Chapter 5. Coastal infrastructure realignment and salt marsh restoration in Nova Scotia, Canada

This chapter describes a project to realign a section of the North Onslow dike near Truro, Canada. This project was intended to achieve the multiple goals of reducing dike maintenance costs, enhancing protection of public and private infrastructure, and enhancing resilience to climate change through the restoration of a coastal flood plain.

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5.1. Context

Canada has the world's longest coastline, bordering three oceans, and is thus highly exposed to sea-level rise (SLR) (Lemmen and Warren, 2016). Approximately 38% of Canada's population lives within 20 km of a coast (Manson, 2005). Climate impacts and risks vary across the three coasts in Canada (Lemmen et al., 2016). The Arctic coast makes up 70% of Canada's shoreline, comprising mostly small villages of largely indigenous inhabitants, where sea levels are expected to drop, but where livelihoods and cultures will be affected by declining sea ice, melting permafrost, and coastal erosion and instability. The Pacific coast is dominated by the large population centres of Vancouver and Victoria, both located in the Fraser lowland area that is expected to see the highest relative SLR for the region. Lemmen and Warren (2016) note, however, that the Pacific region faces higher vulnerability to storm surges than SLR.

The Atlantic coast hosts a few small cities but many towns and villages, including unincorporated shoreline developments, all expected to be affected by and vulnerable to SLR and increasingly extreme weather events (Lemmen and Warren, 2016). Examples of climate adaptation planning include especially vulnerable places, such as Les Îles-de-la-Madeleine in the Gulf of St. Lawrence, which has no alternative but to engage in coastal retreat (McClearn, 2018). Nova Scotia is another jurisdiction with significant exposure to SLR, and numerous local innovations. This chapter describes one such project in Nova Scotia, a dike realignment and tidal wetland restoration project that was largely achieved because of its alignment with government policies unrelated to climate, such as wetland compensation and dike divestment.

5.2. Nova Scotia: A coastal jurisdiction

Nova Scotia is a Canadian province perhaps vulnerable to SLR due to its geography and geologic history. The province's 55 000 km^2 are dominated by an isthmus and the large island of Cape Breton (~10 000 km^2), along with thousands of smaller islands. All of the province is located within 67 km of the coast (Chesworth, 2016). There are 13 different coastal ecosystems in Nova Scotia, from the expansive intertidal mudflats and salt marshes of the Bay of Fundy coast to erosive cohesive bluffs on the Northumberland coast (Savard, van Proosdij and O'Carroll, 2016), to complex rocky shores of the Atlantic coast. Its ~7 600 km coast is highly corrugated, with a complex drainage pattern including tens of thousands of lakes and wetlands, its climate is temperate, and it is relatively low-lying, peaking at 536 metres in Cape Breton Highlands National Park.

Geologically, like the rest of the Atlantic provinces, Nova Scotia is undergoing crustal subsidence, or glacial isostatic adjustment, dipping as more northerly and central areas of Canada spring back from released pressure after glaciation (Greenan et al., 2015). Richards and Daigle (2011) project that by 2100 Nova Scotia will become warmer but also wetter and with precipitation coming more frequently via extreme events. Relative sea-level rise projections (incorporating vertical crustal movement) based on the RCP 8.5 scenario of the 5th Assessment Report of the IPCC (2013), modelled by James et al. (2014) predict an upper bound of 1.30 m (median 0.90 m) by 2100. In the upper Bay of Fundy, these projections will most likely be close to an upper bound of 1.20 m due to amplification of tidal range that is also occurring (Greenberg et al., 2012). This area already has the highest tides in the world. In the provincial capital of Halifax, this is projected to result in extreme wave events during storms under all climate scenarios tested (Xu and Perrie, 2012).

Nova Scotia is already seeing the effects of subsidence, independent of climate-driven change; estimates of increases from the Marine Environmental Data Service range from 24 cm to 32 cm per century across four coastal communities in the province (CBCL Limited, 2009). Increases in extreme weather events and storm surges are of primary concern to coastal residents and decision makers in the province (Rapaport, Starkman and Towns, 2017).

Nova Scotia's coasts are sites of long human occupation. Nova Scotia's first people, the Mi'kmaq, relied on coastal settlements for fishing in the spring and summer, moving inland to hunt for food and furs in the fall and winter (Hornborg, 2008). Records of early contact with European explorers and fishers around the busy Atlantic coast date back to the 1500s, but it was in the 1600s that permanent French settlers arrived, later to be called Acadians. Acadians and later settlers converted most of the rich coastal wetlands of the Bay of Fundy coast to farmland by constructing dikes including one-way drains that allow freshwater to flow out at low tide but close at high tide to keep salt water out (called *aboiteau(x)*) (Bleakney, 2004; Butzer, 2002). Diking practices, combined with contemporary development activities (i.e. causeway construction), resulted in the conversion and loss of nearly 85% of tidal wetlands in the Bay of Fundy (Hanson and Calkins, 1996).

Coasts remain a critical part of Nova Scotia's identity and economy. The province has only 920 000 inhabitants, 40% of whom live in the capital area of the Halifax Regional Municipality, and over 60% of whom live within 20 km of the coast (CBCL Limited, 2009). Though most (77%) of the coast is undeveloped, it is also mostly privately owned (87%) and there is significant pressure in and near its many ports, harbours and estuarine settlements like Truro (CBCL Limited, 2009). Nova Scotia grew from the coast inward, and most development flanks coastal roads. While a few industries important to gross dometic product (GDP) rely specifically on coastal resources (e.g. agriculture, fisheries, shipping), most industries rely on coastal infrastructure such as transportation networks and the utilities such as powerlines that tend to follow them (CBCL Limited, 2009). As transportation infrastructure improves, commuting time decreases, expanding development outward from urban centres and putting additional pressure on coastal areas (Millward, 2005).

Nova Scotia's coastal residents are also vulnerable demographically, in part due to aging in rural areas (Gibson, Fitzgibbons and Nunez, 2015), but also due to seasonal population changes: summer amenity in-migration (due to relatively cheap waterfront) and winter out-migration (snowbirds; Northcott and Petruik, 2011). Seniors (those older than 65) are the fastest growing demographic group in Nova Scotia, comprising 15% of the population overall (CBCL Limited, 2009), but more than a quarter and sometimes over 30% of the population in many rural, coastal places, because of lower birth rates, youth out-migration, retiree influxes (including returnees) and lengthening life spans. (Krawchenko et al., 2016; Coulombe, 2006; Newbold, 2008; Foster and Main, 2017). These older residents are often dependent on services that are themselves vulnerable to SLR (Manuel et al., 2015).

