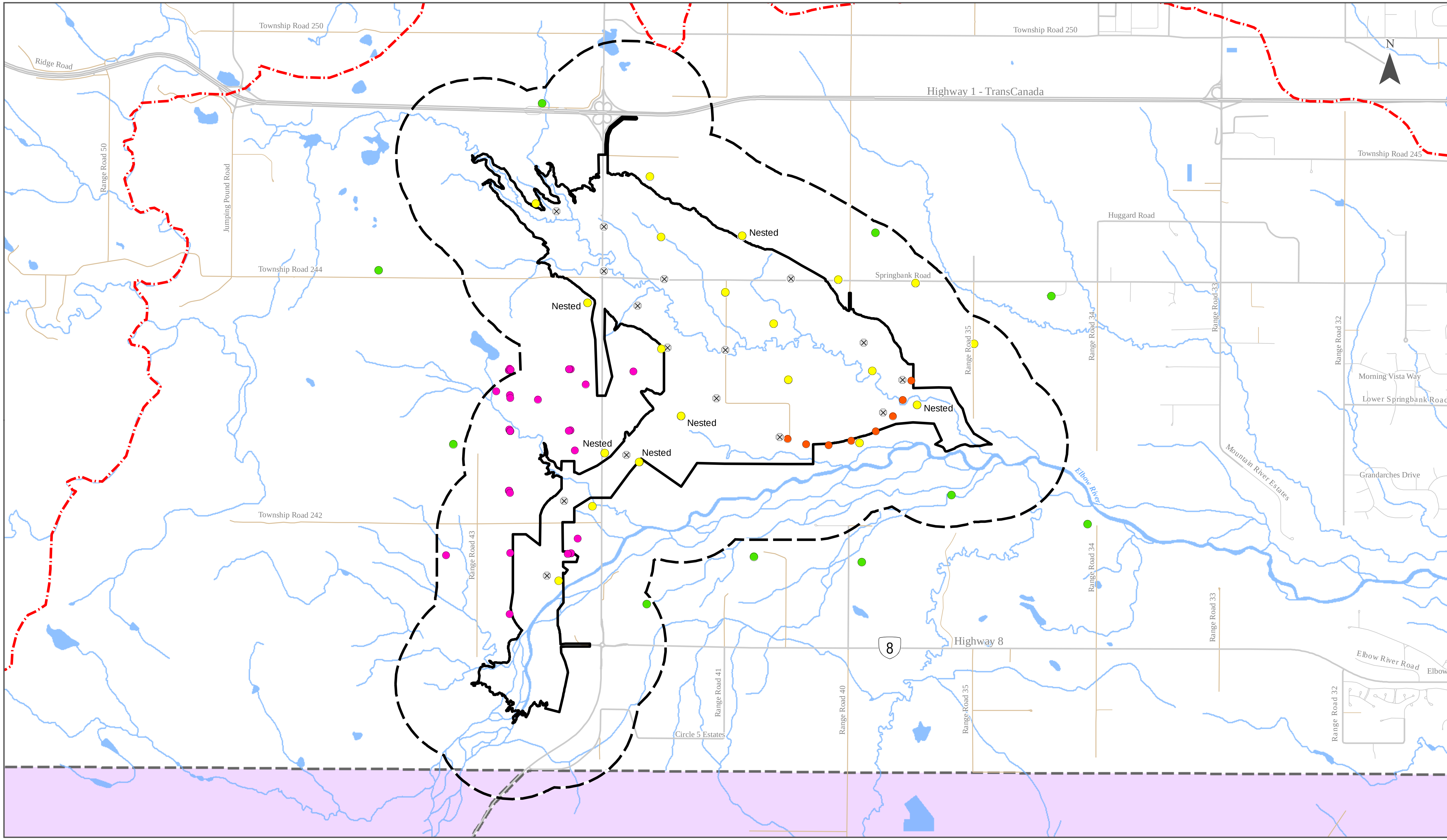
Analytical parameter suites refer to groups of analytes that will be measured either in the field or by the laboratory (or both) receiving the groundwater samples. Analytical parameter suites have been developed to enable characterization of potential changes in groundwater quality through both general measures of groundwater quality (e.g. electrical conductivity (EC)), and through measures of groundwater quality specific to a given chemical compound (e.g. nitrate).

Interactions between the Project and groundwater can include changes to groundwater quantity or flow patterns that can in turn affect groundwater quality. There is also potential for groundwater contamination related to construction activities or the quality of the water in the reservoir during flood operations. The parameter suites were chosen to include a broad range of analytes as well as general indicators of water quality such as pH, electrical conductivity and dissolved organic carbon. Other parameters such as hydrocarbons are aimed at accidental releases or during construction or in presence in floodwater. Similarly bacteriological parameters are intended to address potential impacts from human or animal waste in the floodwater.

The parameter suite to be applied during the monitoring program will vary depending upon the Project phase and monitoring tier. Three parameter suites have been defined for the GWMP:

- Parameter Suite 1 (PS1) includes temperature and electrical conductivity (measured insitu).
- Parameter Suite 2 (PS2) includes combustible headspace vapours, general potability parameters, major ions, bacteriological parameters, dissolved organic carbon (DOC).
- Parameter Suite 3 (PS3) includes those listed in PS2 as well as dissolved metals, nutrients, benzene, toluene, ethylbenzene, xylenes (BTEX), and F1 to F2 fraction hydrocarbons.

The parameter suites to be measured on an ongoing, scheduled basis will be defined. Escalation to a higher parameter suite could still occur during a given event, should the results from the lower, scheduled parameter suite suggest that further analysis is required. For example, should electrical conductivity (as part of PS1) exhibit an unexpectedly elevated reading, then analysis of PS2 could then be implemented to provide further information regarding which specific chemical parameter is contributing to the elevated electrical conductivity.



Sources: Base Data- Government of Alberta, Government of Canada. Thematic Data - Stantec Ltd.

Groundwater Monitoring Network

- Tier 1 (to be determined)
- Tier 2
- Tier 2a (to be verified)
- Tier 3 (to be verified)
- Decommissioned (or to be decommissioned)

- Regional Assessment Area
- Project Development Area
- Local Assessment Area
- Tsuut'ina Nation Reserve

0 1 2
kilometres
NAD 1983 3TM 114

Stantec

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Conceptual Groundwater Monitoring Network Layout

Figure 7.1

7.4 FREQUENCY OF MONITORING

The frequency of monitoring for measurement of groundwater levels and collection of groundwater samples for water quality analysis will be dependent on:

- the phase of the Project under consideration. Project Phases requiring higher levels of monitoring comprehensiveness (e.g., flood operations) will have a higher frequency of events.
- the tier of monitoring well under examination. In general, monitoring wells within the Tier 1 category will have a higher frequency of monitoring relative to the Tier 3 monitoring wells.
- the parameter suite that is under examination. General or bulk parameters (PS1) will have a higher frequency of monitoring than PS2 or PS3.

The planned frequency of monitoring for groundwater levels and quality has been defined at three levels:

- near-continuous measurement (C) of levels and quality through data logging probes that automatically collect and record at high frequency intervals. Telemetry systems could optionally be deployed for some or all wells with data loggers such that near real time monitoring is possible.
- intermittent (I) measurement of routine, scheduled monitoring at set frequency (e.g. semi-annually)
- event (E) based measurement in response to a flood or other operational event (e.g. maintenance) where groundwater could be affected. Frequency during event to be assessed based on accessibility, safety and other constraints.

7.5 OVERVIEW OF GROUNDWATER MONITORING PROGRAM

Figure 7.2 illustrates the implementation of Monitoring Tiers, Parameter Suites, and Monitoring Frequency into an overall program that provides varying levels of monitoring comprehensiveness over the Project Phases.

