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Abbreviations

3D	three-dimensional
3D CSM	three-dimensional conceptual site model
BGL	below ground level
GCDWQ	Guideline for Canadian Drinking Water Quality
LAA	local assessment area
m asl	metres above sea level
PDA	project development area
RAA	regional assessment areas
TDS	total dissolved solids
VC	valued component

5.0 ASSESSMENT OF POTENTIAL EFFECTS ON HYDROGEOLOGY

The scope of the assessment and existing conditions for hydrogeology (which remain valid for Volume 3B) are presented in Volume 3A, Section 5.1 and Section 5.2. This section assesses the effects of the Project on hydrogeology during flood and post-flood operations. The temporal boundary for the assessment of flood and post-flood operations is indefinite, since the Project is a permanent installation.

Flood operations refers to when water is diverted from Elbow River into the diversion channel, into the reservoir and the release of stored water from the reservoir. The assessment focuses on the effects of the diversion on groundwater quantity quality.

Post-flood operations include sediment partial clean-up and maintenance activities required on project infrastructure (e.g., such as the diversion channel, floodplain berm, off-stream dam, access roads, low-level outlet, and bridges).

The effects of both flood and post-flood operations are assessed for three floods using a numerical groundwater modelling approach (more detail is provided in Volume 4, Appendix I, Hydrogeology Numerical Modelling Technical Data Report (TDR)). In order of decreasing flood magnitude, the three floods assessed are the design flood, the 1:100 year and 1:10 year floods.

5.1 PROJECT INTERACTIONS WITH HYDROGEOLOGY

Table 5-1 identifies physical activities that might interact with hydrogeology. These interactions are discussed in detail in Section 5.3 in the context of effects pathways, standard and project-specific mitigation and residual effects. A justification for no interaction is provided following the table.

Table 5-1 Project-Environment Interactions with Hydrogeology during Flood and Post-flood Operations

Project Components and Physical Activities	Environmental Effects	
	Change in Groundwater Quantity	Change in Groundwater Quality
Flood and Post-flood Operations		
Reservoir filling	✓	✓
Reservoir draining	✓	✓
Reservoir sediment clean up	-	-
Channel maintenance	-	-
Road and bridge maintenance	-	-
NOTES: ✓ = Potential interaction – = No interaction		

Reservoir sediment clean up, channel maintenance, and road and bridge maintenance activities that may be required during project operations are not expected to interact with hydrogeology, since such activities occur at or above the ground surface and above the water table.

5.2 ASSESSMENT OF RESIDUAL ENVIRONMENTAL EFFECTS ON HYDROGEOLOGY

5.2.1 Assessment Techniques

A mathematical groundwater model is used to depict the subsurface geologic setting and associated physical parameters that govern the flow of groundwater through porous media (in this case for the PDA, unconsolidated and/or bedrock materials). The model output provides a description of the spatial distribution of potentiometric heads across the modelling domain in response to changes in the hydrogeologic system geometry (e.g., addition of physical infrastructure, excavations) or system stressors (e.g., floods).

A numerical flow model was selected for use over other potential analytical solution methods due to the size of the RAA, complex geologic framework, time-variable boundary conditions, and irregular geometry of the physiographic setting and project components. A numerical solution technique was favoured over analytical methods such that the number of simplifying assumptions required would be minimized, thus yielding a more detailed depiction of the hydrogeologic setting and system response within the RAA.

The development and calibration of the numerical groundwater flow model used for this hydrogeology effects assessment is presented in Volume 4, Appendix I, Hydrogeology Numerical Modelling TDR. A summary of the model development is presented below.

5.2.1.1 Finite Element Numerical Flow Model Development and Calibration

The finite element subsurface flow and transport system (FEFLOW) is a numerical groundwater modelling system that is capable of modelling three-dimensional (3D) groundwater flow and mass transport. FEFLOW was used for the groundwater flow model in combination with the 3D CSM developed with Leapfrog Hydro (Volume 4, Appendix I, Hydrogeology Modelling TDR).

Boundary conditions were set and parameterization of the domain was completed using hydraulic testing results which helped to constrain the calibration. Calibration of the model then proceeded using a combination of heads measured in monitoring wells situated within the LAA, heads measured in domestic wells situated in the RAA, and other information regarding surface water elevations in the LAA. Calibration of the model at steady state conditions was achieved through a combination of parameter estimation routines implemented by FePEST until a reasonable fit between observed and simulated steady state heads was observed. Additional manual calibrations in transient simulations was also completed to refine the model's dynamic response.

5.2.1.2 Evaluating Project Effects through Numerical Groundwater Model Simulations

The FEFLOW model was used to simulate hydrogeologic conditions in the RAA during four flow scenarios:

- A hypothetical non-flood scenario that represents hydrogeologic conditions during non-flood periods of average flow in the Elbow River
- The project design flood (2013)
- A 1:100 year flood
- A 1:10 year flood

The hydrographs for the design, 1:100 year and 1:10 year floods modelled are shown in Figure 5-1.

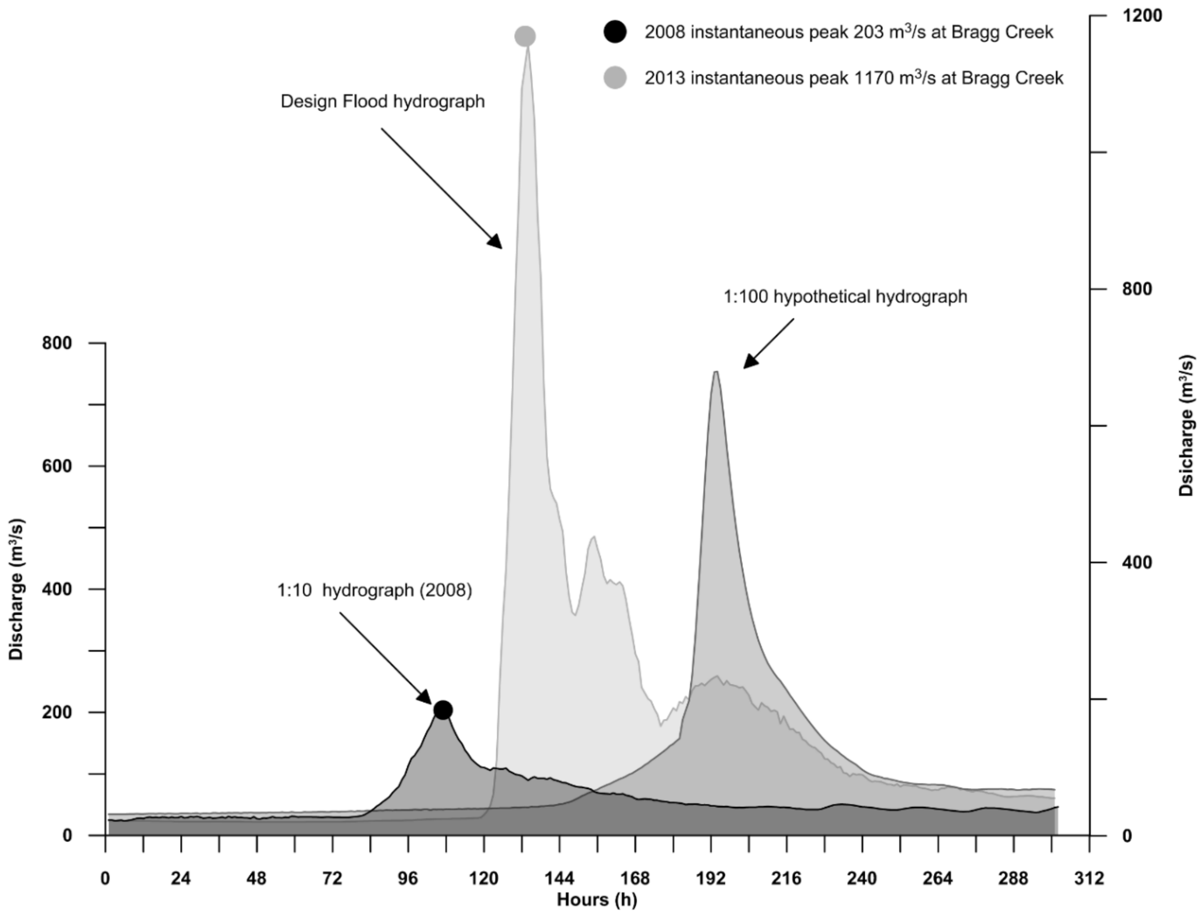


Figure 5-1 Design Flood, 1:100 Year Flood and 1:10 Year Flood Hydrographs

Numerical groundwater modelling of each of the flood events is based on the project diversion operational rules and modelled surface water elevations. Diversion starts when flows exceed 160 m^3/s with increasing diversion occurring until flows in the diversion channel reach a maximum of 600 m^3/s. Any flow remaining in the Elbow River above 760 m^3/s (160 m^3/s plus 600 m^3/s) is allowed to pass downstream while 600 m^3/s is continuously diverted into the diversion channel.

For each of the floods, two FEFLOW simulation runs were completed to represent hydrogeologic conditions without the project operating and operation conditions, yielding a total of eight simulation runs; these are summarized in Table 5-2. The EE-series of simulations (without the project operating) represent the hydrogeologic system in the RAA under various flows. The PP-series of simulations (project operation) represent the hydrogeologic system in the RAA under various flows with the major project features (diversion channel, off-stream reservoir) represented in the model.

Table 5-2 Summary of Numerical Groundwater Model Simulation Runs

Floods in Elbow River	Numerical Model Simulation Run		Effects Evaluated
	Without Project Operation (Existing Conditions)	With Project Operation	
Average Flow Conditions (No Flood)	EE0	PP0	Dry Operations
Design Flood	EE1	PP1	Flood Operations
1:100 Year Flood	EE2	PP2	Flood Operations
1:10 Year Flood	EE3	PP3	Flood Operations

Each of the simulations were run within the FEFLOW model using a constant time step over the entire simulation period. The simulation period varied between runs, depending upon the flood hydrographs, water retention time in the off-stream reservoir, and associated water release times. Additional simulation time was added to represent the post-release period following complete release of water from the off-stream reservoir such that recovery of groundwater levels could be simulated.

Following each of the simulation runs, output files from FEFLOW were exported for post processing and interpretation. Each of the output files detail simulated potentiometric heads at each of the model nodes at each time step of the simulation. These output files were examined using spatial analysis tools to generate interpolated 3D potentiometric surfaces (at various timesteps in the simulation) that were then imported into the 3D CSM developed for the Project for latter evaluation and interpretation. Through examination of the 3D potentiometric surfaces over time, the dynamics of the hydrogeologic system in the RAA could be understood for the eight simulation runs.

Figure 5-2 shows the cross section across the dam structure in a southwest-northeast orientation (A-A'), a cross section across the diversion channel in a west-east orientation (B-B'), and a cross section across the Elbow River valley in a northwest-southeast orientation (C-C').

Data from output files were also extracted to derive simulated hydrographs of groundwater levels at various points of interest within the model domain. These points of interest (see Figure 5-2) were selected based on proximity to project infrastructure (e.g., the diversion channel, off-stream reservoir, dam) and to other potential locations of interest (e.g., the Elbow River valley, points outside the PDA near the LAA boundary). The points of interest were set within the FEFLOW interface and, at each timestep of the simulations, the potentiometric head value was recorded in the output file such that a time-series of water levels could be generated. These simulated hydrographs could then be examined to better understand the dynamic response of the hydrogeologic system in the RAA to floods for both the EE and PP simulations (see Table 5-2).

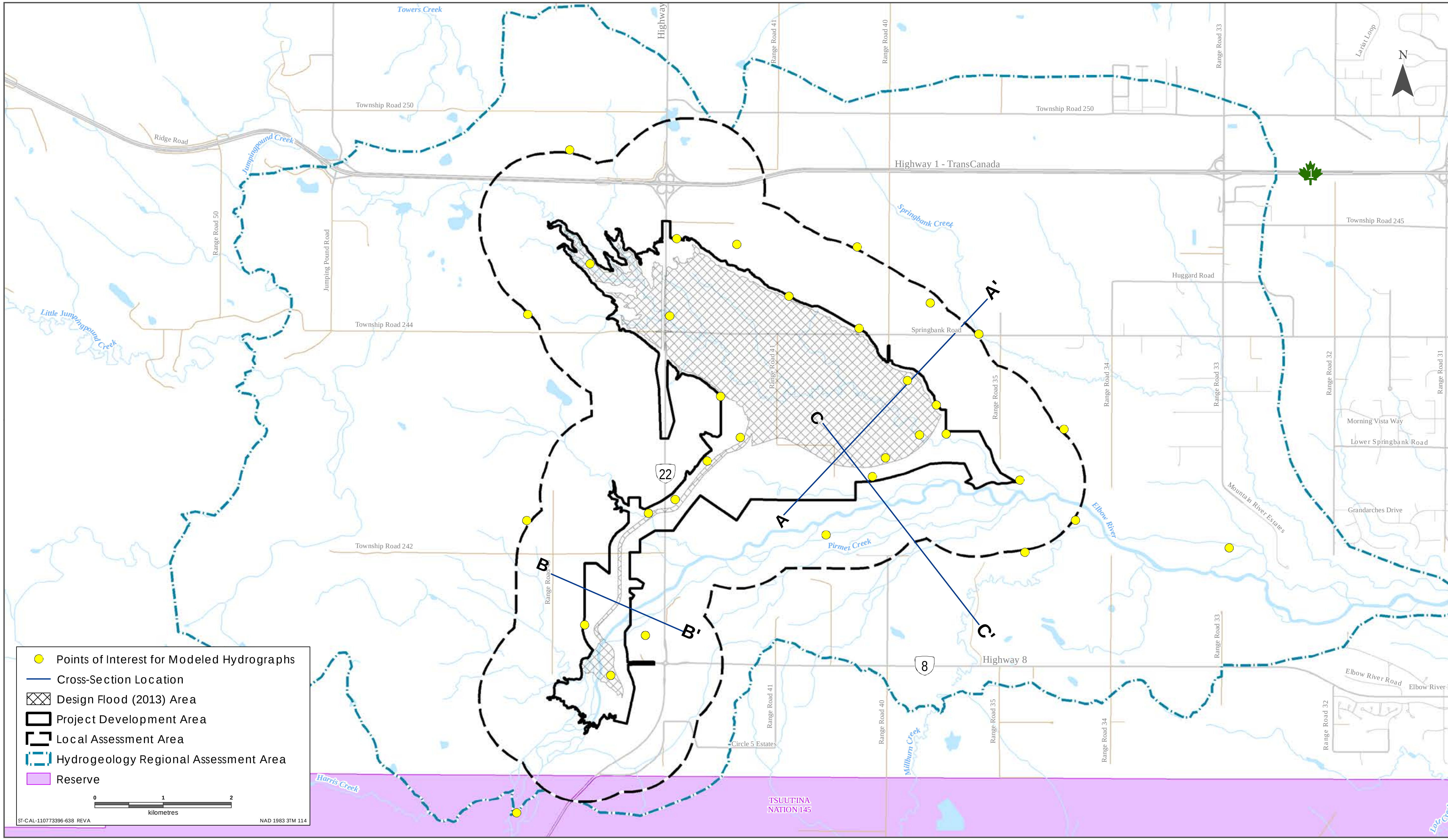
5.2.1.3 Simulation of Existing Hydrogeologic Conditions (EE-Simulations)

Design Flood – EE1 Simulation Results

The numerical groundwater model simulation was started at an arbitrary point in time prior to arrival of the design flood event. Simulated results for a particular point in time are then referenced relative to the start of the simulation. For example, the 10-hour timestep occurs 10 hours following start of the simulation. However, the time lapse of the flood event and operation of the diversion is consistent with the timing used in the hydrodynamic model and engineering design process.

Figure 5-3 presents the simulated potentiometric head distribution of the water table across the RAA under existing conditions (without the addition of the Project components) during the peak reservoir level of the design flood. The results presented in Figure 5-3 occur at the point in time when the off-stream reservoir would just have been filled (at the 655-hour simulated time step), though the reservoir does not exist in this simulation. The 655-hour timestep is the simulated point in time at which flows within the diversion channel would have ceased, since flows within the Elbow River would have dropped below the 160 m^3/s and flow diversion would have stopped (and thus reservoir levels are no longer rising). Reference to this point in time, while not directly pertinent for this simulation, is provided since it is the same point in time at which results from the PP1 simulation (which does include the Project components) will be later presented.

The potentiometric head distribution presented in Figure 5-3 suggests that shallow groundwater flow patterns are controlled to a large degree by the regional topography. Groundwater elevations range from approximately 1,338 m ASL in the southwest regions of the RAA to approximately 1,126 m ASL in eastern regions of the RAA in the Elbow River valley. Regionally, groundwater flow directions are generally from upland areas along topographic ridges, toward lowland areas near creeks, wetlands, and the Elbow River valley. Local scale flow patterns are variable but shallow groundwater flow towards local drainage features (i.e., creeks, wetlands) is commonly observed across the RAA. The Elbow River valley is a hydraulic divide for shallow groundwater, with flow directions on either side of the valley directed inward towards it.



