THE ENVIRONMENTAL HISTORY OF FIVE WATERSHEDS IN NOVA SCOTIA

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Table of Contents

List of Tables

List of Figures

I. Introduction

Nova Scotia is home to some of the oldest human settlements in Canada. This unique locus provides great opportunities to learn, but it also bestows a responsibility to protect the environment so that future generations may continue learning. As a recipient of the Oceans Protections Plan, Coastal Restoration Fund through the Department of Fisheries and Oceans Canada, the Maritime Aboriginal Peoples Council has completed the first year of a five-year project, “Rehabilitating and Restoring Unique Landscapes in Five Nova Scotia Watersheds”. This project aims to address regions of severe coastal erosion and significant barriers to fish passage within five watersheds in Nova Scotia. The area of interest, for this project, encompasses the Chiganois, Debert, Folly, Great Village and Portapique Watersheds of the inner Bay of Fundy (iBoF) (Figure 1). Each of these watersheds fall within the Sipekne’katik region of Mi’kma’ki.

The following report is the result of a seven-month study which sought to determine the natural history of the “Five Watersheds Project” area. In the seventeenth century, the implementation of the aboiteau, a structure halting the incoming flood tide, is of special significance since it drastically shaped the landscape of the region. Aboiteaux are presently in use across the province and act as a major barrier to fish passage. Consequently, the second part of this study examines tidal gate structures in other jurisdictions which improve fish passage and are applicable to the inner Bay of Fundy (iBoF) Atlantic Salmon (*Salmo salar)* region. Of the five watersheds, four are identified as critical habitat for the endangered iBoF Atlantic Salmon (*S. salar)*. Each aspect of this study was conducted while collaborating with federal and provincial government officials, experts, and local residents.

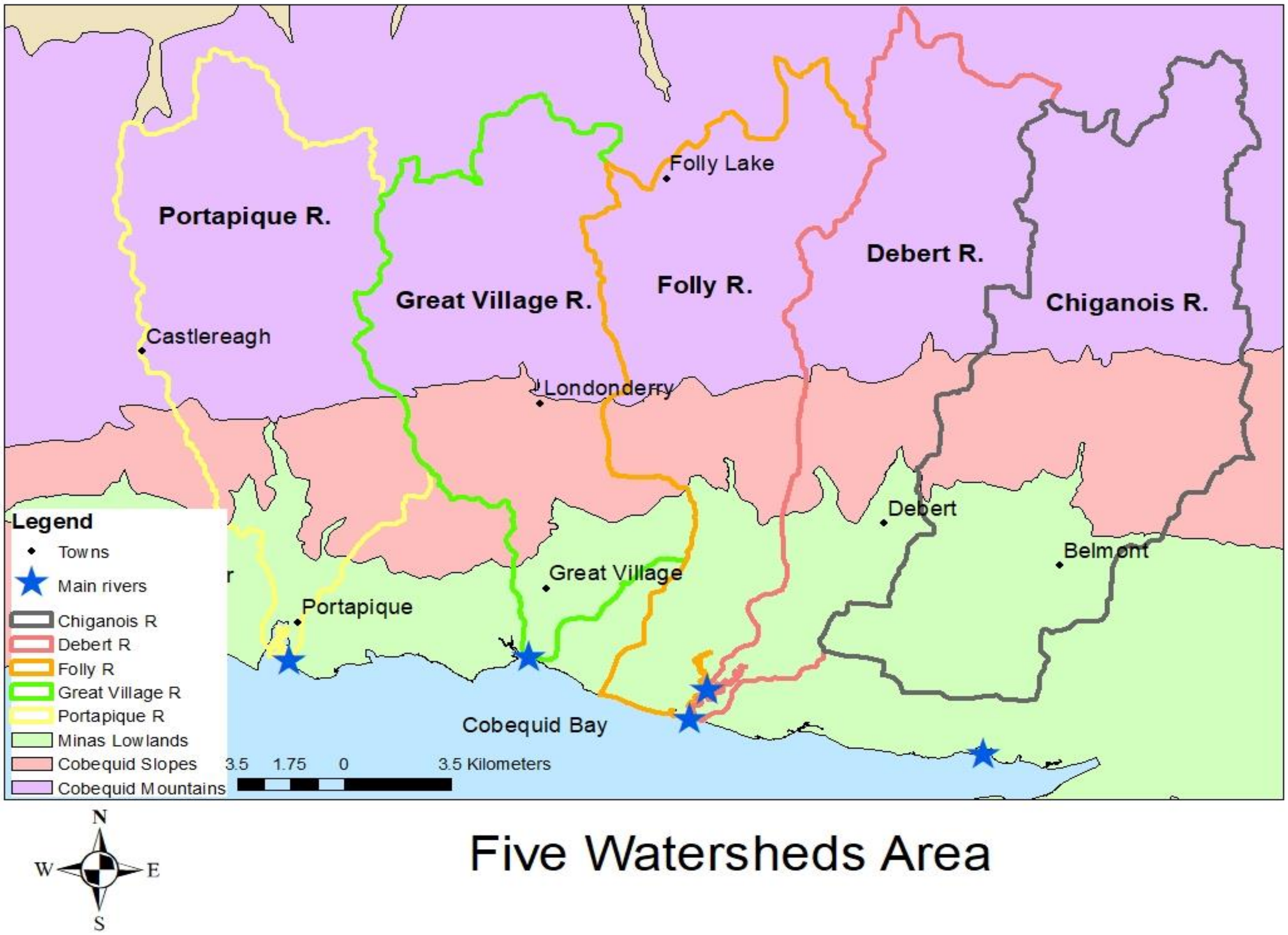

Figure 1. 1 Map of five focal watersheds for Maritime Aboriginal Peoples Council's project, "Rehabilitating and Restoring Unique Landscapes in Five Nova Scotia Watersheds".

II. Methods

The five focal watersheds and the topics of research for this seven-month project were provided upon award of the contract. Literary research began in mid-May 2018 and was concluded with submission of this report in mid-December 2018. Prior to interviews with residents of the “Five Watersheds Project” area, historians and archivists were visited to gain background information. These experts often suggested residents who were likely to be interested in the project. Upon interviewing residents, interviewees were asked if they could suggest any other residents to be interviewed. Interviews often took place at the homes of the interviewees where a project information sheet was provided, and interviewees signed a waiver providing anonymity for this report. Experts such as government officials and historians did not sign such a waiver. Interviewees and experts were not compensated financially.

Three community engagement sessions were held throughout the seven month research period, organized by the former Project Manager, Jamie Knill and the current Project Manager, Chelsey Whalen. The first was held at the Peg in Masstown on June 14, 2018, another at Lowland Gardens in Great Village on July 25, 2018 and the last at Masstown Market on October 17, 2018. The Project Manager and the Project Administrator, Abby MacLeod, advertised the sessions in the local newspaper and on the project’s social media pages. As the Project Researcher, flyers were e-mailed to key respective informants of the respective communities, who then posted the flyers in local churches and halls. During the engagement sessions, large maps of the project area were displayed, and information sheets were available.

III. Aboiteaux in the Maritimes: A Continuing Contribution

"Aboiteau", singular, or "aboiteaux", plural, is the local terminology used in the Maritimes for a tidal gate structure. It is French-Acadian in origin, although universally used throughout the Maritimes today. It has been suggested that the name, "Acadia", or "Acadie" in French, has two origins. The first is a reference to the Greek region of Arcadia. An Italian explorer gave the name "Arcadia" to present-day Virginia while exploring the Atlantic coast in 1524, since the beauty of the landscape reminded him of Greece. It is then believed that mapmakers shifted the place name northward. A variation of the name, "Laracida", was first indicated on a map in 1566, corresponding to present-day Nova Scotia. Over time, the spelling changed to "Larcadia", "Cadie", "La Cadie", and finally, "l'Acadie" (Acadian Museum of Prince Edward Island).

The first area the French successfully settled in 1605, was in Port Royal, present day Nova Scotia, after a failed attempt in 1604, at Ile St Croix. The first aboiteau was built in this area. At this time, the French settlers were exclusively men who were selected for the extensive journey overseas, based on their skills. They included experienced explorers, blacksmiths, tailors, butchers and others with useful skills and backgrounds. Although the settlement was abandoned from 1607 to 1610, the French returned and continued their efforts to colonize the region. Permanent settlements of families and other core settlers from France did not arrive in the region, in present day Nova Scotia until the 1630s when it is estimated that the first aboiteaux were built (Hatvany, 2002). The purpose of the aboiteau was to drain the muddy marshlands of the Bay of Fundy for farming. The twice-daily incoming tides deposited approximately 2 inches of nutrient-rich sediment per tide, entirely lacking stones and requiring no tilling upon drying

(Clark, 1968). Compared to the upland soils, with 15 to 30 centimetres of nutritive soil, the marshlands offered up to thirty metres of nutrient-filled deposited sediment (Whitelaw, 2004).

To this day, the aboiteau maintains a relatively simple design concept. Historically, a sluice was installed in a large, hollowed log. The sluice was then placed in a dyke made of spade-cut mud and various marsh grasses such as salt meadow cordgrass (*Spartina patens*), smooth cordgrass (*Spartina alterniflora*), black grass (*Alopecurus myosuroides*), and marsh sedge (*Carex spp*.) (Whitelaw, 2004). One such unearthed sluice found in farmlands near Grand-Pré, approximately 120 kilometres from Port-Royal, is from an aboiteau built in 1682. The tree itself is dated back to 1412 (Musée acadien de l'Université de Moncton). With the flood tide, the sluice gate flapped shut to prevent the seawater from entering the drained, nutrient rich soils. With the out-tide, the sluice gate would open to continue the draining of rainwater from the nutrient rich deposits.

A tall dyke, holding the draining structure, is known as a bounding or cross dyke (Clark, 1968). The aboiteau and the "bounding" or "cross" dyke were built very close to the sea to minimize the amount of smaller, "running", dykes required and to optimize the area of marsh behind the dyke (Clark, 1968; Whitelaw, 2004). The "running" dykes protected the land from overflowing streams and rivers, and did not have a drainage structure, whereas the "bounding" or "cross" dyke was larger and stronger to secure the aboiteau and withstand the tidal action (Clark, 1968; Whitelaw, 2004). The drying and firming process took two to five years of desalinization and drainage before the soil was ready for cultivation (Clark, 1968; NSDA, 1987). If the dykes or aboiteaux were compromised and flooding occurred, the process was restarted. The structures often protected the farms of multiple families from flooding, which could have detrimental effects on the community as a whole. Consequently, the building and maintenance of the structures was a community affair with teams of men and women, each with their own critical role in building and maintenance.

During the first era of aboiteau building, in the mid-seventeenth century, the work was smaller-scale in Port Royal, where a crew of eight men would determine the site of the aboiteau based on the abundance of sods, firm marsh, and proximity to the sea (NSDA, 1987). This is an important element of the settlement history of this new region, Acadia. The French settlers uniquely chose how to organize, drain and protect the farmlands, instead of officials assigning the work to labourers, which was a practice of others when colonizing new lands (Johnston, 2007). Once the site was chosen, a "trench key" was dug parallel to the sea, along the path of the future dyke, to prevent the dyke from sliding (NSDA, 1987). Identical grass sod bricks were cut and bonded together by the roots of marsh grasses such as black grass (*A. myosuroides*) (NSDA, 1987). A unique tool was required for this work, referred to as a, "dyking spade" (NSDA, 1987). Alternating layers of brush from spruce (*Picea spp.)* trees and mud was plastered between the sod bricks and each layer was tramped down by foot to ensure a watertight fit (NSDA, 1987). An average dyke was twelve feet thick at bottom level and sloped upwards until reaching a one-and-a-half-foot width at the top (Clark, 1968). This was just wide enough to allow men to walk along the tops of the dykes during later inspections. A channel was then excavated from the newly built dyke to place the hollowed log with the sluice where brush and mud was used to cover the log (NSDA, 1987). The structure in its entirety is referred to as the aboiteau.

Dyke building was only conducted at low tide and preferably during the period of neap tides, a time when there is the least difference between high and low tide. Tides are the weakest during neap tides, often falling in the month of June. (Whitelaw, 2004). Depending on the scale of the project, the process varied in time. For a group of eight men in Port-Royal, it's estimated the project lasted a week or two; however, once the Acadian population grew and began migrating elsewhere in the early 1680s, the projects became bigger and more time intensive. Bleakney (2004) estimates that sixty men in Grand-Pré would spend forty-five days building 7,710 feet of new dykes once annually. Grand-Pré as explained by its name, which loosely translates to, “large prairie”, provided a much more expansive new area to develop as compared to the sheltered area of Port-Royal. Women were also integral in these projects, completing domestic duties at the home, as well as cooking and transporting meals to the marshlands while the men worked (Ross, 2004).

Around the turn of the eighteenth century, the Acadians reached the area now encompassing the Maritime Aboriginal Peoples Council, “Five Watersheds Project” area (Figure 1). Many families were hoping to place distance between themselves and the politically-unstable Port-Royal. In 1689, Mathieu Martin was granted seigniory of Cobequid, the historical name of the area surrounding the easternmost inlet of the Minas Basin, otherwise known as Cobequid Bay. The marshes of present day Great Village were the first to be settled by a small number of families at approximately 1697 (“Place-Names and Places of Nova Scotia”, n.d.). In the following years, settlements near the Portapique, Debert, and Chiganois rivers are shown in census records. The marshes of the “Five Watersheds Project” area were developed much like Port-Royal and Grand-Pré, except for the Folly River watershed, which never became an important agricultural site (Wicklund & Smith, 1948). Eventually, the watersheds areas surrounding the Minas Basin became an important hub for the Acadians, where up to two thousand people were deported during the ‘Grand Deportation’ (Table 1).

