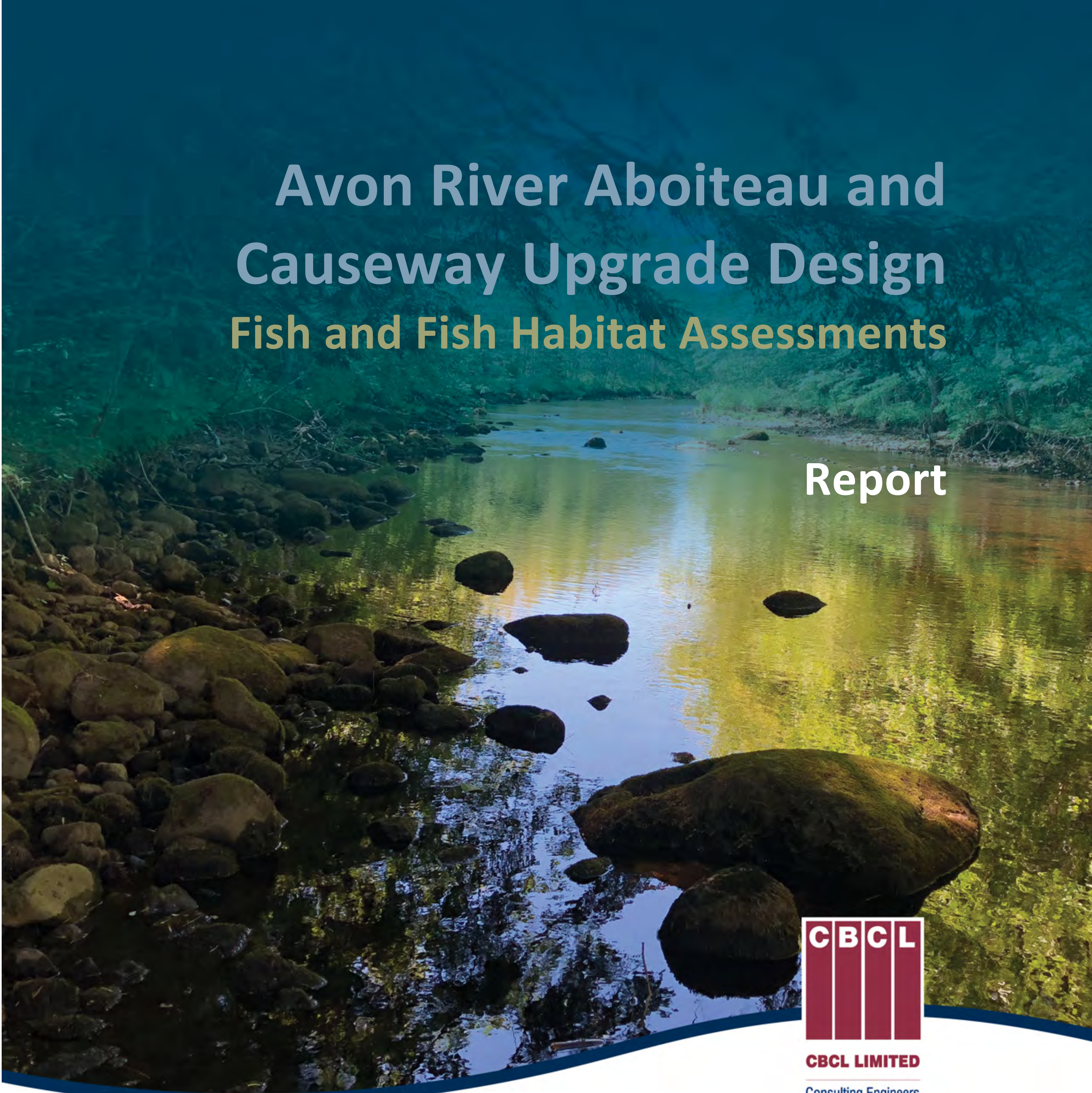
Avon River Aboiteau and Causeway Upgrade Design

Fish and Fish Habitat Assessments



Report

CBCL LIMITED

Consulting Engineers

NOVA SCOTIA

Transportation and Infrastructure Renewal

171046.00 • Report • May 2019

Final Report (REV00)	Ian Bryson	May 3, 2019	Carrie Bentley
Draft Report (REV00)	Ian Bryson	April 17, 2019	Carrie Bentley
Issue or Revision	***Reviewed By:***	***Date***	***Issued By:***

CBCL LIMITED
Consulting Engineers

CBCL LIMITED
Consulting Engineers

1489 Hollis Street
PO Box 606
Halifax, Nova Scotia
Canada B3J 2R7

Telephone: 902 421 7241
Fax: 902 423 3938
E-mail: info@cbcl.ca
www.cbcl.ca

Solving today's problems with tomorrow in mind

May 3, 2019

Mr. Justin Tanner, P.Eng.
Manager, Highway Planning and Design
Transportation and Infrastructure Renewal
1672 Granville – Floor 4 – Johnston Building
Halifax, NS

RE: Avon River Aboiteau and Causeway Upgrade Design: Fish and Fish Habitat Assessments

We are pleased to submit our Fish and Fish Habitat Assessment report, which we hope will assist NSTIR with the ongoing design and decision making for the above noted project. The report summarizes the results of the following key elements of the program:

(1) Fish and fish habitat assessments;
(2) Commercial, Recreational, and Aboriginal (CRA) fisheries assessments;
(3) Aquatic Species at Risk (SAR) assessments; and
(4) Consideration of fish passage requirements.

Thank you for the opportunity to conduct this work on behalf of NSTIR.

Yours very truly,

CBCL Limited

Carrie Bentley

Carrie Bentley, M.Sc., B.Sc. H
Senior Fisheries and Wildlife Biologist
Direct: (902) 421-7241
E-Mail: cbentley@cbcl.ca

Attachments

Project No: 171046.00

CANADA'S BEST MANAGED COMPANIES

Contents

Appendices

List of Tables

CHAPTER 1 INTRODUCTION

1.1 Project Description

Nova Scotia Transportation and Infrastructure Renewal (NSTIR) has initiated a project to twin Highway 101 between the end of the existing divided section at Exit 5 and the beginning of the existing divided highway west of Exit 7. Highway 101 crosses the Avon River at the Town of Windsor on a causeway with an aboiteau structure that provides an outlet for the Avon River, while also providing a barrier to the Bay of Fundy tides and protecting approximately 2,100 hectares of upstream areas from seasonal flooding. The existing causeway consists of a rock fill embankment and aboiteau structure, which were completed in 1970. The construction of the causeway and aboiteau created Pesaquid Lake, a freshwater impoundment which discharges downstream through the aboiteau to the Avon River estuary. Salt water and suspended sediments associated with tidal flows in the estuary and Bay of Fundy are prevented from flowing upstream into Pesaquid Lake by the causeway and aboiteau. Unfortunately, the aboiteau is a major impediment for diadromous[1] fish and other fish species migrating into Pesaquid Lake and upstream habitats in the Avon River and associated tributaries.

Allowance for fish passage was not incorporated into the design of the original causeway and aboiteau. The gates are open for maintenance in the spring, which coincides with gaspereau (*Alosa* spp.) migration. For the remainder of the year, the gates are closed, except for 15 to 20 minute intervals when the tide goes out, if the lake level can be kept high enough for the local community. During this time, the water velocity is quite high (i.e., 7 m/sec), which may impede fish passage (BoFEP, 2008). The aboiteau gates are closed during spawning runs for most salmonids such as sea run brook trout (*Salvelinus fontinalis*) and Atlantic salmon (*Salmo salar*). As the aboiteau is otherwise closed, fish passage is limited to those short time periods in which the gates are open. The causeway and aboiteau, therefore represent a partial barrier to fish passage in the Avon River.

Providing adequate fish passage at the new aboiteau structure is listed as a design requirement, and a condition of the NSTIR EA Approval for the Highway 101 Twinning Project (Submitted: May 8, 2017; Approved: June 27, 2017). Section 20 (3) of the *Fisheries Act* states that if the Minister decides

[1] Fish that migrate between fresh and salt water at some stage of their lifecycle. Those species that spawn in freshwater and later move to seawater as juveniles or adults are referred to as anadromous (e.g., salmon). The American eel is a catadromous species; they spawn in the ocean and migrate into brackish and freshwater habitats as 'elvers' where they spend much of their life as adults in streams, rivers, lakes and estuaries.

that sufficient fish passage is not provided, then the Minister can request that the owner make any provision to ensure fish passage. Therefore, Fisheries and Oceans Canada (DFO) will want to ensure that migrating species can move between the brackish waters of the Avon River estuary and the fresh waters of Pesaquid Lake and the Avon River during spawning and foraging migrations. NSTIR has contracted CBCL Limited (CBCL) to provide preliminary and detailed designs for the new causeway and aboiteau. The alignment of the existing highway across the causeway employs curves that are not adequate for the speed of the new highway, and the existing causeway and aboiteau structure are not wide enough to accommodate additional lanes required for twinning. Thus, a new section of causeway and aboiteau structure are necessary to cross the Avon River to provide a roadbed for the new highway alignment, and to continue to protect the upstream areas from flooding. Given that a new aboiteau structure is necessary, and poor fish passage through the existing structure has been identified as a problem that needs to be corrected, the new structure must also provide improved fish passage from the Avon River estuary to habitats upstream of the causeway. Execution of a design allowing fish passage through the aboiteau was prioritized by NSTIR, therefore CBCL performed fish habitat assessments to support the design effort, on the north and south branches of the Avon River upstream of Pesaquid Lake. The results of CBCL's fish habitat assessment, along with information collected in previous assessments, will assist during the decision-making phases related to the selection of the most practical structure suited to the provision of reliable fish passage through the causeway and aboiteau. The theoretical intent of the requested aboiteau design is to allow for migration between the Avon River estuary and habitats in Pesaquid Lake and the upstream Avon River watershed.

1.1.1 Project Location

The causeway and aboiteau are located in Windsor, NS where the Avon River meets the Southern Bight of the Minas Basin (Appendix A: Figure 1). The causeway extends approximately 700 metres across the Avon River estuary between Highway 101 Exits 6 and 7; the aboiteau was constructed toward the west end of the causeway nearest Exit 7. PID numbers for properties adjacent to the causeway and aboiteau are provided in Appendix A: Figure 2. Fish and fish habitat assessment locations on the north and south branches of the Avon River upstream of Pesaquid Lake are provided in Appendix A: Figure 3.

CHAPTER 2 CRA FISHERIES AND SPECIES AT RISK ASSESSMENT

2.1 Historical Context

Commercial, recreational and Aboriginal (CRA) fisheries have historically played an important role in the Windsor area, and productive commercial fisheries existed prior to the 1850's. Commercial fisheries for Atlantic salmon (*Salmo salar*) and gaspereau (*Alosa* spp.) were very important drivers of the local area economy, and substantial recreational fisheries provided sustenance and entertainment to local residents (Isaacman, 2005; BoFEP, 2008). Over time, however, these populations steadily diminished as a result of the combined effects of small-scale hydroelectric dams, pollution associated with industrial activities, a growing population, and overfishing. This decline accelerated through the twentieth century as development in the Windsor area accelerated, and culminated with the construction of the causeway and aboiteau in 1970, which represents a significant impedance to fish passage into historical upstream habitats in the Avon River watershed (Isaacman, 2005; BoFEP, 2008).

A review of commercial, recreational and Aboriginal (CRA) fisheries that occur in or near the Project area and a functional assessment of habitats that may support the identified CRA fisheries was completed in order to properly assess those species that require fish passage through the proposed causeway and aboiteau. A review of federally listed species under the *Species at Risk Act* and provincially listed species under the Nova Scotia *Species at Risk Act*, as well as Species of Conservation Concern (SoCC) deemed applicable by CBCL ecologists, that occur in or near the Project area, and a functional assessment of habitats that may support the identified SAR and SoCC species was also completed. The results of the functional assessment, along with information on CRA, SAR and SoCC species collected during previously completed assessment in the Project area, will assist in the identification of fish passage requirements for the new causeway and aboiteau.

2.2 CRA Fisheries Assessment

The Project area is located where Highway 101 crosses the Avon River estuary near the town of Windsor, NS (Appendix A: Figures 1 and 2). The Project area falls within Northwest Atlantic Fisheries Organization (NAFO) convention area 4X. This area includes portions of the eastern Bay of Fundy and extends offshore beyond the Scotian Shelf. Where available, data was derived from sources reporting historic and current landings for the eastern Bay of Fundy in this convention area. Commercial fishing areas within NAFO convention area 4X include Lobster Fishing Area (LFA) 35, and Herring and Mackerel Fishing Area (H/MFA) 22/21.

Potential CRA fisheries species that may inhabit the Project area and require passage through the causeway and aboiteau during one or more life history stages were determined using the following sources of information:

- Highway 101 Twinning Three Mile Plains to Falmouth Environmental Assessment (Stantec, 2017);
- The Mi'kmaw Conservation Group (MCG) Report: Electrofishing in the Avon River (Mi'kmaw Conservation Group, 2018) (Appendix B);
- Acadia University Report: Baseline Assessment of Commercial, Recreational and Aboriginal (CRA) Fisheries Adjacent to the Avon River Causeway (Avery et al., 2019);
- Personal communication with DFO advisors in the Truro (NS) area office:
    - Richards, Dale (*pers. comm.,* 2019);
- Personal communication with a commercial fisherman in the Windsor area:
    - Porter, Darren (*pers. comm.,* 2019);
- Personal communication with advisors:
    - Rutherford, Bob, fisheries biologist (*pers. comm*., 2019);
- DFO Marine Fisheries Database; and
- A desktop literature review.

Habitat types identified in the Project area were evaluated in terms of their suitability and functionality for different life history stages of observed or potential CRA fisheries species. Habitat suitability and functionality was determined through an assessment of peer-reviewed scientific literature concerning the life history of selected CRA fisheries species, including critical habitat requirements and preferences, and known distributions and ranges. Habitat features that are important in the determination of marine species suitability and functionality include benthic structure and substrate composition, water depth, macrofloral and coverage, faunal community groups (microfauna, meiofauna, and macrofauna), hydrology, physicochemical characteristics, and anthropogenic alterations and influence. A functional assessment of habitats observed in the Project area was conducted for selected CRA fisheries species. For each CRA fisheries species, a habitat suitability rating for life history stages was assigned. Examples of habitat suitability and life history stage ratings are provided in Table 2.1.

Table 2.1 Key Life History and Habitat Suitability and Functionality Ratings

<table>
<tr><th>Life History Stage</th><th colspan="5">Habitat Suitability and Functionality Ratings</th></tr>
<tr><td>Spawning</td><td rowspan="6">Poor</td><td rowspan="6">Poor-Moderate</td><td rowspan="6">Moderate</td><td rowspan="6">Moderate-Good</td><td rowspan="6">Good</td></tr>
<tr><td>Rearing</td></tr>
<tr><td>Overwintering</td></tr>
<tr><td>Adult foraging</td></tr>
<tr><td>Cover</td></tr>
<tr><td>Migration</td></tr>
</table>

One (1) crustacean and eighteen (18) finfish species were selected for inclusion in the CRA fisheries assessment as depicted in Table 2.2.

Fish species that support a CRA fishery in the Project area are also provided in Table 2.2. These species are present in either the upstream or downstream habitats; their presence was confirmed during survey programs in the Project area or previous studies. These species are denoted in the CRA Inclusion Criteria (Table 2.2) as Support Species. Habitat functional assessments for CRA fisheries species potentially inhabiting the Project area are provided in Appendix C. Species that may support CRA fisheries species were not included in the habitat functional assessments. Field Data Fact Sheets for the areas of the north and south branches of the Avon River assessed by CBCL are provided in Appendix D. Habitat requirements and known fish passage requirements for species confirmed in the Project area are provided in Appendix E.

Table 2.2 Commercial, Recreational and Aboriginal Fisheries Species and Support Species Occurring in the Project Area

Common Name	Scientific Name	CRA Inclusion Criteria	Confirmed Species Presence	
			Pesaquid Lake (Upstream)	Avon River Estuary (Downstream)
Alewife (Gaspereau)	*Alosa pseudoharengus*	Commercial; Recreational	Yes	Yes
Blueback herring (Gaspereau)	*Alosa aestivalis*	Commercial; Recreational	Yes	Yes
American eel	*Anguilla rostrata*	Commercial; Recreational; Aboriginal	Yes	Yes
American lobster	*Homarus americanus*	Commercial; Aboriginal	Yes	Yes
American shad	*Alosa sapidissima*	Commercial; Recreational	No	Yes
Atlantic herring	*Clupea harengus*	Commercial	Yes	Yes
Atlantic mackerel	*Scomber scombrus*	Recreational	No	Yes
Atlantic silverside	*Menidia menidia*	Support species	Undetermined	Undetermined
Atlantic tomcod	*Microgadus tomcod*	Recreational; Aboriginal	Yes	Yes
Banded killifish	*Fundulus diaphanus*	Support species	Undetermined	Undetermined
Brook trout	*Salvelinus fontinalis*	Recreational	Yes	Yes
Brown bullhead	*Ameiurus nebulosus*	Support species	Yes	Yes
Brown trout	*Salmo trutta*	Recreational	Yes	Yes
Fourspine stickleback	*Apeltes quadracus*	Support species	Undetermined	Undetermined
Lake chub	*Couesius plumbeus*	Support species	Undetermined	Undetermined

Common Name	Scientific Name	CRA Inclusion Criteria	Confirmed Species Presence	
			Pesaquid Lake (Upstream)	Avon River Estuary (Downstream)
Mummichog	*Fundulus heteroclitus*	Support species	Undetermined	Undetermined
Ninespine stickleback	*Pungitius pungitius*	Support species	Undetermined	Undetermined
Northern redbelly dace	*Phoxinus eos*	Support species	Undetermined	Undetermined
Rainbow smelt	*Osmerus mordax*	Recreational; Aboriginal	Yes	Yes
Sea lamprey	*Petromyzon marinus*	Support species	No	Yes
Shiner (sp.)	Not determined	Support species	Yes	No
Smallmouth bass	*Micropterus dolomieu*	Recreational	Yes	Yes
Smooth flounder	*Liopsetta putnami*	Recreational	No	Yes
Spiny dogfish (Atlantic Pop.)	*Squalus acanthias*	Recreational	No	Yes
Striped bass (Bay of Fundy Pop.)	*Morone saxatilis*	Recreational; Aboriginal	Yes	Yes
Summer flounder	*Paralichthys dentatus*	Commercial; Recreational	No	Yes
Threespine stickleback	*Gasterosteus aculeatus*	Support species	Undetermined	Undetermined
White perch	*Morone americana*	Recreational	Yes	Yes
White sucker	*Catostomus commersonii*	Support species	Yes	Yes
Winter flounder	*Pseudopleuronectes americanus*	Commercial; Recreational	No	Yes
Yellow perch	*Perca flavescens*	Recreational	Yes	No

2.2.1 Commercial Fisheries

Commercial fisheries presently ongoing in the area around the Avon River causeway were identified during field surveys in the Project area and supplemented by a desktop review and consultation with regulatory agencies. These species include:

- American eel;
- American lobster;
- American shad;
- Atlantic herring;
- Gaspereau (*Alosa* spp.);
- Summer flounder; and
- Winter flounder.

American eel, American lobster, Atlantic herring and gaspereau (including alewife and blueback herring) were confirmed as present in the Avon River estuary as well as Pesaquid Lake or other freshwater habitats further upstream. American eel are caught in the Avon River estuary tidal side channel. Darren Porter, a commercial fisherman based in the Windsor area, stated that eel pots set at the mouth of the tidal side channel return relatively higher catches per unit effort compared to pots set further into the tidal side channel (*pers. comm.*, Porter, 2019). American shad was confirmed in the Avon River estuary, but this anadromous species was not identified in upstream freshwater habitats. Summer flounder and winter flounder were identified in the Avon River estuary, but were not identified in upstream freshwater habitats. These species predominantly inhabit marine and estuarine environments.

2.2.2 Recreational Fisheries

Recreationally fished species around the Avon River causeway were identified by desktop review, during field surveys in the Project area, and supplemented by a desktop review and consultation with regulatory agencies. These species include:

- American eel;
- American shad;
- Atlantic mackerel;
- Atlantic tomcod;
- Brook trout;
- Brown trout;
- Gaspereau (*Alosa* spp.);
- Rainbow smelt;
- Smallmouth bass;
- Smooth flounder;
- Spiny dogfish;
- Striped bass;
- Summer flounder;
- White perch;
- Winter flounder; and
- Yellow perch.

American eel, Atlantic tomcod, brook trout, brown trout, gaspereau (including alewife and blueback herring), rainbow smelt, smallmouth bass, striped bass, and white perch were confirmed as present in the Avon River estuary as well as Pesaquid Lake or other freshwater habitats further upstream. Atlantic mackerel, smooth flounder, spiny dogfish, summer flounder and winter flounder were confirmed in the Avon River estuary, but were not identified in upstream freshwater habitats. These species predominantly inhabit marine and estuarine environments. American shad was confirmed in the Avon River estuary but this anadromous species was not identified in upstream freshwater habitats. Yellow perch, a freshwater species, was confirmed in Pesaquid Lake or other upstream freshwater habitats.

2.2.3 Aboriginal Fisheries

Aboriginal (Mi'kmaq) fisheries potentially ongoing in the area around the Avon River causeway include those species listed below. These were determined during field surveys in the Project area, and supplemented by a desktop review and consultation with regulatory agencies.

- American eel;
- American lobster;
- Atlantic tomcod;
- Gaspereau (*Alosa* spp.);
- Rainbow smelt; and
- Striped bass.

American eel, American lobster, gaspereau (including alewife and blueback herring), rainbow smelt and striped bass were confirmed as present in the Avon River estuary as well as Pesaquid Lake or other freshwater habitats further upstream.

2.3 Species at Risk and Species of Conservation Concern Assessment

Federal and provincial legislations required that the sustainable management of natural resources includes protection of scheduled or listed Species at Risk (SAR) or Species of Conservation Concern (SoCC). Potential occupancy of the Project area by federally or provincially protected SAR or SoCC species was evaluated after thorough vetting of available information including field surveys conducted in the Project area and a desktop literature review of the following:

- Highway 101 Twinning Three Mile Plains to Falmouth Environmental Assessment (Stantec, 2017);
- *Species at Risk Act* (SARA) species at risk public registry under the administration of Fisheries and Oceans Canada (DFO), Environment and Climate Change Canada (ECCC), and Parks Canada (PC);
- Committee on the Status of Endangered Wildlife in Canada (COSEWIC) status reports;
- Personal communication with a commercial fisherman in the Windsor area:
  - Porter, Darren (*pers. comm.,* 2019);
- Nova Scotia Environment provincially protected species registry; and
- A desktop literature review.

Five (5) finfish were selected for inclusion in the Species at Risk assessment for the Project area as presented in Table 2.3. These species were identified during field surveys or through a literature review as potentially inhabiting the Project area during one or more life history stages. Habitat functional assessments and suitability ratings for species potentially inhabiting the Project area are provided in Appendix C.

Table 2.3 Species at Risk and Species of Conservation Concern Identified in the Project Area

Common Name	Species Name	SARA Schedule	SARA Status	COSEWIC Status
American eel	*Anguilla rostrata*	No schedule	No status	Threatened

Common Name	Species Name	SARA Schedule	SARA Status	COSEWIC Status
Atlantic salmon (Inner Bay of Fundy population)	*Salmo salar*	1	Endangered	Endangered
Atlantic sturgeon	*Acipenser oxyrinchus*	No schedule	No status	Threatened
Spiny dogfish	*Squalus acanthias*	No schedule	No status	Special Concern
Striped bass (Bay of Fundy population)	*Morone saxatilis*	No schedule	No status	Endangered

American eel, Atlantic salmon, and striped bass were confirmed as present in the Avon River estuary as well as Pesaquid Lake or other freshwater habitats further upstream (Avery et al., 2019; Darren Porter, *pers. comm.,* January 17, 2019). Spiny dogfish were confirmed in the Avon River estuary, but were not identified in upstream freshwater habitats. This species predominantly inhabits marine environments. Atlantic sturgeon were also confirmed in the Avon River estuary, however this species was not identified in Pesaquid Lake or other upstream freshwater environments.

