8.0 AQUATIC ENVIRONMENT

8.1 SCOPE OF THE REVIEW

The aquatic environment is defined in this review as all freshwater aquatic habitat (excluding wetlands) and includes the species that inhabit those habitats. Of the organisms that inhabit aquatic environments, this review considers fishes, algae, plants, and invertebrates.

8.1.1 Why the Aquatic Environment is a Valued Component

The Saint John River drainage basin, among the largest in North America, supports a diverse aquatic community that includes various species of fishes, algae, plants and invertebrates (CRI 2011). The main channel of the Saint John River is of particular social and economic importance to the people of New Brunswick, including First Nations. The Project Options may interact with the aquatic environment of the river, as well as the socio-economic activities that it supports. The nature and scope of these interactions will be influenced by the Preferred Option selected by NB Power.

8.1.2 Regulations and Policies Relevant to the Aquatic Environment

The aquatic environment is protected by federal and provincial legislation, including but not limited to:

- *Fisheries Act* – the main legislation in Canada protecting fish and fish habitat;
- *Canadian Environmental Protection Act* – governs the management and disposal of toxins, waste, and other pollutants;
- *Species at Risk Act* (*SARA*) – defines the federal conservation status of species and outlines regulations to protect endangered or threatened plant and animal species, including fishes, aquatic invertebrates, and aquatic plants;
- New Brunswick *Species at Risk Act* (NB *SARA)* – similar to the federal *SARA*, the New Brunswick *Species at Risk Act* outlines a number of prohibitions aimed at protecting listed plant and animal species, many of which are also listed under the federal *SARA*;
- New Brunswick *Clean Environment Act – Water Quality Regulation* – prohibits the release of a contaminant that may result in water pollution without an approval under the regulation; and
- New Brunswick *Clean Water Act – Watercourse and Wetland Alteration Regulation* – any work conducted within 30 m of a watercourse or wetland, that might be disruptive to vegetation or soils, requires a permit under this regulation.

8.1.3 Area of Review

The area of review for the aquatic environment includes the section of the Saint John River, upstream and downstream of the Station, which may be affected by the Options. The area is defined as a reach of the Saint John River bounded upstream at the location of the Hartland covered bridge, and downstream at the Gagetown ferry crossing between Gagetown and Scovil, downstream of the new

TransCanada Highway bridge (Figure 8.1). The area allows for consideration of potential interactions with Grand Lake, the Grand Lake Meadows, and Grimross Island. Laterally, the area of review is bounded to within 30 m of the ordinary high water mark for the Saint John River in its current channel.

8.1.4 Key Issues

To understand the potential interactions between the aquatic environment and the Options, it is helpful to review the main interactions associated with the construction of dams.

The environmental interactions of dam construction can be profound (Poff and Hart 2002; Stanley and Doyle 2003; Chateauvert *et al.* 2015). Dam construction can result in physical changes in habitat both upstream and downstream of the dam, and changes to the connectivity of river habitat. Dams interrupt the natural flow of a watercourse, increase the water depth upstream of the dam, slow the current, and may change water characteristics like temperature and dissolved oxygen. Moreover, shoreline land is flooded. The new shorelines may be unstable and susceptible to erosion, and suspended sediments that would normally be transported downstream may be trapped and settle within the headpond. Depending upon local conditions, the turbidity of water discharged from the headpond may increase or decrease. The impounded area upstream of a dam can take on some of the characteristics of lake-like (lentic) habitat, influencing the community of aquatic species suited to inhabit it. Downstream of a dam, sediment (particularly bedload) and nutrient transport may be reduced, and the water flow regime may change. Moreover, water temperature changes in the headpond may result in seasonal temperature changes to the water flowing downstream of the dam. Collectively, these potential changes may influence the productivity and species composition of the downstream environment. The dam structure also disrupts habitat connectivity for aquatic organisms, particularly fishes. Notably, the movement of migratory fish species that require access to habitat upstream or downstream of the dam may be disrupted, leading to changes in fish populations.

Did you know?

Habitat connectivity refers to the ability for aquatic organisms to move both upstream and downstream. Currently the Station acts as a barrier to habitat connectivity.

Not all of the environmental interactions of dam construction may occur or be readily apparent within a short period of time after construction. Some interactions of dam construction, such as sediment transport or erosional regimes, may occur or be ongoing on time scales of decades or longer.

The key issues for the aquatic environment were determined in consideration of the above. This review places particular emphasis on interactions that may cause serious harm to fish, or the productive capacity of aquatic habitat. The key issues for this VC are listed in Table 8.1.

Table 8.1 Description of Key Issues for the Aquatic Environment

Key Issue	Description
Potential change in fish habitat	• Water flow characteristics. • Water quality. • Sediment quality. • Quantity of fish habitat. • Habitat connectivity.
Potential change in fish populations	• Direct and indirect mortality, and injury. • Population level effects on abundance and fish community structure.
Potential change in species at risk or species of conservation concern	• Species-specific sensitivities associated with fish habitat and fish mortality specifically for species at risk (SAR) and species of conservation concern (SOCC), including consideration of Project interactions with all life stages and individual organisms.

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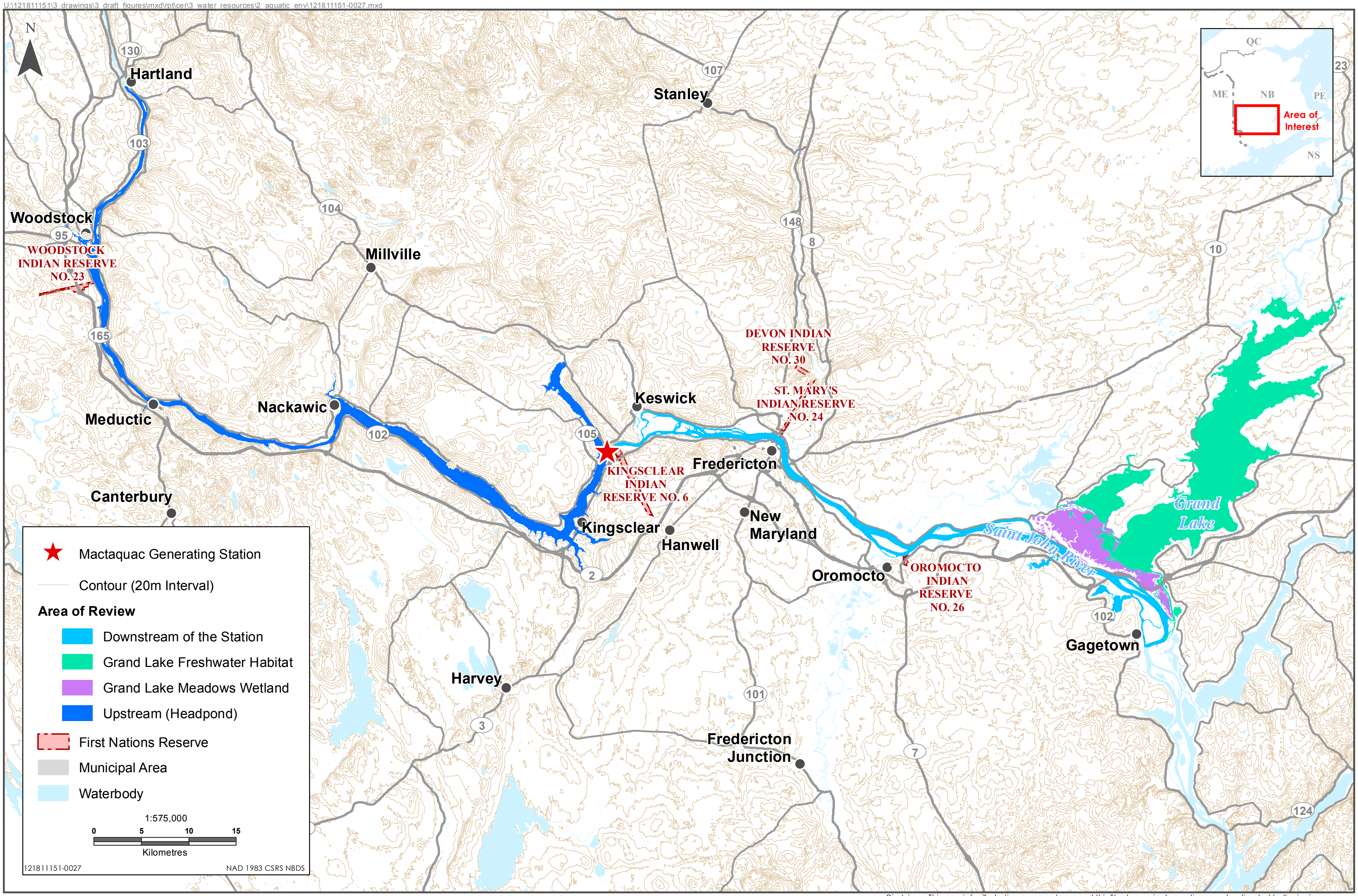

Base Data: Contours, First Nations Reserve and Roads are from SNB and Waterbodies and Watercourses data from NBDNR. All data downloaded from GeoNB.

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

Stantec

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Area of Review for the Aquatic Environment

Figure 8.1

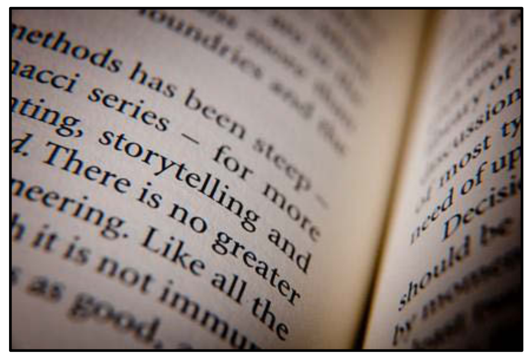
8.2 EXISTING CONDITIONS

8.2.1 Sources of Information

No field investigations were carried out specifically for this CER, although considerable study of the aquatic environment was and is being carried out by the Canadian Rivers Institute (CRI) through the Mactaquac Aquatic Ecosystem Study (MAES), the results of which will be considered by NB Power separately from the CER in its decision-making regarding the Preferred Option. This review of conditions, as they currently exist, presents information available from previous studies and reports. The studies that are ongoing as part of the MAES will provide a more complete description of the aquatic environment in the area of review. The CER contains information from MAES studies to date that has been made available. Further information on the MAES will be available through a series of separate reports, when those studies are completed.

The following sources of information were used to characterize existing conditions for the CER:

- scientific literature on the effects of dams and dam removal on fishes and aquatic habitat;
- scientific literature on the aquatic ecology of the Saint John River and the influence of the Station on fishes and aquatic habitat;
- other consultant reports and ongoing research related to the Project (*e.g.*, MAES being carried out by CRI);



- relevant federal and provincial reports on species at risk (SAR) and species of conservation concern (SOCC) (*e.g.*, COSEWIC status reports); and
- interviews with people knowledgeable about the Saint John River ecology and key SAR and SOCC.

8.2.2 Description of Existing Conditions

8.2.2.1 Fish Habitat

This section presents existing information on the area of review as it relates to key features of fish habitat, including water flow, water and sediment quality, and aquatic habitat. As distinct habitat characteristics exist upstream and downstream of the Station, fish habitat features upstream and downstream of the Station are discussed separately, where necessary.

8.2.2.1.1 Water Flow

The predominant effects of dams on rivers are changes in water flow (hydrology) and the size and shape of the river (river morphology) (Poff and Hart 2002; Stanley and Doyle 2003). The existing morphological and hydrological conditions of the area of review are described in greater detail in Section 6 (surface water). This section summarizes the general water flow characteristics that relate to biological components of fish habitat.

The headpond is the main habitat feature upstream of the Station. The creation of the headpond from a flowing river resulted in a wider main channel, greater depth and numerous flooded valleys that previously contained tributary streams (Figure 2.2). While the headpond resembles a lake (*i.e.*, a lentic environment), many of its characteristics are river-like (lotic) in nature, which is common in large dam headponds. In essence, the headpond is still a river, though now slower moving and deeper.

Currently, the volume of water discharged from the headpond is proportional to what it receives from the watershed upstream (*e.g.*, from runoff, precipitation, springs, and human inputs).The Saint John River watershed is shown on Figure 6.2. Occasionally, the headpond is drawn down in anticipation of large storms, which can expose shallow aquatic habitats in headpond areas closest to the Station, and strand aquatic organisms such as algae and mussels (Martel *et al.* 2010).

The downstream environment below the Station is a river, with shallow and fast-flowing waters that are influenced by water releases during periods of high electrical demand and/or high flow. The Station causes daily downstream water level fluctuations of up to 1 m that are mainly limited to short-term changes within the first 30 to 40 km below the Station (Luiker *et al.* 2013).

The frequent wetting and drying of river margins in areas immediately downstream of the Station create shoreline conditions that can be unfavourable for some plants (*e.g.*, algae and macrophytes) and for aquatic invertebrates and fishes, in the event they are stranded.

8.2.2.1.2 Water and Sediment Quality

Water and sediment quality are important fish habitat characteristics. Changes in their parameters can influence the number, type, and location of species present in the aquatic environment. This section summarizes available existing information on key water and sediment quality characteristics as they relate to fish habitat in the area of review.

Water Quality

Water quality parameters investigated in the area of review include temperature, dissolved oxygen, pH, water clarity, and chemical composition. There has been some systematic effort to measure and track long-term fluctuations in these, or other, water quality parameters in the area of review. Perhaps the best continuous data set comes from the New Brunswick Department of Environment and Local Government (NBDELG 2015g), where surface water quality data have been collected quarterly since 2003 (see Section 6). These data are limited, in that they do not account for periods of high water levels, when water contamination is often greatest. Further, water quality parameters are not measured upstream and downstream on the same days, meaning the values presented in this CER Report may not fully represent the existing water quality conditions in the area of review. However, this review does allow a qualitative understanding of water quality as it relates to fish habitat. Sampling to establish baseline water quality data downstream of the Station is ongoing as part of the MAES (Wallace 2015). Results to date are summarized in Section 6 of this CER Report.

