6.0 SURFACE WATER

6.1 SCOPE OF THE REVIEW

This section reviews the potential interactions between surface water and the Options. The review considers existing characteristics of the Saint John River, including watershed conditions, flow regime, water and sediment quality, and sediment deposition and transport.

6.1.1 Why Surface Water is a Valued Component

Surface water, as it pertains to the quality and quantity of both water and sediment, is an important component of an ecosystem and is integrally linked to several other valued components (VCs). River flow affects the speed, depth, channel shape, sediment transport and ice flow regime (and subsequent flooding), water quality, temperature and oxygen levels. Surface water also generates and transports sediments and other sources of contaminants.

Source: www.google.ca

Surface water is a VC because of its critical importance to natural and human environments, particularly with respect to the aquatic nature of the Options.

6.1.2 Regulations and Policies Relevant to Surface Water

Where applicable, all Options will adhere to standard government legislation and associated regulations, including the following.

- *Canadian Environmental Protection Act (CEPA)* – administered by Environment Canada. The act promotes sustainable development though pollution prevention, and protection of the environment, human life and health from risks associated with toxic substances.
- *Clean Environment Act* – administered by the New Brunswick Department of Environment and Local Government (NBDELG). The Act is in place to protect the physical environment from contamination. Surface water quality in New Brunswick is regulated under the associated *Water Quality Regulation* and other related regulations.
- Guidelines for Canadian Drinking Water Quality (GCDWQ) – administered by Health Canada (2010b). Though they have no formal force of law unless adopted by provinces under a regulatory instrument, these guidelines pertain to potable water and have been adopted by the Canadian Council of Ministers of the Environment (CCME).
- *Clean Water Act* – administered by NBDELG. The Act is in place to protect existing and future sources of surface and drinking water. Surface water in New Brunswick is regulated under the *Potable Water Regulation* and the *Watercourse and Wetland Alteration Regulation* and other related regulations.

- *Navigation Protection Act (NPA)* – administered by Transport Canada. The NPA prohibits unauthorized impediments to navigation, and establishes an approval process for works that may affect navigation on navigable waters in Canada (as defined in the Act). The Saint John River downstream of the Mactaquac Generating Station (the Station) to the confluence with the Bay of Fundy is defined by the *NPA* as a navigable water under the Act.

- CCME Environmental Quality Guidelines, while not having formal force of law unless adopted by provinces under a regulatory instrument, provide additional guidelines that pertain to surface water and sediment quality, including aesthetics, aquatic life, and other matters.

6.1.3 Area of Review

The area of review (see Figure 6.1) includes the upstream extents of the headpond, and downstream at the TransCanada Highway overpass in Coytown. The upstream limit, just downstream of Hartland, is based on the extents of the Mactaquac headpond, approximately 97 km upstream of the Station. The downstream limit was selected to include this newer infrastructure in the analysis of changes due to potential ice jams.

The area of review was limited by the availability of data. Therefore, the area of review may change depending on the key issue and specific interactions with each Option.

6.1.4 Key Issues

The two key issues of concern for this VC are:

- potential change in surface water flow regime; and

- potential change in surface water or sediment quality.

Descriptions of the key issues are listed in Table 6.1.

Table 6.1 Description of Key Issues for Surface Water

Key Issue	Description
Potential change in surface water flow regime	• Water flow pattern changes (Interaction of change to water levels, depths, velocities). • Safety/navigation in the headpond/river. • Flow retention and management. • Ice flow regime. • Sediment transport. • Shoreline stability and slumping.
Potential change in surface water or sediment quality	• Water and sediment quality. • Assimilative capacity/mixing characteristics for existing effluent discharges.

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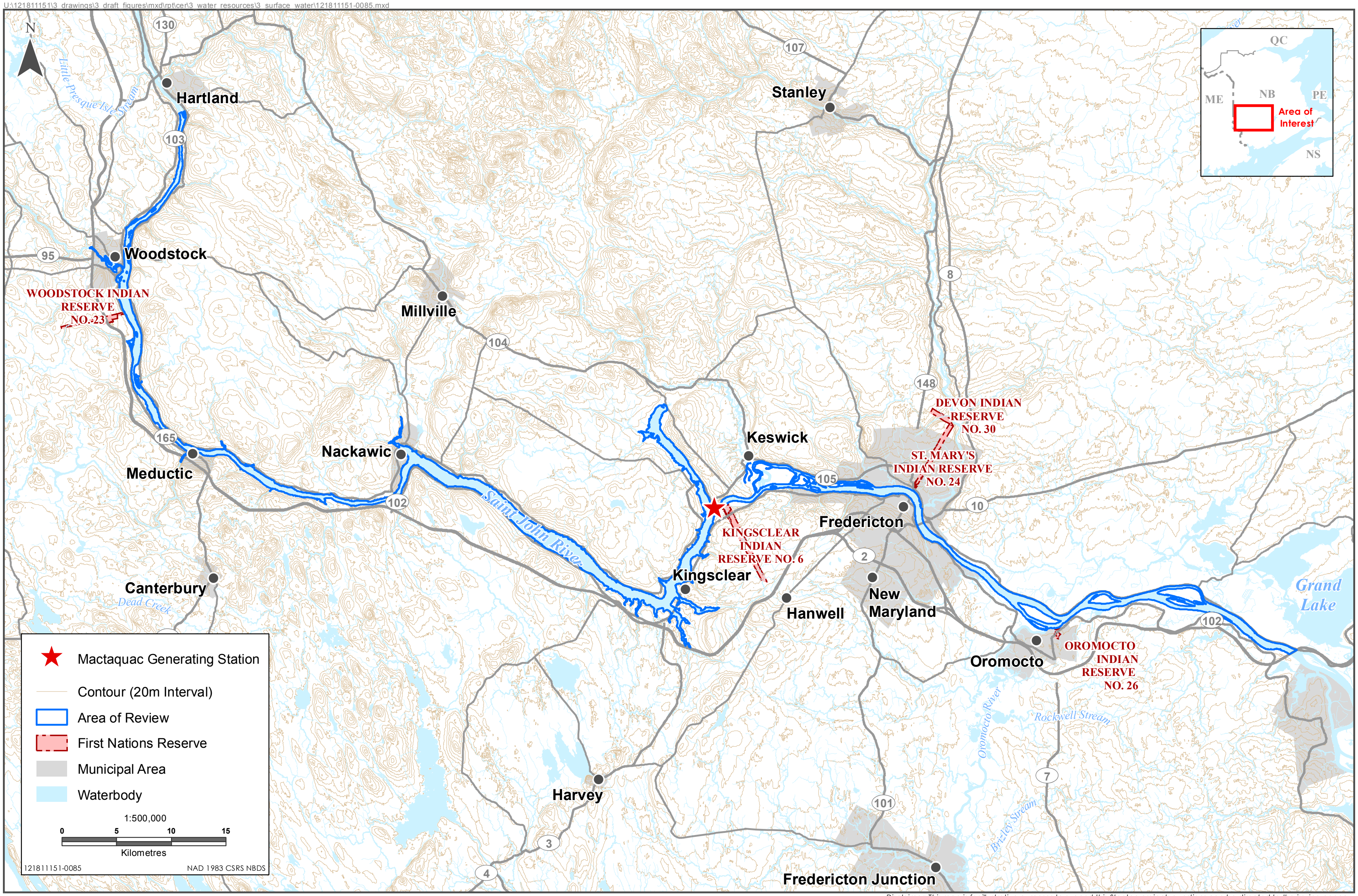

Base Data: Contours, First Nations Reserve and Roads are from SNB and Waterbodies and Watercourses data from NBDNR. All data downloaded from GeoNB.

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

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Area of Review for Surface Water

Figure 6.1

6.2 EXISTING CONDITIONS

6.2.1 Sources of Information

Sources of information used to characterize existing conditions include:

- conceptual engineering design and supporting information for each Option;
- published databases and digital maps, including:
    - the Water Survey of Canada HYDAT database (Environment Canada 2015a);
    - the New Brunswick Waters database (NB Waters 2015);
    - the Fresh Water Quality Monitoring and Surveillance mapping application (Environment Canada 2015f);
    - the New Brunswick Digital Topographic Database (SNB 1998);
    - the "Before the Mactaquac Headpond" story map (Holman 2014);
    - navigational charts of the Saint John River (CHS 1969; 1991); and
    - the New Brunswick Hydrographic Network geographic dataset (NBDNR 2015a);
- Service New Brunswick property information (SNB 2015);
- interviews with relevant government departments;
- preliminary results of field programs and analyses conducted for the Mactaquac Aquatic Ecosystem Study (MAES) being conducted by the Canadian Rivers Institute (CRI), including a bathymetric survey, LiDAR survey (Leading Edge Geomatics 2014), and water and sediment sampling (Kidd *et al.* 2015); and
- past research, studies or assessments conducted in the region.

6.2.2 Description of Existing Conditions

6.2.2.1 Watershed Characteristics

The Saint John River is the largest river in Atlantic Canada (Figure 6.2). Located principally in New Brunswick, it flows 700 kilometres (km) from its origin at Little Saint John Lake in Maine to the Bay of Fundy at Saint John. The tides in the Bay of Fundy cause the river level to fluctuate as far upstream as Fredericton (MacLaren 1979).

The Saint John River watershed basin, as shown in Figure 6.2, occupies an area of 55,100 square kilometres (km²). The watershed receives an average of 1,077 millimetres (mm) of precipitation per year, based on the Canadian Climate Normals (1981 to 2010) for the Fredericton Airport weather station (Environment Canada 2015g). The Fredericton Airport weather data are generally representative of average weather conditions in central New Brunswick. The majority of the precipitation occurs as rainfall, with snowfall accounting for an average of 219 mm per year (Environment Canada 2015g). These precipitation rates result in flowrates in the Saint John River at Mactaquac ranging from about 280 cubic metres per second (m^3/s) in summer, to more than 10,000 m^3/s during the spring freshet (Newton 2011).

Did you know?

The New Brunswick Hydrographic Network (2015) is a digital representation of the location, characteristics and connectivity of water and water-related features within the province. These attributes are fundamental to any GIS analysis of surface flows.

According to MacLaren (1979), the Saint John River drops a total of 480 m in elevation along its length. The Station is situated at a location of natural change in slope along the river. Portions of the river upstream of the Station are steeper than those downstream. The steeper upstream slopes provide suitable conditions for the generation of hydroelectric power. In total, 11 hydroelectric dams are located on the Saint John River and its tributaries (Lantz *et al.* 2011), some of which are operated as an integrated power system by NB Power (*i.e.*, Grand Falls, Sisson, Tobique, Beechwood, and Mactaquac stations).

The extent of the area of review, including the Mactaquac headpond and the Saint John River, is shown in the existing conditions mapbook (attached, under separate cover). The area of review covers a distance of about 159 km, as shown by the lines on the map from the Station along the centreline of the river. A profile of the river bed elevation along the Saint John River, and the bed slope at the Station, is provided in Figures 6.3 and 6.4, based on bathymetric survey data collected in 2014 (CRI 2014).

Drainage areas of the Saint John River (and its tributaries) were calculated using a digital elevation model (DEM) of the ground surface collected as part of the Mactaquac Aquatic Ecosystem Study (MAES) being carried out by the Canadian Rivers Institute (CRI) on behalf of NB Power. As shown in Table 6.2, the drainage area was calculated at the upstream and downstream boundary of the area of review and at the Station.

Table 6.2 Drainage Area of the Saint John River at Key Locations

Location	Distance from Station (km)	Drainage Area (km²)
Downstream of Hartland	97 (upstream)	35,730
Mactaquac Generating Station	0	39,898
Highway 2 bridge crossing in Coytown	62 (downstream)	44,934

A review of the New Brunswick Hydrographic Network (NBHN) database (NBDNR 2015a) identified more than 200 tributaries that flow into to the headpond. These tributaries transport collected runoff from the drainage area to the Saint John River. As a result, the flow rate of the river increases downstream as more tributaries join the river. Major upstream tributaries that flow into the headpond within the area of review include the Meduxnekeag River, Eel River, Shogomoc Stream, Longs Creek, Kellys Creek, Nackawic Stream, Pokiok Stream, and Mactaquac Arm (formerly the Mactaquac Stream). Major downstream tributaries in the area of review include the Keswick River, Nashwaak River, and Oromocto River.

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Sources: Watercourses and waterbodies from NBHN, Watershed data from NBHN, NHN, and USGS.

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

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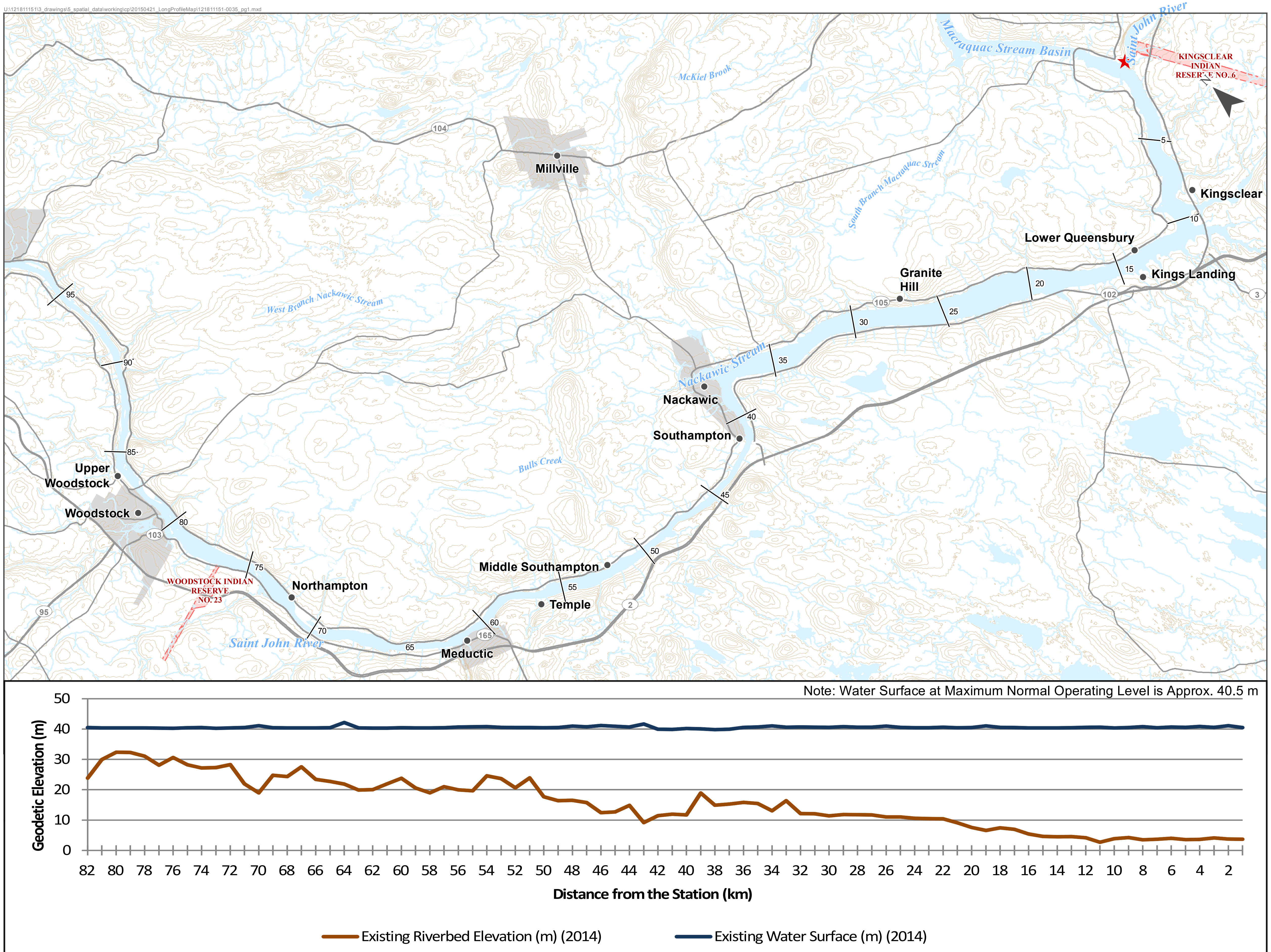
1218111511 - Mactaquac Project - NB Power

Saint John River Watershed

Figure 6.2



Longitudinal Profile of the Area of Review

Along the Saint John River from Upper Woodstock to Mactaquac
New Brunswick

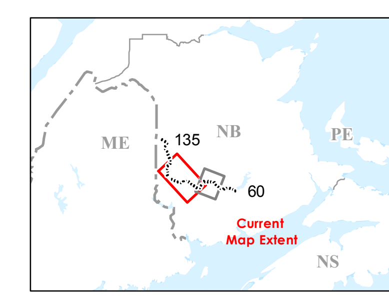
- Mactaquac Generating Station
- Contour (20m Interval)
- Distance from the Station (km)
- Watercourse
- Waterbody
- First Nations Reserve
- Municipal Area

1:210,000

0 2,000 4,000 6,000 8,000
Metres

121811151-0035 NAD 1983 CSRS NBDS

Base Data - Wetlands are fromNBDELG, Roads from SNB, Waterbody and Watercourse data from NB DNR. All data downloaded from GeoNB. Project Data - River Stationing from Stantec. Longitudinal Profile LiDAR Data from Leading Edge Geomatics, Vertical Coordinate System Canadian Geodetic Vertical Datum of 1928 (CGVD28). Bathymery Data from Centre for Research and Innovation.