Table 1. 1 Cobequid population estimates through time.

Year	Approximate population size	Source
1703	90	Patterson, 1934
1720	300 - 400	Whiston, 2015
1748	850 - 1,130	Patterson, 1934
1750	1500	Dunn, 1985
1755	1500 - 2000	Women's Institute of Nova Scotia, 1960

In September 1755, a French official, Winslow, ordered all Acadian men to gather in the churches and informed them that if they did not pledge allegiance to the British Crown, then they would be forcefully removed from their homes, schools, and farms and sent on vessels elsewhere (Clark, 1968). Many people lost their lives during this tumultuous period known as the Great Deportation, and for those who survived, much of their culture was lost. For the families that escaped, most migrated through the dense forests to Miramichi, New Brunswick (Clark, 1968). A few Acadians were harboured by the Mi'kmaq at Mattatall Lake (Miller, 1873). The recolonization of the abandoned villages took years, with the British Government advertising in various international newspapers to encourage people to venture to the Maritimes. The arrival of new families spanned into the 1760s which meant the remaining infrastructure was severely damaged due to neglect; however, the call for settlers was successful and many were granted the best land and marsh surrounding Cobequid Bay (Clark, 1968). Following the Treaty of Paris in 1763, the Acadians were permitted to return upon declaration of allegiance to the Crown and commitment to assisting the Planters. The name 'Planters' was given to the new arrivals from New England, who were seeking assistance in the repair of the dykes and aboiteaux (Musée acadien de l'Université de Moncton). The land that was developed over generations by the

Acadians was inhabited by the new settlers and returning Acadians received rights to the only unclaimed land that was left in southwest Nova Scotia (NSDA, 1987). By 1800, census showed no remaining Acadian settlements in the Cobequid area (Musée acadien de l'Université de Moncton).

The turn of the nineteenth century was important for the expansion of dyke projects across the Maritimes. In 1805, the largest scale project to date began to build a dyke from Wolfville to Grand-Pré, three miles long and with six aboiteaux (Bleakney, 2004). A decade later, construction commenced on The Wellington Dyke, located along the southwest coast of the Minas Basin. The plan was to transform the traditional Acadian method of reclaiming sections of smaller marsh to reclaiming one large section of marsh (NSDA, 1987). The project was completed over seven years and the dyke measured 120 feet at the base (NSDA, 1987), exactly ten times larger than the average dyke from the seventeenth century. The financing for this project was largely from farmers. There were unexpected difficulties associated with such a massive project and many lost their proprieties to pay off the debts (NSDA, 1987). Eventually, the project was considered a success, reclaiming more marsh than ever before, and the aboiteau remains intact to this day.

By the mid-nineteenth century, the Maritime economy was booming with shipbuilding, mining operations and the lumber industry (Creighton, 1980). At this point, census shows that just over half of all Nova Scotians no longer depended on the marshlands for their livelihood (NSDA, 1987). However, the demand for hay increased, since horses were used for transporting supplies, including mining and lumber products. Consequently, the Fundy farmlands were exporting internationally as well as supplying hay to local industries in abundance. This demand for hay remained until the 1920s, when the fossil fuel industry dominated, and horsepower was no longer needed (NSDA, 1987).

With the invention of the internal combustion engine, the 1930s introduced machinery to dyke building. Over the past two-hundred-and-fifty years, horses equipped with wooden shoes and men with dyking spades were the only power behind these great structures. However, this decade also saw the global economic depression which severely limited the money invested in maintaining the aboiteaux. Moreover, as the Second World War began, there was a major loss of the labour force for maintaining the dyke systems and even less monetary resources (Bleakney, 2004). Many described a state of emergency, as the neglect persisted and many farmlands were lost to the sea (NSDA, 1987). In recognition of this crisis, the Maritime Dykeland Rehabilitation Committee was established in 1943, which appointed emergency funds to be shared evenly between the federal and provincial governments of Nova Scotia and New Brunswick (Bleakney, 2004). Machinery was use to make the dykes larger and the drainage ditches wider, but since this agreement only accounted for emergency funds, farmers still financed and maintained much of the dykes themselves. In 1948, the federal government passed the Maritime Marshlands Rehabilitation Act, which relieved farmers of the responsibility of financing and maintaining the marshlands.

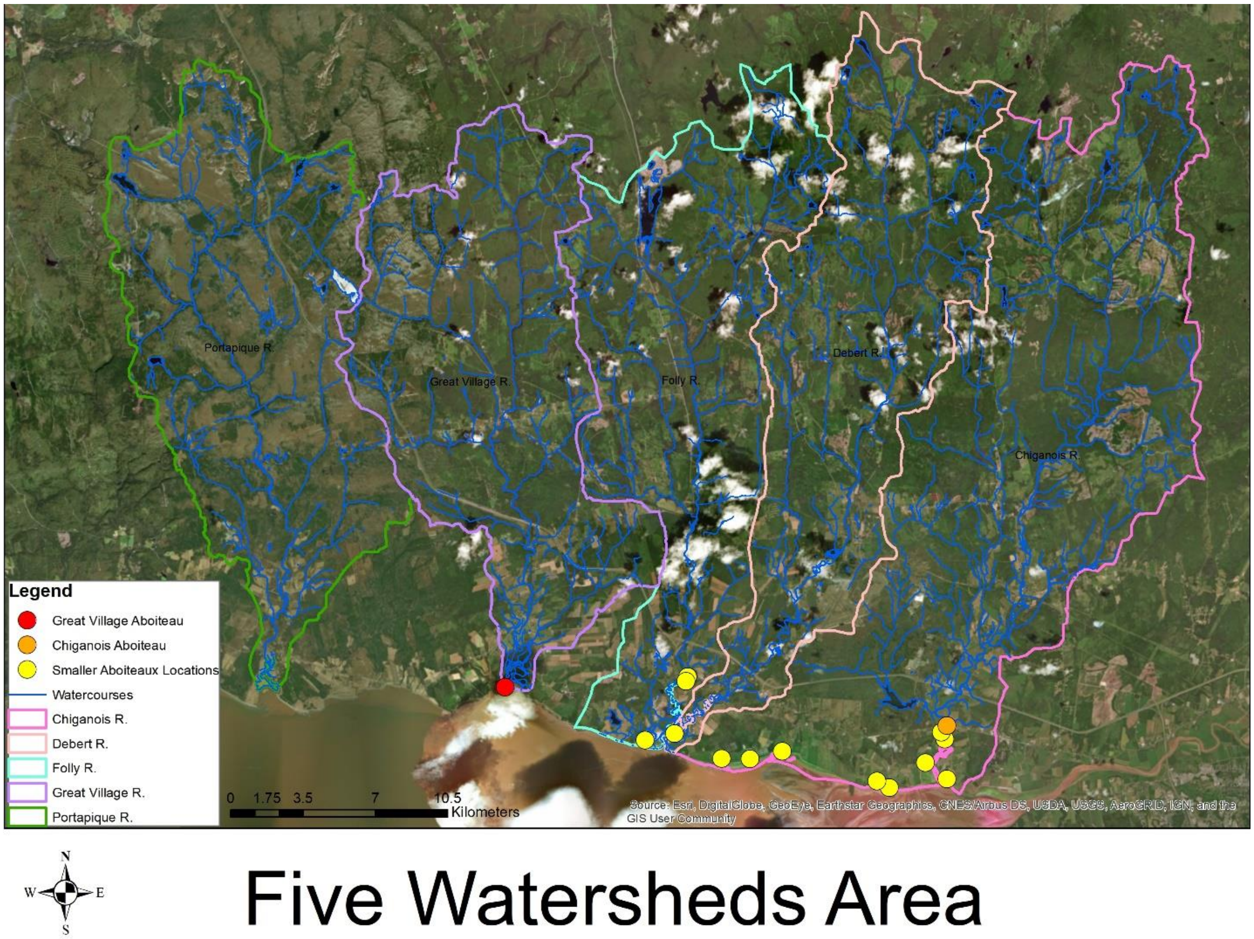

Figure 2. 1 Aboiteaux locations along the Bay of Fundy, for the Maritime Aboriginal Peoples Councils, 'Five Watershed Project'.

As demonstrated in Figure 2, there are two aboiteaux located within the project area, one that was installed in 1955 on the Chiganois river, and another installed in 1967 on the Great Village river (C. Esau, personal communication, Oct. 19, 2018). There are also thirteen smaller aboiteaux used for draining ditches (C. Esau, personal communication, Oct. 19, 2018). The structures on the Great Village and Chiganois rivers are much larger in scale and made of durable materials like concrete (Figure 3). The structures include long culverts, many of which pass under roadways. Instead of a sluice on the inside of the structure, the gate is now attached to the downstream end that faces the Cobequid Bay (Figure 4). The principle function persists, where the pressure of the incoming flood tide shuts the gate and the incoming ebb tide releases the gate or allows it to open. Over the past two decades, a shift from heavy wooden or iron gates to more lightweight materials has been prioritized to facilitate fish passage (see Section IV). The remaining dykes throughout the province now protect various infrastructure such as business parks, university athletic fields, highways, farmland and railroad tracks.

Figure 3. 1 Maintenance work for top-hinged tidal gates of the aboiteau on the Chiganois River at low tide (n.d.). Reproduced with permission from H. Kolstee.

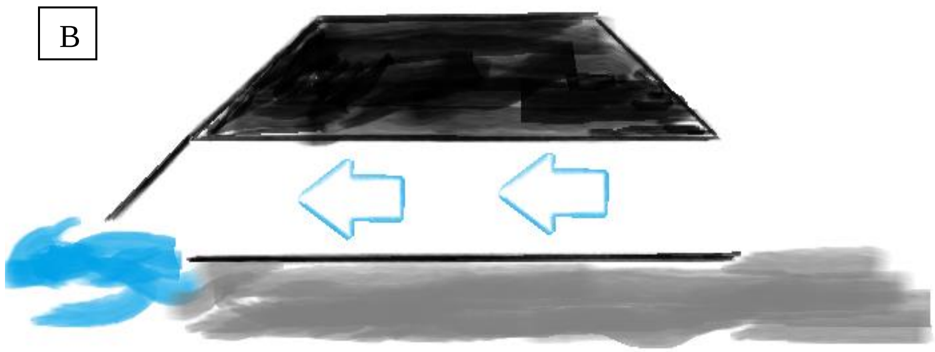

Figure 4. 1 Aboiteau style of the seventeenth century (A) and present-day (B) each at low tide.

Although the aboiteaux within the "Five Watersheds Project" area were installed under the Maritime Marshlands Rehabilitation Act, today it is the sole responsibility of the provincial government and its respective Department of Agriculture to cover dykeland expenses. In 1970, two decades after the proclamation of the Maritime Marshlands Rehabilitation Act, the federal government withdrew its contribution. Since the implementation of the dykes and aboiteaux by the Acadians nearly 400 years ago, the methods of aboiteaux construction and purpose have slightly changed, but the main idea remains: to block out sea water and drain freshwater from soils.

IV. Ecosystems and Environmental Conditions

IV.I. Pre-European Contact

How one uses the earth and its natural resources has the power to alter the environmental conditions. Before European contact, the area of this study was inhabited by the Mi'kmaq continuing on their traditional ancestral homeland territory of Mi'kma'ki. The beliefs and values of the Mi'kmaq People maintained the pristine environmental conditions of Mi'kma'ki, during their ten thousand years of occupation. Records of thousands of years of history of the Mi'kmaq are not readily available like the records on the hundreds of years since European settlement. The Mi'kmaq pass history from generation to generation through oral story telling, a tradition that continues today. Unfortunately, due to the devastating loss of culture and language which many Aboriginal Peoples suffered, an immeasurable amount of history has been lost forever. Moreover, the Europeans explored the Atlantic coast of North America since the early sixteenth century, allowing invasive diseases and European culture to proliferate for one hundred years prior to permanent settlement (Conrad, Finkel & Fyson, 2014). In light of these limitations, this section aims to report on the environmental conditions of the "Five Watersheds Project" area, pre-European contact.

A core belief of the Mi'kmaq People is that all things in the universe have a spirit and are spiritually connected to one another. This includes humans, plants, animals, the winds, land, and sky (Berneshawi, 1997). It is an eco-centric worldview- the relationship with nature. This eco-centric world view is demonstrated through every facet of Mi'kmaq life, from language to hunting, to gathering; establishing encampments and to travel. The Mi'kmaq language has evolved around the living earth, with words stemming from ecological knowledge. (G. Gloade, personal communication, Nov. 2, 2018). Understanding the Mi'kmaq language, provides a unique opportunity to compare the environment, at the time of the origin of the word, to the present day environment. For instance, the Mi'kmaq translation for the month of November is, 'Keptekewiku's' which means, "time that the rivers start to freeze" (G. Gloade, personal communication, Nov. 2, 2018). Today, with the onset of warmer global temperatures, the rivers do not freeze until late December or January, which shows that the climate was colder at the time the word was formed. By understanding these eco-centric relationships and traditions of the time, one can surmise the state of previous environmental conditions.