Temperature

Water temperature is an important factor to consider when describing water quality. Temperature influences the amount of oxygen available in water and affects the metabolic rate and biological function of aquatic organisms, including how fast an organism grows, when it breeds, and its ability to survive. Aquatic organisms have species-specific temperature tolerances and preferences that influence the habitats they occupy (Brett 1956).

The temperature of water in the headpond varies among seasons, years and locations, as well as between the surface and the deeper bottom waters (SJRBB 1975; FAC 1994; FAC 1995; Bradford, R., pers. comm., 2014). Summer surface water temperatures as high as 25.4°C have been recorded (FAC 1995), but the headpond typically exhibits thermal stratification. For example, in winter, surface water temperatures beneath the ice cover (SJRBB 1975) are typically colder than water at depth. The cold winter water likely causes some species (*e.g.*, smallmouth bass) to enter an inactive state until spring (Shuter and Post 1990; Guppy and Withers 1999). Conversely, in summer, warmer water near the surface overlays colder water at depth.

Deep, slow flowing waterbodies in New Brunswick (including the Mactaquac headpond) characteristically undergo periods of mixing in the spring and fall, when water temperatures are around 4°C, from surface to bottom. This period of mixing is important because it also allows gases in the water column to equilibrate with air, allowing carbon dioxide and other gases associated with respiration and decomposition to escape, thereby replenishing oxygen to the entire water column. When the water near the surface undergoes rapid warming (in spring) or cooling (in fall), the resulting thermal stratification and gradient creates a density barrier which inhibits mixing of the whole water column. Because the density of water is at its greatest at a temperature of about 4°C, classical thermal stratification in summer results in a layer of warm water overlying cold water, whereas in winter colder water is found overlying slightly warmer water. The zone where the temperature changes most quickly is termed the thermocline.

Thermal stratification in the headpond means that in summer bottom waters can be 10°C cooler than the overlying surface waters (SJRBB 1975; FAC 1994; FAC 1995; Bradford unpublished data). Headpond thermal stratification has been recorded at depths ranging from 6 to 16 m below the surface in waters that were at least 18 m deep (SJRBB 1975; FAC 1994; FAC 1995). Since stratification usually only occurs in deeper waters it is not found everywhere in the headpond. As such, it is unlikely that stratification occurs much farther upstream than the village of Meductic. The exception to this is localized stratification in areas where cold, dense groundwater seeps into the river, causing stratification at shallower depths near shore.

Water temperatures downstream of the Station also vary with season and year. However, due to the faster moving water and shallower depths downstream, substantial thermal stratification is unlikely. The Station's intake structure extends to depths ranging from 8 to 21 m (SJRBB 1975). As such, the intake may draw from both warmer surface water and the cooler deeper water.

Average daily water temperatures recorded immediately upstream and downstream the Station in May 2012 (Bradford, R., pers. comm., 2014) reveal downstream temperatures that more closely resemble the deeper waters of the headpond. These data suggest that discharge water from the Station may have a slight cooling effect downstream. However, this may vary depending on the depth water is drawn from in the headpond and the time of year. Generally, because daily and seasonal changes in temperature are buffered by the headpond, water downstream may be cooler in spring and summer than before the Station was constructed, and vice versa (*i.e.*, warmer in fall and winter). However, surface water releases from structures like the Station are generally of suitable temperatures for the growth and reproduction of the organisms inhabiting the river (Brittain and Saltveit 1989).

Winter water temperatures below the Station are likely to reflect those in the upper layers of the headpond and remain stable near 0°C during periods of headpond ice cover. The existing winter temperature data appear consistent with this.

Dissolved Oxygen

As with temperature, aquatic organisms have species-specific tolerances to levels of dissolved oxygen (DO), which influence their behaviour and the habitats they occupy (Hochachka and Lutz 2001; Pollock *et al.* 2007). The Canadian Council of Ministers of the Environment (CCME) has set general guidelines for acceptable DO concentrations for the protection of aquatic life, ranging from 9.5 mg/L for early life stages of cold water species to 5.5 mg/L for adult stages of cool water species (CCME 2007).

While DO in the headpond varies slightly between locations and seasons (SJRBB 1975; FAC 1994; FAC 1995; NBDELG 2015g), the majority of recorded DO levels fall within the acceptable range (CCME 2007; CRI 2011). MAES studies to date have confirmed these previous observations (Yamazaki, G., pers. comm., 2016). However, DO levels have been shown to decline markedly near the bottom of the deeper areas of the headpond, reaching values as low as 1.0 mg/L in summer (FAC 1995) and 2.5 mg/L in winter (SJRBB 1975). The decline in DO levels with depth occurs because oxygen is consumed by chemical and biological processes (*e.g.*, respiration by bacteria and other life). In contrast to the shallow surface waters, the presence of a thermocline prevents replenishment of oxygen in deeper waters by exchange with the atmosphere, and limited light penetration precludes photosynthetic activity (Wetzel 1983). Overall, the decline in oxygen at depth is indicative of medium to high biological productivity, which could limit the potential for the headpond to sustain certain fish species (such as salmonids that require cold and well oxygenated water) during summer.

Did you know?

Biological Productivity refers to the production of organic matter in an ecosystem. Typically, freshwater systems with more nutrients have more algae, plants, plankton and bacteria. Such environments tend to use more oxygen in the surface waters, reducing oxygen availability at depth.

Dissolved oxygen levels measured downstream of the Station are generally not a limiting factor to native aquatic organisms (CCME 2007; CRI 2011; Luiker *et al.* 2013; NBDELG 2015g). Spillage from the Station results in aeration of the released water. Even when all water flow is through the turbines, the discharge channel area is turbulent, and enhances gas exchange between the water and the atmosphere. Dissolved oxygen concentrations have been observed to increase below the Station. Measurements of DO upstream and downstream of the Station during the winter months of 1971 to 1973 (SJRBB 1975) indicated DO levels in the downstream sections were higher than those upstream of the Station, and continued to increase with increasing distance downstream. The findings of the SJRBB (1975) support the position of Brittain and Saltveit (1989), who suggest that surface-release facilities like the Station generally discharge water that has an oxygen concentration suitable for the growth and reproduction of local species.

pH

The pH of water is a critical factor in assessing the quality of an aquatic environment. According to CCME (2007), a pH from 6.5 to 9.0 is appropriate for most freshwater life, although some species are more sensitive to pH than others. The pH of natural waters can vary seasonally and daily. Data for pH in the area of review are sparse, but those available suggest there is little variation with depth, location, or season.

NBDELG (2015g) has reported a few pH values below CCME guidelines upstream of the Station; however, these isolated dips in pH likely relate to daily and seasonal fluctuations and are not considered a threat to aquatic life. FAC (1994) reported pH values that ranged from 6.96 to 8.10 upstream of the Station. Similarly, MAES studies to date noted consistent pH values of 7.6-7.8 at the Fredericton walking bridge during the warmer months of 2014, 2015, and 2016 (Yamazaki, G., pers. comm., 2016). The SJRBB (1975) noted a similar trend for the years 1971, 1972 and 1973, and also reported little variation in pH between the headpond and the river below the Station. As such, the pH of water in the area of review appears to be well within a suitable range to support aquatic life (CCME 2007; CRI 2011).

Water Clarity

Water clarity refers to the transparency or clearness of water. Low water clarity can reduce the availability and distribution of photosynthetic organisms, including phytoplankton, periphyton, macroalgae, and macrophytes. Likewise, low clarity may also decrease the effectiveness of visual predators and benefit predators that rely upon other sensory systems (Utne-Palm 2002). Water clarity is influenced by suspended sediment and plankton in the water column, and by the presence of chemical compounds such as dissolved organic carbon in water. Suspended sediments and plankton reduce transparency by increasing both the absorption and the scattering of light in the water column. Chemical compounds can influence clarity by changing the colour of water by absorbing light. One common measure of water clarity is the Secchi depth (Chambers and Kaiff 1985). Secchi depths for the headpond range from 1.8 to 2.2 m (FAC 1994, 1995).

Secchi Depth represents the maximum depth below the surface that a black and white disc (Secchi disc) can be observed with the naked eye. As such, Secchi depths are often used as a representative measure of the maximum depth at which light can penetrate the water column.

Another measure of water clarity is turbidity, which is a general term to describe the lack of transparency or cloudiness of water due to suspended particles in the water. For the area of review, previous studies have reported turbidity levels that were suitable for aquatic life (SJRBB, 1975; NBDELG, 2015g; CRI, 2011). MAES studies to date have confirmed these previous observations, reporting turbidity values ranging from 0.7 to 31.0 NTU (Yamazaki, G., pers. comm., 2016). Turbidity levels can increase substantially under naturally high flow conditions due to increased sediment suspension and transport. High turbidity levels have been recorded upstream and downstream the Station, but are generally short-term and decline with receding water levels.

Chemical Composition

The chemical composition of water refers to both natural and human-made sources of chemical elements and compounds found in water, such as trace metals, organic compounds, chlorinated substances, and nutrients. High nutrient levels can cause excessive plant growth, such as algal blooms, which decrease water clarity and deplete oxygen that is needed for fishes to survive. Enrichment of nutrients in surface waters occurs naturally, but is typically associated with anthropogenic sources, such as nitrogen and phosphorous from fertilizers. Conversely, low nutrient levels can limit growth of algae, thereby limiting the amount of food available to fishes. High levels of metals or other toxic substances in the water can also affect the growth, survival and reproduction of exposed aquatic organisms.

The available data suggest that the chemical composition of the water in the area of review is suitable for the growth, survival and reproduction of aquatic organisms (NBENV 2008; CRI 2011; NBDELG 2015g; Wallace 2015). See Section 6 (Surface Water) for more information related to chemical water quality.

Sediment Quality

Bottom sediment type and composition (*e.g.*, mineral and organic matter) can play a key role in the occurrence and distribution of many aquatic organisms. Some species, such as dwarf wedge mussel (*Alasmidonta heterodon*) which are found in the Saint John River, prefer soft sediments in which they can burrow and hide (Martel *et al.* 2010). In contrast, fallfish (*Semotilus corporalis*) require small pebbles in shallow waters from which they build a spawning mound (Scott and Crossman 1973). Other species may be indirectly influenced by the bottom composition, which determines the presence of aquatic plants which are needed for shelter or spawning for some species. The chemical composition of sediments, including the presence of heavy metals and other compounds, can also influence the survival, growth and distribution of aquatic organisms.

For the most part, deep, slow-flowing lentic environments (such as the headpond) often have fine organic and sandy sediments where substantial biological processes and nutrient cycling may occur (Petticrew and Kalff 1991). Riverine environments, such as those downstream of the Station, are typically characterized by sediments that are distributed based on their size and weight, and on water velocity; faster moving riverine waters have a higher proportion of gravel, rubble and rocks (Wetzel 1983).

Inputs from industrial, agricultural and municipal sources likely affect sediment quality within the area of review. In the MAES data to date, trace metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls and chlorinated pesticides have been found in sediments in the headpond; some exceeded CCME Interim Sediment Quality Guidelines for the Protection of Aquatic life (Kidd *et al.* 2015; see Section 6). While no clear areas of concentration (hot spots) were discovered (Kidd *et al.* 2015), these data suggest that certain contaminant concentrations increase with sediment depth (*e.g.,* chlorinated pesticides). Section 6 (Surface Water) provides more information on chemical sediment quality. Additional information on sediment quality is being collected as part of the MAES.

The presence of the Station may reduce the downstream transport of sediments and organic debris. It is possible that the primary productivity of habitats downstream of the Station, such as Grand Lake Meadows, may be affected by a reduction in nutrient inputs as a result of reduced sediment transport

(Rosenberg *et al.* 1997). The influence this may have on the river is not well understood; however, the existing Station may be limiting the productivity of the downstream ecosystem in the area of review.

8.2.2.1.3 Aquatic Habitat

The abundance and distribution of aquatic species in a watercourse are ultimately governed by the quality and quantity of aquatic habitat. This section summarizes available information on the physical size, location, and structure of aquatic habitats in the area of review. An overview of the species found in each habitat type is also provided.

Upstream of the Station

Aquatic habitats in the headpond can be categorized as littoral (shallow water) or open water (deeper) areas. Open water areas can be further divided into the surface water zone (where there is adequate light penetration to support photosynthesis and warm water temperatures during summer stratification) and the deep water zone (where the water is generally cold and dark throughout the year).

Littoral Zone in the Headpond

The littoral zone is defined here as areas that are 2 m deep or less during the summer; this includes shorelines and shoals. The size of the headpond's littoral zone is approximately 24 km^2, or 29% of the total water surface area. The littoral zone is a biologically diverse area where water temperatures are generally warm during the summer and light can reach bottom substrates, which enables the growth of a variety of periphyton, macroalgae, and vascular macrophytes.

The littoral zone of the headpond includes shallow coves and inlets that support the growth of aquatic macrophytes, periphyton (Culp *et al.* 2006), and filamentous green algae (Cunjak and Newbury 2005). Numerous roots and stumps of trees that were cut prior to flooding of the headpond occur in the littoral zone. These habitats are often used by sunfish, perches, catfish, and minnows, which feed on invertebrates such as larval insects and snails. The littoral zone is also a favourite hunting ground of ambush predators like chain pickerel and smallmouth bass.