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

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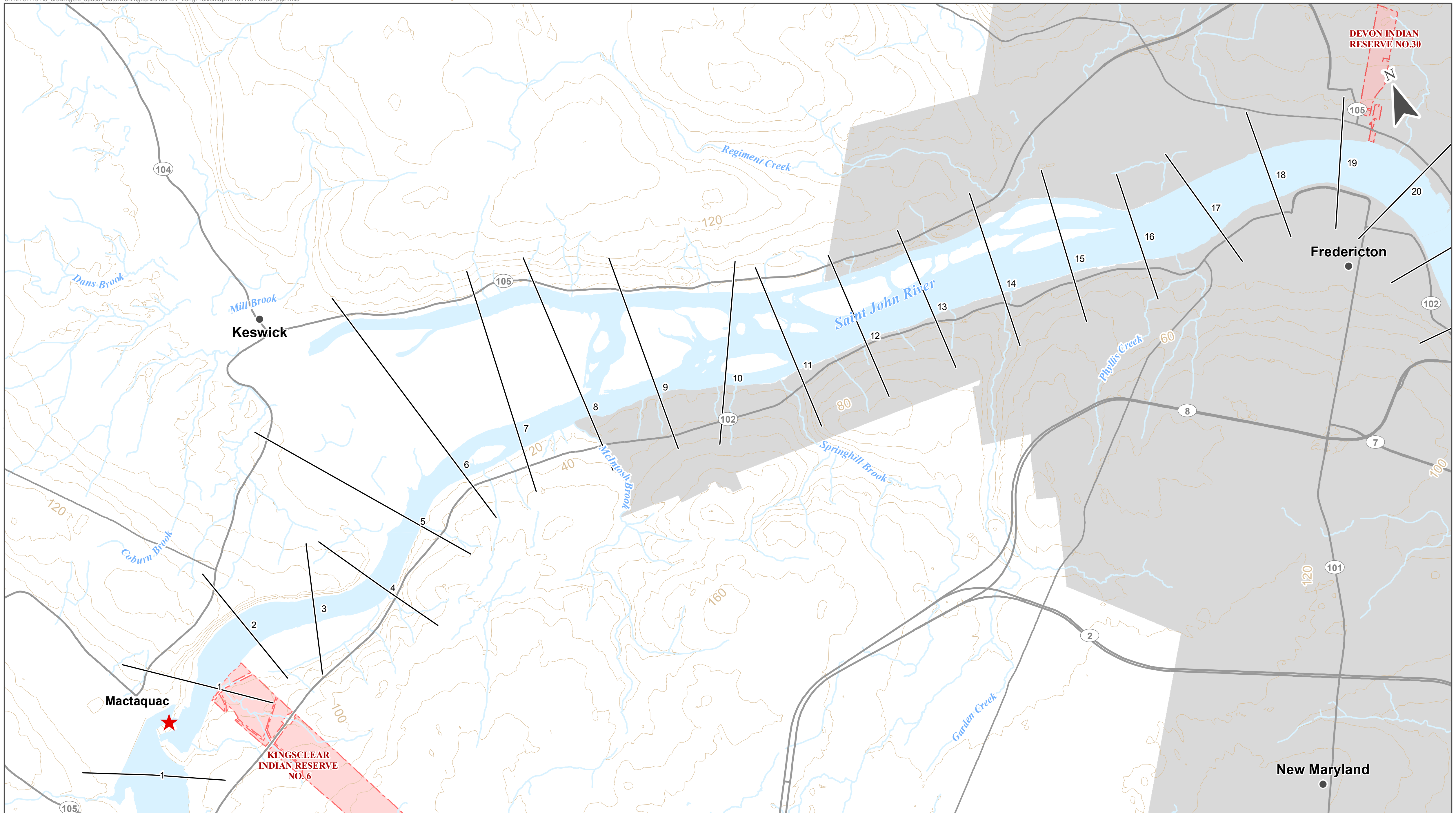
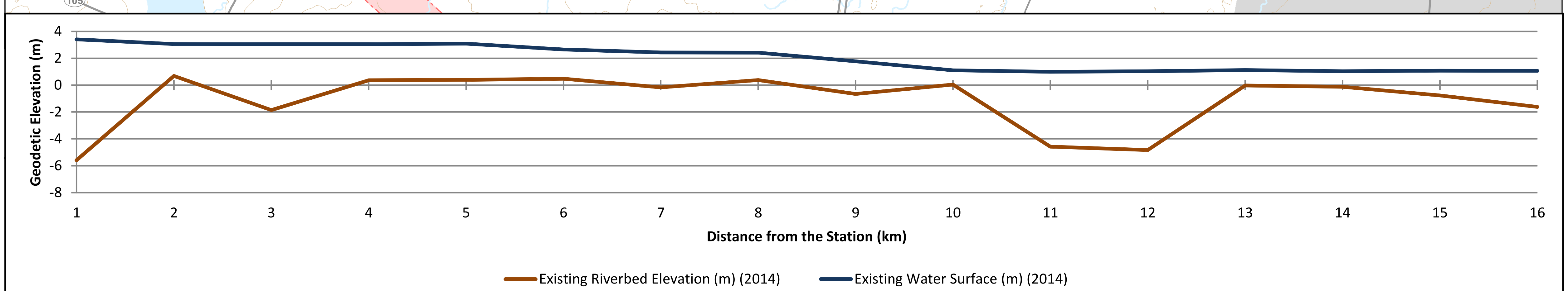
Figure 6.3





Longitudinal Profile of the Area of Review

Along the Saint John River from Mactaquac to Coytown New Brunswick

- Mactaquac Generating Station
- Contour (20m Interval)
- Distance from the Station (km)
- Watercourse
- Waterbody
- First Nations Reserve
- Municipal Area

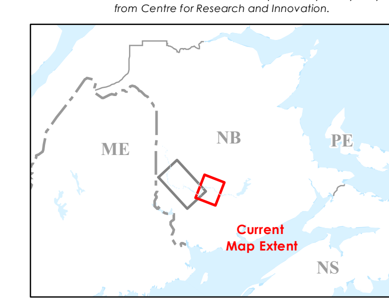
1:60,000

0 500 1,000 1,500 2,000

Metres

121811151-0035 NAD 1983 CSRS NBDS

Base Data - Wetlands are from NBDELG, Roads from SNB, Waterbody and Watercourse data from NB DNR. All data downloaded from GeoNB. Project Data - River Stationing and River. Longitudinal Profile LiDAR Data from LeadingEdge Geomatics, Vertical Coordinate System Canadian Geodetic Vertical Datum of 1928 (CGVD28). Bathymery Data from Centre for Research and Innovation.



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

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Figure 6.4

The characteristics of key features of the Saint John River within the area of review are listed in Table 6.3. The calculations are based on a GIS analysis of the 2014 aerial imagery combined with the calculated NBDNR (2015a) data river features in the headpond.

Table 6.3 Key Features of the Saint John River within the Area of Review

River Features	Upstream of the Station	Downstream of the Station
Length of area of review from the Station (km)	97 [a]	62
Wetted channel area (km²)	83.2	42.3
Average width/depth (m) [c]	740 / 26 [b]	600/6.6
Area of islands (km²)	0.43 [b]	18.0
Shoreline perimeter of islands (km)	18.4 [b]	125.4
Total shoreline perimeter (km)	354.6	236.7

Sources:
a Headpond reach as described by NB Power (Purdy, D., pers. comm., 2015).
b Measured by Stantec (2015b).
c Based on average depth and width measured every 10 km.

6.2.2.2 Flow Regime

Routine monitoring of watercourses in New Brunswick conducted by the Water Survey of Canada (WSC) has established long-term records of flow regimes throughout the province. Several WSC stations exist along the Saint John River. Two of the stations were used to characterize the upstream and downstream flow regime of the river, including:

- the Saint John River downstream of Mactaquac Station (WSC ID 01AK004), located 3.5 km downstream of the Station; and
- the Saint John River near East Florenceville station (WSC ID 01AJ001), located 118 km upstream of the Station.

Table 6.4 summarizes the minimum, mean, and maximum daily flow records for each station. NB Power provided the mean annual river flow downstream of the Station as being 813 m³/s.

Table 6.4 Flow Regime Characteristics of the Saint John River near the Mactaquac Generating Station

Water Survey of Canada (WSC) Hydrometric Station	Period of Record	River Flow (m³/s)			Drainage Area (km²)
		Minimum	Mean	Maximum	
Saint John River near East Florenceville (01AJ001)	1951–1991	13	663	9,170	34,200
Saint John River downstream of Mactaquac Station (01AK004)	1961–1995	21	813	11,100	39,000

Average daily flow records from these stations were used to generate the unit runoff, as shown in Figure 6.5. The unit runoff represents the average daily flow divided by the drainage area upstream of the WSC stations. It is useful to show that, when drainage areas of the same size are compared, the stations show essentially the same river flow response. As shown in the figure, the highest flows in the Saint John River occur in April and May, corresponding to the spring freshet. Flow is slightly higher in the fall (October to December) compared with dry months of January, February, July and August.

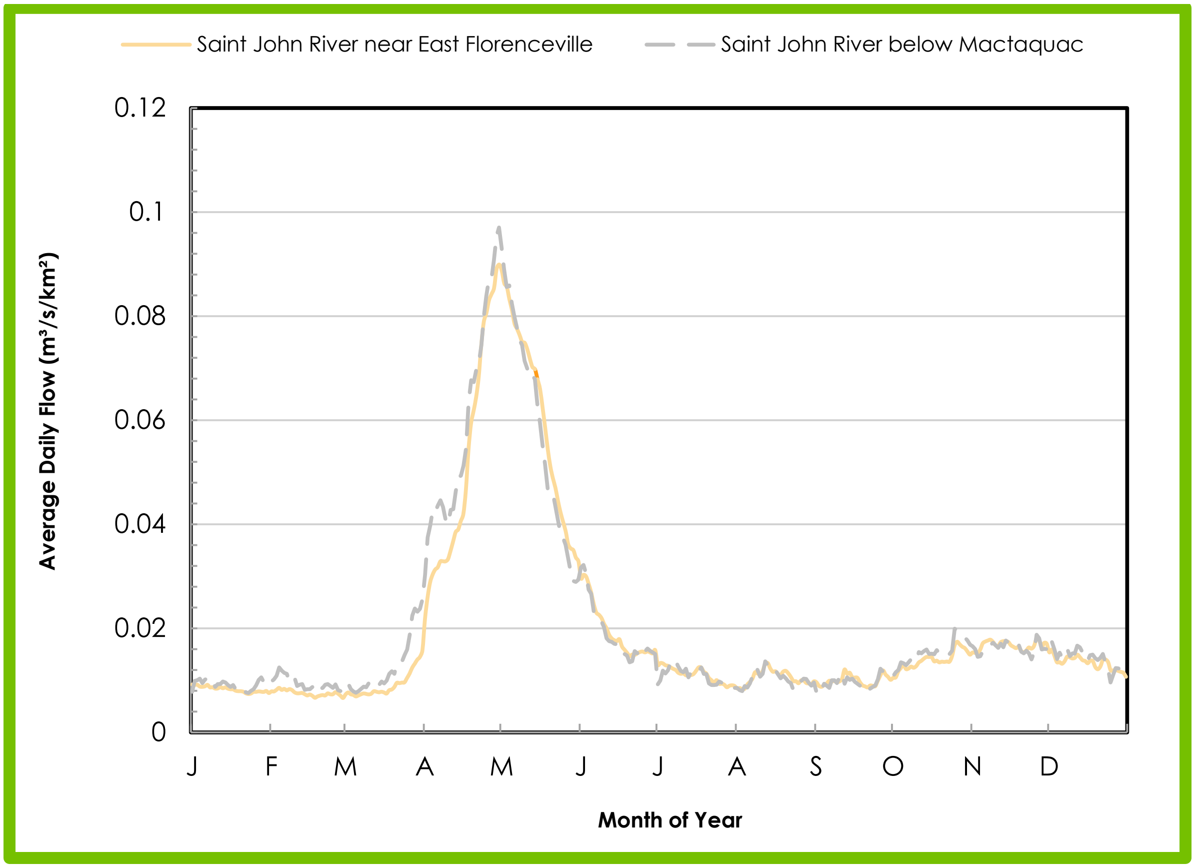


Figure 6.5 WSC Mean Monthly Hydrographs (Environment Canada 2015a)

Power generation at Mactaquac is largely controlled by the natural flow of the river. The Station is operated as a peak-load plant during periods of low flow, and as a base-load plant during periods of high flow (Jessop and Harvie 2003). During the peak-load cycle, which typically occurs in summer, the natural river flow is controlled to meet daily energy demands (Jessop and Harvie 2003). Sudden changes in water level occur during peak periods of power demand (*e.g.*, 07:00, 12:00, and 17:00), although these fluctuations are not observable when reviewing the WSC average daily flow records downstream.

An analysis of the one-day minimum flows (m^3/s) for the Saint John River from 1967 to 2012 was provided by NB Power. The analysis presents the river flows in terms of the return period, or how often the minimum river flow is likely to recur. Low flow events at the Station for return periods of 10, 20, 50 and 100 years are presented in Table 6.5. For example, a ten year low flow event represents a 10% chance of a lower flow in any one year and is more likely to recur than a 100 year low flow event (1% chance of a lower flow in any one year).

Table 6.5 Frequency of Low Flow Events at the Station

Return Period (years)	Minimum River Flow (m^3/s)
10	59
20	49
50	38
100	31
Source: NB Power	

NB Power provided an estimate of potential flood flow in the area of review that may be caused by precipitation events of varying magnitudes. Table 6.6 shows the frequency of flood flow events at the Station for return periods of 2, 5, 10, 20, 50, 100, 1,000 and 10,000 years. The 1,000 and 10,000 year return periods were included in the analysis of high river flow to capture a lower acceptable risk from flooding (0.1 and 0.01 % risk of a flood event occurring any one year).

Table 6.6 Frequency of Flood Events at the Station

Return Period (years)	Maximum River flow (m^3/s)
2	5,497
10	8,030
20	8,998
50	10,251
100	11,190
1,000	14,292
10,000	17,388
Source: NB Power	

The CRI reports that the frequency and magnitude of large floods in the Saint John River has increased since 1968, due to changes in climate in the Saint John River watershed. This is not attributed to the construction of the Station (CRI 2011).

6.2.2.3 Ice Jams and Related Flooding

The Saint John River has solid ice cover in winter with the exception of downstream of Edmundston, where the water is warmed by paper mill effluents, and immediately below the Station due to higher turbulence in the river flow. The average ice thickness in the headpond between 1976 and 2004 was approximately 50 cm (NBDTI 2015). This thickness is consistent with the New Brunswick average reported by LeBrun-Salonen (1983). On the Saint John River, spring break-up usually occurs during the second or third week of April (LeBrun-Salonen 1983).

Ice jams are the most dramatic of flood events, and are caused by the breakup and rapid accumulation of fragmented river ice (Environment Canada 2011). The major factors affecting ice breakup include the rate of snowmelt and rainfall and the subsequent runoff. The water level rises from the added input to the river system exerting pressure on the ice cover and forcing the ice to break-up. As the ice moves downstream it lodges on bars, islands, and at bridge piers (Environment Canada 2013b).

In New Brunswick, approximately 70% of recorded flood damages have been caused by ice-related floods (Environment Canada 2011; Tang and Beltaos 2008). Historic flood events caused by ice jams have been recorded at multiple locations on the Saint John River, including but not limited to the spring floods of 1887, 1936, 1976, 1987, 1991, 1993 and 2012 (NBDELG 2012). These events resulted in extensive damage, including washouts of bridges and roads. For example, the former Jewett's Mills bridge at Mactaquac was carried away in 1887, the Canadian Pacific Railway bridge in Woodstock was washed out in 1976, and the Sharps Island Railway bridge was washed out in 1987. Reports on floods on the Saint John River date to the late 1780s, although this earlier information is limited.

Data on the occurrence of ice jam events upstream and downstream of the Station were compiled based on the published ice jam location data as well as the ice jam database maintained by NBDELG (2013b). The results are shown in Figure 6.6 for three segments (or reaches) of the river:

- one reach downstream of the Station with a reach length based on half the length of the headpond (labelled "Downstream"); and
- two upstream reaches of the Station generally correlated to lengths also based on half the length of the headpond; these are the upper and lower portions of the headpond reaches (labeled as "Upper Headpond" and "Lower Headpond").

