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Onslow-North River Managed Dyke Realignment and Tidal Wetland Restoration Project

A Case Study of Nature-based Coastal Adaptation in Nova Scotia

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Team members from the School of Planning at Dalhousie University compiled the cased studies. Other members of the Making Room for Movement team provided content and insight to one or more of the studies, including Kirsten Ellis, CBWES, Inc; Nancy Anningson, Ecology Action Centre; Dr. Kate Sherren, Dalhousie University; Dr. Danika van Proosdij, Saint Mary's University; Dr. Tuihedur Rahman, McGill University‘ and Tony Bowron, CBWES, Inc.

Case study project participants contributed to documenting the projects by providing project descriptions and technical information. For this case study, the Onslow-North River Managed Dyke Realignment and Tidal Wetland Restoration Project, project team thanks staff with the town of Truro and the Municipality of Colchester and the TransCoastal Adaptions team.

This project was undertaken in Mi'kma'ki, the unceded ancestral territory of the Mi'kmaq. We acknowledge and pay respect to the traditional stewards of the land on which we live and have conducted this work.

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Case Study Context and Purpose

Separate, but complementary needs among provincial and municipal governments and the availability of technical skill, and local and scientific knowledge came together in a managed dyke realignment and tidal wetland restoration initiative on a section of dykeland along the Salmon River in Onslow, Colchester County, Nova Scotia. This case study draws on technical reports, scholarly publications, municipal planning documents, input from project partners, and site visits to describe the project site and context, project planning and development, partnerships for project implementation, local planning regulation, predicted project benefits, project barriers and drivers, and the benefits and lessons of implementing nature-based adaptation at the Onslow-North River dykeland.

Background

The Onslow-North River Managed Dyke Realignment and Tidal Wetland Restoration project (the Onslow-North River project) is located on a section of dykeland in Onslow, Municipality of the County of Colchester (Colchester), on the north side of the Salmon River at the confluence of the North River (Figure 1). The town of Truro (Truro) is opposite the site on the south side of the Salmon River. Colchester encompasses approximately 3600 km^2 and is home to 50,585 residents (Statistics Canada, 2021a). Within the boundaries of the county municipality are two town municipalities, Truro and Stewiacke, two village commissions, and the Millbrook First Nation. The town of Truro, with a population of 12,260 residents (Statistics Canada, 2021b), is the regional service centre for the area. The Salmon River flows through the county from headwaters in the Cobequid uplands to Cobequid Bay (Bay of Fundy) and forms the northern and eastern border between the town of Truro and Colchester County municipality. A tributary, the North River, flows into the Salmon River estuary from the north. Salmon River empties into Cobequid Bay near Truro. The tidal range in Cobequid Bay is 17 metres (Desplanque & Mossman, 2004)

The lower Salmon River floodplain near Cobequid Bay was originally salt marsh but was converted to agricultural land by the Acadians in the 1600s (Bleakney, 2004). Approximately 80% of tidal wetlands in the Bay have been lost, primarily due to dyking for agricultural

purposes (NSDE, 2017). The floodplains are nutrient-rich and highly productive for crop growth (NSDA, 2010). Acadians settlers created a series of dykes and aboiteaux to drain the marshes and to keep floodwaters out (Robinson *et al*., 2004). The dykes and aboiteaux have been in place, rebuilt, and maintained ever since. An aboiteau is a culvert with a hanging gate that allows freshwater from precipitation to drain to the sea while closing during high tides to prevent salt waters from flooding the dykelands. Dykelands are culturally significant for many Nova Scotians because of their long history, creating a sense of place and value (Asiedu, 2013).

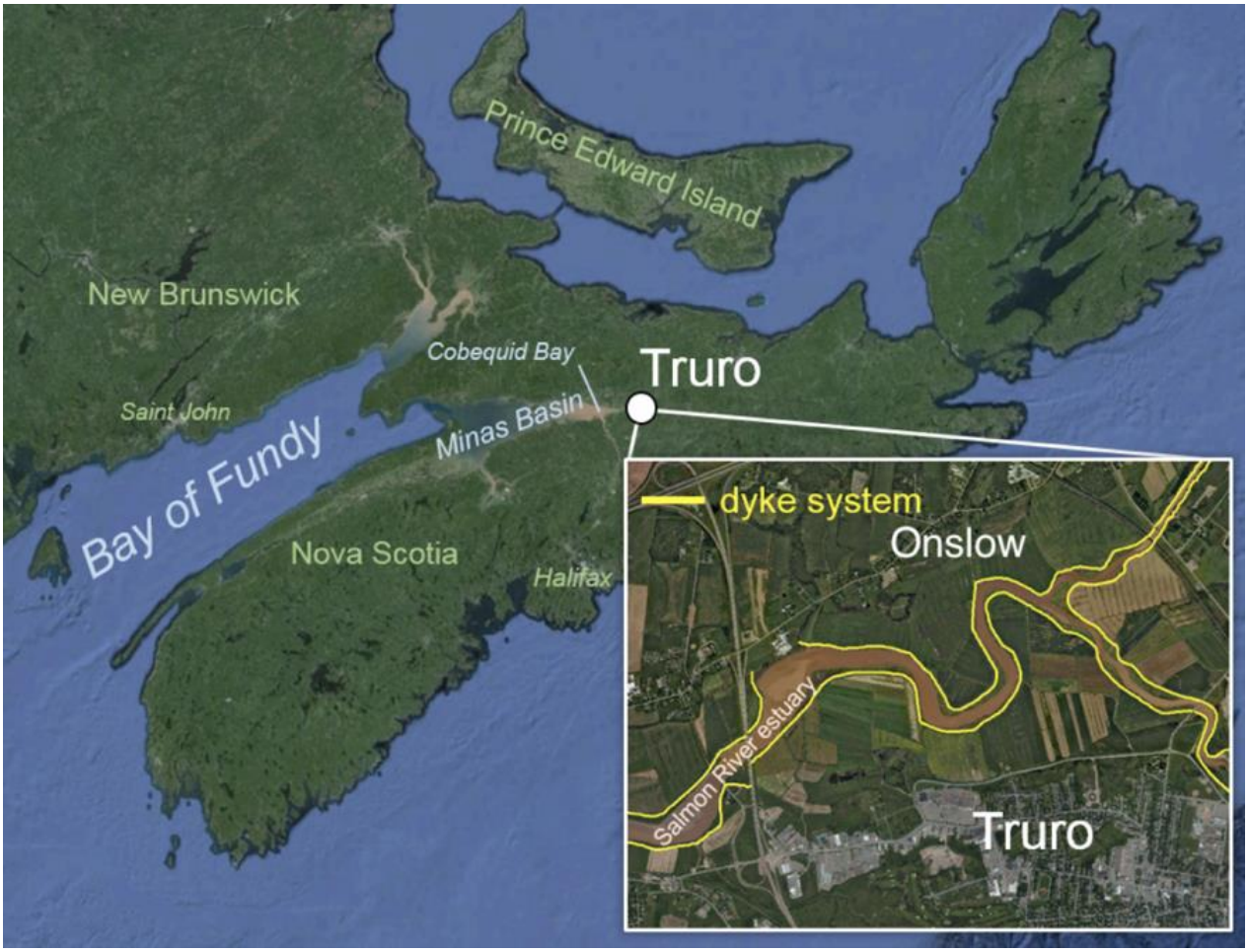

Figure 1: Site map (adapted from Marvin & Wilson, 2016)

Climate change and changing land use have challenged the effectiveness of dykelands and aboiteaux built at a time of lower sea levels (van Proosdij & Page, 2012). Many of the original aboiteaux and dykes in the province were replaced in the 1950s. However, the designs did not

consider climate change or changing land use (van Proosdij & Page, 2012). As Nova Scotia's population and development increased, the function of dykes shifted to include the protection of infrastructure and people. Employment sectors also began to shift. Some agricultural fields became inactive with shifts in employment sectors (van Proosdij &Page, 2012). As a result, dyke monitoring and maintenance in some areas decreased.

The land to the north of the Salmon River in Colchester County remains agricultural, but some agricultural land in Truro has been converted over time to other purposes. Agriculture only makes up 2-4% of employment in Truro (Sherren *et al.,* 2019). Retail, health care, manufacturing, and education are the main economic sectors (Sherren *et al*., 2019). Economic growth drives land development. In Truro, some of the development has expanded into areas at risk of flooding.

Hazards and Risks in Truro and Colchester County

Climate change is creating warmer and wetter conditions in Nova Scotia, leading to more frequent and intense rainfall events (ECCC, 2019). As sea levels rise, coastal flooding is becoming more common at the coast, negatively impacting coastal communities and regions such as Truro and Colchester. Rising sea levels magnify high tides and storm surges (ECCC, 2019).

There is a long history of flooding where the Salmon River meets the North River and changing climate conditions are altering typical flood patterns (Sherren *et al*., 2019; CBCL, 2017). Beginning in the 1970s and continuing into the early 2000s, Truro underwent five flood reviews (Sherren *et al*., 2019). In 1988, the federal government notified the Town that it would receive only one more damage payment through the federal insurance program and federal disaster assistance (Rahman *et al.,* 2019). As a result of the federal decision to not provide any more compensation, flooding responsibility was placed in the hands of the municipality. In 2012, flooding from tropical storm Leslie devastated the Town, and the federal Flood Damage Reduction Program identified Truro as a "high risk" area (Rahman *et al.*, 2019). Over the years, the municipality used a hard infrastructure and soft policy approach to address flooding, but the

flooding in 2012 made it clear that the municipality needed to take a more reliable and adaptive approach to flooding.

In Truro and Colchester, flood risks are greatest when a rainfall event happens during high tide (Rahman *et al*., 2019). Aboiteaux (one way tide gate) close during high tide to prevent sea water from flooding the landward side of the dykes. At the same time, runoff is draining to the river and increasing its volume. The river can't drain into the ocean through the aboiteaux. As a result, water becomes backed-up on both sides of the dyke, creating significant flood risks and dyke erosion. Land use changes that convert permeable land like forested uplands and lowland pasture to urban development further aggravate these risks by sending runoff directly to the river.