Figure 7.2 Overview Summary of Groundwater Monitoring Program

		Baseline (Higher Rigor)			
	Well Count	Levels	PS1	PS2	PS3
Tier 1	TBD				
Tier 2	26	C	C	I	I
Tier 2a	TBD	C	C	I	I
Tier 3	~10	C	C	I	I

		Construction (Medium Rigour)			
	Well Count	Levels	PS1	PS2	PS3
Tier 1	TBD	C	C	I	
Tier 2	26	C	C	I	I
Tier 2a	TBD	C	C		
Tier 3	~10	C	C		

		Dry Operations (Lower Rigour)			
	Well Count	Levels	PS1	PS2	PS3
Tier 1	TBD	C	C	I	
Tier 2	26	I	I	I	
Tier 2a	TBD	I	I		
Tier 3	~10	I	I		

		Flood / Event Operations (Highest Rigour)			
	Well Count	Levels	PS1	PS2	PS3
Tier 1	TBD	C	C	E	E
Tier 2	26	C	C	E	E
Tier 2a	TBD	C	C	E	
Tier 3	~10	C	C	E	

Levels	C - Continuous
	I - Intermittent
	E - Event Based
Parameter Suite	PS1 - temperature and EC
	PS2 - potability, major ions, bacteriological, DOC
	PS3 - dissolved metals, nutrients, BTEX, F1-F2 hydrocarbons

In general, the level of monitoring comprehensiveness would vary as follows (highest to lowest):

- Flood and post-flood operations requires of the most comprehensive monitoring because this is when the most Project interactions are applicable and when effects on groundwater are most likely to be observable.
- Baseline monitoring requires a highly comprehensive monitoring that starts prior to construction of the Project. The comprehensive baseline monitoring may be extended for some monitoring locations if required to assess the natural variability of groundwater quantity and quality. For example, baseline monitoring at monitoring wells not situated near construction areas could extend at least until construction is completed or even further until flood operations occur, if necessary
- Construction monitoring requires medium comprehensive monitoring. This monitoring is more focused on Project interactions that could potentially arise in a localized area due to construction activities (e.g., monitoring around a particular location undergoing construction dewatering).
- Dry operations monitoring has less comprehensive monitoring and occurs during dry operations between floods. This lower level of monitoring reflects the fewer Project interactions that are applicable when the Project is not in operation and flood water is not being retained within the off-stream reservoir.

As the monitoring program progresses through construction, dry operation and flood operation it will be adapted as necessary to address observed effects on groundwater levels and groundwater quality. Adaptations may include augmentation of the monitoring network and/or changes to the monitoring frequency or analytical parameters in these areas.

7.6 MONITORING WELL DEVELOPMENT

All monitoring wells installed specifically for the project to be included in the GWMP have been or, in the case of proposed wells, will be developed following completion. Development is conducted to remove drilling fluids (if used) and fine-grained materials from around the filter pack to improve the hydraulic efficiency of the filter pack and improve hydraulic communication between the filter pack and geologic formation. The objective of the well development is to provide more representative groundwater samples and improved hydraulic conductivity estimates. The well development protocol is determined based on the drilling method used and the unit that the monitoring well is completed in. Based on the installation, one or more of the following methods have been or will be employed:

1. air-lifting refers to using compressed air to remove water from the monitoring well until turbidity is reduced and little or no fines are present (generally only used during mud or air rotary drilling).

2. over-pumping refers to the water level in the monitoring well that is being repeatedly drawn down and allowed to recover until turbidity has been reduced and little or no fines are present.
3. bailing refers to groundwater being s removed manually from the monitoring well by using a disposable bailer or inertial pump until turbidity is reduced and little or no fines are present; bailing is the most common method for low yielding monitoring wells.

7.7 GROUNDWATER MONITORING AND SAMPLING PROTOCOLS

Data logging pressure transducers and multi parameter sondes will be installed in all Tier 2 and Tier 3 monitoring wells as well as select Tier 2a monitoring wells. This equipment will measure and record near continuous pressure (water levels), temperature, and electrical conductivity. Data logging pressure transducers (no electrical conductivity) will be installed at the remaining Tier 2a monitoring wells. Near continuous pressure measurement will also be measured in Tier 1 wells using either pressure transducers or vibrating wire piezometers.

The following field procedures will be used during monitoring to measure groundwater levels and to collect the groundwater samples at Tier 2 monitoring wells:

1. Headspace vapours will be measured at each Tier 2 monitoring well.
2. The depth to water at each monitoring well will be measured and recorded.
3. Each Tier 2 monitoring well will be purged using its own dedicated inertial pump system or bailer until three well volumes are removed or until they are dry. Tier 3 domestic wells will be purged using existing well pumps for a minimum of 15 minutes and until stabilization of field parameters (dissolved oxygen (DO), oxidation-reduction potential (ORP), pH, electrical conductivity (EC))
4. Water samples will be collected into laboratory supplied containers within a day of purging (unless additional time is required for water level recovery) following laboratory instructions for filtering, preservation/treatment, and temperature moderation. Samples will be labeled at the time of collection with the site number, the date of collection, and the analysis required.
5. Field measurements of combustible headspace vapours, DO, ORP, pH, EC and temperature will be made at the time of sample collection.

6. Quality assurance/quality control (QA/QC) samples will be collected at a rate of approximately 10% of the total samples. Duplicate samples for quality control will be obtained by rinsing a clean container with formation water, discarding the rinse water and then collecting the required sample volume. The sample will be split into two aliquots and placed into two different bottles with one bottle identified under a different sample name and the second bottle under the regular sample number. The laboratory will not be informed of the nature of the sample. Demineralized water blanks will also be collected during the sampling periods to determine bottle cleanliness and the effects of sample transport, handling, and collection techniques. All QA/QC water samples will be given realistic sample numbers and submitted as groundwater samples.
7. The samples will be delivered to a Canadian Association for Laboratory Accreditation (CALA) accredited laboratory using standard chain of custody protocols.

8.0 CONCEPTUAL GROUNDWATER RESPONSE PLAN

Potential Project effects on groundwater were identified through the EIA process. Triggers will be developed as part of the GWMP based on the potential effects as a means to quantify changes that may have resulted from the Project. A number of follow-up response actions are then proposed for each type of trigger exceedance.

A conceptual groundwater response plan describes the actions that would be taken should monitoring results exceed a specified trigger and suggest that there may be Project-related effects on groundwater quantity or quality. Triggers cover various aspects of groundwater quantity (levels) and groundwater quality. Once a trigger has been confirmed, further follow up actions will be implemented to confirm and manage the effects as required to mitigate effects to human and/or ecological receptors.

Triggers define when further response actions may be required to investigate and confirm that a Project-related effect has indeed occurred. Activation of a trigger does not necessarily confirm that a Project-related effect has occurred; rather, activation of a trigger causes an immediate investigation and follow up prior to the next routine, scheduled monitoring event.

Trigger events will be summarized in the annual groundwater monitoring reports described in Section 3. Some triggers may require landowner or stakeholder notification, for example if there could be an immediate risk to human health, risk to the environment or risk of property damage. Trigger events which require landowner or stakeholder notification and the notification process will be described in the communication plan to be developed by AT and the construction contractor.

8.1 GROUNDWATER LEVEL TRIGGERS

Triggers for groundwater levels will be established based upon the expected variability that would be defined during the baseline monitoring program for each individual monitoring well. Note that the baseline period is not strictly limited pre-construction but will continue into the operational period for some monitoring wells as discussed in Section 7.5. For example, some monitoring wells that are distal to the construction footprint will continue to gather baseline data up until the first flood event to account for longer term natural variability. It is expected that some monitoring well locations would naturally have a higher variability than others. Monitoring wells that are installed near Elbow River and within the alluvial deposits would exhibit a seasonal trend similar to surface water, with additional precipitation event-based “spikes”. Monitoring wells that are installed deeper into bedrock would exhibit a more muted seasonal variability as these deeper flow systems may not be directly influenced by the surface water flow regime.

Groundwater level triggers will include:

- potential development of flowing artesian conditions during flooding or reservoir retention
- a decrease in water level in a well(s) resulting from construction dewatering or permanent drawdown near the diversion channel to the point where the well(s) are no longer useable

8.2 GROUNDWATER QUALITY TRIGGER VALUES

8.2.1 Control Limits

After a sufficient baseline dataset has been established at a monitoring well (approximately eight monitoring events where possible), trigger values will be determined for parameters that are naturally present at detectible concentrations (e.g., chlorides) to identify changes in groundwater quality that fall outside of the baseline conditions for a given well. Triggers will be developed for each individual monitoring well and will be based on a calculated upper confidence limit (UCL). The baseline historical groundwater monitoring data for each well will be screened and outliers removed prior to the calculation of each UCL. Results that are more than two standard deviations above or below the mean of the historical data will be considered outliers. The UCL will be calculated as follows:

$$UCL = x + Z*s$$

Where:

x = sample mean

Z = multiplier (a value of 4.5 is considered appropriate for groundwater monitoring (Gibbons, 1999))

s = sample standard deviation

US EPA (1989) indicated that the overall confidence levels for the control limits calculated using Z=4.5 is 95% based on a minimum of eight historical monitoring events.