FORESTS

Within the area of the Debert watershed, there remains one of the oldest Paleoindian archaeological sites in North America. The site provides evidence of the oldest human inhabitation within the region. During the Second World War, a site in Debert was excavated for a military base and revealed artifacts that were linked to the Mi'kmaq People. Fifteen years later, a thorough archaeological study was undertaken in 1963 using radio carbon dating, which determined the age of the excavated hunting tools found within the Debert archaeological site (MacDonald, 1968). The animal blood smears from the artifacts revealed that the tools were 10,500 years old and from the Paleoindian era (MacDonald, 1968). This means that at the time these tools were used, Nova Scotia was in an ice age, tundra-like environment (Nova Scotia Museum of Natural History, 1996). After the recession of the glaciers, the tundra environment shifted to the dense boreal forests, dominated by conifers. This extreme environmental change also resulted in a shift in the animals inhabiting the region. Large mammals hunted by the Paleoindians began disappearing and were replaced with smaller-bodied species. As the ice receded and the climate warmed, more plant and animal species from the south migrated to the north and the forests became mixed with hardwood and softwood species, as they are today (Niely et al., 2017).

Various tree species were significant for the Mi'kmaq. The Mi'kmaq men foraged for wood such as spruce (*Picea spp.),* birch bark (*Betula spp.)* and flexible striped maple (*Acer pensylvanicum*) saplings which the women used to build homes, known as, "wigwams" (Nova Scotia Museum of Natural History, n.d.). In addition to these woods, fir, cherry (*Prunus spp.)* and maple (*Acer spp.)* trees were used to create fish traps, also known as weirs (Gordon, 1993). Plants and roots also had important roles in Mi'kmaq subsistence and medicine. Gathering foodstuff was largely limited to the growing season where berries, roots and edible plants were collected throughout the summer (Nova Scotia Museum of Natural History, n.d.). Medicinal plants were actively collected year-round. Medicinal plants within Mi'kmaq medicine was often used as a preventative measure, in which they bathed, exercised, and created saunas in wigwams to induce extreme sweating (Vaillant, 1749).

Pre-European contact, the Mi'kmaq formed clanships and lived an environmentally sustainable life based on rotational settling in areas to benefit from freshwater, game, fish and plant life. This transhumance allowed resources to naturally regenerate. During the winter, inland and forested encampments provided protection from the harsh winds and cold shorelines, and access to game for subsistence. Hunting also provided animal bones, tendons and serviceable organs. In North America, horses are not a native species and were introduced by the Europeans who imported them from overseas to settlements. The Mi'kmaq used other modes of transportation, including snowshoes for various snow conditions, and toboggans throughout the winter to transport resources.

In keeping with their eco-centric view, nothing was hunted or fished in excess. The wigwams were disassembled, transported to each new encampment area, throughout the seasons, and reassembled. (NS Museum, n.d.). During the months of October and November, hunting for beaver (*Castor canadensis*) and elk (*Cervus canadensis*) primarily took place, while otters (*Lontra canadensis*) and muskrats (*Ondatra zibethicus*) also supplemented their diet (AMEC, 2013). Nearly the entire body of an animal was used when harvested. The meat was prepared and consumed, the skins were tanned and cured by smoking or using bird livers and oil, and the women made warm clothing from the pelts. The teeth of the animals were used for tools, the tendons were used to sew leather, and the skin was used to smooth woodwork (Kerr, 2005). By December, wild fowl such as ruffed grouse (*Bonasa umbellus*), duck (*Anas spp.),* and Canada geese (*Branta canadensis*) overwintered in the province. February through March was peak Caribou (*Rangifer tarandus caribou*) hunting season (Vaillant, 1749).

WATER

In January, catfish (likely *Ameiurus nebulosus*) migrated up the freshwater rivers throughout Nova Scotia and were fished by the Mi'kmaq (Vaillant, 1749). By March, more fish began to spawn and crowd the rivers as the ice melted. The Mi'kmaq not only consumed the fish, but also the eggs (Vaillant, 1749). Once the warmer weather arrived, settlements were located along the coasts of rivers and oceans to provide ample fishing opportunities. Throughout the summer, porpoises (likely *Phocoena phocoena*) and whales (likely *Megaptera novaeangliae*, *Balaenoptera physalus*, or *Balaenoptera Acutorostrata*) were not uncommon to see in the Minas Basin and were hunted for sustenance and to derive useful products from the remaining corpses. The salt marshes along the coasts were also significant to the Mi'kmaq for many reasons. For consumption, the Mi'kmaq would gather shellfish, such as periwinkles (*Littorina littorea*), clams, and mussels (*Mytilus edulis*, *M. trossulus* and/or *Modiolus modiolus*), and hunt flounder (likely *Pseudopleuronectes americanus*), a mud-dwelling flatfish, along with one of the few wetland mammals, the muskrat (*O. zibethicus*) (Whitelaw, 2004). Spiritually, the coastal mudflats of the Bay of Fundy have a very deep meaning to the Mi'kmaq as described by the Glooscap legend. The legend speaks of how the first human was created by a bolt of lightning into the Bay of Fundy mud, marking the creation of mankind. (G. Gloade, personal communication, Nov. 2, 2018).

Salmon (*S. salar)* and sturgeon (*Acipenser oxyrynchus*) migrated up the rivers during the fall; each a staple of the Mi'kmaq diet (Clark, 1968). The arrival of autumn in September marked the shift from coastal to inland encampment. During both the summer and winter, birch bark (*Betula spp.)* and moose (*Alces americana* or *Alces andersonii*) skin canoes were built and used to fare the sea and travel across rivers or rapids (NS Museum, n.d.). Simultaneously, American eel (*Anguilla rostrata*) began migrating downstream. The Chiganois river was a historically significant fishing grounds of the Mi'kmaq for eels (*A. rostrata*) (Whiston, 2015). Using eel weirs made of saplings or stone, the Mi'kmaq caught eels to consume (Whitelaw, 2004). This dynamic way of life emphasized to only take what was needed for immediate use and to leave recourses for future generations. The lifestyle minimized the impacts on the earth so much so that when the Europeans arrived in the 1500s through the early 1600s, they described the wilderness as, "untouched" (Kennedy, 2014).

IV.II. 1500s – Pre-Industrial Era (1760)

In the early 1500s, the Europeans began exploring the north eastern coast of North America, the land mass known by Indigenous Peoples as, “Turtle Island”. During this time, the biodiversity of the environment was largely undisturbed, and the north east coast was largely inhabited by the Mi’kmaq Peoples. It was this pristine wilderness with undisturbed lands which attracted the Europeans to attempt settlements in the New World. There are many written accounts about the east coast during the time of exploration, where explorers wrote back to their homeland countries, persuading officials to take the journey overseas to colonize and eventually settle the area. After one such overseas mission, the French explorer, Pierre Du Gua de Monts, returned to France with oddities unique to Nova Scotia, including a six-month old female moose (*A. americana* or *A. andersonii*), a hummingbird (*Archilochus colubris* or *Selasphorus rufus*), horseshoe crabs (*Limulus polyphemus*), moose antlers, dried-out muskrats (*O. zibethicus*), a merganser (*Mergus merganser*), a blue-jay (*Cyanocitta cristata*) and a red-winged blackbird, (Kerr, 2005) to advance his vision to set up a settlement, which was attempted in 1604, at Ile St Croix. (*Agelaius phoeniceus*) (Kerr, 2005).

Following European contact, the Mi’kmaq People witnessed a drastic, anthropogenically induced environmental change. Prior to this era, the changes witnessed during glacial retreats and other major climatic events were natural phenomena. Now, parts of the earth were being molded into unrecognizable landscapes by the settlers; the most notable being the draining of marshlands for farming by the French. Competition for trading goods quickly escalated into clashing between inhabitants. It is through written accounts of the trading race and the use of land during this time that one can infer what the environmental conditions were like during the early sixteenth century, through to the mid-1700s.

A trading system was soon established between the Mi'kmaq and the explorers, which emphasized the difference in environmental conditions between France and Mi'kma'ki. The Mi'kmaq provided food uncommon to the French while the French offered their unique diet, including rice, prunes, olive oil, vinegar, almonds, lemon peel, raisins, bread, peas, beans, and hams (Kerr, 2005). Tools and other convenient materials were also popular, such as mirrors and cookware (Conrad, Finkel, & Fyson, 2014). By the 1530s, Jacques Cartier, on behalf of the French, and Chief Membertou, representing the Mi'kmaq, had formed an alliance that would last for generations (Kerr, 2005). From 1607 to 1610 while the French abandoned Port Royal, Membertou maintained the habitation and was baptized upon return of the French colonists, along with twenty members of his family (Conrad, Finkel, & Fyson, 2014). At this point, the French had been trading with the Mi'kmaq for generations and intermarriage was encouraged within the settlements to introduce the Catholic faith (Great Britain, 1743). The success of the French in this new and unknown land depended entirely on the Traditional Ecological Knowledge of the Mi'kmaq People. Sharing of this Traditional Ecological Knowledge, allowed the Europeans to successfully trap and hunt animals for sustenance throughout the different seasons.

CLIMATE

Since the peninsula of present-day Nova Scotia is situated at nearly the same latitude as France and Britain, explorers were surprised to find the climate was very different ("A genuine account…", 1750). Officials described the climate as cooler with thicker fog, more rain, and more severe winters (Kennedy, 2014; Murdoch, 1865).

FORESTS

Upon arrival of the Europeans, modern-day Nova Scotia was almost entirely covered in forests of conifers, beech (*Fagus spp.),* maple (*Acer spp.)* and oak (*Quercus spp.).* The only gaps in the blanket of trees were either from natural bogs or from natural forest fires (Kennedy, 2014). Within these forests, animals such as black bears (*Ursus americanus*), moose (*A. americana* or *A. andersonii*), elk (*Ce. canadensis)* and hares (*Lepus spp.)* were described in, “infinite”, numbers (“A genuine account…”, 1750). The settlers relied heavily on wood for resources. Throughout Nova Scotia the supply of timber was considered, “inexhaustible” (Murdoch, 1865). Various species were used for fuel, shelter, fences, bridges, sluice gates and tools (Clark, 1968). At this point, lumber export was very limited, especially in the area encompassing the “Five Watersheds Project”. White pine (*Pinus strobus*) and oak (*Quercus spp.)* logs were largely in demand from France and Britain for ship masts but were not an abundant species near the Bay of Fundy (Clark, 1968).

Although the trading of goods between the French and the Mi’kmaq demonstrated the environmental contrast between France and Canada, it also highlighted a common dependence on the natural environment for animal furs. Canada abounded with wild game and the beaver (*Ca. canadensis*) especially became the desired species. In the late sixteenth century, broad-brimmed, beaver-felted hats were trending in Europe. There was evidence of beaver (*Ca. canadensis*) extirpation in the Baltic countries, Europe’s primary source for beaver (*Ca. canadensis*) pelts (Conrad, Finkel, & Fyson, 2014). Consequently, competition to secure Native trading posts in Canada quickly increased. After 1600, the Native woman’s handiwork was nearly exclusively used to create goods for trading with Europeans (Kerr, 2005). The items in highest demand included colourful porcupine (*Erethizon dorsatum*) quillwork on bark which could be made into boxes, chair upholstery and other “European” novelties. Baskets and beadwork items were also popular (NS Museum, n.d.). Many historians pinpoint this shift as a critical loss of culture for the Mi'kmaq People, as the women focused on creating in-demand items and spent less time on domestic duties (Kerr, 2005).

The new trading relationships between the Mi'kmaq and Europeans also introduced various species to the natural environment that were unknown to the Mi'kmaq. New species that remain in the environment are termed invasive, meaning they thrive in the new area often due to their rapid reproduction rates and ability to out-compete native species. One of the most notorious invasive species was the black rat (*Rattus rattus*), known to cause damage to households and carry hantavirus which can lead to death. The rat is not native to North America and likely originated in Asia but was present in Europe since ancient times (CABI, 2018). Another invasive species includes the Canada or Creeping thistle (*Cirsium arvense*), which was one of the first weeds imported by early European settlers (NCC, n.d.). The Creeping thistle (*C. arvense*) was likely transferred from a contaminated seed transferred overseas to cultivate in New France. It continues to thrive throughout Canada, along roadsides, in prairies and in agricultural areas (Moore, 1975). The plant is so common that many are unaware of its invasive status. Another popular crop imported by the Europeans was Wild parsnip (*Pastinaca sativa)* (NCC, n.d.). It was one of the first food plants to be introduced and quickly escaped from cultivation to invade the natural environment (CABI, 2018). It is incredibly abundant today and poses health risks due to its ability to burn the skin upon contact with its sap ("Wild Parsnip", n.d.).

WATER

The New World and its lengthy coastlines motivated the Europeans to develop various fisheries. The environment was rich in fish and molluscs and Nova Scotia abounded with natural harbours, each of which attracted the Europeans to the area ("A genuine account…", 1750; Kennedy, 2014). Long before European colonization of present-day Nova Scotia, the coasts of present-day Newfoundland drew attention from several countries for its abundance of Atlantic cod (*Gadus morhua*). However, the more southernly located Nova Scotia, provided an opportunity for earlier spring fish runs which Newfoundland did not (Debrett, 1784). This was an important incentive for France and Britain to act quickly to colonize Nova Scotia. Moreover, in one written account to the French monarch around 1570, officials describe overfishing of cod (*G. morhua*) and pollution with fish scraps in Newfoundland (Kennedy, 2014). This account suggested that the British were at fault, which further encouraged the French to pioneer Nova Scotia despite Newfoundland's established international cod fishery, with vessels from Britain, France and Portugal. Eventually, the French learned that cod fish did not reach the Bay of Fundy and past present-day Digby until summer and that the climate at the Bay of Fundy was too damp and cool to evaporate salt for the curing of fish, as was done in France (Clark, 1968; Kennedy, 2014). Consequently, the first fisheries were developed by the English along the south Atlantic shore of the peninsula and the Acadians domestically fished salmon (*S. salar),* shad (*Alosa sapidissima),* and gaspereau (*Alosa pseudoharengus)* from the Minas Basin and its tributaries.