In Colchester, flooding happens on underutilized and fallow agricultural land. In Truro, the impacts of flooding are more severe because much of the agricultural land has been converted for commercial, industrial, and some residential purposes. Outside the Halifax Regional Municipality, Truro is one of the fastest-growing communities in Nova Scotia (Town of Truro, 2015). Consequently, there is a need for more services, roads, and housing. Development applications are being approved for residential, mixed-use residential, and institutional infrastructure to support this growth. While the recently approved developments are not located in the current designated flood zone, several sites are near the Salmon River (Town of Truro, 2021) and in the area identified at risk of flooding in the flood risk study prepared for the town by CBCL Limited (2017) (Figures 2 and 3). Development will need to take into consideration adaptations to avoid flood impacts. Figure 3 also illustrates that areas not directly impacted by flooding might still be affected because roads connecting them to essential services and employment could be flooded

Figure 2. Approved development agreements (Town of Truro, 2021)

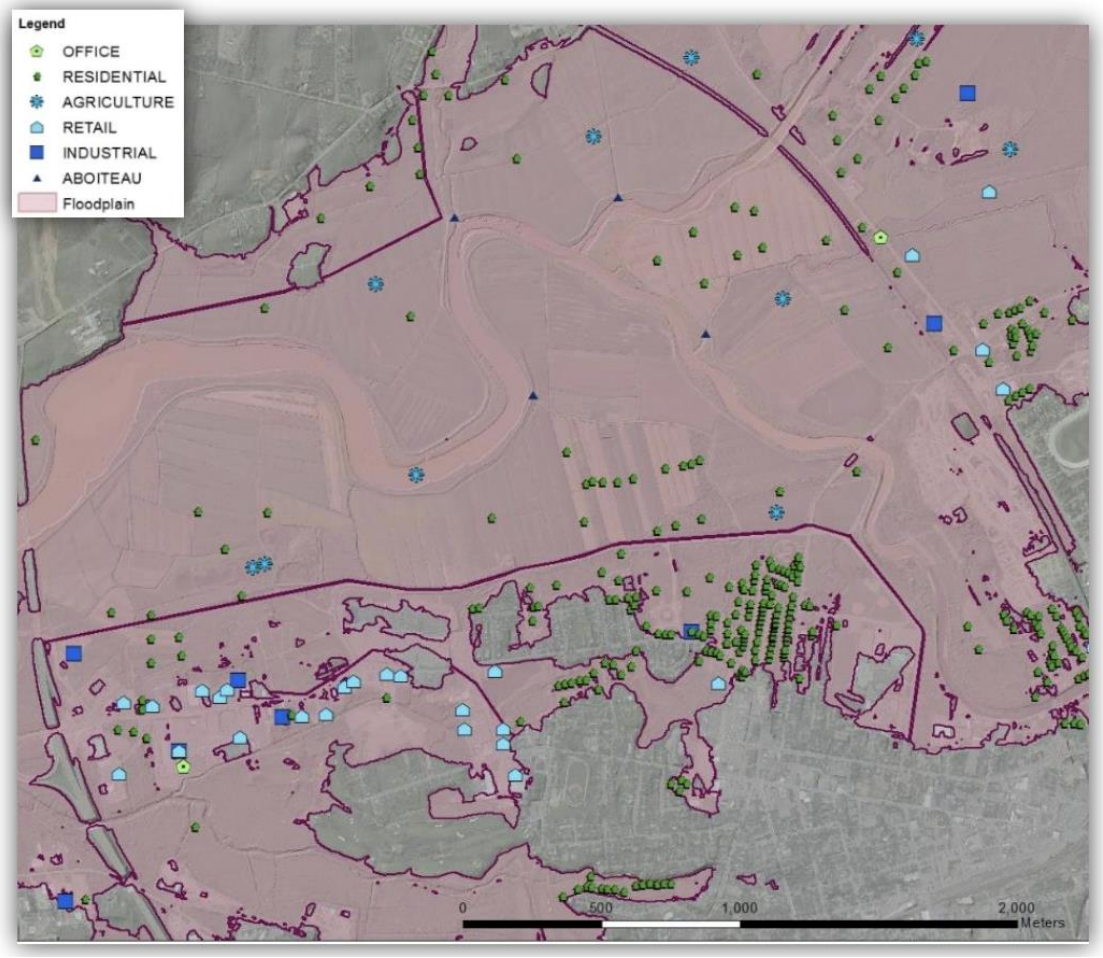

Figure 3. The Salmon and North River floodplains and vulnerable infrastructure and land uses in the Truro and Onslow areas (CBCL, 2017)

Social Vulnerability to Hazard in Truro and Colchester County

Flooding is a natural process that becomes a natural hazard when land development encroaches into flood prone areas, putting people, infrastructure, and land use activity at risk of flood impacts. Natural hazards affect populations differently. The impacts felt by a population, or a population's vulnerability to a hazard (such as flooding), is evident in the ability of the populations ability to respond to, cope with, and recover from the impact of the hazard. A variety of individual and social factors influence vulnerability of a population including income, employment, gender, age, race, education level, household composition, ability to speak the local language, among others. The greater the proportion of the population experiencing conditions

that contribute to vulnerability (such as advanced age, unemployment, being a recent immigrant, etc.), the more vulnerable the population is in that area. Vulnerability is described through indices such as the Social Vulnerability Index (Cutter, *et al*., 2003), or a marginalization index (Matheson, *et al*., 2012), or a deprivation index such as the Canada Index of Multiple Deprivation (CIMD) (Statistics Canada, 2019). The analysis for this case study uses the CIMD.

The CIMD is an area-based index created by Statistics Canada using variables from the 2016 Census of Population at the Dissemination Area (DA) level (Statistics Canada, 2019). A Dissemination Area is the smallest population unit for which Statistics Canada reports the full set of demographic and social statistics, about 400 to 700 people. DAs are relatively stable geographic areas. Statistics Canada developed CIMD datasets across three geographic scales: national, regional (two, including Atlantic), and provincial (three), referenced to 2106. This case study used the Atlantic Region CIMD data set.

The CIMD comprises four dimensions of deprivation and marginalization, with each dimension incorporating influencing indicators derived from the census data: residential instability; economic dependency; ethno-cultural composition; and situational vulnerability. The indicators for each dimension are listed in Figures 3 to 6. DA-level factor scores were calculated for each dimension using factor analysis. Scores were then ordered within each dimension into quintiles and the quintiles were assigned a value of 1 through 5, Quintiles represent fifths of a population; the first quintile is the lowest fifth of the data (1% to 20%) and receives the quintile value '1'; the fifth quintile is the highest fifth of the data (81% to 100%) and receives the quintile value '5'. For the CIMD, '1' represents the scores indicating the least deprived fifth of the population; and '5' indicates the most deprived.

Figures , 4, 5, 6 and 7 are maps developed from the Atlantic Region CIMD data set to show the deprivation levels for the Onslow, Colchester County and Truro area, centred on the Onslow-North River managed dyke realignment location. The shades of green on the maps represent lesser (light) to greater (darker) deprivation. The higher the deprivation the more vulnerable is the population to hazards. Table 1 compares marginalization/deprivation between 2006 and 2016. The 2006 data are from an earlier index, the Canadian Index of Marginalization

(Matheson, *et. al*., 2012). The two indices measure the same factors and are compatible for comparisons to identify trends.

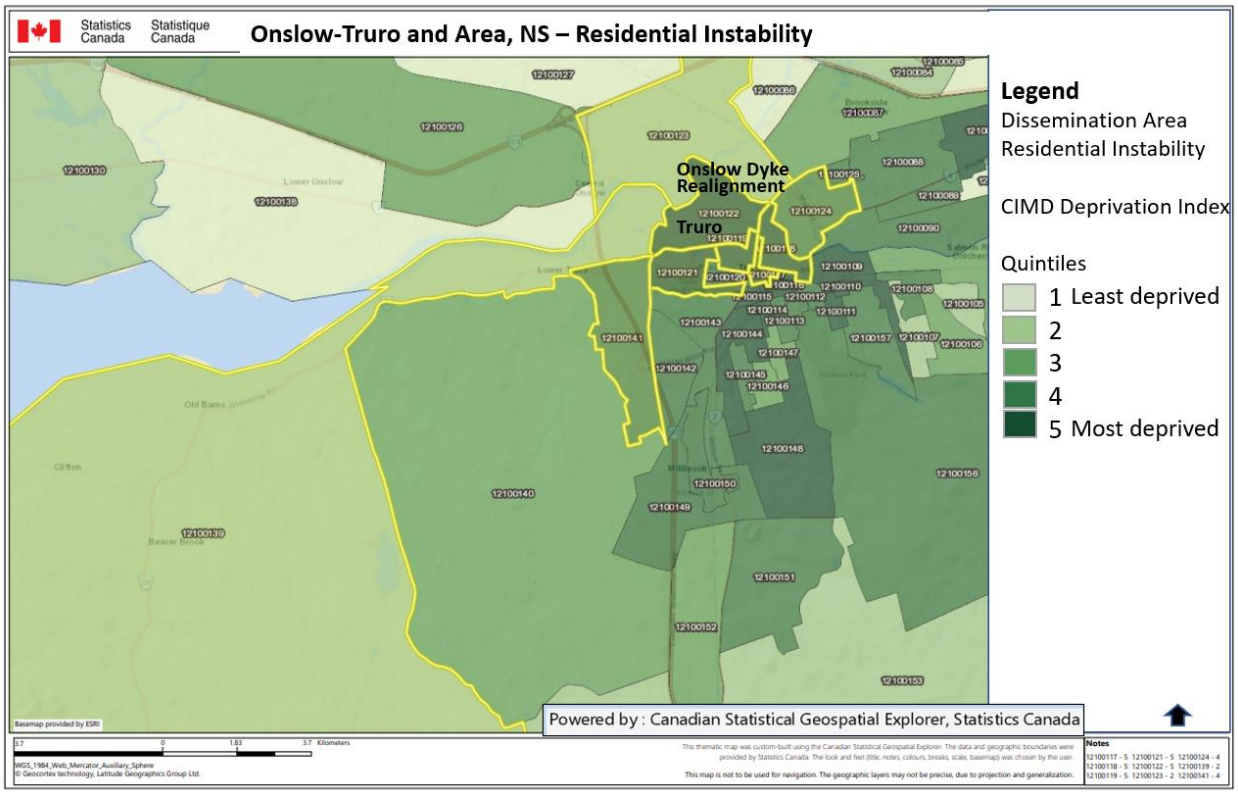

Figure 4. Onslow/Colchester County - Truro and Area - Residential Instability* at 2016 Canadian Index of Multiple Deprivation –(Statistics Canada, 2019)

*Proportion of persons living alone; proportion of dwellings that are owned, proportion of dwellings that are apartment buildings; proportion of the population that is married or common-law, proportion of the population that moved in the last five years.