Where the standard deviation is very large or very small, the coefficient of variation (Cv) will be calculated for the UCL as follows:

Where $Cv < 0.05$ $UCL = 1.225*x$

Where $Cv > 0.5$ $UCL = 3.25*x$

UCL values for parameters that are not naturally present in groundwater (e.g., BTEX, F1-F3 hydrocarbons) will be considered to be equal to the lesser of five times the laboratory reportable detection limit or the referenced guideline for that parameter.

8.2.2 Temporal Trend Analysis

UCL trigger values will not be determined for monitoring wells where impacts are currently above the relevant guidelines. Instead, triggers at monitor wells in the affected areas will be based on increasing temporal trends in groundwater quality over four monitoring events. However sampling frequency in relation to seasonal variation may also need to be taken into consideration.

Non-parametric trend analysis will be conducted for each groundwater monitoring well to determine changes in groundwater quality that may be due to Project operations. Trend analysis will be conducted for select analytes that are most indicative of potential changes in groundwater quality related to Project operations. The results of the trend analysis will be included in the annual groundwater monitoring reports for the Project.

8.3 GROUNDWATER RESPONSE ACTIVITIES

8.3.1 Groundwater Level Trigger Response

If newly developed flowing artesian impacts are identified during Project flood operations, the following mitigation would be used:

- If temporary groundwater discharge to surface is identified during operational monitoring events or by affected landowners, the focus will be on containing and controlling the flow of discharging groundwater. Groundwater discharge at ground surface would be directed to Elbow River or its tributaries through conveyance measures, including shallow ditches or temporary piping. Erosion control and water quality monitoring would be conducted to protect the receiving waterbody and verify that the water quality is appropriate for discharge. Groundwater discharging to ground surface would be of quality similar to baseline conditions (i.e., it would not be floodwater) and may even be of better quality than water in Elbow River during a flood.
- Should a temporary increase in hydraulic head result in flowing artesian conditions in a domestic water well(s), control measures would be put in place. The primary control method would be to pump the well to decrease the hydraulic head and control potential flows out of the well casing. This could be completed with an existing submersible pump, depending on the existing pump capacity and the discharge rate required for control, or a new pump may be temporarily installed. Pumped water would be discharged into Elbow River or its tributaries. Erosion control and water quality monitoring would protect the receiving waterbody and verify that the water quality is appropriate for discharge. Damage to domestic wells is not anticipated as a result of incremental pumping, but repair or replacement of domestic wells would be considered should it occur.

- If a flowing well cannot be controlled through pumping (due to its condition, configuration of pump and header lines, or casing/screen completion issues), or if well damage occurs as a result of increased aquifer pressure, well abandonment will be considered to control the flow and discharge of groundwater. Well abandonment would be completed using standard practices in accordance with the Water Act (Ministerial) regulations and, when complete, would seal the existing pathway through the low permeability clays/tills. Water wells would be replaced when the flood has passed. Replacement wells would be completed such that future flowing artesian pressures could be controlled at the well head to limit the potential for this impact to occur during subsequent floods.

Mitigation measures for decreasing water levels to the point where a well(s) is no longer useable would focus on ensuring an adequate supply of water to affected landowners. For a short term impact due to construction dewatering, water hauling would be considered as a temporary measure until the water level in the well returns to normal. For permanent dewatering adjacent to the diversion channel, depending on the particular circumstance, mitigation could include either recompletion of the existing well to a deeper interval or abandonment of the existing well and replacement with a deeper well.

8.3.2 Groundwater Quality Trigger Response

The exceedance of trigger values (either the UCL or an increasing trend) at any monitoring well will prompt actions to confirm the exceedance, identify possible causes of the elevated concentrations and implement management or management measures, if required. Triggers will include either of the upper control limits or increasing trends observed at any of the monitoring wells.

The staged response to a trigger exceedance follows:

1. reevaluate field and laboratory QA/QC data to identify potential issues that could result in anomalous concentrations and have the lab recheck the results and reanalyze the sample
2. identify potential well integrity issues that could result in anomalous concentrations
3. re-sample (confirmatory sampling) the monitoring well in question and analyze to verify the concentration
4. increase the sampling frequency for the affected monitoring well if the trigger is confirmed

Follow-up action will then be initiated to further address the exceedance. If the trigger exceedance is confirmed, AEP (as operator of the Project) will initiate one or more of the following actions:

- evaluate the potential sources or causes of the parameter concentration increases
- conduct a field assessment which may include installing additional monitoring wells to delineate the extent of impacts, both horizontally and vertically

- implement appropriate management controls to mitigate the impact
- identify, design and implement appropriate engineering control or remedial measures

Continued follow-up monitoring would also be part of the overall response to the confirmation of an exceedance of a trigger. If sampling frequency is increased in response a trigger exceedance, higher frequency monitoring will continue for the monitoring well, or group of wells, until such time that it is no longer deemed necessary. Higher frequency monitoring will be used to assess the effectiveness of management activities. Monitoring frequency would revert to the standard frequency if:

- stable or decreasing trend are noted at the monitoring well(s) over four monitoring events and/or
- parameter concentrations return to values within their historical range or the range of background values.

9.0 REFERENCES

Fenton, M.M., E.J. Waters, S.M. Pawley, N. Atkinson, D.J. Utting and K. Mckay. 2013. Surficial geology of Alberta; Alberta Energy Regulator, AER/AGS Map 601, scale 1:1 000 000

GOA (Government of Alberts). 2014. The Government of Alberta's Guidelines on Consultation with First Nations on Land and Natural Resource Management.

Glass, D.J. [editor]. 1990. Lexicon of Canadian Stratigraphy, Volume 4: Western Canada, including British Columbia, Alberta, Saskatchewan and southern Manitoba. Canadian Society of Petroleum Geologists, Calgary.

Gibbons, Robert D. 1999. Use of Combined Shewhart-CUSUM Control Charts for Groundwater Monitoring Applications. In Groundwater, Volume 37, No. 5. September-October, 1999.

Health Canada (2020). Guidelines for Canadian Drinking Water Quality—Summary Table. Water and Air Quality Bureau, Healthy Environments and Consumer Safety Branch, Health Canada, Ottawa, Ontario.

Hamblin, A. P. 2010. Scollard/Willow Creek/Coalspur Formations: Summary of Literature and Concepts. Geological Survey of Canada, Open File 6555.

HCL (Hydrogeological Consultants Ltd.) 2002. M.D. of Rocky View No. 44 Part of the South Saskatchewan River Basin Tp 021 to 029, R25 to 29, W4M & Tp 023 to 029, R01 to 06, W5M Regional Groundwater Assessment. March 2002.

Jerzykiewicz, T. 1997. Stratigraphic Framework of the Uppermost Cretaceous to Paleocene Strata of the Alberta Basin. Bulletin 510. Geological Survey of Canada

Langenberg, C.W., F.J. Hein, K. Bieber, J. Losert, H. Berhane and D.K. Cotterill. 2000. Regional geology of the Upper Blairmore Group and Bow Island Formation: a subsurface study in southwestern Alberta; Alberta Energy and Utilities Board, EUB/AGS Earth Sciences Report 2000-06, 68 p.

Moran, S. (1986): Surficial geology of the Calgary urban area; Alberta Research Council, ARC/AGS Bulletin 53, 57 p.

Pana, D.I. and R. Elgr. comp. 2013. Geology of the Alberta Rocky Mountains and Foothills; Energy Resources Conservation Board, ERCB/AGS Map 560, scale 1:500,000.

Prior, G.J., B. Hathway, P.M. Glombick, D.I. Pană, C.J. Banks, D.C. Hay, C.L. Schneider, M. Grobe,

R. Elgr. and J.A. Weiss. 2013. Bedrock geology of Alberta; Alberta Energy Regulator, AER/AGS Map 600, scale 1:1 000 00 US EPA (United States Environmental Protection Agency). 1989. Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Interim Final Guidance. Office of Solid Waste Management Division, US EPA.

Stantec Consulting Ltd. 2019. Springbank Off-stream Reservoir Project Environmental Impact Assessment Hydrogeology Technical Data Report Update. Prepared for Alberta Transportation, May 2019.

Waterline (Waterline Resources Inc.). 2011. Groundwater Evaluation and Monitoring Plan Elbow River Watershed Sub-regions Twps 018 to 024, Rges 29W4 to 09W5 Alberta. Prepared for Alberta Environment. Calgary, Alberta.