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

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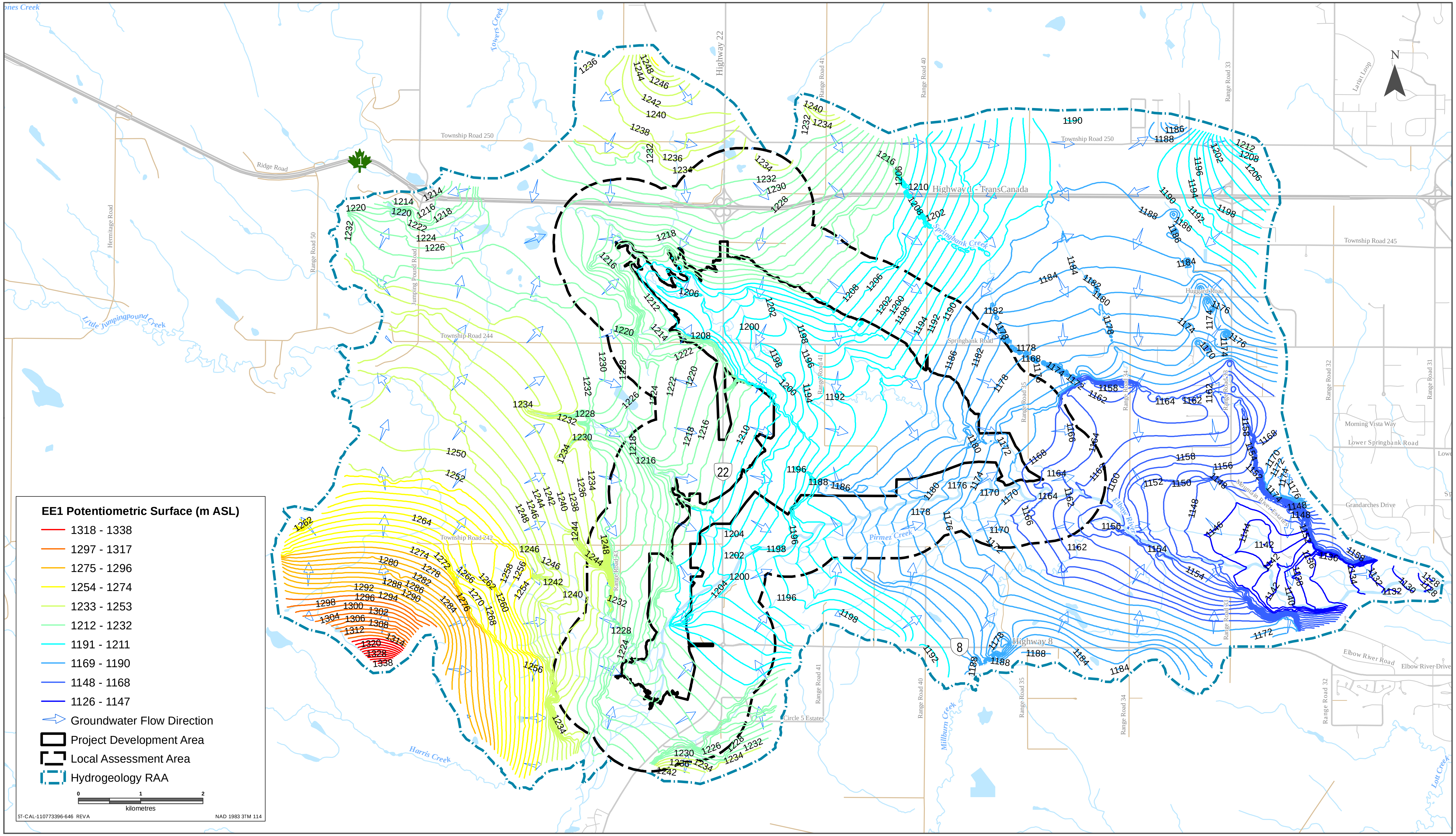
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Key Points of Interest and Cross Section Locations

Figure 5-2



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

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Potentiometric Head Distribution Design (2013) Flood at Peak – Existing Conditions

Figure 5-3

Figure 5-4 presents a hydrogeologic cross section which was exported from the 3D CSM along a line that cuts through the dam structure area (though it is not present in this simulation). This cross section includes the subsurface hydrostratigraphic units underlying the dam area and the modelled water table surface for the EE1 simulation at the 655-hour time step.

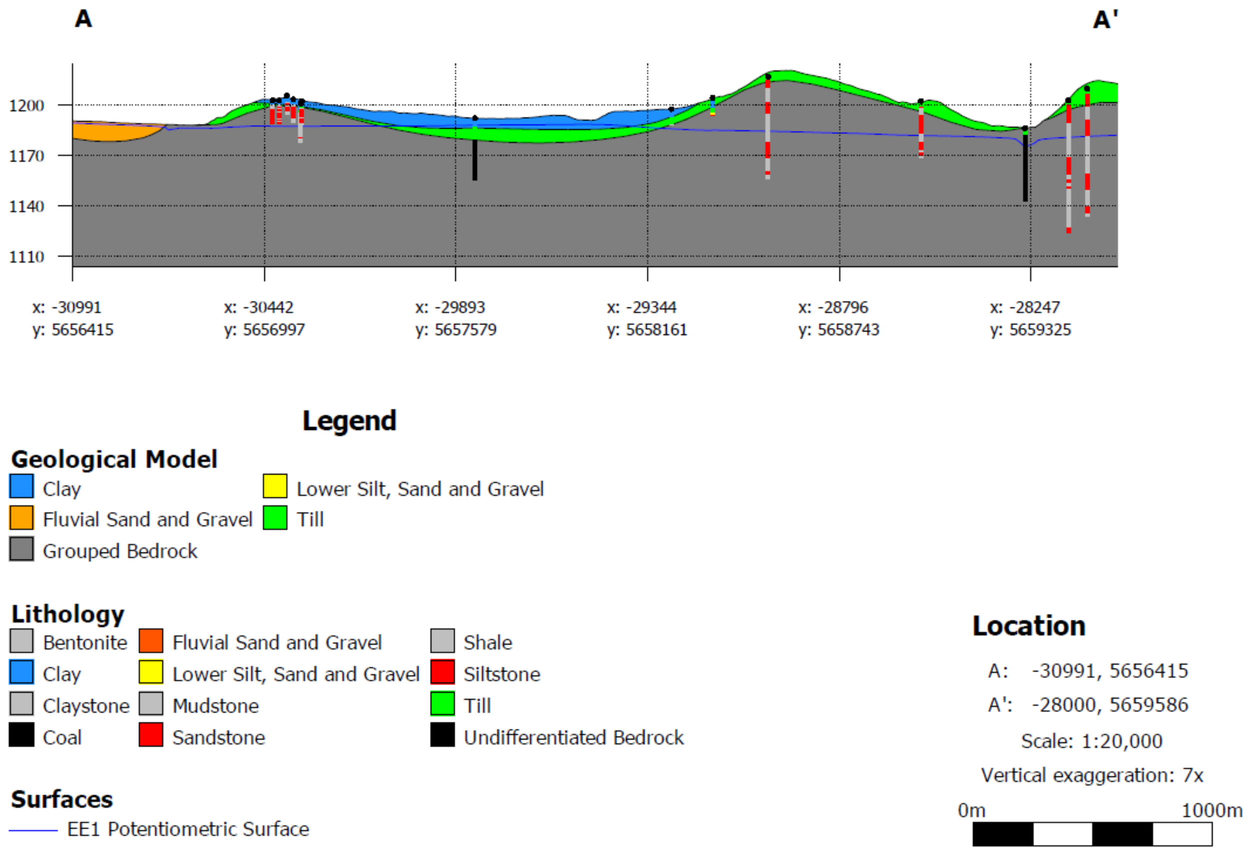


Figure 5-4 Hydrogeologic Cross Section Through Dam Area (EE1)

Figure 5-5 presents hydrogeologic cross section C-C', which was exported from the 3D CSM along a line that cuts through the (proposed) dam structure (not present in this simulation) and extends southeast across the Elbow River valley as is depicted on Figure 5-2. Groundwater levels are represented at the simulated 655-hour time step.

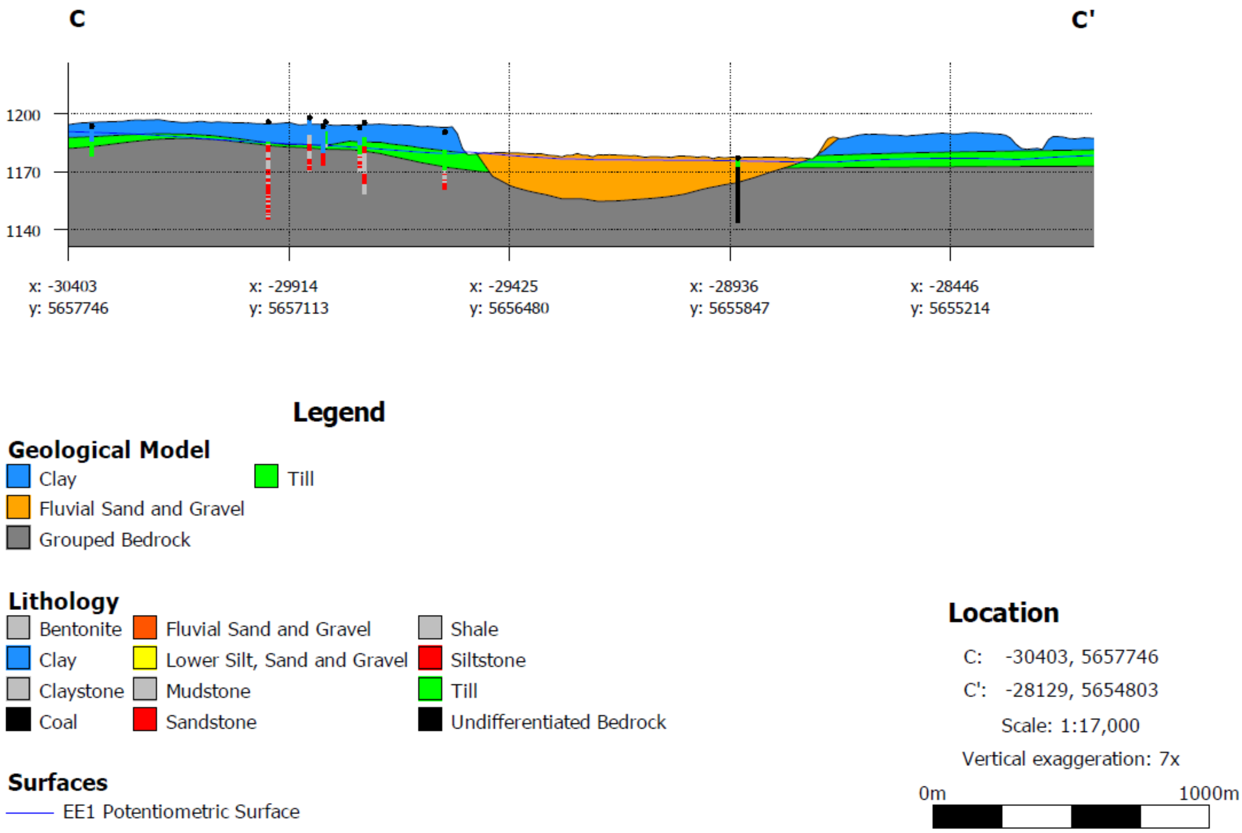


Figure 5-5 Hydrogeologic Cross Section Through Elbow River Valley (EE1)

Figure 5-6 presents hydrogeologic cross section B-B' across the (proposed) diversion channel (which is not present in this simulation) near the inlet structure. The groundwater table is topographically controlled and the potentiometric head distribution tends to drive groundwater from upland areas toward the Elbow River valley (in this area of the PDA).

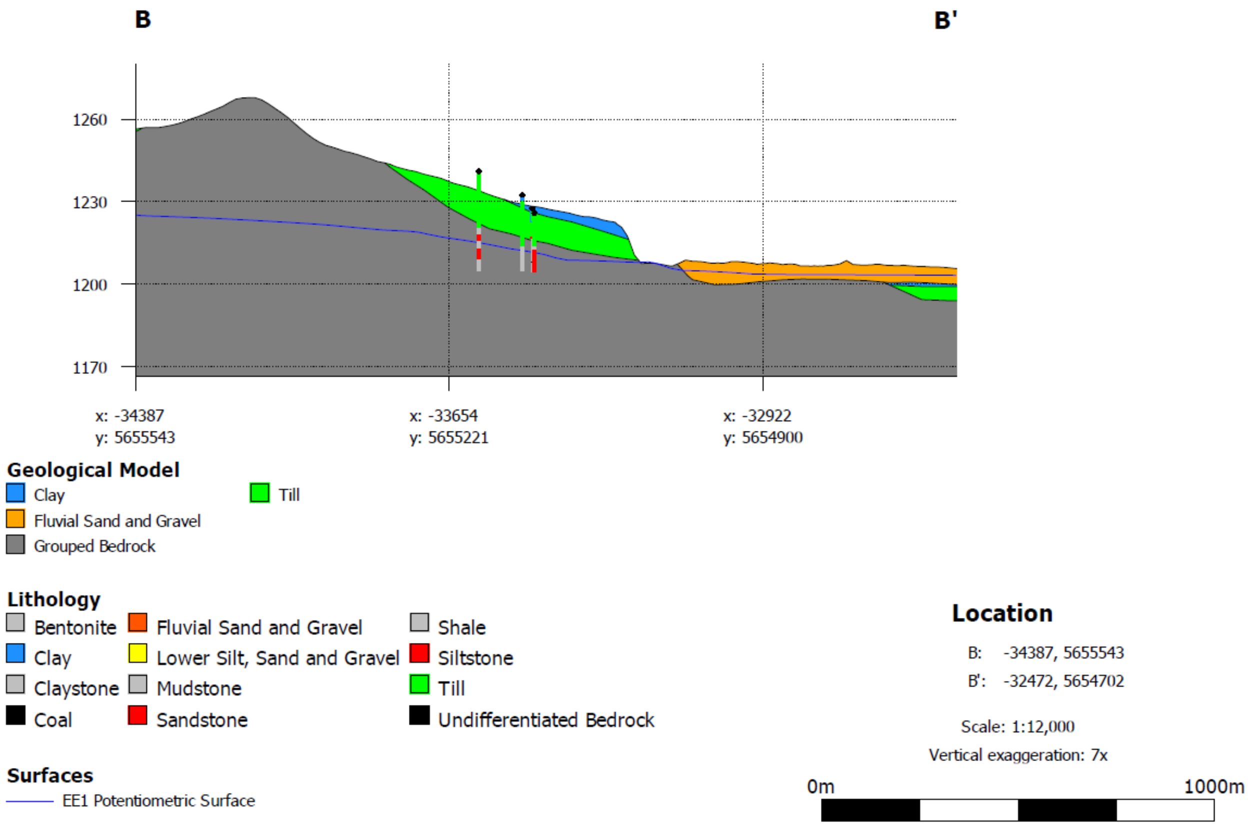


Figure 5-6 Hydrogeologic Cross Section Through Diversion Channel (EE1)

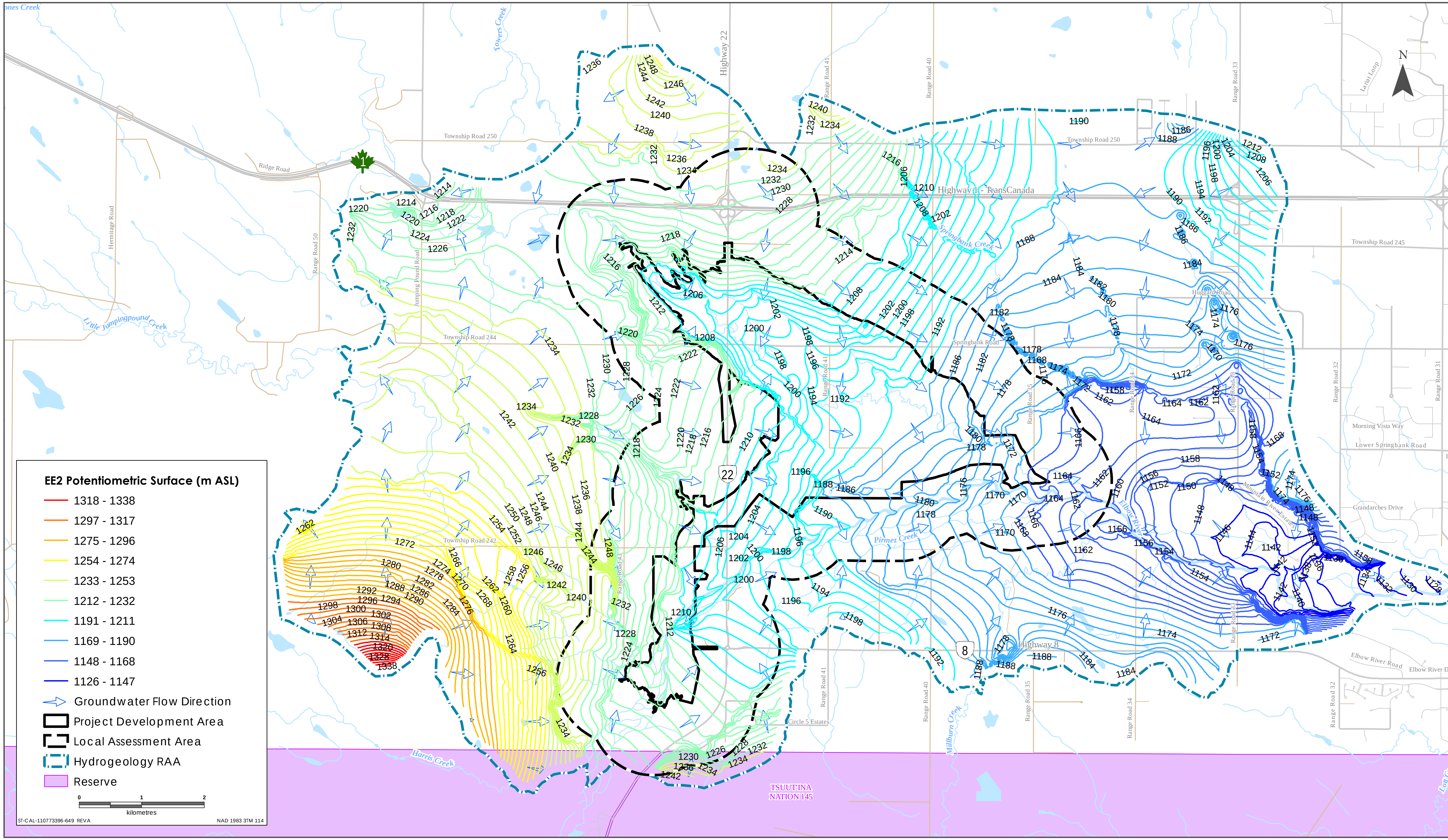
1:100 Year Flood – EE2 Simulation Results

The numerical groundwater model simulation was started at an arbitrary point in time prior to arrival of the 1:100 year flood. Simulated results for a particular point in time are then referenced relative to the start of the simulation. The time lapse of the flood event and operation of the diversion is consistent with the timing used in the hydrodynamic model and engineering design process.