2.4 Migratory Windows

Species determined to potentially inhabit the Project area, which were identified as either part of a CRA fishery or as a SAR or SoCC species, were further researched in order to determine critical times of the year during which these species require passage through the aboiteau. These windows are predominantly associated with annual anadromous spawning migrations from marine and estuarine environments to freshwater environments, post-spawning migrations downstream to marine and estuarine environments, and juvenile migrations to the marine and estuarine environments. These critical periods are provided in Table 2.4. It is noted that certain species require fish passage prior to or following extensive migrations that may not coincide with spawning periods. American eel, for example, are a catadromous species requiring passage in the spring and late summer. These windows correspond with juvenile migrations to upstream freshwater habitats in the spring, and downstream migrations by fecund adults to marine environments in the Sargasso Sea in the summer and early fall. Species inhabiting the Avon River estuary that may require passage during foraging migrations to brackish and freshwater upstream habitats are denoted with an (*) in Table 2.4. Please refer to Appendix C for a list of cited literature.

2.5 CRA Fisheries Species Descriptions

Habitats in the Project area have the potential to provide an array of functions to fish inhabiting the Project area. Assessments of habitat function and suitability ratings for these CRA fisheries species is provided in Appendix C. Species descriptions and habitat requirements for CRA fisheries species that received an evaluation of ‘moderate to good’ or ‘good’ for three or more life history stages include:

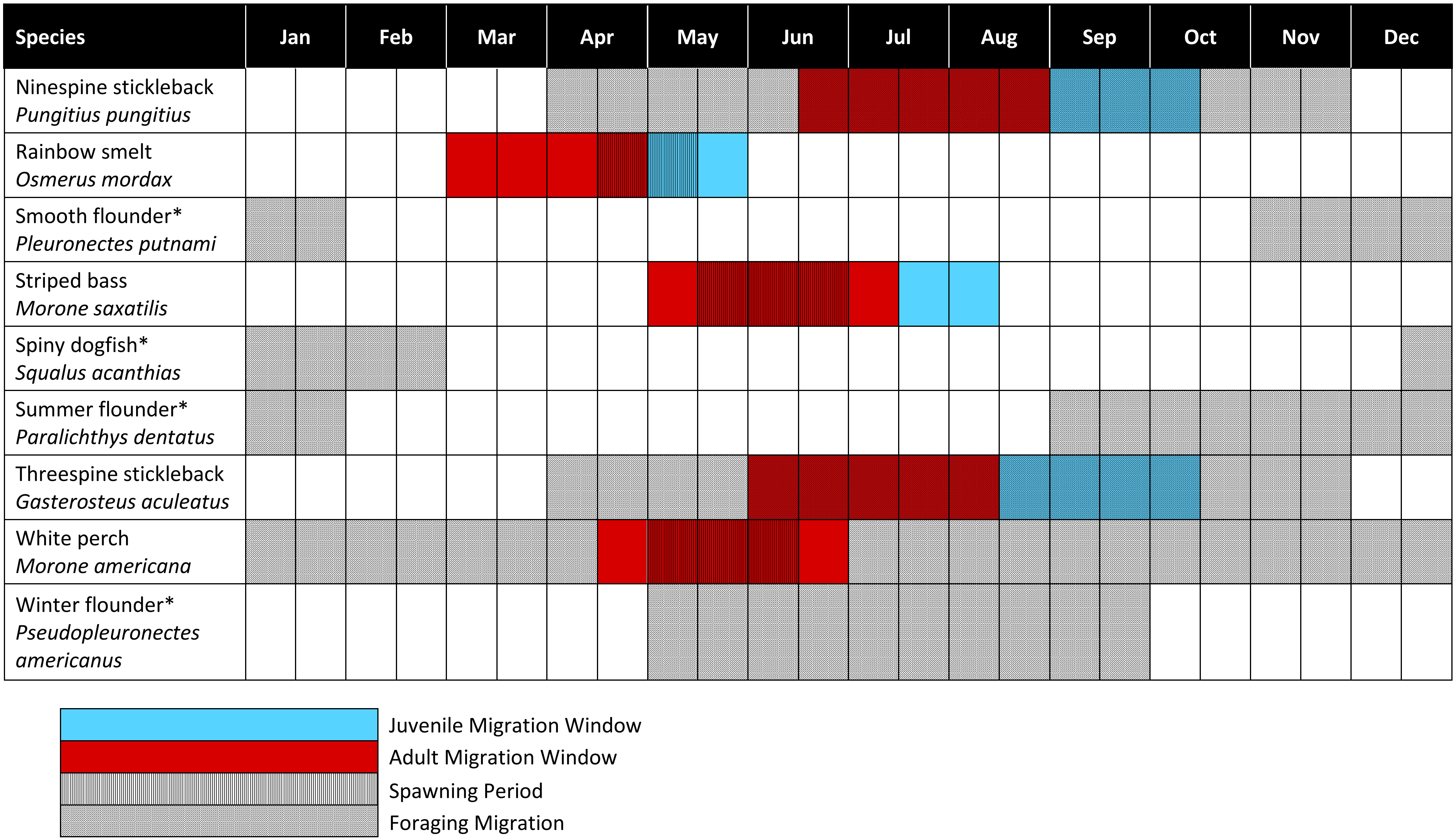
- American eel;
- Atlantic tomcod;
- Brook trout;
- Brown trout;
- Gaspereau;

- Smallmouth bass;
- Smooth flounder;
- Striped bass; and
- White perch.

Species descriptions and habitat requirements for the listed CRA fisheries species are provided in Sections 2.5.1 to 2.5.9.

Table 2.4 Key Migratory Windows for CRA and SAR Species Identified in the Project Area

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
American eel *Anguilla rostrata*												
American shad *Alosa sapidissima*												
Atlantic herring* *Clupea harengus*												
Atlantic mackerel* *Scomber scombrus*												
Atlantic salmon *Salmo salar*												
Atlantic silverside* *Menidia menidia*												
Atlantic sturgeon** *Acipenser oxyrinchus*												
Atlantic tomcod *Microgadus tomcod*												
Brook trout (sea run) *Salvelinus fontinalis*												
Brown trout *Salmo trutta*												
Fourspine stickleback *Apeltes quadracus*												
Gaspereau *Alosa* spp.												
Mummichug* *Fundulus heteroclitus*												



* Project area functions as foraging habitat

** No known breeding population in the Project area

2.5.1 American Eel (Anguilla rostrata)

The American eel is a semelparous, serpentine finfish native to fresh, estuarine and coastal waters connected to the western Atlantic Ocean (COSEWIC, 2012). Adults undergo extensive spawning migrations to the Sargasso Sea, a large body of warm oceanic water off the coast of the southeastern United States and the only known spawning grounds for American eel (COSEWIC, 2012). Spawning, egg hatching and the emigration of larvae occurs sometime over the winter and early spring between February and April (COSEWIC, 2012); larvae borne upon Gulf Stream currents are passively transported out of the Sargasso Sea before undertaking their own migration over the continental shelf to coastal waters of eastern North America. Juvenile eels arrive in estuarine waters between May and July in the Gulf of St. Lawrence (COSEWIC, 2012), and soon after migrate to estuarine, brackish, and upstream freshwater habitats wherein they spend the remainder of their adult lives. Eels in freshwater habitats are tolerant of dissolved oxygen levels as low as 4.0 mg/L (Rulifson et al., 2004), pH as low as 4.0 (Reynolds, 2011) and water temperatures upward of 20^{o}C; temperatures below 5^{o}C in winter induce a state of torpor (COSEWIC, 2012). Adults typically burrow in sediment or seek refuge in interstitial spaces before nightly foraging activities; shallow, protected waters with rocks, fine sediment, woody debris and aquatic vegetation, including eelgrass, are important habitat characteristics (COSEWIC, 2012). Overwintering typically occurs in freshwater muddy bottoms or in shallow bays and estuarine habitats in which adults enter a state of torpor, however their winter habitats are poorly understood. Adult eel forage on a variety of organisms, including small fish, molluscs, crustaceans, insect larvae, surface-dwelling insects, worms, and occasionally plants; some evidence suggests periodic foraging occurs through the winter months (COSEWIC, 2012). After a period of time (upward of 20 years) adult American eel migrate back to the Sargasso Sea to spawn and complete their lifecycle (COSEWIC, 2012; Murua and Saborido-Rey, 2003).

2.5.2 Atlantic Tomcod (Microgadus tomcod)

Atlantic Tomcod are an anadromous inshore, shallow water fish most often found in estuary environments throughout the North Atlantic. Tomcod are highly tolerant of low temperatures and large swings in salinity. Their primary food source is small crustaceans, but as aggressive opportunistic predators they will consume a wide range of organisms. Spawning takes place in the winter as the fish migrate farther into the estuaries and the mouths of rivers (Scott and Scott, 1988). Tomcod prefer a hard substrate to lay their eggs, but will tolerate a range of substrates. Larval tomcod drift out into the estuary and will not survive in completely fresh water, completely landlocked populations do exist are the exception (Stewart and Auster, 1987; Scott and Scott, 1988). Though similar in appearance to the Atlantic cod, tomcod only grow to a fraction of the size maxing out at only 1 ¼ pounds (Bigelow and Schroeder, 1953). Tomcod are commonly targeted during recreational ice-fishing over estuarine waters during the winter months. In the Avon River, the present un-natural circulation in the estuary, due to the aboiteau operation, prevents the eggs laid at the head of tide from surviving as larvae in this marine population.

2.5.3 Brook Trout (Salvelinus fontinalis)

Brook trout are an anadromous or freshwater species native to the western Atlantic Ocean with populations dispersed throughout Canada, including Labrador and northern Quebec, through the

Great Lakes and Atlantic Canada to the northeastern United States (Raleigh, 1982). Brook trout life history alternates between the northern and southern range of the species; populations in the northerly range are longer lived and make foraging migrations into estuaries and near-shore coastal waters, whereas more southerly populations have shorter lives and do not migrate into marine waters (Raleigh, 1982). Brook trout residing in freshwater systems require a year-round supply of cold, clear water and cover from overhanging branches, logs and rocks. Streams with cool, quiet pools between runs of fast water and rapids are typical habitat, as are clear, cold lakes and beaver ponds (OMNR, 2011). Spawning occurs in late summer and the fall within stream riffle habitats, where the female deposits fertilized eggs in a depression she excavates in the gravel substrate (Scott and Scott, 1988; Raleigh, 1982). During winter, trout seek shelter from freezing and ice within deep pools, ponds, lakes, around instream debris and undercut banks (Huusko et al., 2007). Sea-run trout have been reported to make long forays into coastal waters during foraging migrations (Raleigh, 1982) and while seeking preferable habitat conditions in the summer and winter. These foraging migrations occur periodically through the spring as well as the fall and early winter; summer and midwinter foraging migrations are longer and based on the habitat conditions in their environment (Raleigh, 1982; *pers. comm.*, Rutherford, 2019). Sea-run brook trout also reportedly overwinter in estuaries and nearshore coastal waters (Raleigh, 1982). They are aggressive carnivores which feed primarily on aquatic macroinvertebrates and terrestrial insects, in addition to small fish, bivalves, gastropods, frogs and salamanders (NSDFA, 2007).

2.5.4 Brown Trout (Salmo trutta)

Brown trout are native to Europe and were introduced to Atlantic Canada during the latter part of the 19th century and have habitat preferences very similar to those of brook trout (see section 2.5.3). Brown trout were thought to primarily remain in freshwater habitats into which they were introduced. It is now recognized that brown trout make foraging migrations to estuarine and marine waters similar to those of sea-run brook trout (Scott and Scott, 1988). Brown trout home to their natal streams in the fall to spawn, with a preference for riffle habitat free of fines or silt, a constant water flow, and temperatures between 10°C to 12°C (Raleigh et al., 1986). Brown trout prefer watercourses with riffle and pool dominated habitat with at least 15 cm of water depth and a velocity of approximately 0.15 m/sec. Unlike brook trout, brown trout usually inhabit the lower, less steep sections of streams where nutrients are often more abundant. Brown trout can tolerate pH ranges between 5.0 and 9.5 but will avoid areas with less than 5 mg/L of dissolved oxygen (Raleigh et al., 1986). Juvenile brown trout forage upon a variety of aquatic and terrestrial insects. Upon reaching a length greater than 25 cm, trout modify their dietary preferences to include fish, larger crustacean, aquatic amphibians and small mammals. Adult brown trout are active night feeders, and prefer to forage on gaspereau when available.

2.5.5 Gaspereau (Alosa spp.)

Gaspereau are anadromous schooling fish inhabiting pelagic marine waters which undertake seasonal migrations to brackish and freshwater systems once a year to spawn. Gaspereau collectively refers to two closely related species in Atlantic Canadian waters: alewife (*Alosa pseudoharengus*) and blueback herring (*Alosa aestivalis*). Adult gaspereau migrate upstream in spring through summer months to calm areas of rivers and connecting lakes, where spawning occurs over sandy or gravel substrates with submerged vegetation and detritus where the eggs are randomly scattered (CRI, 2014; Pardue, 1983). Large numbers of young gaspereau emigrate from their natal freshwater habitat to occupy shallow inshore waters during the late summer and early fall; juveniles make daily movements between pelagic habitats at night and benthic habitats during the day. Juvenile gaspereau migrate out of their freshwater-estuarine nursery areas in the late fall of their first year and overwinter near the benthos in this area before dispersing to the ocean the following spring (Pardue, 1983). Adults migrate out of natal spawning habitats soon after spawning activities and return to coastal marine waters before overwintering in deeper waters offshore. Gaspereau are repeat spawners, therefore it is important to have downstream passage after the completion of spawning activities (Bergstedt and O'Gorman, 1989; Pardue, 1983; *pers. comm.,* Rutherford, 2019). Adults primarily consume zooplankton in addition to small fish, fish eggs, aquatic insects and occasional plant material (CRI, 2014; Pardue, 1983).

2.5.6 Smallmouth Bass (Micropterus dolomieu)

Smallmouth bass, a non-native species in Nova Scotia, prefer cool mid order streams with good flow, abundant shade and alternating deep pools and riffles (Edwards et al., 1983). They also prefer to inhabit large lakes (>10.5 m wide) with substrates consisting of rocks, fallen trees and crevices that provide interstitial refuges and resting areas (Scott and Crossman, 1973). Adult and juvenile smallmouth bass feed on fish, insects and arthropods. Spawning occurs in mid-April to July in shallow depths (1 - 2.5 m) within areas having large substrate (30 mm) along protected coves or shore lines (Clancey, 1980; Watson, 1955; Henderson and Foster, 1957). They typically nest in sites with gravel substrate, some type of cover, and warmer (13-35°C) temperatures (Scott and Crossman, 1973). Adults prefer deep pools (<12 m) and shaded areas with cooler waters. In the early stages, smallmouth bass are highly sensitive to cooler temperatures and rising water levels. Smallmouth bass can tolerate turbidity to some degree, but excessive turbidity and siltation will have negative effects upon the population (Coutant, 1975). Optimal pH levels for smallmouth bass are between 7.9 and 8.1, while 3 or less is considered lethal (Butler, 1972). They require >6 mg/L dissolved oxygen for growth and cannot survive once oxygen levels drop near 1 mg/L (Buckley, 1975).

2.5.7 Smooth Flounder (Pleuronectes putnami)

Smooth flounder is a small flatfish predominantly found in estuaries and sheltered bays ranging from Labrador and the Gulf of St. Lawrence to Rhode Island. Smooth flounder inhabit nearshore waters year-round and segregate by size; smaller juvenile flounder can be located in shallow intertidal waters whereas adult flounder are found in deeper waters at depths of 5 m or greater. In late autumn, smaller flounder move deeper, likely to avoid scour by ice. Smooth flounder are typically found in habitats consisting of fine substrates, such as sand, sand/silt, and mud. Spawning is thought to occur in early winter when water temperatures approach 0^{o}C. Juvenile and adult smooth flounder feed on small crustaceans, polychaetes, and small molluscs (Hanson and Courtenay, 1997).

2.5.8 Striped Bass (Morone saxatilis)

Striped bass is a semi-anadromous species that occurs naturally along most of the eastern seaboard of North America (Bain and Bain, 1982). Striped bass occur throughout much of the Maritimes, and consists of three separate populations, each with different conservation ranks. COSEWIC has designated the Bay of Fundy population 'Endangered' (COSEWIC, 2013).

Striped bass spend most of their life in marine environments, with spawning occurring at the head of tidal or brackish waters (Bain and Bain, 1982). Eggs and larvae drift in the pelagic zone with juveniles feeding on benthic macro-invertebrates and zooplankton. Adult striped bass diet consists mainly of soft-rayed fishes. Striped bass avoid areas with temperatures above 25°C. Striped bass prefer well oxygenated water with >44% dissolved oxygen. Successful spawning occurs in areas with a velocity of 0.3 m/s or greater, temperatures between 17°C to 19°C and total dissolved solids less than <0.18 ppt. Juvenile striped bass stay near shore and gradually venture further into areas with higher salinity. Striped bass are rarely observed further than six (6) to eight (8) kilometres from shore (Bain and Bain, 1982) and forage within non-natal estuaries throughout the summer before overwintering in estuaries and rivers (Hogans and Melvin, 1984; Bradford et al., 2012; Douglas et al., 2003, 2009). In the Avon River, the present un-natural circulation in the estuary, due to the aboiteau operation, prevents the eggs laid at the head of tide and the larvae from surviving in this system due to low salinity levels (*pers. comm.*, Rutherford, 2019).

2.5.9 White Perch (Morone Americana)

White perch are a semi-anadromous species related to striped bass. Spawning takes place in lakes, rivers and estuaries between April and May. White perch can spawn in water with salinity as high as 4.2 ppt. Silt does not affect developing eggs until it reaches a level of 500 mg/L. Larvae swim up and down in a vertical motion, relying on flow and velocity to help them drift along. Juvenile white perch inhabit streams with mud/silt substrates and prefer an abundance of instream vegetation. The diet of white perch fry consists of mostly zooplankton, while juveniles primarily forage on benthic macro-invertebrates and small crustaceans. Once the adult stage is reached, their diet consists almost exclusively of fish, and they are known to be cannibalistic. White perch can withstand temperatures between 2 and 32.5°C, while spawning occurs between 12 and 14°C. Adults can withstand pH ranges between 6.0 and 9.0 in freshwater (Stanley and Danie, 1983).

2.6 SAR and SoCC Species Descriptions

Habitats in the Project area have the potential to provide an array of functions to fish inhabiting the Project area. Assessments of habitat function and suitability ratings for SAR and SoCC species are provided in Appendix C. Species descriptions and habitat requirements for SAR and SoCC species that received an evaluation of 'moderate to good' or 'good' for three or more life history stages include:

- American eel;
- Atlantic salmon;
- Atlantic sturgeon;
- Spiny dogfish; and
- Striped bass.

Species descriptions and habitat requirements for the listed SAR and SoCC species are provided in Sections 2.6.1 to 2.6.5.

2.6.1 American Eel (Anguilla rostrata)

A description of this species was provided in Section 2.5.1.

2.6.2 Atlantic Salmon (Salmo salar)

Atlantic salmon are an anadromous species native to the northern Atlantic Ocean and Baltic Sea. In the western Atlantic, salmon range from Labrador and northern Quebec to the Gulf of St. Lawrence and south to New York State (COSEWIC, 2010). Atlantic salmon undertake extensive seasonal migrations; long foraging migrations at sea give way to spawning migrations and a return to natal freshwater spawning grounds. Spawning adults move upriver from spring through fall with egg deposition generally occurring in October and November in gravelly substrates near the head of riffles or the tail of a pool (COSEWIC, 2010). Adults return to sea after spawning or remain in freshwater habitats until the following spring, whereas juveniles develop in freshwater habitats over a period of 2 to 3 years in the Minas Basin watersheds prior to emigrating to marine waters in April and May for further development and foraging migrations (*pers. comm.*, Rutherford, 2019). Newly emigrated salmon typically return to their natal streams for spawning after a development period of 1 to 2 years at sea. Physicochemical parameters influencing the productivity of spawning habitats are strongly linked to temperature, water flow and pH; temperature and water flow preference fluctuates depending on life history stage, whereas pH lower than 5.0 negatively impact all life history stages (Elliott and Elliott, 2010; COSEWIC, 2010). Juvenile salmon feed on a variety of aquatic insects, invertebrates and plankton. Adults prefer a diet rich in pelagic and demersal finfish, in addition to small crustaceans and other invertebrates (COSEWIC, 2010).

2.6.3 Atlantic Sturgeon (Acipenser oxyrinchus) – Maritime Population

Atlantic sturgeon (*Acipenser oxyrinchus*) is a large anadromous fish species which occurs in most coastal waters of Canada between the Canada-US border and Ungava Bay, Labrador. This species spawns in relatively shallow freshwater (1-3 metres deep) characterized by strong current and rocky substrate. The Maritime population spawns in the Saint John River in New Brunswick. Juveniles overwinter in either freshwater or estuaries, while mature Atlantic sturgeon prefer estuaries and small bays, presumably to aid in transitioning between freshwater and salt water environments. Adults spend most of the non-breeding season at sea, feeding on worms, crustaceans, molluscs, small fish and aquatic insects while migrating along the coast (DFO, 2018).

2.6.4 Spiny Dogfish (Squalus acanthias)

Spiny dogfish is a small schooling shark that is seasonally present during the summer in inshore waters around Nova Scotia and offshore during the winter. The range of the shark includes most coastal temperate seas around the world. Tolerant of low salinity conditions, spiny dogfish can travel up into estuaries (Scott and Scott, 1988). Spiny dogfish are an opportunistic feeder and will prey on whatever is abundant in the area. Female spiny dogfish have one of the longest gestation periods of any vertebrate at around 22 months. Male spiny dogfish grow to a maximum size of around a meter, females are known to grow to about 1.2 metres and weigh over double of their male counterparts 3 kg vs 7 kg (Scott and Scott, 1988; Stehlik, 2007). Historically the spiny dogfish were fished for its oil rich liver. Presently the shark is valued as a food source in some countries. As a predator of commercially fished species the spiny dogfish is often viewed as a pest species as they consume mackerel and herring. They are known for getting caught on long lines (Stoner and Kaimmer, 2008) and in nets in large numbers due to their schooling nature (Campana, 2007).

2.6.5 Striped Bass (Morone saxatilis)

A description of this species was provided in Section 2.5.8.

CHAPTER 3 FISH AND FISH HABITAT ASSESSMENTS

3.1 Fish Habitat Asessment

On June 27, 2018 and June 28, 2018 CBCL field personnel assessed seven (7) locations along the northern and southern branches of the Avon River for identification and qualification of potential fish habitat (Appendix A: Figure 3). Five (5) sites were located on the northern branch (Avon River North – ARN) and two (2) sites on the south branch (Avon River South – ARS). Methodologies employed during the field assessments are described in Section 3.1.1. The results of CBCL's field assessments are presented alongside the results of electrofishing programs conducted by staff at the MCG in the summers of 2017 and 2018 (Appendix B).