Explorers also wrote of watching the Mi'kmaq harvest porpoises from the Minas Basin and use their blubber to make oil (Clark, 1968). The hunting of whales was initially as attractive a business to the Europeans as the cod fishery and fur trade. The hunt peaked in the 1540s through 1580s when the large mouth plates of the whales were used for support under stylish dresses in Britain and France (Conrad, Finkel, & Fyson, 2014). Contrastingly, the Mi'kmaq used the entire body of the whale.

Upon colonizing, the settlers quickly learned the cycles and the sheer strength of the twice-daily tides of the Bay of Fundy. Since time immemorial, the Mi'kmaq advantageously used the incoming tides and the consequent influx of fish by installing fish weirs in the mudflats. Contrastingly, the Acadians built infrastructure to block the high tide and dry the alluvial land behind (see Section I). Much later, after the deportation of the Acadian people in 1755, the British suffered immensely from the tides without the knowledge and manpower to maintain the infrastructure (see Section I). Extensive flooding occurred, especially in 1759, with the first catastrophic storm tide since European arrival. Unknown to the British at the time, the massive storm was due to an eighteen-year cycle, the *Saros*, first discovered by astronomers in the last several centuries BC, to predict eclipses (Desplanque & Mossman, 1999). Every eighteen years and eleven days, the moon, sun and earth align, and if this alignment coincides with a brewing storm, the results can be disastrous (Desplanque & Mossman, 1999).

SOIL

Since the Acadians had very little involvement in fisheries and lumber export in the "Five Watersheds Project" area, successful farming was critical and of utmost importance. Fortunately, the natural grasses and waterways of the marshlands provided ample support for livestock (Kennedy, 2014). Specifically, salt meadow cordgrass (*S. patens*), smooth cordgrass (*S. alterniflora*), black grass (*A. myosuroides*) and marsh sedge (*Carex spp.)* were used for fodder and the cordgrasses also acted as thatch for roofing (Whitelaw, 1997; Hatvany, 2002).

Upon building of the dykes and aboiteaux in the 1630s onwards, the best marshes were those surrounding the Cobequid Bay and within the "Five Watersheds Project" area (NS Museum, n.d.). The fertile soil near the bays, stone free and requiring no tilling, paired with four to five months of frost-free weather, allowed the Acadians to cultivate many crops for domestic needs and trade. Oats, barley, wheat, flax, peas, rye, beets, carrots, parsnips, cabbage, turnips, hemp, and herbs were among the popular crops (Kerr, 2005; NSDA, 1987; Whitelaw, 2004; Dunn, 1985; Women's Institutes of Nova Scotia, 1960). Acadian flour was renowned and commonly shipped to New England and slave plantations in the tropics (Clark, 1968).

IV.III. Industrial Era (1760-1840) – mid-1900s

The industrial era through to the mid-1900s saw many changes for Nova Scotia. The Acadians were deported in 1755 and Britain won authority of the province for the final time in 1763 (Musée acadien de l'Université de Moncton). Nearly a century later, the colony of the province underwent its greatest economic growth, during the 1850s. The establishment of Canada as a country in 1867, resulted in important shifts in international trade, land use and industry. New industries were introduced such as mining, and others were transformed, using new modes of transportation via railways. Nonetheless, Nova Scotia was not immune to the worldwide economic depression of the 1930s, and underwent devastating economic loss. Overall, the landscape of the province was drastically altered yet again, and resembles what we see today.

Forests

Until the introduction of railways and fossil fuel vehicles, much of the inland and old growth forests remained untouched where waterways and roads for horses did not reach. At this time, the territories of present-day Canada still worked independently of one another and were separated by dense and vast forests. There was very little trade between the six British colonies of Nova Scotia, Newfoundland, Prince Edward Island, New Brunswick and Upper and Lower Canada (Boyko, 2006). In 1784, only two roads allowed extensive travel throughout Nova Scotia, between Halifax and Truro or Halifax and Windsor (Creighton, 1980). The journey from Halifax to Truro lasted three days by horse and was made easiest in the winter in horse-drawn sleighs, without muddy or dusty roads causing delay (Boyko, 2006).

The rise of the lumber industry slowly began in the 1830s, with modest exports to America and Britain, and eventually expanded to include trade with the West Indies (Wynn, 2013). With horsepower as the only means of transporting logs, lumber operations had to be on or near waterways, where logs could be sent barreling down the rivers to their intended destination. Quickly, the forests surrounding the rivers of Great Village, Folly, Portapique, Chiganois and Debert were stripped of their resources (Culgin, 2017). Lumber operations were equipped with milldams, and sawdust-contaminated rivers soon became a concern. Changes with forest harvesting methods in the industrial era include the time of year for logging and the sheer scale of the industry. Previously, wood was cut modestly throughout the summer by the men of the families for domestic use in the winter. Now, across the country, logging expanded into a successful winter industry where the work of teams of men was facilitated by pulling logs through the snow (Wynn, 2013). Trees were cut into a square shape, instead of keeping the circular logs, to facilitate international transport. Unfortunately, considerable waste was produced, with 25 to 30 per cent of each tree being discarded (Wynn, 2013).

During this time, forests provided ample resources for both the lumber and shipbuilding industries. At first, the two industries went hand in hand; as the demand for wooden ships increased, local lumber was harvested in abundance for local supply and international export. In 1787, the first ship built in the Minas Basin was a schooner, “Charles”, which set the shipbuilding era in motion in the “Five Watersheds Project” area (Creighton, 1980). By the mid-1800s, Great Village was a ship building hub, with many master mariners and a wealthy Fundy ship builder residing in the town (Creighton, 1980). Nearby towns including Folly and Lower Debert also joined the industry, with over one hundred ships being built and launched from the area before the twentieth century (Culgin, 2017).

One of the first rail lines to be built in the colonies, was in 1858, connecting Halifax to Truro and Halifax to Windsor (Creighton, 1980). Less than fifteen years later, and after the confederation of Canada as a new nation in 1867, the Intercolonial Railway opened and drastically changed the transportation of goods across the country. The first section of railroad, ran between Amherst and Truro in 1872 and was the only section running for four years (Boyko, 2006). Railroads eliminated the need for lumber operations to be situated in proximity to waterways, allowing extensive deforestation of inland Nova Scotia (Wynn, 2013). In 1883 alone, two million feet of logs were cut near Debert (Culgin, 2017). During this time, the province lost much of its old-growth forests, which includes at least 125-year-old trees (NSDNR, 2017). Although the railways increased opportunities for the lumber industry, many attribute their invention to the decline of shipbuilding, which showed evidence its demise in the late 1860s. The Intercolonial Railway operated until 1918, connecting Nova Scotia, New Brunswick, Quebec and Ontario (Boyko, 2006).

WATER

In the spring of 1840, during the peak economic period of Colchester County and its lumber and shipbuilding industries, a shad (*A. sapidissima*) fishery opened less then twenty kilometres from Portapique, in Economy point. The shad fishery was started by an American man from New England who may have been the first to introduce drift nets to the Cobequid Bay area, as a means of fishing. The method was unknown to fishermen at the time (Gordon, 1993). Within ten years, the shad fishery was expanded to extend along the northern shore of the Minas Basin, reaching Portapique River. Fishing for shad (*A. sapidissima*) would begin between either the end of June or mid-July, and continue for four to eight weeks, until the fish left the Cobequid Bay (Knight, 1867). In the traditional farming county, the prosperous fishing industry quickly dominated. Various types of weirs were used in combination with drift nets; however, officials became aware of the negative effects of standing weirs for shad (*A. sapidissima*) since many species of fish became bycatch (Knight, 1867). Consequently, brush weirs were used to allow smaller fish to escape (Knight, 1867). In 1867, on the North side of the Minas Basin, there were 118 fishing vessels (Knight, 1867). The following year, after the establishment of the Canadian Confederation, the first annual report from the Canada Department of Marine and Fisheries stated that, “shad is taken in large numbers around the North shore of Cobequid Bay” and suggested to ban all drift nets in Minas Basin. The nets were troublesome due to their position at the mouth of the rivers allowing an infinite number of fish to potentially become be trapped during the flood tide.

During this period, a devastating storm, similar to the one in 1759, hit the Bay of Fundy region. In 1869, the Great Saxby Gale made landfall with incredible strength, as a result of the *Saros cycle* (Desplanque & Mossman, 1999). Reaching hurricane force, it destroyed farms and infrastructure throughout Nova Scotia, New Brunswick and Maine. Fortunately, the storm was less severe in the Minas Basin region, but the rainfall was dramatic (Desplanque & Mossman, 1999). Railroads were destroyed and dykes were breached, drowning cattle and sheep. (Desplanque & Mossman, 1999).

Between 1870 and 1900, the Economy shad fishery was the most important fishery along the Bay of Fundy (Gordon, 1993). In 1869, the Department of Marine and Fisheries reported that the rivers of Colchester County were not as badly impacted by mill dams as other counties in the province. Other accounts describe concern among officials for the alewife/gaspereau (*A. pseudoharengus*) specifically, who are no longer attaining the upper reaches of the rivers for spawning (Knight, 1867). Within three years, fish ladders were introduced to the province since milldams now obstructed most of the major rivers in Colchester County (Canada Department of Marine and Fisheries, 1873). Around this time, the Portapique and Folly rivers were also included among the principle fisheries and drift nets were still the primary method of fishing (Canada Department of Marine and Fisheries, 1873). In retrospect, it is difficult to determine the importance of shad (*A. sapidissima*) as an export. Accounts from the Department of Marine and Fisheries around this period firstly state that the consumption of shad and alewives was strictly domestic, but two years later, reports list cod (*G. morhua*) as the domestically consumed fish and shad and salmon (*S. salar)* as exports to America (Canada Department of Marine and Fisheries, 1873).

In the early 1870s, salmon (*S. salar)* were reportedly increasing in numbers in all rivers in Colchester County; however, by the late 1870s, they were noted as, "very scarce" (Canada Department of Marine and Fisheries, 1873; Canada Department of Marine and Fisheries, 1880). By the turn of the century, salmon catches in the Bay of Fundy had decreased by 20 per cent compared to previous years (Canada Department of Marine and Fisheries, 1900). Moreover, the district encompassing the "Five Watersheds Project", saw a 33 per cent decline in herring catch numbers (*Alosa aestivalis)*, the lowest reported herring catch numbers since the district was established. Mackerel (*Somber scombrus*) catch numbers decreased by 40 per cent (Canada Department of Marine and Fisheries, 1900). Alewife populations were also declining across the province, but the catch numbers increased by 175 per cent in the Bay of Fundy (Canada Department of Marine and Fisheries, 1900). In the same district, the catch for halibut increased by over 100 per cent, while cod (*G. morhua*), smelts (*Osmerus mordax)*, and haddock (*Melanogrammus aeglefinus*) each increased by approximately 10 per cent (Canada Department of Marine and Fisheries, 1900). The Department of Marine and Fisheries reported that even in light of the drastic declines, there was no concern for the extinction of any fisheries within the Bay of Fundy (Canada Department of Marine and Fisheries, 1900); however, less than ten years later and into the new century, the shad fishery was "languishing" and exhausted of all fish (Gordon, 1993). Upon discovery of this dramatic decline, the fault was suggested to be due to the damming of natal rivers, pollution, and over-exploitation (Gordon, 1993).

Following the crash of the shad industry at Economy Point, there is no other important fishing industry near the "Five Watersheds Project" area. Silver Hake (*Merluccius bilinearis*) was fished modestly, along with haddock (*M. aeglefinus*), but Colchester proved to be one of the least profitable counties for hake fishing in Nova Scotia (Battle, 1931). By the First World War in 1918, "fishing", remained one of the only major employers in the Maritimes, with fish prices increasing, associated with the war, and also increasing profit. Unfortunately, this trend was not seen in Colchester County. Although the salmon (*S. salar)* catches were increasing in the Bay of Fundy region, and declining throughout the rest of the province, it appears that the brief success of the shad fishery was the maximum extent of commercial fishing near the "Five Watersheds Project" area.

SOIL

The traditional farming practices of the Acadian peoples were largely abandoned, once the immigrants from New England arrived in the 1760s to find the marshes flooded and the dykes and aboiteaux severely damaged. Instead, the coastal uplands were cleared for farming and the dykelands were used for hay, or the marsh mud was dug up for fertilizer (NSDA, 1987). Moreover, with various industries thriving in Nova Scotia, farming became less important. By 1817, census showed that 60 per cent of Nova Scotians no longer lived on the marshlands (NSDA, 1987); however, there was still a demand for hay while horses were used for logging and mining operations (NSDA, 1987). By the 1920s, the use of fossil fuels was booming, and the hay business crashed, as horses were replaced with the internal combustion engine (NSDA, 1987). In Colchester County, hay farming was described as “run out” (White, 1986; Creighton, 1980).