Figure 5-7 presents the simulated potentiometric head distribution of the water table across the RAA under existing conditions (without the addition of the Project components) at the peak reservoir level during the 1:100 year flood. The results presented in Figure 5-7 occur at the point in time when the reservoir water levels are at their maximum (at the 378-hour simulated time step), though the reservoir does not exist in this simulation. Reference to this point in time, while not directly pertinent for this simulation, is provided since it is the same point in time at which results from the PP2 simulation (which does include the Project components) will later be presented. The 378-hour timestep is the point in time at which flows within the diversion channel would have ceased; flows within the Elbow River would have dropped below the 160 m^3/s and flow diversion would have stopped (and thus reservoir levels would no longer be rising).

The potentiometric head distribution presented in Figure 5-7 suggests that shallow groundwater flow patterns are similar to the simulated results for the design flood scenario (Figure 5-3). Groundwater elevations range from approximately 1,338 m ASL in the southwest regions of the RAA to approximately 1,126 m ASL in eastern regions of the RAA in the Elbow River valley. This range of potentiometric heads is essentially the same as was the case for the design flood scenario, though at a local scale some differences in groundwater flow patterns are noted.

Regionally, groundwater flow directions are generally from upland areas along topographic ridges, toward lowland areas near creeks, wetlands, and the Elbow River valley. Local scale flow patterns are variable but shallow groundwater flow towards local drainage features (i.e., creeks, wetlands) is commonly observed across the RAA. As was the case for the design flood scenario, the Elbow River valley is a hydraulic divide for shallow groundwater, with flow directions on either side of the valley directed inward towards it.



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

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Potentiometric Head Distribution 1:100 Flood at Peak Level – Existing Conditions

Figure 5-7

Figure 5-8 presents the hydrogeologic cross section A-A', which was exported from the 3D CSM and is cut through the dam area (though not present in this simulation) as depicted in Figure 5-2. The water table surface presented in this figure was based upon the EE2 simulation at the 378-hour timestep. The water table surface presented in this cross section is similar to that presented for the design flood (Figure 5-4).

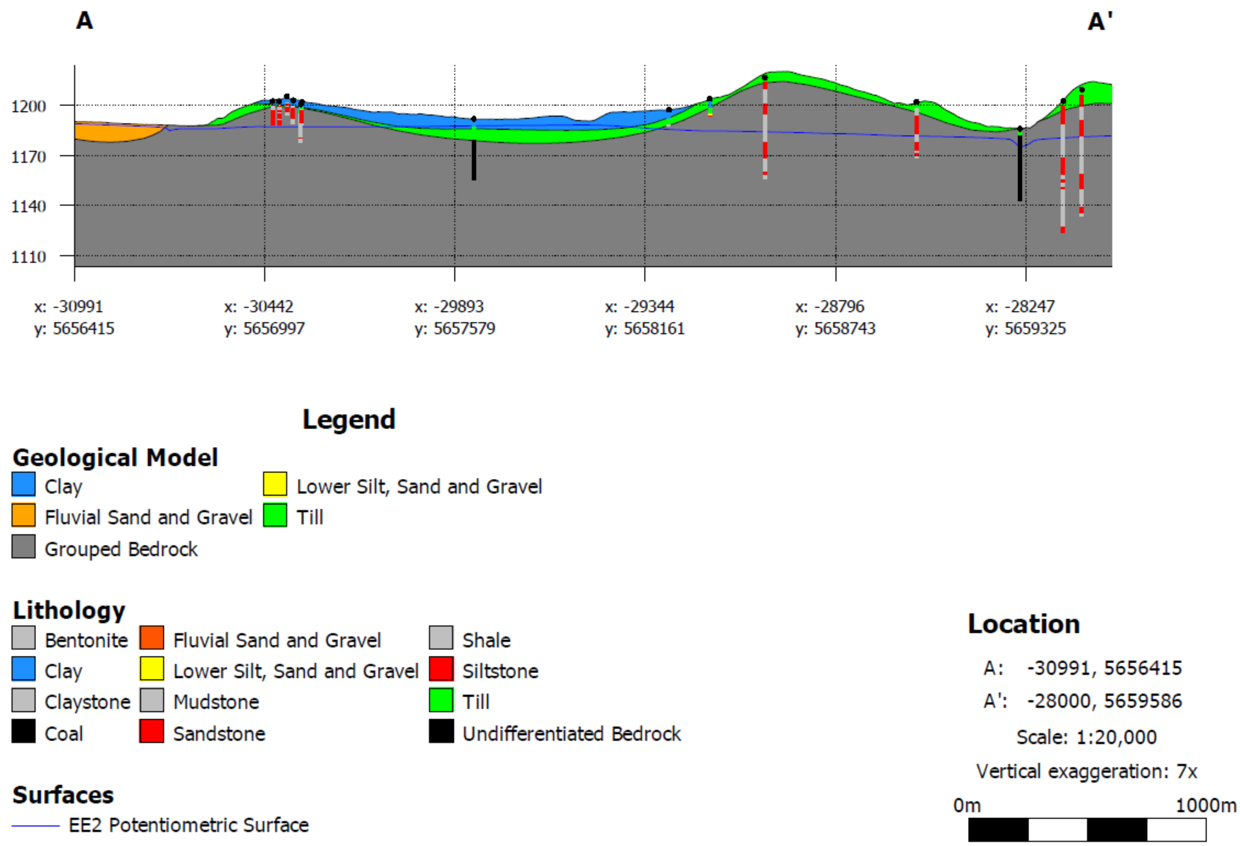


Figure 5-8 Hydrogeologic Cross Section Through Dam Area (EE2)

Figure 5-9 presents the hydrogeologic cross section C-C', which cuts through the proposed dam structure area (not present in this simulation) and extends southeast across the Elbow River valley, as is depicted in Figure 5-2. The water table surface presented is taken from the 378-hour timestep of the simulation. The groundwater table presented in this figure is similar to the design flood.

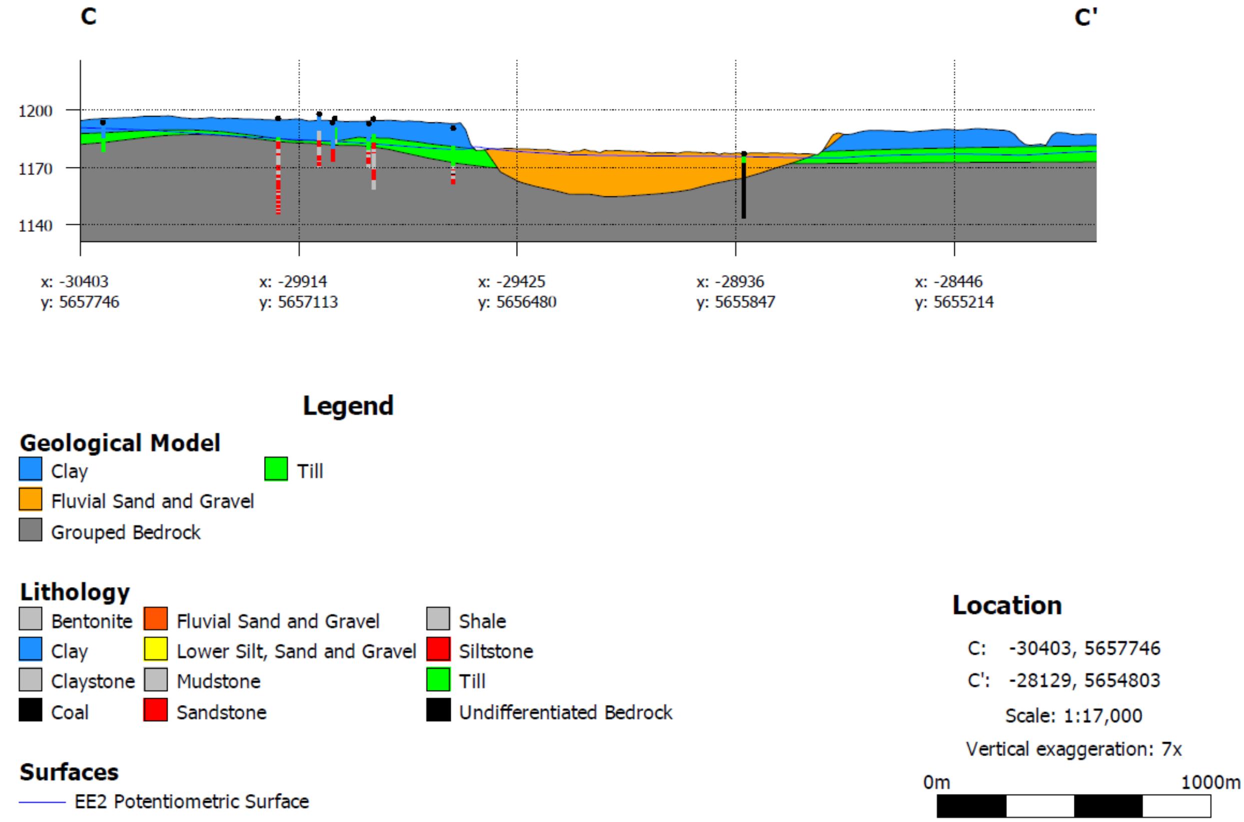


Figure 5-9 Hydrogeologic Cross Section Through Elbow River Valley (EE2)

Figure 5-10 presents the hydrogeologic cross section B-B’, which cuts across the diversion channel (which is not present in this existing conditions simulation) near the inlet structure, as is depicted in Figure 5-2. Similar to the design flood, the simulated water table surface suggests topographically driven groundwater flow from upland areas toward the Elbow River valley.

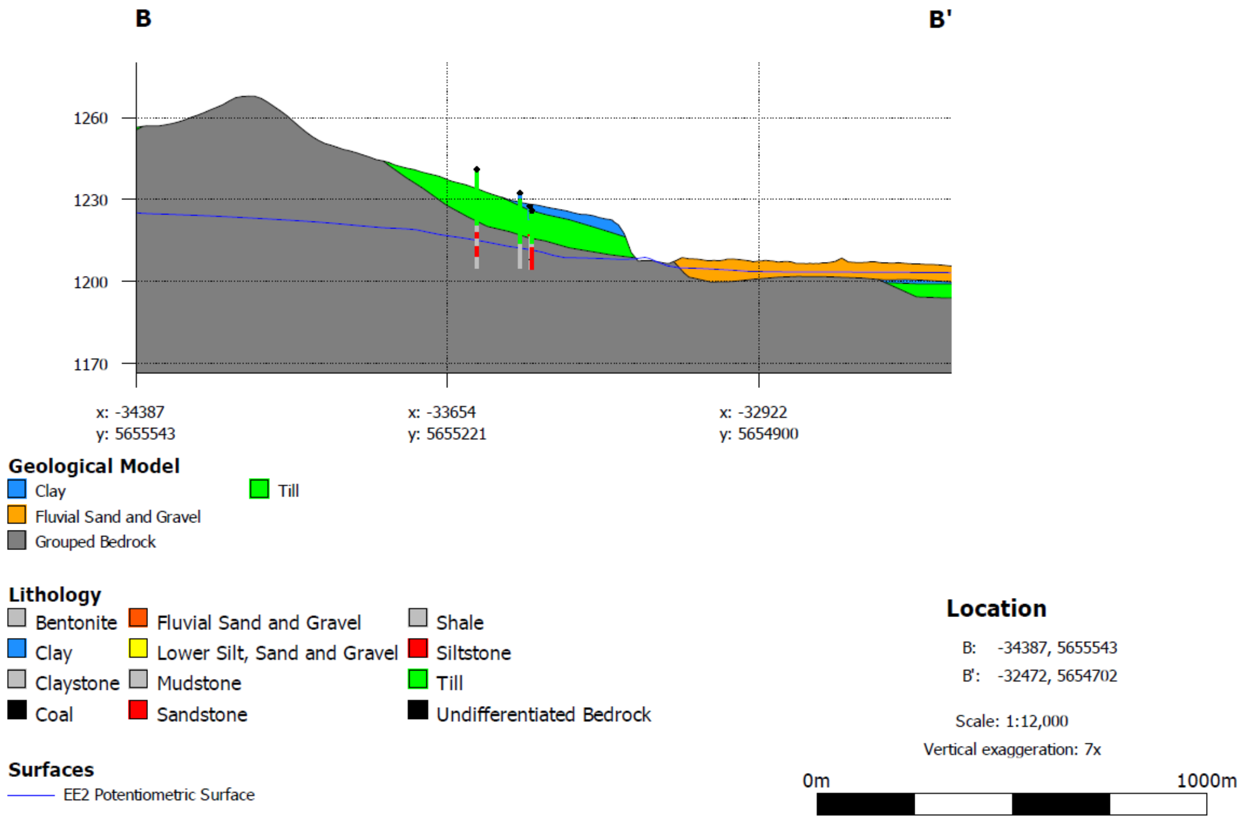


Figure 5-10 Hydrogeologic Cross Section Through Diversion Channel (EE2)

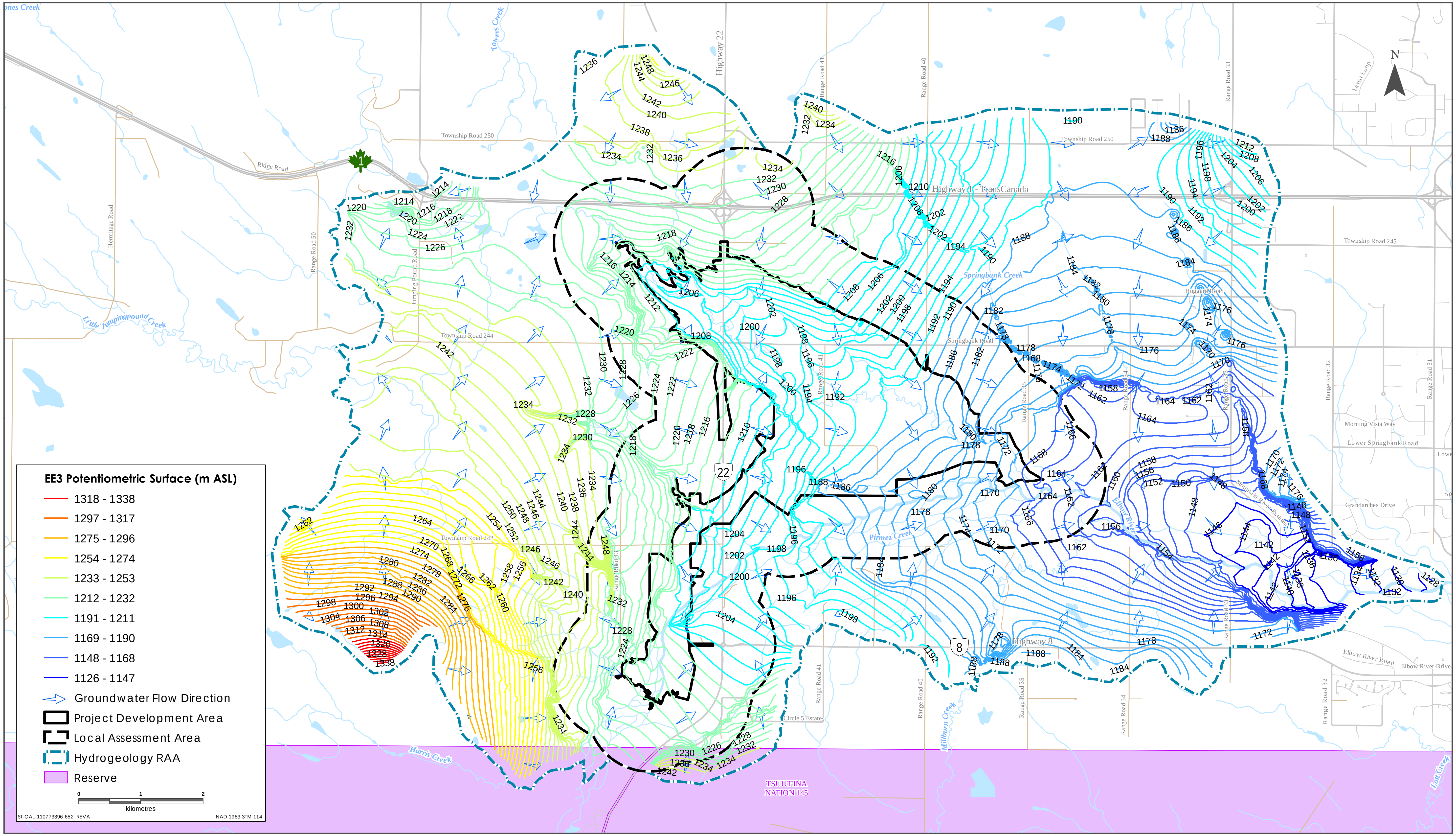
1:10 Year Flood – EE3 Simulation Results

The numerical groundwater model simulation was started at an arbitrary point in time prior to arrival of the 1:10 year flood event. Simulated results for a particular point in time are then referenced relative to the start of the simulation. The time lapse of the flood event and operation of the diversion is consistent with the timing used in the hydrodynamic model and engineering design process.

