Final Report

Coastal Vulnerabilities to Climate Change in the Municipality of the District of Chester, Nova Scotia

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DALHOUSIE UNIVERSITY
Inspiring Minds

For:
Municipality of the District of Chester
c/o Senior Planner, Tara Maguire

Submitted by:
Planadapt Consulting,
Elemental Sustainability Consulting,
and the Dalhousie University
Marine Affairs Class of 2012

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Introduction

This report summarizes the findings of the Dalhousie University Marine Affairs Class' assessment of the Municipality of the District of Chester's vulnerability to climate change impacts, conducted during the fall of 2011. These findings are summarized in the Findings Section, and presented in full in the Appendices. The authors have provided their own observations and knowledge to supplement and help interpret the students' findings.

The class was taught by Kyle McKenzie (Planadapt Consulting) and Lucia Fanning (Dalhousie University), with guest lectures by Anne Warburton (Elemental Sustainability Consulting Ltd.) and others. The individual student contributors are shown on each of the reports in the appendices.

The objectives of the class included exposing graduate students to the concepts of climate change science, impacts, and adaptation, as well as giving them practical experience working with a municipality to assess climate change vulnerabilities in the coastal zone. This experience was set in the greater context of the Municipality's preliminary efforts to develop an amendment to its Integrated Community Sustainability Plan (ISCP), in the form of a Municipal Climate Change Action Plan (MCCAP). The MCCAP is a requirement of Service Nova Scotia and Municipal Relations and will allow the Municipality to access federal gas tax funding.

As this project was a learning experience for the students, it is not meant to be a comprehensive review of the topic within the study area. Rather, it highlights the most obvious threats to the coastal zone of the municipality. Many of these threats are described as site-specific, but may exist in multiple locations.

Although the student reports do address the issue of multiple jurisdictions being responsible for various aspects of the coastal zone under threat, the report does not address responsibility for actions toward adaptation. Rather it is intended to be a starting point for discussion among all stakeholders in the process of adaptation. Similarly, although the report does identify possible adaptation options for consideration, it does not recommend specific actions. The process of prioritizing actions and developing an adaptation plan is the subject of subsequent phases of this project.

Methods

In addition to the instructors, the class consisted of sixteen first year Masters students, most of whom came from outside of Nova Scotia. The students were divided into four teams of and each was assigned a separate section of coastline, collectively covering the entire coastal zone of the Municipality. Each team had to address climate change vulnerabilities according to four criteria: natural environment concerns, infrastructure concerns, socio-economic concerns, and governing and planning concerns. The teams quickly realized that while the first three criteria are site specific, the fourth is not. They therefore documented their findings under the first three criteria with comments about the fourth spread throughout as appropriate.

Team A, unfortunately, lost two participants during the study and as a result was not able to cover its territory in as extensive a manner as the other teams. Regardless, the remaining members made an exemplary effort compensate for their team's deficiency.

The Municipality provided digital maps to the students with five metre contour intervals; the best data that were available at the time. Using these data, the students designated two zones of elevation along the coast for examination. The first area was the land that lay between the zero to five metre contours. This was

considered the zone of primary concern, where the risk of storm surge, flooding, and coastal erosion are greatest and is expected to be exacerbated by sea-level rise over the remainder of this century. The second zone is the area that lay between the five and ten metre contours, which was designated as the zone of secondary concern. This is the zone where coastal wind and wave run up under extreme events will be most prevalent, as well as where surface water runoff and flooding during extreme precipitation events will be the greatest before meeting storm surge induced flooding. Additionally, where the coastline is particularly steep and neither of the previous zones reaches far inland, students examined 100 metres inland. This allowed the students to look at other features that may be impacted such as buildings that are only connected to the road and utility networks through infrastructure located in the zones of primary and secondary concern. See Figure 1 for a map of the study area.

Students visited the Municipality on many occasions throughout the fall of 2011 and mapped out vulnerabilities as they were discovered. Field work was generally limited to public roads. Aerial photos, videos, and published reports were used to supplement understanding of the inaccessible locations. Additionally, the students spent half a day interviewing municipal staff and council in person, and they also communicated with staff and council through electronic correspondence.

Class lecture, library, and Internet research, and individual paper assignments strengthened the students' knowledge of the subject matter and allowed them to apply theoretical understanding of climate change vulnerabilities to what they saw in the coastal zone while doing field work and what they heard from councillors and staff during interviews.

FINDINGS

VULNERABILITIES

Category	Concern	Examples/Locations
Erosion and sediment migration	Drumlin islands	Mahone Bay
	Sand beaches	Aspotogan Peninsula
Significant habitats	Habitat for species of concern	Meisners, Mountain, and Saddle Islands
	Salt marshes	Mahone Bay
	Fresh water wetlands	west side of Goat Lake, near East River, Little East River and Mill Dam Brook
Impacts to flora / fauna	Shift in species assemblages	Throughout
	Invasive species	Throughout
	Threats to biodiversity	Throughout
Fresh water resources	Flooding	Mouths of rivers

Table 1: natural environment concerns.

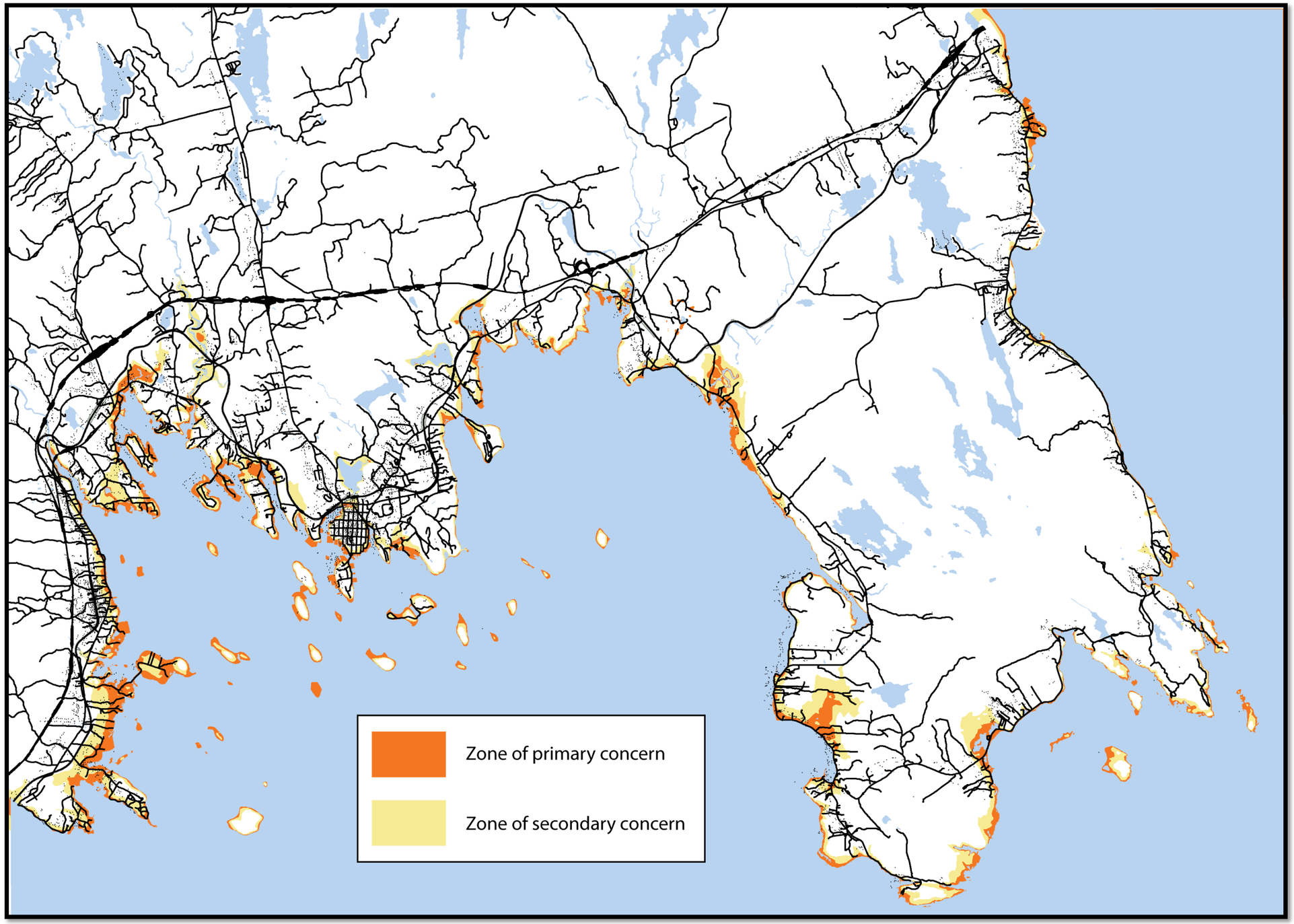

Figure 1: study area with zones of primary and secondary concern indicated.

Category	Concern	Examples/Locations
Waste water system	Sewage lift stations and treatment plants situated at low elevation	Chester, Western Shore
	Sensitive to power outages	Where existing
	Subject to salt water intrusion and illegal connections	Where existing
	Major pumping station already below mean high water mark	Chester
	Failure of wastewater lift stations resulting in sewage backups in private homes	Where existing
Storm water runoff	Undersized culverts may lead to increased flooding risk	Where existing
	May exacerbate illegal connections to municipal wastewater system by private citizens	Where existing
Power and telecommunications	Damage to utility lines	During extreme wind/rain events
	Damage to utility poles	During storm surge and coastal erosion
Roads	Physical damage, impassability	Trunk 3, Highway 329, Water Street, other coastal roads (public and private)
Causeways	Flooding and erosion	Graves Island Provincial Park, Marvin's Island, Oak Island
Bridges	Flooding and damage	Martin's River
Wharves	Flooding and damage	Tancook Islands Ferry Terminal, Public wharves in Aspotogan and Western Shore, boat launch in Blandford, private wharves

Table 2: infrastructure concerns.

Concern	Examples/Locations
Private property damage	Throughout
Public health and safety	Injuries during extreme events
Emergency management and response	Reaching those in need during extreme events
Seasonal residents and tourists	Inappropriate responses to extreme events, maladaptation
Loss of public coastal access	Graves Island, Meisner's Beach, Wharves/Docks, Lido Pool, Freda's Beach, Wild Rose Park
Loss of iconic businesses	Rope Loft, Shatford's Lobster, Granville Gates, Island View restaurant, Atlantica Resort
Loss of cultural resources	All Saints First Cemetery, Oak Island Treasure

Table 3: socio-economic concerns.

Specific Areas of Concern

Martin's River

The bridge at Martin's River (Figure 2) is one of several low points where Trunk 3 is vulnerable to storm surge, flooding, and erosion. Overtopping of the road and bridge here could lead to this section of Trunk 3 being impassable for the duration of the event. In combination with similar flooding to the north (e.g. where Trunk 3 runs along the coast at Western Shore and Gold River) such flooding could lead to residents being isolated for the duration of the event. Erosional damage to the bridge or road could lead to longer inconvenience for residents. As it is between highway exits no formal access to Highway 103 exists along this stretch of Trunk 3.

Figure 2: Trunk 3 bridge at Martin's River.

Mouths of rivers are particularly susceptible to flooding during storm surge and extreme precipitation events because they are where the excess water coming upstream from the ocean and downstream from the river meet. Because this bridge appears to be in the intertidal zone under ideal extreme event conditions this spot may be subjected to flooding beyond expectations for its elevation.

Figure 3: East Side Martin's River Road.

Much of East Side Martin's River Road is close to the shore and vulnerable to flooding and erosion. Although many houses are within the five metre contour they are mostly on the side of the road opposite the water and therefore less exposed to coastal threats (Figure 3). Several coastal wetlands (salt marshes) exist toward the end of the road. How salt marshes react to rising sea-level, storm surges, and coastal erosion depends on a variety of factors, the examination of which is beyond the scope of this study. Possible responses include inland migration, rise in elevation, or even being drowned or eroded out of existence. The smaller of the two (Figure 4) has no room to migrate inland as sea-level rises while the larger (Figure 5) may simply contract toward the back end where elevation is a bit higher.

Figure 4: smaller salt marsh on East Side Martin's River Road.

Figure 5: larger salt marsh on East Side Martin's River Road.

Martin's Point

The road and houses on Martin's Point are, for the most part, outside of the zone of primary concern. However, part of the road near the mainland side of the point crosses a low area, which has salt marshes most of the way across. The salt marsh to the south (Figure 6) has plenty of room to migrate inland between its current edge and the road, while the one to the north (**Figure 7**) does not. At some point in the future this entire low area might wash out resulting in most of the point becoming an island.

Figure 6: salt marsh on Martin's Point with room to migrate.

Figure 7: salt marsh on Martin's Point with little room to migrate.

Oak Island Area

The causeway at Oak Island (Figure 8) is one of several in the Municipality that is within two metres of high tide level, creating an existing vulnerability to flooding and erosion during storm surges at high tide. Because the causeway and island are privately owned, they were not accessible during this study. It is possible that archeological resources on the island may be impacted by sea-level rise, storm surge, and coastal erosion. However, the area identified as a potential 'money pit' appears to be outside the zone of primary concern.

Figure 8: causeway (foreground) to Oak Island (background).

On the mainland near the causeway lies a large salt marsh (Figure 9). It appears to have some room to move inland, but not much relative to its current size. The treed mounds may become islands at some point.

Figure 9: large salt marsh near Oak Island.

Figure 10: Atlantica Hotel & Marina Oak Island oceanfront chalets.

Nearby, in Western Shore, is the Atlantica Hotel & Marina Oak Island. While the main building is outside the zone of secondary concern, the oceanfront chalets (Figure 10) and seaside villas (Figure 11) are well within the zone of primary concern. The latter is less exposed to wave action because of the breakwater (Figure 12).

Figure 11: marine villas at Atlantica Hotel & Marina Oak Island.

Figure 12: marina and breakwater at Atlantica Hotel & Marina Oak Island.

Western Shore and Gold River

Trunk 3 in the Western Shore/Gold River area runs quite close to the shore and lies within the zone of primary concern. Many utility poles on the water side of the road are vulnerable to erosion (e.g. Figure 13). Much of the shore here has been hardened with granite boulders yet erosion continues, as evidenced in Figure 14.

Amenities on the water side of the road here, including Wild Rose Park (Figure 14) and the Island View Family Restaurant and Bakery (Figure 15), are potentially at risk.

Figure 13: vulnerable utility poles in Western Shore.

Figure 14 : Wild Rose Park.

Figure 15: Island View Family Restaurant and Bakery.

Gold River Indian Reserve

Although not under the jurisdiction of the Municipality of the District of Chester, part of the Gold River Indian Reserve of the Acadia First Nation lies within the zone of secondary concern. As the slope is very steep here, there appears to be no built infrastructure or sensitive habitat at risk from sea level rise, storm surge, or coastal erosion.

Figure 16: causeway to Marvin's Island.

Marvin's Island

Marvin's Island is another island with a low causeway (Figure 16) that is vulnerable to storm surge and flooding, possibly stranding residents. Most of the roads on the island are above five metre contour and some are above the ten metre contour, yet many of the homes are within the zone of primary concern.

The island also has a large wetland on the low lying north side. It appears to have plenty of opportunity to migrate inland as sea-level rises.

Chester Basin

Trunk 3 comes close to the shore again at Chester Basin. The parking lot next to the Chester Basin Village Mart shows distinct signs of coastal erosion (Figure 17). Chester Basin Village Mart, McDougall's Drug Store, and Seaside Shanty (Figure 18) are, elevation wise, among the closest buildings to the water in the municipality.

Figure 17: parking lot next to Chester Basin Village Mart.

Figure 18: back sides of businesses in Chester Basin.

Shaw Island

The Shaw Island causeway (Figure 19) is a bit higher than the previously described causeways, but is still potentially vulnerable to flooding during storm surges at high tide. At either end of it is a salt marsh. The island salt marsh (Figure 19) the smaller of the two and has little opportunity to migrate inland. The mainland salt marsh (Figure 20) is much larger and has ample gently sloping higher ground to migrate onto.

Figure 19: Shaw Island causeway (midground) with island salt marsh in the foreground and the mainland in the background.

Figure 20: mainland salt marsh adjacent to the Shaw Island causeway.

Marriott's Cove

Two large salt marshes exist on either side of Marriott's Cove Road West at its north end. Although similar in size and adjacent to each other, the two are a study in contrasts. The inland marsh (Figure 21) drains into the coastal marsh (Figure 22) and is likely at a slightly higher elevation and may be less saline. Although the coastal marsh may be able to migrate laterally as sea-level rises, it is constrained at the back by the road and may be eventually squeezed out. The inland marsh, conversely, is protected by the road and will likely flourish as long as the road is maintained. As sea-level rise, this marsh will likely become more salty and hopefully be able to migrate inland as necessary.

Marriot's Cove Road West is low lying and within the area of primary concern, for the most part, although most buildings are on the landward side and at safer elevation. Two examples of the future fate of many coastal wharves and buildings exist along this road. A building sits on a very low-lying piece of shoreline that is eroding (Figure 23) and the remains of an abandoned wharf sitt barely above the mid-tide mark (Figure 24).

The east side of Marriot's cove is much steeper so the road and structures are not at quite so much risk. In some places owners of private infrastructure are actively reinforcing the shoreline (Figure 24).

Figure 21: Marriott's Cove inland salt marsh.

Figure 22: Marriott's Cove coastal salt marsh.

Figure 23: eroding coastline and threatened building, Marriot's Cove Road West.

Figure 24: abandoned wharf on Marriot's Cove Road West (foreground) and shore hardening on Marriot's Cove Road East (background).

CHESTER VILLAGE

Give the hilly nature of and dense road network of Chester Village, there aren't as many vulnerabilities as one might expect. Regardless, there are still some areas of concern.

Much of the land adjacent to the section of stream connecting Stanford Lake and Mill Cove between Victoria Street and Trunk 3 is within the five metre contour and as such is vulnerable to flooding. The movement of earth and sediment fences in this area implies upcoming construction, which may be vulnerable to flooding.

Sections of Victoria Street, Peninsula Road, South Street, Water Lane, Water Street, Pig Loop Road, and Nauss Point Road are within the area of primary concern. With the exception of Pig Loop Road (Figure 25) most buildings are on the landward side of these roads and given the dense road network many of these properties may be accessible from roads at higher elevation during emergencies. Several of these streets have a high density of wharves, one of which supports a well-known restaurant (Figure 26).

Concern has been expressed about the Lido Pool (Figure 27) although given its concrete structure and operational nature is not likely as vulnerable as other coastal infrastructure.

For the most part, the causeway to The Peninsula (Figure 28) appears to be at higher elevation than other island causeways in the municipality and therefore less vulnerable to flooding. Unfortunately, it quickly drops in elevation once on The Peninsula (Figure 29) so residents may be stranded in a flooding event.

Figure 25: buildings on low stretch of Pig Loop Road.

Figure 26: The Rope Loft.

Figure 27: the Lido Pool.

Figure 28: causeway to The Peninsula.

Figure 29: low point at intersection of Peninsula Road and Freda's Hill Road.

Mahone Bay Islands

Many of the islands in Mahone Bay are drumlins (e.g. Figure 30), which means that they are made of easily eroded sediment rather than hard bedrock. Although many are uninhabited, some contain valuable species habitat, which may be lost as sea-level rises and erosion increases.

Figure 30: drumlin island in Mahone Bay.

Graves Island

Like many other islands, the causeway to Graves Island (Figure 31) is close to high tide level and therefore susceptible to flooding and erosion during storm surge. Because no one lives on this island such impacts will not be as critical to residents, although they may feel inconvenienced if damage to the causeway closes the island for a prolonged period.

Figure 31: Graves Island and causeway as seen from the mainland.

Goat Lake

Goat Lake is very close to Mahone Bay and within the zone of primary concern. As such, it is susceptible to storm surge flooding, which will bring salt water into the lake. As sea-level rises and storms surges increase in frequency, the salinity of the lake will increase and its ecology will change. These two facts may have significant impacts on the wetland on the eastern side of the lake.

East River Point

Because of its granitic bedrock, the Aspotogan Peninsula has a number of white, sandy beaches. Beaches, much like wetlands, are dynamic environments and have the ability to naturally adjust to rising sea-levels by either building upward if there is enough sediment input, or moving inland if the coast is not too steep.

Figure 32: Meisner's Beach.

Meisner's Beach (Figure 32) is an example of a beach that is impeded from moving inland by a road (Route 329). Without the road present, the beach might be able to move inland significantly because of the low elevation, as evidenced by the wetland on the other side of the road.

Route 329 continues for a kilometre or so to the southeast mostly along the water's edge at very low elevation and crosses the river that drains Yellow Marsh Lake in Mahone Bay. The landward side of the road is also at very low elevation and much of the river and adjacent wetlands here are within the zone of primary concern, making them susceptible to coastal flooding and salt water inundation.

Blandford

Much of the Aspotogan Peninsula has steep coastlines so buildings close to the shore are not necessarily as vulnerable as similar ones elsewhere in the municipality (e.g. Figure 33). The Blandford area, however, has a fair bit of shallow coastal land. The District 1 Fire Station and Community Centre (Figure 34) is in this area. Although it is several hundred metres inland and is within the zone of secondary concern, its driveway (and only access point) meets the main road at the shore within the zone of primary concern, making it potentially inaccessible during a flooding event (Figure 35).

Figure 33: houses overlooking Deep Cove.

Figure 34: District 1 Fire Station and Community Centre.

Figure 35: entrance to fire station in Blandford.

Granville Gates and Sons (Figure 36), also in Blandford, is an example of a marine industry that by its nature needs to be close to sea level, but is also particularly vulnerable to sea-level rise, storm surge flooding, and coastal erosion.

Figure 36: Granville Gates and Sons.

BAYSWATER

All Saints First Cemetery (Figure 37) is an example of a cultural heritage resource at risk from climate change. Although the entire cemetery is within the zone of primary concern, the graves are on a mound of slightly higher elevation than the surrounding land. As sea-level rises the mound may at first become an island and subsequently eroded and submerged, resulting in the loss of the grave sites.

Figure 37: All Saints First Cemetery.

Figure 38: Bayswater Beach.

Bayswater Beach (Figure 38) has no room to move inland at its south end because of Route 329 but has some opportunity to move inland at its north end. As sea-level rises it will likely contract toward the north and is there fore a bit less vulnerable than Meisner's Beach.

Mill Cove/Birchy Head

Although the coast is steep here and Route 329 generally runs above the ten metre contours, Mill Cove Shore Road is almost entirely within the zone of primary concern making it vulnerable to storm surge flooding and coastal erosion. Most buildings are on the landward side of the road and some may be able to access Route 329 through their back yards. The aptly named High Tide Cottage (Figure 39) is one of the most vulnerable buildings here because it is on the seaward side of the road.

Figure 39: High Tide Cottage.

Fox Point

The small beach at Fox Point (Figure 40) has a bit of potential to move inland at its north end. A small parking lot exists between the beach and the road, which if removed, could accommodate some movement of the beach inland.

Figure 40: beach at Fox Point.

Shatford's Lobster Pound (Figure 41) is another marine related business that by necessity is very close to the water and thus vulnerable to sea-level rise, storm surge flooding, and coastal erosion.

Figure 41: Shatford's Lobster Pound.

The wreck on Lighthouse Road (Figure 42) serves as both a reminder of the power of storm surges and a historical marker of a past extreme event.

Figure 42: washed up boat on Lighthouse Road.

Fox Point Front Road runs quite close to the shore and as a result many utility poles and support lines are already within the intertidal zone (Figure 43).

Figure 43: vulnerable utility poles.

Adaptation Options

The intent of this section is not to make adaptation recommendations but to present some ideas to initiate discussion of adaptation options in the future.

A major finding of the students was that many of the vulnerabilities within the municipality are within the jurisdiction of other organizations. A possible adaption strategy to deal with these problems could simply be for the municipality to initiate discussions with these other organizations to raise their awareness of the problems.

While it may not be practical to upgrade all vulnerable infrastructure immediately, when the time for replacement comes (e.g. at the end of it planned lifespan or when funding becomes available) infrastructure could be constructed to a higher standard to address the vulnerabilities described here. For example, older bridges such as the one at Martin's River (Figure 2) could be replaced with ones of a more resilient design, such as the one at Gold River (Figure 44). Vulnerable utility poles could be relocated from the seaward sides of roads to the landward sides.

Figure 44: newer bridge at Gold River.

Adaptation plans for many vulnerable transportation routes could include looking for existing alternatives that could be used on temporary basis during emergencies. For example, should the crossing at Martin's River become impassable residents can still safely cross the river on foot or bicycle using the former railway bridge (Figure 45). Houses on roads that are likely to flood may have other roads behind them that will still be passable.

Figure 45: former railway bridge at Martin's River (foreground) with Trunk 3 bridge in the background.

Natural features such as beaches and salt marshes that are threatened by climate change generally need to adapt on their own (e.g. migrate inland if they can). The Municipal adaptation plan could focus on minimizing barriers to natural adaptation. In some cases this just may not be practical so the implications for letting the feature disappear could be discussed in the adaptation plan instead. Such recognition could help the municipality and volunteer groups better allocate resources in terms of protection from other threats, restoration, and providing public access.

Many of the vulnerability issues could be dealt with through emergency management planning, and as such perhaps the Regional emergency Management Organization could be involved in discussing adaption options. Many impacts are short term (i.e. flooding for a few hours during storm surges) and can be predicted several hours ahead of time (such as with Environment Canada's storm surge prediction model). Mapping vulnerable areas ahead of time can lead to adaption plans that include measures such as evacuating people from flood prone areas, opening alternative transportation routes, and moving emergency equipment to higher ground.

These are just a few ideas for adaption discussions. It is hoped that an enthusiastic team with a variety of perspectives can come up with many more creative and practical adaptation ideas.

Conclusions and Future Work

This report finalizes the first phase of the Municipality of the District of Chester's efforts to develop a climate change adaptation plan. The second phase, documented in the companion report *Evaluating municipal options for Climate Change Adaptation using Scenario Planning* examines a method the municipality can use to prioritize the vulnerabilities and evaluate adaptation options. Subsequent work may include the municipality undertaking such an exercise and using the results to write a climate change adaptation plan, which can be included in the amended Climate Change Action Plan portion of its Integrated Community Sustainability Plan.

The authors wish to acknowledge the Nova Scotia Department of Environment (Climate Change Directorate) for funding the review and summary of Phase One of this project. It is hoped that this experience can help other municipalities progress in their own journeys toward adapting to the impacts of climate change.

APPENDICES

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Team B (Chester Basin to Chester): Sarah Deller, Hilary Goodwin, Tim Hayman, and Amy Ryan

Team C (Chester to Deep Cove): Brennan Daly, Brett Howard, Amy Roy, and Tamara Wilson

Team D (Deep Cove to Hubbards): Paola Cisneros Linaros, Samantha Hamilton, Mike Reid, and Sarah Wilkin

Climate Change Vulnerabilities in the Coastal Zone of Chester Municipality

MARA5005

The Chester Project Course

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Executive summary

The Municipality of the District of Chester has asked the students from the Marine Affairs Program at Dalhousie University to assist them with the formation of the Municipal Climate Change Action Plan. The students were asked to conduct a vulnerability assessment of the coastline of the municipality identifying anything that might be at risk to the impacts of climate change that are expected over the next 100 years. This study represents one of four studies that were conducted in four geographical locations of the coastal area of Chester Municipality. The geographical area that was covered in this study extends from Martins River to Chester Basin, hereinafter referred to as the Western Shore.

An extensive literature review was conducted in four pillar areas, which were governance and planning, biogeophysical, socio-economic and infrastructure. A specific study area of the coastal zone was defined as anything that lies below 10 meters in vertical elevation, with a 100-meter inland buffer, which was used if 10 meters of elevation was reached closer to the shore than 100 meters inland. In the Western Shore section, the 100-meter buffer only applied in the area surrounding Gold River.

The current climate of the municipality was identified and the expected climate changes over the next 100 years were researched. Combining the information from the literature review on the four pillars with the expected climate changes was essential for understanding what the potential impacts of climate change would be in the municipality. Within the four pillars a specific set of criteria was used for each pillar, along with the definition of vulnerability from the Intergovernmental Panel on Climate Change to assess specific vulnerabilities in the municipality.

The study area spans over two of the municipal districts, districts four and five. The councilor for district four is Warden Allen Webber and the councilor for district five is Robert Myra. The

planning department is responsible for the Land Use and Sub-division by-Laws, and through these, is able to create restrictions on developments on municipal land. The majority of the land in this section of the municipality is privately owned and therefore the municipality does not have a lot of control over developments. There are 13 drumlin islands within the study area, two of which are inhabited. The mainland is composed of stony, silty till that is easily eroded. Some of the islands within Mahone Bay are tern-nesting sites and the two inhabited islands in the study area, Marvins and Oak, are linked to the mainland by causeways. There are two large rivers that empty into the bay within the study area, Martins River and Gold River, and there are also several salt marshes.

The population of Chester Municipality has grown by 1.5% between 1996 and 2006 and the permanent population is approximately 11,000. It is an aging population and there are a large number of people, in addition to the 11,000 permanent residents, that only reside within the municipality during the summer months. An increase in summer residence has caused an increase in the number of larger waterfront homes in the municipality, thus raising the value of homes and causing an increase in property taxes. The main areas of employment within the municipality are retail trade, manufacturing and construction. The majority of the infrastructure that lies within the study area is composed of private homes and businesses. There are also power poles, a sewage treatment facility, three wastewater-pumping stations, two municipally owned wharves, one municipally owned slip, a small pubic park and many provincially, municipally and privately owned roads.

Between 1850 and 2005 the global average annual temperatures increased by 0.76ºC and by 2099 temperatures are expected to continue to rise by between 1.1ºC and 6.4ºC. Sea-level within

the municipality is expected to rise anywhere between 55 – 95 centimeters. In addition, an increase in the frequency and severity of storm events over the next 100 years is expected.

In the study area, coastal areas below 10 meters in elevation have been identified as vulnerable, with areas that lie below five meters in elevation being the most vulnerable to the impacts of climate change. Within those general vulnerable coastal areas, ten specific vulnerabilities were identified in this study. The ten vulnerabilities are the private causeways, private homes, salt marshes, Highway 3, power lines, the Island View Family Restaurant and Bakery (green canteen), Wild Rose Park, the municipal wharf on the Western Shore, the waste water treatment infrastructure and Martins River Bridge. Possible adaptation options for these specific vulnerabilities have also been identified. The municipality has been identified as being enthusiastic about working towards a climate change action plan and it is important that they contribute some of their efforts toward community education about the potential impacts of climate change so that the whole municipality can work to prepare for a sustainable future.

Introduction

The Municipality of the District of Chester (hereinafter referred to as Chester Municipality), Nova Scotia, has asked for an expert opinion on assessing areas of the coastline within the municipality that are vulnerable to climate change impacts. By assessing these vulnerabilities, they will be better able to complete the Climate Change Action Plan that is required of them to do in order to receive the Provincial Gas Tax Credit. This tax credit is an agreement between the Nova Scotia Provincial Government and the Federal Government of Canada to provide funding for municipalities to plan for climate change impacts, such as the impact of sea-level rise in relation to land-use planning as well as re-thinking the designs of waste water treatment facilities (Nova Scotia Environment, 2009b). Chester Municipality had asked the 2012 graduating class of the Marine Affairs Program at Dalhousie University to provide opinions on the coastal vulnerabilities that should be assessed in the Climate Change Action Plan. The class had divided the coastline into four manageable geographic areas and each area was assessed by a different group within the class, using the same set of criteria. The area that is being assessed in this report is the area from Martin's River to Chester Basin, which will be referred to hereinafter as the Western Shore, see Figure 1. This report includes an overview of the entire municipality from governance and planning, socio-economic and biogeophysical perspectives as well as an overview of the infrastructure of specific geographical study area. This information was necessary to accurately assess the coastal areas that will be vulnerable to the impacts of climate change.