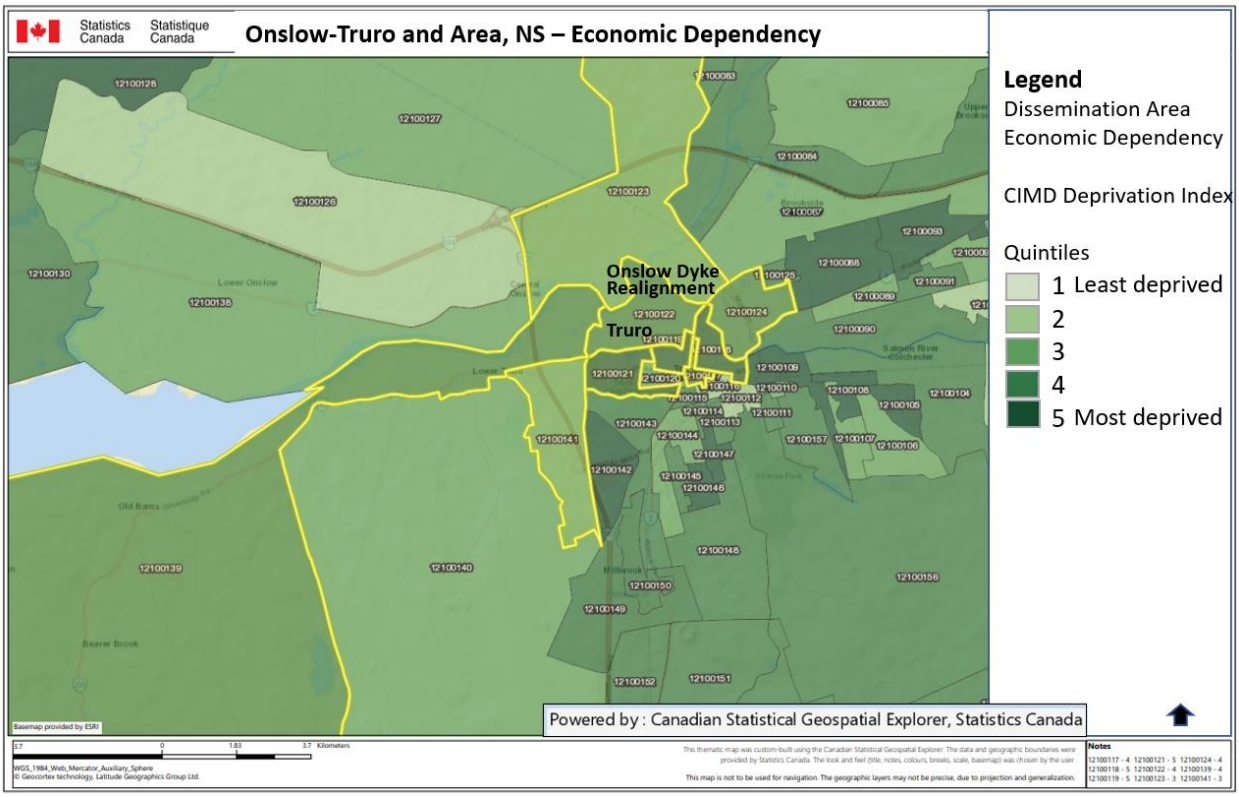

Figure 5. Onslow/Colchester County – Truro and Area - Economic Dependency* at 2016 Canadian Index of Multiple Deprivation - (Statistics Canada, 2019)

*Proportion of population aged 65 and older; proportion of population participating in the labour force -15 and over; dependency ratio (population 0-14 and 65 and over divided by population 15-64; ratio of employment population proportion of population receiving government transfer payments.

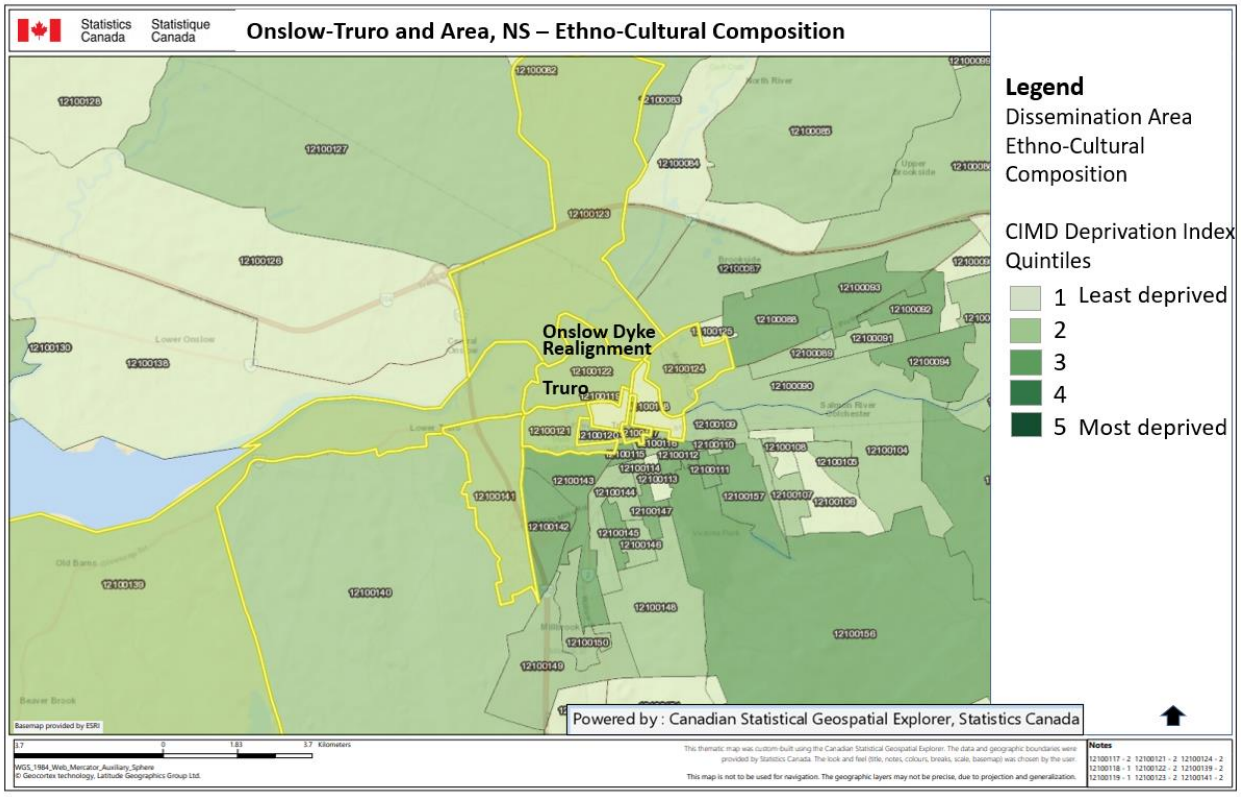

Figure 6. Onslow/Colchester County - Truro and area - Ethno-Cultural Composition* at 2016 Canadian Index of Multiple Deprivation (Statistics Canada, 2019)

*Proportion of population that is recent immigrants; proportion of population that has no knowledge of either official language.

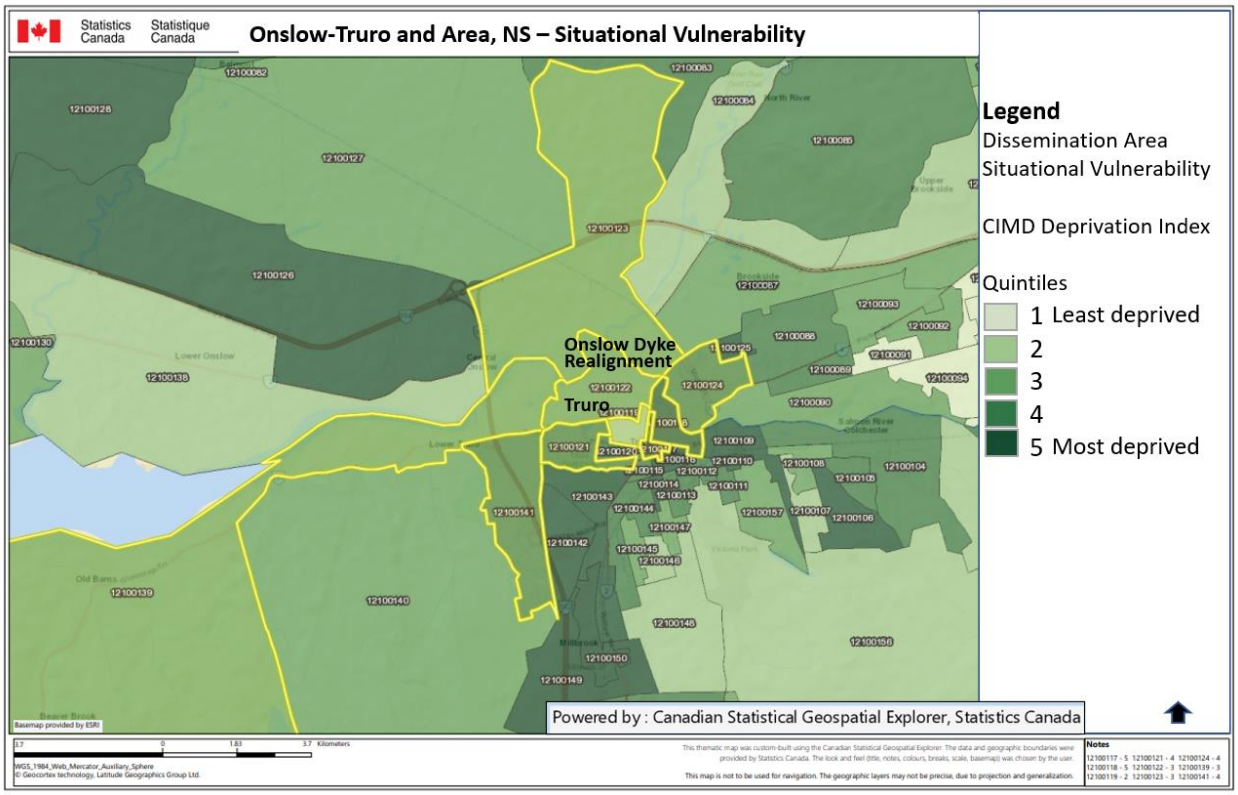

Figure 7. Onslow/Colchester County - Truro and area - Situational Vulnerability* at 2016 Canadian Index of Multiple Deprivation (Statistics Canada, 2019)
*Proportion of the population that identifies as Aboriginal; proportion of dwellings needing major repairs; proportion of population aged 25 to 64 without a high-school diploma.