Appendix A LEGISLATION WITH REGULATORY AUTHORITY OVER GROUNDWATER

Table A.1 Legislation with Regulatory Authority over Groundwater Relevant to the Project

Legislation	Regulatory Agency	Resource
Canadian Environmental Assessment Act, 2012	Impact Assessment Agency of Canada (Environment and Climate Change)	Environmental protection and public interest
Water Act and associated Regulation	AEP	Water

Appendix B HYDROGEOLOGICAL SETTING

The hydrogeologic setting of the regional assessment area (RAA) is summarized below in order to provide context for the GWMP.

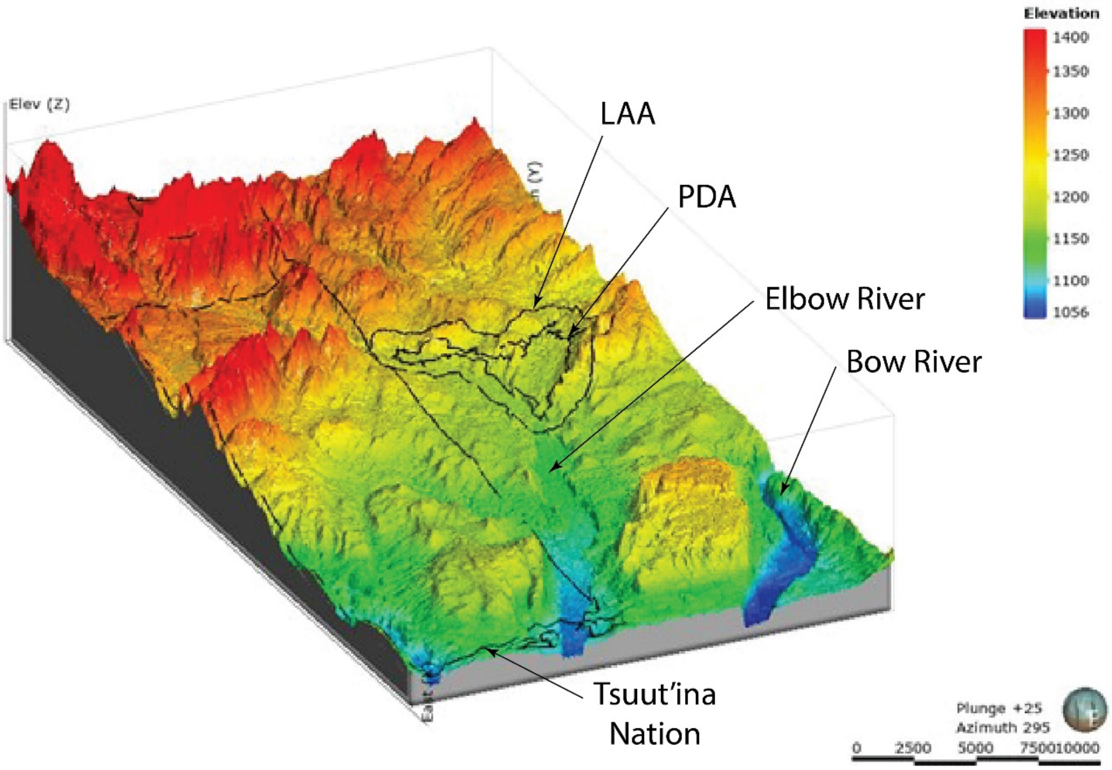
B.1 REGIONAL TOPOGRAPHY AND DRAINAGE

The ground surface topography of the RAA is depicted by the digital elevation model (DEM) in Figure B.1. Outlines of the Hydrogeology PDA/LAA used in the EIA and Tsuut'ina Nation Reserve are also shown as overlays for reference. Areas of higher elevation are denoted by red, and they grade down to areas of low elevation, denoted by blue as shown on the colour scale. The topographic elevation ranges from approximately 1,365 m ASL on the bedrock ridges in the southwest corner of the RAA to approximately 1,125 m ASL along Elbow River at the eastern boundary.

The topography on the north side of the RAA consists of a series of ridges and valleys that are oriented northwest to southeast. The topography of most of the RAA is generally controlled by the bedrock structure, particularly in the southwest, and to a lesser extent, the patterns of glacial sediment deposition modifying the topography in lower areas. Prominent ridges through the assessment area are a result of formations that are more resistive to weathering; the valleys in between the ridges are more easily weathered or recessive.

Near the modern river channels, fluvial erosion and deposition is the primary control agent. Near Elbow River and Jumpingpound Creek, the terrain is incised with one or more fluvial terraces within the river valleys. Hummocky regions have low to moderate relief, with gentle slopes that vary between 2% and 15%. Areas with low relief are underlain by till or glaciolacustrine sediments, while areas of moderate relief are underlain by till and glaciofluvial sediments. Outcrops of bedrock occur along ridges in the lower areas of the RAA and are moderately weathered and fractured, but they are covered by a thick sequence of unconsolidated sediment.

Figure B.1 Topography of the Regional Assessment Area



B.2 REGIONAL HYDROGEOLOGIC SETTING

B.2.1 Conceptual Hydrostratigraphic Framework

The conceptual hydrostratigraphic framework for the LAA and RAA is based on the 3D conceptual site model (3D CSM) developed for the baseline groundwater assessment. Figure B.2 presents an oblique view of the 3D CSM looking from the east with the RAA boundary shown overlain on the model and air photograph for reference.

A regional stratigraphic column that shows the generalized stratigraphy beneath the RAA is depicted in Figure B.3. Brief descriptions of each stratigraphic unit, and a discussion of the additional salient features of the area are presented in the following subsections.

Figure B.2 Oblique Angle Overview of 3D CSM

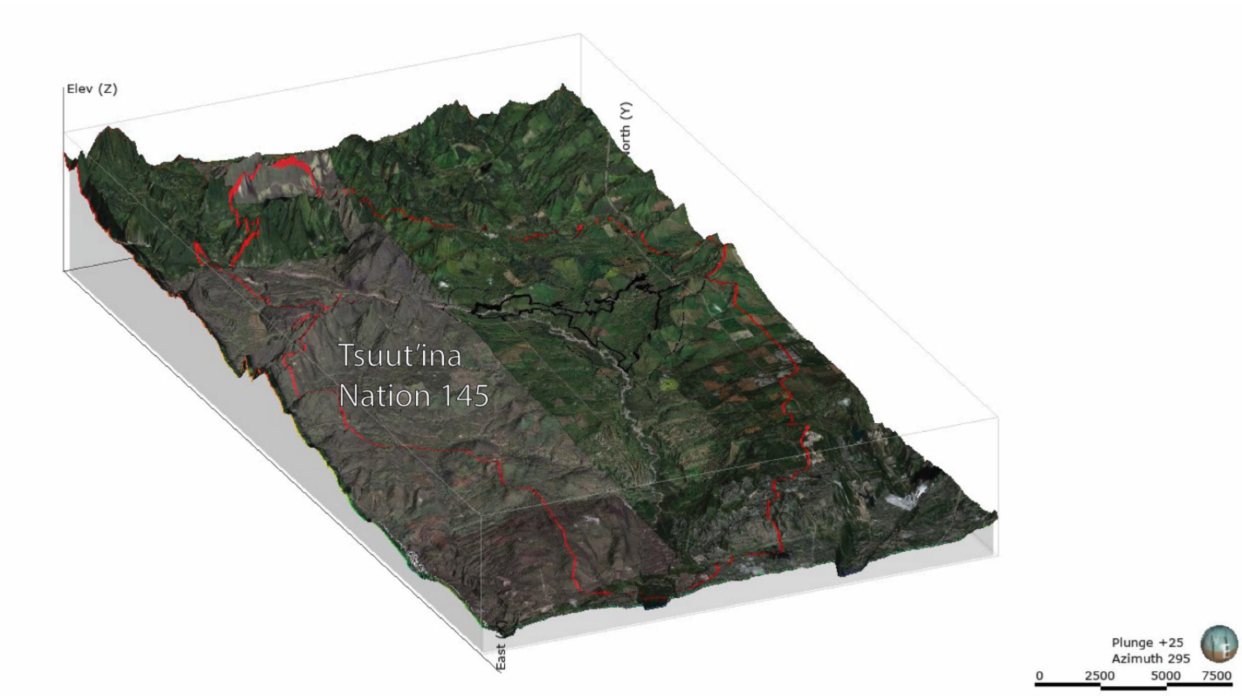
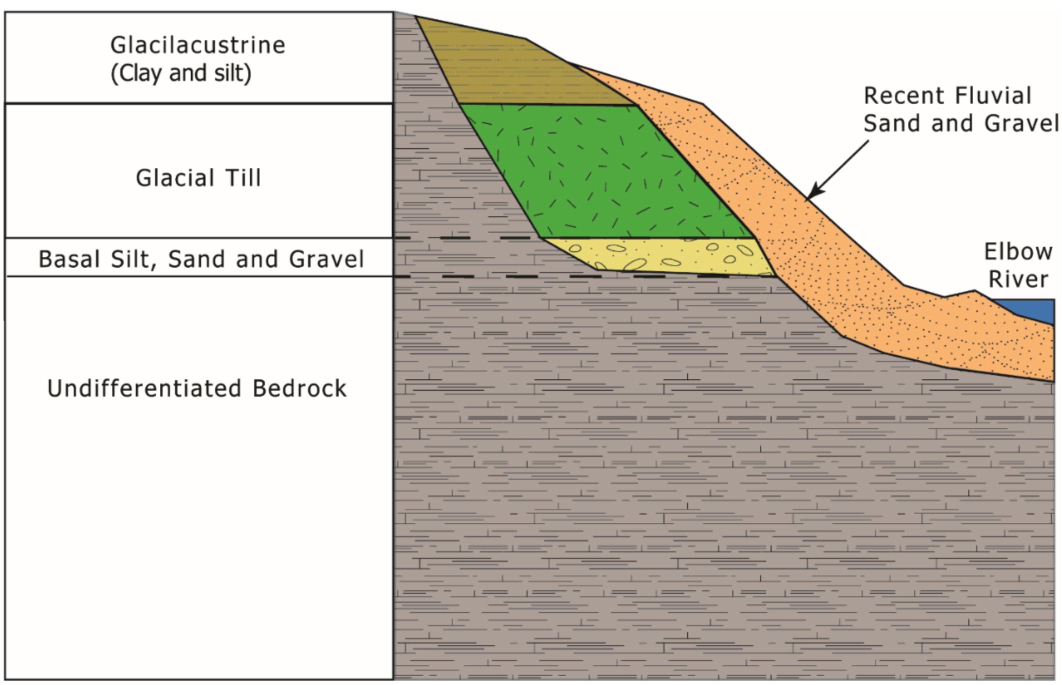