3.1.1 Fish Habitat Assessment Methodology

Methodology for the fish habitat assessments was conducted under the direction of fish habitat biologist Bob Rutherford (Thaumas Environmental Consultants) and was based on the Nova Scotia Adopt a Stream Habitat Suitability Index (2018). One cross section across the watercourse was conducted at each sampling location. Observed conditions were documented and evaluated for quality of overwintering, rearing, spawning, migrating and foraging fish habitats. Data collected included:

- Substrate (types and percent) for bedrock, boulders (>256 mm), cobble (65-256 mm), large gravel (17-64 mm), small gravel (2-16 mm) and fines (< 2 mm);
- Cover (relative abundance) for unembedded cobble and boulder, overhanging vegetation, large and small woody debris, undercut banks, deep pools and instream vegetation;
- Wetted and channel widths (where applicable);
- Water and pool depths (where applicable);
- Morphology of the watercourse (e.g., run, flat, pool, riffle, rapid);
- Bank characteristics (e.g., texture and shape);
- Water quality parameters:
  - pH;
  - Conductivity (µs/cm);
  - Temperature (°C);
  - Salinity (mg/L); and
  - Total Dissolved Solids (g/L);
- Unique watercourse characteristics (e.g., confinement, bars, islands, watercourse pattern);
- Barriers to fish passage (e.g., perched culverts, debris jams);

- Crown closure;
- Incidental vegetation;
- Observations of aquatic invertebrates;
- Photographs; and
- UTM locations.

Watercourses were classified as 'ephemeral', 'intermittent', 'small permanent' or 'large permanent' based on the definitions provided in Table 3.1.

Table 3.1 Description of Watercourse Types

Watercourse Type	Average Channel Width	Description
Large Permanent	>5 m	• Defined channels; • Defined beds and banks; and • Year-round flow.
Small Permanent	2-5 m	• Defined channels; • Defined beds and banks; and • Year-round flow.
Intermittent	<2 m	• Defined channels; • Defined beds and banks; and • Seasonal water flows.
Ephemeral	No defined channel	• No defined channels; • No defined bed or banks; • Typically contain water resulting from rain events or snowmelt; and • Not fish habitat.

Identification of invertebrate species and communities present in a watercourse contributes to the determination of stream health and the likelihood of salmonid presence. Methodology for instream invertebrate identification was directed by fish habitat biologist, Bob Rutherford of Thaumas Environmental Consultants. Three observations of benthic invertebrate communities were completed for each assessed location. Representative samples were collected by targeting riffle areas with different characteristics (varying substrate composition and stream velocity). The field team lifted three cobble or small boulder sized rocks from the watercourse and identified all macroinvertebrates present on the bottom of the rock, documented the findings and took photographs.

An evaluation of potential salmonid spawning, rearing, overwintering, migration and foraging habitat was based on the following:

- Spawning habitat quality was based on water flow and substrate (i.e., large and small gravels);
- Rearing habitat quality was based on cover abundance, water flow and habitat connectivity;
- Overwintering habitat quality was based on the presence or absence of deep pools or ponds (≥50 cm) combined with instream cover and the potential for year-round flow;

- Migration habitat quality is based on the presence of partial and complete fish barriers; and
- Foraging habitat quality is based on the presence and abundance of invertebrates which assist in the determination of the health of the stream and available food for fish.

The potential for fish presence year-round was based on the results of water quality measurements (see Table 3.2), habitat quality at the time of the assessment, the quality of overwintering and spring/summer habitat, and upstream/downstream connectivity of the watercourse to other watercourses.

Table 3.2 Water Quality Limits for Sustaining Salmonids in the Aquatic Environment

Water Quality Parameters	*CCME Water Quality Guidelines for the Protection of Aquatic Life	Brook Trout Tolerance and Optimum Ranges (Raleigh, 1982)
pH	6.5 - 9.0	Tolerance: 4.0 to 9.5 Optimal: 6.5 to 8.0
Temperature (°C)	N/A	Tolerance: 0.5 to 22 Optimal: 11.0 to 16.0

3.1.2 Fish Habitat Assessment Results

The results of the fish habitat assessments conducted on the north and south branches of the Avon River are provided in Section 3.1.2.1 through 3.1.2.7. Specific locations for the fish habitat assessments conducted in the north and south branches of the Avon River, including sample locations and sampling dates, are provided in Table 3.3.

Table 3.3 Fish Habitat Assessments Conducted in the North and South Branches of the Avon River

Station I.D.	Coordinates (UTM)		River Branch	Date
	Easting	Northing		
ARN-1	403970	4977905	Avon River North Branch	26 June 2018
ARN-2	402967	4978688	Avon River North Branch	26 June 2018
ARN-3	396827	4975772	Avon River North Branch	26 June 2018
ARN-4	396883	4975789	Avon River North Branch	26 June 2018
ARN-5	399228	4977183	Avon River North Branch	26 June 2018
ARS-6	404233	4971175	Avon River South Branch	27 June 2018
ARS-7	404810	4973107	Avon River South Branch	27 June 2018

3.1.2.1 ARN-1

At sample location ARN-1, the watercourse flowed in a regular meandering pattern, and was determined to be in a mid-water stage. Overall, the general morphology was flat. The substrate was composed of 5% boulder, 5% cobble and 90% fines. Trace amounts of instream and overhanging vegetation, boulders and large woody debris were present. Deep pools were abundant. The riparian edge was a mix of shrubs and farmland, with a crown closure of 1-25%. Riparian vegetation included trembling aspen (*Populus tremuloides*), white birch (*Betula papyrifera*), speckled alder (*Alnus incana*), and timothy grass (*Phleum pratense*).

The channel width was 20.0 m, wetted width was 19.0 m and water depth was >1.0 m. The left and rights banks were sloped and vertical; they were composed of fines, cobble and boulder. The pH was measured at 7.17, conductivity at 47.5 µs/cm, temperature at 13.4°C and total dissolved solids at 34 ppm. At the time of assessment, temperature and pH was within the optimal range for salmonids (Raleigh, 1982).

Spawning habitat for salmonids was classified as 'poor-moderate', as the substrate was dominated by fines, which may suffocate eggs. Rearing habitat was also classified as 'poor-moderate'; the colour and depth of the water provides cover for juveniles, but there was a lack of other habitat features required for rearing. Overwintering was classified as 'moderate-good', owing to an abundance of deep pools, high flow, and sufficient non-pool depth. Foraging and migration were considered to be 'good' for this location, as there were no apparent blockages and fish could travel up- and down-stream easily. Overall, this location was assessed to have a 'moderate-good' overall habitat rating, while the potential for fish presence during open water and frozen conditions was considered to be 'high'.

3.1.2.2 ARN-2

At sample location ARN-2 the watercourse flowed in a regular meandering pattern and was determined to be in a mid-water stage. Morphology consisted of runs, pools, riffles, and flats. No bars or islands were observed in the assessment area. The substrate was composed of 10% boulder, 40% cobble, 20% large gravels, 15% small gravels and 15% fines. Moderate to abundant amounts of cover under instream vegetation were observed, as well as moderate cover at undercut banks. Trace amounts of cover around boulders, overhanging vegetation and large woody debris were also noted. The riparian edge was a mix of shrub and farmland. The riparian vegetation consisted of white birch, speckled alder, trembling aspen and white pine (*Pinus strobus*). Crown closure was assessed to be in the range category of 1-25%.

The channel width was 13.0 m, wetted width was 11.2 m and water depth was 0.40 m in the run area. The left and rights banks were sloped and confined. The pH was measured at 6.76, conductivity at 36.9 µs/cm, temperature at 13.2°C and total dissolved solids at 26.1 ppm. At the time of assessment, temperature and pH was within the optimal range for salmonids (Raleigh, 1982).

Spawning habitat was classified as 'poor-moderate'. Gravelly substrate suitable for spawning was present, however the substrate also contained a significant amount of fines and primarily consisted of a run without the pool riffle form that provides good interstitial flows. Water velocity was also high enough to be a hindrance. Rearing habitat was also classified as ‘poor-moderate’, as the high velocity flow and limited cover would be a deterrent for juvenile fish. Overwintering was classified as ‘good’ owing to sufficient water depths and good thalweg development which are unlikely to freeze in winter. Abundant invertebrates were observed which lead to a foraging classification of ‘good’. Migration was also classified as ‘good’ as there are no apparent blockages and suitable habitat exists upstream. Overall the location was assessed to have a ‘moderate-good’ rating, while the potential for fish presence was considered to be ‘high’ during open water and frozen conditions.

3.1.2.3 ARN-3

At sample location ARN-3, the watercourse flowed in a regular meandering pattern, and was determined to be in a mid-water stage. Morphology was observed to consist of riffles, runs, pools and flats. The substrate was composed of 15% boulder, 40% cobble, 20% large gravel, 15% small gravel and 10% fines. Trace to moderate boulders were present, as well trace amounts of woody debris, overhanging vegetation, undercut banks and deep pools were noted. The riparian edge was a mix of shrubs and farmland, with a crown closure of 1-25%. The riparian vegetation included eastern hemlock (*Tsuga canadensis*), white birch, speckled alder, royal fern (*Osmunda regalis*) and sensitive fern (*Onoclea sensibilis*).

The channel width was 16.2 m, wetted width was 13.5 m, water depth was 0.25 m on riffles and pool depth was 0.65 m. The left and rights banks were sloped and were composed of fines. The pH was measured at 6.7, conductivity at 23.9 µs/cm, temperature at 15.7°C and total dissolved solids at 17.9 ppm. At the time of assessment, temperature and pH was within the optimal range for salmonids (Raleigh, 1982).

Spawning habitat for salmonids was classified as ‘good’. The substrate contained a large proportion of cobble and gravels which is ideal for spawning. Rearing habitat was also classified as ‘good’; habitat features, such as boulders, would provide adequate cover for juveniles. Overwintering was classified as ‘moderate’ due to the presence of deep pools and sufficient flow. Foraging was classified as ‘good’ for this location, there was an abundance of invertebrates observed. Migration was also classified as ‘good’, as there were no apparent blockages and fish could travel easily. Overall the location was assessed to have a ‘good’ habitat rating. Potential for fish presence was considered to be ‘high’ and ‘moderate’ during open water and frozen conditions, respectively. A fish was observed at the time of assessment, however the species was unable to be identified.

3.1.2.4 ARN-4

At sample location ARN-3 the watercourse flowed in a regular meandering pattern and was determined to be in a mid-water stage, with the morphology consisting of runs, pools and riffles. No bars or islands were observed in the assessment area. The substrate was composed of 10% boulder, 35% cobble, 35% large gravels and 20% small gravels. Moderate amounts of boulders were observed along with trace amounts of overhanging and instream vegetation. Trace to moderate amounts of woody debris and deep pools were also noted. The riparian edge consisted of mature forest and provided 26-50% crown closure. The riparian vegetation included white pine, eastern hemlock, sensitive fern and royal fern.

The channel width was 15.8 m, wetted width was 11.2 m, water depth was 0.50 m in the riffle section and pool depth was 0.55 m. The left and rights banks were sloped and vertical. The pH was measured at 6.12, conductivity at 24.4 µs/cm, temperature at 15.8°C and total dissolved solids at 17.1 ppm. At the time of assessment, temperature was within optimal range salmonid levels while pH was outside optimal levels, but within the tolerance range (Raleigh, 1982).

Spawning habitat was classified as ‘good’. The location contained suitable substrate for spawning and had good flow although the general lack of pool and riffle features will limit spawning. Rearing habitat was also classified as ‘good’ as there are sufficient habitat features (boulders, woody debris and deep pools) to provide cover for juveniles. Overwintering was classified as ‘moderate’ owing to the presence of deep runs and good thalweg development, which will likely prevent freezing. Migration was also classified as ‘good’ as there are no apparent blockages. Abundant invertebrates were observed which lead to a foraging classification of ‘good’. Overall the location was assessed to have a ‘good’ rating. Potential for fish presence was considered to be ‘high’ during open water and frozen conditions. A fish was observed at the time of assessment, however the species was unable to be identified.

3.1.2.5 ARN-5

At this location, the watercourse flows in a regular meandering pattern, and was determined to be in a mid-water stage. Stream morphology consisted of runs, pools and riffles, and the substrate was composed of 50% boulder, 40% cobble and 10% large gravels. Abundant deep pools and boulders were observed, with trace to moderate amounts of overhanging vegetation present. Trace amounts of instream vegetation and woody debris were also noted. The riparian edge was composed of young and mature forest stands. The riparian vegetation included speckled alder, white spruce, white pine and sugar maple (*Acer saccharum*). Crown closure was in the 1-25% cover category. The channel width was 21.0 m, wetted width was 16.2 m, water depth was 0.80 m in the riffle section and pool depth was 0.71 m. The left and rights banks were sloped and composed of fines and boulders. The pH was measured at 6.5, conductivity at 24.6 µs/cm, temperature at 15.8°C and total dissolved solids at 17.4 ppm. At the time of assessment, the water parameters temperature and pH were within the optimal range for salmonids (Raleigh, 1982).

Spawning habitat was classified as ‘poor’, the proportion of boulders and cobbles at this location was too high to provide suitable spawning habitat. There were sufficient amounts of cover for juvenile fish and rearing habitat was classified as ‘moderate-good’. Overwintering habitat is considered to be ‘good’ as there is an abundance of deep pools and adequate depth. Foraging and migration was also classified as ‘good’. Potential for fish during open water and frozen conditions is considered to be ‘high’.

3.1.2.6 ARS-6

At sample location ARS-6 the watercourse flowed in a regular straight pattern and was assessed during a mid-water stage, with the morphology consisting of runs, pools and riffles. No bars or islands were observed in the assessment area. The substrate was composed of 10% boulder, 30% cobble, 25% large gravels, 25% small gravels and 10% fines. Moderate amounts of instream vegetation was present along with trace to moderate boulders and deep pools. Trace amounts of woody debris and overhanging vegetation were also noted. The riparian edge consisted of mature forest and provided 51-75% crown closure. The riparian vegetation included white birch, white pine, and red maple (*Acer rubrum*).

The channel width was 12.6 m, wetted width was 8.7 m, water depth was 0.32 m in the riffle sections and pool depth was 0.70 m. The left and rights banks were sloped. The pH was measured at 6.7, conductivity at 43.7 µs/cm, temperature at 16.1°C and total dissolved solids at 30.7 ppm. At the time of assessment, pH was within the optimal range for salmonids and temperature was within their tolerance range (Raleigh, 1982).

Spawning habitat was classified as 'moderate-good' at this location. There was an adequate proportion of cobbles and gravels as well as sufficient flow. Rearing was considered to be 'moderate-good' as there were habitat features (boulders, deep pools and instream vegetation) that would provide cover for juveniles. This location has low freeze potential due to depth and flow; overwintering habitat was rated as 'moderate-good'. Migration for salmonids into the site for spawning is good as there are no major blockages downstream. Migration upstream is considered poor as there is a known blockage (NSPI's Mill Dam). Taking both of these factors into account, migration was classified as 'moderate'. Foraging habitat was considered to be 'good' as a variety of invertebrates were noted at this location. Potential for fish presence was considered to be 'high' during open water and frozen conditions. Several fish were observed at the time of assessment, however the species was unable to be identified.

3.1.2.7 ARS-7

At this location the watercourse flows in a straight pattern, and was assessed during a mid-water stage and was observed with flat morphology. The substrate was composed of 40% boulder, 30% cobble, 15% large gravel and 15% small gravel. Abundant boulders were observed moderate amounts of instream vegetation. Trace to moderate deep pools were noted and trace amounts of woody debris were also present. The riparian edge was composed of mature forest stands. The riparian vegetation included eastern hemlock, red maple and American beech (*Fagus grandifolia*). Crown closure was in the 26-50% cover category.

The channel width was 18.2 m, wetted width was 13.2 m and water depth was 0.45 m. The left and rights banks were sloped and composed of fines, cobbles and boulders. The pH was measured at 6.7, conductivity at 43.7 µs/cm, temperature at 16.1°C and total dissolved solids at 30.7 ppm. At the time of assessment, pH was within the optimal range for salmonids and temperature was within their tolerance range (Raleigh, 1982).

Spawning habitat was rated as 'poor-moderate' as there are some cobbles and gravels present, however this section of the watercourse lacks pool riffle forms for good interstitial flows, which are needed for spawning, and there is also a large proportion of boulder substrate which is not suitable for spawning. Rearing habitat was considered to be 'moderate-good', boulders could provide cover for juvenile fish and flow is adequate for young. Overwintering is classified as moderate as there is sufficient flow and depth, as well as race to moderate amounts of deep pools. Similarly to ARS-6 migration habitat was rated 'moderate' as the Mill Dam is located upstream. Foraging habitat was rated ‘good’ as a variety of invertebrates were observed. Potential for fish presence is considered to be ‘high’ in both open water and frozen conditions.

3.1.3 Summary of Fish Habitat Assessments

The potential for fish presence during open water and frozen conditions was high across all of the assessed sites in the northern and southern branches of the Avon River. The potential ratings are based upon the assessed water quality parameters and fish habitat assessment results, which are summarized in Table 3.4 and Table 3.5, respectively. In addition, fish were observed at three sites (ARN-3, ARN-4 and ARS-6) although field personnel were not able to identify the observed fish to the species level. Individual sample location fish habitat datasheets are provided in Appendix A: Figure 3.

The Avon River was classified as a large permanent watercourse at all assessed locations. The average channel width of the north branch was 17.2 m and the wetted width was 14.2 m. On average the south branch was narrower with an average channel width of 15.4 m and a wetted width of 10.9 m. The substrate of the sample locations was generally a mixture of boulders, cobbles and gravels with four of the locations (ARN-1, ARN-2, ARN-3 and ARS-6) also containing some fines. The proportion of the types of substrate varied greatly between sites.

Spawning habitat quality between the locations, ranging from ‘poor’ to ‘good’ depending on the proportion of cobble and gravels present, as well as the velocity of the water at each location. Spawning for salmonids was considered good at sites ARN-3, ARN-4 and ARN-6. Rearing habitat quality was also highly variable and noted as ‘poor-moderate’ to ‘good’. Migrating and foraging habitat was rated as ‘good’ across all sites along the north branch. The south branch was rated as ‘moderate’ as no blockages were present until the Mill Dam. Overwintering habitat was generally good among the sites and ranged from ‘moderate’ to ‘good’.

The water quality parameters were compared with the *CCME Water Quality Guidelines for the Protection of Aquatic Life*, and brook trout tolerance and optimum ranges (Raleigh, 1982) (Table 3.4). Across all locations, the average temperature and pH were calculated as 15.2°C and 6.7, respectively. These values are within the CCME guidelines and the optimal range for brook trout (Raleigh, 1982). Only one measurement taken was outside of the CCME guidelines. The pH at sample location ARN-4 was recorded as 6.12, which is below the CCME guideline of 6.5–9.0. A pH of 6.12 is also below the optimal limit for brook trout, but well within the tolerance range (Raleigh, 1982). Two sites (ARS-6 and ARS-7) were recorded with a temperature of 16.1°C, which is just above the optimal range of brook trout, but well within the tolerance range (Raleigh, 1982). Salinity was non-detectable at all locations and the average TDS recorded was 24.8 ppm.

Table 3.4 Water Quality Parameter Summary

ID#	Temp. (^{o}C)	pH	Cond. (µs/cm)	TDS (ppm)
ARN-1	13.7	7.17	47.5	34
ARN-2	13.2	6.76	36.9	26.1
ARN-3	15.7	6.7	23.9	17.9
ARN-4	15.8	6.12	24.4	17.1
ARN-5	15.8	6.5	24.6	17.4
ARS-6	16.1	6.7	43.7	30.7
ARS-7	16.1	6.7	43.7	30.7
Average	15.2	6.7	35.0	24.8

Table 3.5 Summary of Fish and Fish habitat Assessment Results

ID#	Watercourse Type	Substrate	Channel Width (m)	Water Depth (m)	Spawning	Rearing	Overwintering	Migrating	Foraging	Overall Habitat Rating for Salmonids	Potential for Fish Presence (Open Water/ Frozen)
ARN-1	Large Permanent	Boulder, Cobble, Fines	20.0	>1.0	Poor-Moderate	Poor-Moderate	Moderate-Good	Good	Good	Moderate-Good	High/ High
ARN-2	Large Permanent	Boulder, Cobble, Gravels, Fines	13.0	0.40	Poor-Moderate	Poor-Moderate	Good	Good	Good	Moderate-Good	High/ High
ARN-3	Large Permanent	Boulder, Cobble, Gravels, Fines	16.2	0.25	Good	Good	Moderate	Good	Good	Good	High/ High

ID#	Watercourse Type	Substrate	Channel Width (m)	Water Depth (m)	Spawning	Rearing	Overwintering	Migrating	Foraging	Overall Habitat Rating for Salmonids	Potential for Fish Presence (Open Water/ Frozen)
ARN-4	Large Permanent	Boulder, Cobble, Gravels	15.8	0.50	Good	Good	Moderate	Good	Good	Good	High/ High
ARN-5	Large Permanent	Boulder, Cobble, Gravels	21.0	0.80	Poor	Moderate-Good	Good	Good	Good	Moderate-Good	High/ High
ARS-6	Large Permanent	Boulder, Cobble, Gravels, Fines	12.6	0.32	Moderate-Good	Moderate-Good	Moderate-Good	Moderate	Good	Moderate-Good	High/ High
ARS-7	Large Permanent	Boulder, Cobble, Gravels	18.2	0.45	Poor-Moderate	Moderate-Good	Moderate	Moderate	Good	Moderate	High/ High

3.2 Fish Sampling

Electrofishing surveys were performed by the MCG over two field seasons from 2017 to 2018. The purpose of the surveys was to obtain an initial baseline of fish species present in the Avon River and to tag select species of fish for possible future recapture, including American eel and white perch. If captured, these species were tagged with a Passive Integrated Transponder (PIT) tag inserted in the underside below their gills. The full MCG report is available in Appendix B.

3.2.1 Results

Fish sampling was performed by the MCG at five sites along the Avon River. Three of these sites were located on the north branch (ARN-3, ARN-4 and ARN-5), while two were on the south branch (ARS-6 and ARS-8). Table 3.6 summarizes the findings of the fish sampling surveys.

Table 3.6 Summary of MGC Electrofishing Survey Results

Species	ARN-3	ARN-4	ARN-5	ARS-6	ARS-8
Dace sp.	31	45	45	0	0
Shiner sp.	16	14	21	1	3
White sucker	11	17	25	5	13
American eel	7	2	15	10	12
American eel - Elver Stage	0	0	0	37	2
Brook trout	1	1	0	0	0
Brown bullhead	0	0	0	1	4
Smallmouth bass	0	0	0	1	4
Stickleback spp.	0	0	0	1	1
Yellow perch	0	0	0	1	0

Nine (9) different fish species were captured during the electrofishing surveys. Dace sp. was the most abundantly captured species over all sampling locations, however this species was only captured at sampling locations on the northern branch of the Avon River. American eel was the most abundantly captured species on the southern branch of the river. White perch were not captured during the electrofishing survey, therefore there were no instances of white perch tagging. Three (3) tagged American eels were recaptured at the same site at which each had been tagged.

CHAPTER 4 CONSIDERATIONS FOR FISH PASSAGE

4.1 Background

Construction for the present day aboiteau under the Highway 101 causeway commenced in 1968 and was fully established in 1970 (BoFEP, 2008). The aboiteau was installed to prevent flooding of important agricultural lands and protect infrastructure (i.e., roads and railway) and sections of the Town of Windsor. As a result of the aboiteau installation, a freshwater lake formed on the upstream side, which is now known as Pesaquid Lake. The design of the aboiteau did not include adequate passage for fish such as a fishway, despite the historical commercial fisheries for Atlantic salmon, gaspereau, American shad, American eel and winter and smooth flounder in the Avon River. The aboiteau is currently a partial barrier to fish as the gates open for 15 to 20 minutes intervals when the tide goes out; however, the velocity through the opening is too fast for most species to swim through (i.e., 7 m/sec) (BoFEP, 2008) and is a partial barrier to those species that can swim through the confined space and velocity. In addition, the gates are open for maintenance in the spring and at the direction of DFO for the gaspereau migration. The gates are not fully open during the fall which is the peak migration time for salmonids such as brook trout and Atlantic salmon, nor are they operated to provide passage for fish in the late summer when flows are low, as the gates are kept closed to maintain water levels in Pesaquid Lake.