The littoral habitats of the headpond are affected by short-term water level changes associated with the management of the Station, which can strand algae, macrophytes, benthic invertebrates and potentially fishes. Headpond drawdowns may also influence the reproductive success of some shoreline-spawning fishes, such as sunfish, especially in the lower reaches of the headpond where the drawdowns are more pronounced. Water level fluctuations have the most pronounced influence on species that have difficulty moving with the receding water level or those that cannot physiologically cope with the associated air exposure. Since the bathymetry of the headpond is relatively steep, current water level fluctuations do not expose extensive areas of substrate (Richardson *et al.* 2002) relative to some other systems.

Existing information on benthic invertebrates in the area of review suggests that a variety of insect larvae, and other species groups, inhabit shallow areas of the headpond (SJRBB 1974; Cunjak and Newbury 2005). Mussels occur along shallow shoreline areas and at the upstream end of the headpond near Woodstock (Duerden *et al.* 1973; SJRBB 1974; Martel *et al.* 2010). Eleven mussel species occur in the

Saint John River (Table 8.2); at least six of these are likely to occur in the headpond (Martel *et al.* 2010). Freshwater mussels, like the tidewater mucket (*Leptodea ochracea*) and alewife floater (*Anodonta implicata*), have died following stranding during rapid summer drawdowns (Martel *et al.* 2010). The larvae of freshwater mussels must attach to the gills of fishes (often a specific fish host [Table 8.2]) for a brief period; therefore, the distribution of mussel species may depend on the ability of fishes to move throughout the watercourse. A systematic survey to identify the presence, abundance and distribution of benthic invertebrate species in the headpond is planned as part of the MAES.

The littoral zone of the headpond supports a diverse community of aquatic organisms, many of which would not otherwise be abundant in this section of the Saint John River.

Table 8.2 Preferred Habitat and Host Fish of Mussel Species Found Near the Station

Species	Preferred Habitat	Host Fish	Headpond Occurrence?	Downstream Occurrence?
Eastern pearlshell (*Margaritifera margaritifera*)	Cold, running water	Possibly specific to salmonids	Unlikely	Potential
Dwarf wedgemussel (*Alasmidonta heterodon*)	Large, slow-flowing streams and rivers	Various	Probably extirpated	Probably extirpated
Triangle floater (*Alasmidonta undulata*)	Steady-flowing water	Various	Yes	Yes
Brook floater (*Alasmidonta varicosa*)	Moderate to rapidly flowing streams	Various	Unlikely	Unlikely[1]
Alewife floater (*Anodonta implicata*)	Various; lakes and rivers	Alewife and other anadromous fishes	Yes	Yes
Eastern floater (*Pyganodon cataracta*)	Various; lakes and rivers	Various	Yes	Yes
Creeper (*Strophitus undulatus*)	Various; streams, rivers and lakes	Various[2]	Potential	Potential
Eastern elliptio (*Elliptio complanata*)	Various; streams, rivers and lakes	Various[3]	Yes	Yes
Yellow lampmussel (*Lampsilis cariosa*)	Slow- to swift-flowing rivers	Possibly specific to perciformes[4]	Potential	Yes
Eastern lampmussel (*Lampsilis radiata*)	Various; lakes and rivers	Possibly specific to perciformes[4]	Yes	Yes
Tidewater mucket (*Leptodea ochracea*)	Quiet areas of lakes and large rivers	Various, especially white perch	Yes	Yes

Notes:
1 May have existed in the Saint John River historically, but could have been eliminated because of dams.
2 Salamanders may also serve as hosts.
3 Lellis *et al.* (2013).
4 Perciformes are an order of fishes that includes basses, perches and sunfishes.
Source: Martel *et al.* (2010)

Open Water Zone in the Headpond

For the purposes of this review, the open water zone is defined as those areas of the water column that are deeper than 2 m during the summer. The size of the headpond's open water zone is approximately 59 km^2 or 71% of the total surface area of the headpond. Open water habitats are important to fishes, like alewives, for feeding and ease of movement (Bradbury *et al.* 1999). The abundance of plankton in the headpond (SJRBB 1974) may partially explain the ability of alewife to thrive there following construction of the Station (DFO 2001).

The sediment underlying the open water zone is exposed to less light and cooler water temperatures than the littoral zone. As a result, benthic invertebrate communities generally rely more on detritus that falls to the bottom, and are less productive than benthic communities in the littoral zone. Existing information from other systems suggest that the slower moving waters of the headpond may have created a benthic zone that is dominated by at least a thin veneer of soft substrate (Petticrew and Kalff 1991). Characterization of the sediment composition within the headpond is being undertaken as part of the MAES. MAES data to date suggests that the headpond consists of a relatively thin (~5-30cm), film of fine unconsolidated sediments that are somewhat uniformly distributed from the town of Nackawic downstream to the Station (Yamazaki, G., pers. comm., 2016).

Invertebrate communities of the open water zone are dominated largely by sludgeworms (tubificid worms) and chironomid midges (SJRBB 1974). High densities of sludgeworms are often associated with the concentration of organic inputs (Watt *et al.* 1973). Tubificid densities at the bottom of the headpond are notably lower than in headponds further upriver, which may reflect a downstream improvement in water quality (SJRBB 1974). The use of open water habitats for foraging may be limited to fishes like white suckers and brown bullheads, which bottom feed on insect larvae (Scott and Crossman 1973). Additional information on benthic species community composition upstream of the Station is being collected as part of the MAES.

Downstream

Overall, habitats downstream of the Station are typical of a large river environment with higher velocities (particularly in the area upstream of Fredericton) and lower water depths than those in much of the headpond. The shallower depths enable greater mixing, reduced thermal stratification, and more consistent dissolved oxygen concentrations and water temperatures. Unlike habitats in the headpond, downstream habitats cannot be characterized as littoral or open water because of their greater uniformity and shallower depths.

The downstream river banks have a shallow slope; therefore, water depth gradually increases with distance from the shore. Daily water level fluctuations of up to 1 m near the Station (Luiker *et al.* 2013) can create an environment with variable water velocity and intermittent wet and dry periods in shallow areas. These water level fluctuations are likely disruptive to some algae and benthic invertebrates (*e.g.*, mussels), and can lead to stranding of fishes that forage or spawn along the river margins. However, many of the organisms found along the headpond periphery, such as the genera Myriophyllum, Potamogeton, and Vallisneria, are also common in the shallow, calm waters downstream of the Station (Hinds 2000; Tyrrell, C., pers. comm., 2015).

Plankton assemblages downstream of the Station are assumed to be similar in composition as those in upstream impounded areas, but their densities are likely lower. Plankton tend to accumulate in lakes and impoundments but are largely limited to low-flow margins of streams and rivers (Rojo *et al.* 1994). However, the headpond may input downstream areas with plankton in higher abundances than would normally occur if the Station were not present.

Studies of other dammed rivers have routinely shown a predictable downstream progression of benthic invertebrate communities with distance from the dam (Brittain and Saltveit 1989; Camargo and Voelz 1998). Invertebrates that tolerate changes in flow and temperature (*e.g.*, chironomid midges) are more prevalent immediately downstream of a dam, and the relative abundance of species that are sensitive to such alterations (*e.g.*, mayflies, stoneflies and caddisflies) increases with distance downstream. Benthic invertebrate samples from the Fredericton area (approximately 19 km downstream of the Station) were about equally dominated by mayflies (mostly Ephemerellidae) and chironomid midges; caddisflies, stoneflies, oligochaete worms and other taxa also occurred in the samples (Heard and Curry 2003).

Benthic macroinvertebrate (BMI) and paired habitat variables were sampled downstream of the Mactaquac Dam as part of the MAES biological monitoring program (Yamazaki, G., pers. comm., 2016). The following summary of downstream BMI baseline data was provided by the CRI.

"Fifteen core sites were established in the downstream study reach, representing a range of flow habitats, with an additional two sample sites identified outside the influence of direct human impacts of the headpond. Samples were collected in 2014 and 2015 using a modified Canadian Aquatic Biomonitoring Network (CABIN) protocols, adjusted for large river sampling (CABIN 2012). Benthic community samples were identified to genus-level, where possible, and QA/QC checked by Society of Freshwater Science-certified taxonomists. Results indicate that the benthic macroinvertebrate community is generally rich and indicative of a healthy river system" (Yamazaki, G., pers. comm., 2016).

Fish Community Composition and Population Abundance

While the Saint John River is known to contain fifty-three fish species, forty-two have been recorded in the area of review (CRI 2011; Table 8.3). Most are permanent residents in the area and have breeding populations upstream and downstream of the Station. Some species are believed to occur infrequently because their abundance is low (*e.g.,* rainbow trout) or they typically inhabit more estuarine habitats (*e.g.*, tomcod). Five non-native species have been recorded in the area, most notably two popular recreational fishing species: smallmouth bass and muskellunge. Eleven species are diadromous; using both freshwater and marine environments (Table 8.3).

Diadromy refers to a life history behaviour where fishes move between ocean and freshwater habitats for feeding and reproduction. Anadromous fishes begin life in freshwater and migrate to sea to feed before returning to breed. Catadromous fishes begin life in the ocean and migrate to freshwater to feed before returning to breed.

Table 8.3 Fish Species in the Area of Review

Species	Presence		Species at Risk or Species of Conservation Concern?	Native?	River Life History	Habitat
	Upstream of the Station	Downstream of the Station				
Threespine stickleback (*Gasterosteus aculeatus*)	Present	Present	No	Yes	Year-round resident	Main stem, tributaries and estuary.
Fourspine stickleback (*Apeltes quadracus*)	Occasional	Present	No	Yes	Year-round resident	Various; more common in estuary.
Ninespine stickleback (*Pungitius pungitius*)	Present	Present	No	Yes	Year-round resident	Various; widespread throughout tributaries.
Alewife (*Alosa pseudoharengus*)	Present	Present	No	Yes	Migratory; anadromous	Spawn in freshwater and brackish areas in shallow lakes or slow-flowing river habitat; adults overwinter in marine and estuarine areas.
American eel (*Anguilla rostrata*)	Present	Present	Yes	Yes	Migratory; catadromous	Juveniles present year-round throughout the river system; adults migrate to Sargasso Sea in the fall to spawn.
Atlantic salmon (*Salmo salar*)	Present	Present	Yes	Yes	Migratory; anadromous	Prefer cold water; substantial spawning and juvenile rearing habitat exists upstream of the Station.
Atlantic sturgeon (*Acipenser oxyrinchus*)	Historical	Present	Yes	Yes	Migratory; anadromous	Spawn in shallow, gravelly, fast-flowing areas, and overwinter in estuary; adults often spend many years in coastal marine environments.
Atlantic tomcod (*Microgadus tomcod*)	Absent	Occasional	No	Yes	Diadromous; occasionally forage in freshwater	Generally marine but feed in freshwater seasonally.

Table 8.3 Fish Species in the Area of Review

Species	Presence		Species at Risk or Species of Conservation Concern?	Native?	River Life History	Habitat
	Upstream of the Station	Downstream of the Station				
Banded killifish (*Fundulus diaphanous*)	Present	Present	No	Yes	Year-round resident	Brackish and freshwater lakes, ponds and slow backwaters.
Blacknose dace (*Rhinichthys atratulus*)	Present	Present	No	Yes	Year-round resident	Prefer cool, clear streams, but also occurs in slow rivers and lakes.
Blacknose shiner (*Notropis heterolepis*)	Present	Present	No	Yes	Year-round resident	Prefer shallow areas in slow-moving streams and rivers, with relatively clear water.
Blueback herring (*Alosa aestivalis*)	Present	Present	No	Yes	Migratory; anadromous	Spawn in freshwater and brackish areas in shallow lakes or slow-flowing river habitat; adults overwinter in marine and estuarine areas.
Brook trout (*Salvelinus fontinalis*)	Present	Present	No	Yes	Year-round resident[3]	Prefers cool water but is adapted to a variety of conditions; widespread in NB lakes, rivers and streams.
Brown bullhead (*Ameiurus nebulosus*)	Present	Present	No	Yes	Year-round resident	Lakes, backwaters and slow-flowing rivers; bottom-dwelling; tolerates turbid and low oxygen environments.
Brown trout (*Salmo trutta*)	Occasional	Occasional	No	No	Occasional resident[3]	Prefer clean, cold streams and lakes with gravel substrates.
Burbot (*Lota lota*)	Present	Present	No	Yes	Year-round resident	Clean, cool lakes, rivers and large streams; spawns in mid-winter.
Chain pickerel (*Esox niger*)	Present	Present	No	No	Year-round resident	Freshwater or slightly brackish areas; generally, cool to warm lakes and slow-moving rivers .

Table 8.3 Fish Species in the Area of Review

Species	Presence		Species at Risk or Species of Conservation Concern?	Native?	River Life History	Habitat
	Upstream of the Station	Downstream of the Station				
Common shiner (*Notropis cornutus*)	Present	Present	No	Yes	Year-round resident	Various habitats in clean streams, rivers and lakes.
Creek chub (*Semotilus atromaculatus*)	Present	Present	No	Yes	Year-round resident	Various habitats in cool streams and rivers.
Fallfish (*Semotilus corporalis*)	Present	Present	No	Yes	Year-round resident	Clear streams, rivers and some lakes; congregate in pools and runs.
Fathead minnow (*Pimephales promelas*)	Occasional	Historical	No	Yes	Year-round resident	Uncommon in lower Saint John River, below Madawaska County; muddy areas in lakes, ponds and headwater streams.
Finescale dace (*Phoxinus neogaeus*)	Occasional	Absent	No	Yes	Year-round resident	Lakes, ponds and slow-flowing headwater areas.
Golden shiner (*Notemigonus crysoleucas*)	Present	Present	No	Yes	Year-round resident	Shallow areas in lakes and slow-moving rivers.
Lake chub (*Couesius plumbeus*)	Present	Present	No	Yes	Year-round resident	Various; lakes, rivers, streams of various sizes.
Lake whitefish (*Coregonus clupeaformis*)	Occasional	Occasional	No	Yes	Year-round resident	Prefer cool, clear (oligotrophic) lakes; usually occurs in deeper areas; occasionally occurs in rivers.
Longnose sucker (*Catostomus catostomus*)	Occasional	Occasional	No	Yes	Year-round resident	Cool, deep areas of lakes and some tributary streams.
Muskellunge (*Esox masquinongy*)	Occasional	Occasional	No	No	Year-round resident	Shallow, warm waters of lakes and rivers; spawns in spring in shallow, vegetated areas.
Northern redbelly dace (*Chrosomus eos*)	Occasional	Historical	No	Yes	Year-round resident	Mostly lakes and ponds but occasionally impounded areas of streams (*e.g.*, beaver dams).