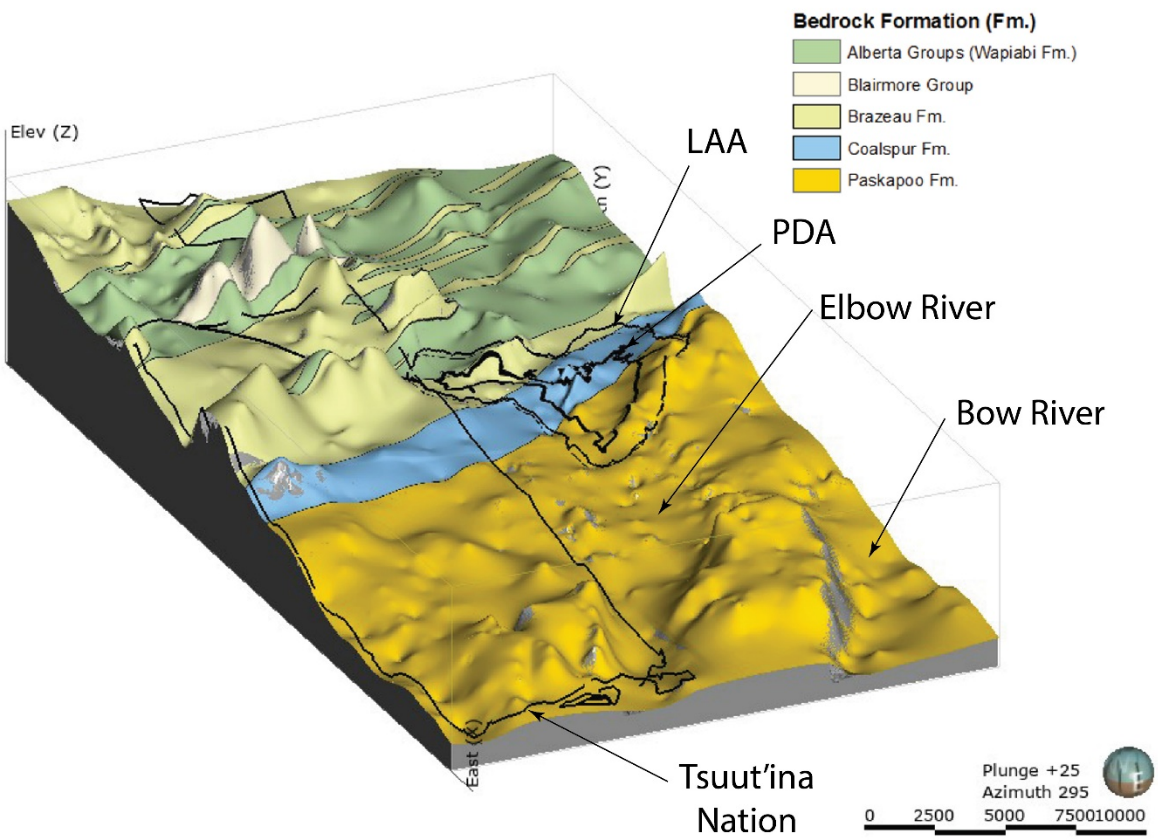
Figure B.3 Conceptual Regional Stratigraphic Column



B.2.2 Bedrock

The bedrock surface within the RAA was shaped by tectonism and associated formation of the Rocky Mountains to the west, glacial erosion/deposition, and erosional incision of modern-day river channels. The RAA is in the disturbed belt which forms a transitional zone (foothills) between the Rocky Mountains to the west and prairie to the east. Bedrock topography is depicted in Figure B.4.

Figure B.4 Bedrock Topography and Subcrop Formations



The bedrock units encountered beneath the quaternary deposits are presented below from oldest to youngest. This generally coincides with how they appear from west to east across the RAA except for the Blairmore Group:

- The lower Cretaceous Blairmore Group dominantly composed of fluvial sediments. The two fluvial formations belonging to the upper Blairmore Group include the Beaver Mines and Mill Creek formations (Langenberg et al. 2000). This unit subcrops over a small topographically elevated area in the southwest of the RAA.
- The upper Cretaceous-aged Wapiabi Formation of the Alberta Group is generally composed of shale and mudstone with minor siltstone, except for the Chungo and Marshybank Members, which are sandstone dominated (Pana and Elgr 2013).
- The upper Cretaceous-aged Brazeau Formation is composed primarily of sandstone and laminated siltstone, along with olive green mudstone and granule to pebble conglomerate in the lower part. The upper part is composed of greenish-grey to dark grey mudstone, siltstone and greenish-grey sandstone. Thin coal and coaly shale beds and thin bentonite layers also occur in the upper part (Prior et al. 2013).
- The Upper Cretaceous-to-Tertiary aged Coalspur Formation formed as a marginal marine fluvial infill of the foreland basin. The Coalspur Formation is composed of thinly bedded to massive sandstone, siltstone, light grey to olive green mudstone, shale, coaly shale, coal seams and minor volcanic tuff in the lower portions (Pana and Elgr 2013).
- The Tertiary-aged Paskapoo Formation is made up of thick tabular sandstone, siltstone and mudstone (Glass 1990). The sandstones are fine to coarse grained and are cliff forming. The Paskapoo Formation also contains a substantial amount of shale, carbonaceous shale, siltstone, rare coals seams and shell beds (Pana and Elgr 2013). In the central Rocky Mountains and foothills, the Paskapoo Formation is dominated by recessively weathering, grey to greenish-grey mudstone and siltstone with subordinate pale grey, thick- to thin-bedded, sandstone; minor conglomerate; mollusc coquina; and coal (Prior et al. 2013). The Paskapoo Formation is the primary bedrock aquifer in the Elbow River watershed. Due to the stratigraphy of the layers of sandstone and shale within this formation, multiple aquifers occur at various depths in the rock (Waterline 2011).

The approximate subcrop boundaries of the bedrock units are presented in Figure B.4 and are based on regional mapping by Pana and Elgr (2013), except for the contact between the Coalspur and Brazeau Formations. This contact was reinterpreted by Jerzykiewicz (1997) based on observation and description of the entrance conglomerate in outcrop along Highway 22. The entrance conglomerate marks the boundary between these two formations, and its presence was confirmed in the field Project-specific data gathering.