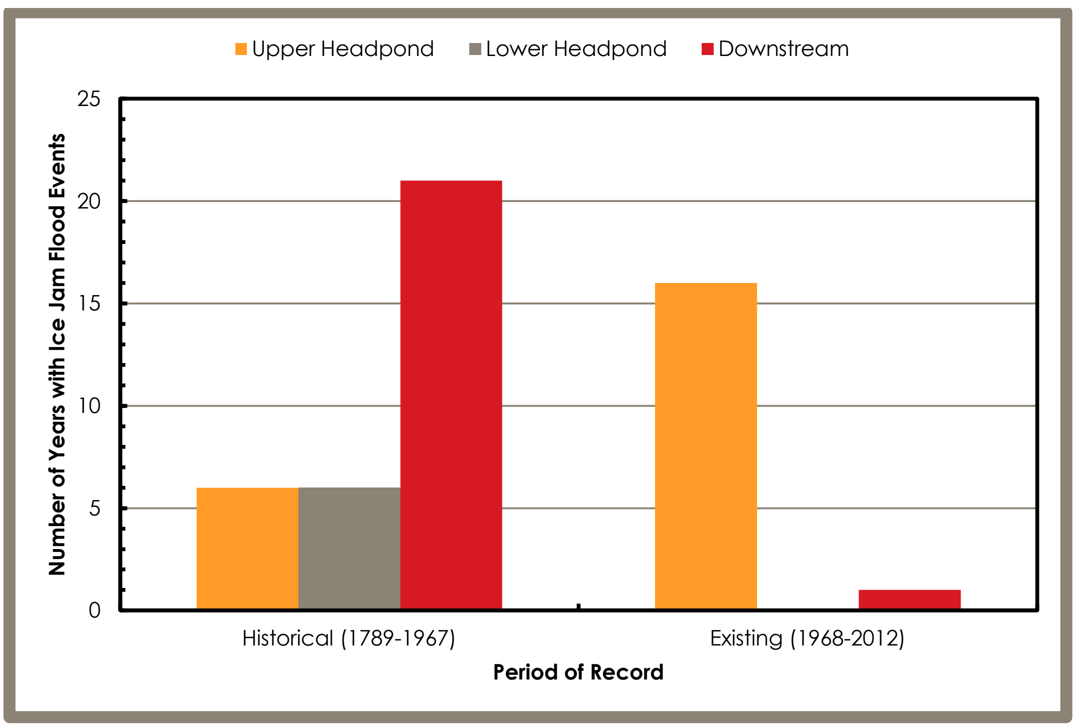
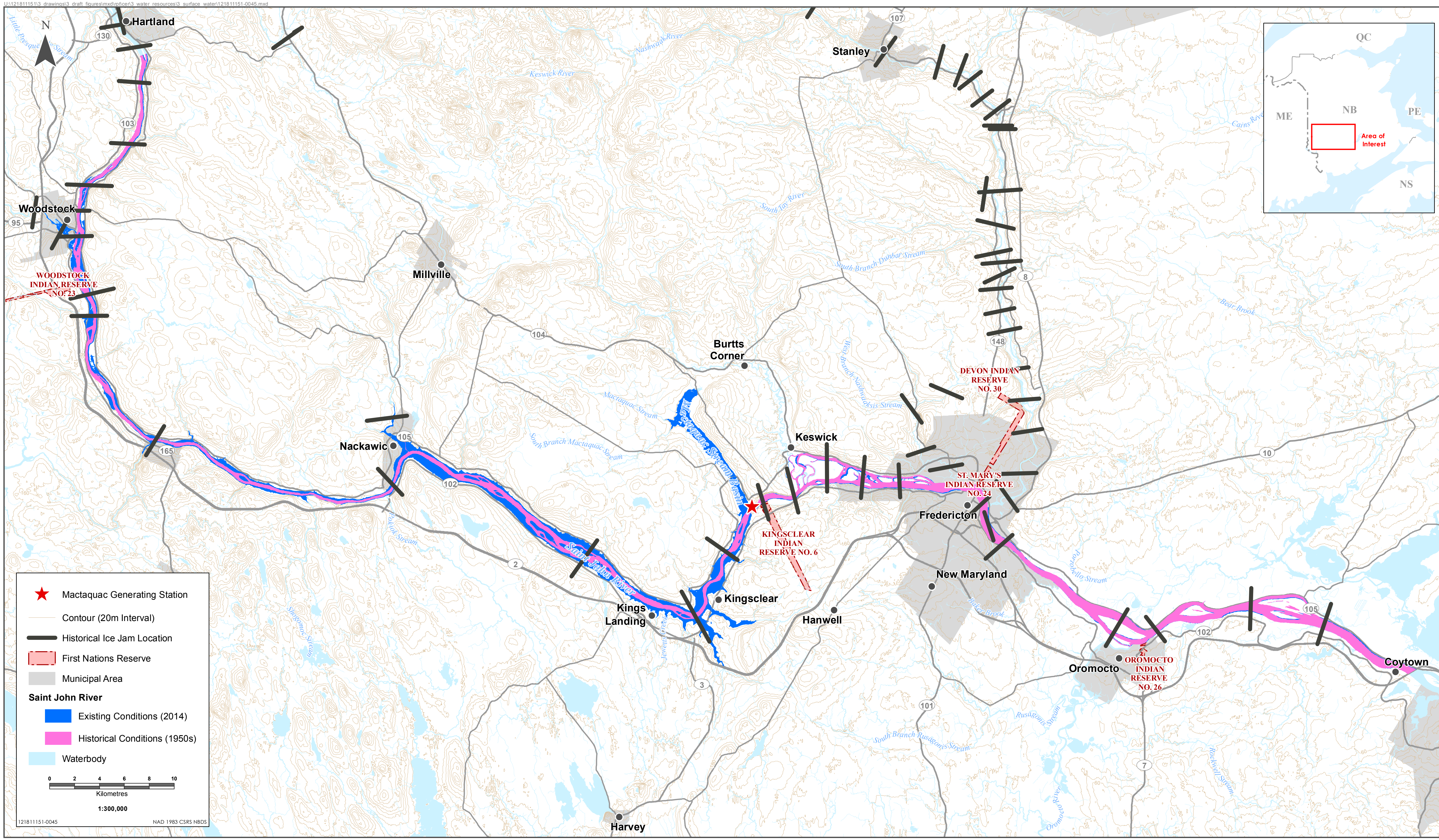


Figure 6.6 Occurrence of Ice Jams Upstream and Downstream of the Station

Historical locations of ice jam events are shown in Figure 6.7 (NBDELG 2013b).



Base Data: Contours, First Nations Reserve and Roads are from Service New Brunswick and Waterbodies and Watercourses data from New Brunswick Department of Natural Resources. All data downloaded from GeoNB.
Project data: Historical shoreline was digitized by Stantec from several NTS topo-maps spanning the 1950s.Historical Ice Jam Locations from NBDELG.

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

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Historical Ice Jam Locations of the Area under Review (after NBDELG 2013b)

Figure 6.7

As shown in Figure 6.6, from 1968 to 2012, 16 ice jams occurred in the upper headpond, none in the lower headpond and one downstream of the Station. Before construction of the Station (1967 and earlier), there were about six ice jams in the upper headpond, six in the lower headpond and just over 20 downstream. The locations of the ice jams are shown in Figure 6.7. While the historical length of record is much longer than the existing record, many historic ice jam flood events may not have been reported. Since the construction of the Station, routine flood monitoring has occurred yearly because of higher potential damages due to more extensive development within the watershed.

The headpond allows for the formation of a thick and extensive ice sheet. This ice sheet is held in the lower headpond, and melts in place prior to spilling over the dam. The Station prevents the migration of large amounts of ice downstream, thus preventing ice jams from occurring both in the lower headpond, and downstream. The upper headpond generally has ice break-up in the spring, which encounters the more intact ice sheet in the lower headpond, thus making the upper headpond more prone to ice jams.

Since construction of the Station, ice jam flooding downstream of the Station as far as Coytown has occurred only once (in 1970) and was likely caused by the release of ice from the Nashwaak River. This suggests that ice jam flooding could occur again downstream; however, the frequency of flooding is greatly reduced as a result of the Station.

6.2.2.4 Sediment Characteristics

Similar to most watercourses, the Saint John River moves sediments suspended in its flow (known as suspended load) and at or near the bottom of the river (known as bed load). The amount of sediments that is transported depends on the instantaneous flow in the river as well as features of the watershed, including its size, its geological and physical characteristics and the land use within the watershed.

Higher flows can move larger amounts of sediment because of higher velocities, which in turn can apply larger forces to sediment. Once sediments enter the stream, the ecosystem strives to reach equilibrium, between the force that moves the sediment downstream (*i.e.,* the flow in the river) and the force that holds the sediment in place (*i.e.*, the force of gravity).

When river flow is altered, sediment movement patterns can also be affected. For example, sediment movement in the Saint John River has changed as a result of changes in flow characteristics (*i.e.*, increased water elevations and reduced water velocities) since construction of the Station. The reduction in water velocities caused by the headpond has created higher sediment deposition rates (meaning larger sediment particles are found at the upstream sections of the headpond), while smaller sediment particles travel farther or even pass the dam structure. This change in sediment movement will continue for the life of the dam.

Particle Size Distribution

Sediment samples from the headpond were collected and analyzed by CRI in 2014 to better understand sediment characteristics. Figure 6.8 shows the variable particle size distributions along the headpond (Chateauvert *et al.* 2015) using the "Wentworth" size class for particle diameters in micrometers (μm). The particle size distribution is defined using the D10, D50, and D90, which refer to the diameter of particles where 10%, 50% and 90%, respectively, of particle diameters are smaller than the sample. The sample site locations are shown in the existing conditions mapbook (attached under separate cover).

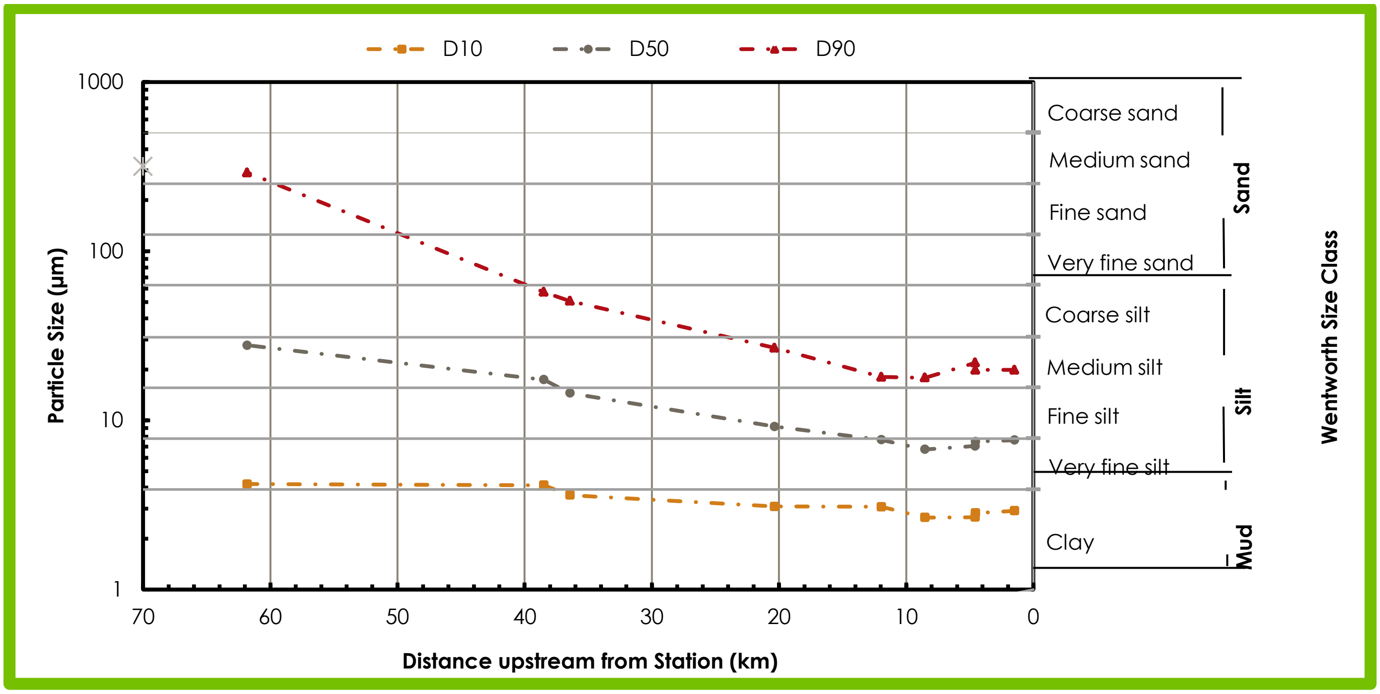


Figure 6.8 Particle Size Distribution in the Headpond

As expected, larger particles were found in the upper reaches of the headpond (very fine silt to medium sand), whereas particle size was smaller towards the middle areas of the headpond (very fine silt to very fine sand) and near the Station (very fine silt to coarse silt). This is because only smaller particles are able to reach the lower reaches of the headpond (Chateauvert *et al.* 2015) due to the reduction in velocity. This is consistent for most dams, although the amount of sediment that is trapped in the headpond is unique to each dam.

Suspended Load and Flow Rates

Limited measurements of suspended load were taken by Environment Canada at monitoring station 01AK004, downstream of the Station (data exist only for November 1966 to November 1967). Since the Station was not operational until 1968, these sediment measurements reflect conditions before flows were fully altered by the dam. Sediment loads and flow rates for 1967 are shown in Figure 6.9.

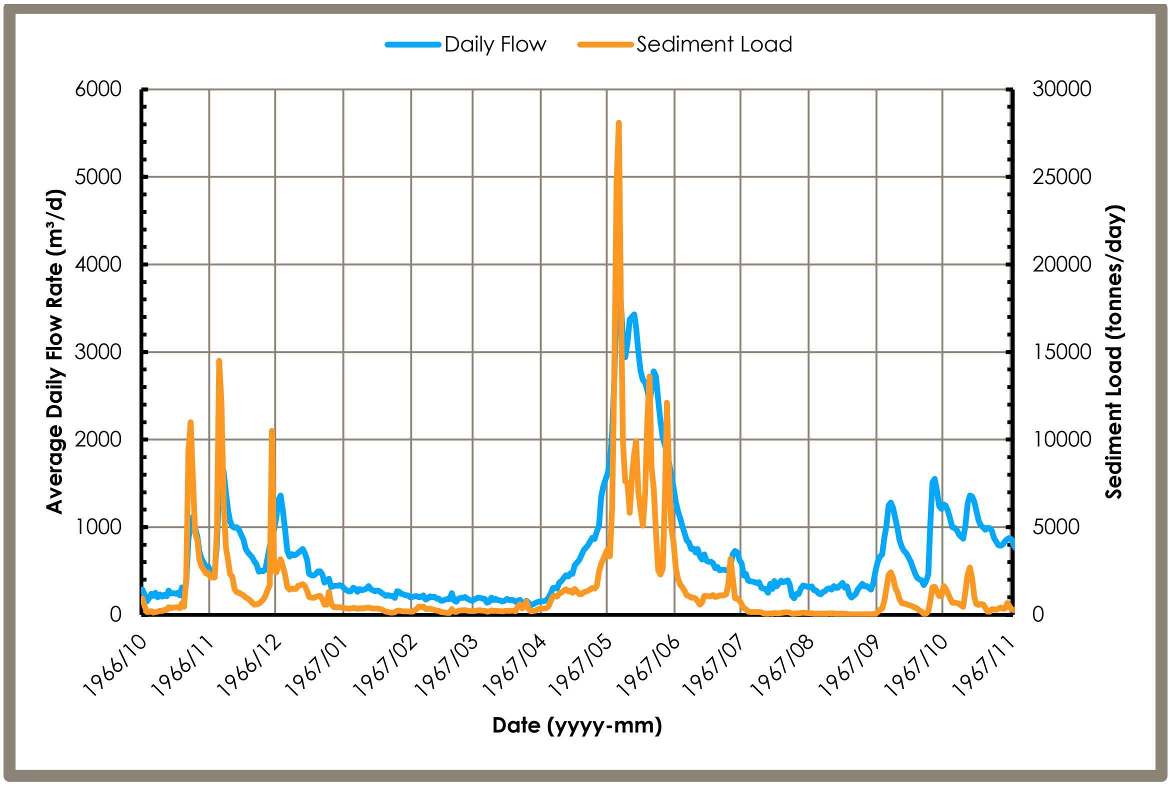


Figure 6.9 Sediment Loads and Flow Rates downstream of the Station – 1967 (Environment Canada 2015a)

Figure 6.9 shows a strong correlation between suspended load and river flow rates. The largest suspended load amounts occurred during the spring freshet in May, when river flows were highest and had more capacity to carry sediments; the lowest sediment loads occurred during low river flow conditions in August. The data also show a quick response between the occurrence of peak times between flows and sediment amounts. The total suspended load estimate between November 1, 1966 and October 31, 1967 was 559,332 tonnes (t). The average suspended sediment concentration for the same period was 18.2 mg/L, with maximum and minimum concentrations ranging from 140.2 mg/L to 0.9 mg/L, respectively.

The average sediment input measured just downstream of the Station for one year of WSC record (1966–1967) was 14 t/km². This is comparable to the sediment input in the Kennebecasis River at the Apohaqui Station (19.1 t/km²), and falls within the range of 6.4 to 29.4 t/km² observed in three watersheds in New Brunswick (Bray and Xie 1993).

Did you know?

A **cross-section** of the river represents a "slice" of the river at a specific location to analyze riverbed characteristics and flows at that location.

Sediment Deposition and Erosion

A total of eight cross-sections were created within the headpond to analyze areas of sediment deposition and erosion, as shown on Figures 6.10 to 6.17. The cross sections present the bathymetry of the headpond for 1969 (CHS 1969) and 2014 (CRI 2014).

By comparing the recent and historical bathymetric data, it is possible to better understand where deposition and erosion have occurred in the headpond. The cross sections are indicative of a particular location and may not be representative of the entire reach.

Based on a review of the cross-sections, it is clear that any changes at these sections have been minimal during the lifespan of the dam. The cross-sections show little change between the years 2014 and 1969, with the exception of the cross-section at Nackawic which shows deposition. At this location, deposition occurred at the inside of a river bend, a typical depositional feature in a watercourse. Deposition may be occurring in areas where data was not available and some sediment fractions may have continued to move downstream past the headpond. Preliminary indications from the MAES work being conducted by the CRI are that while there is a thin film of poorly consolidated sediments throughout the headpond, there are few areas where sediment deposition greater than 30 cm thick has occurred.

Large reservoirs are capable of storing water for long periods of time and therefore are able to remove a large fraction of incoming sediments. Unlike large reservoirs, the Mactaquac headpond follows the river path (mainly a linear feature) with relatively small storage capacity when compared to its annual river flow input. Some incoming sediment fractions may therefore not have enough time to be deposited in the headpond and may spill over the dam. In this way, the headpond likely behaves differently than large reservoirs when considering the amount of sediment deposition.