4.2 Project Regulatory Fish Passage Requirements

As part of the Conditions for the NSTIR Environmental Assessment (EA) Approval for the Highway 101 Twinning Project, NSTIR must provide DFO with the following information:

- Current data on existing fish species near the Avon River causeway; and
- Design a new aboiteau structure that allows for improved fish passage.

In addition to the regulatory requirements, there is pressure from some members of the public such as farmers, recreationists, local businesses and residents to maintain the freshwater lake. Contradictory to this, Mi'kmaq want a tidal structure that allows free passage of all fish species.

Section 20 (1) of the federal *Fisheries Act* states that in order to ensure the free passage of fish, the Minister can request studies, samples, analysis and documentation to determine if fish passage is adequate. Therefore, upon construction completion of the new aboiteau structure for this Project, the determination of whether fish passage is sufficient will be made by DFO, based on the post monitoring fish passage results. Section 20 (3) of the *Fisheries Act* states that if the Minister decides that sufficient fish passage is not provided, then the Minister can request that the owner make any provision to ensure fish passage. This uncertainty presents a risk to the Project. Given the challenges of working in a tidal area with deep silt deposits and soluble bedrock (gypsum, limestone), modifying the structure after its construction may incur substantial construction costs. Additionally, the Avon River is known to have high natural sediment inputs, which make the design of a fishway even more challenging as the structure cannot continuously become blocked with sediment, or else DFO may deem the structure a full or partial barrier to fish and require frequent maintenance.

4.3 Avon River Fish Passage Considerations

The Avon River area provides habitat for a wide range of species, many of which require passage through the Avon River aboiteau to either the marine or fresh water environments to complete their life cycle events. Important life cycle events include spawning, rearing, migration, overwintering, and foraging. For more information on CRA fish in the Avon River please see Chapter 2 for a CRA fisheries assessment.

The Avon River is host to both catadromous and anadromous fish species which require efficient upstream and downstream passage to maintain a viable population. Catadromous species, such as American eel, are born into marine environments and migrate to freshwater habitats as young juveniles, where they undergo development into fecund adults before returning to sea to spawn. Anadromous species, such as gaspereau, Atlantic salmon, and sea run brook trout, are born in freshwater and undergo a period of development before migrating downstream to estuarine and marine environments for development into fecund adults, before returning to freshwater spawning habitats. The existing aboiteau structure may prevent juveniles of these species from migrating to their required habitats, which can result an inability to complete their life cycles. An Atlantic salmon captured in Pesaquid Lake by commercial fisherman Darren Porter in the summer of 2018 (*pers. comm.*, Darren Porter, January 17, 2019) may be an example of an adult salmon prevented from migrating downstream due to the aboiteau structure.

The location of the aboiteau structure along the Avon River naturally functions as an estuary area where the tide meets the river. This section of the Avon River is important as it offers a valuable migration corridor for catadromous and anadromous species while providing foraging opportunities for saltwater species during high tides. Migration runs for spawning vary seasonally between species. Table 2.4 provides a summary of migration times of CRA and Species at Risk identified in the Avon River. In addition, some species follow food sources with the incoming tides, such as flounders, striped bass, Atlantic sturgeon and the dogfish shark. Designing a structure to allow free fish passage for all species potentially using this section of the Avon River is a challenging task as this requires both upstream and downstream passage for a variety of species with a wide range of sizes and swimming abilities.

A table summarising the fish passage design criteria for select species was assembled by a fish passage expert, Bob Rutherford of Thaumas Environmental Consultants, and reviewed by Dr. Graham Daborn, Research Associate at the Acadia Centre for Estuarine Research. The table is presented in Appendix E, and demonstrates the criteria that would need to be met to allow efficient passage for each species. Of note, the table indicates the preferred migration velocities (PMV) and the maximum pool head difference (PHDM) between the ladder slots/weirs and the pool. Many of the species that need to pass the Avon River Aboiteau have not previously been the subject of fish passage designs or studies. Hence, some assumptions would need to be made regarding their swimming ability, based on characteristics such as body shape, size, and (where possible) behaviour.

Fish passage requirements are known for brook trout, Atlantic salmon, American eel, American shad, gaspereau, rainbow smelt, white sucker and yellow perch. Of these species, gaspereau, American eel and Atlantic salmon appear to have similar PMV requirements; whereas, brook trout have different PMV requirements. Fish passage requirements are not well known or known for the remaining species such as flounder, striped bass, smallmouth bass, white perch, stickleback, Northern redbelly dace, mummichog, lake chub, dogfish, Atlantic tomcod, banded killifish, Atlantic silverside or Atlantic sturgeon. Each species has different requirements in order to ensure successful passage through a fishway.

4.3.1 Priorities for Fish Passage

Ensuring that the structure can provide passage for the catadromous and anadromous species that require access to areas upstream of the aboiteau to complete their life cycle will be of highest importance. Large numbers of gaspereau are known to migrate through the current gates while they are open in the spring and spawn in calm areas of rivers and lakes (CRI, 2014; Pardue, 1983). It is estimated by Bob Rutherford, that over one million gaspereau could be using the Avon River system. The fishway will also need to provide adequate passage for Atlantic salmon, sea run brook trout, Atlantic tomcod and American eel as these species have all been documented in the Avon River system (Avery et al., 2019; Darren Porter, *pers. comm.,* January 17, 2019).

Designing a structure that also accommodates the passage of marine species including flounder, striped bass, Atlantic sturgeon and dogfish shark is also necessary as these species require upstream passage through the aboiteau during foraging migrations. The design of a fishway incorporating these species is a challenge, as fish passage requirements for some of these species are not well known and may not be the same as the catadromous and anadromous species in the Project area, whose fish passage requirements are well known. This lack of information, combined with the need for passage at most tidal levels, varying river flows, and very high sand silt bed load, add to the required complexity for both the upstream and downstream fish passage designs.

4.4 Project Fishway Design Options

In consideration of the challenges of designing an aboiteau structure and fishway that satisfies the terms and conditions of EA approval, the public, Mi’kmaq, DFO, high natural sediment inputs and the many fish species with differing passage requirement is a challenging task. In an attempt to meet as many of these needs as possible, project engineers have been designing several different options and running multiple models based on varying locations, configurations, and operation scenarios of the aboiteau structure. The outcome of this process was that it is a challenge for project engineers to design a structure that satisfies all of these aspects. Project engineers are taking into consideration the many challenges associated with designing a fishway at the Avon River causeway including the following:

- A structure that satisfies DFO's requirements outlined in the EA and is in compliance with the federal *Fisheries Act*;
- A scenario that maintains Pesaquid Lake;
- A structure that is designed to minimize issues of sediments blocking the fishway;
- Providing adequate upstream and downstream fish passage for catadromous and anadromous species; and
- Providing adequate passage for feeding runs of saltwater species.

Several fishways have been investigated and presented in the CBCL Options Analysis Report, which include (CBCL, 2019):

- **Pool and Weir Design**: In this type of design, velocities in the fishway have to be high enough to keep the sediment flushed out, but also low enough to provide resting areas and passage for weaker swimming fish. Therefore, this option is likely to fill up quickly with sediment;
- **Baffled Channel Design (Denil Type Fishway):** This type of design would accommodate all known fish passage requirements, and would work with respect to effective silt management, however this design type requires a high flow to prevent inundation with silty sediment, which results in salt water ingress into the headpond; and
- **Vertical Slot Design**: This design would require a combination of careful hydraulic design and long term regular maintenance to ensure that it would flush the silt on each tide. This type of fishway would likely have to be shut off when the tide is at or above the lake level. Attraction flows would be very low and neither small nor large fish would likely ascend. In addition, fish passage would be limited for gaspereau and American shad, depending on the velocity in the pools needed to keep the silt flushed out.

4.4.1 Current Design Option

Project engineers are currently in the process of designing an aboiteau structure with two identical fishways. The two fishways can be operated using either freshwater or saltwater. The method in which the aboiteau may be operated is not decided at this time. Details of the final design have not been completed and are not presented herein.

CHAPTER 5 **CONCLUSIONS**

5.1 CRA Fisheries Assessment

The Project Area was found to provide habitat for the following CRA fish species:

- American eel;
- American lobster;
- American shad;
- Atlantic herring;
- Atlantic mackerel;
- Atlantic tomcod;
- Brook trout;
- Brown trout;
- Gaspereau (*Alosa* spp.);
- Rainbow smelt;
- Smallmouth bass;
- Smooth flounder;
- Spiny dogfish;
- Striped bass;
- Summer flounder;
- White perch;
- Winter flounder; and
- Yellow perch.

Species descriptions and habitat requirements for potential CRA fisheries species that received an evaluation of 'moderate to good' or 'good' for three or more life history stages include:

- American eel;
- Atlantic tomcod;
- Brook trout;
- Brown trout;
- Gaspereau (*Alosa* spp.);
- Smallmouth bass;
- Smooth flounder;
- Striped bass; and
- White perch.

5.2 SAR and SoCC Species

Species descriptions and habitat requirements for SAR and SoCC species that received an evaluation of 'moderate to good' or 'good' for three or more life history stages include:

- American eel;
- Atlantic salmon;
- Atlantic sturgeon;
- Spiny dogfish; and
- Striped bass.

American eel, Atlantic salmon, and striped bass were confirmed as present in the Avon River downstream of the aboiteau as well as upstream. Spiny dogfish and Atlantic sturgeon were only confirmed downstream of the Avon River aboiteau.

5.3 Fish and Fish Habitat Assessments

A total of seven (7) locations were assessed along the Avon River between June 26 and 27, 2018. The Avon River was classified as a large permanent watercourse at all assessed locations. The substrate of the sample locations was generally a mixture of boulders, cobbles and gravels with four of the locations also containing some fines. Spawning habitat quality between the locations, ranging from 'poor-moderate' to 'good' depending on the proportion of cobble and gravels present, as well as the velocity of the water at each location. Spawning for salmonids was considered good at sites ARN-3, ARN-4 and ARS-6 (Appendix A: Figure 3). Rearing habitat quality was variable and noted as 'poor-moderate' to 'good'. Migrating and foraging habitat was rated as 'good' across all sites along the north branch. The south branch was rated as 'moderate' due to the NSPI Mill Dam hydro facility. Overwintering habitat was generally good among the sites and ranged from 'moderate' to 'good'.

The water quality parameters were compared with the *CCME Water Quality Guidelines for the Protection of Aquatic Life*, and indicator species brook trout tolerance and optimum ranges (Raleigh, 1982). Only one measurement taken was outside of the CCME guidelines. The pH at sample location ARN-4 was recorded as 6.12, which is below the CCME guideline of 6.5-9.0. A pH of 6.12 is also below the optimal limit for brook trout, but well within the tolerance range (Raleigh, 1982). In addition, two sites (ARS-6 and ARS-7) were recorded with a temperature of 16.1°C, which is just above the optimal range of Brook trout, but well within the tolerance range (Raleigh, 1982).

Electrofishing surveys were completed by the MCG group between 2017 and 2018 and the following species were identified:

- American eel;
- Brook trout;
- Brown bullhead;
- Dace sp.;
- Shiner sp.;
- Smallmouth bass;
- Stickleback sp.; and
- Yellow perch.

Across all site assessed upstream of the Avon River aboiteau, the potential for fish presence during open water and frozen conditions was considered to be high. The potential ratings are based upon the assessed water quality and habitat. In addition, 10 species of fish were observed during the electrofishing survey conducted by MCG in 2017 and 2018.

5.4 Fish Passage

Adequate fish passage at the new aboiteau structure is a requirement of the NSTIR EA Approval for the Highway 101 Twinning Project. In addition, the *Fisheries Act* states that DFO can require monitoring of fish passage after the structure is complete and request changes to fish passage if they aren't satisfied with the monitoring results.

The fishway will need to provide adequate passage for catadromous and anadromous species that require passage for spawning such as gaspereau, Atlantic salmon, sea run brook trout, Atlantic tomcod and American eel. Each of these species have been documented in the Avon River system (Avery et al., 2019; Darren Porter, *pers. comm*., January 17, 2019). It is important that the fish passage be effective for both upstream and downstream migration of adult spawners and well as juvenile life stages and those fish on feeding runs. Passage for saltwater species requiring access to food is also important, but may be challenging in some design scenarios, as fish passage requirements for these species are not well known and may not be the same as the catadromous and anadromous species, where fish passage is well known for most species.

Many challenges are associated with designing a fishway at the Avon River causeway, including the following:

- A structure that satisfies DFO's requirements outlined in the EA and is in compliance with the federal *Fisheries Act*;
- A scenario that maintains Pesaquid Lake;
- A structure that is designed to minimize issues of sediments blocking the fishway;
- Providing adequate fish passage for catadromous and anadromous species; and
- Providing adequate passage for feeding runs of saltwater species.

Project engineers are currently in the process of designing an aboiteau structure with two identical fishways. The two fishways can be operated using either freshwater or saltwater. The method in which the aboiteau may be operated is not decided at this time. Details of the final design have not been completed and are not presented herein.

CHAPTER 6
REFERENCES

Avery, T., Pomerleau, R., Reinhartsen, M., Yang, Z.J., Killacky, Porter, D. 2019. Baseline Assessment of Commercial, Recreational and Aboriginal (CRA). Fisheries Adjacent to the Avon River Causeway. Draft Preliminary Report. 22pp.

Bain, M.B., and J.L. Bain. 1982. Habitat Suitability Index Models: Coastal Stocks of Striped Bass. U.S. Fish and Wildlife Service, Office of Biological Services, Washington, D.C. FWS/OBS-82/10.1.29 pp.

Bay of Fundy Ecosystem Partnership (BoFEP) 2008. The Cause in Causeway: Crossing the Avon River at Windsor. Fundy Issues: Issue #28. 12 pp. Available online: http://www.bofep.org/wpbofep/wp-content/uploads/2013/05/FI-28-Avon-causeway.pdf

Bergstedt, R.A., and O'Gorman, R. 1989. Distribution of alewives in southeastern Lake Ontario in autumn and winter: a clue to winter mortalities. Transactions of the American Fisheries Society, 118:687-692.

Bigelow, H.B. and Schroeder, W.C., 1953. Fishes of the Gulf of Maine (Vol. 53, p. 588). Washington, DC: US Government Printing Office.

Bonaparte, E. 2018. Personal communication. July 19, 2018.

Bradford, R.G., Tremblay, E., and G.J. Chaput. 1998. Winter Distribution of Striped Bass (*Morone saxatilis*) and Associated Environmental Conditions in Kouchibouguac National Park during 1996, National Ecosystem Monitoring and Data Report 0003. Parks Canada, Ottawa, ON, Canada. 60 pp.

Bradford, R.G., P. LeBlanc, and P. Bentzen. 2012. Update Status Report on Bay of Fundy Striped Bass (*Morone saxatilis*). DFO Can. Sci. Advis. Sec. Sci. Res. Doc. Rep. 2012/021: vi + 46p. in COSEWIC. 2012. COSEWIC assessment and status report on the Striped Bass *Morone saxatilis* in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. iv + 82 pp. (www.registrelep-sararegistry.gc.ca/default_e.cfm)

Brown, T. G., Runciman, B., Pollard, S, Grant A.D.A. and Bradford, M.J. 2009. Biological synopsis of smallmouth bass (*Micropterus dolomieu*). Can. Manuscr. *Rep. Fish. Aquat. Sci*. 2887: v + 50 p.

Brown, T.G., Runciman, B., Bradford, M.J. and Pollard, S., 2009. A biological synopsis of yellow perch (*Perca flavescens*). Canadian manuscript report of fisheries and aquatic sciences, 2883, p.28.

Buckley, J.L. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic): Rainbow Smelt. U.S. Fish Wildl. Serv. Biol. Rep. 82(11.106). U.S. Army Corps of Engineers, TR EL-82-4. 11pp.

Buckley, R. V. 1975. Chemical and Physical Effects on the Centrarchid Basses. Pages 286-294 in H. Clepper, ed. Black Bass Biology and Management. Sport Fish. Ins, Washington, DC.

Buhariwalla, C.F., MacMillan, J.L., Gregoire, M.J., Dadswell, M.J. and M.J.W. Stokesbury. 2016. Population Characteristics of Striped Bass Killed by Cold Shock During Winter Shutdown of a Power Plant in Nova Scotia. *Northeastern Naturalist* 23: 163-173.

Butler, R. L. 1972. Small Mouth Bass Actions Analyzed in Acid Water. Sci. Agric. 19(3):8-9.

Campana, S. 2007. Department of Fisheries and Oceans & Canadian Science Advisory Secretariat, Assessment of spiny dogfish in Atlantic Canada, Centre for Science Advice, Maritimes Region, Fisheries and Oceans Canada, Dartmouth, N.S.

Canadian Council of Ministers of the Environment (CCME). (2016). Canadian Environmental Quality Guidelines Summary Table. Water Quality Guidelines for the Protection of Aquatic Life. Available Online: http://st-ts.ccme.ca/en/index.html Accessed March 2019.

Canadian Rivers Institute (CRI). 2014. NB Freshwater Fisheries: Inland Fishes of New Brunswick. Available Online: http://canadianriversinstitute.com/resources/freshwater-fishes/

CBCL Limited 2019. Avon River Aboiteau Replacement Design Option Analysis: Draft Report. Prepared for Nova Scotia Transportation and Infrastructure Renewal. 206pp.

Clancey, C. G. 1980. Vital Statistics and Instream Flow Requirements of Fish in the Montco Mine area of the Tongue River, Montana. Montana Dept. of Fish, Wildl. Parks, Helena. 55 pp.

Collette, B.B. & C.E. Nauen 1983. FAO Species Catalogue. Vol. 2. Scombrids of the world. An annotated and illustrated catalogue of Tunas, Mackerels, Bonitos and related species known to date. *FAO Fish. Synop.*, (125)Vol.2:137 p.

COSEWIC. 2010. COSEWIC assessment and status report on the Atlantic Salmon *Salmo salar* (Nunavik population, Labrador population, Northeast Newfoundland population, South Newfoundland population, Southwest Newfoundland population, Northwest Newfoundland population, Quebec Eastern North Shore population, Quebec Western North Shore population, Anticosti Island population, Inner St. Lawrence population, Lake Ontario population, Gaspé-Southern Gulf of St. Lawrence population, Eastern Cape Breton population, Nova Scotia Southern Upland population, Inner Bay of Fundy population, Outer Bay of Fundy population) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa. Available online: http://sararegistry.gc.ca/virtual_sara/files/cosewic/AtlanticSalmon.pdf

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2012. COSEWIC Assessment and Status Report on the American Eel (*Anguilla rostrata*) in Canada. Committee on the Status of Endangered Wildlife in Canada. Ottawa.

Committee on the Status of Endangered Wildlife in Canada (COSEWIC). 2013. Striped Bass Southern Gulf of St. Lawrence Population. Available Online: http://www.registrelepsararegistry.gc.ca/species/speciesDetails_e.cfm?sid=829. Accessed March 2019.

Cook, A.M., Duston J., and R.G. Bradford. 2006. Thermal Tolerance of a Northern Population of Striped Bass, *Morone saxatilis*. *Journal of Fish Biology* 69: 1482.

Coutant, C. C. 1975. Responses of Bass to Natural and Artificial Temperature Regimes. Pages 272-285in H. Clepper, ed. Black Bass Biology and Management. Sport Fish. Inst., Washington, DC.

Den Heyer, C.E., Chadwick, E.M.P., and Hutchings, J.A. 2009. Diffusion of American lobster (*Homarus americanus*) in Northumberland Strait, Canada. *Can. J. Fish. Aquat. Sci*. 66: 659-671. Available online: http://www.nrcresearchpress.com/doi/pdf/10.1139/F09-024

Douglas, S.G., R.G. Bradford, and G. Chaput. 2003. Assessment of Striped Bass (*Morone saxatilis*) in the Maritime Provinces In The Context of Species at Risk. Canadian Scientific Advisory Secretariat Research Document 2003/008. Fisheries and Oceans Canada, Ottawa, ON, Canada.

Douglas, S.G., Chaput, G., Hayward, J., and J. Sheasgreen. 2009. Prespawning, Spawning, and Post spawning Behavior of Striped Bass in the Miramichi River. *Transactions of the American Fisheries Society* 138: 121.

Edwards, E. A., Gebhart, G., and O. E. Maughan. 1983. Information: Smallmouth Bass. U.S. Dept. FWS/OBS- 82/10.36. 47 pp. Int., Habitat suitability Fish Wildl. Servo

Elliott, J.M. and Elliott, J.A. 2010. Temperature requirements of Atlantic salmon *Salmo salar*, brown trout *Salmo trutta* and Arctic char *Salvelinus alpinus*: predicting the effects of climate change. Journal of Fish Biology 77: 20 pp. Available online: https://pdfs.semanticscholar.org/05e1.pdf

Evans, D.O. and D.H. Loftus. 1987. Colonization of Inland lakes in the Great Lakes Region by Rainbow Smelt, *Osmerus mordax*: Their Freshwater Niche and Effects on Indigenous Fishes. *Can. J. Fish. Aquat. Sci*. 44(Suppl. 2): 249-266.

Fisheries and Oceans Canada (DFO). 2000a. Integrated Fisheries Management Plan: Gaspereau (Alewife) Prince Edward Island 2000-2004 (Inclusive). Available online: http://www.dfo-mpo.gc.ca/Library/274518.pdf

Fisheries and Oceans Canada (DFO). 2000b. Atlantic Mackerel of the Northwest Atlantic. DFO – Science. Stock Status Report B4-04. 10 pp. Available Online: http://www.dfompo.gc.ca/csas/Csas/status/2000/B4-04e.pdf

Fisheries and Oceans Canada (DFO). 2007. Integrated Fisheries Management Plan: Atlantic Mackerel. Available Online: http://www.dfo-mpo.gc.ca/fm-gp/pechesfisheries/ifmp-gmp/mackerel-atl-maquereau/mac-atl-maq-2007-eng.pdf

Fisheries and Oceans Canada (DFO). 2009. Assessment of American Lobster in Newfoundland. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2009/026.

Fisheries and Oceans Canada (DFO). 2012. Assessment of the Atlantic Mackerel Stock for the Northwest Atlantic (Subareas 3 and 4) in 2011. DFO Can. Sci. Advis. Sec. Sci. Advis. Rep. 2012/031.

Fisheries and Oceans Canada (DFO). 2016a. Assessment of the West Coast of Newfoundland (Division 4R) Herring Stocks in 2015. Canadian Science Advisory Secretariat Science Advisory Report 2016/024. Available Online: http://www.dfo-mpo.gc.ca/csas-sccs/Publications/SAR-AS/2016/2016_024-eng.pdf Accessed March 2019.

Fisheries and Oceans Canada (DFO). 2016b. Underwater World: Alewife. Available Online: http://www.dfo-mpo.gc.ca/science/publications/uww-msm/project-eng.html?id=44. Accessed March 2019.

Fisheries and Oceans Canada (DFO). 2018. Atlantic Sturgeon (Maritimes Population). Retrieved Online: http://www.dfo-mpo.gc.ca/species-especes/profiles-profils/atlanticsturgeon-maritimes-esturgeonnoir-eng.html [Accessed March 2019].

Facey, D.E., and M.J. Van Den Avyle. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic) – American eel. U.S Fish Wildl. Serv. Biol. Rep. 82(11.74). U.S Army Corps of Engineers, TR EL-82-4. 28 pp.

