7.0 GROUNDWATER

Groundwater is important as a water resource in New Brunswick, with more than 75% of the population relying on groundwater as a source of drinking water (Statistics Canada 2010). Groundwater from drilled or screened wells is used for domestic, agricultural, municipal, commercial, institutional, and industrial purposes. Groundwater is most often preferred over surface water as a source of drinking water as it generally can be used with little to no treatment.

7.1 SCOPE OF THE REVIEW

7.1.1 Why Groundwater is a Valued Component

Groundwater is an important resource because it is used for the following purposes:

- domestic uses (including drinking water, food preparation, personal hygiene, cleaning, and outdoor uses);
- agricultural uses (including irrigation);
- municipal uses (including public drinking water, fire protection, and recreation); and
- commercial, institutional, and industrial uses (including manufacturing activities, food preparation, construction, and operation of golf courses).

The water that lies beneath the ground surface is referred to as **groundwater**.

The **groundwater supply** that can be accessed by water wells or springs at the earth's surface is referred to as **groundwater resources**.

7.1.2 Regulations and Policies Relevant to Groundwater

The Province of New Brunswick has legislation in place to manage and protect water resources (both surface water and groundwater), including the *Clean Water Act* and the *Clean Environment Act*. Specific regulations under these acts that relate to the protection of groundwater include the *Wellfield Protected Areas Designation Order–Clean Water Act*, the *Water Well Regulation–Clean Water Act,* and the *Potable Water Regulation–Clean Water Act.*

The *Wellfield Protected Areas Designation Order* defines areas around production wells used for public water supply systems. The *Designation Order* restricts the types of activities that can be carried out within the Wellfield Protected Area, thereby reducing the risk of contaminants (*i.e.*, bacteria and viruses, petroleum products and chlorinated solvents) reaching the wells. The *Wellfield Protected Areas Designation Order* is applicable to the Wellfield Protected Areas for Nackawic and Woodstock, both located within the area of review.

The *Water Well Regulation* defines how water wells are to be constructed in New Brunswick so that water quality is not compromised by local runoff or land use activities. The *Potable Water Regulation* requires water quality testing for all new water wells installed in the province and for regulated water supply systems. The *Water Well Regulation* is applicable to all water wells in the area of review, including future water wells.

Although groundwater resources in Canada are generally managed by provincial regulatory bodies as described above, the Guidelines for Canadian Drinking Water Quality (GCDWQ) published by Health Canada are also applicable to groundwater across Canada, though they have no force of law unless adopted through a regulatory instrument. The GCDWQ are "*established based on current published scientific research related to health effects, aesthetic effects and operational considerations*" (Health Canada 2014).

7.1.3 Area of Review

The area of review for groundwater is shown on Figure 7.1. This area includes a lateral distance (or buffer) of 1 kilometre (km) from the shores of the headpond, and extending from 1 km downstream of the Station to approximately 97 km upstream near the covered bridge at Hartland. This area may be subjected to the largest change from the existing conditions arising from any of the Options.

The City of Fredericton wellfield is located approximately 14 km downstream of the Station. However, beyond 1 km from the shores of the headpond, the presence of the river would likely have minimal to no influence on the groundwater regime. As such, Fredericton or any other downstream communities that use groundwater and are outside of the 1 km buffer are not included in the area of review. It should be noted that NB Power has commissioned a study that is on-going, to further examine the influence of the headpond on groundwater, and preliminary results support the assumptions made in this VC.

7.1.4 Key Issue

Groundwater interacts with surface water features by flowing into and out of rivers and lakes. Groundwater levels near the headpond will vary depending upon the water level in the headpond. The level of the headpond is expected to remain more or less at the current operating level for Option 1 or Option 2. Therefore, changes in groundwater quantity and/or quality are not expected to be wide-spread or long lasting in either of these two Options.

In Option 3, the decommissioning of the Station and removal of the headpond would cause a pronounced drop in the water level of the river upstream of the Station to, or near to, pre-dam levels. In response, a drop in the groundwater level in wells near the river upstream of the Station might be observed, particularly for those wells located close to the headpond. It is possible that water levels in some existing wells could drop to a level that no longer provides sufficient water quantity for the intended use. Potential changes in the groundwater level could also affect mixing of groundwater with surface water, thereby resulting in a change of water quality in wells near the headpond. As water levels below the Station would not be expected to change markedly from current levels, a substantive influence of Option 3 on groundwater is not expected downstream of the Station.

Concentration refers to the mass of a water chemistry parameter per volume of water.

Well Yield refers to the rate at which water can be pumped out of a well.

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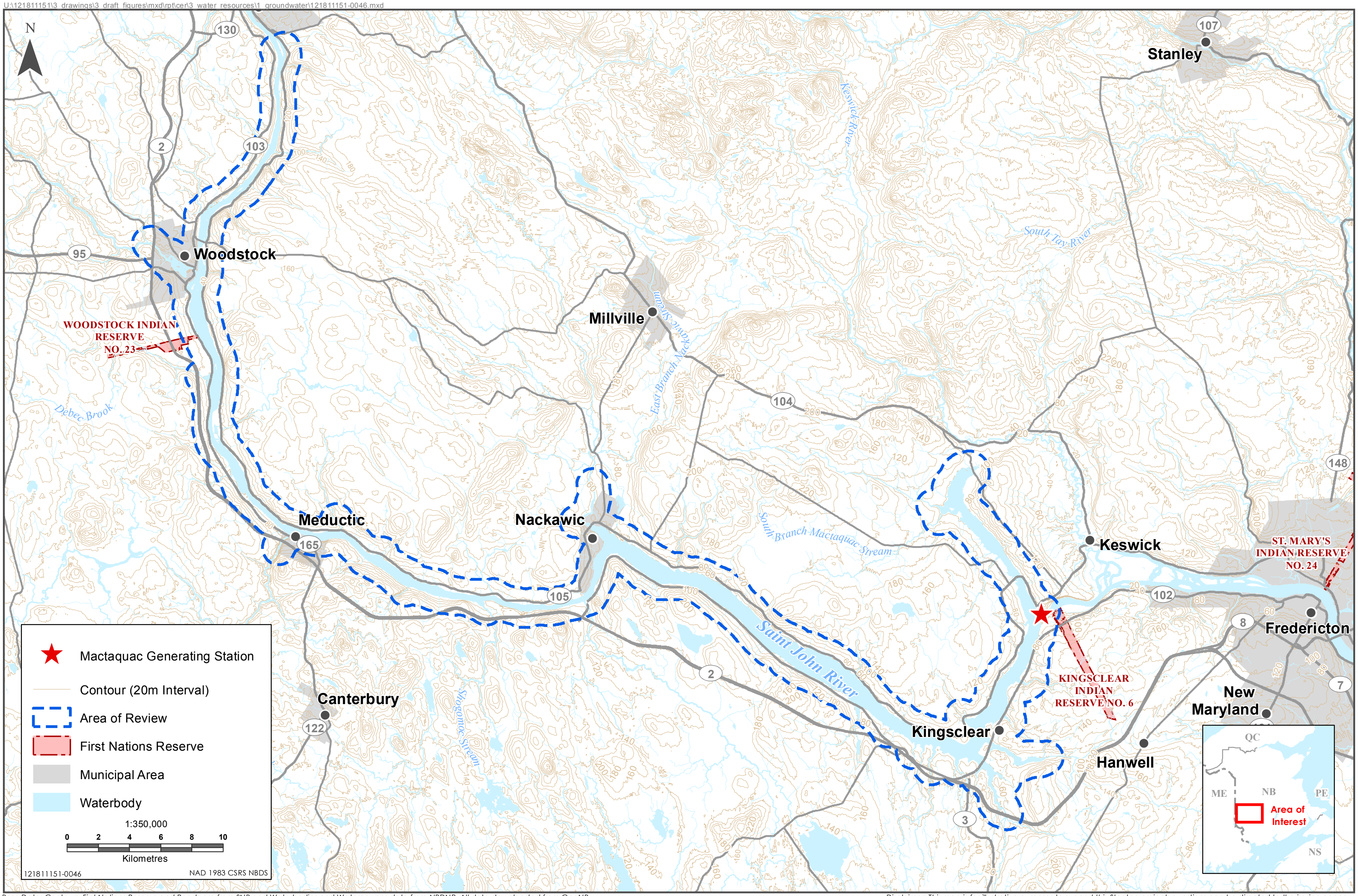

Base Data: Contours, First Nations Reserve and Roads are from SNB and Waterbodies and Watercourses data from NBDNR. All data downloaded from GeoNB.

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Area of Review for Groundwater

Figure 7.1

The key issue for groundwater is outlined in Table 7.1.

Table 7.1 Description of Key Issue For Groundwater

Key Issue	Description
Potential change in groundwater quantity and/or quality	• Changes in groundwater level and subsequent changes in water well yield that may cause water wells to no longer be used for intended purposes. • Change in the concentrations of water chemistry parameters (general chemistry, metals and bacteria) in well water.

7.2 EXISTING CONDITIONS

7.2.1 Sources of Information

Baseline conditions for groundwater were determined by reviewing regional and local geology and publicly available information on water wells and water chemistry in the area of review. Groundwater information was reviewed for geological units down to 150 m below the ground surface. Sources of information included:

- New Brunswick Online Well Log System (NB OWLS) water well database, maintained by the New Brunswick Department of Environment and Local Government (NBDELG 2015e);
- surficial geology map of New Brunswick (Rampton 1984);
- bedrock geology maps of New Brunswick (Potter *et al.* 1979; NBDNRE 2000);
- topography from the Digital Elevation Database (SNB 1998);
- Wellfield Protected Areas (NBDELG 2015f);
- hydrogeological reports (GEMTEC 1991; GEMTEC 2002; NBENV 1993; JWEL 1996);
- interviews with major wells users; and
- New Brunswick Groundwater Chemistry Atlas: 1994 – 2007 (NBENV 2008).