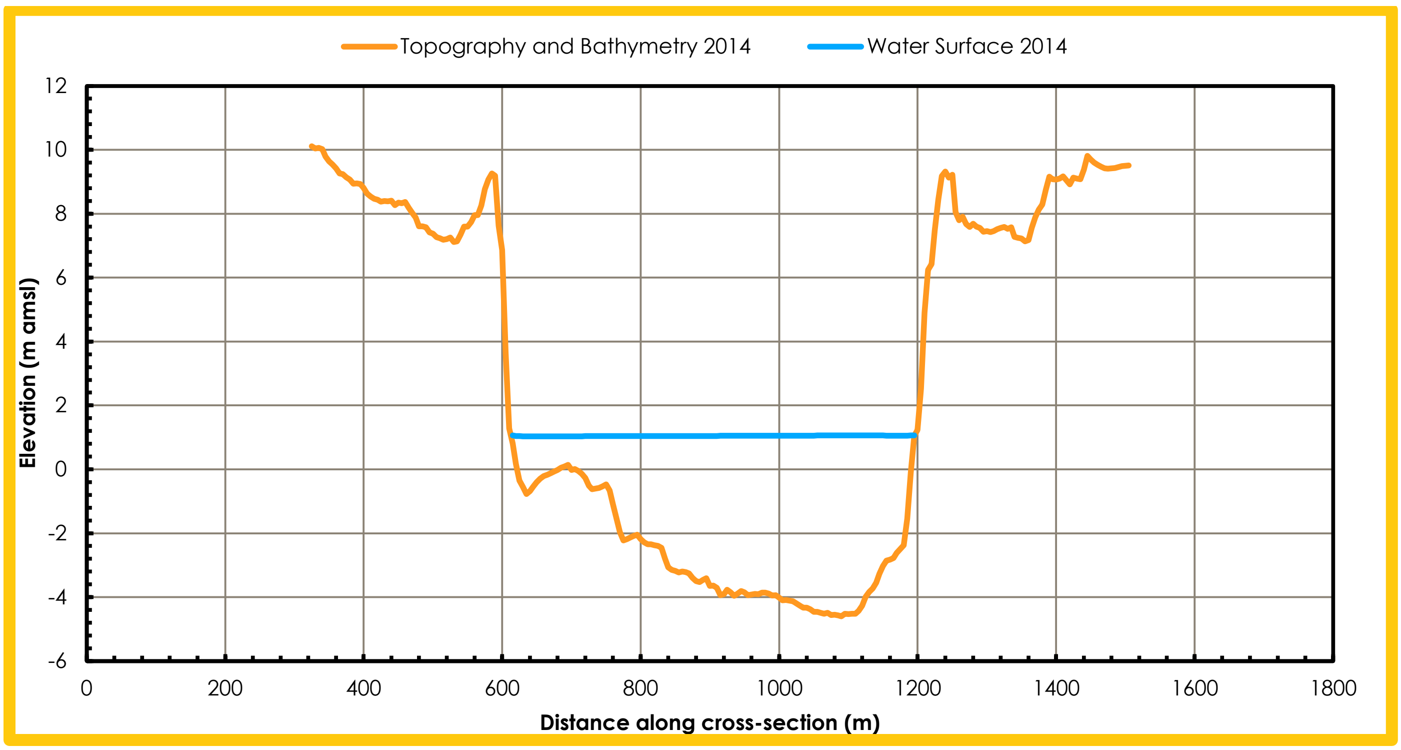


Figure 6.10 River Cross-Section Located 19 km Downstream of the Station at Fredericton

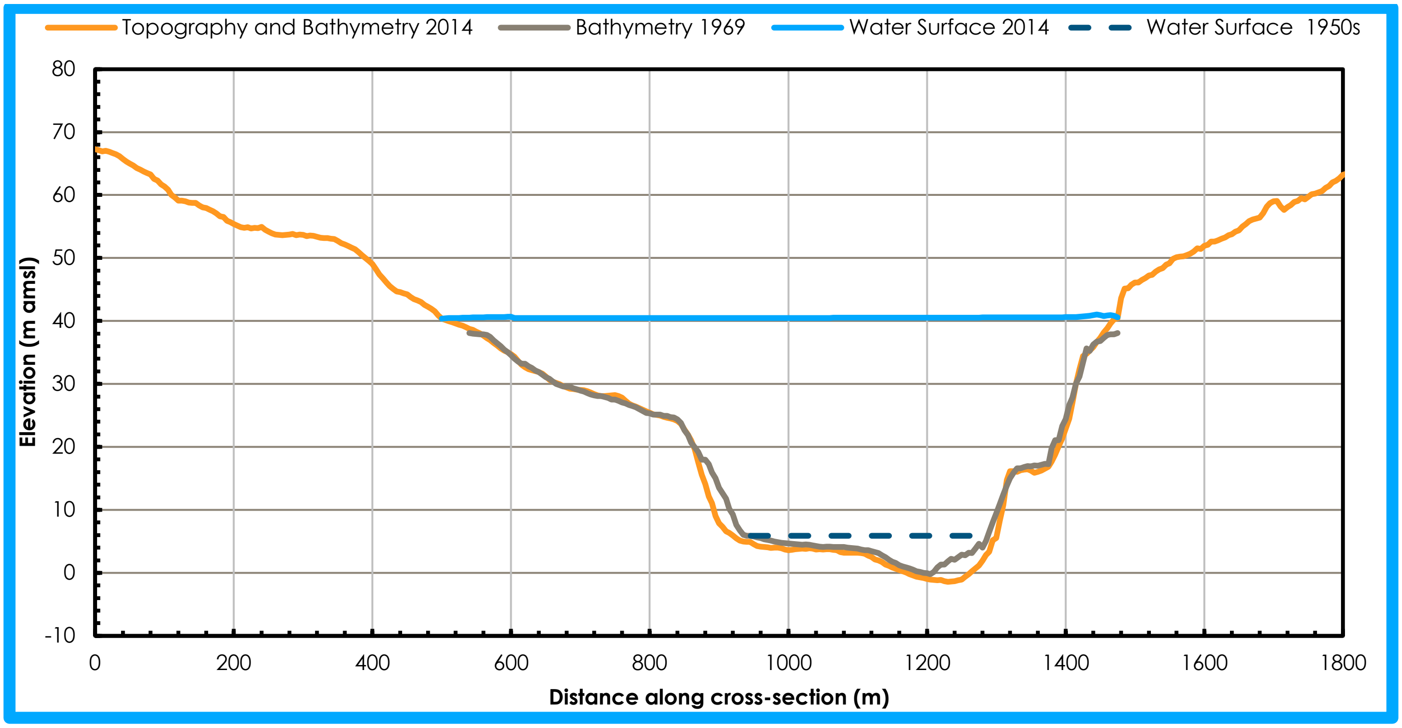


Figure 6.11 River Cross-Section Located 1 km Upstream of the Station at Mactaquac

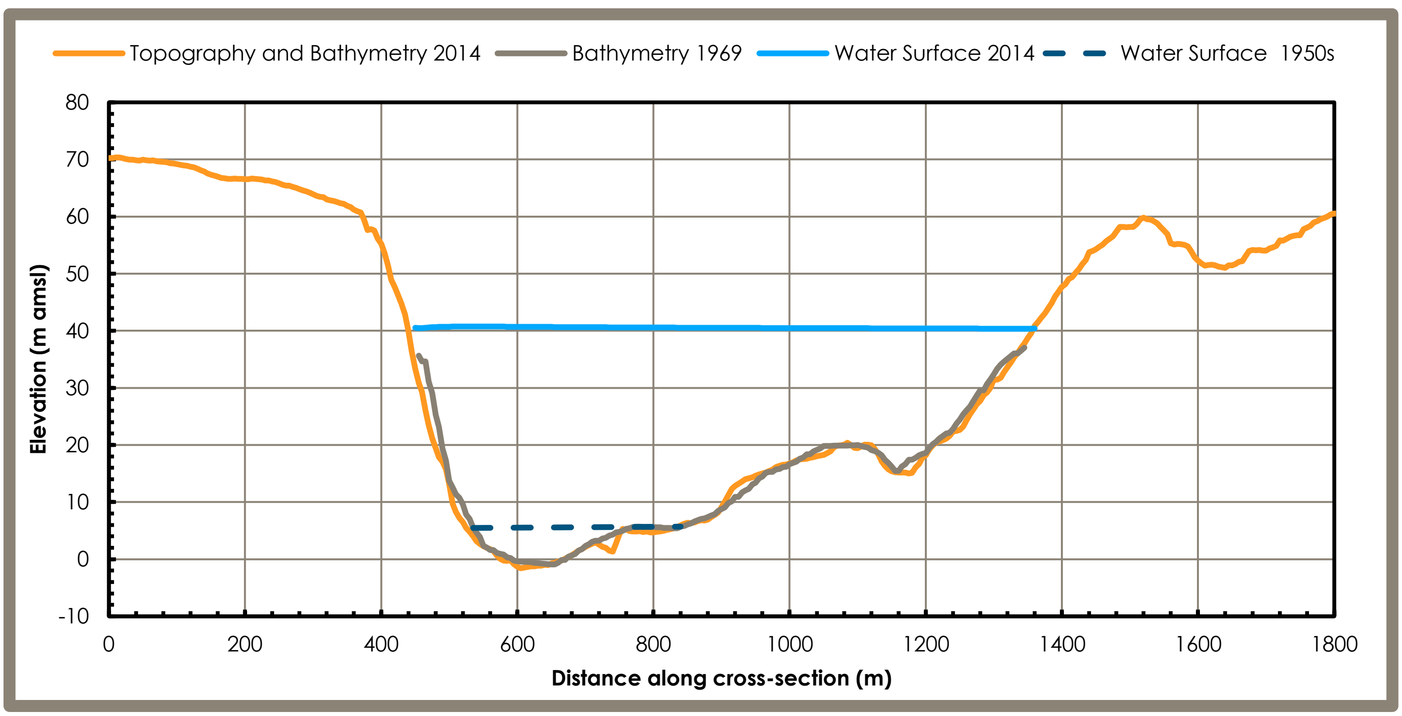


Figure 6.12 River Cross-Section Located 8 km Upstream of the Station at Upper Kingsclear

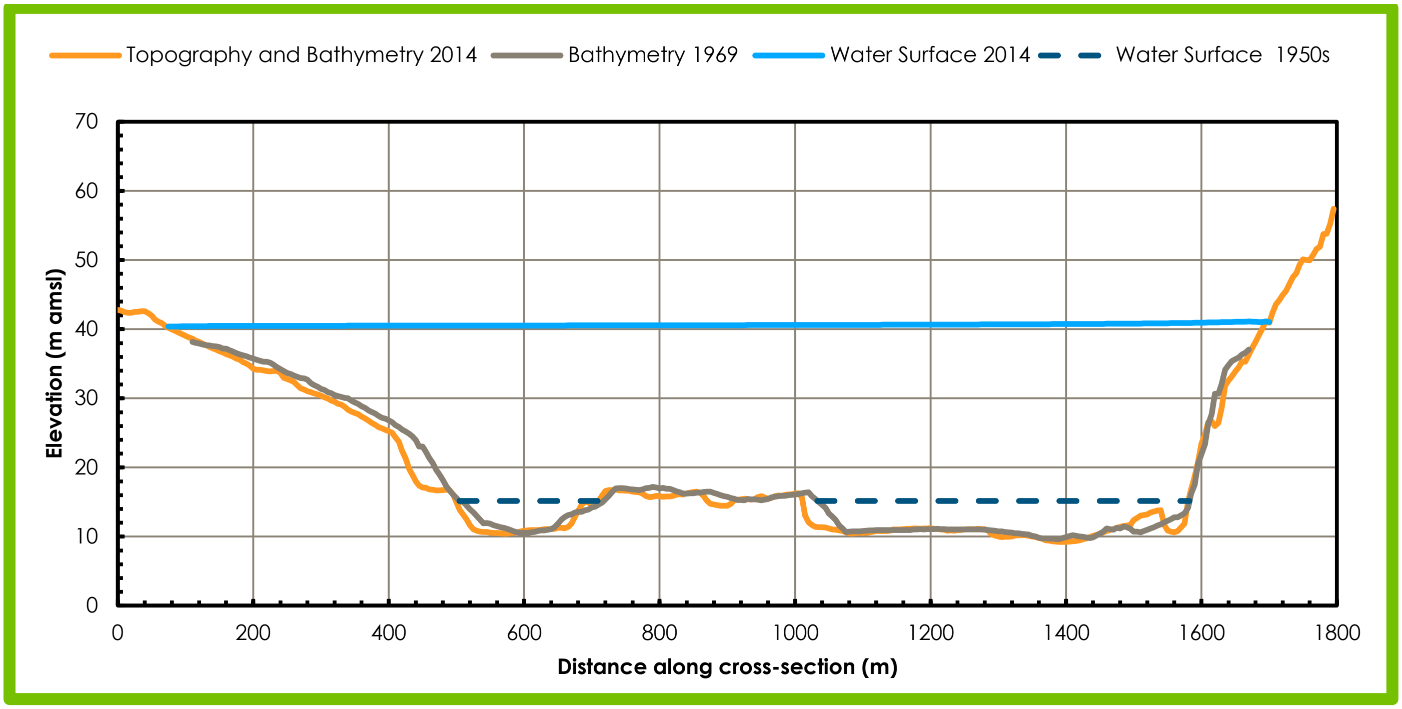


Figure 6.13 River Cross-Section Located 22 km Upstream of the Station at Granite Hill

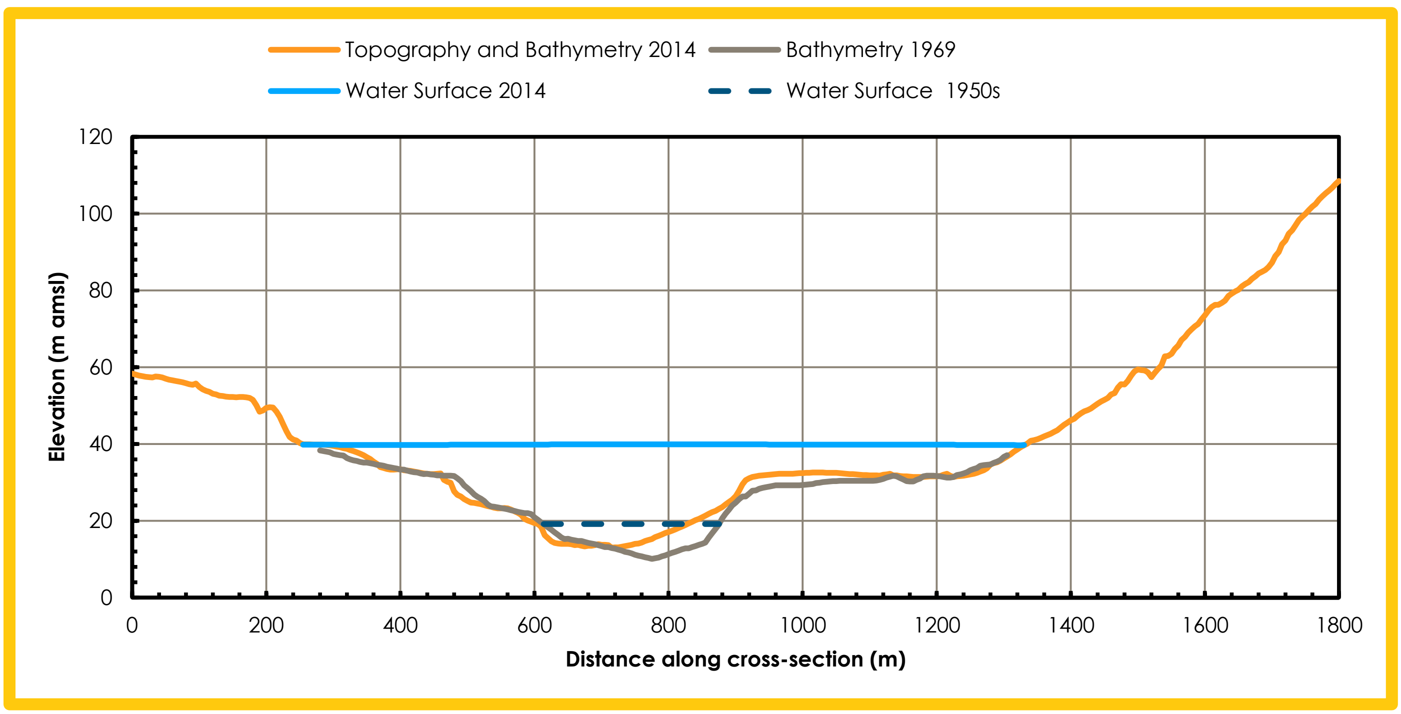


Figure 6.14 River Cross-Section Located 37 km Upstream of the Station at Nackawic

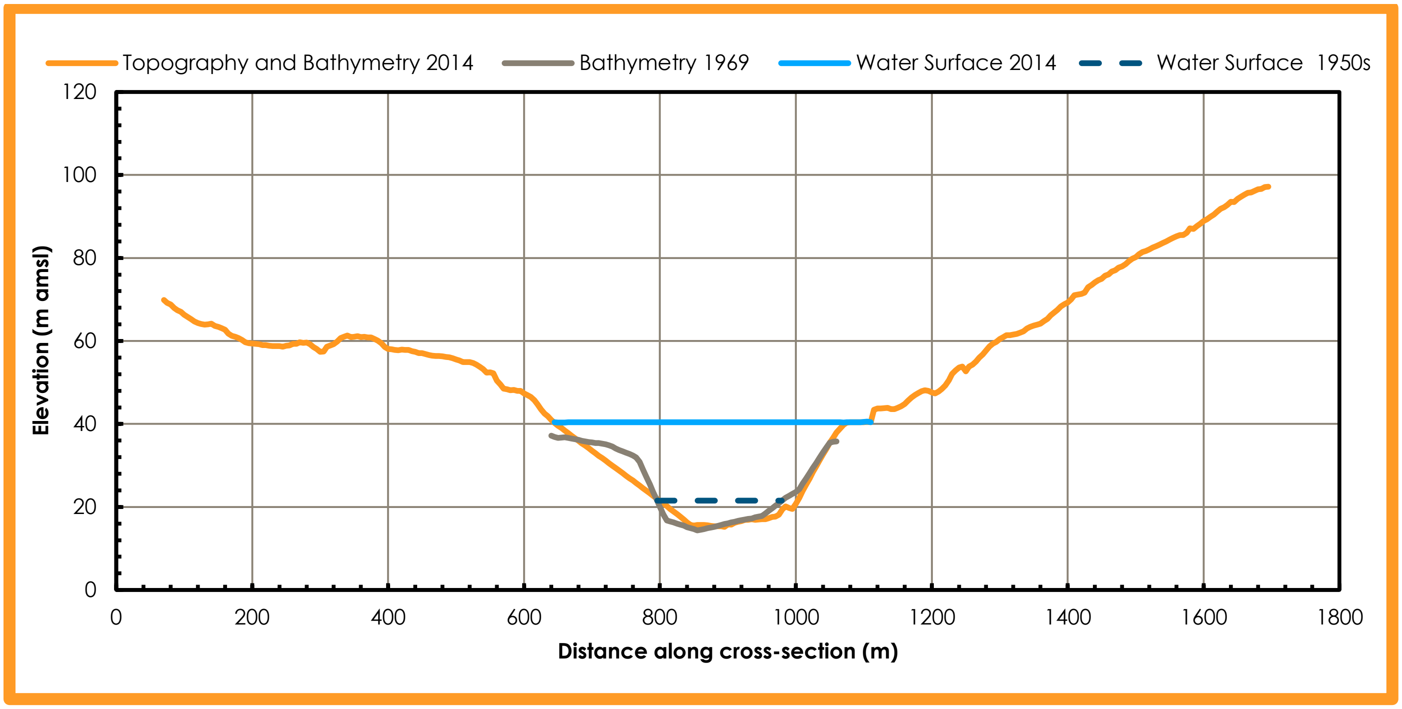


Figure 6.15 River Cross-Section Located 49 km Upstream of the Station at Mid-Southampton