Coastal protection in Nova Scotia has to date been dominated by "hard" solutions, such as dikes, berms and shoreline armoring (van Proosdij, Perrott and Carrol, 2013), but these solutions are beginning to fail under SLR and storm surges (Grieve and Turnbull, 2013; CBCL Limited, 2009). In line with growing global attention to ecosystem- and nature-based alternatives to reinforcing hard infrastructure (Narayan et al., 2016; Cheong et al., 2013; Harman et al., 2013), small-scale experiments in living shorelines and salt marsh restoration have been underway locally. Setbacks or "managed retreat" remain uncommon, in part due to local resistance, as described in Box 5.1 (Savard, van Proosdij and O'Carroll, 2016).

Box 5.1. Local resistance to coastal retreat

Local resistance to new forms of adaptation were apparent after the failure in a storm of a natural cobble barrier that has protected a coastal lagoon called Big Lake from the Atlantic Ocean for decades.

Owners of a dozen small homes and cottages around the lake, newly vulnerable to storm surges, have demanded that the natural barrier be rebuilt to protect their homes. The Nova Scotia Department of Natural Resources (NSDNR) had fixed a similar breach in 2010 but refused to do so again, instead recommending that residents "fortify their properties with protective walls, put their homes on stilts and seek coastal-flooding insurance" (CBC, 2018b) and noting the municipality's responsibility for having issued building permits.

While the cobble barrier was natural in origin, after being repaired it became seen by residents as built infrastructure. Over on the Bay of Fundy coast, hundreds of citizens of the small town of Hantsport recently demanded that the province rebuild a privately owned *aboiteau* (type of dike used for land reclamation). The previous one, which had been in a state of disrepair for many years, completely failed in December 2017, restoring the natural hydrology to the system.

Sources: CBC (2018b), "Hantsport residents tell province to fix dam instead of raising road", https://www.cbc.ca/news/canada/nova-scotia/hantsport-residents-tell-province-to-fix-dam-instead-of-raising-road-1.4779312.

The Nova Scotia Department of Agriculture (NSDA) is responsible for the management and maintenance of the province's 260 *aboiteaux* and 241 km of dikes. The resource (human, financial) and engineering requirements to maintain and upgrade this infrastructure stock in order to withstand SLR exceeds the department's current capacity. The NSDA is mandated to protect agricultural landscapes, but a significant portion of the 17 400 ha of land it protects is now used for non-agricultural practices and developments. Along with a number of other government departments, the NSDA is prioritising which dikelands could potentially be decommissioned (breached) and restored to salt marsh (Bowron et al., 2012; van Proosdij, Perrott and Carrol, 2014). In some of these cases, where built assets would still require protection, the construction of new, shorter, dikes built to modern specifications (including SLR projections) is being considered (MacDonald et al., 2010).

Reducing dike infrastructure and restoring provincially significant wetlands has additional benefits beyond ensuring the protection of core agricultural areas and critical infrastructure. These include climate mitigation benefits, in terms of sequestered carbon in salt marsh, often called "blue carbon" (McLeod et al., 2011), as well as climate adaptation benefits (Wollenberg et al., 2018). Nine such restorations have been carried out in Nova Scotia since the first at Cheverie in 2005 (CBC, 2010), including five culvert replacements and four dikes breached, covering a total of 98 ha. A further nine are pending or in construction (five dikes, four roads) representing an additional 338 ha.

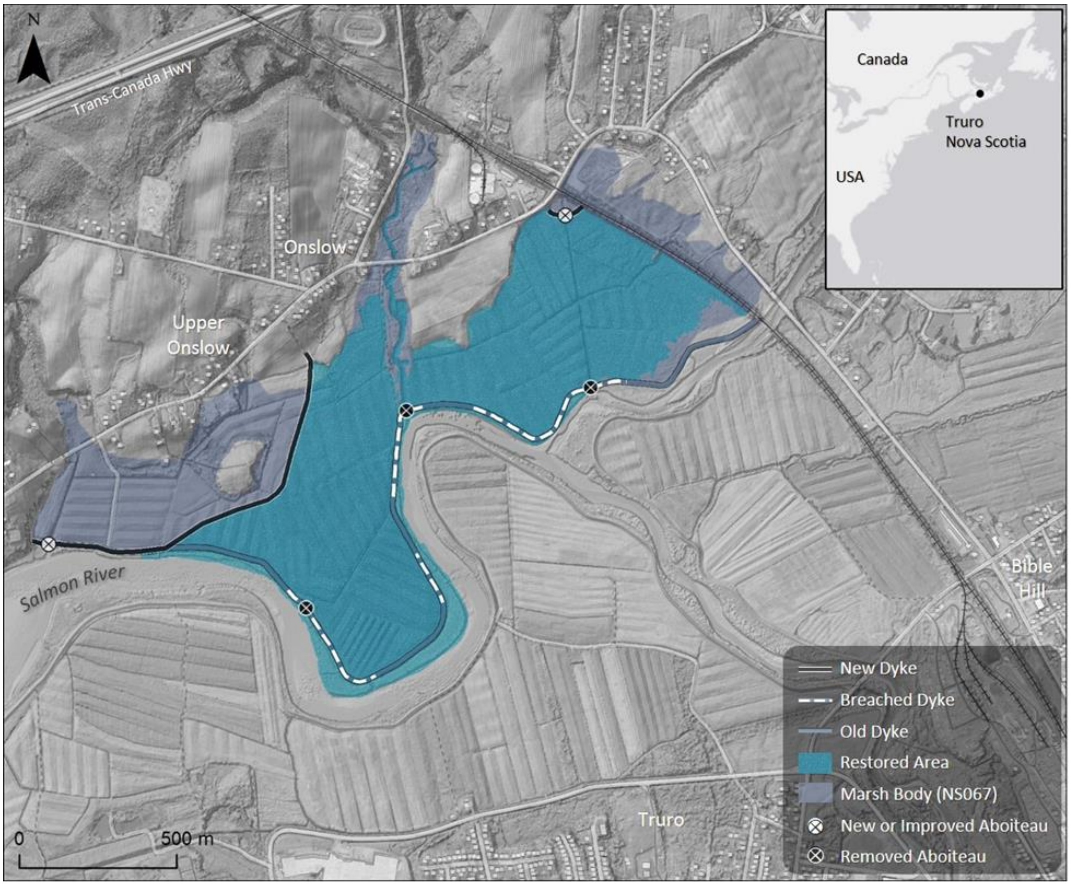
The small town of Advocate Harbour provides a useful example of the sensitivities that exist in discussions of dike futures, which so many Nova Scotia towns will have to face in the coming years. The NSDA held a meeting in early 2018 to discuss the future of the agricultural dike that protects numerous homes and businesses in Advocate Harbour (Cole, 2018). Local preferences are strongly for dike reinforcement. One citizen said, "I feel the best option is to fix the dike [sic] … We have to keep our community intact as much as possible and protect our way of life so people can continue to live in Advocate and know that it's going to be a safe place."