Farming in Colchester county shifted to dairy farming and poultry raising, with the opening of a creamery in Great Village in the 1890s, and another in Folly in 1900 (“Place-Names and Places of Nova Scotia”, n.d.). By the 1930s, Colchester was one of the two most important counties for dairy farming in Nova Scotia. The diary industry provided the most reliable source of income from farming practices in all of Nova Scotia, aside from apple orchards in the Annapolis Valley (Putnam, 1939).

Mining operations became popular in Colchester County throughout the mid-1800s to early 1900s. Nearly each of the five focal watersheds of this study had a colliery or other type of mining operation. The first was at Londonderry, a town within the Great Village watershed area, where in 1849, limonite was mined (“Place-Names and Places of Nova Scotia”, n.d.). Over the next fifteen years, 600 tons of limonite was extracted from Londonderry (Culgin, 2017). By 1850, an iron and steel facility was also constructed in the town (“Place-Names and Places of Nova Scotia”, n.d.). By the 1870s, “ochery” red ore, the mineral required to make paint, was extracted from Folly River. It was considered a, “first class ore” (Culgin, 2017). A silica mine, located within the Portapique watershed, opened in 1892 and a pole railway was built to connect the town with the coastal village of Bass River, facilitating export (“Place-Names and Places of Nova Scotia”, n.d.). In Debert, a colliery opened and operated occasionally from 1908 to 1936 and another small-scale colliery opened in Belmont, for one year, in 1925. In the 1920s, there is an increased demand for coal, as horses are phased out by the internal combustion engine (NSDA, 1987). Leading up to the Second World War, gravel crushing operations began in

Debert in 1925, 1938 and 1941, where millions of tons of gravel were removed (Culgin, 2017). Eventually, the gravel pits filled with water, and became popular fishing spots.

The soil strata underlying Nova Scotia's origin and characteristics were being discovered. Research of the time, show that much of Nova Scotia's soil is thin and porous, which allows exceptional leaching of nutrients (Putnam, 1939). For this reason, by the 1930s, Nova Scotia required more stable manures and commercial fertilizers for crops, compared to other provinces (Putnam, 1939). The focus of the geological research relates to the crop yield of the different soil materials. The bedrock of Colchester County is described as a "geological patchwork", with the underlying rock differing throughout the county (Putnam, 1939). The underlying rock originates from the Triassic period. It is a soft, red sandstone that is more susceptible to weathering than "grey rocks", but is less stony (Wicklund & Smith, 1948). Folly especially, has very stony and hard sandstone, incapable of successful agriculture, and is covered in forests (Wicklund & Smith, 1948). The soil near Portapique, and north of Great Village, is considered suitable soil for a wide variety of crops, as the nutrient-rich profile is deep, well drained and free of stone (Wicklund & Smith, 1948).

IV.IV. Present-day (1970s onwards)

For the first time in history, the natural environment is studied by governmental departments, academic institutions, research centres, and not-for-profit organizations regardless of its contribution to the lumber, fisheries, and mining industries. Furthermore, scientific advances have allowed a deeper understanding of the complex interactions between the species and the environment they inhabit. Within the "Five Watersheds Project" area alone, there are multiple "ecodistricts" traversing its boundaries (Figure 1). Derived from the word, "ecozone", a biogeographic division of the earth's surface based on the distribution of plants and animals, an ecodistrict is smaller than an ecozone, and consequently more specific, while maintaining the same principle (Oxford Dictionary, n.d.). From south to north, the three ecodistricts that pass through the "Five Watersheds Project" area, are the Minas Lowlands, the Cobequid Slopes and the Cobequid Mountains (Figure 1) (Neily et al., 2017). These classifications are relatively recent, since a 1999 report from Environment Canada and Agriculture and Agri-Food Canada only recognized two ecodistricts within the "Five Watersheds Project" area, the Chignecto-Minas Shore and the Nova Scotia Highlands.

Present-times have also brought important changes in climate and increased severity of storms. Such events have devastating consequences on the plant and animal species of the region, including mass mortality events and increased susceptibility to pathogens. Moreover, human land use has continued to accelerate, as observed with each previous time period (see Sections II.I, II.II, and II.III).

Climate

Anthropogenically induced climate change has resulted in important shifts in the global climate. Average surface temperatures have increased across the globe, resulting in increased sea levels, due to thermal expansion of the water. There have also been marked increases in precipitation and severity of storm events. Paired with rising sea levels, this results in increased flooding for many coastal regions of the world, including Nova Scotia. As demonstrated in (Table 2), average temperatures, along with the frequency and amount of precipitation, have increased since the seventeenth and eighteenth centuries. More than one month of fog or rain-days have been added annually. Efforts to combat increased precipitation and flooding in Colchester County, have included the installation of porous asphalt. The porosity allows storm water to flow through the asphalt instead of pooling on top of the surface, as with traditional asphalt (C. Macpherson, personal communications, June 14, 2018).

Table 2.1 Climate trends in Nova Scotia through time.

Year	1600 & 1700s [a]	1980s [b]
Mean summer temperature (˚C)	16	16.9
Mean winter temperature (˚C)	-6	-4.1
Mean annual precipitation (mm)	1000	1352
Days with fog or rain	100	132

[a] Kennedy, 2014
[b] Nova Scotia Environment - Climate Change Unit. Copyright 2014. Retrieved from a

FORESTS

The forests covering the majority of Canada are categorized as boreal forests; however, those of Nova Scotia are Acadian. Acadian forests are often described as a, "transition zone" between the boreal and spruce-fir dominated forests of the north, and the deciduous forests of the south (WWF, 2018). Over 75 per cent of Nova Scotia is forest covered. (NSDNR, 2017). Within the Acadian forests and depending on the ecodistrict, the stands of trees will differ throughout the province. Following the northern shore of the Minas Basin, the Minas Lowlands ecodistrict is a coastal strip of land encompassing the southern region of all five watersheds (Neily, Basquill, Quigley & Keys, 2017). In this region, the forests are dominated by softwood species, including Black spruce (*Picea mariana*) and scattered White pine (*P. strobus*), since much of the soil is poorly drained (Neily et al., 2017). Within the well-drained areas along the steep-sided slopes of rivers, Red spruce (*Picea rubens*) and hemlock (*Conium maculatum*) are present (Webb, Thompson, Beke, & Nowland, 1991). Along the major rivers, such as the Chiganois River, and Great Village River, the alluvial soils were heavily farmed, but remnant forests of Red maple (*Acer rubrum*), Sugar maple (*Acer saccharum*), and White ash (*Fraxinus americana*) remain (Neily et al., 2017). The floodplains also offer great habitat for elm (*Ulmus spp.),* but there are few elms left in eastern Canada, due to Dutch Elm Disease, which had devastating effects in the 1970s and 1980s (Tree Canada, n.d.). The natural disturbances that affect these stands the most are fires and hurricanes, of which Hurricane Juan of 2003 had the most destructive effects, due to the poorly drained soils (Neily et al. 2017).

Moving northward, the landlocked ecodistrict of the Cobequid Slopes are full of shade tolerant species, with pure and mixed stands of Red spruce (*P. rubens*) and Yellow birch (*Betula alleghaniensis*) and interspersed American beech (*Fagus grandifolia*), Sugar maple (*A. saccharum*), and hemlock (Neily et al., 2017). The interspersed species are common near the Debert River and Chiganois River. As discovered by the Europeans when lumber export began to France and Britain (see Section II.II), the White pine is notably absent from this region (Clark, 1968). Fifty-eight per cent of this ecodistrict is comprised of Acadian mixed forest, largely on south facing slopes, providing important winter habitat for white-tailed deer (*Odocoileus virginianus*) that migrate down-mountain to avoid the extreme snow (Neily et al., 2017). The understory of the forest is furnished with regenerating overstory species, herbs, ferns, and an extensive moss layer, whereas, the rocky cliffs provide habitat for a few relatively rare species such as the fragrant wood fern (*Dryopteris fragrans*), hyssop-leaved fleabane (*Erigeron hyssopifolius*), Drummond's rockcress (*Boechera stricta*), and slender cliff brake (*Cryptogramma stelleri*) (Neily et al., 2017). With the Cobequid Slopes and the more northern Cobequid Mountains having a higher elevation, exposure to wind, snow, and ice increases breakage and reduces growth, however, stand-level disturbances are rare (Neily et al., 2017). In rare cases, invasive insects have been destructive, as seen with the spruce bark beetle (*Ips typographus*) epidemic in the 1980s and the tussock moth, (Lymantriinae subfamily) which has appeared annually since the 1930s (Magasi, 1981; NRCAN, 1998). Moreover, ice storms can provide an opening for fungi and insects to enter, and further weaken the damaged trees.

The ecodistrict encompassing the most northern portion of the "Five Watersheds Project" area, is the Cobequid Mountains, a largely intact and late successional Acadian hardwood forest (Neily et al., 2017). The dominant species are Sugar maple (*A. saccharum*), American beech (*Fagus grandifolia*), Yellow birch (*B. alleghaniensis*), White ash (*F. americana*) and Ironwood, (*Carpinus caroliniana*) where nutrient-rich soils permit (Webb, Thompson, Beke, & Nowland, 1991). As a late successional forest, the canopy is closed and regeneration upon a disturbance consists of similar species to those already present (Neily et al., 2017). The understory is composed of an extensive shrub layer and a diverse composition of ferns and mosses (Neily et al., 2017). Although this area boasts some of the highest elevations in the province, it does not have an alpine ecosystem.

Throughout Nova Scotia, the forestry industry continues to be one of the most important employers, especially in rural areas. Colchester County is the fifth leading county for wood harvesting in the province and is home to eight sawmills, contributing a total of eight per cent to Nova Scotia's wood harvest (Pinfold, 2016). Only one of the sawmills is located within the Folly River watershed while another is located approximately two kilometres outside of the Chiganois watershed. Old growth forests have become increasingly rare throughout the province, due to forestry activities. Consequently, in 1999, the government of Nova Scotia introduced the Interim Old Forest Policy for Crown Land to protect and restore old-growth forests (NS forests, n.d.). More recently, the public has expressed concerns with the provincial harvesting methods, which include clear-cutting, and whether the Policy is sufficient to protect old growth forests.

WATER

The rivers of the Chiganois, Debert, Folly, Great Village, and Portapique feed into the Cobequid Bay, the most eastern portion of the Minas Basin and Bay of Fundy. The shape of the Bay acts as a funnel, with the severity of the tides increasing further east in the bay (Figure 1). In the region of the "Five Watersheds Project" area, the tides have been recorded at sixteen metres. These tidal waters provide spawning grounds for various anadromous fish. The tides are also critical for sea faring animals, as they provide a reliable plant energy source. One half of the plant energy sources consumed by microorganisms, zooplankton, invertebrates, fish and seabirds in the upper Bay of Fundy region, is supplied by decaying marsh grass swept out to sea by the tides (Whitelaw, 2004).

The tides also create vast salt marshes where over 440 water dwelling species reside, including mud shrimp, lams, snails and bloodworms (Whitelaw, 2004). The Bay of Fundy mudflats provide the most important feeding ground for migrating shore birds in the western hemisphere, including the American golden-plover (*Pluvialis dominica*), semipalmated plover (*Charadrius semipalmatus*), killdeer (*Charadrius vociferus*), greater yellow leg (*Tringa* *melanoleuca*), willet (*Tringa semipalmata*), spotted sandpiper (*Actitis macularius*), red knot (*Calidris canutus*), semipalmated sandpiper (*Calidris pusilla*) and least sandpiper (*Calidris minutilla*) (Whitelaw, 2004; Neily et al., 2017). Despite an extensive history of dyking and drying of the salt marshes (see Section I), the ecodistrict encompassing the coast of the "Five Watersheds Project" area is home to the second largest proportion of salt marshes in the province (Neily et al., 2017). In the middle and landlocked ecodistrict of the Cobequid Slopes, there are no wetlands, however in the most northerly ecodistrict, 60 per cent of the wetlands are swamps (Neily et al., 2017). A swamp differs from a marsh, due to its abundance of woody plants, whereas, marshes contain herbaceous species, such as marsh grasses (EPA, 2018). Moreover, the wetlands within the northern watershed are not intruded by saltwater, whereas, the southern, coastal ones are.

Contrary to the number of wetlands within the "Five Watersheds Project" area, there are very few freshwater lakes and those that are present are small and shallow; however, Folly Lake is an exception, reaching depths of thirty metres (Neily et al. 2017). Throughout the "Five Watersheds Project" area, there are many rivers and streams that runoff into the lowlands and eventually reach the Minas Basin. Unique features of the area include strait escarpment edges along many rivers, creating several waterfalls and steep sided ravines (Neily et al. 2017). Waterfalls act as a natural barrier to fish passage, but eels (*A. rostrata*) have been seen "climbing" up the waterfalls (anonymous, personal communication, July 25, 2018).

After the Second World War, technological advancements resulted in overfishing with a dominating groundfish industry, which provided over 50 per cent of Nova Scotia's fisheries revenue, collapsed in the 1970s and 1980s (Gough, 2015; Pinfold, 2007). Today, Colchester County is among the counties with the fewest active captive fisheries and processing plants in the province. All three of the captive fisheries are shellfish facilities, with a minimum of 50 per cent of the revenue derived from shellfish captures or processing (Pinfold, 2007). None of the facilities are within the “Five Watersheds Project” boundaries.