Figure 5-11 presents the simulated potentiometric head distribution of the water table across the RAA under existing conditions (without the addition of the Project components) at the peak reservoir level during the 1:10 year flood. The results presented in Figure 5-11 occur at the point in time when the reservoir water levels would be at their maximum (at the 530-hour simulated time step), though the reservoir does not exist in this simulation. Reference to this point in time, while not directly pertinent for this simulation, is provided since it is the same point in time at which results from the PP3 simulation (which does include the Project components) will be later presented. The 530-hour timestep is the simulated point in time at which flows within the diversion channel would have ceased, since flows within the Elbow River have dropped below the 160 m^3/s and flow diversion would have stopped (and thus reservoir levels are no longer rising).

The potentiometric head distribution presented in Figure 5-11 suggests that shallow groundwater flow patterns are similar to the simulated results for the design flood (Figure 5-3). Groundwater elevations range from approximately 1,338 m ASL in the southwest regions of the RAA to approximately 1,126 m ASL in eastern regions of the RAA in the Elbow River valley. This range of potentiometric heads is essentially the same as was the case for the design flood, though at a local scale some differences in groundwater flow patterns are noted.

Regionally, groundwater flow directions are generally from upland areas along topographic ridges, toward lowland areas near creeks, wetlands, and the Elbow River valley. Local scale flow patterns are variable but shallow groundwater flow towards local drainage features (i.e., creeks, wetlands) is commonly observed across the RAA. The Elbow River Valley is a hydraulic divide for shallow groundwater, with flow directions on either side of the valley directed inward towards it.



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

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Potentiometric Head Distribution 1:10 Flood at Peak Level – Existing Conditions

Figure 5-11

Figure 5-12 presents the hydrogeologic cross section A-A', which was exported from the 3D CSM and is cut through the dam area (though not present in this simulation) as depicted in Figure 5-2. The water table surface presented in this figure is based upon the EE3 simulation at the 530-hour timestep. The water table surface presented in this cross section is similar to the design flood (Figure 5-4).

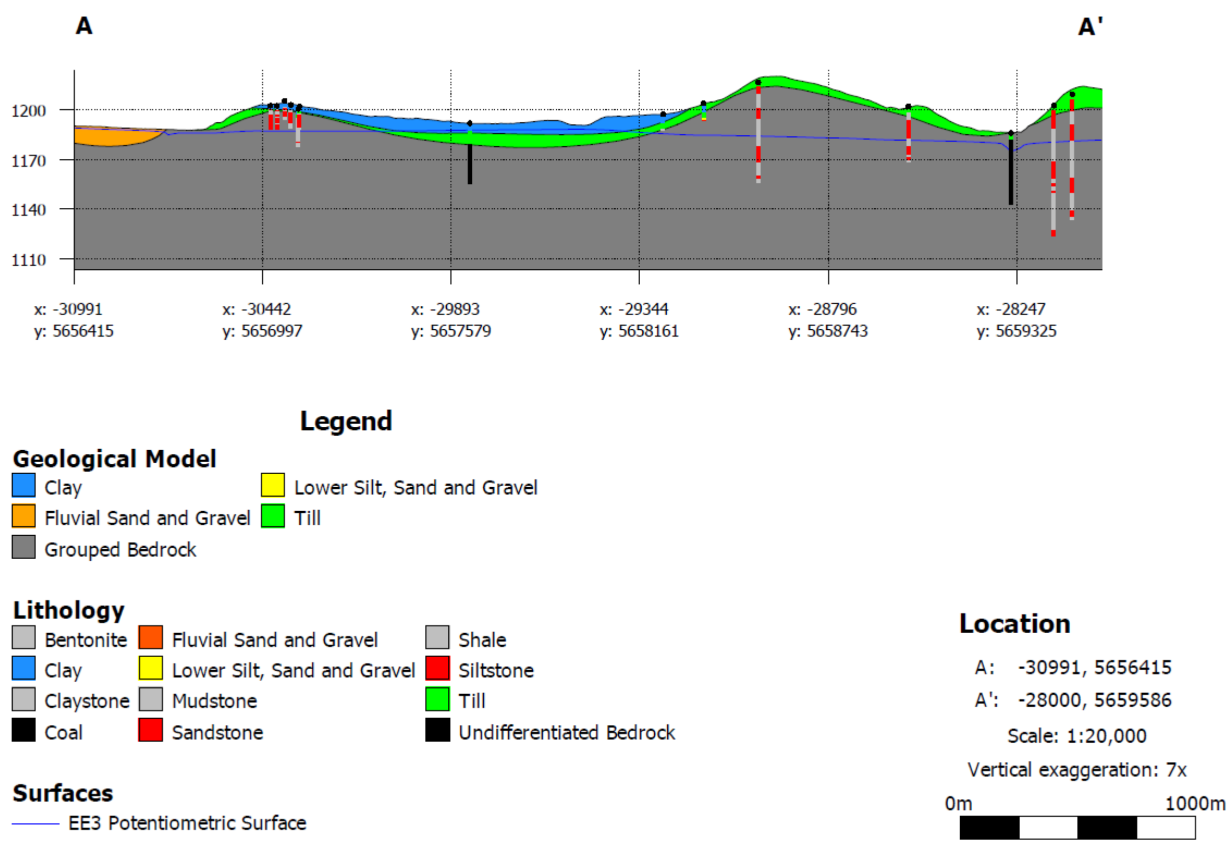


Figure 5-12 Hydrogeologic Cross Section Through Dam Area (EE3)

Figure 5-13 presents the hydrogeologic cross section C-C', which cuts through the proposed dam structure area (not present in this simulation) and extends southeast across the Elbow River valley, as is depicted in Figure 5-2. The water table surface presented is taken from the 530-hour timestep of the simulation. The groundwater table presented in this figure is similar to the design flood and 1:100 year flood; this suggests that flood-related effects on the groundwater table are similar when comparing all three floods.

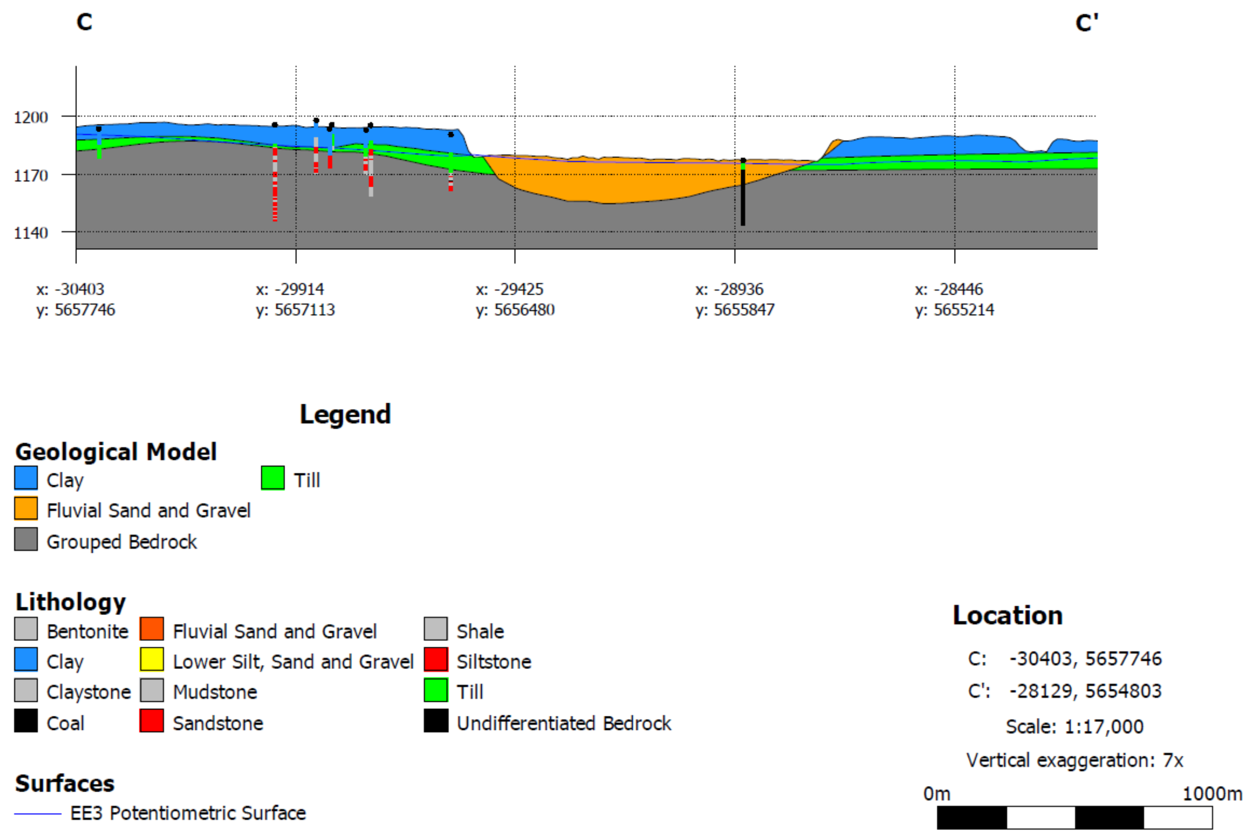


Figure 5-13 Hydrogeologic Cross Section Through Elbow River Valley (EE3)

Figure 5-14 presents the hydrogeologic cross section B-B', which cuts across the diversion channel (which is not present in this existing conditions simulation) near the inlet structure, as is depicted in Figure 5-2. The simulated water table surface suggests topographically driven groundwater flow from upland areas toward the Elbow River valley.

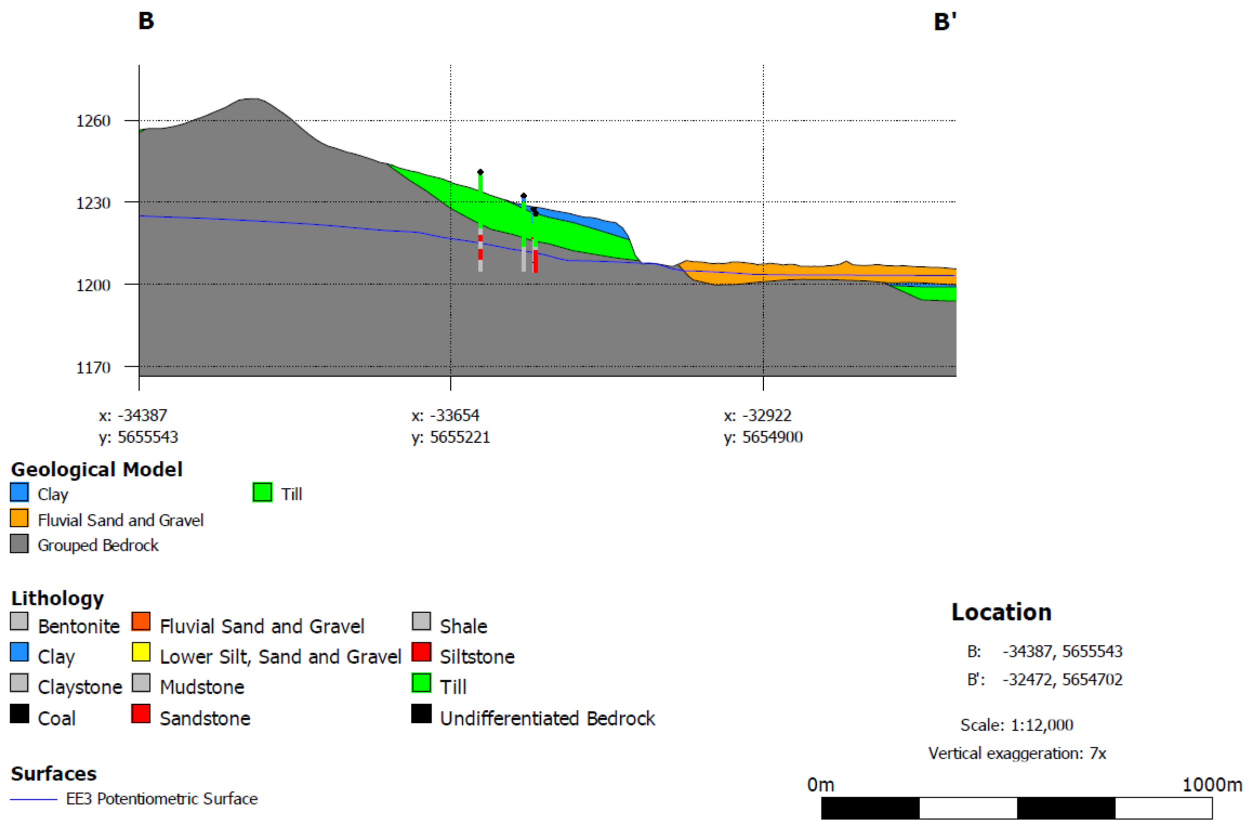


Figure 5-14 Hydrogeologic Cross Section Through Diversion Channel (EE3)

Comparison of Existing Conditions (EE1 – EE3)

When comparing the potentiometric surfaces for the three floods (under existing conditions: EE1, EE2, and EE3), at the regional scale of the model, floods within the Elbow River valley have limited effect on the regional groundwater flow regime, even though there are some local scale changes in flow patterns between the floods, particularly in areas underlain by fluvial sand and gravel deposits (which are limited in distribution to within the Elbow River valley). This is likely due to the degree of topographic relief present across the RAA, which is of much greater magnitude than the relatively small changes in head caused by rising levels in the Elbow River during a flood.

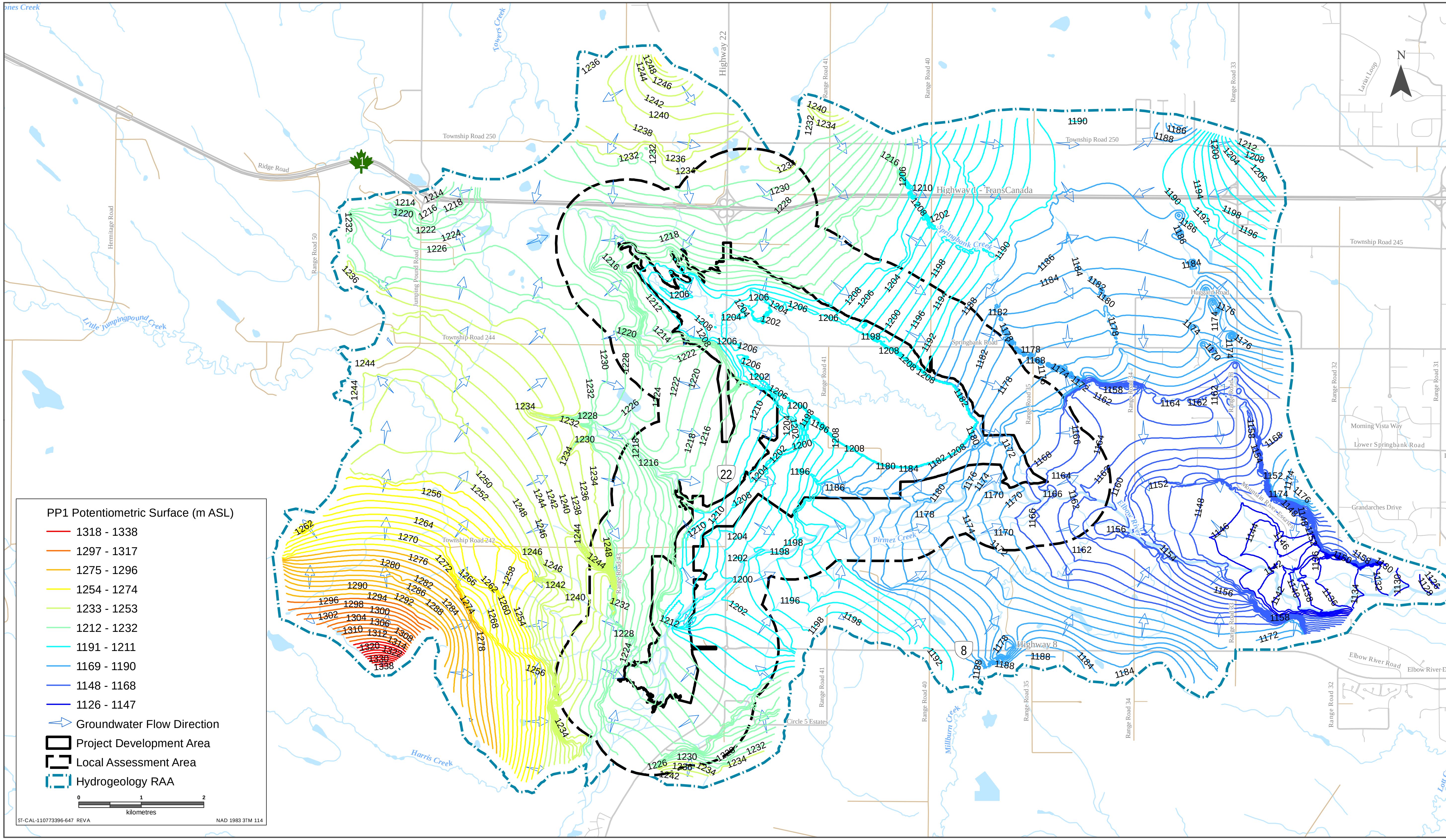
5.2.1.4 Simulation of Post Project Hydrogeologic Conditions (Design Flood (PP1)-Series Runs)

In order to simulate hydrogeologic conditions during Project operations, several modifications to the FEFLOW model (relative to the existing conditions represented by EE-series runs) were implemented to represent major project features. For some areas in the PDA, the topographic surface within the model was reduced in elevation, based on the engineering designs, to represent incision of the diversion channel into the subsurface along its alignment from the diversion inlet structure to the off-stream reservoir. For other areas in the PDA, the topographic surface within the model was increased in elevations to represent construction of the dam and floodplain berm, based on the engineering designs.