Big Lake, Hantsport (Box 5.1) and Advocate Harbour all demonstrate citizen preferences for government intervention with hard options to maintain the *status quo*. This delays difficult decisions to retreat strategically in preparation for what is to come (Sherren, in press). Yet, compared with setback options, investments in hard infrastructure are more expensive and the negative consequences worse if those defences were to fail. Moreover, investment in hard options encourages ongoing development in high-risk areas, as expressed in the quote above, making setback options ever more challenging. Such public sentiments represent – along with limited government budgets – the biggest barrier to coastal adaptation in the region.

5.3. Truro case study: The North Onslow Marsh

Flood risk associated with SLR is a significant driver for action in the case study of the North Onslow Marsh, in Truro, Nova Scotia. Truro is a small regional centre of 12 000 residents located on the floodplain of the Salmon River that flows into Cobequid Bay (Bay of Fundy), and that floodplain is extensively diked: first for agriculture, but now protecting residential, commercial and transportation infrastructure. Even without SLR and storm surges, Truro experiences frequent and severe flooding from the co-occurrence of rainwater accumulation, high tides and ice jams. The region has suffered at least annual floods as far back as records have been kept (CBCL Limited, 2017). None of these events seems to have dampened enthusiasm for floodplain development in the town, meaning repeated exposures for "schools, senior homes and residences ... access roads, commercial areas and industries" (CBCL Limited, 2017). In recent years, research on emergency management has included Truro as a case study (O'Sullivan et al., 2013; Grieve and Turnbull, 2013).

Figure 5.1. Map of North Onslow marsh body



Notes: The North Onslow marsh body being modified (grey), with area to be restored (blue), *aboiteaux* to be removed (black) and new/improved (white), old dike (blue with dotted lines where to be breached), and new dike (black lines).
Source: Jahncke, R. and W. Flanagan (year), Saint Mary's University Department of Geography and Environmental Studies.

While agricultural dikelands dominate the flood plain on which Truro is built, the region is no longer dominated by agricultural employment. In 2016, natural resource industries comprised only 2-4% of employment, dominated instead by retail, healthcare, manufacturing and education sectors (Statistics Canada, 2017). This is reflected in a decline in active farming and the increased abandonment, or "fallowing", of dikelands.

Examinations of Truro's persistent flooding problems and potential solutions were carried out in 1971, 1983, 1988, 1997 and 2006, each inspired by significant flood events. Consistent with the prevailing "command and control" (*sensu* Holling and Meffe, 1996) approach of the time, all of the resulting reports focused on "hard" solutions to the problem. These included raising and strengthening dikes; constructing runoff storage dams, a causeway/tidal dam to "cordon off" Cobequid Bay, or ice control berms; and, approaches to improve drainage and reduce sedimentation such as viaducts, channel straightening and dredging (CBCL Limited, 2017). A significant challenge to addressing this issue has always been the cost involved: Truro and the county of Colchester have relatively healthy balance sheets, but the province's Financial Condition Index suggests they both have inadequate capital reserves relative to the age of their assets, suggesting they may not be able to afford to replace or improve them (NSDMA, 2017). The available technology at the time of those earlier reports, however, made it impossible to distinguish between the various causes of flooding. More recently, efforts to model the river system in combination with the stormwater system has demonstrated the utility of a holistic approach (El-Sharif and Hansen, 2001).

Tropical Storm Leslie in 2012 fuelled a severe September flood in Truro that changed the local conversation (CBC, 2012). Until then, despite the history of flooding, the municipal level had paid little attention to the issue: there existed simply engineering specifications for stormwater such as culvert sizing and new development regulations. The provincial government was considered responsible for the integrity of the dikes on which the region's safety depended.

In that fall 2012 flood, a dike on the North River breached in several places, and politicians and affected citizens alike called for repairs and reinforcement to the dike system (i.e. building it higher) (Hand, 2012). The high school was evacuated and the media shared stories of evacuated residents who live behind dikes, all apparently unaware that the infrastructure was never designed to protect non-agricultural land uses (Tutton, 2012). The breached dike was privately owned and built, but protected numerous businesses, including an important local employer. The province performed repairs for emergency management purposes (Canadian Press, 2012), given that more rain was in the forecast, but the responsibility for ongoing maintenance of this dike was unclear. This flood inspired the creation of a Joint Flood Advisory Committee for the county of Colchester, town of Truro, and Millbrook First Nation, including representation from citizens and provincial government departments.

A comprehensive flood risk study of Truro was commissioned by the Joint Flood Advisory Committee. The consultants developed a set of hydrodynamic computer models to understand the relative influences of rainfall, river hydrology, tides, sedimentation and ice movements using detailed terrain maps derived from Lidar, bathymetric surveys, field measurements and imagery from multiple aerial platforms (Marvin and Wilson, 2016). Climate change projections were explicitly modelled out to 2100. Once these dynamics were understood, which suggested particular sensitivity of the system to rainfall volumes, several dozen flood mitigation options and combinations were modelled. These options were ranked using stakeholder-derived human, land-use and infrastructure priorities (Table 5.1), as well as the protection level that each provided (including in extreme events), its initial and life cycle cost, the value of the land protected, and feasibility given environmental and permitting requirements (CBCL Limited, 2017). Priorities were elicited from targeted stakeholders, as well as at a public meeting with relatively low attendance according to several who were there.

Table 5.1. Stakeholder-derived priorities for the Truro Flood Risk Assessment

Rank	Human health and safety		Land use		Infrastructure services	
1	Life		Hospital		Water supply/treatment	
2	Emergency facilities		Residential properties		Communication	Power supply
3	Necessities of life	Livelihood			Senior homes	Potable water
4	Protection of environment from contamination		Schools		Roads	Wastewater treatment
5	Access to an area		Industrial lane properties		Bridges	
6	Social justice		Agricultural land		Dikes and *aboiteaux*	
7	Regional access routes		Retail properties			
8			Office uses	Recreational facilities		

Source: Adapted from CBCL Limited (2017), *Truro Flood Risk Study*, https://www.truro.ca/living-in-truro/truro-flood-risk-study.html.