The figures show that highest CIMD values are Residential Instability and Economic Dependency in the urban area, which is Truro, and include the DA bordering the Salmon River, across from the Onslow dyke realignment project area. The same variables show lower values in the DA on the Onslow side of the river in the same area. Residential Instability in particular, is two quintile values lower for the Onslow area compared to Truro. However, CIMD values for Residential Instability and Economic Dependency are highest outside the immediate study area. The DAs in the study area have low CIMD values (‘1’ and ‘2’) for Ethno-cultural Composition. Forty-one to 60 percent of the population is experiencing Situational Vulnerability where the CIMD value is ‘3’.

Residential Instability includes factors such as number of individuals living alone, and number of homes in need of major repair. Economic dependency includes the proportion of seniors in the population and the ratio of employed people in the population to those receiving government

transfer payments (employment insurance, pension payments or old-age security). Aging populations may be contributing to higher vulnerability. Seniors (those 65+) are the fastest-growing demographic in Nova Scotia, and rural regions experience this more intensely than cities (CBCL, 2009). Seniors make up 15% of the population in Nova Scotia, and 25-30% in rural areas (CBCL, 2009), including small towns. To support a growing senior population, essential services such as hospitals, access ways to emergency services, and other medical services are essential. Where these services are also vulnerable to climate change and flooding, vulnerability of the population increases.

As previously noted in Figure 3, exposure to flood hazard may be direct or indirect. The figure shows how commercial and residential areas are at risk of direct exposure to flooding, and how other parts of the community that might not flood are still at risk of losing access to services and places of employment. The spatial relationship between areas at risk of flooding and social vulnerability mapping for the Truro-Colchester areas shows that areas of moderate and greater Residential Instability and Economic Dependency might be disproportionately impacted by flooding. Reducing risk includes reducing vulnerability and exposure to hazard. Reducing social vulnerability involves improving a population's capacity to respond to flooding by improving financial security, quality and security of housing, education, among other things as indicated by the CIMD factors.

Reducing exposure to flood hazard involves sound land use planning to avoid flood prone areas and improving the capacity of landscapes to absorb flood waters so it doesn't reach built up areas. Increasing the flood plain is one way to reduce exposure to hazard and is one of the objectives of the Onslow-North River Managed Dyke Realignment and Tidal Wetland Restoration project (https://www.transcoastaladaptations.com/onslow-north-river).

The Onslow-North Dyke Managed Realignment and Tidal Wetland Restoration Project

Dyke realignment is a method to address dyke infrastructure repair and replacement in dykelands and is often used in conjunction with tidal marsh restoration. Although new to Nova Scotia, it is used for flood management and habitat restoration approach in parts of Europe (French, 2001; 2006). It involves moving (relocating) dykes landward and reshaping them (realigning) followed by the deliberate breaching or decommissioning of existing dykes to restore tidal flow to the floodplain area (Rahman *et al*., 2019). The repositioning creates space for salt marshes to grow on the seaward side of dykes. The expansion of the floodplain provides more room for flooding, thereby lessening the flow of floodwater into developed areas.

The Onslow-North River dyke realignment and tidal wetland restoration project arose from multiple complementary needs including the municipal need to manage flood risk and provincial government departments needs to compensate for wetlands lost to public infrastructure development and managing dyke infrastructure maintenance and cost. The project was designed and implemented by a multi-disciplinary team of coastal and wetland experts from CB Wetlands and Environmental Specialists (CBWES), Saint Mary's University (SMU) and Queens University. Engineering consulting firm, CBCL Limited, responsible for an earlier flood risk study for the Truro area, was consulted to verify design at the final stages. The project team coordinated with provincial governmental departments and consulted non-governmental stakeholders. Table 1 shows the government and non-governmental groups' roles and Figure 8 shows government jurisdictions in the coastal zone of the realignment project.

Department	**Role**
Department of Transportation and Infrastructure Renewal (NSDTIR)	Under the provincial wetland conservation policy, NSDTIR must compensate for the removal of wetlands by restoring other wetlands.
Department of Agriculture (NSDA)	Responsible for all dykes and aboiteaux under the *Agriculture Marshland Conservation Act.*
Department of Environment (NSDE)	Regulates activities with respect to wetlands and watercourses. Approves wetland compensation Climate adaptation training, CALP

Department of Communities, Culture, and Heritage	Responsible for archaeological resources including Acadian dykelands and resources found in areas protected by dykes (Sherren *et al*., 2019)
Municipality of Colchester County	Land use planning and regulation, Joint Flood Advisory Committee member; build and maintain municipal infrastructure
Town of Truro	Land use planning and regulation, Joint Flood Advisory Committee member; build and maintain municipal infrastructure
Millbrook First Nation	Area rights-holders, Joint Flood Advisory Committee member
Marsh Body	Association of marshland owners incorporated under the *Agricultural Marshland Conservation Act* for the purpose of managing the dykes and marshland

Table 1. Governmental actors and non-governmental stakeholders and their roles in or relationships to the Onslow-North River Managed Dyke Realignment project:(Rahman *et al*., 2019).

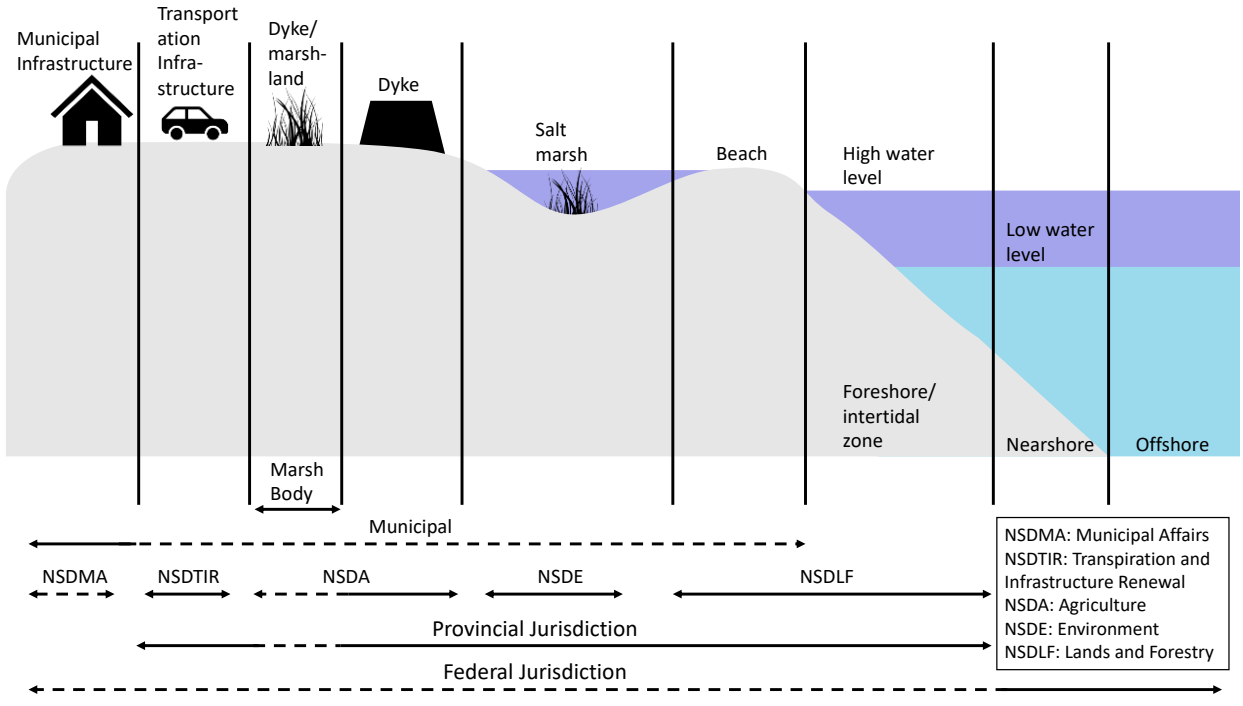

Figure 8. Coastal jurisdictions of Nova Scotia (Solid double-headed arrows indicate direct control on decision making and dotted double-headed arrows indicate no direct control on decision making) (adapted from Rahman *et al.*, 2019).

The following sections describe the circumstances leading to identifying and then agreeing to managed dyke realignment for flood risk management in Truro and Colchester County, and the project design and physical implementation of the work.

The Decision Process

Traditional approaches to manage flooding in Colchester and Truro have included raising and strengthening dykes, construction of runoff storage structures, causeways, tidal dams, ice control berms, drainage improvement, dredging, and channel straightening (Sherren *et al*., 2019). Today, the cost of maintaining this infrastructure is difficult for Colchester and Truro because it requires constant repair (Rahman e*t al*., 2019). The two municipalities, and the provincial government recognized that a comprehensive, integrated regional approach was needed to address coastal and river flooding (Rahman *et al.,* 2019).

In 2012, a Joint Flood Advisory Committee between the Colchester County, the town of Truro, and Millbrook First Nation was established to create a regional approach to flooding issues (Sherren *et al*., 2019). The Committee initiated projects, such as the removal of built-up sediment in the Salmon River to increase river capacity. The Committee also recognized the potential of greater flood risk because of climate change. To better understand the risks and identify flood risk management approaches, the Committee issued a Request for Proposals for a comprehensive flood study in Truro and the surrounding areas in 2013 (Municipality of the County of Colchester, 2020). The work went to engineering firm CBCL Limited.

CBCL reviewed historical data to understand the scope and causes of the flooding in Truro and Colchester, projected possible flood risks in the Truro region to 2100, and identified risk reduction strategies (CBCL, 2017). CBCL modeled over 40 flood scenarios and options to reduce the level of risk. The consultants compared the options for cost-benefit (least cost for greatest protection, while forfeiting the least amount of land) and environmental impact. Because of its location and development pattern, Truro will always be at risk of flooding within the floodplain (CBCL, 2017). But the consultants noted that while future floods can’t be prevented, their threat to public safety and the damage they cause can be reduced. They identified that a

combination of adaptation measures, which included managed dyke realignment, pumping, enhanced stormwater design, and land use planning and regulation changes had the capacity to reduce the priority areas experiencing flooding by 30 percent (CBCL, 2017).