Additional boundary conditions were also added within the FEFLOW model in areas that would become wetted during operation of the Project. Such areas include the diversion channel and the footprint of the off-stream reservoir. Head conditions over time within these features were based upon hydrographs extracted from the hydrodynamic model.

Design Flood – PP1 Simulation Results

Figure 5-15 presents the simulated potentiometric head distribution of the water table across the RAA at the point in time when the off-stream reservoir has just been filled to its maximum design level (at the 655-hour simulated time step). At this point in simulation time, potentiometric heads within the off-stream reservoir are at their maximum and potential changes in groundwater levels and patterns within the RAA that arise from flood operations can be evaluated.



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

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Potentiometric Head Distribution Design Flood at Peak Level – Post Project Conditions

Figure 5-15

From Figure 5-15, during the peak levels of the design flood, flow patterns immediately adjacent to the off-stream reservoir, particularly on its southeast perimeter, show a more radially outward flow pattern, as is expected due to mounding of the water table caused by increased head. In northwestern areas of the off-stream reservoir, flow patterns appear similar to the existing conditions simulation (EE1). This is because the off-stream reservoir, even when full, remains as the local low point and groundwater flow patterns continue to converge towards it. Groundwater flow patterns immediately adjacent to the diversion channel are directed inward toward the channel (relative to EE1), indicating potential groundwater discharge into the diversion channel even during flood operations.

Figure 5-16 presents the hydrogeologic cross section A-A’, that was exported from the 3D CSM. This cross section includes the subsurface hydrostratigraphic units underlying the dam area and the modelled water table surface for the PP1 simulation at the approximate moment when the off-stream reservoir is filled (655-hour timestep). The water table surface is elevated above ground level due to the additional head imparted by surface water stored in the off-stream reservoir. Potentiometric heads decline steeply back toward existing levels in areas just outside the PDA.

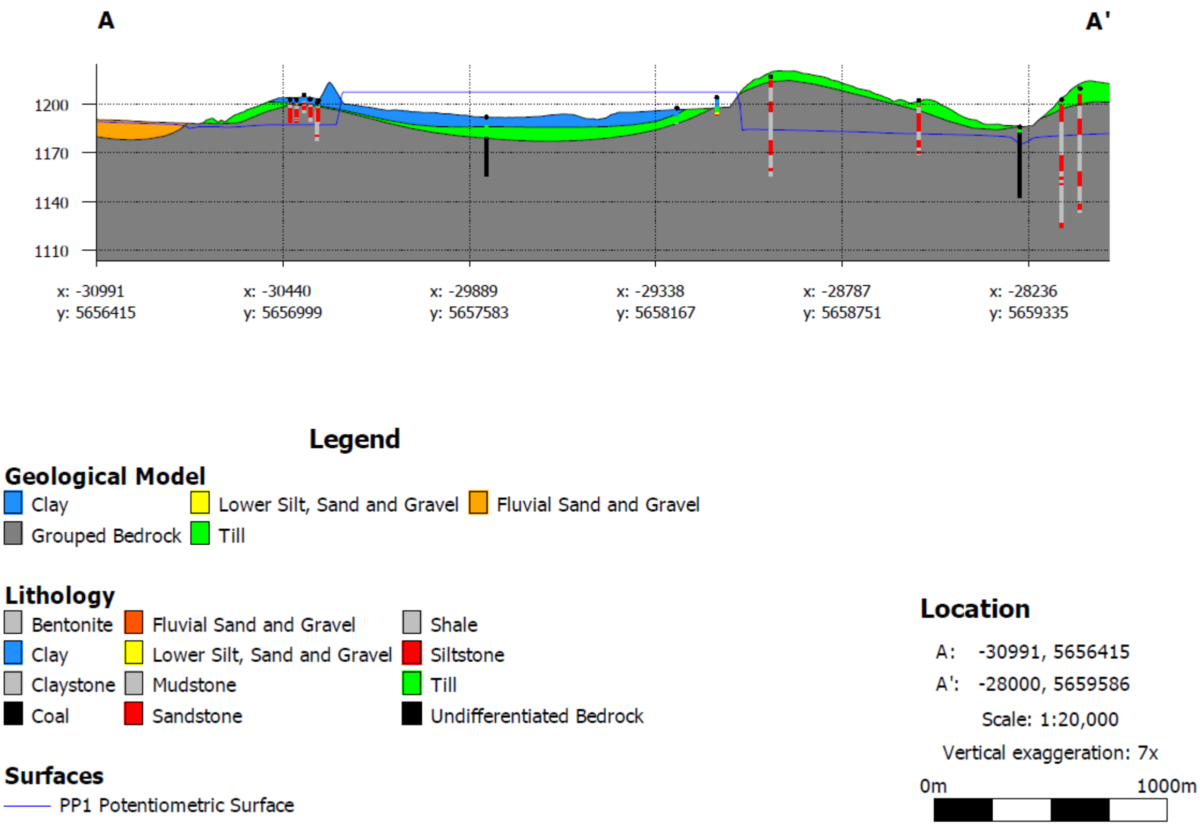

Figure 5-16 Hydrogeologic Cross Section Through Dam Area (PP1)

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Figure 5-17 presents the hydrogeologic cross section C-C' that was exported from the 3D CSM, as is depicted in Figure 5-2. This cross section is cut through the dam area and extends southeast through the Elbow River valley. The dam structure is now visible in the cross section as it has been added as a feature on the topographic surface of the numerical model and 3D CSM. A steep decline in the water table elevations is observed just outside of the dam structure and PDA, returning to existing levels near the alluvium in the Elbow River.

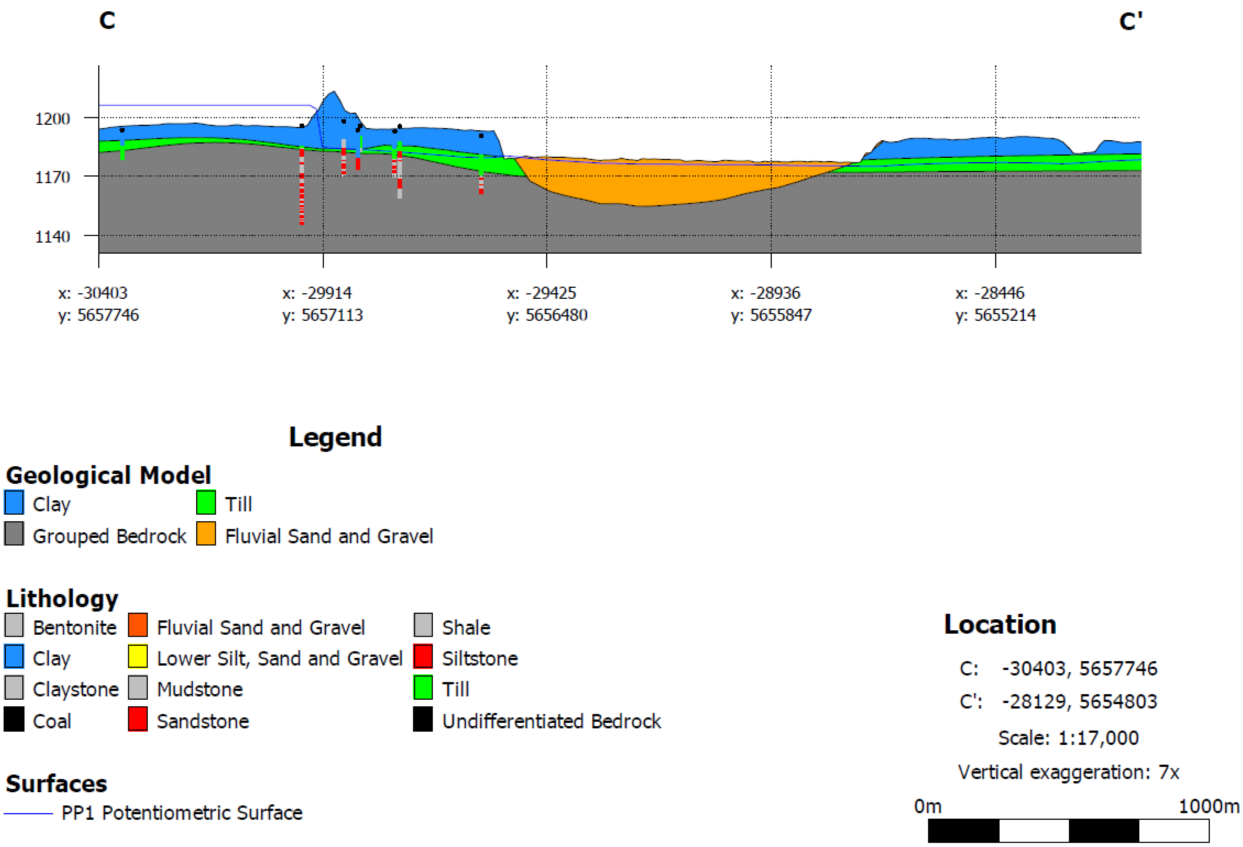


Figure 5-17 Hydrogeologic Cross Section Through Elbow River Valley (PP1)

Figure 5-18 presents the hydrogeologic cross section B-B’, which cuts across the diversion channel (which is now visible incising through the original ground surface) near the inlet structure. The water table surface is depressed in the area near the diversion channel (relative to the EE1 simulation) due to its incision through the natural topography. Although at this point in the PP1 simulation, there is surface water within the diversion channel, the elevation of the surface water remains below the groundwater surface in the EE1 simulation and groundwater flow patterns in these areas are anticipated to be toward the diversion channel (i.e., groundwater discharges into the diversion channel).

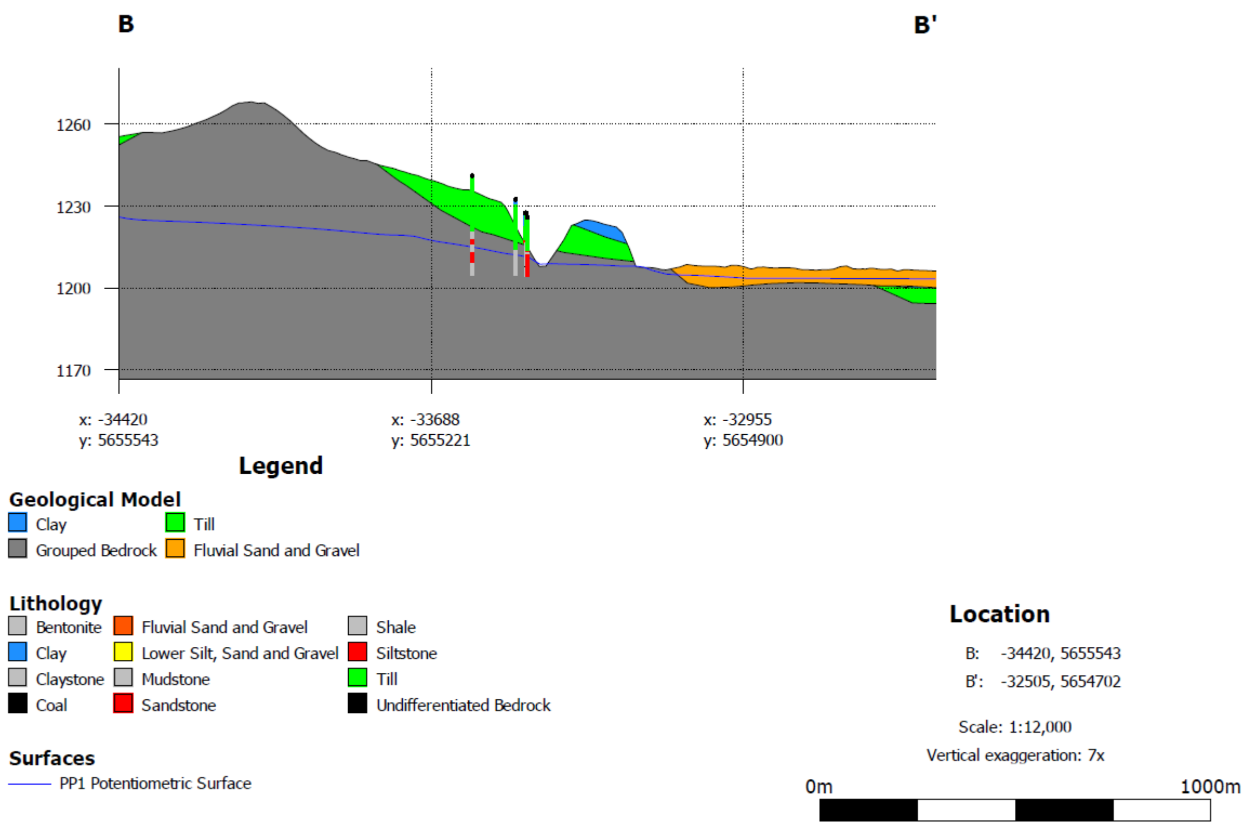
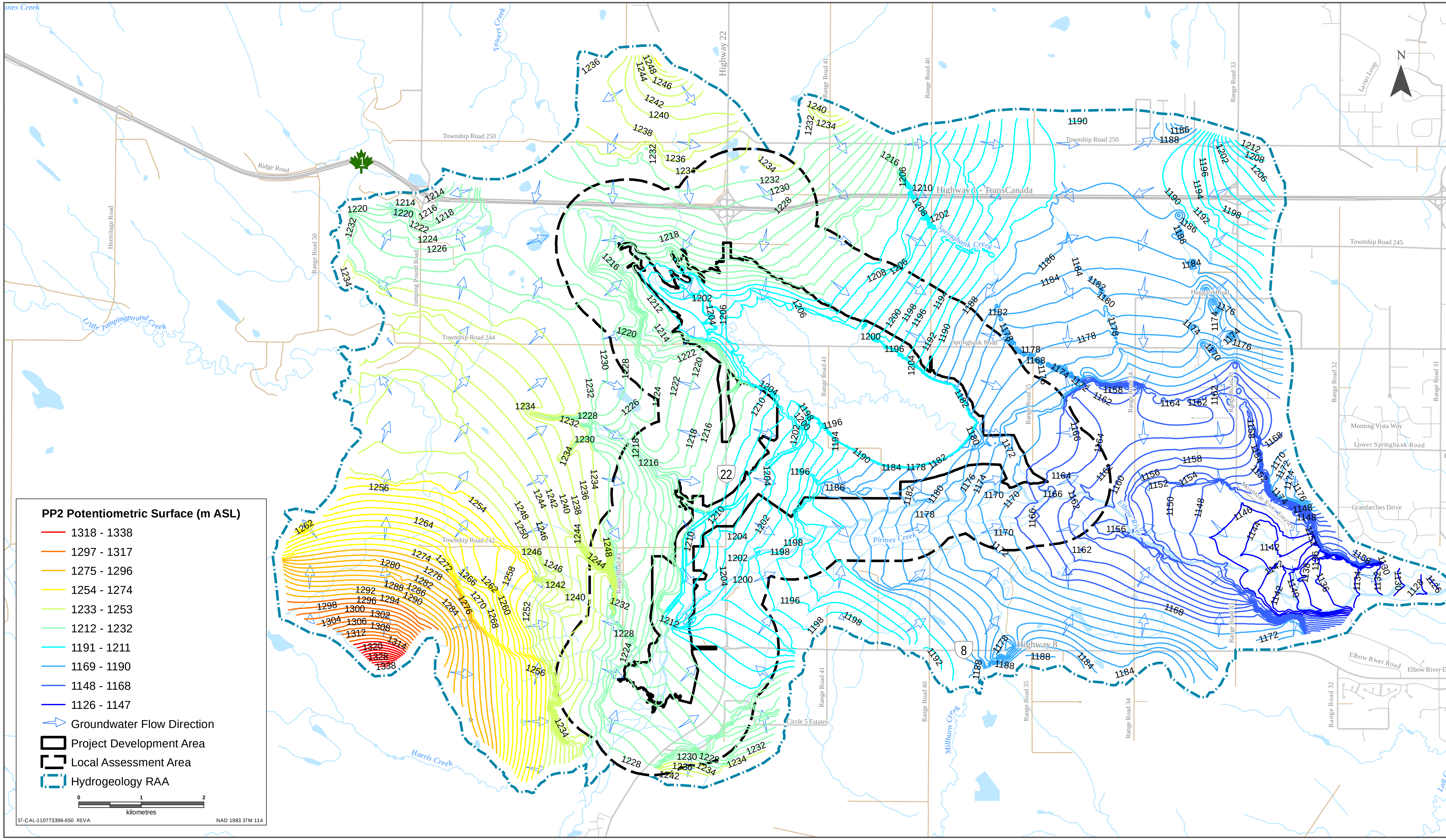


Figure 5-18 Hydrogeologic Cross Section Through Diversion Channel (PP1)

1:100 Year Flood – PP2 Simulation Results

Figure 5-19 presents the simulated potentiometric head distribution of the water table across the RAA at the simulated point in time (the 378-hour timestep) when water levels within the off-stream storage reservoir are at their maximum for the 1:100 year flood. From Figure 5-19, groundwater flow patterns in southwestern regions of the off-stream storage reservoir are radially outward from the reservoir, as is expected due to the mounding effect of the increased heads in the reservoir. Groundwater flow patterns in northwestern areas of the off-stream reservoir are not markedly changed relative to the EE2 simulation because these areas of the reservoir continue to be the local low point and groundwater continues to converge towards it.