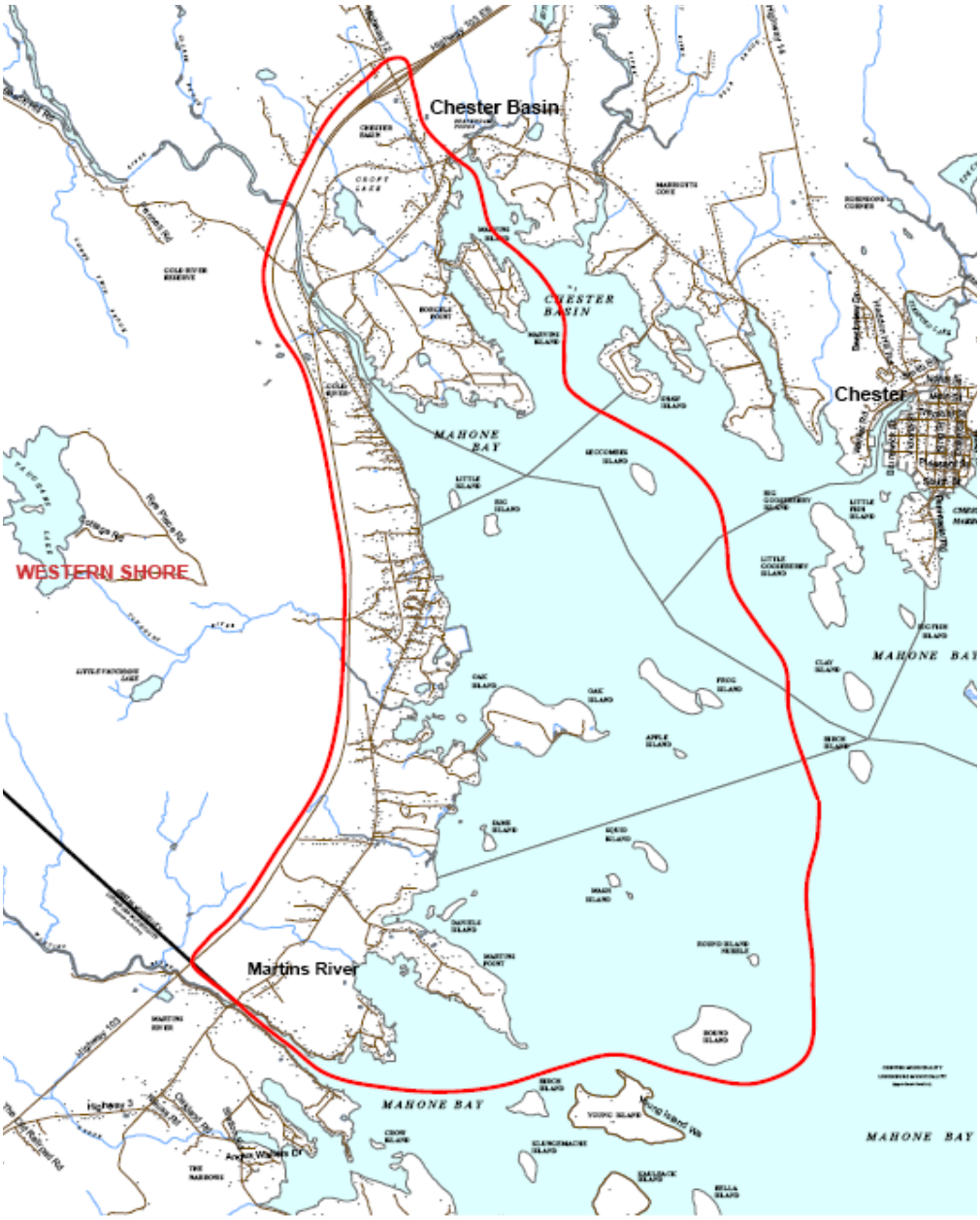

Figure 1. A map highlighting the geographical section of the Municipality of the District of Chester that was assessed for coastal vulnerabilities to climate change in this study.

Methodology

An extensive literature review was conducted in order to determine the current climate of the municipality and what changes are to be expected from climate change. It is vital to have a complete overview of the study area in order to properly assess the vulnerabilities in the area. The information was collected for four main pillar groups; the biogeophysical characteristics of the municipality, the socio-economic information, the infrastructural features and the governance and planning aspects that go into the municipality. Then a designated study area had to be defined. The coastal zone is the main focus of this study, and predictions have been made that within coastal zone, including sea level rise and extreme weather and storm surge events that the areas that will be most impacted are those that lie close to the coast and are below 10 meters in vertical elevation (McGranahan, Balk & Anderson, 2007). Therefore, it was decided that the study area would include the area of the coastal zone that was below 10 meters in elevation. There were some areas, however, that reached 10 meters in elevation very close to the coast and for those areas a 100-meter inland buffer was used to define the study area, the map showing the study area can be seen in Figure 2.

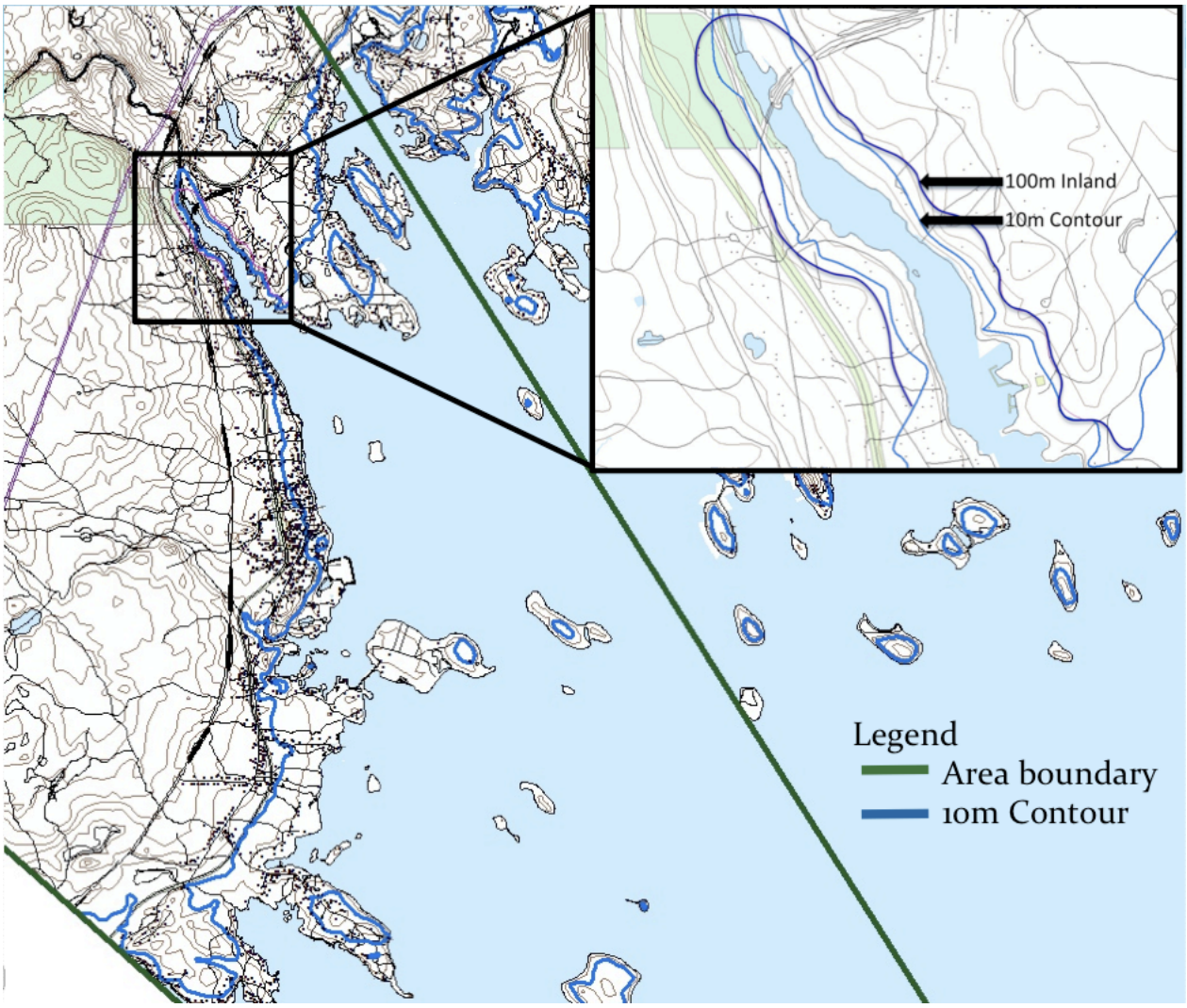

Figure 2. A map highlighting the study area, which is the coastal zone below 10 meters in vertical elevation. The 100-meter inland buffer was used to designate the study area around Gold River and that is highlight in the top right corner.

Then, using ArcGIS software, a map was created depicting areas lying below five meters in elevation as the areas of the highest vulnerability to impacts of coastal climate change. The areas that lie between five and 10 meters in vertical elevation were designated as vulnerable areas but were considered less vulnerable than the areas that were below five meters in elevation, this is shown in Figure 3.

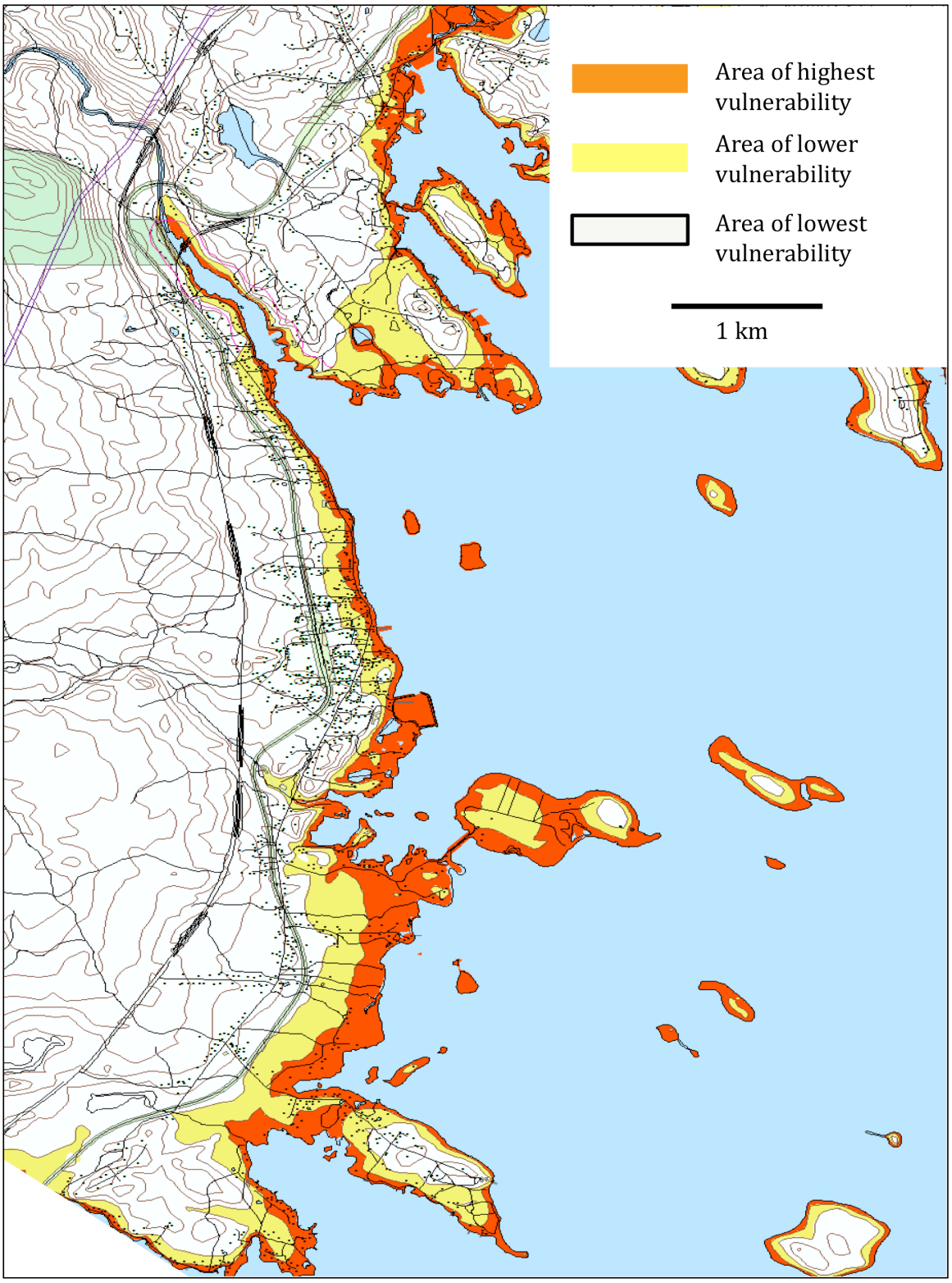

Figure 3. A map depicting the highest, lower and lowest regions of vulnerability to climate change impacts.

The designated areas of vulnerability were used as a guide for identifying the areas where priority vulnerabilities would be identified. In order to identify potential vulnerabilities, the term vulnerability in the context of climate change had to be defined. The definition that was used is from the Intergovernmental Panel on Climate Change and it reads

> The degree to which a system is susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity (IPCC, 2007).

This definition was used as a baseline for the vulnerability assessment in this study. Along with this definition of vulnerability, specific vulnerabilities were assessed within four pillar groups, biogeophysical, infrastructure, socio-economic and governance and planning. Within each of these pillars, a specific set of criteria was established for identifying the potential vulnerabilities in the study area. The criteria for the biogeophysical pillar included habitat type, exposure, proximity to the coastline, proximity to built infrastructure and elevation. The socio-economic criteria included demographics, household type, average incomes and social or cultural importance. The criteria for the infrastructure vulnerabilities included the age of the infrastructure, exposure level, elevation and historical problems that could have the potential to be increased by climate change impacts. For governance and planning, sections within planning and by-law documents were identified where changes could be made to incorporate possible adaptation options for the vulnerable areas.

Once the vulnerable areas were identified on the map and the criteria for the four pillars were assigned, a field survey was conducted to apply the criteria to specific areas of the municipality. This involved driving along the coast of the study area and identifying specific areas, habitats or

pieces of infrastructure that met the assigned criteria. Specific vulnerabilities were identified using this method and are outlined in Vulnerabilities and Adaptation Options section of the report, adaptation options within the governance and planning pillar were also included with each vulnerability.

Nature of the Study Area

Governance and planning

The section of the municipality from Martins River to Chester Basin spans two municipal districts, four and five. The councilor for district four is Warden Allen Webber and the councilor for district five is Robert Myra. The Municipality of the District of Chester has several departments that are responsible for the various operations within the municipality. The building department is responsible for facilitating the application process for building permits and distributing those permits. It is also responsible for appointing building inspectors once a building has been completed (Municipality of the District of Chester, 2010b). The planning department is responsible for the land use by-laws within the municipality as well as providing development services including planning, zoning, developing and mapping of areas within the municipality (Municipality of the District of Chester, 2010c). Through the planning act, the planning department has authority on any developments within the municipality including land use and protection, land development and environmental protection, as well as many other responsibilities (Municipality of the District of Chester, 1997).

Along the Western Shore, the vast majority of the land is privately owned while the area of the Gold River 21 Indian Reserve is under federal jurisdiction (Nova Scotia Department of Natural Resources, 2000). With a few exceptions, the islands in Mahone Bay are also privately

owned (Parker, 2001). In recent years, the Chester Municipality has been able to buy four coastal islands as a means of supporting habitat protection and conservation (IfPD, 2009). In our study area, Round Island Nubble is one of them (Geoff MacDonald, personal communication, November 28, 2011).

In terms of emergency services, each district within the municipality has a fire department that is made up of professional and volunteer fire fighters (Municipality of the District of Chester, 2010b). The fire departments currently rely heavily on their volunteers to provide emergency services to the districts, but volunteer numbers are low and the municipality needs to provide more support to the volunteers (IfPD, 2009). Emergency responses of paramedics fall under the management of the Emergency Management Office of Nova Scotia, which is under the jurisdiction of the Department of Justice within the Nova Scotia Provincial Government (Emergency Management Office, n.d.).

Climate change adaptation strategies for the Municipality of the District of Chester fall under the Integrated Community Sustainability Plan (ICSP). The municipality had to prepare and implement the ICSP following the Canada-Nova Scotia Gas Tax agreement, which will provide funding to the municipality upon implementation of the ICSP (IfPD, 2010). The current planning policy for the Municipality of the District of Chester is from 1997. The municipality is currently revising planning policies in order to update them as well as to include suggestions from the ICSP (Municipality of the District of Chester, 2011b). An issue that the municipality is currently having is with the Atlantica Inn (Oak Island Inn) and their current plan to develop and additional 100 condominium units in the area. The problem is that the municipality does not have any zoning jurisdiction in that area and therefore cannot force any setbacks for the future developments (Geoff MacDonald, personal communication, September 23, 2011). This means

that the developers can continue to build condominium units and chalets that are very close to the high water line and these units become vulnerabilities to potential sea level rise and storm surge events.

Biogeophysical Characteristics of the Study Area

The Municipality of the District of Chester forms the eastern part of the County of Lunenburg, situated on the South Shore of Nova Scotia, about 60 kilometers (km) south-east of Halifax. It covers an area of approximately 1,400 square kilometers (km^2). The study area, the Western Shore, extends eastwards from Highway 103 between Martins River in the south and the wharf at Chester Basin in the north and includes the following 13 islands in Mahone Bay: Marvins, Little, Big, Seccombes, Oak, Frog, Apple, Sams, Daniels, Mash, Squid and Round Islands as well as Round Island Nubble.

Nova Scotia is part of the Appalachian orogen, an old eroded mountain range that was formed in the Carboniferous period (Natural Resources Canada, 2004). Today's landscapes have been shaped primarily by glacial erosion and deposits. Since the melting of the ice age glaciers, the North American landmass is rebounding which is a very slow up and down movement until equilibrium is reached; Nova Scotia is currently in a phase of downward movement (Davis & Browne, 1996).

As defined and mapped by Nova Scotia's protected areas program, the coastal areas of the Chester municipality and the small and medium-sized islands in Mahone Bay belong to the Mahone Bay Islands Landscape (Nova Scotia Environment, 2009). This landscape is dominated by eroding drumlin islands and headlands predominantly comprised of stony and silty till while the bedrock is Cambrian/Ordovician slate and greywacke as well as Devonian/Carboniferous

granite (Parker, 2001; Nova Scotia Department of Environment and Labour, 2002). The islands, locally often called whalebacks (MacLeod, 2002; Parker, 2001), are constantly being reshaped by wind erosion, wave action and ocean currents (Davis & Browne, 1996) and many have depressions filled with silt-based sediment upon which wetlands have formed (Parker, 2001).

The major soil type along the coast is the Barney (Nova Scotia Department of Environment and Labour, 2002). Barney soils are slate based sandy to silty loam, which is coarse and very well drained (Parker, 2001). The coastal environment is low lying, indented, with many bays and predominantly rocky shores with scattered sandy beaches (Nova Scotia Department of Environment and Labour, 2002). On Frog Island, there is a barrier beach and an associated pond (Geoff MacDonald, personal communication, November 28, 2011). In the study area, two islands that are close to the shore, Oak Island and Marvins Island, are linked to the mainland by causeways. Between Oak Island and the mainland there is a tidally submerged gravel ledge.

Nova Scotia lies in the temperate zone and, despite the fact that it is almost completely surrounded by the sea, generally exhibits a continental climate characterized by warm summers and a uniform precipitation distribution. Along the southern and eastern shores, the climate is nevertheless influenced, *i.e.* moderated, by the rather constant temperature of the Atlantic Ocean (Davis & Browne, 1996). The coastal areas of the Chester Municipality exhibit a cool, wet climate with frequent fog and wind all year long (Nova Scotia Department of Environment and Labour, 2002).

While medium to large lakes are common in the upland plain (Nova Scotia Department of Environment and Labour, 2002) there is only one in the study area, Croft Lake, which is located between Gold River and Chester Basin. In addition, there are a few ponds on Borgels Peninsula and in the area south of the village of Western Shore. The drumlins forming the coastal area and

the islands in Mahone Bay are generally well drained terrain (Nova Scotia Department of Environment and Labour, 2002). Two major rivers discharge in the study area: Gold River and Martins River. There are also several patches of salt marshes along the Western Shore. The coastal zone of the municipality is subjected to semi-diurnal tides. The tidal range is approximately between 0.8 and 1.6 m (Department of Fisheries and Oceans Canada, 2008).

The dominant terrestrial ecosystems in the study area are coniferous forest (spruce and fir) along the coast and mainly deciduous trees (maple, birch, and beech) growing on the well drained drumlin islands (Nova Scotia Department of Environment and Labour, 2002).

Mahone Bay is a shallow marine environment, sheltered from the open Atlantic Ocean by shoals and a bedrock ridge (Parker, 2001). The waters of the bay have traditionally been rich with fish and shellfish species, but overharvesting has led to declining and collapsing fish stocks. To compensate for losses, aquaculture is performed. The primary species being cultivated are Blue Mussels and there are two sites in very close proximity to Daniels Island (Josh Blakeney, personal communication, December 15, 2011).

Some islands in Mahone Bay have a long history of seabird use while others are noted for great blue heron (*Ardea herodias*) colonies (Parker, 2001). In terms of colonial nesting birds, none of the islands in the study area are of particular interest at the moment. But this could rapidly change in the future as there is great temporal and spatial variability among the breeding bird species and the sizes of their colonies (Parker, 2001). Of particular interest are the breeding sites of the Roseate Tern (*Sterna dougallii*), which is endangered as only about one hundred breeding pairs are left in Nova Scotia (Nova Scotia's Species at Risk, n.d.).

Socio-Economic Characteristics of the Study Area

The permanent population of the Chester Municipality is approximately 11,000 (Municipality of the District of Chester, 2010a). The majority of the population resides along the shore in the communities of Western Shore, Chester Basin, Chester and Hubbards/Blandford. In the study area from Martins River to Chester Basin, there are two inhabited islands, Oak Island and Marvins Island, both linked to the mainland by causeways.

From 1996 to 2006, the population has grown by 1.5%, which is above average in Nova Scotia. In 2006, 20.2% of the population was under the age of 20 and 18.6% was 65 years or older which represents a slightly older population than the Nova Scotia average (Nova Scotia Community counts, 2011). While the population has only grown modestly, the median age of the population as well as the number of households has increased as couples have fewer children, children leave home at an earlier age, marriages break down more frequently and older people live in their homes longer (IfPD, 2009). An aging population increases the level of care needs while school enrolment is in decline (IfPD, 2009). Family structure has shifted from the traditional larger married families to smaller ones, with an increase in both common-law and single-parent families, a trend observed in all of Nova Scotia (Nova Scotia Community counts, 2011).

In 2006, 98.4% of the municipality's permanent population were Canadian citizens (Nova Scotia Community counts, 2011). The number of residents increases significantly in the summer months due to the influx of seasonal residents (Municipality of the District of Chester, 2010a). They used to come from the east coast of the United States and Germany, but today the majority stems from Ontario (Geoff MacDonald, personal communication, September 23, 2011). There has been a disproportional increase in the number of dwellings compared with the modest

population increase (IfPD, 2009). Lifestyle choices of foreign holiday home owners and affluent people moving to the Chester Municipality from Halifax have led to socio-cultural changes, namely gentrification, as they tend to chose waterfront property. Increased demand for waterfront property led to an increase in house prices. With increased assessments for waterfront property, some long-time residents can no longer afford to live in their homes and have to move (IfPD, 2009). Between 1996 and 2006 the average value of dwellings in the municipality increased by 124.8% (Nova Scotia average 82.5%) to $208,662 and the average monthly rent also increased substantially (Nova Scotia Community counts, 2011). Moderately priced homes are scarce in the municipality (IfPD, 2009).

In 2006, the average income in the municipality was at par with the average for Nova Scotia while the median income, both for individuals and families, was somewhat lower ($21,528 and $53,405 compared with $24,030 and $55,412 respectively) (Nova Scotia Community counts, 2011). In the Chester Municipality, there are much fewer families with low-income status than the provincial average (Nova Scotia Community counts, 2011). Nevertheless, the population is gradually separated into rich and poor with a stagnant middle class, a trend developing throughout the province (IfPD, 2009).

The major areas of employment are in manufacturing, construction and retail trades (major employers are Louisiana Pacific, GN Plastics and Shoreham Village) while there is potential to increase tourism revenue (IfPD, 2009). The employment rate for residents of the Chester Municipality was slightly above the provincial one of 52.9% in 2006 (Nova Scotia Community counts, 2011). Employment in fisheries has been declining since the closure of the cod fishery in 1992. Today, catches are much lower than in the 1980s and early 1990s, but they are of greater value as more lobster and scallops are taken; further opportunities for diversification may lie in

aquaculture (IfPD, 2009). Within the Chester Municipality, there are currently seven active aquaculture leases producing Blue Mussels with submerged suspended mussel line in a cumulative area of approximately 33 ha (Josh Blakeney, personal communication, December 15, 2011).

In the hinterland, the Chester Municipality has great potential for forestry. While the newsprint business is mature and paper mills struggling throughout the province, hardwood supplies are underexploited (IfPD, 2009).

Transportation is a key factor in the economy of the Chester Municipality. In 2006, 92.4% of the municipality's population used a private vehicle (car, truck or van) to get to work (Nova Scotia Community counts, 2011). The construction and subsequent twinning (to Upper Tantallon) of Highway 103 led to rural residential development in the Chester Municipality as commuting time to Halifax was greatly reduced (IfPD, 2009). While new property increases tax revenues, such low-density residential areas also present costs to the community, as it has to provide services and maintain infrastructure (IfPD, 2009). Currently, new developments are stalled due to the worldwide economic crisis and future trends are uncertain. Rural suburban development in the Chester Municipality will depend on the consequences of the Regional Planning Strategy implemented in the Halifax Regional Municipality (HRM), the further twinning of Highway 103, gas price development and public transportation options (IfPD, 2009).

Infrastructure

The vast majority of the infrastructure that resides on the Western Shore of Mahone Bay in the District of Chester is privately owned. There are many private roads and private homes that reside close to the water. Many of the newly built homes in the coastal area of the municipality

have been built as summer homes for people that do not live in the municipality year round. Many of these new summer homes are built by wealthy people and they actually caused the value of the homes in the municipality to increase by over 120% from 1996 to 2006 (Maguire, 2011). There are may private roads leading up to these summer homes that are the responsibility of the owners o the homes on the roads. Along with private roads, in the island communities of Marvin's Island and Oak Island, there are private causeways leading from the main land to the islands. The Marvin's Island causeway is approximately 50 meters long and contains a culvert to allow water to flow beneath the causeway and the Oak Island causeway is approximately 150 meters long and it does not contain any culverts (Robert Myra, personal communication, November 10, 2011).

The main roads in the municipality are owned and maintained by the province, but any new roads constructed in the municipality since 1995/96 that are not private roads are the responsibility of the municipality. Highway 103 is the main highway that leads from the municipality to nearby Halifax and there are plans underway to twin the current highway, which will result in a faster commute from the municipality to Halifax. Halifax is a growing city and as the property taxes are lower in Chester Municipality it is thought that the highway twinning is going to cause a boom in sub-division development in the municipality because more people would be willing to commute to the municipality once the commute time is reduced.

The section from Chester Basin to Martins River also encompasses two bridges, the bridge over Martins River and the Bridge over Gold River. The Gold River Bridge is a large bridge that has been recently replaced. The Martins River Bridge is a smaller and older bridge that is lower to the water than the Gold River Bridge.

Highway 3 from Gold River to the public wharf is a coastal drive that provides public access to the waterfront. There are power lines along Highway 3 and there are some pieces of infrastructure that have social significance to the people of Chester Municipality along the highway. One of those things is the Island View Family Restaurant and Bakery, or known to the locals as the 'green canteen'. This restaurant has been in operation for 50 years (NSLocal, 2011) and it is located adjacent to another important piece of infrastructure, Wild Rose Park. The park is a small strip of green space that runs between Highway 3 and the shoreline. This is one of the few areas in the municipality where the public can enjoy the waterfront.

Other public coastal access infrastructure along Highway 3 includes the municipally owned wharf that is used by some local fisherman as a dock for their boats and the slip that is used by the public to put their boats in the water. The wharf however is currently in a state of disrepair and is not open to vehicles. It is estimated that in order to replace the wharf that it could cost the municipality between $300,000 and $1 million. In terms of public works within the Western Shore area, there is a wastewater treatment facility and three wastewater pumping stations that pump treated water into the bay.

The Atlantica Hotel and Marina is another example of privately owned, waterfront infrastructure. The hotel began construction in the 1970's and they now have 105 rooms, 13 oceanfront chalets and two villas (Atlantica Hotel and Marina Oak Island, 2010). The oceanfront chalets are located approximately 30 meters from the high water mark and are only approximately one meter in elevation above the high water mark. The marina was built by the hotel owners and is contained within large, constructed, riprap breakwaters. There is another marina located toward Chester Basin called the Oak Island Marina. This marina is structurally

different than the marina at the Atlantica Hotel as there are mainly moorings and floating, wooden docks.

Current climate, observed climate changes and expected changes over the next century

Currently, the mean annual temperature in the coastal areas of the Chester Municipality is approximately 6°C and the monthly average temperatures range from -6°C in January to 18°C in August (Environment Canada, 2011). The average annual precipitation amounts to 1400 mm (Environment Canada, 2011). The tidal range in Mahone Bay is approximately between 0.8 and 1.6 m (Department of Fisheries and Oceans Canada, 2008).

The Earth's climate is warming and thus changing in various aspects due to significant and likely unprecedented increases of green house gas emissions that are of anthropogenic origin (Nicholls *et al.*, 2007). From 1850 to 2005, the average global temperature increased by 0.76°C and it is predicted to further increase by 1.1 to 6.4°C by 2099, depending on future emissions (Nicholls *et al.*, 2007). Not only will temperatures on land increase, the mean sea surface temperature is also on the rise. Increasing temperatures will have a series of related impacts such as sea level rise, coastal inundation, erosion, coastal squeeze, salt water intrusion, intensification of storms, larger storm surges; altered wind, precipitation and run-off patterns, and ocean acidification (Nicholls *et al.*, 2007). Such identifiable changes in the variability of climate properties that have been measured over long periods of time are subsumed under the term climate change, as defined by the Intergovernmental Panel on Climate Change (IPCC, 2007).

In coastal areas, sea level rise is the main concern when it comes to climate change impacts (Nova Scotia Environment, 2009b). Increasing temperatures cause glaciers and ice shields to melt, thus adding water to the world's oceans. However, the main cause, accounting for two

thirds of global sea level change, is the expansion of sea water as it takes up heat, known as thermal expansion (Nicholls *et al*., 2007). In the past 50 years, the average sea temperature has increased to depth of at least 3000 m and between 1961 and 2003, global average sea level rose by an average rate 1.8 mm per year, with a much faster rate of 3.1mm per year between 1993 and 2003 (Nicholls *et al*., 2007). The total rise during the 20th century is estimated to be 12 to 22 cm, while the predicted global mean sea level rise by 2100 is between 18 and 59 cm (Nicholls *et al*., 2007).

Climate change impacts, particularly sea level rise, are expected to exhibit substantial regional and local variability (Linham & Nicholls, 2010; Nicholls *et al*., 2007). Local relative sea level changes can differ from global or regional averages due to individual geomorphology, vertical movements of the land or land subsidence as a result of groundwater exploitation (Klein & Nicholls, 1999). In Nova Scotia, the isostatic component of sea level rise is caused by land subsidence as a result of the interior land rising after the melting of the ice-age glaciers (Davis & Browne, 1996).

Based on data collected in Halifax harbour, the area experienced a rise in sea level of 35 cm between 1896 and 1990, of which an estimated 20 cm are the result of land subsidence (Province of Nova Scotia, 2009). Thus, relative sea level rise in the area of Chester is likely to be above global average. It is predicted to be in the range of 55 to 95 cm over the next hundred years (MacDonald, 2007, as cited in IfPD, 2009).