It is notable that despite the area's strong farming culture, agricultural lands and dikeland infrastructure ranked low (6) on both land-use and infrastructure categories of priority for flood protection. This is likely because agricultural dikes were designed to allow some flooding; inundation of farmland every few years was expected and considered low risk and perhaps even positive for sediment deposition. By contrast, residential properties ranked high (2). The housing and infrastructure that was allowed to be built in the flood plain has not been due to financial incentives such as increased amenity, real estate value and thus increased taxes: the assessed value per square metre of single residential units is unrelated to either proximity to water or elevation. Rather, this at-risk development was a natural continuation of early development along shorefront and riverfront roads, and the desire by the municipalities to capitalise on the economic development opportunity of passing highway traffic.

The flooding problem in Truro is indeed complex: no single solution was found to be effective through the 2017 analysis. In fact, no measure under CAD 100 million was found to protect more than 20% of the priority areas, and most require costly earthworks (e.g. river straightening, floodway bypass), maintenance (e.g. dredging) and/or the continual spectre of infrastructure failure (dikes and *aboiteau*). Raising dikes was only modelled as effective at its most costly: when constructed as high as locally necessary (6 metres high in some areas, with commensurate design challenges given the footing width of such a dike), and when accompanied by specialised pumping (30% of priority areas protected for CAD 300 million). Additional *aboiteaux* were considered in the 1970s to hasten drainage, but after modelling found ineffective: while they may protect some areas from storm surges, they hold in rainwater that usually accompanies such storms as well as potentially increasing sedimentation. Modelling dike breaches actually reduced flood risk (CBCL Limited, 2017). Raising priority non-residential areas and roadways, and purchasing homes for removal or relocation, protects the most priority areas, but costs around CAD 200 million (as well as likely representing risks of civic conflict).

The analysis above suggests all that planning and regulatory processes should be designed to avoid further floodplain development. In addition, stormwater infiltration systems should be incorporated into new developments or when infrastructure is being replaced (e.g. permeable surfaces, perforating stormwater pipes). This was modelled to reduce flooding in priority areas by 30-40% at low cost.

The consultants also developed an infrastructure-based recommendation, ready to submit for available funding opportunities. The preferred structural scenario was floodplain restoration, including realigning dikes to re-establish the floodplain and thus its water storage capacity. While cost-effective and protecting 29% of priority areas, combining widening dikes with the construction of pumps to pull water out from behind dikes was expected to cost CAD 99 million. Alone, the dike realignment part was only modelled to reduce risk to priority areas by about 1%.

The full report was never publicised, though it can be found on the municipality of Truro's website and media covered its presentation by CBCL (the consultancy that undertook the study) employees at a coastal flooding conference in 2015 (CBC, 2015). A similar flood risk study by CBCL of a neighbouring jurisdiction had inspired the municipal council to seek to rezone a residential area as a high-risk flood zone to halt further development in the face of climate change. Citizens protested because of the possible detriment of real estate values to the 100 homes there (CBC, 2016). No municipality wanted to expose itself to a similar controversy.

5.4. Policy context for management of sea-level rise in Nova Scotia

The transitional space from ocean to land is a crowded jurisdictional space, so this section covers only the context necessary for understanding this case: climate, coasts, dikelands, floods and wetlands.

5.4.1. Climate adaptation

Canada's approach to climate adaptation varies across scales and provincial jurisdictions, and within jurisdictions between government portfolios (e.g. fishing, tourism, energy, infrastructure, transportation), as well as outside to the private sector. An example of inter-jurisdictional collaboration was the Atlantic Climate Adaptation Solutions Project, a 2009-12 partnership between Canada's four Atlantic provinces and the Climate Change Impacts and Adaptation Division of Natural Resources Canada (NRCan) that funded CAD 8.1 million of research on climate adaptation in the region (https://atlanticadaptation.ca). NRCan continues to provide leadership in this space federally, offering funding and instigating science reviews.

Provincially, the Environmental Goals and Sustainable Prosperity Act in 2007 laid the foundation for climate action with incitement to a range of climate mitigation, adaptation and education activities, including ambitious renewable energy targets (e.g. 25% by 2015, achieved; and 40% by 2020). A Climate Action Plan followed in 2009, committing to create a Climate Change Directorate within the NSDE to "work with provincial departments and municipalities, agencies, schools, and hospitals to reduce [greenhouse gas] emissions and ensure that effective adaptation measures are being implemented" (NSDE, 2009). This is a largely enabling and educating role, rather than a regulatory one. Nonetheless, Nova Scotia mandated the creation of municipal climate change action plans by 2014, making it the first province in Canada to require local-level climate action plans.

5.4.2. Coastal protection

All activities in the exclusive economic zone (i.e. 200 nautical miles from mean low tide mark) fall under federal jurisdiction. For example, the Department of Fisheries and Oceans is the central federal agency in charge of managing offshore activities, while Environment and Climate Change Canada protects water resources from pollution. Above that mean low tide mark, the province dominates. The NSDNR is an important provincial agency for coastal protection decision making with a jurisdiction that includes: beaches, crown lands and provincial parks, trails on lands and over watercourses. The NSDNR also holds responsibility for protecting and conserving endangered species and conserving wildlife and their habitats, except for fish species that are controlled by the Department of Fisheries and Oceans (DFO, 2009). The NSDA controls dikelands (see the next section).

"Nova Scotia has at least 45 pieces of international, federal, provincial, and municipal legislation that deal with its coastal resources" (CBCL Limited, 2009). Yet critical pieces of legislation are missing, such as to guide coastal protection in the province. A long delayed Coastal Strategy is currently in development by the NSDE (Grady, 2018). Decisions in some contexts to abandon or retreat some of this hard infrastructure at the coast in the face of SLR have been hindered by the perceived political costs. Private landowners control most coastlines and have certain roles and responsibilities in risk management decision making and implementation, but as has already been seen, the weak regulatory context creates ambiguity.

Dikelands

The NSDA is responsible for developing and managing dikes and dikelands under the Agricultural Marshland Conservation Act 2000 (Robinson, van Proosdij and Kolstee, 2004). The Minister of Agriculture can decide on developing, maintaining, improving and protecting dikes, dikelands and agricultural marshlands, subject to the approval of the Governor in Council. The Governor in Council can appoint an Agricultural Marshland Conservation Commission to advise the Minister of Agriculture about dike, dikeland and marshland protection and maintenance. This commission also hears appeals related to this act and approves by-laws made by the Marsh Body. The Minister of Agriculture can also appoint a marshland administrator who is responsible for performing administrative duties imposed by the act. Proposed changes to dikelands must also be cleared with the Mi'kmaq First Nations and the Nova Scotia Department of Communities, Culture and Heritage, which is responsible for archaeological resources – including Acadian dikelands themselves as well as other resources found in areas protected by dikes – via the Special Places Protection Act (1989) (NSDE, 2005).