Greene, K.E., Zimmerman, J.L., Laney, R.W. and Thomas-Blate, J.C. 2009. Atlantic coast diadromous fish habitat: A review of utilization, threats, recommendations for conservation, and research needs. Atlantic States Marine Fisheries Commission Habitat Management Series No. 9, Washington, D.C. Available online: https://www.asmfc.org/files/Habitat/HMS9_Diadromous_Habitat_2009.pdf

Grégoire, F., Beaulieu, J.-L., Gendron, M.-H., and LeBlanc, D. 2013. Results of the Atlantic Mackerel (*Scomber scombrus L.*) Egg Survey Conducted on the Scotian Shelf and Newfoundland's South Coast in 2009. DFO Can. Sci. Advis. Sec. Res. Doc. 2012/127. iii + 25 p.

Hanson, J.M., and Courtenay, S.C. 1997. Seasonal distribution, maturity, condition, and feeding of smooth flounder (*Pleuronectes putnami*) in the Miramichi estuary. *Can. J. Zool.* (75): 1226-1240. Available online: http://www.nrcresearchpress.com/doi/pdf/10.1139/z97-145

Henderson, B., and R. F. Foster. 1957. Studies of Small Mouth Black Bass (*Micropterus dolomieui*) in the Columbia River Near Richland, Washington. *Trans. Am. Fish. Soc*. 86:112-127.

Henderson, M.J. and Fabrizio, M.C., 2011. Migration patterns of adult summer flounder from Chesapeake Bay: implications for stock structure. Virginia Institute of Marine Science, Department of Fisheries Science.

Hogans, W.E., and G. Melvin. 1984. Kouchibouguac National Park Striped Bass *Morone saxatilis* (Walbaum) fishery survey. Aquatic Industries Ltd., St. Andrews, NB, Canada.

Hurst, T.P., and D.O. Conover. 2002. Effects of Temperature and Salinity on Survival of Young-Of-The-Year Hudson River Striped Bass (*Morone saxatilis*): Implications for Optimal Overwintering Habitats. *Canadian Journal of Fisheries and Aquatic Sciences,* 59: 787

Huusko, A., Greenberg, L., Stickler,M., Linnansaari, T., Nykaanen,M., Vehanen, T., Koljonen, S., Louhi, P. & K. Alfredsen, 2007. Life in the Ice Lane: The Winter Ecology of Stream Salmonids. *River Research and Applications,* 23, 469–491.

Isaacman, L.A. 2005. Historic Examination of the Changes in Diadromous Fish Populations and Potential Anthropogenic Stressors in the Avon River Watershed, Nova Scotia. Master of Environmental Studies Thesis, Dalhousie University, Halifax, NS, June 2005. Available online: https://hwy101windsor.ca/wp-content/uploads/2018/01/Lisa-Isaacman_2005_Avon-fish_MSc-Thesis_Dalhousie-University.pdf

Keefe, M. and Able, K.W., 1993. Patterns of metamorphosis in summer flounder, *Paralichthys dentatus. Journal of Fish Biology*, 42(5), pp.713-728.

Kenchington, T.J 1980. The Fishes of St. Georges Bay, Nova Scotia. Can. Tech. Rep. Fish. Aquat. Sci. 955: vi + 154 pp.

Kitchell, J. F., Johnson, M. G., Minns, C. K., Loftus, K. H., Greig, L. and C. M. Olver. 1977. Percid Habitat: The River Analogy. *J. Fish. Res. Board Can*. 34(10):1936-1940.

Krieger, D. A., Terrell, J. W. and P. C. Nelson. 1983. Habitat Suitability Information: Yellow Perch. U.S. Fish Wildl. Servo FWS/OBS-83/10.55. 37 pp.

MacKenzie, C., and Moring, J.R. 1985. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic) – American Lobster. U.S. Fish and Wildlife Service. Biol. Rep. 82 (11.33). U.S. Army Corps of Engineers, TR EL-82-4. 19pp.

McLeese, D. W. 1956. Effects of temperature, salinity and oxygen on the survival of the American lobster. *J. Fish. Res. Board Can.* 13: 247– 272.

McMillan, D.G. and Morse, W.W., 1999. Essential fish habitat source document. Spiny dogfish, Squalus acanthias, life history and habitat characteristics.

Migratory Birds Convention Act, 1994 (S.C. 1994, c.22). Available Online: https://laws-lois.justice.gc.ca/eng/acts/m-7.01/. Accessed March 2019.

Murua, H. and Saborido-Rey, F. 2003. Female Reproductive Strategies of Marine Fish Species of the North Atlantic. Journal of the Northwest Atlantic Fishery Science. Volume 33: 23-31.

Nelson, G.A., Armstrong M. P., Stritzel-Thomson, J., and K.D. Friedland. 2010. Thermal Habitat of Striped Bass (*Morone saxatilis*) in Coastal Waters of Northern Massachusetts, USA, During Summer. *Fisheries Oceanography,* 19: 370.

Newfoundland Department of Fisheries and Aquaculture (NLDFA). 2019. Emerging Species Profile Sheets. Atlantic herring (*Clupea harengus*). Available Online (accessed March 2019): http://www.fishaq.gov.nl.ca/research_development/fdp/pdf/herring.pdf

Nova Scotia Adopt a Stream. 2018. Nova Scotia Fish Habitat Assessment Protocol: Habitat Suitability Index. Available online: http://www.adoptastream.ca/training/habitat-suitability-assessment.

Nova Scotia Department of Fisheries and Aquaculture (NSDFA). 2007. Species Fact Sheets: Brook Trout (*Salvelinus fontinalis*). Available Online: https://www.novascotia.ca/fish/sportfishing/species/wper.shtml.

Ontario Ministry of Natural Resources (OMNR). 2011. Cold Water Species: Brook trout. Available Online: http://www.mnr.gov.on.ca/en/Business/LetsFish/2ColumnSubPage/STEL02_165833.html.

Pardue, G.B. 1983. Habitat Suitability Index Models: Alewife and Blueback Herring. U.S. Dept. Int. Fish Wildl. Servo FWSjOBS-82/l0.58. 22 pp.

Pereira, J.J., Goldberg, R., Ziskowski, J.J., Berrien, P.L., Morse, W.W., and Johnson, D.L. 1999. Essential Fish Habitat Source Document: Winter Flounder, *Pseudopleuronectes americanus*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-138. Available Online: https://www.nefsc.noaa.gov/publications/tm/tm138/tm138.pdf

Pezzack, D.S., Frail, C.M., Reeves, A., and Tremblay, M.J. 2009. Offshore Lobster LFA 41 (4X and 5Zc). DFO Can. Sci. Advis. Sec. Res. Doc. 2009/023. vi+118pp.

Phelan, B.A., Manderson, J.P., Stoner, A.W. and Bejda, A.J., 2001. Size-related shifts in the habitat associations of young-of-the-year winter flounder (*Pseudopleuronectes americanus)*: field observations and laboratory experiments with sediments and prey. *Journal of Experimental Marine Biology and Ecology*, 257(2), pp.297-315.

Porter, D. 2019. *Personal communication*. January 2019. Commercial Fisherman.

Raleigh, R.F. 1982. Habitat Suitability Index Models: Brook trout. U.S. Dept. Int., Fish Wildl. Serv. FS/OBS 82/10.24. 42pp.

Ramsar Sites Information Service (RSIS). 2001. Southern Bight – Minas Basin. Available online: https://rsis.ramsar.org/ris/379

Reid, R.N., Cargnelli, L.M., and Griesbach, S.J. 1999. Essential Fish Habitat Source Document: Atlantic Herring, *Clupea harengus*, Life History and Habitat Characteristics. NOAA Technical Memorandum NMFS-NE-126. Available Online: http://www.nefsc.noaa.gov/publications/tm/tm126/tm126.pdf

Resource Inventory Committee. 2001. Reconnaissance (1:20000) Fish and Fish Habitat Inventory for British Columbia: Standards and Procedures. 2001.

Reynolds, C. 2011. The effect of acidification on the survival of American eel. M.Sc. Thesis. Department of Biology, Dalhousie University, Halifax, N.S. vi + 67 p.

Richards, D. 2019. *Personal communication*. January 2019. Fisheries and Oceans Canada (DFO) Fisheries Officer.

Rulifson, R.A., Cahoon, C., and J.L. Cudney. 2004. Critical habitat assessment and population demographics of the American eel fishery in Northwestern Pamlico Sound, North Carolina. Final report for the North Carolina sea grant fishery resource grant program, Project No. 02-EP-13.

Rutherford, B. 2019. *Personal communication*. April 2019. Thaumas Environmental Consultants Senior Fisheries Biologist.

Ryan, P. M., and H. H. Harvey. 1979. Growth Responses of Yellow Perch, *Perca flavescens* (Mitchill), to Lake Acidification in the La Cloche Mountain Lakes of Ontario. *Env. Biol. Fish*. 5(2):97-108

Scott, W.B. and E.J. Crossman. 1973. Freshwater Fishes of Canada. Bull. Fish. Res. Board Can. 184:1-966

Scott, W.B., and Scott, M.G. 1988. Atlantic Fishes of Canada. University of Toronto Press.

Schmidt, R.E., and Stillman, T. 1998. Evidence of potamodromy in an estuarine population of smallmouth bass (*Micropterus dolomieu*). *J. Freshwater Biol*. 13:155-163.

Spares, A.D., Dadswell, M.J., MacMillan, J., Madden, R., O'Dor, R.K. and Stokesbury, M.J.W., 2014. To fast or feed: an alternative life history for anadromous brook trout *Salvelinus fontinalis* overwintering within a harbour. J*ournal of Fish Biology*, 85(3), pp.621-644.

Stanley, J.G. and D.S. Danie. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (North Atlantic – White Perch). U.S. Fish and Wildlife Service, Division of Biological Services, FWS/OBS-82/11.7. U.S. Army Corps of Engineers, TR EL-82-4. 12pp.

Stehlik LL. 2007. Essential fish habitat source document: Spiny dogfish, *Squalus acanthias*, life history and habitat characteristics, 2nd edition. NOAA Tech Memo NMFS NE 203; 44 p.

Stewart, L. L., and P.J. Auster. 1987. Species profiles: life histories and environmental requirements of coastal fishes and invertebrates (North Atlantic)--Atlantic tomcod. U. S. Fish Wildl. Serv. Biol. Rep. 82(11.76). U. S. Army Corps of Engineers, TR EL-82-4. 8 pp.

Stier, D.J. and Crance, J.H., 1985. Habitat suitability index models and instream flow suitability curves: American shad (No. 82/10.88). US Fish and Wildlife Service.

Stoner, A.W. and Kaimmer, S.M., 2008. Reducing elasmobranch bycatch: laboratory investigation of rare earth metal and magnetic deterrents with spiny dogfish and Pacific halibut. *Fisheries Research*, 92(2-3), pp.162-168.

Studholme, A., Packerand, D.B., and Berrien, P.L. 1999. Atlantic Mackerel, *Scomber scombrus*, Life History and Habitat Characteristics. U.S. Dept. of Commerce. NOAA Technical Memorandum NMFS-NE- 141. 44pp.

Tremblay, M.J., Pezzack, D.S., Gaudette, J., Denton, C., Cassista-Da Ros, M., and Allard, J. 2013. Assessment of lobster (*Homarus americanus*) off southwest Nova Scotia and in the Bay of Fundy (Lobster Fishing Areas 34-38). DFO Can. Sci. Advis. Sec. Res. Doc. 2013/078. viii + 125 p.

Unanian, I.M., and S.G. Soin. 1963. On Reproduction and Development of White Sea Smelt. Vesh. Mosk. Gos. Univ. (6)4:25-36.

U.S. Fish and Wildlife Service (USFWS). 2001. Winter Flounder Habitat Model: Gulf of Maine Watershed Habitat Analysis. Available Online: http://www.fws.gov/r5gomp/gom/habitatstudy/metadata/winter_flounder_model.htm

Watson, J. E. 1955. The Maine Smallmouth. Maine Dept. Inland Fish and Game Fish. Res. Bull. 3. 31 pp.

Watson III, W.H., Vetrovs, A. and Howell, W.H., 1999. Lobster movements in an estuary. *Marine Biology*, 134(1), pp.65-75.

West Virginia Department of Environmental Protection. 2010. West Virginia Save Our Streams Program's Advanced Standard Operating Procedures Manual. Available Online (accessed March 2019): http://www.wvca.us/envirothon/stream-assessment-protocols.pdf

CHAPTER 7 LIMITATIONS

The services performed as described in this report were conducted in a manner consistent with the level of care and skill normally exercised by other members of the engineering and science professions currently practicing under similar conditions, subject to the time limits and financial and physical constraints applicable to the services.

This report provides a professional opinion and therefore no warranty is expressed, implied, or made as to the conclusions, advice, and recommendations offered in this report. This report does not provide a legal opinion regarding compliance with applicable laws. With respect to regulatory compliance issues, it should be noted that regulatory statutes and interpretation of regulatory statues are subject to change.

Respectfully submitted,

CBCL Limited

Prepared by:
Chris Thorpe, B.Sc.
Junior Environmental Scientist

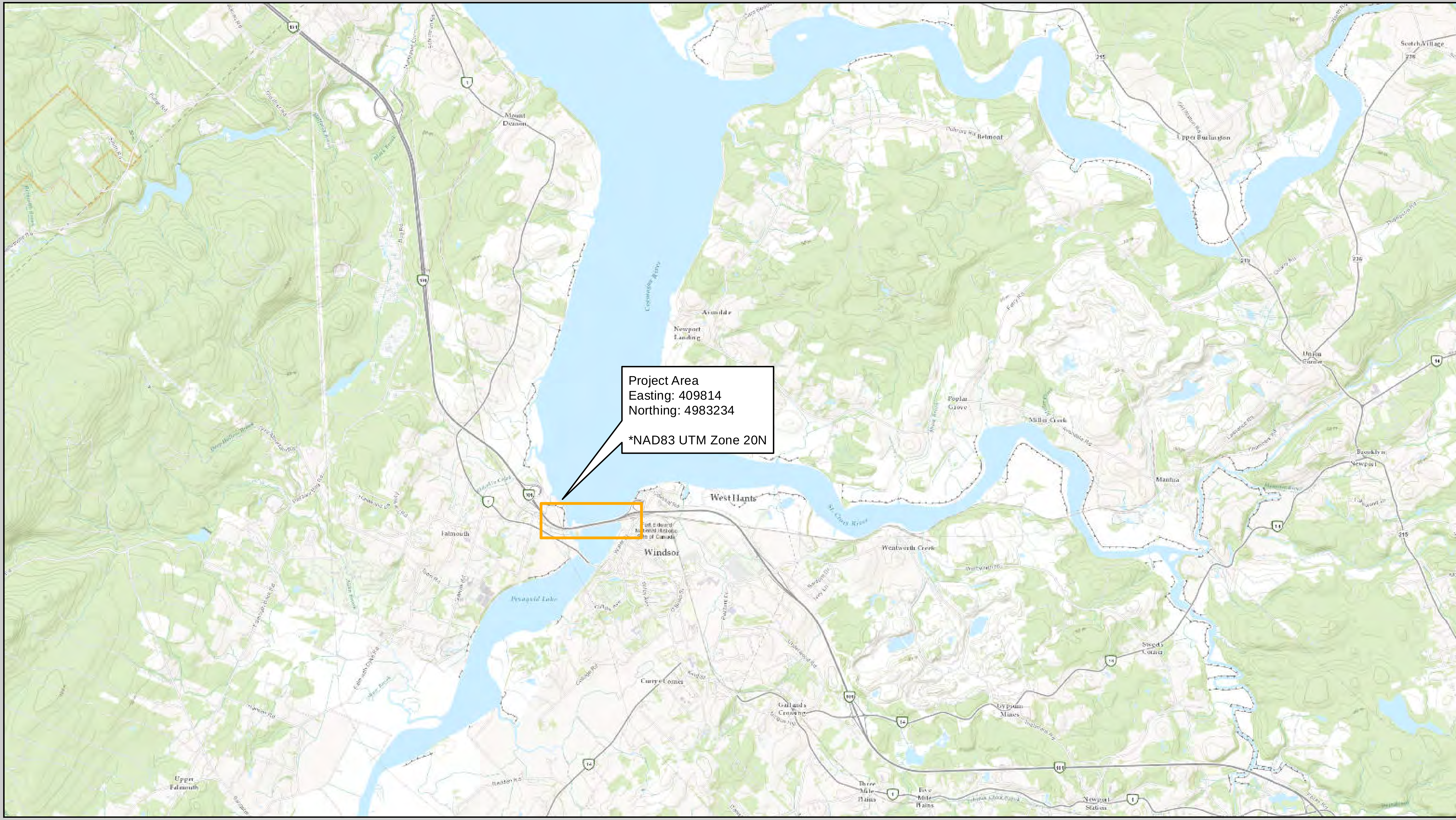
Prepared by:
Colin McVarish, B.Sc. H
Intermediate Environmental Scientist

Reviewed by:
Carrie Bentley, M.Sc., B.Sc. H
Senior Fisheries Biologist

Reviewed by:
Ian Bryson, M.Sc., EP
Principal, Group Leader
Environmental Sciences

APPENDIX A

Figures



CBCL LIMITED

Consulting Engineers

APPENDIX A - Figure 1

Avon River

1: 50 000 Topographic Map

0 590 1,180 1,770 2,360 m

1:50,000 Scale when printed at 11"x17"

Project Area

K:\Projects\171046.00 Avon River Aboiteau\20 CAD\08 GIS\171046.00 - 50 000 TOPO.mxd | Drawn: BH | Approved: CB | CBCL Project # 171046.00 | Date: 10/12/2018

CBCL LIMITED

Consulting Engineers

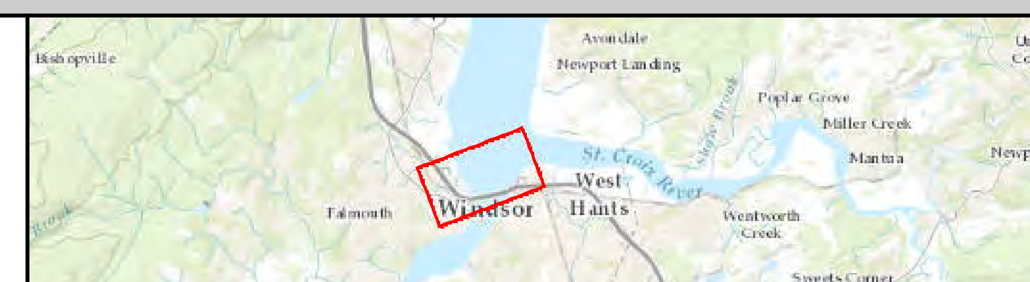
APPENDIX A - Figure 2
Avon River
Land Ownership

0 60 120 180 240 m

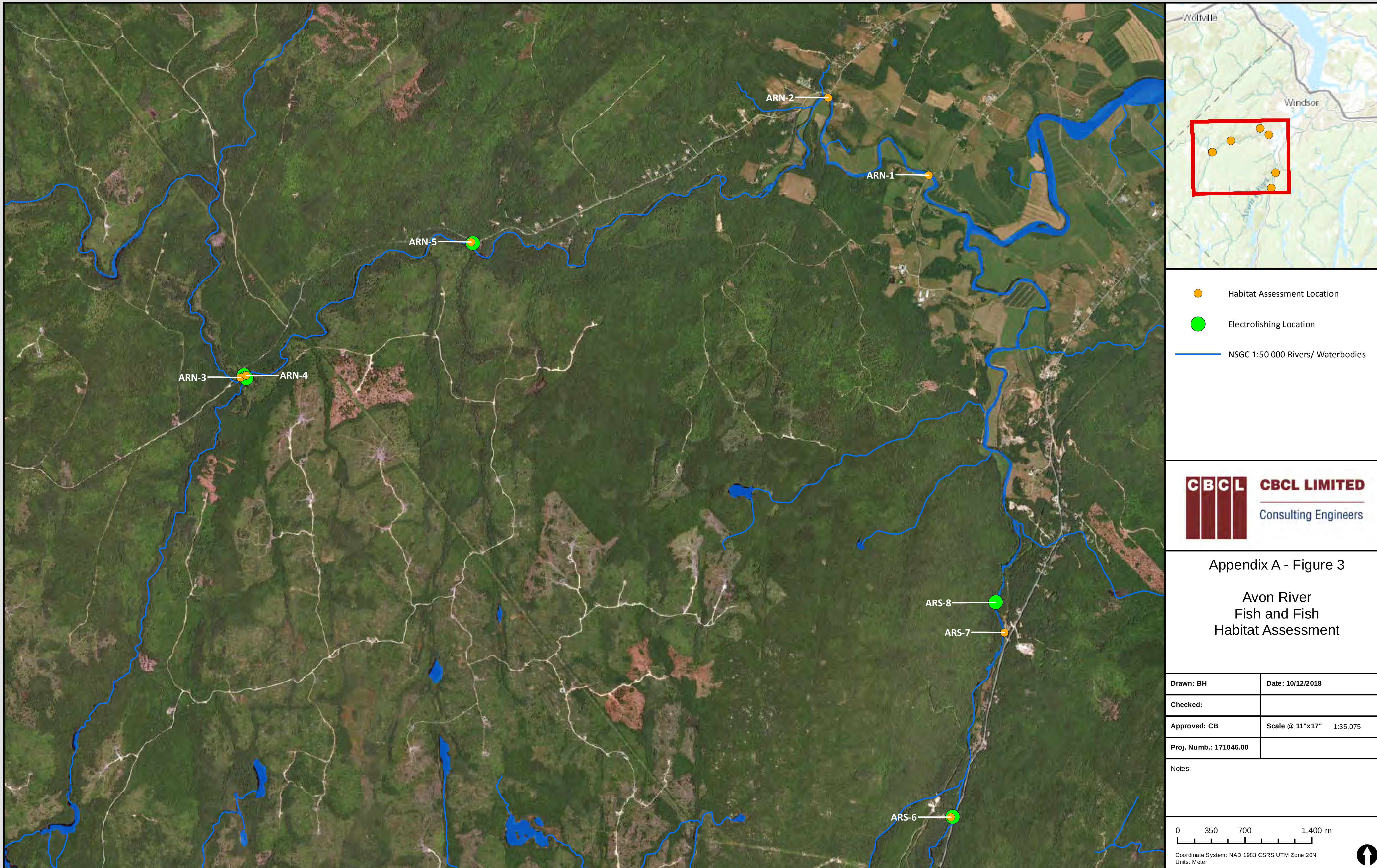
1:5,246 Scale when printed at 11"x17"

PID Boundary

Land Parcel Potentially Affected by Project



K:\Projects\171046.00 Avon River Aboiteau\20 CAD\08 GIS\171046.00 - PID Mapping.mxd | Drawn: BH | Approved: CB | CBCL Project # 171046.00 | Date: 07/12/2018



Habitat Assessment Location

Electrofishing Location

NSGC 1:50 000 Rivers/ Waterbodies

CBCL LIMITED

Consulting Engineers

Appendix A - Figure 3

Avon River
Fish and Fish
Habitat Assessment

Drawn: BH	Date: 10/12/2018
Checked:	
Approved: CB	Scale @ 11"x17" 1:35,075
Proj. Numb.: 171046.00	

Notes:

0 350 700 1,400 m

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Units: Meter

APPENDIX B

MCG Electrofishing Surveys

ELECTROFISHING IN THE AVON RIVER

Baseline Assessment of Commercial, Recreational and Aboriginal (CRA) Fisheries Adjacent to the Avon River Causeway

Prepared for Trevor Avery (Acadia University)

By: Alyssa Palmer-Dixon, Coastal Restoration Project Coordinator

Reviewed by: Jillian Arany, Fisheries Biologist

Mi'kmaw Conservation Group

The Mi'kmaw Conservation Group

The Confederacy of Mainland Mi'kmaq

57 Martin Crescent

Millbrook Mi'kmaw Community, NS

902-895-6385

www.mikmawconservation.ca

Table of Contents

Background

In 1970 the Avon River Causeway was constructed in Windsor, Nova Scotia where it remains to this day. This causeway has been of large concern for many individuals, from fisherman to local community members. The causeway has been found to inhibit proper fish passage from one side (Avon River) to the other side which empties into the Minas Basin. Very few studies have been conducted on assessing the fish within this watershed in past years, apart from a population study completed in 2000 and three other studies conducted by Department of Fisheries and Oceans (DFO) in 2007. In 2017, The Mi'kmaw Conservation Group (MCG) conducted initial baseline electrofishing surveys at six sites along the Avon River: three identified as DFO selected sites from their 2007 study and three identified as Local Knowledge selected sites. The purpose of these surveys was to help contribute to the understanding of fish populations within this watershed system. The overall Baseline Assessment project aims to characterize the use of waters leading to and upstream of the current Avon River Causeway gate system, in order to establish an improved picture of fish species, numbers, life stages, and seasonal timing in this watershed area.