While a hazard in itself, sea level rise will facilitate and exacerbate a series of impacts on the coastal zone. Sea level rise will contribute to increased coastal erosion as well as increased probability and depth of coastal flooding, particularly in conjuncture with an increase in storm frequency (Linham& Nicholls, 2010). Tropical storms are predicted to increase both in

frequency and magnitude as a result of global warming (Nicholls *et al*., 2007) and sea level rise will exacerbate their impacts because of increasing heights of accompanying storm surges (Singh, Walters, & Ollerhead, 2007). These factors can also lead to saltwater intrusion which is an increased input of saltwater into aquifers and fresh water reservoirs, such as wells.

Increasing temperatures will also effect changes in wind, precipitation and run-off patterns. It is very likely that hot extremes, heat waves, and heavy precipitation events will continue to become more frequent, but projections are still rather vague. On a global scale, mean precipitation is predicted to increase while areas with decreased run-off will expand but there will be a high degree of regional and local variation (Kundzewicz *et al*., 2007).

Vulnerabilities and Adaptation Options

Causeways

Two of the islands in the Western Shore area, Marvins Island and Oak Island, are joined to the mainland by causeways. Such structures are by default very exposed to impacts from the sea, be it wave action, the tidal cycle or storm surges. Driving on the causeway to Oak Island a couple of days after a storm with record high sea water levels (Pope, 2011), damages from this storm surge event were witnessed during the field surveys. The storm had coincided with high tide and caused damage to the road, particularly on its north-west facing shoulder, as the storm was a northeaster, pushing the water into the bay, see Figure 4. On this side of the bay, the causeway is much less reinforced than on the other side as, during the storm season in the summer, winds and waves most commonly come from the southeast (Davis & Browne, 1996). From this direction, there are several kilometers of fetch within Mahone Bay, which increases the causeway's exposure to storm surges.

As most of the smaller roads in the Chester Municipality, the Oak Island and Marvin's Island causeways are privately owned. Thus, the municipality has little influence on the structure and maintenance of these roads. In contrast to the Oak Island causeway, there is a culvert built into the causeway linking Marvin's Island to the mainland. This feature allows for some exchange of water across the barrier, facilitating balance and linking the separated areas for fish and other marine species, which renders culverts a desirable part of causeways from a risk management and ecological point of view (Robert Myra personal communication, November 10, 2011). To ensure that future constructions are planned and built to include a culvert, this condition could be incorporated into a by-law. The size and number of culverts could be specified according to the height and length of the causeway. In general, development agreements, also for renovation work, could depend on the construction of a culvert.

Figure 4. A photograph of the road damage leading to the Oak Island Causeway, which was caused by increased storm surge that was brought in by a nor'easter. Photo: Mirjam Held.

Private property

On the Western Shore, the type of infrastructure that is and will most frequently be at risk from climate change impacts is private property (sea walls, residential buildings, businesses, hotels), see Figure 5. The Chester Municipality has only limited legislative power over privately owned land and infrastructure, particularly over what is already built.

Figure 5. An image displaying some of the privately owned waterfront property in Chester Municipality. Photos: Mirjam Held.

The municipality has a vested interest in the waterfront properties within its boundaries, as tax revenue is generated from property values. The demand for waterfront property is unbowed; thus, it is in the interest of the Chester Municipality to continue to approve waterfront developments. However, it is advised that the municipality institute the measure of a coastal

setback in order to ensure that these buildings are safe for the next couple of decades. The municipality could propose to incorporate a vertical setback of five meters as lower lying areas have been identified as being the most vulnerable to the impacts of climate change in the coastal zone (as discussed above). Climate change is happening, but the sea level will not rise over night. This allows the municipality to start with the implementation of a vertical setback lower than five meters and then gradually increase it as the sea level rises.

Salt marshes

All salt marsh areas along the Western Shore are privately owned, see Figure 6. Salt marshes are very valuable coastal wetlands as they have the capability to self adapt to the impacts of sea level rise, *in situ* as the elevation of the sediment surface is expected to keep pace with changes in sea level through increased sediment accumulation (Erwin, 2009; Morris *et al*., 2002) or by migrating inland (Linham & Nicholls, 2010; Singh, Walters, & Ollerhead, 2007).

Figure 6. An example of a privately owned salt marsh in the study area. Photo: Mirjam Held.

However, most salt marshes have been subjected to various human alterations other than climate change impacts (*cf.* Adam, 2002; Bromberg Gedan, Silliman, & Bertness, 2009) and have thus been compromised in their capability to adapt. The biggest hindrance are hard coastal defenses such as seawalls and dikes, but also other infrastructure such as roads and buildings that do not allow salt marshes to move inland (Linham & Nicholls, 2010). This results in what is known as coastal squeeze as salt marshes (and other types of wetlands) that are trapped between the rising sea and static structures loose area due to increased flooding and erosion (Linham & Nicholls, 2010).

Thus, salt marshes should not be blocked from migrating inland. Their protection and conservation is of great importance as they can absorb much of the sea level rise-related impacts in the coastal zone. In addition to this role of a buffer, salt marshes are carbon sinks and thus their conservation helps to mitigate climate change. The Environment Act requires an approval for wetland alterations. In addition, the recent Nova Scotia Wetland Conservation Policy establishes specific objectives to prevent the net loss of Nova Scotia's wetlands and identifies what legislation, regulations, and policies are relevant to achieve them (Nova Scotia Environment, 2011). The government has realized that effective wetland conservation cannot be achieved through policy alone and acknowledges the important role of voluntary conservation efforts (Nova Scotia Environment, 2011). To this effect, Chester Municipality is encouraged to play an active part in protecting and preserving the salt marshes in their municipality even though they are all privately owned.

Highway 3

Highway 3 is one of the main roads that connects all of the communities within the Municipality of the District of Chester. There is a large section of the road, from Gold River to the public wharf, which runs very close to the water and this can be seen in Figure 7. This exposure of the road to the coast makes this section particularly vulnerable to sea level rise and storm surges events.

Figure 7. An image displaying the proximity of a section of Highway 3 to the coastline. Photo: Google Street View.

There is currently a seawall of riprap along this edge of the road, but some of the municipal staff members have expressed that during some storms, some of the riprap gets washed up on to the road. One adaptive option to slow the erosion of the land that runs between the ocean and the road is to continue the maintenance of the existing riprap seawall. This is a low cost adaptation method, but considerations should be made regarding the fact that some of the seawall gets washed into the road during storms. Over the next 100 years, storm intensity, frequency and storm surge is going to increase (Nicholls *et al*., 2007) and these events may further damage the seawall causing it to have to be replaced or repaired more frequently, which could be costly in

the long term. In instances where the seawall is compromised during extreme weather events, the earth under the road could be exposed potentially causing sections of the road to wash away and this would also be costly to fix. The highway also has the potential to become flooded during extreme storm events and both of these issues, flooding and the road washing out, could leave some people stranded in their homes for extended periods of time. Another adaptation option for Highway 3 would be the planned retread option. This option is much more costly upfront, but could be less costly in the long term. The option that could be used is to move that section of the highway further inland. That section of the road could be moved to the area where the old rail line has been turned into a walking and cycling trail. This is not something that would have to be done right away, but thinking about the lifespan of the current road, the next time that it will have to be replaced, rather than replacing it, it could be moved to where the section of trail is. This would result in the loss of the public trail in that area, but the old Highway 3 could be transformed into a new public walking trail.

Power lines

Another vulnerability that is related to the location of Highway 3 is the location of some of the power poles along the highway. The main line runs along the side of the road that is furthest from the water, but there are a few poles present that are underwater at high tide, see Figure 8. This has the potential to be dangerous because the bottom of the pole could slowly be eroded by salt water and wave action and could also start to rot because it is constantly exposed to water. If the base of the pole is compromised, it could break in high winds causing downed power lines and power outages. It could potentially be even more dangerous to the public if the pole falls at the same time that there is a flooding even along the highway.

Figure 8. An example of one of the power poles that has its base covered by water at high tide. Photo: Google Street View.

An adaptation option for this vulnerability is to discuss with the owners of the power poles (Nova Scotia Power) and determine when the poles are due to be replaced. When Nova Scotia Power does replace the poles, they should be moved further from the shore, so that they are not exposed to seawater.

The Green Canteen

The Island View Family Restaurant and Bakery, known locally in Chester as the green canteen, is a piece of infrastructure along the Western Shore that is socially and culturally significant to the people living in the area and it is shown in Figure 9. The restaurant has been

part of the community for 50 years and is popular not only because of the food they serve but also because of their location.

Figure 9. A picture showing the Island View Family Restaurant and Bakery (green canteen) and its proximity to the shore. Photo: Google Street View.

The green canteen is located very close to the shore on Highway 3 and is in an area that has been recognized as an area of high vulnerability. The canteen sits on the built up section of the coastline between Highway 3 and the shore. The breakwater that is holding up this section of coastline has been known to wash up on to the road during large storm events and if the land beneath the restaurant is washed away in a severe weather event, the restaurant could potentially

sink into the land. The restaurants proximity to the shore also makes it vulnerable during severe weather events because of increased storm surge, which could result in short term flooding of the restaurant and storms can also bring high winds that could be damaging.

An example of an adaptation option for this canteen would be to move its location to a less vulnerable area when it is time for the building to be replaced. Having been there for 50 years, the building will need to be replaced or largely upgraded over the next 100 years. When that time does come, it would be recommended that the owners move the canteen to another location.

Wild Rose Park

Wild Rose Park is a small stretch of green space between Highway 3 and the shore and it can be seen in Figure 10. This is a soft piece of infrastructure that is extremely important to the community. The park is one of the only sections of coastline within the study area that is available for public coastal access. The park is located directly adjacent to the green canteen and therefore faces the same exposure, erosion and flooding risks. If the park is lost it will have large impacts on the local community because there will be even less public coastal access in the municipality. Adaptation options for the park are very limited and could be difficult to implement because the land that the park is situated on is owned by many different people (Robert Myra, personal communication, November 10, 2011). The best option for the municipality would be to continue to maintain and upgrade the sea wall that is supporting the park.

Figure 10. An image of Wild Rose Park. Photo: Google Street View.

Wharf

The public wharf in Western Shore was built in 1956 and is in need of repair, see Figure 11. In its current state it is very vulnerable even to a regular storm surge. As many other wharves across the country, it used to be owned by the Federal Government, but to cut costs, they sold them for a dollar each about ten years ago (Lyle Russell, personal communication, November 10, 2011). The wharf is used by a handful of fishermen and it is an important piece of infrastructure as it is the only public coastal access along the Western Shore. The expenses to repair or rebuild it, however, are very big. Repairs to extend the wharf's lifetime for ten years would cost $250,000 while building a new one would amount to $1.5 million (Lyle Russell, personal communication, November 10, 2011).

Given the limited yet continued demand for a public coastal access in Western Shore, it is proposed that the municipality consider building a new wharf but at a reduced size. Another potential option could be a sharing agreement with the nearby Oak Island Marina, a privately owned facility associated with the Atlantica Hotel.

Figure 11. A photograph of the public wharf located on the Western Shore. Photo: Jana Aker.

Waste water treatment

The wastewater treatment facility in the Western Shore is another vulnerable piece of infrastructure as well as the three pumping stations that are associated with the treatment plant, see Figure 12. An increase in sea level rise could cause a blockage of the outflow pipes causing a backup in the sewage system at high tides or during times of high storm surge events. This back up could cause sea water to enter the treatment facility and salt water kills the treatment bacteria that are used to treat wastewater. This would result in untreated water being released into Mahone Bay (Lyle Russell, personal communication, November 10, 2011).

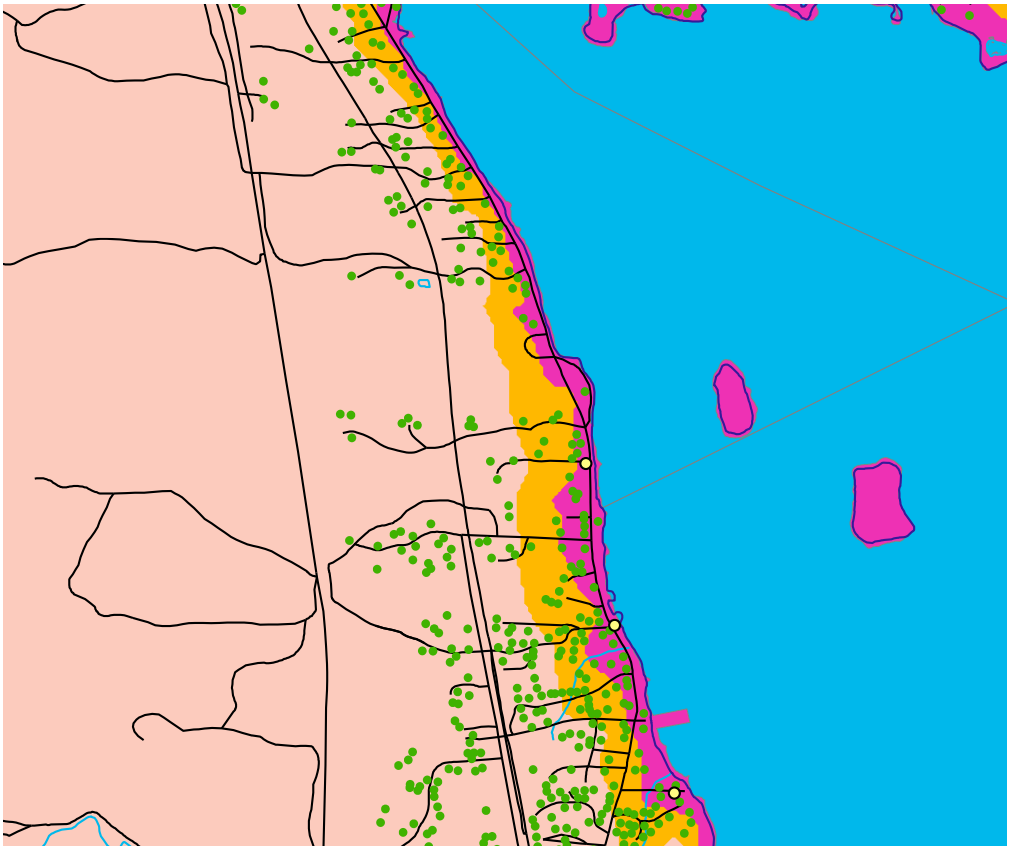

Figure 12. A map depicting the locations of the three pumping stations, shown by the yellow dots, on the Western Shore. All three pumping stations are located close to the shore and are below five meters in vertical elevation.

In terms of a climate change adaptation strategy, it is suggested that the municipality continue with the action in section 2.4.4 of the Municipal Planning Strategy, which states that the municipality will continue to maintain and upgrade the sewage collection and treatment systems (Municipality of the District of Chester, 1997). One improvement that would lower the impacts of sea-level rise would be to move the pumping stations to higher ground so that a rise in sea-level would not cause a backup in the outflow pipe.

Martins River Bridge

Martins River Bridge is considered a vulnerability because it is an older bridge and it lies very low and close to the water where Martins River meets Mahone Bay, see Figure 13. In a high storm surge event that includes a lot of rainfall, there is the potential for the bridge to be washed leaving that access point unavailable for people who live alone Highway 3 impassable. This bridge poses a bit of a challenge, as there are many levels of government that need to be involved in order to upgrade the bridge. Martins River is the dividing point between Lunenburg County and the Municipality of the District of Chester. The bridge, therefore, is divided in the middle between the two municipalities and it is also under provincial jurisdiction, so any repairs or upgrades are the responsibility of the Nova Scotia Department of Transportation and Infrastructure Renewal. This bridge is quite old and will have to be replaced in the next 25 years. When it comes time to replace this bridge, the adaptation option would be to build the bridge higher and stronger so that it will be able to withstand intense storm events. A recommended height would be to have the lowest part of the bridge be five meters above the high water mark. Sea-level is expected to rise between 55 and 95 centimeters (IfPD, 2009) and raising the bridge to five meters above the current high water mark would ensure that even with the sea-level rise

and combined storm surge events that the bridge will be able to remain above the water. Chester Municipality would have to have discussions with Lunenburg County and agree on an adaptation plan for the bridge and put it forward to the Nova Scotia Government to ensure the appropriate changes are made to the bridge.

Figure 13. An image showing the proximity of Martins River Bridge to the water. Photo: Jana Aker.

Conclusions

Over the course of this project, the Chester municipal government and staff has been recognized as stable, capable and proactive. These are excellent conditions to plan for the future. Developing a climate change action plan is not only just a part of the gas tax agreement, but a

crucial step in preparing for a safe and prosperous community in the years to come. There is much uncertainty about what exactly the future will hold; yet climate change is already being observed and will continue to happen. Sea level rise and storm surges will impact the coastal zone, though the exact extent of these impacts is not yet assessable. The expected impacts include accelerated coastal erosion, increased storm surge flooding and salt-water intrusions. Identified areas of coastal vulnerability include the natural habitat, man-made infrastructure, socio-economic factors as well as governance and planning aspects.

Assessing the most vulnerable areas and pieces of infrastructure within the Western Shore, has provided the municipality with a set of information that will help councilors and staff alike to prepare the Climate Change Action Plan. What this report presents are neutral opinions and recommendations for the benefit of the Chester Municipality. However, the councilors, staff and the residents have more insights into their municipality and that their priority vulnerabilities might differ from what has been identified in this report.

In order to find out about the fears, expectations and desires of the population, both resident and seasonal, the municipality is encouraged to hold workshops similar to the ones executed as part of the Integrated Community Sustainability Plan. As climate change and its expected impacts are not tangible yet for most of the general public, it is important to educate the population. Concrete examples and a proactive approach from their community leaders will likely engage them in increasing their knowledge and becoming active stewards of climate change.

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Appendices

Appendix 1: PESTLE Analysis

PESTLE Analysis of the Vulnerability of the Municipality of Chester in Regard to Sea Level Rise

Introduction

The Municipality of Chester seeks to develop a climate change adaptation plan with an emphasis on the coastal areas of the municipality. These are of specific interest because the vast majority of the population and significant infrastructure are based on the coast. With sea level projected to rise up to 95cm in this area in the next century[1], it is extremely important to establish a coastal plan to help prepare the municipality for the climate change events of the next hundred years.

There are several stakeholders that will be directly or indirectly affected by our group's role within the Chester Project. As Marine Affairs students we are representing Dalhousie University during this project and we will conduct ourselves in a professional manner while working with the municipality. Chester Municipality and the community of Chester, as our clients, are the priority stakeholders in this project. We are going to assess the coastal vulnerabilities of the Western Shore and provide the municipality with neutral opinions. As a team, we will provide Chester with an accurate assessment of their coastal vulnerabilities, and make recommendations relevant to their climate change adaptation plan. We will also be working closely with our classmates, as we share objectives, and this way our class will be able to provide the Chester Municipality with consistent and realistic recommendations.

List of relevant forces

Political

- Responsibilities of the municipal government: water, sewage, land use and planning, emergency services, economic development.
- Responsibilities of the provincial government: roads, natural resources and the environment.
- Stability of government
- Land use planning
- Taxation policies

Economic

- Industries: tourism, boat building, forestry, fisheries, harbours, marinas.
- Increase in property values
- Current economic crisis

Social

- Population growth
- Social and economic structure of population
- Socio-cultural changes

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[1] Institute of Planning and Design. (2009). *Integrated Community Sustainability Plan: Chester Municipality Charts its Course*. Retrieved from: http://www.chester.ca/icsp/

Technological
- Infrastructure
- New communication technologies

Legal
- Climate Change Adaption Plans
- Planning strategies
- Land ownership

Environmental
- Geology and relief of coastal area
- Water resources and treatment
- Climate change and sea level rise

Analysis

The Chester Municipal Government is capable, proactive, and stable. Warden Allen Webber was first elected to Council in 1982 and has been serving for 8 terms. Planning Director Geoff MacDonald has also been working for the Municipality of Chester for almost 30 years. In terms of land use planning, the Municipality of Chester only puts forth a few regulations, i.e. zoning exists only in some areas of the village of Chester. There is a land-use by-law in place, but most developments are implemented by development agreements which has resulted in some "parachute planning" developments, i.e. projects that are being realised in complete isolation from the community.

Property taxes are one of the most important sources of income for the municipality. Each year, they are set as a factor of property value assessments in order to balance the budget. Foreign investment in waterfront properties as holiday homes has led to soaring house prices, but new developments are currently halted due to the economic downtrend. There has not been substantial population growth in the Municipality of Chester in the past years, but the number of houses has increased disproportionally. The municipality lies on the outskirts of the Halifax Regional Municipality (HRM); thus, the developments in the municipality depend on trends in Halifax (e.g. housing market, price development, road projects and upgrades, public transport expansions). Lifestyle choices of foreign holiday home owners and affluent people moving in from HRM have led to socio-cultural changes, namely gentrification, in the Municipality of Chester. While foreign seasonal residents dominate waterfront property, the local population tends to reside in areas along Highway 3.

Along the coastline, Highway 3 and privately owned roads dip to elevations close to the high water line. Flooded and washed away roads can present an added risk in times of disaster by cutting people off of essential services. A flat, slowly rising coastline and, being drumlins, easily erodible islands in Mahone Bay add to the municipality's vulnerability to sea level rise. Tancook Island is served by an aging ferry and several major wharfs, including a public one, are in an unusable or unsafe state. These issues will need to be addressed in the near future, and specifically in the context of sea level rise. The sewer pipes in Chester village are located very close to shore. Due to unstable grounds in the intertidal zone, the municipality has to deal with frequent pipe bursts and will have to find more secure locations for their sewage infrastructure with regard to sea level rise.

Appendix 2: Research ethics checklist

MARA5005 Group Members: **Jana Aker, Mirjam Held, Jonathan Underwood and YoungorWanyan**	**Name of Host Organization: Municipality of the District of Chester**		
Overview of proposed project methods (please identify whether or not you will be conducting research with human participants and what methods you will use to capture information – survey, focus group, interviews, etc.) **We will be conducting interviews with certain representatives of Chester Municipality. We may be conducting interviews with community members and/or stakeholders within the western shore of Chester Municipality.**			
	YES	**NO**	**Details**
Will prospective participants in your study / project be provided with a clear and easily understood Letter of Information and be asked to sign a written consent form before their involvement in your study? *(If No, indicate that respondents are adults and that you will have passive consent - through cover letter or the fact that they are filling in a survey)*	**YES**	**NO**	Yes. We will be providing our prospective participants with a letter of information regarding their involvement in our study. No. Participants will not have to sign a consent form, as we will be dealing with adults in the municipality.
Will the participants be told that they can discontinue their participation in the study at any time?	**YES**	NO	
Will any form of pressure or inducement be exerted upon participants to get them to participate in your study / project?	YES	**NO**	
Will the researcher and/or associates be in a position of power vis-a-vis the participants (ie. employer-employee, teacher-student, dominant / marginal race or culture)?	YES	**NO**	
Will it be clear to the participants in your study / project that they are subjects of investigation?	**YES**	NO	
Will it be clear to prospective participants that their participation is voluntary?	**YES**	NO	
Will prospective participants be given the opportunity to discuss and think over their participation in this study / project?	**YES**	NO	
Will the study / project involve participants who may not be in a position to give their valid consent to participate (ie. young children, people with development disabilities, etc.)	YES	**NO**	
Will the study / project involve participants for whom consent to participate in the research project is not meaningful in the context of their cultural background?	YES	**NO**	
Will the participants in the study / project identify themselves by name or by other means that will allow you to match data to specific participants?	YES	**NO**	

Will the confidentiality of the participants identity be protected	**YES**	NO	
Will the study / project involve the use of the identifying information about the participant from any other study / project or resource?	YES	**NO**	
Will information about the participants be obtained from sources other than the participants themselves?	YES	**NO**	
Could publication of the research results allow participants to be identified?	YES	**NO**	
In case there is a possibility that the participant's identity can be deduced by anyone other than the researcher, will the participant be able to withdraw his or her data from the study / project?	**YES**	NO	
Will the study / project involve the deception of the participants? For example, will information be withheld from the participant or will they be misled about the data collected, the purpose of the study / project, the responsibilities of the participants, or other features of the study / project?	YES	**NO**	
Will the study / project involve any foreseeable physical risk, discomfort or inconvenience to the participant?	YES	**NO**	
Will the study / project involve any foreseeable psychological, economic or social risk or discomfort to the participant?	YES	**NO**	
Will the physical safety of the participants be protected?	**YES**	NO	
Will the participants in the study / project be given feedback regarding the results of the study / project?	**YES**	NO	
Will the full nature of the research be disclosed to the participant at the end of their participation?	**YES**	NO	

FACULTY REVIEW:
The proposed research is deemed: LOW-RISK _____ HIGH-RISK _____
Faculty Name: _____ Faculty Signature
_____
If research is deemed HIGH-RISK, the proposal must be forwarded to the Dean for review and approval.

Appendix 3: Group work plan

Deliverable	Due Date (2011)	Action Items	Divisions	Resources	Milestone due dates (2011)
Work Plan	30-Sep	Assignment of tasks		Everyone	19-Sep
		Due Dates of deliverables		Jana	19-Sep
		Establish time line		Jana	19-Sep
		Establish milestones		Jana	19-Sep
		Assignment of tasks		Everyone	19-Sep
PESTLE Analysis	30-Sep	Individual PESTLE rough draft	Political	Jana	22-Sep
			Economic, Legal	Jonathan	22-Sep
			Socio-economic	Youngor	22-Sep
			Technological	Jonathan	22-Sep
			Environmental	Mirjam	22-Sep
		Gathering information in Chester		Everyone	23-Sep
		Continuation of PESTLE	Political	Jana	26-Sep
			Economic, Legal	Jonathan	26-Sep
			Socio-economic	Youngor	26-Sep
			Technological	Jonathan	26-Sep
			Environmental	Mirjam	26-Sep
		Analysis and conclusions		Jana and Mirjam	28-Sep
		Editing PESTLE		Jana	28-Sep
Ethics Checklist	30-Sep	Complete checklist		Mirjam	26-Sep
		Edit Checklist		Jana	28-Sep
Briefing note #1	30-Sep	Finish rough draft briefing note		Youngor	26-Sep
		Edit briefing note		Jonathan	28-Sep
Briefing note #2	28-Oct	Finish rough draft briefing note		Jana	24-Oct
		Edit briefing note		Mirjam	26-Oct
Briefing note #3	25-Nov	Finish rough draft briefing note		Mirjam	21-Nov
		Edit briefing note		Jana	23-Nov
Class presentation	02-Dec	Start working on presentation		Jana and Mirjam	14-Nov
		Complete content component		Jana and Mirjam	21-Nov

		Complete formatting component		Jana and Mirjam	27-Nov
		Edit		Jana and Mirjam	28-Nov
		Practice presentation		Jana and Mirjam	01-Dec
Chester Presentation	08-Dec	Condense class presentation		Class presenters	06-Dec
		Compile class presentations		Class presenters	06-Dec
		Designate presenter		Class presenters	06-Dec
		Practice Presentation		Jana	07-Dec
Final Report	16-Dec	Nature of the study area section	Biophysical	Mirjam	10-Oct
			Socio-economic	Mirjam	13-Dec
			Governance/Planning	Jana	10-Oct
			Infrastructure	Jana	24-Nov
		Climate change		Mirjam	21-Nov
		Methodology		Jana	13-Dec
		Priority vulnerabilities, including the 4 pillars within each vulnerability	Green canteen / Wild Rose Park	Jana	13-Dec
			Wharf	Mirjam	13-Dec
			HWY3 and power lines	Jana	28-Nov
			Waste water treatment	Jana	28-Nov
			Martins River Bridge	Jana	28-Nov
			Salt marshes	Mirjam	28-Nov
			Private property	Mirjam	28-Nov
			Causeways	Mirjam	28-Nov
		Conclusions		Mirjam	12-Dec
		Format document		Jana	14-Dec
		Executive Summary		Jana	14-Dec

Appendix 4: Briefing note 1

Briefing Note for the Chester Municipality, 30 September 2011

Subject
An update for council members on the progress of the coastal climate change impacts and vulnerabilities assessment project.

Background
The Council of the Municipality of the District of Chester has asked us to assess the potential climate change impacts and vulnerabilities on the Western Shore area of Mahone Bay. Tasks were assigned to the individual members of the group. Major components of the paper were discussed and divided based on area of expertise. A work plan was developed which includes a timeline of field trips to Chester, future meetings, due dates of deliverables and results of the study. On September 23rd, our consulting group traveled to the Western Shore where we had the opportunity to meet with Geoff MacDonald and Tara Maguire and visit areas of possible climate change impacts along the coastline. We will conduct subsequent visits to the Western Shore to further identify coastal vulnerabilities.

Issues and Analysis
Atlantica Rising Consultants were originally requested to investigate an area that substantially extended inshore. We have decided to focus our attention on the areas most vulnerable to the effects of climate change and sea level rise. Considering not only sea level rise, but also maximum height of tides, maximum storm surge and swell, a crude estimation for the landward boundary of the coast is 2-3 m above the high water mark[2]. Based on these numbers, we chose the 10m contour in order to make sure to include the entire coastal hazard zone, even in an exceptionally big storm.

A PESTLE analysis was conducted for the municipality as a whole in order to gain understanding of the forces of change that are at work in the coastal zone of the municipality.

In accordance with Dalhousie University research regulations we have submitted a research ethics checklist to the Faculty, and it is pending approval.

Next Steps
Plans are underway for revisiting our area to gather more information. Our next briefing update will be on October 28th

[2] Fanning, L.M. & Burbidge, C.D. (2010). Towards a coastal area definition for Nova Scotia. *Ocean Yearbook 24*:239-267.

Appendix 5: Briefing note 2

Briefing Note for the Chester Municipality, 28 October 2011

Subject
An update for council members on the progress of the coastal climate change impacts and vulnerabilities assessment project.

Background
As a consulting group, we are continuing the assessment of vulnerable areas to climate change and sea level rise along the coast of Chester Municipality at the request of the council. Following our preliminary visit to Chester on September 23rd with Geoff MacDonald and Tara Maguire we have begun preliminary research on our area of the Municipality of the District of Chester, which is the Western Shore. We are researching the social, economic, political and environmental factors that are in our area in order to have a baseline for identifying potential vulnerabilities. In accordance with Dalhousie University research regulations we had submitted a research ethics checklist to the Faculty, and it had been approved and is considered low risk.

Issues and Analysis
We have decided, as a class, that we will be working closely within our groups and in between our groups in order to provide a consistent analysis of the vulnerabilities along the coast of the Chester Municipality. After several class meetings, we have decided on one definition of scope that will outline the coastal area of study. Our previous scope was anything below the 10m contour line, the new scope reads that we will be looking at the area below 10m in elevation, with a maximum of 1km inland and a minimum of 100m inland from the high water mark. Exceptions to this scope can be made with reasonable justification, which must be communicated to the class. The exceptions would be if a significant environmental or infrastructural entity lies past any of our scoping lines, it may be included in the study area with reasonable justification.

One of our team members will be away from the study for an undetermined amount of time.

We are still awaiting GIS data from Chester Municipality in order to get an accurate geographical image of the area that we are studying.

Next Steps
We are planning a trip to the Western Shore on the morning of 10 November 2011, and then we will meet with municipal council members and staff to gather more information.

Appendix 6: Briefing note 3

Briefing Note for the Chester Municipality, 25 November 2011

Subject: An update for council members on the progress of the coastal climate change impacts and vulnerabilities assessment project.

Background:

At the request of the council of the Municipality of the District of Chester, our consulting group is assessing impacts of climate change and sea level rise along the coast of the municipality, more precisely the Western Shore. There are three other groups assigned with the project. We are all collaborating in order to minimize overlap and inconsistencies. A common definition of the coastal zone has been agreed on.

Issues and Analysis:

We have received GIS data from the municipality, which facilitates assessing vulnerabilities to climate change, particularly in the coastal zone. Due to limited experience with GIS, progress was slow, but we succeeded in creating the maps we had aimed for.

On our second trip to the Western Shore on November 10, 2011, we had a closer look at the coastal zone throughout our area, taking note of coastal features, elevation and infrastructure. We were able to collect the information needed to assess coastal vulnerabilities. No further trip to the municipality is planned.

The same day, we also met with municipal councilors and staff. We were able to clarify issues pertaining to the municipality's needs, infrastructure, governmental responsibilities, emergency management and zoning. This was very helpful for further analysis of vulnerabilities and the development of related recommendations. Remaining questions will be directed to Tara Maguire or the respective person in charge via email.