Groundwater flow patterns immediately adjacent to the diversion channel in the southern areas of the channel near the inlet structure are directed inward toward the channel (relative to EE2), indicating potential groundwater discharge into the diversion channel.



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

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Potentiometric Head Distribution 1:100 Flood at Peak Level – Post Project Conditions

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 5-19

Figure 5-20 presents the hydrogeologic cross section A-A', which at the approximate moment when the reservoir water level has reached its maximum for this flood. In general, the modeled water table surface at this cross section location is similar to the design flood. The water table surface is elevated above ground level (albeit at a slightly lower elevation than is the case for the design flood) due to the additional head imparted by the surface water stored in the off-stream reservoir. Potentiometric heads decline steeply toward pre-flood levels in areas just ouside of the PDA.

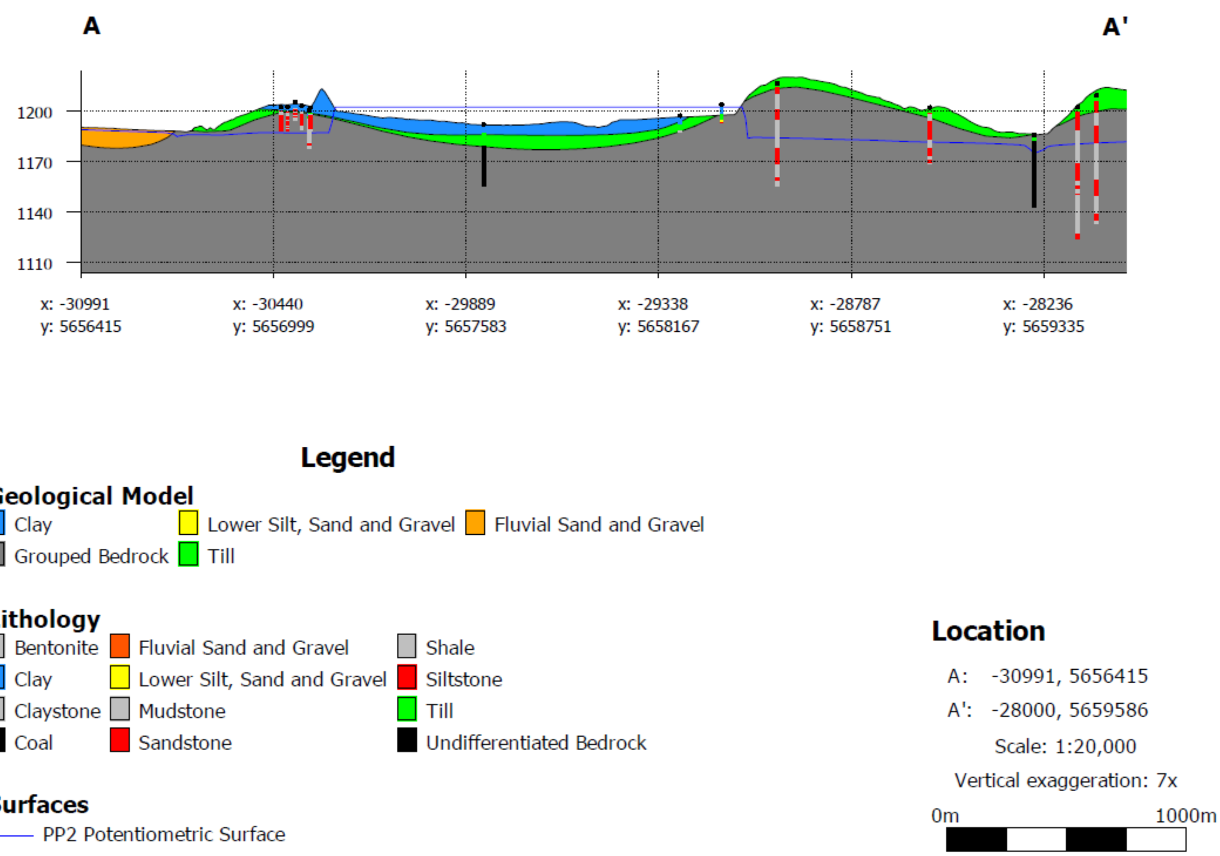


Figure 5-20 Hydrogeologic Cross Section Through Dam Area (PP2)

Figure 5-21 presents the hydrogeologic cross section C-C', which cuts through the dam area and Elbow River valley, as depicted in Figure 5-2. Similar to the PP1 simulation, a steep decline in the water table elevation is noted just outside of the dam structure and PDA, returning to existing levels near the alluvium in Elbow River.

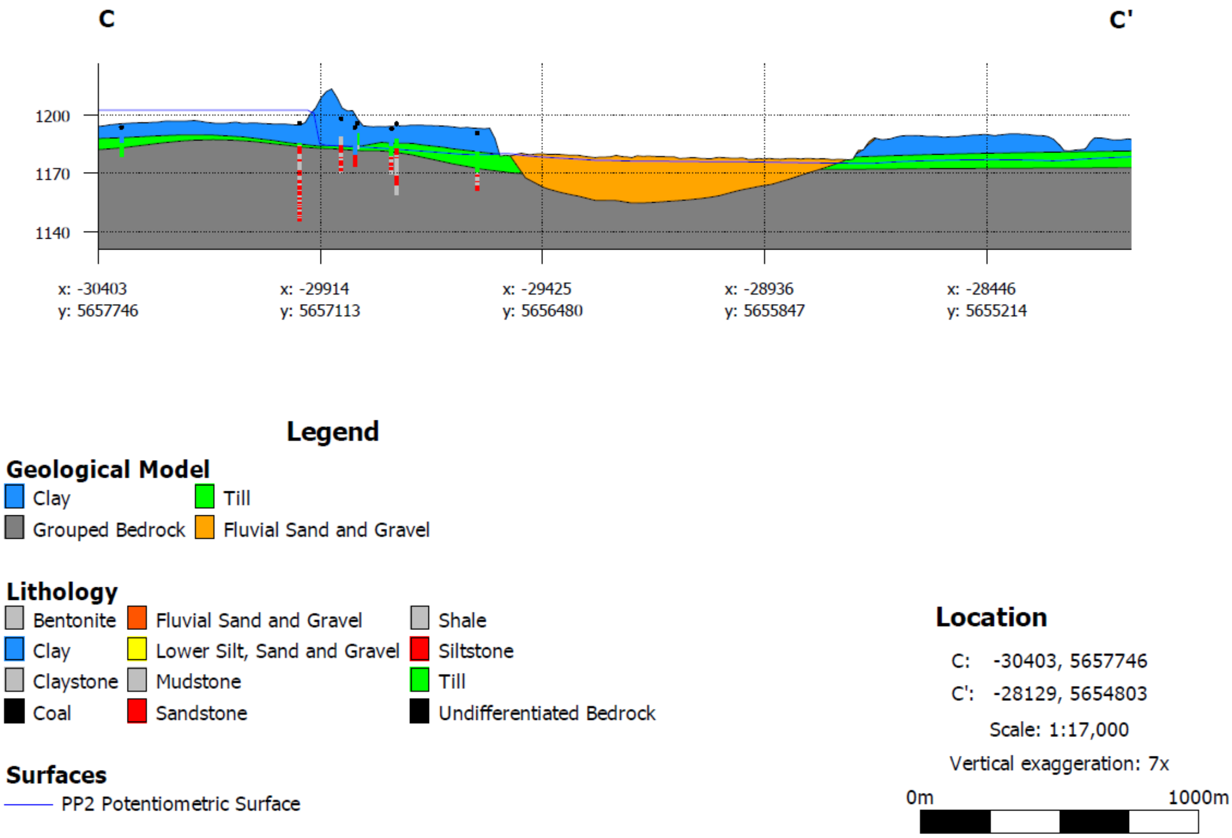


Figure 5-21 Hydrogeologic Cross Section Through Elbow River Valley (PP2)

Figure 5-22 presents the hydrogeologic cross section B-B', which cuts across the diversion channel near the inlet structure. The water table surface is slightly depressed in the area near the diversion channel (relative to the EE2 simulation) due to its incision through the natural topography. Groundwater elevations toward the northwest (left side of this cross section) remain higher than levels at the diversion channel. Even under operating conditions, groundwater is expected to discharge to the diversion channel.

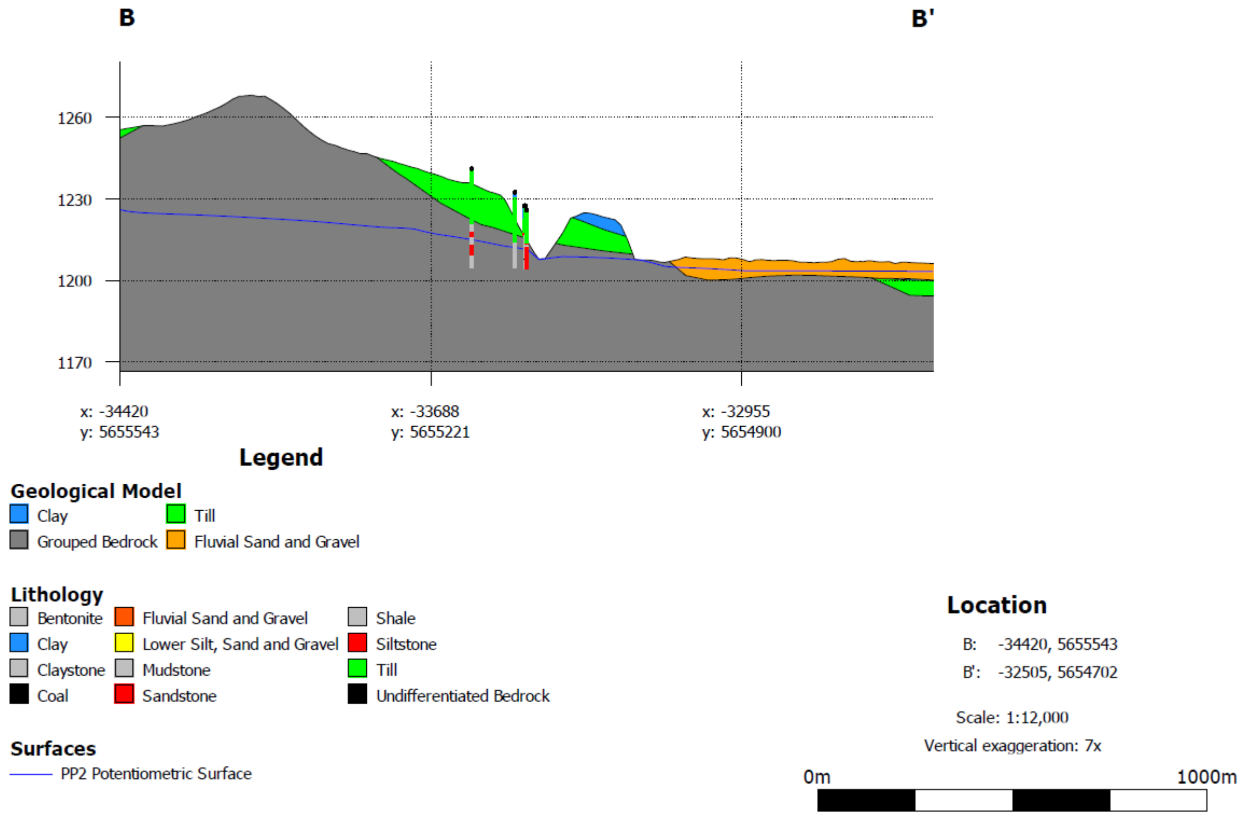
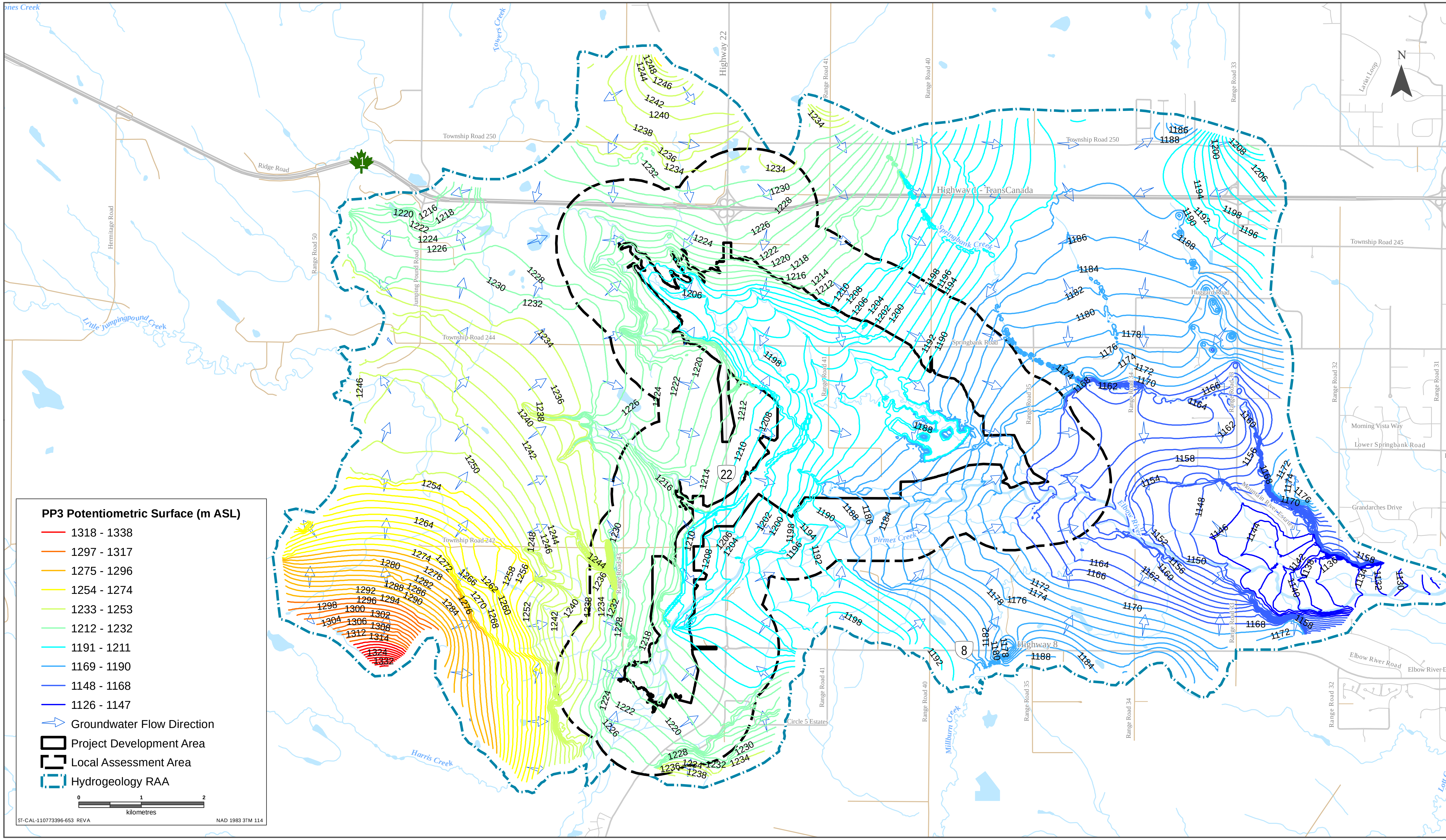


Figure 5-22 Hydrogeologic Cross Section Through Diversion Channel (PP2)

1:10 Year Flood – PP3 Simulation Results

Figure 5-23 presents the simulated potentiometric head distribution of the water table across the RAA at the simulated point in time (the 530-hour timestep) when water levels within the off-stream reservoir are at their maximum for the 1:10 year flood. In general, groundwater levels and flow patterns are similar to the existing conditions simulation for the 1:10 year flood (EE3 simulation). As was the case for the design flood and 1:100 year flood, some changes in groundwater levels and flow directions near the diversion channel and off-stream reservoir are noted, relative to the EE3 simulation. However, in contrast to the PP1 and PP2 simulations, the area over which these changes occur is much smaller because the wetted footprint within the reservoir is also much smaller for this flood.



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

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Potentiometric Head Distribution 1:10 at Peak Level – Post Project Conditions

ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Figure 5-23

Figure 5-24 presents the hydrogeologic cross section A-A', which shows the modeled water table surface at the approximate moment when the reservoir water level has reached its maximum for this flood. In comparison to the PP1 and PP2 simulations, the water table elevation is much lower and is near ground surface across this section. Potentiometric heads decline steeply toward pre-flood levels in areas just outside of the PDA.