Individual landowners play a significant role in the governance of dikelands. A marsh body is a collective of marshland owners who petition the Marshland Conservation Commission to be incorporated (almost like a small municipality) for a marshland section (an area of marshland that may be effectively dealt with as a unit in the construction and maintenance of works – the Agricultural Marshland Conservation Act, 2000). This body can acquire, sell and lease personal property, and can decide on constructing and repairing dikes at its own expense or in an agreement with the Minister of Agriculture. This body also makes by-laws, which are subjected to the approval of the commission.

A marsh body needs to have an executive committee to perform the administrative activities of the body, and assess and value marsh and dikelands. Notably, the chair and secretary of the committee are endowed with the authority equal to the mayor and treasurer of a town to decide on any activity (e.g. dike restoration, drainage maintenance). The executive committee is supervised by the Governor in Council, who can suspend the authority of the committee should the committee cause any permanent injury to the marsh and dikelands. The Governor in Council can, therefore, revert the activities and authority of the committee to the Marshland Conservation Commission. Moreover, the Agricultural Marshland Conservation Commission performs the marsh body's roles and responsibilities in the absence of an active marsh body (Office of the Legislative Counsel, 2000).

Wetlands

The NSDE has jurisdiction over identifying and protecting salt marshes as wetlands of special significance (Environment Act), and reversing historic wetland loss in the province with restoration (Wetland Conservation Policy). Part of the no-net-loss provincial Wetland Conservation Policy (2011) is the requirement that construction work that destroys wetland must be compensated, usually like with like (Austen and Hanson, 2007). A typical offset depends on the type and quality of wetland lost and gained. For instance, freshwater to freshwater compensation requires a 2:1 ratio, two hectares created or restored for every one lost, but it would likely be 4:1 for salt marsh replaced by fresh, or 1:1 for fresh replaced by salt. The most desirable compensation projects are salt marshes, as well as wetlands in parks or drinking water catchments, and restoration is more desirable than creation (as the latter often fails). These differences are due to the extent of coastal wetland or salt marsh losses in Nova Scotia, estimated at 85% on the Bay of Fundy (Hanson and Calkins, 1996).

The NSTIR has many such "compensation" transactions because of its road construction and infrastructure maintenance. Much such maintenance in the face of SLR involves raising infrastructure, which means going not only up, but also "out", to ensure stability, resulting in bigger project footprints. This only exacerbates the "coastal squeeze" underway on foreshore habitats because of coastal infrastructure (Pontee, 2013). The NSDNR is also interested in wetlands for the habitat functions it provides for waterfowl, for instance via the Eastern Habitat Joint Venture of the North American Waterfowl Management Plan.

Flood risk management

Although the federal government no longer holds direct dike and dikeland management responsibilities, it has played an important role in flood risk management. In 1975, the federal government initiated the Flood Damage Reduction Program (FDRP) in collaboration with all provincial and territorial governments (ECCC, 2013). The central objective of this programme was to identify and designate flood risk areas and to encourage the provincial governments not to build, approve or finance any new development in the designated zones. These agreements also aimed to discourage the provincial governments from intervening via "cost-ineffective" structural measures (e.g. dikes, dams) if preventive and non-structural options were available, like mapping or zoning, or if these structural measures were found to be cost-effective and supportive for non-structural measures. In addition, flood damage compensation has been strongly discouraged for any new development in the designated zones (ECCC, 2013).

Truro was one of the high-risk areas identified by the FDRP, but the town was informed after a 1988 study that it would only get one more damage payment after which those would cease. The FDRP was wound down in 1999 (de Loë and Wojtanowski, 2001). Other funds have filled the gap. Today, Public Safety Canada funds a CAD 200 million National Disaster Mitigation Program (2015-20), including disaster financial assistance arrangements, under a co-funding agreement between the federal and the provincial governments. This fund is administrated in Nova Scotia by the Emergency Management Office of the Department of Municipal Affairs (NSDMA), covering up to 50% of eligible provincial projects: flood risk assessment, flood mapping, flood mitigation planning and investment in non-structural and small-scale structural flood risk mitigation projects. The NSDMA also administers the federally funded New Building Canada Fund (also known as the Small Communities Fund), for municipalities and villages with a population of less than 100 000 to develop disaster risk-reduction infrastructures and utility infrastructures.

The federal government has an alternative funding scheme for promoting climate adaptation through influencing infrastructural development at the municipal level. The federal government launched the Gas Tax Fund in the 2005 federal budget as an *ad hoc* funding mechanism for municipal infrastructural development, which was made permanent in 2011 as a stable fund with an endowment of CAD 2 billion per year along with a yearly increment of 2%. This fund is distributed on a per capita basis with a minimum level of funding for least populated regions (0.75% of total fund), regulated under joint agreements between the federal and the provincial governments (Dupuis, 2016). Disaster mitigation is one of the 11 eligibility categories for federal infrastructural expenditure under this fund, including storm water and other utility infrastructures (NSDMA, 2015a). In order to access these funds, the federal government mandated that integrated community sustainability plans be developed by each municipality to guide the effective use of the funding (NSDMA, 2007), and Nova Scotia additionally requires a municipal climate change action plan. Not all municipalities have the in-house capacity to carry out such planning, so many of these plans were developed or facilitated by outsiders, such as consultants or academic teams (Warburton and MacKenzie-Carey, 2013).

Beyond the federal funds mentioned above, the NSDMA operates two other funding schemes for municipal infrastructure (NSDMA, 2015b):

1. The Flood Risk Infrastructure Investment Program (mentioned earlier) is a provincial government initiative to fund inland flood water management infrastructure studies and development programmes (e.g. river training, floodway improvement, flood intensity mitigation, floodwater contamination).
2. The Provincial Capital Assistance Program co-funds high-priority municipal infrastructure programmes to reduce the cost burden for municipal governments, including storm sewer systems.

In general, however, the government of Nova Scotia is concerned with freshwater flooding rather than coastal; there are no legislation, policies or processes yet in place to guide decisions around planning or retreat options (NSTIR Environmental Analyst).