Discussions are under way to streamline the process of presenting the findings of the four project groups as one cohesive assessment of the predicted impacts of climate change on the municipality's coast.

One of our group members is no longer working on the project and we have adjusted to his absence accordingly.

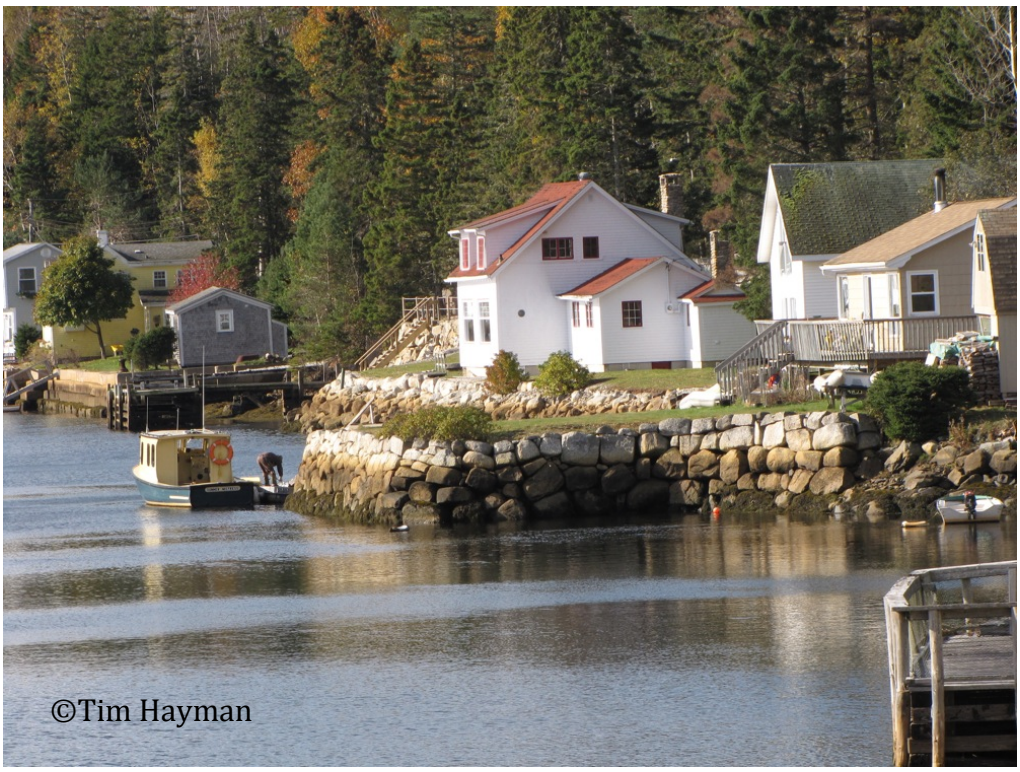
Recommendations:

This is the last briefing note. We will present our findings to project partners and course instructors in class on December 2, 2011. The assessments and recommendations of all four groups will be presented to the council of the Municipality of the District of Chester on December 8, 2011 as part of the regular council meeting. The final reports will be completed on December 16, 2011 and can be accessed through Kyle McKenzie or Dr. Lucia Fanning.

Assessing Coastal Vulnerability in the Municipality of the District of Chester

Team B

Chester to Chester Basin



Sarah Deller
Hilary Goodwin
Tim Hayman
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MARA 5005
December 16, 2011

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Executive Summary

Municipalities throughout Canada are beginning to acknowledge the need for plans to adapt to a changing climate. A vulnerability assessment is necessary to identify the priority areas that may require additional resources to cope with climate change impacts. The purpose of this study is to aid the Municipality of the District of Chester (herein referred to as the Municipality) in meeting the requirements of the Canada-Nova Scotia Agreement on the Transfer of Federal Gas Tax Revenues, and planning effectively for a sustainable future in the face of climate change. This vulnerability assessment will be used as the basis for the development of climate change adaptation strategies through scenario planning, which will ultimately contribute to the development of the Municipal Climate Change Action Plan (CCAP), an amendment to the previously completed Integrated Community Sustainability Plan. The CCAP will contribute to the development of the Municipal Planning Strategy in 2014, which will help the Municipality plan for a successful and sustainable future in the face of uncertain climate changes.

The study area, encompassing parts of Chester and Chester Basin, has the specific borders of Stanford Lake Road in Chester at the brook crossing, south to the intersection of Highway 3 and Duke Street, and south following the east side of Duke Street and Water Street to Front Harbour, continuing to Chester Basin at the Municipal Wharf and north to Highway 103. The scope is further delineated to define the coastal zone using an elevation of 10 metres (m), a one kilometre (km)

inland boundary and a 100 m minimum inland boundary, measured from the high water mark.

Nova Scotia has a modified continental climate largely defined by the ocean, with average monthly temperatures ranging from approximately –6°C in winter to approximately 20°C in summer and average annual precipitation up to 1500 mm. Nova Scotia is prone to tropical storms and hurricanes in summer and autumn and it is not uncommon for these storms to result in extreme storm surges.

There is a growing body of evidence that the Earth's climate is changing, resulting in increased global atmospheric temperatures. Temperatures in Atlantic Canada are projected to rise 2°C to 6°C over the next century, resulting in changes in precipitation patterns, wind activity, and extreme climate events including increased storm intensity and frequency, and sea level rise (SLR). SLR projections indicate that a rise of up to 1 m is expected over the next century, which is exacerbated by storm surge. A 1 m storm surge is predicted for the coastal area of the Municipality over the next century, resulting in water levels during a storm that could reach 2 to 3 m higher than they are currently.

The biophysical impacts from forces such as SLR, storm surges, changes in temperature and precipitation patterns, and wind activity include coastal erosion; flooding; beach, shoreline, and wetland migration or loss; saltwater intrusion; reduced freshwater availability; and impacts to flora and fauna (*e.g*., shifts in species assemblages, loss of biodiversity). The degree to which a coastline may experience these biophysical impacts is influenced by topography, geomorphology, soil type, tidal range, wave height, the frequency and magnitude of storms, the number of

man-made protective structures along the coast, and level of exposure. There are many low-lying zones in the area between Chester Basin and Chester Village that will be sensitive to periodic inundation from high tides and storm surges, as well as permanent flooding from SLR. The coastline in the study area and along many of the Mahone Bay islands is comprised of till and slate making it vulnerable to coastal erosion. There are small sections of marshland and beaches along the coast that will be vulnerable to flooding and erosion and, because of their close proximity to the road preventing their natural landward migration, will likely be permanently lost.

The social capacity to adapt to climate change impacts, coupled with the potential capacity of industries and infrastructure to adapt, will determine the degree to which the community is affected socioeconomically. Socioeconomic vulnerabilities in the Municipality stem from the services it must provide its residents, and the regulations it can implement to protect infrastructure before it is built. Many coastal residences are in the high-risk zone and there are clusters of properties at risk in Chester Village, the Peninsula, Marriotts Cove, Shaw Island, and Chester Basin. With rising sea levels, coastal properties will face damage and potential loss from flooding due to SLR and storm surge. Canadians may need incentives to consider the impact of climate change on major decisions such as deciding where to build a home or what retrofits their house may need. Some socioeconomic vulnerabilities in the Municipality are wastewater treatment, age and fixed income factors, seasonal residents, coastal access, a resource based labour market, and attitudinal factors.

Climate change impacts such as SLR, coastal erosion, and storm surge, precipitation and high winds from stronger and more frequent storms, pose a serious threat to infrastructure located within the coastal zone. Within the Municipality, vulnerable infrastructure includes buildings, roads, causeways, bridges, wells, wharves, and the wastewater and stormwater systems. Specific vulnerabilities exist throughout the study area, although special interest for infrastructure concerns is focused largely within Chester Village and at the entrance to Chester Basin. The Municipality is severely limited in its ability to pursue adaptation options for much of this infrastructure, as jurisdiction over many elements is either private or provincial. The only vulnerable infrastructure element the Municipality has full jurisdiction over is the municipal wastewater system, an element in which adaptation investment is worthy of consideration.

The governance systems within the Municipality primarily consist of the Chester Municipal Council, constituents of the Municipality, and local community groups. The study area includes parts of three constituent zones: Districts 3, 4, and 7. The governance and planning pillar of this study is slightly different from the three others mentioned because the term vulnerability cannot be used. Instead, the term gap is used to identify omissions in policy or planning regulations. Since the Municipality has limited authority over many of the issues identified, adaptation recommendations are made based on the gaps in the current policy and planning regulations, and a literature review. Adaptation strategies typically fall into three categories: retreat, accommodation and protect. For the Municipality, a combination of these strategies is recommended. Adaptation recommendations include the

implementation of coastal setbacks, buffer zones, greenways, an improved municipal water system, increased education and awareness for citizens, and insurance and tax incentives. While these adaptation recommendations will help to reduce the impacts of climate change within the Municipality, it is also recognized that due to political and financial constraints, the timeline for implementation may be quite long.

Introduction

The purpose of the present study is ultimately to identify and assess the vulnerabilities to climate change within the Municipality of the District of Chester (herein referred to as the Municipality). This integrated impact and vulnerability assessment will play a key role in the ongoing process of developing a Municipal Climate Change Action Plan for the Municipality. Beginning in 2005, the Canada-Nova Scotia Agreement on the Transfer of Federal Gas Tax Revenues was established to provide federal funding to invest in municipalities throughout the Province, with the intention of promoting the economic, social, environmental and cultural sustainability of these municipalities (Province of Nova Scotia, 2011). In 2008, the Nova Scotia government extended this agreement for an additional four years. As part of the requirements to receive this funding, municipalities must complete an Integrated Community Sustainability Plan (ICSP), and subsequently, a Climate Change Action Plan (CCAP).

In 2009, the Municipality completed its ICSP, which marked the first step in compiling a comprehensive planning strategy for the future. The CCAP will be an amendment to the ICSP, and will be completed by the Municipality by 2012. The present study provides the first step in moving toward the development of the CCAP. This study identifies and assesses vulnerabilities within the Municipality, which will then be used as the basis for an evaluation of adaptation options through scenario planning. The adaptation strategies developed, based on this vulnerability assessment, will directly contribute to the development of the CCAP. The completed

CCAP will then contribute to the more comprehensive Municipal Planning Strategy, which will be completed for 2014.

Chester Overview

The Municipality of the District of Chester covers approximately 1400 square kilometres in the eastern portion of Lunenburg County on the south shore of Nova Scotia, sharing its eastern boundary with the Halifax Regional Municipality (HRM), and stretching along the coastline to the community of Martin's River (Municipality of the District of Chester, 2010c). Situated along a number of bays and coves of the Atlantic Ocean, Chester is a coastal municipality. Although forming a continuum along one coastline, there is notable variance in geology and elevation along the coast, ranging from granite cliffs to low-lying soft shale (G. MacDonald, personal communication, September 23, 2011).

The permanent population of the Municipality was reported at 10,815 in 2006 (Government of Nova Scotia, 2006), although the region attracts a significant number of seasonal residents, causing the population to swell considerably during the summer months (Municipality of the District of Chester, 2010a). Chester Village is the primary service and commercial hub for the Municipality (Institute for Planning and Design, 2009). The Village of Chester is the most densely populated part of the Municipality, and forms the principle centre for economic activity and governance within the Municipality (Institute for Planning and Design, 2009). The principle drivers of economic activity in the Municipality are the manufacturing, construction, and retail businesses (Institute for Planning and Design, 2009).

Resource extraction (particularly forestry and fishing) and tourism services (such as food and accommodation) also play a role in the Municipality's economy and the proximity to the ocean and beautiful coastline are part of the reason why these industries thrive (Institute for Planning and Design, 2009). Governance and public service authority is concentrated in the Village of Chester, with the Municipality subdivided into seven districts to facilitate effective representation of the unique interests of the diverse areas that make up the Municipality.

The coastal area between Chester Basin and Chester Village has a surficial geology composed of loose materials, such as silty till, drumlin, and hummocky ground moraine deposited by glacial and deglacial processes (Nova Scotia Department of Natural Resources, 2011). The bedrock along the coast from Chester Basin to Haddon Hill is composed of carbonate and evaporate material. The sedimentary rocks are composed of carbonate or magnesium carbonate (*e.g.,* limestone and dolostone) and the evaporate rocks were formed through evaporation of surface water (*e.g*., halite; Nova Scotia Department of Natural Resources, 2011). From Haddon Hill to Chester Village the bedrock is composed of metamorphic rock, which was originally sedimentary or igneous (sandstone and slate) rock and not easily eroded (Nova Scotia Department of Natural Resources, 2011). The coastal area across from Shaw Island is composed of a combination of salt marsh, swamp, and trees (mix of various spruce and fir trees). The soils in the area between Chester Basin and Chester Village are predominantly derived from slate (G. MacDonald, personal communication, September 23, 2011). Most islands are Wolfville drumlins and composed of soft soils. The major soil types of the islands

are derived from slate and have been heavily eroded and form shoals, spits, and bars (T. Maguire, personal communication, September 9, 2011).

Scope and Coastal Zone Uses

Climate change effects can be far-reaching and often span borders and jurisdictions. The given boundaries for this study area are Stanford Lake Road in Chester at brook crossing, south to the intersection of Highway 3 and Duke Street and south following the east side of Duke Street and Water Street to Front Harbour. It continues to Chester Basin at the Municipal Wharf and north to Highway 103. While Highway 103 is the northernmost boundary, it is quite far back from the coastline in some areas and may not be damaged by climate change impacts. In order to develop a comprehensive climate change vulnerability assessment, coastal zone boundaries must be delineated. This study uses an elevation of 10 metres (m), a one kilometre maximum inland boundary, and a 100 m minimum inland boundary, both measured from the high water mark (Figure 1). These boundaries were chosen based on the fact that the maximum predicted sea level rise for Nova Scotia for the next 100 years is between 55 and 95 centimetres (cm) (Institute for Planning and Design, 2009) and accounts for storm surge and maximum high tide. Another important factor involved in defining the coastal zone is the identification of the particular uses. The primary uses of the coast in the Municipality are recreational or commercial fishing, tourist activities, recreational boating, and for aesthetic views (Institute for Planning and Design, 2009).

Current Climate

Nova Scotia lies in the mid-temperate zone and has a modified continental climate that is largely defined by the ocean, which almost entirely surrounds the province (Nova Scotia Museum of Natural History, n.d.). Coastal areas, such as Chester, tend to be several degrees cooler than inland areas because of the cooling effect of the Atlantic Ocean. Average monthly temperature can range from approximately –6°C in January to approximately 20°C in July and August (Environment Canada, 2010). In the Municipality, average annual precipitation, including rain and snow, ranges from approximately 1250 millimetres (mm) to 1500 mm (Nova Scotia Museum of Natural History, n.d.). The main factors influencing Nova Scotia's climate include the effects of the westerly winds, the interaction between three main air masses (the cold continental arctic air, the moister maritime polar air, and the warmer maritime tropical air) which converge on the east coast, Nova Scotia's location on the routes of the major eastward-moving storms, and the modifying influence of the sea (Nova Scotia Museum of Natural History, n.d.). Finally, Nova Scotia is prone to tropical storms and hurricanes in the summer and autumn (*e.g.*, Hurricanes Juan and Earl). Although tropical storms usually weaken by the time they reach Nova Scotia because of the relatively cooler waters off the coast, these storms can result in extreme storm surges. The Municipality already experiences increased storm surge events and this will only worsen with the impacts from climate change.

Climate Change and Expected Changes over the Next Century

There is a growing body of evidence that the Earth's climate is changing. Climate change is a result of natural variability and human activity. While there are natural factors that influence climate variability, it is the anthropogenic factors that are increasing the rate of climate change via the burning of fossil fuels and changes in land-use patterns (Intergovernmental Panel on Climate Change, 2007). As a result, global atmospheric temperatures are expected to rise 0.2°C per decade for the next two decades, which is resulting in warmer sea surface temperatures (Willis, Roemmich, & Cornuelle, 2004). The increased temperature and acidity in the ocean will lead to a multitude of physical and chemical changes in marine systems (Harley et al., 2006). Due to warming ocean temperatures and melting sea ice, the expansion of the oceans has caused the average sea level to rise at a rate of 1.8 mm per year between 1961 and 2003 (Intergovernmental Panel on Climate Change, 2007). Even more worrisome is the increasing rate of sea level rise (SLR) between 1993 and 2003, at about 3.1 mm per year (Intergovernmental Panel on Climate Change, 2007). While the pH of the ocean is changing, certain areas are becoming fresher and other areas are becoming more saline (Intergovernmental Panel on Climate Change, 2007). Scientists estimate that surface ocean pH has fallen by 0.1 from preindustrial times to today (OCB & EPOCA, 2010). While 0.1 may not sound like much, this drop is equivalent to a 26 percent increase in the ocean hydrogen ion concentration (OCB & EPOCA, 2010). This increased acidity makes it hard for organisms that rely on calcium carbonate, such as pteropods, to survive (OCB & EPOCA, 2010). Larger fish like salmon eat pteropods and if the ocean becomes too

acidic to support pteropods, there will be cascading effects that will influence larger organisms as well.

The Earth's climate is expected to continue to change at an unprecedented rate over the next century. Depending on the climate change scenario, the best estimate of projected global average surface air warming over the next century ranges from 0.6°C for the best case scenario to 4.0°C for the worst case scenario (IPCC, 2007). More specifically, mean annual temperature in Atlantic Canada is expected to increase with seasonal (2°C to 4°C in the summer and 1.5°C to 6°C in winter) and geographical (coastal areas will likely experience less change than inland areas) variation (Lemmen, Warren & Bush, 2008). The effects of increased temperatures include changes in precipitation patterns (e.g., heavy precipitation events, drier summer conditions), wind activity, and extreme climate events (Lemmen et al., 2008). Examples of extreme climate events include increased storm intensity and frequency, early or late frost events, river ice jams and flooding, and sea level rise.

Projected SLR estimates vary between 0.18 m to 0.38 m for the best case scenario and between 0.26 m to 0.59 m for the worst case scenario (Intergovernmental Panel on Climate Change, 2007). To complicate matters further, the movement of the Earth's crust is causing the land in the Maritimes and Newfoundland to subside at a rate of approximately 0.3 m per century (K. McKenzie, personal communication, September 9, 2011). The coupling of SLR with crustal subsidence could increase the IPCC projections to 0.90 m. The impact of SLR on coastal communities is further exacerbated by storm surge, which is higher on

coastal waters. For example, a 1 m storm surge is predicted for the coastal area of the Municipality (Lemmen et al. 2008). As a result, water levels during a storm could reach approximately 2 to 3 m higher than they are currently. With over 7600 km of coastline, this renders Nova Scotia vulnerable to the impacts of climate change.

Methodology

The MARA 5005 Chester Project class was divided into four groups each representing a different region of the Municipality. As discussed the study area for this research team (herein referred to as Team B) consisted of the Chester and Chester Basin regions. Team B made several trips to Chester in order to better understand the study area. Visits occurred twice as a class and then again as Team B where individual sections were explored. A vulnerability assessment was completed. Team B used the Intergovernmental Panel on Climate Change (2007) definition which describes vulnerability as:

> the degree to which a system is susceptible to, and unable to cope with, adverse effects of *climate change*, including *climate variability* and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its *sensitivity*, and its adaptive capacity.

To facilitate the creation of an integrated impact and vulnerability assessment, Team B's study was divided into four pillars: biophysical, socioeconomic, infrastructure, and governance and planning. Within each of these pillars, the impacts of climate change were identified along with corresponding vulnerabilities. Although it is not the primary focus, several adaptation strategies were recommended.

To aid in assessing the vulnerabilities of the coastal areas of the Municipality, Geographic Information Systems (GIS) maps were created with data obtained from the Municipality, as well as from the Dalhousie GIS Centre. Individuals from the GIS Centre also assisted with the creation of these maps. Based on IPCC projections, we delineated the zone from sea level to 5 m (depicted in red in Figure 2) as an area that would be most susceptible, or at risk, to inundation from climate change impacts including flooding, SLR and storm surge. The area from 5 m to 10 m (depicted in yellow in Figure 2) is less susceptible, but could possibly be impacted by periodic flooding from storm surge and intense storm activity. The area beyond 10 m elevation is deemed to be at low risk.

Team B originally considered conducting interviews with residents in the Municipality, but decided the information provided by Council and the ICSP was sufficient. To obtain a complete understanding of the potential impacts of climate change, how to perform a vulnerability assessment, and evaluate potential adaptation strategies a comprehensive literature review was completed.

Biophysical Impacts

The biophysical impacts from forces such as relative SLR, storm surges, changes in temperature and precipitation patterns, and wind activity include coastal erosion, flooding, wetland migration or loss, beach and shoreline migration, saltwater intrusion, reduced freshwater availability, and impacts to flora and fauna (*e.g.,* shifts in species assemblages, loss of biodiversity) (Table 1).

Coastal erosion

Coastal erosion is the physical process whereby sediment is moved away from shore via wave and current action (Kosloski, 2008; Linham & Nicholls, 2010). The coupling of relative SLR with wave action will likely increase the rate of coastal erosion, particularly unconsolidated sediment (Shaw, Taylor, Solomon, Christian, & Forbes, 1998). The consequences of coastal erosion include loss of coastal access, property, and infrastructure, as well as shoreline and beach migration.

Flooding

SLR increases the vulnerability of coastal areas to permanent flooding. However, temporary flooding is influenced by heavy precipitation (rain and snow), and will likely become worse with severe winds, increased storm intensity, and storm surge (Kosloski, 2008; Nicholls & Tol, 2011).

Loss or migration of wetland

Wetlands are intertidal areas that include swamps and salt marshes. As wetlands are encroached upon by rising sea level and more frequent flooding they will naturally migrate landward, but can be permanently lost if migration is limited by infrastructure such as roads, buildings, and human-engineered protective structures (*e.g.*, dykes, sea walls) (Shaw & CCAF Project A041 Team, 2001, Kosloski, 2008). This process is known as "coastal squeeze," which can lead to loss of natural water retention of watersheds, subsequently increasing the risk of flooding and coastal erosion (Kosloski, 2008). Although it is possible that some salt marshes will keep pace with relative SLR, some have drowned in the past (Shaw et al., 1998).

Shoreline migration and beach retreat

Coastal erosion and flooding from relative SLR and storm surge can lead to coastal reorganization (Shaw et al., 1998). This could involve changes due to the increased over washing of beaches and higher rates of beach retreat, which is a similar process as wetland migration. As sediment gets pushed landward via wave and tidal action, the beach has a natural tendency to move inland.

Saltwater intrusion

The drawdown of the water table adjacent to the ocean resulting from reduced precipitation in conjunction with SLR can lead to saltwater intrusion into groundwater and wells (Lemmen et al., 2008). This contaminates the wells and renders the water undrinkable. Low lying areas are among the most susceptible to this process, which is of particular concern for the Municipality due to their reliance on wells. Saltwater intrusion can also impact habitat, species, and productivity of agricultural land.

Reduced freshwater availability

Evaporation due to increased precipitation can lead to a decline in water resources. This could have negative effects on hydroelectric, freshwater fisheries, the municipal water supply, agriculture, tourism, and recreation (Lemmen et al., 2008). Lower water levels can also lead to a reduced quality of drinking water.

Impacts to flora / fauna

A significant threat to coastal organisms is habitat loss. It can lead to the extirpation, or extinction, of native, threatened, or endangered species. Habitat loss can also result in species migration (either landward or to another geographic

location) or the replacement of dominant species with subdominant species (Lemmen et al., 2008). Many plant species are sensitive to salination and are unable to survive saltwater inundation that is worsened by SLR and storm surge. Saltwater inundation can also increase the number of invasive species present in an area. Saltwater intrusion can lower the biodiversity and reduce the productivity of estuarine systems by rendering them more brackish (Tobey et al., 2010). Loss of wetlands can displace organisms, as they rely on the carrying capacity of these intertidal areas. Finally, warming temperatures can impact the timing of bird migration and breeding season, as well as the life history stage, species composition, timing of spawning, and feeding habitat of fish, resulting in impacts to fisheries.

Biophysical Vulnerabilities in the Municipality

The degree to which a coastline may experience the biophysical impacts (erosion, flooding, wetland loss, and others) of the physical forcings resulting from climate change is influenced by its topography (elevation, slope), geomorphology (*e.g*., bedrock, sandstone, or cobblestone, marshland), soil type (unconsolidated sediment or weakly consolidated bedrock), shoreline type (protected or not), tidal range, wave height, the frequency and magnitude of storms, the number of man-made protective structures along the coast, and the level of exposure to some of these physical forcings (Kosloski, 2008; Lemmen et al., 2008). For example, densely populated and low-lying areas will be sensitive to inundation from high tides and storm surges because low lying areas drain less as sea level rises and development on former wetlands or flood plains can lead to flooding following rain storms (Shaw

et al. 1998; Intergovernmental Panel on Climate Change, 2007; Lemmen et al., 2008). Although Middle River does not appear to be impacted by tides, heavy precipitation could lead to flooding of this low-lying area (Figure 2). Stanford Lake is another area that could be impacted by periodic flooding resulting from heavy precipitation. However, the lake is almost completely surrounded by trees and the ground will likely be relatively resistant to erosion.

Areas with sensitive shoreline geology (as above) will be impacted by flooding and erosion. For example, much of the coastline from Chester Basin to Chester Village is comprised of till and slate, which is mainly loose sand and gravel material and easily eroded (Nova Scotia Department of Natural Resources, 2011). The coastline along Marriotts Cove will be vulnerable to erosion, especially if the sea walls fail. There are many low-lying areas here that will be vulnerable to both periodic flooding from storm surges, as well as permanent flooding from SLR (Figure 2). There are small sections of marshland in this area that will be vulnerable to flooding and erosion and, because of the close proximity to the road preventing its natural landward migration, will likely be permanently lost. The low-lying coastal forest areas near the Eisnor Road Extension (across from Shaw Island) will be vulnerable to salination, potentially resulting in unsuitable conditions for most of the terrestrial plant species there. Also, the risk of inundation is high as the majority of this land mass is located within the 0 – 5 m zone (Figure 2). The tidal marshes here could be lost over time because the marsh and swamplands are vulnerable to erosion and due to residential development landward migration will be limited. Currently, this marshland is protecting these properties from flooding. However, as

previously mentioned the location of this marshland is in the high risk zone and could be inundated, causing the marsh to drown which could negatively impact the flora and fauna here, as well as result in the loss of its flood moderating capabilities.

Freda's Beach, next to Parade Square Road, will be sensitive to erosion because it is comprised of sand and pebble gravel and this side of the causeway appears to be more exposed to wave action and storm surge. There is potential for this beach to be lost because as it is encroached upon by SLR and impacted by erosion and flooding, its natural tendency for landward migration will be hindered by the causeway connected to the Peninsula.

Finally, the islands in Mahone Bay provide a unique habitat to a diverse collection of plant and animal species. They are comprised of rocky shores, cobble and sand beaches, dune complexes, tidal flats, wetlands, and mature forests (MICA, 2004-2011). Therefore, the vulnerability of some of these islands will vary depending on their geomorphology and the composition of species that inhabit them. Many of the islands are comprised of soft soils and as a result the shorelines there will be vulnerable to flooding and erosion. Of particular note is Quaker Island because it is home to a few bird species that are of conservation concern, including Roseate terns, which are listed as endangered by the Committee on the Status of Endangered Wildlife in Canada (COSEWIC, 2003 as cited in MICA, 2004-2011).

Socioeconomic Impacts

The National Round Table on the Environment and the Economy (NRTEE) report *on Degrees of Change* (2010) notes that "communities in coastal zones will

likely see more and faster erosion, effects of more severe and frequent storm surges, and sea-level rise" (p. 88). The social capacity to adapt to climate change impacts, coupled with the potential capacity of industries and infrastructure to adapt, will determine the degree to which the community is affected socioeconomically. For example, the NRTEE report highlights that Canadians may need incentives to consider the impact of climate change on major decisions such as deciding where to build a home or what retrofits their house may need (NRTEE, 2010). Canadian businesses and Canadian homeowners may save money in certain areas like heating costs (NRTEE, 2010) and these decreased costs could help offset the increased costs of retrofitting a house or business to deal with climate change issues like storm surge.

The *Degrees of Change* report included the following climate change impact categories: 1) Ice, snow, and sea; 2) Ecosystems; 3) Water resources; 4) Human health; 5) Communities and infrastructure; 6) Resources industries; 7) Service industries; and 8) Security and trade (NRTEE, 2010). There are social and economic factors associated with each of these climate change impacts. With rising sea levels, coastal properties will face property damage and potential loss due to flooding and storm surges. Ecosystems will be altered as habitats such as salt marshes may not be able to migrate with increasing sea levels, and one must consider the important ecosystem services salt marshes provide, such as improving water quality (Hilbert, 2006). If the ecosystem is not adequately filtering the water, then municipalities and/or homeowners will have to spend more money to filter their water resources. Saltwater intrusion is another concern municipalities and homeowners could face

with SLR, as seawater could intrude into the groundwater supplies, negatively impacting water security (Lebbe, Van Meir, & Viaene, 2008). As temperatures increase with climate change, there could be increased emergency room visits due to heat stroke (Mehdi, Mrenda, & Douglas, 2006). Elderly people will be particularly susceptible to high temperatures. Communities and infrastructure will be impacted in a multitude of ways as effects like increasing storm intensity could bring down power lines and trees, flood properties, and result in costly damages. Resource industries could be impacted by regime shifts as fishery stocks shift northward and as forest diversity could be impacted by increasing temperatures (Perry, Low, Ellis, & Reynolds, 2005; Bertrand et al., 2011). Service industries could be impacted negatively or positively, depending on the climate changes in the area. Tourism fluctuation could occur due to increases temperature or precipitation. Security and trade is another sector to consider as roads and transportation could be impacted by flooding and potentially higher fuel prices. Combined together, all of these impacts on communities will likely result in increased anxiety and could lead some people to emigrate to areas that are less impacted. Increased education in the community of how to mitigate climate change impacts should reduce their vulnerability. Reduced economic productivity is a major concern for businesses in Canada and steps should be taken to minimize these impacts.

Socioeconomic Vulnerabilities in the Municipality

A report on the vulnerabilities associated with climate change impacts in Australia summed up the importance of considering socioeconomic factors in

tandem with climate change impacts: "socio-economic disadvantage is important both in the short-term capacity of a community to cope with a flood event, and its long-term ability to adapt to the effects of climate change" (Brunckhorst et al., 2011, p. 47). Socioeconomic vulnerabilities in the Municipality stem from the services it must provide their residents, and the regulations it can implement to protect infrastructure before it is built. As can be seen in Figure 3, many coastal residences are in the high-risk zone (red) and there are clusters of properties at risk in Chester Village, the Peninsula, Marriotts Cove, Shaw Island, and Chester Basin.

Wastewater

One of the primary responsibilities of the Municipality is wastewater management in the Chester Village. From discussions with the councillors and engineering staff, it is evident the wastewater pumping stations are already vulnerable to breaking down and these issues are likely to increase with SLR and storm surge. The residents will demand a secure wastewater source and the Municipality must consider investing in generators and other backup methods to ensure that wastewater services are stable.

Age and Fixed Income

Elderly residents are a particularly vulnerable segment of the Municipality's population due to physical limitations. According to Nova Scotia Community Counts statistics (2011b), 23.6 percent of the Municipality's population is over age 65 and 16.5 percent of the population is between 55 and 64. Additionally, this population tends to be on a fixed income which may restrict their ability to spend on adaptation measures to increase the protection of their homes from SLR and storm surge.

According to Nova Scotia Community Counts (2011a), 41.7 percent of the population of the Municipality is not in the labour force, which indicates the high rate of retirees. Furthermore, as inflation is rising in Canada, the purchasing power of residents is decreasing (Canadian wages, 2011). Thus, they will have less disposable income. The physical limitations of the elderly are the concern of the Municipality if Emergency Health Services (EHS) cannot access someone in distress due to washed out roads or causeways.