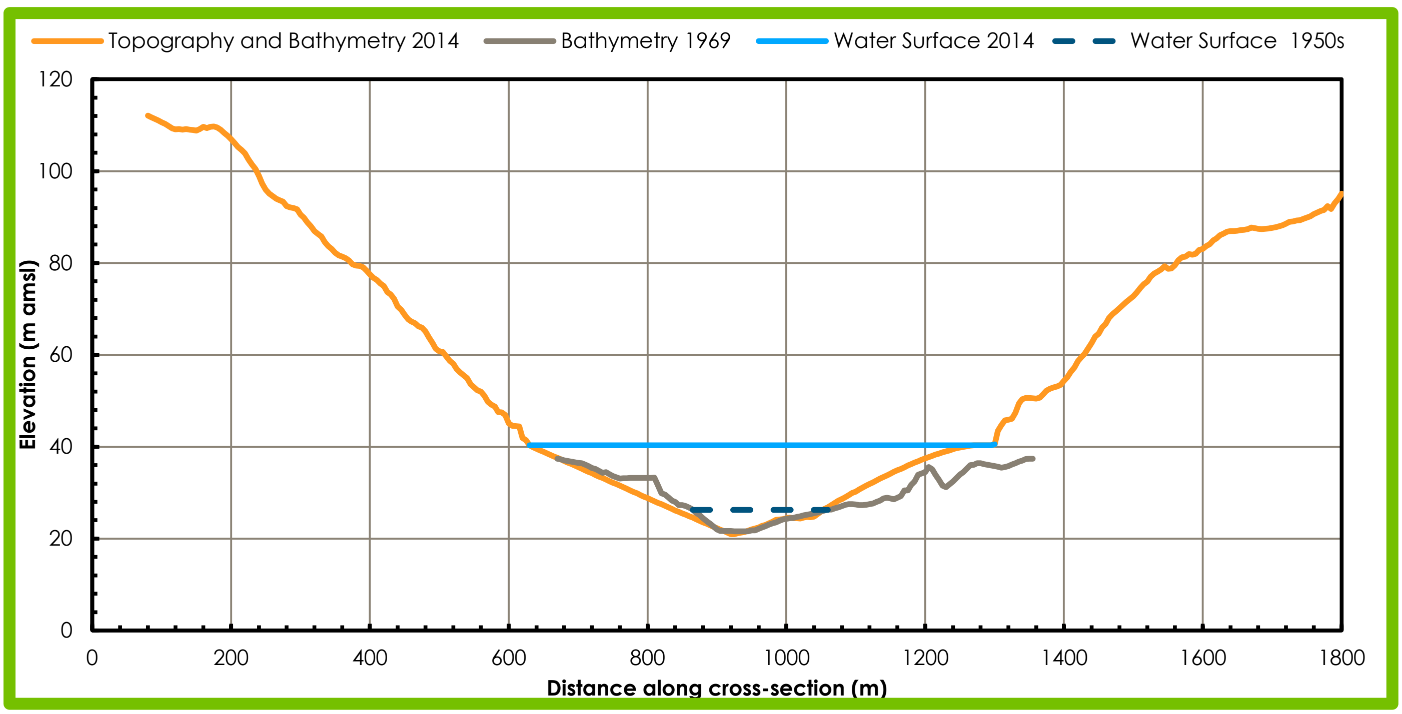


Figure 6.16 River Cross-Section Located 62 km Upstream of the Station at Meductic

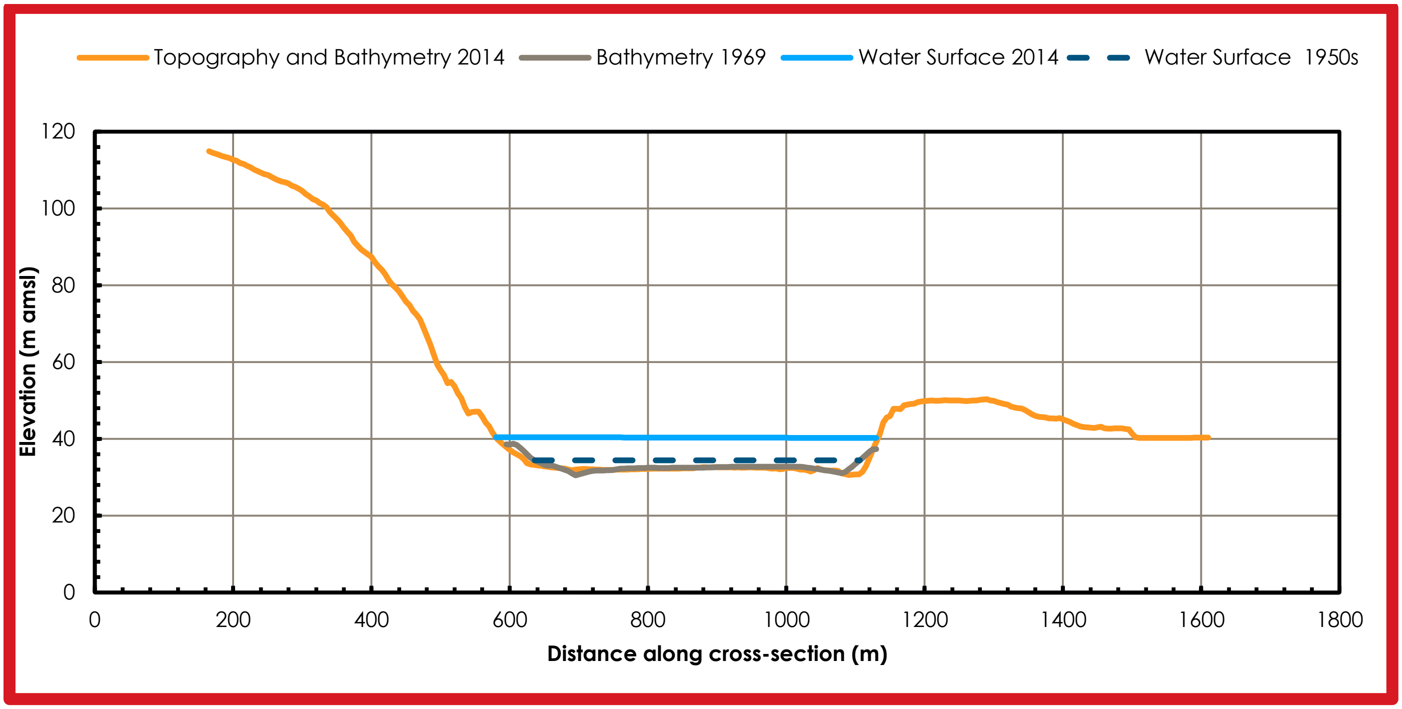


Figure 6.17 River Cross-Section Located 81 km Upstream of the Station at Woodstock

6.2.2.5 Surface Water Use

The Saint John River and its tributaries supply water to several users within the area of review (see Table 6.7). Other municipal and industrial surface water intakes in the river are associated with irrigation and process water supply. Water is also pumped from various locations to fill tankers for fire suppression.

The Mactaquac headpond is heavily navigated, and some areas of the floodplains of both the river and tributaries are populated (*i.e.*, Fredericton). The river is actively used for recreational purposes. Only non-recreational surface water use is described in Table 6.7.

Table 6.7 Surface Water Use

User	Location	Description of Surface Water Use	Source
Gray Aqua Farms Ltd.	71 km upstream of Station	Process water for aquaculture facility	Gray, T., pers. comm., 2015
Town of Nackawic	38 km upstream of Station	Fire suppression, when fire hydrants are not accessible	Walker, D. , pers. comm., 2014
Nackawic Golf and Country Club	Off Nackawic Stream, confluence approximately 37.5 km upstream of Station	Irrigation for the golf course from Nackawic Stream	Nozzillo, D., pers. comm., 2014
AV Nackawic Mill	Off Nackawic Stream, confluence approximately 37.5 km upstream of Station	Process water for mill	NATECH (2015a)
Kings Landing	14 km upstream of Station	Supply for small reservoir used to feed the mill during dry periods	Little, M., pers. comm., 2015

Table 6.7 Surface Water Use

User	Location	Description of Surface Water Use	Source
Riverside Resort and Conference Centre	1.5 km upstream of Station	Potable water supply for resort	Hashemi, S., pers. comm., 2014
Upper Kingsclear Fire Department	8 km upstream of Station	Fire suppression from four locations on the headpond.	MacPhee, pers. comm., 2014
Department of Fisheries and Oceans Canada – Mactaquac Biodiversity Facility (Fish Hatchery in Kingsclear)	1 km upstream of Station	Process water for fish hatchery	Dunbar, R., pers. comm., 2014; Whitelaw J., pers. Comm., 2015; and Rideout, P., pers. comm., 2015
Mactaquac Provincial Park	On Mactaquac Park Arm (Mactaquac Stream), confluence at Station	Potable water supply for park	Sandwith, N., pers. comm., 2015
Kingsclear Tree Nursery, Seedling Production	On a tributary of the Saint John River, confluence approximately 6 km downstream of the Station.	Irrigation for a tree nursery, extracted from ponds linked to tributary	Ringlo, C., pers. comm., 2015
Town of Oromocto/Canadian Forces Base Gagetown	37.5 km downstream of Station	Potable water supply for Town	Weagle, J., pers. comm., 2015
Cranberry Fields Ltd.	42 km downstream of Station	Likely Irrigation for cranberry fields.	Google (2015)

6.2.2.6 Water Quality

The drainage area upstream of the headpond has a long history of farming, mainly cultivation of potatoes and poultry and hog farms. Farming contributes nutrients, sediments and chemicals to nearby watercourses through soil erosion and discharges of effluent. Wastewater effluent discharges, including municipal wastewater treatment plants, are also potential sources of nutrients such as nitrogen and phosphorus.

Did you know?

pH is a measurement of the acidity of water. The pH scale ranges from 0 (very acidic) to 14 (very alkaline). Water has a neutral pH of 7.

CRI (2011) examined available water quality data sampled from the Saint John River between the 1950s and 2011. The results suggested that water quality in the river has improved since the 1960s. The improvement is largely attributed to improved treatment of municipal and industrial wastewaters (CRI 2011).

Water quality data for the Saint John River are summarized in Table 6.8. These results are based on surface water quality data collected quarterly between 2003 and 2015 by NBDELG (2015c) at six water quality stations. Samples were not collected in heavy precipitation events or during the peak of the spring freshet. A summer low river flow sample was intended to be collected each year. The statistics are presented for sampling locations upstream and downstream of the Station.

The water quality data are compared to the Canadian Council of Ministers of the Environment Guidelines for the Protection of Freshwater Aquatic Life (CCME FAL; CCME 2007) and the Health Canada Guidelines for Canadian Drinking Water Quality (GCDWQ; Health Canada 2010b). Under existing conditions, some of the values exceeded guidelines, including for aluminium, cadmium, copper, iron, pH, bacteria and zinc. CRI (2011) found that bacterial levels (*e.g.*, *E.coli*) were highest in locations of wastewater discharges; however, these recent levels were considerably lower than in the 1960s before improvements in wastewater treatment were made. Upstream and downstream water quality was observed to have similar trends. When an exceedance occurred upstream, an exceedance of the same parameter occurred downstream of the Station.

Long-term continuous records of water quality data are not available for the river. These data should be considered snap-shots of information. Additional studies (*e.g.,* water temperature in headpond and correlation with downstream temperatures) are recommended.

Table 6.8 Water Quality Data in the Saint John River Collected Quarterly by NBDELG Between 2003 and 2015 – Upstream and Downstream of the Mactaquac Generating Station

Parameter	Units	Upstream				Downstream				CCME Guideline for the Protection of Freshwater Aquatic Life	Health Canada Guideline for Canadian Drinking Water Quality
		Mean	Min	Max	No. of samples	Mean	Min	Max	No. of samples		
Alkalinity	mg/L	42.3	24.4	75	152	38.3	20.5	52.9	147		
Aluminum	mg/L	0.11	0.02	**2.84**	154	0.10	0.02	**0.38**	154	0.005–0.1[c]	
Ammonia, Total	mg/L	0.02	0.005 (ND)	0.22	154	0.03	0.005 (ND)	0.18	154	> 1	
Antimony	µg/L	1	0.5 (ND)	1	154	1	0.5 (ND)	1	154	2,000	6
Arsenic	µg/L	1.0	0.5 (ND)	1.3	154	1.0	0.5 (ND)	1.3	154	5	10
Cadmium	µg/L	**0.13**	0.0025 (ND)	**2**	154	**0.11**	0.0025 (ND)	**1.1**	154	0.04–0.16[c]	5
Calcium	mg/L	16.9	4.8	35.6	154	14.8	4.3	21.1	154		
Chlorine	mg/L	3.40	0.86	10.5	154	4.11	1.72	12.9	154		
Chromium	µg/L	1.7	0.3	4.7	154	1.7	0.5	4.2	154	8.9	50
Colour	ACU	57.9	15	200	154	63.0	20	150	154		
Conductivity (Field)	µS/cm	87.6	36.6	140	97	83.2	36.5	122	95		
Conductivity (Lab)	µS/cm	110.6	53.3	216	154	101.6	40.7	142	154		
Copper	µg/L	1	0.25 (ND)	***14.2***	154	0.9	0.25 (ND)	**3.2**	154	2–2.43	1
Dissolved Oxygen (Field)	mg/L	10.2	**6.0**	14.9	96	9.4	**5.9**	15.8	96	6.5–9.5[c]	
E.coli	MPN/ 100 mL	14	5 (ND)	120	263	30	5 (ND)	250	264		
Fluorine	mg/L	0.1	0.01 (ND)	0.278	154	0.10	0.01 (ND)	0.1	154		
Hardness	mg/L	50.5	14.6	103	154	44.2	10.1	63.6	154		
Iron	mg/L	0.2	0.05 (ND)	***1.11***	154	0.19	0.05 (ND)	***0.71***	154	300	0.3[AO]
Potassium	mg/L	0.56	0.32	1.1	154	0.55	0.35	1.1	154		

Table 6.8 Water Quality Data in the Saint John River Collected Quarterly by NBDELG Between 2003 and 2015 – Upstream and Downstream of the Mactaquac Generating Station

Parameter	Units	Upstream				Downstream				CCME Guideline for the Protection of Freshwater Aquatic Life	Health Canada Guideline for Canadian Drinking Water Quality
		Mean	Min	Max	No. of samples	Mean	Min	Max	No. of samples		
Lead	µg/L	1	0.5 (ND)	**<u>5</u>**	154	1	0.5 (ND)	1	154	1–3.3 [c]	10
Magnesium	mg/L	2.04	0.63	3.31	154	1.82	0.74	2.68	154		
Manganese	mg/L	0.03	0.01	0.3	154	0.03	0.01	0.09	154		50[AO]
Nickel	µg/L	5	2.5 (ND)	6	154	5	2.5 (ND)	5	154	25–97.75	
Nitrate	mg/L	0.2	0.025 (ND)	1.9	154	0.16	0.025 (ND)	0.52	154		
Nitrite	mg/L	0.05	0.03	0.05	154	0.05	0.03	0.07	154		
Nitrogen Oxides	mg/L	0.27	0.05	1.9	154	0.20	0.05	0.57	154		
Nitrogen, Total	mg/L	0.46	0.30	1.9	154	0.42	0.30	0.9	154		
pH (field)	pH	7.7	**<u>5.9</u>**	8.8	94	7.5	6.7	8.6	93	6.5–9	
pH (lab)	pH	7.8	6.5	8.5	154	7.7	6.9	8.6	154	6.5–9	
Phosphorus, Total	mg/L	0.02	0.01	0.092	154	0.02	0.01	0.06	154		
Sodium	mg/L	3.05	1.56	6.47	154	3.50	1.99	7.54	154		200
Sulphate	mg/L	5.6	2.5	10.8	154	5.2	2.8	9.5	154	100	
Suspended Solids	mg/L	19	10	410	79	12	10	34	90		
Temperature	°C	15.7	0.01	29.9	107	16.5	4.2	25.9	111		
Total Organic Carbon	mg/L	7.4	4.2	12.9	154	7.9	5.2	13.4	154		
Turbidity	NTU	5.5	0.3	441	154	3.4	0.4	52.8	154		
Zinc	µg/L	7.0	2.5	**<u>120</u>**	154	6.30	2.5	**<u>56</u>**	154	30	5,000[AO]

Notes:
Data from NBDELG (2015c).
A value in **<u>bold and underline</u>** indicates a value in excess of CCME FAL guidelines.
A value in ***<u>bold italics and underline</u>*** indicates a value in excess of both the CCME FAL and GCDWQ guidelines.
(ND) = Not detected, reported value half of detection limit.
AO = Aesthetic objectives.
DO Guideline represents the minimum requirement for cold water species at varying life stages.
MPN = Most probable number in 100 mL.
NTU = Nephelometric Turbidity Units
c = Calculated parameter based on the mean. Aluminum concentration (µg/L) = 5 µg/L if pH < 6.5 = 100 µg/L if pH ≥ 6.5; cadmium/copper/lead based on hardness

Various water quality and other aquatic data have been conducted by the CRI since 2013 as part of the MAES. The CRI provided the following update in relation to water quality in the headpond and river reach downstream (Yamazaki, G., pers. comm., 2016).