Table 8.3 Fish Species in the Area of Review

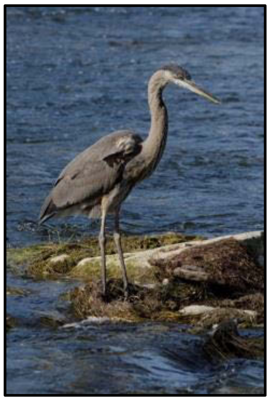
Species	Presence		Species at Risk or Species of Conservation Concern?	Native?	River Life History	Habitat
	Upstream of the Station	Downstream of the Station				
Pearl dace (*Semotilus margarita*)	Occasional	Historical	No	Yes	Year-round resident	Cool waters of bogs, streams and lakes.
Pumpkinseed (*Lepomis gibbosus*)	Present	Present	No	Yes	Year-round resident	Small lakes and slow-flowing rivers; common among aquatic plants.
Rainbow smelt (*Osmerus mordax*)	Occasional	Present	No	Yes	Migratory; anadromous	Spawn in gravel-bottomed rivers and large streams; overwinter in estuary or coastal areas.
Rainbow trout (*Oncorhynchus mykiss*)	Occasional	Occasional	No	No	Occasional resident[3]	Clean, fast-flowing rivers and large streams; captured infrequently in Saint John River.
Redbreast sunfish (*Lepomis auritus*)	Historical	Present	Yes	Yes	Year-round resident	Small lakes and slow-flowing rivers; common among aquatic plants.
Sea lamprey (*Petromyzon marinus*)	Occasional[1]	Present	No	Yes	Migratory; anadromous	Mature lamprey migrate into freshwater tributaries in late spring to spawn; juveniles develop in sandy, shallow areas for several years and go to sea between October and May.
American shad (*Alosa sapidissima*)	Historical[1]	Occasional	No	Yes	Migratory; anadromous	Migrate into large rivers in spring and spawn between May and July; spawn in large rivers and upper estuaries and then return to sea; juveniles make their way to brackish water (lower river) by fall.
Shortnose sturgeon (*Acipenser brevirostrum*)	Historical	Common	Yes	Yes	Migratory; anadromous	Spawn in shallow, fast-flowing riverine areas; juveniles develop in upper estuary; adults rarely leave the estuary.

Table 8.3 Fish Species in the Area of Review

Species	Presence		Species at Risk or Species of Conservation Concern?	Native?	River Life History	Habitat
	Upstream of the Station	Downstream of the Station				
Slimy sculpin (*Cottus cognatus*)	Present	Present	No	Yes	Year-round resident	Cool, rocky streams and rivers; typically freshwater, but also occurs in main-stem brackish areas.
Smallmouth bass (*Micropterus dolomieu*)	Present	Present	No	No	Year-round resident; overwinter in deeper areas	Various; large streams to large rivers and lakes; common in rocky or well-vegetated areas.
Striped bass (*Morone saxatilis*)	Occasional	Present[2]	Yes	Yes	Migratory; anadromous	Typically spawn near tide head; juveniles and adults inhabit coastal and estuarine areas, especially where eelgrass occurs.
White perch (*Morone americana*)	Present	Present	No	Yes	Year-round resident; non-anadromous[3]	Various; clear lakes and medium–large rivers; spawn in shallow areas over various substrates.
White sucker (*Catostomus commersoni*)	Present	Present	No	Yes	Year-round resident	Cool, deep areas of rivers, lakes and large streams; spawn May–June in shallow, gravel-bottom streams and lake margins.
Yellow perch (*Perca flavecens*)	Present	Present	No	Yes	Year-round resident	Cool lakes and rivers; spawn in shoreline areas of lakes and medium to large rivers; those that inhabit brackish water move into freshwater to spawn.

Notes:
1 CRI (2011) reported only historic records of sea lamprey and American shad upstream of the Station.
2 Striped bass may be migrants from other populations that may not breed in the Saint John River.
3 Anadromous populations of this species are known to occur but have not been confirmed in the area of review.
Source: CRI (2011)

The level of fish population monitoring in the area of review is insufficient to estimate population abundances. The most comprehensive and scientifically rigorous study to date was conducted in the summers of 2000 and 2001. Fish community composition surveys were conducted along the length of the Saint John River, including at three sites (Woodstock, Nackawic, and Fredericton) in the area of review (Curry and Munkittrick 2005). Statistically comparing the relative abundances of captured species between headpond and river-type environments suggested that only two species were affected by the type of environment. White sucker relative abundance was greater in the headpond than in river-type environments, while smallmouth bass relative abundance was lower.



While not well documented on the Saint John River, evidence from other systems (Quinn and Kwak 2003; Tiemann *et al.* 2004; Kiraly *et al.* 2015) allows some generalizations to be made regarding the community of fishes upstream and downstream of the Station. Upstream of the Station, community composition and relative abundance are influenced by fish passage challenges, fisheries management decisions, and lake-like habitat features. The dam obstructs the passage of fishes; consequently, the abundance of diadromous species decreases upstream (Curry and Munkittrick 2005). The lake-like habitat of the headpond (which is suitable for reproduction), coupled with the managed transport of gaspereau (*i.e.,* alewife and blueback herring) into the headpond, have resulted in these species becoming abundant in this environment (Jessop 2001). Moreover, as the headpond contains more diverse habitat features, relative abundance likely differs among species within the headpond (Herbert and Gelwick 2003; Guenther and Spacie 2006). For example, protected, heavily vegetated shallow inlets may support greater relative abundances of generalist species that are capable of adapting to warm, lake-like environments. The community composition of fishes upstream and downstream of the Station is being further characterized as part of the MAES.

The Atlantic salmon has been monitored on the Saint John River system for several decades. Atlantic salmon of the Saint John River watershed are managed by Fisheries and Oceans Canada, collectively, as the outer Bay of Fundy population. Information on the breeding population in the river is based on counts of the number of salmon returning from sea to the fish collection facility at the Station and at the Nashwaak River (DFO 2014; Jones *et al.* 2014). Shortly following the construction of the Station in the late 1960s, a fish collection facility and fish hatchery were built at Mactaquac to mitigate the effects of the hydroelectric development on Atlantic salmon. Salmon returns have been recorded there continuously since 1970. The number of salmon returning to the fish collection facility remained relatively consistent until the early 1990s, but then began to decrease. Current returns are the lowest since recording began. Fish returning to the Nashwaak River, downstream of the Station, have been recorded continuously since the early 1990s. While these data are more variable, returning adults in the Nashwaak River also show a declining trend. Importantly, Atlantic salmon commercial fisheries on the Saint John River closed in 1985; recreational and Aboriginal fisheries closed in 1998.

Atlantic salmon populations have been in decline throughout the species range since the early 1990's (COSEWIC 2010a). The widespread nature of this phenomenon has led scientists to believe that the principal cause of these declines is poor marine survival. Although the specific reasons are not known, the decline of Atlantic salmon has been correlated with fundamental changes in the North Atlantic Ocean ecosystem. In the freshwater environment, DFO has identified existing hydroelectric developments, including the Station, as a top conservation concern to Saint John River Atlantic salmon populations (Ritter 2003; Gibson *et al*. 2009; DFO 2014). The outer Bay of Fundy Atlantic salmon was designated as Endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC) and the New Brunswick *SARA*; therefore, it is considered to be a species at risk in the area of review (COSEWIC 2010a).

8.2.2.2 Fish Populations

Fish populations can be directly influenced by human activity in the area of review through pollution, habitat alteration, fishing and obstructions to fish passage (*i.e.* the obstruction of habitat connectivity). In the context of potential interactions associated with the Options, this review focuses on changes to fish populations in relation to fish passage.

Fish Passage

> **Fish passage** refers to the ability of fishes to move around artificial and natural barriers (such as dams or waterfalls) into habitat on the other side. Passage around barriers is important to ensure fishes can access their entire natural habitat (habitat connectivity). Human built fish passage structures are often called fish ladders, fishways, fish lifts, and fish bypasses. There are various types of fish passage structures.

Despite the incorporation of fish passage facilities (fishways), dams represent a barrier to the movement of fish species to spawning/feeding habitat; attempts to pass through these facilities can cause mortality. At the population level, dams can severely influence migrating species with life histories that cannot be completed without traversing the obstruction in good time and without exhaustion (Poff *et al.* 1997; WCD 2000; Larinier 2001). There are a number of interrelated factors that affect the ability of fishes to move upstream and downstream of dams. They include the design and management of fish passage facilities, and the species-specific morphological, physiological and behavioural biology of the fishes (Pon *et al.* 2009; Williams *et al.* 2012; Bunt *et al.* 2012; Noonan *et al.* 2012). Specifically, the greatest challenges involve the attraction and entry of fishes into the fishway, passage through the fishway itself, and, for large systems such as the Station, navigation through a large headpond. To attract fishes to the entrance of a fishway, the water flow must be sufficient enough to compete with water flowing through the turbines (Katopodis and Williams 2012). Additionally, water depth and flow dynamics can affect the ability of some species to find the entrance.

Once at the entrance, species-specific biological factors interact with the fishway design to determine successful passage. Generally, swimming upstream, common fish passage designs seem to work best for strong, sustained swimming species that are motivated and do not panic easily, such as salmon (Mallen-Cooper and Brand 2007; Roscoe and Hinch 2010). Swimming downstream, there are additional common challenges related to passage itself and the conditions directly downstream of the dam. Fishes moving through the turbine cavity may experience direct physical strikes from the turbines themselves and physiological challenges associated with drastic decreases in barometric pressure (Brown *et al.* 2014). Surface passage through a sluiceway also tends to behaviourally exclude bottom-oriented species. Moreover, predation of disoriented or injured fishes following downstream passage has occurred at numerous facilities (Ruggerone 1986; Reiman *et al.* 1991; Blackwell and Juanes 1998).

There are also some issues with dams that can cause mortality to fishes during both upstream and downstream passage. Firstly, the water quality immediately downstream of dams can be supersaturated with gas (especially nitrogen), particularly when turbine operation coincides with low water levels (Penney 1987; Brittain and Saltveit 1989; Toner and Dawley 1995; Klassen and Locke 2010). Moreover, fish that attempt to follow a natural river flow when moving through a large headpond may be disoriented by the weak currents in the lake-like habitat. This can delay or prevent successful migration, which can influence the synchronisation of natural biological cycles and, thus, the success of completing important life history events such as reaching the breeding grounds in time to participate or interacting with seasonally-dependent food resources (Castro-Santos and Haro 2003).

The Station obstructs the passage of fish species both upstream and downstream. In 1968, fish collection facilities were installed on the downstream side of the powerhouse, adjacent to the turbine water outflow of Units 1 and 2, to mitigate the complete obstruction to upstream passage (Ingram 1980). Fisheries and Oceans Canada (DFO) uses this facility to trap Atlantic salmon and gaspereau in support of management objectives. Trapped salmon and gaspereau are transported upstream of the Station by truck and released. Atlantic salmon are transported as far as upstream of the other existing dam structures (Beechwood and Tobique Dams) on the Saint John River watershed. Gaspereau are transported directly to the headpond upstream of the Station. Additionally, the Mactaquac Biodiversity Facility operates a trap that is located downstream of the powerhouse; however, most fishes are captured at the Station (Ingram 1980; Anderson, L., pers. comm., 2015). A number of other migratory species, including American shad, Atlantic sturgeon, shortnose sturgeon, striped bass, rainbow smelt, sea lamprey and American eel, are also obstructed from upstream habitat but are not actively transported upstream.

The migratory cycles of diadromous fish species found in the area of review are shown in Figure 8.2. During the gaspereau migration period, in particular, other species are occasionally transported upstream of the Station (Jones R., pers. comm., 2015), but this does not occur often enough to be relevant at the population level. In the case of some non-native species, specifically muskellunge and rainbow trout, individuals captured in the trap infrastructure are destroyed, or made available for research following current DFO management objectives, and not returned to the river.

The Station does not have infrastructure designed specifically for fish passage that aids the downstream movement of fishes from the headpond past the dam. Fishes must move through the turbines, through the spillway or over the diversion sluiceway; however, the spillway and diversion sluiceway can be accessed only during periods of high water flow, such as during the spring.