Identifying the managed dyke-realignment aligned with another need, this time by Nova Scotia Department of Transportation and Infrastructure Renewal (NSDTIR): compensating for wetlands lost to development. In Nova Scotia, and in accordance with the Nova Scotia Wetland Conservation Policy (Nova Scotia, 2011), certain activities that impact wetlands are managed through the wetland alteration approval process under the *Environment Act* (Government of Nova Scotia, n.d.a). One of the requirements to obtain approval is to compensate for wetland loss resulting from the activity (Government of Nova Scotia, n.d. b). The replacement ratio of new to lost wetlands is a minimum 2:1 ratio. Compensation can include other measures, but they should complement rather than be used instead of wetland replacement (Government of Nova Scotia, n.d. b)

The development and maintenance of public infrastructure including roads, bridges, and buildings is a cause of wetland damage and loss. The provincial Department of Public Works (formerly, the Nova Scotia Department of Transportation and Infrastructure Renewal NSDTIR) is required to replace any wetlands that would be destroyed in the development of public infrastructure. Public Works "banks" wetland restoration projects to compensate for future wetland losses that may arise from public infrastructure projects. In 2016 the (then) NSDTIR purchased inactive dykeland in Onslow. The Truro-Onslow area was recognized as a possible wetland restoration site to mitigate flooding from the Salmon River in Colchester and Truro (CBWES, 2019). CBWES was commissioned to create a dyke realignment and restoration plan for the Onslow region.

Different but complementary needs coincided. The municipalities needs to reduce flood risk to their communities; NSDTIR needs wetland compensation projects. NSDA is making decisions around dyke maintenance. The consultants, CBCL, Ltd., published their study in 2017 pointing to managed dyke realignment. Municipal and provincial governments agreed that salt marsh

restoration combined with traditional approaches at Onslow could reduce flood risks in the region (Rahman *et al*., 2019).

Although NSDTIR had purchased land, additional land was necessary to ensure a successful and long-lasting project. The NSDA consulted with neighbouring landowners who agreed to sell the land for the project (Rahman *et al*., 2019). The land was not valuable to them because it experienced severe flooding and was not being used actively for farming. Anyone who owns land within a provincially recognized dykeland is a member of a connected Marsh Body.

Marsh Bodies

Unique to tidal wetland regions in Nova Scotia is the creation of Marsh Bodies. A Marsh Body is an association of marshland owners incorporated under the Agricultural Marshland Conservation Act (2000, c. 22, s.1) (Nova Scotia Legislature, n.d.) to manage the dykes and marshland under their ownership. When managing dykelands, Marsh Bodies have powers similar to a municipality (Sherren *et al*., 2019). With approval from the Agricultural Marshlands Conservation Commission, Marsh Bodies can create bylaws, buy, sell, and lease property. They also can make decisions about repairing or constructing dykes at the Marsh Body's expense or in partnership with the Minister of Agriculture.

In accordance with the legislation, proposed alteration of marshland under the jurisdiction of the Marsh Body requires a consultation process and an approval by two thirds of the Marsh Body membership. However, the local area Marsh Body, NS67 was not considered active at the start of the project. Without an active Marsh Body, the marsh landowners cannot discuss motions, call for a vote, or make binding decisions. To operate within the legislation, the NS67 Marsh Body reactivated by creating formal positions, following proper procedures, and submitting minutes to the NSDA under the legislation (Sherren *et al*., 2019; Rahman *et al*., 2019).

Consultation

The project proponents and the Marsh Body stakeholders met several times between June and October 2017 (Rahman *et al*., 2019). The sessions covered education on hazards and risks of climate change and flooding, alternative solutions to the flooding problem, jurisdictional constraints and opportunities for addressing the problem, ecological benefits and impacts of using dyke realignment, and socioeconomic effects. The Marsh Body stakeholders did express concern that the re-establishment of salt marshes would increase the mosquito population in the region (Sherren *et al.,* 2019; Rahman *et al*., 2019). Local experts including the curator of zoology of the Nova Scotia Museum and the general director of the Greater Moncton Pest Control Commission met with the Marsh Body members to address the concerns. At the final meeting, the Marsh Body voted on the proposed design. It was supported unanimously with two conditions (Rahman *et al*. 2019):

1. Communication and transparency between project leads and the Marsh Body be ongoing
2. Pest management protocol and monitoring be included in the project scope

Under the *Nova Scotia Special Places Act*, an archaeological study was required before any construction could be approved. Cultural Resources Management (CRM) Group assessed the site for Indigenous and settler historical and archeological significance. The assessment identified an historical cemetery, elevated at the edge of the site, as a feature of concern (Sherren *et al*., 2019).

Additionally, and importantly, CN Rail and NS Power have infrastructure at the project site, although both groups were late to the consultation process (Sherren *et al*., 2019). These groups were consulted to discuss infrastructure location and climate change risks and protection measures.

With consultations and permissions completed, the physical project work began. CBWES, the NSDA, and the Marsh Body collectively identified on the most appropriate location for project construction and where sediments for constructing new dykes could be collected (Sherren *et al*., 2019). After deciding on the project's location, CBWES identified key project barriers and

challenges, highlighting what the restoration project needed to address. Table 4 summarizes the key issues (Graham *et al*., 2018).

Structural barriers and stressors	Infill development, power poles, railroad, railroad crossings, roads, farmland, housing
History	Historical cemetery, history of agriculture, long history of land being used by residents and those in proximity to the site, apprehension about landscape change
Infrastructure at risk	Unstable dykes, non-functioning aboiteaux under current conditions
Hydrology, tidal patterns, and site elevation	Lack of freshwater drainage, dynamic tidal patterns, low elevation
Geology	Isostatic adjustment (post-glaciation) -- land is slowly sinking

Table 4. Issues for consideration in implementing Onslow-North River managed dyke realignment and tidal wetland restoration project.

Dyke realignment and tidal flooding

Figure 9 shows the project area on the north side the Salmon River in North Onslow along the Onslow-North Dyke, and associated infrastructure and land uses, including the old dyke (following the river meanders), the new realigned dyke, a section of 'topped' dyke (increasing height), the breach locations in the original dyke, and the 93 ha tidal wetland restoration area. The physical project impact (i.e. construction) is in the community of Onslow but the adaptation has wider impact as it will address the flooding risks at the project site and provide more natural space in the floodplain for floodwater movement and attenuation. Project work began in 2019 (CBWES, 2019).

The original dyke followed the meanders of the river. The realigned dyke is 1450.3 m comprising the main dyke at the western end of the project site and a short section at the eastern end to protect the rail line (Graham *et al*., 2018). The purpose of these dykes is to protect active farmland, a historic cemetery, and CN Rail infrastructure (Sherren *et al*., 2019). The breaching process involves removing aboiteaux and removing/flattening the old dyke (Graham *et al*., 2018). Following dyke construction, three of the existing four aboiteaux were removed,

including a major aboiteau at McCurdy Brook, flowing into the Salmon River at North Onslow. A single new aboiteau was built to improve drainage at the rail line in the eastern low-lying lands where drainage is crucial. Dyke breaching, originally planned for 2020, was rescheduled for summer 2021 to address CN rail concerns and to relocate Nova Scotia Power infrastructure. Tidal flow onto the site began in 2021 through the existing aboiteau allowing some sediment laden waters to enter the site. Aboiteaux removal was completed in early November 2021 with the high spring tides flowing into the channels and agricultural ditches with the highest tide of the year on Nov 7, 2021 flooding the full site, as expected from model results. However, this full extent of flooding will only occur a few times per year and indicates that there is potential of a wide range of tidal wetland vegetation. Hydrodynamic variables, suspended sediment concentrations and deposition were measured by the TransCoastal team with results being provided on the project website (https://www.transcoastaladaptations.com/onslow-north-river).

The Onslow North Dyke realignment project addresses three goals (Rahman *et al.*, 2019):

1) reducing ongoing maintenance costs for the Nova Scotia Department of Agriculture by reducing the number and length of aboiteaux and dykes
2) enhancing the protection of private and public infrastructure and viable farmland
3) reducing flood risk and enhancing resiliency to climate change impacts through the restoration of a floodplain