Seasonal Residents

Warden Allen Webber estimated that seasonal residents make up 75 percent of the coastal residents in the Municipality (A. Webber, personal communication, November 10, 2011). These residents are also vulnerable due to their substantial investment in secondary properties and their attitudinal vulnerabilities (Brunckhorst et al., 2011). As seasonal residents will not be as familiar with changes in the community, they are less likely to be aware of increasing storm intensities, SLR, and flooding events.

Coastal Access

One of the major attractions to the Municipality is the coast, yet access to the coast is threatened by SLR and could lead to the loss of wharves, docks, and beaches. The Tancook ferry was within an inch of being flooded from a storm in October 2011 (B. Armstrong, personal communication, November 10, 2011), which demonstrates the need to raise the wharf. The wharf is owned by the province and the Municipality will need to communicate these concerns to the relevant authorities. Lido pool and Freda's beach are both threatened with SLR. Both of these

facilities offer coastal recreation opportunities to the residents and as they disappear, the Municipality will need to consider ways to protect coastal access.

Resource Based Labour Market

Another socioeconomic vulnerability in the Municipality is the residents that rely on jobs in the resource based labour market. As fisheries stocks migrate due to climate change, the corresponding jobs may be lost or move elsewhere. Similarly, if residents are relying on jobs in the timber industry, then their jobs could be at risk if the forests are impacted by climate change. The Municipality can assist residents by diversifying job opportunities in different sectors. Tourism may be one sector to benefit from climate change impacts and increasing the number of restaurants and accommodations in the Municipality could be beneficial.

Attitudinal Factors

Two social factors make the residents of the Municipality particularly vulnerable to climate change impacts. From discussions with the councillors, it appears that residents are noticing certain climate change impacts like the flooding of streets, but they are not connecting these impacts to climate change. Additionally, many residents in the Municipality have built their properties as close to the ocean as possible which makes their properties particularly vulnerable to damage and flooding from SLR and storm surges.

Specific Areas

As the Municipality does not have control over personal property, it should concentrate on suggesting the protection of commercial properties, EHS services, and wastewater services. Additionally, the Municipality will need to communicate

vulnerable areas under provincial jurisdiction. For example, Water Street in the Chester Village is vulnerable to flooding and is a key access road for people disembarking from the Tancook ferry. These ferry passengers are travelling to Chester to purchase goods and services; thus it is essential that their ability to travel to Chester not be compromised by flooded roads or flooded wharves. The Municipality must communicate to the province about the need to protect Water Street from flooding and about the need to raise the wharf to protect it from flooding events.

The Rope Loft is a restaurant on Water Street that sits directly on the water and is in danger from flooding from storm surges. Furthermore, the Rope Loft is one of the oldest commercial properties in Nova Scotia and is a historical part of Chester (Rope Loft, 2011). Other commercial properties to consider for protection are Misty Meadows Farm in Marriotts Cove and a section of properties in Chester Basin including ValuFoods, PharmaSave, and the Seaside Shanty restaurant. All of these low-lying properties are at risk from flooding. The Sword and Anchor Bed and Breakfast is located across the street from the Chester Basin commercial properties and their business could be impacted if patrons could not enjoy the nearby services.

Emergency services should be a priority area for the Municipality and efforts should be made to increase awareness of potential vulnerabilities from climate impacts. For example, the causeway leading to Shaw's Island is vulnerable to being washed out which could be a concern for emergency services if there is a medical emergency. While the Municipality owns at least one emergency rescue boat, they should consider investing in additional boats.

Infrastructure Impacts

In the context of this report, coastal infrastructure refers to any type of infrastructure, including residential and commercial buildings, roads, and docks, that is located within the coastal zone as defined in the scope of this project. Coastal infrastructure is a major concern with regard to climate change impacts because much of the Municipality's important infrastructure is located in the coastal zone. With climate change predicted to bring higher sea levels and stronger, more frequent storms, coastal infrastructure will have to contend with flooding, high rates of coastal erosion, and frequent battering by high winds and storm surges. With much infrastructure located in the coastal zone and with climate change impacts becoming more pronounced, there is the potential for coastal infrastructure in the Municipality to be particularly affected by the impacts of climate change in the future. The potential types of infrastructure that can be affected by climate change impacts are discussed in more detail below.

Buildings

The wide array of types, locations, and uses of buildings makes it inherently difficult to generalize statements about the effects of climate change impacts on buildings. However, in the case of buildings located adjacent to the coast, the same impacts are likely to be of greatest concern. Increased sea levels, coupled with more frequent and severe storms, will lead to permanent flooding in some areas, and more frequent and damaging temporary flooding in others (Canadian Council of Professional Engineers [CCPE], 2008; Royal Academy of Engineering, 2011). Additionally, increased rates of coastal erosion can undermine the foundational

stability of certain buildings, and can lead to severe structural damage or collapse (CCPE, 2008; Royal Academy of Engineering, 2011).

Roads, Bridges and Causeways

Although roads can be affected by a number of climate change effects regardless of their location, such as integrity issues resulting from changes in the cycle of freezing and thawing and higher overall summer temperatures, roads in the coastal zone are particularly vulnerable (CCPE, 2008). From the landward side, roads can be washed out or flooded by run-off from increased precipitation in storm events, while from the seaward side, higher sea levels coupled with stronger and more frequent storms can permanently flood, temporarily wash-out, or erode away certain sections of coastal roads (CCPE, 2008; Royal Academy of Engineering, 2011). One of the most significant concerns for road systems are places where a road crosses either a bridge or causeway. Causeways are particularly susceptible to washout and flooding, especially if located across wind-exposed sections of water (CCPE, 2008). Bridges, especially those across tidal rivers where both tidal influx and river discharge are factors, can be overwhelmed by high flows during storms, and represent a potential weak-point in a road system (CCPE, 2008).

Water Resources

Climate change poses a threat to the availability of water resources of a variety of sources. Municipal systems that rely on lakes and reservoirs could be negatively affected by droughts resulting from higher temperatures, and flooding during storm events can damage distribution infrastructure (CCPE, 2008; Royal Academy of Engineering, 2011). The combination of higher temperatures and more

sporadic, intense precipitation events could result in severe water pollution problems (CCPE, 2008). In a coastal community, wells are of particular concern. Extended periods of drought can cause groundwater supplies to be depleted, while for those located near the coast, increasing sea levels can result in salination of groundwater resources through saltwater intrusion, reducing the availability of drinkable groundwater (CCPE, 2008).

Wharves

By nature of their low elevation and location on the water, wharves have the capacity to be seriously affected by climate change impacts. Increasing sea levels will reduce the elevation above sea level of fixed wharves, and docks of a floating design will also be affected if sea levels rise above the elevation of the dock moorings on land. Increased storm intensity and frequency, bringing stronger and more regular storm surges and waves, will expose wharves to more frequent damages and flooding.

Wastewater and Stormwater

Wastewater and stormwater systems typically represent a significant infrastructure investment on the part of any given municipality, and as such, concerns about the impacts of climate change need to be taken seriously. Wastewater and stormwater infrastructure can be affected by a variety of climate change impacts. Dry periods that result from increased temperatures can reduce base flows in the system to dangerous levels, while increased precipitation (especially in extreme storms) will put a greater demand on the systems, and can lead to pipe overflows and flooding (CCPE, 2008). SLR can cause pipes and pumping

stations that were previously located near the sea level to become regularly submerged at high tide, and exposed to more frequent flooding, both of which will lead to overflows and failures in the system (reference). Temporary flooding and saltwater influxes resulting from storm surge can also overwhelm these systems, causing physical structural failures, or damaging treatment by killing treatment bacteria (G. MacDonald, personal communication, September 23, 2011).

Infrastructure Vulnerabilities in the Municipality

Not all coastal infrastructure will be equally vulnerable to the effects of climate change. Infrastructure located in low lying coastal areas, for example, will be more likely to experience flooding as a result of SLR, and will be more susceptible to damage from higher storm surges. Assessing the vulnerability of a particular piece of infrastructure is a complex issue, and is dependent on the geophysical features of the coastline, local climate patterns, and elements of the infrastructure itself (Nicholls & Hoozemans, 2000). These complications make comprehensive vulnerability assessments difficult, and inherently case-specific (Nicholls & Mimura, 1998).

Any infrastructure located within an elevation of 0 to 5 m above sea level was identified as vulnerable, and particular considerations were determined by observation and site-specific evaluation. Although limited by the inherent uncertainty of climate prediction models, and the lack of detailed elevation measurements, the following discussion highlights the key infrastructure within the Municipality that is likely to be of significant concern.

Buildings

There are a variety of low-lying buildings throughout the Municipality, including both private homes and businesses. Some particular examples are the private homes on Shaw Island, as well as those on Walker Road and many on low-lying roads in Chester Village. Businesses like the Rope Loft and those located at the entrance to Chester Basin (Seaside Shanty, Pharmasave, ValuFoods and Ultramar) all fall within the area of highest vulnerability, and are therefore likely to see the impacts of climate change in the form of flooding, erosion, and storm surge. Due to the fact that the homes and buildings most likely to be affected are primarily private, the Municipality may be more limited in its ability to address these vulnerabilities.

Roads, Bridges and Causeways

As indicated in Figure 4, there are a number of roads that pass through the area of highest vulnerability. Of major concern is the section of Highway 3 entering Chester Basin, where flooding (be it temporary or permanent) could disrupt a significant transportation link in the region. This could be of particular concern during emergencies, as it could limit the ability of first responders to access certain areas. Additionally, there are several roads around Chester Village and the surrounding area that enter or pass through low, vulnerable elevations. Two major causeways are also at risk: the Parade Square/Peninsula Road causeway and the private causeway to Shaw Island. The Shaw Island causeway will likely be of greatest concern, as it is long, low-lying, and particularly exposed, making it more vulnerable to damage by storm surges. In addition to these causeways are two bridges at Victoria Street next to Walker Road and Highway 3 over Middle River.

Although there are clearly vulnerable roads, causeways, and bridges in the Municipality, there is little municipal control over these particular elements. Jurisdiction over roads and all related infrastructure belongs to the Nova Scotia Department of Transportation and Infrastructure Renewal. Private roads, such as the one leading to Shaw Island, are under the jurisdiction of the private citizens who built and maintain them. As such, the Municipality has limited control over the placement and nature of roads and the bridges and causeways they cross, meaning it will need to communicate and cooperate with the Province and private citizens in order to achieve any adaptation strategies.

Water Resources

Another significant area of concern for municipal residents is the potential for climate change impacts to disrupt private wells. There is currently no public water infrastructure in Chester Village or towards Chester Basin, with all residents instead relying on private wells for their water supply. Increasing sea levels bring the potential for saltwater intrusion problems, which may pose a threat to many private wells throughout the region. From field observation, it was possible to determine that many of the wells for low-lying waterfront properties are also located within a very close proximity to the ocean. As a result, it is likely that these will be of significant concern in the future. However, as is the problem with other private infrastructure, the operation and maintenance of these wells is the responsibility of the private citizens, meaning that any adaptation strategies relating to wells will need to be undertaken through cooperation with private residents.

Wharves

Due to their low proximity to the water level, wharves are certain to be affected by rising sea levels and the potential for damage during storm events. Private wharves are common on waterfront properties throughout the region, and are all inherently at risk from climate change impacts. A major concern is the Tancook Ferry wharf, located in Chester Village. This wharf has historically flooded in major storm events (G. MacDonald, personal communication, November 10, 2011), and is very likely to be flooded more frequently and more severely with the increasing impacts of climate change. Although this wharf is undoubtedly important due to its part in maintaining a transportation link for residents on Tancook Island, there is little the Municipality can do to directly address concerns about this wharf, as it is also under the jurisdiction of the Province of Nova Scotia. In similar fashion to the challenge with roads, the Municipality will have to communicate and cooperate with private citizens and the Province in order to address climate change impacts on wharves.

Wastewater and Stormwater

One of the most significant vulnerable infrastructure components in Chester Village will be the municipal wastewater system. As shown in Figure 4, there are four sanitary pumps, or lift stations, located within the area of high vulnerability. These lift stations are a critical element of the system, and a threat to their integrity constitutes a major threat to the operation of the entire system. There have already been problems with flooding, corrosion, and saltwater intrusion in the current system during very high tides and storms (G. MacDonald, personal communication

September 23, 2011). With higher sea levels bringing an increased high tide elevation, and storm events becoming more frequent, it is certain that these pumping stations will experience these same problems more frequently, and more severely. Within the last year, the Municipality spent $4,500 on vacuum trucks to assist with overflow in the wastewater system, a cost that will rise in the future as these events become more frequent (L. Russell, personal communication, November 10, 2011).

It is also likely that the stormwater system will be affected, as increased precipitation will place higher loads on the current infrastructure, and some of the same problems seen in the wastewater system will plague pipes located near sea level. However, it is the wastewater system that is of most significant concern for the Municipality, specifically due to the fact that it is one infrastructure element over which they have complete jurisdiction. It is therefore possible to implement adaptation strategies without requiring the consent or action of some other party.

Governance and Planning

The governance and planning systems of a region are central to developing effective strategies for coping with climate change impacts. Governance drives an organization's ability, whether it be regional, national, or local, to create policy and strategies to mitigate and adapt to climate change impacts. It can be defined as the process by which different societal elements exert power and authority and influence regulations and policies (Ehler, 2003). Governance can also dictate the type of planning and zoning policies that are put in place and ensure effective

enforcement of these policies. In the case of the Municipality, the main societal elements that exert power and influence regulations and policies are the Chester Municipal Council and the constituents of the Municipality, which in of themselves, can be further broken down into important societal groups. Other major players are the Province of Nova Scotia, since they have already created some policy around climate change that may affect the Municipality, and the Federal Government of Canada, who provided the funding for the study. Since it is unlikely and unnecessary for any of these players to change, the key aspect of governance in the Municipality is the current planning policy that they have in place. Since the term vulnerability cannot be applied to policy, an assessment of current planning and policy strategies in place will examine gaps. For this paper, a gap will be defined as a lack or omission of plans or policies that adequately manage projected climate change impacts that may occur.

Current Governance in the Municipality

The study area for this project encompasses parts of three different constituent zones of the Municipality. The three districts are: District 3 (Village of Chester, Chester Commons and Chandler's Cove), District 4 (Chester Basin and Chester Grant) and District 7 (Robinson's Corner, Windsor Road, and Canaan) (Figure 5). The current councillors for these three regions are Mr. Brad Armstrong, Warden Allen Webber and Ms. Sharon Church-Cornelius respectively. Conversations with these individuals helped to better understand some of the priority issues and concerns in their regions.

With respect to the current legislation and planning guidelines in the Municipality, it became obvious early on in this study that the Municipality would be somewhat limited by its ability to implement adaptation options. This is primarily due to the fact that being a municipality, main infrastructure and planning legislation is set by the provincial or in some cases, federal government and as a result, the Municipality does not have control over them. While the Municipal Government Act clearly outlines the responsibilities that a Municipality may have over their city and seems to indicate that the Municipality should have control over their roads (Nova Scotia Department of Housing and Municipal Affairs, 1999), the main roads in the Municipality (Hwy 3 and 103) are considered to be provincial highways and thus remain under the control of the province. Furthermore, the Municipality has made arrangements with the province to allow them to maintain the roads. While these jurisdictional issues may affect some of the ways in which the Municipality can adapt to climate change impacts, it is important to understand that there are some key things the Municipality does have authority over that can greatly mitigate these impacts.

Perhaps the best resource the Municipality has in order to help address climate change impacts is the control over planning and zoning bylaws. Currently, these bylaws do not incorporate any consideration of SLR, storm surge or flooding (G. MacDonald, personal communication, November 10, 2011). There are however, restrictions and zoning areas set up for particular purposes, especially within Chester Village. Areas are zoned based on the type of residence (low density, single unit, central village and estate residential, waterfront), commercial use,

institutional, park and water access (Municipality of the District of Chester, 2010b). The study area for this project consists of a mix of all types of land uses including residential of all sizes, commercial, industrial, recreational and agricultural (Municipality of the District of Chester, 2010c). These types of zoning guidelines will help the Municipality to determine appropriate adaptation measures to cope with the identified vulnerabilities in this study.

Adaptation Strategies

Adaptation can be defined as an action that reduces the negative impacts of climate change or takes advantage of potential new activities (Mehdi, Mrenda, & Douglas, 2006). In the Municipality, many of the adaptation strategies that can be implemented lie within the current governance and planning systems.

Typical approaches for adapting to climate-related coastal hazards include protection, accommodation, or retreat (Lemmen et al., 2008). Protection involves defending vulnerable areas (populated centres, natural resources, economic activities) to reduce the risk of hazards, such as erosion or flooding via physical reinforcement by either "hard" (sea walls, breakwaters, riprap composed of either granite or limestone) or "soft" (nature-based protection such as vegetating dunes, salt marshes, etc.) measures.

Accommodation entails continuing to occupy vulnerable areas while modifying existing practices to minimize the impact of climate-related coastal hazards. For example, construction that involves structures that minimize damage (e.g., building on pylons, vertical zoning) or developing land-use and zoning by-laws

to only allow construction near shore if necessary (*e.g.,* fish plants) and prohibiting private residences (Lemmen et al., 2008). For the Municipality of the District of Chester a couple of recommendations would be to discourage, or prohibit, the infill of wetlands, or promote wetland enhancement (Kosloski, 2008). Also, it might be useful to identify or map flood plains with the purpose of developing flood risk zones that would prevent future construction in these areas.

Retreat is a strategy that can eliminate hazards through avoidance. Examples of retreat tactics include abandoning structures in currently developed areas, only allowing temporary or expandable structures to be built on the coastline, land swapping, implementing zoning by-laws, and legislating setbacks (Lemmen et al., 2008).

Since the Municipality has a lot of new and old buildings, different land uses and zoning bylaws, a recommendation of using a combination of these three types of adaptation strategies is suggested. Given that the Municipality is small and may be concerned about the costs of implementing adaptation strategies, it is important that they consider adopting no-regrets or low-regrets adaptation options. This means that regardless of the likelihood or intensity of climate change impacts, the strategies are not detrimental to the Municipality (Mehdi, Mrenda, & Douglas, 2006).

Aside from the types of adaptation strategies that the Municipality may want to consider, it is also important to determine some guiding principles. One major guiding principle is to ensure that any climate change planning or policy anticipate rather than respond to climate change impacts (Collins, Smith & Allen, 2005). More specifically, this means adopting a proactive rather than a reactive approach to

planning. For the Municipality, since the major impacts of climate change are likely to be flooding and storm surge from increased storm events, it is with policies that relate to zoning and planning where a proactive approach would be beneficial. It is also important to ensure that policies are made flexible and do not constrain future options to variable climate change scenarios (Collins, Smith & Allen, 2005). In other words, if the impacts from climate change effects are more or less severe than originally anticipated, it should be easy to change and adapt to these differences. In association with flexibility within policy, there should also be consideration for whether policies are developed for short, medium or long-term timelines (Collins, Smith & Allen, 2005). Since there is so much uncertainty surrounding the timing and severity of climate change impacts, it is important that planning and policy adapt and fit within the timelines. With these guiding principles in mind, some specific recommendations for adaption strategies for the Municipality can be given.

Coastal Setbacks

As previously mentioned, the Municipality has control over land-use planning and zoning regulations and bylaws and this may be one of their greatest tools for combating the effects of climate change impacts. Land-use planning and zoning can help to address the vulnerabilities in all three of the pillars: biophysical, infrastructure and socioeconomic. The first recommendation is that the Municipality establish coastal setbacks. A coastal setback can be defined as a "buffer space where permanent constructions are not allowed, defined by a specific distance from the shoreline's highest water mark" (Sano et al., 2011, p. 943). The distance of setbacks can be different depending on where they are and can be determined based on soil

type, steepness of shoreline, erosion rate or flood severity (Kosloski, 2008). The distances can either be fixed or not. For example, HRM requires a 30 m horizontal setback from water bodies and a 2.5 m vertical setback from the high water mark in some areas (Graham & Musselman, n.d.). In contrast, regions such as Hawaii and North Carolina develop setbacks based on the annual erosion rate (Graham & Musselman, n.d.). The Maui Planning Commission requires setbacks to be 50 times the annual erosion rate plus 20 feet (Graham & Musselman, n.d.). In the Municipality's Land Use By-Law (1997), within the zone standards for each type of dwelling (*e.g.* Section 6.2.2 for Single Residence Zoning) a minimum elevation above marine mean high water mark and a minimum distance from watercourse are assigned. These numbers could be updated depending on how the Municipality wishes to determine their setback distances and would help to adapt to impacts from storm surge and SLR.

Buffer Zones

Setbacks also have the dual purpose of creating buffer zones, which can both protect infrastructure and citizens from climate change impacts, but can also serve as protection for biophysical resources. Buffer zones are areas that allow the coastal zone to expand or contract naturally (New Brunswick Department of the Environment and Local Government, 2001). For the Municipality, a couple of recommendations would be to establish buffer zones for future developments that would allow the natural inland migration of wetlands and beaches, which would be more cost effective then continuing to build expensive human-engineered protective structures. There are many different ways the Municipality can ensure the

conservation and creation of buffer zones including mapping coastal ecosystems, prioritizing coastal areas for conservation or restoration, protecting key coastal land and coordinating restoration programs with local conservation groups (Government of Nova Scotia, 2011). The Municipality has already taken some steps in preserving wetlands and coastal ecosystems for example, in their land-use planning and zoning maps, they have designated a category for conservation areas (CA) and protected watersheds (PW). Since these zones are relatively sparse throughout the Chester Village and Chester Basin regions, it might be beneficial for the Municipality to reexamine the zones and keep the vulnerable areas identified in this study in mind.

Greenways

In addition to protecting the wetlands and coastal shorelines that already exist, the creation of greenways along roads and sidewalks can help to divert flooding and reduce the severity of climate change impacts. Types of greenways vary but generally, they are defined as a green patch along a recreational trail or road that are designed using trees, soil, or shrubs that can reduce the amount of flooding that will occur in that area (Honguy & Ruhai, 2010). While the Municipality may not have the authority over the maintenance of many of their roads and sidewalks, they do have authority over the land adjacent to these sidewalks and greenways can divert flooding from manmade infrastructure, as well as help to replace coastal habitats that may have been eliminated due to coastal squeeze.

Municipal water system

While the implementation of greenways may be somewhat of an inexpensive and easy fix to some of the Municipality's infrastructure issues, there is one

infrastructure system that will require a much more intensive adaptation effort: the wastewater system. As discussed, the wastewater system in the Municipality is already experiencing overflow and saltwater intrusion and with the projected climate change impacts, it is only expected to get worse. In the medium-term, the Municipality may want to consider relocating pumping stations since they are in highly vulnerable locations along the coast and invest in better overflow protection and backup generators. The Municipality is looking into a public water facility that would require using water from the nearby Spectacle Lake (L. Russell, personal communication, November 10, 2011). This system will likely not be implemented for at least a few years (L. Russell, personal communication, November 10, 2011), but it is strongly recommended that the Municipality pursue this effort. It would create a more secure water source for residents and eliminate their dependence on the current well systems. While all these adaptation strategies are costly, implementing them gradually and over a number of years may help the Municipality to better cope with the cost, but still allow for effective management of what may be severe impacts to their water system.

In the short-term, implementing policy or regulations that enforce the use of water-saving devices such as low-flush toilets and taps, and rainwater barrels can help to reduce the stress that is placed on the current water system. Reducing the amount of pressure placed on the system may allow for repairs and upgrades to be completed in a more reasonable time frame (Land Use Consultants et al., 2006).

Education and awareness

As mentioned, the Municipality's population has a high proportion of retirees and seasonal residents. Since the population fluctuates with the seasons and new residents are often moving into the Municipality, increasing education and awareness about possible climate change impacts and what to do in the case of severe storm events is important. The Municipality already has some flyers that let citizens know what actions they should take should they be affected by flooding (Municipality of the District of Chester, 2010d). This is a great first step. A recommendation would be to further increase education and awareness perhaps by creating more flyers about other climate change impacts or holding workshops so that people can better understand what action they might need to take should a severe storm occur.

Holding workshops would create a mechanism where Chester residents can come face to face with each other and build a stronger sense of community. Research has shown that strong bonds can actually increase a community's resiliency should an extreme climate change event occur (Beatley, 2009). While there is no doubt that the Municipality is already a strong community, it may be necessary to further increase this bond within seasonal residents and between retirees and permanent residents. One way of doing this may be to set up a community-monitoring network. Communities could map out their neighbourhoods and take note of any changes they may see with respect to climate change impact events (Beatley, 2009), taking particularly notice of the vulnerable areas that were

identified in this study. They may also be able to look out for the homes of seasonal residences and notify them should any damage occur.

Insurance and taxes

Insurance and taxes can be an effective method to deter or encourage actions that may reduce the impacts of climate change. While commercial businesses are not under the jurisdiction of the Municipality, tax incentives could be offered to encourage businesses to implement adaptation methods to reduce their vulnerability. As commercial businesses are important to attract additional residents and tourists, it is in the interest of the Municipality to have stable businesses in the community. The Municipality may also want to be aware of programs offered by the Province or Federal governments. Often, there are options for smart-growth incentive programs or tax credits for renovation or adaptation efforts (Beatley, 2009).

The role of insurance can either help or hinder socioeconomic and infrastructural problems that may occur from impacts of climate change. The Disaster Financial Assistance Arrangement (DFAA) is a fund administered by the Federal Government of Canada that is provided to provinces and territories across the country who then can distribute and manage the funds through their own programs (NRTEE, 2010). This fund may be beneficial because it can help to provide insurance to municipalities that may experience an extreme event and may not be covered under regular Canadian insurance (NRTEE, 2010). The problem however, is that it can also create a false sense of security and encourage homeowners to build in flood prone areas because they know they will be insured by the Federal

Government should a disaster occur (NRTEE, 2010). The Municipality may want to consider this and either enforce the zoning by-laws to ensure residents do not build close to the coast or reassess their involvement in the DFAA. These recommendations are all of course political and could be contentious; therefore, it is important the Municipality act in a way that provides the greatest benefits, while still remaining manageable.

Conclusion

The climate is changing and will result in numerous and varied impacts across the country. The Municipality will experience increased SLR and severe storm events in the future, resulting in flooding, erosion, and heavy precipitation. Permanent flooding from SLR is not the main concern, but temporary flooding from storm surge and erosion are major priorities that should be factored into future planning and development. It is important to note, that while these changes will occur, their impacts will not be immediate. As a result, the Municipality has time to implement adaptation strategies, but in order to ensure a proactive approach, planning should begin now. Using a combination of adaptation strategies can result in a 96 to 97 percent reduction in costs of cumulative damages that could occur without adaptation to climate change (NRTEE, 2011).

While most climate change impacts addressed in this study result in negative consequences, it is important to note that there may be positive outcomes such as reduced snowfall and warmer temperatures. This may lead to reduced snow removal costs and a longer tourism season (NRTEE, 2010). Ultimately, the impacts

of climate change are uncertain but through the identification of vulnerable areas, as noted in this study, the Municipality is well on its way to developing a comprehensive approach to adapting to climate change.

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Tables

Table 1. Summary of the biophysical impacts from forces such as relative sea level rise (SLR), storm surges, changes in temperature and precipitation patterns, and wind activity.

Impacts	Forces				
	Relative sea level rise	Storm surge	Temperature changes	Precipitation changes	Wind activity
Flooding	✓	✓		✓	
Coastal erosion	✓	✓		✓	✓
Saltwater intrusion	✓	✓		✓	
Beach migration	✓	✓		✓	
Wetland migration	✓	✓		✓	
Shoreline Migration	✓	✓		✓	
Loss of habitat	✓	✓	✓	✓	✓
Loss of biodiversity	✓		✓		
Shift in species assemblages	✓		✓	✓	

Figures

Figure 1. Study area from Chester Basin to Chester Village. The 10 metre (m) contour is highlighted in red.

Figure 2. Study area from Chester Basin to Chester Village. The zone from sea level (0 m) to 5 m depicted in red is an area at risk of inundation from climate change impacts including flooding, SLR and storm surge. The area from 5 m to 10 m depicted in yellow is an area that could be impacted by periodic flooding from storm surge and intense storm activity. The area beyond 10 m elevation is deemed to be at low risk.

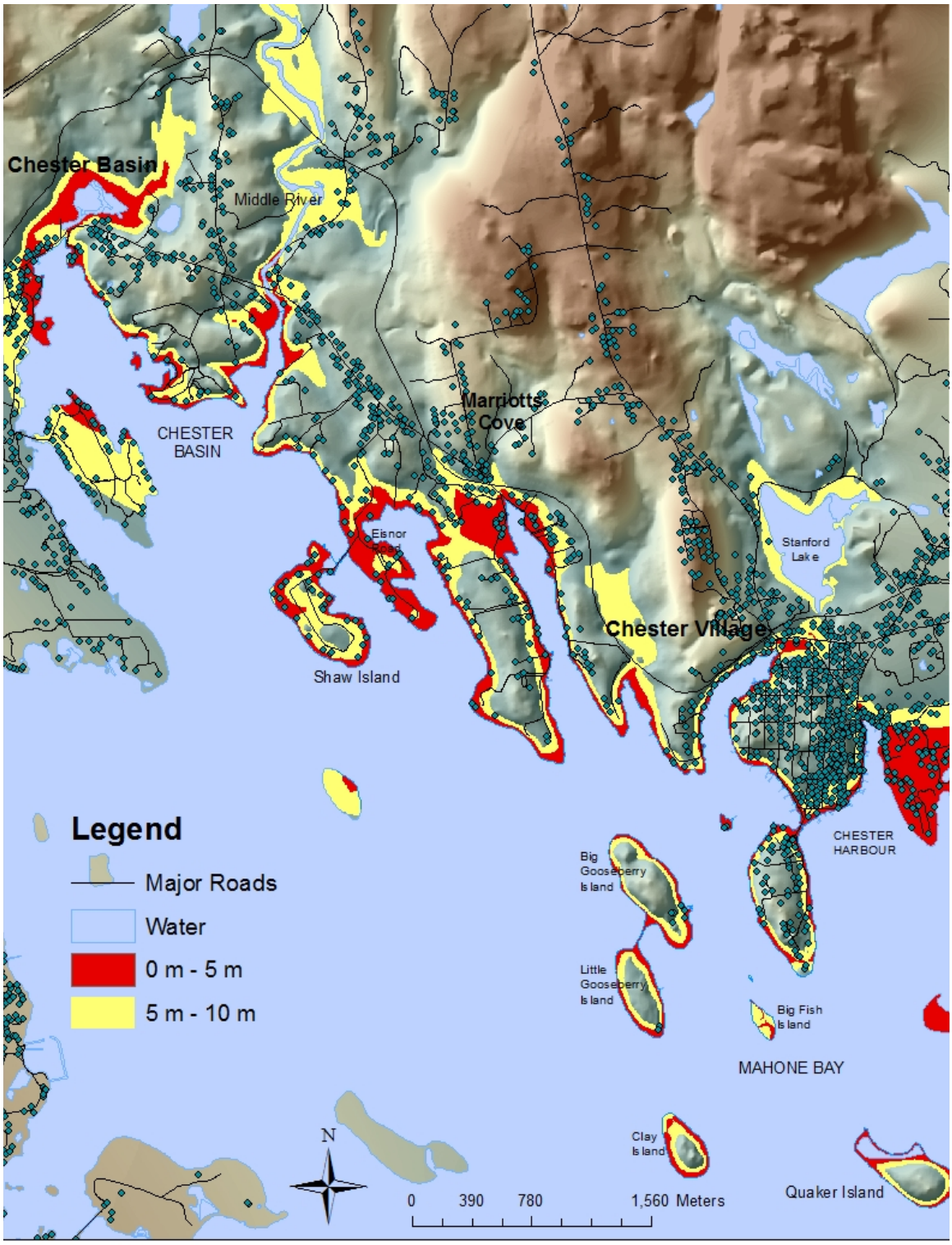

Figure 3. Study area from Chester Basin to Chester Village. The zone from sea level (0 m) to 5 m depicted in red is an area at risk of inundation from flooding, SLR and storm surge. The area from 5 m to 10 m depicted in yellow is an area that could be impacted by periodic flooding from storm surge and intense storm activity. The buildings are represented by the green circles.

