Appendix H.1

Fish and Fish Habitat Baseline Report - Part 1 of 5

Goldboro Gold Project-
Fish and Fish Habitat
2020-2021 Baseline Report

PREPARED FOR

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March 21, 2022

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EXECUTIVE SUMMARY

Anaconda Mining Inc. is proposing to develop the Goldboro Gold Mine Project in Goldboro, Guysborough County, Nova Scotia. This Baseline Fish and Fish Habitat Technical Report was prepared as background information in support of a provincial Environmental Assessment Registration Document (EARD) with Nova Scotia Environment.

Fish and fish habitat surveys have been completed with the key objectives of facilitating avoidance of fish habitat where practicable, understanding the potential project interactions with fish and fish habitat, and to support fish and fish habitat regulatory applications. This is achieved by completing a review of background desktop resources in combination with field studies to identify potential environmental constraints and sensitivities. This report outlines the methods and results of field evaluations completed within an expanded Project Area in 2021. A separate report has been prepared for all baseline fish and fish habitat work completed between 2017-2019 ("2017-2019 Baseline Report", Appendix F).

The 2020 field program involved four main tasks within the Project Area, including:

- a continuation of seasonal high flow trapping and barrier assessment of WC9 from Fall 2019,
- three rounds of fish sampling (i.e., electrofishing and trapping) within selected watercourses and waterbodies,
- detailed fish habitat characterization and quantification of watercourses predicted to be directly and indirectly affected by Project development, and,
- a continuation of baseline field delineation of watercourses and wetlands within the unmapped portions of the expanded Project Area.

The 2021 field program involved five tasks within the PA:

- Three rounds of fish sampling (electrofishing and trapping) within watercourses and waterbodies predicted to be directly affected, indirectly affected, and within reference sites unlikely to be impacted by Project development (Summer 2021);
- Detailed fish habitat characterization and quantification of watercourses and waterbodies predicted to be directly and indirectly affected by Project development (Summer 2021);
- Continuation of baseline field delineation of watercourses and wetlands within an expanded PA (throughout 2021);
- eDNA sampling (Fall 2021); and,
- Benthic sampling (Fall 2021).

Water quality measurements were recorded in-situ during fish and fish habitat surveys. Throughout the Project Area, recorded summer temperatures ranged from 11.7°C to 28.3°C in 2020 and in 2021 temperatures ranged from 10.3°C to 25.8°C. Temperatures within smaller, first and second order streams remained within the suitable temperature range for cold-water species, including salmonids, throughout the summer, whereas temperatures measured within larger watercourses and waterbodies regularly measured above suitable range for cold-water fish species. The pH range for aquatic features sampled within the PA was 3.89 to 7.71, with an average pH of 4.97. Only two sampling sites (WC1 and WC3) exhibited pH levels within CCME recommended range for freshwater aquatic life (6.5-9). About two thirds of the measurements recorded in-situ during fishing efforts and habitat assessment exhibited pH levels so low (<5.0) as to expect to cause harm to the eggs and fry of salmonid species (CCREM, 1987). More than 75% of dissolved oxygen (DO) levels recorded across aquatic features within the Project Area were below the minimum CCME recommended concentration of DO for early life stages of cold-water fishes, while 27% were below levels suitable for any life stage of cold or warm-water fishes (CCME, 1999). Low DO levels were measured throughout watercourses during detailed habitat assessments conducted in mid-August. Overall, low pH levels, elevated summer temperatures, and low DO concentrations limit fish habitat quality within select systems.

Benthic invertebrate community sampling was completed within Gold Brook (3 locations) and Gold Brook Lake (1 location) in October of 2021. Within lotic systems, benthic communities had a low to high diversity of organisms (12 – 26 taxa per sample); and low to high abundances (770 – 12,463 individuals per metre squared). Within Gold Brook Lake, communities had a low to low/moderate diversity of organisms (3 – 11 taxa per sample); and low to high abundances (301 – 7,568 individuals per metre squared).

Environmental DNA (eDNA) sampling was conducted at four locations within the PA, and at a fifth location outside of the PA. eDNA samples were collected for two main purposes. First, to identify whether fish (of any species at all) are present within the historic settling ponds using the eFish primer developed by BV laboratory. The second purpose of eDNA sampling is to use another method to understand potential distribution of Atlantic salmon within the Gold Brook shore direct watershed (1EQ-SD31). Atlantic salmon are expected to occur in the eastern adjacent New Harbour watershed (1EQ-4), but the species is not believed to occur within the watershed containing Gold Brook Lake and Gold Brook. Samples were collected within 3 locations in the 1EQ-SD31 watershed, with a fourth sample location within the 1EQ-4 watershed. Analysis of these samples confirm detection of fish DNA in the historic settling ponds. Atlantic salmon DNA was not detected in the three samples collected within the PA; however it was detected in the samples collected in the adjacent New Harbour watershed.

During the 2019-2021 field program, a total of six species and 1817 individual fish were captured within the Project Area, including yellow perch, American eel, brook trout, golden shiner, banded killifish, and blacknose shiner. While not identified through dedicated fishing surveys, ninespine stickleback are expected to be present within the Project Area based on fish studies conducted for the Goldboro LNG project (AMEC, 2006).

Detailed fish habitat surveys within selected watercourses were conducted using standard methodologies to gather key measurements such as reach length (m), reach wetted and bankfull width (m), reach slope (%), stream substrate composition (% composition), water depths (m), water velocities (m/s), cover (%), and riparian habitat per habitat unit. The data was used to determine the overall habitat area within each reach as well as the habitat suitability based on measured stream substrate, water depths, and water velocities (habitat parameters) for each fish species identified within the Project Area. Lacustrine surveys were completed within Rocky Lake and Gold Brook Lake, where measurements of depth (m), substrate composition, cover and water quality were recorded.

During detailed habitat assessment completed in 2020, WC3 and WC4 were assessed in their entirety within the 2020 Study Area. This study area has since expanded west-ward, and the watercourses now extend 200 m and 690 m upstream of the area previously assessed (respectively). Detailed habitat assessments were not completed in this section in 2021. For the purposes of effects assessment, the physical characteristics of the measured stream below will be extrapolated to the new section upstream; and detailed habitat evaluation will occur in this reach in 2022. Detailed habitat assessments were not completed in WC16, as no indirect effects were predicted in this catchment area at the time of the assessment. WC99 was delineated in late August following completion of the detailed habitat assessments. The qualitative descriptions of each of these watercourses will be used to advise the effects assessments, and a detailed habitat evaluation is recommended during the 2022 field season.

Overall, fish habitat viability and accessibility within first and second order intermittent streams, which are the dominant stream types within the Project Area, are restricted by seasonal dryness and obstacles to fish passage. These features predominantly provide potential suitable habitat for juvenile and adult life forms of American eel and brook trout, with other species confirmed or potentially residing in the Project Area restricted to low velocity areas with a direct connection to Gold Brook or Gold Brook Lake. No suitable spawning habitat for brook trout was found within any of the assessed watercourses.

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1.0 INTRODUCTION

The Goldboro Gold Project (the Project) is located approximately 175 kilometres (km) northeast of Halifax, 60 km southeast of Antigonish, and 1.6 km northeast of the community of Goldboro on the eastern shore of Isaac's Harbour, in Guysborough County, Nova Scotia, Canada. Anaconda Mining Inc. (Anaconda) proposes to develop the Project as a 4,000-tonne per day (tpd) mine and processing facility. For the purposes of this environmental assessment, a Project Area (PA) was defined as the footprint of Project related infrastructure plus a buffer of 100 – 200 m. The mine plan includes two surface extraction areas (open pits), an ore processing facility, a tailings management facility (TMF), three waste rock storage areas (WRSAs), overburden and organic stockpiles, support buildings including an employee accommodation building, and associated infrastructure. The anticipated mine life for extraction of ore is approximately 11 years.

The scope of the Project includes activities associated with construction, operation, and closure. Project construction activities will include clearing and grubbing the overburden and organic stockpiles, WRSAs, pit, plant, and TMF areas, and construction of the initial lift of the TMF, plant site, secondary access roads, construction laydowns, Run-of-Mine (ROM) pad, surface water management and other site infrastructure. The operation phase will include conventional ore extraction methods (drilling, blasting, loading, and hauling), ore processing, and waste management. ROM ore will go directly to the crusher while stockpiled high-grade and low-grade ore will be progressively processed throughout the mine life. Non-ore bearing waste rock, not used for construction or backfill, will be stockpiled at its final disposal point, managed and reclaimed in place. The closure phase will include earthworks and demolition required to return the Project Area to a safe, stable, and vegetated state, and all monitoring and treatment, if required.

The site contains a mixture of habitat types, including intact natural forests and wetlands, and anthropogenic disturbance from historic mining activities, road construction and timber harvesting. The region is known for its historic gold deposits and about half of the parcel is currently under mineral exploration licenses including the known Goldboro (Upper Seal Harbour), Isaacs Harbour, Forest Hill, and Lower Seal Harbour deposits.

McCallum Environmental Ltd (MEL) was retained to complete fish and fish habitat surveys within and in the vicinity of the Project Area (PA) to support the preparation and submission of a provincial Environmental Assessment Registration Document (EARD) with Nova Scotia Environment and Climate Change (NSECC). Fish and fish habitat surveys have been completed with the key objectives of facilitating avoidance of fish habitat where practicable, understanding the potential project interactions with fish and fish habitat, and to support fish and fish habitat regulatory applications. This is achieved by completing a review of background desktop resources in combination with field studies to identify potential environmental constraints and sensitivities. This report outlines the methods and results of field evaluations completed within the Project Area in 2020-2021.

A separate report has been prepared for all baseline fish and fish habitat work completed between 2017-2019 ("2017-2019 Baseline Report", Appendix F). The 2017-2019 baseline report incorporates results of initial fish and fish habitat assessments, and it provides useful background information for the Project. Prior to the commencement of the 2020 field season, in response to the modernized *Fisheries Act* (amended in 2019), MEL re-evaluated the approach to fish and fish habitat assessments, and developed a more detailed scope to be implemented in aquatic habitats across the PA. This more detailed scope developed in 2020 was carried through 2021 evaluations. As a result, fish and fish habitat evaluations completed in 2020-2021 supersede the evaluations presented in the 2017-2019 baseline report.

1.1 **Project Team**

A project team consisting of aquatic ecologists proficient in fish biology and fish habitat description were selected to complete the field studies and reporting for these surveys. Team members with integral roles in the surveying, reporting and project management are listed below (**Table 1-1**).

Table 1-1. Project Team Members

Team Member	Role and Duties
Melanie MacDonald, B.Sc, ISAR & Bio, MREM	Senior Ecologist and Report Writer
Amber Stoffer, B.Sc, MREM	Aquatic Ecologist, Field Lead
Katrina Ferrari, B.Sc	Aquatic Ecologist and Report Writer
Levi Cliche	Aquatic Ecologist, Field Lead: Fish Collection
Meghan Milloy, B.Sc., M.E.S.	Vice President and Project Manager

1.1 Regulatory Context

The *Fisheries Act* defines fish as "(a) parts of fish, (b) shellfish, crustaceans, marine animals and any parts of shellfish, crustaceans or marine animals, and (c) the eggs, sperm, spawn, larvae, spat and juvenile stages of fish, shellfish, crustaceans and marine animals;", and fish habitat as "waters frequented by fish and any other areas on which fish depend directly or indirectly to carry out their life processes, including spawning grounds and nursery, rearing, food supply and migration areas".

Within the *Fisheries Act*, activities which result in the harmful alteration, disruption or destruction (HADD) of fish habitat are prohibited. Under Section 35(2) of the *Act,* authorization may be granted for a proposed work, undertaking or activity that may, respectively, result in the death of fish or the harmful alteration, disruption or destruction of fish habitat.

Section 36(3) of the *Fisheries Act* prohibit the deposition of deleterious substances into waters frequented by fish. Waters frequented by fish means all Canadian waters such as rivers, lakes, creeks, canals and other water bodies. According to the Government of Canada (2020), "if fish use the water, even if only annually for a short period, then such water qualifies as 'waters frequented by fish'". Under the Mineral and Diamond Mining Effluent Regulations (MDMER), a project may obtain permission to deposit deleterious substances (such as mine waste) in waters frequented by fish, upon approval and addition of the waters to Schedule 2 of the MDMER.

Throughout this report, fish habitat is described in the context of watercourses. The Nova Scotia *Environment Act* defines a watercourse as:

(i) the bed and shore of every river, stream, lake, creek, pond, spring, lagoon or other natural body of water, and the water therein, within the jurisdiction of the Province, whether it contains water or not; and,

(ii) all groundwater.

While groundwater is included in the regulatory definition of a watercourse under the Environment Act, this report focuses on surface water features in the context of fish habitat provision. In addition to the above-mentioned definition and in accordance with the Guide to Altering Watercourses (NSE, 2015), the watercourse parameters listed in this document were used to aid in determining the presence of a watercourse. This guide indicates that at least two of the following characteristics are needed to be present for a water feature to be determined a watercourse:

- Presence of mineral soil channel;
- Sand, gravel and/or cobbles evident in a continuous pattern over a continuous length with no vegetation;
- Indication of water flowing in a path sufficient to erode a channel/pathway;
- Presence of pools, riffles and/or rapids; and,
- Presence of aquatic animals and plants.

Using this guidance, watercourses have been identified and described throughout the PA to support the description of fish habitat.

1.2 Project Area

The Project Area (PA) for the proposed Goldboro Gold Project is located in Goldboro, Guysborough County. The Project is centered at coordinates 5007200 mN, 606900 mE (UTM Zone 20 NAD83), approximately 2.5 km northeast of Goldboro on the Atlantic coastline. Since the completion of the 2017-2019 baseline field programs, the PA for the Project has been expanded to accommodate revisions to infrastructure layouts in 2020 and 2021. Throughout this report, the PA refers to the current 2021 EARD PA; however, it is acknowledged that fish and fish habitat work completed in 2020 was completed under a smaller 2020 Project Area (Figure 1, Appendix A).

A separate report has been prepared for all baseline fish and fish habitat work completed between 2017-2019 (Appendix F). The methods used in the 2017-2019 baseline report were based on a now outdated *Fisheries Act*, therefore the 2020-2021 fish and fish habitat evaluation supersede works completed in previous years. For the purpose of fish habitat assessments and the analysis of the Project's potential indirect impacts to fish habitat, a Fish Habitat Project Area was established. This encompasses the entirety of the 2021 EARD PA, with a southern extension 1 km in length along the main channel of Gold Brook (Figure 1, Appendix A).

The EARD PA is located on approximately 1055 ha of both crown and private property. In general, the Site is primarily disturbed by historical and current mining activities, and timber harvesting. Soils are generally nutrient poor and acidic, supporting softwood stand types such as spruce and balsam fir. Herbaceous layers are often dominated by ericaceous shrubs and bryophytes such as Schreber's moss, representing nutrient poor soils. Areas located in the southern portion of the Project Area and in close proximity to Gold Brook generally consist of mature undisturbed conifer dominant stands.

The Goldboro area was an active and productive mining area from 1893 to 1910. Between 1912 and 1981, intermittent work was conducted on the property, with modern exploration beginning in 1981. Four locations are known to have been used for tailings disposal during historic mining operations, none of which were contained or remediated. Tailings migrated from the streams and wetlands where they were deposited into the downstream receiving environment (Gold Brook) and are likely to present a continuing threat to fisheries resources. Other areas that may be subject to continued effects from historic activities include the old mill sites and unidentified waste rock and ore storage sites (Anaconda Mining Inc, 2018).

1.2.1 Watersheds

The PA is predominantly found within the New Harbour/Salmon Primary watershed (1EQ), and the secondary shore direct watershed (1EQ-SD31, herein referred to as the "Gold Brook secondary watershed") (Figure 1, Appendix A). The topography gently slopes towards Gold Brook Lake, and, as the lake empties into the Gold Brook system, the landscape flattens further into a low-relief valley. Elevation within the PA ranges from 42-95 meters above sea level. This watershed has a total surface area of 4,003 ha, extending from Oak Hill Lake in the north to Drum Head in the south.

Gold Brook Lake is the predominant feature within the Gold Brook secondary watershed. It collects flow from Oak Hill Lake in the north and Rocky Lakes in the east. Gold Brook flows out of Gold Brook Lake, into Seal Harbour Lake, which has two main mapped outlets. East Brook and West Brook both flow into Warringtons Cove and Long Cove, respectively, approximately 7 km southwest of the outlet of Gold Brook Lake. Crane Lake, Hay Lake, Rush Lake and Three Corner Lake are present within the watershed as well. The watershed is largely undeveloped, and in natural condition, with the exception of timber harvesting, historic mining activity within the PA, and the decommissioned Sable Offshore Energy facility, which is present south of the PA, west of the confluence of Gold Brook into Seal Harbour Lake.

The Country Harbour Primary Watershed (1EP) hugs the western edge of the PA, which is further subdivided by two secondary watersheds: a shore direct watershed (1EP-SD1, herein referred to as the "Isaacs Harbour secondary watershed") and the Isaacs Harbour River secondary watershed (1EP-1).

Approximately 17 ha of the northwestern edge of the PA falls within the Isaacs Harbour River secondary watershed (1EP-1). This watershed has a total surface area of 7,824 ha, which extends south through Isaacs Harbour River and Meadow Lake to Isaacs Harbour at Route 332. The upper watershed includes several second and third order streams, and contains more than a dozen lakes, wetlands, and tributaries. Its lower reach is more linear and has a single point discharge to the ocean at Isaacs Harbour via Meadow Lake and the Isaac's Harbour River. Meadow Lake, located near the bottom of the watershed, is the largest lake present in the watershed encompassing an area of roughly 104 ha.

The southwestern corner of the PA (85 ha) falls within the Isaacs Harbour secondary watershed (1EP-SD1). This shore direct watershed encompasses 697 ha along the eastern shoreline of Isaacs Harbour. Water is directed southwest down a relatively steep gradient towards Isaacs Harbour via a number of unnamed topographically mapped channels. The watershed does not contain any named watercourses or waterbodies. Secondary watersheds that overlay the PA are shown on Figure 1, Appendix A. Field delineated wetlands and watercourses are shown on Figure 2, Appendix A.

1.2.2 Desktop Evaluation of Fish and Fish Habitat

MEL reviewed the Nova Scotia Freshwater Fish Species Distribution Records (NSDFA, 2022) for records of fish species. None of the waterbodies located within the Gold Brook secondary watershed have records in this database. The proposed Goldboro LNG facility is located within the Gold Brook secondary watershed, south of the PA. According to Pieridae Energy (2013), brook trout, American eel, stickleback (threespine, fourspine and ninespine), banded killifish and mummichog have been documented within the watershed. Field studies conducted from 2017-2021 for the Project have confirmed the following species as present within the PA:

- American eel
- banded killifish
- blacknose shiner
- brook trout
- golden shiner
- yellow perch

Atlantic salmon (Nova Scotia Southern Uplands population) were not observed within the PA during 2017-2019 or 2020-2021 field studies. The waterbodies and watercourses within the Gold Brook secondary watershed (1EQ-SD31) have not been identified to presently or historically support Southern Upland (SU) Atlantic salmon (ASF, 2019), nor are there any documented catches within these systems.

Regionwide SU electrofishing surveys for juvenile salmon conducted by DFO recorded Atlantic salmon presence in Isaacs Harbour River during surveys conducted in 2000, but none during 2008/2009 surveys (Gibson et al., 2011). In addition, fish collection completed in Meadow Lake (watershed 1EP-1) for the Goldboro LNG Project recorded one adult male Atlantic salmon in 2001, but none during surveys conducted in 2004 and 2005 (AMEC, 2006). AMEC (2006) also reported local residents indicating low flows had precluded salmon migration into Isaacs Harbour River.

The Isaacs Harbour River secondary watershed has historically supported SU Atlantic salmon, but current abundance is expected to be extremely limited. The SU Population of Atlantic Salmon has experienced significant reductions over the last few decades, with adult abundance declining from 88% to 99% from observed abundances in the 1980s (DFO, 2013). Current adult and juvenile abundance has been assessed as critically low in most rivers, and there is strong evidence for river-specific extirpations – only 54% of rivers in the SU region were found to contain salmon in 2000 and only 38% were found to contain salmon in 2008 (Bowlby et al., 2013). The main contributing factors to these declines are considered to be degradation of freshwater habitat, acidification, and poor marine survival (Bowlby et al., 2014).

1.3 Regional Hydrometeorology

The ECCC St. Mary's River at Stillwater hydrological monitoring station was selected as the most representative regional station for hydrology at the Project, based on proximity and record length (Table 1-2).

Table 1-2: Average Monthly Discharge (ECCC, 2020)

Description	Unit	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Recorded Discharge	m^3/s	50.3	40.8	56.3	88.8	54	24.2	14.7	14.8	17.7	34.6	58	60	42.9
Unit Discharge	$L/s/km^2$	37.3	30.2	41.8	65.8	40.1	17.9	10.9	11	13.2	25.8	43.2	44.3	31.8
Runoff[1]	mm	100	73	112	170	107	46	29	29	34	69	111	119	1,002

[1]*Runoff calculated using watershed area of 1,350 km^2.*

Records from this regional hydrological station indicate that the lowest flows occur during the summer months, which coincide with less precipitation and higher potential evapotranspiration. Regional high flows occur in the late fall through early winter (November and December) and again in the spring (March-April). These data were used to identify seasonal high flows to determine fish passage and develop fish collection protocols for high flow events.

2.0 FIELD PROGRAM METHODOLOGY

This section summarizes the methods used during evaluation of fish and fish habitat in 2020-2021 at linear watercourses, waterbodies, and wetlands throughout the PA. Initial watercourse, waterbody, and wetland identification and characterization within a smaller PA was conducted from 2017-2019 through a series of field programs conducted by GEMTEC and MEL biologists (refer to the 2017-2019 Baseline Report, Appendix F). Field programs conducted between 2020-2021 were performed by teams of biologists from MEL and the Clean Annapolis River Project (CARP). *In situ* water quality parameters were recorded throughout all tasks listed below.

The 2020-2021 field program involved six tasks within the PA:

- Continuation of baseline field delineation of watercourses and wetlands within an expanded PA (2020-2021);
- Continuation of seasonal high flow trapping and barrier assessment of WC9 (spring 2020);
- Three rounds of fish sampling (electrofishing and trapping) within all watercourses and waterbodies predicted to be directly affected, indirectly affected, and within reference sites unlikely to be impacted by Project development (summer 2020-2021);
- Detailed fish habitat characterization and quantification of all watercourses predicted to be directly and indirectly affected by Project development (summer 2020-2021);
- eDNA sampling (fall 2021); and,
- Benthic invertebrate sampling (fall 2021).

2.1 Wetland and Watercourse Delineation

Watercourse identification and description, as well as wetland delineation and evaluation were completed across the PA in 2017-2021 in accordance with Nova Scotia standards for identification of watercourses and wetlands. A detailed account of wetland delineation methods and results is provided in the Goldboro Wetland Baseline Report (2022), and further detail related to initial baseline fish habitat characterization is outlined in the Fish and Fish Habitat Technical Report 2017-2019 (Appendix F). Each of these systems was evaluated for the presence of fish habitat and potential ability to support fish species during initial assessment and identification. Qualitative descriptions are provided for each watercourse identified within the PA, to provide a general description of each watercourse, and to advise further detailed fish habitat assessments and fish collection. Qualitative assessment methods varied slightly throughout the various years of fish habitat identification; however each description included a characterization of the flow regime (perennial, intermittent, ephemeral), estimate of gradient and velocity, bankfull width, average depth, and a description of substrate composition, habitat types and overall cover (submergent, emergent, overhanging, etc).

Fish habitat is described in the context of any aquatic feature which is contiguous with a fish bearing stream, whether it is located within a watercourse, wetland, waterbody, or other (i.e. wetland mosaic).

Throughout this report, this will primarily be described in the context of watercourses and lakes, however the terms ‘open water’ and ‘wetland mosaic’ will be occasionally used.

Open water features were identified as either off-line ponds or components of linear watercourses that were more accurately represented graphically by polygon files rather than lines. From a regulatory perspective, open water features are defined as watercourses by the Environment Act. Features referred to as open water habitats were typically less than 2 m depth, <8 ha in size, and had less than 50% vegetative cover following guidance from the Army Corps of Engineers wetland delineation manual (United States Army Corps of Engineers, 2009). The term wetland mosaic is used to describe habitats where a watercourse disperses widely into wetland habitat in an undefined channel within a wetland boundary. These habitats provide ephemeral or perennial fish access, depending on the contribution of flow from the associated watercourse.

The results of baseline wetland and watercourse delineation were used to inform all additional field programs; particularly detailed fish habitat evaluations and fish collection.

2.2 Water Quality

In-situ water quality measurements were recorded at all 2020-2021 electrofishing and trapping sites prior to each sampling event. In addition, water quality measurements were recorded for each watercourse reach delineated through detailed habitat assessments. These water quality measurements were collected using a calibrated YSI Multi-Probe water quality instrument (or equivalent) or a combination of a Myron Ultrapen DO Pen Probe and Hannah Combo pH/Conductivity/TDS Probe at the time of the sampling event/survey. Locations of water quality measurements coincide with fish collection locations, shown on Figure 3(a and b), Appendix A.

2.3 Benthic Invertebrate Community

Secondary productivity surveys were conducted to describe existing environmental conditions and to support fish habitat evaluations for aquatic ecosystems in the PA. These assessment areas are herein referred to as Fish Impact Areas (FIA). Each FIA was confirmed to include the following criteria:

- Reaches that best represent system characteristics (flow rate, substrate composition);
- Reaches that represent fish habitat types present within the system (riffle, run, pool); and,
- Reaches that provide optimal physical characteristics to meet the requirements of sampling methodologies.

Four FIAs were identified and sampled within the PA, comprising three lotic systems (linear watercourses) and one lentic system (Gold Brook Lake). Locations of the FIAs and sampling locations within are presented below in Table 2-1 and on Figure 3 in Appendix A.

Table 2-1: Benthic Invertebrate Community Sampling Locations and Details (2021)

FIA	Watercourse/Waterbody ID	Location ID	Location Coordinates (UTM)
1	22 (Inlet to Gold Brook Lake)	1.1	606989, 5008543
		1.2	606988, 5008541
		1.3	606987, 5008546
2	64 (Gold Brook – Outlet of Gold Brook Lake)	2.1	607086, 5006284
		2.2	607085, 5006280
		2.3	607089, 5006280
3	64 (Gold Brook – Outlet of Gold Brook Lake near end of PA)	3.1	607379, 5005219
		3.2	607378, 5005218
		3.3	607371, 5005221
4	Gold Brook Lake	4.1 (mid-depth)	606646, 5007706
		4.2 (max-depth)	607061, 5007368
		4.3 (littoral zone)	607084, 5006399

Benthic sampling was completed to support fish habitat evaluation as a baseline measurement, as biological parameters may detect impacts to the aquatic ecosystem that the physical and chemical parameters cannot, such as changes in water quantity, presence of invasive species, and habitat degradation. Benthic macroinvertebrates are common inhabitants of streams and lakes and are important in moving energy through food webs as the dominant source of secondary production. Benthic macroinvertebrates are relatively long-lived (one to three years), and therefore, can reflect cumulative impacts to aquatic ecosystem.

At each lotic FIA, three benthic community samples were collected using a 12" x 12" Surber Sampler equipped with a 500 µm Nitex Net. Sampling was conducted in shallow riffle locations when available, and habitat type (riffle, run, pool) was noted at each sampling location. Benthic invertebrates were collected in the net by disturbing the area within the 12" x 12" frame, which was placed firmly in contact with the stream bottom. Field staff stood upstream of the Surber Sampler and scrubbed rock, vegetation and woody debris within the frame area, allowing for the current to push dislodged invertebrates into the net. Once scrubbed, larger objects were removed from the frame area and the top 2-5 cm of fine substrate remaining was disturbed to complete sample collection. Sampling within lotic FIAs was conducted by MEL biologists on October 14th, 2021.

Three samples were collected in the lentic FIA 4 (Gold Brook Lake), comprising of one littoral zone sample, one mid-depth sample, and one maximum depth sample using an Eckman Dredge. Sampling within the lentic FIA was conducted by MEL biologists on October 20th, 2021. Once collected, samples were transferred to sample bags and preserved in the field using a 99% isopropyl alcohol solution. Samples were delivered to Envirosphere Consultants Ltd. in Windsor, Nova Scotia for biological analysis.

2.4 Fish Collection

2.4.1 Electrofishing

Three rounds of quantitative and qualitative electrofishing surveys were conducted between June 1st and September 30th, 2020, and June 1st and September 30th, 2021 to identify seasonal fish usage within different parts of the PA. Quantitative electrofishing sites (approximately 100m in length) were established in areas of confirmed or potential fish habitat within the PA. Site selection was based on habitats with known or expected fish presence, in watercourses with predicted direct and indirect impact, as well as reference sites (Figure 3, Appendix A). These reaches were isolated by barrier nets to meet the conditions for accurate depletion method estimates. Quantitative electrofishing methodology is further described in Section 2.4.1.1.

Qualitative electrofishing surveys were performed in aquatic features with the goal of evaluating fish species presence and to measure relative abundance (Catch Per Unit Effort, CPUE) as a function of electrofishing seconds. Qualitative electrofishing sites were established in particular aquatic features where reach isolation or depletion could not be achieved. Qualitative electrofishing methodology is further described in Section 2.4.1.2.

Electrofishing was completed using guidance from a McCallum Environmental Ltd. Standard Operating Procedure (SOP) for Fish Collection (Appendix B). The methods and data collection forms outlined in the SOP were developed using the following sources:

- A review of fish sampling methods commonly used in Canadian freshwater habitats (Portt et al., 2006)
- New Brunswick (NB) Aquatic Resources Data Warehouse, the NB Department of Natural Resources and Energy, and the NB Wildlife Council (2002, updated 2006)
- Fisheries and Oceans Canada's Interim Policy for the Use of Backpack Electrofishing Units (2003)

Fisheries and Oceans Canada's Interim Policy for the Use of Backpack Electrofishing Units (2003) was reviewed and followed by all members of the electrofishing crew. This document provides a detailed list of standard equipment, safety, training, and emergency response procedure requirements for electrofishing. Each electrofishing crew consisted of two individuals, one of which (the crew lead) was a qualified person as defined under the DFO Interim Electrofishing Policy. The crew lead is responsible for operating the backpack electrofisher according to their training and the Policy, and for communicating safety policies and electrofishing procedures to the second crew member.

Fish were sampled using a Halltech Battery Backpack Electrofisher (HT-2000) with un-pulsed direct current (DC). A crew member walked alongside the electrofisher operator to net any stunned fish using a D-frame landing net (1/8" mesh). All captured fish were held in a live well containing ambient stream water, which was kept out of the sun and fish were checked regularly for any signs of stress. At the conclusion of each pass, fish in the live well were identified (species confirmation) and the first 50 individuals of each species were measured (length and weight). After recuperating, all fish were released back into the watercourse, downstream of the isolated reach. Any fish observed within the reach but not captured were also counted on field forms, accompanied by an estimate of length. All fish captured or observed have been included in estimates of population or relative abundance.

2.4.1.1 *Quantitative Electrofishing*

The following thirteen sampling reaches were selected for quantitative electrofishing surveys in linear watercourses within the PA (Figure 3):

- WC1
- WC3
- WC4
- WC7
- WC8
- WC9 (two reaches, A and B)

- WC14
- WC20
- WC22 (reach B)
- WC43 (two reaches, A and B)
- Settling Pond Outlet (SPO1)

Quantitative electrofishing was undertaken using barrier nets (1/8” mesh) that were secured to the stream bed at either end the reach to isolate an area of habitat within each watercourse. Within each isolated reach, a minimum of three passes with the electrofisher were completed. Additional passes were completed if depletion in catch was not obtained after the first three passes. If no fish were captured after two passes, the third pass was abandoned. The number and characteristics of fish collected during each pass were recorded so that quantitative fish population estimates could be calculated. The total seconds of electrofishing effort were also recorded.

Quantitative estimates of overall fish abundance were calculated using the multiple-pass depletion method (Lockwood and Schneider, 2000). The following conditions must be met for accurate depletion method estimates:

- Emigration and immigration by fish during the sampling period must be negligible. This was accomplished by establishing a “closed” reach by installing barrier nets at both upstream and downstream ends of the electrofishing reach;
- All fish within a specified sample group must be equally vulnerable to capture during a pass;
- Vulnerability to capture of fish in a specified sample group must remain constant for each pass (e.g. fish do not become more wary of capture); and,
- Collection effort and conditions which affect collection efficiency, such as water clarity, must remain constant. To minimize error, the amount of effort used on each pass was kept as consistent as possible.

Details of quantitative electrofishing locations and survey dates are provided in Table 2-2. Electrofishing locations are shown on Figure 3, Appendix A, and representative photos of each electrofishing reach and trapping location are provided in Appendix C (Photos 11-39).

Table 2-2: Quantitative Electrofishing Locations and Details (2020-2021)

Location	**Stream Order**	**Survey Dates**	**Upstream Coordinates (UTM)**		**Downstream Coordinates (UTM)**		**Reach Length (m)[1]**
			Easting	**Northing**	**Easting**	**Northing**	
WC1	1	June 22, 2020 August 1, 2020 August 20, 2020	606709	5006148	606753	5006064	99
WC3[2]	1	June 22, 2020 July 31, 2020	606529	5006039	606588	5005967	110
WC4	1	June 23, 2020 July 29, 2020 August 23, 2020	606258	5006560	606343	5006532	89
WC7	2	June 23, 2020 July 28, 2020 August 22, 2020	606351	5006630	606389	5006556	84

Location	Stream Order	Survey Dates	Upstream Coordinates (UTM)		Downstream Coordinates (UTM)		Reach Length (m)[1]
			Easting	Northing	Easting	Northing	
WC8	2	June 26, 2020 July 27, 2020 August 19, 2020	606660	5006501	606747	5006538	96
WC9 Reach A	1	June 24, 2020 July 30, 2020 August 21, 2020	607522	5006826	607489	5006911	79
WC9 Reach B	1	June 24, 2020 July 30, 2020 August 21, 2020	607465	5007002	607470	5007065	95
WC14	1-2	June 26, 2021 July 21, 2021 August 23, 2021	607813	5007414	607734	5007445	90
WC20	2	June 24, 2021 July 24, 2021 August 27, 2021	606300	5008073	606356	5008010	100
WC22 Reach B	1	June 25, 2021 July 22, 2021 August 26, 2021	606954	5008184	606997	5008124	100
WC43 Reach A[3]	1	June 28, 2021	608139	5008208	608191	5008162	100
WC43 Reach B	1	June 27, 2021 July 25, 2021 August 28, 2021	607974	5007585	607907	5007554	100
Settling Pond Outlet (SPO1)	3	June 25, 2020 July 27, 2020 August 22, 2020	606971	5005892	606958	5005806	96

[1] Field crews attempted to establish 100 m linear sampling reaches but were often limited by site conditions and overall watercourse length.
[2]Only 2 rounds of fishing was conducted on WC3 due to dry channel conditions during Round 3.
[3]One round of quantitative electrofishing was completed in WC43; based on site conditions rounds 2 and 3 were completed using an open site setup (qualitative electrofishing)

2.4.1.2 *Qualitative Electrofishing*

The following sixteen sampling reaches were selected for qualitative electrofishing surveys in linear watercourses within the PA (Figure 3):

- WC1*
- WC2*
- WC11
- WC12
- WC13*
- WC22 (reach A)
- WC43 (reach A)
- WC49 (two reaches, A and B)*
- WC57*
- WC63*
- WC70*
- Gold Brook (two reaches, A and B)

- Settling Ponds (1 and 2)*

Watercourses listed above with an asterisk were electrofished a single time during mid-summer as a 'spot-check' for fish access. These systems typically represent smaller, discontinuous habitats, where fish collection was completed a single time to identify fish presence. To clarify; absence of evidence of fish in these systems based on a single fish collection event does not constitute evidence of absence. To confirm that these systems are not fish habitat would require multiple fish collection types across multiple seasons.

When reach isolation was not possible (for example, due to significant braiding or channel widths wider than barrier nets), qualitative electrofishing surveys were performed using an "open" site methodology with no barrier nets. One pass with a backpack electrofisher was performed unless crew members noted a high number of fish that evaded capture. In that case, a second or third pass was performed to obtain greater species representation. In the Salmonid Field Protocols Handbook: Techniques for Assessing Status and Trends in Salmon and Trout Populations, Temple and Pearsons (2007) describe the use of single-pass electrofishing without barrier nets and provide a summary of academic reports supporting this method (Johnson et al., 2007). Though the technique does not support estimates of absolute abundance or population estimates, research has found that single-pass electrofishing works well to determine species richness (Simonson and Lyons, 1995), and relative abundance (Kruse et al., 1998). Qualitative species abundance estimates were calculated using electrofishing CPUE indices, standardized to 300 seconds of effort (Scruton and Gibson, 1995).

Details of qualitative electrofishing locations and survey dates are provided in Table 2-3. Electrofishing locations are shown on Figure 3, Appendix A.

Table 2-3: Qualitative Electrofishing Locations and Details (2020-2021)

Electrofishing Location	**Stream Order**	**Survey Dates**	**Upstream Coordinates (UTM)**		**Downstream Coordinates (UTM)**		**Reach Length (m)**
			Easting	**Northing**	**Easting**	**Northing**	
WC1	1	August 31, 2021	606709	5006148	606753	5006064	100
WC2	1	July 27, 2021	606468	5006239	606480	5006204	90
WC11	1	June 28, 2021 July 26, 2021 August 29, 2021	607958	5005984	607901	5005943	100
WC12	1	June 25, 2020 July 28, 2020 August 19, 2020	607354	5006162	607278	5006178	63
WC13	1	July 27, 2021	607214	5006692	607158	5006667	87
WC22 Reach A	1	June 27, 2021 July 19, 2021 August 23, 2021	607098	5008620	607022	5008625	100
WC43 Reach A	1	July 26, 2021 August 30, 2021	608139	5008208	608191	5008162	100
WC49 Reach A	1	July 27, 2021	607340	5008270	607273	5008196	100
WC49 Reach B	1	July 28, 2021	607097	5008123	607060	5008065	90
WC57	1	July 29, 2021	607456	5008010	607352	5008005	100
WC63	1	July 29, 2021	607325	5007954	607259	5007876	120

Electrofishing Location	Stream Order	Survey Dates	Upstream Coordinates (UTM)		Downstream Coordinates (UTM)		Reach Length (m)
			Easting	Northing	Easting	Northing	
WC70	1	July 27, 2021	605978	5006319	606009	5006235	90
Gold Brook Reach A	3	June 27, 2020 July 28, 2020 August 23, 2020 June 26, 2021 July 23, 2021 July 26, 2021 August 29, 2021	607075	5006290	607136	5006205	100
Gold Brook Reach B	3	June 21, 2021 July 23, 2021 August 29, 2021	607151	5006171	607147	5006073	100
Settling Pond 1	N/A	August 30, 2021	606921	5006028	N/A	N/A	27
Settling Pond 2	N/A	August 30, 2021	606938	5006011	N/A	N/A	10

2.4.2 Trapping

During Summer of 2020 and 2021 fishing program, trapping was used to supplement fish collection efforts when electrofishing was not practical across the PA (e.g., in open water areas, unconsolidated substrate, temperatures exceeding 22°C, etc.). At each sampling location, biologists deployed either baited minnow traps or eel pots. Fyke nets were used at various locations and seine netting was performed at one location (near the outlet of Gold Brook Lake). CPUE was determined for each trap type and fish species based on trapping effort, which was calculated as total catch or total catch per species per wetted hour. Details of fish collection locations, survey dates, and traps deployed provided in

Table 2-4. Trap locations are shown on Figure 3, Appendix A.

Table 2-4: Trapping Locations and Details (2020-2021)

Trapping Location	Stream Order	Survey Dates	Traps Deployed[1] (#)
WC8	2	July 27-28, 2020	MT(2)
WC9 Reach A	1	April 3-4, 2020 April 18-19, 2020	MT(4) MT(4)
WC9 Reach B	1	April 3-4, 2020 April 18-19, 2020	MT(4) MT(4)
WC12	1	June 23-24, 2020	MT(2)
WC14	1-2	June 22, 2021 July 20, 2021 August 28, 2021	MT(5), EP(1) MT(5), EP(1) MT(5), EP(1)
WC22 Open Water	1	June 22, 2021 July 19, 2021 August 27, 2021	MT(5), EP(1) MT(5), EP(1) MT(5), EP(1)
WC23/20	1-2	June 24, 2021 July 23, 2021 August 25, 2021	MT(10) MT(10) MT(10)
Beaver Pond	N/A	April 18-19, 2020 June 24-25, 2020	MT(4) MT(2)

Trapping Location	Stream Order	Survey Dates	Traps Deployed[1] (#)
		July 28-29, 2020 August 22-23, 2020	MT(2) MT(2)
Gold Brook Reach A	3	August 24, 2021	EP(1)
Gold Brook Lake North	N/A	June 24, 2021 July 23, 2021 August 24, 2021	MT(10), EP(2), FN(1) MT(10), EP(2), FN(1) MT(10), EP(2), FN(1)
Gold Brook Lake East	N/A	June 23, 2021 July 23, 2021 August 24, 2021	FN(1) FN(1) FN(1)
Gold Brook Lake South	N/A	June 23, 2021 July 20, 2021 August 24, 2021 August 27, 2021	MT(3), EP(2), SN MT(3), EP(2), SN MT(3), EP(2), SN EP(2)
Gold Brook Lake West	N/A	June 23, 2021 July 23, 2021 August 25, 2021 August 29, 2021	FN(1) EP(1), FN(1) EP(1), FN(1) EP(3)
Rocky Lake 1	N/A	June 22, 2021 July 19, 2021 August 24, 2021	MT(5), FN (2) MT(5), FN(1) MT(5), FN(1)
Rocky Lake 2	N/A	June 22, 2021 July 19, 2021 August 14, 2021	EP(2) EP(2) EP(2)
Settling Pond 1	N/A	April 3-4, 2020 August 30, 2021	MT(3) MT(2), EP(1)
Settling Pond 2	N/A	August 30, 2021	MT(2), EP(1)

[1]Trap Types – Minnow Trap (MT), Eel Pot (EP), Fyke Net (FN), and Seine Netting (SN).

2.5 eDNA

Environmental DNA (eDNA) is a well-established technique which identifies environmental or exogenous DNA molecules from aquatic or semi-aquatic organisms. The premise of eDNA is that all organisms shed genetic material into the environment: water samples are collected, filtered and analyzed using a qPCR (quantitative polymerase chain reaction) technique to extract eDNA and identify organisms present within the aquatic environment. When genetic material found in the collected water sample matches with a known genetic primer for the target species or taxa, a positive result is provided by the production of fluorescence in the qPCR process. Genetic primers can be species-specific (i.e., based on matching 20 base pairs of a genetic sequence), or generic (i.e., identifying presence of particular taxa such as fish, amphibians, etc., based on a shorter genetic sequence of ten base pairs). One example of a generic test is the eFish primer, developed by the University of Victoria, and used extensively by Bureau Veritas (BV) Laboratory (Bureau Veritas, n.d.).

MEL completed a study design to identify presence of fish within the historic settling ponds using the eFish primer developed by BV Laboratory. To date, fish collection effort has not resulted in fish capture in either portion of the historic settling ponds. There is no inlet to the settling ponds, and anthropogenic barriers to fish passage were observed at the outlet of each portion of the historic settling pond; so it is expected that any fish present would be a resident population of forage fish. Typically, sample timing is based on the highest genetic output of the target species; however, the eFish primer has been developed to identify fish at the taxon level, rather than species level. Given that the movement of fish into and out of these small ponds is limited, it is expected that genetic material would be detectable at any time of year. eDNA samples were collected in the downstream portion of the settling ponds (highest likelihood of fish presence).

Based on the review of fish species expected within the Gold Brook Lake watershed presented in Section 1.2.2, Atlantic salmon are not expected to be present. Through this desktop review and through consultation with DFO, it is expected that Atlantic salmon are present in the adjacent eastern New Harbour River secondary watershed (1EQ-4). eDNA samples for Atlantic salmon were collected within three locations in the PA, along with one reference site in the New Harbour River watershed. This survey was completed to supplement the desktop review for fish species within the PA, and the fish collection work presented herein (multiple years of fish collection using multiple collection methods across varying seasons and flow regimes). Sample locations are shown on Figure 3, Appendix A.

Sample collection was completed on 13 October 2021 to reflect the fall spawning period for Atlantic salmon (high genetic output). Samples were collected in conjunction with a spawning habitat survey, which involved two fisheries biologists searching two large reaches of Gold Brook for suitable spawning substrate or evidence of redds (Figure 3, Appendix A). While no evidence of spawning or suitable habitat was observed, sample collection locations were selected based on the habitats most suitable to spawning depths and substrates for Atlantic salmon.

Standard protocols outlined by the British Columbia Ministry of Environment (MOE) were strictly adhered to for sample collection, labelling, filtration and sanitization between samples at every stage of the process (BC Ministry of Environment, 2017). Each sample was collected in triplicate. Sample filtration occurred in the evening of 13 October 2021. As described in the BC MOE protocol, one field blank sample per day is recommended. Since sample analysis was complete at two separate laboratories, however, two field blank samples were completed, allowing one field blank to accompany samples submitted to each laboratory. Sample collection and filtration details are provided in Appendix E.

Settling pond samples (analyzed for eFish) were filtered, preserved eDNA samples were shipped via courier to BV Laboratory in Guelph, Ontario, within a week of sample collection. A detailed Chain of Custody (CoC) accompanied the samples, and an electronic version of the sample collection and filtration data was provided to BV via e-mail.

The eFish primer was developed in western Canada, and confirmed to detect primarily western fishes. Within the SA, three species have been identified as the most widespread and abundant: American eel, brook trout and yellow perch. American eel is one of the species confirmed as detectable in the eFish prier validation. Prior to the submission of eDNA samples, MEL collected a fin clip sample of genetic DNA (or gDNA) from a brook trout (*Salvelinus fontinalis*) identified within the West River Sheet Harbour watershed, and a fin clip from a yellow perch (*Perca flavescens)* from within the PA. The samples were submitted to BV laboratory to confirm detection of these species using the eFish primer. BV laboratory confirmed detection of the brook trout and yellow perch gDNA using the eFish primer (as noted in the general comments section of the BV eDNA results, provided in Appendix E).

The laboratory completed a quantitative polymerase chain reaction (qPCR) analysis with each sample, using the eFish primer assay to identify presence of fish DNA in each sample. The laboratory assay includes checks for false positive and false negative errors in the laboratory analysis stage. This includes a check for DNA integrity, assay inhibition and contamination using the field blank (negative control).

To improve detection probability and statistical confidence in assay results, each sample is analyzed using eight technical replicates per sample, on each of the three field replicates per Site. The results are presented as a fraction of eight; the numerator indicates the number of detections (amplification of fish DNA) observed in the qPCR analysis out of the eight technical replicates. As each site contains three samples, results are provided for 1A, 1B, and 1C (and so on); the interpretation of the overall site result is determined considering the results of all three replicates per site.

BV laboratory does not currently have a genetic primer developed for identification of Atlantic salmon; as a result, samples collected for identification of salmon (Sites 1-4) were submitted instead to Dr. Paul Bentzen's laboratory at Dalhousie University.

Following extraction of eDNA from filters, hydrolysis probe assays were performed in 10 µl volumes in a Roche LightCycler 480 II qPCR machine. Each eDNA extraction was run in three replicates. Cycling conditions were 95 °C 3 min, 50x (95 °C 15 s, 60 °C 1 min) with fluorescence acquisition following each extension step. Negative (water) and positive (genomic Atlantic Salmon DNA) controls were run in triplicate with each assay. For quality assurance, all samples were analyzed a second time using ten-fold diluted eDNA to eliminate the possibility of a PCR inhibitor interfering with PCR amplification.

The hydrolysis probe assay is used to determine presence of Atlantic Salmon in the eDNA sample. When DNA is amplified during PCR, the fluorescence of the reaction increases. The PCR cycle at which fluorescence exceeds background is reported as the crossing threshold (Ct). Any assay with a positive Ct value is defined as positive for Atlantic Salmon presence. Assays which measured no change in fluorescence (have no Ct value) are considered negative for Atlantic Salmon.

2.6 Detailed Fish Habitat Surveys

2.6.1 Lotic Habitat Assessment

Detailed fish habitat surveys were completed by MEL for watercourses providing fish habitat predicted to be directly and indirectly affected by Project development. Fish habitat characterization was completed using guidance from the MEL Standard Operating Procedure for Fish Habitat Assessments in the lotic environment (Appendix B). The methods outlined in the SOP were derived from the following sources:

- The Nova Scotia Fish Habitat Assessment Protocol: A Field Methods Manual for the Assessment of Freshwater Fish Habitat (NSLC, 2018);
- DNR / DFO – New Brunswick Stream Habitat Inventory Datasheets;
- Standard Methods Guide for the Classification and Quantification of Fish Habitat in Rivers of Newfoundland and Labrador for the Determination of Harmful Alteration, Disruption and Destruction of Fish Habitat (DFO, 2012a);
- Reconnaissance (1:20,000) Fish and Fish Habitat Inventory (RIC, 2001);
- The US EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (Barbour et al., 1999); and,
- The Canadian Aquatic Biomonitoring Network Field Manual, Wadeable Streams (EC, 2012).

To support fish habitat assessments, each surveyed watercourse was delineated into individual reaches defined by discrete homogeneous units (e.g., riffle, run, pool, flat, etc.) as determined in the field in an upstream to downstream direction. Each habitat type contains discrete gradient, substrate types, water depth, and velocity ranges which have been determined using the described biological 'preferences' outlined in Grant and Lee (2004), whenever possible. In smaller, first-order streams, habitat types were often found to be extremely short and variable. For efficiency in the field, when individual habitat types were less than five meters in overall length, they were be grouped together into one reach containing multiple smaller habitat units. The upstream and downstream ends of each reach were recorded with handheld GPS device. Watercourses selected for detailed habitat evaluations are shown on Figure 4, Appendix A.

For each reach (i.e., homogenous section of watercourse), a detailed fish habitat survey was completed which included water quality measurements, designation of substrate and cover types, riparian habitat descriptions, and barrier assessments. Cross-sectional measurements (transects) were established to describe morphological (i.e., channel and wetted widths, bank heights) and flow characteristics (i.e., velocities and depths) within the reach. Transect measurements were recorded at every 50 m length of reach – for example, if a reach was 150 m in total length, three transects were established within the reach. If multiple habitat types (<5 m in length) were grouped together to form a reach, transects were established within each habitat type represented within the reach. The number of transects and transect locations were selected and modified as needed in the field based on specific habitat features observed, or limitations related to access, wadeability, and safety concerns.

For non-wadable sections of Gold Brook, depth and substrate were estimated at various locations throughout the reach. Cover types (vegetation, woody debris, large substrate) were documented and total cover (%) was estimated. Where the system widens into an open water feature, a revised method was employed to describe habitat. In open water features, the habitat type was described, along with measurements of depth, substrate, velocity (where possible), vegetative cover and width (where possible) were measured.

During detailed habitat assessment within linear watercourses and thermal imaging completed by Terrane Geoscience Inc. (Appendix E) areas with potential habitat for Atlantic Salmon were identified. MEL biologists then conducted redd surveys in the fall of 2021 to identify potential spawning activity and fish use of the impacted watercourses identified. During redd surveys biologists work downstream to upstream scanning the substrate for evidence of redds. When the substrate is visible from the bank, biologists walk along the banks as to not disturb fish and/or spawning sites. When possible, biologists walked on each bank, as redds may be more visible from a different angle. In locations where the substrate is not visible from the bank, biologists surveyed carefully from within the stream channel while looking for redds. Upon identification of a redd, biologists identify the macrohabitat (ie. Riffle, run, pool, etc), identify species of salmonids observed (if possible), and make notes of any observed signs of spawning.

Detailed fish habitat surveys were performed on watercourses 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 19, 20, 22, 23, 24, 39, 43, 45, 47, 49, 50, 55, 57, 58, 59, 61, 63, 65, 69, and Gold Brook. Redd surveys were conducted at three sites within the PA, the inlet to Gold Brook Lake (WC22), the outlet of Gold Brook Lake (WC64) and the outlet of Gold Brook Lake near the end of the PA (WC64). Redd survey locations are summarized in Table 2-5 and shown on Figure 3, Appendix A.

Table 2-5. Redd Surveys (Fall 2021)

Site #	Location	Survey Date	Upstream Coordinates (UTM)[1]		Downstream Coordinates (UTM)[1]		Observations
			Easting	Northing	Easting	Northing	
1	Inlet to Gold Brook Lake (WC22)	October 13, 2021	606942	5008532	606988	5008541	No redds, salmonids or suitable habitat for salmonids observed.
2	Outlet of Gold Brook Lake (WC64)	October 13, 2021	607082	5006268	607371	5005221	No redds, salmonids or suitable habitat for salmonids observed.
3	Outlet of Gold Brook Lake near end of PA (WC64)	October 13, 2021	607371	5005221	607086	5002686	No redds, salmonids or suitable habitat for salmonids observed.

[1]Upstream and downstream coordinates for Sites 2 and 3 are the same because sites were grouped together as biologists surveyed Gold Brook in its entirety while walking to and from Site 3.

2.6.2 Lentic Habitat Assessment

Detailed fish habitat surveys were completed by MEL for waterbodies providing fish habitat predicted to be directly and indirectly affected by Project development. Fish habitat characterization was completed using guidance from the Standard Methods Guide for the Classification/Quantification of Lacustrine Habitat in Newfoundland and Labrador. (Fisheries and Oceans, 2001).

Detailed habitat assessments within lentic systems were completed in Rocky Lake and Gold Brook Lake on 18-19 October, 2021, respectively. To assess the lentic systems, a series of transects was developed. Gold Brook Lake was described using a series of 13 parallel transects, separated by 85-170 m. Within Gold Brook Lake, the selection of transects was guided by a bathymetry map; so transects were selected to assess the range of depths present within the lake. Six transects were established to assess Rocky Lake, with transect spacing ranging between 50-100 m (Figure 4, Appendix A).

Along each transect, measurements were recorded at three or four separate locations, evenly spaced along the transect. These were spread out along the transect to ensure collection of data throughout deeper basins and the littoral zones of the lake. At each measurement location on the transect, depth, vegetation cover, and substrate type were recorded. Substrate was described using a variety of methods depending on the depth and clarity of the water, including visual assessments, probing with a paddle, or collection of substrate samples using an eckman dredge. In the central point of each transect, a temperature profile was recorded using a YSI multi-parameter probe, recording temperature and dissolved oxygen at 0.5m depth increments. Secchi depth was recorded once along each transect, and a description of the shoreline substrate was recorded.

3.0 RESULTS

3.1 Wetland and Watercourse Delineation

Throughout the PA, 66 watercourses were delineated and qualitatively described. In 2021, MEL completed wetland and watercourse delineation within a broader Project Area to identify constraints for alternative infrastructure locations. The following watercourse numbers lie outside of the current EARD PA and are therefore not described throughout this report: WC25-38, 40-42, 46, 48, 74-76, 78-80, 84, 89-93, 95, and 97.

Physical characteristics of each watercourse are provided in Table 3-1. A total of 223 wetlands have been identified and delineated throughout the PA, which are described in the Goldboro Wetland Baseline report (MEL 2022). Wherever fish habitat extends into wetlands, it is described herein under the context of contiguous watercourses, open water bodies and/or wetland mosaics. Delineated wetlands and watercourses are shown on Figure 2, Appendix A.

In addition to wetlands and watercourses, waterbodies within the PA include Gold Brook Lake and Rocky Lake. Additional open water features identified include the historic settling ponds (two), the Beaver Pond (which is located within WL18), and portions of Gold Brook where it opens into wide open flat habitat. Furthermore, two wetland mosaics were identified; Wetland Mosaic A is located south of the Settling Ponds, and Wetland Mosaic B is located at the convergence of channels A and H of Gold Brook. These features are shown on Figure 6g and 6h, respectively, Appendix A.