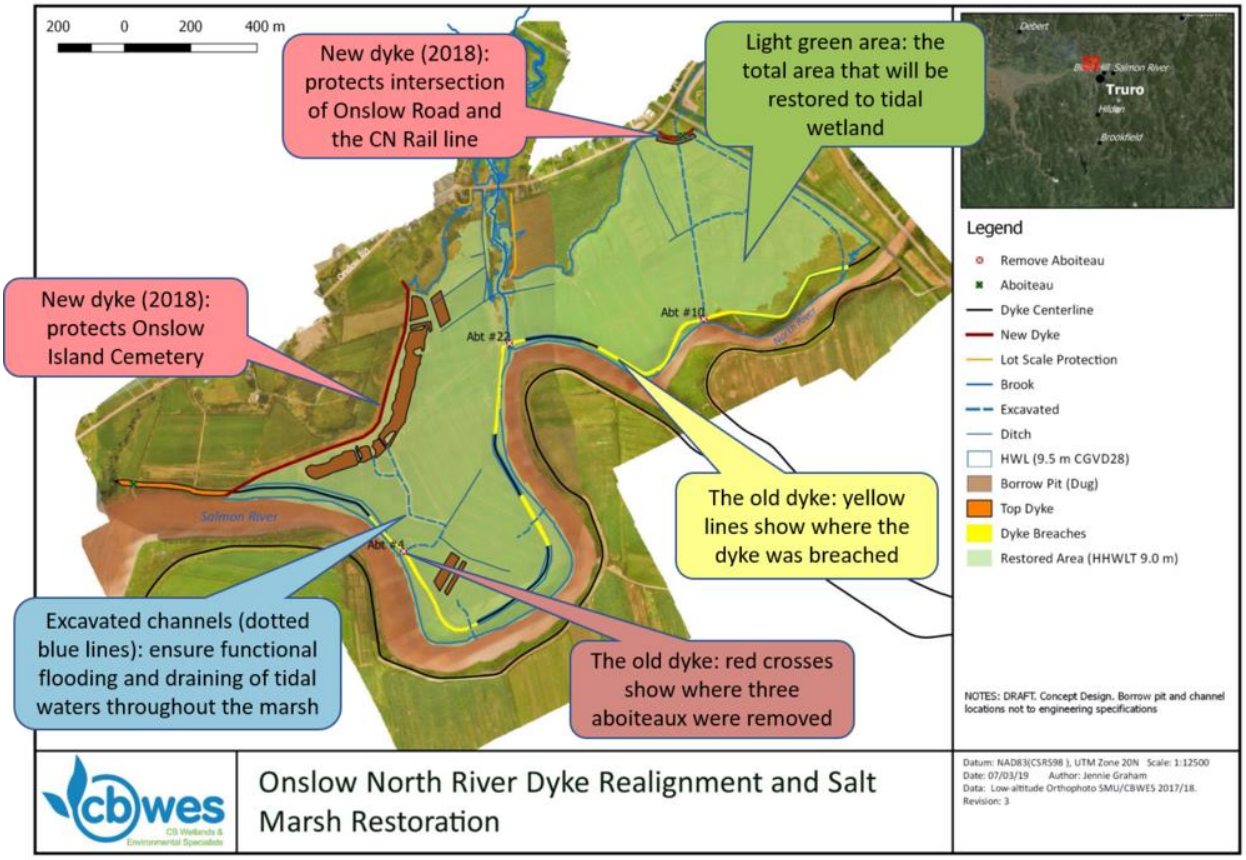

Figure 9. Onslow dyke realignment site design features. CBWES-map design and TransCoastal Adaptations – interpretive text (TransCoastal Adaptations, 2021)

Project funding

The total cost for the dyke realignment project was estimated at $1,655,559 (in 2018 CAD) (Sherren *et al*., 2019). Table 2 shows the costs break down and Table 3 shows the funding sources for the work leading to and including the dyke realignment project. These figures do not include costs for removal of power lines nor further work conducted after 2018.

Land purchase (92ha)	$798,000
Archeological study	$ 71,559
Earthworks and breach	$ 625,000
Feasibility, design, and baseline data collection	$161,000

Table 2. Onslow North Dyke realignment project cost estimates in 2018 (Sherren *et al*, 2019)

Department/program	Funding allocation
Department of Transportation and Infrastructure (NSDTIR)	Pre/post monitoring and adaptation plan development costs
Nova Scotia Department of Agriculture (NSDA)	50% of costs not covered by NSDTIR
National Disaster Mitigation Program	50% of costs not covered by NSDTIR
Flood Risk Infrastructure Investment Program	$400,00 for comprehensive flood risk study in Truro

Table 3 Funding sources for Truro flood risk study and the Onslow North River dyke realignment and tidal wetland restoration project (Sherren *et al.*, 2019)

Municipal land use planning

The Onslow-North River dyke realignment and tidal wetland restoration project came about in part from the need for Truro and Colchester municipalities to address the increasing risk of and damage from flooding in their communities. It its recommended strategy, CBCL identified storm water management, pumping, and innovative land use planning along with managed dyke realignment for flood risk reduction. Land use planning works with nature-based and hard engineering measures to reduce risk to hazards.

Colchester and Truro are the municipal stakeholders for this project. Current and future land use and development in these communities, especially near the rivers, will influence the Onslow-North River dyke realignment and tidal wetland restoration project's success. Municipalities have the power to protect buildings and other infrastructure, people, and the environment by establishing setbacks and standard lot sizes that consider climate change projections and are adaptive to changing conditions. These policies and regulations will determine the communities' vulnerability to flooding and permitted development can affect the floodplain's capacity to regulate coastal and river flooding.

The Salmon River is the municipal boundary between Truro and Colchester; the municipalities share a common concern for the health of the river, but also the flood risk that it poses. In 1985, the Government of Canada and Province of Nova Scotia collaborated in a floodplain study for the Colchester/Truro area (Municipality of the County of Colchester, 2002a), mapping the 1-in-20 year, and 1-in-100 year flood probability. This mapping was the basis for floodway zoning. Both municipalities zoned the land along the river as a floodplain zone with development restrictions.

In 1998, the two municipalities established a Study Steering Committee to oversee the Truro Flood Plain Study, completed by Environmental Design & Management Ltd 1996 to "examine development alternatives in the developed parts of both the Town and County exposed to flood risks." (Municipality of the County of Colchester, 2002a, p. 5) The study provided the scientific base for both municipalities to use a "cut and fill" approach modify flood risk lines "to facilitate meaningful and economic development patterns." (p. 5). This study was followed in 1998, by an initiative to a draft Inter-Municipal Planning Strategy and Land Use Bylaw for Flood Risk Areas which "transformed many of the Study recommendations into suggested land use policy and regulations." (p. 5). The inter-municipal plan did not materialize, however, and the municipalities pursued their own approaches to land use regulation.

Flooding continued to be a problem for the municipalities, however, such that they created the Joint Flood Advisory Committee between the Colchester, Truro, and Millbrook First Nation in 2012, which resulted in the CBCL (2017) flood risk study. The current flood zoning is inadequate for current and future flooding based on climate change projections. At the time of this case study reporting, the provincial government is undertaking province-wide coastal and river flood line mapping that incorporates climate change projections into IDF curves and sea level rise projections (Nova Scotia Department of Municipal Affairs and Housing, 2020). Municipalities will then use the mapping to update or create floodplain zoning or setbacks. Protecting the floodplain is an essential planning tool for addressing current and future flood and erosion hazard and risk, but not the only tool. Integrating attention to environmental processes and climate change impacts throughout land use planning is necessary for communities to manage overall climate change impacts.

The Onslow-North River managed dyke realignment and tidal wetland restoration project is a hybrid, nature-based/engineering approach to climate adaptation which the municipalities embraced. A review of municipal land use planning can identify the municipalities' readiness for climate change through its policies and land use by-laws and an orientation to adopt nature-based adaptation approaches. The following review draws on plan and by-law analysis for the town of Truro and Colchester County by K. Sonier (2018) and K. Warren (2020a, b)**,** specific to the Onslow-North River managed dyke realignment and tidal restoration project. The planning and regulation documents include the Town of Truro Municipal Planning Strategy and Land Use By-law (Town of Truro. (2010 a, b), and the Central Colchester Municipal Planning Strategy and County of Colchester Land Use Bylaw (Municipality of the County of Colchester, 2002 a, b).

Colchester

Colchester is predominantly rural outside of incorporated villages and concentrations of residential and commercial development within the municipality. The village of Bible Hill and Lower Truro-Truro Heights are urban and urbanizing areas of the municipality that border the town of Truro and the Salmon River (Lower Truro, Bible Hill). The municipality acknowledges that development has intensified in recent decades, and especially in the vicinity of Hwy 102-Robie Street (which is a commercial corridor through Lower Truro and Truro) and is encroaching into flood-prone areas. Initially, development in this area consisted of agricultural structures and sparse home and small business infrastructure. Today, Robie Street is highly developed with numerous commercial buildings with large parking lots (Municipality of the County of Colchester, 2002a). Onslow is also experiencing development in an ex-urban, suburban form.

Colchester acknowledges that maintaining the natural environment is a fundamental principle for flood mitigation and incorporates statements of floodway and flood plain protection into its policy statements, specifically its environmental policies, Part 3 of the Municipal Planning Strategy (Municipality of the County of Colchester, 2002a Warren, 2020 a, b). The Municipality acknowledges that future growth in regions that experience flooding with a relative frequency of 1-in-20 years be restricted (Municipality of the County of Colchester, 2002a; Warren, 2020 a, b). However, development may be permitted in areas that experience flooding with a relative

frequency of 1-in-100 years, In these areas, construction should have approved floodproofing measures, although these measures involve raising the land elevation with fill which compromises the flood capacity of the 1-in-100 year floodway (Warren, 2020a, b). Figure 10 illustrates the flood plain zones (not flood zoning) and upland, with cut and fill development in the flood fringe.

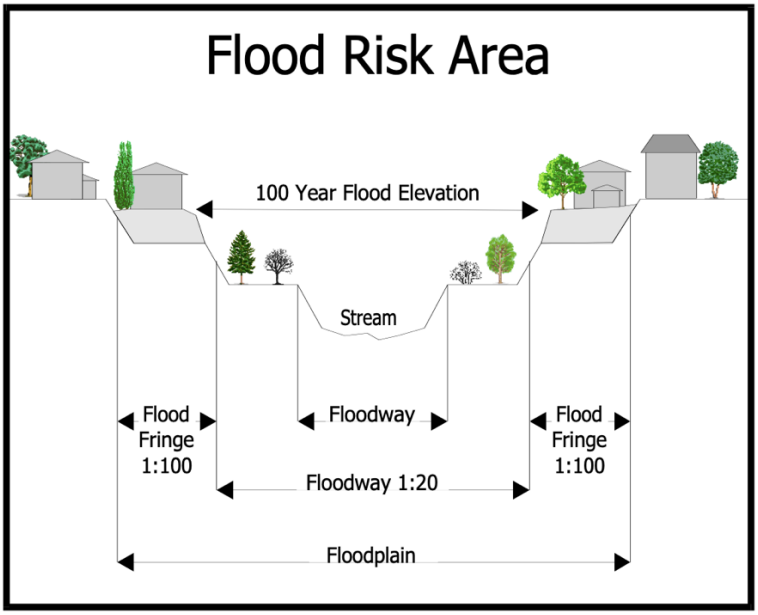

Figure 10. Permitted floodplain development (Municipality of the County of Colchester, 2002a)

Colchester land use zoning applies to the land surrounding the Town of Truro (Figure 11) (Sonier, 2018). The most recent *Municipal Planning Strategy* was developed in 2002. Most of the municipality does not have zoning. Areas without zoning are subject only to provincial regulations. In areas without zoning, all structures are permitted. However, the structures must comply with the *Nova Scotia Building Code Regulations* (Nova Scotia, n.d.) and all developments require a development permit. In 2019, the province mandated that municipalities create land use bylaws for their entire municipality (Province of Nova Scotia, 2019a). Areas without land use planning are often the rural areas of the municipality, as is the case of Colchester. By 2023, all municipalities must have land use planning and land use bylaws for the entire municipality to meet new minimum planning requirements. At the time of this case study reporting, Colchester was undertaking land use planning.