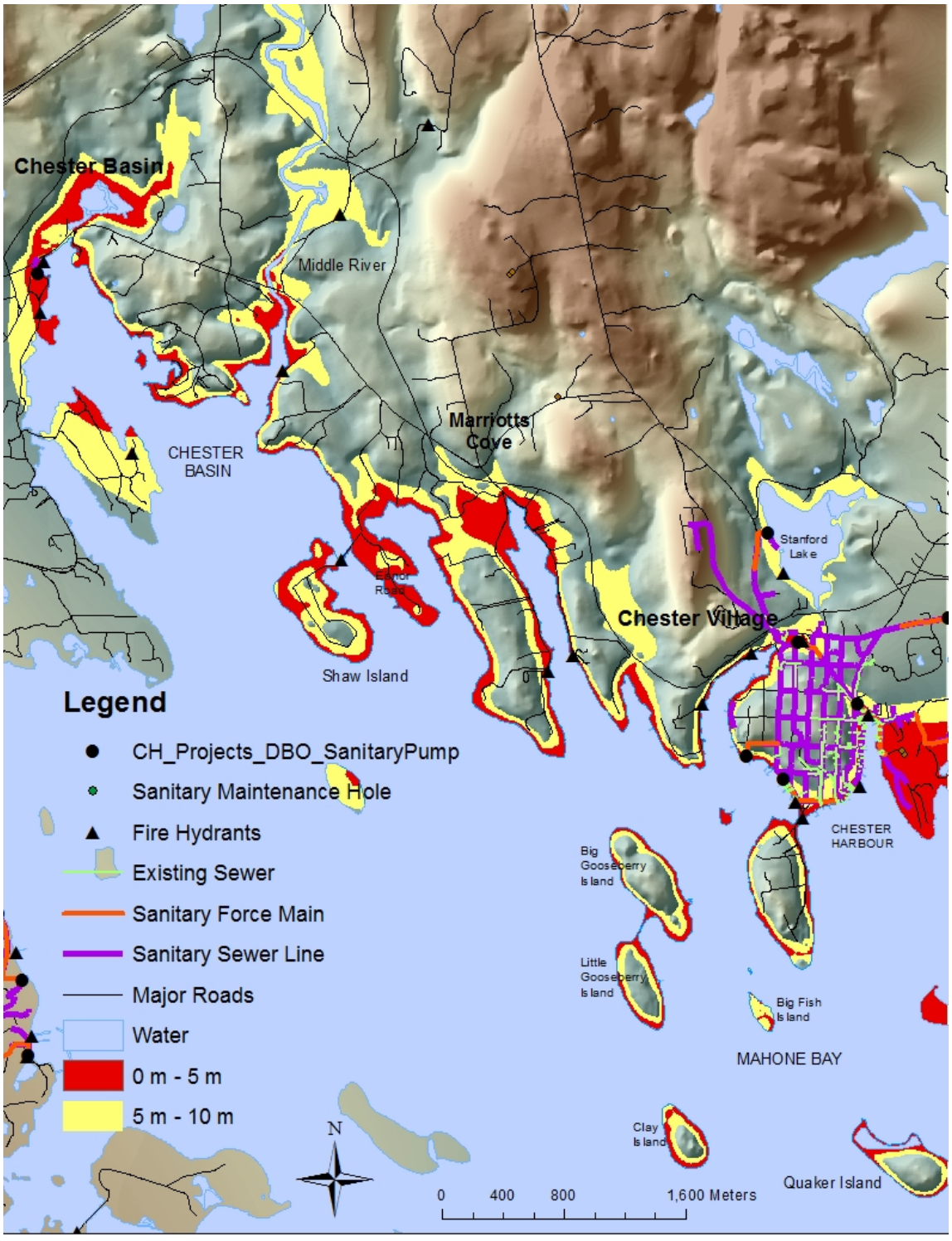

Figure 4. Study area from Chester Basin to Chester Village. The zone from sea level (0 m) to 5 m depicted in red is an area at risk of inundation from flooding, SLR and storm surge. The area from 5 m to 10 m depicted in yellow is an area that could be impacted by periodic flooding from storm surge and intense storm activity. Important infrastructure is highlighted.

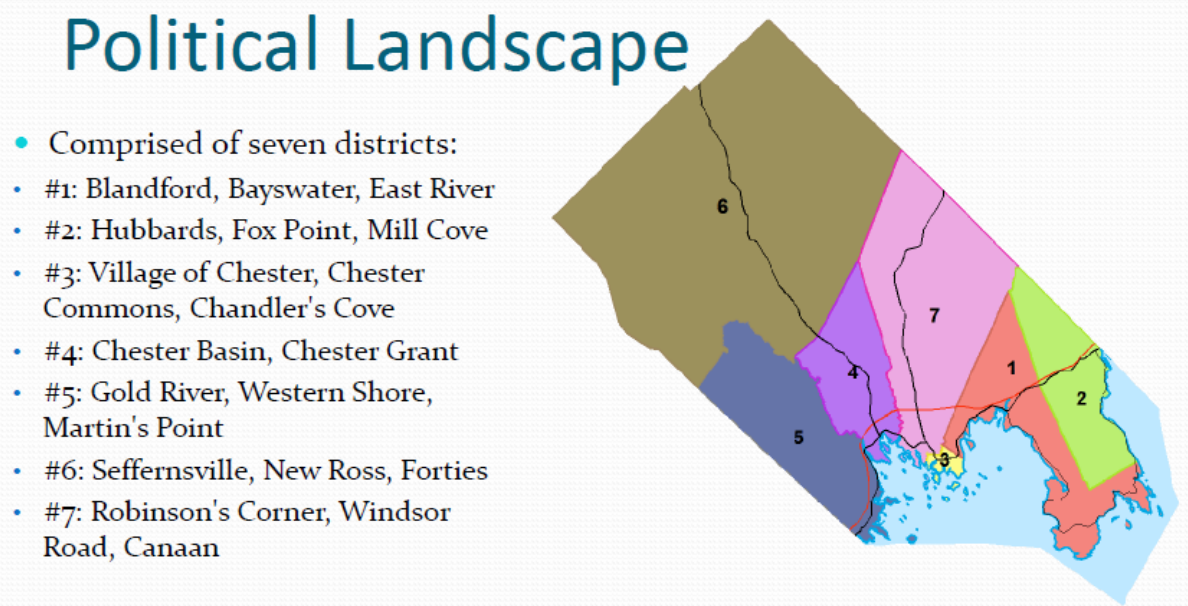

Figure 5. District boundaries for the District of the Municipality of Chester (adapted from T. Maguire, personal communication, September 9, 2011).

Appendix I – PESTLE Analysis

Chester Project - Group B - PESTLE Analysis
Submitted by: Sarah Deller, Hilary Goodwin, Tim Hayman and Amy Ryan

Introduction

The purpose of the study is to assess vulnerabilities of a coastal community, the Municipality of the District of Chester (herein referred to as "the Municipality") to the effects of sea level rise due to climate change. Coastal inhabitants will likely be the most impacted by a 1 to 2 m rise in sea level. Coupled with a 2 m storm surge, the impacts of sea level rise could be devastating. The best strategy to cope with the potential impacts of climate change right now is by implementing adaptation strategies. The purpose of adaptation is to reduce vulnerability, or enhance resilience, to climate change (Adger et al. 2009). The success of this strategy can be limited by political, economic, social, technological, legal and environmental (PESTLE) factors. The following is a PESTLE analysis examining the potential factors that could affect the implementation of an adaptation strategy.

Political Factors

The political considerations for this study come from both the municipal and provincial level. The political forces include: budget, political priorities, cohesiveness between political regions and the governance system.

As an adaptation plan for sea level rise begins to develop, it would be useful to know if there is a budget for the plan, how much it might be, and its priority level. The budget would affect the extent to which the adaptation plan might be implemented and may indicate that a phased or scaled-back approach would be necessary. It would be good to know where this study lies on the list of provincial and municipal priorities. It is important to realize however that even if it is not a top priority, full effort should be put toward the study and will help to manage expectations for all involved.

Another force that may have an impact on the Municipality's development of a sea level rise adaptation plan is the fact that the Municipality is divided up into several districts. For example, our study area includes coastline in both District #3 (Village of Chester, Chester Commons, Chandler's Cove) and District #7 (Robinson's Corner, Windsor Road, Canaan) and as a result, there are different councilors representing these regions (Municipality of the District of Chester, 2009). It is possible that different districts may have varying priorities or opinions. In order to mitigate problems that may arise from these differences, it is important to have clear communication between the City Council and residents of Chester. This aspect should be considered throughout the process. Communication should also be maintained between the municipality and provincial government to ensure there are no shifts in priorities, budget, or guidelines.

Lastly, it is important to understand the governance within the municipality and provincial government. Roles and responsibilities need to be clearly outlined in order to ensure that the appropriate people are involved in both the development and implementation of this study. It should also be clear as to whether the plan will require policy, binding legislation and/or additional regulations.

Economic Considerations

Economic considerations in the Municipality concern the seasonal residents, increase in housing prices, the disparity in demographics, and the concentration of jobs in industry and retiree services. The Municipality is home to 11,000 permanent residents (Maguire, 2011) but there is a considerable influx of seasonal residents in the summer. In turn, the Municipality partially relies economically on the additional revenue obtained from property taxes and money spent on needed goods by these seasonal residents. The income gap is a social concern in Chester between the seasonal residents and the permanent residents (Institute for Planning and Design, 2009). The Integrated Sustainability Plan (ICSP) noted that tourism is on the decline, partially due to the lack of restaurants and hotels in Chester (Institute for Planning and Design, 2009). The Municipality should consider ways to increase the services necessary to support the tourist industry, which would increase revenue for the town. While planning possible new infrastructure, the Municipality should consider the impacts of sea level rise when zoning new developments or businesses.

The demographics of Chester include an aging population and modestly growing population, due to an increase in retirees.. There are economic considerations with an aging population because they are no longer contributing to income tax revenue; 20.2 percent of Chester's population is under age 20 while 18.6 percent of the population are over age 65 (Maguire, 2011). One challenge the Municipality will face in the future is to try and retain the younger people in the town, and jobs are essential to attract younger adults to the town of Chester.

The median family income of permanent residents in Chester is $53,495 which is slightly less than the $55,512 median income of Nova Scotia (Maguire, 2011). The lower family income presents a challenge to residents of Chester as the cost of dwellings in the area increases. Between 1996 and 2006, the average value of dwellings increased 174.3 percent, from $208, 662 to $325, 096 (Maguire, 2011). While this increase in value would be beneficial to those homeowners that wish to sell their property, the increased cost is a negative point to those permanent residents who are earning a median income and cannot afford to buy a house. Additionally, the younger residents may be deterred from living in the Municipality if they do not think they can afford a house to raise a future family in or a basic apartment to initially live in. The ICSP also indicated that developers in Chester are not required to offer subsidized housing, which is an equity concern (Institute for Planning and Design, 2009). Another equity concern is that the wealthier residents will have more disposable income to adapt their properties to sea level rise than residents or businesses with less disposable income.

From observing the town of Chester, one can see that the village is primarily residential and that retail businesses do not dominate the town. Economically, it is a concern if the town cannot bring in additional business, jobs and services. The

Chester Municipal Plan mentions that the municipality intends to preserve the residential feeling of the town, which is stated in their by-laws (Maguire, 2011). While the desire to keep out high density buildings like apartment buildings and condos does help to preserve the beauty of Chester, it could mean potentially losing residents who cannot afford the more expensive homes.

According to the ICSP, the primary employers in the Municipality are Louisiana Pacific, GN Plastics and Shoreham Village. Louisiana Pacific primarily manufactures building materials (LP Building Corp, 2011), GN Plastics manufactures thermoforming machines for the plastics industry (GN Plastics, 2011), and Shoreham Village is a seniors complex (Shoreham Village, 2011). These three employers indicate that the industry focus in the Municipality is on manufacturing and services for retirees. As the cost of fuel rises, the manufacturing industry in the Municipality could be affected (Institute for Planning and Design, 2009). The collapse of the fisheries industry in Nova Scotia affected the Municipality and there are now fewer fishermen, but the landings they target such as lobster and scallop, are of more value (Institute for Planning and Design, 2009). The ICSP stated that hardwood supplies are underexploited in Nova Scotia and this industry has the potential to be further developed in the Municipality in order to add more jobs and revenue to the town (Institute for Planning and Design, 2009). Climate change could further impact these industries, in particular if the infrastructure for these companies is located along the coast. If employees move due to the rising cost of housing costs, it could also result in a loss of personnel for the companies.

The construction of Highway 103 has connected the South Shore with larger cities like Halifax, and has had a positive economic impact on the South Shore towns such as Chester (Institute for Planning and Design, 2009). In the future, it looks like the town of Chester will continue to attract residents who are retirees and commuters to Halifax. However, climate change could negatively impact the property values if proper precautions are not made by the Municipality and its residents.

Social Considerations

The social forces that influence the Municipality were identified as demographics (population growth, age distribution, seasonal residents), health and safety (access to emergency services, communication, infrastructure), financial resources (affluence, cost of living, affordable housing), education, and employment. Many people appear to have a laissez-faire attitude concerning climate change and do not think long-term with regards to property development (Geoff MacDonald, Planning Director for the Municipality of the District of Chester, Personal Communication, 2011). This attitude is likely driven by age distribution and lack of knowledge, or education, of climate change impacts. Age can influence individual perception of risk and occasionally older generations think that climate change will not impact them in their lifetime. At the other end of the spectrum, the younger generation might think that if they are leaving anyway, then they will not be impacted. Education then becomes an important force for improving knowledge and encouraging acceptance and buy-in to the idea of climate change. A large percentage of the population has less than a high school diploma and less than half of the population has post-secondary education (Nova Scotia Community Counts, 2006).

Wealth was identified as a significant driver of the Municipality as demonstrated by the clear separation between rich, poor, and middle class (Institute for Planning and Design, 2009). The most densely populated areas are along the coast providing an attractive area for affluent people. Many the homes have been developed either near, or less than, 1 m above high tide, making them more vulnerable to the impacts of sea level rise and perhaps more likely to protect their property and assets regardless of the cost of implementation.

Health and safety are important forces because people tend to respond to issues, risks, or concerns that they consider personally relevant. In the Municipality the level of healthcare is increasing because of the ageing population and emergency services are already strained in the area because they are highly dependent on volunteers (ICSP, 2009). Impacts of sea level rise pose increased health and safety risks in the form of emergency and communication system shutdown. Also, most people rely on wells for water. Sea level rise can lead to saltwater intrusion into the well water, which can lead to health risks.

The social forces most crucial to the successful implementation of a climate change adaptation strategy will likely be wealth, individual perception of risk, and education. The values that society places on items like property, access to the coast, infrastructure, and health and safety will likely reflect the cost and affordability of protecting and maintaining these things in the face of sea level rise. Age, wealth, lack of knowledge, and level of education can influence individual perception of risk. Education about the impacts of climate change will therefore be one of the most crucial parts of a strong adaptation plan. A society's adaptive capacity is partly determined by its capacity for learning (Adger et al. 2009).

Technological Considerations

The technological forces acting on the Municipality consist primarily of infrastructure considerations. In addition to a great deal of residential and commercial physical infrastructure near the coast, important Municipal infrastructure such as sewage treatment facilities are located in potentially vulnerable areas. There have already been problems with the breaks in sewage lines as a result of tidal action, and with sea level rise, this is likely to become a more persistent problem, permeating progressively farther inland (Geoff MacDonald, Personal Communication, 2011). If the population of the municipality continues to grow, there will be an increased demand placed on the sewage system, requiring expansions to capacity. Increased sewage treatment requirements, as well as the possibility of a water treatment and distribution system for the village of Chester in the future, are a critical requirement for the population, and must therefore be accounted for when planning any use of the coastal region, and when assessing coastal vulnerabilities.

With the potential for more frequent, and more extreme weather events stemming from climate change (refer to "Environmental" factors), the maintenance of adequate emergency services will become an important technological factor. Emergency services require effective communication lines, reliable transportation links, and a comprehensive plan for evacuations and allocation of services (Chen et al., 2005). In order to effectively orchestrate an emergency response plan, there

must be a thorough understanding of the areas of highest potential vulnerability in a severe event, and consideration of several key questions, including: who is there, how can they be accessed, what sort of assistance will they likely require, how can it be provided, and where will they go?

For emergency services to operate effectively, roads must be adequately maintained, and transportation routes must provide access to all areas of the municipality. In the case of extreme storm events, coastal roads may be damaged or rendered inaccessible, especially at vulnerable points such as causeways and low bridges. It is important then to evaluate which important transport links are susceptible to such damage, and ensure that alternative routes exist to reach destinations within the Municipality. This is valuable to consider for transportation concerns outside of the emergency services as well.

Legal Considerations

Legal forces may not be major driving influences for this study, however we still believe they are important to mention particularly because of the close link to political forces. The legal forces include: disputes between planners and developers, property law, compensation, insurance claims and the role of policy within a provincial and possibly national sea level rise management plan.

Part of the analysis of vulnerable areas along the coastline of the Municipality may require an evaluation of coastal development strategies from the past in order to make recommendations for the future. Often times, the perception has been that coastal development in vulnerable areas is an issue for the developer and not the planner (Lee, 1993). While this idea has shifted since sea level rise has become more apparent (Lee, 1993), it is possible caution may be needed when criticizing previous development strategies. In an extreme case, if effects of sea level rise on a particular coastal development in the Municipality seem quite severe, individuals may want to take legal action against developers or planners but hopefully this can be avoided.

Property law, compensation and insurance claims may not have immediate implications to this study but they may be forces that affect the municipality's development of an adaptation plan. It is important to understand what rights property owners have with respect to these issues. For example, if a resident is at risk of losing their property due to sea level rise, considerations will need to be given as to whether or not they would have a legal case under property law, if they are eligible for compensation and how much, and whether or not insurance companies will cover damages or complete loss of property. These considerations will not drive this particular study, but are important to understand since increased insurance rates and property taxes may deter residents from staying in the Municipality, further contributing to the problem of retaining the Chester population identified in the ICSP (Municipality of the District of Chester, 2009, p.8).

Lastly, since this study is to be part of the Climate Change Adaptation Plan required by the Province of Nova Scotia, a good understanding of how this plan fits within the province's plans and policies is needed. The Municipality should be clear on whether or not the adaptation plan is legally binding and understand the implications of such a policy.

Environmental Considerations

The most significant environmental force acting on the Municipality is climate change, especially considering that the present objective is to assess specific vulnerabilities to sea level rise. Sea levels are expected to rise by as much as 2 m over the next century, posing a particular threat to coastal communities (Allison et al., 2009). Much of the population of the Municipality lies in close proximity to the coast, as well as notable infrastructure such as sewage treatment facilities, roads, bridges and causeways (Geoff MacDonald, Personal Communication, 2011). This coastal infrastructure stands to be threatened directly by encroaching sea levels in the future. Higher sea levels will result in coastal flooding, but will also lead to greater devastation as the result of storm surges in extreme weather events (Michener et al., 1997).

Along with increasing sea levels, climate change is expected to contribute to more frequent and more severe storm events (Meehl et al., 2000). In 2003, Hurricane Juan demonstrated the extent to which coastal areas in Nova Scotia can be affected by extreme storms of tropical origin (Fogarty et al., 2003). If the frequency of these storms were to increase, and were to be coupled with higher sea levels that exacerbate the effects of storm surges, coastal regions such as Chester could be severely affected on a regular basis. These factors alone make climate change a critical environmental force to consider.

The composition of the coastal geology also plays a key role in defining several environmental factors. Coastal erosion is a serious concern in areas of soft sedimentary rock such as slate, and may be a particular concern to much of the Municipality where the predominant rock type is slate (Geoff MacDonald, Personal Communication, 2011). Coastal erosion processes may be further accelerated by climate change effects, and can dramatically alter the coastline, causing concerns for beaches (especially when they are bounded by roads and cannot recede in a natural progression), salt marshes, and coastal infrastructure such as roads, causeways, and buildings (Zhang et al., 2004).

Groundwater wells form the basis of the drinking water supply for Chester, so the issue of saltwater intrusion into groundwater supplies may become of particular importance. Saltwater intrusion refers to the process by which seawater infiltrates into freshwater aquifers, resulting in groundwater that is not fit for human consumption. This is only a problem in coastal regions, and is largely influenced by the composition of the coastal geology, the proximity of wells to the coast, the depth of these wells, and the rate of pumping (Cummings, 1971). All of these factors will need to be considered for the particular regions of the Municipality where aquifers are located, to assess how vulnerable these may be to saltwater intrusion now, and in the future.

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Appendix II – Research Ethics Checklist

MARA 5005: RESEARCH ETHICS CHECKLIST

Due Monday, September 30, 2011

One assignment submitted per group via email and hard copy to Course Instructor, copied to the TA.

- **Please submit the document as a Microsoft Office document.**
- FILE NAMING CONVENTION: ie. MARA5005G#_Research Ethics Checklist.doc
  - MARA 5005= course id
  - G#= Group number 1, 2, 3 or 4

MARA5005 Group Members: Sarah Deller, Hilary Goodwin, Tim Hayman, Amy Ryan	**Name of Host Organization: Municipality of the District of Chester**

Overview of proposed project methods (please identify whether or not you will be conducting research with human participants and what methods you will use to capture information – survey, focus group, interviews, etc.)

We plan on conducting interviews with residents of Chester to determine how they perceive the impacts of sea level rise and to get a better sense of vulnerability and perception of risk. Interviewees will be chosen based on proximity to vulnerable areas that will be identified in the first half of our study.

	YES	**NO**	**Details**
Will prospective participants in your study / project be provided with a clear and easily understood Letter of Information and be asked to sign a written consent form before their involvement in your study? *(If No, indicate that respondents are adults and that you will have passive consent - through cover letter or the fact that they are filling in a survey)*		X	The respondents will be adult participants that have given passive consent.
Will the participants be told that they can discontinue their participation in the study at any time?	X		
Will any form of pressure or inducement be exerted upon participants to get them to participate in your study / project?		X	
Will the researcher and/or associates be in a position of power vis-a-vis the participants (ie. employer- employee, teacher-student, dominant / marginal race or culture)?		X	
Will it be clear to the participants in your study / project that they are subjects of investigation?	X		
Will it be clear to prospective participants that their participation is voluntary?	X		
Will prospective participants be given the opportunity to discuss and think over their participation in this study / project?	X		

Will the study / project involve participants who may not be in a position to give their valid consent to participate (ie. young children, people with development disabilities, etc.)		X	
Will the study / project involve participants for whom consent to participate in the research project is not meaningful in the context of their cultural background?		X	
Will the participants in the study / project identify themselves by name or by other means that will allow you to match data to specific participants?		X	The researchers will know the identity of the interviewees, but personal information will not be reported.
Will the confidentiality of the participants identify be protected	X		
Will the study / project involve the use of the identifying information about the participant from any other study / project or resource?		X	
Will information about the participants be obtained from sources other than the participants themselves?		X	
Could publication of the research results allow participants to be identified?		X	
In case there is a possibility that the participant's identity can be deduced by anyone other than the researcher, will the participant be able to withdraw his or her data from the study / project?	X		
Will the study / project involve the deception of the participants? For example, will information be withheld from the participant or will they be misled about the data collected, the purpose of the study / project, the responsibilities of the participants, or other features of the study / project?		X	
Will the study / project involve any foreseeable physical risk, discomfort or inconvenience to the participant?		X	
Will the study / project involve any foreseeable psychological, economic or social risk or discomfort to the participant?		X	
Will the physical safety of the participants by protected?	X		
Will the participants in the study / project be given feedback regarding the results of the study / project?		X	Feedback will not be given unless requested.
Will the full nature of the research be disclosed to the participant at the end of their participation?	X		

Appendix III – Briefing Notes

Briefing Note #1 to the Municipality of the District of Chester
Team B - Chester Basin to Chester
Submitted by: Sarah Deller, Hilary Goodwin, Tim Hayman, Amy Ryan

Subject: Addressing sea level rise impacts and identifying vulnerabilities for our study region.

Background: As of September 30th, our team has met on three occasions and have had one visit to Chester for a preliminary overview and meeting with planners. Based on our visit to Chester, we have identified key issues to consider when assessing vulnerabilities to sea level rise for our study region. These include but are not limited to infrastructure (sewers, roads, water supply, causeways), dwellings, and emergency services.

We have designated Sarah Deller as the point of contact for communications between our group and the Chester Municipal Council. We have assigned a member of our team to each of the four impact and adaptation issues. Biophysical, socio-economic, governance/planning, and infrastructure issues will be examined by Amy Ryan, Hilary Goodwin, Sarah Deller and Tim Hayman respectively. We have completed our workplan, PESTLE analysis and research checklist with possible interview questions.

Work Plan Summary: Our methods for this study include working with GIS to develop a map that identifies some of the components that we believe will affect our study area. Our plan is to create a map showing projected sea level rise. Once we have created these GIS maps we plan to compile the layers to identify the vulnerable areas in our study region. Once we have identified the vulnerable areas, we will conduct interviews with the individuals, communities, and business owners that stand to be affected most by sea level rise. We will conduct these interviews and visit these sites to help prioritize the vulnerable areas and create recommendations for adaptation plans. We have designated times for weekly meetings and plan on making at least one more trip to Chester. We have established goals and developed check points that coincide with the timing of our briefing note submissions which will ensure that we stay on track. It is important to note that this work plan is tentative.

We will be focusing our study near the coastline of our designated region, with primary consideration placed on the densely populated and potentially more vulnerable area between Highway 3 and the coast. We will adjust the specific scope of our study area as we progress to ensure that the areas of greatest vulnerability are sufficiently addressed.

Next Steps: Between the submission of this Briefing Note and Briefing Note #2, we plan to obtain the GIS data from the Municipality of Chester and begin the creation

of the map. Upon completion of the map we will have a better idea of the people or businesses that would be more vulnerable to sea level rise, which will help us to narrow down our list of interviewees. We will look to the municipality as needed for contact information and suggestions.

Marine Affairs Program
Dalhousie University
October 28, 2011

Briefing Note 2:

Group B – Chester Basin to Chester

Sarah Deller, Hilary Goodwin, Tim Hayman, Amy Ryan

Attention: Ms. Tara Maguire - Municipality of the District of Chester

Subject: An update on the progress of Group B as we evaluate the climate change effects and possible adaptation methods for the region of Chester Basin to Chester.

Background:

As of October 28th, 2011, our group has had four meetings since the submission of our first briefing note. We also had a meeting with the whole class where we established a common scope so that when we present to the Municipality of the District of Chester in December, we all present a consistent scope. As a class group, we also met to clarify the goal of our project and ensure we are all moving in the same direction. Each of our team members has begun preliminary research of the four topic areas: biophysical, socio-economic, governance/planning, and infrastructure. We have developed a table of contents and outline for our final paper and designated tasks and set deadlines based on our work plan. We have obtained GIS data for our area but it is topographical information only, therefore, we still require additional data. We have identified the city councillors for our region (Brad Armstrong and Sharon Church-Cornelius) and we plan on contacting them between now and the submission of Briefing Note #3 to better understand the important

issues and concerns for our region. Lastly, we have set a date for our group to visit Chester to explore the coastline (November 5th) and will be sending representatives from our group to the large group visit to Chester on November 10th.

Issues and Analysis:

Some of the issues that we have encountered include a delay in obtaining access to the GIS data that is necessary for our vulnerability assessment. Therefore, our data collection process is taking longer than we had initially anticipated. Although we are still working in our individual groups to collect the data, the class is now working cooperatively in terms of our scope. We collectively decided that this would facilitate the final compilation of each group's data for the final report to the Municipality. In order to do this, we have developed a community database via Dropbox to encourage information sharing among the class. Finally, as a group we have decided to reconsider our interview process.

Recommendations:

Our group has assigned different writing tasks from the introduction section of our report with the goal of drafting text by November 4th. On October 24th, we created our first GIS maps using various data such as contour information and property locations obtained from the Dalhousie GIS Centre. We plan to search for additional data sets from places such as Service Nova Scotia Land Use Planning website. We are concerned with the delay in obtaining GIS data from the Municipality of Chester. We need this data in order to help us identify the vulnerabilities in our study area. Ideally, we would like to map more detailed information before our planned trips to Chester on November 5th and November 10th. The mapped data will help us to identify vulnerabilities and help to direct us where to concentrate our time during our November 5th trip to Chester. We intend to contact Ms. Maguire before the November 10th trip to specifically request to contact councillors, Brad Armstrong and Sharon Church-Cornelius, before we meet with them in person. Before November 10th, we will narrow down our interview questions and plan to restrict the number of interviewees.

Marine Affairs Program
Dalhousie University
November 25, 2011

Briefing Note:

Group B – Chester Basin to Chester

Sarah Deller, Hilary Goodwin, Tim Hayman, Amy Ryan

Attention: Ms. Tara Maguire - Municipality of the District of Chester

Subject: An update on the progress of Group B as we evaluate the climate change effects and possible adaptation methods for the region of Chester Basin to Chester.

Background:

On November 5th, our group traveled to Chester and drove along the coastline of our area, to help us identify potential vulnerabilities. We thoroughly examined coastal housing, low-lying roads, causeways, bridges, and the location of wells and other features of interest. We made extensive written and photo documentation of coastal features to aid in our subsequent analysis. We also reviewed the fly-over video to identify coastal issues we could not access by car. In addition to this visit, our class traveled to Chester on November 10th and met with the councillors for the two districts within our region (Brad Armstrong & Sharon Church-Cornelius), as well as Geoff MacDonald (Planning Director), Lyle Russell (Assistant Engineer, Public Works), and two representatives from the Regional Emergency Management Organization. Through our conversations with these individuals, we were able to accumulate useful information on a variety of subjects and were able to have many of our outstanding questions addressed. Our discussion with the councillors from Districts 3 and 7 allowed us to better identify key issues within these districts. Using GIS data obtained from the Municipality and the Dalhousie GIS Centre, we have created several GIS maps of the area, showing projected sea level rise, the projected areas of impact, and the location of buildings, roads, and other significant features. These maps, along with our research, have allowed us to identify vulnerable areas, and we have started to determine potential adaptation strategies through a review of relevant literature.

Issues and Analysis:

We made a change to our work plan and decided to forego public citizen interviews. The main reason for this decision is that we discovered that much of the information we would be hoping to receive from the residents of Chester could be found in the ICSP report. Further, we were able to identify priority issues in our two districts from conversations with the councillors. Public citizen interviews would only serve to give us an idea of whether Chester residents are aware of climate change effects, and ultimately, this would not have an impact on the recommendations in our study. The second issue we need to keep in mind as we develop our adaptation plan is that the GIS data are not as accurate as LIDAR and therefore, we cannot assume that the projected sea level rise is accurate, but it does help to provide a general overview of the most vulnerable areas. Devoting time to this project has also become increasingly difficult given that it is the end of the term and there are four different individuals' schedules to consider. Sticking to our work plan is helping and we do not feel that there have been any major problems yet. The last major issue we have encountered is difficulty with obtaining comprehensive property values for Chester. The Land Registration office requires registration in order to acquire access to their online database and there is a significant fee associated with its use. Property values are needed in order to determine the economic impacts that climate change effects may have on the Municipality of the District of Chester.

Recommendations:

We have contacted Jennifer Graham from the Ecology Action Centre, as suggested by Councillor Brad Armstrong, to obtain information related to her interviews of citizens in the community to determine their views on coastal issues, in addition to obtaining any relevant information on the NS Coastal Strategy and Chester. In order to determine property values, we can utilize the Property Valuation Services Corporation website to look up exact locations that are identified as vulnerable. Our next step is to develop our presentation for the Municipality of the District of Chester on December 8th. We have created an outline for our presentation and will incorporate photographs of our section to give a better image of the vulnerabilities. Concurrently, our team will focus on writing our report as outlined in our table of contents. We will work together on creating a comprehensive table of climate change issues, impacts, adaptive options and also discuss the utility of these adaptive options on our four pillars: biophysical, socioeconomic, policy/governance, and infrastructure.