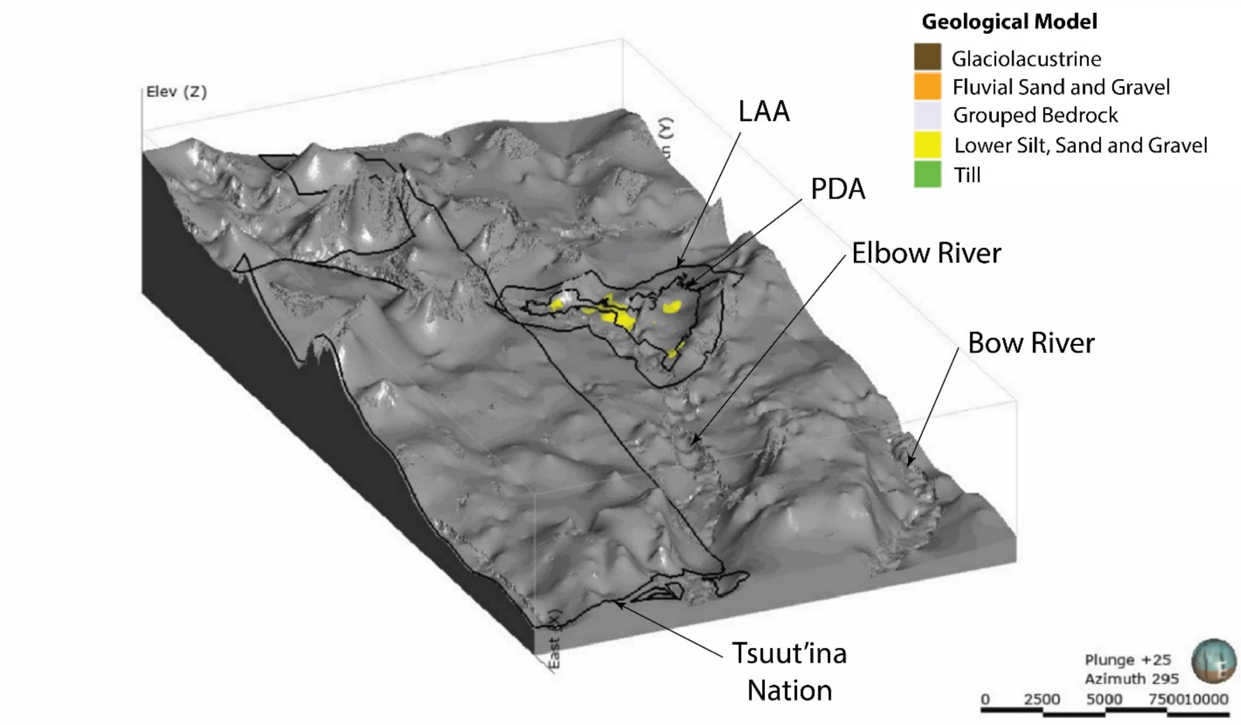
The bedrock descriptions from boreholes drilled to support the Project consist of varying thicknesses of alternating siltstone, sandstone mudstone and claystone. Descriptions of each of these lithological units are as follows:

- Grey to brown, fine to medium-grained sandstone ranges from completely unlithified to well cemented and dry. Significant fracturing was noted in many intervals, with oxidation common along fracture planes. The upper sandstone beds beneath the unconsolidated deposits are highly weathered. Thicknesses of individual sandstone beds range from thin, centimetre-scale beds to a maximum of 15.3 m and an average thickness of 2.5 m.
- Grey to brown and, in some intervals, greenish-grey siltstone occurs and is extremely weak and friable to well cemented. It is highly fractured in some intervals, with oxidation along fracture planes. The average thickness of the interbedded siltstone beds is 2.5 m.
- Medium grey to brown claystone, generally blocky and not fissile-like shale, dry except where fractures are saturated occurs. Fracturing varies from completely unfractured to, more often, highly fractured with oxidation and alteration of clay along fractures. Claystone is interbedded with the other lithologies described above, with an average thickness of 1.9 m for each of the interbedded layers.

B.2.3 Basal Silt, Sand and Gravel

In some portions of the LAA, a coarser grained unit occurs above the bedrock at the base of the till. This unit is most prominent near the Elbow River valley and consists of a mixture of brown sand, silt and gravel with variable fines. The unit ranges in thickness from 0.9 to 4.2 m with an average of 2.4 m in the boreholes where it was encountered. The distribution of the basal silt, sand and gravel deposits is shown in yellow in Figure B.5. While this unit may be more widespread within the RAA than the distribution shown, the data density in the LAA was sufficient based on Project-specific data to allow correlation and mapping of this unit.

Figure B.5 Distribution of Basal Silt, Sand and Gravel



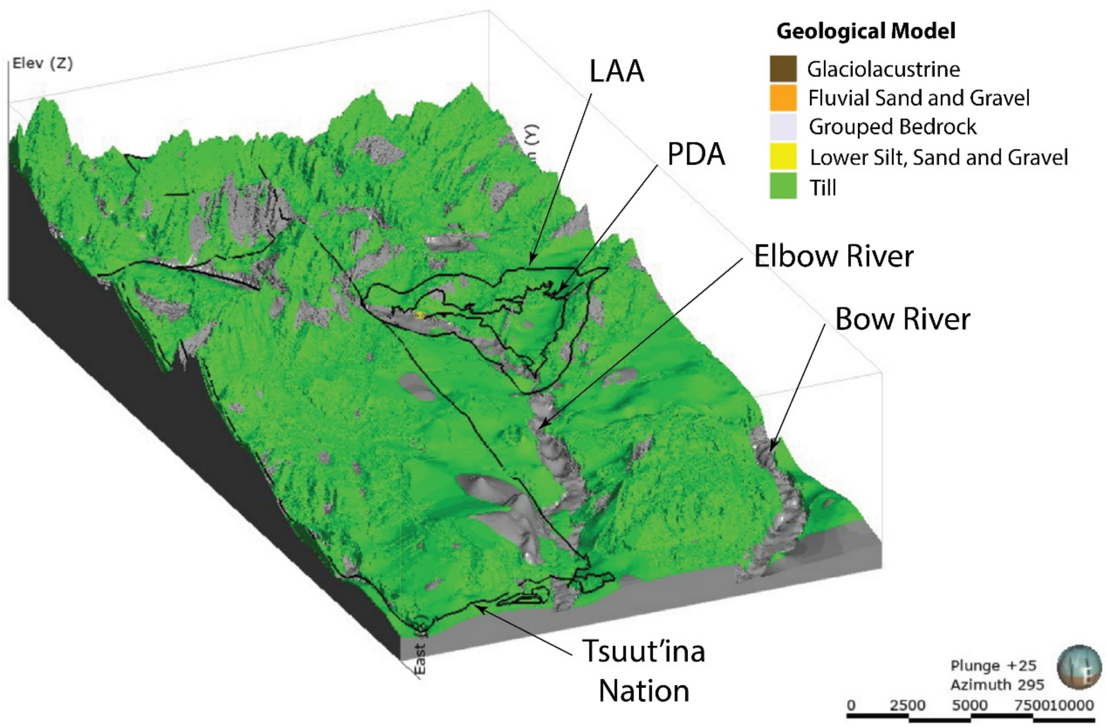
B.2.4 Till

The unconsolidated deposits present beneath the majority of the RAA consist of Pleistocene Age glaciolacustrine clay and till (Fenton et al. 2013; Moran 1986). In the RAA, the till material was deposited by glacial ice as basal or lateral moraines. Based on the field observations and laboratory grain size analyses completed as part of the geotechnical drilling program, the till in the LAA is composed of a heterogeneous mixture of approximately equal parts clay and silt, a lower proportion of sand, and minor gravel. Silt and sand lenses are also present within the heterogeneous matrix. The till is described as generally stiff to very stiff or hard, medium to high plastic clay with silt and more minor sand. Where present, the till ranges in thickness from 0.2 m to greater than 50 m with an average thickness of 10 m across the RAA.

Two main till sub-units are summarized as follows:

- Brown-grey subglacial till is dark brown to grey sandy, silty, clay with variable gravel. The till is hard with low to medium plasticity. The brown-grey subglacial till was encountered throughout the dam and diversion footprint. Cobble-sized clasts within the matrix were rounded to sub-rounded sandstones and carbonates.
- Upper brown till occurs above the subglacial till and is a massive, matrix-supported, olive brown to brown, medium plastic clay, clay and silt with sand content increasing with depth. This unit was encountered in boreholes in the dam footprint and eastern portion of the diversion channel.