Municipalities along the coastline in Nova Scotia hold important roles, responsibilities, power and authority in flood risk management given under the Municipal Government Act 1998. As directed in this act, every municipal government can develop municipal planning strategies, a document that contains a detailed layout of existing infrastructure and admissible future development along with other land-use practices (e.g. agriculture, recreation). Municipal governments can also enact land-use by-laws for the execution of the municipal planning strategy. However, municipalities are not required to put these strategies in place: because of very different resourcing and in-house skills, 40 out of 51 municipalities have developed comprehensive strategies, including Truro; the other 11 municipalities have only single-issue coverage (GNS, 2018). The plans are guided by a statement of provincial interest (NSDMA, 2016), which is a provincial government guideline managed by the Department of Municipal Affairs for developing the municipal planning strategies and land-use by-laws, covering five broad areas: 1) drinking water; 2) flood risk areas; 3) agricultural land; 4) infrastructure; and 5) housing.

The guidelines for flood risk areas are based on the erstwhile Nova Scotia-Canada FDRP, which identified high flood areas (NSDMA, 2016). Infrastructural development is highly discouraged in these high-risk areas under this guideline, although the enforcement of the guideline falls under the jurisdiction of the municipal governments (NSDMA, 1998). Since most of the coastal protection infrastructure (e.g. dikes, dams) and coastal public land (e.g. beaches, wetlands, crown lands) managements are vested in the provincial agencies, and agricultural marshland management is vested in the NSDA and the marsh bodies, none of the guidelines directly address coastal flooding. That said, a number of the municipal climate change action plans in the Bay of Fundy do include coastal protection infrastructure such as dikes, and even go so far as to reference foreshore and fringe marsh size requirements, so municipalities can wield considerable authority in coastal areas if they so choose.

At present, coastal flooding is not an insurable hazard covered by the majority of insurance companies, but in May 2018, The Co-operators became the first insurance company to cover coastal flooding and storm surge damages through its Comprehensive Water Policy. Such products require good risk mapping, which is only now becoming available, but an additional complication is that "flood-related losses are often directly attributable to under-investment in public infrastructure, poor asset management, obsolete building codes and ineffective land-use planning" as well as a lack of functioning wetlands. As the Truro case study demonstrates, however, the line between coastal and overland flooding is sometimes fuzzy.

Even with flood mitigation by homeowners and communities, insurance experts suggest the increasing expense of insurance products, and dwindling support or capacity for taxpayers to subsidise rebuilding when large-scale events occur, will require serious consideration of retreat options and other nature-based options (Moudrak et al., 2018). In fall 2017, the Insurance Board of Canada was asked to chair a working group by Canada's Minister of Public Safety, "charged with creating a roadmap for ensuring that flood risk is transferred from taxpayers to those who hold the risk". A potential move to increasing homeowner responsibility runs contrary to perceptions held by residents, as heard in towns like Big Lake, Hantsport and Advocate Harbour.

5.5. Dike realignment and salt marsh restoration at North Onslow

The Onslow-North River Dike Realignment and Tidal Wetland Restoration project was a collaboration between government, community, academic and industry partners. Initiated by the NSTIR in co-operation with the NSDA and the NSE, the primary purpose of the project was to create a "bank" of salt marsh "habitat credits" for offsetting the loss or damage to wetlands arising from future NSTIR infrastructure projects. Being part of the Bay of Fundy's Minas Basin, tidal influence within the Salmon River that runs past Truro extends upriver beyond the North Onslow (NS067) project site. The position of the site at the confluence of the Salmon River and North River creates complex patterns of water, sediment and ice movement, which result in high maintenance costs for dike and *aboiteau* infrastructure, the build-up of ice in winter, and an increased risk of flooding. As such, the project was also intended to:

- reduce ongoing dike maintenance costs for the NSDA by reducing the total length of dike and number of *aboiteaux*
- enhance the protection of both public and private infrastructure, as well as viable farmland
- reduce flood risk and enhance resiliency for climate change through the restoration of floodplain, one of several actions recommended by the 2017 Flood Risk Study (CBCL, 2017).

No residential buildings would need to be relocated under this strategy, but some small berms would need to be added to one property to ensure its protection. Access to some electrical transmission infrastructure will need to be maintained as the former dikeland is converted to foreshore marsh, as it would be too costly to move.

5.5.1. Governance

CB Wetlands and Environmental Specialists (CBWES), in partnership with Saint Mary's University and Queens University, was commissioned in December 2016 to develop a dike realignment and restoration design plan for the "northern parcel" of the Onslow-North River dikeland. The scope of work included working with the NSDA and the marsh body to determine the optimal location for new dikes and construction materials (e.g. "borrow pits"), identifying the location and size of breaches in the old dike, creating a restoration design for the tidal wetland, and anticipating habitat response to restoration. This component was financed by the NSTIR as part of the wetland compensation process.

In Nova Scotia, any proposed activity that has the potential to alter the boundaries of a marshland section for which the marsh body is incorporated requires consultation with and agreement by two-thirds majority vote of the marsh body, in accordance with the Agricultural Marshland Conservation Act (2000, c.22, s.13b). The marsh body engagement process expanded upon the consultation process as outlined in the Marshland Act, engaging with the members of the marsh body and bordering landowners and inviting them into the project design process. Consultation with Canadian National (CN) Rail and Nova Scotia Power was also necessary due to the presence of rail and power transmission infrastructure on the project site. Finally, an archaeological resource assessment was required.

At project initiation, the site was a mix of forage (hay, grazed) and fallow agricultural land. The NSDA could not afford to maintain the dike, and there was an *aboiteau* in need of replacing to remain functional. The majority of the dikeland property needed for the project was purchased by the NSTIR in 2016 in anticipation of the project. However, several parcels adjoining the floodplain had not been purchased. For these parcels, flood vulnerability was assessed and mitigation actions would be recommended as part of the design. Despite its agricultural origins, the site is complex for this kind of realignment: the CN Rail line defines its eastern border, the 1763 Onslow Island Cemetery is within its western boundary and a power transmission line dissects the site. Consultation with CN Rail and NS Power was necessary to address any potential risks to their respective infrastructure either through the inclusion of flood protection measures or their relocation, but were notified along with other landowners they were late to join the planning table.

Following consultation with NSDA staff and additional analysis of the marshland, which included site history, habitat conditions and hydrology, several preliminary dike alignments were drafted as a proof of concept to guide early planning and consultation. Various dike realignment and tidal wetland restoration design options were tested using Delft 3D hydrodynamic modelling software (including tidal, overland and river flows) and validated with the same field measurements of water levels and sediment transport as available to CBCL for its flood risk study. All such validation work is hampered by inadequate records; for instance, a lack of long-term tide gauges near the site. The closest permanent gauge operated by the Canadian Hydrographic Service is 200 km across the Bay of Fundy, in Saint John, New Brunswick; all other available tide gauge records come from short-term consulting or research projects.