Table 3-1. Physical Characteristics – Watercourses (2017-2021)

Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
1	1	P	2	M	2.0	0.15	Rubble = 75% Boulder = 15% Silt = 10%	Run = 80% Riffle = 12% Pool = 8%	In-stream vegetation: 10% In-stream cover:40% Overhanging vegetation: 40-50% Shade: 40% LWD: M
2	1	I	2	M	1.0	0.05	Muck = 90% Cobble = 5% Boulder = 5%	Run = 50% Flat = 50%	In-stream vegetation: 10% In-stream cover: 5% Overhanging vegetation: 90% Shade: 90% LWD:M
3	1-2	P	2	M	1.8	0.25	Rubble = 70% Boulder = 20% Muck = 10%	Run = 80% Riffle = 10% Pool = 10%	In-stream vegetation: 20% In-stream cover: 40% Overhanging vegetation: = 60-70% Shade: 70% LWD: M
4	1	I	4	M	4.0	0.1	Cobble = 60% Boulder = 40%	Run = 80% Riffle = 20%	In-stream vegetation: 10% In-stream cover: 5% Overhanging vegetation: 20% Shade: 75% LWD: M
5	1	I	3	M	4.0	0.15	Muck = 70% Boulder = 30%	Run = 70% Pool = 30%	In-stream vegetation: 25% In-stream cover: 5% Overhanging vegetation: 40% Shade: 80% LWD: M
6	1	I	4	M	4.0	0.1	Muck = 60% Boulder = 40%	Run = 100%	In-stream vegetation: 15% In-stream cover: 5% Overhanging vegetation: 30% Shade: 90% LWD: L
7	1-2	P	3	M	4.0	0.1	Muck = 30% Cobble = 20% Gravel = 15% Sand = 10% Rubble = 10% Bedrock = 10% Boulder = 5%	Run = 80% Pool = 10% Riffle = 10%	In-stream vegetation: 5% In-stream cover: 5% Overhanging vegetation: 30% Shade: 70% LWD: M

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Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
8	2	P	2	M	0.8-4.4	0.15	Bedrock = 5% Boulder = 20% Rubble = 25% Cobble = 15% Gravel = 15% Sand = 5% Muck = 40% Clay = 5%	Run = 40% Riffle = 40% Flat = 20%	In-stream vegetation: 10% In-stream cover: 30% Overhanging vegetation: 40% Shade: 70% LWD: L
9.1	1	I	0	L	1.5	0.45	Muck = 90% Boulder = 10%	Flat = 100%	In-stream vegetation: 15% In-stream cover: 15% Overhanging vegetation: 30% Shade: 30% LWD: M
9.2	1	I	3	L	0.5	0.1	Cobble = 40% Rubble = 20% Muck = 20% Gravel = 10% Sand = 10%	Run = 100%	In-stream vegetation: 5% In-stream cover: 20% Overhanging vegetation: 70% Shade: 70% LWD: H
9.3	1	I	3	L	0.85	0.1	Muck = 70% Cobble = 30%	Run = 100%	In-stream vegetation: 10% In-stream cover: 10% Overhanging vegetation: 90% Shade: 90% LWD: L
9.4	1	I	1	L	1.2	0.1	Muck = 50% Rubble = 25% Boulder = 15% Gravel = 10%	Run = 90% Pool = 10%	In-stream cover: 15% Overhanging vegetation: 85% Shade: 85% LWD: L
10	1	P	2	M	0.5	0.15	Muck = 45% Cobble = 25% Rubble = 20% Sand = 10%	Run = 80% Pool = 20%	In-stream vegetation: 5% In-stream cover: 10% Overhanging vegetation: 85% Shade: 70% LWD: M
11	1	P	2	M	2.5	0.25	Boulder = 50% Muck = 35% Rubble = 15%	Run = 75% Riffle = 15% Pool = 10%	In-stream vegetation: 20% In-stream cover: 30% Overhanging vegetation: 40% Shade: 40% LWD: M
12	1	E	2	M	0.5	0.1	Muck = 85% Rubble = 15%	Run = 50% Flat = 50%	Overhanging vegetation: 95% Shade: 95% LWD: H
13	1	I	2	L	0.6	0.3	Muck = 100%	Flat=100%	In-stream vegetation: 40%

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Watercourse*	**Stream Order**	**Flow**	**Gradient (%)**	**Velocity[1]**	**Bankfull width (m)**	**Average Depth (m)**	**Substrate (%)**	**Habitat Types**	**Cover %[2]**
									In-stream cover: 5% Overhanging vegetation: 50% Shade: 50% LWD: L
14.1	1-2	P	1	L	1.0	0.15	Boulder = 65% Muck = 25% Cobble = 10%	Run = 50% Flat = 30% Riffle = 10% Pool = 10%	In-stream vegetation: 5% In-stream cover: 40% Overhanging vegetation: 85% Shade: 85% LWD: M
14.2	1-2	P	1	L	1.0-2.5	0.2	Muck = 90% Boulder = 10%	Flat = 100%	In-stream vegetation: 20% In-stream cover: 5% Overhanging vegetation: 5% Shade: 5% LWD: L
14.3	1-2	P	3	L	2.0	0.2	Boulder = 50% Cobble = 20% Muck = 15% Boulder = 10% Gravel = 5%	Run = 40% Pool = 30% Riffle = 15% Flat = 15%	In-stream vegetation: 5% In-stream cover: 35% Overhanging vegetation: 90% Shade: 90% LWD: M
15	1	P	4	L	1.0	0.08	Boulder = 60% Cobble = 20% Muck = 20%	Run = 75% Riffle = 10% Flat = 15%	In-stream vegetation: 10% In-stream cover: 10% Overhanging vegetation: 100% Shade: 100% LWD: M
16	1	E	0	L	0.5	0.1	Boulder = 90% Muck = 10%	Flat = 85% Run = 15%	In-stream vegetation: 20% In-stream cover: 20% Overhanging vegetation: 90% Shade: 90% LWD: M
17	1	P	2	M	1.35-2.25	0.15-0.25	Boulder = 25% Rubble = 30% Cobble = 30% Gravel = 10% Sand = 5%	Riffle-Run, Flat	N/A
19	1	P	<1	L	0.8-1.25	0.20-0.10	Cobble = 30% Muck = 70%	Flat	N/A
20	1-2	P	<1	L	2-3	0.25-0.30	Boulder = 30% Cobble = 10% Rubble = 10% Muck = 50%	Flat	N/A
21	1	P	2	L	0.35-0.45	0.15-0.20	Boulder = 10%	Run	LWD: 10%

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Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
							Rubble = 35% Cobble = 30% Sand = 25%		Boulders: 30% Undercut banks: 10% Overhanging vegetation: 45% Emergent vegetation: 5% Submergent vegetation: 5%
22.1	1	P	1	L	0.2-0.35	0.15-0.20	Muck = 100%	Run, Flat	LWD: 2% Boulders: 5% Undercut banks: 10% Deep pools: 10% Overhanging vegetation: 5%
22.2	1	P	<1	L	0.3-0.9	0.05-012	Rubble = 5% Muck = 95%	Flat	LWD: 2% Boulders: 5% Undercut banks: 10% Deep pools: 10% Overhanging vegetation: 5%
23.1	1	P	<1	L	1-2	0.35-0.45	Muck = 100%	Flat	LWD: 5% Boulders: 10% Undercut banks: 10% Emergent vegetation: 10%
23.2	1	P	<1	L	1.8	0.45-0.50	Boulder = 40% Rubble = 25% Cobble = 25% Muck = 10%	Flat	LWD: 20% Undercut banks: 10% Overhanging vegetation: 35%
24	2	P	2	L	2.5-4	0.15-0.40	Boulder = 95% Rubble = 5%	Run	Boulders: 20% Undercut banks: 20% Overhanging vegetation: 45%
39	1	P	2	M	0.3-1.5	0.1-0.2	Rubble = 50% Cobble = 50%	Run and riffle	LWD: 30% Boulders: 5% Undercut banks: 30% Overhanging vegetation: 95%
43	1	P	<1	L	0.5-1.6	0.13	Muck = 100%	Flat	Overhanging vegetation: 30%
44	1	P	1	L	0.2-1.3	0.08-0.35	Rubble = 5% Cobble = 30% Gravel = 20% Silt = 10% Muck = 20% Clay = 15%	Run, flat, step-pool	N/A
45	1	P	2	L	0.17-1.3	0.08-0.20	Boulder = 5% Rubble = 20% Cobble = 20% Gravel = 10%	Run, flat	LWD: 5% Undercut Banks: 10% Deep pools: 5% Overhanging vegetation: 20%

Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
							Sand = 15% Silt = 10% Muck = 1-% Clay = 10%		
47	1	I	1	L	0.12-0.19	0.08-0.25	Gravel = 20% Sand = 20% Muck = 50% Clay = 10%	Run, flat	Undercut banks: 5% Overhanging vegetation: 5%
49	1	P	1-2	n/a	0.5-2.0	0.2-0.8	Boulder = 25% Rubble = 25% Cobble = 25% Gravel = 10% Muck = 15%	Riffle, run	LWD: 70% Boulders: 15% Undercut banks: 40% Deep pools: 5% Overhanging vegetation: 90% Emergent vegetation: 10% Submergent vegetation: 10%
50	1	P	2	L-M	0.42-1.35	0.2-0.56	Boulder = 10% Rubble = 30% Cobble = 30% Gravel = 10% Silt = 2 %	Riffle, run, flat	LWD: 25% Overhanging vegetation: 30%
51	1	P	<1	L	0.2-1.25	0.08-0.35	Boulder = 2-% Rubble = 15% Cobble = 5% Muck = 60%	Flat, run	LWD: 20% Overhanging vegetation: 30%
52	1-2	P	1-2	L-M	0.45-1.0	0.1-0.25	Boulder = 20% Rubble = 20% Cobble = 1-% Muck = 50%	Flat, run	LWD: 20% Overhanging vegetation: 30%
53	1	I	2	L	0.1-1.75	0.02-0.12	Muck = 100%	Flat , run	Overhanging vegetation: 70%
54	1	P	2	L-M	0.20-0.40	0.08-0.15	Boulder = 35% Rubble = 5% Cobble = 5% Muck = 55%	Run	Overhanging vegetation: 10%
55	1	I	<1	L	0.3-2	0.1-0.3	Bedrock = 5% Boulder = 5% Rubble = 10% Cobble = 5% Gravel = 5% Sand = 70%	Run, pool	LWD: 10% Undercut banks: 25% Deep pools: 5% Overhanging vegetation: 70%
56	1	P	1-4	M	0.6-0.7	0.08-0.2	Boulder = 15%	Riffle, pool	LWD = 3%

Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
							Rubble = 65% Cobble = 10% Muck = 10%		Undercut banks = 2% Overhanging vegetation: 2%
57	1	P	1-4	L-M	1-1.5	0.2-0.3	Boulder = 30% Rubble = 30% Muck = 40%	Run, pool	LWD = 50% Boulders: 10% Undercut banks: 10% Deep pools: 5% Overhanging vegetation: 95%
58	1	P	1-4	L-H	0.5-2.5	0.15-0.5	Boulder = 10% Rubble = 35% Cobble = 20% Muck = 35!	Riffle, run, pool	LWD = 8% Undercut banks: 2% Overhanging vegetation: 5% Emergent vegetation: 1% Submergent vegetation: 1%
59	1	I	1-4	L	1	0.25	Boulder = 25% Rubble = 25% Cobble = 25% Muck = 25%	Run	LWD: 60% Undercut banks: 25% Overhanging vegetation: 50%
60	1	P	1-4	L	1-2.5	0.2-0.4	Boulder = 10% Rubble = 15% Muck = 75%	Flat	Undercut banks: 2% Deep pools: 5% Submergent Vegetation: 5%
61	1	P	1-4	L	1	0.35	Muck = 90% Clay = 1-%	Run	LWD: 50% Undercut banks: 10% Overhanging vegetation: 50%
63	1	P	4-7	L-M	0.3-1	0.3-0.5	Sand = 10% Muck = 90%	Pool, riffle	LWD: 20% Overhanging vegetation: 80%
64[3] Gold Brook	3	P	1-4	L-M	1.9-34	11-32	Various.	Riffle, run, pool, flat	Various
65	1	P	1-4	L	1.0	0.3	Cobble = 10% Muck = 90%	Run	Overhanging vegetation: 80%
66	1	P	1-4	L	0.3-1	0.1-0.2	Boulder = 5% Rubble = 30% Cobble = 30% Muck = 35%	Flat, run, riffle	LWD: 10% Undercut banks: 30% Overhanging vegetation: 80%
67	1	P	<1	L	1.0	n/a	Rubble = 25% Cobble = 25% Muck = 50%	Run	LWD: 5% Undercut banks: 10% Overhanging vegetation: 20%
68	1	P	1-4	L	0.4-1.5	0.09-0.35	Boulder = 40% Cobble = 30% Clay = 30%	Run, riffle, flat	LWD: 20% Overhanging vegetation: 40% Submergent vegetation: 10%
69	1	P	1-4	M	1.7-5.5	0.4	Boulder = 30% Rubble = 30%	Run, riffle, pool	LWD: 10% Undercut banks: 20%

Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
							Cobble = 20% Muck = 20%		Deep pools: 2% Overhanging vegetation: 20% Emergent vegetation: 5% Submergent vegetation: 10%
70	1	P	1	L	-	-	Muck = 100%	Run, flat	-
71	1	P	<1	L	0.6-1.1	0.05	Rubble =15% Cobble = 5% Muck = 80%	Flat, run	Overhanging vegetation: 20%
72	1	I	<1	L	0.2-2.0	0.03	Rubble = 50% Cobble = 30% Muck = 20%	Flat	LWD: 40% Undercut banks: 20% Overhanging vegetation: 90%
73	1	P	1-4	L	0.25-1.0	0.15	Rubble = 20% Cobble = 30% Muck = 50%	Flat	LWD: 20% Overhanging vegetation: 75%
77	1	E	1-4	L	0.5-0.7	0.43	Muck = 100%	Flat	LWD: 50% Overhanging vegetation: 80%
81	1	P	1-4	L	0.9-2.2	0.15	Boulder = 5% Rubble = 5% Muck = 90%	Flat	LWD: 2% Overhanging vegetation: 1% Undercut banks: 10% Overhanging vegetation: 95% Submergent vegetation: 10%
82	1	P	1-4	L	0.3-1.4	0.09	Bedrock = 5% Boulder = 20% Rubble = 10% Cobble = 10% Gravel = 5% Muck = 55%	Flat, run	LWD: 10% Overhanging vegetation: 5% Undercut banks: 30% Deep pools: 15% Overhanging vegetation: 15%
83	1	I	1-4	L	0.3-1.0	0.23	Boulder = 5% Rubble = 40% Cobble = 20% Muck = 35%	Flat, run	LWD: 30% Undercut banks: 30% Overhanging vegetation: 60%
85	1	I	<1	L	0.3-0.5	0.06	Muck = 100%	Flat	Overhanging vegetation: 60%
86	1	E-P	<1	L	0.2-0.9	0.08	Boulder =30% Gravel =5% Muck = 65%	Flat	LWD: 10% Overhanging vegetation: 100%
87	1	-	-	-	-	-	-	-	-
88	1	P	1-4	L	0.35-0.75	0.06	Rubble = 5% Cobble = 10% Gravel = 10% Sand = 10% Muck = 40%	Flat, run	Overhanging vegetation: 75% Emergent vegetation: 10%

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Watercourse*	Stream Order	Flow	Gradient (%)	Velocity[1]	Bankfull width (m)	Average Depth (m)	Substrate (%)	Habitat Types	Cover %[2]
							Clay = 25%		
94	1	I	<1	L	0.3-0.7	0.08	Boulder = 5% Rubble = 10% Sand = 5% Muck = 40% Clay = 40%	Flat	Overhanging vegetation: 10%
96	1	P	<1	L	0.3-0.45	0.08	Boulder = 40% Rubble = 30% Cobble = 5% Muck = 25%	Run, flat	LWD: 10% Overhanging vegetation: 20%
98	1	P	<1	-	-	-	-	-	-
99[4]	1	P	1-4	L	0.45-1.3	0.19	Cobble = 15% Rubble = 15% Gravel = 20% Sand = 10% Muck = 30% Clay = 10%	Run, flat	LWD = 5% Undercut banks = 5% Deep pools = 5% Overhanging vegetation = 30% Submergent vegetation = 5%

[1]*L: Low velocity (<0.15m/s). M: Moderate velocity (0.15-0.3m/s). H: High velocity (>0.3m/s).*
[2]*L: Low. M: Moderate. H: High. Includes cover provided by large woody debris; boulders; undercut banks; deep pools; overhanging vegetation; emergent vegetation; submergent vegetation.*
[3]Gold Brook was described initially through a series of 12 individual transects by Gemtec in 2017. The detail associated with that initial assessment is provided in the 2017-2019 report, appended. This table provides a range of measurements recorded across the 12 transects in that evaluation. Additional detailed habitat assessment for Gold Brook is provided in Section 3.6.
* The following watercourse numbers lie outside of the current EARD PA: WC18, 25-38, 40-42, 46, 48, 74-76, 78-80, 84, 89-93, 95, and 97.

3.2 Water Quality

Water quality results are reported and discussed as it relates to the chemical characteristics required for suitable fish habitat. Where applicable, water quality sampling results are measured against the CCME Guidelines for the Protection of Freshwater Aquatic Life (FWALs). Summaries of water quality measurements are presented in Table 3-2 and Table 3-3 for sampling conducted during fish surveys and detailed habitat descriptions, respectively. Water quality measurement locations coincide with fish collection are shown on Figure 3a and b, while reach-level data collected during fish habitat assessments are shown on Figure 6a to i, Appendix A.

Table 3-2. Summary of In-situ Water Quality Measurements recorded during Electrofishing and Trapping Surveys (2020-2021)

Site	Sampling Dates	Water Temp (ºC)	pH	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)
WC1	June 22, 2020	17.9	7.21	7.66	133	100.1
	August 1, 2020	19.7	7.60	6.80	144	104.0
	August 20, 2020	16.4	7.55	7.84	85	66.3
	August 31, 2021	17.6	6.90	6.85	123.3	93.6
WC2	July 27, 2021	18.1	5.43	**4.10**	63	-
WC3	June 22, 2020	11.7	6.71	8.10	25	22.1
	July 31, 2020	16.9	5.22	6.47	32	24.7
WC4	June 23, 2020	14.0	**4.97**	8.70	26	21.4
	July 29, 2020	15.8	**4.85**	7.76	31	24.7
	August 23, 2020	17.1	**4.98**	**3.55**	35	26.6
WC7	June 23, 2020	13.8	5.51	7.82	25	20.8
	July 28, 2020	16.2	**4.49**	7.25	32	25.3
	August 22, 2020	18.5	5.59	6.50	37	24.7
WC8	June 26, 2020	16.9	5.80	6.98	28	21.4
	July 27, 2020	18.7	-	8.28	32	24.0
	August 19, 2020	16.1	5.18	5.52	33	26.0
WC9 Reach A	April 3, 2020	2.8	**3.99**	14.38	15	-
	April 18, 2020	4.1	5.08	9.35	22	-
	June 24, 2020	18.7	5.00	**4.88**	28	20.8
	July 30, 2020	17.7	**4.38**	**4.35**	33	25.3
	August 21, 2020	14.0	5.43	**4.14**	30	24.7
WC9 Reach B	April 3, 2020	1.7	**4.32**	15.73	15	-
	April 18, 2020	3.2	**4.18**	10.20	22	-
	June 24, 2020	14.7	5.23	7.84	26	21.4
	July 30, 2020	18.6	**4.47**	6.31	35	26.0
	August 21, 2020	14.9	6.20	**4.71**	33	26.6
WC11	June 28, 2021	16.6	**4.87**	6.66	32.4	25.35
	July 26, 2021	15.5	5.02	**5.22**	32.0	25.35
	August 29, 2021	15.6	5.13	**2.70**	43.2	34.45
WC12	June 23, 2020	11.8	**4.98**	5.96	27	24.0
	June 25, 2020	13.2	5.36	**2.62**	33	27.9
	July 28, 2020	15.8	**3.97**	6.38	43	27.9
	August 19, 2020	14.4	5.33	9.50	21	17.5
WC13	July 27, 2021	15.6	**4.52**	8.57	50	-
WC14	June 22, 2021	15.3	5.11	7.42	26.6	20.8
	June 26, 2021	14.6	5.25	7.65	29.2	23.2
	July 20, 2021	20.4	**4.98**	8.14	28.8	20.8
	July 21, 2021	17.1	**4.98**	8.61	27.9	21.45
	August 23, 2021	16.2	5.42	8.65	43.3	28.6

Site	Sampling Dates	Water Temp (ºC)	pH	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)
	August 27, 2021	23.0	5.27	5.77	37.7	25.35
WC20	June 24, 2021 July 24, 2021 August 27, 2021	14.5 13.6 18.0	**4.88** **4.58** 5.12	7.24 **4.56** **3.26**	27.3 27.5 38.3	22.1 22.75 28.60
WC22 Open Water	June 22, 2021 July 19, 2021 August 27, 2021	18.2 20.5 24.3	**4.78** **4.64** **4.90**	7.67 **3.37** **3.67**	27.7 29.2 41.2	21.4 20.8 28.6
WC22 Reach A	June 27, 2021 July 19, 2021 August 23, 2021	16.5 19.3 16.5	**4.78** **4.42** 5.27	8.68 8.28 7.84	27.6 29.4 38.5	21.45 21.45 29.90
WC22 Reach B	June 25, 2021 July 22, 2021 August 26, 2021	15.8 17.8 19.2	**4.77** **4.56** **4.99**	9.25 6.65 7.57	27.0 29.5 39.3	21.45 22.10 28.6
WC23/20	June 24, 2021 July 23, 2021 August 25, 2021	19.2 26.0 25.9	**4.91** **4.51** **4.95**	6.36 8.12 **3.54**	29.6 40.0 50.9	21.45 - 32.5
WC43 Reach A	June 28, 2021 July 26, 2021 August 30, 2021	12.8 13.6 12.6	5.76 5.50 6.06	8.73 7.38 6.95	35.5 35.5 45.9	29.9 29.25 39.65
WC43 Reach B	June 27, 2021 July 25, 2021 August 28, 2021	13.4 13.0 14.7	5.53 5.18 5.18	7.71 8.58 8.50	30.9 28.2 36.5	25.35 24.05 29.25
WC49 Reach A	July 27, 2021	12.9	5.03	9.82	42	-
WC49 Reach B	July 28, 2021	12.7	**4.88**	10.35	42	-
WC57	July 29, 2021	15.5	**4.15**	9.85	58	-
WC63	July 29, 2021	14.9	**4.97**	5.35	51	-
WC70	July 27, 2021	17.7	**4.88**	**2.60**	58	-
Gold Brook Reach A	June 27, 2020 July 28, 2020 August 23, 2020 June 26, 2021 July 23, 2021 August 24, 2021 August 29, 2021	18.6 21.4 23.7 20.3 20.4 18.8 19.2	5.65 5.16 5.28 **4.95** **4.73** 5.67 5.24	7.62 7.88 8.31 8.8 8.72 6.06 8.27	21 25 24 25.8 25.0 36.1 31.4	15.6 17.5 17.5 18.2 17.55 26.65 22.75
Gold Brook Reach B	June 21, 2021 July 23, 2021 July 26, 2021 August 29, 2021	21.8 18.9 20.4 17.5	**4.92** **4.64** **4.74** 5.31	8.39 8.62 7.85 7.86	27.5 24.7 25.2 30.9	18.85 18.2 18.2 23.40
Gold Brook Lake North	June 24, 2021 July 23, 2021 August 24, 2021	21.1 23.2 23.5	**4.98** **4.72** 5.12	7.37 7.75 7.91	25.7 26.8 34.5	18.2 18.2 23.40
Gold Brook Lake East	June 23, 2021 July 23, 2021 August 24, 2021	22.0 23.0 23.2	**4.80** **4.81** 5.08	8.03 7.33 6.73	25.6 26.6 34.2	17.55 18.20 22.75
Gold Brook Lake South	June 23, 2021 July 20, 2021 August 24, 2021 August 27, 2021	20.9 22.2 21.8 24.2	5.00 **4.82** 5.06 **4.74**	6.9 6.74 6.58 7.25	25.3 26.4 34.2 35.2	17.55 18.2 23.4 23.4
Gold Brook Lake West	June 23, 2021 July 23, 2021	20.2 22.2	**4.91** **4.73**	7.29 7.16	27.1 26.2	19.50 18.2

Site	Sampling Dates	Water Temp (^oC)	pH	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)
	August 25, 2021 August 29, 2021	20.6 21.7	5.07 5.02	6.13 7.46	45.6 33.1	31.85 22.75
Rocky Lake 1	June 22, 2021 July 19, 2021 August 24, 2021	21.4 23.6 23.1	5.20 5.31 5.43	**5.35** 6.81 5.72	25.6 25.9 30.8	18.2 17.55 20.8
Rocky Lake 2	June 22, 2021 July 19, 2021 August 24, 2021	22.1 24.2 23.3	5.26 5.18 5.31	**5.19** 5.88 6.98	25.4 26.1 30.9	17.55 17.55 20.80
Settling Pond Outlet (SPO1)	June 25, 2020 July 27, 2020 August 22, 2020	20.5 21.6 19.1	5.51 6.25 **4.92**	8.12 8.91 8.27	22 25 25	15.6 17.5 18.8
Settling Pond 1	August 30, 2021	18.8	6.02	**3.56**	67.7	50.05
Settling Pond 2	August 30, 2021	19.1	6.01	5.62	63.3	46.15
Beaver Pond	April 18, 2020 June 24, 2020 July 28, 2020	8.5 28.3 22.6	**4.18** 5.02 **4.92**	10.63 6.10 **4.23**	26 37 40	- 22.7 26.0

Note: Values in bold indicate parameters recorded as below CCME guidelines for the protection of aquatic life, including: DO levels not suitable for any life stage of warm or cold-water fish species (<5.5 mg/L) (1999), and pH levels below 5.0 (CCREM, 1987). Missing measurements reflect equipment malfunctions in the field.

Table 3-3. Summary of In-situ Water Quality Measurements recorded during Detailed Fish Habitat Surveys (2020-2021)

Site	Reach #	Sampling Date	Water Temp (^oC)	pH	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	Turbidity[1]
WC1	1	August 18, 2020	19.5	7.11	**5.10**	168	122.2	C
	2	August 18, 2020	19.7	7.38	6.70	166	120.2	C
WC2	1	July 6, 2021	12.1	5.67	**-**	54	-	L
WC3	1	August 18, 2020	14.8	5.44	**1.80**	33	27.3	L
	2	August 18, 2020	17.9	7.67	9.30	149	112.4	C
	3	August 18, 2020	18.1	7.71	9.20	147	110.5	L
WC4	1	August 14, 2020	16.8	5.06	**0.20**	40	30.5	M
	2	August 14, 2020	16.1	5.12	**3.01**	44	40.2	C
WC5	1	August 14, 2020[2]	-	-	-	-	-	-
WC6	1	August 14, 2020	17.6	**4.61**	**3.10**	42	31.8	L
WC7	1	August 14, 2020	16.7	5.15	**2.80**	37	29.2	L
WC8	1	October 14, 2021	15.7	5.62	-	63	-	M
	2	October 14, 2021	16.2	5.01	-	70	-	M
	3	August 18, 2020	13.5	5.38	**4.15**	35	29.2	C
	4	August 18, 2020	14.4	**4.90**	**4.91**	34	27.9	C
	5	August 18, 2020	14.6	5.23	**3.32**	32	26.0	C
WC9	1	August 18, 2020	17.2	5.56	**3.91**	53	10.9	L
	2	August 18, 2020[2]	-	**-**	-	-	-	-
	3	August 18, 2020	17.3	**4.58**	5.52	38	29.2	L
	4	August 18, 2020	16.1	5.34	5.72	31	24.7	L
WC10	1	July 15, 2021	17.1	**4.76**	-	47	-	L
	2	July 15, 2021	19.1	**4.36**	-	47	-	L
WC11	1	July 14, 2021	15.4	**4.67**	-	52	-	M

Site	Reach #	Sampling Date	Water Temp (°C)	pH	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	Turbidity[1]
	2	July 14, 2021	21.1	**4.66**	-	49	-	L
	3	July 14, 2021	21.3	**4.81**	-	46	-	L
	4	July 14, 2021	20.0	**4.71**	-	47	-	L
	5	July 14, 2021	19.0	**4.50**	-	49	-	L
WC12	1	July 13, 2021[2]	-	**-**	-	-	-	-
	2	July 13, 2021	19.6	5.23	-	55	-	-
	3	July 13, 2021	22.0	5.49	-	51	-	-
	4	July 13, 2021[2]	-	**-**	-	-	-	-
WC13	1	July 13, 2021	14.0	**4.38**	7.93	44	-	L
WC14	1	July 7, 2021	16.8	**4.29**	6.24	33	-	L
	2	July 7, 2021	17.9	**4.37**	8.72	33	-	C
	3	July 7, 2021	17.0	**4.25**	8.03	36	-	L
	4	July 8, 2021	14.3	**4.27**	11.84	37	-	C
	5	July 8, 2021	14.3	**4.37**	9.72	38	-	M
	6	July 8, 2021	14.9	**4.40**	9.47	37	-	C
	7	July 8, 2021	15.2	**4.51**	9.65	39	-	C
WC15	1	July 8, 2021	17.6	**4.75**	-	49	-	L
	2	July 8, 2021	14.4	**4.85**	-	43	-	L
	3	July 9, 2021	15.2	**4.62**	-	43	-	L
	4	July 9, 2021	15.6	**4.64**	-	43	-	C
	5	July 9, 2021	16.3	**4.64**	-	42	-	L
	6	July 9, 2021	15.7	**4.66**	-	43	-	L
	7	July 9, 2021	14.0	**4.60**	-	42	-	L
	8	July 13, 2021	13.1	**4.78**	-	45	-	L
	9	July 13, 2021	13.0	5.10	-	40	-	L
WC19	1	July 20, 2021	13.0	5.07	9.93	40	-	C
WC20 & WC24	1	July 20, 2021	13.3	**4.96**	9.96	38	-	C
	2	July 21, 2021	12.4	**4.52**	7.96	39	-	C
WC22	1	July 7, 2021	-	-	-	-	-	-
	2	July 7, 2021	22.7	**4.11**	-	67	-	C
	3	July 7, 2021	-	-	-	-	-	-
	4	July 7, 2021	21.4	**4.21**	-	63	-	L
	5	July 7, 2021	21.0	**4.12**	-	63	-	L
	6	July 7, 2021	18.5	**4.66**	-	46	-	L
	7	July 8, 2021	19.2	**4.21**	-	46	-	L
WC23	1	July 21, 2021	14.2	5.31	8.64	47	-	C
WC39	1	July 7, 2021	17.3	5.37	9.09	29	-	C
WC43	1	July 14, 2021	10.3	5.39	7.98	50	-	L
WC45	1	July 6, 2021	12.5	**4.10**	-	59	-	L
	2	July 6, 2021	13.2	**4.06**	11.11	67	-	C
	3	July 6, 2021	13.5	**4.10**	9.46	90	-	L
	4	July 6, 2021	12.8	**4.01**	9.84	109	-	L
WC47	1	July 13, 2021	12.2	**4.41**	9.27	50	-	L
WC49	1	July 21, 2021	16.7	**4.72**	8.99	48	-	C
WC50	1	July 7, 2021	11.1	**3.93**	7.50	47	-	L
	2	July 7, 2021	11.8	**4.22**	9.68	46	-	L
	3	July 7, 2021	12.3	**4.27**	8.76	46	-	L
WC51	1	July 20, 2021	14.7	**4.76**	7.46	47	-	C
WC55	1	July 22, 2021	11.0	5.12	6.13	51	-	C

Site	Reach #	Sampling Date	Water Temp (⁰C)	pH	DO (mg/L)	Conductivity (µS/cm)	TDS (mg/L)	Turbidity[1]
WC57	1	July 14, 2021	15.3	**4.28**	6.70	51	-	L
WC58	1	July 13, 2021	13.8	**4.53**	7.98	42	-	L
WC59	1	July 15, 2021	15.0	**4.76**	-	56	-	M
WC61	1	July 15, 2021	12.7	**3.89**	6.42	52	-	L
WC63	1	July 15, 2021	14.1	**4.31**	**3.76**	53	-	M
WC65	1	July 15, 2021	14.5	**4.22**	9.01	50	-	L
WC69	1	July 7, 2021	18.0	**4.50**	-	62	-	L
	2	July 7, 2021	18.5	**4.43**	-	57	-	L
	3	July 7, 2021	17.7	**4.40**	-	62	-	L
Gold Brook	1	August 3, 2021	21.4	5.18	9.14	33	-	L
	2	August 3, 2021	22.4	**4.79**	9.27	33	-	L
	3	August 3, 2021	25.9	5.68	8.59	62	-	M
	4	August 4, 2021	19.2	**4.61**	9.66	33	-	L
	5	August 4, 2021	25.8	5.12	8.78	33	-	L
	6	August 5, 2021	20.2	5.28	9.58	33	-	M
	7	August 6, 2021	21.4	**4.13**	9.24	38	-	M
	8	August 19, 2021	20.0	5.62	7.07	110	-	M
	9	August 19, 2021	19.0	5.32	10.98	50	-	M
	10	August 19, 2021	21.4	5.03	10.34	47	-	L
	11	August 19, 2021	20.7	5.31	10.72	47	-	L
	12	November 17, 2021	6.5	**4.53**	13.30	25.6	26.00	C
Rocky Lake	1	October 18, 2021	16.1	**4.62**	11.65	230	181.35	-
	2	October 18, 2021	15.9	**4.75**	10.36	235.4	169.75	-
	3	October 18, 2021	15.6	**4.69**	10.18	241.7	180.40	-
	4	October 18, 2021	15.6	**4.70**	9.96	240.6	179.35	-
	5	October 19, 2021	13.4	**4.68**	11.67	214.8	179.40	-
	6	October 19, 2021	12.7	**4.79**	10.15	212.0	180.70	-
Gold Brook Lake	1	October 19, 2021	13.3	**4.69**	9.52	260.0	208.85	-
	2	October 19, 2021	14.0	**4.45**	10.14	284.0	234.55	-
	3	October 19, 2021	14.2	**4.44**	10.57	320.7	270.50	-
	4	October 19, 2021	14.1	**4.56**	10.87	297.8	285.75	-
	5	October 19, 2021	14.3	**4.44**	10.42	331.9	272.05	-
	6	October 19, 2021	14.2	**4.41**	10.66	330.8	276.90	-
	7	October 19, 2021	14.2	**4.49**	10.64	312.8	261.75	-
	8	October 19, 2021	14.2	**4.46**	10.76	329.5	269.75	-
	9	October 19, 2021	14.4	**4.48**	10.69	330.8	269.75	-
	10	October 19, 2021	14.3	**4.65**	10.59	319.0	260.55	-
	11	October 19, 2021	14.5	**4.61**	10.03	329.4	267.15	-
	12	October 19, 2021	14.3	**4.52**	10.61	330.5	269.75	-
	13	October 19, 2021	14.8	**4.63**	11.00	335.3	271.05	-

Note: Values in bold indicate parameters recorded as below CCME guidelines for the protection of aquatic life, including: DO levels not suitable for any life stage of warm or cold-water fish species (<5.5 mg/L) (1999), and pH levels below 5.0 (CCREM 1987). Missing measurements reflect equipment malfunctions in the field.
[1]Turbidity assessed visually as Clear (C), Light (L), Moderate (M), or Turbid (T).
[2]WC5, WC9 Reach 2 and WC12 Reach 1 and 4 not sampled – water depths too shallow for probe.

3.2.1 Temperature

Water temperature affects the metabolic rates and biological activity of aquatic organisms, thus influencing the use of habitat by aquatic biota. There are no CCME guidelines related to temperature and aquatic biota. Temperature preferences of fish vary between species, as well as with size, age, and season.

Salmonids are cold-water fish species, meaning they require cold water to live and reproduce (Bowlby et al., 2014). The optimal temperature range for these species (growth of juvenile) is 10-20˚C (The Stream Steward n.d.) to 16-20˚C (DFO, 2012b) (brook trout and Atlantic salmon, respectively). Other species documented within the PA have higher temperature ranges. The optimal temperature range for Yellow Perch is 21-24˚C (Brown et al., 2009). American eel have a broader temperature range and can tolerate temperatures from 4 to 25ºC (Fuller et al., 2019).

The results shown in the tables above generally provide a snapshot of temperatures from early (June), mid (July), and late summer (August) for watercourses and waterbodies within the PA for 2020 and 2021. Throughout the PA, recorded summer temperatures ranged widely in 2020, from 11.7℃ in WC3 to 28.3℃ in the Beaver Pond. Summer temperatures in 2021 also ranged widely, with the lowest of 10.3℃ in WC43 and the highest in Gold Brook at 25.8℃.

Within the PA, only six of the 27 aquatic features sampled (WC3, WC4, WC7, WC22, Gold Brook in 2020 and Gold Brook Lake) throughout the summer displayed a general warming trend into later parts of the season. Temperatures within smaller, first and second order streams remained within the suitable temperature range for salmonids (<20 ºC), whereas temperatures measured within larger watercourses and waterbodies including Gold Brook, Gold Brook Lake, Rocky Lake 1&2, the Settling Pond Outlet and the Beaver Pond regularly measured above suitable range for cold-water fish species but would be suitable for intermediate or tolerant species such as perch and eel. Consecutive temperatures recorded upstream to downstream during habitat assessments were relatively consistent throughout each watercourse, ranging within a couple degrees. WC11 displayed the largest temperature range, from 15.4℃ at its upper reach (Reach 1) to 19.0℃ within its lowest reach (Reach 5). This downstream warming trend can be attributed to the widening of the stream and reduction of stream shade as the watercourse approaches Gold Brook.

3.2.2 pH

CCME FWALs establish that a range of pH from 6.5 to 9.0 is suitable within freshwater habitat to support aquatic health. Kalff (2002) indicates that the loss of fish populations is gradual and depends on fish species, but decline is evident when pH is <6.5. Kalff (2002) further states that a 10-20% species loss is apparent when pH <5.5.

Yellow perch are found in Ontario lakes with a pH range from approximately 3.9 to 9.5. Yellow perch are relatively tolerant of low pH, but reproductive success is reduced in lakes with pH < 5.5 (Krieger, Terrell & Nelson 1983). Brook Trout tolerate acidic conditions particularly well, compared with other species. They have been known to survive at pH 3.5 in laboratory settings (Daye and Garside, 1975). Raleigh (1982) proposed an optimal pH range for brook trout as 6.5-8.0, with a tolerance range of 4.0-9.5. American eel are also more tolerant of low pH than many other species, although densities and growth rates may be adversely affected by direct mortalities or declining abundance of prey as productivity declines at low pH (Jessop, 1995).

The pH range for aquatic features sampled within the PA was 3.89 to 7.71, with an average pH of 4.97. Only two sampling sites (WC1 and WC3) exhibited pH levels within CCME recommended range for freshwater aquatic life (6.5-9). About two thirds of the measurements recorded in-situ during fishing efforts and habitat assessment exhibited pH levels so low (<5.0) as to expect to cause harm to the eggs and fry of salmonid species (CCREM, 1987).

3.2.3 Dissolved Oxygen

The atmosphere and photosynthesis by aquatic vegetation are the major sources of DO in water (CCME, 1999). However, the amount of oxygen available for aquatic life (i.e., the concentration of oxygen in water) is affected by several independent variables including water temperature, atmospheric and hydrostatic pressure, microbial respiration, and growth of aquatic vegetation; DO can vary daily and seasonally (CCME, 1999). The CCME FWALs establish a minimum recommended concentration of DO of 9.5 mg/L for early life stages of cold-water biota and 6.5 mg/L for other life stages. For warm-water biota, the CCME guidelines recommend 6.0 mg/L for early life stages, and 5.5 mg/L for all other life stages.

Seventy-eight percent (78%) of DO levels recorded across aquatic features within the PA were below the minimum CCME recommended concentration of DO for early life stages of cold-water fishes (<9.5 mg/L). Twenty-seven percent (27%) of DO levels recorded for watercourses were below levels suitable for any life stage of cold-water fishes (<6.5 mg/L), and seventeen percent (17%) were below levels suitable for any life stage of cold or warm-water fishes (<5.5 mg/L). No consistent trends in DO were observed throughout the PA or sampling period; however, consistently low DO concentrations were recorded throughout watercourses measured during detailed habitat assessments in mid-August. It is likely that DO concentrations within some of these features limit the quality of fish habitat, at least seasonally.

3.2.4 Conductivity, Total Dissolved Solids, Turbidity

Total Dissolved Solids (TDS) is a measurement of inorganic salts, organic matter and other dissolved materials in water. Conductivity, which is a measure of water's capacity to conduct an electrical current, is correlated to TDS as increases in the mineral and salt content of water will increase its capacity to carry a charge. Toxicity in fish can be achieved through large increases in salinity, changes in the ionic composition of the water and toxicity of individual ions. A study by Weber-Scannell and Duffy (2007) reported a variety of studies that evaluated the effect of elevated TDS on freshwater aquatic invertebrates. These studies reported the commencement of effect at 499 mg/L, with most effects not observed until >1000 mg/L. With fish, research is limited, but preliminary studies reported in Weber-Scannell and Duffy (2007) demonstrated survival rates of salmonid embryos to elevated TDS (38% survival when exposed to 2229 mg/L for brook trout, and 35% survival when exposed to 1395 mg/L). Environment Canada has established a freshwater conductivity target of 500 µS/cm (conductivity must not exceed target) as part of its Environmental Performance Water Quality Index (EC, 2011).

Turbidity is the measure of light clarity. High turbidity levels can negatively affect fish in a number of ways, including decreases in food sources and DO levels, reduction in foraging and predation success, egg suffocation, and direct mortality (ENR, 2013)

Conductivity, TDS, and turbidity are often used as baseline for comparison with background measurements. Significant changes in these three parameters could indicate that a discharge or some other source of pollution has entered the aquatic resource. Conductivity, TDS and turbidity levels measured within the PA are considered acceptable for aquatic life.

3.3 Benthic Invertebrate Community

The total number of animals of each type (taxonomic group) was determined for each sample collected within the PA. These numbers were used to calculate several indices of baseline benthic community health and secondary productivity, which can be compared between sites and, with time, at each site. Indices calculated are all commonly used in studies of this kind and include total abundance (number of organisms in the sample and per unit area) and taxon richness (number of taxa per sample). All organisms present were included in estimates. Laboratory methods, as well as sediment descriptions for the twelve samples and species identifications, are presented in the report prepared by Envirosphere Consultants Limited, included in Appendix E. Total Abundance and Taxon Richness are presented in Table 3-4. Lotic and lentic FIA benthic sampling results are discussed separately.

Table 3-4. Benthic Invertebrate Community Characteristics (2021)

FIA	Sample	Abundance (# individuals/m^2)	Taxa Richness (# of species)
1 **WC22** Inlet to Gold Brook Lake	1.1	3,718	21
	1.2	4,202	22
	1.3	12,463	26
	Average	6,794	23
	Std. Dev.	4,915.2	2.6
2 **Gold Brook** Outlet of Gold Brook Lake	2.1	6,567	24
	2.2	847	13
	2.3	3,168	21
	Average	3,527	19
	Std. Dev.	2,876.9	5.7
3 **Gold Brook** Near south end of PA	3.1	1,507	19
	3.2	1,804	22
	3.3	770	12
	Average	1,360	18
	Std. Dev.	532.4	5.1
4 **Gold Brook Lake**	4.1 (mid-depth)	645	3
	4.2 (max-depth)	301	3
	4.3 (littoral zone)	7,568	11
	Average	2,838	6
	Std. Dev.	4,099.9	4.6

<u>*Lotic Systems*</u>

There are several factors that regulate the distribution and abundance of benthic macroinvertebrates, including current speeds, temperature, altitude, season, substratum, vegetation, dissolved substances (e.g., oxygen), and pH (Hussain & Pandit 2012). To illustrate the effects of some of these factors, temperature and pH is discussed in relation to their effects on benthic macroinvertebrates. The distribution and community structure of benthic macroinvertebrates is limited by their ability to live within a specific temperature range. Temperature affects their emergence patterns, growth rates (Sweeney & Schnack

1977), metabolism (Angelier 2003), reproduction (Vannote & Sweeney 1980), and body size (Sweeney & Schnack 1977). Benthic macroinvertebrates also vary in their sensitivity to pH. Values below 5.0 and greater than 9.0 are considered harmful (Yuan 2004); studies have shown that low pH values are associated with lower diversity of benthic macroinvertebrates (Thomsen & Friberg 2002) and can cause decreased emergence rates (Hall et al. 1980).

All lotic FIA (1-3) samples contained freshwater animals with major organism groups represented, primarily Diptera (midge fly larvae (Chironomidae)), Trichoptera (caddisfly larvae), and Coleoptera (aquatic beetles). Minor numbers of other groups occurred such as Ephemeroptera (mayfly larvae), Plecoptera (stonefly larvae), Hemiptera (aphididae), Odonata (damselfly larvae), Hydrachnidia (water mites), other Diptera (Empididae, Simuliidae and Tipulidae), the amphipod *Hyalella azteca*, Oligochaetes (aquatic worms), and Mollusca (bivalves Pisidiidae; gastropod *Ferrissia*). Communities had a low to high diversity of organisms (12 – 26 taxa per sample); and low to high abundances (770 – 12,463 individuals per metre squared). The highest average abundance per site was found at the inlet to Gold Brook Lake (Site 1), with an average abundance of 6794 individuals per square meter. Abundance was lower at each subsequent downstream sample with an average abundance of 6527 and 1360 individuals per square meter at Sites 2 and 3, respectively. Biomass was highest at site 2, with 8.19 g/m^2, compared with 6.63 g/m^2 and 1.11 g/m^2 on average at sites 1 and 3, respectively.

Taxon richness indicates the health of the community through its diversity, and increases with increasing habitat diversity, suitability, and water quality. Taxon richness equals the total number of taxa represented within the sample. The healthier the community is, the greater the number of taxa (i.e., diversity of taxa) found within that community. Similarly, a high abundance may indicate a healthier waterbody. Overall average taxon richness was moderate for all three lotic FIAs (13-26 taxa identified).

Gold Brook Lake

Samples from Gold Brook Lake sites contained freshwater animals with major organism groups represented, primarily Diptera (midge fly larvae (Chironomidae)). Minor numbers of other groups occurred such as Ephemeroptera (mayfly larvae), Trichoptera (caddisfly larvae), Lepidoptera (aquatic moth and butterfly larvae), Megaloptera (alderfly larvae), other Diptera (Ceratopogonidae and Chaoboridae), the amphipod *Hyalella azteca*, Mollusca (gastropod *Ferrissia*), and oligochaetes (aquatic worms). Communities had a low to low/moderate diversity of organisms (3 – 11 taxa per sample); and low to high abundances (301 – 7,568 individuals per metre squared). Abundance, diversity and biomass were all highest at site 3, which is located in the southern potion of the lake, relatively close to the outlet.

3.4 Fish Surveys

A total of six species and 1817 individual fish were captured across twenty-six of the forty survey locations as a result of fishing efforts (i.e. all electrofishing and trapping surveys) completed in 2020-2021 within the PA, including:

- WC1
- WC8
- WC9 (Reach A and B)
- WC13
- WC14
- WC20

- WC22 (Reach A, B and Open Water)
- WC23/20
- WC43 (Reach A and B)
- WC49 (Reach B)
- Gold Brook (Reach A and B)
- Gold Brook Lake (North, East, South, and West)
- Rocky Lake (1 and 2)
- Settling Pond Outlet

No fish were captured during any survey conducted in WC2, WC3, WC4, WC7, WC11 WC12, WC49 (Reach A), WC57, WC63, WC70, the Beaver Pond, or either Settling Pond. The results of the 2020-2021 electrofishing and trapping surveys within the PA are presented on Figure 4 a and b, Appendix A.

Table 3-5 presents a summary of fish species captured through all electrofishing and trapping surveys within the PA, listed in order of abundance. Individual data for fish captured at each sampling site within the PA are presented in Appendix D, and representative photos of each species captured are presented in Appendix C (Photos 40-45).

Table 3-5. Fish Species Captured within the PA (2020-2021)

Species	**SRank**	**SARA/COSEWIC/NSESA**	**Total Catch**	
			Total #	**% Catch**
yellow perch (*Perca flavescens*)	S5	N/A	547	30.1%
American eel (*Anguilla rostrata)*	S2	COSEWIC: Threatened	537	29.6%
brook trout *(Salvelinus fontinalis*)	S3	N/A	394	21.7%
golden shiner (*Notemigonus crysoleucas)*	S4	N/A	186	10.2%
banded killifish (*Fundulus diaphanous)*	S5	COSEWIC: Not at Risk	128	7.0%
blacknose shiner (*Notropis heterolepis)*	S4	N/A	25	1.4%
Total			**1817**	

3.4.1 Fish Species Observed

Within the PA, six different species of fish were identified through electrofishing and trapping surveys. Yellow perch and American eel were the most commonly captured and widely distributed species, representing almost 60% of the total catch for all fishing efforts. Brook trout and golden shiner were less frequently represented, accounting for 21.7% and 10.2% of the total catch, respectively. Banded killifish and blacknose shiner were lowest represented fish, accounting for 7.0% and 1.4% of all fish caught throughout the 2020-2021 studies. Only one yellow perch was caught within Gold Brook through all fish collection surveys.

Life stage and freshwater habitat descriptions for all species captured within the PA during the 2020-2021 fishing efforts are provided in the following paragraphs.

3.4.1.1 *Yellow Perch*

Yellow perch are a schooling, shallow water fish that can adapt to a wide variety of warm or cool habitats. Most yellow perch do not appear to migrate, but some do in patterns which tend to be short and local (Brown et al., 2009). Adults and juveniles are found in large lakes, small ponds, or gentle rivers but are most abundant in clear, highly vegetated lakes (1-10 m depth) that have muck, sand, or gravel bottoms (Brown et al., 2009). They prefer summer temperatures of 21-24°C.

Spawning occurs in the spring, with adults moving to lake shallows or low velocity areas of rivers with moderate vegetation. Within 1 to 2 months of emergence, young of the year perch move to open water (Krieger, Terrell & Nelson, 1983).

Yellow perch are considered provincially secure by the ACCDC (S5). During the 2020-2021 field program, yellow perch made up over 30% of all fish caught within the PA. A total of 547 yellow perch of all stages of life, Young-of-the-Year (YOY), juvenile and adults were caught in WC20, Gold Brook and Gold Brook Lake.

3.4.1.2 *American Eel*

Suitable habitat for eel is varied. As a catadromous species, eel spend the majority of their lives in freshwater, moving to the Sargasso Sea to spawn. Once hatched, American eel larvae drift back to the coast, undergoing several phases of metamorphosis. By the time they reach freshwater, young glass eel have developed pigment and are now referred to as elvers (Scott and Crossman, 1973). In freshwater, elvers develop into yellow eels – immature adults and at which point sexual differentiation occurs. As growth proceeds, the yellow eel metamorphoses into silver eel, or mature adults that are now physiologically prepared to return to the sea to spawn (COSEWIC, 2012).

American eel are frequently found in watercourses that offer structural complexity and shade in the form of coarse woody debris, rocks, in-stream vegetation for daytime cover, and an available food source of forage fish, invertebrates, molluscs and vegetation. Migrating elvers are bottom dwellers and spend most of their time burrowed or hidden, including directly into soft bottom sediments (Tomie, 2011). In freshwater, yellow eel continue their migration upstream into rivers, streams, and muddy or silt bottomed lakes (Scott and Crossman, 1998). Like elvers, yellow eel are primarily nocturnal, spending most of the day under cover or buried in soft substrates. These soft substrates are particularly important for overwintering, where the eel hibernate by burying themselves into the bottoms of lakes and rivers (Smith and Saunders, 1995; Scott and Scott, 1998). Trautman (1981) also reported that eel partially or completely bury themselves in mud, sand and gravel during the day, emerging at dusk to begin feeding.

American eel have been assessed as threatened by COSEWIC (2012) and are considered provincially imperiled by the ACCDC (S2). American eel are not currently protected under SARA or NSESA. During the 2020-2021 field program, American eel made up almost 30% of all fish caught within the PA. A total of 537 American eel between the life stages of juvenile and adult were confirmed in WC1, WC8, WC9 Reach A and B, WC13, WC14, WC20, WC22, WC43, Gold Brook, Gold Brook Lake, the Settling Pond Outlet and Rocky Lake 1&2.

3.4.1.3 *Brook trout*

Brook trout are known to inhabit a wide range of cool, freshwater environments, from small headwater streams to large lakes. Water temperature is a critical factor influencing brook trout distribution and production. Though typically not anadromous, brook trout require free passage along streams to move between areas of use, including spawning grounds, overwintering areas, and summer rearing areas.

In Nova Scotia, mature brook trout migrate to spawn in lakes or streams in the fall of the year. Brook trout spawning sites are usually near groundwater upwelling or spring seeps and within a lake or stream with gravel substrate (NSDFA, 2005). Optimal spawning conditions for brook trout include clear substrate 3-8 mm in size in shallow water with limited fines (<5%), and velocities of 25-75 cm/s (Raleigh, 1982).

Young of the year brook trout require cold water, stable, low velocities and an abundance of in-stream cover. Optimal temperature for juvenile growth is 10-16°C, while cover in the form rubble, vegetation, undercut banks, and woody debris should account for a minimum of 15% of total stream area (Raleigh, 1982). In winter, brook trout aggregate in pools beneath silt-free rocky substrate and close to point sources of groundwater discharge (Raleigh, 1982; Cunjak and Power, 1986). Adults use both pools and riffles, with more than 25% in-stream cover being optimal (Raleigh, 1982). Brook trout respond negatively to flashy or hydrologically dynamic systems and require stable flow for all life stages (Raleigh, 1982).

Brook trout are considered provincially vulnerable by the ACCDC (S3) but have not been assessed by COSEWIC nor are they currently listed under SARA or NSESA. During the 2020-2021 field program, brook trout made up almost 22% of all fish caught within the PA. A total of 394 brook trout of all stages of life, YOY, parr and adult, were captured within the PA in WC1, WC9, WC14, WC20, WC22, WC43, WC49, Gold Brook, and Gold Brook Lake.

3.4.1.4 *Golden Shiner*

Golden shiner are habitat generalists, primarily found schooling in well vegetated lakes with extensive shallows (Scott and Crossman, 1973). The species can tolerate a wide range of oxygen concentrations and temperatures (Murdy et al., 1997).

Spawning takes place from June to August, when temperatures reach 20°C, during which adhesive eggs are scattered over the substrate, attaching to filamentous algae or other aquatic vegetation (Scott and Crossman, 1973).

Golden shiner are considered provincially apparently secure by the ACCDC (S4). During the 2020-2021 field program golden shiners made up about 10% of all caught fish within the PA. A total of 186 golden shiner between the life stages of juvenile and adult were caught within Gold Brook, Gold Brook Lake and Rocky Lake 1&2.

3.4.1.5 *Banded Killifish*

Banded killifish are freshwater habitat generalists found within the quiet waters of lakes, ponds, and sluggish streams, tolerating a broad temperature, salinity, and DO range (COSEWIC, 2014). Adults tend to school in shallow water characterized by sand, gravel, or muddy substrate, with submerged aquatic plants (Scott and Crossman, 1973). Banded killifish are generally not considered a strong swimmer, and high velocities are thought to limit the species' movement within a watershed (DFO, 2011). Seasonal movement by the species has not been documented, and it is not considered migratory (COSEWIC, 2014).

Banded killifish spawning has been seldom documented; however, it is thought that aquatic vegetation within quiet shallows is a key component in spawning habitat as an attachment point for externally fertilized eggs (Richardson, 1939).

Banded killifish are considered provincially secure by the ACCDC (S5). During the 2020-2021 field program banded killifish made up 7% of all fish caught within the PA. In total, 128 banded killifish between the life stages of juvenile and adult were captured within WC20, Gold Brook, Gold Brook Lake, and the Settling Pond Outlet.

3.4.1.6 *Blacknose shiner*

The blacknose shiner prefers clear, vegetated bays and quiet streams, with shallow water and sand or gravel bottoms (Scott and Crossman, 1973). Spawning is thought to occur in spring and summer, though blacknose shiner spawning has been largely undocumented.

Blacknose shiner are considered provincially apparently secure by the ACCDC (S4). During the 2020-2021 field program blacknose shiners made up only 1.4% of all caught fish within the PA. Twenty-five juvenile blacknose shiners were caught within Gold Brook Lake.

3.4.2 Quantitative Electrofishing

The results of quantitative electrofishing surveys are presented in Table 3-6. When practical, population estimates, the probability of capture, and standard errors of population estimates have been provided for each individual survey. Quantitative estimates of overall fish abundance were calculated using a multiple-pass depletion method based on the total number of fish captured within a closed site through each successive pass. Population estimates were not able to be calculated for those surveys resulting in no catch or very low catch numbers, nor were they calculated for individual species. Detailed results for individual fish captured and processed (lengths and weights) have been provided in Appendix D.

Table 3-6. Summary of Quantitative Electrofishing Efforts within the PA (2020-2021)

Site	Survey Dates	Fish Species Collected	Catch Per Species	Total Catch	Total Catch Per Pass ($1^{st}/2^{nd}/3^{rd}$ etc.)	Population Estimate (*N*)	Probability of Capture (*p*)	Standard Error	95% Confidence Limit
WC1	June 22, 2020	American eel brook trout	6 4	10	2/3/3/2/0	N/A	N/A	N/A	N/A
	August 1, 2020	American eel brook trout	8 13	21	21[2]	N/A (CPUE = 4.53)	N/A	N/A	N/A
	August 20, 2020	American eel brook trout	7 14	21	14/4/3	21	0.6774	0.0	N/A
WC3	June 22, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	July 31, 2020[1]	none	0	0	0/0	N/A	N/A	N/A	N/A
WC4	June 23, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	July 29, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	August 23, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
WC7	June 23, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	July 28, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	August 22, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
WC8	June 26, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	July 27, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	August 19, 2020	American eel	1	1	0/1	N/A	N/A	N/A	N/A
WC9 Reach A	June 24, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	July 30, 2020	American eel	1	1	1/0/0	N/A	N/A	N/A	N/A
	August 21, 2020	none	0	0	0[3]	N/A	N/A	N/A	N/A
WC9 Reach B	June 24, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	July 30, 2020	none	0	0	0/0	N/A	N/A	N/A	N/A
	August 21, 2020	American eel brook trout	2 1	3	3/0/0	N/A	N/A	N/A	N/A
WC14	June 26, 2021	American eel brook trout	5 59	64	33/25/6	70	0.5378	3.9	70 ± 7.8
	July 21, 2021	American eel brook trout	1 7	8	4/1/3/0	8	1.1429	0.0	8 ± 0.0
	August 23, 2021	American eel brook trout	4 35	39	15/10/9/4/1	41	0.4190	1.9	41 ± 3.8
WC20	June 24, 2021	American eel brook trout	6 5	11	9/2/0	11	0.8462	0.0	11 ± 0.0
	July 24, 2021	American eel	11	15	8/6/1	18	0.4688	5.8	18 ± 11.6

Site	Survey Dates	Fish Species Collected	Catch Per Species	Total Catch	Total Catch Per Pass (1st/2nd/3rd etc.)	Population Estimate (*N*)	Probability of Capture (*p*)	Standard Error	95% Confidence Limit
		brook trout	4						
	August 27, 2021	American eel brook trout	11 6	17	6/8/3	20	0.4250	2.9	20 ± 5.8
WC22 Reach B	June 25, 2021	American eel brook trout	10 7	17	11/5/1	19	0.5667	4.3	19 ± 8.6
	July 22, 2021	American eel brook trout	10 14	24	15/6/3	25	0.6154	1.3	25 ± 2.6
	August 26, 2021	American eel brook trout	9 15	24	11/4/7/2	27	0.4000	2.9	27 ± 5.8
WC 43 Reach A	June 28, 2021	brook trout	5	5	2/3	N/A (CPUE=1.40)	N/A	N/A	N/A
WC 43 Reach B	June 27, 2021	American eel brook trout	1 17	18	10/6/2	22	0.4500	7.0	22 ± 14.0
	July 25, 2021	brook trout	73	73	23/10/12/11/9/8	99	0.2500	7.8	99 ± 15.6
	August 28, 2021	brook trout	71	71	39/17/10/5	77	1.0143	0.3	77 ± 0.6
Settling Pond Outlet	June 25, 2020	American eel banded killifish	19 7	26	17/8/1	26	0.7222	0.0	N/A
	July 27, 2020	American eel banded killifish	12 2	14	14[2]	N/A (CPUE = 3.77)	N/A	N/A	N/A
	August 22, 2020	American eel banded killifish	8 3	11	11[2]	N/A (CPUE = 2.19)	N/A	N/A	N/A

*N/A Indicates that no fish were caught, or fish were captured in low abundance limiting the ability to provide statistically relevant population estimates. CPUE (calculated as fish/300 electrofishing seconds) has been presented as a measure of abundance when possible.
[1]Could not electrofish WC3 in late August – water depths too shallow to submerge anode ring.
[2]Could not complete subsequent passes due to water temperatures exceeding 22°C.
[3]Extremely low water levels did not warrant a second pass.

No fish were captured during any quantitative electrofishing survey in WC3, WC4, and WC7. Only one American eel was captured in both WC8 and WC9 Reach A throughout all three surveys, and no fish were recorded in WC9 Reach B until the third round of electrofishing in August, during which two American eel and one brook trout were captured. Population estimates were not calculated for these reaches due the extremely low or zero catch.

Quantitative population estimates were able to be calculated for the late summer survey of WC1 and the early summer survey of the Settling Pond Outlet. Population estimates for WC1 and the Settling Pond Outlet were 21 fish and 26 fish, respectively. American eel and brook trout were captured in WC1, while American eel and banded killifish were the only species captured within the Settling Pond Outlet. No temporal trends in fish populations throughout the three rounds could be deduced from the available data. WC1 is a first order stream that feeds into Gold Brook via WC3. The Settling Pond Outlet is a western branch of Gold Brook which intercepts the outflow of a series of historic settling ponds. Only one round of quantitative fishing was done on WC43 Reach A and 5 brook trout were caught over two passes. A population estimate could not be calculated, but a CPUE of 1.40 was determined.

WC14, WC20, WC22 Reach B and WC43 Reach B had quantitative estimates calculated for all 3 rounds of electrofishing done in 2021. WC14 had its greatest range in population estimate of 70 in early summer and 8 in mid-summer. The estimated population increased again for late summer. During all three rounds of electrofishing in WC20 and WC22 Reach B, American eel and brook trout were caught each round, resulting in relatively similar population estimates in both watercourses. In WC20, early summer had the lowest population estimate of 11 and mid-summer the highest of 20. Whereas in WC22 Reach B, the estimated population grew from early summer estimated at 19 to 27 in late summer. No temporal trends in fish populations throughout the three rounds could be deduced from the available data for WC20 or WC22 Reach B. Three rounds of electrofishing were completed in WC43 Reach B in the summer of 2021. Brook trout was caught in all three rounds of fishing, but American eel was only caught in early summer. Estimated population grew throughout the summer from 22 in early summer, peaked at 99 in mid-summer and declined to 77 in late summer.

3.4.3 Qualitative Electrofishing

The results of qualitative electrofishing surveys are presented in Table 3-7. Relative abundance has been expressed through CPUE calculated as the number of fish captured per 300 seconds of electrofishing effort.