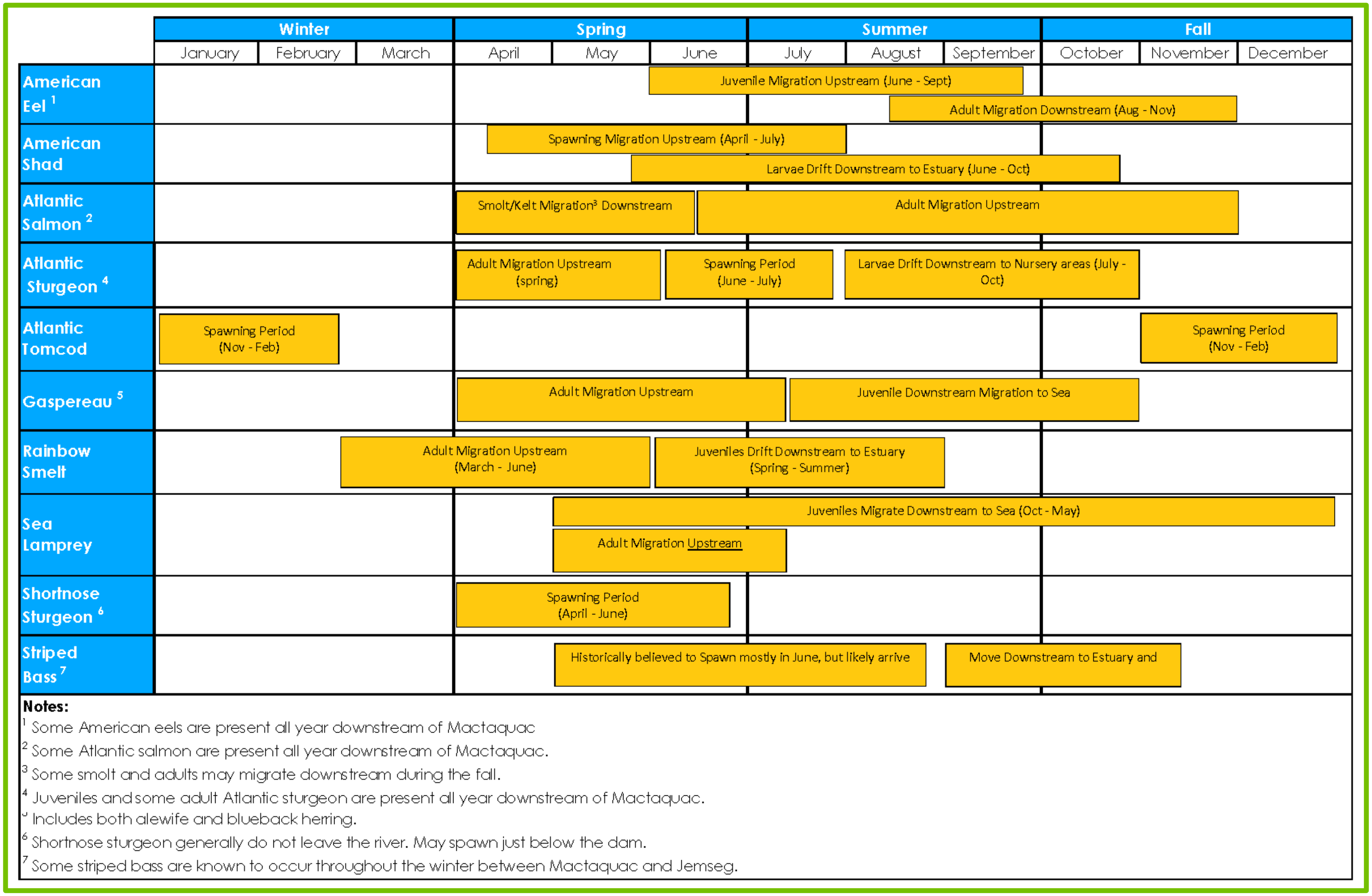


Figure 8.2 Migratory Timing of Diadromous Fishes Found in the Area of Review

There is no existing research estimating the success rate of any fish species ability to move upstream or downstream of the Station. Presumably, the Station obstructs the upstream passage of all unmanaged species; therefore, population-sustaining numbers of those species likely cannot access the Saint John River habitat upstream of the Station. Passage of managed species, Atlantic salmon and gaspereau, is also inhibited. For Atlantic salmon, predictions that navigating the headpond is a challenge for both adults moving upstream to spawning grounds and juveniles/adults moving downstream to the sea have recently been confirmed from MAES research. Specifically, it has been demonstrated that juvenile and adult salmon can be delayed, or are unable, to navigate the headpond (Linnansaari, T., pers. comm., 2016). This information may, in part, explain previous unpublished observations suggesting that the rate of mortality of salmon smolts is greater among Saint John River populations originating above the Station than below it (Ritter, J., pers. comm., 2016). Gaspereau populations have increased since the construction of the Station, reflecting the suitability of these species to the lake-like conditions of the headpond (O'Gorman and Stewart 1999; Jessop 2001). While there are limited data on the success rate of downstream passage by gaspereau or Atlantic salmon, it is likely that a considerable number are not surviving (Bunt *et al.* 2012; Noonan *et al.* 2012). Additionally, substantial fish kills have been observed directly downstream of the Station as a result of nitrogen supersaturation (Penney 1987).

Construction of the Station may have also affected freshwater mussels, including the *SARA*-listed yellow lampmussel, by causing flooding of previously suitable habitat and by obstructing the movement of host fishes to which mussel larvae attach (Watters 1996; COSEWIC 2004).

8.2.2.3 Species at Risk and Species of Conservation Concern

Species at Risk (SAR) are defined as species listed as Extirpated, Endangered, Threatened, or Special Concern under the NB *SARA* or federal *SARA*, or by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). While some species included under this definition currently have regulatory protection under Schedule 1 of the federal *SARA* or the *Prohibitions Regulation* of NB *SARA*, the definition above also includes those species on the NB *SARA List of Species at Risk Regulation* and those listed by COSEWIC that are candidates for further review and may become protected within the timeframe of this Project.

Species of Conservation Concern (SOCC) are not listed under federal or provincial legislation but are considered rare in New Brunswick and the long-term sustainability of their populations has been evaluated as tenuous. SOCC are typically included in the description of existing conditions (Section 8.2) as a precautionary measure, in order to reflect observations and trends in the provincial population status. For this CER, SOCC are defined as species that do not meet the above definition of SAR but have been ranked in the province by the Atlantic Canada Conservation Data Centre (AC CDC) as S1 or S2, or S3 with a Canadian Endangered Species Conservation Council (CESCC) general status rank of "at risk," "may be at risk," or "sensitive."

Ten aquatic SAR/SOCC may exist in the area of review, or may have been recent residents (Table 8.4). They include six fish species—American eel (*Anguilla rostrata*), Atlantic salmon (*Salmo salar*), Atlantic sturgeon (*Acipenser oxyrinchus*), redbreast sunfish (*Lepomis auritus*), shortnose sturgeon (*Acipenser brevirostrum*), and striped bass (*Morone saxatilis*); two mussel species—brook floater (*Alasmidonata varicosa*) and yellow lampmussel (*Lampsilis cariosa*); and two aquatic insects (dragonflies)—pygmy snaketail (*Ophiogomphus howei*) and skillet clubtail (*Gomphus ventricosus*).

Table 8.4 Aquatic Species at Risk and/or Species of Conservation Concern That May Occur in the Area of Review

Species	Local Distribution, Key Life History Traits, and Anthropogenic Interactions	Conservation Status		
		SARA[1]	COSEWIC[2]	NB *SARA*[3]
Fishes				
American eel (*Anguilla rostrata*)	Common throughout the Saint John River, from headwater tributaries to the Bay of Fundy. A long-lived, bottom-dwelling predator, it spends most of its life in freshwater and estuarine environments, and then migrates to sea to spawn and die. Spawning migration occurs in the fall; larvae arrive in estuaries in spring and early summer (Groom 1975; COSEWIC 2012a). Existing population pressures include habitat degradation and barriers to migration (Chaput *et al.* 2014).	No status	Threatened (2012)	Threatened
Atlantic salmon[4] (*Salmo salar*)	Atlantic salmon of the Saint John River are of the Outer Bay of Fundy (OBoF) population. This population has nearly collapsed; recent returns to the Saint John River are a fraction of historical stocks (DFO 2014). An anadromous species; spawns in clean, gravel-bottomed freshwater environments and migrates to the sea to feed and mature for 1–4 years before returning to its natal streams and rivers (COSEWIC 2010a; DFO 2014). Dams and other migration obstructions represent an important pressure on the persistence of OBoF salmon populations (Fay *et al.* 2006; Clark *et al.* 2014).	No status (under consideration)	Endangered (2010)	Endangered
Atlantic sturgeon[5] (*Acipenser oxyrinchus*)	A large, long-lived, bottom-dwelling anadromous species, it spends much of its life in the sea and spawns in large rivers and is believed to spawn in June or July (COSEWIC 2011). The Maritimes population spawns only in the lower Saint John River area, downstream of the Station (COSEWIC 2011; CRI 2011). The species may have inhabited areas further upstream prior to construction of the Station (DFO 2009a).	No status	Threatened (2011)	Threatened
Redbreast sunfish (*Lepomis auritus*)	Found in low abundance in the lower Saint John River drainage, it has recently been reported in the Oromocto River, the Canaan River and Longs Creek (CRI 2011; Stantec 2014). A small inhabitant of warm water lakes and slow-moving rivers with rocky or well-vegetated habitat, it spawns in the spring (COSEWIC 2008a). New Brunswick is the northern extent of its range, and there is no recent evidence that its distribution reaches the Station. However, it may have been present in upstream reaches before the Station was constructed (Meth 1973).	Special Concern, Schedule 3	Data deficient (2008)	No status

Table 8.4 Aquatic Species at Risk and/or Species of Conservation Concern That May Occur in the Area of Review

Species	Local Distribution, Key Life History Traits, and Anthropogenic Interactions	Conservation Status		
		SARA[1]	COSEWIC[2]	NB *SARA*[3]
Shortnose sturgeon (*Acipenser brevirostrum*)	A large, long-lived, bottom-dwelling fish, in Canada, it is known to occur only in the lower Saint John River drainage. Occupies very similar freshwater habitats to those of Atlantic sturgeon. Believed to spawn in the spring (COSEWIC 2005). An anadromous species; downstream migration of the Saint John River population is believed to be limited to the estuary. Construction of the Station could have limited habitat for the local population to areas downstream of the Station.	Special Concern, Schedule 1	Special Concern (2015)	Special Concern
Striped bass[6] (*Morone saxatilis*)	A large, anadromous predator (COSEWIC 2012b), it occurs within the Saint John River system, generally downstream of the Station. There has been no evidence of reproduction in the Saint John River for several decades. Current inhabitants may be foraging migrants from United States or Nova Scotia populations. Historically, it spawned in areas upstream of the Station (CRI 2011).	No status (under consideration)	Endangered (2012)	Endangered
Molluscs				
Brook floater (*Alasmidonata varicosa*)	A medium-sized freshwater mussel found in small streams, over sandy substrates (COSEWIC 2009a), its larvae are parasites on the gills or fins of various fishes; therefore, it can disperse over considerable distances. Only one historical record exists within the Saint John River system (Aroostook River, 1960), but the species could reside in other areas of the watershed. The primary existing population pressures include anthropogenic activities that lead to siltation.	Special Concern, Schedule 1	Special Concern (2009)	Special Concern
Yellow lampmussel (*Lampsilis cariosa*)	A relatively large freshwater mussel that prefers slow-moving water and sand/small gravel substrates (COSEWIC 2004), it is common in the lower Saint John River system downstream of Mactaquac. It may currently be, or have historically been, present upstream of the Station (Sabine *et al.* 2004; DFO 2009b). Local population is relatively stable. Existing population pressures include habitat degradation related to siltation and other pollutants. Distribution may be limited by the abundance and distribution of host species (e.g., perches) for larvae.	Special Concern, Schedule 1	Special Concern (2013)	Special Concern

Table 8.4 Aquatic Species at Risk and/or Species of Conservation Concern That May Occur in the Area of Review

Species	Local Distribution, Key Life History Traits, and Anthropogenic Interactions	Conservation Status		
		SARA[1]	COSEWIC[2]	NB *SARA*[3]
Arthropods				
Pygmy snaketail (*Ophiogomphus howei*)	A dragonfly species that has been found in only one location along the Saint John River (Baker Brook, NB) but could be widespread throughout the watershed (Catling 2002; COSEWIC 2008b; Brunelle, P.M., pers. comm., 2015). Larvae are benthic predators that develop among sand/small gravel substrates in fast-flowing sections of large (>10 m wide) rivers. Adults are terrestrial. Breeding is generally unsuccessful directly upstream and downstream of dams (Environment Canada 2013c). Potential population pressures include nutrient loading, sedimentation, pesticides and recreational boating (COSEWIC 2008b).	Special Concern, Schedule 1	Special Concern (2008)	Special Concern
Skillet clubtail (*Gomphus ventricosus*)	A dragonfly species that occurs frequently in the lower Saint John River, between Fredericton and Washademoak Lake (COSEWIC 2010b). Occurs in large, slow-flowing rivers and lakes with sand and mud substrates. Larvae are benthic predators that are somewhat sensitive to siltation but commonly occur in relatively turbid waters. Construction of the Station may have destroyed considerable upstream habitat for this species, but it does not appear to disrupt breeding in downstream areas.	No status (in progress)	Endangered (2010)	Endangered

Notes:
1. Source: http://www.sararegistry.gc.ca/.
2. Source: http://www.cosewic.gc.ca/eng/sct5/index_e.cfm.
3. Source: http://www2.gnb.ca/content/gnb/en/departments/natural_resources/wildlife/content/SpeciesAtRisk.html.
4. Outer Bay of Fundy population.
5. Maritimes population.
6. Bay of Fundy population.

8.3 SUMMARY OF STANDARD MITIGATION FOR AQUATIC ENVIRONMENT

Standard mitigation and best management practices that are relevant to the aquatic environment VC will be implemented during all phases of the Preferred Option. These measures are based on normal operating procedures and regulatory requirements (Section 2.6). In general, these mitigation measures are intended to accommodate fish passage, reduce erosion and sediment loading, reduce harmful changes in water level and flow, and reduce direct changes in aquatic habitat and fish populations. The standard mitigation measures that will be implemented under each Option are as follows.