5.5.2. Consultation

The intent was to collaboratively arrive at a realignment and restoration design that was not just accepted, but supported, by the marsh body. This was to be achieved through a series of community hall style meetings, a special topic meeting and "kitchen table" conversations with individual stakeholders. Prior to the initiation of this project, however, the Onslow Marsh Body was not active and so the first step in the process was to reactivate the group and provide it with the structure, information and tools needed to effectively participate. At the first meeting, the idea and rationale for the project was presented. The questions arising from the marsh body at this stage were about alternative solutions to the flooding problems, which were difficult to debunk given that the CBCL report was not yet publicly available. A second challenge was difficulty interpreting the flood modelling maps: when residents saw the modelled flood boundary under preliminary scenarios, they struggled to understand how rarely the water would reach that level given the hypertidal conditions of that site (Archer, 2013[1]).

Over the period of meetings, the most contentious issue proved to be the issue of mosquitoes. Concern was raised that the restoration to tidal wetland habitat would lead to an increase in mosquito populations like what was experienced in Moncton following the opening of the Petitcodiac tide gates (Gerwing et al., 2017). This was of particular concern to a landowner who ran a nearby tourist attraction. To address this issue, experts from the region were invited to discuss the process of monitoring for mosquito larva in their stormwater impoundments in fallow dikelands, and applying larvicide as necessary to limit mosquito levels. In addition, once predator populations became established in the salt marsh, they would eventually control mosquito populations, and effective drainage would ensure balance was maintained.

The marsh body's final meeting presented the proposed realignment design, answered any remaining questions and conducted a vote in accordance with the Marshland Act to vary the boundaries of the dike and by doing so allow the project to proceed. While adjacent landowners could attend, only marshland owners could vote. Each landowner gets a single vote, regardless of how much land they might own, and a two-thirds majority is needed. The Marsh Body Chair reported that the landowners appreciated that they were "sure giving us a lot of time to think about this." The vote passed unanimously, with two caveats: 1) that a pest-management protocol be developed as part of the project, including monitoring; and 2) that ongoing communication with the marsh body be maintained.

5.5.3. Design

With the successful marsh body vote and a final alignment selected, the technical specifications of the design could be finalised (Figure 5.1), which would mitigate concerns of the creation of additional mosquito breeding habitat, create healthy salt marsh ecosystems and hopefully reduce flood risk for Truro. The fundamental control on the structure and function of tidal wetland habitat is flooding with salt water (Mitsch and Gosselink, 1986; Neckles and Dionne., 2000). It is the hydroperiod (frequency and duration of tidal flooding) of a wetland that determines the area of marsh directly available as habitat, and thus useful as compensation credits. The first step of such design is modelling the outright removal of the barrier, in this case the dike, to see how the site would naturally flood. This also allows for the identification of features, areas or infrastructure that are likely to be at risk or negatively affected. Modifications to the design and the incorporation of mitigation measures (i.e. new dikes, ditching, amending land elevation) to alleviate these effects can then be explored and modelled.

For this project, it was determined that two new dikes would need to be constructed landward of the existing structure: 1) the primary dike (1 km) along the western end of the site to protect active marshland and the historic cemetery; and 2) a small dike in the eastern corner of the site to protect infrastructure owned by CN Rail. In addition, for effective flooding to occur, and to reduce standing water, which could serve as mosquito breeding habitat, a channel network would need to be created and the old dike breached in several places. Dike breach and channel widths were calculated using hydraulic geometry (Graham, 2012; Williams and Orr, 2002), and channel locations selected based on the channel network delineation and relict historic tidal channels identified in historic aerials. Three of the four existing *aboiteaux* would be eliminated, including the large three-barrel structure on McCurdy Brook, and a new *aboiteau* constructed within the eastern dike to ensure protection and drainage of low-lying lands above the rail line. LiDAR DEM, topographic surveys and several tide gauges deployed by CBCL in 2014 and CBWES in 2017 helped the design of the hydraulic network for the new marsh.

5.5.4. Implementation

The implementation of the above design is still underway. The archaeological phase one assessment, conducted in accordance with the Nova Scotia Special Places Protection Act under a Heritage Permit by a consulting firm, noted an artefact scatter at the northern end of the proposed inner dike footprint of a kind already recorded within the Maritime Archaeological Resource Inventory. No additional significant archaeological resources were identified in the area; however, as mentioned earlier, the inner dike was moved slightly to the east to avoid any potential damage to the 250-year-old cemetery situated on an upland portion of the marshland.

Monitoring will be extensive, as this realignment represents an important precedent. Although not yet provincially mandated, over the last 15 years, the NSTIR has funded baseline (pre) and 5-year post-restoration monitoring at all of its tidal wetland restoration sites. CBWES is responsible for data collection and analysis of changes in hydrological condition, vegetation, water quality, soils and sediments, marsh morphology, nekton biology, and marsh surface elevation change. Saint Mary's University will also track its geomorphological change, for instance monitoring sediment accretion using drones, as well as working to quantify the carbon sequestration potential represented by the restored salt marsh. It is also estimated that within 8-10 years post-breach, the restored North Onslow tidal wetland will be operating as a near optimum salt marsh habitat and regulating (e.g. acting as a storm buffer) ecosystem services.

While a comprehensive cost-benefit analysis (including in-direct ecosystem and flood mitigation benefits) was not performed for this project, the direct costs accounting currently available supports the North Onslow realignment as a cost-effective option. It is estimated that the dike realignment will result in approximately CAD 520 000 of savings (Table 5.2). Additional benefits such as carbon sequestration and flood mitigation will be empirically quantified as the project proceeds, and be used to inform future decisions. The current land value of the land protected is CAD 400 000, excluding utility (NS Power) and federal infrastructure (e.g. CN Rail).