7.2.2 Description of Existing Conditions

7.2.2.1 Geology

Groundwater typically occurs in soil deposits (referred to as overburden) or in cracks or crevices in the underlying rock (*i.e.*, fractured bedrock). As groundwater moves through soil and rock, minerals in the soil and rock can be dissolved into the groundwater, resulting in a change in the water quality. As a result, the quantity and quality of groundwater that can be extracted using water wells depends on the geology of an area. Overburden and fractured bedrock formations that are capable of producing useable amounts of groundwater are called aquifers.

As the quantity and quality of groundwater in the area of review depends on the geology of the area, regional geology maps and well drillers logs were reviewed. The surficial and bedrock geology are shown in the groundwater mapbook (attached under separate cover). The surficial geology illustrates the geology exposed at ground surface which is generally overburden within the area of review. The bedrock geology illustrates the types of rock formations that are present below the overburden materials.

The surficial and bedrock geology varies across the area of review. Surficial deposits include, till, silt, sand, gravel and bedrock rubble ranging in thickness from less than 0.5 m to 3 m (Rampton 1984; NBDELG 2015). Bedrock includes greywacke, slate, siltstone, sandstone, conglomerate, limestone, granite, quartz monzonite, granodiorite, greywacke and quartzite (NBDELG 2015e; Potter *et al.* 1979; NBDNRE 2000).

Within the area of review, water wells in sand and gravel aquifers located close to the Saint John River and wells in highly-fractured sandstone and conglomerate aquifers typically have high yields. Water wells in less fractured bedrock aquifers including granite, quartzite and slate or in glacial till (*i.e.*, soil with high silt and clay content) provide low to moderate groundwater quantity.

To illustrate the geology in the area of review, four cross-sections were developed. The locations of these cross-sections are shown on Figure 7.2 and the cross-sections themselves are shown in Figures 7.3 to 7.6. Each cross-section is roughly perpendicular to the Saint John River. Well identifier numbers shown on the cross-sections indicate those well records that were used to draw the cross-sections.

The first cross-section (A-A') shown on Figure 7.3 is located downstream of the Station near the Kingsclear First Nation. This cross-section shows relatively uniform bedrock geology consisting of shale with a granite intrusion, overlain by glacial till and clay overburden.

The second cross-section (B-B') shown on Figure 7.4 is located upstream of the Station in the Mactaquac Stream Basin (also known as the Mactaquac Arm) and shows a relatively uniform bedrock geology consisting of greywacke and shale bedrock overlain by glacial till overburden of relatively consistent thickness. This type of geology would be expected between the Station and mid-way to the Town of Nackawic.

The third cross-section (C-C') shown on Figure 7.5 is located in the Town of Nackawic, within the Wellfield Protected Area, and shows unconsolidated sedimentary deposits of sand and gravel interlayered with glacial till near the river channel, overlying granite bedrock.

The fourth cross-section (D-D') shown on Figure 7.6 is located in the Town of Woodstock and shows relatively uniform shale bedrock (with a granite intrusion) overlain by till, clay and gravel.

As illustrated on Figures 7.3 to 7.6, the bedrock is not expected to be in direct contact with the headpond. This is due the presence of overburden materials beneath the headpond acting as a barrier. Sand and gravel aquifers are anticipated to be in direct contact with the river in some locations (*e.g.*, in Nackawic as shown on Figure 7.5), but may also be separated from the river by a layer of clay (*e.g.*, in Woodstock as shown on Figure 7.6).

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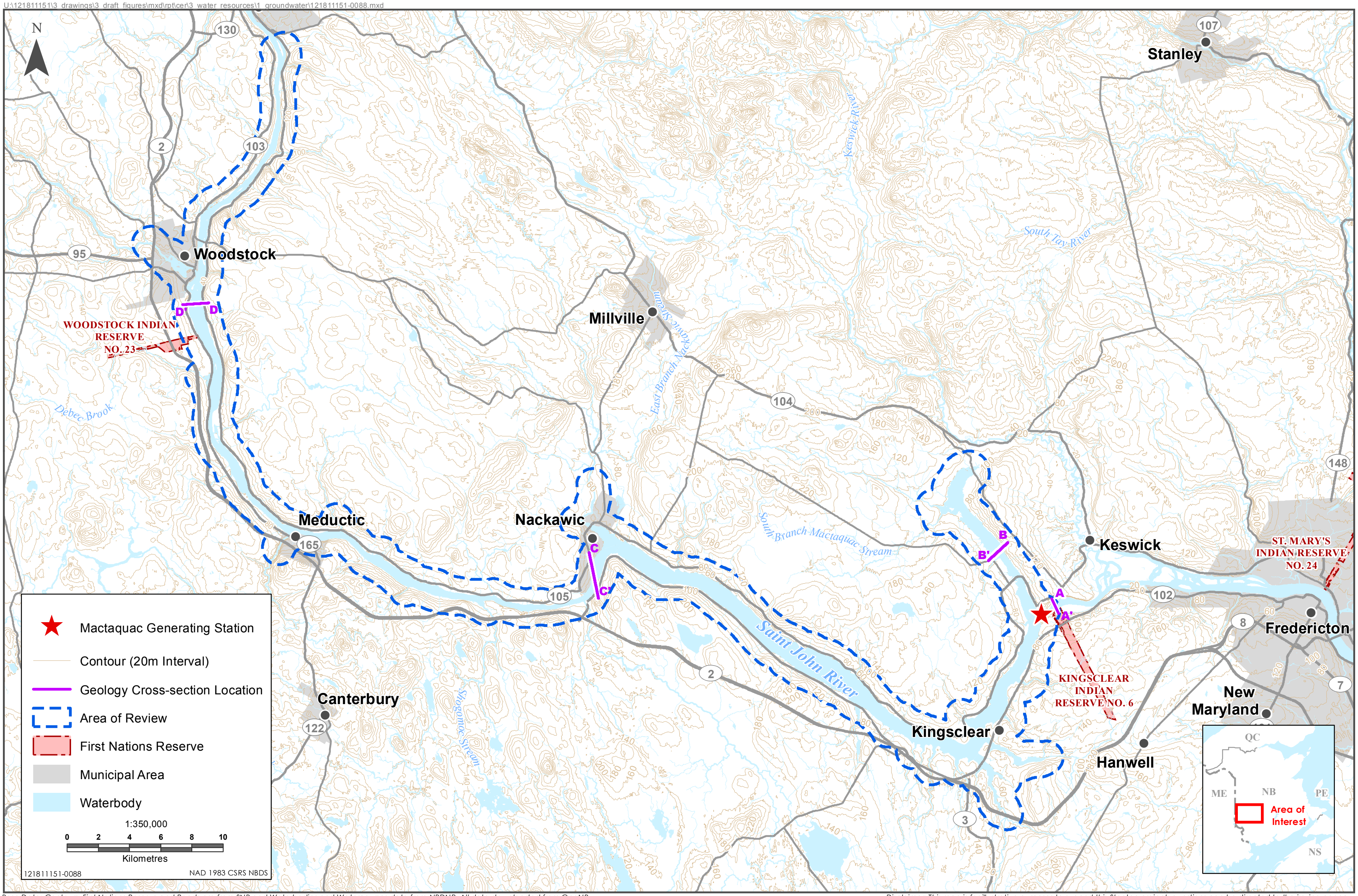

Base Data: Contours, First Nations Reserve and Roads are from SNB and Waterbodies and Watercourses data from NBDNR. All data downloaded from GeoNB.

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

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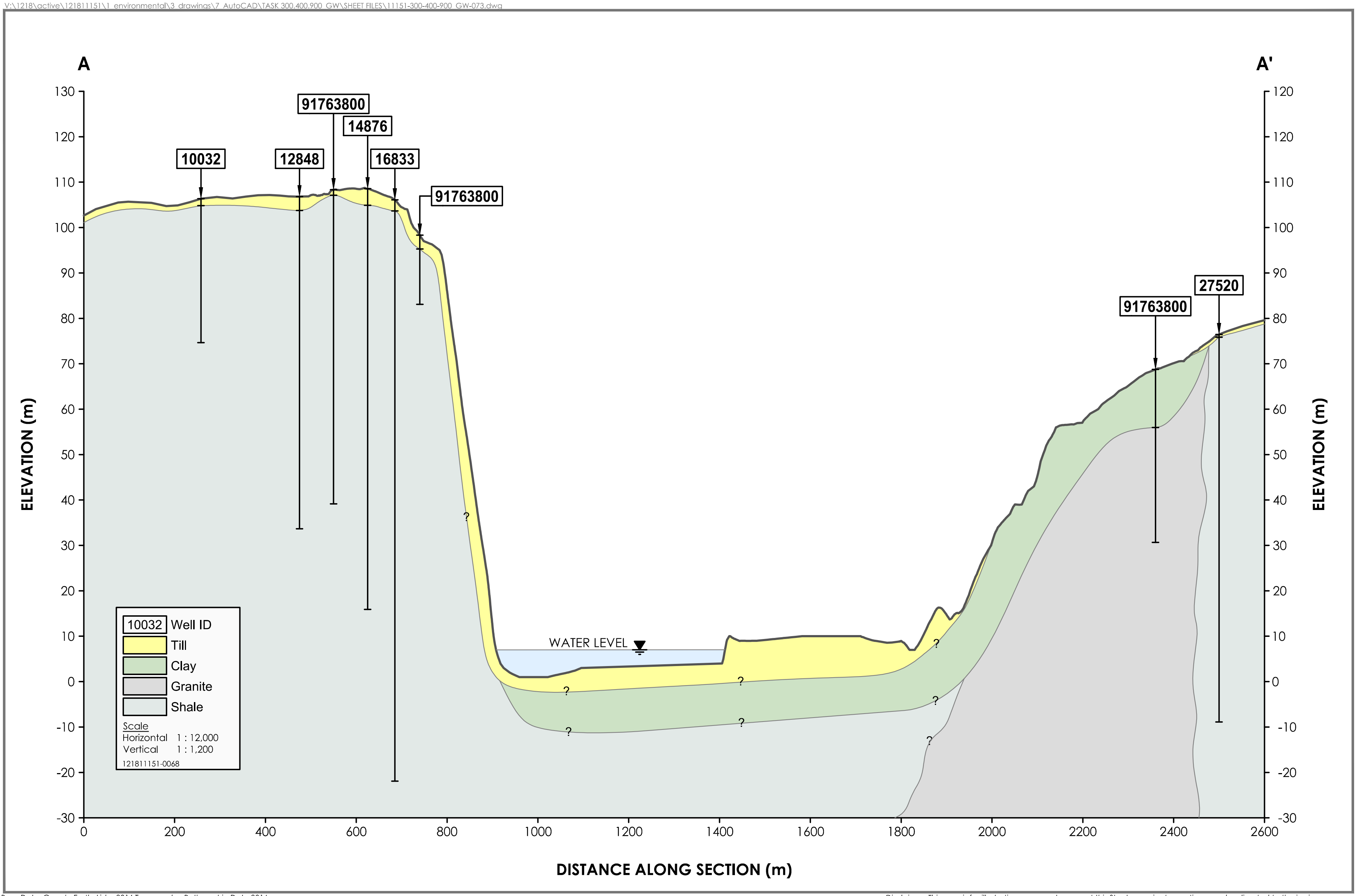
Geology Cross-section Locations

Figure 7.2



Base Data: Google Earth; Lidar 2014 Topography; Bathymetric Data 2014.