- Blasting near watercourses will follow the requirements of the *Fisheries Act* and the *Guidelines for the Use of Explosives In or Near Canadian Fisheries Waters* (Wright and Hopky 1998).
- Erosion and sedimentation control structures will be used and maintained throughout construction activities.
- Erosion and sedimentation control structures will be inspected regularly, especially before and after heavy rain events.
- Erosion and sedimentation control structures will remain in place until the disturbed area is stabilized or natural revegetation occurs.
- Dewatering of excavated areas will control the release of sediment-laden water (*e.g.,* filtration through vegetation or engineered erosion control devices.
- Overburden storage piles and exposed topsoil will be covered or seeded and revegetated, 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 (*e.g.*, settling ponds) will be constructed to treat surplus water from the Project before it is discharged.
- Construction material (*e.g.,* gravel) placed in or next to watercourses will be free of debris, fine silt and sand, and chemical contaminants.
- Cofferdams will be used where feasible during the demolition/decommissioning of structures located below the waterline.
- Excavations for new in-water structures will be completed "in-the-dry" to the extent practicable.
- All fuels and lubricants used during construction will be stored according to containment methods in designated areas. Storage areas will be located at least 30 m from watercourses, wetlands and water supply areas (including known private wells).

- Refueling of machinery will not occur within 30 m of watercourses and water supply areas (including known private wells). Where stationary equipment is situated near a wetland, special precautions will be implemented to prevent spills during refueling (*e.g.,* absorbent pads will be placed below nozzles, and spill response kits will be located at the refueling site).
- All sites will be kept free of loose waste material and debris.
- Solid wastes, including waste construction material, will be disposed of in approved facilities.
- 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.

8.4 POTENTIAL INTERACTIONS BETWEEN AQUATIC ENVIRONMENT AND THE OPTIONS

Options 1 and 2 maintain the existing influences of the current Station, whereas Option 3 essentially transforms the river into a state more similar to that which existed prior to the 1968 construction of the Station. Given that all three Options require short- and long-term changes directly to a major physical structure within the Saint John River, there are potential interactions with the aquatic environment under for all Options and all phases (Table 8.5). The following sections describe the potential interactions for each of the three Options.

Table 8.5 Potential Interactions between the Aquatic Environment and the Options

Phase	Option 1			Option 2			Option 3		
	Potential Change in Fish Habitat	Potential Change in Fish Populations	Potential Change in Species at Risk or Species of Conservation Concern	Potential Change in Fish Habitat	Potential Change in Fish Populations	Potential Change in Species at Risk or Species of Conservation Concern	Potential Change in Fish Habitat	Potential Change in Fish Populations	Potential Change in Species at Risk or Species of Conservation Concern
Construction (new facilities, Option 1 or Option 2)	✓	✓	✓	✓	✓	✓			
Demolition (existing structures, Option 1 or Option 2)	✓	✓	✓	✓	✓	✓			
Operation (Option 1 or Option 2)	✓	✓	✓	✓	✓	✓			

Table 8.5 Potential Interactions between the Aquatic Environment and the Options

Phase	Option 1			Option 2			Option 3		
	Potential Change in Fish Habitat	Potential Change in Fish Populations	Potential Change in Species at Risk or Species of Conservation Concern	Potential Change in Fish Habitat	Potential Change in Fish Populations	Potential Change in Species at Risk or Species of Conservation Concern	Potential Change in Fish Habitat	Potential Change in Fish Populations	Potential Change in Species at Risk or Species of Conservation Concern
Decommissioning (Option 3)							✓	✓	✓

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

8.4.1 Potential Change in Fish Habitat

8.4.1.1 Option 1

Construction and Demolition

The construction and demolition phases of Option 1 (repowering) are expected to include a variety of activities that could result in short-term interactions with, or changes to, fish habitat, particularly downstream of the Station. These activities may include blasting, vegetation clearing, excavation, dredging, installation of coffer dams and flow diversion channels, and the draining of construction areas (Section 2). Long-term changes to fish habitat resulting from construction and demolition are not anticipated.

Construction and demolition activities are expected to cause primarily short-term changes in flow conditions, soil erosion, and in-water sedimentation. Other interactions could result from blast residues or contaminants (*e.g.*, fuel, grease) entering the river, non-native species transfer from equipment, nutrient inputs from organic waste, or localized disturbance of fish habitat from in-water or near-water activities (*e.g.,* blasting). These potential interactions related to contaminants, nutrient inputs, and in-water activities are expected to be minimized through the application of mitigation measures. These mitigation measures may include the relocation of fishes stranded in temporarily drained areas; efforts to avoid activities in sensitive biological time periods; and avoidance of SAR/SOCC disturbance.

Drawdown of the headpond is not required during Option 1. Therefore, the amount of water available in the upstream and downstream environments will generally not change compared to current conditions. Although not planned, if power generation stops for a period during construction, short-term flow patterns could likely change because daily water level fluctuations associated with electricity production would cease. This scenario will likely not result in adverse changes to aquatic habitat, although downstream fish passage may be restricted to the floodgate or temporary channels constructed for mitigation. It is expected that any temporary shutdown of power generation and the associated change in short-term flow patterns will have minimal adverse interactions with organisms downstream.

Even though mitigation strategies will be implemented, some increased erosion and sedimentation will likely occur, which could interact with the aquatic environment downstream of the Station. Bottom sediments in the headpond are not expected to be disturbed, so any increased sedimentation of downstream areas will be caused by demolition debris, bank erosion, channel disturbance or water flow changes. Increased suspended sediment could cause disruption of fish behaviour, physiological stress, decreased growth of aquatic vegetation due to reduced light penetration, and decreased oxygen availability (Bruton 1985; Henley *et al.* 2000). The subsequent settling of sediment may cover important benthic habitats, such as spawning substrates, and aquatic vegetation that is important for feeding or predator protection (Lisle and Lewis 1992; Rabeni *et al.* 2005). Overall, the magnitude of sediment-related interactions is expected to be low. Minor, short-term increased sedimentation is not expected to change fish habitat such that it affects aquatic organisms at the population level.

Population Level is a phrase used in reference to the potential changes to fish habitat or fish mortality from Project interactions. Changes that are low may affect fish habitat and cause mortality, but not in a manner that the abundance or distribution of populations is influenced substantially. Conversely, changes in fish habitat and mortality that are high may influence the abundance and distribution of populations.

Operation

Option 1 during operation will generally be similar to existing conditions. Two interactions with fish habitat could occur: changes associated with water flow and with habitat connectivity (fish passage).

Changes in operational water flow will be a direct consequence of rebuilding the Station and relocating the powerhouse. While the overall water velocity and volume is not expected to change appreciably from current conditions, the new configuration of the Station would change the water flow patterns downstream of it. This will affect river morphology by altering sediment erosion and deposition patterns. These changes are expected to be localized to the waters just downstream of the Station. Changes in fish habitat associated with water flow are not expected to influence aquatic organisms at the population level.

Changes in habitat connectivity will likely be the most influential interaction associated with Option 1 during operation. Currently, the movement of fishes upstream is effectively limited to Atlantic salmon and gaspereau with a trap and truck system designed after the completion of the existing Station. There are no fish passage structures to aid downstream movements, so fishes must move through the turbine cavities, through the spillway, or over the diversion sluiceway. With the consideration of fish passage and discussions with fisheries regulators, the design of Option 1 has the potential to increase the ability of fishes to move across the structure and, therefore, improve habitat connectivity.

In this review, it is assumed that fisheries regulators would prefer, as mandated, to protect access to habitat for all species of fish. Notwithstanding limitations associated with power generation and the height of the dam, there are numerous mitigative fish passage design considerations that can affect the movement of fishes across the Station (Schilt 2007). Due to the height of the dam, a fish trap, in combination with a lift or a truck transport system, may be needed to aid fish movements upstream. The use of a fish ladder for strong swimming species, like Atlantic salmon and American shad, could also be considered. These structures, and the powerhouse itself, could be designed to enhance fish attraction by providing sufficient water flow velocity. Further, the fish passage structures could be designed to improve the movement of a greater number of migratory species by taking into account their behavioural and morphological requirements. This may require designing and operating more than one type of fish trap/ladder or, for example, species-specific solutions, such as ramps for American eel or sea lamprey (Knights and White 1998; Moser *et al.* 2011). Fish passage facilities (*i.e.*, bypass structures [Schilt 2007]) could also be designed to enhance fish attraction to, and use of, the structures during downstream movements. Species-specific designs could be used to assist the passage of some species. For example, spillway and bypass structures could be designed with full-depth entries or strategic entry locations to accommodate both surface- and bottom-oriented species. Such structures may also be designed to provide passage beyond periods of high water flow. In consultation with fisheries regulators and stakeholders, the management of the new facilities and fish passage capacity could further enhance the passage of multiple fish species by considering their migratory cycles (Figure 8.2). Overall, fish habitat could be enhanced under Option 1. This could affect fish populations positively, particularly those of migratory fish species.

As described previously, the presence of the Station may be reducing the downstream transport of sediments and organic debris, therefore reducing the primary productivity of downstream habitat. With Option 1, this would continue during operation.

8.4.1.2 Option 2

Construction and Demolition

Option 2 construction and demolition activities could result in short-term changes in fish habitat, particularly downstream of the Station. The potential interactions and associated mitigation are not expected to differ substantially from those described above under Option 1. Therefore, as with Option 1, they are not expected to produce population-level changes in any fish species.

Operation

Option 2 during operation will generally be similar to existing conditions. Three interactions with fish habitat could occur: changes associated with managed water levels, water flow, and habitat connectivity (fish passage).

Currently, daily water levels fluctuate upstream and downstream of the Station and expose shoreline areas. Option 2 will not involve power generation; therefore, daily water level fluctuations as a result of power generation are expected to be reduced. However, water level fluctuations associated with seasonal or severe weather events are expected to increase because water will not be stored for power generation, creating the conditions for potentially more flash floods and more variable flow conditions downstream. This water level instability is not expected to change fish habitat in a manner that could affect most species at the population level.

Similar to Option 1, operational water flow will change as a result of rebuilding the water level control structures associated with Option 2. Although water flow dynamics will differ between Options 1 and 2, the predicted interactions will be largely similar to existing conditions, and are not expected to affect fish species at the population level.

A change in habitat connectivity will be the most influential interaction associated with the operation of Option 2. With the consideration of fish passage and discussions with fisheries regulators, the design of Option 2 has the potential to increase the ability of fishes to move across the structure and, therefore, improve habitat connectivity.

Similar to Option 1, a number of mitigative fish passage design considerations could be used to aid the movement of fishes across the dam. However, under Option 2 there will be more potential to enhance fish movements because power generation will not occur. Additionally, the ability to attract fishes to fish pass structures may be enhanced because flow can be manipulated without the concern for the maintenance of power output. Thus, habitat connectivity could be improved under Option 2. This may result in population level changes, particularly for migratory fish species.

As described previously, the presence of the Station may be reducing the downstream transport of sediments and organic debris, therefore reducing the primary productivity of downstream habitat. With Option 2, this would continue during operation.

8.4.1.3 Option 3

Decommissioning

Decommissioning under Option 3 includes all of the short-term interactions associated with construction and demolition under Options 1 and 2. Therefore, this section focuses on the interactions that are unique to Option 3.

NB Power has considered two principal scenarios for the controlled reduction of the headpond water level under Option 3; a slow drawdown scenario (over 1-3 years) and an accelerated drawdown scenario. A slow drawdown scenario was presented in the draft CER Report (Stantec 2015b); however, information from the MAES and preliminary engineering design have led NB Power to prefer an accelerated drawdown plan.

An accelerated drawdown would consist of two rapid drawdown events over the course of approximately seven months. The first drawdown event will coincide with the end of the spring freshet (a seasonal phenomenon that corresponds with the greatest yearly downstream water flows on the Saint John River). The second drawdown event will occur during or immediately after the fall recharge period of the same year (a seasonal period characterized by heavier precipitation and high downstream water flows). A more complete description of the drawdown, and associated demolition sequences, is contained in Section 2 of this document.

If Option 3 is selected as the Preferred Option, NB Power may also consider other drawdown scenarios as new information is developed. Modifications to the current drawdown scenario are expected to influence the interactions of the Project with the aquatic environment. Recent large dam removals in the northwestern United States have opted for a slow drawdown scenario; however, the best course of action is thought to be case-specific (Chateauvert *et al.* 2015). An accelerated drawdown, such as that planned, and slower scenarios trade off potentially large initial changes and immediate commencement of recovery with smaller changes and delayed commencement of recovery. However, it is the magnitude, rather than the types, of interactions that are expected to change among drawdown scenarios.

NB Power's current planning to use an accelerated drawdown is, in part, influenced by evidence generated by the MAES that indicates sediment quantity and quality are generally not of concern, suggesting interactions with the aquatic environment may not be severe and recovery may be quick. This determination is aided by planning drawdown events to coincide with naturally turbid, high water flow seasons. Under the planned accelerated scenario, downstream water and sediment flow below the Station is expected to result in a temporary period of elevated sediment concentrations that would quickly return to seasonal conditions; few fish would be expected to be migrating during these periods, thereby limiting potential adverse effects on fish populations. As a result, the planned accelerated drawdown scenario is preferable to longer drawdown scenarios that may require the release of sediments throughout a greater proportion of the year. .

The removal of the Station under Option 3 will result in both short-term and long-term changes in aquatic habitat in the area that would have been formerly defined as the headpond. The immediate changes resulting from the headpond drawdown will include the physical loss of lake-like habitat and the gain of river-like habitat. Changes in characteristics such as temperature, dissolved oxygen, nutrient supply, depth, and water flow arising from the creation of a river-like environment will alter aquatic habitat. Specifically, the reduction in the width and depth of aquatic habitat in concert with increased water flow velocity in the restored river channel will reduce the variation in temperature and dissolved oxygen within the existing headpond. Consequently, the variation in physical habitats that are typically found in lake-like environments will also be reduced. As a result, the relative abundance of species that currently thrive in the headpond is expected to decline, and the relative abundance of species that are better suited to river environments may increase. Moreover, the removal of the headpond may require the restoration of the newly exposed land that was formerly submerged, causing a further potential interaction with the aquatic environment, principally through erosion and sedimentation. Current engineering for Option 3 includes shoreline interventions and other mitigation to reduce erosion and sedimentation during Project activities.