Figure B.6 Distribution of Till



B.2.5 Glaciolacustrine Deposits

Glaciolacustrine clay overlies the till in the low-lying areas of the LAA. The silty clay was deposited in Glacial Lake Calgary, a proglacial lake formed by ice damming during the last deglaciation. The glaciolacustrine deposits have been named the Calgary Formation (Moran 1986).

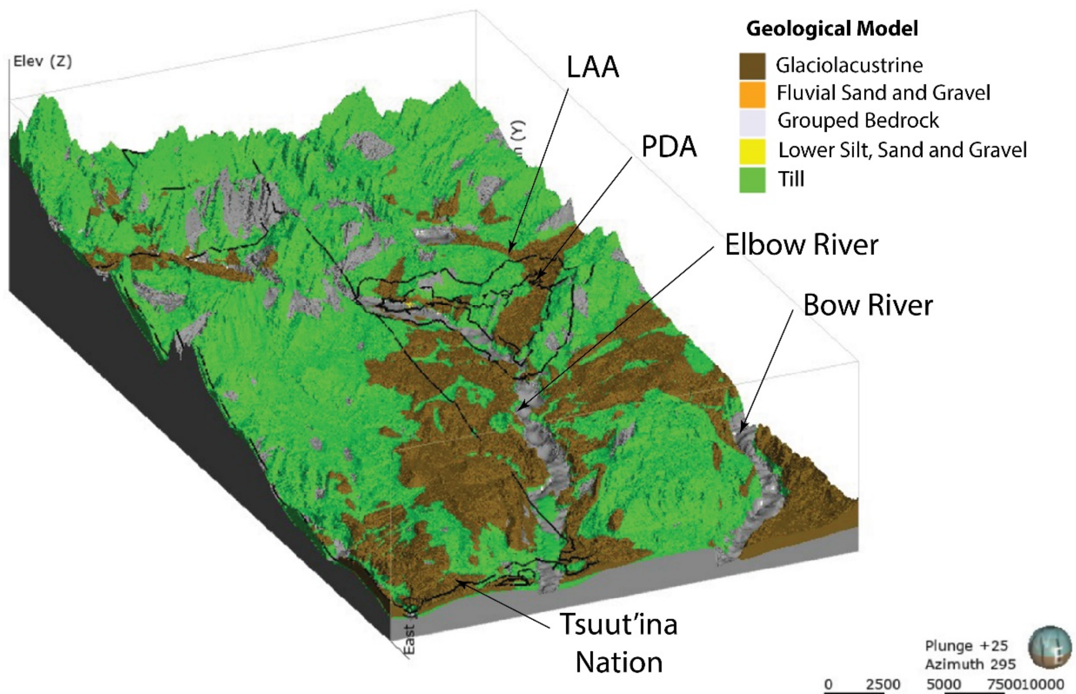
The distribution of this unit is presented in blue in Figure B.7. Outlines of the Tsuut'ina Nation Reserve and the Hydrogeology PDA/LAA are also shown as overlays for reference. Within the LAA, the glaciolacustrine clay averaged 5.3 m thick in the boreholes where it was encountered.

Based on the field observations and laboratory grain size analyses, the glaciolacustrine clay in the LAA is composed of 50-70% clay, 30-40% silt and a minor proportion of sand. Typical of a lacustrine deposit, the clay was found to be laminated with silt and fine sand. This layering has resulted in the following:

- relatively high hydraulic conductivities for silty clays (measured at 1.4×10^{-7} m/s and model calibrated at 5.1×10^{-6} m/s) and anisotropy ratios (horizontal hydraulic conductivity: vertical hydraulic conductivity) compared to the underlying till
- groundwater preferentially flows through the silt

The laminations and rhythmic bedding of the glaciolacustrine deposits can be observed along the banks of Elbow River in the RAA.

Figure B.7 Distribution of Glaciolacustrine Deposits



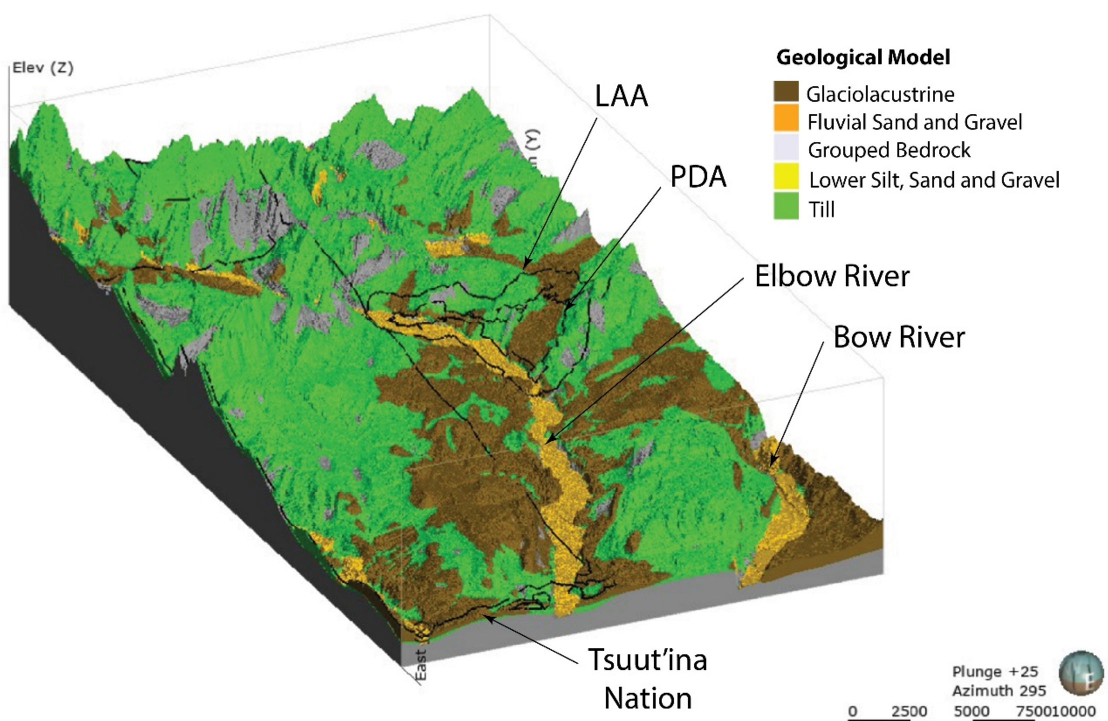
B.2.6 Recent Fluvial Deposits

Post-glacial fluvial channel sediments are in the Elbow River valley that extends across the RAA and in the Jumpingpound Creek channel in the western portion of the RAA. These sediments developed as the high-energy rivers, eroded and exported material from upstream areas and deposited coarse alluvium (sand and gravel) in the river channel. Localized areas of overbank deposits consisting of fluvial silt are also present (Moran 1986). The deposition of alluvium over Quaternary deposits or bedrock in the valleys resulted in the formation of alluvial aquifers, which are an important source of groundwater for the river and residents.

The alluvial aquifers provide temporary storage for water from Elbow River and Jumpingpound Creek during floods; the water is naturally released back into the rivers from bank storage after a flood recedes. Groundwater from the alluvial aquifer of Elbow River is essential in maintaining baseflow. Yields for the Elbow River alluvial aquifer range from 175 m^3/day to 2,500 m^3/day (Waterline 2011).

Recent fluvial deposits are depicted in orange in Figure B.8. Outlines of the Tsuut'ina Nation Reserve and the Hydrogeology PDA/LAA are also shown as overlays for reference. The fluvial deposits in this area are brown and grey silty gravel with more minor sand, cobbles and boulders.

Figure B.8 Distribution of Recent Fluvial Deposits



B.3 GROUNDWATER FLOW

B.3.1 Groundwater Flow in the Unconsolidated Glacial Deposits

Groundwater levels within the surficial deposits generally follow the topography and range from 0 m BGL, where the water table intersects ground surface at springs and along stream and river banks, to approximately 8.0 m BGL. The corresponding groundwater elevations range from approximately 1,380 m ASL in the topographically elevated areas in the of the RAA southwest to 1,080 m ASL along the eastern boundary of the RAA.

There is high potential for perched water table development within the RAA because of the following landscape and geological controls:

- permeability contrast created by an unconsolidated sediment veneer over the bedrock
- steep land surface gradients and erosional unconformities that truncate hydrostratigraphic units within the RAA
- mapped contact springs that indicate perched conditions in topographically elevated areas.