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

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Geology Cross-Section Downstream of the Mactaquac Generating Station (near Kingsclear First Nation)

Figure 7.3

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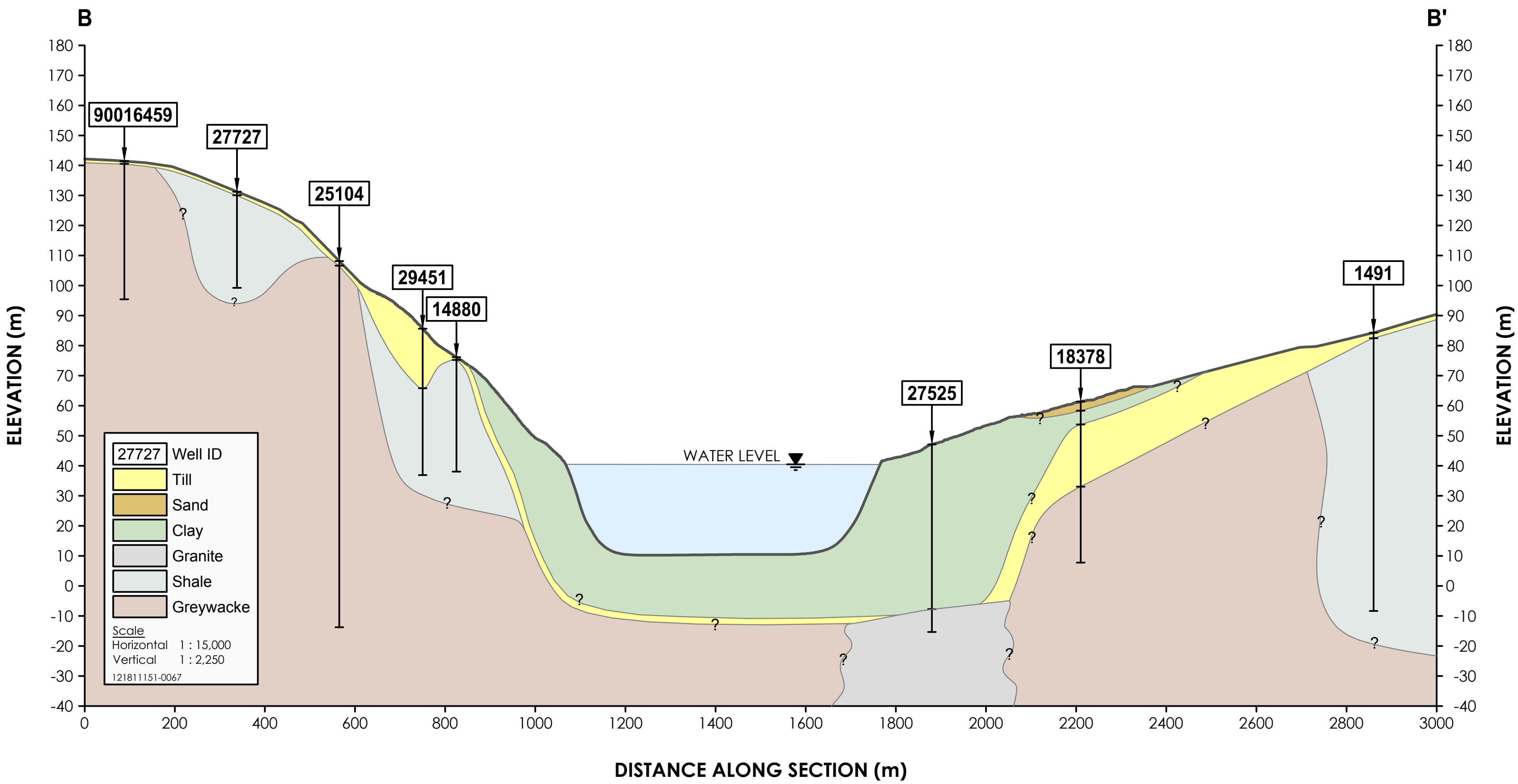

Base Data: Google Earth; Lidar 2014 Topography.

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Geology Cross-Section near Mactaquac Generating Station (Keswick Ridge - Scotch Settlement)

Figure 7.4

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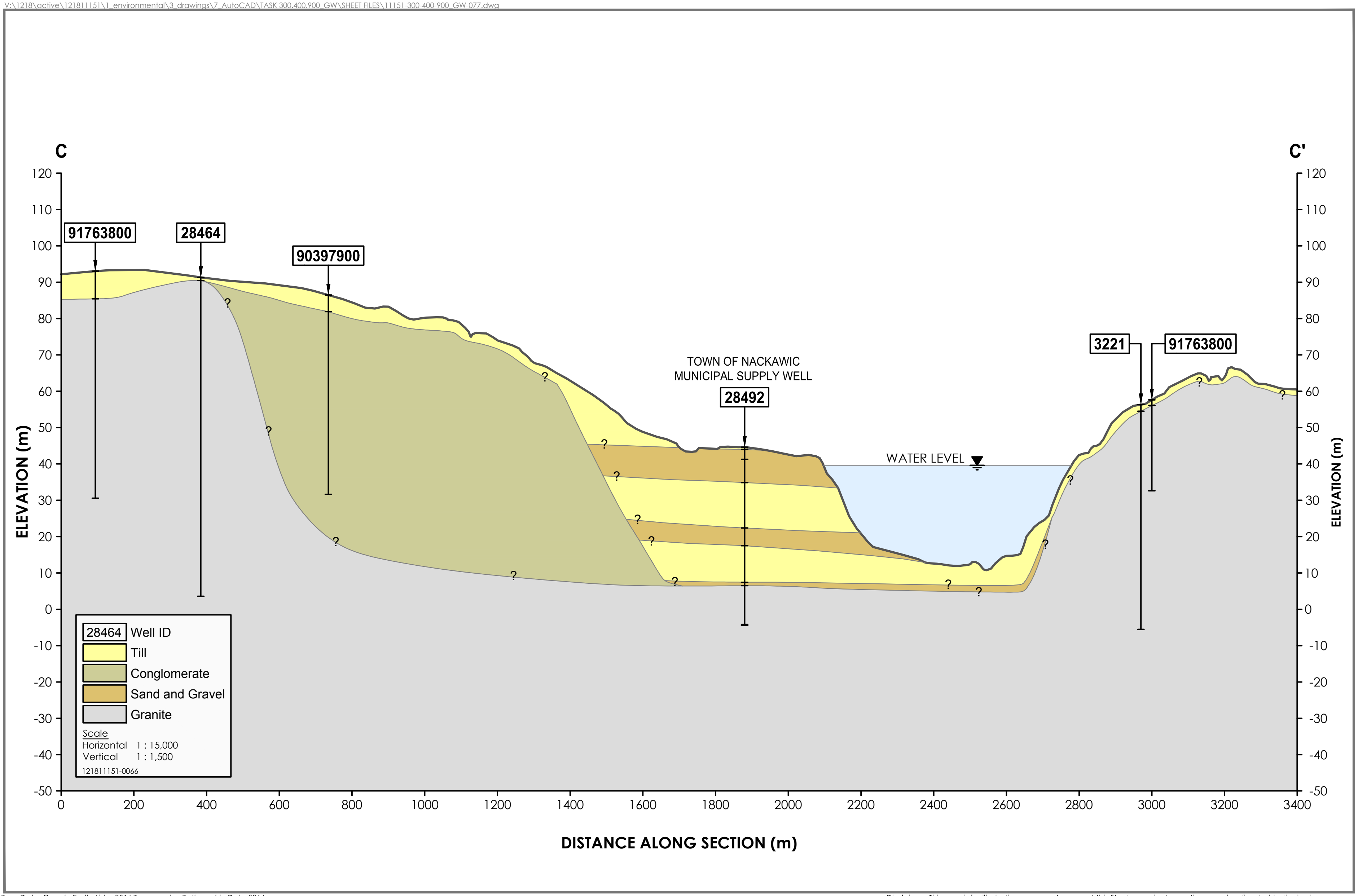

Base Data: Google Earth; Lidar 2014 Topography; Bathymetric Data 2014.