In 2018 (this past field season), MCG's role for the project this year was continue with baseline electrofishing surveys and additionally, tag select species of fish.

Site Locations

This year, 5 sites were selected and each site was visited a total of 3 times (Figure 1). Of the 5 Sites electrofished this year, Site 2, 3, and 5 were previously electrofished (in the 2017 season) by MCG. Site 1 and 4 were new this year, and their locations were selected based on local knowledge obtained from Darren Porter and his discussions with local community members. Above Site 4 and 5, Nova Scotia Power operates a hydro dam, creating a closed system between the dam and the causeway (excluding small tributaries).

Site 1 - 44°56'27.30"N, 64°16'37.94"W
Site 2 - 44°55'41.26"N, 64°18'25.46"W
Site 3 - 44°55'40.56"N, 64°18'24.07"W
Site 4 - 44°53'15.12"N, 64°12'44.86"W
Site 5 - 44°54'28.39"N, 64°12'25.30"W

Methods

Certified MCG staff used a 2017 Halltech BackPack Electrofisher to stun fish and two Halltech dipnets to catch fish and eel species present at each site. On average, from the start point at each site, 100 meters in distance was measured upstream to the end-point. This distance was then electrofished using a zig-zag pattern moving across the width of the river and from down-stream to up-stream.

Although electrofishing could have been completed with two staff, it was determined safer and helpful to have a third and fourth staff member to aid in the catching and collection of fish and eels (one aided with catching using a dip net and the other carried a cooler which was used as a holding tank for fish).

Once electrofishing was completed, fish identification, weight (grams), and total length (cm) were recorded in a data field sheet. As directed by the project lead (Trevor Avery), all American Eels and White Perch were tagged. When these species were caught, they were scanned for presence of a PIT tag. If no tag was present, they were tagged after data measurements were completed. Scanning was completed for mark-recapture purposes.

Tagging involved the use of Passive Integrated Transponder (PIT) tags inserted in the underside below their gills. Each tag contains a unique number, which was recorded for identification.

Basic water quality data was also collected at each site visit, where/when possible. Water quality data included dissolved oxygen (mg/L), conductivity (us/cm), water temperature (^{o}C), and pH.

Results

For the 2018 field season, electrofishing was completed at five sites in total along the Avon River watershed and each site was electrofished three separate times from July 16th, 2018 to September 30th, 2018.

The most abundant species of fish that was found was the Common Dace, however this species was only found at sites 1, 2, and 3, all which are located along the right diverging branch of the Avon River. No Common Dace were found at Sites 4 and 5, which are located on the left diverging branch of the Avon River (Site locations are found in Figure 1).

At Site 1, there were four species of fish found; Common Dace, Shiner Sp., White Sucker, and American Eel. At Site 2, there were five species of fish found; Common Dace, Shiner Sp., White Sucker, American Eel, and Brook Trout. At Site 3, there were five species of fish found; Common Dace, Shiner Sp., White Sucker, American Eel, and Brook Trout. At Site 4, there were eight species of fish found; Shiner Sp., White Sucker, American Eel, Elver stage American Eel, Brown Bullhead, Small Mouth Bass, Stickleback Sp., and Yellow Perch. At Site 5, there were seven species of fish found; Shiner Sp., White Sucker, American Eel, Elver stage American Eel, Small Mouth Bass, Stickleback Sp., and Brown Bullhead.

Total numbers of counts for each species are represented below in Table form and Graphical representation. It was also found that in total there were three American Eels that were identified as a “recapture”. One American Eel was tagged and recaptured at Site 2 and two other American Eels were tagged and recaptured at Site 4. Out of MCGs five sites, no American Eels were tagged at one site and then recaptured at a second site.

Further, no White Perch were caught at any site.

Tables

Table 1. Fish species counts per electrofishing pass at Site 1 (44°56'27.30"N, 64°16'37.94"W) along the Avon River, Windsor, Nova Scotia.

Species	**1**	**2**	**3**
Dace	7	3	35
Shiner	6	4	11
White Sucker	3	7	15
Eel	3	7	5
Elver	0	0	0
Brook Trout	0	0	0
Brown Bullhead	0	0	0
Small Mouth Bass	0	0	0
Stickleback	0	0	0
Yellow Perch	0	0	0

Table 2. Total fish species counts across all three (3) electrofishing passes at Site 1 (44°56'27.30"N, 64°16'37.94"W) along the Avon River, Windsor, Nova Scotia.

Species	Count
Dace	45
Shiner	21
White Sucker	25
Eel	15
Elver	0
Brook Trout	0
Brown Bullhead	0
Small Mouth Bass	0
Stickleback	0
Yellow Perch	0

Table 3. Fish species counts per electrofishing pass at Site 2 (44°55'41.26"N, 64°18'25.46"W) along the Avon River, Windsor, Nova Scotia.

Species	**1**	**2**	**3**
Dace	11	2	18
Shiner	9	3	4
White Sucker	6	0	5
Eel	4	2	1
Elver	0	0	0
Brook Trout	0	0	1
Brown Bullhead	0	0	0
Small Mouth Bass	0	0	0
Stickleback	0	0	0
Yellow Perch	0	0	0

Table 4 . Total fish species counts across all three (3) electrofishing passes at Site 2 (44°55'41.26"N, 64°18'25.46"W) along the Avon River, Windsor, Nova Scotia.

Species	Count
Dace	31
Shiner	16
White Sucker	11
Eel	7
Elver	0
Brook Trout	1
Brown Bullhead	0
Small Mouth Bass	0
Stickleback	0
Yellow Perch	0

Table 5. Fish species counts per electrofishing pass at Site 3 (44°55'40.56"N, 64°18'24.07"W) along the Avon River, Windsor, Nova Scotia.

Species	**1**	**2**	**3**
Dace	14	17	14
Shiner	2	8	4
White Sucker	1	8	8
Eel	1	0	1
Elver	0	0	0
Brook Trout	0	1	0
Brown Bullhead	0	0	0
Small Mouth Bass	0	0	0
Stickleback	0	0	0
Yellow Perch	0	0	0

Table 6. Total fish species counts across all three (3) electrofishing passes at Site 3 (44°55'40.56"N, 64°18'24.07"W) along the Avon River, Windsor, Nova Scotia.

Species	**Count**
Dace	45
Shiner	14
White Sucker	17
Eel	2
Elver	0
Brook Trout	1
Brown Bullhead	0
Small Mouth Bass	0
Stickleback	0
Yellow Perch	0

Table 7. Fish species counts per electrofishing pass at Site 4 (44°53'15.12"N, 64°12'44.86"W) along the Avon River, Windsor, Nova Scotia.

Species	**1**	**2**	**3**
Common Dace	0	0	0
Shiner Sp.	1	0	0
White Sucker	3	2	0
American Eel	3	3	4
Elver - American Eel	8	15	14
Brook Trout	0	0	0
Brown Bullhead	0	0	1
Small Mouth Bass	0	1	0
Stickleback Sp.	0	1	0
Yellow Perch	1	0	0

Table 8. Total fish species counts across all three (3) electrofishing passes at Site 4 (44°53'15.12"N, 64°12'44.86"W) along the Avon River, Windsor, Nova Scotia.

Species	**Count**
Common Dace	0
Shiner Sp.	1
White Sucker	5
American Eel	10
Elver - American Eel	37
Brook Trout	0
Brown Bullhead	1
Small Mouth Bass	1
Stickleback Sp.	1
Yellow Perch	1

Table 9. Fish species counts per electrofishing pass at Site 5 (44°54'28.39"N, 64°12'25.30"W) along the Avon River, Windsor, Nova Scotia.

Species	1	2	3
Dace	0	0	0
Shiner	3	0	0
White Sucker	11	1	1
Eel	7	3	2
Elver	0	0	2
Brook Trout	0	0	0
Brown Bullhead	1	1	2
Small Mouth Bass	1	1	2
Stickleback	0	0	1
Yellow Perch	0	0	0

Table 10. Total fish species counts across all three (3) electrofishing passes at Site 5 (44°54'28.39"N, 64°12'25.30"W) along the Avon River, Windsor, Nova Scotia.

Species	Count
Dace	0
Shiner	3
White Sucker	13
Eel	12
Elver	2
Brook Trout	0
Brown Bullhead	4
Small Mouth Bass	4
Stickleback	1
Yellow Perch	0

Figures

Figure 1. Map of five sites where electrofishing was performed by Mi'kmaw Conservation Group from July 16th, 2018 to September 30th, 2018. Created by Jillian Arany (MCG).

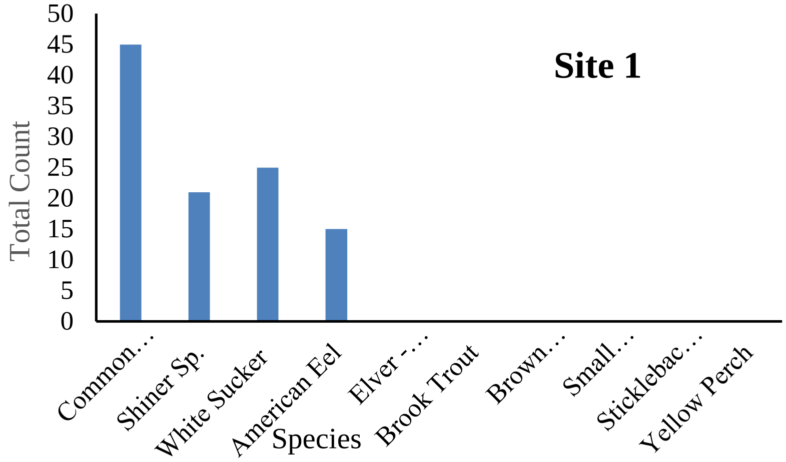


Figure 2. Bar graph representation of total fish species counts across all three (3) electrofishing passes at Site 1 (44°56'27.30"N, 64°16'37.94"W) along the Avon River, Windsor, Nova Scotia.

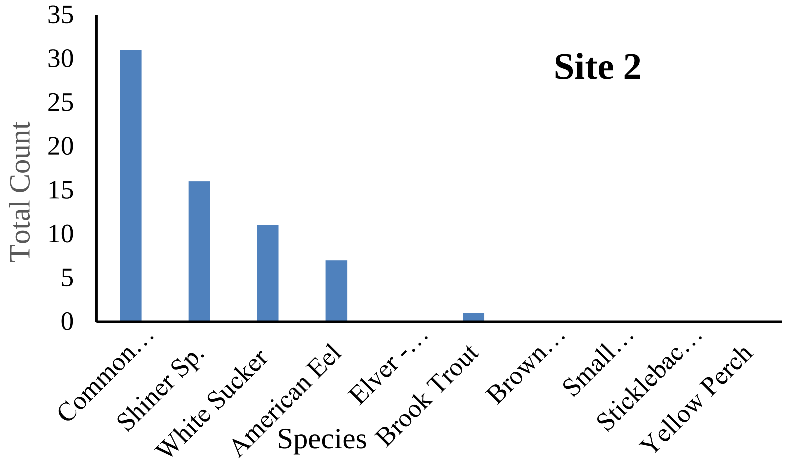


Figure 3. Bar graph representation of total fish species counts across all three (3) electrofishing passes at Site 2 (44°55'41.26"N, 64°18'25.46"W) along the Avon River, Windsor, Nova Scotia.

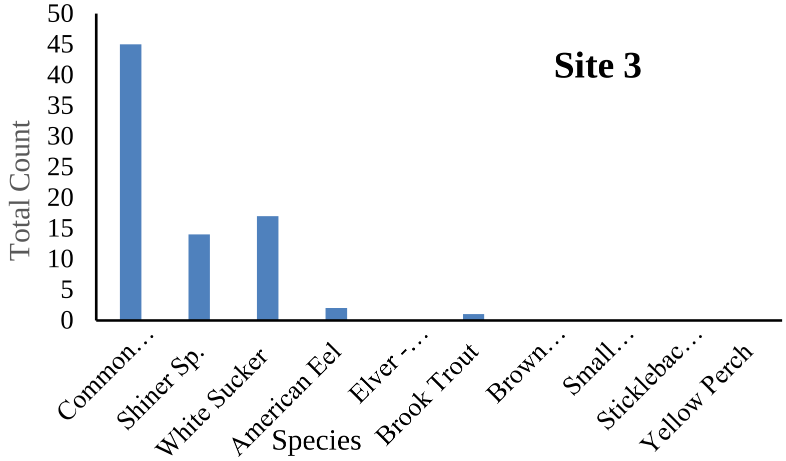


Figure 4. Bar graph representation of total fish species counts across all three (3) electrofishing passes at Site 3 (44°55'40.56"N, 64°18'24.07"W) along the Avon River, Windsor, Nova Scotia.

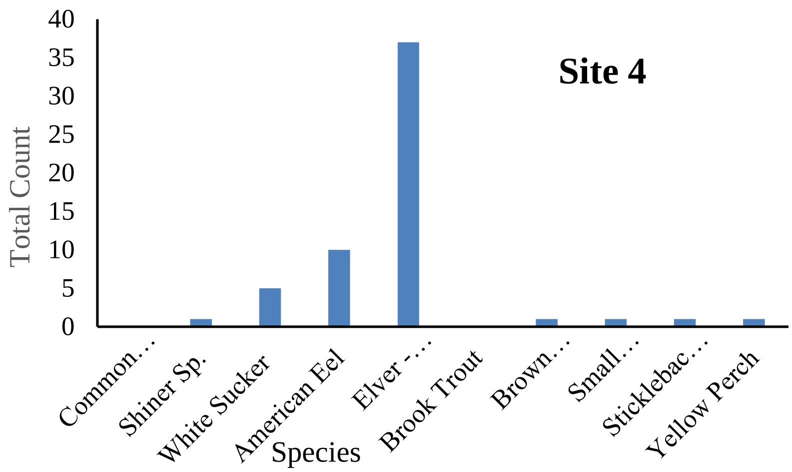


Figure 5. Bar graph representation of total fish species counts across all three (3) electrofishing passes at Site 4 (44°53'15.12"N, 64°12'44.86"W) along the Avon River, Windsor, Nova Scotia.

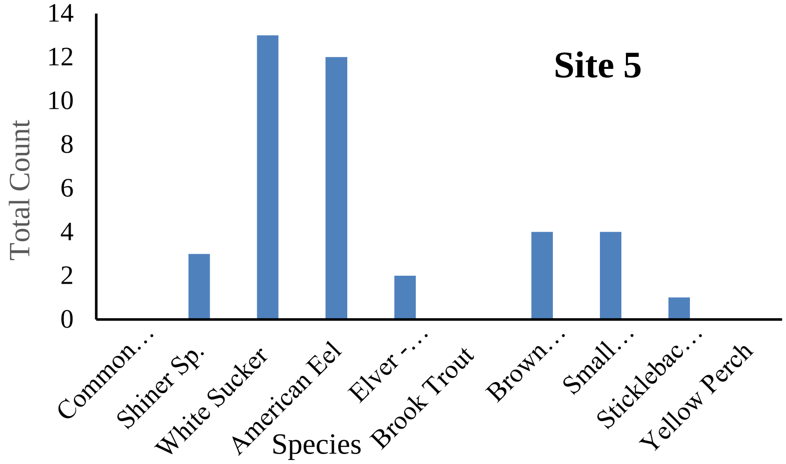


Figure 6. Bar graph representation of total fish species counts across all three (3) electrofishing passes at Site 5 (44°54'28.39"N, 64°12'25.30"W) along the Avon River, Windsor, Nova Scotia.

APPENDIX C

Functional Habitat Assessment

Appendix B: Habitat Functional Assessment

Habitat Type	Taxon	Species	CRA Fisheries Status	Species at Risk Status	Spawning	Rearing	Overwintering	Adult Foraging	Cover	In River Migration	References
					Avon River above Causeway Habitat Function Assessment - Avon River Aboiteau and Causeway Upgrade Design, Windsor, NS						
River	Crustacean	American Lobster *Homarus americanus*	Commercial; Aboriginal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	McLeese 1956; Watson III et al. 1999; Tremblay et al 2013; DFO 2009; MacKenzie and Moring 1985; Pezzack et al. 2009; Den Heyer et al 2009
River	Chondrichthyes	Spiny dogfish *Squalus acanthias*	Recreational (Groundfish)	SARA: Not Listed COSEWIC: Special Concern	N/A	N/A	N/A	N/A	N/A	N/A	Stehlik 2007; Scott and Scott 1988; McMillan and Morse 1999; Stoner and Kaimmer 2008; Campana 2007
River	Finfish	American eel** *Anguilla rostrata*	Commercial; Recreational; Aboriginal	SARA: Not Listed COSEWIC: Special Concern	N/A	Moderate-Good	Moderate	Moderate-Good	Moderate	Good	COSEWIC 2012a; Scott and Scott 1988; Facey and Van Den Avyle 1987
River	Finfish	American Shad *Alosa sapidissima*	Commercial; Recreational	N/A	Moderate-Good	Moderate-Good	Poor	Poor	Poor	Good	Scott and Scott 1988; Stier and Crance 1985
River	Finfish	Atlantic herring *Clupea harengus*	Commercial	N/A	N/A	N/A	N/A	N/A	N/A	N/A	DFO 2016a; Reid et al. 1999; Scott and Scott 1988; Kenchington 1980; DFA 2019
River	Finfish	Atlantic mackerel *Scomber scombrus*	Recreational	N/A	N/A	N/A	N/A	N/A	N/A	N/A	DFO 2000a; DFO 2007; DFO 2012; Studholme et al. 1999; Scott and Scott 1988; Collette and Nauen 1983; Grégoire et al. 2013; SNC-Lavalin 2015
River	Finfish	Atlantic Tomcod* *Microgadus tomcod*	Recreational (Groundfish)	N/A	Poor	Poor	Poor	Moderate-Good	Poor	Moderate	Stewart and Auster 1987; Scott and Scott 1988;Bigelow, and Schroeder 1953
River	Finfish	Brook trout *Salvelinus fontinalis*	Recreational	N/A	Moderate-Good	Moderate-Good	Moderate-Good	Good	Moderate-Good	Moderate-Good	Spares et al. 2014; Scott and Scott 1988; Raleigh 1982; Huusko et al 2007; OMNR 2011; NSDFA 2007
River	Finfish	Brown trout *Salmo trutta*	Recreational	N/A	Moderate-Good	Moderate-Good	Moderate-Good	Good	Moderate-Good	Moderate-Good	Scott and Scott 1988; Raleigh et al. 1986
River	Finfish	Gaspereau/Alewife* *Alosa* spp.	Commercial; Recreational; Aboriginal	N/A	Moderate-Good	Moderate-Good	Moderate	Poor	Moderate	Good	DFO 2000b; DFO 2016b; DFO 1997; Scott and Scott 1988; Pardue 1983; Greene et al. 2009
River	Finfish	Rainbow Smelt* *Osmerus mordax*	Commercial; Recreational; Aboriginal	N/A	Moderate	Moderate	Poor	Poor	Poor	Moderate	Buckley 1989; CRI 2014; Spares et al. 2014; Unanian and Soin 1963; Evans and Loftus 1963
River	Finfish	Smallmouth Bass *Micropterus dolomieu*	Recreational	N/A	Poor-Moderate	Moderate	Poor-Moderate	Moderate-Good	Moderate	Moderate	Brown et al. 2009; Schmidt and Stillman 1998; Buckley 1975; Butler 1975; Clancey 1980; Watson 1955; Coutant 1975; Edwards et al 1983; Henderson 1957; Scott and Crossman 1973
River	Finfish	Smooth flounder *Pleuronectes putnami*	Recreational (Groundfish)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Hanson and Courtenay 1997; Scott and Scott 1988
River	Finfish	Striped Bass* *Morone saxatilis*	Recreational	SARA: Not Listed COSEWIC: Endangered	Poor	Poor	Moderate	Moderate-Good	Moderate	Good	Bain and Bain 1982; Bradford et al. 2012, 2016; COSWIC 2013; Cook et al. 2006; Douglas et al 2003, 2009; Hurst and Conover 2002; Nelson et al. 2010; Buhariwalla et al. 2016; Hogans and Melvin 1984
River	Finfish	Summer flounder *Paralichthys dentatus*	Recreational (Groundfish)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Henderson and Fabrizio 2011; Keefe and Able 1993; Scott and Scott 1988;
River	Finfish	White Perch* *Morone americana*	Recreational	N/A	Moderate	Moderate	Good	Moderate-Good	Poor-Moderate	Moderate	Stanley and Danie 1983; Scott and Scott 1988
River	Finfish	Winter flounder *Pseudopleuronectes americanus*	Recreational (Groundfish)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Phelan et al. 2001; USFWS 2001; Pereira et al. 1999; Scott and Scott 1988
River	Finfish	Yellow Perch *Perca lavescens*	Recreational	N/A	Moderate	Moderate	Good	Good	Poor-Moderate	Moderate	Scott and Crossman. 1973; Kitchell et al. 1977; Krieger et al. 1983; Ryan and Harvey 1979; Brown et al. 2009