Appendix IV – Workplan

Chester Project Work Plan

Team Name
Team Members Sarah Deller Hilary Goodwin Tim Hayman Amy Ryan
Final Report Due Date 16/12/2011
Start Date 20/09/2011

Task/Activity	Details/Description	Start Date	Deadline	Effort (hrs)	Date Completed	Comments/Issues	Lead
Pre-orientatin Meeting (meeting 1)	Brainstorm relevant factors for each level of PESTLE and determine who will research each level				20/09/2011		Everyone
Chester Orientation	Drive coast of Chester. Meet with key staff.				23/09/2011		Everyone
Post-orientation Meeting	Assign duties, prepare work plan, prepare interview quest., complete research ethics checklist, decide on communications person			4	25/09/2011		Everyone
Weekly meeting 1	As a group decided that we will not meet and just post PESTLE analysis on Google Docs for editting				28/09/2011		Everyone
Assign roles	Biophysical	25/09/2011	27/09/2011		27/09/2011		Amy
	Socio-economic	25/09/2011	27/09/2011		27/09/2011		Hilary
	Governance/planning	25/09/2011	27/09/2011		27/09/2011		Sarah
	Infrastructure	25/09/2011	27/09/2011		27/09/2011		Tim
Draft interview questionnaire		25/09/2011	29/09/2011		29/09/2011		Everyone
PESTLE Analysis	Research P & L		28/09/2011		28/09/2011		Sarah
PESTLE Analysis	Research E		28/09/2011		28/09/2011		Hilary
PESTLE Analysis	Research S		28/09/2011		28/09/2011		Amy
PESTLE Analysis	Research T & E		28/09/2011		28/09/2011		Tim
Edit PESTLE, work plan	Go over these items before due date		29/09/2011		29/09/2011		Everyone
Briefing 1			30/09/2011		30/09/2011		Everyone
Write briefing note 1		25/09/2011	28/09/2011		28/09/2011		Everyone
Edit Briefing Note 1		28/09/2011	29/09/2011		29/09/2011		Everyone
Final Review/send briefing note 1			29/09/2011		29/09/2011		Sarah
Weekly meeting 2					05/10/2011		Everyone
Weekly meeting 3					12/10/2011		Everyone

Weekly meeting 4					19/10/2011		Everyone
Weekly meeting 5					26/10/2011		Everyone
Weekly meeting 6					02/11/2011		Everyone
Weekly meeting 7					09/11/2011		Everyone
Weekly meeting 8					16/11/2011		Everyone
Weekly meeting 9					23/11/2011		Everyone
Weekly meeting 10					30/11/2011		Everyone
Weekly meeting 11					07/12/2011		Everyone
Weekly meeting 12					14/12/2011		Everyone
Obtain GIS data	E-mail Tara for GIS data (contours, sewage, property values, etc.)		21/10/2011				Sarah
Create GIS Map	Meet in GIS lab and create map	24/10/2011	25/11/2011		11/22/2011	Had difficulty creating maps, specifically mapping the projected sea level rise. Got help from GIS centre.	Amy
Analyze GIS Map	Use map to determine sensitive areas to sea level rise		27/10/2011		24/11/2011		Everyone
Briefing 2			28/10/2011		28/10/2011		Everyone
Write briefing note 2			25/10/2011		25/10/2011		Everyone
Edit briefing note 2			26/10/2011		26/10/2011		Everyone
Final Review/send briefing note 2			27/09/2011		27/09/2011		Everyone
Trip to Chester (class trip #2)					04/11/2011		Everyone
Interviews			08/11/2011		N/A	because we were able to obtain all of the information we needed from talking to councillors and doing a literature review.	Everyone
Write briefing note 3		21/11/2011	22/11/2011		22/11/2011		Everyone
Edit briefing note 3			23/11/2011		23/11/2011		Everyone
Final Review/send briefing note 3			24/11/2011		24/11/2011		Everyone
Group Presentation			02/12/2011		02/12/2011		Everyone
Prepare Presentation			28/11/2011		28/11/2011		Everyone
Practice presentation			30/11/2011		30/11/2011		Everyone
Presentation to Municipality of Chester Council			08/12/2011		08/12/2011		Everyone
Final Report			16/12/2011		16/12/2011		Everyone
Write Report		11/12/2011	11/12/2011		12/12/2011		Everyone
Edit final report			14/12/2011		13/12/2011		Everyone
Complete Final Report			15/12/2011		15/12/2011		Everyone
Meet council			08/11/2011		10/11/2011		Everyone

CLIMATE CHANGE VULNERABILITY ASSESSMENT

for The Municipality of the District of Chester, Nova Scotia

~ CHESTER COMMONS TO DEEP COVE ~

Meisners Beach, Chester, Nova Scotia (© Brett Howard, 2011)

By Brennan Daly, Brett Howard, Amy Roy & Tamara Wilson

Completed for partial credit in MARA 5005.03 (Independent Reading Course) on December 16, 2011

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report investigates areas vulnerable to climate change within the coastal zone of the Municipality of the District of Chester. The specific area of interest is the stretch of coast between Chester Commons and Deep Cove. The coastal zone was defined to be the area ranging from 0 to 10 meters above sea level, with a minimum inland distance of 100 meters. The main purpose of the report was to identify the areas vulnerable to climate change impacts and suggest adaptations to the municipality to lessen those impacts. Four aspects of the area were investigated separately for their primary vulnerabilities: the biophysical environment; public infrastructure; community socioeconomics; and governance and planning.

The authors travelled to the Municipality of Chester on three separate occasions. The first visit was to meet with planners and to travel the coastline of the Municipality in order for the planners to identify some of their concerns. The second visit allowed the researchers to further observe specific vulnerabilities through a field survey. The third visit provided an opportunity for the researchers to talk with councillors and municipal staff about specific vulnerabilities associated with each of the four categories. Other data collection methods included using Geographical Information Systems data (GIS) to prepare maps, and researching scientific, governmental and media publications on the topics of assessing and adapting to climate change vulnerabilities. The main areas of vulnerability in the area studied were identified as sections of Highway 3, Goat Lake/ Squid Cove, the causeway to Grave's Island, East River basin, Meisners Beach, Little East River basin, Mountain and Saddle Islands, and the saltmarsh at the Chester Golf Club.

The primary planning document currently used by the Municipality for issues related to climate change is the Integrated Community Sustainability Plan (ICSP). Though the ICSP addresses many of the issues related to these vulnerable areas, there are gaps and barriers that exist in current legislation that may make it difficult for the Municipality to adapt to climate change. The

recommendations for future governance and planning include amending bylaws and implementing the planning processes outlined in the ICSP as soon as the funding becomes available.

Limitations of the project included the resolution of GIS data, uncertainty regarding the actual measure of sea level rise, and the short duration of the project.

1. CLIMATE CHANGE & THE STUDY AREA

Our Changing Climate: Causes & Effects

Climate change is defined by the Intergovernmental Panel on Climate Change as a "change in the state of the climate that can be identified (e.g. by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer…" (Baede, Linden, & Verbruggen, 2007). Consequently this definition includes changes in climate caused by natural variability as well as changes caused by anthropogenic forces. It is important to note that while the planet has experienced major climate shifts over its 4.5 billion year history, the current rate of climate change is unprecedented. Typically, the planet will warm by several degrees over thousands of years, while current climate models are projecting an increase of 2-4°C in the next century (Pachauri & Reisinger, 2007).

This rapid warming has been attributed to anthropogenic causes, primarily greenhouse gas emissions. As humans emit large quantities of greenhouse gases (i.e. water vapour, H2O, carbon dioxide, CO2, nitrous oxide, N2O, methane, CH4, and ozone, O3) to the atmosphere, the gas molecules interact with reflected infrared radiation, effectively trapping the thermal energy in the atmosphere of the planet, rather than allowing the radiation to escape to space (Baede, Linden, & Verbruggen, 2007). The trapped heat then builds up, while the planet continues to absorb solar energy from the sun. Although these gases naturally occur in the atmosphere, greenhouse emissions (primarily CO2) are being added in increasingly large amounts through mankind's use of fossil fuels (Baede, Linden, & Verbruggen, 2007).

The authors recognize that this is a highly simplified explanation of the greenhouse effect and climate change drivers, and it is intended to function solely as an introduction to climate change. Currently, climate change science is much further advanced than this primer suggests. The

Intergovernmental Panel on Climate Change (IPCC) is a Nobel prize-winning, United Nations-endorsed, international science body designed to assess climate change. Thousands of scientists contribute to its knowledge base. As a result, the UN officially sanctions the IPCC's projections for climate change. In 2007, it published its fourth assessment report. Canada's *From Impacts to Adaptation: Canada in a Changing Climate*, is based on the IPCC's 2007 projections (Lemmen, Warren, Lacroix, & Bush, 2008).

Using complex global climate models, the IPCC has projected how the climate will likely continue to change as a result of our emissions. Numerous scenarios have been developed to better understand how climate change will impact the global environment. Over the next century (i.e. until 2100) the IPCC Forth Assessment Report projects that globally:

- Mean air temperatures will increase 2-4°C (ocean temperatures will also increase)
- Sea levels will rise 0.26-0.56 m
- Precipitation patterns will change
- Storms will increase in frequency, or severity, or both
- Wind patterns may change (Pachauri & Reisinger, 2007)

However, for Nova Scotia, more specific projections are available. After the retreat of the glaciers at the end of the last ice age, Nova Scotia's landmass rebounded upwards and is currently subsiding back into the Earth's mantle. This rate of subsidence is approximately 0.3 m per century. Combined with the projected absolute sea level rise of 0.26-0.56 m, Nova Scotia will likely experience up to 1 m of relative sea level rise between 2000 and 2100 (Nova Scotia, 2009). It is predicted that precipitation will increase by up to 20% per year (e.g. from 1.4 m per year to 1.7 m per year) for Atlantic Canada. Consequently, the Municipality of the District of Chester will experience climate change.

The Study Area

The Municipality of the District of Chester's current climate is moderated by its proximity

to the Atlantic Ocean. Daily mean temperatures range from -6°C in the winter to +18°C in the summer (Environment Canada, 2011). Before wind-chill, the minimum recorded temperature for this region was -32.8°C in January 1925, with a maximum recorded temperature of +36°C in June 2001 (Environment Canada, 2011). Annual mean precipitation is 1.36 meters (m), 90% of which is rain (Environment Canada, 2011). The tidal range for Chester is approximately 1.5 to 2 m (Fisheries and Oceans Canada, 2011).

The study area includes the area from the intersection of Duke Street and Pig Loop Road in the village of Chester (Chester Commons), around the western side of the Mahone Bay and up the Aspotogan peninsula to the back Deep Cove, at the intersection of Highway 3 and Deep Cove Road. This area spans across municipal districts one and three, currently represented by Marshal Hector and Brad Armstrong respectively. This area is sparsely populated, with most of the infrastructure located along both sides of Highway 3, which follows the coastline. Although there is a small portion of Chester village included in the westernmost zone, the area is predominantly the 'road between' Chester and Blandford. The area is home to the Chester Golf Club, Graves Island and East River Provincial Parks, Meisner's Beach and the Louisiana Pacific Hardboard plant in East River.

Due to the arbitrary limits associated with this zone it is difficult to determine the population of the area. Based on population statistics for the Chester village and Hubbards/Blandford it is estimated to be approximately 1000 people. The population is aging, approximately 35% of the residents are over the age of 54 (Government of Nova Scotia, 2011b). There are many seasonal residents who own homes in the area, however most of these are in the western section, nearest to the village (A.W., personal communication[1]). The value and number of homes in the area is increasing, although the population numbers and income remain relatively constant (Government of Nova Scotia, 2011b). The area is a popular tourist destination, Mahone Bay is renowned for its

[1] Authors Note: **A.W.** refers to Allen Webber, current Warden of the Municipality of the District of Chester

beautiful drumlin islands and protected sailing conditions. Other economic activity includes manufacturing, resource extraction and service industries.

Climate Change Impacts

Coastal regions, like the Municipality of Chester, will experience climate change in a variety of forms. The major impacts of climate include (but are not limited to): extreme weather events, flooding, seawater intrusion, erosion, coastline migration, loss of natural habitats and/or species biodiversity. Many of these impacts will be caused by sea level rise (SLR), storm surge, storms, precipitation and temperature increases. Table 1 indicates the likely causes of each coastal climate change impact.

Table 1: Coastal climate change impacts and their possible causes.

Impact	Sea Level Rise	Storm Surge	Storms	Precipitation	Temperature
Extreme Weather Events			✔	✔	✔
Flooding	✔	✔		✔	
Seawater Intrusion	✔	✔		✔	✔
Erosion	✔	✔	✔	✔	
Coastline Migration	✔	✔			
Loss of habitat/ biodiversity	✔			✔	✔

Extreme weather events are typically defined as a weather event (e.g. storm) that occurs during a time of the year or place that is rare. An example of this would be Hurricane Juan, which struck southern Atlantic Canada in 2003. Flooding may be permanent (in the case of sea level rise), or temporary (in the case of storm surge, or snow melt). Seawater intrusion (alternatively known as saltwater intrusion) is the displacement of freshwater by seawater in groundwater reservoirs or surface water systems. Seawater intrusions alter the salinity of the water system, usually rendering it

undrinkable. Erosion is the removal of surface sediments (e.g. dirt, soil, sand) by physical or chemical means (e.g. wind and wave action). Coastline migration occurs as the land-sea interface moves inland or seaward due to sea level rise, erosion, deposition, etc. Loss of natural habitats and biodiversity can occur as the environment or species composition changes in response to natural or anthropogenic forces.

The Coastal Zone & Assessing Vulnerability

For the purposes of this assessment, the coastal zone was defined as the area between zero and 10 meters (m) vertical elevation above mean sea level, with a minimum inland distance of 100 m. In other words, if the 10 m vertical contour was within 100 m of the land/sea interface, the coastal zone was extended inland to 100 m, regardless of elevation. Using this definition, two zones of risk were determined. From zero to five meters above sea level (highlighted in dark pink in Figure 1), is the zone of greatest exposure to coastal climate change impacts. Part of this zone will be permanently inundated by sea level rise over the next century, and during severe weather events or storm surge events much of this region will be temporarily flooded. Current official climate projections suggest that relative sea level rise for Nova Scotia will be approximately one meter, and storm surge during extreme storms tends to be three to four meters, delineating the first five meters as high exposure. From five to 10 m above sea level (highlighted in orange in Figure 1), is the coastal region that may occasionally be impacted by extreme weather events and may considered an area of moderate exposure. This gradation of risk includes a degree of precaution, due to the uncertainty inherent in climate change projections and the limitations of available GIS data.

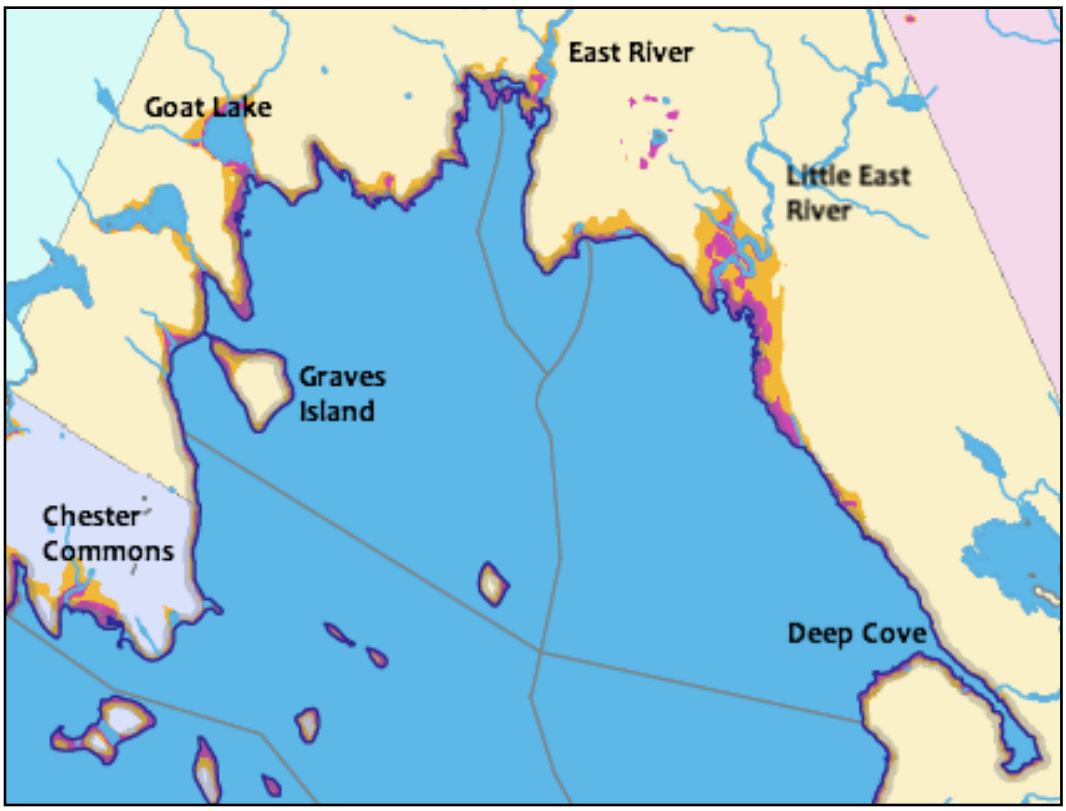

Figure 1: The area between Chester Commons and Deep Cove (with major landmarks indicated) assessed for climate change vulnerability. The coastal zone (grey) was defined as 0-10 m vertical elevation and a minimum inland distance of 100 m. Two zones of risk were determined. From 0-5 m (dark pink) is the most vulnerable to climate change impacts. Between 5-10 m (orange), may considered an area of moderate exposure

Vulnerability Assessment Methods

In order to assess the vulnerabilities along the coastal zone of the Municipality of the District of Chester, three primary methods were used. A literature review was conducted to determine what the official climate change projections are, how those changes will impact coastal zones and to a lesser extent, what are possible adaptation strategies for these impacts. Next, visual observations were made of the coastal zone from Chester Commons to Deep Cove, to identify areas that may be vulnerable. Finally, using GIS data of the Municipality, the two zones of exposure were plotted and then compared to the observations made in the field study (Figure 1). Consequently, this study is primarily qualitative, rather than quantitative.

Governance & Planning

Once the biophysical, infrastructure, and socio-economic vulnerabilities were determined, relevant sections of the ICSP and legislation were investigated to address specific barriers or gaps that may prevent the implementation of the ICSP or other climate change adaptations. All levels of government were included in the investigation. A gap was identified as an omission in the ICSP or municipal legislation related to the biophysical, infrastructural, and socio-economic vulnerabilities outlined by the researchers during the project. A barrier was identified as a piece of provincial or federal legislation preventing the Municipality from integrating specific climate change adaptations.

A coastal community needs to have both the appropriate planning strategies and corresponding government legislation to adapt to climate change. If a coastal community is aware of its climate change vulnerabilities and identifies these vulnerabilities during the municipal planning processes, the opportunity exists for the Municipality to address barriers and gaps within current governance and planning. Unfortunately, provincial and federal government legislation may present barriers that cannot be addressed at a municipal level. In addition, barriers may be presented by private companies responsible for the maintenance of integral components of the community. The main planning strategies and current corresponding municipal, provincial, and federal legislation of Chester Municipality will be discussed prior to discussing governance and planning issues related to the biophysical, infrastructure, and socioeconomic categories.

The main planning document currently implemented by Chester Municipality, to address the impacts of climate change, is the Integrated Community Sustainability Plan (ICSP). The ICSP, which was incorporated into council in 2009, was part of the requirement for Chester Municipality to receive funding from the Canada Nova Scotia Gas Tax Agreement (Municipality of the District of Chester, 2009). In 2010, Chester Municipality developed the Resource and Implementation Plan for the ICSP to outline the funding and methods needed to execute the ICSP (Municipality of the

District of Chester, 2010). Due to the implementation of the ICSP, the Municipality must evaluate the Municipal Planning Strategy (MPS), the Land-Use By-law (LUB), and the Subdivision By-law (SUB) (Municipality of the District of Chester, 2010). Other planning documents that will be used by Chester Municipality to incorporate ICSP strategies include the Municipal Specifications Document, various by-laws, and separate bylaws and planning documents for the Village of Chester including the Chester Village Secondary Planning Strategy and the Chester Village Area Land Use Bylaw (Municipality of the District of Chester, 2010). Provincial legislation that Chester Municipality must follow with respect to planning include the Municipal Government Act, the Nova Scotia Building Code Act, and the Nova Scotia Building Code Regulations. Federal legislation regarding municipal governance and planning will be discussed as it applies to each category. Adaptation suggestions regarding each category will also be discussed throughout the following sections, however adaptation was not the focus of this report and will be addressed in greater detail in future workshops and collaborations with the Municipality of Chester and Dalhousie University.

2. BIOPHYSICAL VULNERABILITY ASSESSMENT

Within the coastal area examined in this study, there are provincially designated significant habitats on Meisners, Mountain and Saddle Islands for species of concern, a saltmarsh on the west side of Chester Golf Club and wetlands near Goat Lake, East River, and Mill Dam Brook (Nova Scotia Department of Natural Resources, 2004). The surficial geology of this area includes drumlin islands, some sand and mixed sediment beaches (e.g. Meisners Beach), and the granite bedrock of the Aspotagan peninsula (personal observation). Much of this area's coastline is protected from the full fetch of the Atlantic by the Tancook Islands.

Priority Vulnerabilities & Possible Climate Impacts

Six areas from Chester Village to Deep Cove were identified as biophysical vulnerabilities. These vulnerabilities will be presented from west to east, and the order of presentation does not indicate any prioritization. The first area of concern is the small islands in Mahone Bay. These include Meisners Island, Woody Island, Mark Island, Saddle Island and Snake Island. As they are drumlins (mixed sediment glacial deposits), they are subject to erosion. When sea level rises and storms increase in severity or intensity, these islands will continue to erode, perhaps sinking below the surface of the Bay. However, as all but Meisners Island are uninhabited, the loss of these islands is unlikely to be significant.

The next area of vulnerability is the saltmarsh located on the west side of Chester Golf Club. Saltmarshes protect coastlines from erosion and can also act as a buffer for groundwater resources. The saltmarsh will likely attempt to migrate inland towards the golf course as sea level rises. Depending on the coastal defenses used by the golf club, this saltmarsh may experience coastal

squeeze if its retreat from rising sea levels is prevented. Finally, increased storms and storm surge or rising sea levels may cause some seawater intrusion into the marsh. However, as this is already a brackish environment, the effects of the seawater intrusion will likely be minimal.

The third area of vulnerability occurs around Schnare Cove, Scotch Cove, Graves Island, and Hume Point. This area has low vertical elevation, some small rocky beaches and is close to Hennebury Lake. As a result of these conditions, this area will likely experience erosion, some coastal migration inland, flooding (temporary and permanent) and possibly seawater intrusion to the groundwater and surface water around Hennebury Lake.

Goat Lake will likely experience the same issues as the Schnare Cove/Graves Island area. Of particular concern in this area is the proximity of Highway 3 to the coastline, limiting the ability of the wetlands to migrate inland, and likely causing coastal squeeze. Since Goat Lake is connected to Mahone Bay via a small brook, it will probably experience some degree of seawater intrusion during storm events or as a result of sea level rise.

Meisners Beach is another vulnerability from a biophysical perspective. The sand beach will experience erosion, attempt to migrate inland as sea levels rise and likely be subject to coastal squeeze due to the physical barrier that Highway 3 presents. On the landward side of Highway 3 are some wetlands. This environment may experience some seawater intrusions during storm events and, if both the beach and road become permanently inundated by seawater, it is possible the wetlands may migrate inland.

The last vulnerability is the area around Little East River. Much of this region is extremely low-lying and will be subject to some permanent inundation due to sea level rise and more frequently, temporary flooding during storm events. The flooding in this area may be caused by increased precipitation and flooding Little East River, or by storm surge. In all likelihood, during an extreme weather event, both types of flooding will occur, exacerbating the possible extent of the flood. Snow and ice melt may also cause flooding in the spring.

Planning & Governance

The ICSP addresses the issues of coastal zone and lakefront protection, erosion, setbacks, and wetland preservation in detail in the Action Plan Section, but it is important to note that the term "vulnerable" is not used within the ICSP (Municipality of the District of Chester, 2009). The Resource & Implementation Plan for the ICSP only outlines the funding that will be provided to address these issues according to the Action Plan Section of the ICSP (Municipality of the District of Chester, 2010). There seem to be no major gaps with regards to planning within the biophysical category, provided the Municipality follows the ICSP in their Climate Change Action Plan.

Legislation gaps at the municipal level include lack of bylaw regulations regarding coastal development in vulnerable areas; there is no existing legislation that encourages sustainable developments in these areas. For instance, the lack of regulations regarding setbacks in the LUB prevents new developments from being built near coastlines and/or wetlands. Another municipal legislation issue concerns zoning processes. There are three main zoning areas in the Municipality of Chester and each zone has different by-laws and levels of regulations (T.M., personal communication[2]). Provincial and federal legislation may create barriers for the municipality and overlaps between federal policies may increase barriers for the municipality. The Nova Scotia Wetland Policy, the Beaches Act (Nova Scotia), and the Environment Act (Nova Scotia) (personal communication) may create barriers for the Municipality during the amendments of municipal legislation. The Canadian Environmental Assessment and Protection Acts may override provincial legislation during the amendment process. The Fisheries and Oceans Acts may cause barriers to offshore developments such as seawalls.

[2] Author's Note: **T.M.** refers to Tara Maguire, Senior Planner for the Municipality of the District of Chester.

Possible Adaptation Strategies

From a biophysical perspective, threats to freshwater reservoirs along the coastline are likely to be an increasingly important issue over the next century. Adaptation strategies to protect freshwater resources can include protecting existing wetlands (including saltmarshes), or restoring degraded ones, as these habitats behave as a buffer between salt and freshwater systems. To prevent coastal squeeze, it is important to minimize the physical barriers to inland migration of the coastline. Developing freshwater reservoirs away from the coastline to limit the risks and consequences of seawater intrusion to the human drinking supply is also important. Monitoring groundwater quality is a possible first step.

Monitoring, enforcement, and education need to be a part of these adaptations for them to be effective. The Municipality has allotted quite a substantial amount of funding for education as indicated by the Resource & Implementation Plan for the ICSP (Municipality of the District of Chester, 2010).

3. INFRASTRUCTURE VULNERABILITY

"Common sense and observation will tell you a lot." Chester Municipality Warden Allen Webber (December 8, 2011)

Most of the scientific literature on the effects of climate change on coastal infrastructure focusses on large urban centres, due to their higher population densities (McGranahan, Balk & Anderson, 2007). There is a gap in the research on affluent, rural communities, like the Municipality of the District of Chester where the infrastructure challenges will be different in both the scope of the problem and the possible solutions. Where the infrastructure challenges of large coastal urban centres and megacities can be addressed with elaborate and expensive solutions, communities like Chester facing a similar suite of challenges will be hindered in their ability to deal with them due to the capital required and widely dispersed population.

Due to the unique infrastructure challenges in rural, coastal communities, vulnerability assessment and subsequent adaptation strategies must be based on more than the available literature, since this community type is underrepresented in the research. However, quantitative vulnerability assessment methods like mathematical modeling and network mapping (Solano, 2010) are expensive to implement and probably provide a level of detail beyond the needs of climate change adaptation in Chester.

This project used a combination of qualitative methods, including "common sense and observation", to compile a a report on the primary infrastructure vulnerabilities of the Chester Municipality. This analysis identifies waste water, power and telecommunications, public roads and storm water runoff systems as the critical public infrastructure assets requiring ongoing vulnerability and adaptation assessments. Table 2 outlines the major climate change impacts on the infrastructure systems of concern and their possible effects on public infrastructure.

Methodology

Vulnerability was defined as a system that was "susceptible to, and unable to cope with, adverse effects of climate change, including climate variability and extremes" (ICSP, 2007). In the context of infrastructure, the ability to cope included a system's built-in capacity to absorb any negative consequences of climate change and how easily the system could be repaired, rebuilt or relocated; also considered a community's adaptive capacity (Canadian Council of Professional Engineers (CCPE), 2004). For example, power lines are highly susceptible to damage, but they have a high adaptive capacity, as they are relatively easy to repair after a storm compared to other systems like wastewater lift stations. It is important to note that although all the infrastructure systems discussed in this report are considered vulnerable, their susceptibility and their adaptive capacity are variable.

The methodology used was adapted from the Canadian Council of Professional Engineers (CCPE) 2004 Engineering Vulnerability Assessment Protocol (Figure 2). This five-step protocol was designed by the CCPE to be flexible enough to be applied to any public infrastructure system, while still systematizing the process and producing reliable information. Of the five steps outlined by the CCPE, only Steps 1-3 were the focus of the current report. Although Steps 4 and 5 are addressed briefly, they will be the major focus of upcoming workshops, projects and reports with the Municipality of Chester and Dalhousie University.

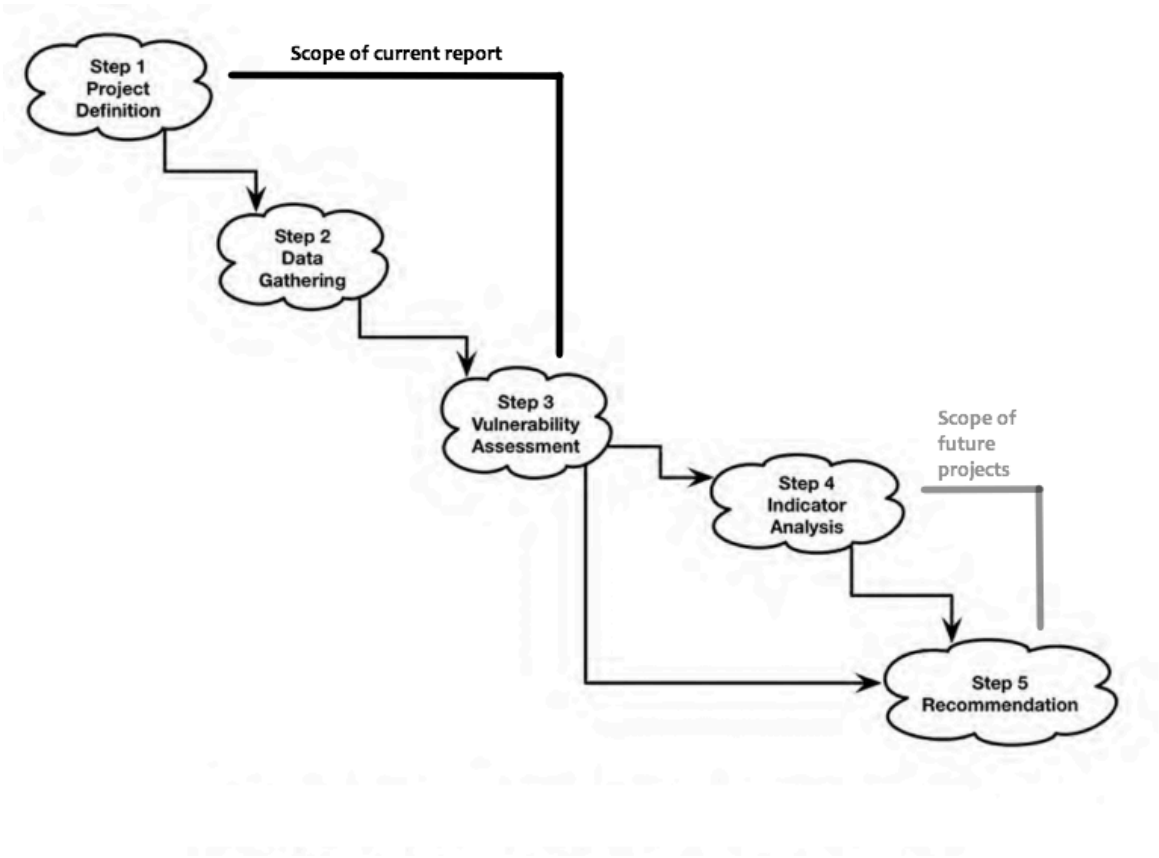

Figure 2: The five steps of the Engineering Vulnerability Assessment Protocol (adapted from CCPE, 2004, p.20).

Step 1: Project Definition

The scope of the infrastructure vulnerability assessment was largely determined by the definition of the coastal zone (between zero and 10 meters (m) vertical elevation above mean sea level, with a minimum inland distance of 100 m). The scope of the project was limited to public infrastructure, although the interaction between public and private infrastructure is briefly discussed due to the large number of private coastal residences within the area assessed.