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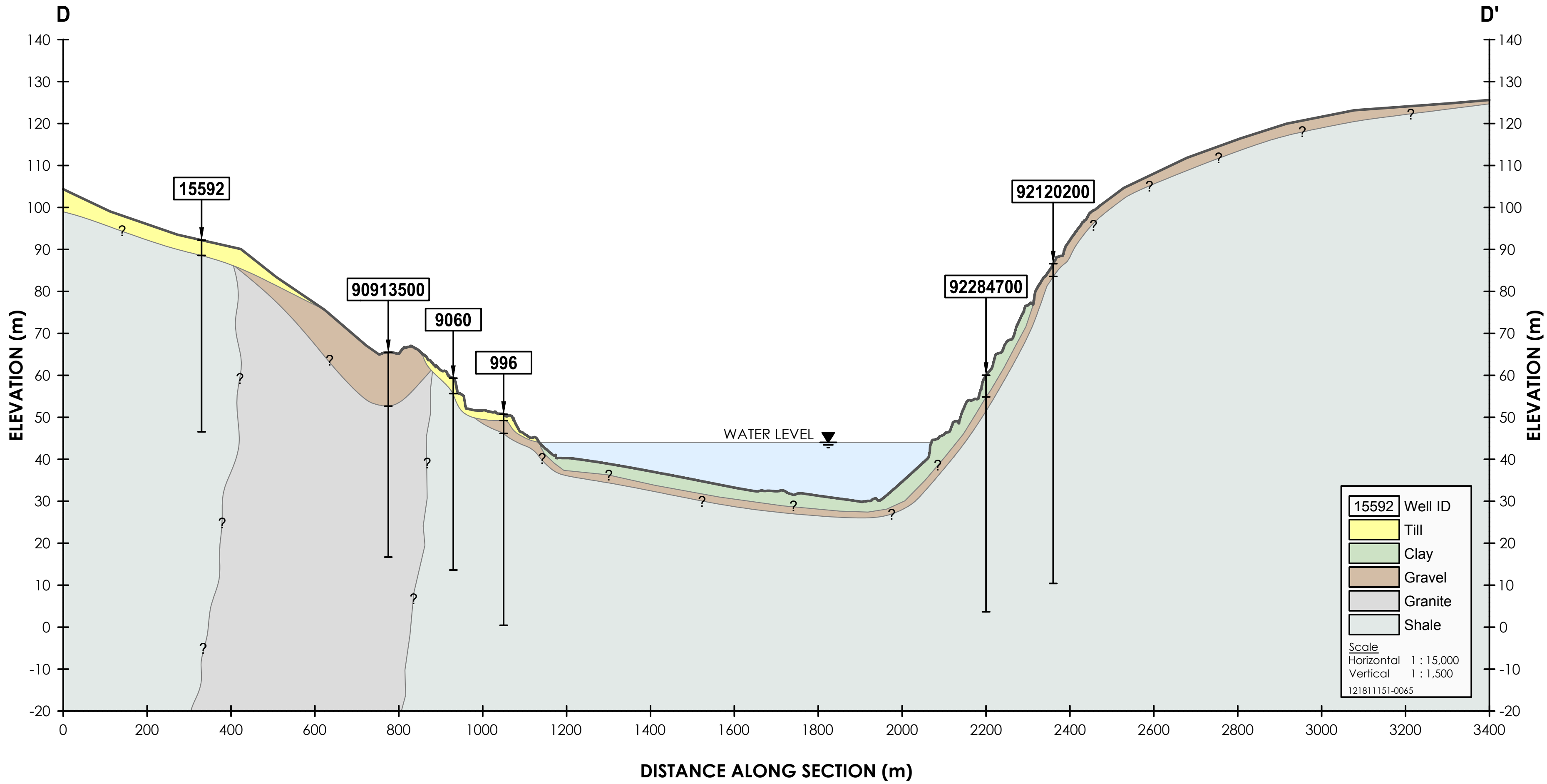
Geology Cross-Section Through the Town of Nackawic Wellfield Protected Area

Figure 7.5



Base Data: Google Earth; Lidar 2014 Topography; Bathymetric Data 2014.

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Geology Cross-Section in the Town of Woodstock

Figure 7.6

7.2.2.2 Groundwater Flow

Typically, shallow groundwater flows from areas of high elevation (*e.g.,* hilly areas) to areas of low elevation (*e.g.,* river valleys and depression areas). The level where an aquifer is saturated (*i.e.,* where all voids in the soil or bedrock are filled with water) is called the water table. Areas of high elevation are groundwater recharge areas where water (*e.g.,* from rainfall or snowmelt) seeps into the ground and moves downward to aquifers. In general, the depth to the water table below the ground surface is deepest in areas of high elevation and shallowest in areas of low elevation. Areas of low elevation are groundwater discharge zones, where groundwater moves out of aquifers into rivers, streams, and wetlands, for example.

In the area of review, groundwater is expected to flow from areas of high elevation adjacent to the headpond, to towards the headpond. Groundwater is expected to percolate downward, and a downward vertical groundwater movement would be expected from overburden to bedrock. However, close to the headpond, upward groundwater movement is possible and could lead to flowing artesian conditions (*i.e.*, groundwater flowing out of a well at the ground surface under non-pumping conditions).

7.2.2.3 Water Well Information

The New Brunswick *Water Well Regulation* requires that information on the well construction and water chemistry be provided to NBDELG for water supply wells drilled by a provincially licenced well driller in New Brunswick. The NBDELG maintains a database (the New Brunswick Online Well Log System (NB OWLS) database) of water well records for wells completed since 1994 (NBDELG 2015e). Well record information for wells installed prior to 1994 is sparse (if any) and is not readily available (Chiasson, M., pers. comm., 2015). The following information is included for water wells in the NB OWLS database: location, depth, depth to bedrock, static water level and estimated safe well yield. Water quality information is also included in the database; however, water quality data are not provided for specific well locations, thereby allowing only a general characterization of groundwater. Groundwater chemistry is discussed in Section 7.2.2.6.

A summary of well record information in the NB OWLS database is shown in Table 7.2.

Table 7.2 Well Records Summary (NBDELG 2015e)

Lateral Distance from the Headpond	Number of Well Records	Well Depth (m bgs)			Percentage of Wells Less than 30 m Deep (%)	Percentage of Wells Greater than 30 m Deep (%)	Average Bedrock Level (m bgs)	Average Static Water Level (m bgs)	Average Estimated Safe Yield
		Minimum	Maximum	Average					(m³/d)
Within 0 m to 300 m	417[1]	10.1	626	67.3	9.6	90.4	6.9	10.8	290
Within 300 m to 1 km	275[2]	0.91	185	55.4	10.1	89.9	4.2	6.9	290
Total for Area of Review (0 m to 1 km)	692	0.91	626	62.6	9.8	90.2	6.3	9.4	290

Notes:

1 One exploratory well and 416 domestic drinking water wells.

2 Three abandoned drinking water wells, one industrial non-drinking water well, one municipal drinking water well, and 270 domestic drinking water wells.

m bgs = Metres below ground surface.

As shown in Table 7.2, the NB OWLS database contains 692 groundwater well records in the area of review. It is likely that other wells constructed prior to 1994 exist in the area of review which are not recorded in the NB OWLS database (which only includes well records from 1994 onward); these could be identified as part of baseline, door-to-door groundwater studies. The location of the water wells are shown in the groundwater mapbook, according to location data presented in the database (NBDELG 2015e). Approximately 60% of the records are for wells located within 300 m of the headpond, and the remaining 40% are for wells located between 300 m and 1 km of the headpond.

Well depth is an important indicator of the volume of water in storage within a well that can be used during peak water use times (*i.e.,* morning and evening). Shallow wells tend to have less water in storage than deeper wells. Therefore, shallow wells are generally more susceptible to decreases in water levels than deeper wells. Approximately 10% of the wells in the area of review are shallow (*i.e.,* have well depths less than 30 metres below ground surface (m bgs)), with an average shallow well depth of 22 m. The remaining 90% of the wells in the area of review are deep (*i.e.,* have well depths greater than 30 m bgs), with an average deep well depth of 67 m (Figure 7.7).

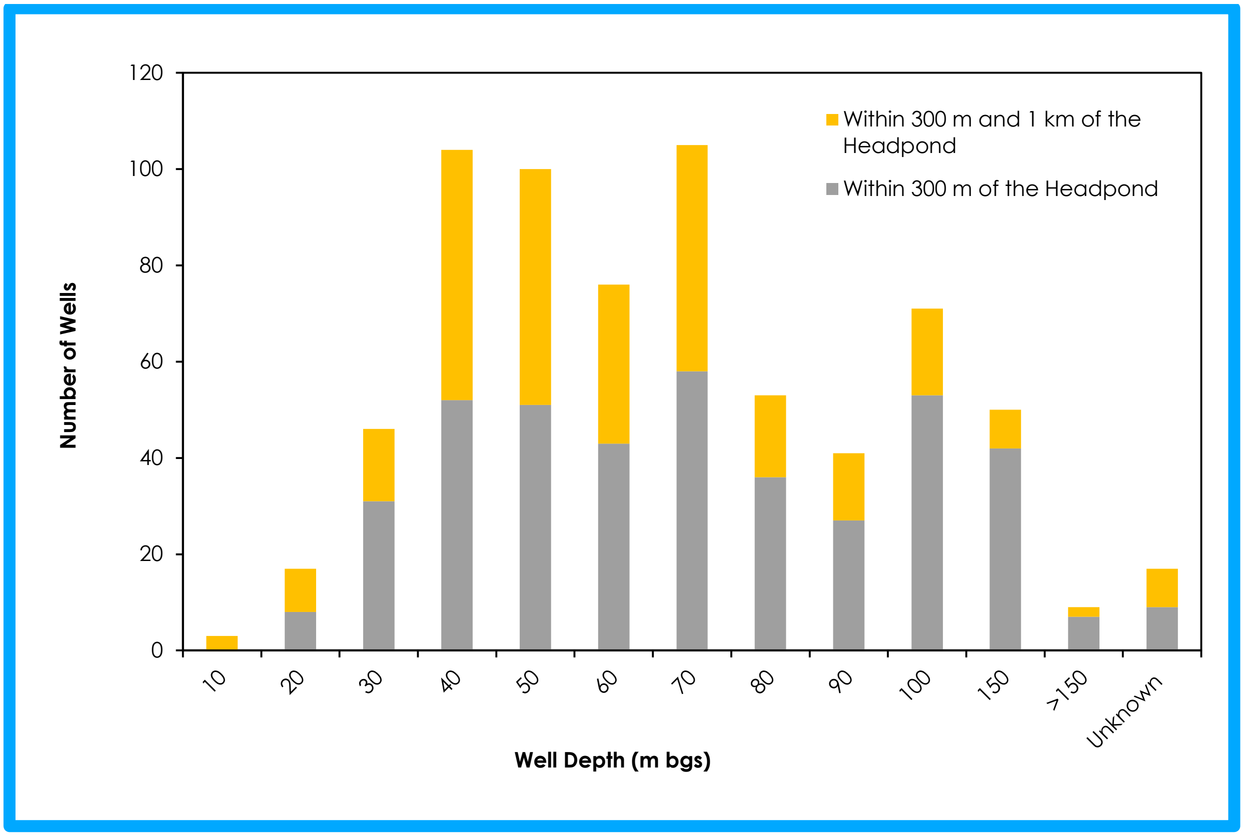

Figure 7.7 Histogram of Well Depths in the Area of Review

Most wells within the area reviewed obtain water from bedrock aquifers. However, there are a few high-yielding wells in sand and gravel aquifers along the headpond.