Many residents of the towns surrounding the Chiganois and Great Village watersheds, fished for salmon (*S. salar)* and trout (*Salmo trutta*) recreationally throughout their childhood, in the 1950s and early 1960s (anonymous, personal communication, July 25, 2018). Some described as many as thirty to forty salmon (*S. salar*) in the swimming holes; however, many claim that the salmon disappeared around the time the aboiteaux were built on the rivers in 1955 and 1967. However, the decline of the Atlantic salmon was not well documented until after 1978 with the creation of the Committee on the Status of Endangered Wildlife in Canada (COSEWIC). Consequently, commercial fisheries in the inner Bay of Fundy area were closed in 1985 (COSEWIC, 2006). The inner Bay of Fundy (iBoF) Atlantic Salmon (*S. salar*) population was listed as endangered in 2001 by COSEWIC, followed by the federal governments listing under SARA, in 2003, under the Species at Risk Act (SARA) (COSEWIC, 2006). The Indigenous peoples harvesting the iBoF salmon, as their artisanal fishery, in 1992, advised the Department of Fisheries and Oceans, of the decline and voluntarily ceased to harvest iBoF salmon.

Soil

The geology of the “Five Watersheds Project” area is complex, changing throughout the three ecodistricts, and is largely influenced by the historic retreat of glaciers. Soft sedimentary rock from the Triassic period is the dominate substrate on the northern shore of the Minas Basin (Neily et al., 2017). Sedimentary rock is typically deposited by water or air (Geology dictionary, n.d.). There is also older rock from the Carboniferous period present in some areas. Below the sedimentary rock, the bedrock is dominated by sandstone, siltstone, shale, and conglomerate (Neily et al., 2017). Conglomerate is a coarser-grained sedimentary rock composed of rounded fragments within a matrix of finer grained material (Geology dictionary, n.d). This gives the region its famous red tones, since the bedrock is easily eroded. Moreover, the region is often exploited for its aggregate sources, as described in Debert, for the Second World War (see Section II.III), but also Folly, due to its sandy and gravelly deposits. The soil is derived from a gravelly sandy loam till (Neily et al., 2017), meaning a sand, clay and silt mixture deposited by melting glaciers or ice sheets (Geology dictionary, n.d). During the summer, the soils near Debert often experience droughts (Webb, Thompson, Beke, & Nowland, 1991).

The Cobequid fault line runs through the “Five Watersheds Project” area, separating the next ecodistrict, the Cobequid Slopes, from the Cobequid Mountains, to the north. A second fault line within the Portapique watershed distinguishes the Slopes from the Minas Lowlands on the south (Neily et al., 2017). The bedrock underlying this ecodistrict is also sedimentary, but from the earlier Carboniferous period, and has older igneous rock intruding (Neily et al., 2017). The well-drained soil is made from a gravelly, sandy loam till, high in conglomerate, sandstone, and igneous rock (Neily et al., 2017).

The most northerly ecodistrict in the “Five Watersheds Project” area, is the Cobequid Mountains, which boast the oldest and widest variety of geological strata. The area is underlain by a wide variety of igneous, sedimentary and metamorphic rocks from the Precambrian through to the Carboniferous Period (Webb, Thompson, Beke, & Nowland, 1991). The dominant rock types include granodiorite, diorite, rhyolite, basalt, sandstone, and siltstone with various faults and folding, resulting in higher surface elevations and undulating terrain (Neily et al., 2017). The bedrock is exposed in various places over the thin and stony, glacial-tilled soil and it is well drained (Neily et al., 2017).

In 2011, Colchester County was among the four leading farming counties in the province, providing 10 per cent of the provincial gross farm profit (NSDA, 2012). The agriculture industry has vastly changed since the Acadians cultivated wheat, hay and root vegetables in the seventeenth and eighteenth centuries, (see Section II.II) and since the popular dairy farming of the twentieth century (see Section II.III). Another notable change within the project area is that from 2006 to 2011, the number of hay farms increased by 29 per cent (NSDA, 2012). Today, Colchester County is the leading county for apiculture and has the third highest number of fruit farms in the province (NSDA, 2012).

In 2011, a belt of potential epithermal gold was discovered in Carboniferous volcanic rocks, in the Cobequid Highlands near Warwick Mountain (NSDNR, 2018). Although the Warwick Mountain does not fall within the "Five Watersheds Project" boundaries, many residents have expressed concerns about well water and other waterway contamination, as well as the potential destruction of the intact stands of Acadian forests. In March of 2018, the Council of Colchester County unanimously sent a request to the province to delay the request for proposals for mining exploration (Faulkner, 2018). Nonetheless, the Nova Scotia Department of Natural Resources is calling for companies to submit exploration proposals from November 2018 until March 2019, with a successful proposal to be chosen by late winter of 2019.

V. Interviews

Conducting interviews over the seven-month period of this study was important to engage stakeholder participation and collect local knowledge. Various experts and residents within the "Five Watersheds Project" area were consulted. Interviews ranged from formal and premeditated meetings, to casual and spontaneous discussions at community engagement sessions. The type of interview that was conducted is described in each interview description. The identity of all experts is revealed and those of the residents are protected. As such, any interviews labelled as, "Anonymous X - Y", were conducted with residents of the "Five Watersheds Project" area. "X" represents the chronological order of the interviews throughout the seven-month study and "Y" represents the watershed the resident is associated with.

Table 3. 1 Experts consulted throughout the study.

Name	Position	Organization
Ashley Sutherland	Archivist	Colchester Historeum
Gerald Gloade	Program Development Officer	Mi'kmawey Debert Cultural Centre
Joanne McCarthy O'Leary	Local History and Genealogy Librarian	Halifax Central Library
Hank Kolstee	Retired Aboiteau Superintendent	Nova Scotia Department of Agriculture
Jeanne-Mance Cormier	Curator	Université de Moncton
Anita MacLellan	Chair	Cobequid Interpretive Centre
Carl Esau	Agricultural Engineer	Nova Scotia Department of Agriculture
Tony Henderson	Biologist	Department of Fisheries and Oceans

Joanne McCarthy O'Leary - *Local History and Genealogy Librarian, Halifax Central Library*

Joanne McCarthy O'Leary has been a local history and genealogy librarian with the Halifax Public Libraries for over twenty years. She is one of the original librarians involved in the inception of the Local History and Genealogy section in the Halifax Central Library. With such experience, comes an incredible grasp of the resources the local history section contains. She was visited by the project researcher on May 29, 2018 and July 17, 2018.

McCarthy O'Leary was very hands-on and sat with the researcher for nearly an hour during each of the two meetings at the Halifax Central Library. She provided dozens of books and a bibliography containing over one hundred potentially relevant materials. Many of the books she provided were cited in this final report. Although a formal interview was not conducted, her help cannot be understated. She continued to pull resources over the passing months and informed the researcher when she had discovered new materials that could be relevant to the project.

Jeanne-Mance Cormier – *Curator, Université de Moncton*

Ashley Sutherland – *Archivist, Colchester Historeum*

Jeanne-Mance Cormier was visited by the researcher at the Université de Moncton on June 5, 2018. Ashley Sutherland was visited the following day on June 6, 2018 at the Colchester Historeum. Upon learning of the "Five Watersheds Project", each expert provided resources such as historic newspaper articles, census records, research papers and books relevant to the project. Formal interviews were not conducted. Instead, upon receiving the relevant resources, the experts allowed time for the researcher to study the materials and were available for questions. The Colchester Historeum and the Musée Acadien were critical in providing background information and timelines of Acadian history. Moreover, the institutes provided different resources than those available at the Halifax Central Library.

Anonymous 1 – *Chiganois & Debert*

Anonymous resident 1 was consulted during the first community engagement session on June 14, 2018 in Masstown, Nova Scotia. This resident was raised in Belmont, a town within the

Chiganois watershed. They are an archaeology student and an avid hiker. This combination has provided them with impressive knowledge on the topography of the Chiganois watershed.

This resident is extremely concerned with the land use of the watershed, specifically the deforestation and mining. They spoke of waterfalls on a brook leading to Frog Lake becoming a trickling stream, possibly due to the dramatic clear cutting within the Chiganois and Debert watersheds. These falls are north of the aboiteau on the Chiganois river. As an archaeology student, they are aware of carboniferous fossils currently eroding, due to a watermill within the watershed. Moreover, the resident opposes the prospective coal mine in the protected Staples Brook Nature Reserve. The resident provided various examples of how regulators are doing the environment a disservice with the land use management of the Chiganois and Debert watersheds.

Anonymous 2 – *Portapique*

The first formal interview conducted with an anonymous resident was in Portapique on the morning of July 5, 2018 at their home. Although the resident moved here in the 1970s, they had an impressive knowledge of the local history. Upon arrival in Portapique forty years ago, the resident befriended many key community members including a representative of the Great Village Women's Institute and the owner of the Bass River chair factory. The resident has remained very active in the community.

The home of the resident was built over one-hundred years ago, on nineteen acres of land. The house looks out over the marshland surrounding the Portapique River. Before the house was built, the land was used by a nearby Acadian farm, and remnants of an Acadian dyke could be found on the property. There is also an old aboiteau nearby. Much later after the Acadians were deported, people took over the property and abandoned the aboiteau and dyke structure. The original structure was a barn built by a poor farming family in 1874 [there appears to be a discrepancy in time since the Acadians were deported in 1755]. The walls were insulated with seaweed. The field was then only used to grow salt hay since it could be inundated with saltwater and still grow.

Upon arrival of the resident in the 1970s, the house was comprised of two rooms and a basement. The kitchen had a hook up for cold water and there was an outhouse. The house was equipped with only fifteen-amp electricity which meant the home had to be entirely rewired to support modern-day appliances. The resident and their partner also built on to the house to expand it, adding various rooms and an upper level.

When the resident first moved to Portapique, they enjoyed kayaking down the Portapique River, to where it met the bay, where they used a fishing line to catch fish. The fish line was comprised of twenty-five hooks, each with a three-foot drop line. The resident spoke of catching eels (*A. rostrata)*, flat fish, and shad (*A. sapidissima*) using the fish line. The resident also described salmon fishermen fly fishing from bridges along the Portapique River. The resident also described many people, in the 1970s, running along the marsh at the end of April or early May with long fishing nets, to catch smelt (*O. mordax)*. Within a year of the resident living in Portapique, the government had set a limit of sixty smelt allowed to be caught at one time. Eventually, netting was no longer permitted and only fishing hooks could be used to catch smelts. To this day, one can tell when the smelts are present because eagles and seagulls hover above the river.

An important change that the resident has witnessed over forty years is the erosion along the riverbanks and the channel changing course over time. Moreover, the resident spoke of how salmon fishermen quickly disappeared from the Portapique River.

Anita MacLellan – *Cobequid Interpretive Centre*

The researcher visited Anita MacLellan while she was the working chair of the Cobequid Interpretive Centre in Economy, Nova Scotia. Anita MacLellan wears many hats. She is very active in her community, and is also acting as the director of the Economy Recreation Centre. Although Economy is twenty kilometres from Portapique, the nearest town incorporated within the "Five Watersheds Project" area, the Interpretive Centre provides resources on other areas surrounding the Bay of Fundy. She was visited by the researcher twice in July 2018, and corresponded via e-mail after the centre closed for the season.

MacLellan provided a fantastic resource from another local resident, Stacey Culgin. Culgin wrote the historical book, "Debert", which is cited throughout this final research report. Moreover, MacLellan's father was a logger in Castlereagh, a town which falls on the border of the Debert watershed. She therefore spoke firsthand of how the logging operations altered the environment from the 1940s onwards. Important points included dynamite blasting and extensive log jams in the rivers, as well as the obvious deforestation. Another valuable resource MacLellan provided were journal entries written by a resident from Masstown, throughout 1869 to 1905. This time period is important because it is after the economical crash of the previously bustling county, as the ship building era passed. Lastly, MacLellan provided names of people who might be interested in also being interviewed for the project.

This interview was important because Anita MacLellan not only provided unique written resources, but she could also speak firsthand of her experience growing up in Castlereagh. Moreover, as the Chair of the Cobequid Interpretive Centre, Anita MacLellan had knowledge of various obscure materials. The Cobequid Interpretive Centre is a great resource, as its collections contains materials that are not found at other museums or libraries.

Anonymous 3 – *Chiganois;* **Anonymous 4** – *Great Village*

Anonymous residents 3 and 4 participated in a group discussion during a community engagement session on July 25, 2018 in Great Village, Nova Scotia. The two anonymous residents have lived in the "Five Watersheds Project" area for much of their lives and are now senior citizens. Each of their concerns, related to the land management within the "Five Watersheds Project" area. They described the spraying of fertilizers on a large-scale farm in the area, the clear cutting and its effects on the flow of water, and the aboiteaux. Each had grown up in the area and spoke of the abundance of salmon (*S. salar*) in the 1950s, when they would fish and swim along the main rivers, as children. Although many of their concerns were outside the scope of this project, they voiced appreciation for such a project being conducted in the area, and were hopeful for improvements with the salmon populations.

Hank Kolstee – *Retired Aboiteau Superintendent – Nova Scotia Department of Agriculture*

Hank Kolstee retired from his position as Aboiteau Superintendent for the Nova Scotia Department of Agriculture nine years ago. His detailed memory of the various aboiteau structures throughout Nova Scotia is incredible. He worked for the department for nearly forty years and witnessed firsthand the technological advancements in dyke and aboiteau construction through time. He has also witnessed the problems associated with such construction, namely, siltation, ice jamming, and halted fish passage. He was visited at his home in Brookfield on October 12, 2018.