"Water Quality in the Headpond

The water quality of the headpond appears unchanged from the last report in 2011 (CRI. 2011). Across depths and seasons, pH is 6.2-8.4 (n = 2,056), conductivity ranges from 0.052 to 0.145, and oxygen saturation is greater than 40% at the surface but drops below 40% only in the hypolimnion. Thermoclines develop where depths are greater than 10 m. There are 223 species of phytoplankton (n = 161 and 62, summer and fall respectively). Based on cells/mL, cyanobacteria ("blue-green algae") can make up to 4% of the community in summer and 46% in fall.

Water Quality of the Saint John River of MAES Study Reach

The water quality of the study area downstream of the Station is assessed at different location relevant to specific MAES work streams, and with a systematic sampling at the Bill Thorpe Walking Bridge in Fredericton. At least monthly samples (n = 10) were collected and analyzed at the NBDELG laboratory. All parameters were within the observed ranges reported in recent analyses (CRI 2011). Total alkalinity varied from 24.9 to 49.5 mg/L, and pH from 7.6 to 7.8. Turbidity ranged from 0.7 to 31.0 NTU, reflecting the variable sediment loads related to rain events. E. coli levels ranged from 10 to 240 (MPN/100 ml) which is not uncommon for the river inside the city limits."

6.2.2.7 Wastewater and Storm Water Outfalls

Much of the land bordering the Saint John River and its tributaries is developed. The river receives discharged treated water from bordering municipalities within the area of review, including the town of Woodstock, Woodstock First Nation, the town of Nackawic, the city of Fredericton and the town of Oromocto. Businesses outside of the municipal service areas may have private outfalls that also discharge to the river. The locations of known outfalls are listed in Table 6.9 and shown in the existing conditions mapbook (attached under a separate cover). The SNB property identification (PID) numbers are noted, where applicable. The permitted discharge limits are presented in a study by NATECH (2015a) and are not presented in this review.

Agricultural operations do not require a permit to discharge into the river and therefore the existing conditions of these outfalls have not been included.

Table 6.9 Location of Outfalls Discharging to the Saint John River

Name	Description of Surface Water Use/Infrastructure	Source
Town of Woodstock	The Town has a waste water treatment facility with a submerged outfall to the headpond. There are also three lift stations or overflows associated with the municipal wastewater treatment facility: 1. Near marina and water supply wells. 2. Near former train bridge (now walking bridge) that is part of TransCanada Trail on the Meduxnekeag River. 3. Behind NBCC Woodstock Parking lot on the Meduxnekeag River.	Harding, K., pers. comm., 2015
Woodstock First Nation	The Woodstock First Nation is equipped with a sewage treatment system that has an outfall to the headpond.	Dunbar, R., pers. comm., 2015
Gray's Aqua Farms Ltd.	One effluent outfall to the headpond submerged 3–4 feet below surface.	Gray, T., pers. comm., 2015
Town of Nackawic	Two sewage treatment facilities with outfalls to the headpond.	Walker, D., pers. comm., 2014

Table 6.9 Location of Outfalls Discharging to the Saint John River

Name	Description of Surface Water Use/Infrastructure	Source
AV Nackawic Mill	An effluent outfall (no distinct PID) for the mill.	NATECH (2015a)
Kings Landing	According to NBDELG, there are two sewage treatment system outfalls at Kings Landing. One is located on the westernmost property (PID 75214304) and the other is on the easternmost property (PID 75214296). Based on conversations with a facility representative, the westernmost sewage system may not have a direct outfall as it is located away from the headpond, and believed to be equipped with a settling field.	Little, M., pers. comm., 2015
Woolastook Park	According to NBDELG, there is a sewage treatment system outfall.	Lloy, S., pers. comm., 2014
Riverside Resort and Conference Center	This resort has a sewage treatment system outfall to the headpond.	Hashemi, S., pers. comm., 2014
York Centennial Park	The southern portion of Mactaquac Park, known as York Centennial Park, has a sewage treatment system with an outfall located on the southern shore of the marina cove.	Sandwith, N. , pers. comm., 2015
Mactaquac Provincial Park	The northern portion of Mactaquac Park is equipped with a sewage treatment lagoon that has an outfall to the headpond (PID 75132449).	Sandwith, N., pers. comm. , 2015
NB Power - Mactaquac Generating Station	There is a sewage discharge outfall associated with the Station located just downstream of the Station.	Gorman, M., pers. comm., 2015
Kingsclear First Nation	Sewage treatment outfall to a small drainage ditch/tributary to the Saint John River (PID 75052241), approximately 1 km downstream of the Station.	Dunbar, R., pers. comm., 2015
City of Fredericton	Fredericton has two wastewater treatment plant outfalls on the Saint John River (PIDs 1499268 and 60000791) and a third wastewater treatment plant (PID 75431718) with an outfall that discharges into the Nashwaak River, at the confluence with the Saint John River. All three outfalls are located at the shore.	Thomas, N., pers. comm., 2015
Tamarack Mobile Home Parks Ltd.	Lagoon treatment system outfall to a small tributary to the Saint John River (PIDs 60028131 and 60116126).	McCaw, R., pers. comm., 2015
New Brunswick Department of Transportation and Infrastructure—Lincoln Elementary School	The school has a wastewater treatment system with an outfall that discharges to a wetland located to the east of the school (PID 60031796), approximately 460 m from the Saint John River.	Cliff, P., pers. comm., 2015
Fredericton International Airport	Wastewater treatment outfall that discharges to a ditch on the airport property, which eventually runs to the Saint John River (PID 60181831, 60181286), approximately 24 km downstream of the Station.	Mathers, K., pers. comm., 2015; Russell, J., pers. comm., 2015
Gillies Court Subdivision	Outfall pipe located on PID 60115367 at shore of Saint John River. Untreated effluent is discharged directly to the river.	Russel, J., pers. comm., 2015
Roblin Village Park Ltd. (Mobile Home Park)	Sewage lagoon on PID 60099892 and 60044435) that potentially discharges to the Saint John River.	Google (2015)
Burton Trailer Park	Treatment lagoon for mobile home park that discharges to an adjoining wetland to the Saint John river, which is connected by a ditch (PID 60099892 and 60044435).	McCaw, B., pers. comm., 2015; McCaw, R., pers. comm., 2015; and Carr, J., pers. comm., 2015

Table 6.9 Location of Outfalls Discharging to the Saint John River

Name	Description of Surface Water Use/Infrastructure	Source
Town of Oromocto (west)	Sewage treatment plant outfall to the Oromocto River, approximately 5 km upstream of the confluence with the Saint John River. The treatment plant is on PID 60005576.	Weagle, J., pers. comm., 2015
Town of Oromocto (east)/Canadian Forces Base Gagetown	Wastewater treatment facility outfall for the Base and the eastern portion of the Town of Oromocto, approximately 38 km downstream of the Station.	Elliott, H., pers. comm., 2015

6.2.2.8 Sediment Quality

Sediment quality is a good indicator of the environmental conditions of a watercourse. This is because substances that originate from agricultural and forestry activities and outfall discharge tend to adhere to sediments, especially to the smaller sediment fractions (Bednarek 2001). Once attached to sediments, these substances can be transported over long distances.

Chemical analyses of the sediment samples collected by CRI in 2014 were used to characterize conditions within the headpond. Available laboratory results include concentrations of a suite of trace metals, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs) and chlorinated pesticides. A detailed description of the laboratory analysis and results for these parameters can be found in Kidd *et al.* (2015).

Preliminary data provided by CRI are summarized in Table 6.10 and compared to the CCME Sediment Quality Guidelines for the Protection of Aquatic Life Probable Effects Levels (PEL; CCME 1998-2001) and the CCME Soil Quality Guidelines (SoQC) for the Protection of Environmental and Human Health for agricultural land use (CCME 1991-2009). The PEL represents the lower limit of the range of chemical concentrations that is frequently associated with adverse biological effects to biota that might be present in sediments, and is applicable to sediments submerged in the headpond. The SoQC becomes applicable if the sediments become exposed on shore and left as soils.

Table 6.10 Sediment Quality Data in the Headpond – Upstream of Mactaquac Generating Station

	Parameter	Units	Upstream			CCME Sediment Quality Guidelines of Aquatic Life (PEL)	CCME SoQC for Protection of Environmental and Human Health
			Minimum	Maximum	No. of samples		
Trace Metals	Aluminum	mg/kg	16,540	39,080	20		
	Arsenic	mg/kg	6	**<u>22</u>**	20	17	12
	Cadmium	mg/kg	0.08	0.24	20	3.5	1.4
	Chromium	mg/kg	29.7	61.1	20	90	64
	Cobalt	mg/kg	9.3	18.6	20		40
	Copper	mg/kg	6.8	25.2	20	197	63
	Iron	mg/kg	21,600	45,230	20		
	Lanthanum	mg/kg	14.7	31.5	20		
	Magnesium	mg/kg	6,202	9,901	20		
	Manganese	mg/kg	484	4,207	20		

Table 6.10 Sediment Quality Data in the Headpond – Upstream of Mactaquac Generating Station

	Parameter	Units	Upstream			CCME Sediment Quality Guidelines of Aquatic Life (PEL)	CCME SoQC for Protection of Environmental and Human Health
			Minimum	Maximum	No. of samples		
	Mercury (Total)	µg/kg	16	120	20	486	6,600
	Nickel	mg/kg	27.8	**52.5**	20		50
	Phosphorus	mg/kg	445	1563	20		
	Lead	mg/kg	8.4	20.4	20	91.3	70
	Rubidium	mg/kg	20.1	63.7	20		
	Sulphur	mg/kg	74	908	20		
	Strontium	mg/kg	16.8	45.7	20		
	Titanium	mg/kg	1.3	2.11	20		
	Vanadium	mg/kg	46.4	89.9	20		130
	Zinc	mg/kg	58	116	20	315	200
Polycyclic Aromatic Hydrocarbons (PAHs)	Acenaphthylene	mg/kg	0.005	0.028	20	0.128	
	Anthracene	mg/kg	0.005	0.043	20	0.245	
	Benz(a)anthracene	mg/kg	0.005	0.094	20	0.385	
	Benzo(a)pyrene	mg/kg	0.005	0.083	20	0.782	
	Benzo(b)fluoranthene	mg/kg	0.005	0.107	20		
	Benzo(g,h,i)perylene	mg/kg	0.005	0.045	20		
	Benzo(k)fluoranthene	mg/kg	0.005	0.087	20		
	Chrysene	mg/kg	0.03	0.09	20	0.862	
	Fluoranthene	mg/kg	0.041	0.174	20	2.355	
	Fluorene	mg/kg	0.005	0.018	20	0.144	
	Indeno(1,2,3-cd)pyrene	mg/kg	0.005	0.088	20		
	Phenanthrene	mg/kg	0.025	0.091	20	0.515	
	Pyrene	mg/kg	0.041	0.141	20	0.875	
	Total Polycyclic Aromatic Hydrocarbons	mg/kg	0.173	0.978	20		
Chlorinated Pesticides and Total Polychlorinated Biphenyls	Aldrin	µg/kg	0.2[a]	0.3	20		
	Hexachlorobenzene	µg/kg	0.19[a]	0.24	20		50
	Methoxychlor	µg/kg	1.1	6.0	20		
	Nonachlor (Total)	µg/kg	0.1[a]	0.4	20		
	Chlordane (Total)	µg/kg	0.17[a]	0.68	20	8.87	4.5
	Heptachlor Epoxide (Isomer B)	µg/kg	< DL	< DL	20	2.74	
	Dieldrin	µg/kg	< DL	0.4	20	6.67	
	DDE (Dichlorodiphenyldichloroethylene) (Total)	µg/kg	2.95	**29.5**	20	6.75	
	DDD (Dichlorodiphenyldichloroethane) (Total)	µg/kg	1.14	**16.3**	20	8.51	
	DDT (dichlorodiphenyltrichloroethane + DDD+DDE) (Total)	µg/kg	4.23	**34.8**	20	4.77	700
	Endosulfan (Total)	µg/kg	0.2[a]	4.0	20		
	Endrin	µg/kg	0.39[a]	1.31	20	62.4	

Table 6.10 Sediment Quality Data in the Headpond – Upstream of Mactaquac Generating Station

	Parameter	Units	Upstream			CCME Sediment Quality Guidelines of Aquatic Life (PEL)	CCME SoQC for Protection of Environmental and Human Health
			Minimum	Maximum	No. of samples		
	γ-HCH (Lindane)	µg/kg	0.13[a]	0.26	20	1.38	10
	PCBs (Total)	µg/kg	0.13[a]	0.52	20	277	500
Organics	Organic Carbon	%	0.2	3.9	20		
	Kjeldahl Nitrogen	mg/kg	340	3,760	20		
	Phosphorus	mg/kg	430	1,490	20		

Notes:
Data from Kidd *et al*. (2015)
A value in **bold and underline** indicates a value in excess of the CCME PEL guidelines.
A value in ***bold italics and underline*** indicates a value in excess of both the CCME PEL and CCME SoQG guidelines.
(ND) = Not detected, reported value half of detection limit
mg/kg = milligrams per kilogram (dry weight)
µg/kg = micrograms per kilogram (dry weight)
DL = detection limit, value was not reported for that parameter (Kidd *et al.* 2015)
a = the minimum result is reported, however the minimum value is less than the unknown detection limit
SoQC = guidelines assuming agricultural land use (most conservative).

The results presented in a report by Kidd *et al.* (2015) show values in excess of guideline values for arsenic, nickel and DDT compounds for the 20 sediment samples collected in the headpond. All other parameters are below guidelines. The arsenic exceedance (maximum of 22.38 mg/kg, guideline of 12 mg/kg) is likely due to naturally-occurring geological conditions in New Brunswick (NBENV 2008). In comparison, CRI (2011) reports arsenic concentrations below CCME sediment guidelines for the protection of freshwater aquatic life. Sediment samples with exceedances were measured in locations near the Station; however, they appear to have no particular distribution pattern along the headpond. Results for nickel were consistently above the CCME Soil Quality Guidelines, which is consistent with nickel concentrations in agricultural soils reported by Loro (1996).

Preliminary analyses of PAHs indicated the presence of several constituents found at different sites below sediment quality guidelines. Kidd *et al.* (2015) indicate that since no other data regarding PAHs are known to be available, it is uncertain if these PAHs concentrations are typical for the Saint John River.

Preliminary analyses of PCBs show that the concentrations of individual PCB components were not detected for the majority of samples. All concentrations of PCBs were below sediment quality guidelines. Chlorinated pesticides were found in sediment at different sampling sites. Out of all the individual chlorinated pesticides that were analyzed, exceedances of Total DDD, Total DDT and Total DDE were above sediment quality guidelines.

Kidd *et al.* (2015) suggest that results showed similar sediment contaminant concentrations at most sites in the headpond. The lowest concentrations were found at a site farthest upstream, corresponding with lower organic carbon and concentrations of nitrogen and phosphorus than other locations of the headpond. The report suggests that some of the spatial variability in contaminants was likely due to the differences in sediment composition. The interim report did not indicate any sediment chemistry hot spots related to human activities in the headpond based on the interim sampling. The full results of CRI's sampling in this regard are available through the final reports on the MAES work.

6.3 SUMMARY OF STANDARD MITIGATION FOR SURFACE WATER

Standard mitigation and best management practices that are relevant to the Surface Water VC will be implemented for construction and operation. These are based on normal operating procedures and regulatory requirements, which are detailed in Section 6.1.2, and include mitigation specific to the Surface Water VC, such as the following.

- Cleared areas will be re-vegetated where possible.
- Natural vegetation will be preserved when possible.
- The area of exposed soil will be limited, and the length of time soil is exposed without mitigation (*e.g.*, mulching, seeding, rock cover) will be reduced through scheduled work progression.
- Erosion and sedimentation control structures will be maintained throughout construction activities and inspected regularly, especially before and after heavy rain events as well as during the freshet.
- Water released from the site will be monitored for quality to be consistent with suspended sediment limits specified by regulatory approvals.
- Erosion and sedimentation control structures will remain in place until the area is stabilized or natural re-vegetation occurs.
- Dewatering of excavated areas will control release of sediment-laden water (*e.g.*, filtration through vegetation or engineered erosion control devices).
- Overburden storage piles and exposed topsoil will be seeded and re-vegetated as soon as possible.
- Engineered surface water drainage and diversion channels will be constructed to direct flow around the construction site and away from watercourses and wetlands.
- A water treatment facility to treat surplus water from the site before discharge (*e.g.*, settling ponds) will be constructed.
- Construction material (*e.g.*, gravel) placed in or next to watercourses will be free of debris, fine silt and sand and chemical contaminants.
- Coffer dams will be used where feasible during the demolition/decommissioning of structures located below the water line.
- The excavations for new in-water structures will be completed in-the-dry, to the extent feasible.
- Features such as on-site borrow pits and quarries not required for future dam operation or other uses will be decommissioned and rehabilitated.