Table 3-7. Summary of Qualitative Electrofishing Efforts within the PA (2020-2021)

Site	Survey Date	Fish Species Collected	Catch Per Species	Total Catch	Total Effort (seconds)	CPUE (fish/300 seconds)
WC1	August 31, 2021	none	0	0	691.6	0
WC2	July 27, 2021	none	0	0	180.6	0
WC11	June 25, 2021	none	0	0	205.4	0
	July 28, 2021	none	0	0	231.1	0
	August 19, 2021	none	0	0	253.2	0
WC12	June 25, 2020	none	0	0	275.9	0
	July 28, 2020	none	0	0	256.5	0
	August 19, 2020	none	0	0	295.1	0
WC13	July 27, 2021	American eel	1	1	346.1	0.87
WC22 Reach A	June 27, 2021	American eel	4	5	847.9	1.77

Site	Survey Date	Fish Species Collected	Catch Per Species	Total Catch	Total Effort (seconds)	CPUE (fish/300 seconds)
		brook trout	1			
	July 19, 2021	American eel	2	2	717.2	0.84
	August 23, 2021	American eel brook trout	4 1	5	1044.9	1.44
WC43 Reach A	July 26, 2021	brook trout	10	7 3	P1- 504.5 P2- 486.4	4.17 1.85
	August 30, 2021	brook trout	7	4 3	P1- 951.6 P2- 770.8	1.26 1.17
WC49 Reach A	July 27, 2021	none	0	0	525.8	0
WC49 Reach B	July 28, 2021	brook trout	2	2	482.7	1.24
WC57	July 29, 2021	none	0	0	437.1	0
WC63	July 29, 2021	none	0	0	295.3	0
WC70	July 27, 2021	none	0	0	202.4	0
Gold Brook Reach A	June 27, 2020	American eel banded killifish brook trout	49 1 2	52	2669.8	5.84
	July 28, 2020	American eel banded killifish brook trout	41 2 3	46	4477.4	3.08
	August 23, 2020	American eel banded killifish brook trout yellow perch	52 15 7 1	75	2097.8	10.73
	June 26, 2021	American eel brook trout	38 1	39	1894.2	6.18
	July 23, 2021	American eel banded killifish brook trout yellow perch	27 3 1 1	32	1630.3	5.89
	July 26, 2021	American eel banded killifish brook trout yellow perch	26 5 2 3	36	2004.5	5.39
	August 29, 2021	American eel banded killifish	28 14	42	1730.0	7.28
Gold Brook Reach B	June 21, 2021	American eel yellow perch	32 1	33	1972.4	5.02
	July 23, 2021	American eel brook trout yellow perch	26 2 2	30	2047.7	4.40
	August 29, 2021	American eel banded killifish brook trout golden shiner yellow perch	27 7 3 1 7	45	1964.8	6.87
Settling Pond 1	August 30, 2021	none	0	0	186.0	0
Settling Pond 2	August 30, 2021	none	0	0	103.4	0

No fish were captured during any qualitative electrofishing surveys within WC1, WC2, WC11, WC12, WC49 Reach A, WC57, WC63, WC70 or either of the Settling Ponds. WC22 Reach A had American eel

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and brook trout in all three rounds of fishing in 2021, except Round 2. CPUE for this reach was highest in early summer (1.77 fish per 300 electrofishing seconds) and lowest in mid-summer (0.84 fish per 300 electrofishing seconds). WC49 Reach B had two brook trout caught during the single pass conducted on it, resulting in a CPUE of 1.24. Open site electrofishing in Gold Brook over the summers of 2020 and 2021, resulted in the capture of five species: American eel, banded killifish, brook trout, golden shiner, and yellow perch, with American eel accounting for the majority of fish captured. CPUE for Gold Brook was highest in the late summer of 2020 (10.73 fish per 300 electrofishing seconds), and lowest in mid-summer of 2020 (3.08 fish per 300 electrofishing seconds).

3.4.4 Trapping

The results of trapping efforts are presented in Table 3-8. Relative abundance has been expressed through CPUE per trap type and per species.

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Table 3-8. Summary of Trapping Efforts within the PA (2020-2021)

Site	Survey Date	Fish Species Collected	Total Catch	Total Effort Per Trap Type (hours)	Total Catch Per Trap Type	CPUE (per trap type)	CPUE (per species)
WC8	July 27-28, 2020	none	0	MT- 46.83 hrs	0	0	0
WC14	June 22, 2021	brook trout	4	MT- 112.50 hrs EP- 22.50 hrs	2 2	0.018 0.089	brook trout – 0.030
	July 20, 2021	brook trout	1	MT- 116.42 hrs EP- 23.28 hrs	0 1	0 0.043	brook trout – 0.007
	August 28, 2021	brook trout	1	MT- 117.92 hrs EP- 23.58 hrs	1 0	0.008 0	brook trout – 0.007
WC12	June 23-24, 2020	none	0	MT- 48.17 hrs	0	0	0
WC22 Open Water	June 22-23 2021	none	0	MT- 108.17 hrs EP- 21.63 hrs	0 0	0 0	0
	July 19-20, 2021	none	0	MT- 122.92 hrs EP- 24.92 hrs	0 0	0 0	0
	August 27-28, 2021	none	0	MT- 119.17 hrs EP- 23.83 hrs	0 0	0 0	0
WC23/WC20	June 24-25, 2021	yellow perch	62	MT- 261.67 hrs	62	0.237	yellow perch – 0.237
	July 23-24, 2021	banded killifish yellow perch	1 30	MT- 233.33 hrs	31	0.133	banded killifish – 0.004 yellow perch – 0.129
	August 25-26, 2021	banded killifish yellow perch	2 91	MT- 236.67 hrs	93	0.393	banded killifish – 0.008 yellow perch – 0.385
Beaver Pond	April 18-19, 2020	none	0	MT- 84.00 hrs	0	0	0
	June 24-25, 2020	none	0	MT- 46.00 hrs	0	0	0
	July 28-29, 2020	none	0	MT- 51.67 hrs	0	0	0
	August 22-23, 2020	none	0	MT- 49.50 hrs	0	0	0
Gold Brook Reach A	August 24-25, 2021	American eel brook trout yellow perch	3 1 1	EP- 143.87 hrs	5	0.035	American eel – 0.021 brook trout – 0.007 yellow perch – 0.007
Gold Brook Lake North	June 24-25, 2021	banded killifish golden shiner yellow perch	2 2 54	MT- 255.00 hrs EP- 52.00 hrs FN- 25.50 hrs	39 11 8	0.153 0.211 0.314	banded killifish – 0.006 golden shiner – 0.006 yellow perch – 0.162
	July 23-24, 2021	American eel golden shiner yellow perch	1 4 45	MT- 243.00 hrs EP- 48.60 hrs FN- 24.30 hrs	35 12 3	0.144 0.247 0.123	American eel – 0.003 golden shiner – 0.013 yellow perch – 0.143
	August 24-25, 2021	banded killifish	1	MT- 210.83 hrs	13	0.062	banded killifish – 0.004

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Site	Survey Date	Fish Species Collected	Total Catch	Total Effort Per Trap Type (hours)	Total Catch Per Trap Type	CPUE (per trap type)	CPUE (per species)
		brook trout golden shiner yellow perch	2 1 14	EP- 42.17 hrs FN- 21.08 hrs	2 3	0.047 0.142	brook trout – 0.007 golden shiner – 0.004 yellow perch – 0.051
Gold Brook Lake East	June 23-24, 2021	golden shiner	3	FN- 26.13 hrs	3	0.115	golden shiner – 0.115
	July 23-24, 2021	none	0	FN- 25.25 hrs	0	0	0
	August 24-25, 2021	golden shiner yellow perch	1 1	FN- 21.17 hrs	2	0.095	golden shiner – 0.047 yellow perch – 0.047
Gold Brook Lake South	June 23-24, 2021	banded killifish golden shiner yellow perch	8 1 39	MT- 78.20 hrs EP- 52.13 hrs SN- N/A	8 14 26	0.102 0.269 N/A	banded killifish – 0.061 golden shiner – 0.008 yellow perch – 0.299
	July 20-21, 2021	American eel banded killifish yellow perch	3 11 35	MT- 70.50 hrs EP- 47.00 hrs SN- N/A	24 8 17	0.340 0.170 N/A	American eel – 0.026 banded killifish – 0.094 yellow perch – 0.298
	August 24-25, 2021	American eel banded killifish blacknose shiner yellow perch	5 44 25 42	MT- 69.25 hrs EP- 46.17 hrs SN- N/A	21 23 72	0.303 0.498 N/A	American eel – 0.043 banded killifish – 0.381 blacknose shiner – 0.217 yellow perch – 0.364
	August 27-28, 2021	yellow perch	52	EP- 59.50 hrs	52	0.874	yellow perch – 0.874
Gold Brook Lake West	June 23-24, 2021	American eel golden shiner yellow perch	1 2 1	FN- 26.45 hrs	4	0.151	American eel – 0.038 golden shiner – 0.076 yellow perch – 0.038
	July 23-24, 2021	American eel golden shiner yellow perch	2 1 50	EP- 24.50 hrs FN- 24.50 hrs	51 2	2.082 0.082	American eel – 0.041 golden shiner – 0.020 yellow perch – 1.020
	August 25-26, 2021	American eel	1	EP- 24.33 hrs FN- 24.33 hrs	1 0	0.041 0	American eel – 0.021
	August 29-30, 2021	American eel yellow perch	6 13	EP- 68.65 hrs	19	0.277	American eel – 0.088 yellow perch – 0.189
Rocky Lake 1	June 22-23, 2021	American eel golden shiner	2 34	MT- 118.75 hrs FN- 47.50 hrs	36 0	0.303 0	American eel – 0.012 golden shiner – 0.205
	July 19-20, 2021	American eel golden shiner	5 97	MT- 114.58 hrs FN- 22.92 hrs	102 0	0.890 0	American eel – 0.036 golden shiner – 0.705
	August 24-25, 2021	American eel golden shiner	1 29	MT- 117.50 hrs FN- 23.50 hrs	29 1	0.247 0.043	American eel – 0.007 golden shiner – 0.206
Rocky Lake 2	June 22-23, 2021	American eel golden shiner	2 3	EP- 46.67 hrs	5	0.107	American eel – 0.043 golden shiner – 0.064

Site	Survey Date	Fish Species Collected	Total Catch	Total Effort Per Trap Type (hours)	Total Catch Per Trap Type	CPUE (per trap type)	CPUE (per species)
	July 19-20, 2021	American eel golden shiner	1 5	EP- 51.00 hrs	6	0.118	American eel – 0.020 golden shiner – 0.098
	August 14-15, 2021	American eel golden shiner	5 2	EP- 47.00 hrs	7	0.149	American eel – 0.106 golden shiner – 0.043
Settling Pond 1	April 3-4, 2020	none	0	MT- 57.00 hrs	0	0	0
	August 30-31, 2021	none	0	MT- 43.50 hrs EP- 21.75 hrs	0 0	0 0	0
Settling Pond 2	August 30-31, 2021	none	0	MT- 42.57 hrs EP- 21.28 hrs	0 0	0 0	0

No fish were caught as a result of minnow trapping efforts in 2020, which equated to 708.17 hours of trapping. This includes seasonal high flow trapping in WC9 (April 2020). Similarly, no fish were caught in either settling pond in 2021 after a combined 129 hours of trapping. Three rounds of trapping within the open water feature in WC22 resulted in no caught fish after 420 hours of trapping were completed

Of the watercourses, waterbodies and open water features sampled within the SA, Gold Brook Lake South and North in late summer had the highest diversity of all sites, with four species present of the total of six species captured during fishing efforts within the PA. Twenty-seven of the sixty-eight trap groupings (i.e., collection of a single trap type at a site) resulted in zero catch. CPUE by trap type ranged from 0.008 (minnow traps in WC 14) to 2.082 (eel pot in Gold Brook Lake West).

3.5 eDNA

The results of eDNA samples collected in the PA on October 13, 2021 are provided in Table 3-9. The laboratory results report is available in Appendix E. Results from the analysis for Atlantic salmon are shown as 'un-diluted'/'diluted'. To rule out false-negatives, samples were diluted ten-fold and re-analyzed, to reduce any PCR inhibiting compounds. To confirm detection at site 4, samples were analyzed, un-diluted, an additional time for extra confidence in the detection of Atlantic Salmon.

Table 3-9. Summary of eDNA Sample Results (2021)

Site ID	WC Number	Analysis		Result	Interpretation
1	WC22 – Inlet to Gold Brook Lake	Atlantic Salmon (Dalhousie)	1A	0/3, 0/3	Negative
			1B	0/3, 0/3	
			1C	0/3, 0/3	
2	WC64 (Gold Brook) – Outlet of Gold Brook Lake	Atlantic Salmon (Dalhousie)	2A	0/3, 0/3	Negative
			2B	0/3, 0/3	
			2C	0/3, 0/3	
3	WC64 (Gold Brook) – Outlet of Gold Brook Lake near end of SA	Atlantic Salmon (Dalhousie)	3A	0/3, 0/3	Negative
			3B	0/3, 0/3	
			3C	0/3, 0/3	
4*	Ocean Lake System	Atlantic Salmon (Dalhousie)	4A	3/3, 2/3, 0/3	Positive
			4B	3/3, 1/3, 2/3	
			4C	3/3, 1/3, 3/3	
5	Settling Pond	eFish (BV Laboratory)	SP A	8/8	Positive
			SP B	8/8	
			SP C	8/8	

*Positive control sites where Atlantic salmon is expected to be present. Analysis for Atlantic Salmon was completed by Dr. Paul Bentzen's laboratory at Dalhousie University. Analysis using the eFish primer was completed by BV Laboratory. Full details on sample analysis and interpretation for these samples are provided in the Dalhousie and BV technical reports, Appendix E.

Sample results for Atlantic Salmon are consistent with expectations based on site knowledge and fish collection efforts to date. While conventional fish collection was not completed in the Ocean Lake system (New Harbour River secondary watershed (1EQ-4)), Atlantic Salmon detection was expected based on consultation with DFO and desktop studies on fish distribution. While fish collection to date has not resulted in any fish capture at Site 5 (Settling Pond), eDNA analysis resulted in strong detection of fish DNA.

3.6 Detailed Fish Habitat Surveys

For detailed fish habitat assessments, each habitat type has been characterized via surveys using standard methodologies to gather key measurements such as reach length (m), reach wetted and channel widths (m), reach slope (%), stream substrate composition (% composition), water depths (m), water velocities (m/s), cover (%), and riparian habitat. The data was used to determine the overall habitat area within each reach as well as the habitat suitability based on measured stream substrate, water depths, and water velocities (habitat parameters) for each fish species identified or potentially residing within the PA.

A summary of key fish habitat characteristics within each linear watercourse surveyed, and the fish species and life stages they support, are presented in Table 3-10 , Table 3-11 and Table 3-12. Delineated watercourse reaches are presented on Figure 6 a to i, Appendix A, and representative photos are presented in Appendix C (Photos 46-122).

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Table 3-10: Summary of Key Diagnostic Features of Fish Habitat within Linear Watercourses (2020-2021)

Water-course	Reach	Stream Order	Flow Type[1]	Reach Characteristics										Fish Support[6]					
				Channel Width (m)[2]	Wetted Width (m)[2]	Reach Length (m)	Dominant Habitat Type	Other Habitats Present	Slope (%)[3]	Average Velocity (m/s)	Average Depth (m)	Dominant Substrate	Cover (%)[4]	Confirmed Species (2020-2021)[7]	Probable Species[5]	Spawning	YOY	Juvenile	Adult
1	1	1	P	2.0	1.4	90	Run	-	1	0.08	0.11	Muck/Detritus	12	BKT, EEL	BKT, EEL	-	-	-	BKT, EEL
	2	1	P	0.5-2.0	1.4-2.1	273	Riffle	Pool	2	0.08	0.10	Boulder	27			-	BKT	BKT, EEL	BKT, EEL
2	1	1	P	0.8-1.4	0.4-0.8	212	Flat	Riffle	<1	<0.05	0.09	Muck/Detritus	87	None	BKT, EEL	-	-	-	EEL, BKT
3	1	1-2	I	0.5-2.4	Dry-1.4	921	Run	Riffle	1	0.09	0.14	Boulder	16	None	BKT, BKF, EEL, GSH, YLP	-	BKT	EEL, BKT	EEL, BKT
	2	2	I	1.2	0.75	81	Riffle	-	2	0.11	0.07	Boulder	17			-	BKT	EEL, BKT	EEL, BKT
	3	2	P	1.2-1.6	0.75-1.1	113	Flat	-	<1	<0.05	0.09	Muck/Detritus	58			BFK, GSH	BFK, GSH	BFK, GSH	EEL, BKT, BFK, GSH
4	1	1	I	0.9	0.6	19	Flat	-	<1	<0.05	0.11	Muck/Detritus	8	None	BKT, EEL	-	-	-	EEL, BKT
	2	1	I	1.4-2.6	1.2-2	426	Riffle-Run	Pool	2-4	0	0 (0.14 where water present)	Rubble	5			-	BKT	EEL, BKT	EEL, BKT
5	1	1	I	0.4-0.5	Dry	260	Run	-	1-2	0	0	Rubble	4	N/A	BKT, EEL	-	BKT	BKT	EEL, BKT
6	1	1	I	0.5-0.9	Dry-0.5	103	Riffle-Run	Step-pool	2-4	0	0 (0.14 where water present)	Muck/Detritus	8	N/A	BKT, EEL	-	-	-	EEL, BKT
7	1	1-2	I-P	0.5-1.5	Dry-1.5	486	Riffle-Run	Flat	2-4	0	0 (0.13 where water present)	Muck/Detritus	18	None	BKT, EEL	-	-	-	EEL, BKT
8	1	2	P	1.1-2.4	0.5-1.0	75	Flat	Riffle	<1	<0.05	0.29	Bedrock, Cobble, Clay	53	EEL	BKF, BKT, BNS, EEL, GSH, YLP	-	BKT	BKT	BKT
	2	2	P	0.85-1.3	0.6-1.0	120	Riffle	Flat	3	<0.05	0.08	Cobble, Gravel	37			-	BKT	BKT	BKT
	3	2	P	0.7-0.8	Dry-0.8	70	Run	Pool	1	<0.05	0.12	Boulder, Rubble, Cobble, Gravel, Muck/Detritus	12			-	BKT	EEL, BKT	EEL, BKT
	4	2	P	0.65-1.0	Dry	145	Riffle	-	2-4	0	0	Rubble, Cobble, Gravel	32			-	BKT	BKT	BKT
	5	2	P	1.1	0.5	113	Run	-	1	<0.05	0.06	Boulder, Rubble	15			BKF, BNS, GSH, YLP	BKF, BNS, GSH, YLP	BKT, EEL, BKF, BNS, GSH, YLP	BKT, EEL, BKF, BNS, GSH, YLP
9	1	1	I	0.8-1.3	0.5-1.3	400	Flat	-	<1	<0.05	0.23	Muck/Detritus	78	BKT, EEL	BKF, BKT, BNS, EEL, GSH, YLP	-	-	EEL	EEL
	2	1	I	0.8	Dry	110	Run	-	2-3	0	0	Boulder	11			-	BKT	BKT	BKT, EEL
	3	1	I	0.2-2.4	0.2-2.4	357	Flat	Riffle	<1	<0.05	0.10	Muck/Detritus	15			-	-	-	BKT, EEL
	4	1	I	1.0-1.5	Dry-1.0	154	Run	-	2-4	<0.05	0.04	Rubble	10			-	BKT	BKT	BKT, EEL
10	1	1	P	0.3-0.9	0.3-0.85	292	Flat	-	<1	<0.05	0.10	Muck/Detritus	17	N/A	BKF, BKT, EEL, GSH, YLP	-	-	-	EEL, BKT
	2	1	P	0.8	0.7	15	Riffle	-	2	<0.05	0.06	Boulder	25			-	-	BKT	EEL, BKT
11	1	1	E	0.35-1.7	0.35-1.45	756	Flat	-	<1	<0.05	0.10	Muck/Detritus	50	None	BKF, BKT, EEL, GSH, YLP	-	-	-	EEL, BKT
	2	1	E	0.4	0.3	69	Riffle	-	1-2	<0.05	0.012	Boulder	75			-	-	BKT	EEL
	3	1	E	1.25	1	94	Flat	-	<1	<0.05	0.14	Muck/Detritus	5			-	-	-	EEL, BKT
	4	1	E	1-1.1	0.6	224	Riffle	-	1-2	<0.05	0.08	Boulder	50			-	-	BKT	EEL, BKT
	5	1	E	0.7-1.45	0.6-1.25	229	Flat	-	<1	<0.05	0.04	Muck/Detritus	20			-	-	-	EEL

Water-course	Reach	Stream Order	Flow Type[1]	Reach Characteristics										Fish Support[6]					
				Channel Width (m)[2]	Wetted Width (m)[2]	Reach Length (m)	Dominant Habitat Type	Other Habitats Present	Slope (%)[3]	Average Velocity (m/s)	Average Depth (m)	Dominant Substrate	Cover (%)[4]	Confirmed Species (2020-2021)[7]	Probable Species[5]	Spawning	YOY	Juvenile	Adult
12	1	1	E	1.0	0.0	60	Flat (dry)	-	<1	0	0	Muck/Detritus	25	None	BKF, BKT, EEL, GSH, YLP	-	-	-	EEL
	2	1	E	1.2	0.4	41	Flat	-	<1	<0.05	0.11	Bedrock	35			-	-	-	-
	3	1	E	0.3-2.7	0.3-2.5	59	Flat	-	<1	<0.05	0.08	Clay	5			-	-	-	-
	4	1	E	1.5	0.0	252	Flat (dry)	-	<1	0	0	Muck/Detritus	60			-	-	-	EEL, BKT
13	1	1	P	0.65-1.25	0.55-1.0	87	Flat	-	<1	<0.05	0.09	Muck/Detritus	20	EEL	BKF, BKT, BNS, EEL, GSH, YLP	-	-	-	EEL, BKT
14	1	1-2	P	1.8-3.25	1.55-2.8	280	Riffle-run	Flat	1-2	0.070	0.19	Boulder, Rubble, Muck/Detritus	75	BKT, EEL	BKF, BKT, BNS, EEL, GSH, YLP	-	BKT	BKT	EEL, BKT
	2	1-2	P	1.75	1.5	36	Boulder-bed	-	2	<0.05	0.22	Boulder	72			-	BKT	BKT	EEL, BKT
	3	1-2	P	1.35-9.0	1.1-7.0	103	Flat	Riffle	<1	0.064	0.24	Muck/Detritus	72			-	-	-	EEL, BKT
	4	1-2	P	2.95	2.5	260	Rapid	-	4	0.515	0.18	Boulder	47				BKT	BKT	EEL, BKT
	5	1-2	P	1.8-9.0	1.7-8.0	56	Flat	-	<1	<0.05	0.33	Muck/Detritus	50			-	-	-	EEL, BKT
	6	1-2	P	1.95	1.80	29	Riffle	-	2	0.462	0.09	Boulder	33			-	BKT	BKT	EEL, BKT
	7	1-2	P	1.9-4.25	1.35-3.25	269	Riffle-run	Rapid	1	0.121	0.14	Boulder	60			-	BKT	BKT	EEL, BKT
15	1	1	P	0.6-1.7	0.6-1.7	747	Flat	-	<1	<0.05	0.16	Muck/Detritus	96	N/A	BKT, EEL	-	-	-	EEL, BKT
	2	1	P	0.6	0.6	40	Riffle-run	-	2	<0.05	0.02	Muck/Detritus	67			-	-	-	EEL, BKT
	3	1	P	1.25-1.5	1.7-1.8	147	Flat	-		<0.05	0.19	Muck/Detritus	45			-	-	-	EEL, BKT
	4	1	P	1.5	0.7	26	Riffle	-	2	<0.05	0.03	Muck/Detritus	67			-	-	-	EEL
	5	1	P	2.1	1.8	39	Flat	-	<1	<0.05	0.18	Muck/Detritus	65			-	-	-	EEL, BKT
	6	1	P	1.7-1.9	1.45-1.6	89	Riffle	Pool	2	<0.05	0.05	Muck/Detritus	65					EEL, BKT	EEL, BKT
	7	1	P	2.1	1.4	74	Flat	-	<1	<0.05	0.07	Muck/Detritus				-	-	-	EEL, BKT
	8	1	P	0.95-1.0	0.6-0.8	83	Riffle	-	2	<0.05	0.07	Muck/Detritus	85			-	-	-	EEL, BKT
	9	1	P	1.0-2.5	1.2-2.9	91	Riffle-run	-	1	<0.05	0.15	Muck/Detritus	20			-	-	-	EEL, BKT
19	1	1	P	1.2	0.65	40	Flat	-	<1	<0.05	0.07	Muck/Detritus	41	N/A	BKF, BKT, EEL, YLP	-	-	-	EEL, BKT
20& 24	1	2	P	0.7-5.2	0.45-5.05	624	Flat	-	<1	<0.05	0.31	Muck/Detritus	54	BKF, BKT, EEL, YLP	BKF, BKT, BNS, EEL, GSH, YLP	BKF, YLP, GSH	BKF, YLP, GSH	BKF, YLP, GSH	EEL, BKT, BKF, GSH, YLP
	2	2	P	2.6-3.3	1.5-3.0	26	Rapid	Run	6	<0.05	0.11	Boulder	65			-	BKT	BKT	EEL, BKT
22	1	1	P	12.0	12.0	183	Pool	-	<1	<0.05	~1.00	Muck/Detritus	100	BKT, EEL	BKF, BKT, BNS, EEL, GSH, YLP	GSH	GSH	EEL, GSH	EEL, BKT, GSH
	2	1	P	1.55-2.7	1.35-2.5	117	Riffle	Run, Pool	2	<0.05	0.32	Boulder	9			GSH	BKT, GSH	BKT, GSH	EEL, BKT, GSH
	3	1	P	3.2	3.2	113	Pool	-	<1	<0.05	~1.00	Muck/Detritus	100			GSH	GSH	GSH	EEL, BKT, GSH
	4	1	P	3.5	3.2	35	Flat	-	1	<0.05	0.26	Muck/Detritus	12			-	-	-	EEL, BKT
	5	1	P	1.7-4.95	1.5-4.7	722	Riffle-run	-	2	<0.05	0.10	Boulder	12			-	BKT	BKT	EEL, BKT
	6	1	P	3.1	3.1	57	Flat	-	<1	<0.05	0.17	Muck/Detritus	12			-	-	-	EEL, BKT
	7	1	P	2.0	1.3	62	Riffle-run	Pool	2	<0.05	0.07	Boulder	16			GSH	BKT, GSH	EEL, BKT, GSH	EEL, BKT, GSH
23	1	1	I	1.2-1.5	0.95-1.1	143	Flat	-	<1	<0.05	0.06	Muck/Detritus	23	BKF, YLP	BKF, BKT, BNS, EEL, GSH, YLP	BKF, YLP	BKF, YLP	BKF, YLP	EEL, BKT, BKF, YLP
39	1	1	P	0.95	0.35	39	Riffle-run	-	3	<0.05	0.04	Boulder, Rubble	29	N/A	BKT, EEL, GSH	-	-	BKT	EEL, BKT

Water-course	Reach	Stream Order	Flow Type[1]	Reach Characteristics										Fish Support[6]					
				Channel Width (m)[2]	Wetted Width (m)[2]	Reach Length (m)	Dominant Habitat Type	Other Habitats Present	Slope (%)[3]	Average Velocity (m/s)	Average Depth (m)	Dominant Substrate	Cover (%)[4]	Confirmed Species (2020-2021)[7]	Probable Species[5]	Spawning	YOY	Juvenile	Adult
43	1	1	P	0.5-1.6	0.3-1.5	684	Flat	-	<1	<0.05	0.13	Muck/Detritus	30	BKT, EEL	BKT, EEL	-	-	-	EEL, BKT
45	1	1	P	0.6-1.85	0.45-1.65	143	Flat	-	<1	<0.05	0.11	Muck/Detritus	72	N/A	BKT, EEL	-	-	-	EEL, BKT
	2	1	P	0.95	0.65	22	Riffle	-	2	<0.05	0.07	Muck/Detritus, Boulder	70			-	BKT	BKT	EEL, BKT
	3	1	P	0.65-1.7	0.5-1.55	73	Flat	Riffle, Pool	<1	<0.05	0.16	Muck/Detritus	69			-	-	EEL	EEL, BKT
	4	1	P	0.75	0.6	402	Riffle	-	2	<0.05	0.06	Muck/Detritus	69			-	-	-	EEL, BKT
47	1	1	I	0.8	0.65	47	Flat	-	<1	<0.05	0.55	Muck/Detritus	47	N/A	BKT, EEL	-	-	-	-
49	1	1	P	0.55-1.55	0.3-1.3	855	Flat	Riffle	1	<0.05	0.09	Muck/Detritus	67	BKT	BKF, BKT, BNS, EEL, GSH, YLP	-	-	-	EEL, BKT
50	1	1	P	0.55-1.9	0.35-1.75	123	Run	-	1	<0.05	0.15	Muck/Detritus	40	N/A	BKT, EEL	-	-	-	EEL, BKT
	2	1	P	0.7-1.2	0.55-0.9	64	Riffle-run	-	3	<0.05	0.19	Rubble, Cobble	31			-	BKT	BKT	EEL, BKT
	3	1	P	0.8-1.2	0.55-1.0	120	Run	Riffle	2	<0.05	0.08	Muck/Detritus	43			-	-	-	EEL, BKT
51	1	1-2	P	1.35-2.75	0.8-2.05	230	Flat	Riffle	<1	<0.05	0.11	Muck/Detritus	45	N/A	BKF, BKT, EEL, YLP	BKF	BKF	EEL, BKF, BKT	EEL, BKF, BKT
55	1	1	P	0.7-1.0	0.25-0.9	215	Flat	-	<1	<0.05	0.07	Muck/Detritus	30	N/A	BKF, BKT, EEL, GSH, YLP	-	-	-	EEL, BKT
57	1	1	P	0.91-1.35	0.6-1.1	442	Riffle-run	-	2-3	<0.05	0.12	Muck/Detritus	33	None	None	-	-	-	-
58	1	1	P	0.6-0.8	0.4-0.65	61	Flat	-	<1	<0.05	0.15	Muck/Detritus	23	N/A	BKT, EEL	-	-	-	EEL, BKT
59	1	1	I	0.8-0.95	0-0.5	120	Flat	-	<1	<0.05	0.07	Muck/Detritus	27	N/A	None	-	-	-	-
61	1	1	P	0.6-1	0.4-0.85	81	Riffle-run	-	1-3	<0.05	0.09	Muck/Detritus	30	N/A	BKF, BKT, BNS, EEL, GSH, YLP	-	-	-	EEL, BKT
63	1	1	P	0.3-0.8	0.15-0.4	120	Riffle	-	1-3	<0.05	0.06	Muck/Detritus	36	None	BKF, BKT, BNS, EEL, GSH, YLP	-	-	-	EEL, BKT
65	1	1	P	0.6	0.45	57	Riffle-run	-	1-3	<0.05	0.16	Muck/Detritus	37	N/A	BKF, BKT, BNS, EEL, GSH, YLP	-	-	-	EEL, BKT
69	1	1	P	0.85-1.75	1.6-2.1	325	Flat	Riffle, Pool	<1	<0.05	0.20	Bedrock	16	N/A	BKT, EEL	-	-	-	-
	2	1	P	1.25-1.3	1.45-1.5	125	Riffle	-	2	<0.05	0.11	Bedrock	16			-	-	-	-
	3	1	P	4.0	3.85	44	Pool	-	<1	<0.05	0.21	Boulder, Rubble	96			-	BKT	EEL, BKT	EEL, BKT
Gold Brook	1	3	P	13.6-18.8	13.3-17.8	35	Run	Riffle	1-2	0.192	0.15	Muck/Detritus	59	BKF, BKT, EEL, GSH, YLP	BKF, BKT, BNS, EEL, GSH, YLP	-	-	-	EEL, BKT
	2	3	P	3.4-7.6	2.9-7.3	270	Riffle-run	-	2	0.25	0.19	Muck/Detritus	42			-	-	-	EEL, BKT
	3	3	P	2.2	1.4	30	Flat	-	<1	<0.05	0.12	Muck/Detritus	53			BKF, GSH, YLP	BKF, GSH, YLP	BKF, GSH, YLP	BKF, EEL, BKT, GSH, YLP
	4	3	P	1.5-7.0	1.3-6.45	895	Riffle	Run	2	0.183	0.10	Boulder	24			-	BKT	BKT	EEL, BKT
	5	3	P	1.1-8.9	0.75-8.4	200	Run	-	1	0.080	0.15	Boulder	29			-	BKT	BKT	EEL, BKT
	6	3	P	1.7-9.0	1.6-8.2	1655	Riffle-run	-	1-2	0.151	0.15	Boulder	35			-	BKT	BKT	EEL, BKT
	7	3	P	8.4-15.5	7.7-14.1	85	Run	-	1	<0.05	0.26	Boulder, Muck/Detritus	83			-	BKT	BKT	EEL, BKT

Water-course	Reach	Stream Order	Flow Type[1]	Reach Characteristics										Fish Support[6]					
				Channel Width (m)[2]	Wetted Width (m)[2]	Reach Length (m)	Dominant Habitat Type	Other Habitats Present	Slope (%)[3]	Average Velocity (m/s)	Average Depth (m)	Dominant Substrate	Cover (%)[4]	Confirmed Species (2020-2021)[7]	Probable Species[5]	Spawning	YOY	Juvenile	Adult
	8	3	P	1.2-4.9	1.2-4.6	110	Flat	-	<1	<0.05	0.12	Boulder, Muck/Detritus	21			BKF, GSH, YLP	BKT, BKF, GSH, YLP	BKT, BKF, GSH, YLP	EEL, BKT, BKF, GSH, YLP
	9	3	P	3.7-29.8	3.45-29.8	350	Run	-	1	<0.05	0.15	Muck/Detritus	34			-	-	-	EEL, BKT
	10	3	P	1.7-2.4	1.6-2.2	125	Riffle	-	1-2	0.374	0.19	Boulder	45			-	BKT	BKT	EEL, BKT
	11	3	P	2.3-2.6	2.3-2.6	75	Run	-	1	<0.05	0.23	Muck/Detritus	44			-	-	-	EEL, BKT
	12	3	P	40.0-240.0	40.0-240.0	1278	Flat	-	<1	<0.05	0.20 – >1.0*	Muck/Detritus	73			BKF, GSH, YLP	BKF, GSH, YLP	BKF, GSH, YLP	EEL, BKT, BKF, GSH, YLP

[1]Perennial (P) – A stream that flows continuously throughout the year, Intermittent (I) – Streams that go dry during protracted rainless periods when percolation depletes all flow, Ephemeral (E) – A watercourse that flows during snowmelt and rainfall runoff periods only (AT, 2009).
[2]Ranges are provided for reaches measured through multiple transects.
[3]Slopes were estimated based on overall habitat type (DFO, 2012a).
[4]Cover is calculated as a sum of all available cover types present (large woody debris, boulders, undercut banks, deep pools, overhanging vegetation, emergent vegetation, and submergent vegetation).
[5]Probable species presence determined for watercourses based on direct aquatic connectivity with another fisheries resource with confirmed species presence and habitat suitability, and/or previous baseline studies as presented in the 2017-2019 Baseline Report.
[6]Fish support determined through habitat suitability of all confirmed or probable species. Probable species not brought forward if suitable habitat not identified through detailed habitat evaluation. Species codes: American Eel (EEL), Banded Killifish (BKF), Brook Trout (BKT), Blacknose Shiner (BNS), Golden Shiner (GSH), Yellow Perch (YLP).
[7]N/A indicates that no effort was conducted within the watercourse to confirm species presence during 2020-2021.
*Estimated main channel depth in areas not accessible due to depth and substrate.

Table 3-11: Summary of Key Diagnostic Features of Fish Habitat within Open Water Features and Wetland Mosaic (2021)

Water-course	Reach	Reach Characteristics										Fish Support[3]				
		Habitat Type	Gradient (%)[1]	Vegetation /Water Ratio	Dominant Substrate	Width (m)			Depth (m)			Probable Species[2]	Spawning	YOY	Juvenile	Adult
						Max	Min	Avg	Max	Min	Avg					
Settling Pond Outlet	N/A	Wetland Mosaic A	<1	50/50	Muck/Detritus	60	30	45	0.14	0.05	0.10	EEL, BKF	BKF, GSH, YLP	BKF, GSH, YLP	BKT, BKF, GSH, EEL, YLP	BKT, BKF, EEL, GSH, YLP
64 (Gold Brook)	Between 64A Reach 7 and 64H Reach 10	Wetland Mosaic B	<1	50/50	Muck/Detritus	0.35	0.04	0.18	1.5	0.11	0.72	BKF, BKT, EEL, GSH, YLP	BKF, GSH, YLP	BKF, GSH, YLP	BKT, BKF, GSH, EEL, YLP	BKT, BKF, EEL, GSH, YLP
Settling Ponds	N/A	Open water	<1	40/60	Muck/Detritus	29	76	n/a	Exceeding 1 m			EEL, BKF	BKF, GSH, YLP	BKF, GSH, YLP	BKT, BKF, GSH, EEL, YLP	BKT, BKF, EEL, GSH, YLP
Beaver Pond	N/A	Open Water	<1	20/80	Muck/Detritus	17	36	n/a	Exceeding 1 m			BKT, EEL	-	-	BKT, EEL	BKT, EEL

[1]Whenever possible, slope measurements were taken in-field using a clinometer and meter stick (“F”). If clinometer readings were not possible due to length of reach or visibility obstructions, slopes were estimated based on overall habitat type (“E”,DFO, 2012a).
[2]Probable species presence determined for open water features based on direct aquatic connectivity with another fisheries resource with confirmed species presence and habitat suitability, and/or previous baseline studies as presented in the EIS (AMNS, 2020).
[3]Species codes: American Eel (EEL), Banded Killifish (BKF), Brook Trout (BKT), Blacknose Shiner (BNS), Golden Shiner (GSH), Yellow Perch (YLP).

Table 3-12: Summary of Key Diagnostic Features of Fish Habitat within Lentic Waterbodies (2021)

Waterbody	Transect	Reach Characteristics						Fish Support[4]					
		Depth Range (m)	Secchi Depth (m)	Dominant Substrate[1]	Vegetation	Cover (%)[2]	Dominant Shoreline Substrate	Confirmed Species (2020-2021)	Probable Species[3]	Spawning	YOY	Juvenile	Adult
Gold Brook Lake	1	1.39-1.90	0.83	Boulder	Submergent	25	Boulder	BKF, BKT, BNS, EEL, GSH, YLP	BKF, BKT, BNS, EEL, GSH, YLP	BKF, BNS, GSH	BKF, BNS, GSH, YLP	EEL, BKF, BKT, BNS, GSH, YLP	EEL, BKF, BKT, BNS, GSH, YLP
	2	0.72-1.56	1.02	Boulder	None								
	3	0.67-2.75	1.01	Boulder	None								
	4	0.84-2.85	0.75	Boulder	Submergent								
	5	0.65-2.55	0.88	Boulder, Rubble	Submergent								
	6	0.52-2.55	0.85	Boulder	None								
	7	0.85-3.05	1.00	Boulder	None								
	8	1.25-2.95	0.94	Boulder	Submergent								
	9	0.95-3.09	0.86	Boulder	Submergent								
	10	1.19-3.09	0.91	Boulder	None								
	11	0.87-1.83	1.06	Boulder, Rubble, Cobble	Submergent								
	12	0.90-2.08	0.80	Boulder, Rubble, Cobble, Muck/Detritus	Submergent								
	13	0.65-1.13	N/A	Cobble, Gravel, Sand, Silt, Muck/Detritus	Emergent, Submergent								
Rocky Lake	1	0.65-1.95	1.48	Muck/Detritus	Submergent	43	Boulder	EEL, GSH	EEL, GSH	BKF, GSH	BKF, GSH, YLP	EEL, BKF, BKT, GSH, YLP	EEL, BKF, BKT, GSH, YLP
	2	0.72-1.01		Muck/Detritus	Submergent								
	3	0.51-1.51		Boulder	Submergent								
	4	1.41-1.62		Boulder, Muck/Detritus	Submergent								
	5	0.61-1.33		Boulders	Submergent								
	6	0.61-1.25		Boulder, Muck/Detritus	Submergent								

[1]Dominant substrate was visually estimated or was estimated by touching bottom with the canoe paddle. If neither was possible substrate was not estimated.
[2]Cover is calculated as a sum of all available cover types present (large woody debris, boulders, overhanging vegetation, emergent vegetation, and submergent vegetation
[3]Probable species presence determined for watercourses based on direct aquatic connectivity with another fisheries resource with confirmed species presence and habitat suitability, and/or previous baseline studies as presented in the 2017-2019 Baseline Report.
[4]Species codes: American Eel (EEL), Banded Killifish (BKF), Brook Trout (BKT), Blacknose Shiner (BNS), Golden Shiner (GSH), Yellow Perch (YLP).
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4.0 SUMMARY OF FISHERIES RESOURCES

The following sections provide fish habitat summaries for all watercourses assessed during the 2020/2021 field program through quantitative detailed habitat mapping. Fish habitat assessments of waterbodies within the PA including Gold Brook Lake, the Beaver Pond, and the historic settling ponds are provided in the 2017-2019 Baseline Report (Appendix F). The baseline fish habitat assessments conducted on delineated watercourses throughout the PA and outlined in Section 3.1 have not been included in this summary as the level and effort of fish habitat assessment was significantly reduced for the purposes of initial watercourse mapping. If required, these watercourses may be reassessed through detailed habitat mapping at a later date. Detailed fish habitat assessments were completed on any watercourses expected to be impacted (directly or indirectly) by the Project.

4.1.1 Watercourse 1

WC1 is a perennial, first order stream that originates in a northwestern lobe of WL1, flowing southeast and eventually draining into WC3. As part of the 2020 field program, fish collection and detailed habitat description were completed (Figure 5b, Appendix A). The watercourse was delineated into two homogenous fish habitat reaches during detailed habitat mapping (Figure 6e and g, Appendix A).

Reach 1 is a 90 m long, moderately entrenched run. Channel and wetted widths are 2 and 1.4 m, respectively, and average water depth is 11 cm. Substrate in this reach is dominated by muck, with boulder, rubble, and cobble present in lesser amounts and embedded in the muck substrate. A moderate amount of cover is provided by a mixture of large woody debris, boulders, undercut banks, and overhanging vegetation.

The channel then increases in gradient, transitioning into a 273 m long series of riffles connected by short pools (Reach 2). Abundant cover is provided by large woody debris, boulder substrate, undercut banks, deeper pools, overhanging vegetation, and small amounts of in-stream vegetation. Channel and wetted widths range from 1.4-2.1 m and 0.5-2.1 m, respectively, and average water depth is 10 cm. Substrate in this reach is dominated by boulders, with rubble, cobble, and muck also present. At the end of Reach 2, the watercourse converges with WC3.

During baseline electrofishing surveys conducted in 2019, four American eel and two brook trout were captured within WC1. Over the three electrofishing rounds conducted in Summer 2020, no additional species were captured. Ten fish comprising American eel and brook trout were captured during the first electrofishing survey, while 21 individuals were captured during the second and third electrofishing surveys. Population estimates calculated for WC1 were only able to be calculated for the third round of electrofishing, resulting in 21 individuals. The number of brook trout captured within the watercourse increased over the summer, from four individuals in late June to 14 individuals in August. Of all fish survey sites sampled during the 2020 field program, WC1 was the most productive in terms of brook trout abundance, with 31 individuals captured, accounting for 70% of the total number of brook trout captured over the three electrofishing surveys (31 of 44 individual fish). Both brook trout parr (juveniles) and adult life stages were captured in WC1, with total lengths ranging from 3 cm to 19 cm.

As outlined in Table 3-10, habitat provisions for the two fish species confirmed within WC1 vary between reaches. Suitable habitat for juvenile and adult life forms of American eel was noted in Reach 2 (soft bottom sediments and cover), with Reach 1 only providing habitat for adult eel. The abundance and variety of in-stream cover and small-scale habitat variation in Reach 2 provides suitable habitat for young of year, juvenile and adult brook trout, while the homogenous, muck-dominated run in Reach 1 may support adult life stages of the species. No suitable brook trout spawning substrate was observed (clean gravel) in either reach of WC1.

Water quality measurements recorded throughout the 2020 field program showed relatively stable water temperatures throughout the summer, with temperatures remaining within the optimal range for brook trout from June through August (<20°C). The watercourse also had the highest pH measurements of all watercourses measured in the PA ranging from 7.11 to 7.60 - well above the average PA-wide pH of 4.97 and within the CCME FWAL guidelines (6.5-9.0). DO concentrations within the watercourse largely remained above the minimum CCME FWAL concentration of DO for other life stages of cold-water biota (6.5 mg/L), with only one DO record measured during detailed habitat surveys on August 18th in Reach 1 (5.1 mg/L) falling below the minimum recommended concentration for all other life stages of warm-water species (5.5 mg/L). Water quality within WC1 is generally considered suitable for overall fish productivity.

4.1.2 Watercourse 2

WC2 is a perennial, first order stream that originates in a southeastern lobe of WL21, flowing southeast under Gold Brook Road and eventually draining into WL1 where is stops. As part of the 2021 field program, the watercourse was electrofished and a detailed fish habitat assessment was performed (Figure 5b, Appendix A). The watercourse was delineated into one homogenous fish habitat reaches during detailed habitat mapping (Figure 6e, Appendix A).

WC2 is a 212 m flat watercourse with a riffle section that intermittently goes underground approximately five times for 1-2 meters. The watercourse has an average depth of 9 cm and is dominated by a muck/detritus substrate with sparse boulders found within the watercourse. Channel width ranges from 0.8 m to 1.4 m, whereas the wetted width is 0.4 m to 0.8 m. The watercourse has about 87% cover over it with overhanging vegetation being the dominant form of cover and large woody debris, emergent and submergent vegetation providing some coverage.

One, open pass of electrofishing was conducted on WC2 over the summer of 2021. This pass did not result in fish capture or observation. Passage of fish into WC2 is limited by an improperly installed culvert across Goldbrook Road. Habitat within the watercourse has the potential to support adult American eel and brook trout.

Water quality measurements recorded throughout the 2021 field program showed a relatively slow increase in water temperatures throughout the month of July. However, temperatures remained within the optimal range for brook trout during the month of July (<20°C). The watercourse also had relatively low pH measurements during electrofishing and habitat assessment - below the average PA-wide pH of 4.97. pH within WC2 ranged from 5.43 to 5.67, these levels are nearing CCME FWAL guidelines stating that <5.0 is expected to harm eggs and fry of salmonid species. Only one measurement of DO was obtained of 4.91 mg/L which falls below the minimum recommended concentration for later life stages of warm-water species (5.5 mg/L). Water quality within WC2 is generally considered limiting for overall fish productivity.

4.1.3 Watercourse 3

WC3 originates within WL44 as a first-order stream flowing southeast through the Nova Scotia Maritimes and Northeast Pipeline corridor. WC3 then flows southeast into WL23, flowing under Goldbrook Road. During habitat assessment completed in 2020, this upstream section of watercourse was not assessed as it was outside the 2020 Study Area. This study area has since expanded west-ward, and the upper 150 m of the watercourse now falls within the study area. For the purposes of effects assessment, the physical characteristics of the measured stream below will be extrapolated to the new section upstream; and detailed habitat evaluation will occur in this reach in 2022.

After flowing under Goldbrook Road WC3 flows into WL1 where it transitions into a second order stream at its confluence with WC1 with more perennial characteristics. The watercourse continues southeast and eventually drains into Gold Brook from the west. The watercourse was both electrofished and received a detailed fish habitat assessment during the 2020 field program (Figure 5b, Appendix A), during which three homogenous fish habitat reaches were delineated (Figure 6e and g, Appendix A).

The uppermost assessed reach of WC3 is the longest of the three – a 921 m series of long runs connected by short, intermittent sections of riffle habitat with an average depth of 14 cm. Substrate is dominated by boulders which is mixed with rubble, cobble, and muck. Channel widths range from 0.5-2.4 m. Five of the 13 transects completed in WC3 contained no water at the time of the assessment. In the remaining transects, wetted widths ranged from 0.2-1.4 m. A moderate amount of cover is provided mostly in the form of boulders, while overhanging vegetation, large woody debris, and undercut banks are sparse.

Located in upland habitat between two lobes of WL1, Reach 2 is an 81 m long, shallow riffle with an average water depth of 7 cm. Channel and wetted widths are 1.2 and 0.75 m, respectively. Boulders dominate the substrate while lesser amount of rubble, cobble, muck, and scarce gravel are also present. Abundance and types of cover are similar to that of Reach 1, with an increase in overhanging vegetation provided by dense, alder-lined banks.

The final and most downstream reach (Reach 3) is a 133 m long, low gradient, low velocity flat, which commences as the watercourse transitions back into wetland habitat (WL1) before emptying into Gold Brook. Emergent vegetation covers approximately 50% of the reach. Substrate is predominantly muck, while some boulder and rubble were observed to be highly embedded within the organic substrate. Channel and wetted widths are 1.4 and 0.9 m, respectively.

During habitat assessment completed in 2020, WC3 was assessed in its entirety within the 2020 Study Area. This study area has since expanded west-ward, and the watercourse was mapped an additional 200m upstream to its headwater in WL44. Detailed habitat assessments were not completed in this section. For the purposes of effects assessment, the physical characteristics of the measured stream below will be extrapolated to the new section upstream; and detailed habitat evaluation will occur in this reach in 2022.

One individual American eel was captured in WC3 during baseline 2019 electrofishing efforts. No fish were captured during either of the two rounds of electrofishing surveys in 2020 (a third round could not be completed in late summer due to dry channel conditions). Though no fish were confirmed in WC3 in 2020, probable fish presence has been inferred based on the results of 2019 electrofishing efforts and confirmed or potential species within contiguous fish bearing systems (WC1, Gold Brook).

Reaches 1 and 2 are considered to provide suitable habitat for both freshwater life stages of American eel and for young of year, juvenile and adult life stages of brook trout. Water depths within Reach 2 may limit access to only adult brook trout and American eel. In addition, habitat within Reach 1 is considered seasonally restricted, and is likely not accessible to fish or viable habitat during periods of low flow. This is supported by the results of 2020 electrofishing surveys, during which no fish were captured in WC3 over 1400 seconds of electrofishing effort.

The low-velocity, highly vegetated flat of Reach 3 is considered to provide suitable habitat for adult American eel, brook trout, and based on its proximity to Gold Brook, all life history stages of banded killifish and golden shiner. No brook trout spawning habitat was identified in WC3. Recorded temperatures in WC3 remained optimal for brook trout throughout the summer, and pH levels are not expected to cause harm to freshwater fish. However, the DO concentration recorded in Reach 1 during detailed habitat assessments (1.8 mg/L) is considered severely limiting to fish productivity, and likely caused by the lack of flowing water through the reach at the time of the assessment.

4.1.4 Watercourses 4, 5, 6, 7 and 8

Watercourses 4, 5, 6, 7, and 8, located north of Goldbrook Road and west of Gold Brook Lake, are small first and second order tributaries that drain in a general southeast direction, eventually dispersing into the flooded area of WL18 (i.e., the Beaver Pond), before flowing through WC8 into Gold Brook Lake. As part of the 2020 field program, each watercourse received a detailed fish habitat assessment. In addition, three rounds of electrofishing were performed within WC4, WC7 and WC8 (Figure 5b, Appendix A). It should be noted that due to predominantly dry channel conditions, the assessment of habitat types in these watercourses were limited and mostly based on the physical attributes of the channel (Figure 6e, Appendix A).

WC4 is an intermittent, first order stream that commences within the PA east of a utility access road in WL16. The watercourse empties in to WC7 shortly before it dechannelizes into the Beaver Pond. The watercourse was delineated into two homogenous reaches during detailed habitat mapping.

Reach 1 is a short, low gradient flat totalling 19 m in length. Substrate is dominated by muck with highly embedded, scattered rubble. Channel and wetted widths are 0.9 and 0.6 m, respectively, and average water depth is 11 cm. A small amount of cover is provided in the form of large woody debris, overhanging vegetation, and in-stream vegetation.

The watercourse gradient increases through Reach 2 - a 426 m section of riffle-run habitat, with one short, deeper pool also noted within the reach. At the time of the assessment, most of the stream was dry, with residual water largely confined to the one pool located approximately mid-way through the reach. Where water is present, average depth is 14 cm. Substrate is dominated by rubble, with lesser amount of cobble, boulder, muck, and trace amounts of gravel. A small amount of cover is provided by large woody debris, the deeper pool, and overhanging vegetation.

There is an old gravel access road which crosses the watercourse at 280 m down the length of the watercourse. There is currently no provision for fish access upstream or downstream of the road, though pieces of an old culvert were noted among the road infill. The road presents a complete barrier fish passage into the upper 280 m of WC4.

During habitat assessment completed in 2020, WC4 was assessed in its entirety within the 2020 Study Area. This study area has since expanded west-ward, and the watercourse was mapped an additional 690m upstream to its headwater in WLs 17 and 176. Detailed habitat assessments were not completed in this section. For the purposes of effects assessment, the physical characteristics of the measured stream below will be extrapolated to the new section upstream; and detailed habitat evaluation will occur in this reach in 2022.

WC5 and WC6 are also both intermittent, first order streams which drain into WC7. WC5 commences at the western extent of WL18, while WC6 collects surface water from a southern lobe of WL17. Both watercourses comprise one homogenous fish habitat reach.

WC5 is a 260 m long run. At the time of the assessment, the watercourse was completely dry. Channel widths range from 0.4-0.5 m and substrate is dominated by rubble, with lesser amounts of boulder, cobble, and muck. A very small amount of potential cover is provided by a combination of large woody debris and overhanging vegetation.

WC6 is a 103 m long series of riffle-runs, and a short (<5 m long), steeper section of step-pools at located at the start of the watercourse. Substrate is dominated by muck, with lesser amounts of highly embedded boulder, rubble, and cobble. A small amount of cover is provided by a combination of large woody debris and overhanging vegetation. At the time of the assessment, the watercourse was dry up until the most downstream 25 m, at which point average water depth was 14 cm. A 32 m long section of intermittent, underground flow was mapped beginning approximately 60 m upstream of its confluence with WC7 (see Photo 55, Appendix C). This feature is considered a seasonal barrier to upstream fish passage, with access likely restricted to periods of high flow.

WC7 is a first order stream which commences from pockets of surface water within WL17. The watercourse receives inputs from WC4, WC5, and WC6, and flow is predominantly intermittent but becomes more permanent at its downstream end as it enters WL18, shortly before dispersing into the flooded Beaver Pond. WC7 comprises one homogenous fish habitat reach, characterized as a 486 m long riffle-run series combined with short sections of flats. At the time of the assessment, WC7 was approximately 95% dry upstream of its confluence with WC4, with residual pockets of water confined to flats. Residual water depths measured on average 13 cm. Substrate is dominated by muck with highly embedded boulders, rubble, cobble, and scarce gravel. A moderate amount of cover is composed mainly of large woody debris, with smaller amounts of unembedded boulders and overhanging vegetation.

No fish were captured in WC4 or WC7 during 2019 baseline electrofishing surveys, nor were any fish captured in these watercourses during the three rounds of electrofishing completed in 2020. As tributaries to the Beaver Pond, these watercourses may be accessed by resident American eel and brook trout as identified within the Beaver Pond in 2018. However, no fish were captured in the Beaver Pond during follow-up trapping surveys in 2019, nor through trapping conducted during the 2020 field program. The exceptionally low catch numbers in the Beaver Pond have been attributed to a natural obstacle to fish passage (forested swamp) located downstream associated with WC8. Watercourses 4, 5, 6, 7 and 8 also go dry during low-flow periods; as such, fish habitat provisions are further limited to seasons with adequate flow. It should be highlighted that any habitat provisions within these watercourses are temporally restricted and are not viable or accessible during periods of low flow. Fish passage is further restricted in WC4 and WC6 by anthropogenic and natural barriers. These watercourses are unlikely to support resident fish due to the temporal variability of fish habitat provisions within these systems.

No juvenile brook trout were captured within the Beaver Pond in 2018, nor has any spawning habitat been identified within the Beaver Pond or its tributaries. As such, young of year and juvenile life stages of brook trout have not been included in the fish habitat assessment for these watercourses. Watercourses with more complex micro-habitats (WC4 Reach 2, WC6, and WC7) may provide suitable, seasonal habitat for adult brook trout, whereas as habitat generalists, all watercourses are considered to provide suitable, seasonal habitat for adult American eel. Potential juvenile eel habitat is found in those watercourses that provide soft substrates and a variety of cover types.

Optimal temperatures for cold-water species were observed to persist within these systems throughout the summer. However, DO levels recorded during detailed habitat assessments on August 14th are considered extremely limiting to fish productivity, particularly for cold-water species like brook trout. In addition, these watercourses are considered acidic, which likely further limits fish productivity, particularly in watercourses 4, 6, and 7 in which recorded pH levels were less than 5.0.

WC8 is a second order perennial stream with intermittent characteristics and serves as the sole outlet of the Beaver Pond (WL18). After exiting the Beaver Pond, WC8 flows east for approximately 200 m in a linear, historically ditched channel, then disperses into a forested swamp (WL20). Through multiple assessments, this natural obstacle was determined to restrict the upstream and downstream passage of fish from Gold Brook Lake to the Beaver Pond, and vice-versa. Still, the wetland may be potentially navigable by American eel, which are considered adept at climbing over vertical surfaces and wet, low-lying areas (GOMC, 2007; MacGregor et al., 2011). In addition, it is possible that during extreme flows that of brook trout may be able to navigate through WL20 to the channelized sections of WC8. No other species within the PA are considered capable of navigating the obstacle (Figure 6e, Appendix A). Full accounts of the the multiple barrier assessments of WC8 are provided in the 2017-2019 Baseline Report (Appendix F).

The watercourse channel re-forms approximately 30 m north, still within WL20. A detailed fish habitat assessment was performed from this point to its downstream extent at Gold Brook Lake. In addition, three rounds of electrofishing were completed upstream of the dechannelized section through WL20 (Figure 5b, Appendix A). WC8 was delineated into five homogenous fish habitat reaches during the detailed habitat assessment (Figure 6e, Appendix A).

The outlet of the Beaver Pond (WC8 Reach 1) begins as a low gradient flat with small sections (under 5 m) of riffle habitat. This historically ditched channel is 75 m long with a channel width ranging between 1.1 to 2.4 m, with a depth average of 0.29 m. This reach was dominated by bedrock, cobble and clay substrate, the only watercourse in the PA to have bedrock as one of the dominant substrates. This reach was highly entrenched with most of the in-stream cover coming from deep pools.

The gradient in Reach 2 increases (3%) and transitions into riffle habitat with sections (under 5 m) of flat habitat. This 120 m reach is slightly entrenched and has cobble and gravel as the dominant substrate. The width within this reach narrowed down to 0.85 to 1.3 m, with a depth average of 0.08 m. The watercourse then disperses into a forested swamp (WL20) and eventually the channel reforms (Reach 3) 30 m north, still within WL20.

Reach 3 is a moderately entrenched, 70 m long run with occasional small pools. At the time of the assessment, water was mostly confined to residual pools, with wetted widths up to 0.8 m and an average depth of 12 cm. Channel widths range from 0.7-0.8 m. Substrate is composed of an equal mix of boulder, rubble, cobble, gravel, and muck. Moderate cover is provided mostly by large woody debris, with only a small proportion provided by undercut banks, overhanging vegetation, and boulders.