The average static groundwater level (*i.e.*, the water level when there is no pumping of the well) within 1 km of the headpond is 9.4 m bgs. The average water level for wells within 300 m of the headpond is similar at 10.8 m bgs. These depths to the water table are considered shallow and are typical in the Maritimes (Rivard *et al.* 2008). Static water level is used to estimate the safe yield of a well. The safe yield of a water well is defined as the amount of water that can be withdrawn from an aquifer over a period of time without depleting the supply of water in the aquifer. Based on the typical water demand of a four-person residence in New Brunswick of 1.8 m^3/d (NBENV 2009), and the average estimated safe yield within 1 km of the headpond of 290 m^3/d (NBDELG 2015e), it is generally believed that water wells in the area of review currently provide adequate water for well users in the area.

7.2.2.4 Wellfield Protected Areas

The Nackawic Wellfield Protected Area and the Woodstock Wellfield Protected Area are located approximately 28 km and 58 km upstream from the Station, respectively. The Nackawic Wellfield Protected Area has three protection zones, all of which are located within 1 km of the headpond (Figure 7.8). There is one protected production well, which is 48.8 m deep and screened into sand and gravel. A back-up well has been installed adjacent to the production well, and was undergoing a Water Supply Source Assessment but has not yet been approved at the time of drafting the CER Report (NBDELG 2015d). It is planned for production from the back-up well to alternate with production from the existing well, and therefore changes to the existing protected wellfield are not required (Dietrich, A., pers. comm. 2015). An older backup production well for Nackawic that is located on the bank of Culliton Cove near the convergence of the Nackawic stream and the Saint John River (GEMTEC 2002) is no longer in service due to contamination (Dietrich, A., pers. comm. 2015).

The Woodstock Wellfield Protected Area has one protection zone. There are two protected production wells that are located on an island within the headpond near the west bank of the Saint John River (Figure 7.8). The depths of these protected wells are 47 m bgs and 50 m bgs. The wells are located in a sand and gravel aquifer that is recharged by the river.

The City of Fredericton wellfield is not in the area of review for groundwater; it is located approximately 14 km downstream of the Station. The City of Fredericton Wellfield Protected Area has three protection zones. There are 10 groundwater production wells located in deep saturated sand and gravel deposits in that are hydraulically connected with the adjacent Saint John River. Water levels have been reported to fluctuate with the level of the Saint John River (Violette 1990; TerrAtlantic 2001; TerrAtlantic 2002). Minor water level fluctuations are observed daily in response to the operation of the Station and tidal influences from the Bay of Fundy, located approximately 100 km to the south.

7.2.2.5 Major Groundwater Users

Major groundwater users (*e.g.*, industrial, institutional, municipal and commercial) within the area of review (Table 7.3) were identified through a review of available information from Service New Brunswick and are shown in Figure 7.8. Individual residential groundwater users are not considered to be major users.

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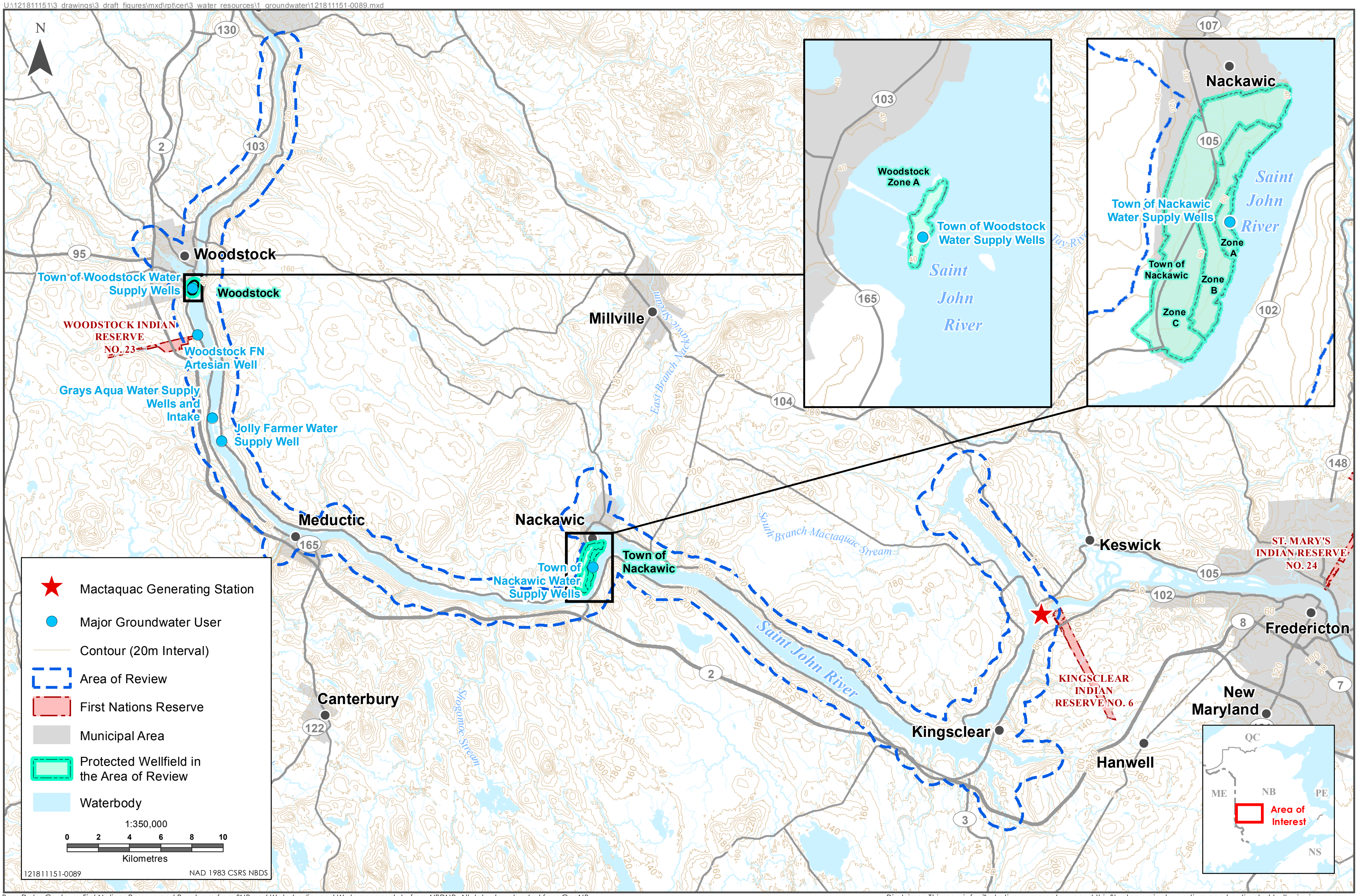

Base Data: Contours, First Nations Reserve and Roads are from SNB and Waterbodies and Watercourses data from NBDNR. All data downloaded from GeoNB.
Project Data: Groundwater user from NATECH. Protected Wellfieds from NBDELG.

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Major Groundwater Users

Figure 7.8

Table 7.3 Major Groundwater Users (excluding Individual Residential Users) in the Area of Review

Major Groundwater User in Area of Review	Number of Groundwater Production/Supply Wells	Approximate Usage or Estimated Yield (m^3/d)	Aquifer Description	Aquifer Transmissivity (m^2/s)	Well Information	Water Quality Information (without Treatment)	Reference
Upstream of the Mactaquac Generating Station							
Town of Nackawic	2	3,269 (Main Well) 2,618 (Back-up Well)	Semi-confined, sand and gravel aquifer.	1,225 (main well) 850 (back-up well)	The groundwater production well and back-up well are adjacent to the Saint John River. The main well is 48.8 m deep, 0.356 m in diameter and has a casing length of 27.4 m. The back-up well (not yet approved) is 26.8 m deep, 0.305 m in diameter, and has a casing length of 23.8 m.	Main well is good with no exceedances of the GCDWQ. Back-up well - exceedances of iron, chloride and manganese above the GCDWQ.	Walker, D., pers. comm., 2014, Walker, D., pers. comm., 2015, GEMTEC (2002), and Dietrich, A., pers. comm. 2015.
Jolly Farmer Products Inc.	1	490	Shale bedrock aquifer.	Unknown	One 122 m deep groundwater supply well, 0.254 m to 0.3048 m in diameter, located directly adjacent to the edge of the Saint John River (between Route 105 and the headpond).	Unknown	NBDELG (2010), Darrow, J., pers. comm., 2014.

Table 7.3 Major Groundwater Users (excluding Individual Residential Users) in the Area of Review

Major Groundwater User in Area of Review	Number of Groundwater Production/Supply Wells	Approximate Usage or Estimated Yield (m^3/d)	Aquifer Description	Aquifer Transmissivity (m^2/s)	Well Information	Water Quality Information (without Treatment)	Reference
Gray's Aqua Farms Ltd.	12	55,000 to 65,000	Gravel aquifer with a direct hydraulic connection to the river.	Unknown	11 groundwater production wells, each 0.3556 m in diameter with depths ranging from 18 to 27 m. In each well, the pump intake is located at a depth of 10 m. One potable water well located adjacent to the headpond.	Unknown	Gray, T., pers. comm., 2014; and NATECH (2015c.)
Woodstock First Nation	3	87	Quartzite bedrock aquifer.	Unknown	One artesian groundwater supply well located directly adjacent to the headpond. The well is 62.5 m deep.	Unknown	Dunbar, R., pers. comm., 2015; and NBDELG (2015).
Town of Woodstock	2	11,129 (Each)	Sand and gravel aquifer overlain by a thick clay layer in the area of the wells.	6,566	Two municipal groundwater supply wells, each 0.4064 m in diameter, 47 and 50 m deep, respectively, located on an island (in the headpond) near the west bank of the Saint John River The wellfield is recharged from the river.	Exceedances of manganese (up to 0.49 mg/L) above the GCDWQ aesthetic objectives. Water is very hard (*i.e.*, >180 mg/L calcium carbonate).	Harding, K., pers. comm., 2014; GEMTEC (1991); NBENV (1993); and JWEL (1996).