Specifically, at the project site in Upper Onslow, the following zones restrict development on the floodplain and permit low-intensity uses such as public works projects, trails, agriculture, sports fields, camping facilities, parking lots, outdoor storage, and golf courses (Sonier, 2018).

- Environmental Flow Way (E-1)
- Environmental Flood Way (E-2)
- Environmental Flood Way Modification (E-3)
- Environmental Flood Way Fringe (E-4)

Several of these uses impact the floodplain's natural capacity to mitigate flooding. For example, parking lots and outdoor storages are hard surfaces restricting water absorption.

The Municipality does not permit any variance within these zones (Municipality of the County of Colchester, 2002b). All new structures must comply with all requirements of the bylaw. For example, there are minimum building elevation requirements. Development agreements that request modifications of any type will not be approved (Municipality of the County of Colchester, 2002b). However, existing structures that were developed prior to the bylaw do not have to comply (Municipality of the County of Colchester, 2002a).

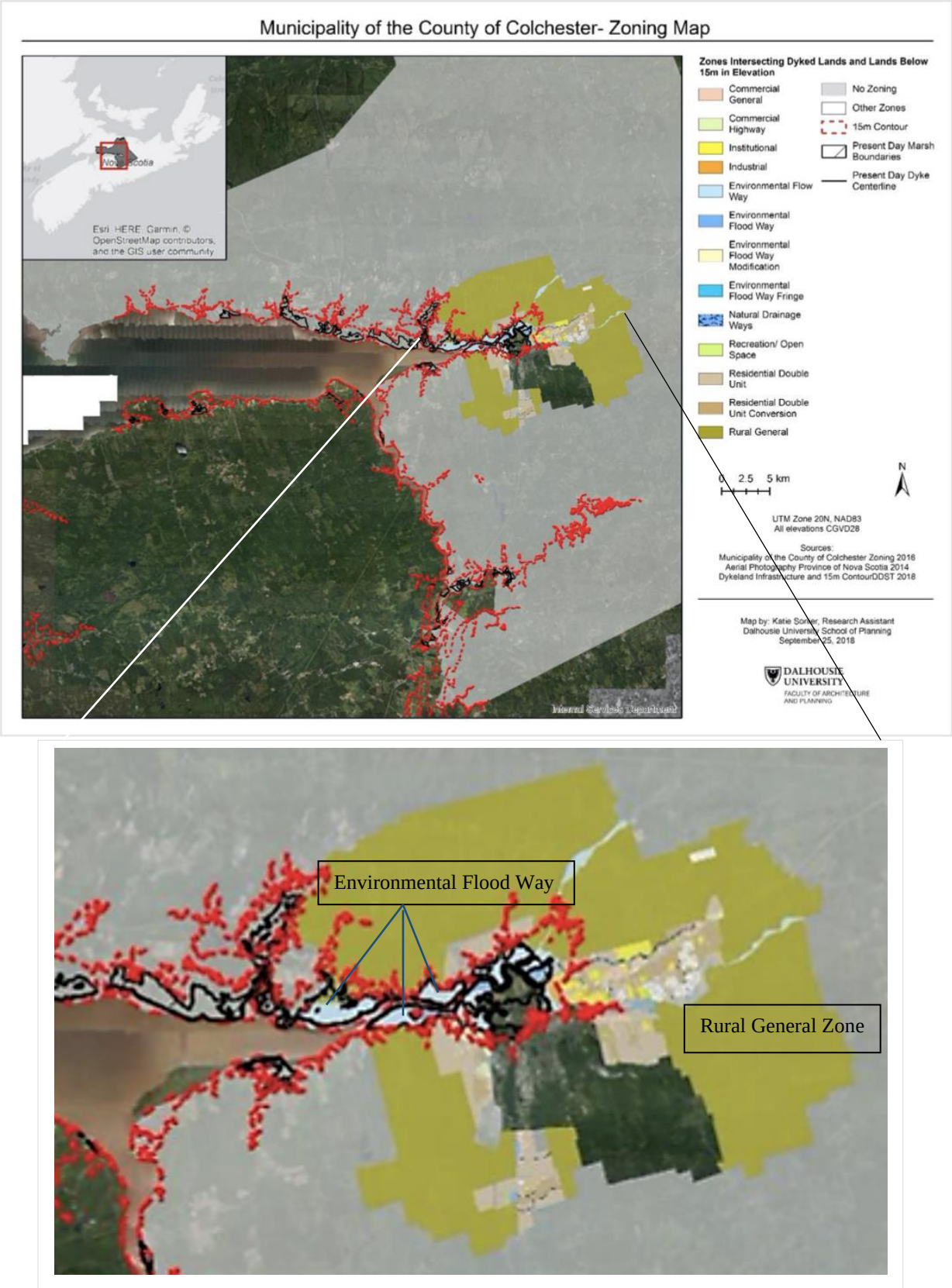

Figure 10. Colchester zoning (Sonier, 2018; Municipality of the County of Colchester)

Alterations to an existing structure are permitted if acceptable floodproofing alternatives are provided (Municipality of the County of Colchester, 2002b). Several zones permit development on lands adjacent to dykelands. These developments must have approved flood mitigation measures such as “cut and fill”. These zones allow a range of commercial, institutional, industrial, and residential land uses (Sonier, 2018).

- Commercial General (C-1)
- Commercial Highway (C-2)
- Institutional (I)
- Industrial (M)
- Recreational-Open Space (P-1)
- Residential Double Unit (R-2)
- Residential Double Unit Conversion (R-2C)
- Rural General Zone (RG)

Within Central and Upper Onslow, the primary zones are E-2, C-2, and R-2. Though C-2 and R-2 zones do not restrict nature-based adaptation, they do not directly support nature-based adaptation. A lack of non-supportive policies can be a barrier to the Onslow Dyke Realignment project and nature-based adaptation in general.

Truro

Town of Truro, through it Municipal Planning Strategy (Town of Truro, 2018a), acknowledges the Salmon River as a defining feature of the town yet is underappreciated and has been disconnected from the community by the contruction of dyke and industrial development in the flood plain (Chapter 8 ParParks and Open Space). The Plan identifies the problems related to the flood risk from rivers in the area, the long history of studying the risk, that these impacts will increase with climate change, and that it is best to preserve natural drainage and systems to minimize erosion and runoff, but also identifies that land use can be suitably developed in flood risk areas with floodproofing measure, (Chapter 2, Community Profile, Chapter 9 Environmental Management, Chapter 10 Storm Water Management) (Warren, 2020a, b). With some flood prone areas already developed, and despite the flooding impacts of the past, there continues to be

interest in developing within flood risk areas. With its need for development space, the town appears to be pursuing a protect and accommodate adaptation approach

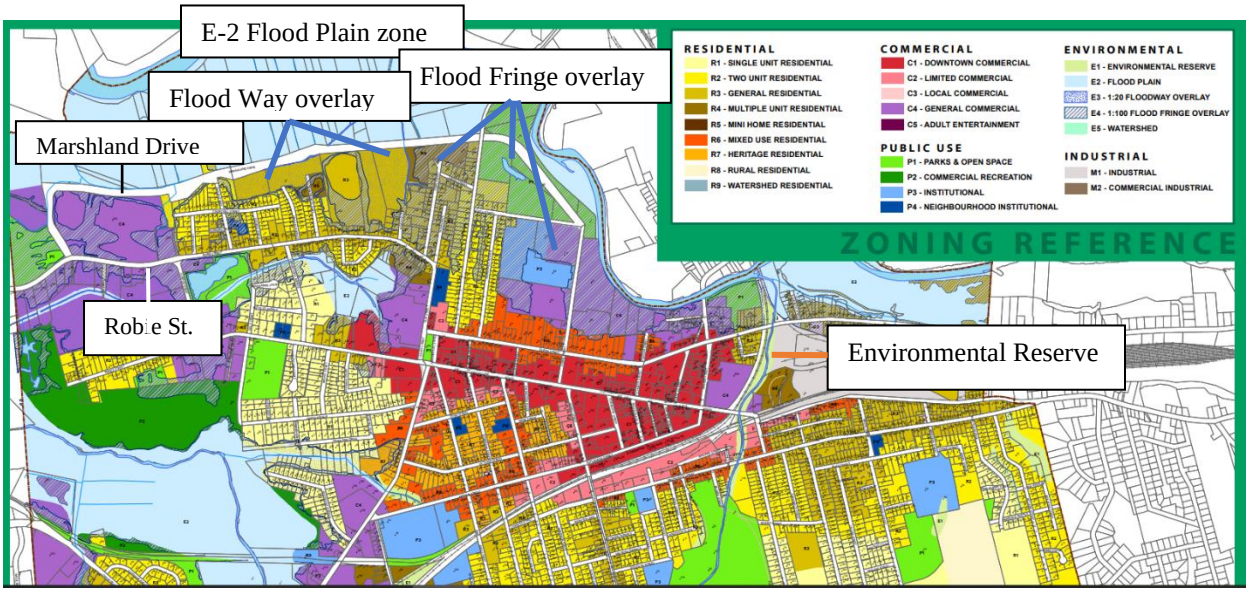

Figure 12. Truro land use zoning–north section of town. Labels added (Town of Truro, 2018)

Figure 12 shows land use zoning for the north section of the town of Truro (Town of Truro, 2018). Environmental zoning in the Town of Truro, where environmental protection or environmental hazard avoidance are the objectives, include the E-2 Flood Plain Zone, the Environmental Reserve Zone, and the Watershed Zone. (Figure 12).

The E-2 Flood Plain Zone borders the Salmon River and is the zoning along the river opposite the Onslow-North River managed dyke realignment and tidal wetland restoration project site. Most of the dykelands and areas with dyke infrastructure in the town are designated as the E-2 zone. Development is restricted within the Flood Plain (E-2) zone. Permitted uses include agriculture, community gardens, golf courses, parks, public works and utilities, sports fields, and walking/multi-purpose trails. Existing uses comply with the E-2 zone (Sonier, 2018).