WC8 then transitions into a steeper, 145 m long riffle (Reach 4). At the time of the assessment, the reach was completely dry, with channel widths ranging from 0.65-1.0 m. Substrate is composed of an equal mix of rubble, cobble, and gravel, with less frequent boulder. Abundant cover is provided by a high amount of large woody debris and frequent undercut banks. At the end of Reach 2, WC8 dechannelizes, dispersing into wetland habitat with no visible bed or bank (Photo 59, Appendix C). Substrate is mostly contiguous wetland surface, with some exposed areas of muck in more frequently inundated areas. During low flow conditions, the wetland dries completely. During high flow conditions, the wetland inundates, hydrologically connecting the channelized reaches of WC8 through wetland surface flow. At this point, the wetland also intercepts a 90 m long, ephemeral tributary which forms from pockets of standing water east of the main channel in WL20 but shares similar physical characteristics to Reach 2. The watercourse re-channelizes shortly after the confluence with the eastern tributary.

The final reach of WC8 (Reach 5) is a lower gradient, 113 m long homogenous run, with channel and wetted widths of 1.1 m and 0.5 m, respectively. Average water depth is 6 cm, and substrate is dominated by a combination of boulder and rubble with occasional cobble and muck. Moderate cover is provided by a variety and relatively equal mix of cover types, including large woody debris, boulders, undercut banks, overhanging and emergent vegetation. At its downstream extent, the watercourse channel flattens further through WL20, where there is bi-directional flow to and from Gold Brook Lake.

As detailed in the 2017-2019 Baseline Report (Appendix F), electrofishing was conducted at nine stream assessment locations along WC8 in June 2018, during which one American eel and one yellow perch were captured. The American eel was captured approximately 50 m upstream of the natural obstacle in WL20, while the yellow perch was captured near the outlet, where WC8 empties into to Gold Brook Lake. During the three rounds of electrofishing conducted in 2020, only one adult American eel was captured in WC8 during the third round in August, while no fish were captured during the first or second rounds in June or July.

With reaches 1 and 2 there is suitable habitat for young of year, juvenile and adult brook trout. Potential suitable habitat for young of year, juvenile and adult life stages of brook trout and American eel were identified in Reach 3 in the form of moderate cover, a variety of substrate types, and multiple microhabitats (runs and pools). However, habitat viability is limited by the seasonality of flow through the system and is contingent on access through wetland sheet flow during high flow conditions, which serves as a navigational barrier at the bottom of Reach 4. Habitat, abundant cover, and substrates (clean gravel and larger rocks) were observed in Reach 4 that may support young of year, juvenile and adult brook trout, as well as juvenile eel, but is also seasonally restricted and contingent on access. Based on its connectivity to Gold Brook Lake, the lowest portion of Reach 5 has been conservatively presumed to provide habitat for the following additional species: banded killifish, blacknose shiner, golden shiner, and yellow perch. Reach 5 is also considered to support juvenile and adult life stages of American eel and brook trout.

Though suitable habitat may be present for brook trout and American eel within the upper reaches of WC8, fish passage through the system is considered to be extremely limited, which is supported by the exceptionally low number of fish captured during the 2018 and 2020 fish surveys within WC8 and the upstream Beaver Pond. DO levels in WC8 may limit fish production at least seasonally, which was measured throughout the watercourse in August 2020 during detailed habitat assessment as below the CCME recommended guidelines for any life stage of cold or warm-water fishes (3.32-4.91 mg/L).

4.1.5 Watercourse 9

WC9 is a first order, intermittent stream located east of Gold Brook Lake. The watercourse originates in WL25, flowing northwest through WL12, eventually emptying into Gold Brook Lake along its eastern shore. A barrier assessment and trapping program on WC9 was continued through April 2020 to document watercourse conditions during seasonal, spring high flow (see short memo, Appendix G). This high flow assessment was completed to support our understanding of the spatial extent of fish access, and the permanence of a potential fish barrier. Following completion of the high flow assessment in April 2020; eel have been captured in a section upstream of the potential fish barrier, confirming this entire watercourse is fish habitat. It is important to note that usage of habitat upstream of the potential barrier is very limited. In Summer 2020, three rounds of electrofishing were conducted in WC9 across two survey reaches, and a detailed habitat assessment was performed (Figure 5a, Appendix A), during which four homogenous fish habitat reaches were delineated (Figure 6d, Appendix A).

Reach 1 is a 400 m stretch of low gradient, homogenous flat through WL25. Channel and wetted widths range from 0.8-1.3 m and 0.5-1.3 m, respectively. Average water depth is 23 cm, and cover through the channel is abundant, composed primarily of large woody debris, undercut banks, and overhanging, emergent, and submergent vegetation. Substrate is largely dominated by muck, with the occasional highly embedded boulder. At the end of Reach 1, a 20 m section of dechannelized, underground flow acts as a natural obstacle to fish passage (Photo 62, Appendix C). Based on the results of multiple assessments, including fall and spring high flow assessments, the subterranean section was described as a complete barrier to fish, excluding eel, during low flow. During seasonal high flow, the subterranean section has more contiguous flow, but still presents considerable navigational challenges to fish species known or expected to be present in this system. This was supported by trapping and electrofishing efforts conducted during the 2020 field program, during which only one adult American eel was captured upstream of the subterranean section.

Reach 2 is a 110 m long, moderately entrenched run located primarily within upland habitat between WL25 and WL12. At the time of the assessment, the reach was completely dry. Channel width through the reach is 0.8 m, and substrate is dominated by boulders, with lesser amounts of rubble, cobble, and muck. Some cover is provided by small amounts of large woody debris, unembedded boulders, overhanging vegetation, and in-stream vegetation.

As it enters WL12, WC9 transitions into a 357 m long series of low gradient flats connected by multiple small riffles through upland lobes (Reach 3). Channel and wetted widths range from 0.2-2.4 m, and average water depth is 10 cm. Muck is the dominant substrate type, with less frequent boulder, rubbles, and cobbles and largely contained to the small riffle sections. Moderate cover is provided by a combination of large woody debris, boulders, undercut banks, and overhanging vegetation.

The final reach of WC9 is a 154 m long homogenous run. The reach was mostly dry at the time of the assessment, with an average water depth throughout the reach measured as 4 cm. Channel widths range from 1.0-1.5 m, and substrate is dominated by rubble, with lesser amounts of boulder, cobble, and muck. Some cover is provided by a combination large woody debris, undercut banks, and overhanging vegetation (Photo 65, Appendix C). At the end of Reach 4, a dry, 10 m long rock-filled berm disconnects the mouth of WC9 and the wetted edge of the Gold Brook Lake during seasonal low-flow periods.

Electrofishing and trapping surveys were conducted within WC9 on seven separate occasions in 2019 to reflect watercourse conditions under various flow regimes. No fish were captured or observed during any of these surveys, which amounted to 1305 hours and 48 minutes of trapping effort and 306.2 seconds of electrofishing. The details of 2019 fishing efforts within WC9 are provided in the 2017-2019 Baseline Report (Appendix F). In 2020, no fish were captured as a result of spring high flow trapping. During the three rounds of electrofishing surveys, only one adult American eel was captured upstream of the subterranean section located at the end of Reach 1, while two adult American eel and one brook trout parr were captured downstream of the subterranean section. Two of the three electrofishing rounds within both survey reaches resulted in no fish.

Fish passage and habitat availability through this system is restricted by seasonal dryness and also by the presence of the two noted obstacles to fish passage. Due to the presence of the subterranean obstacle at the lower end of Reach 1, the uppermost reach of WC9 is considered to be accessible only to American eel, which is supported by the results of fish collection efforts. The sluggish flow, muck substrate, and in-stream vegetation may provide suitable habitat for juvenile and adult life stages of American eel. Within subsequent reaches, the stream may additionally provide suitable young of year, juvenile and adult brook trout habitat in the form of a variety of cover types and unembedded rocky substrate. No suitable brook trout spawning habitat was observed. Water quality measurements for WC9 suggest optimal temperatures for cold-water species likely persist throughout the summer. However, seasonally low DO levels are likely limiting to fish productivity, particularly within the upper reach of the watercourse. The acidity of the watercourse is also considered limiting, with approximately half of the 13 recorded pH levels measuring less than 5.0.

4.1.6 Watercourse 10

WC10 is a perennial, first order stream that originates just outside of WL1, south of WC11, and flows southwest into Gold Brook (Photo 66, 67 Appendix C). As part of the 2021 field program, detailed fish habitat assessment was performed on the watercourse. The watercourse was delineated into two homogenous fish habitat reaches during detailed habitat mapping (Figure 6d, Appendix A). Reach 1 is a flat, represented by a perennial flow regime, up to 0.9m wide, with a muck and detritus substrate. Reach 2 is a riffle habitat type with perennial flow and a boulder substrate. Both reaches of WC10 provide suitable habitat for adult brook trout and American eel. Additionally, the moderate water and boulder substrate in Reach 2 provide habitat for juvenile brook trout. This watercourse is considered acidic, which likely limits fish productivity, as recorded pH levels were less than 5.0.

4.1.7 Watercourse 11

WC11 is an ephemeral, first order stream located in the southern section of the PA (Photo 68-72, Appendix C). The watercourse originates within the eastern lobe of WL1 flowing southwest. WC11 runs under a service road off Gold Brook Road and continues until it connects into Gold Brook in the same general location as WC10. The watercourse was both electrofished and received a detailed fish habitat assessment during the 2020-2021 field program (Figure 5b, Appendix A), during which five homogenous fish habitat reaches were delineated (Figure 6d, Appendix A). All five reaches were identified as ephemeral in nature. Reach 1 is a flat habitat type, with muck and detritus substrate. The four remaining reaches within WC11 alternate between riffles dominated by boulder substrate and flat habitats, which are dominated by muck and detritus. No fish were caught during fish collection in WC11, however, most reaches throughout the watercourse provide suitable habitat for juvenile and adult brook trout, and adult American eel. Five out of the eight pH measurements within this watercourse were below the CCME guidelines for the freshwater fish (<5.0), this is likely to limit fish productivity.

4.1.8 Watercourse 12

WC12 is a discontinuous, ephemeral into perennial, first order stream (Photo 74, Appendix C). This watercourse is discontinuous sections that originates at a service road off Gold Brook Road. The discontinuous watercourse begins within WL1 and flows west, through habitat disturbed by historic mining, exiting and entering wetland multiple times before connecting into Gold Brook. During the 2020 field program, trapping was conducted within WC12 along with three passes of qualitative electrofishing (Figure 5b, Appendix A). As part of the 2021 field program, detailed fish habitat assessment was performed on the watercourse. The watercourse was delineated into four homogenous fish habitat reaches during detailed habitat mapping (Figure 6f, Appendix A). All four of the reaches of WC12 were classified as flat habitats, however two of these were dry at the time of the assessment.

No fish were caught or observed during fish collection in 2020. This watercourse presents suboptimal fish habitat, and fish passage challenges for most species of fish. Some reaches within WC12 provide suitable habitat for adult American eel and brook trout. Recorded temperatures in WC12 remained relatively optimal for brook trout throughout the summer with only one measurement going above the upper limit of brook trout tolerance (<20°C). pH levels may potentially cause harm to freshwater fish as two out of the six measurements were recorded below CCME guidelines and can limit fish productivity (<5.0). However, the DO concentration recorded in June of 2020 during fish surveys (2.62 mg/L) is considered severely limiting to fish productivity, and likely caused by the lack of flowing water through the reach at the time of the assessment.

4.1.9 Watercourse 13

WC13 is a small perennial, first order stream found in the eastern section of the PA near Gold Brook Lake (Photo 75, Appendix C). This watercourse originates within WL5 and flows west into Gold Brook Lake (Figure 5b, Appendix A). As part of the 2021 field program, detailed fish habitat assessment was performed on the watercourse. The watercourse was delineated into one homogenous fish habitat reach during detailed habitat mapping (Figure 6d and e, Appendix A). WC13 was described as a single reach: a flat, 87 m in length, with substrate is dominated by muck and detritus. American eel was identified within WC13 during the 2021 sampling program; and suitable habitat is provided for adult brook trout and American eel. Water temperatures and DO levels recorded within this watercourse are not considered limiting (<20°C and 6.5-9.0). pH levels recorded during fish surveys and detailed habitat assessments were considered acidic and below CCME guidelines (<5.0), these pH levels may be limiting to fish productivity.

4.1.10 Watercourses 19, 20, 23, 24 & 51 (Western Tributary)

Watercourses 19, 20, 23 and 24 together form the western tributary system to Gold Brook Lake, flowing east into the lake (Figure 5a, Appendix A, Photos 88-90 and 94, Appendix C)). These watercourses are connected to others (51, 52, 42) which were not described in detail as part of the fish habitat assessment. This collection of watercourses lies within one large wetland complex (WL42) which is comprised of fen and raised bog habitats. Watercourses delineated within this wetland are highly entrenched.

WC19 consists of a single, short reach, characterized as a flat habitat type (Figure 6b, Appendix A). This reach is only 40 m long and dominated by muck and detritus substrate. After flowing aboveground for 40m, WC19 dissipates and flows subterranean for approximately 45m before emerging as WC20. Fish collection was not completed within WC19, and it is expected that the subterranean section between WC19 and WC20 limits passage of some fish species into WC19. WC19 provides suitable habitat for adult brook trout and American eel.

WC20 has been described in two separate reaches (Figure 6b, Appendix A). The first reach, a flat, is 624 m in length, ranges between 0.7-5.2 m wide, and is dominated by a muck and detritus substrate. Reach 1 flows into an open water section adjacent to Gold Brook Lake. This open water feature flows into Gold Brook Lake via two small channels, WC20 (Reach 2) and WC24. Both of these are classified as rapid habitat with boulder substrate and high (65%) instream vegetative cover. Through fish collection completed in 2021, banded killifish, brook trout, American eel and yellow perch have been identified within this western tributary system. Suitable habitat is provided for all life stages of yellow perch, golden shiner and banded killifish, additionally suitable habitat is also found for young of year, juvenile and adult brook trout and adult American eel. pH and DO levels recorded during fish surveys (3.26 and 4.56 mg/L) may be severely limiting to fish productivity, and likely caused by the lack of flowing water through the reach at the time of the assessment.

WC23 is a first order stream originating in WL52, flowing as a single reach (flat habitat type) into Gold Brook Lake (Figure 6b, Appendix A). This watercourse ranges between 1.2-1.5 m in width, with a muck and detritus substrate. Banded killifish and yellow perch were identified by trapping where WC23 discharges into Gold Brook Lake during fish collection in 2021. Additionally, suitable habitat is provided for adult brook trout and American eel.

A short section of WC51 was assessed to support eventual permitting for a proposed road crossing (Figure 6b, Appendix A). WC51 is a first order stream that transitions into a second order stream at the confluence with WC52. This single reach (230 m in length) exists within WL58, which eventually flows into WC20 and Gold Brook Lake. Reach 1 of WC51 is a flat habitat type with a perennial flow regime, and it exists entirely within WL42. The substrate is dominated by muck and detritus, and the channel width ranges between 0.8-2.75 m with a depth average of 11 cm. Fish collection was not completed within WC51; however, this reach provides suitable habitat juvenile and adult American eel and brook trout, and additionally all life stages of banded killifish. pH recorded during detailed habitat assessment was considered acidic (4.76) and may be limiting to fish productivity.

4.1.11 Watercourses 22, 69 & 58 (Northern Tributary)

Gold Brook Lake has one primary northern tributary, which flows from Oak Hill Lake via WC69 and WC22. WC69 has been described in detail for fish habitat evaluation, along with a portion of WC22, from the point of convergence with WC69 downstream to the confluence with Gold Brook Lake. Other watercourses which are part of this system include WC58, 56, 68 and 60. A small portion of WC58 has been described to support a proposed road crossing (Figure 5a, Appendix A).

WC69 flows south from Oak Hill Lake in three distinct reaches (Figure 6b, Appendix A). Reach 1 is a flat habitat type with smaller components of riffle and pool. It is 325 m in length, and ranges between 0.85 and 1.75 m in width, with a bedrock substrate and little vegetative cover (15 %). Reach 2 is a riffle, 125 m in length, ranging between 1.25-1.3 m in width, flowing over a bedrock substrate. Reach 3 is a pool, 44 m in length over a bedrock/rubble substrate. Fish collection was not completed in WC69, however throughout the three reaches, suitable habitat is provided for YOY, and both juvenile and adult brook trout, juvenile and adult American eel.

WC69 converges with WC22 (which flows in from the northeast) at a pool/still-water habitat type, which represents the first of seven reaches described on WC22 (Figure 6b, Appendix A). This pool is 183 m in length, approximately 10 m in width. This reach exceeds 1 m in depth; however the exact depth could not be safely determined from a shore-based survey. The substrate is dominated by muck and detritus, and cover is provided by a combination of vegetative cover and depth.

Reaches 2-7 alternate between riffles, flats and riffle-run habitats, with one additional pool habitat (Reach 3). This riffle and riffle-run habitats flow over boulder dominated substrates, while flat habitats are typically underlain by muck and detritus. This watercourse ranges between 1.35 m and 4.95 m in width, and vegetative cover is generally low (916%), aside from pool habitats where cover is provided by depth and vegetation. Brook trout and American eel have been captured within WC22 using electrofishing methods during the 2021 field program. Throughout the seven reaches, suitable habitat is provided for all life history stages of golden shiner, YOY, juvenile and adult brook trout life history stages, juvenile and adult American eel.

A short section of WC58 was assessed to support eventual permitting for a proposed road crossing (Figure 6b, Appendix A). This single reach, 61 m in length, exists at the upstream extent of WC58, which eventually flows into WC22 and Gold Brook Lake. Reach 1 of WC58 is a flat habitat type with a perennial flow regime, and it exists entirely within WL194. The substrate is dominated by muck and detritus, and the channel width ranges between 0.6-0.8 m. Fish collection was not completed within WC58; however, this reach provides suitable habitat adult brook trout and American eel.

Optimal temperatures for cold-water species were observed to persist within these systems throughout the summer. DO levels recorded during fish surveys and detailed habitat assessment were above the minimum level needed for warm or cold-water fish species (<5.5 mg/L). In addition, these watercourses are considered acidic and had pH levels recorded below 5.0, which limits fish productivity.

4.1.12 Watercourses 43, 14, 15, 47, 45, 50, 39, 16 (Eastern Tributary)

Gold Brook Lake has one primary eastern tributary system, which includes WC43/15/47, WC45/50/16, and WC14 (Photos 76-87, 95-101, and 103-105, Appendix C). This system includes Rocky Lakes and their headwaters, which extend east outside of the PA (Figure 5a, Appendix A).

WC43 commences as a first order stream within WL156 (Figure 6c, Appendix A). This system was described as a single reach; a flat habitat type which flows southeast for approximately 684 m. WC43 crosses a forestry road through a culvert and continues flowing SE as WC15 within WL83. WC47 is a small tributary to WC15, and it flows from WL161 into WC15 within WL83. WC47 was described as a single reach – a flat habitat type underlain by muck/detritus substrate. It is 47 m long and less than 1m wide, with approximately 50% vegetative cover. WC15 has been described as seven individual reaches, alternating between flat, riffle-run and riffles (Figure 6c and d, Appendix A). This watercourse is entirely underlain by muck and detritus substrate, and it flows through WLs 173, 148 and 144 before flowing into WL27 where it converges with the main branch of this system (WC14). During fish collection completed in 2021, brook trout and American eel have been identified in WC43, but no fish collection was completed in WC15. Suitable habitat within WC15 is provided for adult brook trout, juvenile and adult American eel. Habitat within WC43 is limited to adult brook trout and American eel.

WC45 commences in WL161 and flows SW and W through WL172 and WL139 (Figure 6c and d, Appendix A). WC45 was described as four separate reaches. Reach 1 is a flat habitat, 143 m long and ranging between 0.6-1.85 m in width. It is underlain by muck/detritus substrate, with approximately 72% vegetative cover. Reach 2 is a riffle habitat with similar characteristics to Reach 1; however the substrate is dominated by boulder with muck and detritus in the interstices. Reach 3 is a flat habitat, 73 m in length, with smaller components of riffle and pool habitats and abundant (69%) vegetative cover. Reach 4 is a 405 m long riffle with abundant vegetative cover and a muck/detritus substrate. Fish collection was not completed within WC45 in 2020-2021, however this watercourse provides suitable habitat for adult brook trout and American eel.

WC50 is a perennial, first order stream that originates in a mixed-wood forest just east of Gold Brook Road, flowing west into WL27 (Figure 6d, Appendix A). Eventually WC50 flows south into WC14. As part of the 2021 field program, detailed fish habitat assessment was completed on WC50. The watercourse was delineated into three homogenous fish habitat reaches during detailed habitat mapping (Figure 6d, Appendix A).

Reach 1 is a 102 m long slightly entrenched run that flows underground for 1m and through a culvert. The culvert was deemed accessible to fish, except perhaps during extreme low flow. Channel width ranged from 0.55 m to 1.9 m and has a wetted width ranging from 0.35 m to 1.75 m. Substrate is dominated by muck and detritus, with rubble and cobble present in lesser amounts strongly embedded into the muck substrate. Reach 1 has about 40% cover throughout it, with overhanging vegetation and emergent vegetation making up half of all coverage, and large woody debris and submergent vegetation providing smaller amounts of cover.

The channel then increases in gradient, transitioning into a 52 m long series of riffle-run habitat. Reach 2 is narrower and deeper then reach 1, with a channel width ranging from 0.7 m to 1.2 m, a wetted width between 0.55 m and 0.9 m and an average depth of 19 cm. Rubble and cobble dominate the substrate in this reach, with boulder and muck/detritus making up lesser amounts. The dominant cover within Reach 2 changed to undercut banks, overhanging vegetation, emergent and submergent vegetation all making up 21% of cover within the stream out of the total 31%.

The channel then flows into WL27 and decreases in gradient, transitioning into a run for the final 142 m. Less then 5 m of this reach is characterized as a riffle habitat. Channel and wetted width remain relatively similar to reach 2. However, the substrate changes back to having muck and detritus dominating and boulder, rubble, and cobble present in lesser amounts. Depth within this reach decreased to an average of 8 cm throughout the 142 meters. Submergent vegetation is the dominate cover. At the end of reach 3, WC50 converges with WC14.

WC16 is a 302 m first order stream originating in WL27 and flowing northwest into WC14. During both the 2020 and 2021 field program detailed habitat assessment was not completed within this watercourse as there was no predicted impacts to the watercourse catchment. After a shift in infrastructure in 2022, WC16 will be indirectly impacted; and detailed habitat evaluation will occur within this watercourse in 2022.

Fish collection was not completed in WC50 over the 2020-2021 field programs, however, direct connectivity to WC14 gives the watercourse the potential to have brook trout and American eel present. Habitat within the watercourse has the potential to support young of year, juvenile and adult brook trout and adult American eel.

WC39 is a perennial, first order stream that originates from Rocky Lake and flows west eventually draining into WL133 (Figure 6d, Appendix A). As part of the 2020 field program, a detailed fish habitat assessment was completed on WC39. The watercourse was delineated into one homogenous fish habitat reaches during detailed habitat mapping (Figure 6d, Appendix A).

Reach 1 is a 30 m long, moderately entrenched riffle-run. Channel and wetted widths are 0.95 and 0.35 m, respectively, and average water depth is 4 cm. Substrate in this reach is dominated by boulder and rubble, with rubble, and cobble present in lesser amounts. A moderate amount of cover is provided for the watercourse with overhanging vegetation being the dominant form of cover. WC39 eventually disappears underground and flows into WC14.

Fish collection was not completed on WC39 through the 2020-2021 field programs, however, direct connectivity to Rocky Lake and possible connectivity to WC14 in high flow events, gives the watercourse the potential to support brook trout, American eel and golden shiner. Habitat within the watercourse has the potential to support juvenile and adult brook trout, and adult American eel.

WC14 is a perennial, third order stream found in the eastern section of the PA, near Rocky Lake, draining into Gold Brook Lake. As described above, WC14 receives flow from various tributaries including W39 & Rocky Lakes, WC40 and WC15. WC16 flows into WC14 from the south within WL27, however this watercourse was not described in the detailed fish habitat evaluation; because at the time of the assessment, no indirect effects were expected within this watercourse (Figure 6d, Appendix A). For the purposes of effects assessment, the qualitative description of WC16 will be used, and detailed habitat evaluation will occur in this reach in 2022.

WC14 originates within WL133 (likely flowing in from the southern Rocky Lake outside of the PA) and flows west under Gold Brook Road. WC14 eventually flows through WL27, then a mixed wood forest and finally WL28 before connecting into Gold Brook Lake. The watercourse was both electrofished and received a detailed fish habitat assessment during the 2020-2021 field program, during which seven homogenous fish habitat reaches were delineated (Figure 6d, Appendix A).

Reach 1 is a 280 m long riffle-run with smaller components of flat habitat, underlain by a mixture of boulder, rubble, muck and detritus. Abundant vegetative cover is present, and the watercourse ranges between 1.8-3.25 m in width. Reach 2 is a short boulder-bed section, approximately 36 m in length and up to 1.75 m in width with a boulder dominated substrate. Reach 3 is a 103 m long flat with small riffles present, and a muck/detritus substrate. This section ranges from 1.35-9.0 m in width and it contains over 70% cover. Reach 4 is described as a 260 m long rapid with boulder substrate and higher velocities than other reaches of this watercourse. Reach 5 contains habitat consistent with Reach 3, with very low flow, wide and flat, and a muck dominated substrate. Reaches 6 and 7 are described as riffle and riffle-run habitats, dominated by boulder substrate and typically less than 2 m in width.

Brook trout and American eel were identified within WC14 during fish collection completed in 2021. This watercourse provides suitable habitat for young of year, juvenile and adult brook trout, along with adult American eel.

Optimal temperatures for cold-water species were observed to persist within these systems throughout the summer, excluding WC14 which had water temperatures recorded above 20˚C twice throughout the summer (July and August 2021). DO levels recorded during fish surveys and detailed habitat assessment were above the minimum level needed for warm or cold-water fish species (<5.5 mg/L). In addition, most of these watercourses are considered acidic, which likely further limits fish productivity, particularly in watercourses 14, 15, 47, 45, and 50 in which recorded pH levels were less than 5.0.

4.1.13 Watercourse 49

WC49 is a perennial first order stream which commences in WL215 (Photo 102, Appendix C). It flows through WL174 and WL189, then diverges into two separate branches before flowing into Gold Brook Lake (Figure 6b and c, Appendix A). The entirety of WC49 is described as a flat habitat type, with smaller components of riffle. The watercourse ranges from 0.55-1.55 m in width, and the substrate is dominated by muck and detritus (Figure 6b and c, Appendix A). Vegetative cover is high (67%) and depth is quite shallow, at 0.09m. During fish collection completed in 2021, brook trout were identified within WC49. This watercourse provides suitable habitat for adult brook trout and American eel. During fish surveys and detailed habitat assessment, WC49 had pH levels that were considered acidic (<5.0) and may be limiting to fish productivity.

4.1.14 Watercourses 57, 59, 61, 63, & 65

This group of watercourses is combined in the descriptions due to their similarities in physical characteristics, and their shared origin and outflow locations (Photos 107, 109-111, Appendix C). This system commences as WC57 within WL193. It diverges into two channels within WL187, flowing south as WC59 and continues west as WC57. Each of these watercourses dissipate and flow underground with no defined channel or obvious flow path (based on visual, audible, and ecosystem setting cues such as shifts in vegetation community) (Figure 6b and c, Appendix A).

WC57 is a described by a single habitat type; a riffle-run, underlain by a muck/detritus substrate. This watercourse is approximately 0.9-1.35 m in width, and the length of this reach is 442 m. WC57 is a single habitat type as well (a flat), 120 m in length, ranging between 0.8-0.95 m in width (Figure 6b and c, Appendix A). This watercourse is intermittent in nature and was largely dry at the time of the assessment.

Approximately 55 m downstream of WC59, WC63 commences as an outlet of WL187. It continues to flow southwest through WL199 and into Gold Brook Lake. Parallel to WC63, WC65 and W61 also flow southwest towards Gold Brook Lake. Aside from WC57 and WC59 which are connected, the rest of these watercourses are isolated from each other.

WC61 is a perennial, first order stream that flows out of upland forest habitat, in a single reach (riffle-run habitat) for approximately 81 m. It flows into WL197 towards Gold Brook Lake, however no direct connectivity was observed between WC61 and the lake. WC61 ranges between 0.6-1.0m in width, with a muck/detritus substrate, and 30% vegetative cover.

WC63 is a perennial, first order stream that drains out of WL187, flowing southwest towards Gold Brook Lake. WC63 flows through WL199 and disperses just before WL197. WC63 ended 14 meters before Gold Brook Lake and no direct connectivity was observed. WC63 is described as a single homogeneous unit (Reach 1) (Figure 6b and c, Appendix A). Reach 1 is a 120 meter long, slightly entrenched riffle. Channel width ranges from 0.3 m to 0.8 m whereas wetted width ranges from 0.15 m to 0.4 m. Muck and detritus is the dominant substrate with boulders and rubble present in smaller amounts and embedded in the muck substrate. A moderate amount of cover is provided by overhanging vegetation, undercut banks, large woody debris, and emergent vegetation.

WC65 is a perennial first order stream that originates within WL199, flowing southwest to the northwest side of Gold Brook Lake. During the time of detailed fish habitat assessment, WC65 ended 7 m before connecting to Gold Brook Lake and no direct connectivity was observed. WC65 is described as a single reach (Figure 6b and c, Appendix A). Reach 1 is a 57 m long slightly entrenched riffle-run that flows underground approximately five times for about 1 meter each time. Channel and wetted widths are 0.6 m and 0.45 m, respectively, and average water depth is 16 cm. muck and detritus dominate the substrate, with boulder, rubble and cobble are sparsely present and embedded in the muck substrate. There is moderate cover in the watercourse, overhanging vegetation and large woody debris make up over half of the present cover, whereas undercut banks, emergent and submergent vegetation provides little cover.

One pass of electrofishing was conducted within WC63 and WC57. No fish were observed within either watercourse, and it is expected that fish usage of WC57, 59, 61, 63 and 65 is very low, if at all, and limited to high flow events, given that these reaches are generally dis-contiguous with each other and with

Gold Brook Lake. Suitable habitat is provided for adult brook trout and American eel in all these watercourses, excluding WC57 and WC59. Optimal temperatures for cold-water species were observed to persist within these systems throughout the summer. However, DO levels recorded within WC63 during detailed habitat assessments (July 2021) are considered extremely limiting to fish productivity, particularly for cold-water species like brook trout. In addition, these watercourses are considered acidic with pH levels recorded below 5.0, which likely further limits fish productivity.

4.1.15 Watercourse 99

WC99 is a perennial first order stream that originates within WL158 and flows south into WL151 (Figure 6c, Appendix A). This watercourse is a run habitat, 245 m in length, with depths ranging between 15-25 cm, and widths ranging between 0.5-1.3 m. The substrate is dominated by muck. A detailed habitat assessment was not completed on this watercourse, as the watercourse was delineated in late August after the detailed habitat assessments were completed. For the purpose of effects assessment, the qualitative description will be used to describe the habitat, and detailed habitat assessment will follow during the 2022 field program.

WC99 flows into WL151, where it disperses into discontinuous pools. The nearest channelized watercourse (WC57) is located 255 m directly west (downstream) of WC99. Fish passage into WC99 is limited by this 255 m subterranean section, and further limited by another 70 m subterranean section located between WC57 and WC61. However, habitat within WC99 is suitable for all life stages of American eel, banded killifish, and brook trout (excluding juvenile life stage), along with spawning golden shiner. Fish collection was not conducted during the 2020-2021 field program in WC99.

4.1.16 Gold Brook & WC55

During the 2020-2021 field program, three rounds of electrofishing and additional trapping were completed to confirm fish presence in two sections of Gold Brook (Figure 5a, Appendix A, Photos 30-35, Appendix C)). These efforts resulted in the capture of five species of fish throughout the system. Species captured were banded killifish, brook trout, American eel, golden shiner, and yellow perch, which represents almost the entire diversity of fish captured within the PA, excluding blacknose shiner.

Water quality measurements recorded throughout the 2020 field program show a general increase in water temperatures throughout the summer with a peak of 23.7ºC in August. However, water temperatures over the summer of the 2021 field program showed a slight increase between early summer and mid-summer but dropped in late summer, peaking at 20.4ºC in July. The watercourse is considered acidic and somewhat limiting to fish as pH levels were periodically recorded below 5. The feature is considered non-limiting fish habitat with habitat suitable for cold-water species. Benthic invertebrate community assessment analyses completed within Gold Brook show that the aquatic ecosystem supports secondary productivity at a capacity that supports the fish community.

Gold Brook is a perennial, third order watercourse. This watercourse is a braided system that has one main channel (WC64A) and approximately 10 branches (WC64, branches B through K) these reaches can be seen on Figures 6d to h in Appendix A. As part of the 2021 field program, detailed fish habitat assessment was completed for over 5 km of linear habitat on Gold Brook. Fish collection was completed in Gold Brook in 2020 and 2021 (three rounds); supplemented by benthic sampling, a spawning survey and eDNA analysis. This watercourse was delineated into twelve homogenous fish habitat reaches during detailed habitat mapping (Figure 6e to i, Appendix A).

Gold Brook originates at the southern outlet of Gold Brook Lake and flows south through the PA. The entirety of Gold Brook remains within WL1 as it braids numerous times before flowing into the final reach (Reach 12) where it becomes a large open flat with no observed branches. Watercourses 3, 10, 11, 12 and 55 all flow into Gold Brook, along with a wetland mosaic at the Settling Pond Outlet (Figure 6e to h, Appendix A). At the confluence of WC64A and WC64H, just upstream of Reach 12, there is wetland mosaic (Wetland Mosaic B) which also drains into Gold Brook (Figure 6h and i, Appendix A).

Run habitat was the dominant form of fish habitat for five out of twelve reaches within Gold Brook (Reaches 1, 5, 7, 9 and 11) seen on Figure 6e to i, in Appendix A. These five reaches comprised approximately 750 m of Gold Brook. Throughout these reaches muck and detritus was observed as the dominant substrate, with one reach dominated by boulder. Wetted and channel width within the run habitats ranged between the various channels: Reach 5, for instance, was the narrowest reach at 0.75 m-1.1 m in width, while Reach 9 was the widest, at 5.0-29.8 m. Velocity for Reaches 7, 9 and 11 remained below the detectable level of 0.05 m/s, while Reaches 1 and 5 had average velocities between 0.192 m/s and 0.080 m/s, respectively. Depth averages across the reaches ranged from 15cm to 26cm. Cover within the run habitats ranged between 29-83%, with deep pools and emergent vegetation providing the most cover. These reaches provide suitable habitat for adult American eel and brook trout.

Three out of the twelve reaches within Gold Brook are reaches with flat as the dominant habitat and they make up approximately 1400m of Gold Brook (Reaches 3, 8 and 12) seen on Figure 6e to i, in Appendix A. Due to the width and depth of Reach 12, a modified habitat assessment was completed on that reach, where accessibility prevented completion of the standardized transects. This involved field confirmation of the western boundary of the open water feature, while the eastern boundary was estimated by a combination of rangefinder measurements recorded in the field and interpretation of arial photographs Within reaches 3 and 8 channel width had a range between 1.2 to 4.9 m. Limitations from the landscape (island within line of sight) within Reach 12 had a channel width measured by rangefinder between 40 m and 155 m, this was adjusted based on aerial photo interpretation to a max width of 240 m. Velocity between all these reaches did not exceed the detectable level of 0.05 m/s.

Depths within Reach 3 and 8 both had an average of 12 cm. Reach 12, had an average depth of 20 cm in areas where wading was possible. The main channel flowing through Reach 12 has an estimated depth exceeding 1 m. Substrate and depth measurements were estimated from the western shore, where depth exceeded 1 m, and muck/detritus was the dominant substrate. Cover for each reach varied, with Reach 8 having 21% cover provided by emergent vegetation. Reach 12 had the highest percent cover, with 73% cover provided by submerged aquatic vegetation. These reaches provide suitable habitat for all life stages of golden shiner, yellow perch, and banded killifish, and adult American eel and brook trout.

Two of the twelve reaches within Gold Brook had riffle-run as the dominant habitat (Reaches 2 and 6), however these two reaches comprised almost 2 km of the 5 km assessed within Gold Brook (Figure 6e to i, Appendix A). Reach 2 had muck and detritus as the dominant substrate whereas Reach 6 was dominated by boulder substrate. Wetted and channel widths were more consistent throughout, ranging from 1.6-8.2 and 1.7-9.0m, respectively. The average velocity ranged between 0.151-0.250 m/s throughout the two reaches, with average depths ranging from 15-25cm. Cover within riffle-run habitat ranged between 35-42%, with cover provided by boulder and submergent vegetation. These reaches provide suitable habitat for adult American eel and brook trout, with Reach 6 also providing suitable habitat for young of year and juvenile brook trout.

The remaining reaches (Reach 4 and 10) are described as riffle habitat, representing approximately 1 km of the assessed linear length of Gold Brook (Figure 6d to h, Appendix A). Boulder was the dominant substrate for both reaches. Wetted widths ranged between 1.3 and 6.45 m, and the average velocity ranged between 0.183-0.374 m/s. Average depths were relatively shallow, ranging between 10-19 cm. These reaches provide suitable habit for adult American eel, young of year, juvenile and adult brook trout.

Two wetland mosaics were found that drain into Gold Brook. Wetland Mosaic A is located south of the settling pond outlet, between the historic settling ponds and Gold Brook (Figure 6d and f, Appendix A, Photos 123-24, Appendix C). At the time of detailed habitat assessment, no direct connectivity was observed between Wetland Mosaic A and Gold Brook. Ten measurements (focused on depth and substrate) were recorded throughout the wetland mosaic. Muck and detritus was the only observed substrate. The width of the wetland mosaic was estimated to be about 30m by 60m. Depth ranged from 0.05-014 m with an average of 0.10 m and velocity was never recorded above 0.05 m/s. This wetland mosaic is predicted to support all life stages of banded killifish, golden shiner and yellow perch. Fish habitat provisions may be limited to times of high flow. Additionally, this wetland mosaic provides suitable habitat for juvenile and adult brook trout and American eel. The ratio of standing water to vegetation within the wetland mosaic is approximately 50/50.

The second wetland mosaic (Wetland Mosaic B) is located between WC 64A Reach 7 and WC 64H Reach 10 (Figure 6g and h, Appendix A). This wetland mosaic has connectivity to WC 64H and flows into the confluence between WC 64A and 64H. Muck and detritus was the only substrate observed within the feature. This wetland mosaic has pockets of standing water ranging in width from 0.04-0.35m, with depths ranging between 0.11-1.5 m. This feature has the habitat to support all life stages of banded killifish, golden shiner and yellow perch. Fish habitat provisions may be limited to times of high flow.

Additionally, this wetland mosaic provides suitable habitat for juvenile and adult brook trout and American eel.

WC55 is a small (215 m long) perennial, first order tributary to Gold Brook (Figure 6g, Appendix A). This watercourse originates within WL1 and flows southeast into the second largest branch within Gold Brook (WC 64H). This watercourse is one homogeneous flat reach that is dominated by a muck and detritus substrate (Figure 6g, Appendix A). Wetted width ranged between 0.25-0.9m and the channel width ranged between 0.7-1.0m throughout. The average depth was recorded as 7 cm and no velocities were above 0.05 m/s. Cover is provided by overhanging vegetation. Due to its direct connectivity to Gold Brook, this watercourse has the potential to have banded killifish, brook trout, American eel, golden shiner, and yellow perch, but only has suitable habitat for adult American eel and brook trout. No electrofishing was conducted within the watercourse to confirm presence of fish.

4.1.17 Gold Brook Lake

Gold Brook Lake is the predominant aquatic habitat present within the PA (Photos 127-28, Appendix C). It collects flow from three main tributary systems described above as the northern tributary (including WC22 and WC69 bringing flow from Oak Hill Lake in the headwaters of the secondary watershed), eastern tributary and western tributary (which includes flow from two Rocky Lakes, one of which is assessed and described below). The lake is relatively large at approximately 79 hectares in size compared with the area of the secondary, shore direct watershed (~4000 ha) (Figure 6a to d, Appendix A).

Depths range between 0.61 m to 3.05 m, with the deepest basin running north to south through along the central-eastern extent of the lake based on bathymetry data provided to MEL by GHD (Figure 6, Appendix A). This littoral zone, which typically extends up to 2 m in depth, accounts for approximately 40% (32 ha) of the lake’s overall area. Field measurements of depth matched the bathymetry data very closely, with 3.35 m representing the maximum recorded depth throughout Gold Brook Lake.

Using bathymetry data, MEL selected 13 transects to record measurements of fish habitat parameters within the lake (Figure 4a, Appendix A). These transects ran diagonally across the lake, from southwest to northeast, spaced between 85-170 m apart. Along each transect, measurements were recorded at 3-4 locations, including a depth measurement, and a description of the substrate and vegetative cover. Throughout these 39 individual locations, which are described as representative of the lake overall, vegetation was lacking in 79%. Where vegetation was observed, it was typically scarce, and limited to near-shore or shallow habitats. The highest component of vegetative cover was recorded along transect 13 which is the southern-most transect, in the shallow basin upstream of the outflow to Gold Brook. In this area, vegetation was dominated by *Equisetum sp.* and various grasses and sedges. Based on visual assessment, vegetation growth throughout Gold Brook Lake is sparse throughout the summer, with sparse cover provided for fish. Overhanging vegetative cover is present in a thin ring along the shoreline, though cover provided by overhanging shoreline vegetation is limited to 1 m from the shore. In-situ cover is provided by boulder and cobble substrate throughout the Lake.

Throughout various fish collection programs conducted through the summer, the water within Gold Brook Lake was relatively clear indicating likely low levels of primary productivity. Evidence of tannins (clear, yet tea-colored water) was observed throughout the Lake. Secchi depths recorded within the lake ranged between 0.75-1.06 m. Based on trophic status indices presented in Carlson and Simpson (1996), lakes with secchi disk measurements below 2 m typically fall into the eutrophic category. Eutrophic lakes tend to be shallow and warm, with relatively high nutrient inputs; and they are known to support warm water fish species. It is important to note, however, that secchi depth is to be considered indicative, rather than conclusive, of trophic status, as there are multiple factors affecting water clarity and therefore secchi depth measurements (Carlson and Simpson, 1996).

Water quality measurements recorded within Gold Brook Lake show consistent acidic conditions, with pH measurements ranging between 4.41 and 4.65. All of these measurements fall outside of the CCME FWALs and indicate suboptimal pH range for some fish species. Information provided above in Section 3.2.2 state that species such as yellow perch and brook trout are fairly tolerant of acidic conditions, which is reflected in the fish collection results documented within Gold Brook Lake. Dissolved oxygen levels were favorable to fish habitat, with measurements ranging between 9.52-11 mg/L. Temperature profiles recorded throughout the lake did not provide evidence of an obvious thermocline. This may be the result of data collection occurring in October, potentially during fall turnover of the lake. The other potential explanation is that with a maximum depth of 3.35 m, the lake is too shallow to develop thermal stratification.

Benthic sample collection indicated a low to low-moderate diversity, with between 3-11 taxa per sample. Taxon richness indicates the health of the community through its diversity, and increases with increasing habitat diversity, suitability, and water quality. Taxon richness equals the total number of taxa represented within the sample. The healthier the community is, the greater the number of taxa (i.e., diversity of taxa) found within that community. Similarly, a high abundance may indicate a healthier waterbody. While diversity was relatively low, abundance and biomass was relatively high, indicating presence of a food source for fish present within the lake.

Fish collection was completed in four main areas within Gold Brook Lake (north, east, south and west) three times throughout the summer (Figure 5a and b, Appendix A). A variety of methods was used in fish collection, including deployment of eel pots, minnow traps, fyke nets and seine netting. A total of 473 individuals were collected and released throughout all seasonal fish collection programs completed within Gold Brook Lake. Yellow perch represented 62% of all fish captured from Gold Brook Lake (n = 294). Smaller components of banded killifish, American eel, golden shiner, brook trout, and blacknose shiner were observed throughout the fish collection program.

4.1.18 Rocky Lake

Rocky Lake is a small lake, approximately 3.9 ha in size, located at the eastern extent of the PA (Photo 129-30, Appendix C). This is a headwater system, whose outlet (WC39) converges with the outlet of another Rocky Lake (both together are called Rocky Lakes) located east of the PA boundary. These form the headwaters to the eastern tributary, WC14, which drains west to Gold Brook Lake (Figure 6c, Appendix A).

A series of six transects were established to record measurements of fish habitat parameters within the lake, spaced between 50-100 m apart (Figure 4a, Appendix A). Along each transect, measurements were recorded at 3-4 locations, including a depth measurement, and a description of the substrate and vegetative cover. Throughout these 19 individual locations, which are described as representative of the lake overall, submergent vegetation (bladderwort) was documented in 17 locations (89%). Emergent and overhanging vegetation is generally lacking, except for the thin perimeter of shoreline vegetation, which provides share within 1 m of the shore. In-situ cover is provided by boulder substrate throughout approximately 63% of the Lake. Muck /detritus was the second most dominant substrate observed.

The average depth throughout Rocky Lake was 1.07 m, with a maximum depth observed at 1.95 m. One secchi depth was recorded at 1.48 m. Based on trophic status indices presented in Carlson and Simpson (1996), lakes with secchi disk measurements below 2 m typically fall into the eutrophic category. Eutrophic lakes tend to be shallow and warm, with relatively high nutrient inputs; and they are known to support warm water fish species.

Water quality measurements recorded within Rocky Lake show consistent acidic conditions, with pH measurements ranging between 4.62 and 4.79. All these measurements fall outside of the CCME FWALs and indicate suboptimal pH range for some fish species. It is likely that species such as brook trout and yellow perch tolerate these low pH conditions, as described above related to Gold Brook Lake. Dissolved oxygen levels were favorable to fish habitat, with measurements ranging between 9.96-11.67 mg/L.

Fish collection was completed in four main areas within Rocky Lake three times throughout the summer 2021 (Figure 5a, Appendix A). A variety of methods was used in fish collection, including deployment of eel pots, minnow traps, and fyke nets. Seine netting was attempted but could not be effectively completed based on substrate composition and unstable substrate for walking. A total of 186 individuals were collected and released throughout all seasonal fish collection programs. Ninety-one percent of the individuals observed were golden shiner (n=170), while the remaining 9% (16 individuals) were American eel.

5.0 SUMMARY OF BASELINE CONDITIONS

This Baseline Fish and Fish Habitat 2021 Technical Report was prepared as baseline information in anticipation of an EARD for the Goldboro Gold Project. The purpose of this report was to further describe the existing baseline conditions of fish and fish habitat within an expanded PA by building on previous baseline studies conducted from 2017-2019 (report presented in Appendix F).

This Technical Report presented details of field studies conducted in 2020-2021 and the resulting data collected, supplementing information presented within the 2017-2019 Baseline Report and published literature. It is anticipated that this information will support the registering of a provincial EARD by understanding the potential project interactions with fish and fish habitat, and to facilitate regulatory approvals for impacts to fish and fish habitat wherever necessary.

Overall, the aquatic ecosystem within the PA is characterized by acidic conditions, with a site-wide average pH of 4.98 (ranging from 3.89-7.71). Elevated summer temperatures with larger, unshaded watercourses and waterbodies limit fish habitat quality for cold-water species like brook trout within these systems. eDNA sampling confirmed detection of fish DNA within the settling ponds, yet no Atlantic Salmon DNA was detected within samples collected in the Gold Brook system. Atlantic Salmon DNA was detected successfully in the Ocean Lake system, which is located in the New Harbour watershed (1EQ-4).

During habitat assessment completed in 2020, WC3 and WC4 were assessed in their entirety within the 2020 Study Area. This study area has since expanded west-ward, and the watercourses now extend 200 m and 690m upstream of the area previously assessed (respectively). Detailed habitat assessments were not completed in this section in 2021. For the purposes of effects assessment, the physical characteristics of the measured stream below will be extrapolated to the new section upstream; and detailed habitat evaluation will occur in this reach in 2022. Detailed habitat assessments were not completed in WC16 as no indirect effects were predicted in this catchment area at the time of the assessment. WC99 was delineated in late August following completion of the detailed habitat assessments. The qualitative descriptions of each of these watercourses will be used to advise the effects assessments, and a detailed habitat evaluation is recommended during the 2022 field season.

Fishing efforts confirmed the presence of six fish species within the PA, including American eel, brook trout, banded killifish, blacknose shiner, golden shiner and yellow perch. In addition, ninespine stickleback is expected to be present within the PA based on fish studies conducted for the Goldboro LNG project (AMEC, 2006). Overall fish species diversity and abundance throughout the PA was low. All species documented within the PA were observed within Gold Brook Lake, and all except blacknose shiner were documented within Gold Brook. Only American eel and golden shiner were observed within Rocky Lake.

Detailed fish habitat assessments revealed that overall fish habitat viability and accessibility within first and second order intermittent streams (which are the dominant stream types within the PA) predominantly provide potential suitable habitat for juvenile and adult life forms of American eel and brook trout, with other species confirmed or potentially residing in the PA restricted to low velocity areas with a direct connection to Gold Brook or Gold Brook Lake. No suitable spawning habitat for brook trout was found within any of the assessed watercourses. It is possible that brook trout use the lake shoreline for spawning purposes or watercourses lower in the watershed than the PA.

6.0 CERTIFICATE

This document has been prepared by Fisheries Biologist Katrina Ferrari (B.Sc.) and reviewed by the undersigned.

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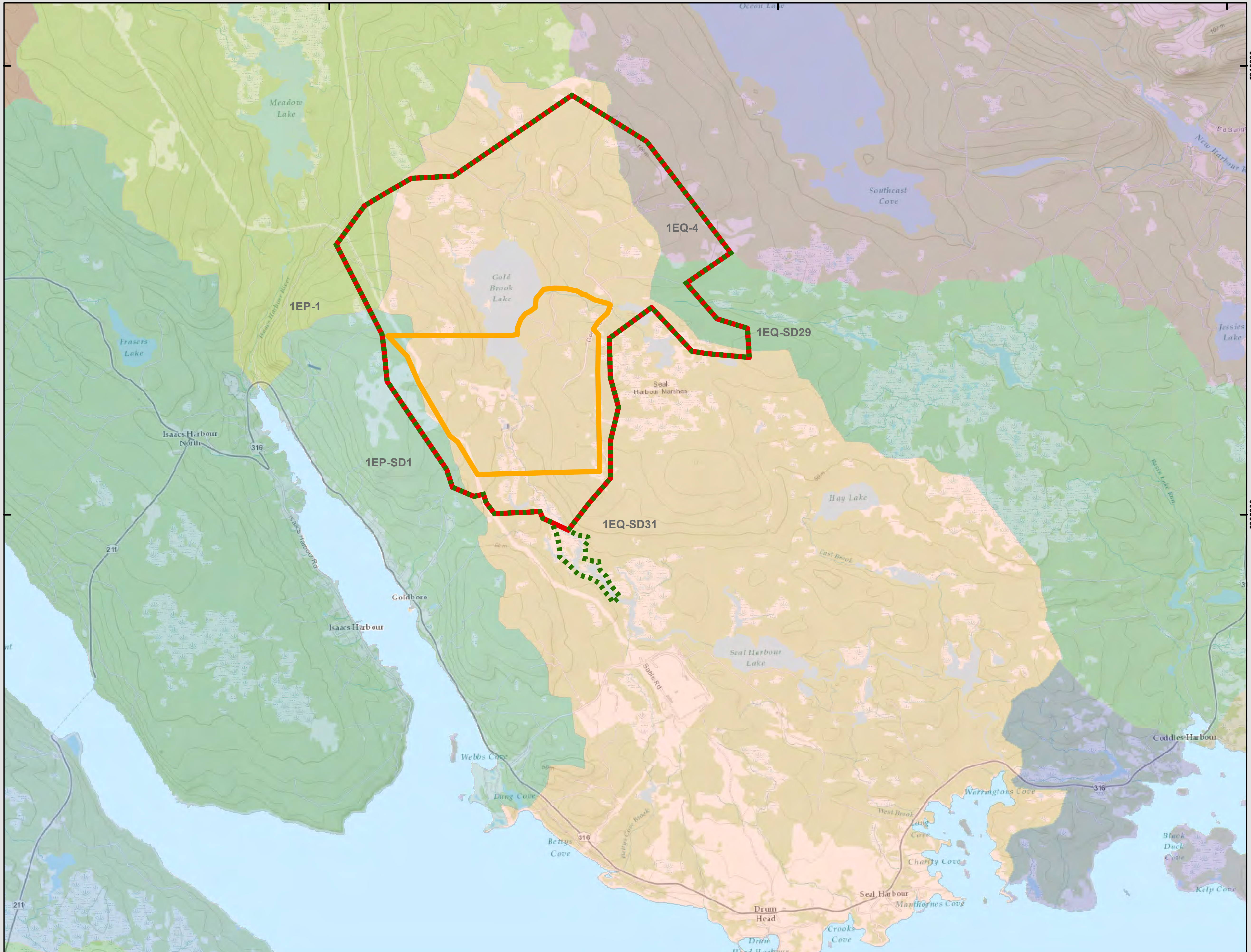
APPENDIX A. FIGURES



Prepared For:

Anaconda Mining
From the ground up

FIGURE 1

Goldboro Gold Project Study Area

Goldboro, Guysborough, NS

Fish Habitat Study Area
2021 Study Area
2020 Study Area

Secondary Watersheds

1EP-1
1EP-SD1
1EP-SD11
1EP-SD12
1EP-SD2
1EP-SD3A
1EQ-4
1EQ-SD28
1EQ-SD29
1EQ-SD30
1EQ-SD31
COSTAL ISLAND

***1EQ-SD31: Secondary Watershed Codes**

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.5 1 2 km

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Reviewed By: MM
Date: 2022-03-01

McCallum Environmental Ltd.

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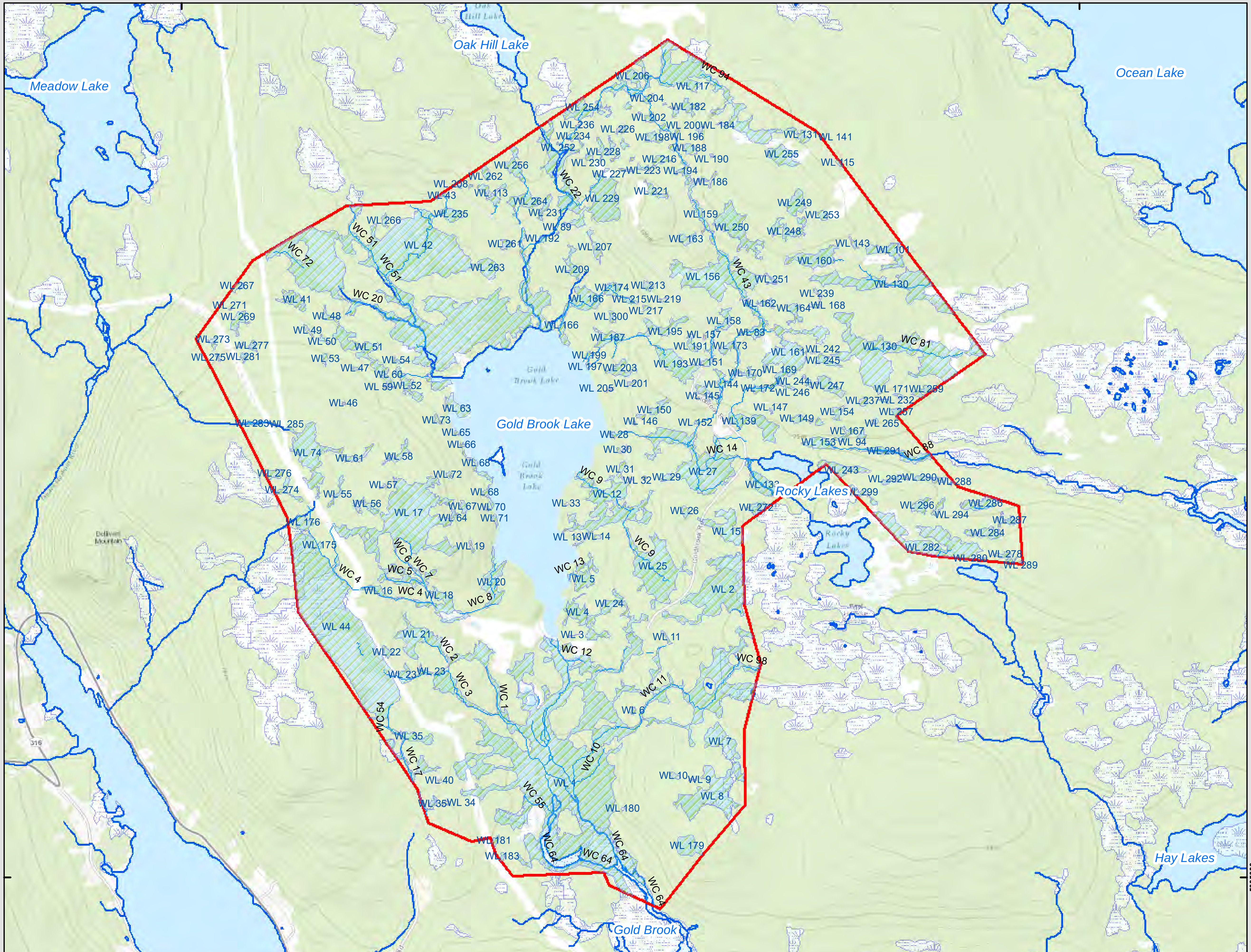

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From the ground up

FIGURE 2

Goldboro Gold Project Delineated Wetlands and Watercourses

Goldboro, Guysborough, NS

Watercourses
Delineated Wetlands
NSE Wetlands outside of Project Area
Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.25 0.5 1 km

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McCallum Environmental Ltd.