Table 7.3 Major Groundwater Users (excluding Individual Residential Users) in the Area of Review

Major Groundwater User in Area of Review	Number of Groundwater Production/Supply Wells	Approximate Usage or Estimated Yield (m^3/d)	Aquifer Description	Aquifer Transmissivity (m^2/s)	Well Information	Water Quality Information (without Treatment)	Reference
Downstream of the Mactaquac Generating Station							
Kingsclear First Nation	1	Driller's estimated safe yield is approximately 1,800 m^3/d.	Graywacke bedrock aquifer.	Unknown	There is one groundwater supply well that is 38.1 deep.	Unknown	NBDELG (2015f).

7.2.2.6 Groundwater Chemistry

A total of 1,269 water quality records were available for the area of review (NBDELG 2015e). A statistical summary of these water quality data is presented in Table 7.4. In general, the groundwater quality is good and is described as hard, slightly alkaline with a dominant calcium-bicarbonate water type. The dissolved solids are low. Some groundwater wells have reported concentrations of arsenic, barium, chromium, fluoride, lead, antimony, and uranium exceeding the respective health-based GCDWQ that require treatment for use as a drinking water supply (Health Canada 2014). Some wells also have pH values outside the GCDWQ range. Most wells have concentrations of iron and manganese that exceed GCDWQ aesthetic objectives, which is common in New Brunswick because of the local geology (NBENV 2008).

E.coli and total coliform bacteria counts were noted in some wells. The presence of bacteria could be due to poor well construction, particularly casing integrity or they could be relicts of the drilling and well constructing process, depending on how and when the sample was collected. Typically the well is treated with chlorine after a positive bacteria result, and additional water samples are collected until a negative result is achieved.

Table 7.4 Summary of Groundwater Quality Data

Parameter	Units	Guideline for Canadian Drinking Water Quality (GCDWQ) (MAC unless otherwise noted)	Data for Area of Review				
			Minimum Concentration	Maximum Concentration	Average Concentration	Number of Samples	Percentage of Samples Exceeding the GCDWQ
Alkalinity	mg/L	-	10.4	17	15.1	7	-
Total Alkalinity	mg/L	-	16.9	546	124	794	-
Aluminum	mg/L	-	0.008	1.82	0.043	799	-
Arsenic	µg/L	10	0.5	**117**	3.21	801	6%
Boron	mg/L	5	0.0001	0.34	0.032	796	0%
Barium	mg/L	1	0.002	**2.71**	0.108	802	0.1%
Bromine	mg/L	-	<0.1	3.69	0.063	777	-
Conductivity	µSIE/cm	-	33.6	12900	383	801	-
Calcium	mg/L	-	<0.1	431	40.4	802	-
Cadmium	µg/L	5	0.01	0.7	0.2	801	0%
Chloride	mg/L	≤250[AO]	0.142	**4,577**	37.1	801	1%
Chromium	µg/L	50	0.5	**117**	8.4	794	0.3%
Copper	µg/L	≤1,000[AO]	4	720	17	798	0%
E.coli	Ab/Pr	Ab	Ab	**Pr**	-	916	3%
	MPN/100 ml	0	0	**>200**	-	10	10%
Fluoride	mg/L	1.5	0.06	**7.36**	0.27	801	4.0%
Iron	mg/L	≤0.3[AO]	<0.01	**77**	**0.47**	802	29%
Hardness	mg/L	-	<0.67	1,220	138	807	-
Potassium	mg/L	-	<0.1	15	1.1	802	-
Magnesium	mg/L	-	<0.1	49	9.0	802	-
Manganese	mg/L	≤0.05[AO]	0.004	**22**	**0.14**	800	26%
Nitrite (as N)	mg/L	1	<0.05	0.13	0.03	794	0%
Nitrate (as N)	mg/L	10	0.01	5.6	0.41	750	0%
Nitrate + Nitrite (as N)	mg/L	10	0.01	5.7	0.39	797	0%
Sodium	mg/L	<200[AO]	1.22	**2,820**	25.8	802	1%
Lead	µg/L	10	0.7	**84.7**	2.1	787	3%

Table 7.4 Summary of Groundwater Quality Data

Parameter	Units	Guideline for Canadian Drinking Water Quality (GCDWQ) (MAC unless otherwise noted)	Data for Area of Review				
			Minimum Concentration	Maximum Concentration	Average Concentration	Number of Samples	Percentage of Samples Exceeding the GCDWQ
Sulphate	mg/L	<200[AO]	<0.05	159	16	782	0%
Antimony	µg/L	6	<1	**<u>40.6</u>**	1.1	798	2%
Selenium	µg/L	50	<1	11	1	788	0%
Total Coliform	MPN/100 ml	0	0	**<u><200</u>**	-	2	50%
	Ab/Pr	0	Ab	**<u>Pr</u>**	-	916	36%
Turbidity	NTU	1	0	**<u>340</u>**	**<u>4.4</u>**	798	51%
Titanium	µg/L	-	0	1.5	0.5	802	-
Uranium	µg/L	20	0.5	**<u>133</u>**	4.1	659	6%
Zinc	µg/L	<5,000[AO]	0	**6870**	51	801	6%
pH	unitless	6.5-8.5	**<u>5.4</u>**	**<u>9.54</u>**	7.96	801	5%
Total Dissolved Solids (Calculated)	mg/L	<500[AO]	18.482	**<u>8,328</u>**	209	695	2%

Notes
MAC = Maximum allowable concentration (Health Canada 2014).
AO = Aesthetic objective (Health Canada 2014).
MPN = Most probable number.
Pr = Present, Ab = Absent
"-" = Not applicable.
A value in **<u>bold and underline</u>** indicates a value in excess of the GCDWQ maximum allowable concentration.
A value in **bold** indicates a value in excess of the GCDWQ aesthetic objectives.

7.3 SUMMARY OF STANDARD MITIGATION FOR GROUNDWATER

Standard mitigation and best management practices relevant to groundwater will be implemented prior to or during construction, demolition, decommissioning and operation of all Options. These are based on normal operating procedures and regulatory requirements and include mitigation specific to groundwater. Some examples of standard mitigation are provided below.

- Mechanical excavation measures will be used in lieu of blasting where practical.
- Landowners near the construction site will be notified of any blasting activities.
- All blasting will be supervised by certified professionals.

7.4 POTENTIAL INTERACTIONS BETWEEN GROUNDWATER AND THE OPTIONS

Table 7.5 provides an overview of how the Options might interact with groundwater.

Table 7.5 Potential Interactions between Groundwater and the Options

Phase	Option 1	Option 2	Option 3
	Potential Change in Groundwater Quantity and/or Quality	Potential Change in Groundwater Quantity and/or Quality	Potential Change in Groundwater Quantity and/or Quality
Construction (new facilities, Option 1 or Option 2)	✓	✓	
Demolition (existing structures, Option 1 or Option 2)	NI	NI	
Operation (Option 1 or Option 2)	NI	NI	
Decommissioning (Option 3)			✓

Notes:
✓ = Potential interactions.
NI = No interaction.
Shaded cells are not applicable to the particular option and phase.

No interactions are anticipated to occur for Option 1 or Option 2 during the demolition or operation phases. The demolition of existing structures for Option 1 or Option 2 is not anticipated to require excavation or blasting below the water table; therefore, these actions are not likely to interact with groundwater. The operation of new facilities at the current Station location will maintain the current water level in the headpond. Because there will be little change to the existing (baseline) groundwater conditions, changes to groundwater quantity and quality are not anticipated.

7.4.1 Potential Change in Groundwater Quantity and/or Quality

Because Options 1 and 2 include many of the same activities and are of similar nature and duration, the potential interaction between groundwater and Option 1 or Option 2 is expected to be similar for both options. They are thus evaluated together, below.

7.4.1.1 Option 1 or 2

During activities associated with construction of new facilities in Option 1 or Option 2, blasting of hard bedrock and the removal of water from excavations where construction is taking place (*i.e.*, dewatering) may be required. Blasting may cause changes (increases or decreases) in the yield of groundwater wells located within 500 m of these activities. Well yield could increase if new fractures are created by shifting of the bedrock during blasting that can carry more groundwater to the well. Well yield could also decrease if open fractures in the bedrock are closed or partially infilled with sediment during blasting activities. The resulting change in well yield (if any) would depend of the following factors: distance of the well from the blasting activities; the physical and chemical properties of the bedrock, the yield of the well prior to construction, and the age and condition of the well. Shallow, very low yield wells located in the immediate vicinity of the construction activates will be more susceptible to changes in well yield from blasting. Deep wells, especially those located further away from the blasting activities would be expected to have small changes in well yield, if any.

Any change in well yield that might arise is expected to be site-specific with any interactions expected within 500 m of the construction activities. If new fractures are opened or existing fractures are closed during blasting, there could be long-term changes in well yield.

Blasting of bedrock could also cause minor changes to the groundwater quality, particularly the turbidity of the groundwater. Vibrations in the bedrock caused by the blasting may dislodge or move sediments present in the fractures. This may temporarily decrease the clarity of the groundwater (*i.e.*, increase the turbidity) in a well connected to these fractures. Interactions between the blasting activities and groundwater quality are expected to be temporary as the turbidity would return to pre-blast conditions shortly after a blasting event as dislodged sediment settles in the fractures.