Groundwater flow direction is interpreted to be toward Elbow River across the majority of the RAA, except for areas 1) northwest where shallow groundwater flows west toward Jumpingpound Creek, 2) areas along the north side of the RAA across the flow divide, and 3) in the Bow River watershed where groundwater flows north. Horizontal gradients beneath the LAA range from 0.003 in the central portion of the reservoir to 0.1 in the southern portion of the LAA that is adjacent to the Elbow River near the diversion structure.

As noted above, the unconsolidated sediment above bedrock is also thought to host-perched water tables in which groundwater flow is typically dictated by local-scale topography where the permeability contrast exists to support development of perched groundwater.

The average linear groundwater velocity in the unconsolidated glaciolacustrine deposits and till is estimated to range from less than 0.01 m/year to approximately 2.3 m/year. However, it should be noted that flow velocities through sand lenses within, or at the base of, the till could be higher.

B.3.2 Groundwater Flow in the Upper Bedrock Aquifers

The potentiometric surface elevation in the upper bedrock ranges from approximately 1,400 m ASL in the southwest to 1,080 m ASL at the base of the Elbow River valley along the eastern boundary of the RAA. The potentiometric surface elevation in the mountainous southwest area of the RAA is predicted above land surface between topographically elevated areas. This suggests the presence of locally perched bedrock aquifers in this area that are poorly hydraulically connected to the underlying regional bedrock aquifer.

Groundwater flow direction in the bedrock is dominantly controlled by the bedrock surface-topography. On the north side of Elbow River, the bedrock generally slopes towards the river, while being influenced by variation in the bedrock surface topography. There are some topographic low areas in the bedrock on the north side of the river that focus groundwater flow in the bedrock beneath the PDA and LAA before trending towards Elbow River. The bedrock topography is significantly more complex on the south side of Elbow River and the flow patterns in the bedrock demonstrate radial flow away from elevated bedrock features. Correspondingly, the surface water drainage features to Elbow River on the south side appear to act as groundwater discharge features that focus flow between topographically-elevated bedrock features.

Horizontal gradients in the upper-bedrock aquifers beneath the LAA range from 0.005 in the central portion of the proposed reservoir to 0.02 in the southern portion of the LAA adjacent to Elbow River near the diversion structure.

The average linear groundwater velocity in the shallow bedrock is estimated to range from less than 0.01 cm/year in the unfractured portions of the claystone bedrock to approximately 30 m/year in the more permeable sandstone in the areas of higher hydraulic gradient near the Elbow River.

B.4 EXISTING GROUNDWATER AND SURFACE WATER USE

Groundwater use in the RAA is primarily from shallow bedrock aquifers with some wells also completed in the recent fluvial deposits along Elbow River. Regional mapping by HCL (2002) indicate yields from the bedrock aquifers in the disturbed belt range from 10 m^3/day to 75 m^3/day. Yields from wells completed in the recent fluvial deposits along Elbow River are expected to range from 175 m^3/day to 2,500 m^3/day (Waterline 2011).

The base of groundwater protection (BGP) is an estimate of the elevation of the base of the geological formation in which the groundwater is deemed useable with a total dissolved solids (TDS) concentration of less than 4,000 mg/L. West of the RAA, the BGP is defined as the base of the Paskapoo Formation; however, because the RAA lies within the disturbed belt of the Rocky Mountains, the AGS has set an arbitrary BGP of 600 m BGL.

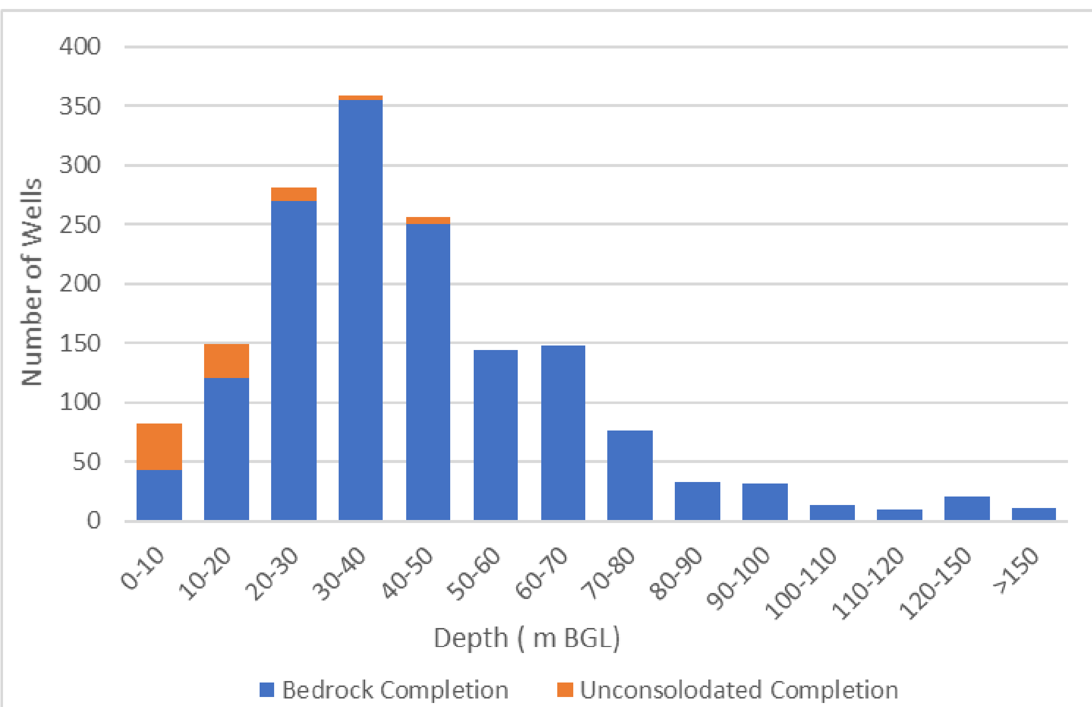
Water well drillers records for groundwater wells completed in the RAA were queried from the AWWID. A total of 2,140 unique well records were identified within the RAA. A number of well record types were removed from the raw data such as abandoned test holes, dry holes, piezometers, and seismic test holes, which are not reflective of groundwater use. A total of 1,708 water well drilling records remained after removing irrelevant data. The proposed use of the wells associated with the AWWID drilling records within the expanded were as follows:

- 1,458 for domestic use
- 71 for stock use

- 75 for domestic and stock use
- 15 for commercial purposes
- 16 for industrial purposes
- 5 for irrigation purposes
- 9 for municipal use
- 59 for unknown use

Water well depths ranged from 1.5 m to 246 m BGL. Figure B.9 presents a histogram of the total depth recorded on the drilling records. The number of wells completed in bedrock and unconsolidated units are also summarized in the figure. A total of 83 well records were for wells installed in unconsolidated deposits with completion depths ranging from 0 to 50 m BGL. It is worth noting that many of the wells will not currently be in use considering the average age of the records is 33 years and some are as old as 80 years. Additional detail and mapping regarding groundwater use are presented in the Hydrogeology Technical Data Report (TDR) Update (Stantec 2019).

Figure B.9 Histogram of Water Well Depth in the RAA



B.5 IMPLICATIONS FOR THE GROUNDWATER MONITORING PLAN

The following factors were considered during development of the GWMP based on the hydrostratigraphic framework and summary of groundwater use presented above:

- The hydrogeologic setting in the RAA is complex and consists of a series of unconsolidated deposits overlying bedrock. The GWMP describes monitoring of both unconsolidated and bedrock hydrostratigraphic units.
- The distribution of the unconsolidated units is highly variable across the RAA, but generally consist of low permeability (10^{-10} to 10^{-6} m/s) deposits in areas outside of river valleys. Higher permeability deposits are generally confined to the Elbow River valley and within some of the smaller tributary valleys. The GWMP considers the variable distribution of the unconsolidated deposits and describes monitoring in both permeable units (potential aquifers) and low permeability units (aquitards).
- Bedrock in the RAA is also variable and heterolithic, generally consisting of interbedded sequences of fine-and-coarse grained deposits varying from mudstones to sandstones. When the position of monitoring wells is better constrained, the completion interval for the monitoring well will need to carefully consider the lithology encountered during drilling/installation to reflect the uppermost interval most likely to be used domestic/agricultural use.
- Groundwater use for domestic and agricultural purposes in the RAA is sourced from both unconsolidated and bedrock units. However, use from the bedrock units dominates, particularly for wells with depths greater than 10 m. As such, the draft GWMP considers monitoring of the deeper bedrock units, particularly in areas distant from Project infrastructure, such that unexpected change in groundwater levels can be detected in hydrostratigraphic units currently being used for domestic and agricultural purposes.