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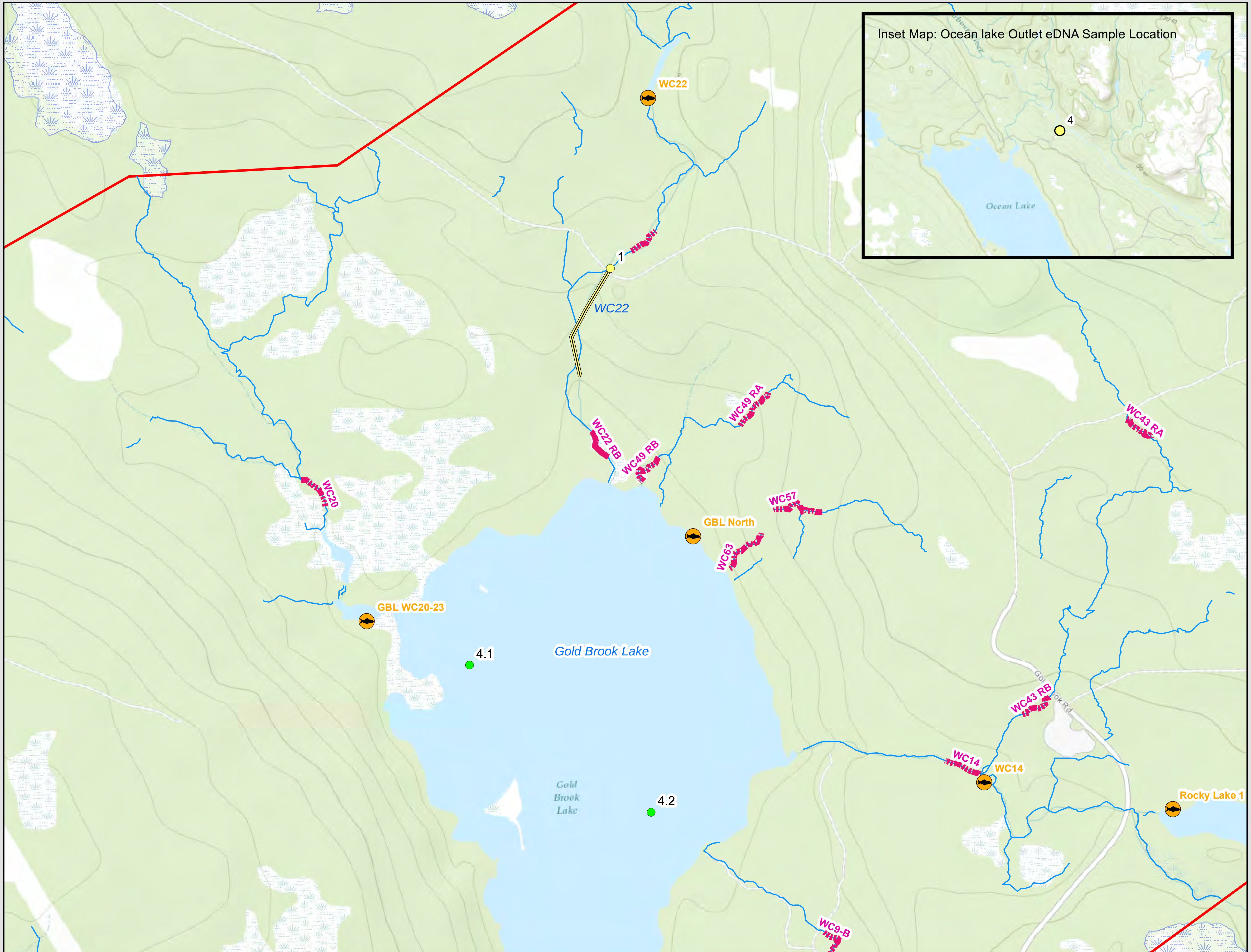

Prepared For:

Anaconda Mining
From the ground up

FIGURE 3a

Goldboro Gold Project
Fish Collection Methods

Goldboro, Guysborough, NS

- FIA (Benthic)
- FIA (Benthic) + eDNA
- eDNA
- Fish Collection: Trapping
- Fish Collection: Electrofishing
- Redd Surveys
- Watercourses
- Study Area

*Points showing Fish Collection via trapping represent multiple traps and trap types. Full details on trapping effort per location are provided in Section 2.5.2 of the 2020-2021 Fish and Fish HabitatTechnical Report.

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.075 0.15 0.3 km

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McCallum Environmental Ltd.

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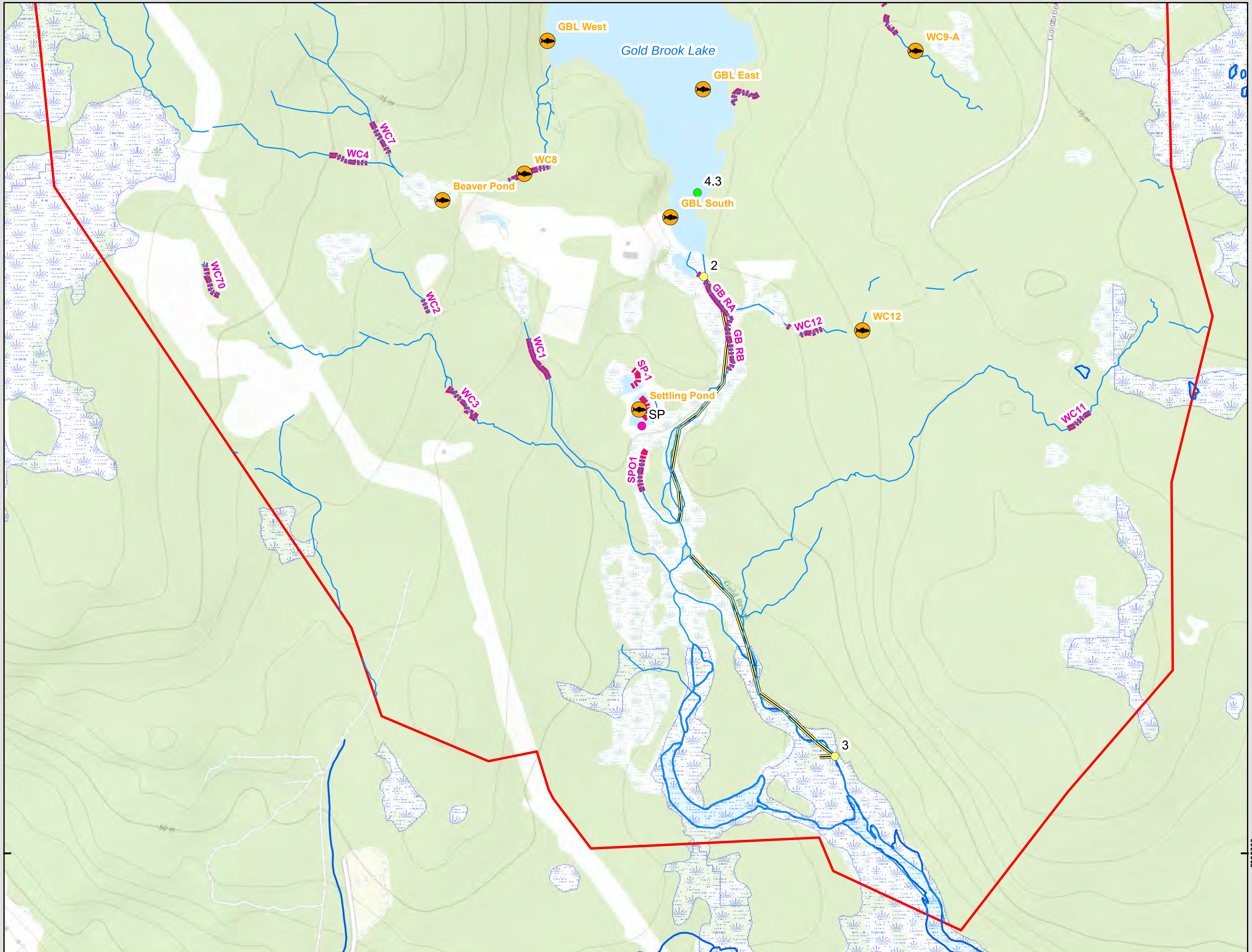


Prepared For:

Anaconda Mining

From the ground up

FIGURE 3b

Goldboro Gold Project
Fish Collection Methods

Goldboro, Guysborough, NS

- Benthic
- Benthic + eDNA
- eDNA
- Fish Collection: Trapping
- Fish Collection: Electrofishing
- Redd Surveys
- Watercourses
- Study Area

*Points showing Fish Collection via trapping represent multiple traps and trap types. Full details on trapping effort per location are provided in Section 2.5.2 of the 2020-2021 Fish and Fish HabitatTechnical Report.

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

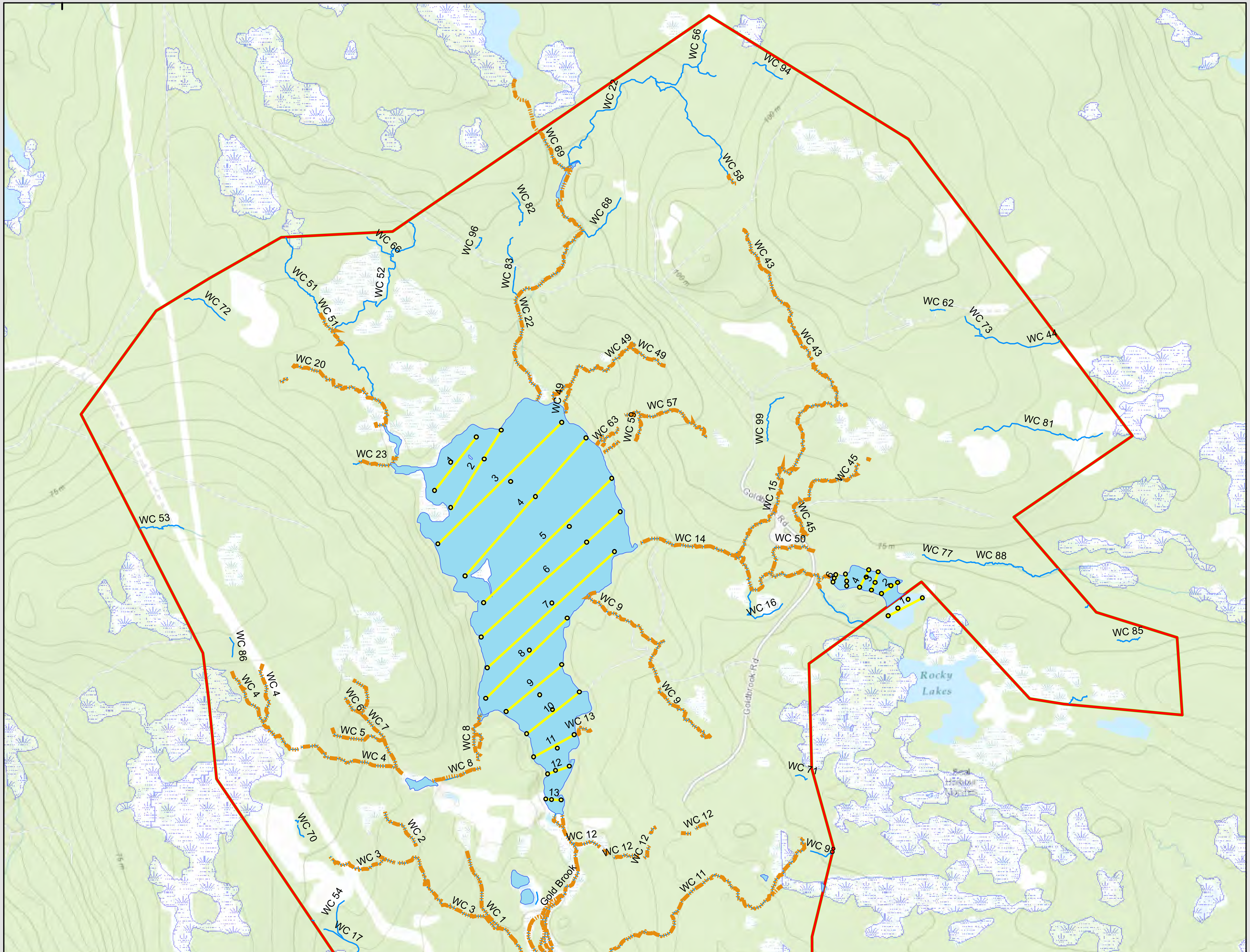
0 0.075 0.15 0.3 km

1:8,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM Date: 2022-03-21

McCallum Environmental Ltd.

Document Name: 220111_Fig3



Prepared For:

Anaconda Mining

From the ground up

FIGURE 4a

Goldboro Gold Project
Fish Habitat Methods

Goldboro, Guysborough, NS

- Lake Measurement Points
- Detailed Fish Habitat Assessment
- Lake Transects
- Watercourses
- Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.175 0.35 0.7 km

1:15,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-03-21

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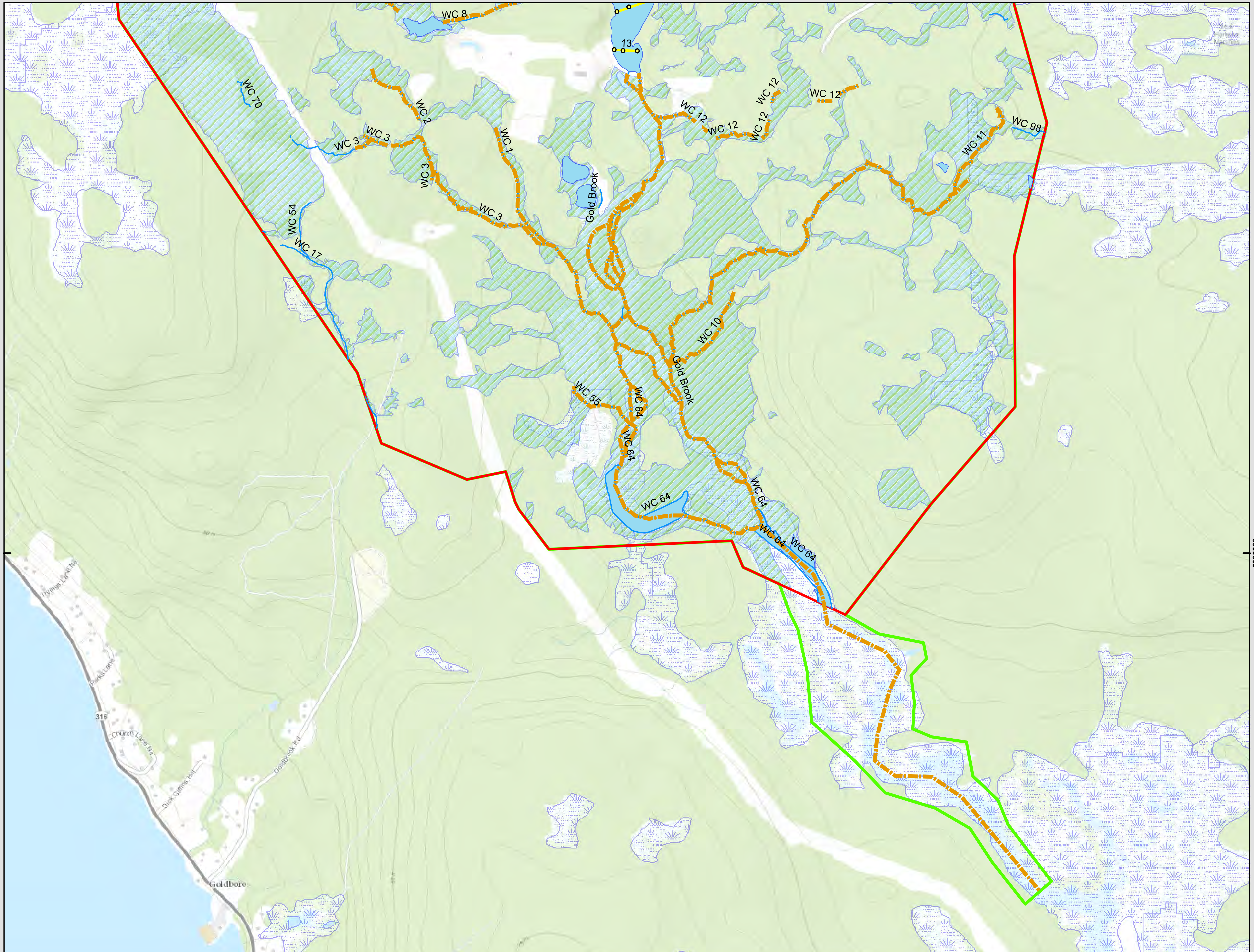
Document Name: 220111_Fig4



Prepared For:
Anaconda Mining
From the ground up

FIGURE 4b

Goldboro Gold Project
Fish Habitat Methods

Goldboro, Guysborough, NS

- Lake Measurement Points
- Detailed Fish Habitat Assessment
- Lake Transects
- Watercourses
- Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

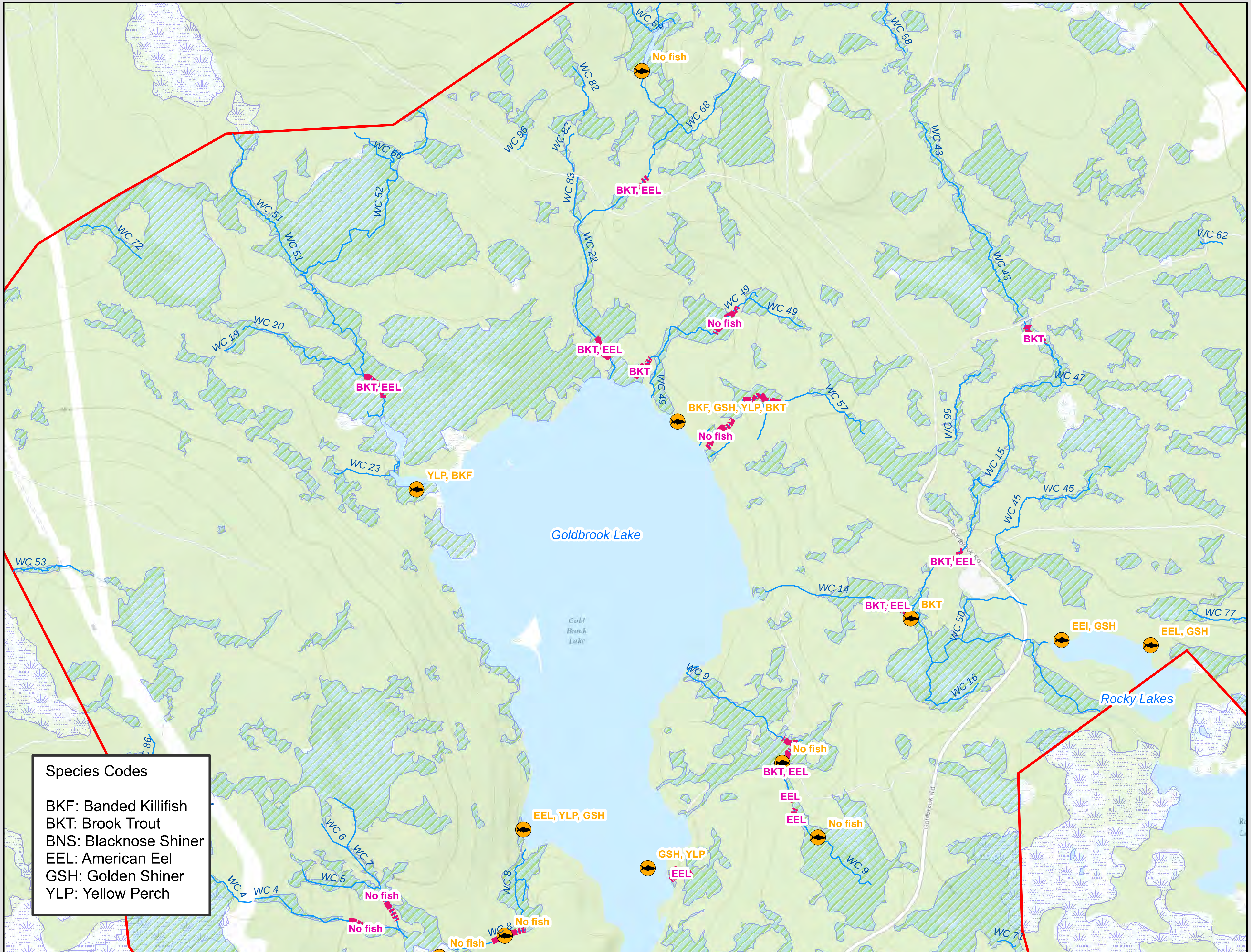
0 0.125 0.25 0.5 km

1:10,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-03-01

McCallum Environmental Ltd.

Document Name: 220111_Fig4



Prepared For:

Anaconda Mining

From the ground up

FIGURE 5a

Goldboro Gold Project
Fish Collection Results

Goldboro, Guysborough, NS

- Fish Collection: Trapping
- Fish Collection: Electrofishing
- Watercourses
- Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

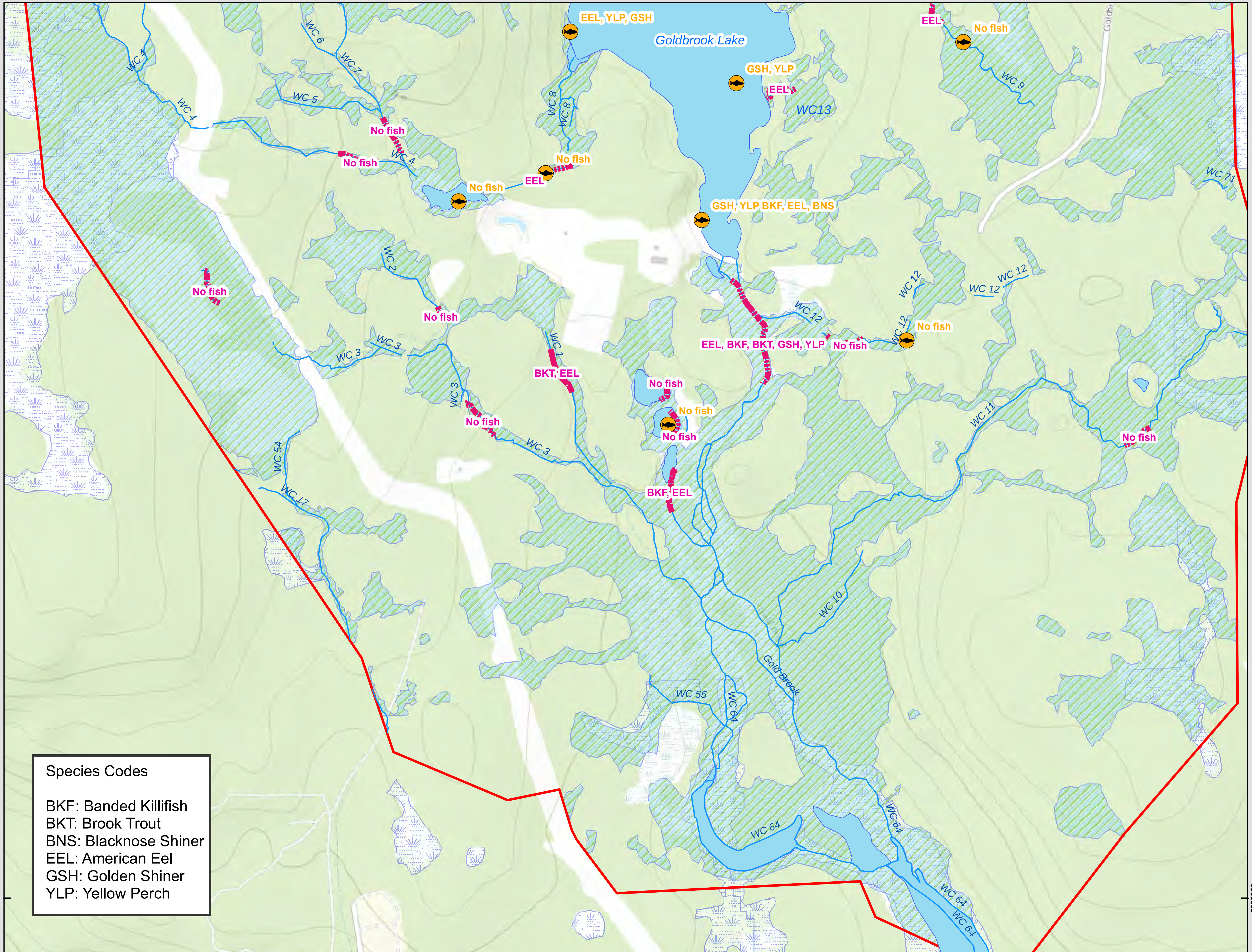
0 0.125 0.25 0.5 km

1:10,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM Date: 2022-03-01

McCallum Environmental Ltd.

Document Name: 220111_Fig5



Prepared For:

Anaconda Mining

From the ground up

FIGURE 5b

Goldboro Gold Project
Fish Collection Results

Goldboro, Guysborough, NS

Fish Collection: Trapping
Fish Collection: Electrofishing
Watercourses
Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

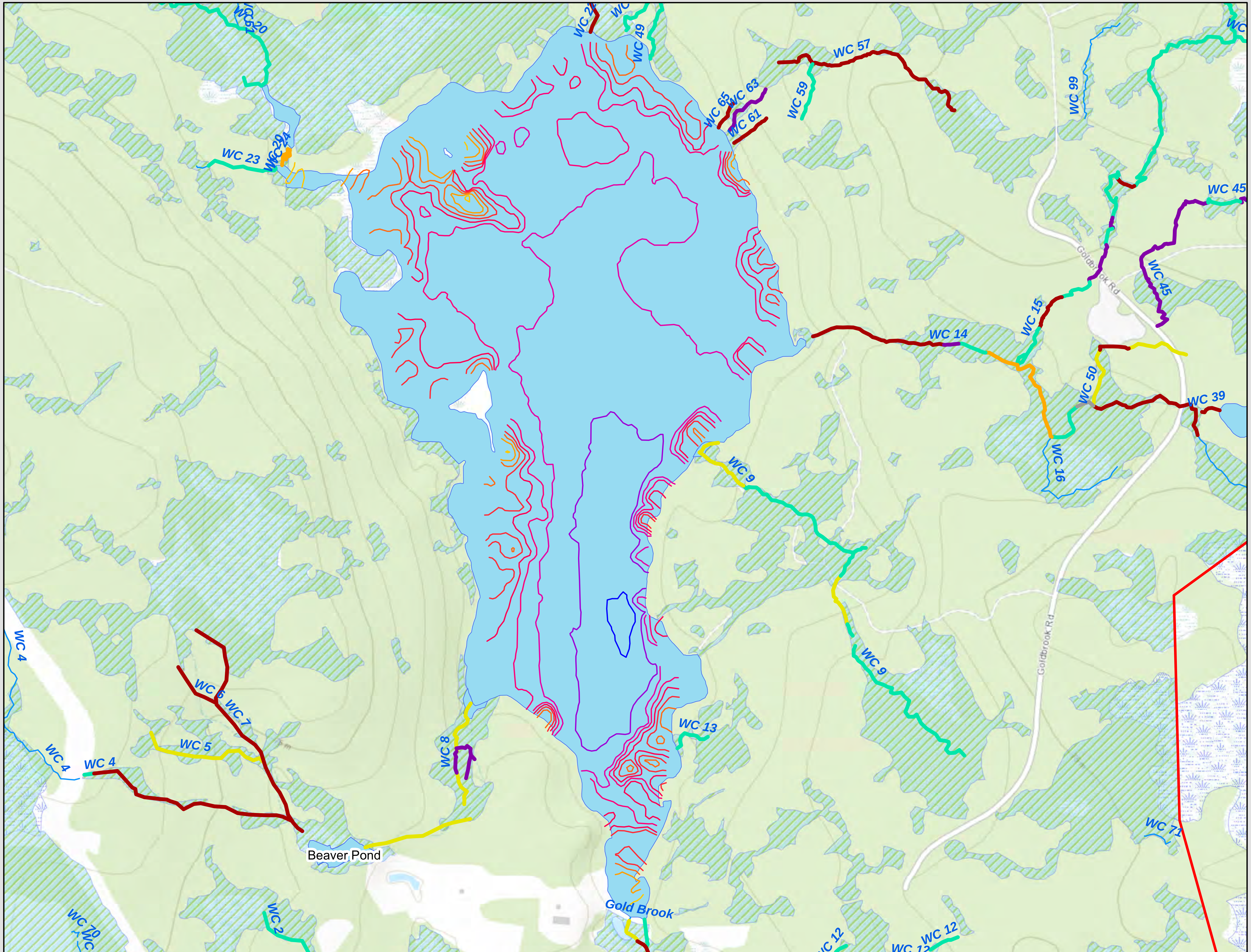
0 0.075 0.15 0.3 km

1:7,500 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-03-01

McCallum Environmental Ltd.

Document Name: 220111_Fig5b



Prepared For:
Anaconda Mining
From the ground up

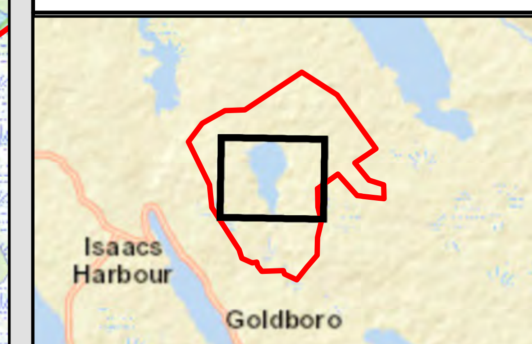
FIGURE 6a

Goldboro Gold Project
Fish Habitat Results
Gold Brook Lake

Goldboro, Guysborough, NS

Bathymetry (m)
- 0.6096
- 0.9144
- 1.2192
- 1.524
- 1.8288
- 2.1336
- 2.4384
- 2.7432
- 3.048

Habitat Type
- Boulder-bed
- Flat
- Pool
- Rapid
- Riffle
- Riffle-run
- Run
- Mosaic
- Open Water
- Watercourses
- Study Area



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.075 0.15 0.3 km

1:7,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6_GBL

Prepared For:

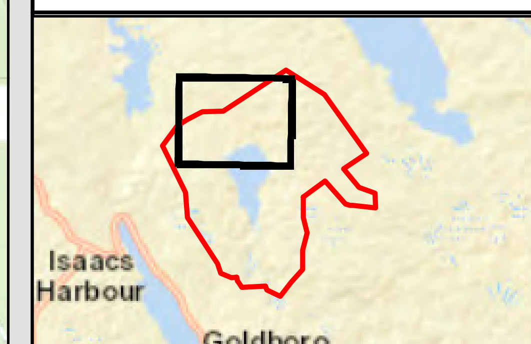
Anaconda Mining
From the ground up

FIGURE 6b

Goldboro Gold Project
Fish Habitat Results
North and West Tributaries

Goldboro, Guysborough, NS

Habitat Type	Bathymetry (m)
Boulder-bed	0.6096
Dry	0.9144
Flat	1.2192
Pool	1.524
Rapid	1.8288
Riffle	2.1336
Riffle-run	2.4384
Run	2.7432
Watercourses	3.048
	Study



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

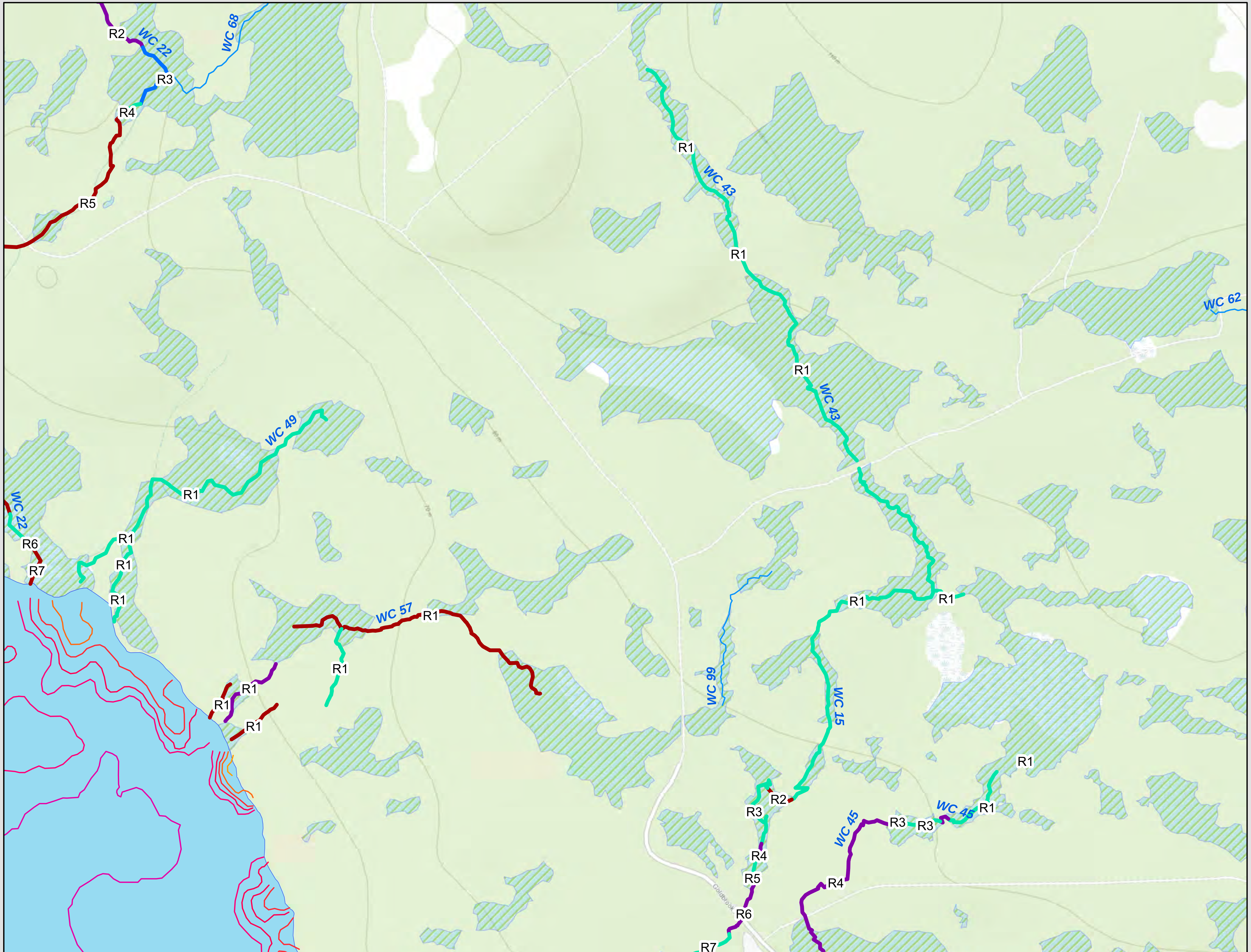
0 0.075 0.15 0.3 km

1:7,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-03-21

McCallum Environmental Ltd.

Document Name: 220111_Fig6a



Prepared For:

Anaconda Mining

From the ground up

FIGURE 6c

Goldboro Gold Project
Fish Habitat Results
Northeast of Gold Brook Lake

Goldboro, Guysborough, NS

Bathymetry (m)	Habitat Type
0.6096	Boulder-bed
0.9144	Flat
1.2192	Pool
1.524	Rapid
1.8288	Riffle
2.1336	Riffle-run
2.4384	Run
2.7432	Watercourses
3.048	Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

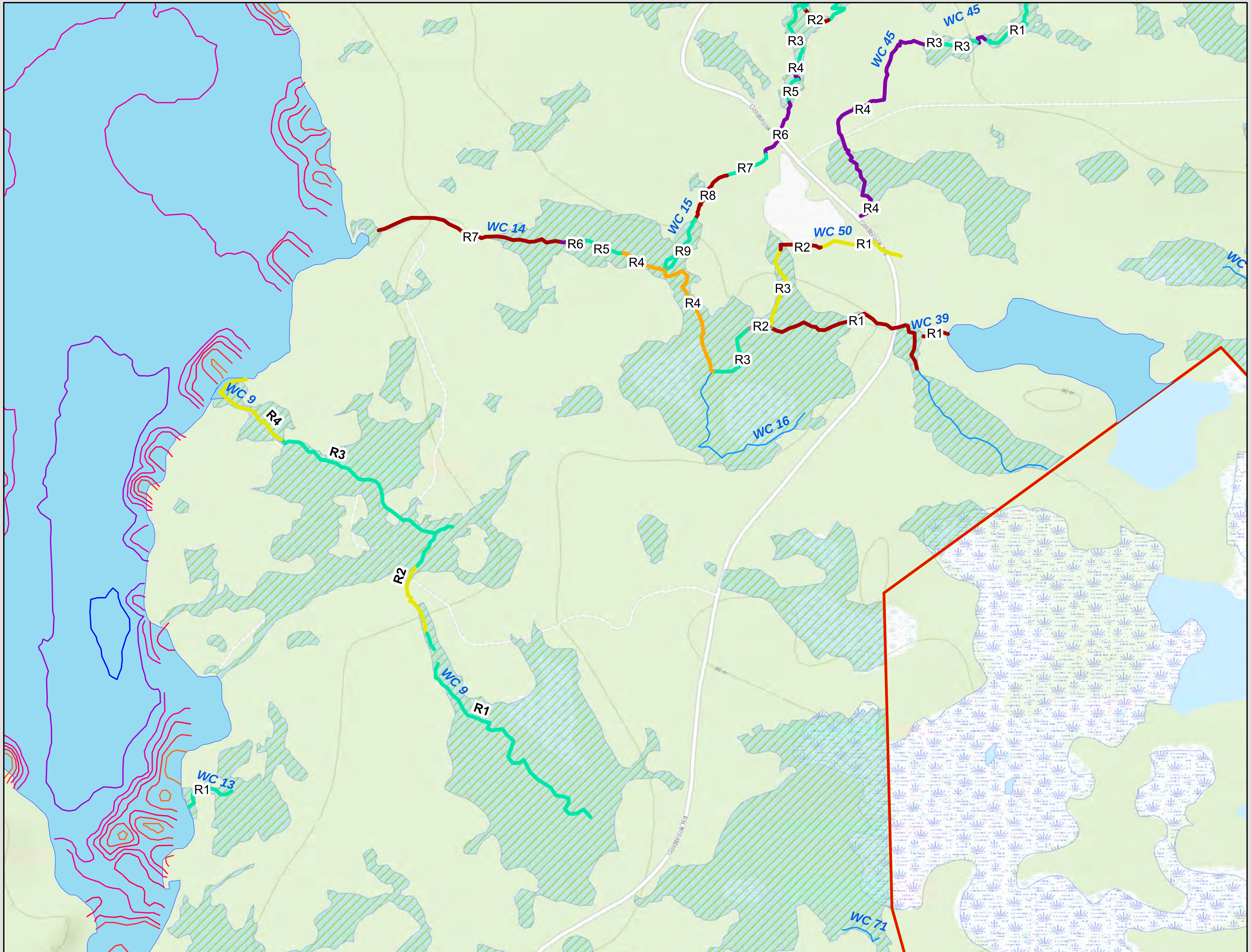
0 0.05 0.1 0.2 km

1:5,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-01-11

McCallum Environmental Ltd.

Document Name: 220111_Fig6b



Prepared For:

Anaconda Mining

From the ground up

FIGURE 6d

Goldboro Gold Project
Fish Habitat Results
Eastern Side of Gold Brook Lake

Goldboro, Guysborough, NS

Bathymetry (m)	Habitat Type
0.6096	Boulder-bed
0.9144	Flat
1.2192	Pool
1.524	Rapid
1.8288	Riffle
2.1336	Riffle-run
2.4384	Run
2.7432	Watercourses
3.048	Study Area

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

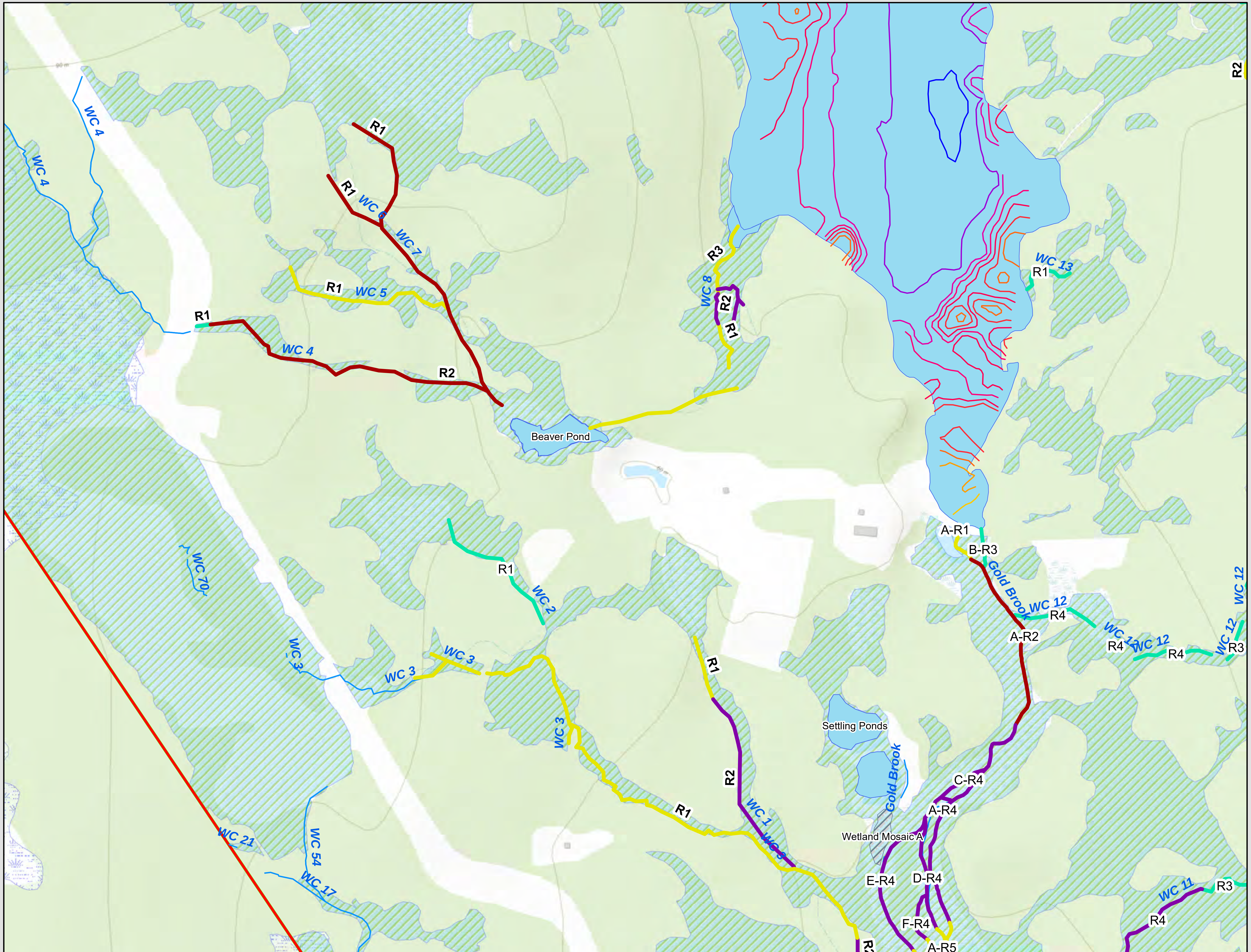
0 0.05 0.1 0.2 km

1:5,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6c



Prepared For:

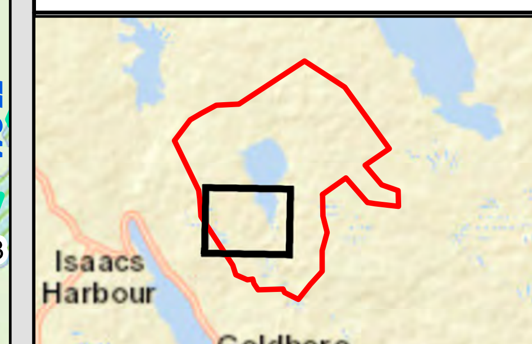
Anaconda Mining
From the ground up

FIGURE 6e

Goldboro Gold Project
Fish Habitat Results
Southwest of Gold Brook Lake

Goldboro, Guysborough, NS

Bathymetry (m)	Habitat Type
0.6096	Boulder-bed
0.9144	Flat
1.2192	Pool
1.524	Rapid
1.8288	Riffle
2.1336	Riffle-run
2.4384	Run
2.7432	Watercourses
3.048	Mosaic
	Open Water
	Study Area



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

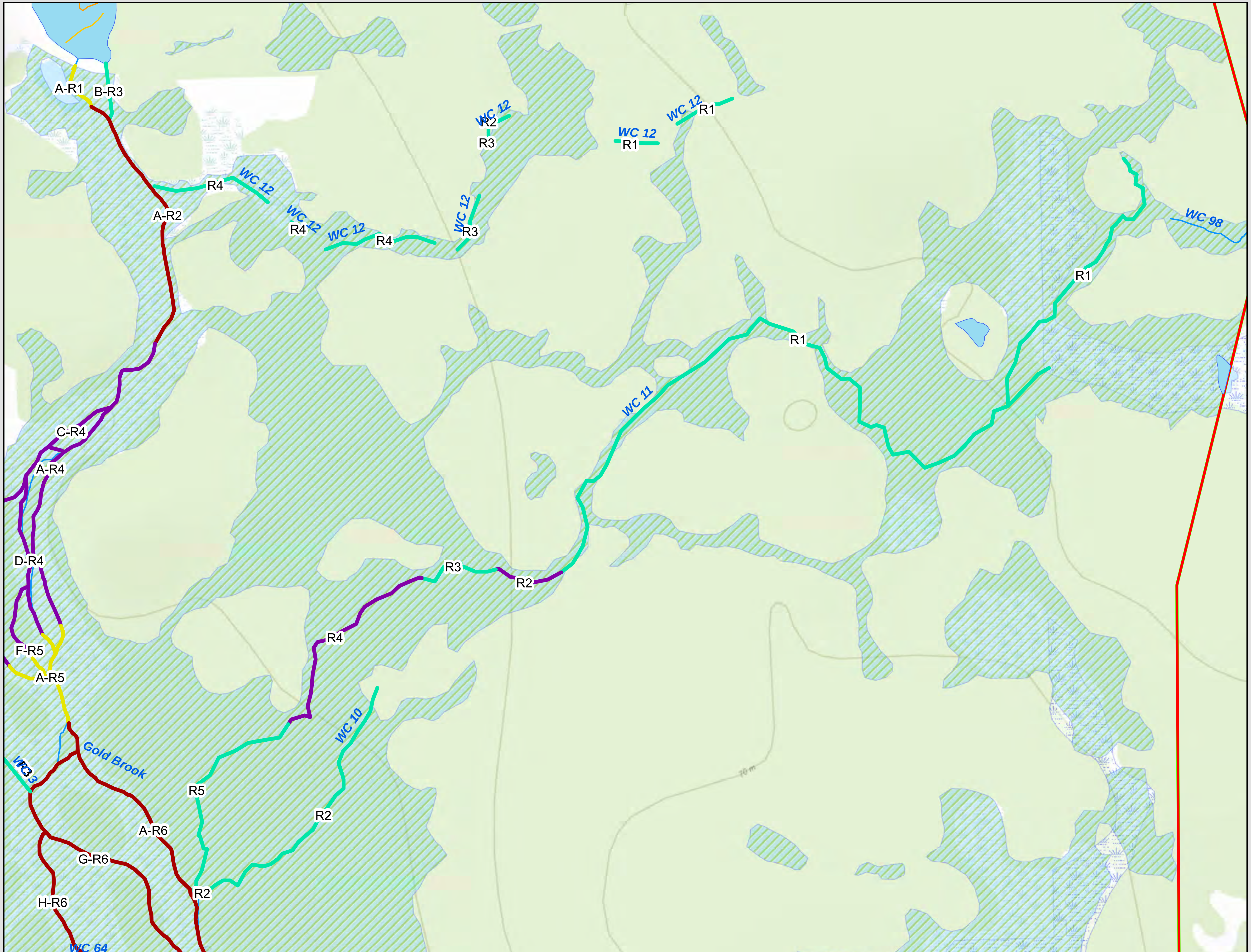
0 0.05 0.1 0.2 km

1:5,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By:MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6d



Prepared For:

Anaconda Mining

From the ground up

FIGURE 6f

Goldboro Gold Project
Fish Habitat Results
Eastern Tributaries to Gold Brook
Goldboro, Guysborough, NS

Habitat Type

- Boulder-bed
- Flat
- Pool
- Rapid
- Riffle
- Riffle-run
- Run
- Watercourses
- Mosaic
- Open Water
- Study Area

Gold Brook (WC64) is labelled according to lettered channels, and numbered reaches

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

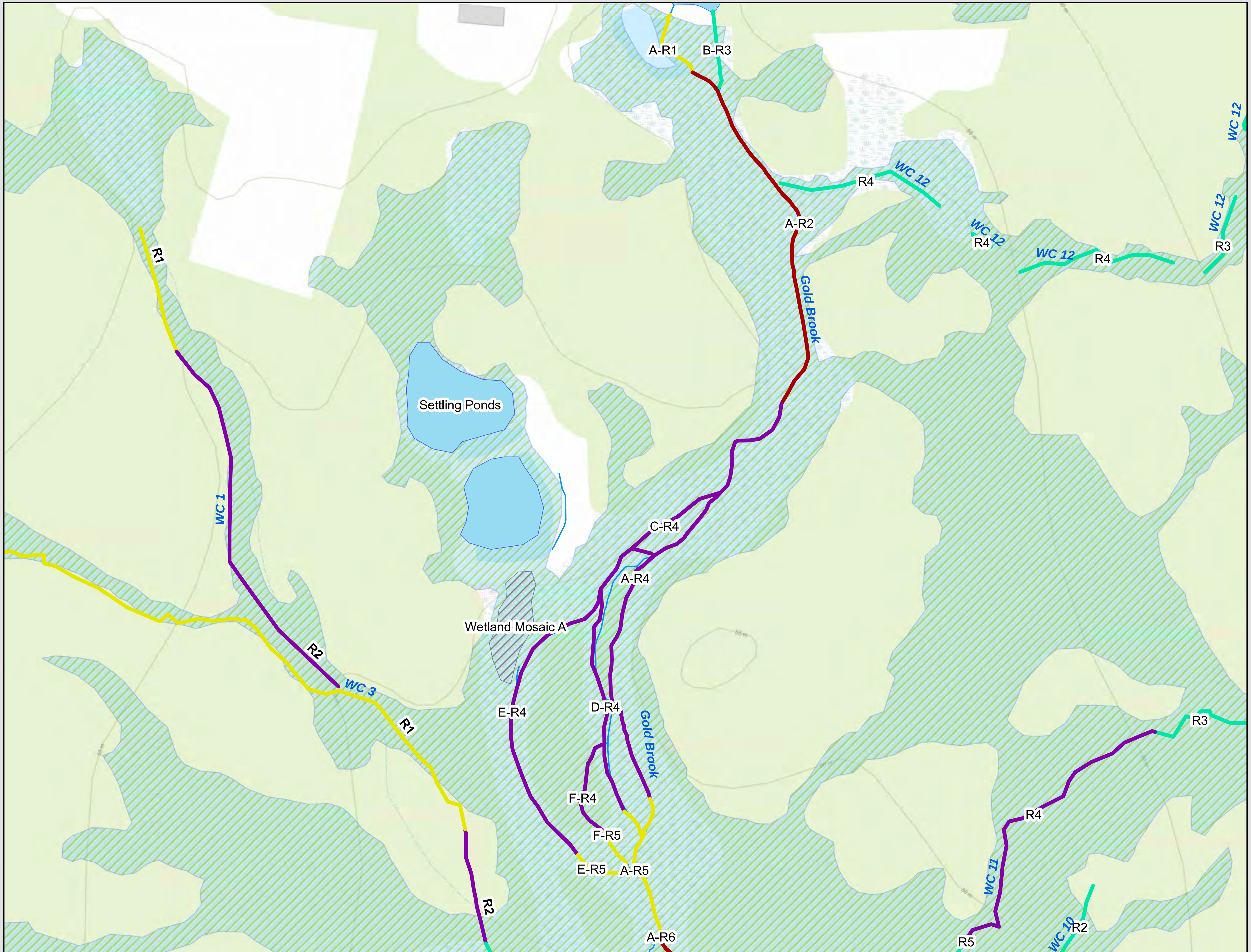
0 0.045 0.09 0.18 km

1:3,500 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6e



Prepared For:
Anaconda Mining
From the ground up

FIGURE 6g

Goldboro Gold Project
Fish Habitat Results
Gold Brook

Goldboro, Guysborough, NS

Habitat Type

- Boulder-bed
- Flat
- Pool
- Rapid
- Riffle
- Riffle-run
- Run
- Watercourses
- Mosaic
- Open Water
- Study Area

Gold Brook (WC64) is labelled according to lettered channels, and numbered reaches

Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

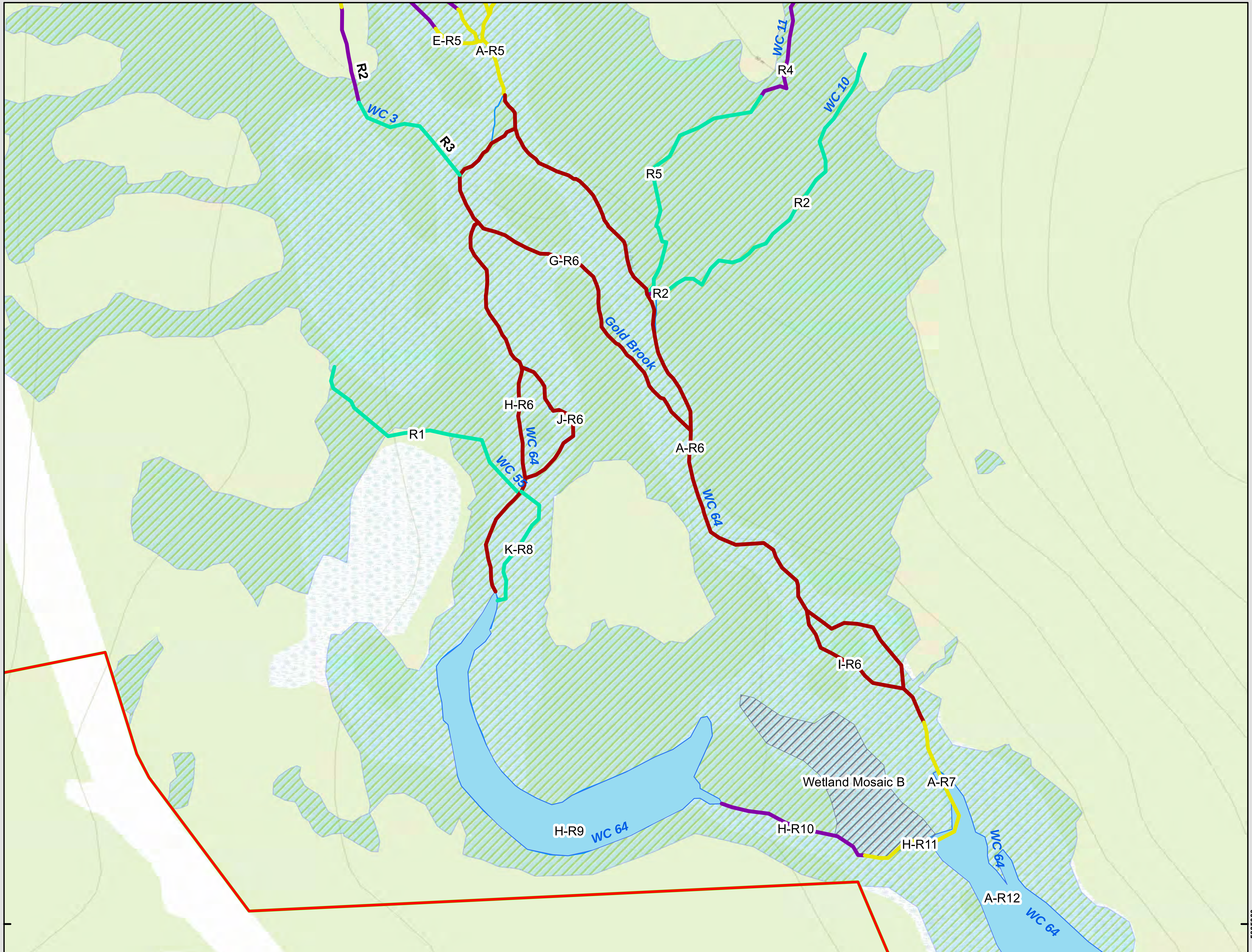
0 0.03 0.06 0.12 km

1:2,500 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By: MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6f



Prepared For:

Anaconda Mining

From the ground up

FIGURE 6h

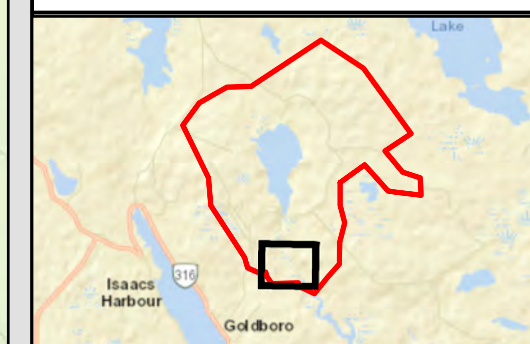
Goldboro Gold Project
Fish Habitat Results
Gold Brook

Goldboro, Guysborough, NS

Habitat Type

- Riffle-run
- Boulder-bed
- Run
- Flat
- Mosaic
- Pool
- Open Water
- Rapid
- Watercourses
- Riffle
- Study Area

Gold Brook (WC64) is labelled according to lettered channels, and numbered reaches



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.0375 0.075 0.15 km

1:3,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By:MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6g

Prepared For:

Anaconda Mining

From the ground up

FIGURE 6i

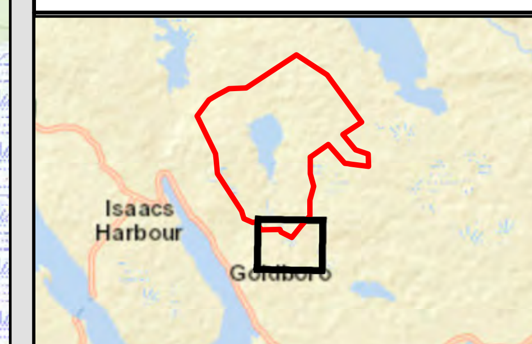
Goldboro Gold Project
Fish Habitat Results
Gold Brook

Goldboro, Guysborough, NS

Habitat Type

- Boulder-bed
- Flat
- Pool
- Rapid
- Riffle
- Riffle-run
- Run
- Mosaic
- Open Water
- Watercourses
- Study Area
- Fish Habitat Study

Gold Brook (WC64) is labelled according to lettered channels, and numbered reaches



Coordinate System: NAD 1983 CSRS UTM Zone 20N
Projection: Transverse Mercator
Datum: North American 1983 CSRS
Units: Meter

0 0.05 0.1 0.2 km

1:5,000 Scale when printed @ 11" x 17"

Drawn By: MMD
Reviewed By:MM
Date: 2022-01-12

McCallum Environmental Ltd.

Document Name: 220111_Fig6h

APPENDIX B. STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE: FISH COLLECTION

1 PURPOSE

The purpose of this document is to provide standard methods for fish collection techniques performed by McCallum Environmental Ltd. (MEL) employees and subconsultants in freshwater habitats.

2 SCOPE

This document provides standards for data collection and measurements, and gives details on a limited range of fish collection methodologies/gear for linear watercourses and littoral habitats of open water areas (i.e. ponds, lakes), including:

- Electrofishing
- Minnow traps
- Eel pots
- Fyke nets
- Seine nets

Subject to study design, these sampling techniques can provide both qualitative information (i.e. species presence, community composition, and relative abundance) and quantitative information (i.e. population estimates) on fish species within freshwater habitats. A clear understanding of the purpose of the sampling program will help define the fish trapping methodology that is needed.

It is important to note that all gear types have certain limitations, including but not limited to catch selectivity and sampling efficacy. The best fish collection studies will employ variety of gear types to sample as many habitat types as possible, thus ensuring the widest possible range of fish species and sizes are collected. A summary of gear types (i.e. sampling methodologies) presented within this document and their limitations are provided in Section 5. There are several resources that provide greater detail and a wider range of procedures for fish collection - see Portt et al. (2006) for a comprehensive review of fish sampling methods in freshwater habitats.

It is also important that all field staff understand the habitat preferences of fish expected to be encountered within the study area. All field staff should have a general understanding of the biology and habitat preferences of anticipated fish species and age groups. This knowledge can greatly improve the sampling efficiency of the field crew and provides important information for gear selection. Detailed information on the biology of fishes in Nova Scotia can be found in Scott and Crossman (1973), McPhail and Lindsey (1970), and the Nova Scotia Adopt A Stream Manual (2005). Fact sheets for common freshwater fish species have been provided in Appendix C.

3 PERMITTING

Before engaging in any fish collection survey, MEL must apply for, and obtain a Licence to Fish Finfish for Scientific Purposes, issued by Fisheries and Oceans Canada (DFO). This is required under the provisions of the Fisheries Act, and any fishing completed without a permit can be subject to criminal charges under the Act. Project managers must ensure proper notification is provided to DFO as outlined in the licence, and must confirm that there are no variation orders in effect which may limit fish sampling methods.

All field staff must read and understand the conditions of the fishing licence and are required to have a hard copy of the licence on hand during all fish collection surveys.