- Disturbed areas will be returned to pre-construction grades, where feasible, with remaining organic material or topsoil redistributed over the disturbed areas.
- Where possible, compacted areas will be scarified or ripped after the temporary fill (rock/gravel) is removed to loosen the ground before new topsoil is added.
- Exposed slopes with high potential for slumping or erosion will be stabilized as early as possible to prevent erosion.
- All fuels and lubricants used during construction will be stored according to containment standards (*e.g.*, secondary containment) in designated areas. Storage areas will not be located within watercourses, wetlands or water supply areas (including the location of known private wells), and permits will be obtained if they need to be located within 30 m from watercourses or wetlands.
- Refueling of machinery will not occur within 30 m of watercourses and water supply areas (including known locations of private wells). Where stationary equipment is situated near a wetland, special precautions will be implemented to prevent spills during refueling (*e.g.*, absorbent pads located below nozzles and spill response kits located at the refueling location).
- Emergency response plans will be in place for spill response with spill kits and trained personnel present on-site at all times.
- Temporary storage of waste materials on-site will be located at least 30 m from watercourses, wetlands, and water supply areas (including known private wells).
- Temporary on-site sewage systems will be installed and operated according to relevant provincial legislation.

6.4 POTENTIAL INTERACTIONS BETWEEN SURFACE WATER AND THE OPTIONS

The construction and demolition activities associated with Option 1 include the demolition of existing concrete structures. New facilities would be constructed on the right bank of the Saint John River, as well as within the existing power channel on the left bank. The existing facilities will remain in operation and generate power while the new facilities are constructed and commissioned.

Under Option 1 or Option 2, the dam and Station act as a barrier to downstream movement of water, ice, and sediment. Historically low-lying floodplains and islands that existed prior to the Station are now submerged beneath the headpond that was created. The supply of sediments from the upper Saint John River to feed agricultural lands, islands and wetlands downstream of the Station has likely been reduced. Option 1 or 2 would not likely result in a long-term change to the flow regime from existing conditions.

Did you know?

The surface water flow regime is characterized by the volume of water passing a given point over time. The components of flow regime include the magnitude, frequency, duration, timing (seasonality), and rate of change (flashiness) in flows. All play a direct or indirect role in maintaining the ecological integrity of the aquatic system.

While it will result in a free-flowing river, Option 3 will result in flow characteristics more similar to characteristics of the Saint John River before the construction of the Station. For example, navigation may be restored in some parts of the Saint John River but impeded in other areas, such as popularly navigated tributaries. Water velocities may increase and water depths will decrease. These effects may be exacerbated by sediment deposited in the headpond or derelict infrastructure that is currently submerged in or near tributary channels impeding water flows. The assimilative capacity of the river may be decreased due to lower volumes available for mixing with effluents, which may become non-conforming to permitted regulatory requirements. The occurrence of ice jams and related flooding during ice break-up downstream of the Station (*e.g.*, Kingsclear, Fredericton, Maugerville) may change compared to current conditions. Downstream infrastructure, much of which was put in place after the Station was constructed, may be exposed to altered ice forces and erosion during ice break-up events. Sediment that has deposited in the headpond may be flushed downstream with potentially contaminated sediment re-suspended in the water column. Intakes and outfalls may require relocation due to changes in the flow regime. Exposed shorelines, previously part of the headpond, may be susceptible to erosion and/or slumping temporarily until mitigation measures can be put in place. Interactions between Option 3 and infrastructure or land use along the headpond or downstream of the Station resulting from changes in flow characteristics are discussed in Section 12 (human occupancy and resource use) and Section 13 (infrastructure and services).

During the construction phase for all Options, heavy equipment activity may temporarily cause erosion and sediment to enter the river. Equipment used during construction may affect water quality from potential spills of petroleum hydrocarbons and hydraulic fluids.

Table 6.11 provides an overview of how the Options might interact with surface water. Shaded cells are not applicable to the particular Option and phase.

Table 6.11 Potential Interactions between Surface Water and the Options

Phase	Option 1		Option 2		Option 3	
	Potential Change in Surface Water Flow Regime	Potential Change in Surface Water or Sediment Quality	Potential Change in Surface Water Flow Regime	Potential Change in Surface Water or Sediment Quality	Potential Change in Surface Water Flow Regime	Potential Change in Surface Water or Sediment Quality
Construction (New facilities, Option 1 and Option 2)	✓	✓	✓	✓		
Demolition (Existing structures, Option 1 and Option 2)	✓	✓	✓	✓		
Operation (Option 1 and Option 2)	NI	NI	NI	NI		
Decommissioning (Option 3 only)					✓	✓

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

The operation of the Station under Option 1 or 2 is anticipated to be relatively similar to existing conditions. Though hourly and daily variations in water levels and flows will occur, the maximum and minimum operating water levels will be maintained at or very near to the current operating levels under both Options. Some minor changes to the operating practices may occur for both Options based on an improved understanding of the interaction between flows and the environment. However, these changes would not interact with surface water much beyond the current range of daily variations.

In both Options 1 and 2, the presence of the dam and Station will continue to act as a potential barrier to sediment flow. Indications are that the accumulation of sediment behind the dam (upstream of the Station) appears to be relatively small compared to the footprint of the river and will be confirmed in sediment sampling field programs and hydrodynamic modelling completed as part of the MAES. The continued presence of the Station would not likely result in a substantive change to sediment flow compared to existing conditions.

Similarly, the continued operation of the Station at or near the existing conditions is not anticipated to result in a change to surface water or sediment quality for Option 1 or 2.

6.4.1 Potential Change in Surface Water Flow Regime

6.4.1.1 Option 1 or 2

Surface water flow will be directed to the new powerhouse and/or main spillway from the existing powerhouse and main spillway during the construction and demolition of Option 1 or 2. The flow in the existing diversion spillway will be maintained throughout construction. The changes to the surface flow regime will change the local flow patterns and velocities resulting in local changes in erosion and deposition patterns immediately downstream of the Station. These changes will be permanent in nature, but will occur quickly after the completion of the construction and demolition activities. Any required intervention in these areas would be quickly identified and established as necessary to minimize erosion and to protect the new infrastructure.

A fish passage facility will be constructed for Option 1 or 2 to allow the upstream migration of targeted fish species to be determined by Fisheries and Oceans Canada (DFO). Several concepts for this fish passage facility were considered as part of the conceptual design of Options 1 and 2, and will be refined following the completion of MAES work. A portion of the surface water flow will likely be directed to the fish passage facility, as required to achieve the desired upstream fish passage goals. The changes to the surface flow regime will change the local velocities adjusting the erosion and depositional areas from existing conditions, but this will likely be limited to the immediate area downstream of the Station and quickly remedied as necessary to protect this infrastructure. As with the construction of the new spillway, these changes will be established over a short period of time following the completion of the construction and demolition activities.

The construction and demolition of the facilities in Option 1 or 2 would result in areas of physical disturbance from site preparation activities (*e.g.,* clearing, grubbing, grading) and excavation/blasting activities. These activities would occur in and around the banks of the new approach and discharge channel, the banks of the fish passage facility, and around the footprint of the new main spillway structures for both Options. The footprint of the new powerhouse would result in an area of physical disturbance for Option 1 only, as this infrastructure is not necessary in Option 2. The excavation of a new approach and discharge channel, which will house the new powerhouse in Option 1 and new main spillway in Option 1 or 2, will require the removal of overburden and bedrock. This material would be an additional source of sediment that would be at risk of release to the river if not properly managed.

The areas of physical disturbance associated with Options 1 or 2 will likely consist of un-vegetated and exposed soils that might become susceptible to erosion from runoff generated from rain events running to the river. This increased sediment entering the river can be managed by temporary erosion control measures, such as silt booms, bales of hay, phased construction sequencing and working in the dry. Maintaining minimal areas of disturbance by fencing off assigned laydown areas and controlled access routes would also serve as a sediment control measure. The need for sediment control measures would be temporary until exposed soils have stabilized with growth of new vegetation.

Construction of a new approach and discharge channel will be required for both Options. Bypassing the flow from the existing power channel to the newly constructed approach channel may introduce sediment from placed substrate material and initial stabilization of the channel. In the short term, there may be an increase in suspended sediments transported in the river. In the long term, the new approach channel and discharge channel may result in a localized change of sediment movement from scour or deposition as a function of the new channel geometry. The discharge channel will include energy dissipation structures designed to reduce the risk of scour. Implementation of natural channel design can further reduce the risk of scour.

Water required during construction and demolition activities will be withdrawn from the headpond. The quantity of surface water use is likely to be small and will cease upon completion of the construction.

6.4.1.2 Option 3

Potential Change in Flow Conditions

Activities associated with Option 3 include the decommissioning of the powerhouse, main spillway, diversion sluiceway and associated infrastructure, and the removal of the earthen dam structure. Option 3 would allow the Saint John River to revert to near natural-flow conditions. The flow regime of the river would remain controlled, in part, by other generating stations upstream, but would flow freely through the former location of the Station following its decommissioning.

Did you know?

The change to the river characteristics and flow regime in Option 3 is unknown. This review assumes that this change would be similar to river characteristics and flow regime before construction of the Station. Predictive modelling and field data collection would be necessary to confirm this assumption.

It is expected that the decommissioning of the Station will return the river to near-natural conditions similar to those that existed prior to the construction of the Station. The most pronounced change will be the loss of the headpond, which will expose currently submerged land and sediment. Water levels will return to near those present before the construction of the Station. This will result in physical changes to the river, including reduction in water depth, river width, and river volume.

Studies are currently in progress to predict the future flow conditions upstream and downstream of the Station; however, full results are not yet available. Those studies, being carried out by CRI, will be considered separately from this CER Report by NB Power in its decision-making regarding the Options. However, at this time, it is anticipated that the future flow conditions for Option 3 (*i.e.*, after the removal of the Station) would likely be relatively similar to the historical flow conditions that existed prior to the construction of the Station, apart from natural changes in precipitation that may have occurred since that time.

The removal of the headpond is expected to result in minor changes to the river flow rate. The change in flow rate, combined with the reduction in river width and water depth due to the removal of the headpond, will result in an increase in flow velocity upstream of the Station. The historical and current flow conditions in the Saint John River are illustrated on river cross-sections shown in Figures 6.10 to 6.17. Cross-sections were prepared at municipalities of interest (*e.g.*, Fredericton, Nackawic, Woodstock), at major tributaries, and at the limits of the available bathymetric data sets.

The physical changes and the average flow velocity were estimated at 12 cross-sections along the length of the headpond and its major tributaries (see Table 6.12). As identified in the table, the historical conditions observed prior to the construction of the Station are generally assumed to be representative of anticipated future conditions, in the absence of any specific information on future flows in this regard.

Table 6.12 Potential Change in River Flow Conditions at Cross-Sections of the Headpond for Option 3

Cross-Section Location	Mean Annual River Flow Rate (m^3/s)[a]	Average Water Depth across Section (m)		Wetted River Width (m)		Average Flow Velocity (m/s)	
		Existing	Historical	Existing	Historical	Existing	Historical
81 km upstream of Station in headpond at Woodstock	720.1	7.6	2.0	553	470	0.171	0.752
62 km upstream of Station at Meductic	726.5	9.8	2.7	645	195	0.114	1.363
Tributary – Longs Creek	1.3	14.1	0.03	816	15	0.000	1.300
Tributary – Kellys Creek	0.7	20.6	0.2	471.5	12	0.000	0.350
49 km upstream of Station at Mid Southampton	739.9	14.5	4.7	466	183	0.109	0.850
Tributary – Nackawic Stream	9.3	15.9	0.6	1336	45	0.000	0.321
37 km upstream of Station in headpond at Nackawic	764.3	12.4	5.6	1053	263	0.059	0.516
22 km upstream of Station at Granite Hill	764	22.4	3.8	1622	765	0.021	0.266
8 km upstream of Station in headpond at Upper Kingsclear	772.5	27.5	2.2	909	22	0.031	1.554
Tributary – Mactaquac Arm	4.3	18.6	0.8	873	120	0.000	0.047
At the Station	813	23.1	2.1	979	311	0.036	1.223
19 km downstream of the Station at Fredericton	830.9	3.5	NA	606	NA	0.387	NA

Notes:
NA = Not Applicable
a River flow rates prorated from mean annual river flow estimates at Water Survey of Canada Stations 01AJ001 and 01AK004.

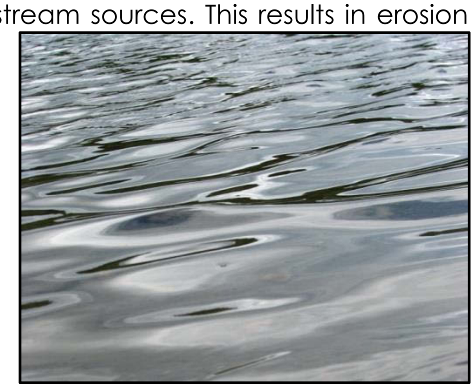
The relative change in the river features associated with Option 3, including river area and shoreline perimeter of islands, is presented in Table 6.13. The historical river condition before the construction of the Station was used to represent the future river condition under Option 3, except for the historical upstream water elevation which is based on existing conditions immediately downstream of the Station. The existing (2014) aerial imagery and historical topographic maps (1950s) were used to delineate the perimeter of the islands. These measurements are approximate given the variability of the historical water level. The large reduction in water elevation from 40.5 m amsl to 6.6 m amsl (a 33.9 m drop) at the Station under Option 3 may result in changes to how the river is used by humans and aquatic life.

As shown in Table 6.13, the historical river area upstream of the Station was much smaller than the existing river area. As a result, the historical river had more islands and the associated shoreline perimeter exposed upstream of the Station was greater. It was assumed that Option 3 would likely result in similar river features to the historical river features. Downstream of the Station, the existing river area is currently slightly less than historical features and with slightly more island area exposed than historically. This small change in river features may be attributed to water use or water level represented in the topographic database.

Table 6.13 Potential Change in Saint John River Features in the Headpond for Option 3

River Features Upstream of the Station	Existing	Historical
Length of area of review from the Station (km)	97	97
River area (km^2)	83.2	32.7
Maximum normal water surface elevation at the Station (m amsl)	40.5	6.6
Area of islands (km^2)	0.4	4.2
Shoreline perimeter of islands (km)	18.4	52.1
Total shoreline perimeter (km)	354.6	250.0

A change in the surface water flow parameters may affect how sediment moves through the river and result in changes to water quality parameters. For example, suspension of sediment in the river may increase as a result of erosion of exposed and unstable river banks, or sediment deposits from high flow events. Rivers naturally make adjustments in shape. The bed of the river is mobile (though slow-moving), and sediment is transported downstream and re-supplied from upstream sources. This results in erosion and depositional areas shifting over time. In the short term, these adjustments in the river may be more substantial because of the recent physical changes in the river form after removal of the Station. The river will attempt to find its new equilibrium.



The drawdown of the headpond may create land barriers between the main river and its tributaries, which can impede water flows and result in the ponding of water. Specifically, following years of submersion, channels that once connected tributaries in the present day headpond to the Saint John River may no longer be defined, or exposed former parts of the headpond bed now being dry and thereby limiting connectivity to upstream tributaries. There is also the possibility that infrastructure that has been submerged since the creation of the headpond (*e.g.,* roads, culverts, bridges) no longer functions and could create a barrier to water flows in smaller tributaries. Therefore, water from these tributaries may not flow into the river following drawdown and require mitigation in the form of the excavation of sediment, or removal of derelict infrastructure. A preliminary water management study that assesses the connection of these tributaries to the river under Option 3 has been conducted and preliminary design options for a variety of tributary flow conditions have been completed. An assessment of infrastructure submerged under the headpond has been completed and identified 458 submerged structures, including 314 buildings, 125 culverts, 16 bridges, 2 wharves, and 1 unknown structure.

Potential for Slope Failure and Erosion

The sediments deposited in the headpond exposed during dewatering of the headpond under Option 3 will be prone to erosion during precipitation events, and some steep slopes may become erodible or unstable. The resulting sediments may be carried into the river through runoff or blown into the river from wind. These sediments could be stabilized by shoreline interventions and stabilization measures, such as planting vegetation immediately (either alone, or to supplement natural vegetation growth) following dewatering, removal through dredging or the use of sediment screens/traps, or a combination of these methods. Channel design could also be considered for areas naturally prone to erosion, such as the outside banks of river bends, to promote long-term stability. A preliminary shoreline protection study that assesses the potential bank erosion as a result of channel re-alignment processes under Option 3 has been conducted and conceptual design options for a variety of slope conditions have been completed. Changes to water quality as a result of sediment entering the river are described in Section 6.4.2.

After dewatering, the exposed and undrained soils and new river banks could become unstable and lead to slope failure. An accelerated drawdown may wash unstable soils downstream, similar to a spring freshet event. While a slow drawdown (over 1-3 years) would be more likely to provide adequate time for soils to drain and reduce the risk of slumping, an accelerated drawdown is currently preferred based on the MAES and preliminary engineering design. Current plans for the accelerated drawdown scenario are that it will be completed in two stages, in the spring and fall of the same year, coinciding with the spring freshet and fall recharge period.

Carrying out the accelerated drawdown in two stages may lessen the potential for slumping as compared to a slow drawdown. Steeper banks may be more likely to fail with an accelerated drawdown compared to a slow drawdown, however, resulting in wedges of banks sliding into the floodplain or even the bed of the river, but this risk of slumping could be reduced through grading and mechanical stability techniques. A preliminary geotechnical slope stability assessment of the existing river banks has been completed to identify potential areas where slope failures are more likely to occur during and following drawdown. This analysis has identified areas expected to be most vulnerable to slumping, and it was concluded that these slopes could generally be controlled through shaping and grading to create a flatter slope less prone to slope failure. Other potential mitigation that could be considered includes:

- placing of a rip-rap berm near the bottom of a bank to control slope movement in localized areas;
- stabilizing the banks in localized areas by inserting reinforcing bars into the bank, such as soil nails or rock anchors; and/or
- installing a retaining wall to protect banks near vulnerable infrastructure (*e.g.*, roads, bridges, outfalls) (this is typically used when other mitigation options are not appropriate).

It is expected that mitigation, as required, will be initiated immediately upon the start of dewatering and proceed throughout and following the stages of drawdown. Monitoring is recommended during dewatering to observe changes in these slopes to support the implementation of mitigation.