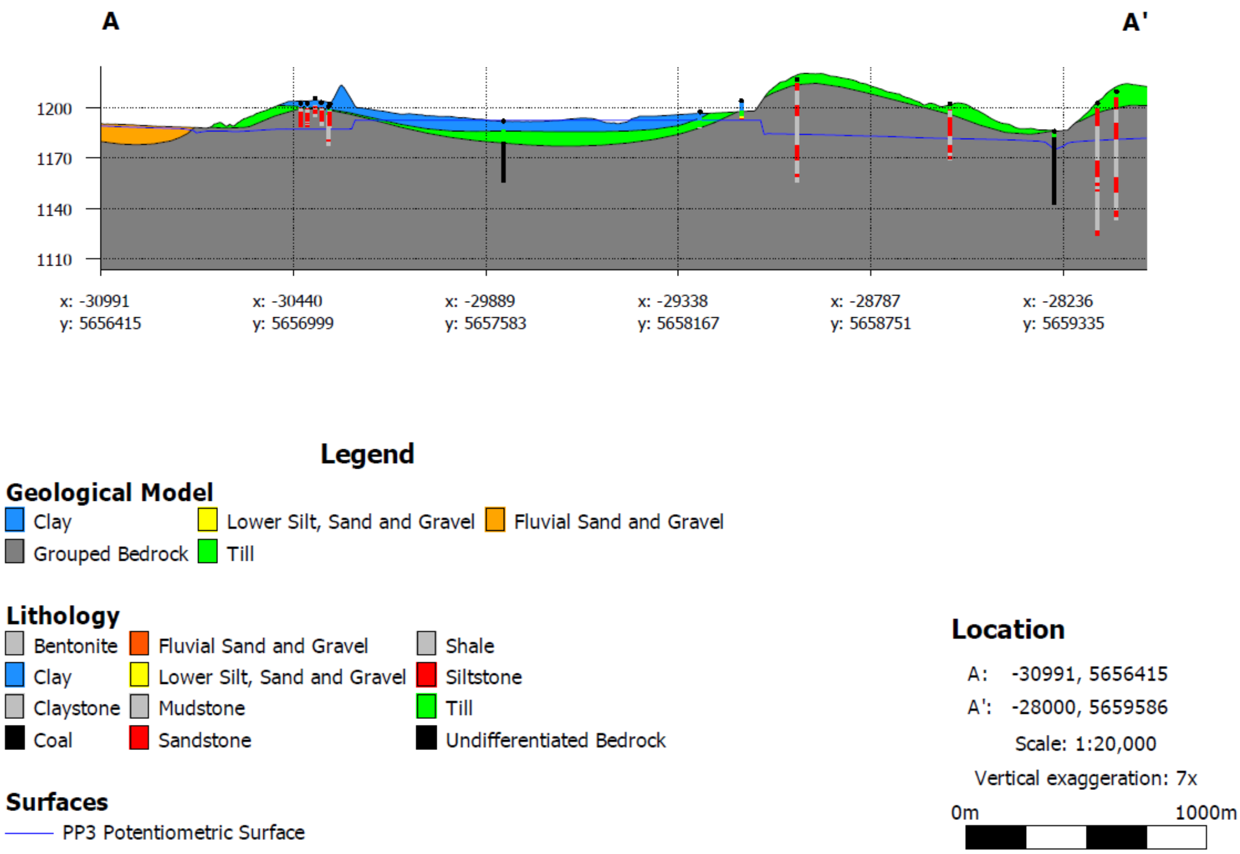


Figure 5-24 Hydrogeologic Cross Section Through Dam Area (PP3)

Figure 5-25 presents the hydrogeologic cross section C-C', which cuts across the dam area toward the Elbow River valley, as is depicted in Figure 5-2. In contrast to the PP1 and PP2 simulations, the simulated water table elevations are below the ground surface in all areas of this cross section. This is because the cross section location is outside the wetted footprint of the reservoir during the 1:10 flood.

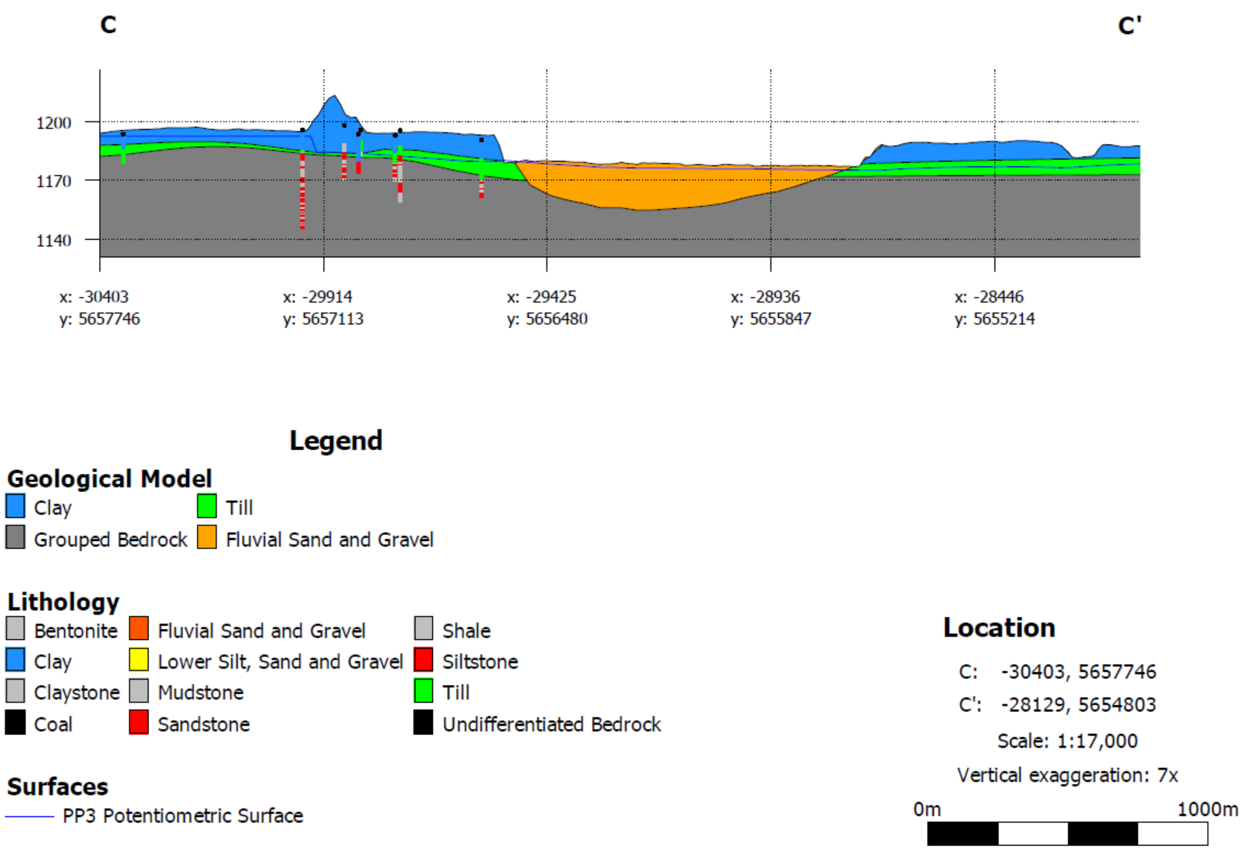


Figure 5-25 Hydrogeologic Cross Section Through Elbow River Valley (PP3)

Figure 5-26 shows the hydrogeologic cross section B-B', which cuts across the diversion channel near the inlet structure. Similar to the PP1 and PP2 simulations, the water table surface is slightly depressed in the area near the diversion channel (relative to the EE3 simulation) due to its incision through the natural topography. Groundwater elevations toward the northwest (left side of this cross section) remain higher than levels at the diversion channel. Even under operating conditions, groundwater is expected to discharge to the diversion channel.

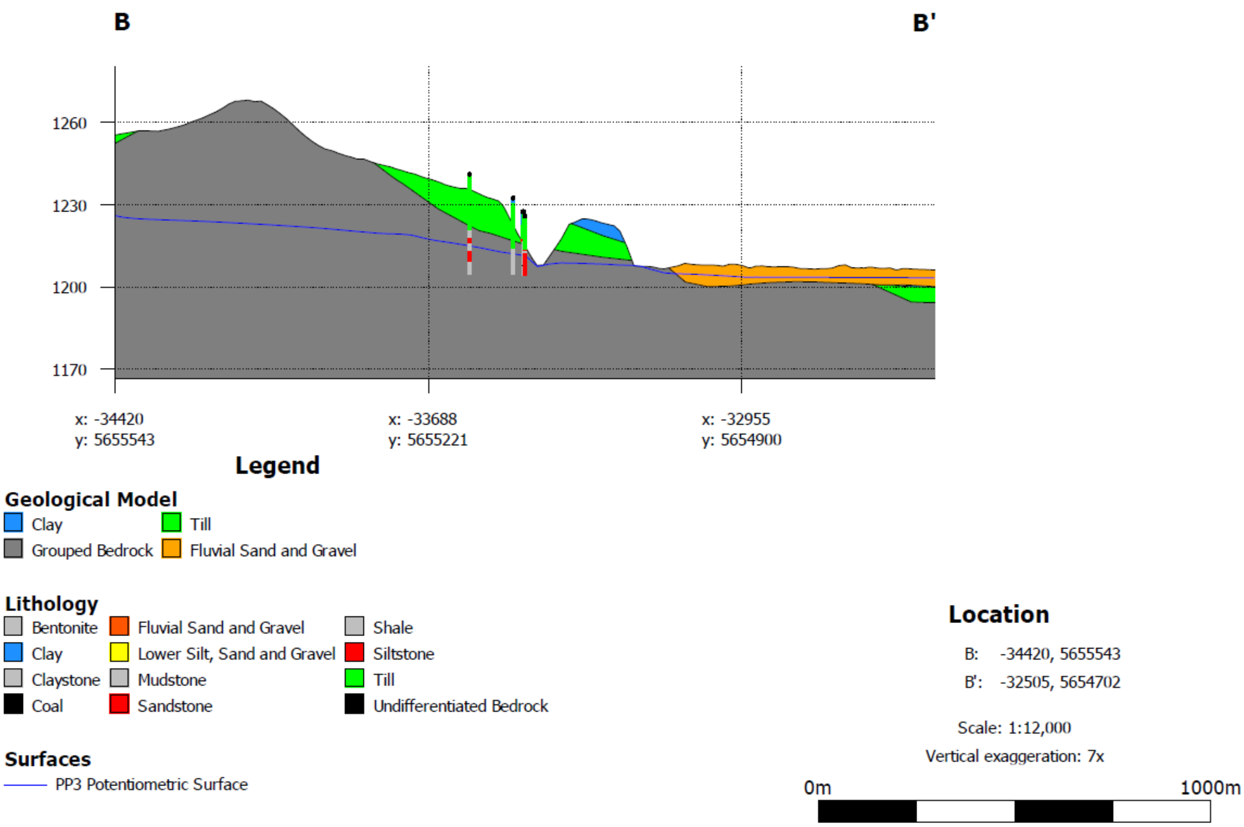


Figure 5-26 Hydrogeologic Cross Section Through Diversion Channel (PP3)

5.2.2 Change in Groundwater Quantity

In order to evaluate potential change in groundwater quantity resulting from the Project, it is necessary to separate groundwater level change that is a response to a particular flood from groundwater level change that is a result of Project construction and operations, so that the incremental effect of the Project can be isolated. This was accomplished by comparing the EE-series run and the PP-series run results for a given flood in order to calculate the net change in groundwater level at a given point that could be attributable to the Project.

5.2.2.1 Project Pathways

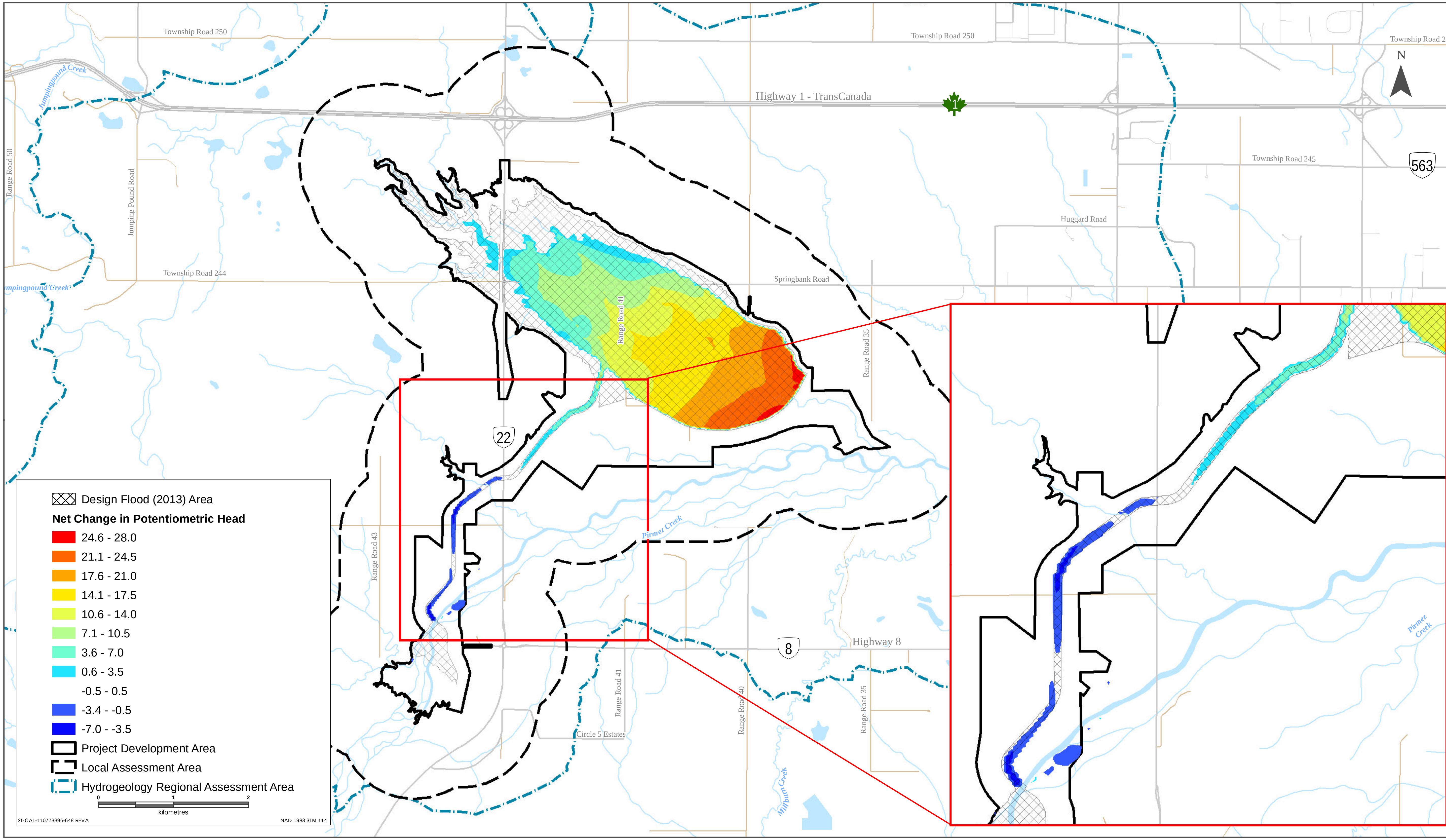
Groundwater levels in the RAA are anticipated to respond to floods in the Elbow River due to their hydraulic connection to surface water and interactions between the hydrologic and hydrogeologic systems. These responses to floods are anticipated to occur with or without the Project.

Design Flood

For the design flood, net changes in groundwater levels that could be attributable to the Project were examined by subtracting potentiometric head values from the EE1 run from the potentiometric head values from the PP1 run (PP1-EE1 = net change in head).

Positive net change in head would represent increased groundwater levels attributable to construction and operation of the Project. In the off-stream reservoir area, increases in hydraulic head are attributable to the added weight of the water stored on the land surface. Negative change in head would represent decreased groundwater levels attributable to construction and operation of the Project. The net change in head values were then interpolated and plotted within the 3D CSM to understand the spatial distribution of changes in potentiometric head that could be attributable to the Project. This general process was repeated for each of the floods.

The net change in groundwater levels resulting from operation of the Project during the design flood is depicted in Figure 5-27. This figure was generated from data at the 655-hour timestep when water levels in the off-stream reservoir peak (i.e., the reservoir is filled). This is consistent with the timestep presented for the existing conditions simulation for the design flood (EE1).



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

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Net Change in Potentiometric Head - Design (2013) Flood Scenario

Figure 5-27

From Figure 5-27, the net change in head, at the point in time the reservoir is filled, varies from an increase of 28 m (near the upstream toes of the dam) to a decrease of 7 m (in the diversion channel near the inlet structure). This increase in head in the reservoir is a result of the added “weight” of the water stored there.

The areas over which changes in head are observed are areas near the diversion channel, off-stream reservoir, and dam. Some effects are noted just outside of the PDA in areas near the off-stream reservoir. However, in all cases, effects on groundwater levels are well within the LAA, and changes are only observed north of the Elbow River.

1:100 Year Flood

The net change in groundwater levels resulting from operation of the Project during the 1:100 year flood is depicted in Figure 5-28. This figure was generated from simulated data at the 378-hour timestep when water levels in the off-stream reservoir peak for this flood.

From Figure 5-28, the net change in head varies from an increase of 23.5 m (near the upstream toe of the dam) to a decrease of 5.5 m (in the vicinity of the diversion channel near the inlet structure).

Similar to the design flood, the areas over which changes in head are observed are areas near the diversion channel, off-stream reservoir, and dam. Some effects are noted just outside of the PDA in areas near the off-stream reservoir. However, in all cases effects on groundwater levels are well within the LAA.

1:10 Year Flood

The net change in groundwater levels resulting from operation of the Project during the 1:10 year flood is depicted in Figure 5-29. This figure was generated from simulated data at the 530-hour timestep when water levels in the off-stream reservoir peak for this flood.

From Figure 5-29, Figure 5-28 the net change in head varies from an increase of 14 m (near the upstream toe of the dam) to a decrease of 5.5 m (near the diversion channel near the inlet structure).