4 SAFETY

The following documents provide important safety considerations and Personal Protective Equipment (PPE) for this type of work, and should be consulted before proceeding with any fish collection survey:

- MEL HSE Policy;
- MEL Remote Work Policy; and,
- Fisheries and Oceans Canada's Interim Policy for the Use of Backpack Electrofishing Units (2003)

The following sections provide important information pertaining to the prevention and avoidance of injury to personnel and fish during fish collection surveys. Unique safety considerations that apply to each fishing method are outlined in Sections 5.1 through 5.5, and procedures outlined in Section 6.0 contain safety checks and emergency response protocols to be followed by all field crew members.

5 FISH COLLECTION METHODS - THEORY

Gear types used for sampling can be divided into two categories: active and passive. Active gear includes those that are moved through the water either by machine or with human power (e.g. electrofishing). Passive gear is usually set and left stationary for a period of time (e.g. minnow traps).

Although gear will be selected prior to the field survey, the surveyors will exercise their judgment in using any combination of gear types to ensure that all habitat types are surveyed within the watercourse reaches or waterbodies of interest.

Certain criteria assist in selection of appropriate gear types. These criteria can include, for example, the overall objective of the fish collection survey, anticipated fish species to be encountered, and in-field limitations such as the physical characteristics of the watercourse/waterbody being surveyed. Fish mortality is also an issue that must be considered, with preference for non-lethal or low-mortality methods wherever possible. Gear types known to have high mortality rates (e.g. gill nets) are not proposed for use as part of MEL fish collection efforts at this time.

Certain limitations may restrict the use of a particular gear type to a lake, a stream, or a particular habitat type. For example, electrofishing is effective in shallow areas of with higher velocity but cannot be used efficiently in deep open waters. Site accessibility, substrate, vegetation, time constraints, size, and accessibility of the habitat of the lake or stream may further affect deployment of each gear type. The best results are obtained by using a variety of gear types to sample as many habitat types as possible, thus ensuring the widest possible range of fish species and sizes are collected.

Many factors affect fish sampling. These include water depth, conductivity, water clarity, water temperature, water velocity, fish size and behavior. The effects these factors have on sampling efficiency vary, and many of the factors are interrelated. Efficacy and limitations of specific gear types are summarized in Table 1.

5.1 Electrofishing

Electrofishing is the technique of passing electric current through the water to attract and stun fish, thus facilitating their capture. This SOP pertains to backpack electrofishing only. It is most useful in streams and rivers, but can also be used to sample shallow littoral areas of lakes. The deeper and wider a sampling area, the more likely fish will be able to avoid capture.

The electrofishing unit is essentially a portable transformer carried on the back of the operator (like a backpack), with probes, controls, and gauges. An electrical current is produced by the unit and is passed through the water from the cathode (negatively (-) charged probe) to the anode (positively (+) charged probe). This current produces an electric field in the water that will affect any fish in a variety of ways depending on where the fish is situated in relation to the electrical field (flight, attraction, or stun). It is also influenced by environmental conditions such as flow rate and conductivity, and the size of the fish present.

Electrofishing is the preferred MEL method for fish collection. Ideally, electrofishing reaches will be free of safety or navigation hazards such as abundant woody debris, deep pools, unstable substrate, or high flow. Although larger fish are typically more easily stunned, electrofishing can be effective at capturing all species and sizes of fish.

Photo 1: Example of an electrofishing crew in action

Electrofishing can be used to determine both qualitative metrics (i.e. determining species presence, diversity, or relative abundance) and quantitative metrics (i.e. estimating population size, absolute abundance), depending on the characteristics of the habitat and the overall objective of the survey. Electrofishing procedures presented in Section 7.2 outline techniques for both qualitative and quantitative surveys. Quantitative surveys (i.e. the depletion method) is the preferred procedure and should be completed whenever site conditions allow.

The depletion method (also known as the “Zippin” method, see Zippin, 1958) is a suitable method for population estimates when the stream is very small, it is expedient to collect all data within a short time period such as one day, and the population being estimated is relatively small (roughly less than 2,000 individuals). This type of freshwater habitat is typical of what MEL biologists encounter throughout Nova Scotia's landscape, especially within headwater inland systems.

The depletion method requires that an adequate number of fish be removed on each sampling pass so that measurably fewer fish are available for capture and removal on a subsequent pass. The number of passes required generally depends on the capture result of each pass; however, a minimum of three passes is generally recommended. Two passes may be sufficient if the second catch is < 10% of the first, and if catches have not declined in the first three sweeps then additional passes are required until catches are < 25% of that in the initial pass.

The following conditions must be met for accurate depletion method estimates:

1. Emigration and immigration by fish during the sampling period must be negligible. This is accomplished by installing barrier nets at both upstream and downstream ends of the electrofishing reach.
2. All fish within a specified sample group must be equally vulnerable to capture during a pass.
3. Vulnerability to capture of fish in a specified sample group must remain constant for each pass (e.g. fish do not become more wary of capture).
4. Collection effort and conditions which affect collection efficiency, such as water clarity, must remain constant. To minimize error, the amount of effort used on each pass should be as constant as possible.

The depletion method is ineffective when more individuals are caught in the second or third passes than were caught in previous passes. This may be particularly problematic for streams containing low numbers of fish. In addition, the depletion method can only be used when barrier nets can be effectively deployed to reduce fish movement. When sampling reaches where blocking nets are not practical (i.e. large rivers), a qualitative survey (single pass without the use of barrier nets) should be performed, which will allow an estimate of relative abundance (Catch Per Unit Effort, known as CPUE).

Electrofishing must be done with a minimum crew size of two people: a "crew leader" and the other "crew members". The crew leader must be a qualified person and be certified to conduct backpack electrofishing surveys. The crew leader is responsible for the instruction of all other crew members. At least one crew member must have up-to-date Standard First Aid and CPR training.

Unsafe working conditions that may cause one to halt electrofishing operations (this list is not exhaustive and the final decision is generally left to the crew leader):

- Temperature
  - Electrofishing cannot be conducted in water temperatures >22°C
- Weather conditions
  - Moderate rain (enough to soak through clothing)
  - thunder and lightening
  - extreme heat (above 30°C)
- Dark water, deep water, fast flowing waters
  - unsure footing
  - inability to properly see substrate and/or fish
  - difficult to net fish efficiently and safely

- Stream conditions
    - thick, hidden, difficult vegetation and other debris in site
    - in-stream or overhanging vegetation

If any of these situations arise, the team must stop to evaluate conditions, and determine whether it is safe to proceed with electrofishing surveys. All crew members will work as a group to discuss and evaluate options to proceed with the survey. The final decision to proceed, delay, or forego the survey will be left to the crew leader. The crew leader must contact the Project Manager within 24 hours if a survey is delayed or skipped due to safety concerns.

5.2 Minnow Traps

Minnow traps are small, wire or plastic enclosures used to trap live fish. They are typically circular and slightly tapered towards the ends, with inward facing funnels at each end. The opening size for most minnow traps is 3 – 5 cm in diameter, with a standard mesh size of 6 - 8 mm, giving it an effective catch range of body depths approximately 6 - 50 mm. Small fish can swim inside through funnels that guide them from the large opening near the outside of the trap to the narrow opening close to the centre of the trap. Once inside it is difficult for the animal to locate the opening and escape.

Minnow traps consist of two wire baskets held together by a clip. The baskets are interlocked and the clip is inserted to hold the two halves together. The trap is attached with rope to a fixed object to it can be retrieved, and is positioned either on the bottom or suspended at a particular depth. Minnow traps are set with bait, which is discussed further in Procedures (Section 7).

Photo 2: Typical metal minnow trap (Source: https://dynamicaquasupply.com/products/minnow-trap-gee-style-1-8-mesh)

Minnow traps are also size selective and are best suited for sampling juvenile fish or adults of small species. They are most commonly used in littoral habitat and low velocity streams, especially within areas that may be difficult to sample with nets or electrofishing, such as deep areas, or habitats with abundant aquatic vegetation or woody debris. Water depth must be sufficient to submerge the trap entrances. As for all trap and net types, the length of set time for minnow traps should account for activity levels of fish at various times of the day (daylight, dusk, overnight, and dawn). Generally, traps should be set for approximately 24 hours (set on the first day and retrieved the following day). Traps may be re-deployed on successive days, provided they are checked once per 24 hours. If minnow trapping is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis).

Minnow traps provide a qualitative metric of abundance (i.e. relative abundance), with effort expressed in terms of catch per trap per length of time set (CPUE).

5.3 Eel Pots

Eel pots are similar to minnow traps in that they allow fish into an opening in a rigid metal trap. MEL's eel pots are rectangular and are available in a variety of lengths (2-5 ft). A single, inward facing funnel (6.5 - 8 cm opening) is located at one end of the trap, through which small and medium sized fish can swim inside through. This longer funnel guides the fish from the large opening near the outside of the trap to the narrow opening situated closer to the opposite end of the trap. This end of the trap acts like a door which can be opened to retrieve trapped fish and to install bait. A bungee cord and hook keep this door closed when the trap is set. With a wire mesh size of 1-2 cm, the effective catch range of eel pots are fish with body depths of 10 - 80 mm. The trap is attached with rope to a fixed object to it can be retrieved, and is positioned on the bottom substrate.

Photo 3: Typical metal eel pot (Source: https://ketchamsupply.com/product/eel-trap/)

This sample method is selective towards small-medium sized fishes, and can be deployed wherever water depth allows the opening of the eel pot to be submerged. Eel pots target slightly larger fish which may be excluded from the minnow trap; however as a larger trap, it is typically deployed in larger, deeper pools or littoral zones without many obstructions, whereas minnow traps can be selected to sample small watercourses where other methods cannot be used. Pots should be set for approximately 24 hours (set on the first day and retrieved the following day). Traps may be re-deployed on successive days, provided they are checked once per 24 hours. If trapping is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis). Eel pots can provide a qualitative metric of abundance (i.e. relative abundance), with effort expressed in terms of catch per trap per length of time set (CPUE).

5.4 Fyke Nets

A fyke net is a type of hoop net which traps fish inside mesh enclosures. The mesh is supported by a series of rigid hoops, which become smaller towards the back of the net. The opening of the trap contains a D-shaped hoop, and all subsequent hoops are round. The fyke net is characterized by "wings" which lead fish to the fyke net opening. The wings are short lengths of mesh with float (on the top, with buoys) and lead (on the bottom, weighted) lines that are attached to the lateral margins of the first hoop and extended at a 45º angle to the opening of the trap.

Fish that enter the fyke net pass through constrictions called tunnels. The tunnels are cones of mesh that are attached to the hoops, so that when the net is set and the hoops are separated the narrow end of the tunnel points to the rear. Usually there are multiple tunnels per net which get smaller towards the back of the net. Fyke nets are normally not baited, relying instead on the wings to guide fish into them. Fyke nets are accessed at the posterior end, where the mesh that extends beyond the last hoop is closed by a drawstring.

Fyke nets can be set in littoral and stream habitats in water that is deeper or shallower than the height of the hoops, as long as the tunnels are submerged. These nets are difficult to set where the bottom is

Photo 4: Example of a fyke net installation in an open waterbody

uneven, such as among boulders, and where there is dense vegetation or an abundance of other obstructions such as logs or stumps. In littoral habitats, fyke nets should be installed perpendicular to the shoreline, with the posterior end of the net positioned farthest offshore. In stream setting, the net is normally set with the opening facing upstream. One of the main drawbacks of a fyke net in stream environments is that debris can collect in or damage the net, reducing catch efficiency.

Fyke nets are size and species selected – they tend to target larger bodied fish as smaller fish like juvenile salmonids and forage fish may escape through the mesh (2 cm openings), and are more likely to capture roaming species than sedentary species. When deployed, fyke nets should remain in place for approximately 24 hours (set on the first day and retrieved the following day). Fyke nets may be re-deployed on successive days, provided they are checked once per 24 hours. If netting is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis). Nets can provide a qualitative metric of abundance (i.e. relative abundance), with effort expressed in terms of catch per trap per length of time set (CPUE).

5.5 Seines

Seine nets (which also double as barrier nets for use during electrofishing surveys) consist of a length of fine mesh strung between a positively buoyant line (the float line) and a negatively buoyant line (the lead line) that is pulled through the water to encircle fish. Typical seines used in research are made of a woven (also called knotless) nylon mesh with small (in our case, 1/8th inch) openings. This SOP pertains only to seines used through wading, though they may also be deployed from a boat.

Seines can be used in both littoral habitat and slackwater areas of larger rivers, but generally cannot be used in moderate-fast currents. Seines are normally only used in water depths that are less than two thirds the depth of the seine, so that the lead line remains on the bottom and the float line remains at the surface as the net is pulled forward. Seining is easiest over smooth bottoms with no debris or obstructions, which may cause the net to lift off the bottom substrate, causing a loss of fish.

The simplest deployment technique involves two people, one on each end of the seine. One person stays fixed at the shore, while the second person wades through the water with the seine in a smooth arc. The seine haul ends by bringing the two ends of the seine together and pulling the net forward so that the encircled fish end up in the mesh that is between the lead and float lines.

Photo 5. Example of seining within riverine habitat
(Source: https://commons.wikimedia.org/wiki/File:Seining_for_wild_fish.jpg)

Efficiency varies widely among species, with benthic species being less susceptible to capture than mid-water species. Smaller individuals are more susceptible than large individuals, which may avoid capture by swimming out of the path of the seine. Qualitative abundance estimates can be expressed in terms of catch per haul if all hauls are similar, whereas more quantitative abundance estimates can be expressed as catch per unit area seined (e,g, catch per m^2).

Table 1. Efficacy and limitations of gear types (adapted from Portt el al. 2006)

Gear	Limitations			Survey Objective			Units
	Depth	**Habitat**	**Selectivity**	**Presence**	**Relative Abundance**	**Absolute Abundance**	
Electrofishing	Limited to safe wading depths for backpack; <2 m for boat. Only requires enough water to submerge the anode ring and tail.	Cannot conduct in water >22°C, or in the rain. Currents must be low enough to safely wade. High turbidity, vegetation, woody debris, soft substrate, and low conductivity decreases efficiency. Efficiency lower in large streams than in small streams.	Capture efficiency greater for large individuals. Benthic species are easy to overlook.	✓	✓	✓	CPUE (effort = electrofishing seconds) or catch per square m
Minnow Traps	Requires depths sufficient to submerge trap (>15cm). Not suitable for extremely shallow water.	Limited to low velocity habitat.	Limited to small-bodied fish (6 - 50 mm).	✓	✓		CPUE (effort = trap time in hours)
Eel Pots	Requires depths sufficient to submerge interior funnel (>20cm) along the entire length of the trap. Not suitable for extremely shallow water.	Limited to low velocity habitat.	Limited to small/moderate bodied-fish (10 - 80 mm).	✓	✓		CPUE (effort = trap time in hours)

Gear	Limitations			Survey Objective			Units
	Depth	**Habitat**	**Selectivity**	**Presence**	**Relative Abundance**	**Absolute Abundance**	
Fyke Nets	Requires depths sufficient to submerge interior funnel (>20 cm). Not suitable for extremely shallow water.	Limited to low-moderate velocity habitats with limited amounts of debris.	High selectivity for roaming species (vs. sedentary). Good for intercepting fish during migration. Effective catch range 20 mm + body depth.	✓	✓		CPUE (effort = net time in hours)
Seines	Limited to safe wading depths. Ideal water depths are less than 1/2 – 2/3 depth of the seine, so that the lead line can rest on the substrate, while the float line remains above water.	Limited to stream or littoral habitat with small, rocky substrate and limited obstructions.	Benthic species less catchable than mid-water species. Smaller individuals more susceptible than large individuals.	✓	✓	✓	CPUE (effort = number of hauls) or catch per square m

6 MATERIALS

The materials and equipment required to safely perform fish capture surveys in the field are listed below. The list is inclusive of all materials required to perform any fish capture survey (electrofishing, trapping, and netting).

- Electrofishing Kit
  - backpack electrofisher in Pelican case
  - anode pole and ring
  - cathode tail
  - batteries and battery charger
  - gloves (long-armed, lineman's gloves)
  - polarized sunglasses
  - long-handled landing net
  - wader repair kit
- Traps and nets
  - minnow traps
  - eel pots
  - fyke nets
  - seine nets (i.e. barrier nets)
  - rope
  - rebar or stakes to aid in setup
- Fish Processing Kit
  - clear tupperware with ruler
  - plexiglass fish viewer
  - electronic balance scale (including calibration weights and extra batteries)
  - spring scale (and extra batteries)
  - live-well buckets (plastic, 5-gallon)
  - small dip net
- Additional Equipment
  - standard MEL PPE
  - Required PPE for electrofishing:
    - Leak-free chest waders with wading belt
    - Wide brimmed hat
    - Polarized sunglasses
    - Long-armed gloves/linesman gloves
  - first aid kit
  - personal flotation device if deemed necessary based on site characteristics
  - field sheets on write-in-the-rain paper ("Fish Collection Tracking Sheet", Appendix D)
  - fish ID books, identification key
  - pencils
  - multi-parameter water quality instrument (YSI or equivalent)
  - GPS
  - hand sanitizer
  - flagging tape
  - measuring tape

- meter stick
- phone or digital camera
- **hard copy of DFO fishing licence**

7 FISH COLLECTION METHODS – PROCEDURES

7.1 Planning: Before You Leave

1. Review detailed written scope provided to you by the Project Manager. This will identify priority deliverables, timelines, and budget allowed for each task. Detailed methods will be provided in this scope (i.e. # of traps required, set time required, etc).
2. Identify the crew supervisor/operator and crew members. The crew supervisor must have an Electrofishing Crew Leader Certification and proper training for the use of the electrofisher and safety procedures. The primary responsibility of the crew supervisor is to ensure the safety of all crew members. Their secondary responsibility is to direct the survey. A field team must consist of a minimum of 2 people, and all crew members are responsible for working in a safe manner, bearing mind that any action can affect the safety of other crew members.
3. Determine the location(s) of the survey, size of area to be surveyed and easiest access to the site based on the work scope provided by the Project Manager. Sample design should be verified by the Project Manager.
4. Prepare site maps and GPS units as required.
5. Ensure that all personal safety equipment and field gear are in good working order. Check the electrofisher unit and traps for any obvious signs of damage. Ensure all traps and nets have clear markings on them identifying the licence number, a contact person, and an emergency contact number.
6. Fill out a field tracking sheet. Have all crew members review and sign off on the field tracking sheet.

7.2 Electrofishing

7.2.1 Site Setup

1. Ensure that all personal safety equipment is in good working order and remove all jewelry including watches, necklaces or rings before commencing electrofishing.
2. Assign roles for the following:
   - electrofisher operator
   - primary netter
   - secondary netter (if third crew member is available)
3. Prepare the workstation for the survey by laying out the first aid kit(s) and other equipment to ensure fast and easy access. Set-up any equipment to be used for processing fish.
4. Measure a 100 m survey reach along the contours of the stream channel, marking the beginning and end of the survey reach with flagging tape and take GPS waypoints. For "closed" sites, install the barrier nets at the downstream extent, and then upstream extent of the reach, ensuring that the lead line is placed firmly against the bottom substrate and that the nets cover the entire channel width. This is not required for larger streams greater than the width of the barrier nets (on average > 7 m across); however, whenever possible, adjust the downstream and upstream extent locations of reaches to allow for use of barrier nets (try to find a narrow channel section). For

larger streams, a qualitative, single-pass survey using an open-site methodology should be employed.

5. Take representative photos of the following:
   - Looking upstream
   - Looking downstream
   - Right bank (downstream orientation)
   - Left bank (downstream orientation)
   - Substrate
   - Any distinct physical features
6. Sketch a rough drawing of the site on the Fish Collection Tracking Sheet, noting any distinct physical features of the site (barriers, pools, braiding etc.), and discuss any potential safety hazards with all crew members. Discuss how to proceed through the survey reach.
7. Record the site identifier information, general site conditions (air temperature, weather, previous precipitation), and physical characteristics of the reach (widths, depths, substrate, habitat types, etc) on the Fish Collection Tracking Sheet.
8. Measure and record temperature, conductivity (SPC, CON), total dissolved solids (TDS), pH, dissolved oxygen (DO), and salinity (SAL) on the Fish Collection Tracking Sheet.

   Note: If performing multi-pass surveys, water temperature must be recorded at the beginning of each pass. ***Electrofishing cannot be conducted in water >22°C.***

9. Assemble the electrofishing unit.
   - With the main power switch in the OFF position, and emergency shut off switch pressed down, plug the anode and cathode into their proper connectors located on the bottom of the Pelican case and install the battery
   - Ensure the tilt switch is turned on
   - Reset the 'elapsed time' counter
   - Check that emergency releases are in good working order
   - Set a low output voltage (100 or 150V) and frequency (40 or 60Hz) to start
   - Ensure that the audible safety tone and light are working
   - Keep the emergency shut off switch pressed down when entering the stream
10. Outside of the closed survey reach, test the voltage and frequency settings and adjust if necessary. Voltage and frequency may need to be changed to get a desired response. In general, lower frequencies are safer for larger fish than higher frequencies. If the unit is not producing satisfactory results, try increasing the frequency a few levels before increasing the output voltage. Only increase the output voltage one-step at a time, releasing the anode pole switch to change the electrofisher output frequency and/or voltage levels.

    Note: Observe fish closely. In general, if it takes more than 5 seconds for a fish to recover it may have been shocked too much. If it takes more than 15 seconds for a fish to recover it was definitely shocked too much; therefore reduce the frequency or output voltage. Another common indication of an excessive voltage setting is "burn marks" on fish caused by the triggering of pigment cells in the flesh and visible as dark discolorations. Burn marks are temporary, but when observed the voltage should be decreased. The voltage should only be increased if fish are consistently in the fright zone and are not completely stunned.

7.2.2 Surveying

1. The survey should be completed in an upstream direction. Start at the most downstream point of the sampling site and work your way upstream. Once in the reach, the backpack operator will release the emergency shut off switch on the electrofishing unit. The operator must always give a verbal indication to, and receive a verbal acknowledgement from, all crew before commencing each sweep.
2. The electrofisher operator must say aloud “Power On” each time they begin electrofishing. Begin the first sweep by shocking water at the designated starting point.
3. The netter should be positioned downstream of the operator, approximately 2-3 m apart. The netter should set the pole net flush with the bed of the stream and perpendicular to flow.
4. Continue sweeping the anode ring wading from one bank to the other, always in line with the pole net, thus sampling a “lane” of the stream. When fishing undercut banks or log jams, fish can be drawn out by inserting the uncharged anode, switching it on and then pulling the anode out and away. Creating currents using the anode ring or dip-nets can often assist with pulling stunned fish out of complex structure when using this technique. When the opposite bank is reached, both the machine operator and pole netter move upstream 2–3 m and begin fishing again. Continue fishing until the entire sample reach has been fished.

   Note: If you get water in waders or gloves, or it begins to rain hard enough to saturate clothing, ***STOP WORK*** *immediately and get dry clothing. Never reach into the water in vicinity of an electrode, even if rubber gloves are being worn. To further prevent electrical shock, never touch an electrode while the circuit is energized, even while wearing rubber gloves and waders.*

5. Transfer captured fish to live wells where they can be held until the completion of the electrofishing pass. Keep the live well in a shaded area. When fish are held for a longer period of time, particularly during warm conditions, regularly change the water maintain water quality.
6. Record pass details (seconds of electrofishing, voltage, and frequency) on the Fish Collection Tracking Sheet. Reset the elapsed time counter for each pass.
7. Process the captured fish (refer to Section 8). Once processed, return captured fish to watercourse/ waterbody, outside of the barricaded reach (if using barrier nets).
8. Repeat steps 1-8 until the required number of passes have been completed. The number of passes required will depend on the type of survey (qualitative or quantitative) being employed.
   a. For a **qualitative, open-site survey,** one pass should be sufficient, unless crew members note a high number of fish that evaded capture. In that case, perform a second or third pass to obtain greater species representation. For all qualitative electrofishing surveys, crews should aim for at least 300 seconds of effort (i.e. minimum effort).
   b. In **quantitative, closed-site surveys,** a minimum of three passes should be performed. The requirement for additional passes is determined by the total catch on the last run. If the catch on the last run is <20% of the catch on the first pass and <50% of the catch of the previous pass, no additional passes are required. If no fish are captured or observed on the first two passes, the third pass is not necessary.
9. At the conclusion of all electrofishing surveys, inspect all equipment and note any problems requiring correction. Disconnect the battery and all attachments. Batteries must be charged at the

end of each day's use to maintain the life expectancy and all equipment must be thoroughly dried and stored in the appropriate manner.

7.3 Trapping and Netting

As previously stated, fish collection surveys are most effective when using a variety of gear types to sample as many habitat types as possible. Efforts should be made to supplement electrofishing surveys with other fishing techniques (trapping and netting) when the watercourse reach or portions of the reach being surveyed are not suitable for electrofishing (i.e. non-wadeable, deeper pools, high concentration of woody debris). Trapping and netting are also the preferred method for the open water habitats (e.g. ponded wetlands) and littoral habitats of lakes, where electrofishing tends to be inefficient. The types of traps and nets suitable for each survey depends largely on physical habitat characteristics of the watercourse or waterbody and the fish species anticipated to inhabit them. However, the main objective for netting and trapping should be to set the most diverse combination of traps and nets possible. The habitat limitations and selectivity of each trap type are summarized in Table 1.

7.3.1 Site Setup

Note: if trapping/nettings occurs within the same survey reach as electrofishing, combine all data onto one Fish Collection Tracking Form. Trapping/netting completed within a watercourse/waterbody without electrofishing requires its own tracking form.

1. Ensure that all traps and nets are in good working order (no tears and holes). Ensure all passive traps that are to be left unattended have an identification tag (licence number, contact name and emergency contact number) attached.
2. Select suitable locations within the watercourse/waterbody for deployment that are accessible by wading. Consider the physical characteristics of the habitat being surveyed, the fish species anticipated to be present, and the likelihood of fish to congregate in certain areas based on the species and time of year. Plan to distribute traps so they will be independent of each other. Target in-stream habitats such as:
    - Areas with suitable water depths for trap deployment
    - Slack-water areas (particularly in rivers)
    - Potential refuge/cover areas, including snags, deep pools, highly vegetated areas, and undercut banks
    - Off-channel habitats, side channels, and backwaters
3. If considering seining, identify any possible snags, large substrate, deep areas, or other safety hazards which may impede the survey. Discuss and mitigate with all crew members. Only seine if it is safe and appropriate to do so.
4. When trap/net locations are confirmed, take a GPS waypoint and a water depth reading of each location. Record the UTM coordinates and water depth for each trap/net on the Fish Collection Tracking Sheet.
5. Sketch a rough drawing of the site on the Fish Collection Tracking Sheet, noting any distinct physical features of the site (barriers, pools, braiding etc.), and discuss any potential safety hazards with all crew members.

6. Record the site identifier information, general site conditions (air temperature, weather, previous precipitation), and physical characteristics of the watercourse/waterbody (when applicable) on the Fish Collection Tracking Sheet.
7. Measure and record temperature, conductivity (SPC, CON), total dissolved solids (TDS), pH, dissolved oxygen (DO), and salinity (SAL).
8. Proceed with trap/net deployment or seining (if conditions allow).

Note: As standard practice, all passive traps and nets (minnow traps, eel pots, and fyke nets) should be set for approximately 24 hours. The involves setting traps/nets on one day, and retrieving traps the following day them the following day. Traps may be re-deployed on successive days, provided they are checked once per 24 hours. If trapping is completed to supplement electrofishing efforts, shorter set times may be suitable (to be determined on a project-by-project basis).

7.3.2 Trap/Net Deployment (Day 1)

1. If deploying minnow traps or eel pots, place bait in inner compartment, bearing in mind various mesh sizes so the bait stays inside the traps. Possible bait includes dry or wet cat/dog food, or Cheetos. Ensure rope is attached to each minnow trap/eel pot and tie the other end to a stationary object. Identify the stationary object with flagging tape. This will assist in locating the traps and will also prevent the trap from floating away.
2. If deploying fyke nets, face the opening upstream if in riverine habitat, or perpendicular to the shoreline if in an open waterbody with the opening facing the shore. Fix the wings in place using stakes driven into the substrate, or rope attached to stationary objects to achieve a 45º angle to the opening of the trap. Ensure that the lead line lays flat on the bottom substrate – this can be ensured by placing rocks along the bottom edge of the wings. Ensure that each funnel is open and not twisted to allow for the passage of fish to the back of the net. Tie off the posterior drawstring and extend the traps back so that each segment is fully extended and the hoops are upright. To maintain this position, the posterior end of the trap may need to be fixed in place – this can be achieved with a stake, stick, rope, rock or other heavy object.
3. Ensure all entries into the traps and nets are submerged.
4. Record deployment time on the Fish Collection Tracking Sheet.
5. Take photos of each trap setup.

7.3.3 Trap/Net Retrieval (Day 2)

1. If multiple traps are used, retrieve in the order they are deployed, one at a time. Record retrieval time for each trap/net on the Fish Collection Tracking Sheet. Set times and retrieval times can be rounded to the closest 5-minute interval.
2. Deposit fish captured into a live well.
3. Process captured fish (refer to Section 8).
4. Rinse the traps/nets clean after all of the fish have been released. Allow the traps/nets to dry once the field survey is complete.
5. If re-deploying traps, follow outlines in Section 7.3.2.

7.3.4 Seining

1. Attach a pole (stake, rebar, etc.) to each end of the seine and used as a handle. The lead line should be attached to the bottom of the pole, which is kept on or at the substrate. An alternate method is to tie a loop in each end of the lead line and place it over the operators' feet that are

closest to the net, and to hold the float line in the hand closest to the net. The bottom line is pulled forward by the operator's leg.

2. With one crew member staying stationary on the shore/bank holding one end of the seine, the other crew member drags the other end of the net into the water by wading in a perpendicular line to the shore, keeping the lead line on the bottom substrate and the float line at the water's surface.
3. Once almost all of the net has been pulled into the water, the wading crew member arcs back to the shoreline/bank, creating an arc shape with the net. The wading operator then pulls their end of the net back to the shoreline, lining up parallel to the stationary operator.
4. To retrieve the net, pull the net to shore with one person on each end of the net. The float and lead lines should be pulled in together at a slow, even pace. Do not pull too quickly, as this could cause the float line to become submerged and possibly allow fish to escape over the net. If the float line is pulled in ahead of the lead line, the flow of water will be downward causing the lead line to lift off the bottom, allowing fish to escape underneath the net.
5. As the net approaches shore, the lead line should be kept on the bottom and the float line should be lifted slightly to stop fish from jumping out of the net. The entire net should be pulled onto the shore and the catch quickly transferred into live wells and processed.

8 FISH PROCESSING

Fish should be handled as little as possible and processed quickly. The water quality of the live wells should be maintained as close as possible to the fish's natural habitat, and should be kept out of direct sunlight. Monitor condition of fish on a regular basis to ensure the temperature and oxygen levels in the well are adequate, and replace water if fish show signs of stress (i.e. gasping at surface, frantic swimming, lethargy, rapid gill movements, etc.). Note that these processing procedures do not include anesthetic. Gentle pressure should be used to immobilize fish on the measuring board - ensure that this pressure remains slight and is not focused on the eye area or the operculum.

1. Prepare the onshore workstation to commence the processing of captured fish. Layout/assemble all equipment from the Fish Processing Kit. Level the electronic balance scale and calibrate prior to use.
2. If fish have been captured through multiple gear types, process fish from each gear type one at a time. This is necessary to infer qualitative abundance data for each method of fish collection.
3. Any crew member involved in fish handling procedures will ensure that hands are free of chemical contaminants (i.e. insect repellent, sunscreen) prior to any handling of fish. If additional surveys are to take place in the same day, crew members must sanitize hands prior to handling fish from different areas in order to minimize the risk of disease transfer.
4. Prepare the live well (fish captured during electrofishing should be actively placed in a live well during sampling), ensuring that water is refreshed regularly, especially on warm days. Prepare multiple live wells and separate fish species if predation within the well is likely to occur (i.e. American eel captured with other fish species).
5. On the Fish Collection Tracking Sheet under Individual Fish Measurements (Appendix D), assign each fish captured with a number starting from 1, and continue numbering for each fish (1, 2, 3…) captured within a particular survey site. Photograph each individual fish with the fish number in the photograph (or photograph the fish number prior to photographing the fish). Record the collection method - if electrofishing with multiple passes, record what pass the fish was captured during (e.g. Pass 1), or if captured with a trap or net, record the gear type and ID if using multiples of the same type (e.g. MT1). Gear type codes are presented on the Fish Collection

Tracking Sheet. Record the fish species using the 3-letter codes provided in Appendix B. If species is unknown, record with a "U".

6. Measure and record the total length (TL, mm), fork length (FL, mm), weight (in grams), and life stage (if known). See Appendix B for terms and definitions:
    - Small fish (<500g) are to be weighed with the electronic balance scale, measuring to with +/- 0.01g.
    - Large fish (>500g) are to be weighed on a spring scale using a tared mesh net.
7. Note whether or not the adipose fin is clipped, as this will indicate that the fish is from a hatchery. Watch for burn marks and note any other pertinent observations. Note any mortalities, and overall condition. Appendix A provides anatomical features and morphological definitions for fish.
8. Return captured fish to the habitat area. In the case of multi-pass electrofishing surveys, captured fish may should be returned outside and downstream of the barrier nets so as to avoid being double counted.

9 REPORTING

Reporting and data management requirements will be communicated to the field crew by the Project Manager. At a minimum, the following parameters must be communicated to the Project Manager for submission to DFO under Appendix A of the License to Fish for Scientific Purposes:

- Dates of the fishing activity
- Fishing location (waterbody, county and province)
- Gear type used
- Number of fish caught by species
- Life stage of fish caught by species
- Number of fish sampled/tagged by species if applicable
- Fate of fish by species:
    - Number released alive
    - Number of incidental mortalities
    - Number retained alive
    - Number of retained mortalities.

10 REFERENCES

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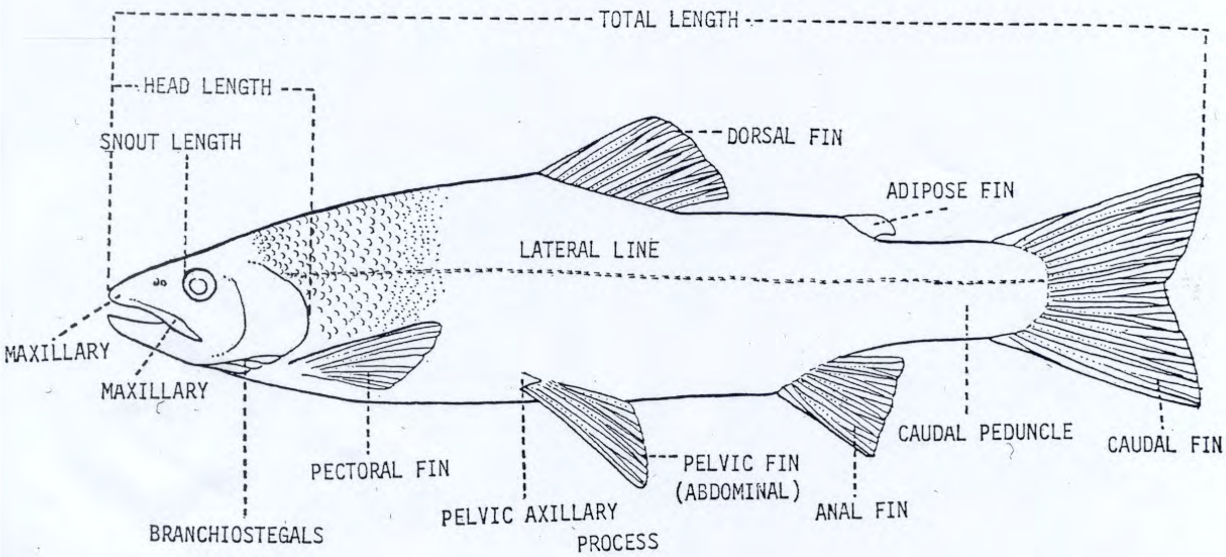
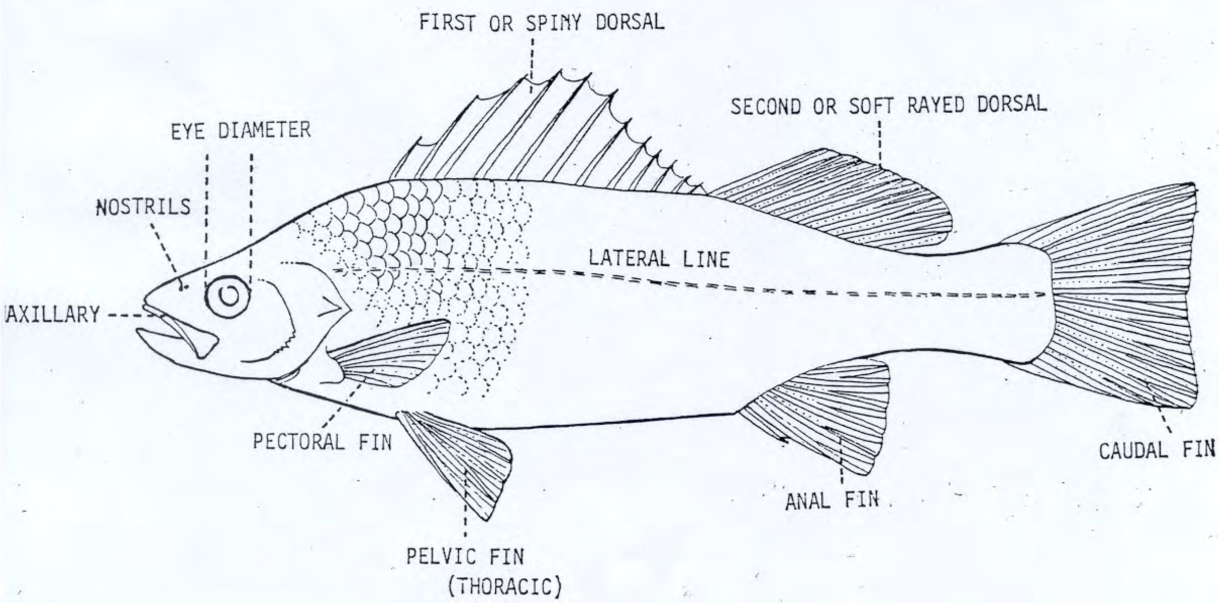
Appendix A: Anatomical Features of Fish


TOTAL LENGTH
HEAD LENGTH
SNOUT LENGTH
DORSAL FIN
ADIPOSE FIN
LATERAL LINE
MAXILLARY
MAXILLARY
PECTORAL FIN
BRANCHIOSTEGALS
PELVIC AXILLARY PROCESS
PELVIC FIN (ABDOMINAL)
ANAL FIN
CAUDAL PEDUNCLE
CAUDAL FIN


FIRST OR SPINY DORSAL
SECOND OR SOFT RAYED DORSAL
EYE DIAMETER
NOSTRILS
LATERAL LINE
AXILLARY
PECTORAL FIN
PELVIC FIN (THORACIC)
ANAL FIN
CAUDAL FIN

Appendix B: Fish Species Codes & Definitions

Code	Species Name	Code	Species Name
ALE	Alewife (*Alosa pseudoharengus*)	LKC	Lake chub (*Couesius plumbeus*)
EEL	American eel (*Anguilla rostrata*)	LKT	Lake trout (*Salvelinus namaycush*)
AMS	American shad (*Alosa sapidissima*)	LWF	Lake whitefish (*Coregonus clupeaformis*)
ARC	Arctic char (*Salvelinus alpinus*)	LLS	Landlocked salmon (*Salmo salar*)
ATS	Atlantic salmon (*Salmo salar*)	LNS	Longnose sucker (*Catostomus catostomus*)
AST	Atlantic sturgeon (*Acipenser oxyrhynchus*)	MUM	Mummichog (*Fundulus heteroclitus*)
ATC	Atlantic tomcod (*Microgadus tomcod*)	MUS	Muskellunge (*Esox masquinongy*)
BKF	Banded killifish (*Fundulus diaphanus*)	9SB	Ninespine stickleback (*Pungitius pungitius*)
BND	Blacknose dace (*Rhinichthys atratulus*)	NRD	Northern redbelly dace (*Chrosomus eos*)
BNS	Blacknose shiner (*Notropis heterolepis*)	PLD	Pearl dace (*Semotilus margarita*)
BSS	Blackspotted stickleback (*Gasterosteus wheatlandi*)	PSF	Pumpkinseed Sunfish (*Lepomis gibbosus*)
BLH	Blueback herring (*Alosa aestivalis*)	RBS	Rainbow smelt (*Osmerus mordax*)
BKS	Brook stickleback (*Culaea inconstans*)	RBT	Rainbow trout (*Salmo gairdneri*)
BKT	Brook trout (*Salvelinus fontinalis*)	RSF	Redbreast sunfish (*Lepomis auritus*)
BBH	Brown bullhead (*Ictalurus nebulosus*)	RWF	Round whitefish (*Prosopium cylindraceum*)
BNT	Brown trout (*Salmo trutta*)	SLP	Sea lamprey (*Petromyzon marinus*)
BUR	Burbot (*Lota lota*)	SST	Shortnose sturgeon (*Acipenser brevirostrum*)
CHP	Chain pickerel (*Esox niger*)	SLS	Slimy sculpin (*Cottus cognatus*)
CSH	Common shiner (*Notropis cornutus*)	SMB	Smallmouth bass (*Micropterus dolomieui*)
CRC	Creek chub (*Semotilus atromaculatus*)	SPL	Splake (*S. namaycush x S. fontinalis*)
FLF	Fallfish (*Semotilus corporalis*)	STB	Striped bass (*Morone saxatilis*)
FHM	Fathead minnow (*Pimephales promelas*)	3SB	Threespine stickleback (*Gasterosteus aculeatus*)
FSD	Finescale dace (*Chrosomus neogaeus*)	WHP	White perch (*Morone americana*)
4SB	Fourspine stickleback (*Apeltes quadracus*)	WHS	White sucker (*Catostomus commersoni*)
GSH	Golden shiner (*Notemigonus crysoleucas*)	YLP	Yellow perch (*Perca flavescens*)
GLF	Goldfish (*Carassius auratus*)		

Total Length: the distance from the most anterior part of the head to the tip of the tail when the fin lobes of the tail are pressed together. This is the only length measurement collected for fish without forked tails such as banded killifish.

Fork length: measured from the most anterior part of the head to the median caudal fin rays (fork of tail). This measurement is only appropriate for fork tailed fish such as trout and salmon.

CPUE: Catch per unit effort = catch (fish) / survey effort (time).

Appendix C: Fish Fact Sheets for Common Freshwater Species (Source: NSSA, 2005)

SECTION 6.0. FISH FACTS

THIS SECTION CONTAINS:

- Some notes on fish anatomy
- Habitat requirements of salmon and trout
- Fish facts on many Nova Scotia fish species

6.1. Understanding Fish

This first section contains information on the anatomy of fish. Although different species of fish vary, what is described here is a general description of a trout or salmon.

> A woman wrote the very first published fishing manual nearly 500 years ago. Dame Juliana Berners, prioress of the Benedictine convent near St. Albans, England hand wrote the treatise f Fishing with an Angle in 1496. The boll included advice on how to construct a two-section rod and where the best places were to fish

Eyes and Sight

As with the eyes of mammals, fish eyes serve a number of purposes: to find food, to watch for enemies and other dangers, and to navigate perhaps even during ocean migrations. The pupil bulges outward to take in a wider field of vision, and although the eyes are set on the side of the head, they have all-around vision, giving the fish stereoscopic vision in a forward direction. The lens of the fish eye can move in and out like a camera lens. Trout and salmon appear to have the ability to see well into air and have good vision in semi-darkness. They respond strongly to sudden changes in light intensity (which would usually indicate danger), especially if they are within a closed environment from which they are unable to escape.

Gills

Fish gills are composed of two basic parts: the gill covers and the gill filaments. The gill covers protect very delicate threads or **filaments** that are located in cavities on either side of the head. A special pump called the **brachial pump** maintains a flow of water over the gills. When the mouth closes, water passes through the gills and out through the gill covers which open. The gill filaments are richly supplied with blood vessels that pick up oxygen out of the water. Carbon dioxide is released as a waste product. More activity increases the need for oxygen and this results in a corresponding increase in the opening and closing of the mouth and gills.

Nostrils and Smell

Trout and salmon have a well-developed sense of smell. It is believed that they use this ability to seek out and recognize the chemical characteristics of their home streams for spawning. This sense is sometimes helpful in avoiding predators. Fish breathe through their gills and mouth, not their nose.

Lateral Line (line along the side of the body)

There is a row of special scales with small holes along each side of the fish's body called the **lateral line**. The system is connected to a series of nerve endings can detect changes in pressure, sound, and movement. The lateral line helps to warn the fish of the approach of predators and search for prey.

Mouth

The mouth is used to catch and hold food of various types; but food is not chewed before being swallowed. The mouth is also important for breathing or respiration. Water is constantly taken in through the mouth and forced out over the gill filaments through the gills. This fish receives its oxygen by moving water over its gills.

Fins

Most fish have two sets of paired fins: the pelvic and pectoral fins, and four single fins: dorsal, caudal, anal and adipose. Some fins are spiny (although not on salmon or trout). Spines can be used for protection or for sexual display.

- The dorsal and anal fins are used for maintaining vertical balance and achieving quick changes in direction.

- The pelvic and pectoral fins are used for horizontal or lateral balance and resting.

- The adipose fin is small and fleshy on trout, salmon and whitefish and we don't know its purpose. Fishery managers, to identify certain stocks of fish or indicate that a fish is tagged, often clip it off.

- The caudal or tail fin is the most important fin as it is used to propel the fish through water by the flexing of strong muscles along the sides of the body. The caudal fin is also used by the female salmonids and male smallmouth bass to move gravel and scoop out the nests (redds) in which eggs are deposited.

Scales

The body surface skin of the fish, except for the head and fins, is protected by overlapping scales that grow in regular patterns and by an outer coating of mucus, which protects the fish from disease. Growth of the scales is continuous and takes place around the perimeter of each scale. Growth is more rapid in summer than in winter, thus, growth rings (looking somewhat similar to those of trees) of summer are farther apart than those of winter, and indicate the age and life history of the fish. When fish are sick or stressed, the rings are closer together. Rings spaced more apart indicate healthy growth and environmental conditions.

Ears

Fish do not have external ears but they can detect sound with an inner ear and labyrinth that function as organs of balance as well as hearing. Low frequency sounds can also be detected in the water by the lateral line system.

6.2. Habitat Requirements

If you know what a fish needs in a stream in order to survive, it is a natural progression to determine where and what is in need of protection or rehabilitation. This section will concentrate primarily on the needs of trout and salmon (referred to as **salmonids** by biologists). These fish can be found in many different habitats in our part of the world. Because they often have to cope with severe and varying conditions they can be remarkably resilient in habitat use, in feeding, growth and reproduction. Despite the fact that these fish adapt to change well they can be highly sensitive, environmentally "fussy" fishes; particularly in the "egg" and "young" stages.

The habitat requirements for fish are the things they need to live. As we learned in the first section, this is a combination of water, food, space, and cover. In this next section we'll look at the important habitat requirements of fish. Even within one species different habitat combinations are required for nursery areas, feeding and spawning. Understanding habitat will help you to better determine the health of the stream, its potential for trout and salmon and other fish, and the locations most likely to benefit from rehabilitation and enhancement.

Trout and salmon require very special conditions for:

- Successful **spawning** (the production of eggs)
- The development and hatching of eggs
- Growth and survival for their young
- Feeding

In general, salmonids require streams that have:

- **Temperatures** that are fairly cool
- **Shade**; there should be trees and shrubs along the bank of the stream
- Water with lots of **oxygen**
- Clean **gravel** of different sizes on the stream bottom
- Sufficient **flow of water**
- No major **physical obstructions** which will stop them from moving up or downstream
- **Cover** or places to hide when it gets too hot and to hide from predators
- **Clear water** so they can see insects to feed on
- **The right combination of habitats** for different parts of their life cycle
- Lots of small insects and animals for **food**

Let's look at each one of these in turn.

Temperature

Salmonids need much cooler water than other fish such as perch, bass, gaspereau or suckers. For example, if water temperature rises much above 20 - 25·C, for very long, most salmonids, especially in early stages, will become seriously stressed or will die. On the other hand, many species of bass, suckers and perch for example, thrive in much higher temperatures. Young trout and salmon prefer a water temperature between 15 and 18·C. Brook trout will die if the water temperature rises above 22 C. (72 degrees F.) for more than several consecutive days; rainbow and brown trout will die if it's hotter than 24·C. (75 degrees F.). Fish can adapt to a gradual change in temperature, but sudden drastic changes can shock and kill them.

Also, fish are cold blooded which means that their body temperature varies according to the temperature of the surrounding water. The warmer it gets, the faster their metabolism gets so they need more oxygen. The problem is that warmer water holds less oxygen.

Temperature also affects the growth and reproduction of fish. Fish lay eggs only at certain temperatures. Most salmonids prefer cooler temperatures: salmon, brown trout, brook trout and lake trout spawn during the late autumn and early winter; rainbow trout prefer the warmer temperatures from mid-April to late June. Temperature is also a major factor in the timing of fish migrations.

The temperature of a stream is regulated by springs, shade, and the stream width to depth ratio. Most streams begin as springs bubbling out of the ground. The spring water comes from snow melt and rain water that percolated into the soils of the surrounding hillsides the previous week, day, month, or year. Sometimes because of human activity the amount of rainwater that goes deep down into the soil is reduced, not allowing the water table to be replenished. This can cause springs to dry up, so that water levels in rivers decrease and water temperatures increase. Many streams come from lakes and their water is warmer when it enters the stream. In these streams even more care must be taken to make sure that the water doesn't get too hot.

Shade

The amount of shade along a stream is very important. Too much shading in a stream reduces the growth of instream plants (algae). This will mean less food for insects, and in turn less food for fish. In some places it can also make spring-fed streams too cool for salmonids, which prefer 16-17 C. temperatures for growth.

Too little shading encourages heating of the stream and raised temperatures. The percent of shading needed varies from stream to stream and depends upon the amount of spring water available to cool the stream, the stream's width and depth, and human land use activity in the area. There is a balance in all these and the optimum appears to be about 60% shade during the peak of the day. In general, most streams don't have enough shade. A narrow, deep river channel also maintains cooler water temperatures by having less surface exposed to the air. Where width greatly increases, the shallow water is then highly susceptible to heating by direct contact with the air. Even in well-shaded streams, the water temperature follows the air temperature very closely if pools are poorly developed and the channel is wide and shallow. Direct sunlight warms things up even more, as everyone knows; it's cooler in the shade.

Oxygen

Trout and salmon that live in streams require high levels of **dissolved oxygen** (the amount of oxygen contained in the water). Fish are extremely sensitive to any decrease in the available supply of oxygen and can suffocate very quickly if they are forced to endure a low level for even a short period of time. Young fish or breeding fish have even greater oxygen requirements. Eggs lying in the gravel take in oxygen through their shell. A lowered level of oxygen may result in a delay in the development of the embryo and the hatching. These low levels can be caused by increases in temperature, excessive nutrients and silt which all can deplete oxygen. Moving water adds oxygen to the stream. The faster the water moves, the more oxygen goes in.

Gravel and Stream Bottom

For successful egg-laying, salmonids require clean, stable gravel of 1-10 cm in diameter, depending on size of the adult fish. The gravel must be clean and loose, so that water can flow through the gravel to provide each egg with enough oxygen, and so that waste products emitted by the eggs (such as carbon dioxide and ammonia) will flow away from the egg. The gravel must contain different sized stones. Smaller gravel is used for egg laying, larger stones are needed for many of the insects which live in the water, and boulder sizes are needed to ensure spaces for fish to hide and over-winter.

The best bottom for a trout and salmon stream is a mixture of gravel, rubble, rock, and boulder with a liberal sprinkling of sunken logs and stumps. The rock/gravel bottom, especially in riffles and runs, offers the best habitat for insects that the fish eat. This mixture should have very little sand and silt in it. You should be able to pick up the surface stones without exposing sand or silt and see insects on them.

Stream flow

Nova Scotia is known for extreme changes in the amount of water that flows in streams. In the spring the water often flows high because of winter snow melt and spring rains. This is called the **spring freshet** or flood. In the hot weather of summer many streams experience droughts and have very little water flowing through them. This is extremely hard on salmon and trout. The best streams have flows without these extremes. It is especially important to have enough water flowing in the normal low flow period of late August and September to provide adequate nursery areas for young fish. It is also important during the winter, so that embryos and alvins do not freeze. Human activity in the watershed can result in higher freshets, lower summer and winter flows, and excessive ice formation.

Barriers to swimming up and downstream

During migrations between the ocean and the spawning and rearing sites in lakes and rivers, an unobstructed path is necessary for adults. Fry and juveniles also move to different habitats, as they grow older, so they require access up and down the stream and into side-channels and tributaries. Obstructions such as logjams, hydro power dams, and poorly installed culverts are especially damaging to the migrations of salmonids unless provisions for passage are made.

Clean Water

Clean, clear water is very important to trout and salmon. The water must be clear enough to permit the sunlight to reach the stream bottom where important plants and algae grow. These plants and algae are important food sources for many of the insects upon which trout and salmon feed. Also, high concentrations of solids such as silt in the water can damage the fragile breathing systems of insects and fish.

While some fish, such as suckers, locate food chiefly by smell or feel, trout and salmon need to see their food. Therefore, they feed and grow better in clear water. Water quality is critical during the spawning, incubation, and hatching periods. Heavy sedimentation can smother eggs in gravel and easily destroy them.

Cover/Shelter

Stream salmonids require cover such as undercut banks, logs, spaces under large rocks and boulders, overhanging trees and plants, and deep pools. This cover is used for feeding, hiding, resting, and over wintering. Additionally, overhanging plants shade the river to help control stream temperatures.

Fish spend a lot of time hiding from various predators, whether these predators be the web-footed, clawed, four-footed, or the two legged kind. Their hiding locations are commonly called areas of shelter. Shelter is critical to a fish's survival in a stream and various sizes of trout or salmon require different ranges of shelter. Ideally, most fish like to be protected or sheltered on three sides. This often means on the top, one side and bottom (e.g. an undercut bank). They also require a shelter that is a snug fit and not too roomy. Therefore, a fish will select a shelter that is close-fitting to its body size.

A shelter should break the water flow so that a "dead-space" or slow current area is created near it. A popular misconception is that salmonids like to swim against heavy currents. On the contrary, they prefer to rest where they don't have to exert themselves too much. As unlikely as it may seem, there are many "dead-spaces" among swift currents. Even the most torturous rapids will have holding areas as long as there is a structure that acts as a buffer to the current.

Fry not only prefer the shallow, slow margins of a stream, but also seek shelter that conceals them. In the shallows, woody debris such as branches, twigs, and small fallen tree limbs can provide many nooks and crannies for small fish. Where this material is absent, jumbles of large sticks and small boulders can also provide good shelter areas. Larger, older trout look for more substantial cover in the deeper areas of the stream. Undercut banks, log-jams, stumps, and boulders all offer hiding spaces for the larger fish.

Relatively shallow water can also be a holding location as long as the surface is riffled, which masks the presence of the fish. Weed beds composed of healthy aquatic plants provide additional cover for young and adult alike.

To add variety to the shelter equation, shelter can be species-specific to a certain degree. Brown trout and brook trout prefer areas with overhead cover and therefore select the margins and edges of the stream. Rainbow trout, however, are not as selective and often position themselves in mid-river if a suitable shelter or current break is available. Salmon parr prefer the cover of broken water surface (e.g. on riffles) and spaces under rocks in riffle areas.

There is an approach to assessing salmonid habitats presented in section 9 which provides additional information on the specific needs and when you need to undertake restoration.

6.3. FACTS ON FISH

The next section contains fact sheets on the following fish species found in Nova Scotia:

Atlantic Salmon
Brook Trout
Brown Trout
Rainbow Trout
Smallmouth Bass
Striped Bass
Alewife
American Eel
American Shad
Brown Bullhead
Rainbow Smelt
White Perch
Yellow Perch
White Sucker

Atlantic Salmon (Salmo salar)

One of the best-known members of the salmonid family is the Atlantic salmon which is also known as: grilse, grilt, fiddler; landlocked salmon, ouananiche and grayling (all for landlocked fish); black salmon, slink, kelt (all for post-spawning fish); smolt, parr, Kennebec salmon, and Sebago salmon.

Physical Characteristics

Salmon can vary in colour depending on the water they're in, their age, and sexual activity. In fact there are so many different physical looks in the life of a salmon that it can be confusing. What follows are some of the common colour characteristics:

Salmon in saltwater: blue, green or brown on the back and silvery on the sides and belly. On the upper body you can find several x-shaped black spots.

Salmon in freshwater: bronze-purple in colour and sometimes with reddish spots on the head and body.

Spawning males: these fish develop a hooked lower jaw (kype)

Salmon finished spawning (kelts): very dark in colour

Facts on Salmon

The name salar comes from the Latin "salio" whish means to leap. The Atlantic salmon can make leaps 3.7 m (12 ft) high and 5 m (16.3 ft) long!

Atlantic salmon are mentioned in the Magna Carta.

In the wild about 1 in 10 young salmon survive to become smolts and in many rivers fewer than 1 in 25 of those will return to spawn.

Most grilse are male.

Biologists can "read" the scales of salmon to determine how old they are, how many years they spent in fresh water, how many years they spent at sea and at what ages they spawned.

Young salmon (parr) in freshwater: 8 to 11 dark bars on the side with a red spot between each one.

Young salmon leaving fresh water for the sea (smolts): silvery in colour and usually about 12 to 20 cm (5-8 in) long.

Atlantic salmon can be easily confused with both brown trout and rainbow trout. However there are several characteristics that can help you distinguish the different species. Rainbow trout have a rows of spots on the tail (caudal) fin that is not found in salmon and brown trout have a reddish colouring on the adipose fin (the small fin in front of the tail on top of the body). Some of the different characteristics can be observed on the following pages in the line drawings.

Salmon Sizes

Sea-run salmon - can be as big as 1.5 m (59 in) and 36 kg (79 lb) but most are 9 kg (20 lb) or less.

Biggest known fish ever caught in Canada: a 25.1 kg (55 lb) fish caught in the Grand Cascapedia River, Quebec.

After two winters at sea: 2.7 to 6.8 kg (6-15 lb).

After one winter at sea (grilse): 1.4 to 2.7 kg (3-6 lb)

Landlocked Atlantic - 0.9 to 1.8 kg (2-4 lb). However a 16.1 kg (35.5 lb) specimen was taken in Sebago Lake, Maine over 50 years ago.

Distribution

Atlantic salmon are native to the North Atlantic Ocean and coastal rivers and can be found on both sides of the ocean including parts of Russia, Portugal, Iceland, and Greenland. In Canada and the U.S. they can be found from Northern Quebec and Labrador to the Connecticut River. Due to over fishing and the destruction of habitat, salmon no longer can be found in much of its original range and the numbers of fish have seriously declined. As an example, since the late 1800's, there has been no salmon in Lake Ontario. Landlocked populations of Atlantic salmon exist in some lakes of eastern North America, particularly in Newfoundland, Labrador and Quebec.

Natural History
Atlantic salmon spend part of their life feeding and growing during long migrations in the sea, and then return to reproduce in the fresh water stream where they hatched. This type of pattern, moving from the sea to freshwater, is described as being **anadromous**.