In order to establish the site-specific interactions on water wells, it is recommended that well owners within 300 m of dewatering activities or 500 m of blasting activities be given the option to participate in a baseline pre-construction water well monitoring program. This program would collect information on water level, pump intake setting, well depth, and peak water demand, and the collection of water samples for analysis of general chemistry parameters, metals and coliform bacteria. This program would be used to identify wells at higher risk for interactions. It is also recommended that water level and groundwater quality surveys be conducted at specified locations and at specified frequencies during and following the construction activities. The results from the additional surveys can be used to characterize the interactions that were encountered during and following the construction program. Standard mitigation noted above will be employed during blasting activities to minimize potential interactions with groundwater.

In the unlikely event of loss of well yield or changes to water quality, further mitigation could include deepening of an existing well, replacement of a well, provision of larger capacity indoor water storage tanks, installation of a treatment system to meet the GCDWQ, or a combination of these or other measures. Provision of a temporary alternate source of drinking water (such as bottled water) could also be provided while permanent mitigation measures are being implemented.

Development of trenches for construction and the associated dewatering of the trenches could also cause changes in well yield. The dewatering will only be required while construction is active; therefore, the duration is anticipated to be short-term. Groundwater levels could be lowered to levels slightly below the depth of construction or to the base of the excavation. Well yields of groundwater wells located within 300 m of the dewatering activities could decrease during dewatering as the groundwater levels in the surrounding aquifers are lowered as a result of the dewatering.

The lowering of the groundwater level and any potential decrease in well yield that might occur due to dewatering during foundation construction for the new structures are expected to be minimal, site-specific (*i.e.,* within 300 m of the dewatering activities) and lessen as the distance from the excavation site increases. Groundwater removed during the dewatering process would be returned to the local watershed; therefore, after dewatering stops, groundwater levels are expected to return to regional groundwater levels and well yields to pre-dewatering quantities. The baseline, construction, and post-construction surveys of at-risk wells presented for blasting above will also address this potential interaction.

7.4.1.2 Option 3

A pronounced lowering of the headpond water level would occur in Option 3. This could lower the water table adjacent to the headpond. As discussed earlier, groundwater flows from areas of high elevation to areas of low elevation. When there is a water body such as a river in the low areas, the water level in the river affects the position of the water table. As illustrated on Figure 7.9, the water table close to the headpond is largely based on the water level in the headpond.

Changes of the water table position depend on a number of factors including the distance of the well from the headpond, the properties of the aquifer in which the well is located, the depth of the well, and the current yield of the well. For example, the water table position does not change in areas located farther away from the headpond (see Figure 7.9). There is also less change in the water table position in areas of groundwater recharge.

The amount of water that can be pumped from a well depends on a number of factors including the amount of water stored in the well (*i.e.,* the volume of water located between the water table and the depth of the pump intake screen), and how quickly water flows into the well from the surrounding aquifer. If the depth to the water table below the ground surface drops, the amount of water stored in a well is reduced.

Sand and gravel aquifers in the area of review tend to receive recharge from the headpond. This is illustrated on Figure 7.5, where the sand and gravel aquifer supplying the Town of Nackawic are shown to be in contact with the headpond. Surface water flows readily into the groundwater in these aquifers. As a result, the water table in these sand and gravel aquifers tend to quickly equilibrate (*i.e.,* balance equally) with the surface water level in the headpond. Therefore, if the headpond water level drops, the static groundwater level in these wells will also drop.

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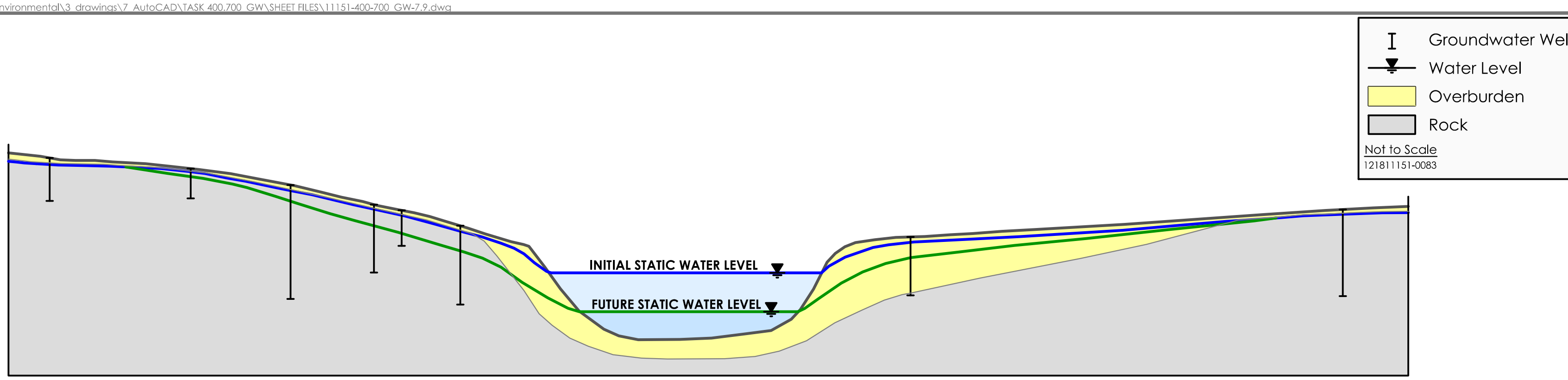
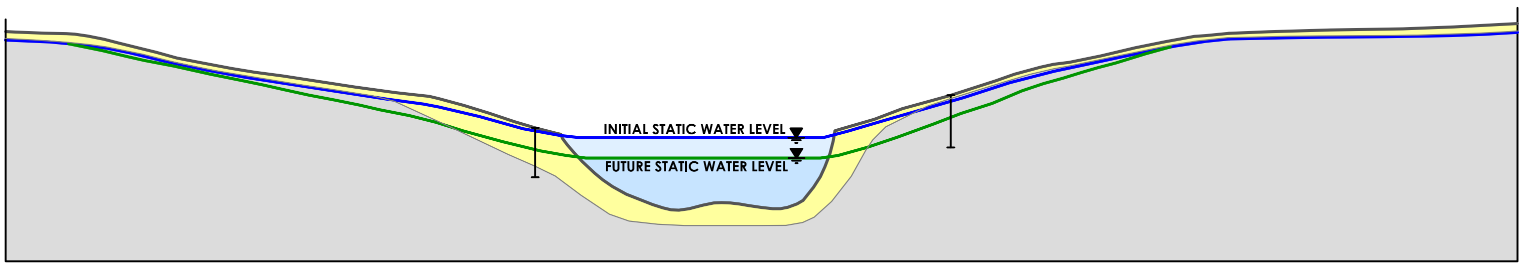
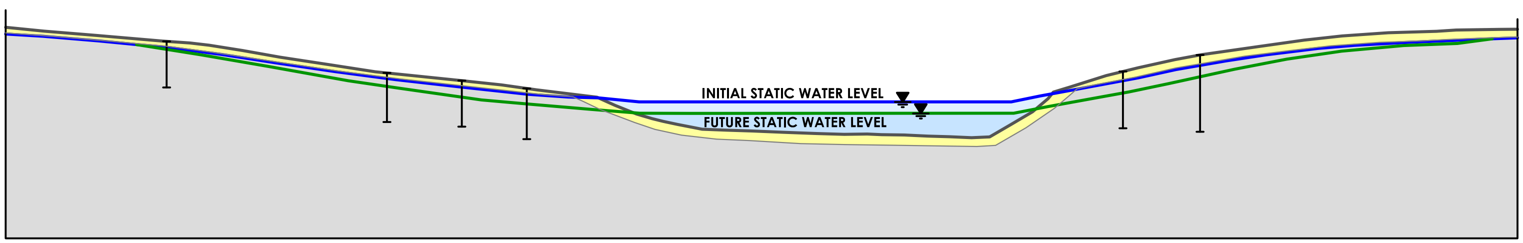


CROSS SECTION NEAR MACTAQUAC GENERATING STATION ILLUSTRATING THE POSSIBLE CHANGE IN GROUNDWATER LEVEL FOLLOWING HEADPOND REMOVAL IN OPTION 3



CROSS SECTION NEAR THE TOWN OF NACKAWIC ILLUSTRATING THE POSSIBLE CHANGE IN GROUNDWATER LEVEL FOLLOWING HEADPOND REMOVAL IN OPTION 3



CROSS SECTION NEAR THE TOWN OF WOODSTOCK ILLUSTRATING THE POSSIBLE CHANGE IN GROUNDWATER LEVEL FOLLOWING HEADPOND REMOVAL IN OPTION 3

Base Data: Google Earth; Lidar 2014 Topography.

Disclaimer: This map is for illustrative purposes to support this Stantec project; questions can be directed to the issuing agency.

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Cross Sections Illustrating the Change in Groundwater Level for Option 3

Figure 7.9

Bedrock aquifers in the area of review are less likely to receive recharge from the headpond. As shown on Figures 7.6 to 7.9, there is some thickness of overburden such as till or clay that separates the bedrock aquifer from the headpond. As described earlier, the water table position is less dependent on the water level in the headpond with increasing distance from the headpond, towards areas of groundwater recharge. Therefore, a well located in a bedrock aquifer will generally be less affected by a change in the headpond water level than a well in a sand and gravel aquifer.

Major well users including industrial, institutional, municipal and commercial groundwater present in the area of review could see drops in well yields in response to the lowering of the water level in the headpond associated with Option 3. Based on preliminary information, these major users collectively extract a large volume of groundwater on a regular basis (NATECH 2015a) and could see changes in groundwater quantity and/or quality in Option 3.

The illustrative cross-sections presented on Figure 7.9 show the anticipated change in the headpond water level near the Station, near Nackawic and near Woodstock. As shown on Figure 7.9, the most pronounced drop of the headpond water level is expected at the Station, while the least pronounced drop in the headpond water level is expected at the far end of the headpond near Hartland. Therefore, the most pronounced decreases in groundwater level and well yields would be expected near the Station, where the drop in headpond water level will be greatest. Likewise, the least decrease in groundwater level and well yields would be expected near Hartland, where the drop in the headpond water level will be least.