Connectivity upstream and downstream of the Station will be restored under Option 3. Therefore, the movement of water and sediments along this stretch of river will be unimpeded following removal of the Station. Many fishes, particularly migratory fishes, and some macroinvertebrates will also have greater access to new habitat used for reproduction or feeding. However, connectivity will also be improved for non-native species, which may have greater opportunity to expand their existing range (McLaughlin *et al.* 2013; Rahel 2013). These connectivity interactions include approximately 140 km of river between the Station and Beechwood dam in Victoria County.

The drawdown of the headpond may create land barriers between the main river and its tributaries, which can inhibit access to and from these habitats. 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 parts of the former headpond bed may then be dry. There is also the possibility that culverts that have been submerged since the creation of the headpond no longer function and could create a barrier to water flows, especially in smaller tributaries. Therefore, water from these tributaries may not flow into the river following drawdown. Left unmitigated, this would represent a barrier to organisms that seek access between the river and these tributaries. However, this interaction could be mitigated by applying stream restoration measures, and the removal of derelict infrastructure or perched culverts.. NB Power has made preliminary surface water management plans to maintain habitat connectivity between the main stem of the Saint John River and its tributaries, should Option 3 be selected.

Downstream of the Station, changes in aquatic habitat will be driven mainly by the consequences of any changes in water flow dynamics and the potential for an increase in sediment transport and deposition. The magnitude of these changes will be greater than those associated with the construction and demolition phases of Option 1 or 2; therefore, they are more likely to have population level interactions. The planned accelerated drawdown will cause a large temporary increase in water flow downstream. This increase may not exceed natural water levels that occur in the spring, but it may be unnaturally high during the fall drawdown event. Despite this, the increased water flows are not expected to interact with the aquatic environment at a population level. Following drawdown, downstream flows and water levels would be expected to more closely mimic natural conditions of the river compared to the current operating regime.

Downstream, sediment transport will increase during dewatering under Option 3. In the planned accelerated drawdown scenario, sediments that have accumulated in the headpond could be transported downstream rapidly (Hart *et al.* 2002). As these sediments settle, they may cover sensitive spawning/feeding habitats, and along with changes in water flow dynamics, may change the morphology of the river. The sediments may also transport nutrients that influence primary production or contaminants that may accumulate in the tissues of organisms. Changes in the circulation of chemical nutrients may change the quantity, quality and location of suitable aquatic habitat (Stanley and Doyle 2002). However, once the previous headpond bed stabilizes, sediment transport downstream would be expected to resemble more natural pre-dam conditions.

Modelling of the potential future hydrodynamic regime downstream of the Station, and associated sediment transport under the planned accelerated and slow drawdown scenarios is ongoing as part of the MAES. MAES studies to date indicate that sediment quantity and quality are not generally of concern under an accelerated drawdown conducted outside of key migrating periods. Under the planned accelerated drawdown scenario, the sediment quantity and quality data coupled with the selection of drawdown events that coincide with naturally turbid, high water flow seasons, suggest that unacceptable interactions with the aquatic environment are not expected downstream of the Station.

8.4.2 Potential Change in Fish Populations

8.4.2.1 Option 1

Construction and Demolition

The possible causes of fish population changes during construction and demolition of Option 1 could include stranding of fishes in drained areas, direct mortality from machinery, blasting-related mortality, and increased sedimentation downstream (Coker *et al.* 2010). Active work areas near the Saint John River will be enclosed by cofferdams or other water retaining structures, and the water within them will be removed so that work can be carried out “in-the-dry”. Fishes and other organisms trapped inside these structures could become stranded when the area is drained, unless they are physically rescued and removed from within the enclosure. Small, slow-moving fishes, like slimy sculpin, or other immobile organisms are the most vulnerable to machine-induced mortality because they are more challenging to remove from project sites. Blasting can be lethal to fishes if it induces a sudden shock wave.

Fish mortality resulting from construction and demolition activities is expected to be minimal, and population-level changes to fish species are not anticipated. Mitigation will involve rescuing fishes from drained areas within the construction site before all water is removed. Mortality caused by machinery will be largely mitigated by using in-water barriers and concentrating activities in drained, dry areas. The risk of blasting-related mortality will be minimized by excluding, removing or frightening fish away from blast sites and following DFO guidelines for blasting in or near water.

Despite planned mitigation including the use of erosion and sedimentation control structures during construction activities, increased erosion and sedimentation could occur downstream of the Station as a result of construction activity. Increases in suspended sediments could affect fish habitat and influence the survival of some aquatic species. Suspended sediments may also cause the abrasion and coating of fish gills (Goldes *et al.* 1988), and affect the capture of food items (Utne-Palm 2002). The subsequent settling of sediments may smother fish eggs and larvae (Lisle and Lewis 1992; Rabeni *et al.* 2005). However, the magnitude of sediment-related fish mortality as a result of Option 1 is expected to be low during construction and demolition. With mitigation, the minor, short-term increase in sedimentation that could occur is not expected to affect aquatic organisms at the population level.

Operation

Option 1 during operation will generally be similar to existing conditions. Two interactions with fish populations could occur: changes associated with water flow, and with habitat connectivity (fish passage).

Changes in operational water flow dynamics will be a direct consequence of rebuilding the Station and relocating the powerhouse. While the overall water velocity, volume, and operating regime is not expected to change appreciably from current operations under Option 1, the new configuration of the Station will affect downstream water flow patterns. This will affect river morphology by altering sediment erosion and deposition patterns, which could result in fish mortality. However, these interactions are expected to be localized to the area immediately downstream of the Station, and will be engineered to minimize adverse impacts to populations of aquatic organisms. Any associated fish mortality that might occur is not expected to affect aquatic organisms at the population level.

Changes in habitat connectivity will likely be the most influential interaction associated with Option 1 during operation. Currently, the movement of fishes upstream of the Station is effectively limited to Atlantic salmon and gaspereau with a trap and truck system that was designed after the completion of the Station. There are no fish passage structures to aid downstream movements currently, so fishes must move through the turbine cavities, through the main spillway, or over the diversion sluiceway in order to pass downstream. When traversing dams, fishes may be subjected to physical, physiological and behavioural stressors that can cause injury or mortality (Pon *et al.* 2009; Williams *et al.* 2012; Bunt *et al.* 2012; Noonan *et al.* 2012). Moreover, for individuals that can get across the Station, delays in the movement of migratory species can also affect reproduction and survival, which can cause changes in populations (Castro-Santos and Haro 2003). With the consideration of fish passage and discussions with fisheries regulators, the design of Option 1 has the potential to reduce fish mortality or related issues that can cause serious harm to fishes.

Numerous fish passage design considerations could be used as mitigation to limit fish mortality associated with crossing the new facilities constructed as part of Option 1. Due to the height of the dam, a fish trap, in combination with a lift or a truck transport system, may be needed to aid fish movements upstream. Additionally, the use of a fish ladder for strong swimming species, like Atlantic salmon and American shad, could also be considered. These structures could be designed to accommodate the physical and behavioural limitations of the fish species that will pass through them (Schlit 2007; Williams *et al.* 2012). For example, American shad have shown apparently high levels of stress in the existing fish trap, which may be associated with mechanical vibrations during its operation, high densities of fishes in the trap, and holding periods prior to processing (Jessop 1975). Shad appear to panic and thrash about in the fish trap, which results in physical damage and mortality. The use of design best practices could reduce fish mortality associated with a lift or ladder (Haro and Castro-Santos 2012). Downstream movement is currently limited to passage through the turbine cavity and, during spring high water levels or extreme storm events, the main spillway and/or diversion sluiceway. Passage through turbine cavities can cause mortality due to shear stress, direct physical contact with the turbine blades or cavity walls, or internal gas exchange issues related to barometric pressure changes in the turbine cavity (Brown *et al.* 2014). However, some turbine designs are believed to be less likely to kill or injure fish during passage than those currently installed at the Station (Hogan *et al.* 2014; Section 2.3.5). Consideration of these more fish-friendly turbine designs may reduce fish mortality relative to existing conditions. Moreover, the use of specifically designed bypass structures and spillways, if implemented, will further reduce mortality associated with turbine cavity passage. Overall, fish mortality could be reduced under Option 1. This could affect fish populations positively, particularly those of migratory fish species.

8.4.2.2 Option 2

Construction and Demolition

The possible causes of changes to fish populations during construction and demolition of Option 2 are the same as those under Option 1.

Operation

Option 2 during operation will generally be similar to existing conditions. Three interactions with fish populations could occur: changes associated with managed water levels, water flow, and habitat connectivity (fish passage).

Currently, daily water levels fluctuate upstream and downstream of the Station and expose shoreline areas. Option 2 will not involve power generation; therefore, daily water level fluctuations as a result of power generation are expected to be reduced. However, water level fluctuations associated with seasonal or severe weather events are expected to increase because water will not be stored for power generation, creating the conditions for potentially more flash floods. This water level instability is not expected to influence fish mortality in a manner that could affect most species at the population level.

Similar to Option 1, operational water flow will change as a result of new facilities constructed as part of Option 2. Although water flow dynamics will differ between Options 1 and 2, the predicted interactions will be similar to existing conditions, and are not expected to affect fish mortality of any species at the population level. New facilities would be engineered to minimize adverse impacts to aquatic organisms.

A change in habitat connectivity will be the most influential interaction associated with the operation of Option 2. The design of Option 2 has the potential to enhance upstream fish passage and reduce fish mortality during downstream passage.

Similar to Option 1, a number of fish passage designs could be used as mitigation to reduce fish mortality associated with movement across new facilities constructed under Option 2. The lack of turbine operation under Option 2 is expected to further reduce downstream fish passage mortality. Thus, relative to existing conditions and Option 1, fish mortality could be reduced under Option 2. This could have beneficial population level interactions, particularly for migratory fish species.

8.4.2.3 Option 3

Decommissioning

Decommissioning under Option 3 includes all of the short-term interactions associated with construction and demolition under Options 1 and 2. Therefore, this section focuses on the interactions that are unique to Option 3.

Removal of the Station under Option 3 will result in both short-term and long-term changes in aquatic habitat in the headpond that may cause changes to fish populations. The immediate change associated with headpond drawdown is the loss of habitat area. This may strand aquatic organisms, particularly species that cannot easily move with the receding water during drawdown. This may affect fish populations. Changes in water quality and water flow dynamics will replace lake-like habitat with river-type habitat. Consequently, the populations of species that are adapted to standing water in the headpond may be reduced. Populations of species that are better suited to river-type habitats, however, may increase. Fish rescue operations during drawdown conditions will be considered to minimize stranding of slower moving species and avoid potential mortality.

Fish passage upstream and downstream of the Station will be greatly improved under Option 3. Migratory fish species, and some macroinvertebrates, will have greater access to historical habitat used for reproduction or feeding, which may elicit positive, population-level benefits. However, connectivity will also be improved for non-native species, which may have greater opportunity to expand their existing range (McLaughlin *et al.* 2013; Rahel 2013).

Downstream of the Station, fish mortality will be influenced mainly by changes in water flow dynamics and potential increased sediment transport and deposition arising from Option 3. The magnitude of these changes will be relatively greater than those associated with the construction and demolition phases of Options 1 and 2; therefore, they may have population level interactions.

Downstream sediment transport will likely increase in the short-term and long-term under Option 3. In the short-term, sediments that may have accumulated in the headpond will be susceptible to erosion and downstream transport (Hart *et al.* 2002). These suspended sediments could be detrimental to fishes, however, the timing of the accelerated drawdown scenario outside of key migration periods may mitigate effects of suspended sediment on fish. In the long-term, Station removal will prevent the trapping of sediments in the upper headpond. This will result in greater downstream transport of sediment on an ongoing basis, including sand and silt, particularly as bedload. This could change fish habitat downstream of the Station by replenishing sand and silt in areas that have predominantly coarse sediment and increasing nutrient transport.

8.4.3 Potential Change in Species at Risk and/or Species of Conservation Concern

Potential interactions of the Options with SAR/SOCC will be similar to those described under a change in fish habitat and change in fish populations above. Therefore, the following highlights some species-specific interactions associated with each Option, with particular emphasis on SAR or SOCC.

8.4.3.1 Option 1

Option 1 during operation will generally be similar to existing conditions, and will result in a continued barrier to fish passage.

Of the aquatic SAR/SOCC included in this review, five are diadromous fish species, and two are freshwater mussel species which rely on host fishes to support and disperse their parasitic larvae. The existing Station acts as a barrier to fish movements upstream and downstream, which can lead to mortality. However, under Option 1, modifications to the existing fish passage infrastructure may increase habitat connectivity and reduce passage-related mortality for these SAR/SOCC. This is especially true for the unmanaged diadromous fishes, including American eel, Atlantic sturgeon, shortnose sturgeon, and striped bass. Prior to the construction of the existing Station, American eel used the aquatic habitat upstream of the Station for feeding and during growth. The two sturgeon species likely also used this habitat for feeding. Striped bass may have used feeding and spawning habitat upstream of the Station. Improved passage may restore habitat use by these species, depending upon the availability and accessibility of suitable habitat. Achieving a goal of enhancing both upstream and downstream fish passage will require careful consideration of each species' requirements; however, this may not be achievable for all species.

A few of the SAR/SOCC in the area of review are unlikely to be influenced by the existing Station; therefore, Option 1 is unlikely to have an interaction with their populations. These species include the brook floater, redbreast sunfish, and pygmy snaketail. The brook floater has been recorded only once in the Saint John River system; it is generally found only in smaller streams and rivers (COSEWIC 2009a). The redbreast sunfish may have inhabited areas upstream of the Station prior to its construction, but there is no evidence that its local range extends upstream of the Oromocto area. The anticipated interaction of Option 1 with the redbreast sunfish is limited to minor sedimentation in the main stem of the river. Increased sediment load and deposition could have minor influences on spawning areas and general habitat quality. The headpond may limit the local distribution of pygmy snaketail, but there is no evidence that this species occurs in the upstream or downstream area of review.