Hank witnessed salmon successfully passing through the aboiteau on the Great Village River in the 1970s and 80s. The structure required a fishway because it was built on top of sandstone, which was impossible to drill through. This meant the aboiteau, without the fishway, was too high above the water for fish to pass.

On the Chiganois river, erosion is a significant problem. Although, the river also provides important spawning opportunities for salmon (*S. salar*) since much of the river bed is gravel. The Chiganois river also has siltation issues, especially in the summer. The main channel reaching the bay is longer than that of the Great Village River, therefore, more silt is carried to the aboiteau. Hank described that annually during the dry season, he could watch the silt accumulate on the structure at a rate of two to three inches per day when there was no freshwater flushing from the upstream side.

The area surrounding the two rivers underwent significant dyke reconstruction in the late 1960s. Prior to this, many small-scale dykes and aboiteaux were built along the rivers, which made it difficult to maintain the many structures. Once the federal government implemented the Maritime Marshlands Rehabilitation Act, they opted for larger dykes and aboiteaux to replace the smaller ones to facilitate manageable maintenance.

In terms of fish passage, Hank was adamant that fish do not require passage, "100 per cent of the time". Hank describes twenty minutes, four times a day, during the incoming and outgoing tide, as being sufficient for fish passage. [Research regarding the amount of time tidal gates are open is explored in section 4].

Anonymous 5 – *Portapique*

This resident from Portapique was visited on October 24, 2018 at their home. The resident grew up in the area, but lived out of province for thirty-three years. Upon return twenty-five years ago, the resident and their family first lived in Debert, followed by Portapique. Today, the resident lives in a remodeled farmhouse in Portapique that was built in the nineteenth century.

When the interviewee was a child, in the 1950s, who frequented the Portapique River. They described the river as much deeper, and attribute the frequency of flooding today to its shallower nature. The resident described flooding as a common occurrence today, but one especially intense flooding event three years ago, took out the Portapique bridge and turned many of their neighbours' properties into "islands". The resident also suggested that the Portapique River is a shorter distance to the bay than it was historically, which they believe plays a roll in the increased flooding. The resident also described the small gravel dyke their family built on their property along the river to protect from flooding.

The partner of the resident, who is now deceased, enjoyed fishing recreationally out of province and in Colchester county once the couple moved back. When the couple arrived in Debert in the early 1990s, the two witnessed salmon (*S. salar*) and trout (*S. trutta*) in the rivers and in the fishing holes. However, once the two moved to Portapique eight years later, the resident "couldn't believe that there were no fish coming up the rivers".

The property the resident currently occupies is a remodeled farmhouse, which was built nearly 125 years ago. The family that previously owned the property visited the current owner fourteen years ago and provided their family history. The previous family farmed hay, potatoes and grain for generations. The current resident's family abandoned much of the farming practices. They occasionally sold blueberries and kept horses on the farm, for which they farmed hay.

The resident ultimately provided first- or second-hand accounts of various historic events and lifestyles, confirmed by the researcher's work. This interview emphasized the importance of not only learning of history by reading textbooks, but also to sit and listen to those who hold the knowledge and wish to share it.

Gerald Gloade - *Program Development Officer, Mi'kmawey Debert Cultural Centre*

Gerald Gloade is the Program Development Officer for the Mi'kmawey Debert Cultural Centre, and was visited at the Millbrook Cultural and Heritage Centre on November 2, 2018. He was raised in the community of Millbrook and still resides there. This provides him with ample Traditional Ecological Knowledge of the area.

A formal interview with Gloade was not conducted. An interpretive walk along the Mi'kmawey Debert Interpretive Trail was scheduled but had to be cancelled due to weather. Consequently, Gloade invited the researcher to attend an educational presentation he was offering for elementary school-aged children. Gloade is a fantastic storyteller and kept listeners intrigued with his vivid account of history. Important points covered by Mr. Gloade were the tools the Mi'kmaq used, the European influence on the Mi'kmaq, the ecological nature of the Mi'kmaq language and the significance of the Debert Paleoindian site for Mi'kmaq continuum, and the contemporary history of Canada.

Unfortunately, Gloade was the only person consulted for this report who could provide firsthand accounts of Mi'kmaq culture and heritage. The researcher lacked connections in the Mi'kmaq community, and those that were suggested were not interested in being interviewed. Gloade's participation was greatly appreciated and his presentation emphasized the importance of Mi'kmaq history, especially for the region of the "Five Watersheds Project".

Anonymous 6 – *Debert and Folly*

This resident was visited at their property in Little Dyke, between the Debert and Folly watersheds, on November 27, 2018. Their contact information was provided by Anita MacLellan. The resident is the seventh generation occupying the property which was previously used for farming.

This resident's family tree began on this property in 1765 with the settlement of the New England Planters. The family became owners of a farm which remained in use until 1972. The property is smaller today than it was historically, as some of the land was sold for cottages.

A unique feature of the property is the buried forest. Seven years ago, the current resident was excavating the marsh to form ponds for watering blueberries. Surprisingly, the resident found buried trees dated as 400 years old. The resident was well informed on the *Saros cycle* and the consequent dramatic storms. It is likely that one such storm resulted in a nearby freshwater lake flooding and becoming intruded with salt water, burying the trees in sediment. In the case of such extreme flooding events, the resident has built dykes on their property to protect the acreage from the Minas Basin (Figure 5).

This resident is the only interviewee to have such a long family tree within the "Five Watersheds Project" area, dating back to the eighteenth century. This provided an incredible opportunity to tour the property and learn of their family history which pertains to the project.

Figure 5. 1 Dykes built by resident on property (2010). Reproduced with permission from Anonymous 6.

VI. International Tidal gate Structures

Nova Scotia is considered one of the most vulnerable places in the world to rising sea levels, with infrastructure and residents' homes at sea level in many areas (John, Taylor, Solomon, Christian & Forbes, 2008). This conflict between the sea and its inhabitants has been an important issue since the seventeenth century, when the French began building the aboiteaux (see Section I). Today, throughout Nova Scotia, there are 241 kilometres of dykes containing 260 aboiteaux to protect important infrastructure. Notably, this problem is not unique to Nova Scotia and is a predicament many countries across the globe are facing. The international search for better ways of protecting infrastructure and land from flooding is becoming omnipresent.

Aboiteau, as a tidal gate structure, is one of many popular options that are used in tidally influenced regions across the globe, including Atlantic Canada. The structures are often for flood control but can also be used for pest control, such as with mosquitos that spawn in stagnant water (Boys & Pease, 2017). With tidal gate structures, an abrupt halt of tidal waters occurs in which salt water can no longer flow upstream and reach coastal wetlands. This blockage results in a considerably smaller and newly predominant freshwater environment upstream of the tidal gate structure. A drastic environmental shift such as this is known to have detrimental ecological effects on the environment.

The following sections of this paper aim to first describe how tidal gates have functioned throughout history. Secondly, present restoration projects from across the globe are examined to determine the most suitable tidal gate modifications for the Chiganois River. Lastly, the various species of the Chiganois River and their specific preferences for tidal gate passage are examined to ensure a proper tidal gate modification choice.

VI.I Historic Review

The invention of tidal gate structures is relatively recent, although derived from ancient technologies. The hydroengineering methods that inspired the eventual construction of tidal gate structures in North America were applied for nearly two millennia in various European countries. This section aims to explore the historical water management structures that were built across the globe which provided the French-Acadians with important knowledge which was consequently applied in building aboirteaux in Acadia, in the seventeenth century.

Dykes and drainage canals were the first structures built for halting the influx of the sea and draining accumulated freshwater. The oldest archaeologically discovered dykes are in the province of Friesland, in the northern Netherlands, along the coast of the Wadden Sea (Nieuwhof, 2010). A dyke, named Peins, measuring 54 metres long, thirteen metres wide and only 1 ¼ metres tall, was discovered. It was first built in the first century BC, although it was much smaller during its initial stages and underwent nearly a century of enlargements and additions to reach its final length and size (Nieuwhof, 2010). Another few metres of a dyke in Friesland, named Dongjum, was discovered dating back to the second century AD (Nieuwhof, 2010). Both dykes, although built centuries apart, are low-lying. It is suggested that the human settlers still led nomadic lifestyles during these eras, and the small dykes would allow seasonal flooding during the winter months when the habitants were settled inland (Nieuwhof, 2010). Such flooding would renew the nutrients in the soil and allow further cultivation in the summer without the need for fertilization by manure (Nieuwhof, 2010).

The similarity is staggering between the techniques for building the Friesland dykes and those in Acadie. Both include sods of salt marsh grass placed in layers to allow continued growth of vegetation (Nieuwhof, 2010; NSDA, 1987). The cohesion of the plant roots increased the stability of the dykes. Moreover, during the early Roman Iron Age, spanning from 1 to 400 AD, there is evidence of tree trunks being used as culverts within the dykes in Friesland, just as the Acadians did more than a millennium later (Nieuwhof, 2010; Whitelaw, 2004). Important differences between the Friesland and Acadian agro-technologies include the annual burning of plants, which the Friesland inhabitants did to increase the productivity of the lands (Nieuwhof, 2010). There is no evidence of this practice being adapted by the French-Acadians. Moreover, the Acadians built much higher dykes than did the Dutch. This is likely because the Bay of Fundy provides the world's highest tides, a phenomenon the Dutch did not have to tackle. Ultimately, it is clear that the knowledge of dyke building originated in the Netherlands during ancient times; however, the question remains as to how the techniques proliferated through time and space to finally reach the Acadians.

Historians have observed that wetland reclamation spread simultaneously across Europe with the expansion of medieval monastic orders, such as the Roman Catholic Cistercian monks. It is likely that the Dutch adapted the reclamation methods to other nearby European countries like Germany and France; however, the Cistercians are responsible for the proliferation of these methods throughout Europe in the twelfth century (Leonard, 1991; Charlier, Chaineux & Morcos, 2005). The Cistercian expansion was rapid and phenomenal, beginning near Dijon, France and quickly becoming the dominating monasticism in Europe through the Middle Ages (OCSO, 2018). Cistercians chose valleys and the riverain countryside as the locale to construct abbeys, which met the three fundamental demands of the Cistercian orders: isolation, water and stone (Maduro, Mascarenhas & Jorge, 2017). In these regions, swamps were drained by ditches and dykes to provide firm ground for building and agriculture. River channels were also altered to facilitate water evacuation and direct it as a supply for various mills. The most important feature of the Cistercian government was uniformity, so that all monasteries were exactly alike across the Western world (Maduro, Mascarenhas & Jorge, 2017). This consequently had an important effect on the coastal regions the Cistercians inhabited.

Although the French likely learned the techniques for water management from the Dutch and expanded the methods throughout the country with the Cistercian order, there is eventually an important shift in the purpose of the dyke and drainage systems. At the end of the Middle Ages in western France, during the late fifteenth to early sixteenth century, the building techniques are adapted to produce salt (Hatvany, 2002). Interestingly, western France is where many of the Acadians emigrated from for the New World and retrospectively, it is known that the climate of Acadie was too damp to evaporate salt as was done in France (see Section II). Consequently, historians suggest that the Acadians instead used the dyke systems and drainage culverts as the Dutch did in the first centuries AD, for agriculture.

The invention and expansion of dykes and drainage canals throughout the Western world can be very difficult to tease apart and may have simultaneous origins and as such, this review should act as a brief overview. It is likely that the tidal gate structures in place today were inspired by the tree log culverts built by the Acadians in the seventeenth century. The Acadians likely applied the techniques from western France for salt making and the salt makers likely applied methods learned from the Dutch and Cistercians.

VI.II. Modifications

Across the globe, tidal gate structures vary in design while maintaining the same function: controlling flooding to surrounding lands. This variability in design permits various degrees of fish passage or “fish-friendliness”, and modifications are sometimes made to increase opportunities for fish passage. For this study, commissioned by the “Five Watersheds Project”, to research tidal gate, coastal restoration projects from across the globe have been examined to determine the efficacy of various tidal gate structures. Since the focus of this study is to improve fish passage through tidal gates, herein tidal gate "efficiency" will refer to the degree to which a tidal gate allows fish passage, and not the ability of the tidal gate to protect the surrounding lands from inundating tides and flooding. The purpose of a tidal gate is to efficiently block tidal flows into inland areas, therefore the flood protection ability, regardless of the type of gate described in this report, is assumed to be efficient. It is important to note, that much of the research shows that even if tidal gates are retrofitted with modifications, the gated channels remain extremely dissimilar from non-gated channels in terms of species richness and habitat quality (Kroon & Ansell, 2006). Fortunately, small improvements in fish passage play an important role in recolonizing struggling fish populations, ultimately allowing a compromise between complete ecological restoration and protection of surrounding infrastructure and land use.

A traditional tidal gate structure is installed on a tidal river and is comprised of a series of round or box culverts, each with a gate fitted on the downstream side of the culvert. (Figure 3). The gates of a traditional tidal gate structure are top-hinged, and function based on gravity and the water differential between up- and downstream. The gates of the structure may open during the ebb tide to allow freshwater to flow downstream, and promptly close upon the flood tide to stop the inundating salt water from reaching upstream. During a typical tidal cycle, the gates will open twice a day; however, field research has shown that in many study areas this is an overestimation of gate opening occurrence since debris, siltation, ice and drought conditions can significantly reduce the amount of time the gates are open (H. Kolstee, personal communication, Oct. 18, 2018). Some gates have never been observed opened, while others remain closed for days at a time (Seifert & Moore, 2018). Closed gate structures likely provide a significant migratory delay for diadromous species that require transitions between fresh and saltwater, during their life cycle.