Adverse changes in groundwater quantity and/or quality are unlikely to occur at wells located downstream of the Station. Some changes in groundwater quantity and/or quality could occur seasonally due to the absence of the river flow regulation currently provided by the Station. This would be most pronounced during spring flooding and low flow stream regulation.

In order to establish the site-specific interactions with water wells, as further mitigation it is recommended that well owners within 1 km of the headpond be given the option to participate in a baseline pre-decommissioning water well monitoring program. This program could include:

- field verification of well locations on each property (including those constructed prior to 1994) and the collection of the following information regarding water wells: water level, pump intake setting, well depth, casing length and water demand;
- identification of wells at risk close to the headpond (*i.e.,* very shallow, low yield wells which could become unsuitable for domestic use in the event of small (1 to 3 m) declines in the headpond water level); and/or
- Installation of automated water level data loggers at selected location that assess the aquifers that service the major groundwater users.

It is also recommended that water level and groundwater quality surveys be conducted at specified locations and at specified frequencies during and following the decommissioning activities for Option 3. The results from the additional surveys can be used to quantify the interactions that were encountered during and following the decommissioning activities. This could include the installation of automated water level data loggers, particularly in wells that serve major groundwater users.

In the event that a well no longer provides sufficient yield for its intended use, recommended further mitigation could include deepening of an existing well, replacement of a well, provision of larger capacity indoor water storage tanks, or a combination of these or other measures. Provision of a temporary alternate source of drinking water (such as bottled water) could also be provided while permanent mitigation measures are being implemented.

Changes in groundwater quality could also occur as a result of the lowering of the headpond water level due to changes in the direction of groundwater flow near the headpond. If more surface water flows from the headpond into the groundwater aquifer, or if less surface water moves into the aquifer from the headpond following the lowering of the headpond water level. In Option 3, the mixture of groundwater and surface water in a well would change. The change could be negative or neutral. Changes in the existing mixture of groundwater and surface water in wells are anticipated to be limited to wells located within 300 m of the headpond, or in wells located in sand and gravel aquifers in direct connection with the headpond.

Further mitigation to address changes in groundwater quality (if they occur) could include installation of a treatment system to meet the GCDWQ, deepening of well casing or well casing liners, well replacement, or a combination of these or other measures. An alternate source of drinking water (such as bottled water), may be provided while mitigation measures are being implemented.

7.5 SUMMARY OF INTERACTIONS BETWEEN GROUNDWATER AND THE OPTIONS

As described in Section 7.4, several interactions between groundwater and each of the Options are anticipated. These are summarized in Table 7.6.

Table 7.6 Summary of Interactions between Groundwater and the Options

Key Issue	Is the interaction negative, or positive?	What is the amount of change?	What is the geographic extent?	How long does it last?	How often does it occur?	Has additional mitigation been recommended?
Potential Change in Groundwater Quantity and/or Quality						
Option 1 or 2	Negative	Low	Site	Short	Single or Continuous	Yes
Option 3	Negative	Low or High	Area	Permanent	Continuous	Yes

KEY

Is the interaction negative or positive?
- Positive.
- Negative.

What is the amount of change?
- Low – a change that remains near existing conditions, or occurs within the natural variability for groundwater.
- Medium – a change that occurs outside the natural variability for groundwater but does not change the overall status of groundwater.
- High – a change that occurs outside the natural range of change for groundwater that will change the status of groundwater locally or regionally.

What is the geographic extent?
- Site – the interaction is limited to the immediate area where Project-related activities occur.
- Area – the interaction is limited to the general area surrounding the Station.
- Region – the interaction occurs throughout the area of review and may extend to other regions.
- Province – the interaction affects the entire province.

How long does it last?
- Short – the interaction occurs for less than 3 months.
- Medium – the interaction occurs for 3 months – 1 year
- Long – greater than a year.
- Permanent – There is no foreseeable end-date for the interaction.

How often does it occur?
- Single – the interaction occurs once.
- Multiple – the interaction occurs several times, either sporadically or at regular intervals.
- Continuous – the interaction occurs continuously.

Has additional mitigation been recommended?
- Yes.
- No.

Note:

[1] Some of the ratings for the environmental interactions in the table above have been updated from those provided in the Draft CER Report dated September 2015 (Stantec 2015b), to more accurately reflect the nature and extent of the anticipated interactions with the Options and to reflect feedback received during the public comment period.

7.5.1 Summary of Additional Potential Mitigation and Information Requirements

As described in Section 7.4, this review has identified some additional potential mitigation and requirements for further study in some areas. These are summarized in Table 7.7.

Table 7.7 Summary of Additional Potential Mitigation and Information Requirements

Option	Additional Potential Mitigation	Additional Information Requirements
Option 1 or 2	• Potentially affected landowners will be notified of blasting activities. • Mechanical excavation measures will be used in lieu of blasting wherever practical. • Blasting activities will be conducted and monitored by certified professionals. • In the event of a decrease or loss of well yield, mitigation could include deepening of an existing well, relocation/replacement of a well, provision of indoor water storage tank(s), or a combination of these. • Mitigation to address changes in groundwater quality could include installation of a treatment system to meet the GCDWQ, deepening of well casing or well casing liners, well replacement, or a combination of these or other measures. Provision of an alternate source of drinking water (such as bottled water) may be provided while mitigation measures are being implemented.	• Identification of landowners within 500 m of blasting activities. • Establish baseline groundwater conditions for well users within 500 m of blasting and 300 m of dewatering activities. The baseline conditions would include collection well details, water level and water quality sampling. • A water level and groundwater quality survey will be completed at specified locations and at specified frequencies during the construction activities. Water quality samples will be analyzed for general chemistry, metals and bacteria. • Post-construction survey of at risk supply wells sampled during the pre-construction survey. The post-construction survey would include measurement of water levels and the collection of water samples for analysis of general chemistry, metals and bacteria.

Option 3	• In the event of a decrease or loss of well yield, mitigation could include deepening of an existing well, replacement of a well, provision of larger capacity indoor water storage tank(s), or a combination of these.
	• Mitigation to address changes in groundwater quality could include installation of a treatment system to meet the GCDWQ, deepening of well casing or well casing liners, well replacement, or a combination of these or other measures. An alternate source of drinking water (such as bottled water) may be provided while mitigation measures are being implemented.
		• Assess wells within the area of review to identify wells at risk of interactions with Option 3. Complete a baseline pre-decommissioning survey of wells identified to potentially be at-risk of interactions with Option 3. The potentially affected wells are between the current location of the Station and the Town of Woodstock. The multi-stage pre-decommissioning survey could include:
		  ◦ field verification of well locations on each property (including those constructed prior to 1994) and the collection of the following information regarding water wells: water level, pump intake setting, well depth, casing length and water demand;
		  ◦ identification of wells at risk close to the Station-controlled upstream river reaches (*i.e.*, very shallow, low yield wells which could become unsuitable for domestic use in the event of small (1 to 3 m) declines in stream stage);
		  ◦ collection of water samples from at-risk water for analysis of general chemistry, metals and bacteria; and/or
		  ◦ assessment of dry period effects on the Fredericton aquifer recharge, water quality and sustainable yield after removal of the Station.
		• Installation of automated water level data loggers would be installed in aquifers that service the major groundwater users.
		• Additional water level and groundwater quality monitoring will be done at specified locations and at specified frequencies during the decommissioning activities and lowering of the

Table 7.7 Summary of Additional Potential Mitigation and Information Requirements

Option	Additional Potential Mitigation	Additional Information Requirements
		headpond water level. • Post-decommissioning survey of at risk water-well users included in the pre-decommissioning survey. The survey would include measurement of water levels and the collection of water samples for analysis of general chemistry, metals and bacteria.

7.5.2 Discussion

Option 3 has the most potential to interact with groundwater and would require more mitigation than Option 1 or Option 2. The construction of new facilities for Option 1 or Option 2 has limited potential to cause a change in groundwater quantity and/or quality, as the current operating water level of the headpond is not expected to change substantially in either of these Options. However, in Option 3, the removal of the Station will result in the lowering of the water level of the headpond, resulting in a lowering of the static groundwater level adjacent to the headpond, which will likely result in lower well yields and negative changes to water quality in some wells.

In Option 3, some groundwater aquifers, especially those in sand and gravel immediately adjacent to the headpond could be adversely affected by lowered water levels in the river, thereby causing a reduction or complete loss of well yield. Low yield bedrock wells and shallow wells within 300 m of the current headpond as well as major groundwater users in the area of review could see pronounced changes in well yield that could render these wells unsuitable for their intended uses. In the event of decreased well yield, or if a well no longer provides sufficient yield for the intended use, further mitigation measures would be required including deepening of an existing well, replacement of a well, provision of higher capacity indoor water storage tank(s), or a combination of these. Further mitigation could also include provision of a temporary alternate source of drinking water (such as bottled water), while permanent mitigation measures are being implemented. Some large groundwater users near the headpond may need additional production wells or water quality treatment if an alternate water supply is required.

7.5.3 Assumptions and Limitations

The review is based on the following assumptions.

- Changes to groundwater quantity and/or quality will be observed at a distance no greater than 1 km from the shoreline of the headpond. Based on the regional and local geology in the area and most wells in the area are bedrock wells, this assumption is will likely lead to an overestimate of the potential interactions with groundwater.
- Water quality information was not correlated to distance from the headpond, or with well depth, based on the limitations of the *Potable Water Regulation* and associated lack of data in the NB OWLS database.

- Analysis of water well record information for wells constructed in 1994, or after, is sufficient to conduct the statistical analyses. Although information on water wells installed prior to 1994 are not included in the NB OWLS water well database, over 600 well records were available in the database and were considered to be sufficient to complete the analyses.

- Wells within 1 km of the headpond are assumed to be located at the spatial position provided in the database. Although this location usually is not the actual location of a well on a property, it provides a good indication of well locations over a large area. The available well logs and property identifiers, such as whether users are residential or commercial, are considered appropriate to evaluate the likely distribution of well users in the area.