*Anadromous species require passage

**Catadromous species require passage

Appendix B: Habitat Functional Assessment

					Lake Pesaquid Area Habitat Function Assessment - Avon River Aboiteau and Causeway Upgrade Design, Windsor, NS						
Habitat Type	***Taxon***	***Species***	***CRA Fisheries Status***	***Species at Risk Status***	***Spawning***	***Rearing***	***Overwintering***	***Adult Foraging***	***Cover***	***Migration***	***References***
Fresh Water Lake	**Crustacean**	American Lobster *Homarus americanus*	Commercial; Aboriginal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	McLeese 1956; Watson III et al. 1999; Tremblay et al 2013; DFO 2009; MacKenzie and Moring 1985; Pezzack et al. 2009; Den Heyer et al 2009
	Chondrichthyes	Spiny dogfish *Squalus acanthias*	Recreational (Groundfish)	SARA: Not Listed COSEWIC: Special Concern	N/A	N/A	N/A	N/A	N/A	N/A	Stehlik 2007; Scott and Scott 1988; McMillan and Morse 1999; Stoner and Kaimmer 2008; Campana 2007
	Finfish	American eel** *Anguilla rostrata*	Commercial; Recreational; Aboriginal	SARA: Not Listed COSEWIC: Special Concern	N/A	Good	Good	Good	Poor-Moderate	Good	COSEWIC 2012a; Scott and Scott 1988; Facey and Van Den Avyle 1987
		American Shad *Alosa sapidissima*	Commercial; Recreational	N/A	Poor	Poor	Poor	Poor	Poor	Poor	Scott and Scott 1988; Stier and Crance 1985
		Atlantic herring *Clupea harengus*	Commercial	N/A	N/A	N/A	N/A	N/A	N/A	N/A	DFO 2016a; Reid et al. 1999; Scott and Scott 1988; Kenchington 1980; DFA 2019
		Atlantic mackerel *Scomber scombrus*	Recreational	N/A	N/A	N/A	N/A	N/A	N/A	N/A	DFO 2000a; DFO 2007; DFO 2012; Studholme et al. 1999; Scott and Scott 1988; Collette and Nauen 1983; Grégoire et al. 2013; SNC-Lavalin 2015
		Atlantic Tomcod* *Microgadus tomcod*	Recreational (Groundfish)	N/A	Poor	Poor	Poor	Moderate-Good	Poor	Moderate	Stewart and Auster 1987; Scott and Scott 1988;Bigelow, and Schroeder 1953
		Brook trout *Salvelinus fontinalis*	Recreational	N/A	Poor	Moderate-Good	Good	Moderate-Good	Moderate	Moderate	Spares et al. 2014; Scott and Scott 1988; Raleigh 1982; Huusko et al 2007; OMNR 2011; NSDFA 2007
		Brown trout *Salmo trutta*	Recreational	N/A	Poor	Good	Good	Good	Moderate	Moderate	Scott and Scott 1988; Raleigh et al. 1986
		Gaspereau/Alewife* *Alosa* spp.	Commercial; Recreational; Aboriginal	N/A	Moderate	Good	Good	N/A	Moderate	Moderate	DFO 2000b; DFO 2016b; DFO 1997; Scott and Scott 1988; Pardue 1983; Greene et al. 2009
		Rainbow Smelt* *Osmerus mordax*	Commercial; Recreational; Aboriginal	N/A	Poor	Poor	Poor	Moderate-Good	Poor	Moderate	Buckley 1989; CRI 2014; Spares et al. 2014; Unanian and Soin 1963; Evans and Loftus 1963
		Smallmouth Bass *Micropterus dolomieu*	Recreational	N/A	Moderate-Good	Moderate-Good	Good	Moderate-Good	Moderate	Moderate	Brown et al. 2009; Schmidt and Stillman 1998; Buckley 1975; Butler 1975; Clancey 1980; Watson 1955; Coutant 1975; Edwards et al 1983; Henderson 1957; Scott and Crossman 1973
		Smooth flounder *Pleuronectes putnami*	Recreational (Groundfish)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Hanson and Courtenay 1997; Scott and Scott 1988
		Striped Bass* *Morone saxatilis*	Recreational	SARA: Not Listed COSEWIC: Endangered	Poor	Poor-Moderate	Poor-Moderate	Moderate	Moderate	Moderate	Bain and Bain 1982; Bradford et al. 2012, 2016; COSWIC 2013; Cook et al. 2006; Douglas et al 2003, 2009; Hurst and Conover 2002; Nelson et al. 2010; Buhariwalla et al. 2016; Hogans and Melvin 1984
		Summer flounder *Paralichthys dentatus*	Recreational (Groundfish)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Henderson and Fabrizio 2011; Keefe and Able 1993; Scott and Scott 1988;
		White Perch* *Morone americana*	Recreational	N/A	Moderate	Moderate	Good	Moderate-Good	Poor-Moderate	Moderate	Stanley and Danie 1983; Scott and Scott 1988
		Winter flounder *Pseudopleuronectes americanus*	Recreational (Groundfish)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Phelan et al. 2001; USFWS 2001; Pereira et al. 1999; Scott and Scott 1988
		Yellow Perch *Perca lavescens*	Recreational	N/A	Moderate	Poor-Moderate	Good	Good	Poor-Moderate	Moderate	Scott and Crossman. 1973; Kitchell et al. 1977; Krieger et al. 1983; Ryan and Harvey 1979; Brown et al. 2009

*Anadromous species require passage
**Catadromous species require passage

Appendix B: Habitat Functional Assessment

Habitat Type	Taxon	Species	CRA Fisheries Status	Species at Risk Status	Spawning	Rearing	Overwintering	Adult Foraging	Cover	Migration	References
					Estuary below Causeway Habitat Function Assessment - Avon River Aboiteau and Causeway Upgrade Design, Windsor, NS						
Estuary - Fines Dominated	Crustacean	American Lobster *Homarus americanus*	Commercial; Aboriginal	N/A	Poor	Poor	Poor	Moderate	Poor	Moderate	McLeese 1956; Watson III et al. 1999; Tremblay et al 2013; DFO 2009; MacKenzie and Moring 1985; Pezzack et al. 2009; Den Heyer et al 2009
	Chondrichthyes	Spiny dogfish *Squalus acanthias*	Recreational (Groundfish)	SARA: Not Listed COSEWIC: Special Concern	Poor	Poor	Poor	Moderate-Good	Poor	Poor	Stehlik 2007; Scott and Scott 1988; McMillan and Morse 1999; Stoner and Kaimmer 2008; Campana 2007
	Finfish	American eel** *Anguilla rostrata*	Commercial; Recreational; Aboriginal	SARA: Not Listed COSEWIC: Special Concern	N/A	Moderate-Good	Good	Good	Good	Good	COSEWIC 2012a; Scott and Scott 1988; Facey and Van Den Avyle 1987
		American Shad *Alosa sapidissima*	Commercial; Recreational	N/A	Poor	Moderate-Good	Poor	Poor-Moderate	Poor	Good	Scott and Scott 1988; Stier and Crance 1985
		Atlantic herring *Clupea harengus*	Commercial	N/A	Poor-Moderate	Moderate	Moderate	Poor-Moderate	Poor	Moderate	DFO 2016a; Reid et al. 1999; Scott and Scott 1988; Kenchington 1980; DFA 2019
		Atlantic mackerel *Scomber scombrus*	Recreational	N/A	Poor	Poor	Poor	Poor-Moderate	N/A	Poor-Moderate	DFO 2000a; DFO 2007; DFO 2012; Studholme et al. 1999; Scott and Scott 1988; Collette and Nauen 1983; Grégoire et al. 2013; SNC-Lavalin 2015
		Atlantic Tomcod* *Microgadus tomcod*	Recreational (Groundfish)	N/A	Moderate	Moderate	Good	Good	Poor	Good	Stewart and Auster 1987; Scott and Scott 1988; Bigelow, and Schroeder 1953
		Brook trout *Salvelinus fontinalis*	Recreational	N/A	Poor	Good	Good	Good	Poor	Good	Spares et al. 2014; Scott and Scott 1988; Raleigh 1982; Huusko et al 2007; OMNR 2011; NSDFA 2007
		Brown trout *Salmo trutta*	Recreational	N/A	Poor	Good	Good	Good	Poor	Good	Scott and Scott 1988; Raleigh et al. 1986
		Gaspereau/Alewife* *Alosa* spp.	Commercial; Recreational; Aboriginal	N/A	Poor	Poor-Moderate	Good	Good	Poor	Good	DFO 2000b; DFO 2016b; DFO 1997; Scott and Scott 1988; Pardue 1983; Greene et al. 2009
		Rainbow Smelt* *Osmerus mordax*	Commercial; Recreational; Aboriginal	N/A	Poor	Poor	Good	Moderate	Poor	Moderate	Buckley 1989; CRI 2014; Spares et al. 2014; Unanian and Soin 1963; Evans and Loftus 1963
		Smallmouth Bass *Micropterus dolomieu*	Recreational	N/A	Poor	Poor	Poor	Moderate	Poor	Poor	Brown et al. 2009; Schmidt and Stillman 1998; Buckley 1975; Butler 1975; Clancey 1980; Watson 1955; Coutant 1975; Edwards et al 1983; Henderson 1957; Scott and Crossman 1973
		Smooth flounder *Pleuronectes putnami*	Recreational (Groundfish)	N/A	Moderate	Moderate-Good	Moderate	Moderate-Good	Moderate	Good	Hanson and Courtenay 1997; Scott and Scott 1988
		Striped Bass* *Morone saxatilis*	Recreational	SARA: Not Listed COSEWIC: Endangered	Poor	Poor-Moderate	Moderate	Good	Poor	Good	Bain and Bain 1982; Bradford et al. 2012, 2016; COSWIC 2013; Cook et al. 2006; Douglas et al 2003, 2009; Hurst and Conover 2002; Nelson et al. 2010; Buhariwalla et al. 2016; Hogans and Melvin 1984
		Summer flounder *Paralichthys dentatus*	Recreational (Groundfish)	N/A	Poor	Poor-Moderate	Poor	Moderate	Poor	Good	Henderson and Fabrizio 2011; Keefe and Able 1993; Scott and Scott 1988;
		White Perch* *Morone americana*	Recreational	N/A	Moderate	Moderate	Good	Good	Poor	Good	Stanley and Danie 1983; Scott and Scott 1988
		Winter flounder *Pseudopleuronectes americanus*	Recreational (Groundfish)	N/A	Poor	Poor-Moderate	Poor	Moderate	Poor	Good	Phelan et al. 2001; USFWS 2001; Pereira et al. 1999; Scott and Scott 1988
		Yellow Perch *Perca lavescens*	Recreational	N/A	Poor	Poor-Moderate	Good	Good	Poor	Moderate	Scott and Crossman. 1973; Kitchell et al. 1977; Krieger et al. 1983; Ryan and Harvey 1979; Brown et al. 2009

*Anadromous species require passage

**Catadromous species require passage

APPENDIX D

Watercourse Fact Sheets and Photographs

WATERCOURSE INFORMATION		
Watercourse ID:	**ARN-1**	
General Site Location:	Windsor	
Watercourse Assessor(s):	CB, BR	
Affiliation:	CBCL Limited	
Field Assessment Date:	26-Jun-18	
UTM Coordinates:	E-403970	N-4977905
Datum:	NAD83 UTM 20N	

HABITAT QUALITY	
Overall	Moderate-Good
Spawning	Poor-Moderate
Rearing	Poor-Moderate
Overwintering	Moderate-Good
Migration	Good
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	High

FISH OBSERVED
No

WATER QUALITY	
Temperature (Deg. C)	13.4
pH	7.17
Conductivity (µs/cm)	47.5
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	34

SUBSTRATE	
% Bedrock	0
% Boulder	5
% Cobble	5
% Large gravel	0
% Small gravel	0
% Fines	90

CHANNEL MEASUREMENTS	
Channel width (m)	20
Wetted width (m)	19
Depth (m)	>1.0
Pool depth (m)	-

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Flat
Channel depth class	Class 1: >1.0m
Islands	None
Bars	None
Pattern	Regular Meanders
Confinement	Confined

INSTREAM COVER	
Boulder	Trace
Overhanging vegetation	Trace
LWD	Trace
Undercut banks	None
Deep pool	High
SWD	None
Instream vegetation	Trace

RIPARIAN INFORMATION	
Crown closure %	1-25%
Bank texture	Fines, Cobble, Boulder
Left bank shape	Sloped, Vertical
Right bank shape	Sloped, Vertical
Vegetation stage	Farmland, Shrub

HABITAT QUALITY RATIONALE	
Spawning	This location is not ideal spawning habitat as it is dominated by fines which may suffocate the eggs.
Rearing	There is some clumped large-woody debris present that could provide cover for juvenile fish, the depth and colour of the water would also provide cover.
Overwintering	This location is deep with adequate flow and could provide overwintering habitat.
Migration	This location would provide excellent migration habitat as there are no apparent blockages and fish could travel easily.
Foraging	Foraging habitat is considered to be good for this section.

INVERTEBRATES		
#	**Order**	**Common Name**
1		
2		
3		
4		
5		
6		

RIPARIAN VEGETATION		
#	**Species**	**Common Name**
1	*Betula papyrifera*	White Birch
2	*Alnus Incana*	Speckled Alder
3	*Populus tremuloides*	Trembling Aspen
4	*Ranunculus repens*	Creeping Buttercup
5	*Phleum pratense*	Timothy Grass
6		
7		
8		
9		
10		

ADDITIONAL NOTES
Instream cover for this location is not abundant; however the depth (average 1.5 m) and colour of the water would provide cover for juvenile fish. Depth of pools was unable to be assessed owing to the overall size and depth of the watercourse at this location. Invertebrates were not sampled here due to the depth of the watercourse.


Figure 1: Upstream view


Figure 2: Downstream view

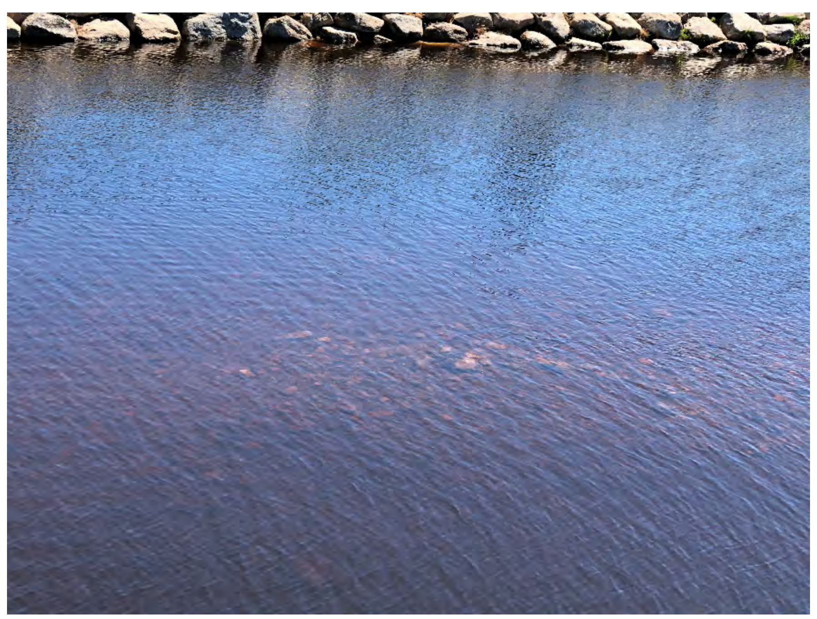


Figure 3: Substrate

WATERCOURSE INFORMATION		
Watercourse ID:	**ARN-2**	
General Site Location:	Windsor	
Watercourse Assessor(s):	CB, BR	
Affiliation:	CBCL Limited	
Field Assessment Date:	26-Jun-18	
UTM Coordinates:	E-402967	N-4978688
Datum:	NAD83 UTM 20N	

HABITAT QUALITY	
Overall	Moderate-Good
Spawning	Poor-Moderate
Rearing	Poor-Moderate
Overwintering	Good
Migration	Good
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	High

FISH OBSERVED
No

WATER QUALITY	
Temperature (Deg. C)	13.2
pH	6.76
Conductivity (µs/cm)	36.9
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	26.1

SUBSTRATE	
% Bedrock	0
% Boulder	10
% Cobble	40
% Large gravel	20
% Small gravel	15
% Fines	15

CHANNEL MEASUREMENTS	
Channel width (m)	13
Wetted width (m)	11.2
Depth (m)	0.4
Pool depth (m)	-

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Flat, Riffle, Run, Pool
Channel depth class	Class 3: <0.5m
Islands	None
Bars	None
Pattern	Regular Meanders
Confinement	Confined

INSTREAM COVER	
Boulder	Trace
Overhanging vegetation	Trace
LWD	Trace
Undercut banks	Moderate
Deep pool	Trace-Moderate
SWD	None
Instream vegetation	Moderate-Abundant

RIPARIAN INFORMATION	
Crown closure %	1-25%
Bank texture	Fines
Left bank shape	Sloped
Right bank shape	Sloped, Confined
Vegetation stage	Farmland, Shrub

HABITAT QUALITY RATIONALE	
Spawning	This location has some suitable substrate for spawning, however this location had high velocity which would be a hindrance to spawning.
Rearing	There is adequate cover for juveniles (boulders, deep pools, instream vegetation); however the high velocity would be a deterrent for juvenile fish.
Overwintering	This location is deep with high velocity and could provide overwintering habitat.
Migration	This location would provide excellent migration habitat as there are no apparent blockages and fish could travel easily, there is also suitable habitat upstream.
Foraging	This location would provide excellent foraging habitat as there were an abundance of invertebrates present.

INVERTEBRATES		
#	**Order**	**Common Name**
1	*Ephemeroptera*	Mayfly
2	*Plecoptera*	Stonefly
3	*Trichoptera*	Caddisfly
4		
5		
6		

RIPARIAN VEGETATION		
#	**Species**	**Common Name**
1	*Betula papyrifera*	White Birch
2	*Alnus Incana*	Speckled Alder
3	*Populus tremuloides*	Trembling Aspen
4	*Pinus strobus*	White Pine
5		
6		
7		
8		
9		
10		

ADDITIONAL NOTES


Figure 1: Upstream view


Figure 2: Downstream view


Figure 3: Substrate


Figure 4: Right bank shape

WATERCOURSE INFORMATION		
Watercourse ID:	**ARN-3**	
General Site Location:	Windsor	
Watercourse Assessor(s):	CB, BR	
Affiliation:	CBCL Limited	
Field Assessment Date:	26-Jun-18	
UTM Coordinates:	E-396827	N-4975772
Datum:	NAD83 UTM 20N	

HABITAT QUALITY	
Overall	Good
Spawning	Good
Rearing	Good
Overwintering	Moderate
Migration	Good
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	Moderate

FISH OBSERVED
Yes, Species Unknown

WATER QUALITY	
Temperature (Deg. C)	15.7
pH	6.7
Conductivity (µs/cm)	23.9
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	17.9

SUBSTRATE	
% Bedrock	0
% Boulder	15
% Cobble	40
% Large gravel	20
% Small gravel	15
% Fines	10

CHANNEL MEASUREMENTS	
Channel width (m)	16.2
Wetted width (m)	13.5
Depth (m)	0.25
Pool depth (m)	0.65

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Flat, Riffle, Run, Pool
Channel depth class	Class 3: <0.5m
Islands	None
Bars	None
Pattern	Regular Meanders
Confinement	Confined

INSTREAM COVER	
Boulder	Trace-Moderate
Overhanging vegetation	Trace
LWD	Trace
Undercut banks	Trace
Deep pool	Trace
SWD	Trace
Instream vegetation	Trace

RIPARIAN INFORMATION	
Crown closure %	1-25%
Bank texture	Fines
Left bank shape	Sloped
Right bank shape	Sloped
Vegetation stage	Mature Forest

HABITAT QUALITY RATIONALE	
Spawning	The substrate present is ideal for spawning, there was also suitable flow which would ensure the eggs remain oxygenated.
Rearing	There is adequate habitat features (boulders, woody debris) to provide cover for juveniles.
Overwintering	This location has a trace amount of deep pools, and sufficient flow; however the depth is shallow is some places. This location may provide overwintering habitat.
Migration	There are no blockages present at this location, use for migration of fish species is likely.
Foraging	This location had an abundance of invertebrates and would provide excellent foraging habitat.

INVERTEBRATES		
#	**Order**	**Common Name**
1	*Ephemeroptera*	Mayfly
2	*Plecoptera*	Stonefly
3	*Trichoptera*	Caddisfly
4	*Diptera*	Midge
5		
6		

RIPARIAN VEGETATION		
#	**Species**	**Common Name**
1	*Betula papyrifera*	White Birch
2	*Alnus Incana*	Speckled Alder
3	*Ranunculus repens*	Creeping Buttercup
4	*Pinus strobus*	White Pine
5	*Pteridium aquilinum*	Bracken Fern
6	*Osmunda regalis*	Royal Fern
7	*Abies balsamea*	Balsam Fir
8	*Tsuga canadensis*	Eastern hemlock
9	*Betula populifolia*	Gray Birch
10	*Onoclea sensibilis*	Sensitive Fern

ADDITIONAL NOTES

Figure 1: Upstream view

Figure 2: Downstream view

Figure 3: Substrate

Figure 4: Right bank shape

WATERCOURSE INFORMATION	
Watercourse ID:	**ARN-4**
General Site Location:	Windsor
Watercourse Assessor(s):	CB, BR
Affiliation:	CBCL Limited
Field Assessment Date:	26-Jun-18
UTM Coordinates:	E-396883 N-4975789
Datum:	NAD83 UTM 20N

HABITAT QUALITY	
Overall	Good
Spawning	Good
Rearing	Good
Overwintering	Moderate
Migration	Good
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	High

FISH OBSERVED
Yes, Species Unknown

WATER QUALITY	
Temperature (Deg. C)	15.8
pH	6.12
Conductivity (µs/cm)	24.4
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	17.1

SUBSTRATE	
% Bedrock	0
% Boulder	10
% Cobble	35
% Large gravel	35
% Small gravel	20
% Fines	0

CHANNEL MEASUREMENTS	
Channel width (m)	15.8
Wetted width (m)	11.2
Depth (m)	0.5
Pool depth (m)	0.55

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Riffle, Run, Pool
Channel depth class	Class 3: <0.5m
Islands	None
Bars	None
Pattern	Regular Meanders
Confinement	Frequently Confined, Unconfined

INSTREAM COVER	
Boulder	Moderate
Overhanging vegetation	Trace
LWD	Trace-Moderate
Undercut banks	None
Deep pool	Trace-Moderate
SWD	Trace-Moderate
Instream vegetation	Trace

RIPARIAN INFORMATION	
Crown closure %	26-50%
Bank texture	Fines
Left bank shape	Sloped, Vertical
Right bank shape	Sloped
Vegetation stage	Mature Forest

HABITAT QUALITY RATIONALE	
Spawning	This location would provide excellent spawning habitat, there is adequate substrate and acceptable flow which would ensure the eggs remain oxygenated.
Rearing	This location has an abundance of habitat features (boulders, woody debris and deep pools) that would provide cover for juvenile fish.
Overwintering	Overwintering freeze potential is low as deep pools are present and there is adequate depth and flow.
Migration	There are no blockages present at this location, use for migration of fish species is likely.
Foraging	A variety of invertebrates were present at this location, which would provide excellent foraging habitat.