Retention and Management of Surface Water Flow

The removal of the Station will result in a minor change in the retention and management of surface water flow. The operation of the existing Station has minimal capacity to control flood and drought conditions. NB Power also has limited ability to manage the water level during operation of the Station [less than 1 m of fluctuation is typical; Acres (1975)]. For example, Dineen (1974) describes the operation of the Station as it applied to a high flood event in 1973, reporting that if the headpond was drawn down to the lowest operating level of 39.6 m amsl, it would take about six hours to fill to flood-like flows of 11,327 m^3, which was the flood peak in 1973 (Dineen 1974).

Potential Change in Flood Levels

Flood levels in the headpond may decrease to varying degrees at different locations in response to the decrease in the water surface elevation of the river. The hydrotechnical modelling conducted by NATECH may be able to address this in more detail (NATECH 2015b). The linkages of this interaction to aquatic and wildlife species are addressed in Section 8 (aquatic environment) and Section 10 (wildlife and wildlife habitat).

Existing flood boundaries established by NBDELG may not accurately represent conditions after removal of the dam. Hydrotechnical modelling would update flood risk area mapping to reflect the reduced water surface elevation by approximately 33.9 m amsl at the Station. The reduced flood risk may benefit those who have developed land in the floodplain, such as NBDTI roads and bridge infrastructure and private housing developments.

Fluctuation of Water Levels

As part of the MAES, the CRI conducted an analysis of the interaction of the Station on low flows in the river as a result of operation. The analysis considered the observed seven-day average daily minimum flow between the periods of record of 1970 to 2012 at the Mactaquac Generating Station. A prediction of low flow conditions without the Station was modelled based on operation of the Station. Preliminary model results predicted about a 20% reduction between existing low flow conditions (283 m^3/s) and low flows without the Station (226 m^3/s) (Curry *et al*. 2015). However, this reduction only accounts for approximately 7% from the mean annual flow of 813 m^3/s. This variance in low flows was reportedly attributed to operation of the Station, affecting downstream low flow conditions (Curry *et al.* 2015). Under Option 3, low flow conditions may be slightly lower than existing conditions; however, the interaction with fish passage and navigation is not anticipated to change appreciably from flow conditions.

Construction of the Station did not substantively change downstream water levels. However, operation of the Station results in highly regulated fluctuations throughout the day. Hourly fluctuations of water demand are a result of hourly demand fluctuations in power during peak load operation. These fluctuations tend to level out over a daily river flow scale.

Under Option 3, fluctuations in flow as a result of operation of the Station would cease. This would greatly benefit local aquatic species and is discussed further in Section 8 (Aquatic Environment).

Potential Change in Navigation

Changes in surface water flow will result in long-term changes to navigation in the area of review. Free navigation by boat will be restored on the Saint John River to the Beechwood dam. However, the lower water depths may cause some areas to be unpassable during drier conditions. Popularly navigated tributaries, coves and basins that feed the headpond may no longer be navigated by boat due to the reduced depths and channel opening, including: Mactaquac Stream (known as Mactaquac Arm); Walinaik Cove; Hammond Brook Basin; McNallys Cove; Kellys Creek Basin; Longs Creek Arm; Wheeler Cove; Jewetts Cove; Burden Cove; Course Cove; Cliffs Cove; Joslin Creek Basin; Culliton Cove and Shogomoc Cove, among others. The interaction of navigation with the Options is discussed in Section 12 (Human Occupancy and Resource Use).

Potential for Ice Jam Flooding

The frequency analysis of historic ice jam flooding events on the Saint John River was conducted primarily based on the NBDELG Ice Jam Location Map (2013). Results showed that ice jam flooding historically occurred downstream prior to construction of the Station, and this could again occur upon removal of the Station, particularly since there has been an increase in ice jam flooding in the upper headpond reach.

Physical attributes of a watercourse can increase the probability for an ice jam near specific locations. Ice jams tend to form at sites of surface obstructions (such as islands or bridge piers), confluence of two rivers, river bends, river channel slope changes, constrictions, low velocity pools and shallow river sections. The edge of a solid ice cover will also initiate an ice jam (Environment Canada 2011). Buildings, bridges, embankments, dykes and similar structures erected on the floodplain can obstruct the passage of floodwaters, which may increase the likelihood of local flooding and ice jam events.

Ice mitigation measures to reduce the damage costs from ice jam related flood events on the Saint John River may be necessary for Option 3. Based on the reviewed literature and interviews with water resource specialists (Sullivan, D., pers. comm., 2014; Burrell, B., pers. comm., 2014), engineered ice control structures should be investigated with the objective to reduce flood damages resulting from ice jam flooding downstream of the Station, particularly in Fredericton, should it occur. Ice control structures would focus on limiting the occurrence of ice jams downstream of the Station (*i.e.*, the Fredericton area), where the most notable change in the ice jam occurrence and associated costs of flood damages is likely to occur. The anticipated potential flood damages within the former headpond reach, particularly the lower headpond reach, would be minimal because of the currently undeveloped floodplain; however, this requires further analysis to confirm this hypothesis. The former headpond area should be maintained as undeveloped land to reduce potential flood damages in the future.

Ice jam forecasting may be necessary for both emergency response and to mitigate flood damages associated with Option 3. Available base data necessary for modelling is limited within the area of review. Base data that may be necessary includes: geometric data, ice thickness data, monitoring of ice movement, delineation of the areal extent of ice jam related flooding and resultant areas prone to flood damages, records of ice jam length and coordinate location data.

The New Brunswick River Ice Manual (Environment Canada 2011) contains the primary ice management and ice jam mitigation options available in New Brunswick, which include the following engineering-based options:

- use fixed structures to stabilize an ice cover or prevent the downstream movement of broken ice such as, ice control dams and weirs;
- install ice booms across a watercourse to control the movement of ice and reduce the supply of ice to downstream jamming sites;
- modify channels to reduce the likelihood of ice jams, including remove constrictions and surface obstructions such as piles, old bridge piers, and natural islands, and sand and gravel bars or channel diversion to bypass the ice jam;
- spread a thin layer of a dark substance (sand, fly ash) over an ice cover to weaken the ice through increased heat absorption;
- blast ice cover to initiate break-up, or weaken a solid ice cover prior to the arrival of upstream ice;
- cut, saw or split ice cover to cause it to melt faster or to break it into smaller pieces, to be transported more readily when water levels rise; and/or
- remove ice using construction equipment before ice jams form.

In an effort to reduce the damages caused by ice jam flood events, flood proofing and relocation initiatives have been conducted in Perth-Andover (NBDELG 2014). These initiatives could also be carried out within the area of review where applicable and in conjunction with or instead of engineering controls.

6.4.2 Potential Change in Surface Water or Sediment Quality

6.4.2.1 Option 1 or 2

Construction and demolition activities associated with Option 1 or 2 will include the use of motorized equipment such as heavy equipment vehicles and pumps which have potential to release petroleum products and hydraulic fluid into the river. This risk can be reduced through the implementation of a spill response plan and spill containment measures, such as designated fuelling areas, spill kits and absorbent materials. No other changes to surface water or sediment quality are anticipated to occur as a result of Option 1 or 2.

6.4.2.2 Option 3

As noted in Section 6.4.1, during Option 3 potentially low-quality (*i.e.*, contaminated) sediment may become exposed on the banks of the river and migrate to other areas of the river.

A human health and ecological risk assessment would need to be conducted to assess the interaction of impurities in mobilized sediments with the ecosystem. In general, mitigation measures to reduce the risk of exposure can be put in place to limit erosion and sedimentation and exposure to contaminated soils.

As discussed, in the review of surface water flow in Section 6.4.1, sediment exposed on the banks of the river could contribute to sediment runoff, slumping and temporary increases in suspended sediment levels or turbidity levels in the river. Preliminary findings based on sediment grab sampling field work conducted by Chateauvert *et al.* (2015) found low levels of sediment deposition in the headpond. The magnitude of sediment exposed on the banks of the river is anticipated to be low, despite there being an estimated 19 million m^3 of sediment in the headpond currently.

Two scenarios were initially considered for the dewatering of the headpond: an accelerated (quick) drawdown intended to mimic a spring freshet, and a slow drawdown intended to reduce movement of sediments downstream. The accelerated drawdown is a flush of the water and sediment retained by the dam downstream, occurring over a period of a few weeks to a few months. The slow drawdown is a gradual release of water to the river downstream occurring over a much longer period (progressively over 1-3 years). Information from the MAES and preliminary engineering design have led NB Power to prefer an accelerated drawdown completed in two stages coinciding with the spring freshet and the fall recharge period within the same year. The specific sequence and duration may change as a result of further study, should Option 3 be selected as the Preferred Option.

Preliminary modelling results of sediment migration in the accelerated drawdown scenario predicted that most sediment would travel to the Bay of Fundy in the short term, with some deposition occurring in low velocity areas of the river. High concentrations of total suspended solids for a short period could be expected. The Saint John River downstream of the Station is a shallower gradient than upstream and is inherently a lower energy system with more depositional reaches. Should it occur, deposition would likely occur in areas such as the inside of bends, deeper areas, wetland areas, and areas with islands. Predictions of sediment migration would be required in future modelling work. If Option 3 is selected as the Preferred Option, the timing of the drawdown should be further studied to identify the optimal drawdown scenario.

Reduction in water volume within the headpond also changes the receiving environment at outfalls within the headpond. Concentrations of effluent in the river, arising from release of industrial and municipal effluents as well as from other non-point sources (*e.g.,* agriculture, forestry), may be proportionally higher under Option 3 as less water could be available in the receiving environment to achieve mixing. On the other hand, water may be carried away faster until the river reaches the tidal influence at Fredericton, where the rate of movement is governed by tides. Further, mixing of effluents within the river may happen faster due to the now more turbulent waters. Modelling will be necessary to predict the ability of the river to assimilate these changes and the implications on water quality. Mitigation may include further treatment prior to release, an adjustment of the timing of the release (*e.g.,* not during low flows), or other physical or operating changes.

The loss of the headpond would result in the reach of the river between the Station and Hartland changing from a lake-like system back to a river-like system. Water quality parameters in the headpond such as conductivity, pH, temperature and turbidity are anticipated to change. In particular, the water temperature would be substantially different in Option 3. Additional long-term continuous temperature monitoring should be considered within the headpond. The interactions of these changes are presented in Section 8 (Aquatic Environment).

6.5 SUMMARY OF INTERACTIONS BETWEEN SURFACE WATER AND THE OPTIONS

A summary of the anticipated interactions between Surface Water and each of the Options is found in Table 6.14. Additional potential interactions for Options 1, 2 and 3 are discussed below.

Table 6.14 Summary of Interactions between Surface Water 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 the interaction last?	How often does it occur?	Has additional mitigation been recommended?
Potential Change in Surface Water Flow Regime						
Option 1	Negative	Low	Site	Long	Single	Yes
Option 2	Negative	Low	Site	Long	Single	Yes
Option 3	Positive and Negative	High	Region	Permanent	Continuous	Yes
Potential Change in Surface Water and Sediment Quality						
Option 1	Negative	Low	Site	Long	Single	Yes
Option 2	Negative	Low	Site	Long	Single	Yes
Option 3	Negative	High	Region	Permanent	Multiple	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 surface water.
- Medium – a change that occurs outside the natural variability for surface water but does not change the overall status of surface water.
- High – a change that occurs outside the natural range of change for surface water that will change the status of surface water 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.

6.5.1 Summary of Additional Potential Mitigation and Information Requirements

As described in Section 6.4, the review has identified some additional potential mitigation and requirements further study in some areas. These are summarized in Table 6.15.

Table 6.15 Summary of Additional Potential Mitigation and Information Requirements

Option	Additional Potential Mitigation	Additional Information Requirements
Option 1	• Channel design to reduce erosional forces.	• Assess water management for effects on the ecosystem to update the minimum flow requirements.
Option 2	• Channel design to reduce erosional forces	• Assess water management for effects on the ecosystem to update the minimum flow requirements.
Option 3	• Removing submerged infrastructure or sediment deposits in areas that may prevent access to historically accessible portions of the river and tributaries. • Removing and/or covering exposed soils (potentially contaminated) as a result of the drop in water level from removal of the Station. • Planting vegetation and stabilizing exposed soils and/or exposed river banks where required to prevent slumping or erosion. • Channel design to stabilize the system/ reduce energy in the system and protect areas of the river naturally prone to erosion. • Further mitigation for permitted sources of effluent that are affected by reduced mixing, such as treatment of wastewater effluent discharges or adjustment to the timing of the release (*e.g.*, not in low flows), or other physical or operational changes. • Update and create floodplain mapping within the headpond to represent the lower water elevation for emergency preparedness. • Maintain the floodplain of the existing headpond as undeveloped to reduce potential future flood damage. • Monitor potential for ice jams downstream of the Station through expansion of EMO's River Watch program. • Implement ice jam mitigation measures as required, such as engineered ice control structures to reduce flooding, ice flow management measures and flood proofing. • Implement slope stability measures such as specifying the timing of drawdowns, shaping and grading of steep slopes, toe berm protection, soil nails, and retaining walls.	• Further modelling to predict the volume and migration of sediments and anticipated water quality, and plan accordingly for optimal means of achieving drawdown (*i.e.*, quick drawdown, slow drawdown, or somewhere in between). • Completion of a human health and ecological risk assessment to determine the effects of impurities in sediments on the ecosystem. • Modelling to predict the ability of the river to accept wastewater effluent discharges after reductions in water volume and the implications to receiving environment water quality. • Long-term temperature monitoring upstream and downstream of the Station. Modelling to predict the temperature changes after dam removal. • Collect base data necessary for modelling of the ice flow regime. Base data required includes long-term records of ice thickness, ice movement during break-up events, records of ice jam length and location. • Model the ice flow regime in order to predict related ice jam flood events. Predictive modelling is necessary for emergency response of ice jam flood events. • Further slope stability analysis and testing in areas prone to erosion or slumping.

6.5.2 Discussion

Surface water, including the sediment it contains, is important to the entire ecosystem and linked to all VCs. By physically blocking the river (as was done with the original construction of the Station), storing excess runoff, or releasing water according to human needs, dams alter natural flow regimes. The headpond is heavily navigated by water transport and the river valley of both the river and tributary streams are populated in some areas, particularly in the Mactaquac area. Changes in surface water result in concerns for surface water quantity and quality and water and sediment retention and management.

Option 1 or 2 would not result in a substantive change to the existing flow regime or to surface water and sediment quality as compared to currently. Construction and demolition activities associated with Option 1 or 2 may result in a temporary change in water quality conditions in the form of increased suspended sediment levels. This risk can be reduced by installing temporary erosion control and spill containment measures. The new approach channel and discharge channel may result in a localized change to scour and deposition; however, this may be reduced through channel design. The characteristics of the Saint John River watershed govern the quality of the surface water runoff entering the river and are expected to remain largely unchanged under Option 1 or 2. Operation of the Station would influence the flow velocity and resultant sediment movement.

Option 3 would result in the greatest long-term change in the surface water flow regime and river characteristics such as depth, width, velocity, and shoreline perimeter, as compared to currently. Option 3 would return the river to the surface water flow regime more similar to what would be natural for the Saint John River without human alteration, similar to that which might have existed prior to the construction of the Station.

Under Option 3, the change in flow regime and the restoration of river characteristics to the area currently covered by the headpond would have implications that will include reduced floodplain elevation in most of the headpond area, modified navigation opportunities (reduced in headpond areas, but restored connection to downstream river reaches), and possible reductions in the ability to achieve mixing from effluent discharges in the headpond. Additional studies required would include an assimilative capacity study and hydrotechnical modelling to determine new floodplain elevations/extents and related mixing.

Removal of the Station would also temporarily leave exposed sediments and unstable and exposed banks, which may be a concern for both erosion and slumping. Erosion of the sediment can be mitigated through the implementation of temporary erosion control measures, such as stabilizing soils through vegetation or removal of sediment through the use of screens or traps. Slumping of exposed banks can be mitigated by stability techniques such as sloping and grading work, toe berm protection, and soil nails or other means. The MAES and preliminary engineering design have recommended that an accelerated drawdown is preferred and was used for the advancement of conceptual engineering design and planning for Option 3. Further studies on slope stability have been completed and included preliminary design to protect and stabilize slopes, and the shoreline of the Option 3 river channel.

Under Option 3, potentially contaminated sediments may be exposed on the side of banks. The effect of these sediments on human health and the ecosystem will need to be further assessed to determine the risk and the appropriate mitigation measures.

The removal of the Station may leave the downstream reaches of the Saint John River susceptible to ice jam flood events. Prior to the construction of the Station, ice jam flood events were reported to frequently occur in the Fredericton area. With the exception of one ice jam event in Fredericton since the construction of the Station, ice jam flood events causing damage have not been reported to have occurred. The risk of ice jam flooding can be reduced or controlled by various means including ice control structures and ice booms or other ice mitigation techniques. Further base data is necessary on the ice flow regime for emergency response measures and to mitigate flood damages.

6.5.3 Assumptions and Limitations

Key assumptions and limitations for the review of surface water include the following.

- This review assumed that river conditions prior to the construction of the Station can adequately represent potential post-Station removal conditions of surface water flow and water and sediment quality. However, predictive modelling and extensive field data collection would be necessary to confirm this assumption.

- Historical aerial imagery was not available in a format or quality to complete a detailed GIS analysis of historical conditions. This imagery was reviewed to make a high-level estimate of historical wetted width and area of islands.

- Field data collection or modelling was not conducted as part of this review. This work is currently underway as part of CRI's MAES program and is not complete. Without more detailed characterization of the existing conditions, or predictions of changes through modelling, a characterization of interactions from each Option with surface water could only be completed at a preliminary level..

- Results of a human health and ecological risk assessment or other further study would be required before recommendations can be made for mitigating existing contaminated sediments.

- Ice jam monitoring and modelling would help to identify the particular sensitive areas and predict the response to ice jam mitigation measures.

- The existing sediment load in the river was assumed to be represented by the WSC hydrometric station record of 1966 to 1967. A more comprehensive characterization of the existing river sediment load would be necessary should Option 3 be selected.