Atlantic salmon that are ready to spawn begin moving up rivers from spring through fall. These spawning runs are surprisingly consistent and occur at the same time each year for each river. Salmon populations are often spoken of as "early run" or "late run". Salmon travel long distances, as much as 500 km (312 mi) upstream and are known for their ability to leap small waterfalls and other obstacles. During this journey, the salmon does not eat, though it rises readily to an artificial fly. Landlocked salmon living in lakes move up into tributary streams to spawn.
Spawning occurs during October and November usually in gravel-bottom riffles at the head or tail of a pool. The female looks for places where the water is seeping down into clean gravel. Spawning occurs in the evening and at night. The female digs a nest **(redd)** 15-35 cm (6-14 in) deep in the gravel by turning on her side, flipping her tail upward and pulling the gravel up until a hole is excavated. She then usually moves upstream and repeats the whole process. After the female and male spawn in the redd the 5-7 mm eggs are buried with gravel by the female and the whole process is repeated several times until the female has shed all of her eggs. Females produce an average of 1500 eggs per kilogram of body weight (700 eggs/lb). After spawning the adults (now called kelts) usually drop downstream to rest in a pool. Contrary to some stories, adults do not die after spawning. Exhausted and thin, they often return to sea immediately before winter or remain in the stream until spring. Some will survive to spawn a second time but few survive to spawn 3 or more times.

Salmon eggs develop slowly (about 110 days) over the winter while water flowing through the nest keeps the eggs clean and oxygenated. In most of our rivers the eggs survive quite well and are protected from freezing or silt. The eggs hatch in the spring, usually April, and the young salmon (alvins) remain buried in the gravel for up to 5 weeks while they absorb the large yolk sac. It's at this stage that many young fish are lost. Over the winter silt and sand often move

Fishing Facts

The Atlantic salmon has been prized for centuries, both commercially and for sport. However, dam construction in rivers has blocked access to many spawning streams and siltation has destroyed many others.

In addition pollution, acid rain, over fishing and poaching have all contributed to a drastic decline in ·Canada's Atlantic salmon stocks.

Today, except for small fisheries in Quebec and Labrador, ·Canada's commercial fishery is closed. Recreational fisheries are very closely regulated, and "hook and release" angling is increasingly promoted.

Through salmon enhancement programs biologists and local community groups are working to restore the production potential of many salmon rivers.

into the nest and can trap the young fish. If they make it through this stage, the young salmon that emerge are about 2.5 cm (1 in) long in May or June.

During this freshwater stage before they migrate to sea they are known as parr. Salmon parr are territorial and feed during the day. They eat mainly water insects but will also eat other invertebrates when available. Young salmon usually live in shallow riffle areas 25 to 65 cm (10-26 in) deep that have gravel, rubble, rock, or boulder bottoms. Salmon parr may be eaten by many kinds of predators including trout, eels, other salmon, mergansers, kingfishers, mink and otter. During their first winter the parr stay under rocks on the bottom of the stream.

After two or three (but anywhere from 2 to 8) years in fresh water salmon parr turn into smolts and prepare for life in salt water. In the spring, these parr become slimmer and turn silvery. During the spring run-off, as water temperatures rise, smolts form schools and migrate downstream at night. It is during this downstream migration that smolts "learn" or become imprinted with the smell or other features of their particular river.

More Facts on Salmon

Salmon have been reared in hatcheries for decades to provide smolts for river stocking programs.

Today they are commercially farmed in large ocean pens, a rapidly growing industry in Atlantic Canada.

At sea salmon are known to travel long distances. Many salmon from Maritime rivers travel as far as the western coast of Greenland where the waters are rich in food. Here, salmon grow rapidly, feeding on crustaceans and other fishes such as smelt, alewives, herring, capelin, mackerel, and cod. Salmon will stay at sea for one or more years. The salmon will spend only one year at sea are smaller and called grilse when they return to freshwater to spawn. At sea, salmon are eaten by cod, pollack, swordfish, tunas and sharks but have been known to live to 11 years.

Brook trout (Salvelinus fontinalis)

This salmonid is also called speckled trout, brook charr, brookie, lake trout, square tail, sea-trout, Eastern brook trout, native trout, coaster, and breac.

Physical Characteristics

The brook trout is a handsome fish. Like salmon, their colour varies depending on the water they are in and their sexual activity. Here are some of the common characteristics:

Adult in freshwater: green to dark brown and black on the back and sides. Light-coloured wavy lines on upper back, dorsal fin and upper part of the caudal (tail) fin. Red spots surrounded by blue halos and many light spots are usually present on the sides. The belly is lighter, white to yellow in females, or reddish in males. The leading edges of the lower fins have a bright white border followed by a black border and reddish coloration.

Facts on Brook Trout

Larger brook trout that live in northern waters sometimes eat small mammals such as mice, shrews and voles.

A 61 cm (24 in.) sea-run trout that weighed 3.4 kg (7.5 lb) was caught in Halifax ·County Nova Scotia in 1871.

It can be seen today in the Nova Scotia Museum.

During spawning: colours intensify and males can become a deep orange-red on the belly.

Adult in saltwater: silvery on the sides and dark blue or green on the back. Pale red spots may be visible on the sides as well as the white leading edge on the fins. When returning from the sea these trout regain their freshwater colours.

Young brook trout or parr: 8 to 10 dark vertical bars (called parr marks) on the sides.

The largest "brookie" on record was taken in Ontario in 1915 weighing 14.5 lb (6.6 kg) and 34 in (86 cm) long. Brookies in Nova Scotia typically range from 15-35 cm (6-14 in) long.

Distribution

The brook trout is native to eastern North America from the Atlantic seaboard to Massachusetts, south along the Appalachian Mountains, west to Minnesota and north to Hudson Bay. It is found in a range of waters from tiny ponds to large rivers, lakes, and salt-water estuaries. Its popularity as a sport fish has resulted in brook trout introductions throughout the world. Widely distributed throughout the Maritimes, brook trout are our most sought-after freshwater fish.

Natural History

Brook trout prefer cool clear waters of 10 to 18·C with a lot of cover. Usually they live in spring-fed streams with many pools and riffles where they can use undercut banks, submerged objects such as large rocks and stumps, deep pools, and shelter from overhanging vegetation as hiding places. Brook trout are meat-eaters (carnivorous). They eat mostly water and land insects but will take anything they can swallow. Larger trout will eat leeches, small fish, mollusks, frogs, and salamanders.

Fishing facts

The brook trout is the most popular sport fish in the Atlantic Provinces. It is taken with spinning tackle, live bait or flies.

Unfortunately many natural populations of brook trout in Nova Scotia have declined. They are vulnerable to over fishing and human practices that affect their habitat. For example, siltation can smother developing eggs, dams can block access to spawning areas, or the loss of trees along a stream bank can reduce shade and cause summer water temperatures to get too high.

Brook trout have been reared in hatcheries for over a hundred years. Hatchery trout are widely stocked in natural waters to supplement "wild" populations or to introduce the brook trout to new areas. Sometimes trout are stocked in small ponds or lakes near urban areas to provide "put and take" [8]sport fisheries.

Brook trout in Nova Scotia spawn in October and November in shallow, gravelly areas of streams where there is a clean bottom and good water flows. Spring-fed headwaters are ideal but they'll also spawn in the gravel-bottomed areas of lakes where spring waters occur. The female digs a nest (redd) 10-15 cm (4-6 in) deep in the gravel with her body. After the eggs have been laid and fertilized, they are covered and left to develop slowly over the winter. A 25 cm (10 in) female trout can produce about 500 three to five mm eggs. Water flowing through the redds keeps the eggs clean and oxygenated. Hatching occurs in the spring and the larvae (alvins) remain still and undisturbed in the gravel while they absorb the large yolk-sac.

Young trout (fry) emerge from the gravel at a length of 2.5-3.5 cm and begin feeding on aquatic insects. They prefer shallow areas where the temperatures are 11-15·C and where rubble (rocks of 10-40 cm (4-16 in)) on the stream bottom provides cover. At the end of their first year, brook trout in Nova Scotia are 5-10 cm (2-4 in) long. Their growth depends very much on local conditions. Brook trout living in larger rivers and lakes would probably be 25 or 30 cm (10-12 in) at age 3, but those in small streams might only reach a length of 15 cm (6 in). Trout usually mature at three years old and rarely live past age 5.

Some populations of brook trout migrate to sea for short periods. They move downstream in the spring or early summer and remain in estuarine areas where there's lots of food. After about 2 months they return to freshwater. Brook trout probably migrate to sea in response to crowded conditions, low food supplies, or unfavourable temperatures in their home waters. Some over-winter in estuaries, and there are shore movements along our coast. Not all fish in a population migrate nor do they necessarily go every year. Sea-run brook trout live longer and grow larger than strictly freshwater trout. Brook trout predators include mergansers, herons, kingfishers, mink, owls, osprey, otter, perch, eels, and other trout.

Brown Trout (Salmo trutta)

The brown trout is also a salmonid and is known as German brown trout, German trout, Lochleven trout, European brown trout, or brownie.

Physical Characteristics

"Brownies" get their name from the brown or golden brown on their backs. Here are some of their other characteristics:

- their sides are silvery and bellies are white or yellowish • dark spots, sometimes encircled by a pale halo, are plentiful on the back and sides
- spotting also can be found on the head and the fins along the back
- rusty-red spots also occur on the sides
- the small top fin in front of the tail has a reddish hue
- sea-run brown trout have a more silvery coloration and the spotting is less visible.

Facts on Brown Trout

Apart from moving upstream to spawn, adults tend to stay at the same station in a river with very little movement to other areas of the stream areas. They can be found at these stations day after day, even year after year!

The closest relative of the brown trout is the Atlantic Salmon (Salmo salar). The brown trout's name (Salmo trutta) means salmon trout.

The largest brown trout ever taken was hooked recently in Arkansas, U.S weighing just over 40 pounds.

They closely resemble Atlantic salmon and rainbow trout but the salmon has no red coloration on the adipose fin and the rainbow trout has distinct lines of black spots on the tail. Young brown trout (parr) have 9-14 dark narrow parr marks along the sides and some red spotting along the lateral line.

Brown trout can grow to be quite large, especially sea-run fish. Brown trout weighing up to 31 kg (68 lb) have been recorded in Europe and a specimen weighing 13 kg (28.5 lb) was caught in Newfoundland. Typically they range from 2.3 to 3.2 kg (5-7 lb) but reach 5.9 kg (13 lb) in Guysborough Harbour.

Distribution

Brown trout naturally occur throughout Europe and western Asia. They range from Finland south to North Africa, west to Iceland and as far east as Afghanistan. Introduced throughout the world, they were first placed in Canadian waters in 1890. Today they are well established in rivers, lakes and coastal areas in much of North America and are found in all Canadian provinces except Manitoba, Prince Edward Island, and the Northwest Territories. Sea-run populations occur in Atlantic Canada and Quebec.

Brown trout are well established in several Nova Scotia watersheds. They are no longer being stocked in areas that they inhabit. Nova Scotia brown trout come from German and Lochleven (Scotland) ancestral stocks.

Fishing Facts

Brown trout prefer very similar habitats to our native brook trout except that they can tolerate slightly higher temperatures. They often use the lower reaches of rivers and streams where it is unsuitable for brook trout.

Biologists thought the brown trout out-competed and displaced the native brook trout and stocking programs were discontinued.
Brown trout do live longer and grow larger than brook trout. They have become quite popular with anglers and are caught in estuaries with lures and streamer-type flies. There is no commercial fishery.

Natural History

Brown trout prefer cool clear rivers and lakes with temperatures of 12-19·C. They are wary and elusive fish that look for cover more than any other salmonid. In running waters they hide in undercut banks, instream debris, surface turbulence, rocks, deep pools and shelter from overhanging vegetation. Brown trout are meat-eaters (carnivorous). They eat insects from water and land, and take larger prey such as worms, crustaceans, mollusks, fish, salamanders, and frogs as their size increases.

Brown trout spawn in the fall and early winter (October to February) at the same time or later than brook trout. They return to the stream where they were born, choosing spawning sites that are spring-fed headwaters, the head of a riffle or the tail of a pool. Selected sites have good water flows through the gravel bottom. The female uses her body to excavate a nest (redd) in the gravel. She and the male may spawn there several times. A 2.3 kg (5 lb) female produces about 3400 golden coloured eggs that are 4-5 mm in diameter. Females cover their eggs with gravel after spawning and the adults return downstream. The eggs develop slowly over the winter, hatching in the spring. A good flow of clean well-oxygenated water is necessary for successful egg development.

After hatching the young fish (alvins) remain buried in the gravel and take nourishment from their large yolk-sacs. By the time the yolk-sac is absorbed, water temperatures have warmed to 7-12·C. The fish (now known as fry) emerge from the gravel and begin taking natural food.

Brown trout fry are aggressive and establish territories soon after they emerge. They are found in quiet pools or shallow, slow flowing waters where older trout are absent. They grow rapidly and can reach a size of 165 mm (6.5 in) in their first year.

Yearling brown trout move into cobble and riffle areas. Adults are found in still deeper waters and are most active at night. They are difficult to catch and are best fished at dusk. Brown trout living in streams grow to about 1.8 kg (4 lb) but lake residents and sea-run fish grow larger. Most mature in their third to fifth year and many are repeat spawners.

In sea-run populations, brown trout spend 2-3 years in freshwater then migrate downstream to spend 1 or 2 growing seasons in coastal waters near the river mouth. There they feed on small fishes and crustaceans. Most return to their home streams to spawn but some straying occurs. Brown trout live up to 14 years and can spend as long as 9 years in the sea.

Rainbow Trout (Oncorhynchus mykiss)

This member of the salmonid family is also called Steelhead, Kamloops trout, steelhead trout, silver trout, or coast rainbow trout.

Physical Characteristics

Like most other members of the salmonid family, the appearance of rainbow trout varies.

Adults in freshwater: colour varies from metallic blue to green or yellow-green to brown on the back becoming silvery on the sides and light on the belly. Many small black spots cover the head, back, sides and fins, and spots on the tail are in obvious rows. The adipose fin (small fin in front of the tail on the back) has a black border. Mature fish have a distinctive rosy stripe along the side that extends from the gill cover to the caudal fin.

Facts on Rainbow Trout

The largest rainbow trout was caught in Alaska in 1970 and weighed 19.10 kg (42 lb).

The rainbow trout is commonly used as a laboratory animal for water quality testing.

Adults in saltwater: sea-run rainbow trout (steelheads) are more silvery in colour, may lack the rosy stripe, and show less spotting on the sides.

Young rainbow trout (parr): have 5-13 well-spaced dark parr marks on the sides and show less spotting on the body than adults.

Rainbow trout may look very similar to Atlantic salmon and brown trout, but can be distinguished by the regular rows of spots on the tail, the lack of any coloured spots and the absence of red in the adipose fin.

Rainbow trout can grow as big as 25.8 kg (57 lb) but in Nova Scotia usually grow up to 2.7 kg

(6 lb).

Distribution

Rainbow trout are actually native to the eastern Pacific Ocean and fresh waters of western North America. They naturally ranged from Mexico to Alaska and inland to the Rockies. However, they have been widely introduced throughout the world, and now occur across central North America to the eastern coast. Rainbow trout were first introduced to Atlantic Canada in the late 1800's. Today they are stocked in rivers and lakes throughout Nova Scotia and are known to reproduce in the Bras d'Or Lake watershed.

Fishing Facts

A popular sport fish, rainbow trout are fished with wet and dry flies, lures or natural bait.

The flesh is tasty and may be prepared many ways.

Rainbow trout have been reared in hatcheries for decades to support stocking programs. They are also reared commercially in ponds for food and for sport, and more recently in salt water pens.

Natural History

Different populations of rainbow trout may have very different life history patterns. Rainbow trout may live in lakes or ponds, they may be stream dwellers or they may spend part of their lives at sea before returning to freshwater (anadromous) to reproduce.
They prefer water temperatures of 12-18·C and do well in clear, cool, deep lakes or cool, clear, moderately-flowing streams with abundant cover and deep pools. They spawn in the spring (usually from March to May in Atlantic Canada) in small tributaries of rivers, or in inlets or outlets of lakes. Rainbow trout usually home to the streams where they hatched.

Spawning occurs in shallow riffles with gravel bottoms. The female uses her body to dig a nest (redd) in the gravel. One or two males will spawn with her in the nest, after which she buries the fertilized eggs. She repeats this process until all her eggs are used. Most female rainbow trout produce about 1,000-4,000 eggs. The eggs are 3-5 mm in diameter and hatch in 4-7 weeks depending on the temperature. In another 3-7 days the young absorb the yolk sac and emerge from the gravel.

The young of lake-dwelling fish may move into the lake by the end of their first summer. Some stay in a tributary up to 3 years before entering the lake. Young rainbow trout seek cover and prefer slow- moving shallow stream areas where rubble, rocks, instream debris and undercut banks provide shelter. Older trout move into faster and deeper stream waters. Rainbow trout that migrate to sea (steelheads) spend from 1-4 years in freshwater before they transform into smolts to prepare for life in salt water. Rainbow trout smolts lose their parr markings and become silvery. They migrate to sea in spring and remain there for a few months to several years before they return to fresh water.

Rainbow trout take a wide variety of foods, but in freshwater they eat mainly insects, crustaceans, snails, leeches, and other fish if available. At sea they eat mainly fish, crustaceans, and squid. Rainbow trout growth varies widely depending on their habitat, diet and life history pattern. Generally fish that go to sea or live in large productive lakes, grow largest and live longer. Rainbow trout usually mature at ages 3 to 5 at sizes that range from 15-40 cm (6-16 in) long. Many will spawn repeatedly. Rainbow trout can live to 11 years.

Smallmouth bass (Micropterus dolomieui)

This fish, a member of the sunfish family is also called northern smallmouth bass, smallmouth black bass, black bass, and brown bass.

Physical Characteristics

The smallmouth bass has the following characteristics:

- A robust, slightly laterally compressed fish
- Its colour varies from brown, golden brown, olive to green on the back becoming lighter to golden on the sides and white on the belly
- It has 8-15 narrow, vertical bars on the sides and dark bars on the head that radiate backwards from the eyes
- Its head is relatively large, with a large red, orange, or brown eye
- Its lower jaw protrudes
- Its two dorsal fins are joined; the front one is spiny and the second one has 1 spine followed by soft rays
- Its pelvic fins sit forward on the body below the pectoral fins
- Three spines border the front of the anal fin and a single spine is found on each pelvic fin
- Young fish have more distinct vertical bars or rows of spots on their sides and the caudal or tail fin is orange at the base followed by black and then white

Facts about Smallmouth Bass

Some male smallmouth bass return to the same nest year after year; over 85% of them build their nest within 138 m (150 yd) of where they nested in earlier years.

The world record smallmouth bass was caught in Kentucky, U.S.A. in 1955 and weighed 5.4 kg (11.9 lb). It measured 68.6 cm (27 in) long and 54.9 cm (21.7 in) in girth.

They have been seen "sunning" in pools with water temperatures of 26.7· C.

Smallmouth bass can reach over 4 kg (9 lb) in parts of central Canada but usually don't exceed 1.1 kg (2.5 lb) in Nova Scotia.

Distribution

The smallmouth bass is a freshwater fish originally found in lakes and rivers of eastern and central North America. As a result of widespread introductions, it now ranges from southern Nova Scotia and New Brunswick, south to Georgia, west to Oklahoma, north to Minnesota, west to North Dakota and east from southern Manitoba to Quebec. It also occurs in a few areas of western North America and has been introduced in Europe, Asia, and Africa.

Natural History

Smallmouth bass prefer clear, quiet waters with gravel, rubble, or rocky bottoms. They live in mid-sized, gentle streams that have deep pools and abundant shade, or in fairly deep, clear lakes and reservoirs with rocky shoals. Smallmouth bass tend to seek cover and avoid the light. They hide in deep water, behind rocks and boulders, and around underwater debris and crevices. Smallmouth bass prefer temperatures of 21-27· C. As temperatures fall, they become less active and seek cover in dark, rocky areas. In the winter they cease feeding, remain inactive on the bottom, staying near warm springs when possible.

Spawning takes place from late May to July in shallow (usually 0.3-0.9 m (1-3 ft) deep) protected areas of lakes and rivers, when the water temperature is 16 to 18· C. The male prepares a nest on a sandy, gravel or rocky bottom by cleaning an area 0.3 to 1.8 m (1-6 ft) in diameter. He defends the nest from other males and attracts a series of females into the nest to spawn. After spawning the female leaves and the male remains to guard the nest and fan the eggs. Females usually produce from 5,000 to 14,000 eggs, depending on their size. The eggs are from 1.2-2.5 mm in diameter and stick to stones in the bottom of the nest.

The young are about 5.8 mm long when they hatch in 4-10 days depending on the temperature. Hatching success can vary a lot. Sudden changes in temperature or water level can cause the eggs to die from shock or cause the male to abandon the nest, leaving it open for predators. After hatching, the male remains with the young for another 3-4 weeks while they absorb the yolk sac and begin to leave the nest.

Young fish tend to stay in quiet, shallow areas with rocks and vegetation. They begin feeding on plankton (tiny organisms suspended in the water), and switch to larger prey like water insects, amphibians, crayfish, and other fish as they grow. (Crayfish are native to New Brunswick but are not found in Nova Scotia). Two-year old bass are about 12.7 cm (5 in) long.

Older bass prefer rocky, shallow areas of lakes and rivers and retreat to deeper water at high water temperatures. Most bass do not travel great distances and those in streams spend all season in the same pool. Smallmouth bass mature at ages 3-6 when they are about 17 to 28 cm (6.7-11 in) long. Males usually mature a year earlier than females. They are known to live 15 years.

Some smallmouth bass predators are yellow perch, sunfishes, catfishes, white suckers and turtles.

Fishing Facts

Smallmouth bass are a fish of great sporting quality that have been popular with anglers since the early 1800's.

This popularity led to widespread introductions and the culture of smallmouth bass. It was harvested commercially until the 1930's but over-fishing led to its restriction as a sport fish.

Smallmouth bass can be taken with wet or dry flies, by trolling or casting with live bait or lures, or still fishing with crayfish, minnows or frogs.

Striped Bass (Morone saxatalis)

Other common names for this fish include: striper bass, striped sea bass, and striper.

Physical Characteristics

Striped bass have the following characteristics:

- A long, laterally compressed fish
- Its colour is olive green to blue or black on the back; the sides are pale to silvery (sometimes with brassy reflections); its belly is white
- It has 7-8 dark horizontal stripes on the sides
- Both eyes and mouth are relatively large and the lower jaw protrudes
- The pelvic fins sit forward on the body below the pectoral fins
- The first dorsal fin (on the back) is spiny and the second has one spine followed by several soft rays
- A single spine lies at the front of each pelvic fin and three short spines precede the anal fin
- Young often lack stripes and have 6-10 dusky bars on the sides

Striped bass have been recorded as large as

Facts about Striped Bass

A striped bass weighing 28.6 kg (62.9 lb) was caught near Reversing Falls in the Saint John River, New Brunswick in 1979.

The world record (angling) striped bass weighed 35.6 kg (78 lb) was caught at Atlantic City, New Jersey in 1982.

A striped bass tagged and released in the Saint John River, New Brunswick was recaptured 36 days later in Rhode Island, U.S.A. 805 km (503 mi) away! (22.4km/day 14 mi/day)

After fertilization striped bass eggs swell to about three times their original diameter to a size of 3.6 mm.

Surveys show the average striped bass angler on the Annapolis River, Nova Scotia spends about 50 hours on each fish caught.

56.7 kg (124.7 lb) North Carolina, 1891). However most striped bass caught are 13.6 kg (30 lb) or less.

The short (less than half the fin length) anal fin spines and body stripes distinguish striped bass from white perch, the other member of the temperate bass family found in Maritime waters. The white perch lacks stripes and 2 of its anal spines are longer than half the fin length.

Distribution

The striped bass is a coastal species found in rivers, estuaries, and inshore waters of eastern North America from the St. Lawrence River and southern Gulf of St. Lawrence to northern Florida, as well as the northern coast of the Gulf of Mexico. It was introduced on the Pacific coast of North America over 100 years ago, where it now ranges from California to southern British Columbia. Striped bass have been introduced and become established in some landlocked lakes in the southern and central U.S.

Striped bass have been introduced to parts of Europe and Asia.

Natural History

Striped bass is a schooling fish, living in the sea and returning to fresh water to spawn (anadromous). It is most common in steady-flowing, turbid rivers that have low slopes and large estuaries. During their saltwater life many striped bass make long sea migrations. However not all fish migrate and some populations do not migrate at all. Some fish remain in the estuary of their home rivers.

Striped bass spawn in May and June after moving upriver the previous fall, usually at water temperatures of 14 to 22· C. The length of this journey can vary from a long journey inland to just above the head of tide. Striped bass sometimes spawn in brackish water.

Striped bass produce many eggs. In fact, more than three million have been recorded for a 22.7 kg (50 lb) female! About 100,000 eggs is more typical of bass in our rivers. Striped bass spawn near the water surface in water 0.3-6.1 m (1-20 ft) deep. The eggs have a large oil globule and

Fishing Facts

Historically valued both for food and for sport, stocks of striped bass have been declining since the 1970's. This is probably due to a combination of over fishing, habitat destruction, pollution and natural population cycles.

The striped bass is becoming a popular sport fish in ·Canadian waters and can be caught by casting, trolling, jigging, and fly fishing. They are fished in the surf or along shorelines and estuaries wherever schools of small food fishes are found and best fishing is often in the evening at high tide. Striped bass can be fished with live bait, lures (bucktails, Rapalas), plugs and poppers (skipping bugs). Bait success depends on the location and feeding habits of bass at the time but gaspereau, eels and worms are popular.

It is not fished commercially in Nova Scotia.

are semi-buoyant. Ideally the current that prevents them from getting silted over and smothered on the bottom carries them along. The eggs hatch in 2-3 days depending on the temperature (15-18.6·C).

Newly hatched fish are about 5 mm long. After absorbing yolk-sac, they feed on zooplankton (tiny invertebrates suspended in the water).

Striped bass are carnivores and take progressively larger prey as they grow. They eat a variety of invertebrates such as insect larvae, marine worms, and crustaceans as well as many kinds of schooling fishes, especially herring and gaspereau.
Adults feed most actively just after sunset and just before dawn and can be seen moving in with the tide, rolling and flashing as they feed on smaller fish. Canadian striped bass grow fairly rapidly and can be 14.5 cm (5.7 in) at age 1. They usually mature at age 3-6 years when they are about 34-53 cm (13.4-21.7 in) long. Males usually mature a year earlier than females, but do not live as long. Striped bass can live to 31 years.

Other fish such as Atlantic tomcod, Atlantic cod, silver hake and larger striped bass eat small striped bass. Adult striped bass have few predators except humans.

Young striped bass form schools and spend their first two or three years in the lower reaches of rivers and in estuaries, preferably where there is a sand and gravel bottom and some current. After this period, many leave their home waters and make long sea migrations along the Atlantic coast. Striped bass populations from North Carolina to the Bay of Fundy are typically migratory and travel in large schools moving north in the summer and south in the winter. They probably return to their home rivers when they reach sexual maturity and are ready to spawn, however mature fish do not necessarily return every year to spawn. In general, most migrating striped bass are female. Some of the large striped bass caught along the Maritime coasts probably originate from U.S. rivers.

Striped bass populations go through cycles. Every so many years the young-of-the-year offspring survive in particularly high numbers and become what is called a dominant year class in the population. Year class success is probably determined in the first two months of life and may be related to environmental conditions during this period.

Alewife (Alosa pseudoharengus)

Common names for the alewife are gaspereau, river herring, sawbelly, or kiack.

Physical Characteristics

The alewife is a member of the herring family. Here are some things to look for:

• A slender, laterally compressed fish coloured greyish-green on the back, and silvery on the sides and belly

• Gasperaux entering freshwater are often copper-tinged

• A single black spot is present on each side, just behind the head

Facts on Alewife

Alewife eggs, or roe, are canned and sold as a delicacy.

Despite the many thousands of eggs laid by spawning alewife very few offspring actually survive. In some populations as few as three young-of-the-year fish migrate downstream for each female that spawned.

• The eye is relatively large and has an obvious eyelid

• A row of scales, known as scutes, form a sharp edge along the mid-line of the belly which is how the alewife came to be called "sawbelly".

The alewife in Nova Scotia is usually 25-30 cm (10-12 in) long and weighs up to 340 gr (12 oz). There is no lateral line.

Another species known as the blueback herring is very difficult to distinguish from the alewife. They inhabit the same watersheds and have similar natural histories. Many reports of alewife probably include the blueback herring as well.

Distribution

The alewife is found in rivers and lakes along the eastern coast of North America from Newfoundland to North Carolina and the adults live in coastal marine waters 56-110 m (180-350 ft) deep. Landlocked populations exist in several Ontario and New York lakes. Since the Welland Canal was built in 1824, the alewife has spread throughout the Great Lakes.

Fishing Facts

During the spawning runs commercial fishermen set large trap nets or enclosures called weirs in coastal rivers and estuaries to catch migrating alewives. Major Canadian fisheries are on the Shubenacadie, Miramichi, and Saint John Rivers.

The catch is used for fishmeal, lobster bait, pet food or it is smoked, canned, salted or pickled. Although tasty, alewives are not favoured locally for human consumption due to their large number of bones.

Natural History

In the Maritimes the alewife spends most of its life growing in salt water feeding mainly on zooplankton, tiny invertebrates, that live in the water column. Each spring from April to July large runs of adult alewives migrate up coastal rivers to spawn in freshwater lakes, ponds and streams (this movement from sea to freshwater makes the alewife an anadromous fish).

Alewives also spawn in brackish water. Like trout and salmon, alewives use their sense of smell to return to the streams and lakes where they hatched or near by watersheds. Female alewives usually begin spawning at age 4, repeat spawn each following year and may live to be 10. Male alewives often mature a year earlier than females. About 75% of alewives entering Nova Scotia rivers are repeat spawners. Alewives can move into coastal areas in late winter but will not migrate into fresh water until river temperatures begin to warm. Males enter the river first. Alewives only migrate into freshwater during daylight hours. However spawning occurs at night and can occur in standing, slow moving or fast mid-river water. A single female can lay as many as 200,000 eggs.

After spawning the adults begin the downstream migration to the sea within a few days.

Alewife eggs are about 1mm in diameter and are left to lie on the bottom or float with the current. Depending on the water temperature, the eggs hatch in about a week. After the yolk-sac is absorbed the tiny, larval fish stay near the spawning grounds preferring shallow, warm and sandy areas. They feed on tiny species of zooplankton. From August to October young-of-the-year, (sizes from 32-152 mm (1.25-6 in) migrate downstream in large groups or schools to live in estuaries and coastal areas. Adults over winter at sea in the George's Bank, Gulf of Maine or Nantucket Shoals and as far south a Florida. Alewives can live at least 10 years.

Alewives are eaten by many species of fish and birds including striped bass, salmonids, smallmouth bass, eels, perch, bluefish, weakfish, terns and gulls.

American Eel (Anguilla rostrata)

Physical Characteristics

The American eel has a long snake-shaped body. It has no pelvic fins and the fins along the top of the body are continuous. The body is covered with mucus, which is where the expression "slippery as an eel" comes from. Their colour changes as they grow up and there are different names for eels at these different stages.

"Glass eels" are young eels approaching the shore at sea. Their bodies are transparent with a distinct black eye.

"Elvers" are eels that are just adapting to fresh water and are greyish-green in colour.

"Yellow eels" are adults in freshwater. Their colour varies from yellowish to greenish to olive-brown, being darker on the back and lighter on the belly.

"Silver, bronze, or black eels" are sexually mature eels which darken to a bronze-black hue on the back with silver underneath.

American eels can grow to a size of 1270 mm (50 in) and weigh up to 4.5 kg (10 lb).

Fishing Facts

Commercial fishermen harvest silver and yellow eels with many kinds of gear including weirs, traps, otter trawls, nets, handlines, eel pots and spears.

Eels are sold for human consumption and as bait for other fisheries. Many are shipped fresh or frozen to Europe where they are considered a delicacy and served smoked or jellied.

Elvers have been harvested for use in pond culture and grow-out operations. The American eel is caught by recreational fishermen.

Distribution

American eels are found in freshwater streams and rivers, brackish coastal waters and the Atlantic Ocean of eastern North America from southern Greenland and Labrador to the Gulf of Mexico and northern South America. It is the only member of the freshwater eel family found in North America and is wide spread in the Maritime Provinces.

Natural History

The American eel goes on long oceanic migrations to reproduce. Unlike fish such as Atlantic salmon and alewife that return to freshwater to spawn, eels are catadromous, which means they spend most of their lives in freshwater lakes and streams, returning to sea to spawn. No one has ever seen American eels spawn but it is believed to occur in the Sargasso Sea, east of the Bahamas.

Spawning occurs from February through April and hatching probably occurs within a few days. The tiny transparent eel larvae (known as leptocephali), only a few millimetres long, drift with ocean currents to the coastal areas of North America. They grow rapidly until the fall.

Once they are between 8-12 months old and about 55-65 mm (2.1- 2.6 in) long they transform into glass eels. At this stage, eels actively migrate toward freshwater. As they enter brackish and freshwater they begin to develop colour and are known as elvers. Elvers and glass eels reach the Maritime coasts in April and May. At first the elvers are active at night and rest near the bottom during the day. They may stay in estuaries for some time moving up and downstream with the tide as they physiologically prepare to live in fresh water. When elvers begin to migrate upstream they become active during the day and are thought to use the current and the odour of brook water to find their way. This upstream migration can take several years with distances as far as 1000 km (600 mi) involved.

Elvers eat aquatic insects, small crustaceans and fish parts. After a year in freshwater elvers are about 127 mm long (5 in). Following this stage, eels enter a growth phase lasting many years in which they are known as yellow eels. Some eels do not migrate upstream as elvers but

Facts about Eels

Eels do not become definitely male or female until they are 20-25 cm (8-10 in) long!

What sex an eel becomes is thought to be partly determined by environmental conditions such as crowding and food abundance.

In areas (southern U.S.) where food abundance and water temperatures favour rapid growth rates, a higher percentage of male eels are found. In cooler areas, such as Nova Scotia, where eels grow more slowly but reach an overall larger size, there tends to be more females. This is an advantage since larger females produce more eggs and can contribute more offspring.

Eels can absorb oxygen through their skin and can travel overland particularly in damp, rainy weather.

remain instead to live in estuaries. Yellow eels are most active at night and spend the day concealed in vegetation or burrowed in the bottom. Their diet includes insect larvae, fish, crabs, worms, clams, and frogs. They also feed on carrion and are able to tear pieces off food items too large to be swallowed whole.

In late summer and fall some adult American eels in eastern Canada begin their spawning migration to the Sargasso Sea. During this time they change to the "silver eel" stage and become sexually mature. Males can mature at age 3 but females mature later usually at ages 4-7. However eels can spend up to 40 years in fresh water. Female eels produce from 0.5 to 4.0 million eggs. It appears that all eels die after spawning. Adult eels are eaten by larger fish such as sharks, haddock, and swordfish and also by gulls and bald eagles.

Facts on Fishing

American shad were much more abundant in the past. During the 1800's a thriving fishery for shad existed along the Atlantic coast supporting an annual catch as high as 23,000 tons (50 million pounds). Today small commercial fisheries exist but numbers have greatly declined due to over-fishing and changes in our rivers. Dams often block access to vast areas of spawning habitat. Even where fishways provide access, many young shad may not survive the downstream migration.

Shad are fished commercially in rivers during the spawning runs. The eggs (roe) are most desirable so large numbers of mature females are taken. The flesh is sold fresh and salted. Shad are angled and considered a fine game fish.

American Shad (Alosa sapidissima)

Physical Characteristics

The American shad, like the alewife (gasperau), is a member of the herring family and has the following characteristics:

- Slender and silvery-coloured with a blue-green metallic hue on the back
- Has a black spot, similar to the alewife, located on the side, just behind the head - on the shad, this spot is followed by several smaller dark spots
- The eye has an obvious eyelid
- A row of scales known as scutes form a sharp "sawbelly" edge along the midline of the belly
- There is no lateral line

American shad can grow to 76 cm (30 in) and weigh 6.8 kg (15 lb). However, adults found in Canadian rivers are usually 45 to 50 cm (18-20 in) long and weigh from 1.4 to 2.7 kg (3-6 lb).

Distribution

American shad are anadromous (moving from the sea to freshwater) fish found along the Atlantic coast of North America from Newfoundland to Florida. Large spawning runs used to occur in the Shubenacadie and Annapolis rivers (also Saint John, Petitcodiac and Miramichi) but they are found in many Maritime coastal rivers. They have been introduced along the Pacific coast and now range from Alaska to California.

Natural History

The American shad lives for several years at sea before returning to spawn in the stream where it hatched. Shad avoid cold temperatures and prefer to stay in water 8·C or warmer. Water temperature and currents determine much of their migration and behaviour.

Each spring, schools of shad, using their sense of smell, begin to migrate up coastal rivers and tributaries when water temperatures reach 12·C.

Spawning in the Maritimes occurs during June and July in water temperatures of 13-20·C. Migration stops in temperatures over
20·C. American shad do not usually travel as far upstream as the alewife. They spawn in rivers at night in mid-water in streams with a wide range of bottom types. The eggs are about 3 mm across and drift along with the current to hatch in 8-12 days depending on the temperature.

A female can produce anywhere from 60,000-600,000 eggs but shad in Canadian rivers usually produce about 130,000 eggs. Many shad in the Maritimes are repeat spawners, however shad in southern populations die after spawning.

Young shad spend their first summer in the river feeding on insects and crustaceans. They swim near the bottom in water as deep as 3.7 to 4.9 m (12-16 ft) but at night they are found near the surface. When they migrate to sea in the fall, they have grown to a size of 7.5 to 12.5 cm (3-5 in). They migrate to the sea as temperatures in the river drop.

At sea, shad live in schools and move according to the bottom temperatures, seeking areas that are 7-13· C. They stay near the bottom during the day, dispersing at night to all depths. Immature and spawned-out adults remain offshore in areas like the Bay of Fundy until winter, when they move farther out to sea in order to stay in preferred water temperatures. At sea they eat zooplankton (tiny invertebrates that live in the water), small bottom crustaceans, and occasionally small fish. Most shad mature at age 4 or 5 when they are about 48-53 cm (19-21 in) long. Shad can live up to 13 years.

Although not a major food source for other animals, shad are eaten at sea by seals, sharks, blue-fin tuna, kingfish, and porpoises. Young shad in freshwater are eaten by bass, American eels, and birds.

Brown bullhead (Ictalurus nebulosus)

Physical Characteristics

Nova Scotia's only member of the freshwater catfish family is easy to identify with its distinctive sets of whisker-like formations around the mouth. These are called barbels and the bullhead has four pairs.

The following can also identify the bullhead:

• A thick rounded body, heaviest toward the front

• A broad, large, somewhat flattened head

• Sharp, saw-toothed, spines at the base of the dorsal and pectoral fins. These spines can be "locked" in an erect position.

• The tail or caudal fin is square and there is an adipose fin (small fin on the back in front of the tail)

Facts about Bullheads

The spines at the base of the dorsal and pectoral fins can be "locked" into an erect position. This is thought to help protect the bullhead against predators, making it much harder to swallow.

Brown bullheads take many kinds of bait and can be easily caught by anglers. They are best fished with worms at dusk.

The flesh of the brown bullhead is very tasty. They are reared commercially in the southern U.S.

Brown bullheads are extremely resistant to pollution. In areas of heavy pollution they can be the only fish species present.

• Its colour is dark brown to olive green on the back ; its sides are sometimes mottled with dark blotches and the belly is cream coloured

• There are no scales but the skin has many taste glands

In Nova Scotia it seldom grows more than 30 cm (1 ft) long and 0.5 kg (1 lb) in weight. Bullheads weighing as much as 2.7-3.6 kg (6-8 lb) have been caught in Ontario.

Distribution

The brown bullhead is found in the fresh waters of eastern and central North America, from the Maritime Provinces to Florida, and westward to southern Saskatchewan, Missouri, and Texas. It occurs across southern Canada from Saskatchewan to the Maritimes. The brown bullhead has been introduced to western North America and Europe.

In Atlantic Canada the brown bullhead exists only in New Brunswick and mainland Nova Scotia.

Natural History

Brown bullheads usually live on the bottom in the shallow, weedy, mud-bottomed areas of lakes or large slow-moving streams. They tolerate higher water temperatures and lower oxygen levels than many other fish species.

They feed on the bottom at night, using their barbels to search for food. They eat a variety of foods including insects, fish eggs, leeches, mollusks, crayfish, worms, algae, plants, and small fishes. Young bullheads feed mainly on insects and plankton (tiny organisms suspended in the water).

Bullheads spawn in the late spring when water temperatures approach 21·C. One or both parents excavate a shallow nest in a protected area of mud or sandy bottom. Spawning occurs in the daytime and several thousand cream coloured eggs are deposited in the nest. The parents care for the eggs by fanning them with their fins and physically stirring them up. After hatching, the young catfish are jet black and resemble tadpoles. They swim in a "school" and are protected by their parents for several weeks until they are about two inches long.

The brown bullhead usually matures at age 3 and lives for 6-8 years. The chain pickerel and other members of the pike and perch families eat them.

Rainbow smelt (Osmerus mordax)

Other common names are Atlantic rainbow smelt, smelt, American smelt, freshwater smelt, Atlantic smelt, leefish, and frost fish.

This fish is one of two members of the smelt family found in Atlantic Canada. The other member found here is capelin.

Physical Characteristics

The rainbow smelt is a small slender fish that grows to about 25 cm (10 in). It has the following characteristics:

- Olive-green on the back, becoming lighter on the sides
- Sides have a purple, pink and blue iridescence especially when freshly caught
- The belly is silvery
- Relatively large mouth with fang-like teeth and a protruding lower jaw
- The caudal (or tail) fin is deeply forked
- An adipose fin (small fin in front of the caudal fin on the top) is present
- The lateral line is incomplete
- Spawning males are covered on the head, body and fins with tiny bumps (nuptial tubercles)
- Smelt in freshwater are darker becoming almost black on the back

Facts about Smelt Freshly caught smelt smell very much like cucumber! No doubt this feature is responsible for the common name "smelt". This odour disappears after preservation or freezing.

Males smelt are more abundant on the spawning grounds than females. This is probably because they can spawn up to 8 consecutive nights but females may spawn only 3 or 4 nights.

Distribution

The rainbow smelt is found in rivers and coastal areas of eastern North America from Labrador to New Jersey and on the west coast from Vancouver Island around Alaska to the Arctic Ocean. Landlocked populations also occur in lakes and ponds throughout the Atlantic region. They have been introduced in the Great Lakes and have increased their range to other Ontario drainages through unauthorized introductions.

Fishing Facts

Smelt are fished commercially and for sport. Winter fishing for smelt is a popular sport. Anglers take them on lines through the ice, using worms as bait. In spring, anglers dipnet or seine them in the spawning tributaries.

Commercial fisherman catch them in box nets, bag nets, gillnets or by trawling.

The largest Maritime fishery occurs in the Miramichi estuary. Smelt are sold fresh or frozen and are very tasty.

Natural History

The rainbow smelt is a schooling fish, which grows and matures in shallow coastal waters and migrates up freshwater streams to spawn (anadromous). Smelt move into estuaries in the fall and begin to move up the streams after the spring thaw.

Spawning occurs from February-June usually at water temperatures from 4-10·C). Smelt do not necessarily return to the stream of their birth to spawn, especially if there are other nearby streams. Smelt in landlocked lakes swim up tributary streams or in some cases spawn along the shoreline. Spawning occurs at night in fast moving water. Several males spawn with one female. The fertilized eggs become sticky and attach to the bottom, sometimes forming a thick layer. One female can produce as many as 93,000 eggs. After spawning the adults return to the estuary during the day but may return upstream to spawn again on subsequent nights. Some fish die after spawning. The rest leave freshwater after spawning to spend the summer in coastal waters.

Smelt eggs are about 1mm in diameter and take anywhere from 11-29 days to hatch, depending on the temperature. Smelt fry are 5 to 6 mm long when they hatch and drift downstream to brackish water. They use water depth for cover and feed near the surface at night. Young smelt feed on plankton (tiny organisms suspended in the water), and may grow to 5 cm (2in) by August.

Older fish eat larger invertebrates and other fish. Smelt grow most rapidly in their first year and can tolerate increasing amounts of saltwater, as they get older. They prefer temperatures of 6-14· C and stay close to shore, seeking cover in eelgrass beds or below the water.

Smelts in the Miramichi average 13.9 cm (5.3 in) at age 2, and 20.6 cm (8.1 in) by age 5, southern populations grow faster. Smelt in small landlocked lakes may only reach a length of 10.2 cm (4 in). Smelt usually mature at age 2 in the Maritimes and can live to age 17. Females live longer and grow larger than males.

Smelt are eaten by bluefish, striped bass, salmonids as well as birds, and harbour seals.

White Perch (Morone americana)

Oddly enough, the white perch is actually a member of the bass family and is not a true perch. Other common names for the white perch are silver perch, sea perch, silver bass, narrow-mouthed bass, and bass perch.

Facts about White Perch

The oldest known white perch lived 17 years.

The world angling record for white perch is a 2.15 kg (4.7 lb) fish taken in Messalonskee Lake, Maine in 1949.

Physical Characteristics

The white perch has the following characteristics:

- A deep, thin body that slopes up steeply from the eye to the beginning of the dorsal fin
- Colours which can be olive, grey-green, silvery-grey, dark brown or black on the back becoming a lighter green on the sides and silvery-white on the belly
- The pelvic and anal fins (both on the belly) are sometimes rosy coloured
- Like all members of the bass family it has two dorsal fins on the back and the pelvic fins sit forward on the body below the pectoral fins
- The first dorsal fin has nine spines but the second one is soft rayed • there are three spines at the front of the anal fin, and a single spine precedes the second dorsal fin and each pelvic fin
- It has many small sharp teeth
- Its scales are relatively large and the lateral line is complete

It can grow to 48.3cm (19 in) and 2.72 kg (6 lb).

It is very similar in shape to the striped bass, also found in our waters. The white perch has a deeper, less rounded body than the striped bass. The anal fin spines of the striped bass are less than one-half the fin length, but the second and third anal spines in the white perch are greater than this.

Distribution

White perch are found in fresh and brackish waters along the Atlantic coast from the southern Gulf of St. Lawrence to North Carolina and inland along the upper St. Lawrence River to the lower Great Lakes. It is present in all three Maritime Provinces.

Fishing Facts

The white perch has very tasty flesh and where it grows large enough can be a popular sport fish. They are caught on bait (worms, small minnows) lures, or streamer-type flies.

White perch are fished commercially in Chesapeake Bay, U.S. and the lower Great Lakes.

Natural History

White perch is a fish that can live in fresh or salt water and does best when summer water temperatures reach 24·C. In the Maritimes, it occurs mostly in freshwater lakes and ponds. Sea-run populations are found in some coastal rivers and estuaries.

Spring spawning takes place when water temperatures are 11-16·C, late May-late July in shallow water over many kinds of bottom. Males and females each spawn several times and the tiny 0.9 mm eggs become sticky after fertilization and attach to vegetation and bottom materials. White perch are quite prolific; a 25 cm (10 in) female can produce 247,700 eggs.

The length of time for hatching depends on the water temperature. When the water is cooler, hatching takes longer (4-4.5 days at 15·C versus about 30 hours at 20·C). Newly hatched white perch are 2.3 mm long and feed on plankton (tiny organisms in the water). They grow rapidly and can reach 65 mm (2.5 in) by late summer.

Growth rates of white perch vary among regions and populations. Few studies have been done on Maritime populations. Most perch in our waters are less than 15 cm (6 in). Larger pan-sized white perch that weigh 225 to 450 g (0.5-1 lb) are taken in some Nova Scotia lakes. Lake Ontario fish can reach 33.5 cm (13.2 in) and 780 g (1.72 lb). Even larger sizes have been reported in some U.S. waters.

White perch in lakes are known to feed both during the day and at night. Fresh and saltwater populations move to surface (or inshore) waters at night, retreating to deeper water during the day. They perch eat mostly aquatic insect larvae when they are small. As they grow, many kinds of fish such as smelt, yellow perch, killifish, and other white perch are eaten. They usually mature at 3 years and live 5-7 years.

White perch are thought to compete with some game fishes for food. In some places a lack of harvesting, either by anglers or other species of fish, can lead to large populations of stunted, small white perch. Smallmouth bass, chain pickerel, and large trout will eat white perch.

Yellow perch (Perca flavescens)

This, the only true member of the perch family in Nova Scotia, is also called perch, lake perch, and American perch.

Physical Characteristics

The yellow perch has the following characteristics:

- Its colour is black-green, to olive, to golden brown on the back and extending down the sides in tapered bars
- The rest of the sides are yellowish becoming grey to white on the belly
- It has two dorsal fins (on the back), the first one has 13-15 sharp spines, the second has only one spine followed by soft rays
- The pelvic fins with one spine sit forward on the belly almost directly below the pectoral fins
- The pectoral fins are amber-coloured and transparent whereas the pelvics are yellow to white and opaque
- Eyes are yellow to green
- The scales feel rough to the touch
- The colour of a spawning male fish intensifies; its lower fins can become orange to bright red.
- Young yellow perch are first transparent, then silvery or pale green

Facts about Yellow Perch

Occasionally yellow perch are found with the unusual colouring of grey-blue or red and the absence of dark bars on the side.

The yellow perch has been called "a good bold-biting fish" "the most extravagantly handsome of fishes" "a ravager of all smaller fish" and "bait-stealing little devils".

Students studying the anatomy of bony fishes most often use the yellow perch.

The yellow perch can grow to 1.9 kg (4.2 lb) but in Nova Scotia it does not exceed 30 cm (12 in) and 450 g (1 lb).

Distribution

Yellow perch can be found in freshwater of North America from Nova Scotia south along the Atlantic coast to Florida, west from Pennsylvania to Missouri, northwest to Montana, north to Great Slave Lake, southwest to James Bay and east to New Brunswick and Nova Scotia. It has been introduced widely in the south and western U.S.and has spread to southern British Columbia. Yellow perch cannot be found in Prince Edward Island, Cape Breton Island or Newfoundland. It is occasionally found in brackish water along the Atlantic coast.

Facts about Yellow Perch

The yellow perch is fished both for sport and for food. Anglers can catch them in summer and winter with fish or worms as bait. Yellow perch have been fished commercially in Canada for over a hundred years and are sold both fresh and frozen. The flesh is white and tasty.

Yellow perch are sometimes infected with the broad tapeworm (Diphyllobothrium latum) that can be transmitted to humans if the flesh is improperly cooked.

Natural History

The yellow perch is a schooling, shallow water fish that can adapt to a wide variety of warm or cool habitats. They are found in large lakes, small ponds, or gentle rivers but is most abundant in clear, weedy lakes that have muck, sand, or gravel bottoms. They prefer summer temperatures of 21-24· C. Yellow perch feed on aquatic insects, crustaceans, and a variety of fishes and their eggs.

Spawning occurs from April through July, but usually during May in Nova Scotia, at water temperatures of 9-12·C. The adults move into shallow areas of lakes or up into tributary streams. Males are first to arrive and the last to leave. Yellow perch spawn at night or in early morning, most often in areas where there is debris or vegetation on the bottom.

The female perch sheds her eggs in a long jelly-like spiral or accordion-folded strand. Several males fertilize the eggs during spawning. The egg mass can be as much as 2.1 m (7 ft) long, 51-102 mm (2-4 in) wide and weigh 0.9 kg (2 lb)!

Females produce an average of 23,000 eggs but have been known to shed up to 109,000 eggs. The egg masses are semi-buoyant and attach to the vegetation or bottom material. They receive no parental care and can be cast ashore during storms or eaten by predators. Yellow perch eggs are 3.5 mm in diameter and hatch in 8-21 days, depending on the temperature. Newly hatched perch are about 5 mm long.

Young perch grow quickly and remain near the shore during their first summer, swimming in large schools that often include other species. Perch in Nova Scotia waters do not grow as large as those living in the warmer, larger, or more productive habitats of central Canada. In general northern populations grow more slowly but live longer, and females grow faster than males.

Adults move in schools farther offshore than the young. They move between deeper and shallow water in response to changing food supplies, seasons, and temperatures. Perch feed in the morning and evening, taking food in open water or off the bottom. At night they rest on the bottom. Yellow perch remain active and feed during the winter.
Yellow perch can outbreed and out-feed speckled trout or other fish in a lake. This can sometimes lead to an overpopulation of small, stunted fish (less than 15 cm (6 in).

Other fish such as smallmouth bass, chain pickerel, and lake trout eats yellow perch. Birds like mergansers, loons, kingfishers and gulls also take them.

White Sucker (Catostomus commersoni)

This fish, the only member of the sucker family found in Nova Scotia, is also called the common sucker, common white sucker, eastern sucker, sucker, black sucker, mud sucker, mookie and muckie.

Fishing Facts
The flesh of the white sucker is bony but can be very tasty, particularly when hot-smoked.

Young suckers are sold as bait but there is little other commercial interest in the species. Suckers should not be used as bait in lakes that do not already contain suckers.

White suckers are not a popular sport fish but they can be caught on wet flies, small spinners and small hooks baited with dough balls or worms.

Physical Characteristics

The white sucker has the following characteristics:

- A torpedo-shaped fish distinguished by its sucker-like mouth located on the underside of its blunt, rounded snout
- Its mouth has thick lips covered with little fleshy bumps (papillae)
- Its colour varies from grey to coppery brown to almost black on the back and upper sides, becoming lighter on the lower sides to white on the belly
- During spawning, the darkness on the back intensifies and the body becomes more golden in colour
- Spawning males develop coarse bumps (nuptial tubercles)on the anal fin and lower tail (caudal) fin
- It has relatively large scales, one dorsal fin, no adipose fin and the lateral line is complete
- Young white suckers from 5 to 15 cm (2-6 in) in length usually have three large dark

spots on the sides

They can grow to 63 cm (25 in) and more than 3.2 kg (7 lb) but reach about 46 cm (18 in) in Nova Scotia.

Distribution

The white sucker is a North American species found in freshwater lakes and streams from Labrador south to Georgia, west to Colorado and north through Alberta and British Columbia to the Mackenzie River delta. In Canada, it is absent from Newfoundland, eastern Labrador, Prince Edward Island, south-western British Columbia and much of the far north.

Facts about Suckers

Spawning migrations of white suckers can be numerous and very dense - 500 have been known to swim upstream past a single point in 5 minutes.

Although examining the growth rings on their scales ages most fish, this method is not always reliable for suckers older than 5 years. They are best aged using sections of their pectoral fin rays.

Natural History

The white sucker can adapt to a wide range of environmental conditions but generally lives in the warm, shallow waters of lakes and quiet rivers. They prefer summer temperatures of 24·C. In streams they are most abundant in pool areas with ample underwater debris, streamside vegetation, and water depth to provide cover.

In lakes they are usually found in the upper 6.2-9.2 m (20-30 ft) of water, moving to shallows to feed. They are bottom feeders that browse the bottom, sucking in aquatic insects, small clams, and snails, and then spitting out the inedible sand and gravel. They feed mostly at dawn and dusk, and are active year round.

White suckers spawn in the spring (May and June), migrating upstream to spawning areas (small streams and tributaries) when water temperatures are 10-18·C. Suckers typically spawn in shallow gravel riffles where the water is up to 30 cm (1 ft) deep and where the speed is moderate. Lake populations of white suckers with limited access to streams will occasionally spawn on gravel shoals where there are waves. Although some spawning occurs in daytime, most takes place at sunrise and sunset. One female spawns with several males. Females usually produce 20,000-50,000 eggs, but can produce up to 139,000 eggs. Suckers do not build a nest, but scatter their eggs, which stick to the bottom, or drift downstream and attach elsewhere.

The eggs hatch in 8 to 11 days, depending on the temperature (10-15· C). The young remain in the gravel for 1or 2 weeks and then migrate downstream at a size of 12 to 17 mm. Sometimes only 3% of white sucker eggs survive to this stage. Young suckers in lakes are found along shorelines with sand or gravel bottoms. In streams they prefer sand and gravel shallow areas with moderate currents.

At first white suckers do not feed on the bottom. Their mouth is at the end of their snout, and they feed near the surface of the water on plankton (tiny organisms suspended in the water). When they grow to about 16-18 mm (0.6-0.7 in), their mouths shift to the underside of the head and they begin taking food from the bottom. White suckers grow most rapidly during their first year and can reach a length of 17.9 cm (7 in) by age 1. Growth rates vary considerably in different areas, but in all populations females grow more rapidly than males, reach larger sizes, and live longer. They usually mature at ages 5 to 8, and males mature a year earlier than females. Suckers can live up to 17 years.

Although there is evidence that suggests that the white sucker can compete for food with other sport fish, they can be a major food item in the diet of other fish such as Atlantic salmon, brook trout, pike and bass. Birds and mammals also eat them.

Appendix D: Fish Collection Tracking Sheet

Fish Collection Tracking Sheet

McCallum Environmental Ltd.

Pre-Job General Information		
Project:	Project Number:	Task:
Date:	Personnel:	WC/WB ID:
Weather:	Precipitation (past 24 hours):	Reach ID:

Site Characteristics **Photos taken of the site?** ☐ **Yes (US, DS, LB, RB, Substrate)**

Stream Type (% Surface Area)		Water Quality Measurements	
Riffle		pH	
Run		SAL (ppt)	
Pool		CON (µS/cm)	
Other (specify)		SPC (µS/cm)	
Substrate (% Surface Area)		TDS (mg/L)	
Bedrock		DO (%, mg/L)	
Boulder (>25 cm)		* Temp measurements are recorded below	
Rubble (14-25 cm)			
Cobble (3-13 cm)		**Physical Measurements (average over reach)**	
Gravel (0.2-3 cm)		Bankfull width (cm)	
Sand (0.06-2 mm)		Wetted Width (cm)	
Silt (<0.006 mm)		Depth (cm)	
Muck/Detritus		Length of Reach (m)	
Clay/Mud		Velocity (estimate)	

Fish Caught? (if so, list species)
Add any commentary or observations from survey effort.

Revisions to Electrofisher settings required?

Sketch of Site: Include flow direction, locations of habitat features/cover ex. Large boulders, large woody debris, overhanging vegetation, and undercut banks

ELECTROFISHING (Electrofishing must proceed in an upstream direction)

		Pass 1	Pass 2	Pass 3
Method Used: ☐ Depletion ☐ CPUE				
Site Set-up: ☐ Open ☐ Closed	**Effort (seconds)**			
Upstream Waypoint:	**Voltage**			
Downstream Waypoint:	**Frequency**			
Water visibility: ☐ Good ☐ Fair ☐ Poor	**Water temp (℃)**			
***Measure Temperature at Beginning of each pass**	**Air Temp (℃)**			
*****DO NOT Electrofish if water temp is greater than22ºC *****	**# of Fish Caught**			
*** Do NOT Electrofish if temperature is greater than 22ºC**				

TRAPPING & NETTING

Gear Used:	☐ Fyke Nets (#__) ☐ Minnow Traps (#__) ☐ Eel Pots (#__) ☐ Seine	**Bait:**
Locations and Depths (UTM, cm):		**Time In (hr):**
		Time Out (hr):

Fish Collection Tracking Sheet

McCallum Environmental Ltd.

Individual Fish Measurements

Pre-Job General Information		
Project:	Project Number:	Task:
Date:	WC/WB ID:	Reach ID:

Individual Fish Measurements – Photograph EACH individual – with enough detail to confirm ID if required								
Capture Method*	Fish ID #	Species Code	Fork Length (mm)	Total Length (mm)	Weight (g)	Age/Age Class	Mark observed? State type and tag # if poss.	Comments (e.g. parasites, lesions, net marks, dead, etc)

*PASS(#) = Electrofishing, MT = Minnow Trap, EP = Eel Pot, FN = Fyke Net, SN = Seine

McCallum Environmental Ltd.

STANDARD OPERATING PROCEDURE: DETAILED FISH HABITAT ASSESSMENT – STREAMS

1 PURPOSE

The purpose of this document is to provide standard methods for detailed fish habitat assessments performed by McCallum Environmental Ltd. (MEL) employees and subconsultants in lotic, freshwater habitats.