In contrast to the other two floods, the area over which net change in head is observed is much smaller and is generally confined to low drainage areas within the reservoir and areas near the upstream toe of the dam structure. Some effects are noted just outside of the PDA in areas near the off-stream reservoir. However, in all cases, effects on groundwater levels are well within the LAA.

5.2.2.2 Mitigation Measures for Effects on Groundwater Quantity

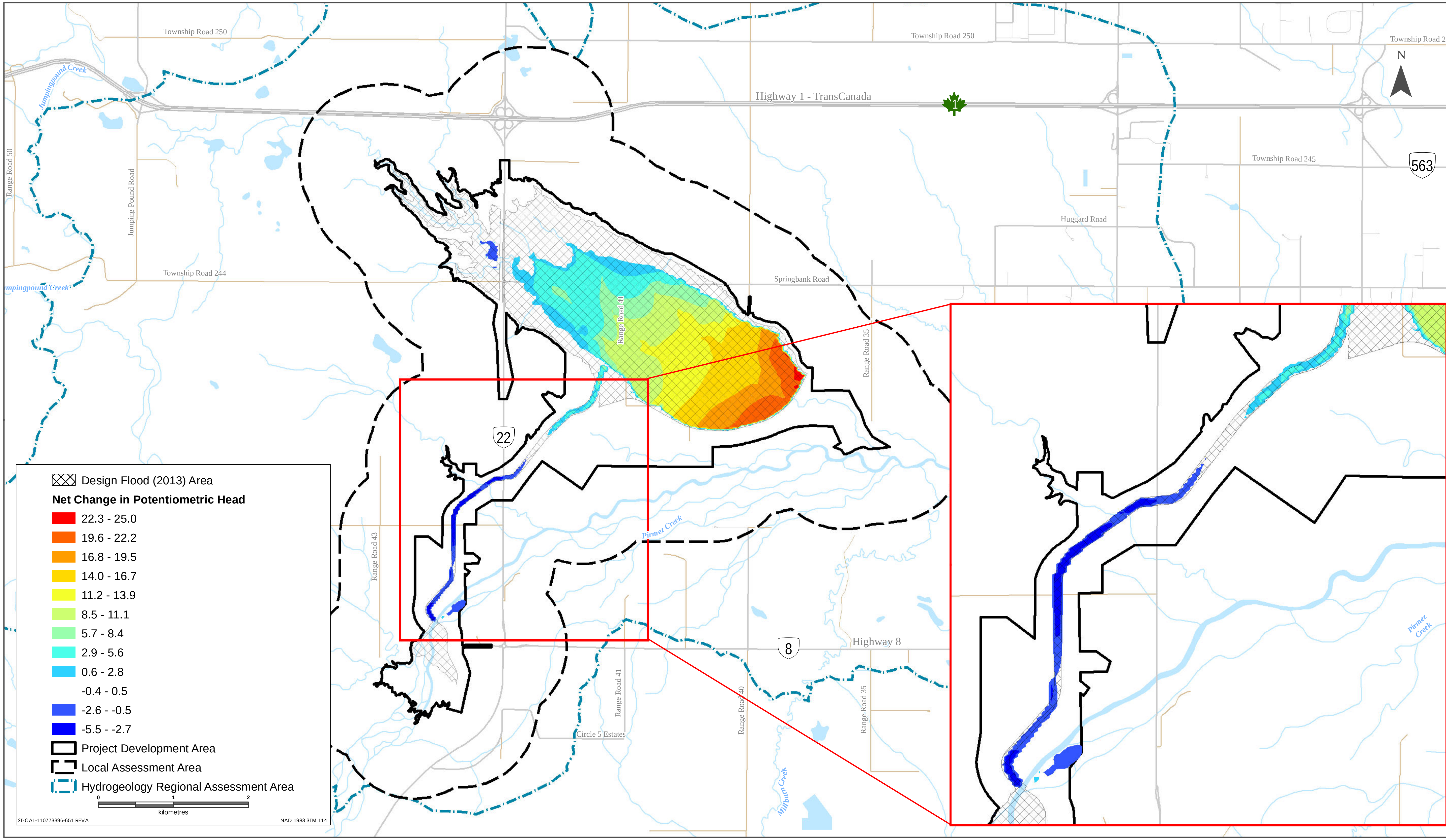
Because the Project is a mitigation measure, the changes in groundwater quantity is a result of intentional changes in surface water storage in the PDA. No specific mitigation for the temporary increases in groundwater quantity are presented.

5.2.2.3 Residual Effects on Groundwater Quantity

Based on the results of the three flood simulations, net changes in groundwater levels are greatest for the design flood event. The 1:100 year and 1:10 year flood events also result in net changes in groundwater levels, but to a lesser degree and areal extent. Thus, for the purposes of characterizing potential residual effects on groundwater quantity, the results from the design flood are used as a conservative measure.

The potential effects on groundwater quantity related to flood and post-flood project operations can be characterized as follows:

- Direction is adverse (in areas where net change in groundwater level is negative) to positive (in areas where net change in groundwater level is positive).
- Magnitude is considered to range from low (in areas where net change in groundwater levels is not predicted) to high (in areas near the diversion channel and off-stream reservoir).
- Geographic extent of the effects are limited to the LAA, based on the design flood simulation.
- Frequency of the effects in the off-stream reservoir area are irregular, depending upon the flood. Frequency of effects in the diversion channel area, near the inlet structure are continuous because seepage into the channel will continue indefinitely.
- Duration of the effects are considered to be short term in the off-stream reservoir: groundwater levels will recover to pre-flood levels with one year following the end of the flood. Duration of the effects near the diversion channel are long term because seepage into the channel will continue indefinitely.
- The effects on groundwater quantity are anticipated to be reversible once the flood has passed and the off-stream reservoir has been emptied. The effects on groundwater quantity near the diversion channel are anticipated to be irreversible because the diversion channel will be in place indefinitely.
- The ecological and socio-economic context is disturbed because the PDA has been substantially previously disturbed by human development.
- Timing is not applicable because effects from project activities would be similar regardless of season or other timing characteristics



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

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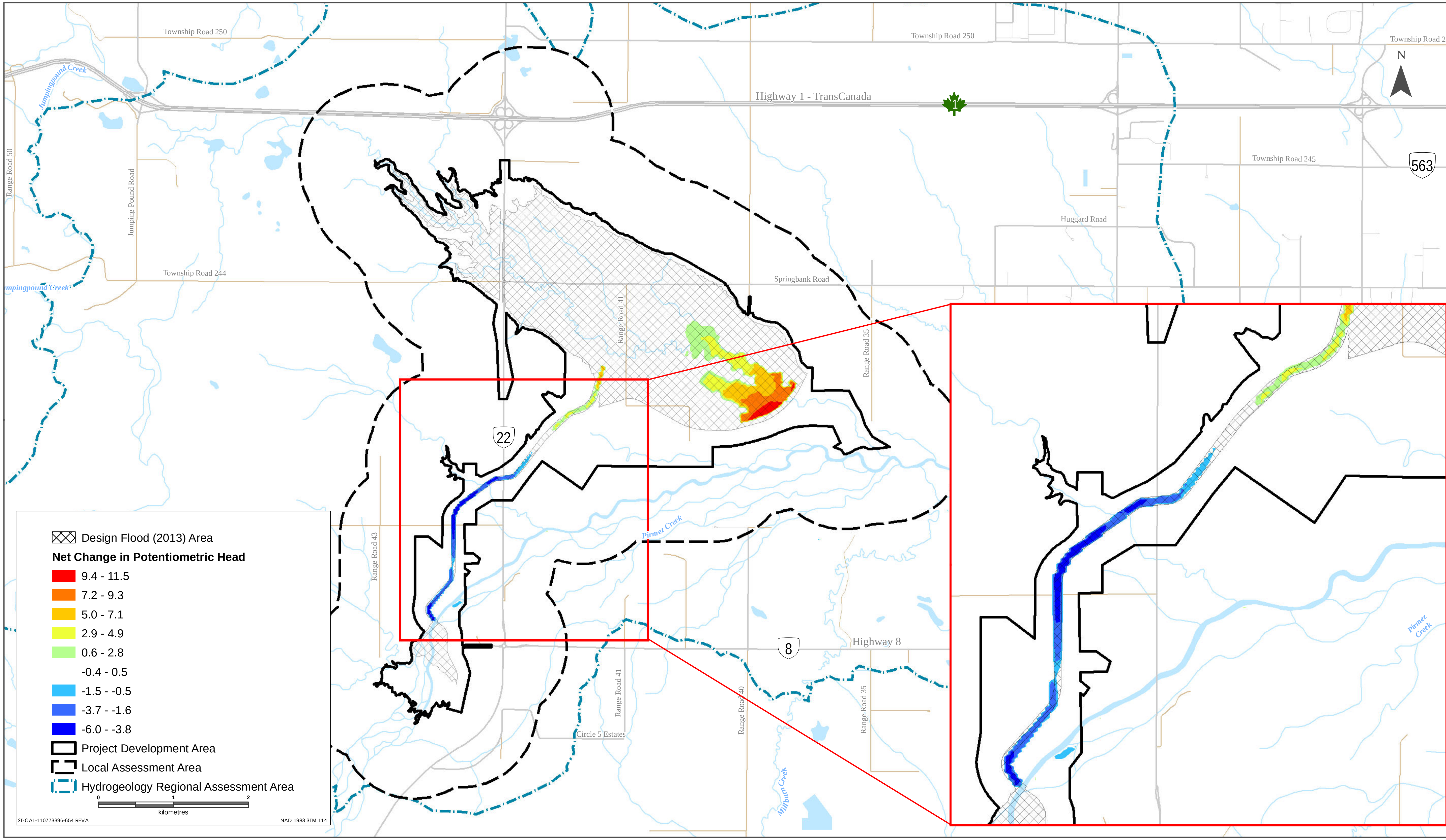
ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Net Change in Potentiometric Head – 1:100 Flood Scenario

Figure 5-28



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

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ALBERTA TRANSPORTATION SPRINGBANK OFF-STREAM RESERVOIR PROJECT ENVIRONMENTAL IMPACT ASSESSMENT

Net Change in Potentiometric Head – 1:10 Flood Scenario

Figure 5-29

5.2.3 Change in Groundwater Quality

5.2.3.1 Project Pathways

Potential changes in groundwater quality could occur during floods due to alterations in groundwater flow patterns in areas near the Elbow River valley or in areas near the diversion channel and off-stream reservoir. Downward or lateral infiltration of flood affected surface water into the subsurface groundwater system could result in changes in groundwater quality. These potential changes in groundwater quality near the Elbow River are possible because of a flood with or without the Project, but the potential for these changes to be further exacerbated by the Project are examined in this section.

Surface water during a flood is expected to be relatively high in total suspended solids due to the high sediment load caused by high flows. This is a marked contrast to (unimpacted) groundwater quality, in-situ groundwater is generally free of suspended solids due to the low flow velocities and porous media, which does not allow for migration of suspended solids. Suspended sediments in groundwater cannot readily migrate through the subsurface in fine grained sediments such as clays and silts that overly much of the RAA (except for areas in the Elbow River valley that are dominated by coarse grained fluvial deposits). The relatively small aperture size of the interstitial spaces between fine grains in the sediment matrix act to "filter out" suspended materials from groundwater in the subsurface. Thus, it is expected that suspended sediment would not readily infiltrate into the subsurface where it could affect underlying aquifers.

In contrast to suspended solids in the subsurface, dissolved species in groundwater can migrate through porous media through advective and hydrodynamic dispersion processes. The movement of dissolved species can also be retarded in the subsurface through adsorptive processes, chemical reaction with other dissolved species and other geochemical reactions with the host matrix.

Figure 5-15 presents the simulated potentiometric head distribution for the design flood at the point in time when the off-stream reservoir has filled. Flow patterns in much of the northwest regions of the off-stream reservoir area continue to be directed inward toward the reservoir area. Therefore, flood affected surface water is not expected to infiltrate and migrate away from the reservoir in these areas. In the southeastern areas of the off-stream reservoir, groundwater flow patterns would be altered such that flow paths are directed radially outward from the reservoir area. In such areas, surface water could infiltrate into the subsurface and begin to migrate away from the off-stream reservoir.

The dynamics of the groundwater flow patterns over time can be examined through particle tracking, whereby modelled "particles" of groundwater are flow into the subsurface, and the numerical model predicts their movement over time. The particle tracking only models advective transport of a particle through the subsurface and does not describe the attenuating mechanisms that retard the movement of a solute through the subsurface. Therefore, the results would tend to overestimate the movement of dissolved substance.

Due to the very low hydraulic conductivities of the upper sediments in the reservoir area, which are dominated by clayey and silty lithologies, the groundwater flow velocities are very low. Particle tracking indicates that advective flow outward from the reservoir area is limited to within the LAA within the timeframe of a flood.

5.2.3.2 Mitigation Measures for Effects on Groundwater Quality

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

5.2.3.3 Residual Effects on Groundwater Quality

The potential effects on groundwater quality related to flood and post-flood operations of the Project can be characterized as follows:

- Direction would be positive or adverse, depending upon the chemical species under consideration. Some parameters in surface water are anticipated to be lower in concentration than in groundwater, and in such cases the infiltration of surface water would tend to further dilute their concentration in groundwater. For other parameters, their concentration in surface water during a flood could be higher than in groundwater, and in such cases the infiltration of surface water would tend to increase their concentration in groundwater.
- Magnitude would be low to high depending upon the chemical species under consideration.
- Geographic extent of the effects would be limited to the LAA because potential seepage out of the off-stream reservoir would be directed back toward the Elbow River valley within the LAA.
- Frequency of the effect would be irregular, depending upon the flood and approximate return period for that flood.

- The duration of the effect on groundwater quality would be short term as the modelling results suggest that groundwater levels would recover to pre-flood levels with one year following the end of the flood, and in turn infiltration of surface water and migration away from the off-stream reservoir would be limited to the same time period.
- The effects on groundwater quality due to infiltration of surface water and subsequent migration away from the off-stream reservoir would be reversible, because once the reservoir is emptied of its inventory, then no further flood affected water can infiltrate into the subsurface.
- The ecological and socio-economic context is disturbed because the PDA has been previously disturbed by human development.
- Timing is not applicable because effects from project activities would be similar regardless of season or other timing characteristics

5.2.4 Summary of Project Residual Effects

Table 5-3 summarizes the residual environmental effects on hydrogeology during flood and post-flood operations.

Table 5-3 Project Residual Effects on Hydrogeology during Flood and Post-flood Operations

Residual Effect	Residual Effects Characterization								
	Project Phase	**Timing**	**Direction**	**Magnitude**	**Geographic Extent**	**Duration**	**Frequency**	**Reversibility**	**Ecological and Socio-economic Context**
Change in Groundwater Quantity	F/PF	N/A	P/A	L-H	LAA	ST-LT	IR/C	R/I	D
Change in Groundwater Quality	F/PF	N/A	P/A	L-H	LAA	ST	IR	R	D

KEY

See Table 5-2 in Volume 3A for detailed definitions

Project Phase
F: Flood Operations
PF: Post-Flood Operations

Timing Considerations
S: Seasonality
T: Time of day
R: Regulatory

Direction:
P: Positive
A: Adverse
N: Neutral

Magnitude:
N: Negligible
L: Low
M: Moderate
H: High

Geographic Extent:
PDA: Project Development Area
LAA: Local Assessment Area
RAA: Regional Assessment Area

Duration:
ST: Short-term
MT: Medium-term
LT: Long-term

N/A: Not applicable

Frequency:
S: Single event
IR: Irregular event
R: Regular event
C: Continuous

Reversibility:
R: Reversible
I: Irreversible

Ecological/Socio-Economic Context:
D: Disturbed
U: Undisturbed

5.3 DETERMINATION OF SIGNIFICANCE

The residual effects on groundwater quantity during flood and post-flood operation phases of the Project are assessed as not significant because they would not decrease the yield of groundwater supply wells to the point where they can no longer be used.

The residual effects on groundwater quality during flood and post-flood operation phases of the Project are assessed as not significant because changes in groundwater quality at existing wells would not deteriorate to the point where it becomes non-potable or cannot meet the Guidelines for Canadian Drinking Water Quality for a consecutive period exceeding 30 days (for those parameters which don't already, under existing conditions, exceed those guidelines).

5.4 PREDICTION CONFIDENCE

The hydrogeology effects assessment is based primarily on interpretations of simulated results from the FEFLOW model. Numerical groundwater modelling is the best practice and the only predictive tool that can simulate the potential response of a complex hydrogeologic system to floods. In cases where the hydraulic parameters used by the model were not entirely constrained by existing data, a conservative approach was applied to overestimate Project effects, where possible. In consideration of these factors and constraints, prediction confidence for potential effects of the Project on groundwater quantity and quality is moderate.

5.5 CONCLUSIONS

5.5.1 Change in Groundwater Quantity

Changes in groundwater quantity during flood and post-flood operations of the Project were evaluated in the context of the hydrogeological framework of the RAA and in consideration of Project infrastructure and activities occurring during these phases. Due to the limited interaction of the Project with groundwater resources, the residual effects on groundwater quantity would be not significant, with a moderate degree of confidence.

5.5.2 Change in Groundwater Quality

Changes in groundwater quality during flood and post-flood operations of the Project are related to potential infiltration of flood affected surface water into the subsurface groundwater system. Due to the limited areas over which this infiltration could occur, and the short time period and eventual flow paths of for this flood affected water, the residual effects on groundwater quality would be not significant, with a moderate degree of confidence.