In many regions, the minimum modification to the traditional top-hinged tidal gate structure is to install side-hinged gates. Although this is a seemingly simple modification, the entire structure may have to be replaced so that the culvert has a precise vertical angle to allow for proper gate opening and closing (Giannico & Sourder, 2005). Side-hinged gates may open with a hydraulic differential of just one inch, whereas top-hinged gates have required up to one foot (Giannico & Souder, 2004; Giannico & Souder, 2005). A smaller hydraulic differential, results in a longer period of gate opening, especially if the gate is made with a lightweight material, such as aluminum. Side-hinged gates also offer a wider gate opening angle (Giannico & Souder, 2005). Although research on the various tidal gate modifications is very limited, one study demonstrated that Chinook salmon (*Oncorhynchus tshawytscha*) showed no preference for gate angles or tidewater depths during upstream passage through side-hinged gates, which allowed passage during the entire gate open period (Bass, 2010). In the same study, upstream passage by salmon (*O. tshawytscha*) was only observed through a top-hinged gate during the last hour of the gate open period, indicating specific preferences for gate opening angle (see Section IV.IV) which severely limits passage opportunities.

A recently popular tidal gate modification in North America, the United Kingdom and Belgium is the installation of an orifice in a tidal gate, sometimes referred to as a, "pet door". These holes are built with or without top-hinged or side-hinged cover doors and are placed in the top, middle, or bottom of a tidal gate. Theoretically, the orifice modification permits tidal flushing, improving water temperature and salinity, and provides an avenue for fish passage regardless of the tidal gate status (Giannico & Souder, 2005). For these reasons, orifices have been suggested as upgrades for tidal gate structures in Nova Scotia, such as the Avon river aboiteau (anonymous, personal communication, Aug. 15, 2018). Contrarily, research in the UK has shown that these modifications have not improved the migratory delay or passage efficiency experienced by brown trout (*S. trutta*), regardless of whether the orifice was open for the entirety of the tidal cycle (Wright et al. 2014; Wright et al. 2016). Moreover, a restoration project in Oregon, USA saw no improvement in fish passage or water quality with the utilization of a pet door (Johnson et al. 2013). Lastly, a Belgic study demonstrated that the water velocity for the pet door under submerged conditions was 40 per cent higher than the water velocity of the tidal gate, making the pet door unusable for most fish species within the study system (Patrik et al. 2009). The British and Belgic studies also demonstrated unexpected leakage with the orifice modification, which could lead to degradation of the structure over time, and in the case of the "Five Watersheds Project" system, upstream siltation (H. Kolstee, personal communication, Oct. 18, 2018).

Another modification is the "mitigator fish-passing device". This is a float-operated, cam-lock system that is typically added to the traditional top-hinged tidal gate, propping the gate open to allow a narrow space of around 20˚ (Giannico & Souder, 2005). The only study on tidal gate opening angle and fish passage, showed that Chinook salmon (*O. tshawytscha*) would only pass upstream of a top-hinged tidal gate at angle openings of 40˚ or larger (Bass, 2010). Although this modification would not likely facilitate fish passage, it could improve tidal flushing and habitat upstream of the structure by reducing temperature and increasing salinity. Notably, this idea was introduced with the orifice modification and was not successful (Johnson et al., 2013). Moreover, based on preliminary data, the temperature and salinity of the Chiganois River provides a suitable spawning habitat.

One of the most wide spread modifications to tidal gate structures is a float device which makes the tidal gate “self-regulating”. As opposed to solely relying on gravity and the water level difference between upstream and downstream, a floating device is set to a predetermined water level on the upstream side, ultimately increasing the time the gate is open (Giannico & Souder, 2005). This shifts the tide-gate from a default closed position to a default open position (Johnson et al., 2013). There are various styles of self-regulating tidal gates, whether the gate itself is made of a more buoyant material in combination with float devices or whether the original tidal gate is retrofitted with a floating device (Giannico & Souder, 2005). One study has shown a significant improvement in the amount of time all gates were open while only one of the tidal gates was retrofitted with the floating device (Bocker, 2015). Another study demonstrated that if none of the gates of a structure are retrofitted and consequently have a small opening, fish are deterred from passing through; however, if one gate is opened wider (i.e. the one retrofitted with the float device), fish preferentially used this gate (Wright et al., 2014). These are both cost-saving options in which only one gate must be retrofitted, although these are the only two studies that have tested and exhibited this.

It is important to note that, ultimately, the management of the tidal gate is the most important factor, and not the style that is installed. For instance, a modification that allows three feet of upland inundation year-round is likely not as beneficial to fish populations as is a side-hinged gate, without any modifications, that is shut when fish are not present but open for the entirety of their migratory period (CTC & Associates LLC, 2016; Greene, Hall, Beamer, Henderson, & Brown, 2012). The migratory patterns of various diadromous fish in the “Five Watersheds Project” area, is described in Table 4. Unless otherwise indicated in brackets, the upstream migrations are for spawning and the downstream migrations are of juveniles. An agricultural engineer for the Nova Scotia Department of Agriculture is interested in a versatile gate design in which doors or half-doors could be removed, depending on the time of year, to allow constant fish migration (C. Esau, personal communication, Oct. 19, 2018).

Table 4. 1 Seasonal gate openings required to accommodate fish passage.

Time of Year	Upstream Migrations	Downstream Migrations
April to June	Alewife/Gaspereau Spring-run salmon Smelt Eel	Sea-trout Tomcod Striped bass (after over-wintering) Salmon Smelt (and spent adults) Alewife/Gaspereau (spent adults)
July to August	Alewife/Gaspereau Sea-trout	Eel (spawning) Alewife/Gaspereau (and spent adults) Shad
September to November	Fall-run salmon Striped bass (over-wintering)	Shad Eel (spawning) Salmon (spent adults)
November to February	Tomcod	Tomcod (spent adults)

Note. Adapted from “Historic examination of the changes in diadromous fish populations and potential anthropogenic stressors in the Avon river watershed, Nova Scotia” by L. A. Isaacman. Retrieved from Library and Archives Canada. Copyright 2005 by Lisa A. Isaacman. Adapted with permission.

A problem that is unique to the “Five Watersheds Project” area, is the amount of silt that is flushed into the rivers by the Bay of Fundy tides. It was for this reason that tidal gate modifications were not implemented in the past (H. Kolstee, personal communication, Oct. 18, 2018). This is not an issue in each river of the “Five Watersheds Project”, and is dependent upon the length of the river channel from the bay, leading to the aboiteau. The longer the channel is, the more siltation will occur. For instance, the aboiteau at Great Village does not typically have problems with silt accumulation, but the Chiganois aboiteau is silted regularly (H. Kolstee, personal communication, Oct. 18, 2018).

The only other country that has installed tidal gate structures and must also mitigate problems associated with extreme siltation, is China. In China and Nova Scotia, tidal gate managers have dredged the rivers and hydraulically pressure-washed the gates; however, each of these methods are time consuming, costly, and are not a one-time fix (Ji, Yang, Zhang, & Lu, 2013). For smaller aboiteau structures, the Nova Scotia Department of Agriculture installed two culverts of varying lengths, so that when one of the gates are blocked by silt, the flow of water from the other pipe can remove the silt (H. Kolstee, personal communication, Oct. 18, 2018). A structure with this design is currently upstream and behind Truro, but is likely not feasible for the scale of the Chiganois structure. Unfortunately, no other solutions were discovered during this research and the extreme siltation must be considered when installing any tidal gate modifications.

VI.III. Species-Specific Traits

Recent research examining the "fish-friendliness" of various tidal gate structures, has determined that many species have specific preferences for entering and passing a structure. For many species within a system, the preferences may overlap, and the preferences may also be dependent upon the life stage of the species, changing throughout their lifetimes. Consequently, the tidal gate may only need to satisfy the requirements of a certain life stage during a certain time of year and not indefinitely. For this section, research from the Department of Fisheries and Oceans and other research institutions, has been compiled to provide an overview of various passage preferences for species of the "Five Watersheds Project" area.

There are upwards of fifteen species that frequent the rivers of the "Five Watersheds Project". These species are summarized in (Table 5). In a system with many fish, the function of the tidal gate structure must seek to facilitate the passage of as many species as possible, or the passage of the most important species, such as endangered species or those with a critical life stage that could be delayed or blocked completely by the tidal gate (i.e. diadromous fish spawning). Depending on size, life history and other various factors, the species-specific preferences may vary for water velocity, overhead cover, open gate angle, and the amount of time the gate is open. Unfortunately, the research on species-specific preferences for tidal gate structure parameters is very limited and is often deduced from research based on other fish passage barriers, such as culverts.

Table 5. 1 Fishes frequenting the rivers of the Chiganois, Debert, Folly, Great Village, and Portapique watersheds.

Common Name	Latin Name
Atlantic Salmon	*Salmo salar*
Speckled or Brook Trout	*Salmo trutta*
Rainbow trout	*Oncorhynchus mykiss*
Atlantic Mackerel	*Somber scombrus*
American Shad	*Alosa sapidissima*
American Eel	*Anguilla rostrata*
Alewife/Gaspereau	*Alosa pseudoharengus*
Atlantic sturgeon	*Acipenser oxyrynchus*
Blueback herring	*Alosa aestivalis*
Fourspine stickleback	*Apeltes quadracus*
Threespine stickleback	*Gasterosteus aculeatus*
Atlanic tomcod	*Microgadus tomcod*
White perch	*Morone Americana*

Striped bass	*Morone saxatilis*
Rainbow or American smelt	*Osmerus mordax*
Sea lamprey	*Petromyzon marinus*
Ninespine stickleback	*Pungitius pungitius*
Sea-run brook trout	*Salvelinus fontinalis*

WATER VELOCITY

Species-specific preferences for water velocity are very dependent upon the body size of the fish, and often the body size is dependent upon the life stage. Typically, a larger fish is capable of swimming faster than a smaller-bodied fish. Fish are capable of swimming at various speeds and can therefore adjust their speeds to successfully pass a barrier, although there are limitations to these speeds. At a "sustained" speed, a fish is limited to a slower speed, but can maintain this speed for a longer distance and time. While maintaining the sustained speed, the fish can swim for under thirty minutes (T. Henderson, personal communications, Oct. 12, 2018). At a "burst" speed, a fish is swimming at its maximum capacity, but is limited to traversing a short distance. If maintaining the burst speed, the fish can only swim for approximately twenty seconds (T. Henderson, personal communications, Oct. 12, 2018).

Adult fish from the Salmonidae family are strong swimmers; however, as juveniles they are among the weakest. For instance, a 1996 report by the Department of Fisheries and Oceans Canada lists juvenile Atlantic salmon (*S. salar)* and juvenile brook trout (*S. trutta*) as two of the four weakest swimmers in eastern waters. Adult alewives (*A. pseudoharengus)* and adult American smelt (*O. mordax)* are listed as the two other weakest swimmers, both of which are smaller-bodied species (Conrad & Jensen, 1996). The swimming speeds of these fish are summarized in (Table 6).

Table 6. 1 Swimming velocities for the four weakest swimming species in the region.

Species	Burst swim velocity (m/s)	Sustained swim velocity (m/s)
Juvenile Atlantic Salmon	1.22	0.61
Juvenile brook trout	1.22	0.46
Adult alewives	3.04	0.46
American smelt	0.76	0.37

Note: Adapted from Fish Passage and Habitat Preservation for Highway Culverts, Eastern Canada by Vern Conrad and Hans Jansen. 1996.

The most important migration of an anadromous fish may include passing against the current of an open tidal gate to reach spawning grounds within the watersheds, as is the case with gaspereau (*A. pseudoharengus*), Atlantic salmon (*S. salar)*, smelt (*O. mordax)*, and shad (*A. sapidissima*) (Isaacman, 2005). Often the length of the tidal gate structure is not a short enough distance for a fish to swim at burst speeds, incessantly, until reaching the upstream side. For instance, the aboiteau on the Chiganois River is 120 feet long from the tidal gate on the downstream side to the upstream entrance (C. Esau, personal communications, Oct. 3, 2018). A fish entering from the downstream side would be unable to swim at burst speed for 120 feet against the out-going current. To mitigate this problem within culverts, baffles are installed which are small, affordable additions that pool water, providing fish with resting stations to regain energy. This sort of modification, allowing resting stations, has not been created for tidal gate structures (see Section IV.III). Consequently, the water velocity must therefore meet the limited “sustained” speed of the weakest swimming species. By designing a tidal gate that meets the requirements of the weakest swimmer it ensures that all fish will be able to swim at the present water velocity.

Open gate angle

As a rule of thumb, a wider gate opening angle increases fish passage efficiency and the gate opening angle is dependent upon the type of tidal gate. For instance, a side-hinged gate will typically allow a wider gate opening angle than that of a top-hinged gate. A study demonstrated that for upstream passage of Chinook salmon (*O. tshawytscha*) through a side-hinged gate, there was no preference for gate opening angle during the entire tidal cycle because the gate was consistently open wide enough to allow passage (Bass, 2010). Contrastingly, for a top-hinged gate during spring tide conditions, there was only one hour per tidal cycle where the gate was open above 40˚ and salmon (*O. tshawytscha*) passed through successfully (Bass, 2010). Another study examining eel (*A. anguilla*) migration showed that in a tidal gate structure with a series of tidal gates, eels preferentially used a tidal gate that was open wider than those that had a narrower opening (Mouton et al., 2011).

VII. Sources

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