2 SCOPE

This document provides standards for data collection for detailed fish habitat assessments and describes a limited range of field-based measures for linear watercourses (i.e. lotic systems).

Fish habitat is inherently difficult to measure and quantify directly. Therefore, this SOP incorporates measures that evaluate specific features that are characteristics of, or inherent to a function of fish habitat and can indicate the extent to which a particular fish habitat characteristic or function is provided within a stream. This SOP aims to provide procedures for detailed fish habitat assessments which may be modified depending on the requirements and scope of a particular project.

Measures are habitat variables that can be quantified directly, or if not, visually estimated in the field. This SOP aims to incorporate measures of fish habitat with the following criteria, whenever possible:

- Quantifiable – habitat variables can be measured numerically, or when not possible, visual-based methods are standardized to the maximum practical extent.
- Rapid – habitat variables can be measured within the expected time frame of assessment (1/2 – 1 day per watercourse depending on watercourse size).
- Repeatable – a clear protocol for taking measurements can be described such that different users taking the measurement on the site would arrive at similar conclusions.
- Sensitive – changes or impacts to the stream would result in changes/impacts in the habitat variable. Variables are responsive to changes in the stream system.

It is important to note that the methods outlined in the SOP are best suited for previously mapped watercourses as they employ the use of transects. MEL defines watercourses based on guidance from Nova Scotia Environment (NSE, 2015). The following parameters were used to define watercourses:

- Presence of a mineral soil channel;
- Presence of sand, gravel and/or cobbles evident in a continuous patter over a continuous length with little to no vegetation;
- Indication that water has flowed in a path or channel for a length of time and rate sufficient to erode a channel or pathway;
- Presence of pools, riffles or rapids;
- Presence of aquatic animals, insects or fish; and,
- Presence of aquatic plants.

According the guidance provided by NSE, any surface feature which meets two of the criteria above meets the definition of a regulated watercourse. In MEL's experience, many first-order, headwater streams which meet the criteria of a regulated watercourse in Nova Scotia are not represented on topographic mapping or through provincial GIS layers. As such, it is critical that a general reconnaissance of watercourses within a study area is completed prior to undertaking detailed fish habitat assessments as outlined in this SOP.

It is also important to note that many rivers and stream comprise areas of "open water" – areas where the watercourse takes on more pond-like conditions, often times caused by beaver dams or other natural or anthropogenic obstructions. "Open water" areas are defined in this SOP as areas of stillwater, or a flat, wide portion of a watercourse with no visible current. The scope of this SOP for fish habitat assessment in streams includes open water habitat up to a maximum depth of 2 m. For open water areas with depths greater than 2 m, fish habitat assessments procedures for lentic areas (ponds and lakes) should be followed. However, the decision of whether to apply lotic or lentic fish habitat assessments to open water areas depend on a number of other factors, including overall goals of the survey, and will ultimately be at the discretion of the Project Coordinator. Procedures for fish habitat assessments in lentic systems are outlined in a separate SOP.

Prior to conducting fish habitat assessments, all field staff should acquire knowledge on the habitat preferences of fish expected to be encountered within a particular freshwater system. All field staff should possess a general understanding of the biology and habitat preferences of anticipated local fish species and age classes. This knowledge will provide important context to empirical habitat assessments and will help field crews identify unique habitat features in the field. Detailed information on the biology of fishes in Nova Scotia can be found in Scott and Crossman (1973), McPhail and Lindsey (1970), and the Nova Scotia Adopt A Stream Manual (2005).

3 SAFETY

The following documents provide important safety considerations and Personal Protective Equipment (PPE) for this type of work, and should be consulted before proceeding with any fish collection survey:

- MEL HSE Policy;
- MEL Remote Work Policy; and,
- MEL Working Near Shallow Water Policy.

A Field Work Tracking Sheet must be completed and signed by all field crew members prior to departing for any field work. Refer to Section 6.1 for details on field planning.

Water levels can change dramatically and can be hazardous to those working in large river flows. Field crews should not enter watercourses with swift water or dangerous currents. Discuss any potential safety concerns when completing the Field Work Tracking Sheet with the entire field crew, and before entering any streams.

4 FISH HABITAT ASSESSMENT - THEORY

Field approaches to fish habitat assessments and evaluations are incredibly varied. The selection of appropriate habitat assessment tools or evaluation methods is determined by the questions you wish to answer about a particular system. Depending on survey objectives, a variety of methods may be employed. Overall, fish habitat assessments are site-specific and methods must be tailored to the freshwater habitats being investigated.

As described by DFO (2012), methods for fish habitat assessments fall into three stages based on the potential impacts of a project – Primary, Secondary, and Tertiary. A Primary assessment is generally desktop based and may incorporate a rapid field reconnaissance to qualitatively assess fish habitat. This stage of assessment is usually sufficient when the magnitude of effect from a project is considered relatively low. A Secondary assessment is heavily field-based and involves validating habitat types within a Project Area by quantitatively measuring stream features. This stage of assessment is required when predicted fish habitat impacts from a project cannot be fully mitigated. Tertiary assessments are typically reserved for anticipated impacts on large river systems and changes in natural flow patterns, which fall outside the scope of this SOP. The methods outlined in this SOP fall under the Secondary stage of assessment methods. This SOP has been designed specifically to collect data to define existing fish habitat attributes in targeted mapped or field-delineated streams. Streams may be targeted for detailed fish habitat assessments for a number of project-related reasons, including project design, assessment of anticipated project-related effects, and restoration or engineering work. However, the scope of this SOP does not include fine-scale delineation of fish habitat (i.e. habitat mapping).

The measurable features outlined in this SOP are based on the following general attributes that are important in influencing fish habitat within a given stream. These include:

- channel dimensions, gradient, and velocities
- channel substrate size and type
- habitat complexity and cover
- riparian vegetation cover and structure
- anthropogenic alterations or disturbance

The methods outlined in this SOP and the field sheet (Detailed Fish Habitat Assessment – Streams", Appendix A, herein referred to as "field sheet") were derived from the following sources:

- The Nova Scotia Fish Habitat Assessment Protocol: A Field Methods Manual for the Assessment of Freshwater Fish Habitat (2018);
- DNR / DFO – New Brunswick Stream Habitat Inventory Datasheets;
- Standard Methods Guide for the Classification and Quantification of Fish Habitat in Rivers of Newfoundland and Labrador for the Determination of Harmful Alteration, Disruption and Destruction of Fish Habitat (2012);
- Reconnaissance (1:20,000) Fish and Fish Habitat Inventory (2001);
- The US EPA Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish (1999); and,
- The Canadian Aquatic Biomonitoring Network Field Manual, Wadeable Streams (2012)**.**

Specific stream terminology is used and referred to throughout the procedures outlined in Section 6. Definitions of specific terms and associated acronyms, as well as diagrams and calculations are provided in a Glossary at the end of the document (Section 8).

For larger river systems (typically 3rd order streams and over), detailed, low-elevation aerial imagery can be interpreted to support habitat descriptions. This technique is particularly useful when habitat complexity increases or water depths/flows reduce wadeability. In addition, aerial imagery interpretation is helpful when assessing areas that have been historically altered through anthropogenic activities, such as freshwater systems that have been ditched or diverted, which are difficult to delineate in the field.

Low-elevation aerial imagery is especially effective in determining channel dimensions (bankfull and wetted widths) and instream habitat features (e.g. islands, gravel bars, etc.) for larger rivers that are not obscured by crown closure. However, for smaller, headwater streams, channel size and crown closure eliminate the effectiveness of aerial interpretation. Drones can be used to collect fine-scale aerial imagery if not already publicly available. Whenever possible, aerial imagery should be followed with field verification using the procedures outlined in this SOP.

5 MATERIALS

- standard MEL PPE
- chest waders with wading belt
- polarized sunglasses (useful for reducing glare)
- field sheets on write-in-the-rain paper
- pencils
- multi-parameter water quality instrument (YSI or equivalent)
- GPS
- velocity meter
- measuring tape
- meter stick (2 m length)
- clinometer
- phone or digital camera
- a copy of the Stream Habitat Mapping Legend (Appendix B)

6 FISH HABITAT ASSESSMENT METHODS – PROCEDURES

A watercourse, as defined in Section 2, is bound by distinct downstream and upstream endpoints when delineated in the field. MEL biologists typically identify unnamed, linear watercourses with numbers starting with first-order, headwater streams. When first order streams combine, the second order stream will be designated with a new number, unless flow is significantly disproportionate across headwater streams (i.e. one first-order stream contributes the vast majority of flow to the second order stream).

A reach is length of stream comprising one homogenous habitat type (i.e. a run). Reaches are numbered from an upstream – downstream orientation. Larger streams comprising variable habitat types are therefore divided into multiple reaches. In smaller, first-order streams, major habitat types may be so short as to not warrant the continuous establishment of very small reaches. For efficiency in the field, <u>when individual habitat types are small in overall length (<5 m), they may be lumped together into one reach.</u>

A **transect** is a particular location within a reach where a cross-sectional survey is performed. A transect is line across a stream perpendicular to the flow and along which measurements are taken (e.g. velocities, depths, etc.), so that morphological and flow characteristics along the line are described from bank to bank. Transects are numbered from an upstream-downstream orientation. For the purposes of this SOP, one transect is to be completed for every 50 m length of reach (e.g. if a run is 150 m in length, 3 transects would be established along the run). If multiple habitat types have been lumped together (< 5 m in length) to form a reach, a transect must be established within each habitat type represented within the reach. However, the amount of transects and transect locations may be shifted slightly or altered during the field assessment based on specific habitat features observed, or access, wadeability, and safety concerns.

The watercourses to be surveyed will be defined by the Project Coordinator – these may comprise an entire watercourse, or a section of a watercourse.

The procedures outlined in Section 6 include both reach-scale and transect-scale data collection – that is to say that some measurements are taken repeatedly at cross-sections (predominantly quantitative measurements), whereas other measurements are based on reach averages (predominantly qualitative, visual-based assessments). Generally speaking, a detailed habitat assessment for streams involves walking the length of the watercourse chosen for assessment, establishing reaches for each change in habitat type, and stopping to take specific cross-sectional measurements along the length of each reach.

6.1 Planning: Before You Leave

1. Review detailed written scope provided to you by the Project Coordinator. This will identify priority deliverables, timelines, and budget allowed for each task. Detailed methods should be provided in this scope (i.e. watercourses to be surveyed).
2. Determine your field crew – fish habitat assessments should be completed with a minimum crew size of 2 people.
3. Determine the location(s) of the survey, size of area to be surveyed and easiest access to the site based on the work scope provided by the Project Coordinator. Sample design should be verified by the Project Coordinator.
4. Complete a review of available data from watercourse delineation surveys. If fish collection surveys have been completed, review the results of those surveys prior to commencing field work. A desktop review of fish species distribution records should be conducted if no fish collection surveys have been completed.
5. Print field sheets and prepare site maps and GPS units as required.
6. Fill out a field tracking sheet. Have all crew members review and sign off on the field tracking sheet.

6.2 Field Procedure

6.2.1 Site Setup

1. It is preferable to begin surveys at the top (upstream end) of the watercourse to be surveyed as reaches and transects are to be numbered in an upstream-downstream orientation.
2. Record general survey data including Project name, date, crew member names, weather, and watercourse identification information. If stream order is known, record on the field sheet. Stream order can be identified through desktop mapping prior to or after field data collection.
3. Begin to establish a reach. Identify the habitat type present. If smaller (<5 m in length) habitat types are to be lumped together, identify all present. Record the upstream boundary coordinate (for smaller reaches the upstream and downstream coordinates can likely be established at the same time). For longer reaches, when the downstream end can't be seen from the upstream end, the downstream boundary coordinate can be recorded once the entire reach has been surveyed.
4. Describe and record general reach characteristics including flow type and entrenchment.
5. Measure the gradient of the stream:

- If conditions allow (clear visibility of the meter stick is obtainable along the entire reach), measure the gradient of the reach in the field using a clinometer. To use the clinometer, first determine the height from the ground to the eyes of the person holding the clinometer. This height can be flagged on the meter stick, which will be held vertical from the base of the survey point by a second team member at the downstream end of the reach. Starting at horizontal from the upstream end of the reach, the observer will tilt or lower the clinometer until it is aligned with the flagged point on the meter stick, and then will read the degrees changed off the clinometer.
- If the clinometer cannot be used to measure gradient in-field, estimate the gradient based on the following morphological thresholds:
  i. <1% (flat)
  ii. 1-4% (riffle/run)
  iii. 4-7% (rapids)
  iv. >7% (step-pool, cascade, falls)
- Estimated gradients should verified by desktop mapping using elevation data such as Digital Elevation Models (DEM) or Google Earth.

6. Measure and record water quality parameters, including temperature, conductivity (SpC), total dissolved solids (TDS), pH, dissolved oxygen (DO). Record turbidity based on a visual assessment of the watercourse if not included as a parameter on the water quality meter (refer to Section 8 – Glossary).
7. Begin a field sketch (aerial view) which will be completed for each reach. The Stream Habitat Mapping Legend (Appendix B) can be used as a drawing and labelling guide. Note the locations of the transects and width measurements used in the assessment. Indicate left and right banks, flow direction, orientation, significant landmarks and landscape, barriers, channel shape and habitat types.

   Note: the legend presented in Appendix B is extensive and incorporates a number of habitats/features that MEL biologists do not frequently encounter within Nova Scotia's headwater inland systems. New symbols/labels can be created so long as they are described in a legend superimposed on the field sketch.

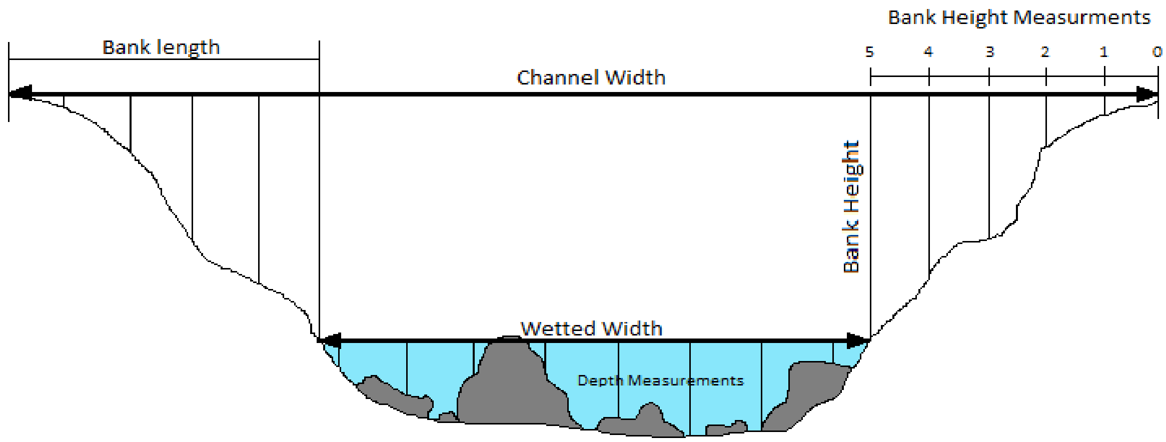
6.2.2 <u>Transects</u>

Record the GPS location (waypoint) of each transect surveyed. Identify each transect with a sequential number from upstream to downstream. A transect must be established for every 50 m of a particular habitat type (reach). If smaller habitat types (< 5 m in length) have been lumped together into a single reach, a transect must be established within each habitat type represented.

1. Record the habitat type being surveyed.
2. Begin measuring the channel cross-section from the left bank looking downstream. Pin the measuring tape into the banks or have a crew member hold the tape at the bankfull level and record the bankfull width on the field sheet. Keep the measuring tape in this position for the duration of cross-section measurements.
3. Measure and record wetted width.
4. Record bank height measurements from the both the left and right banks out to the wetted width of the stream (see diagram below – this is also provided on the field sheet). To do this, divide each bank into equidistant intervals (5 is typical for larger streams but this may be reduced for smaller streams, particularly when bankfull width and wetted width are similar). The distance to

be recorded refers to the distance from each bank as noted on the measuring tape (left bank would be '0', right bank would be the full bankfull width). Using a meter stick, measure the height of the bank (as inferred from the measuring tape across the stream) from the substrate. Note that if wetted width is equal to bankfull width, only one bank height measurement would be recorded for both the left and right bank (at '0' and at full bankfull width). Also note that left and right bank may vary in terms of distance to the wetted stream.

5. When wetted widths are > 1 m, perform a <u>minimum of 10</u> depth and velocity measurements at equidistant intervals along the transect (see diagram below). If wetted width is < 1 m, record 3 depth and velocity measurements. Starting at the left bank, use the meter stick and a velocity meter to determine the depth of the water and water velocity at equal distances cross the wetted portion of the cross-section. Velocity measurements should be taken at 0.6 water depth. The distance to be recorded refers to the distance from the left bankfull width as recorded from the measuring tape (left bank would be '0'). Use the water level on the downstream side of the meter stick to determine depth as the level on the upstream side may be affected by stream velocity. An estimated negative depth, or height above the water level, should be taken if a measurement is located with no water depth in the adjacent area (an island or section of riffle with no significant depth or flow). A measurement of zero can also be taken if the river bottom is approximately the same height as the water level.



6. If substrate varies significantly at the transect location from that estimated for the entire reach (which may occur if smaller habitat types are lumped together), note it on the field sheet and record percent composition by substrate type.
7. Take representative photos at each transect of the following:
    a. Looking upstream
    b. Looking downstream
    c. Right bank (downstream orientation)
    d. Left bank (downstream orientation)
    e. Substrate

6.2.3 <u>Between Transects</u>

1. Once transect measurements are complete begin walking to the next transect location.
2. Note, waypoint, and photograph any unique habitat features or observations, including any information that will aid in producing a field sketch for the site:
    - Areas of upwelling or groundwater seeps
    - Gravel or point bars

- Ice scarring
- Beaver dams
- Back channels or off-channel habitats
- Islands
- Potential spawning areas (e.g. redds)
- Culverts

3. Note any potential barriers to fish passage/migration observed and mark and record their waypoints. Describe the permanency of the barrier – for example, barriers like waterfalls are permanent whereas a channel may be seasonally dry. Record any applicable measurements or observations of the barrier on the field sheet. Take photos and/or videos of each potential barrier. Refer to the Glossary (Section 8) for details on barriers to fish passage.
4. Once the next transect is reached, repeat procedures outlined in Section 6.2.2.

6.2.4 Reach Assessment

1. Once all transect cross-section measurements are taken within a reach, estimate the percent composition of streambed substrates according to the categories identified on the field sheet. Substrates categories are defined by the length of the intermediate axis (see Glossary for details).
2. Record the average degree of embeddedness of the substrate (see Glossary for details).
3. Conduct a pebble count whenever conditions are suitable. To conduct a pebble count, streams must be wadeable across the entire transect and the majority of the substrate must be of mineral origin. Pebble count tables are provided at the end of the field sheet:
    - Measure the intermediate axis of 100 randomly chosen rocks. One crew member will conduct the pebble count while the other crew member records the count measurement on the field sheet.
    - Beginning at one bank of the channel cross section, begin walking to the opposite bank, putting one foot directly in front of the other. Lean down and touch the substrate material that is nearest to the toes on your front foot without looking.
    - Pull out the material (if possible) that the tip of your finger is touching. Be careful not to bias the substrate to the largest pebble nearest to your finger rather than the one touching your finger. Do not bias the selection by avoiding larger boulder on the stream bed when walking across the stream.
    - Measure its intermediate axis in centimeters (cm). This is the diameter perpendicular to the longest axis (see Glossary for diagram). If the rock cannot be pulled out then measure it in the water. Relay the diameter (to the nearest 10th of a cm) to the other crew member. The recording crew member will record the measurement in the pebble count table on the field sheet.
    - Continue walking and measuring until 100 measurements are recorded. If the measuring crew member reaches the opposite bank before 100 measurements are taken, begin a zig-zag pattern through the stream, walking one foot in front of the other from bank to bank.
4. Estimate the amount of in-stream cover available within the entire reach. Record the percent area of the stream within the reach that each cover-type provides as potential refuge for fish. Note that overhanging vegetation must be within 1 m of the water's surface to count as cover. To assess whether pool depth provides cover, hold your boot above the bottom of the pool to what would be equivalent to residual depth of the pool. If you cannot see your boot, you can consider that area as instream cover. Add cover percentages of all cover types within the reach to obtain total instream cover.

5. For riparian areas, estimate the percentage of ground covered by trees, shrubs, grasses (includes sedges and ferns, and bare ground within 10 m from the bank's edge within the reach and record them on the field sheet. These values may add to more than 100%, as there can be different levels of vegetation covering the same area of ground.
6. Estimate the percentage of both left and right riverbanks within the reach with active erosion.
7. For the entire reach, estimate the percent stream shade and record it on the field sheet.
8. For the entire reach, identify the dominant riparian vegetation category on the field sheet (Grass, Shrub, Coniferous Forest, Deciduous Forest, Mixed Forest, Wetland, or None).
9. Finish the field sketch (aerial view) for the entire reach, using the Stream Habitat Mapping Legend as a guide. Note the locations of the transects used in the assessment. Indicate left and right banks, flow direction, orientation, significant landmarks and landscape features, barriers, channel shape and habitat types.

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8 GLOSSARY

Bankfull Level – the level of water flow in a river just before it spills over the banks into the floodplain. The bankfull level can be identified by changes in bank angle, vegetation, and soils.

Bankfull Width (i.e. channel width) - the width of the river channel at the bankfull level.

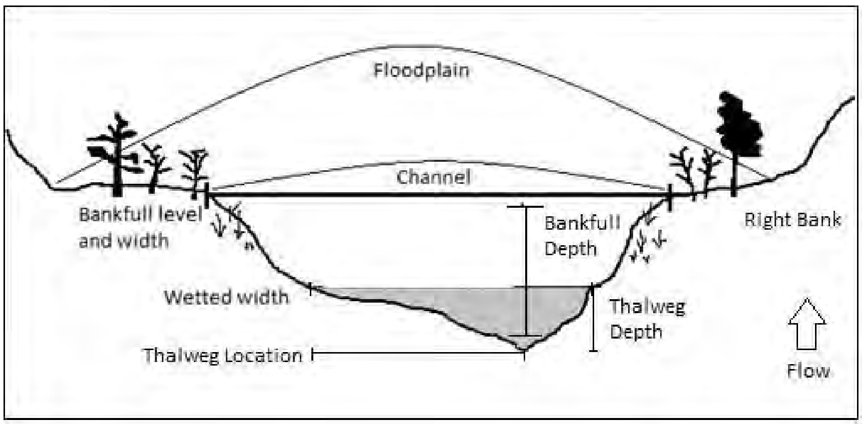


Image 1: Components of a channel cross-section

Barrier - areas or objects that may potentially be barriers to the movement of fish. Barriers can be natural (e.g. waterfalls), or man-made (e.g. culverts). Water velocity can also act as a barrier when the velocity (due to constriction or some other variable) is too great for fish to swim against. It is important to document all barriers or obstructions for each section of stream that is assessed. Record the following information for all barriers observed, when applicable:

- type of barrier
- location of barrier (waypoint)
- barrier permanency
- vertical height of the barrier (measured or estimated)
- length and width of the barrier
- slope of the barrier
- additional observations that help to describe the obstruction

Embeddedness - refers to the degree larger substrate is surrounded by finer sand and silt material that fills in spaces between the individual rocks. Highly embedded substrate limits spawning and rearing success of fish, reduces habitat for benthic macroinvertebrates, and impairs a river's ability to form a thalweg and transport material. A stain line on the rock may indicate the level of burial and aid in the estimation. Note: Bedrock would be recorded as unembedded. Sandy or organic substrate is recorded as completely embedded because it is embedded within itself.

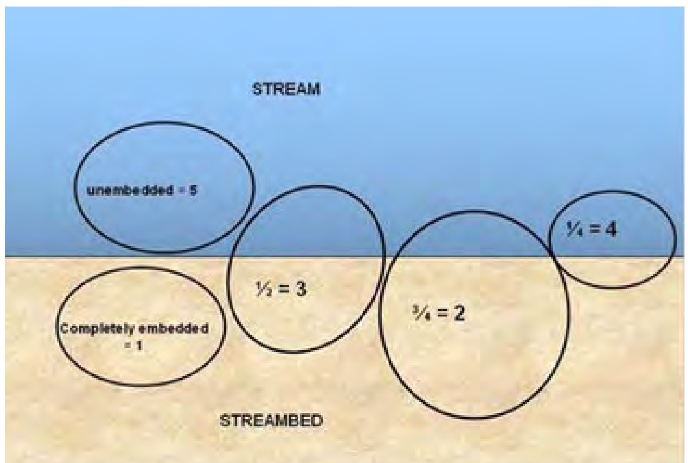


Image 2: Varying substrate embeddedness (Source: EC, 2012)

Entrenchment - the vertical containment of a stream, or the disconnection of the channel from a floodplain. A stream may also be entrenched by the use man-made berms. In streams that are highly entrenched, overbank flooding occurs less frequently than less entrenched streams. For the purposes of this SOP, entrenchment is qualitatively described in the field through a visual assessment, and is categorized as one of the following: Highly Entrenched (HE), Moderately Entrenched (ME), Slightly Entrenched (SE), or Not Entrenched (NE). "Not Entrenched" streams are typically associated with streams areas that have no defined channel (see "Habitat Types" for description).

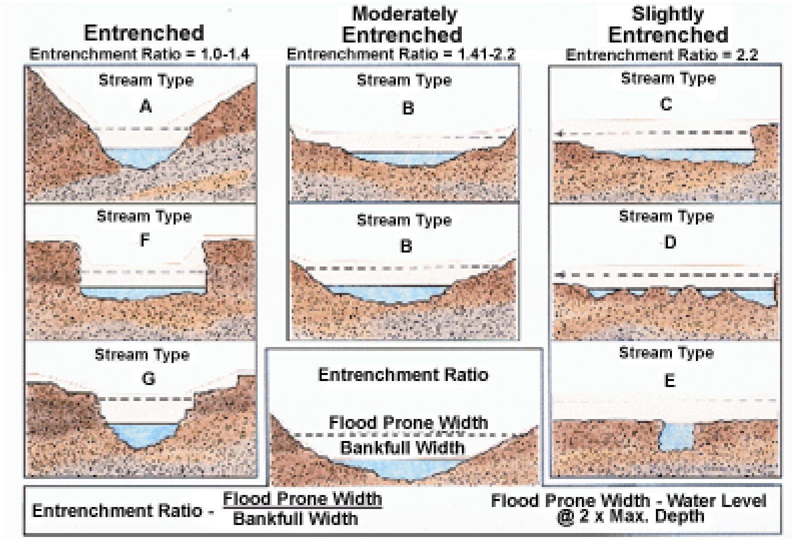


Image 3: Degrees of entrenchment (the term "entrenched" equates to "highly entrenched" for the purposes of this SOP. Source: https://cfpub.epa.gov/watertrain/moduleFrame.cfm?parent_object_id=1259)

Erosion - an area of slumping displaying a loss of bank material. Do not confuse an eroded band with undercut bank. While eroding forces create undercut banks these banks tend to remain stable due to an established root system.

Flow Type – refers to the presence of flowing water within a stream on a temporal scale. For the purposes of this SOP, streams are categorized into the following flow types (source: AT, 2009):

- **Perennial (P) -** A stream that flows continuously throughout the year.
- **Intermittent (I) -** Streams that go dry during protracted rainless periods when
- percolation depletes all flow.
- **Ephemeral (E) -** A watercourse that flows during snowmelt and rainfall runoff periods only.

Any watercourse or watercourse reach may have components of each flow type. For instance, perennial, with intermittent sections.

Gradient - The slope of the stream, or rate of vertical drop per unit of length of the channel bed (presented as a percentage). The following is a simple desktop method using Google Earth to determine stream gradient. This method will not be as precise as a direct field survey but should provide a good estimate of stream gradient:

Using Google Earth, determine the elevation at the upstream extent of the stream (the beginning) and the downstream extent (the end). If you are looking for the slope of a particular section (i.e. reach) instead of the entire stream, use the boundaries of the survey section for your endpoints.

Calculate **Rise** by subtracting the elevation at the downstream extent from the elevation at the upstream extent. Determine **Run** by measuring the length of the stream using the Google Earth ruler tool.
Use the following basic formula to calculate the stream's slope/gradient:

SLOPE = RISE / RUN

Habitat type - a categorical description of the types of aquatic environments within a stream. Habitat types that are commonly encountered include:

- **Riffle** - a shallow and fast section of stream with, often within a series of pools and runs. Water flow is agitated and surface is broken by rocky substrate, which appears turbulent. Substrate is coarse (gravel – cobble dominated).

Image 4: A riffle (Source: http://smallstreamreflections.blogspot.com/2017/05/in-riffles.html)

- **Pool** – a deep and slow section of river, generally occurring near the corners of meanders, or created by the vertical force of water falling down over logs or boulders. Pools have a rounded bottom and may comprise the full or partial width of the stream. For the purposes of this SOP, a pool is defined as having a minimum residual depth of 20 cm.
- **Run** - an area of stream characterized by moderate current, continuous, smooth surface and depths greater than riffles. Runs are stretches of the stream, typically downstream of pools and riffles, where stream flow and current are moderate.

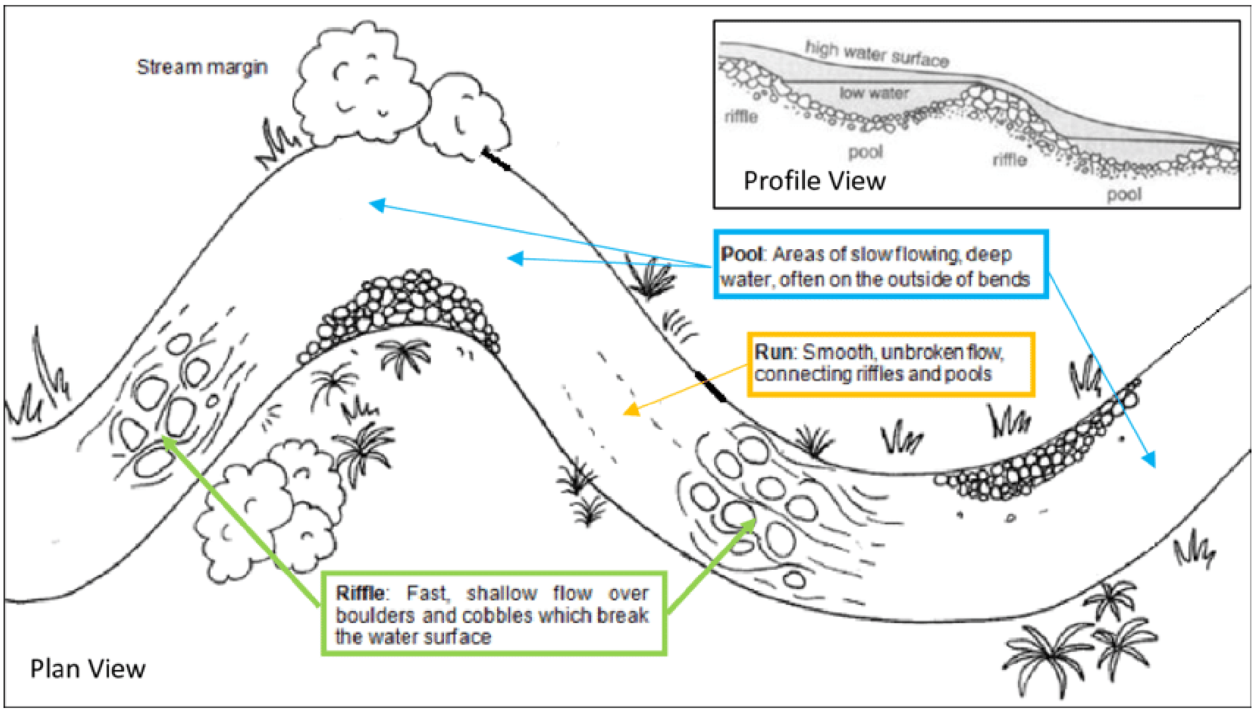


Image 5: A typically riffle-run-pool sequence within a stream (Source: https://www.researchgate.net/figure/Elements-of-a-river-reach-pool-riffle-and-run_fig13_322765638)

- **Rapids** – area of steeper gradient with irregular and rapid flows, often with turbulent white waters. Deeper than riffles, with substrate being extremely coarse (large cobble – boulder).

- **Chute/Falls/Cascade –** Significant white water present. Can be an area of channel constriction, usually due to bedrock instructions. Associated with a rapid change in stream gradient with most water free-falling over a vertical drop or series of drops.

Image 6: A cascade

- **Step-pool** – a series of staircase like pools which occur in steeper channel sections. Each pool has a defined step made of larger substrate, followed by a drop into a pool.

Image 7: Step-pool habitat (Source: https://www.researchgate.net/figure/Artificial-step-pool-sequence-in-the-Mala-Raztoka-Brook_fig6_277075982)

- **Flat –** associated with low gradient streams, water is very smooth (flow is not obvious), and substrate often comprises organic matter, mud, and sand. Area characterized by low velocity and near-uniform flow; differentiated from pool habitat by high channel uniformity.

Image 8: A flat

- **Boulder-bed –** area characterized by a significant occurrence of large boulders as a result of glacial till deposits. Water may be visible between boulders or heard flowing subsurface

Image 9: A boulder-bed

depending on the time of year of the survey. Channel dimensions may be obscured. Boulders may be bare or have vegetation cover (typically mosses or alders).

- **No defined channel (NDC)–** typically occurring in small headwater streams, these areas are more accurately characterized as general drainage, with poorly or no defined channel banks and substrates largely comprised of organic forest soils. Water flow is diffusely spread out (i.e. sheet flow). Often associated with wetland habitat. NDCs may have diffused standing water during higher seasonal flow periods, or may be completely dry and lacking surface water of any kind, but may act as a connection between defined channels upstream and downstream.

Image 12: An area of a stream with NDC during high flow

Image 11: An area of a stream with NDC during low flow

The following table provides additional detail to aid in identificaiton of habitat types (McCarthy, Grant, and Scruton, 2006).

Habitat Type	Habitat Parameter	Description
Fast Water	**Mean Water Velocity**	**> 0.5m/s**
	Stream Gradient	**Generally > 4%.**
Rapid	General Description	Considerable white water[1] present.
	Mean Water Velocity	> 0.5 m/s
	Mean Water Depth	< 0.6 m
	Substrate	Usually dominated by boulder (Coarse[2]) and rubble (Medium[2]) with finer substrates (Medium and Fine[2]) possibly present in smaller amounts. Larger boulders typically break the surface.
	Stream Gradient	Generally 4-7%
Falls/ Chute/ Cascade	General Description	Mainly white water present. The dominating feature is a rapid change in stream gradient with most water free-falling over a vertical drop or series of drops.
	Mean Water Velocity	> 0.5 m/s
	Mean Water Depth	Variable and will depend on degree of constriction of stream banks.
	Substrate	Dominated by bedrock and/or large boulders (Coarse).
	Stream Gradient	> 7% and can be as high as 100%.
Run	General Description	Relatively swift flowing, laminar[3] and non-turbulent.
	Mean Water Velocity	> 0.5 m/s
	Mean Water Depth	> 0.3 m
	Substrate	Predominantly gravel, cobble and rubble (Medium) with some boulder (Coarse) and sand (Fine) in smaller amounts.
	Stream Gradient	Typically < 4% (exception to gradient rule of thumb)
Moderate Water	**Mean Water Velocity**	**0.2-0.5m/s**
	Stream Gradient	**>1 and < 4%**
Riffle	General Description	Relatively shallow and characterized by a turbulent surface[4] with little or no white water.
	Mean Water Velocity	0.2 – 0.5 m/s
	Mean Water Depth	< 0.3 m
	Substrate	Typically dominated by gravel and cobble (Medium) with some finer substrates present, such as sand (Fine). A small amount of larger substrates (Coarse) may be present, which may break the surface.[5]
	Stream Gradient	Generally >1 and < 4%
Steady/ Flat	General Description	Relatively slow-flowing, width is usually wider than stream average and generally has a flat bottom.
	Mean Water Velocity	0.2 - 0.5 m/s
	Mean Water Depth	>0.2 m
	Substrate	Predominantly sand and finer substrates (Fine) with some gravel and cobble (Medium).
	Stream Gradient	> 1 and < 4%
Slow Water	**Mean Water Velocity**	**Generally < 0.2m/s (some eddies can be up to 0.4m/s).**
	Stream Gradient	**< 1%.**
Plunge / Trench / Debris Pools	General Description	Generally caused by increased erosion near or around a larger, embedded object in the stream such as a rock or log or created by upstream water impoundment resulting from a complete, or near complete, channel blockage. These pool types may be classified as an entire reach (e.g., pools greater than 60% of the stream width) or as sub-divisions of a fast water habitat.
	Mean Water Velocity	< 0.2 m/s
	Mean Water Depth	> 0.5 m depending on stream size (e.g., may be shallower in smaller systems).
	Substrate	Highly variable (i.e., coarse, medium or fine substrates)
	Stream Gradient	Generally < 1%
Eddy	General Description	Relatively small pools caused by a combination of damming and scour; however scour is the dominant forming action. Formation is due to a partial obstruction to stream flow from boulders, roots and/or logs. Partial blockage of flow creates erosion near obstruction. It is typically < 60% of the stream width and hence will be a sub-division of a faster-water habitat type (e.g., Run with 20% eddies).
	Mean Water Velocity	Typically < 0.4 m/s, but can be variable.
	Mean Water Depth	> 0.3 m. May vary depending on obstruction type, orientation, streambed and bank material and flows experienced.
	Substrate	Predominantly sand, silt and organics (Fine) with some gravels (Medium) in smaller amounts.
	Stream Gradient	Variable

1 White water is present when hydraulic jumps are sufficient to entrain air bubbles which disturb the water surface and reduces visibility of objects in the water.

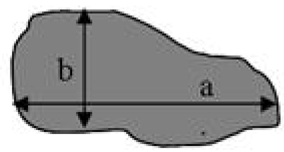
2 Coarse, Medium and Fine substrate types are classified according to the Standard Methods Guide for the Classification/Quantification of Lacustrine Habitat in Newfoundland and Labrador (Bradbury *et al*. 2001).

3 Laminar describes the surface of the water as smooth and glass-like with no reduced visibility of objects in the water.

4 Turbulence is present if there are local patches of white water or if water movement disturbs a portion of the surface.

5 Pocket water often constitutes an important component of riffles in Newfoundland and Labrador and is characterized by a predominance of larger substrates (e.g., boulders) breaking the surface. The result is a riffle with many eddies around the boulders.

Intermediate Axis - the axis on which the pebble will roll down the stream.



The intermediate axis of a substrate (b).

Image 13: (Source: EC, 2012)

Instream Cover - includes large woody debris, undercut banks, unembedded large substrate, aquatic vegetation, deep pools, and overhanging vegetation within 1 m of the water's surface. These features provide valuable refuge and resting areas for fish. As the instream features become embedded by fine silt and sand, cover for fish is reduced. To be considered viable instream cover for this assessment, areas must be obscured from the surface by the cover element itself (boulder, LWD, vegetation, bank).

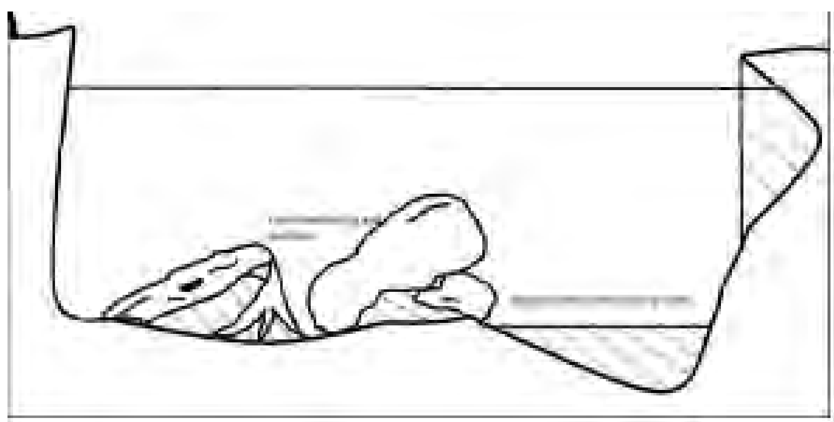


Image 14: Example of cover types within a transect (Source: NSHSI, 2018)

The following terms may be used to guide the description and identification of cover. Bolded cells indicate categories of in-stream cover, specifically.

Large Woody Debris	Fallen trees, logs and stumps, root wads, and piles of branches within or along the edges of streams.
Boulders	Large substrate under which fish can hide. Refuge for fish must be provided between the boulder and the channel bottom (i.e. a boulder that is complete embedded does not provide in-stream cover).
Undercut Banks	An undercut bank occurs when the river cuts into the bank, removing rocks and soil while leaving some portion of the bank overhanging the river. Undercut banks generally are stabilized by the presence of vegetation and roots that hold the topsoil intact.
Deep Pools	To assess whether pool depth provides cover, hold your boot above the bottom of the pool to what would be equivalent to residual depth of the pool. If you cannot see your boot, you can consider that area as instream cover.

Overhanging vegetation	Riparian cover overhanging the stream. Note: overhanging over must be within 1 m of the water's surface to count towards in-stream cover.
Emergent vegetation	Aquatic plants growing above or extending above the water surface (e.g. cattails, sedges, grasses, rushes)
Submergent vegetation	Aquatic plants that grow entirely below the water surface (e.g., elodea, bladderwort, pipewort, potamogeton), and includes numerous mosses and macroalgae)

Riparian Area – strip of land adjacent to watercourses which plays an important role in stream productivity and overall function. For the purposes of this SOP, the riparian area is considered all ground within 10 m from the bank's edge.

Redd – salmonid spawning nests. Characterized as circular to oblong patches of recently cleaned, gravel-cobble-sized substrate that contrasts the surrounding substrate. Redds typically have a depression from the surrounding substrate and may have a 'mound' on the downstream end of the disturbance. If identified, redds would be measured, photographed and their location recorded on GPS.

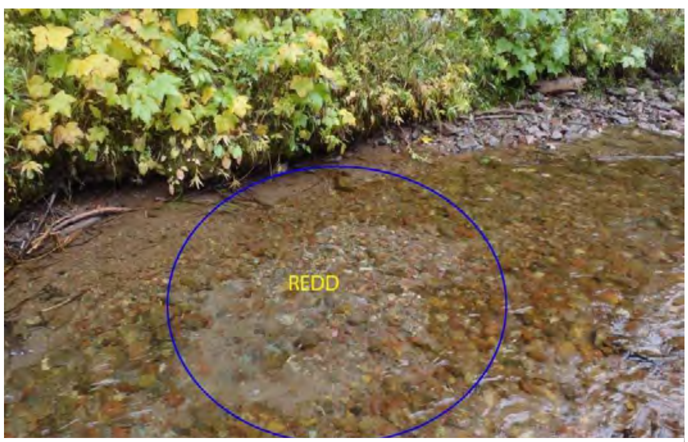


Image 15: A salmonid redd (Source: https://www.tu.org/blog/redd-surveys-shaping-priorities-in-michigans-pere-marquette/)

Stream Order - the hierarchical ordering of streams based on the degree of branching. It is a simple quantitative method to categorize stream segments based on their relative position within the drainage basin. Stream order provides a general indication of stream size, stream function and energy sources. Determine the stream order by labeling the first stream at the head of the watershed as 1 and increasing the order by 1 each time two streams of the same order join until you reach the watercourse/watercourse reach being assessed.

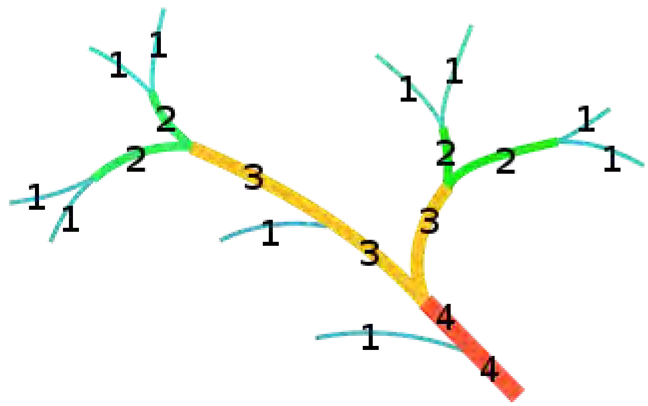


Image 16: Example of stream order classifications (based on Strahler, 1957).

Stream Shade – this is the canopy cover created by riparian vegetation above the stream. Midday sun is the most direct and influential on stream temperatures, so shade estimates should be made between 10:00 am and 2:00 pm, when possible.

Substrate Types – The following table may be used to aid in identification of substrate types (from DFO 2012).

Bedrock	Continuous solid rock exposed by the scouring forces of the river/stream
Boulder	Rocks ranging from 25cm to >1 m in diameter
Rubble	Rocks ranging from 14-25 cm in diameter
Cobble	Rocks ranging from 3-13 cm in diameter
Gravel	Small stones ranging from 2mm to 3 cm in diameter
Sand	Grains ranging from 0.06 to 2 mm in diameter, frequently found along stream margins or between rocks and stones.
Silt	Very fine sediment particles, usually <0.06 mm in diameter
Muck/detritus	Organic material from dead organisms (plant and/or animal)
Clay/mud	Find deposits between rocks and covering other substrates

Transect - A line across a stream perpendicular to the flow and along which measurements are taken, so that morphological and flow characteristics along the line are described from bank to bank. For the purposes of this SOP, "transect" and "cross section" are used interchangeably.

Watercourse - Any provincially regulated watercourse as defined by NSE guidance (2015).

Watercourse Name - The official name of the stream being surveyed as referenced on provincial topographic maps. If no official name exists, enter "unnamed".

Watercourse Reach - A length of stream characterized by a single habitat type (e.g. a run). Complex streams will comprise many reaches. In smaller, first-order streams, major habitat types may be so short as to not warrant the continuous establishment of very small reaches. When individual habitat types are small in overall length (<5 m), they may be lumped together into one reach.

Wetted Width – the width of the stream that contains water at the time of the assessment.

Turbidity - The concentration of suspended sediments and particulate matter in the water. Measure of the relative clarity of a liquid. If not measured, turbidity is to be visually assessed and recorded based on the following codes:

- T (Turbid) - very turbid or muddy appearance, objects visible to 15 cm depth
- M (Moderately Turbid) - cloudy, objects visible to 45 cm depth
- L (Lightly Turbid) - occasionally cloudy, objects visible to 1 m
- C (Clear)

McCallum Environmental Ltd.

APPENDIX A

Detailed Fish Habitat Assessment – Streams

Detailed Fish Habitat Assessment - Streams

General Survey Data			
Project:	Project #:	Date:	Surveyors:
Watercourse Name:	Watercourse #:	Reach #:	Stream Order:
Weather (℃, cloud %, precipitation):			
Reach Boundary Coordinates: U/S____________________________ D/S____________________________			
Photos: Transects ☐ Barriers ☐ Other Features (____)			

Reach Characteristics		
Reach Length (m):	Gradient* (%):	Entrenchment: HE ☐ ME ☐ SE ☐ NE ☐
Flow Type*: P ☐ I ☐ E ☐	Does reach include other habitat types (< 5 m in length)? ☐	
Habitat Type:	If applicable, check all habitat types included in reach: Riffle ☐ Run ☐ Flat ☐ Pool ☐ Cascade ☐ Step ☐ Other ☐ (_______________)	

Water Quality		
Temperature (℃):	pH:	Dissolved Oxygen (mg/L):
Conductivity:	TDS:	Turbidity (T, M, L, C, or NTU):

Substrate	
% Bedrock	
% Boulder (>25 cm)	
% Rubble (14-25 cm)	
% Cobble (3-13 cm)	
% Gravel (0.2-3 cm)	
% Sand (0.06-2 mm)	
% Silt (<0.006 mm)	
% Muck/Detritus	
% Clay/Mud	
Embeddedness (%)	
Pebble Count?	☐

Cover	
% Large Woody Debris	
% Boulders	
% Undercut Banks	
% Deep Pools	
% Overhanging Veg	
% Emergent Veg	
% Submergent Veg	
Total Cover (%)	

*P: perennial, I: Intermittent, E: Ephemeral
*Note methodology (clinometer, estimate, desktop). Categories for estimates: <1% (flat), 1-4% (riffle/run), 4-7% (rapids), >7% (step-pool, cascade, falls)

Banks and Riparian Area (Right and Left Banks are looking downstream)

Bank	**% Trees**	**% Shrubs**	**% Grass**	**% Bare**	**% Eroding**	**% Shade**	**Dominant Riparian Veg.**
Left Bank							Grass ☐ Shrub ☐ Coniferous Forest ☐ Deciduous Forest ☐ Mixed-wood Forest ☐ Wetland ☐ None ☐
Right Bank							

Barriers		
Types (circle all present): No visible channel Underground flow Velocity Beaver Dam Dry Falls Culvert Other (___________)	**Locations and Comments** (waypoint, height, width, slope of barrier and depth of plunge pool. Note any hydrological indicators if no visible channel or underground flow are circled):	**Permanency:** Permanent ☐ Temporary/Seasonal ☐ Undetermined ☐ Manmade ☐ **Date Observed:**

Date: Location: Assessor:

Detailed Fish Habitat Assessment - Streams

Note: Transect measurements are to be taken every **50 m** of a single habitat type (i.e. reach). If minor habitat types (<5 m) have been lumped into the overall reach, take representative transect measurements at each habitat type present. See diagram under “field sketch” for reference.

Transect Information		
Transect #:	Easting:	Northing:
Habitat Type:	Wetted Width (m):	Bankfull Width (m):

Cross-Section Measurements (all measurements in m, taken in increments from max bank out to wetted edge)							
Left Bank	Distance:						
	Height:						
Right Bank	Distance:						
	Height:						

Velocities (taken from left bank to right bank – left and right banks are looking downstream)										
Distance (m):										
Depth (m):										
Velocity (m/s):										
Substrate Obs:										

Photos: Downstream ☐ Upstream ☐ Left Bank ☐ Right Bank ☐ Substrate

Transect Information		
Transect #:	Easting:	Northing:
Habitat Type:	Wetted Width (m):	Bankfull Width (m):

Cross-Section Measurements (all measurements in m, taken in increments from max bank out to wetted edge)							
Left Bank	Distance:						
	Height:						
Right Bank	Distance:						
	Height:						

Velocities (taken from left bank to right bank – left and right banks are looking downstream)										
Distance (m):										
Depth (m):										
Velocity (m/s):										
Substrate Obs:										

Photos: Downstream ☐ Upstream ☐ Left Bank ☐ Right Bank ☐ Substrate

Transect Information		
Transect #:	Easting:	Northing:
Habitat Type:	Wetted Width (m):	Bankfull Width (m):

Cross-Section Measurements (all measurements in m, taken in increments from max bank out to wetted edge)							
Left Bank	Distance:						
	Height:						
Right Bank	Distance:						
	Height:						

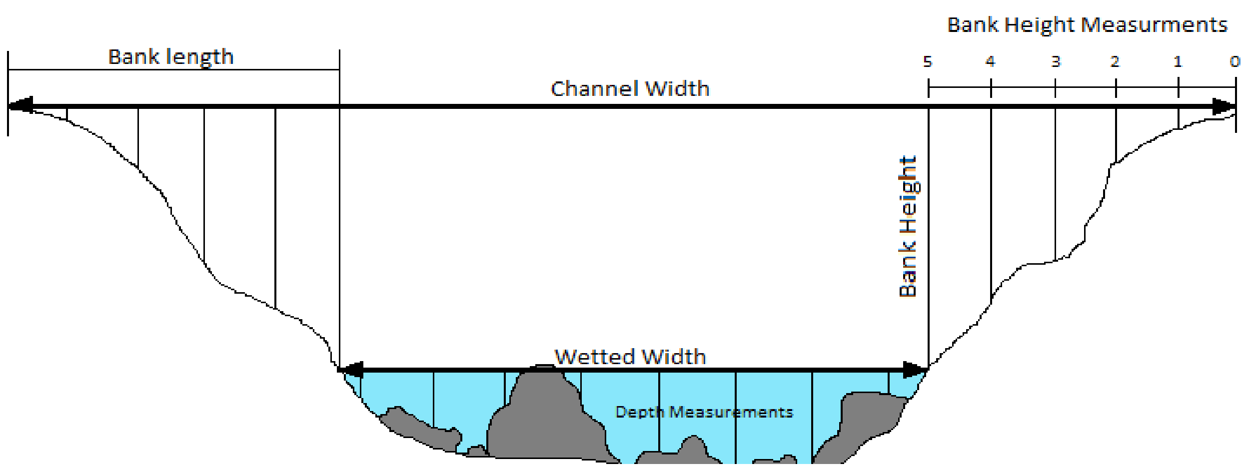
Velocities (taken from left bank to right bank – left and right banks are looking downstream)										
Distance (m):										
Depth (m):										
Velocity (m/s):										
Substrate Obs:										

Photos: Downstream ☐ Upstream ☐ Left Bank ☐ Right Bank ☐ Substrate

Date: Location: Assessor:

Detailed Fish Habitat Assessment - Streams

Field Sketch



Date:

Location:

Assessor:

Detailed Fish Habitat Assessment - Streams

Pebble Count: Transect #___. Record intermediate axis in cm.

Pebble Count: Transect # ___. Record intermediate axis in cm.

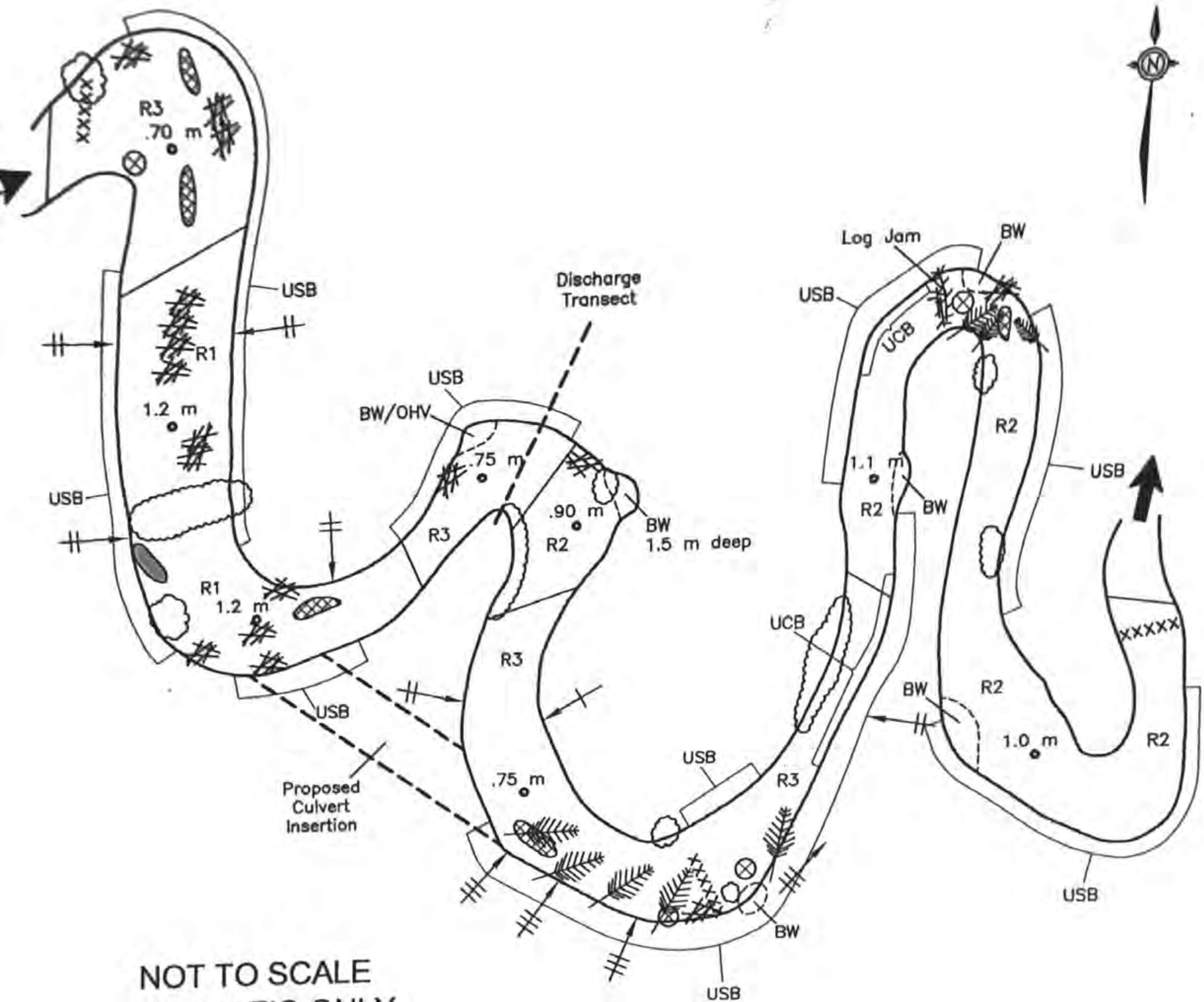
Pebble Count: Transect # ___. Record intermediate axis in cm.

Pebble Count: Transect # ___. Record intermediate axis in cm.

Date: Location: Assessor:

APPENDIX B

Example Stream Habitat Mapping Legend



NOT TO SCALE
SCHEMATIC ONLY

LEGEND - STREAM HABITAT MAPPING SYSTEM

Channel Unit/Habitat Type:

FA	Falls; Very Swift, Vertical Drop; Impassable to Fish
CA	Cascade; Very Swift, Turbulent; Passable to Fish
CH	Chute; Channel Restricted, Swift, Moderate Depth
RA	Rapids; Very Swift, Deep, With Cover
RF	Riffle; Swift, Shallow, Turbulent
R1	Class 1 Run; Moderately Swift, Deep With Cover
R2	Class 2 Run; Moderately Swift, Moderate Depth and Cover
R3	Class 3 Run; Moderately Swift, Shallow, Limited Cover
FL	Flat, Slow, Laminar Flow, Depositional
P1	Class 1 Pool; Slow, Deep
P2	Class 2 Pool; Slow, Moderate Depth
P3	Class 3 Pool; Slow, Shallow
IP	Impoundment Pool; Pool Formed by Dam
BW	Backwater; Slow, Reverse Flow
BG	Boulder Garden
SN	Snye; Isolated Area of Zero Velocity
∘ 1.5 m	Indicates Channel Unit Depth
|	Channel Unit Divider

Substrate Particle Size:

Si	Silt (<0.06mm)
Sa	Sand (0.06 –2mm)
Gr	Gravel (2–64mm)
Co	Cobble (64–256mm)
Bo	Boulder (>256mm)
Bd	Bedrock

Shore and Bottom Slope:

- Flat (Shallow slope)
- Repose (moderate, stable slope)
- Steep Slope
- Vertical

Habitat Feature:

	Sand/Mud Bar
	Gravel Bar
	Island
	Woody Debris Pile
⊗	Root Wad
UCB	Undercut Bank (fish cover)
USB	Unstable Bank (slumping or eroding)
OHC	High Quality Overhead Cover
ISC	High Quality Instream Cover
LE	Ledge; Bedrock Intrusion, Vertical Drop
	Overhanging Vegetation (Tree)
	Overhanging Vegetation (Shrub)
	Overhanging Vegetation (Grass)
	Inundated Vegetation
SV	Submergent Vegetation
EV	Emergent Vegetation
TV	Terrestrial Vegetation
BA	Bare—no vegetation
SH	Shrubs
GF	Grass/Forbs
DF	Deciduous Forest
CF	Coniferous Forest
MW	Mixed Wood Forest
MT	Minnow Trap
BL	Beaver Lodge
XX	Beaver Dam
➔	Direction of Flow
⊙ᵀ	Benchmark