The Flood Way and Flood Fringe overlays signal an environmental constraint that dictate requirements for and control over flood proofing new development as needed to accommodate occupancy in these areas and subject to managing impacts on and of local drainage (Sections

9.3.4 Alteration to Topography, 9.3.5 Infilling, 9.3.5 Additional Fill) (Town of Truro, 2010b). Development is permitted according to the zoning for the area. Land use zones bordering or influenced by the Salmon River and subject to the overlays in this area include

- Commercial Recreation (P-2)
- General Commercial (C-4)
- General Residential (R-3)
- Mixed Use Residential (R-6)
- Multiple Unit Residential (R-4)
- Two Unit Residential Zones (R-2)
- Single Unit Residential (R-1)
- Institutional
- Neighbourhood Institutional
- Park and Open Space

The Park and Open space zone is the least intensive use of the flood prone areas. The Parks and Open Space zone allows for cemeteries, community gardens, cultural facilities, memorial parks, municipal campgrounds, parks, recreation facilities, walkways and trails and wilderness education. Some of these uses require an intact natural environment, while others will require alterations.

Two other environmental zones are the Environmental Reserve and Watershed zones, neither of which apply to the Salmon River, but do apply to other water ways in town. These zones are the most restrictive land use zones with the objective of environmental protection or environmental hazard avoidance. For example, the Environmental Reserve zone allows for forest conservation and management, passive recreation, walkways and trails, wilderness education uses, picnic areas, and public works and utilities.

Truro created the Environmental Designation (Figure 13), which recognizes regions that are not suitable for development, and which are the justification for the Environmental Reserve, Watershed, and Flood Plain zones.

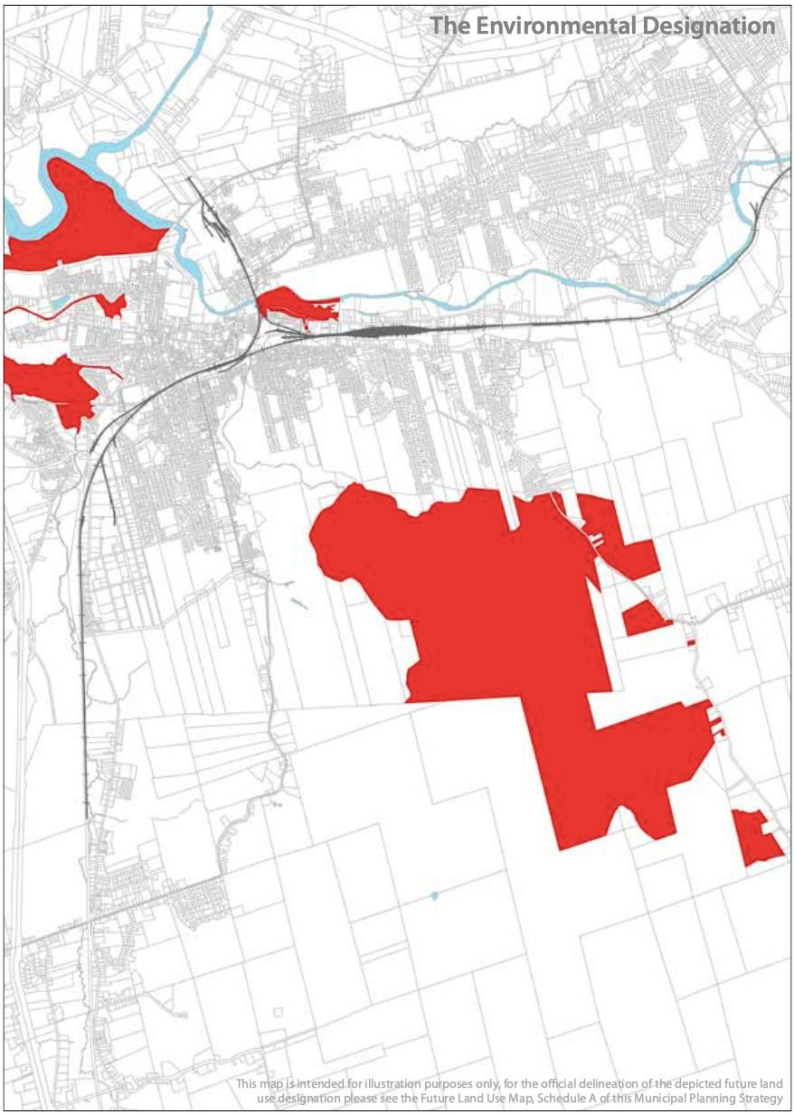

Figure 13: Environmental Designation (Town of Truro, 2010b)

Both Colchester and Truro acknowledge flooding as a perennial, serious challenge for their communities, have jointly conducted studies to understand the problem and determine flood management approaches, and have restricted development the 1-in-20 year probability flood zone. The CBCL flood risk study (2017) identifies that the zoning is inadequate to protect against future flooding driven by climate change and exacerbated by continued development in areas where flood risk will increase overtime. Regardless, both municipalities are willing to enable development in areas identified as flood way and flood fringe – the 1-in-100 year probability flood zones, measured before climate change projections were available. The

municipalities appear to be taking a reserve (flood plain zoning), accommodate (flood way and flood fringe zoning or overlay) and protect (the dykes) to coastal and river climate change adaptation for development. New flood line mapping from the province (Province of Nova Scotia, 2019b), incorporating climate change projections, will guide adjusting these zones as needed. Accommodating development in increasingly risky locations by allowing elevation through raising the site elevation might protect a structure, but flooding may isolate people from services, potentially critical ones like health, emergency, and security services during a flood. Colchester and Truro have supported the hybrid nature-based/engineering managed dyke realignment and tidal marsh restoration adaptation option for the flood mitigation function. While the project can address some flooding by making room for flood waters in a renewed flood plain, it is not an approach, even if expanded, that can solve urban flood problems. Flood mitigation and adaption to flooding requires multiple complementary approaches, as noted by CBCL in their recommendations (CBCL, 2017).

Expected Outcomes and Benefits of the Onslow-North River Managed Dyke Realignment and Tidal Wetland Restoration Project

Drawing from two decades of experience working tidal wetland restoration in the Bay of Fundy, the project team estimates that with breaching and tidal flooding salt marsh will gradually re-establish over a period of three years, moving through three phases (Graham *et al*., 2018). The first stage is *"transition".* During this period, the landscape will begin to adjust to the new conditions. There will be a large influx of water, new sediments will be deposited, and new plants will start to grow. The next phase is *"establishment".* During this period, plants become well-rooted with vegetation covering more of the tidal flat surface (Graham et al., 2018). Finally, a tidal wetland and stable creek network will reach *"equilibrium".*

Post-project monitoring is an essential part of project implementation. The NSDTIR (now Public Works) will provide five years of post-restoration funding for monitoring (Sherren *et al*., 2019). CBWES is responsible for observing and documenting changes in hydrology, vegetation, water quality, soils, and overall marsh health (Sherren *et al*., 2019). SMU will also track changes in the tidal wetlands and potential benefits such as capturing carbon dioxide from the atmosphere and

storing it in marsh vegetation and sediments, further mitigating negative climate change effects (Sherren *et al.*, 2019). Predicted project benefits also include storm wave buffering and habitat for fish and other marshland species.

There are also social and economic benefits. The tidal wetland is space where flood water can spread out during high tides and storms, with benefit to development in flood prone areas. The tidal wetland will support environmental education and awareness, scientific study, nature-based adaptation training, and passive recreation (for example, bird watching). Attention is also now being given to the blue carbon function of tidal wetlands (Macreadie, *et. al*., 2019)

Alone, initiation of this project can be considered a success. It is one of the first times Nova Scotians – the Marsh Body - have voted for moving infrastructure back from the shore and giving up private land for ecosystem services (Sherren *et al*., 2019). Support from the Marsh Body was key to the success of this project.

Lessons, Barriers, and Drivers

The Onslow dyke realignment project is one of the most complicated nature-based coastal adaptation projects in Canada to date. Collective action and resourcefulness among the partners department drove this project forward, even though climate change and coastal protection policies are limited in the province. These partnerships were initially created because of budgetary limitations (Sherren *et al*., 2019). However, in the end, it resulted in a comprehensive nature-based approach with benefit to the multiple partners in different but complementing ways, including compensating for wetland losses elsewhere by restoring valuable tidal wetland habitat, protecting a new, realigned dyke, and demonstrating an approach to flood management in Truro and Colchester.

Working with the Marsh Body, the project team identified concerns that were managed by providing accurate information (such as the possibility of increasing mosquito populations and protecting cultural spaces (the graveyard). In consultation with CN Rail and NS Power, the project team identified barriers of impacts to infrastructure, resolved by moving a utility line and

providing added protection for the rail line. Except for moving a utility line, the project did not involve relocation of community infrastructure. Some small berms were created adjacent to some private properties. The higher the value of existing infrastructure and land use, the more difficult it becomes to advocate its relocation. However, the project demonstrates the benefits of restoring active floodplain for flood mitigation with benefits to ecosystems, land use, and public safety.

Municipalities have great influence in flood management through land use planning and regulation and storm water control. From an urban flood mitigation perspective, the dyke realignment and tidal wetland restoration can not solve flooding problems on its own. Colchester and Truro will need to continue assessing their land development patterns, planning, and regulation for a multi-pronged approach to coastal and river climate change adaptation. Municipalities will have a new tool with the Coastal Protection Act regulations for managing development at the shoreline and protecting coastal ecosystems (Province of Nova Scotia, 2021). The Onslow-North River managed dyke realignment and tidal marsh restoration project is a nature-based solution. Nature-based approaches to storm water management can also be part of a comprehensive approach, implemented from the site to the municipal and regional level.

Education and communication are fundamental for successful nature-based adaptation, including this project. This project has built capacity among decision makers and coastal planning and management practitioners in Nova Scotia, continues as a source for scientific research to better understand the managed realignment technique, tidal wetland restoration and their benefits, and has achieved global recognition (Sherren *et al*., 2019). The project can invest more into public education. That process has started with a website describing and explaining the project (https://www.transcoastaladaptations.com/onslow-north-river); other techniques used at other locations developed by TransCoastal include interpretive signage. The project will explore other public education approaches, potentially in partnership with other organizations.

Education and communication for the Onslow-North River managed dyke realignment and tidal marsh restoration project should continue or aim to achieve the following objectives:

1. Providing the necessary tools and information to practitioners and decision-makers to make informed decisions about reducing flood and erosion hazard and risk, especially through nature-based approaches
2. Building stakeholder engagement and informed citizens
3. Promoting communication of science, climate change, hazards, and risks to the general public
4. Encouraging collaboration between multiple groups and levels of government
5. Creating an opportunity to demonstrate successful examples of nature-based adaptation in Nova Scotia
6. Developing support for the use of nature-based adaptation in the future

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