8.4.3.2 Option 2

Option 2 during operation will generally be similar to existing conditions, and the interactions will be similar to those related to Option 1.

Similar to Option 1, a number of mitigative fish passage design considerations could be used to improve habitat connectivity for SAR/SOCC. This may allow American eel, Atlantic sturgeon, shortnose sturgeon and striped bass to pass upstream of the dam. However, because power generation will not occur under Option 2, it will be easier to create flow that will attract fish to fish passage infrastructure. Moreover, the lack of turbine operation under Option 2 is expected to further reduce downstream fish passage injury and mortality. This will directly benefit Atlantic salmon, or any other SAR/SOCC, moving downstream.

Similar to Option 1, interactions with the brook floater, redbreast sunfish and pygmy snaketail are not expected under Option 2.

8.4.3.3 Option 3

In general, dam removal can cause a number of changes in the structure and function of an existing river, which may influence populations of aquatic organisms. However, dam removal interactions with the aquatic environment are case-specific and difficult to quantify ahead of decommissioning (Poff and Hart 2002). The key interactions with the SAR/SOCC in the area of review would be associated with:

- conversion of the lake-like habitat of the headpond back into river-like habitat;
- potential erosion and sedimentation during and after drawdown;
- changes in water flow and sediment transport downstream; and
- changes in habitat connectivity (including fish passage) at the existing Station location.

Under Option 3, SAR/SOCC mortality and habitat changes may occur downstream of the Station due to changes in water flow dynamics and potentially increased sediment transport and deposition (Hart *et al.* 2002). These changes could affect the location and amount of suitable habitats downstream. Sediment release from the headpond has the potentially greatest interaction with the aquatic environment. Four general short-term interactions could occur: scouring by bedload and suspended sediment, changes in substrate composition, smothering of habitat, and interactions with biota (*e.g.*, clogging of fish or invertebrate gills; smothering of algae, macrophytes and invertebrates). All of the aquatic SAR/SOCC that exist downstream of the Station have some sensitivity to suspended sediment (*i.e.*, turbidity) and sediment deposition. Fish species that inhabit the area near the Station, such as Atlantic salmon, American eel, and striped bass, are most likely to be disrupted by turbidity created by sediment release. The severity of this interaction could range from temporary displacement to mortality. At some point downstream, the sediment will settle on the river bottom. However it is unclear how much sediment will settle or where it will be deposited.

Bedload refers to the portion of total sediment transported along the bottom of the stream bed by rolling, sliding or bouncing.

The ability of aquatic organisms, fishes in particular, to access habitat upstream and downstream of the existing Station will improve substantially under Option 3. Removal of the Station will eliminate artificial obstructions to fish passage that may cause stress or mortality, or limit access to important habitat for SAR/SOCC. This is expected to have long-term positive implications for SAR/SOCC, particularly migratory fish species (Hitt *et al.* 2012). Molluscs, such as yellow lampmussel, may begin using upstream habitat as a result of increased passage for host fishes, and restoration of the headpond into more suitable river-like habitats. Construction of the Station likely destroyed considerable upstream habitat for skillet clubtail. Thus, removal of the Station could allow the local distribution of this species to expand into upstream areas.

8.5 SUMMARY OF INTERACTIONS BETWEEN AQUATIC ENVIRONMENT AND THE OPTIONS

Table 8.6 summarizes potential interactions between each of the Options and the aquatic environment.

Table 8.6 Summary of Potential Interactions between the Aquatic Environment 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 the interaction occur?	Has additional mitigation been recommended?
Potential Change in Fish Habitat						
Option 1: Construction, demolition and operation	Negative	Low	Region	Permanent	Continuous	Yes
	Positive	Low	Region	Permanent	Continuous	Yes
Option 2: Construction, demolition and operation	Negative	Low	Region	Permanent	Continuous	Yes
	Positive	Medium	Region	Permanent	Continuous	Yes
Option 3: Decommissioning	Positive	High	Region	Permanent	Continuous	Yes
	Negative	High	Region	Permanent	Continuous	Yes
Potential Change in Fish Populations						
Option 1: Construction, demolition and operation	Negative	Low	Region	Permanent	Continuous	Yes
	Positive	Low	Region	Permanent	Continuous	Yes
Option 2: Construction, demolition and operation	Negative	Low	Region	Permanent	Continuous	Yes
	Positive	Medium	Region	Permanent	Continuous	Yes
Option 3: Decommissioning	Positive	High	Region	Permanent	Continuous	Yes
	Negative	High	Region	Permanent	Continuous	Yes
Potential Change in Species at Risk and/or Species of Conservation Concern						
Option 1: Construction, demolition and operation	Negative	Low	Region	Permanent	Continuous	Yes
	Positive	Low	Region	Permanent	Continuous	Yes
Option 2: Construction, demolition and operation	Negative	Low	Region	Permanent	Continuous	Yes
	Positive	Medium	Region	Permanent	Continuous	Yes
Option 3: Decommissioning	Positive	High	Region	Permanent	Continuous	Yes
	Negative	High	Region	Permanent	Continuous	Yes

Table 8.6 Summary of Potential Interactions between the Aquatic Environment 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 the interaction occur?	Has additional mitigation been recommended?

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 the aquatic environment.
- Medium – a change that occurs outside the natural variability for the aquatic environment but does not change the overall status of the aquatic environment.
- High – a change that occurs outside the natural range of change for the aquatic environment that will change the status of the aquatic environment 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.

8.5.1 Summary of Additional Potential Mitigation and Information Requirements

As described in Section 8.4, this review has identified the requirement for some additional potential mitigation and requirements for further study in some areas. These potential requirements are summarized in Table 8.7.

Table 8.7 Summary of Additional Potential Mitigation and Information Requirements

Option	Additional Potential Mitigation	Additional Information Requirements
Option 1: Construction, demolition and operation	• All equipment should be inspected and cleaned prior to use on site to prevent the transfer of non-native species. • Fish relocation efforts will be conducted in areas where fishes could become stranded, such as dewatering associated with coffer dams or headpond drawdown. • Critical habitat and life cycle phases of aquatic SAR/SOCC that occur within the Project area will be identified, and activities that disrupt SAR/SOCC will be avoided. • Natural flow patterns (timing and quantity) will be maintained so as not to disrupt fish life cycles. • Development of temporary fish passage solutions for the construction phase.	• Consultation with regulators and stakeholders to determine priority management species to aid in the design of fish passage. • Species-specific behavioural and physiological research in support of effective fish passage solutions. • Hydrodynamic and computational fluid dynamics modelling to optimize the orientation of the powerhouse and the spillway structures for fish passage. • Current information on hydrogeological conditions, water and sediment quality, sediment quantity (upstream), and species abundance, distribution and community composition.

Table 8.7 Summary of Additional Potential Mitigation and Information Requirements

Option	Additional Potential Mitigation	Additional Information Requirements
	• Design and operation of multi-species fish passage facilities (as appropriate). • Seasonal timing of construction and demolition to avoid sensitive biological periods (*i.e.*, create fish windows).	• Hydrogeological/biochemical modelling associated with potential downstream changes to water flow and sediment erosion/deposition patterns.
Option 2: Construction, demolition and operation	• All equipment should be inspected and cleaned prior to use on-site to prevent the transfer of non-native species. • Fish relocation efforts will be conducted in areas where fish could become stranded, such as dewatering associated with coffer dams or headpond drawdown. • Critical habitat and life cycle phases of aquatic SAR/SOCC that occur within the Project area will be identified, and activities that disrupt SAR/SOCC will be avoided. • Natural flow patterns (timing and quantity) will be maintained so as not to disrupt fish life cycles. • Development of temporary fish passage solutions for the construction phase. • Design and operation of multi-species fish passage facilities (as appropriate). • Seasonal timing of construction and demolition to avoid sensitive biological periods (*i.e.*, create fish windows).	• Consultation with regulators and stakeholders to determine priority management species to aid in the design of fish passage. • Species-specific behavioural and physiological research in support of effective fish passage solutions. • Hydrodynamic and computational fluid dynamics modelling to optimize the orientation of the powerhouse and the spillway structures for fish passage. • Current information on hydrogeological conditions, water and sediment quality, sediment quantity (upstream), and species abundance, distribution and community composition of the area of review. • Hydrogeological/biochemical modelling associated with potential downstream changes to water flow and sediment erosion/deposition patterns.
Option 3: Decommissioning	• All equipment should be inspected and cleaned prior to use on-site to prevent the transfer of non-native species. • Fish relocation efforts will be conducted in areas where fish could become stranded, such as dewatering associated with coffer dams or headpond drawdown. • Critical habitat and life cycle phases of aquatic SAR/SOCC that occur within the Project area will be identified, and activities that disrupt SAR/SOCC will be avoided. • Natural flow patterns (timing and quantity) will be maintained so as not to disrupt fish life cycles. • Restoration of exposed headpond lands and river channel. • Restoration of habitat connectivity between the new river channel and its tributaries. • Potential removal or stabilization of sediment deposits in the headpond prior to removal of the Station. • Selection of drawdown (water and sediment release) scenario based on additional information. • Seasonal timing/management of drawdown to minimize overlap with sensitive biological periods (*i.e.*, create fish windows).	• Current information on hydrogeological conditions, water and sediment quality, sediment quantity (upstream), and species abundance, distribution and community composition of the area of review. • Hydrogeological/biochemical modelling of associated with potential Project interactions during drawdown and long-term changes to water flow and sediment erosion/deposition patterns. • Further planning and specific timing information associated with the accelerated drawdown scenario.

8.5.2 Discussion

The Project will interact with the aquatic environment of the area that was reviewed and the socio-economic activities that rely upon it (*e.g.* tourism, recreation, fishing). Each Option could have both positive and negative interactions with the aquatic environment. The magnitude of these interactions will be influenced by the Option selected by NB Power, and the mitigation that can reasonably be developed and implemented.

Options 1 and 2 are expected to produce similar interactions. Changes in upstream and downstream fish passage facilities will be the most influential long-term interaction under Options 1 or 2. It is expected that new fish passage designs will follow current best practices, and passage efficiency will generally improve. Therefore, fish passage changes under Options 1 or 2 are expected to be a positive interaction. However, because every dam is unique, the implementation of fish passage solutions that have been effective elsewhere does not guarantee that they will function well at the Station. Therefore, for either Option 1 or Option 2, considerable dialogue among the design engineers, fish passage experts, stakeholders and Fisheries and Oceans Canada will be required to make sure fish passage improves. Further, additional biological research and water flow modelling related to species-specific passage and powerhouse/spillway orientation may be required prior to design and construction in order to improve the chances of effective passage.

Option 3 will be associated with a greater number and magnitude of interactions relative to Options 1 or 2. More extensive mitigation will also be required under Option 3. The removal of the Station will fundamentally alter the aquatic environment in the area of review. Water and sediment flows will be restored to conditions that are expected to be largely similar to that prior to dam construction. Fish passage will improve, which is expected to be positive for migratory species such as Atlantic salmon and American shad. The unique features of the headpond ecosystem are expected to revert to a more natural river environment, similar to conditions prior to construction of the Station in the late 1960s. This will affect the existing community of fishes in the headpond. Following headpond drawdown, mitigation may be required to restore fish passage to streams that no longer have unimpeded access from the restored river channel.

Downstream of the current Station, the principal interaction will be potential damage to fish habitat from increased sediment transport. However, the results of sediment quality and quantity sampling and modelling completed as part of the MAES suggest that minimal adverse interactions with the aquatic environment may be expected downstream of the Station if key migration periods are avoided during the drawdown.

8.5.3 Assumptions and Limitations

This review is limited by the amount of information on existing conditions in the area of review. Further, because NB Power is in the early stages of planning, considerations for issues like fish passage engineering (Options 1 and 2) have not been fully defined. Parallel studies being carried out on engineering aspects of the three Options, as well as aquatic ecosystem baseline and predictive information being collected as part of the MAES, will provide further information to NB Power (beyond this CER Report) to inform its decision-making with respect to the Preferred Option.

Major dam projects often lack information on existing hydrogeological conditions, water and sediment quality, sediment quantity (upstream of the Station), and species abundance, distribution and community composition in the area that will be affected. As this review attests, the current Project is no exception. Accordingly, NB Power has commissioned the Canadian Rivers Institute to conduct the MAES, which aims to provide a clearer understanding of existing conditions in the area of review. Together with this review, the results of this multi-year study will provide NB Power with a greater ability to assess the potential interactions associated with the proposed Options and to inform its decision relating to the Preferred Option.

Considerations associated with fish passage design or drawdown timeline will have a major influence on potential interactions with the aquatic environment. In terms of fish passage, it is difficult to predict the interactions that may occur at the individual species level under Option 1 or 2 in the absence of detailed design and management information. Fish passage design will likely involve a trade-off between financial constraints and the need to meet acceptable regulatory objectives. Therefore, some species may be given priority over others in the design. Details of the drawdown scenario being considered for Option 3 may have a substantial influence on the interactions with the aquatic environment.

As a result of these limitations, this review is confined to qualitative and general interpretations of the potential interactions with the aquatic environment. However, in addition to this CER Report, NB Power will separately consider the results of other parallel studies being carried out, in particular the MAES and engineering considerations, in its decision-making regarding the Options, and further planning and mitigation following selection of the Preferred Option will better inform the execution of the selected Option in a manner that meets regulatory requirements and minimizes environmental interactions. Further clarity will be provided once the Preferred Option has been selected, as part of an eventual EIA/EA of the Preferred Option.