Table 5.2. Direct costs of maintaining dike in place (including "topping" to predicted 2055 high-water levels) versus realignment of dike infrastructure and tidal wetland restoration

2018 CAD

Maintain status quo and top dike in place		Realignment of dike infrastructure	
Upgrade McCurdy's brook *aboiteau*	1 500 000	Land purchase (18 parcels, 92.5 ha)	798 000
Top 3.5 km of dike in place	500 000	Archaeology	71 559
Estimated ten-year standard maintenance	180 000	Earthworks and breach	625 000
		Feasibility, design and baseline	161 000
Total	2 180 000	Total	1 655 559

5.6. Outcomes and lessons learnt

This project remains under construction, so its effectiveness in reducing flood risks in Truro has yet to be tested. There are many uncertainties: the lag time involved in the re-establishment of the tidal wetland and its ability to play an effective buffer role; the impact of dike realignment on sedimentation patterns and ice movement; and how such changes will affect the dynamic hydraulic system in place. As with previous tidal wetland restoration projects undertaken by CBWES (Bowron et al., 2012), a comprehensive five-year post-restoration monitoring programme will help fill this gap in understanding. Despite the inability to reflect directly on the physical outcomes, it is possible to identify several other outcomes and lessons for governance of this kind of social and landscape change.

First, thanks to effective collaboration across scales of government, a lack of climate change or coastal protection policy did not hamper action toward climate adaptation in this case study. A number of pieces fell into place at the same time that allowed this project to be put forward as a potential solution to many problems, and allow multiple jurisdictions to work together. Marginal dikeland came up for sale at the same time as the NSTIR needed wetland credits to offset its construction work. The size of the projected salt marsh habitat restoration that would be involved (~93 ha) was particularly attractive to the NSDE, with its responsibility over the no-net-loss Wetland Policy. This allowed the NSDE to offer half the normal offset ratio to the NSTIR as is usually required. This agreement with the NSDE meant that the NSTIR could make the case for purchasing the dikeland at a price attractive to the landowner. The capital costs of the dike infrastructure protecting that marginal land were already problematic for the NSDA, and the department was already engaged in a prioritisation process for informing dikeland decisions such as maintenance, realignment or abandonment. In this case, realignment would reduce the length of dike to be maintained from 3 000 m to 1 250 m. The non-NSTIR half of the cost of the project could be provided by National Disaster Mitigation Program funds via the municipality, thanks to reasonable modelling evidence from the CBCL flood risk analysis that widening the dikes would contribute to the reduction of flood risk in Truro.

The above represents a positive outcome for wetland coverage, construction offsets, dike maintenance and landholder compensation. It is worth noting that this collaboration came about in part because of constrained budgets.

Climate adaptation is notably absent from that list of clear wins. This is because despite strong evidence of the utility of such approaches for flood and erosion protection, as well as potentially climate mitigation through sequestration, it is not yet known whether the restored marsh will prove adaptive to SLR in this complex setting. In the absence of strong policy, it is difficult to credit any of the above positive outcomes to government commitment around climate action. Yet, the NSDE was a critical guide to this process in more ways than the wetland offset agreement discussed above. The NSDE Climate Change Directorate has been working to change the culture in government around climate issues for many years, including running courses for government managers.

Even if the flood protection outcomes are uncertain, the value of the replicable process is not. As such, climate goals underlie the whole undertaking, and if successful, the project will serve as an important precedent. It is an important start on this long-term project of adaptation, and a relatively low-risk one, given that the project is already meeting so many other goals.

This project is not, of course, a no-risk option. Changing any one thing in a hydrologic system as dynamic as Truro's can lead to unexpected outcomes. The dike realignment design being used in this project has not been systematically modelled for its impacts on flood or public safety upstream of the predicted extent of penetration of tidal waters for 2100. For instance, it is possible that the change in hydrology resulting from this project could exacerbate sedimentation issues in the main river channel, alter local flood and drainage patterns, or adversely affect the behaviour of ice. Similarly, while an option may have performed well in terms of the per cent of overall priority areas where flood risk was mitigated, people may still be at risk in specific places. There is some indication from modelling of similar options by CBCL that a dike realignment project such as this one could shift some flood risk to other specific areas, such as low-income housing sites upstream. This remains to be seen, but is an important consideration.

Given the tendency to prefer *status quo* landscapes, this project represents an important opportunity to show Nova Scotia citizens what adaptation may look like, on the land and in public process. The social achievements of this project could lead to greater cultural change. This project created a marsh body organisation where none was previously active. It engaged that group in difficult conversations with a range of government representatives and researchers. The proponents listened meaningfully and made adaptations to their plan, including dike placement and adding monitoring for mosquitoes. The NSDE Adaptation Specialist noted that one thing that is lost by the fact that climate adaptation was not the explicit project goal, was the fact that this is the first time affected residents in Nova Scotia have voted for a managed retreat: basically sacrificing private land for ecosystem purposes.

It is possible that this project set an important precedent: it was quickly followed by a similar verdict about a managed realignment proposal on the Cornwallis River to the west. Such outcomes with informed, engaged citizens are a significant departure from recent headlines presented above about similar situations in Advocate Harbour, Hantsport and Big Lake. Effecting "public good" landscape changes of this type is a non-trivial social challenge. However, the marsh body came together, reviewed the options, asked questions and voted in favour of change. As the NSDE carries out public consultation for the long-awaited Coastal Strategy, projects like this one provide important leverage as well as a place for Nova Scotians to observe salt marsh restoration and the potential role it can play in adaptation. The comprehensive monitoring framework established will contribute to a growing database of pre- and post-empirical field data and visual representations of the changing landscape.

It is argued by many involved in this process that the Bay of Fundy and its erstwhile salt marsh ecosystem itself must be considered a stakeholder of such decisions. The salt marsh ecosystem that is restored may represent a range of ecosystem services, including fish nursery habitat, storm buffer and carbon sequestration through so-called "blue carbon".

The multifunctionality of wetlands that allowed other policies to be used to achieve this project. Ecosystem services may well be a useful way of exploring the costs and benefits of other such nature-based adaptation options (ICF, 2018).

There is a desire by the NSDA and other proponents of this project to carry out similar projects elsewhere in Nova Scotia, including on the south side of the Salmon River from the North Onslow project. That southern lobe of dikeland is closer to the town centre, as well as being more actively farmed. Additional creative approaches may be necessary where farmers are unwilling to sell land, such as the NSDA negotiating trades of dikeland parcels rather than simply buying out active producers, as one of its goals is to maintain agriculture where viable. The expansion of the dike realignment strategy may struggle in the absence of a strong provincial strategy and leadership on coasts and climate. Nonetheless, this project represents an important learning experience as well as precedent: an exemplar of the value of a genuine and patient consultation process.

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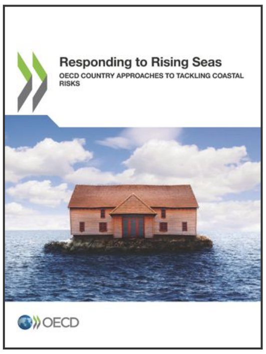

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