INVERTEBRATES		
#	**Order**	**Common Name**
1	*Ephemeroptera*	Mayfly
2	*Megaloptera*	Alderfly
3	*Trichoptera*	Caddisfly
4	*Diptera*	Midge
5	*Odenata*	Dragonfly
6		

RIPARIAN VEGETATION		
#	**Species**	**Common Name**
1	*Tsuga canadensis*	Eastern hemlock
2	*Osmunda cinnamomea*	Cinnamon Fern
3	*Onoclea sensibilis*	Sensitive Fern
4	*Pinus strobus*	White Pine
5	*Acer saccharum*	Sugar Maple
6	*Osmunda regalis*	Royal Fern
7		
8		
9		
10		

ADDITIONAL NOTES

Figure 1: Upstream view

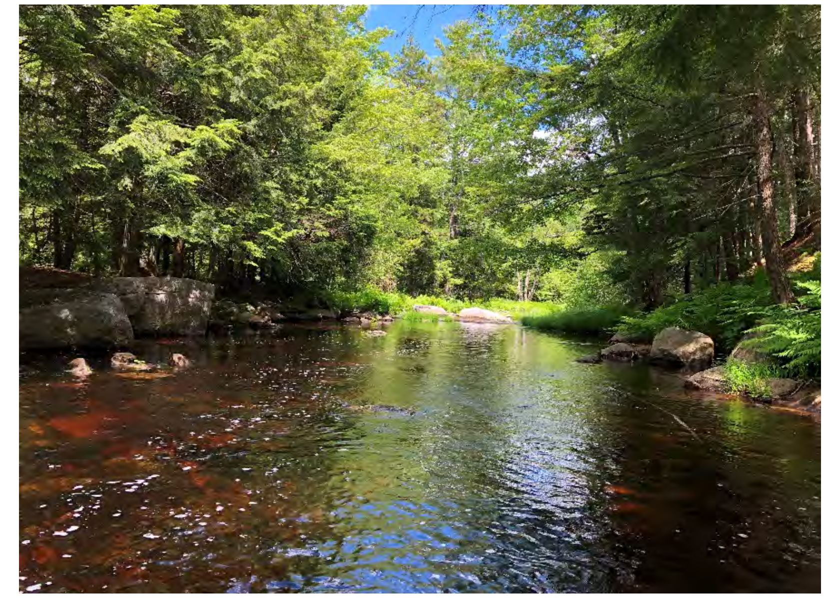


Figure 2: Downstream view

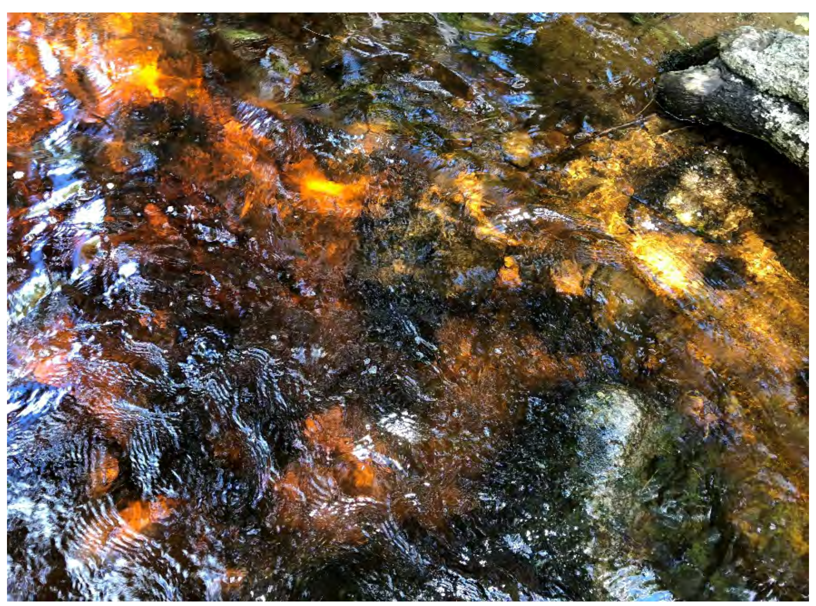


Figure 3: Substrate

Figure 4: Right bank shape

WATERCOURSE INFORMATION	
Watercourse ID:	**ARN-5**
General Site Location:	Windsor
Watercourse Assessor(s):	CB, BR
Affiliation:	CBCL Limited
Field Assessment Date:	26-Jun-18
UTM Coordinates:	E-399228 N-4977183
Datum:	NAD83 UTM 20N

HABITAT QUALITY	
Overall	Moderate-Good
Spawning	Poor
Rearing	Moderate-Good
Overwintering	Good
Migration	Good
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	High

FISH OBSERVED
No

WATER QUALITY	
Temperature (Deg. C)	15.8
pH	6.5
Conductivity (µs/cm)	24.6
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	17.4

SUBSTRATE	
% Bedrock	0
% Boulder	50
% Cobble	40
% Large gravel	10
% Small gravel	0
% Fines	0

CHANNEL MEASUREMENTS	
Channel width (m)	21
Wetted width (m)	16.2
Depth (m)	0.8
Pool depth (m)	> 1.0

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Riffle, Run, Pool
Channel depth class	Class 2: 0.5-1.0m
Islands	Occasional
Bars	None
Pattern	Regular Meanders
Confinement	Occasionally Confined

INSTREAM COVER	
Boulder	Abundant
Overhanging vegetation	Trace-Moderate
LWD	Trace
Undercut banks	None
Deep pool	Abundant
SWD	Trace
Instream vegetation	Trace

RIPARIAN INFORMATION	
Crown closure %	1-25%
Bank texture	Fines, Boulders
Left bank shape	Sloped
Right bank shape	Sloped
Vegetation stage	Young Forest, Mature Forest

HABITAT QUALITY RATIONALE	
Spawning	This location would provide poor spawning habitat as there is insufficient substrate, there are to many boulders present.
Rearing	This location has an abundance of habitat features (boulders, woody debris and deep pools) that would provide cover for juvenile fish.
Overwintering	This location would provide excellent overwintering habitat, there is adequate flow and depth, as well as an abundance of deep pools.
Migration	This location would serve as migration habitat, there are no major blockages and there is suitable fish habitat upstream.
Foraging	Foraging habitat was considered to be good at this site.

INVERTEBRATES

#	**Order**	**Common Name**
1		
2		
3		
4		
5		
6		

RIPARIAN VEGETATION

#	**Species**	**Common Name**
1	*Alnus incana*	Speckled Alder
2	*Picea glauca*	White Spruce
3	*Osmunda regalis*	Royal Fern
4	*Pinus strobus*	White Pine
5	*Acer saccharum*	Sugar Maple
6		
7		
8		
9		
10		

ADDITIONAL NOTES

Invertebrates were not sampled at this location as there was a no trespassing sign present in the area that needed to be accessed. In addition, the majority of rocks were large boulders that were hard to lift.

Figure 1: Upstream view

Figure 2: Downstream view

Figure 3: Substrate

Figure 4: Right bank shape

WATERCOURSE INFORMATION		
Watercourse ID:	**ARS-6**	
General Site Location:	Windsor	
Watercourse Assessor(s):	CB, BR	
Affiliation:	CBCL Limited	
Field Assessment Date:	27-Jun-18	
UTM Coordinates:	E-404233	N-4971175
Datum:	NAD83 UTM 20N	

HABITAT QUALITY	
Overall	Moderate-Good
Spawning	Moderate-Good
Rearing	Moderate-Good
Overwintering	Moderate-Good
Migration	Moderate
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	High

FISH OBSERVED
Yes, Species Unknown

WATER QUALITY	
Temperature (Deg. C)	16.1
pH	6.7
Conductivity (µs/cm)	43.7
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	30.7

SUBSTRATE	
% Bedrock	0
% Boulder	10
% Cobble	30
% Large gravel	25
% Small gravel	25
% Fines	10

CHANNEL MEASUREMENTS	
Channel width (m)	12.6
Wetted width (m)	8.7
Depth (m)	0.32
Pool depth (m)	0.70

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Riffle, Run, Pool
Channel depth class	Class 3: <0.5 m
Islands	None
Bars	None
Pattern	Straight
Confinement	None

INSTREAM COVER	
Boulder	Trace-Moderate
Overhanging vegetation	Trace
LWD	Trace
Undercut banks	None
Deep pool	Trace-Moderate
SWD	Trace
Instream vegetation	Moderate

RIPARIAN INFORMATION	
Crown closure %	51-75%
Bank texture	Cobble, Gravels, Fines
Left bank shape	Sloped
Right bank shape	Sloped
Vegetation stage	Mature Forest

HABITAT QUALITY RATIONALE	
Spawning	Adequate substrate and flow for spawning were presenet at this location.
Rearing	The flow at this location was sufficient for juvenilles, there was also cover in the form of instream vegetation, boulders and deep pools.
Overwintering	There is adequate flow and a trace of deep pools in this location which has the potential to provide overwintering habitat.
Migration	Migration for salmonids into the site for spawning is good as there are no major blockages downstream. Migration upstream is considerd poor as there is a known blockage (Mill Dam).
Foraging	A variety of invertebrates were noted at this location which would provide excellent foraging habitat.

INVERTEBRATES		
#	**Order**	**Common Name**
1	*Ephemeroptera*	Mayfly
2	*Diptera*	Midge
3	*Trichoptera*	Caddisfly
4		
5		
6		

RIPARIAN VEGETATION		
#	**Species**	**Common Name**
1	*Betula papyrifera*	White Birch
2	*Acer rubrum*	Red Maple
3	*Pinus strobus*	White Pine
4		
5		
6		
7		
8		
9		
10		

ADDITIONAL NOTES


Figure 1: Upstream view


Figure 2: Downstream view


Figure 3: Substrate


Figure 4: Right bank shape

WATERCOURSE INFORMATION		
Watercourse ID:	**ARS-7**	
General Site Location:	Windsor	
Watercourse Assessor(s):	CB, BR	
Affiliation:	CBCL Limited	
Field Assessment Date:	27-Jun-18	
UTM Coordinates:	E-404810	N-4973107
Datum:	NAD83 UTM 20N	

HABITAT QUALITY	
Overall	Moderate
Spawning	Poor-Moderate
Rearing	Moderate-Good
Overwintering	Moderate
Migration	Moderate
Foraging	Good

BARRIERS
No Barriers

POTENTIAL FOR FISH PRESENCE	
Open Water	High
Winter (Frozen)	High

FISH OBSERVED
No

WATER QUALITY	
Temperature (Deg. C)	16.1
pH	6.7
Conductivity (µs/cm)	43.7
Salinity (mg/L)	0.0
Total Dissolved Solids (ppm)	30.7

SUBSTRATE	
% Bedrock	0
% Boulder	40
% Cobble	30
% Large gravel	15
% Small gravel	15
% Fines	0

CHANNEL MEASUREMENTS	
Channel width (m)	18.2
Wetted width (m)	13.2
Depth (m)	0.45
Pool depth (m)	-

WATERCOURSE MORPHOLOGY	
Watercourse type	Large Permanent
Stage	Mid
Morphology (assumed in dry areas)	Flat
Channel depth class	Class 3: <0.5 m
Islands	None
Bars	None
Pattern	Straight
Confinement	None

INSTREAM COVER	
Boulder	Abundant
Overhanging vegetation	Trace
LWD	None
Undercut banks	None
Deep pool	Trace-Moderate
SWD	Trace
Instream vegetation	Moderate

RIPARIAN INFORMATION	
Crown closure %	26-50%
Bank texture	Cobble, Boulder, Fines
Left bank shape	Sloped
Right bank shape	Sloped
Vegetation stage	Mature Forest

HABITAT QUALITY RATIONALE	
Spawning	There are some cobbles and gravels present which is ideal for spawning, however there is also a large proportion of boulders which is not suitable.
Rearing	Boulders could provide cover for juvenile fish and flow is adequate for young.
Overwintering	There is sufficient flow and depth in this location, there is also a trace-moderate amounts of deep pools.
Migration	Migration for salmonids into the site for spawning is good as there are no major blockages downstream. Migration upstream is considered poor as there is a known blockage (Mill Dam).
Foraging	A variety of invertebrates were noted at this location which would provide excellent foraging habitat.

INVERTEBRATES		
#	**Order**	**Common Name**
1	*Ephemeroptera*	Mayfly
2	*Diptera*	Midge
3	*Trichoptera*	Caddisfly
4		Crustacean
5		
6		

RIPARIAN VEGETATION		
#	**Species**	**Common Name**
1	*Tsuga canadensis*	Eastern Hemlock
2	*Acer rubrum*	Red Maple
3	*Fagus grandifolia*	American Beech
4		
5		
6		
7		
8		
9		
10		

ADDITIONAL NOTES

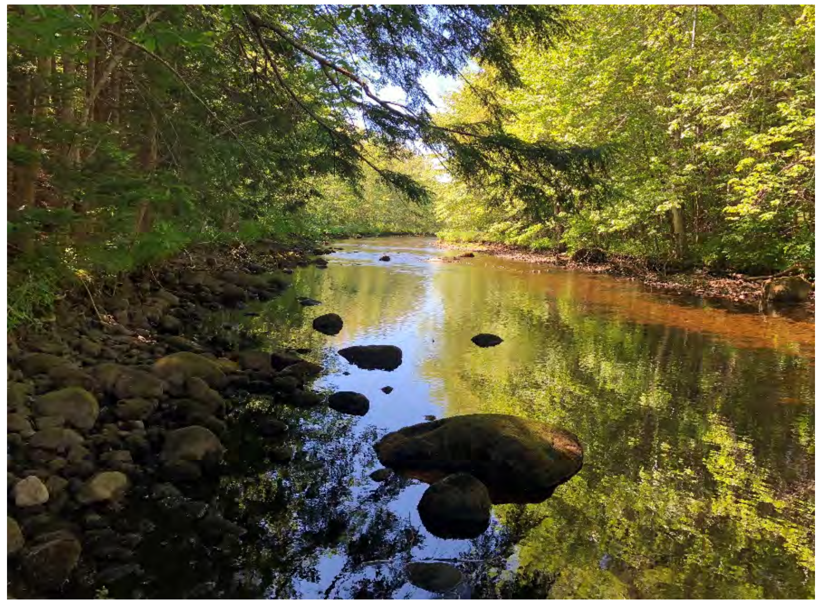


Figure 1: Upstream view

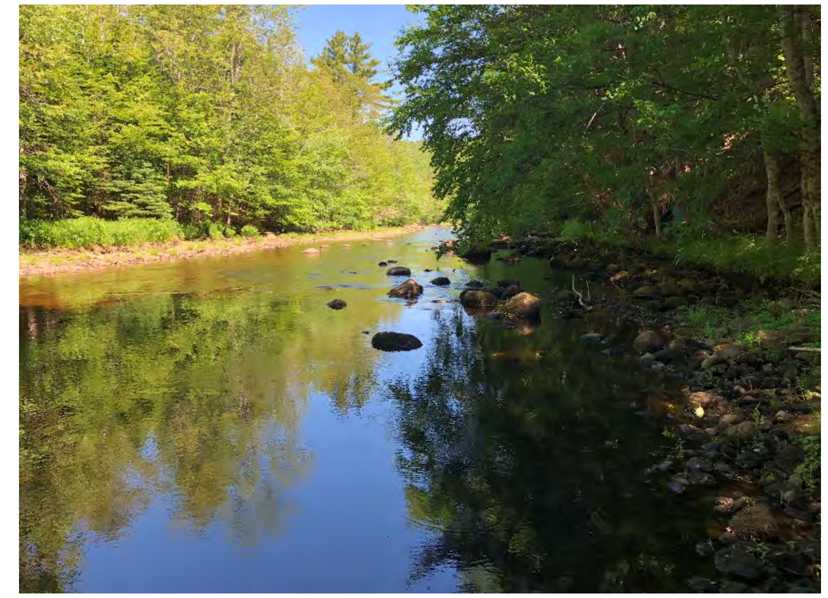


Figure 2: Downstream view

Figure 3: Substrate

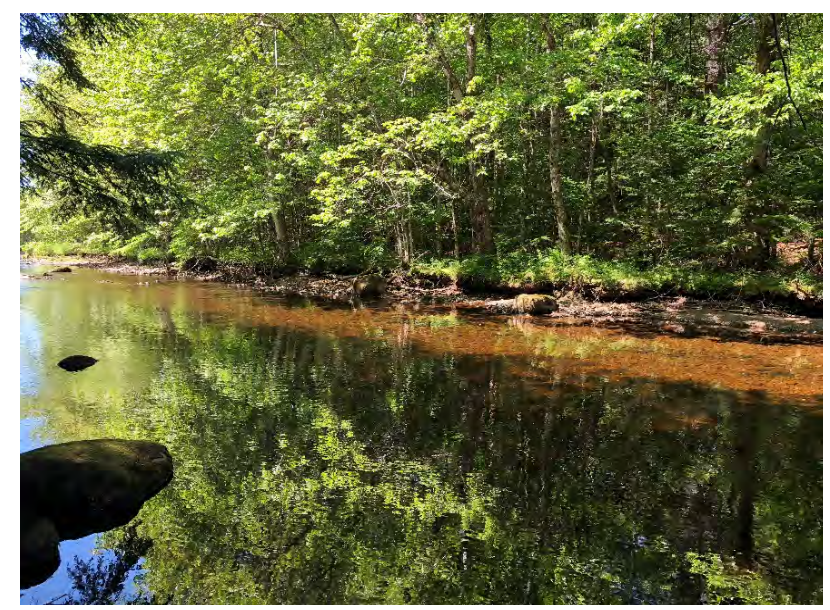


Figure 4: Right bank shape

APPENDIX E

Bob Rutherford Fish Passage Information Table

Common Name	Scientific Name	Marine/ FW	Need to pass causeway to complete life cycle	Habitat	Passage requirements. Preferred migration velocity (PMV) Pool head difference max. (PHDM)	Potential for passage and issues	Opening sizes
Alewife Blueback Herring	Alosa pseudoharengus Alosa aestivalis	Marine but Spawn in FW; migrate in spring; adults leave after spawning ; young leave Aug to Sept	yes	Spawn in FW lakes. Salinity tolerance low in eggs and early larvae. Habitat lakes as stillwater along the river on north branch approx. popln 1,200,000 plus the Pisiquid lake if fully fresh water of 402,000 fish. The south branch has habitat only if it has fish passage at the power houses approx. popln would be 7,000,000. This is currently blocked by NSP dams.	Known. PMV 0.60 m/sec to 0.75m/sec PHDM 0.20m	Need light and visibility in built fishways. Sediment is an issue here for visibility so need a fishway approaching natural river design. Downstream juveniles do best with consistent downstream flow though head ponds	Schooling fish wide enough for schools best >45cm Vertical circulation needed not horizontal flows in pools
American Eel	Anguilla rostrata	Elvers run in the spring could live in brackish, marine or FW Freshwater adults move downstream to spawn at sea	yes	Live in all river habitats FW and estuary Avon habitat is good for eels Elvers travel near surface adults on bottom which is an issue for their downstream migration	Known for elvers and adults PVM elvers use a skim of water over rough surface. Adults downstream around 0.60m/sec consistent flow preferred at bottom PHDM elvers on roughened surfaces up to 3:1 slope	Text book Elver fishway structures would be hard/ impossible to design here and maintain with the sediment. Best to use textured surface or Denil type baffled section. Adults travel along the bottom so need suitable slope up to outlet or bottom outlet.	Small
American Shad	Alosa sapidissima	Marine but FW spawners in spring; adults leave after spawning young leave in summer	yes	Spawning in slow moving FW Under the right upper lake conditions shad ther is spawning habitat	Known PVM PHDM	Do not deal with turbulence well tend to panic -- need deep smooth flows ie drowned weirs in fishways	Openings Min 0.40m wide Use natural channel design numbers below for velocities Like a smooth laminar flow. Sunken weirs on pool and weir fishways Vertical circulation needed not horizontal flows in pools
Atlantic Salmon	Salmo salar	Marine as adults; migrate mainly in spring and fall but also in summer too; spawners may leave after fall spawning but may stay till spring; young live in FW for 2 to 3 years move out as smolts in the spring	yes	FW spawning Head of riffle/tail of pool typical cobble gravel watercourse reaches. Avon has habitat below the power dams on the south branch but it lacks needed pool riffle structure for spawning and rearing water depth as it is all shallow run. Would need restoration and suitable flow patterns established. North branch has some potential spawning habitat in the lower reaches the rest is good rearing habitat being cascade and run. Spawning habitat limited.	Known PVM grilse 0.60m/sec to 1m/sec Adults and multi sea year up to 1.5m/sec PHDM 0.30m	Follow flows in migration range for common designs. Fish passage good in typical fishway if the right size pools.	Varies with size of the fish 0.03 for grilse and adults but multi sea year 0.40 or more. Would use all standard fishway types.
Atlantic Silverside	Menidia menidia	Marine/ brackish	no But may need to if upper side brackish	marine and spawn in brackish water	Not Known PVM PHDM	Assume design criteria based on body form and length but behaviour not known –schooling fish	
Atlantic Sturgeon	Acipenser oxyrinchus	Marine/ brackish/ some times in freshwater	no	Feeding runs Use of a restored estuary limited as it would be fresh to marine salt depending on river flow and tide.	Not well Known PVM PHDM	Assume based on body form and length -- travel on the bottom so need suitable slope to follow up. Behaviour not known but individuals migrate.	Use natural channel design numbers
Atlantic Tomcod	Microgadus tomcod	Marine / fw spawning	yes	Spawn head of tide late Jan into Feb suitable hard bottom habitats may be available in the lower reaches of both branches and tributaries. Eggs and larvae slat tolerant and need to move to brackish water soon after hatch.	Not well Known PVM PHDM	Assume based on body form and length but behaviour not known -- some info	Use natural channel design numbers

Common Name	Scientific Name	Marine/ FW	Need to pass causeway to complete life cycle	Habitat	Passage requirements. Preferred migration velocity (PMV) Pool head difference max. (PHDM)	Potential for passage and issues	Opening sizes
Banded Killifish	Fundulus diaphanus	FW	no	May go to brackish water but mainly FW spawn in FW	Not Known PVM PHDM	Fish passage not known – base on body form – behaviour not known	
Brook Trout	Salvelinus fontinalis	Sea run marine	Yes sea run	May sea run so may have to pass to spawnin in freshwater Migrate as adults mainly summer and winter but undertake feeding runs following other spawning fish. Often move in and out several times a year	Known PVM 0.30m/sec to 0.45m/sec PHDM up to 0.30 but better at lower drops	Fish passage well known	Min width 0.30m depth size dependant usually use 0.20m
Dogfish (Atlantic Pop.)	Squalus acouldthias	marine	No	May be feeding runs	Not Known PVM PHDM	Would come in with Salt water option	
Fourspine Stickleback	Apeltes quadracus	Brackish	yes	They are a brackish popl'n all spawn in FW Avon habitat	Not Known PVM PHDM	Assume based on body form and length but behaviour not known	
Lake Chub	Couesius plumbeus	Fw	no	Fw popl'n Have anadromous brackish popl'n Not known here	Not Known PVM PHDM	Assume based on body form and length but behaviour not known	
Mummichog	Fundulus heteroclitus	marine	no	Marine spawn in mussel shells. Although there are a few in FW -- popln not in Avon	Not Known PVM PHDM	Assume based on body form and length but behaviour not known	
Ninespine Stickleback	Pungitius pungitius	Depends on popl'n	yes	Could live in marine , brackish or FW spawns in FW Avon popln	Not Known PVM PHDM	Assume based on body form and length but behaviour not known	
Northern Redbelly Dace	Phoxinus eos	Fw	no	FW only	Not Known PVM PHDM	N/A	
Rainbow Smelt	Osmerus mordax	Marine fw spawning	yes	Anadromous Avon habitat early spring run spawning habitat in lower reaches of both branches on hard bottom	Known PVM PHDM	Criteria set but needs some modification --criteria to be considered max levels.	0.15m drops max
Smallmouth Bass	Micropterus dolomieu	Fw	no	FW fish -- lakes mainly but also streams -- Lake spawners not a natural species here	Not clear Known PVM PHDM		
Smooth Flounder	Liopsetta putnami	marine	no	Marine only	Not Known PVM PHDM	On the bottom – salt water option only	
Striped Bass (Bay of Fundy Pop.)	Morone saxatilis	Marine & estuary	Marine move to brackish for spawning	Right now no; just feeding runs no habitat for spawning - spawn in low salinity water and tidal and river flows have to keep eggs and larvae in 1.5 to 15 ppt salinity	Not Known PVM PHDM	Strong swimmers –need to look at size requirements – is there spawning habitat or just feeding. Stay low in the system.	Use natural channel design numbers
Threespine Stickleback	Gasterosteus aculeatus	Marine / FW Depends on popl"n	yes	Could live in marine , brackish or FW -- spawns in FW Avon habitat	Not Known PVM PHDM	Assume based on body form and length but behaviour not known	
White Perch	Morone americoulda	Depends on popl'n	possibly	Live in FW low salinity water -- spawn in FW or brackish water do not have to pass	Not Known PVM PHDM	Expect success the same as smallmouth bass which 60% passage in v-slot 15cm drops	
White Sucker	Catostomus commersonii	Fw	no	FW	Known PVM PHDM	Generally use std pool and weir alewife fishways quite well – only 30% in v slot with 15cm drops	
Winter Flounder	Pseudopleuronectes americouldus	marine	no	marine	Not Known PVM PHDM	Salt water option only	

Common Name	Scientific Name	Marine/ FW	Need to pass causeway to complete life cycle	Habitat	Passage requirements. Preferred migration velocity (PMV) Pool head difference max. (PHDM)	Potential for passage and issues	Opening sizes
Yellow Perch	Perca flavescens	FW	no	Fresh water but can enter low salinity water.	Known PVM PHDM	Generally use std alewife fishways well. But Assume based on body form and length but behaviour not known	


CBCL LIMITED
Consulting Engineers
www.CBCL.ca
Nova Scotia: Halifax, Sydney
Prince Edward Island: Charlottetown
New Brunswick: Saint John, Fredericton, Moncton
Newfoundland & Labrador: St. John's, Happy Valley-Goose Bay
Ontario: Ottawa