Step 2: Data Gathering

The CCPE Vulnerability Assessment Strategy recommends identifying and assessing specific components of the infrastructure being considered. However, this report does not go to this level of

specificity, as it would require technical knowledge not readily available and not necessarily required for the scope of this project. However, future assessments may benefit from additional technical information.

Three methods of data collection were used: a media review of climate impacts, field surveys of the area and informal discussions with municipality councillors and staff. The media review was a survey of *The Chronicle-Herald* articles published between 2000-2011 involving major weather incidents, storm surge or rainfall and resulting in infrastructure concerns in the Chester area. Of the 40 news articles found, the vast majority of them covered traffic incidents and power outages. The field surveys conducted largely entailed driving the highways and public roads, observing the infrastructure systems throughout the area and identifying areas where climate change impacts would likely be the most hazardous. Finally, informal discussions were held on November 10, 2011. The purpose of these discussions was to gain more technical insight on the infrastructure systems and known vulnerabilities. For example, the assessment presented in this report on the vulnerabilities of the Chester wastewater and storm water systems is largely supported by the expertise of Lyle Russell, Public Works Assistant Engineer for the Municipality.

Step 3: Vulnerability Assessment

The information gathered in Step 2 was used to "identify relationships between the infrastructure components, the climate and other factors that could lead to infrastructure vulnerability" (CCPE, 2004). First, the types of climate change impact most likely to effect the function of infrastructure systems was identified (e.g. wastewater lift stations are likely going to be impacted by storm surge and SLR). Then the potential consequences of this interaction were extrapolated from the current situation (e.g. wastewater lift stations at very low elevations currently experience flooding and power failure during storm surge events, therefore as both SLR and storm surge increase, more lift stations will be vulnerable to these impacts). Finally, the infrastructure

systems were mapped over topographical maps predicting the risk areas for climate change effects (Figure 1). The purpose of this was to identify areas with multiple, overlapping infrastructure vulnerabilities, and which systems should be prioritized by the Municipality for adaptation. The primary findings of this step are summarized in Table 2.

Priority Vulnerabilities & Possible Climate Impacts

Wastewater System

The infrastructure system currently of greatest concern to the Municipality is wastewater treatment. Although the system is not currently in a state of disrepair or outdated, the environmental forces that act on the system make maintenance and repair an ongoing challenge. Dealing with these issues has required the municipality to request federal and provincial funding for connecting homes to the sewer system properly and the ongoing maintenance of the sewer lines (Government of Nova Scotia, 2007).

Vulnerabilities already being faced include seawater intrusion into the system and storm surge, both of which can cause system failure, sewage backups and damage to system components. The vulnerabilities are exacerbated because a major component of the system, the sewage lift (or pump) stations, are intentionally located a low elevations near the coast. If stations are forced to operate overcapacity during a storm event due to fresh and seawater intrusion, they have to be manually operated by pump trucks (which is expensive) or turned off (letting raw sewage into the marine environment, resulting in a possible health hazard and the involvement of the Department of the Environment). Already some pump stations experience these issues (e.g. the station at Otter Point Road) and sea level rise will increase the vulnerability of more stations, more frequently (L.R.; personal communication[3]).

[3] Authors Note: **L.R.** refers to Lyle Russell, Public Works Assistant Engineer for the Municipality

Power and Telecommunication Lines

Power lines in the community are all supplied by private industry (currently Nova Scotia Power Inc. (NSPI)), which is unlikely to change. While NPSI will continue to supply most of the electrical power, the Government of Nova Scotia will be putting increasing emissions restrictions on the company between 2010-2020, which may influence how NSPI supplies power to the Municipality (NS Department of the Environment, 2009). However, for the foreseeable future the current power line infrastructure remain unchanged.

Power lines are the most vulnerable in areas where they are closest to the ocean (due to the lack of windbreaks) and areas that are heavily treed (where blowing debris may damage the lines). Because the power lines run along the major highways in the area studied, they often have spatially overlapping vulnerabilities. For example, at Goat Lake/Squid Cove, the road and power lines run along the coast, such that some power poles are located in the water. It is an open, low area, so the power lines are vulnerable to offshore winds and the road is vulnerable to flooding (Figure 3). Additionally, resulting blackouts present safety hazards to residents and challenges to emergency response.

Figure 3: Image, taken from Hwy 3, of a power pole located on the south side of the road. © B. Howard 2011

The telecommunications infrastructure in the Chester Municipality has many of the same vulnerability aspects as the power lines, as they occur in the same place, usually along the major highways and roads. These lines were identified as a vulnerability because, due to the rural nature of the area cell phone coverage is not uniform (personal observation), and if the telephone lines are damaged by high winds or debris there is a risk that residents could be cut off from their primary means of communicating with emergency services during a storm event. If cell coverage and cell

phone ownership increases, it can be assumed that the vulnerability of telecommunications infrastructure will decrease. Currently, maintenance and repair of both power and telecommunication lines are the responsibility of the private companies and therefore are outside the jurisdiction of the Municipality.

Public Roads

Since public roads fall under provincial jurisdiction, the Municipality is not responsible for their upkeep and construction. Although there are some municipally owned roads, their maintenance has largely been contracted out to the province (G.M., personal communication[4]). Even though road repairs therefore fall to the provincial government, any damage or road washout is a concern for the municipality, as it may impact emergency access to residents. Additionally, with increasing road vulnerability the demand for road repair crews may cause longer construction times, resulting in major inconveniences for residents, especially given the rural nature of the area where homes often only have one access road.

In addition to many residential roads, the major road infrastructure of concern in this area are the coastal highways. Anywhere Highway 3 or Highway 329 run less than 5 m in elevation from the coastline may be seriously compromised due to sea level rise, especially during a large storm surge. Where stretches of highway prevent the landward migration of natural habitats (e.g. Meisner's Beach), these roads will become increasingly vulnerable as the natural buffer provided by the habitat disappears with sea level rise. Also of concern are public causeways, especially the one leading to Graves Island Provincial Park, which is currently at less than 5 m elevation, and vulnerable to flooding and washout.

[4] Author Note: **G.M.** refers to Geoff MacDonald, Planning Director for the Municipality of the District of Chester.

Storm Water Runoff

One of the major infrastructure issues currently faced by the Municipality is the illegal connection of private storm water drainage (e.g. basement sump pumps) to the public wastewater system, which is not designed to handle either storm water or seawater intrusion (L.R., personal communication). As previously discussed, an increase in the amount of water going into the wastewater system exposes it to damage or failure. This problem may worsen as the amount of precipitation in Chester increases due to climate change.

Therefore, it is important that the vulnerabilities in the storm water system be adapted, so that the system is able to adequately drain the predicted levels of precipitation and prevent flooding on private properties. In addition to handling more land-based runoff, rising sea level and storm surge may reduce the seaward drainage, possibly causing flooding of ditches and culverts. Of highest priority are coastal roads that run overtop river basins or marshlands, where freshwater runoff is entering the ocean in high volumes. Throughout the area studied, there are several such sections of road, which are all vulnerable to flooding due to possible insufficient drainage of runoff (e.g. Goat Lake/Squid Cove).

Planning & Governance

Storm Water Runoff & Wastewater

There are gaps in planning methodologies regarding the adaptation of current storm water run-off and waste water systems to climate change. Though the Nova Scotia Department of Environment and the Nova Scotia Department of Transportation and Infrastructure Renewal are responsible for storm water systems, planning processes need to be put in place to discourage illegal connections to storm water systems. Gaps exist within planning processes with respect to wastewater because it was not mentioned as a concern by the Institute for Planning and Design (the organization that assisted the Chester Municipality in writing the ICSP), stakeholders, or community

members during the development of the ICSP. Wastewater is briefly mentioned in Initiative 3 under the Senior Staff Initiatives section of the ICSP regarding Environmental Protection/Water Resources: "Waste water collection and treatment systems will also be required" (Municipality of the District of Chester, 2009). There are no other details provided about waste water in the ICSP. In addition, the Resource and Implementation Plan for the ICSP indicates that zero funding has been assigned to the maintenance of waste water treatment systems (Municipality of the District of Chester, 2010). The Nova Scotia Climate Change Action Plan (NSCCAP) does mention waste water as a priority in Action 46:

> "Action 46 - Using funds from the federal Gas Tax Agreement provide funding in 2009 to help municipal governments plan for climate change. A key focus will be the impacts of sea-level rise on land-use planning and on the design of wastewater treatment plants." (Nova Scotia Department of the Environment, 2011).

Consequently, the Municipality may need to assign a priority to wastewater as it could be required by the province to indicate how much funding will be assigned to the adaptation of the wastewater systems.

The main documents used to govern wastewater systems are the Municipal Specifications Document and the Sewer Bylaw 034 (Municipality of the District of Chester, 2010). The Municipal Specifications Document does not include processes to prevent wastewater systems, including municipal and private systems, from being built near coastal zones or other ecologically fragile habitats such as wetlands (Municipality of the District of Chester, 2008). In addition, it is unclear as to whether capacity specifications for either storm water systems or wastewater systems are suitable because of the storm frequency on which they are based. Although the Sewer Bylaw addresses the issues of illegal connections of private systems to public systems and illegal discharge, the fines are minimal and the wording is weak (Municipality of the District of Chester, 2008). For instance, the

words "shall be a debt payable" or "may require" regarding illegal connections and discharge does not infer serious charges for these actions or motivate the public from discontinuing these actions. Both documents contain few details regarding monitoring and enforcement of illegal activities. Specifications for storm water runoff mentions high tides, but there are no details regarding system changes if high tides reach a certain level or if storm surges increase. The provincial and federal legislation mentioned in the biophysical section may affect the Municipality with regard to storm water runoff and wastewater by creating financial barriers such as fines due to inadequacies in these systems.

Power Lines, Telecommunications, & Roads

Difficulties may arise regarding planning that involves power lines and telecommunications due to ineffective communication between the municipality and private companies. For instance, there may be a lack of communication between NSPI and the municipality regarding power outages and repairs. In addition, gaps in planning processes regarding public roads may exist due to a lack of communication between the municipality and the provincial government.

The municipality is vulnerable due to governance with respect to this type of infrastructure because it is outside of their jurisdiction; they have no control over the potential situations that may arise.

Private Residence Planning and Governance

The major planning gap regarding private residences is the zoning issues within the Municipality. New processes need to be put in place to address the zoning issues that currently exist within the Municipality. For private residences, the ICSP should be able to address planning processes regarding coastal zone and lakefront protection, erosion, setbacks, and wetland preservation.

Major municipal legislation affecting private residences includes the LUB, SUB, and the Chester Village Area Land Use Bylaw. There are gaps in this legislation regarding coastal zone and lakefront protection, erosion, setbacks, and wetland preservation. Provincial legislation that may present barriers to the Municipality include the Nova Scotia Building Code Act and the Nova Scotia Building Code Regulations.

Possible Adaptation Strategies

Adaptations for wastewater may include installing a more technologically resilient system or making design changes to the current system, installing generators for pumping stations to ensure continual pumping during a power outage, and increased fines for illegal connections (G.M., personal communication). Adaptations for storm water runoff may include the preservation of wetlands through the Nova Scotia Wetland Policy and environmental assessments to determine areas that require improvements in exiting systems. Similar to biophysical adaptations, infrastructure adaptations need monitoring, enforcement, and education for changes to be effective.

Zoning issues related to private residences could involve a process similar to that suggested by New Brunswick's Coastal Areas Protection Policy, which includes dividing the coastal zone into three different zones: core, buffer, and transition (New Brunswick Department of the Environment and Local Government, 2002). The Municipality could also attempt to standardize their current zoning processes to make monitoring and enforcement of news developments less difficult.

Table 2: Summary of the assessment of major infrastructure system vulnerabilities (including locations), the types of climate impacts that can be expected to affect these systems, and the potential consequences of those impacts, including increased hazards for the public.

Major Infrastructure System and Locations of Increased Vulnerability	Climate Change Impacts	Potential Consequences
Sewage lift stations (pumps) - Between 5-10 m elevation: • Pig Loop Road, Millennium Drive - <5 m elevation: • Otter Point Road	Sea level rise Storm surge	- Seawater intrusion causing the system to run above design capacity, increasing the risk of system and/or pump failure. - Pump failure requires either pumping trucks (expensive), or direct release of sewage into the marine environment (involvement of the Department of Environment, health hazard).
Wastewater treatment facilities - Nauss Point Road Facility	Sea level rise	- Seawater intrusion causing the system to run above design capacity, increasing risk of system failure. - Increased salinity in the system will kill the bacteria at the plant, which are required for treatment of waste.
Power lines - Wherever Hwy 3 runs < 5m from the coastline. - At Goat Lake power and/or telecommunications poles are located in the water. - Areas without a windbreak (e.g. trees, buildings).	Storms (extreme weather)	- Power lines are damaged or broken by high winds or debris. - Blackouts increase vulnerability of residents. - Damaged power lines are a hazard, especially if located near water. - Repair/replacement is not within the jurisdiction of the Municipality.
Telecommunications lines - Wherever Hwy 3 runs <5 m from the coastline. - At Squid Cove/Goat Lake power and/or telecommunications poles are located in the water. - Areas without a windbreak (e.g. trees, buildings).	Storms (extreme weather)	- Telecommunication lines are damaged or broken by high winds or debris. - Failure of communications infrastructure could effect emergency response. - Repair/replacement is not within the jurisdiction of the Municipality.

Table 2: Summary of the assessment of major infrastructure system vulnerabilities (including locations), the types of climate impacts that can be expected to affect these systems, and the potential consequences of those impacts, including increased hazards for the public.		
Public roads - Anywhere Hwy 3 runs <5 m elevation from the coastline. • Scotch Cove, Squid Cove/Goat Lake, East River Bay - Anywhere Hwy 329 runs <5 m elevation from the coastline. • **Meisners Beach** - Causeways (public and private), particularly to Graves Island.	Sea level rise Storm surge	- Increasing frequency and/or severity of road washouts. - Encroachment of seaward habitats (e.g. beaches, saltmarshes) towards roads. - Flooding of causeways. - Reduced access for emergency service vehicles - Repair/replacement is not within the jurisdiction of the Municipality.
Culverts (storm water runoff) - Throughout area, particularly Squid Cove/Goat Lake	Sea level rise Storm surge Storms (extreme weather)	- Increasing rainfall and storms causing runoff system to function above design capacity. - Rising sea level and storm surge reducing the seaward drainage of runoff. - Where culverts run under roads, increasing risk of road flooding/ washout. - Increasing risk of flooding in homes and public buildings near the coast.

4. SOCIOECONOMIC VULNERABILITY

Vulnerability is a concept which is widely used in decision making and management processes that contain a high degree of uncertainty. It is versatile and dynamic concept that can be defined in a variety of ways depending on the context or problem (Downing & Patwardhan 2004). Socioeconomic vulnerability in terms of climate change refers to the ability of groups or individuals to cope with the wide variety of adverse effects and extreme events that will result due to a rapid increase in global temperatures. These include primary effects such as sea level rise or increased storm severity, as well as secondary effects such as a downturn in the economy resulting from climate change.

The factors which influence socioeconomic vulnerability can generally be divided into three categories; the exposure, sensitivity and adaptive capacity (IPCC, 2007). In this context exposure refers to the degree of which a system is impacted by an event, while sensitivity refers to how susceptible the system is to adversity or impacts from the event. Therefore a high degree of exposure will not necessarily cause a high degree of harm if the sensitivity of the systems is low. Likewise low exposure does not guarantee lack of harm if the level of sensitivity is high. The final aspect of vulnerability deals with adaptive capacity, which for communities can be defined as the ability for self organization, learning and adaption (Walker, 2002). This is a key factor in assessing vulnerability as it is the element in which human agency plays a leading role, meaning that people are able to influence they way in which they respond to adversity.

The definitions used in this section are general, with an intentional focus on the human element of vulnerability. In the context of the current project this allows for some flexibility regarding the identification and substantiation of vulnerabilities; this useful due to the dynamic and heterogenic nature of coastal communities. Human and social institutions are difficult to work with due to their transient and constantly evolving nature.

> "Even when we focus on people as the target, we have to account for the fact that they are organized into groups at various scales – from individuals to households to communities and complete settlements. At each stage there are different sets of resources, institutions and relationships that determine not only their interaction with climate but also their ability to perceive problems, formulate responses and take actions." (Downing & Patwardhan 2004, p. 73).

In this context the current vulnerability assessment will then act as a 'snapshot' of the current situation in the East Chester to Deep Cove area; however it should be not be considered exhaustive or representative of a static state of existence. Instead the study aims to bring to light the various issues and areas of concern, in order to help guide decision makers to informed choices.

Methodology

Vulnerability assessments are a common part of climate change adaptation and mitigation strategies, however the majority of these assessment focus on urban areas in developed countries or rural areas in underdeveloped regions. This leaves a large gap in the literature when dealing with affluent, rural areas in developed countries. Due to the lack of a standardized framework this study was completed using a variety of methods, including international documents, regionally relevant examples, expert interviews and site visits. Vulnerability studies from other areas in Eastern Canada were compared with international standards to obtain a better understanding of the current state of vulnerability assessment methods. Local context was gained from various field visits, interviews with municipal staff members and review of local documents such as the Chester Municipality's Integrated Community Sustainability Plan (ICSP). Due to limited time, it was not possible to conduct community workshops or a comprehensive survey. While this methodology lacks a formal framework it is an example of how rural municipalities can synthesize available information and

approach complex issues in a manner which is efficient and feasible given budget and time constraints.

Priority Vulnerabilities & Possible Climate Impacts

For the purposes of this study the identified vulnerabilities will be divided into two categories, primary and secondary. Primary vulnerabilities will focus on short term, extreme event impacts, while secondary vulnerabilities will cover the longer term, gradual changes. This approach is not intended to rank vulnerabilities in terms of importance, but rather help to demonstrate the variety of challenges that will be faced, as well as show the variety of time scales the in which the events will be occurring. Specific examples from the study area will be drawn upon, however within the socioeconomic dimension vulnerabilities were not easily associated to geographic locations.

Primary Vulnerabilities

There are a wide array of potential effects that will increase social vulnerability in the coastal zone in the Municipality of Chester. Some of these will be felt much sooner than others, and will have a direct relationship to the physical impacts of the environment through extreme weather events. These events are characterized as short term high impact events and are expected to cause the most dramatic effects due to the high energy potential and short time duration. Examples are the increased severity of storm events and the heightened exposure that will result from storm surge or flooding events. These events are categorized as primary vulnerabilities because they will be both the first effects felt as a result of climate change, but also those which have the highest potential for adverse effects.

One method of determining the socioeconomic vulnerability in coastal areas is to use quantitative indicators. This was done in a vulnerability assessment from Australia by Dwyer et al. (2004) in which vulnerability was determined using socioeconomic indicators. These included: age,

income, residence type (e.g. house, apartment, etc.), employment, household type (e.g. nuclear family, single parent, etc.), house insurance and access to a vehicle, among others (Dwyer et al, 2004, p.16). Through the study the authors were able to make links between increased vulnerability and older residents, lack of housing tenure, lack of insurance and many others. While it is was not possible to obtain socioeconomic data for the study area in Chester that was detailed enough to utilize this exact methodology, these indicators can be operationalized through general knowledge about the study area, allowing for a qualitative analysis to be done.

The coastal zone from Chester Commons to Deep Cove is predominantly composed of sparse residential housing which occurs along the coastline and adjacent to Highway 3. In the Municipality of Chester 85% of households are owned, with an average value between $200 000 and $350 000 (Government of Nova Scotia, 2011b). These houses are generally occupied by older couples, either retired or seasonal residents; approximately %35 of the population is aged 55 years or more, a proportion of the population which is rising (Government of Nova Scotia, 2011b). The number of houses in has increased by nearly a third between 1996 and 2006 (Government of Nova Scotia, 2011b).

Although this representation of the demographics surely does not hold true for all the residents in our study area, it is safe to assume this is the general trend due to the high price of properties adjacent to the ocean, observations made during field surveys and information from municipal councillors (personal communication). The houses present in the coastal zone are quite large, many of which include luxury infrastructure such as personal docks, swimming pools and tennis courts. Thus using available statistics and general information it is safe to say our area is generally composed of elderly residents, living independently on high value properties. Therefore, the primary vulnerabilities in the study area are determined to be associated with the age and household type of the residents and the value of the property. In particular, older residents generally have higher needs in terms of health care and assistance, which will be especially so during an

extreme or emergency event. This creates a social vulnerability for residents whose homes are located within the ten meter contour line as sufficient emergency assistance may not be available to them during extreme events. Emergency management operations (EMO) policy in the municipality recommends that residents be prepared for a 72 hour response time during extreme events (personal communication). Traditionally, high property values would indicate a lower level of vulnerability, however in the case of our study zone this conclusion can not be drawn until further studies are done, to determine the level of insurance coverage along the coast due to the potential for high levels of damage during extreme events.

Secondary Vulnerabilities

Although the short term effects of climate change will have the most dramatic effects on coastal zone, it is the longer term gradual effects which will alter the livelihoods and social fabric of the municipality. There are several important economic issues present in the study area which are vulnerable to climate change. These include the Chester Golf Club, the Louisiana Pacific hardboard plant and many coastal recreational activities such as beach combing and sailing which are part of the attraction of the area, for both tourism and seasonal residents. The golf course is located directly adjacent to the ocean; however it is protected by a salt marsh on west and steep embankments, leaving it predominantly outside of the ten meter contour line. While some physical change may occur due to sea level rise and storm events the main vulnerability to the golf course is represented due to a downturn in the economy due to climatic factors. Likewise the hardboard plant, located in East Chester is located well above the ten meter contour line, however it has already shown to be sensitive to shifting markets. In 2008 the plant was forced to close due to poor market conditions, temporarily causing the loss of 350 jobs (CBC News, 2008). Tourism is an important sector of the local economy, employing over 2700 people across the county (Municipality of Chester, 2009). A downturn in the economy would mean less disposable income available to most people, making it is safe to assume traveling or purchasing a second home in the area will become

less common. This will affect the municipality through a loss of income and tax revenue. Regardless of climate change impacts, there are other issues that the municipality should consider. The future twinning of Highway 103 from Halifax to Hubbards could result in an influx of permanent residents (Government of Nova Scotia, 2011a). This would increase the demand on municipal services, especially in the Aspotogan area. There are many failed subdivision developments already present in the area, such as Lloyds Landing. The locations of these developments are important to the Municipality due to the demands on services that could be created if they are to become quickly populated.

In terms of social vulnerabilities, the most prevalent issue is public access to coastal areas. This has been identified as a priority by the municipality (Municipality of Chester, 2009), as well as the province (Government of Nova Scotia, 2009). In the study area there are three key areas for public access to the coast, Graves Island Provincial Park, the East River Provincial Park and Meisner's Beach. While there are no public wharves in the area, there is a slipway at Graves Island that can be used to launch boats. All three of these areas will be affected by sea level rise as they are all (at least partially) located below the ten meter contour line. As access to the coast is such a central aspect of living in a coastal community this should be taken seriously as many cultural traditions depend on these areas. While the physical impacts of climate change will certainly affect the socioeconomic aspects of life in the municipality, human agency should also be considered. The adaptive capacity of a community is the ability of people to adapt and learn from stress events such as climate change. While the external thresholds mentioned in this report are important there has also been recognition to the importance of internal value systems and perceptions of climate change (Adger et al. 2009). Given the heterogeneity aspirations of any collective group of people there is bound to be multiple goals, aspirations and conceptions of the problems being faced and the validity of potential solutions. Therefore an obvious adaptation from a biophysical standpoint may not be deem socially or culturally appropriate within a given portion of the community. Understanding the

full array of viewpoints present in the municipality will not only provide a more diverse array of solutions, but also prevent potential conflicts due to marginalization of a given population. It is therefore strongly recommended that the Municipality engage the public through awareness activities in order to create a transparent and inclusive approach to adaption measures.

Socioeconomic Planning & Governance

The ICSP addresses the issues of guaranteed beach access and promotion of economic development, but there are no specific details as to how these issues will be dealt with. There are no planning procedures in the ICSP that address the issue of keeping neighbours in rural areas safe during severe storms when EMO requires residents be prepared to manage without assistance for up to 72 hours.

There are a lack of suitable municipal policies and regulations pertaining to socioeconomics. The only municipal by-law that exists regarding social vulnerabilities is the Heritage Bylaw (Municipality of the District of Chester, 2010).

Possible Adaptation Strategies

Adaptations include ensuring that community members are prepared for a 72 hour emergency wait by implementing the appropriate planning measures. In addition, further social analysis and public participation through a social asset mapping procedure can identify what skills and experience exists within the community to determine the community's current capacity (A.W., personal communication).

Increasing public awareness, especially to those residents whose houses are located within the five meter contour line is recommended. Methods could include an information packet to be distributed to all property owners on the south side of the Highway 3. Households within the high

risk zone could be invited to meetings to discuss the potential physical impacts they could face, for example protection, adaptation, retreat and abandonment options. Similarly the municipality could use free software platforms, for example Google Earth (™), to create an interactive learning environments and invite residents to join the conversation and planning process through social asset mapping.

5. SUMMARY

Throughout the area studied, the most vulnerable sections were areas with low elevation (<5 m above sea level), where the sediments are sand or mixed-grain, wetlands or areas near freshwater systems. Among the effects of climate change, sea level rise, extreme weather events and storm surge will likely lead to biophysical issues such as coastal migration, inundation (either permanent or temporary) and seawater intrusion. Infrastructure further complicates the vulnerability of these areas as roads can cause coastal squeeze, as the coastline attempts to shift inwards and is physically prevented by barriers such as Highway 3. Additionally, because the other important infrastructure systems are typically associated with the roads and low elevation areas for engineering purposes, these areas (already vulnerable from a biophysical perspective) have many co-occurring infrastructure vulnerabilities; primarily, exposed power and telecommunication lines, inadequate storm water culverts and ditches and wastewater lift stations. Since these vulnerable infrastructures are the ones providing vital services to the residents in the area, when these infrastructures become insufficient, or worse, fail entirely, it is these residents that will be directly affected, whether through flooding, sewer backups, or losses of power, telecommunications and road access. In the long term, these compounded negative impacts of climate change could lead to a decrease in the social and economic viably of these highly vulnerable area, and possibly the whole study area - Chester Commons to Deep Cove.

However, the situation is not so dire that effective planning and management cannot adapt these areas to reduce their vulnerability to climate change. Future planning strategies and governance must address the current and potential vulnerabilities identified in this report in order for the Municipality to proactively adapt to the potential impacts of climate change in advance of their effects.

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The Chester Project

December 16th, 2011

Stage 3 - Final Report

P.E.A.C.E.: Planning Effectively for the Aspotogan Coastal Environment

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Introduction

The Aspotogan Peninsula is located in Southern Nova Scotia, and separates Mahone Bay from St Margaret's Bay. It is within the Municipality of the District of Chester, which is part of Lunenburg County (Tara McGuire, September 9, 2011, personal communication). In the following report, the coastal zone of the Aspotogan spanning from Hubbards, along route 329, to Deep Cove will be discussed in regards to its vulnerabilities to climate change. This report will provide guidance for the Municipality to develop a climate change adaptation plan.

The Intergovernmental Panel on Climate Change (IPCC) has emphasized that climate change is a reality and will cause damaging effects. Coastal communities must take precautions, especially in regards to sea level rise and expected increasing storm surge (Intergovernmental Panel on Climate Change (IPCC), 2007). The vulnerabilities of the Aspotogan will be discussed in light of biophysical, socio-economic, infrastructure, and governance features. These vulnerabilities were assessed through a background review of the region, discussions with municipal councillors and staff, field surveys, and an analysis of Geographical Information System (GIS) data.

1.0 Nature of the Aspotogan

1.1 Biophysical

To understand the geology and landscape of the study area, it is necessary to point out that its formation started 360-290 million years ago and was completed in the middle of the Carboniferous period. The erodible soil surface of St. Margaret's Bay and Mahone Bay during that period of time contributed to the extension of the Carboniferous sea and, therefore, to the deposition of limestone (Nova Scotia Museum of Natural History, n.d. (a)). To date, only the periphery of the two bays show the remainder of this type of rock (Nova Scotia Museum of Natural History, n.d. (a)). "A coastal lowland that developed on Carboniferous rocks around the bays is abruptly terminated by the steep-sloping granite inland. On the Aspotogan Peninsula, which separates Mahone Bay from St. Margaret's Bay, the till is very thin

as a result of the scarcity of softer Carboniferous rocks" (Nova Scotia Museum of Natural History, n.d. (a), para. 3).

Granite is the principal rock-type present in the bedrock in the coastal areas of the peninsula (Nova Scotia Museum of Natural History, n.d. (a)). This granite rock acts as a quartz supply with occasional small, white, sandy pocket beaches (*e.g*. Bayswater beach). In general, this sediment supply is very limited (Figure 1-1) (Nova Scotia Museum of Natural History, nod (b)). Due to the relative impermeability of the bedrock, freshwater is accumulated, which allows the formation of streams, lakes, and bogs (*e.g.* Bayswater pond, Fox Point Lake, Mill Cove Cranberry Lake, Blandford Lake) (Nova Scotia Museum of Natural History, n.d. (b))

Figure 1-1. Sandy pocket beach next to highway 329 and rocky shore road

The soil types of the Aspotogan peninsula are less variable compared to other coastal areas of the Municipality of the District of Chester. For instance, the types of soils identified from Mahone Bay to Upper Blandford are the following: granite, quartzite, and slate, Bridgewater soil (sandy loam derivated from slate), Gibraltar soil, Danesville, Farmville (derived from a mixture of granite, quartzite, and slate), and Wolfville loams (Nova Scotia Museum of Natural History, n.d.1). In contrast, Gibraltar soil (coarse-textured, well-drained gravely, sandy loam derived from granite), Rockland areas, and a few small patches of Wolfville soil form the Aspotogan peninsula, which resembles the soil composition of St. Margaret's Bay (Nova Scotia Museum of Natural History, n.d.(c)).

Finally, the Aspotogan peninsula encompasses three types of contours: cobble and boulder shores (*e.g.* Fox Point Harbour) (Figure 1-2), rocky shores (*e.g.* granite rock exposition in New Harbour), and sandy shores (*e.g.* Bayswater). The first two types are the predominant shores around the peninsula (personal observation).

Figure 1-2. Cobble and boulder shore in Fox Point

The formation of the rocky shore is the result of "marine erosion of the overburden and the bedrock, due to a combination of rising sea level and wave action in areas where there is low sediment supply" (Nova Scotia Museum of Natural History, n.d. (f), p.405). Due to these geological characteristics, the coastal barrens of the peninsula allow the growth of vegetation such as reindeer moss, lichens, broom-crowberry, and sedge bogs (Nova Scotia Museum of Natural History, n.d., (e))

1.2 Socioeconomic

Approximately 2,000 residents live on the Aspotogan peninsula, the largest community of which is Blandford. The 2006 Census of Population published by the Nova Scotia Department of Finance provides demographic and economics statistics specific for the community of Blandford, which is also said to include the smaller communities of Aspotogan, Bayswater, Birchy Head, Deep Cove, East River, East River Point, Mill Cove, New Harbour, Northwest Cove, Southwest Cove, The Lodge, and Upper Blandford (Nova Scotia Community Counts, 2011).

For the residents of the Aspotogan, trends in age, income, and employment mirror those seen in the District as a whole. The average age of residents in the Aspotogan region has increased slightly, with roughly 5% fewer residents under the age of 34 and 7% more residents 55 or above. In 2006, 32.3% of all residents were 35 – 54 years of age. This highlights a slightly higher average age of the community in the Aspotogan than in the province overall. The income of families in these communities is also comparable to that of the province, although slightly higher. In 2006, families had a median income of $62,880 per year, and average income of $66,904. This represents an increase of roughly 45% since 2001 (Nova Scotia Community Counts, 2011).

In 2006, approximately half of the residents aged 25 years and older were employed, increasing marginally over the previous ten years. More significantly, the employment rate of residents between the ages of 15 and 24 increased by 22% to a rate of 51.9% in 2006 (Nova Scotia Community Counts, 2011). Despite a small

population increase of 10.2%, past and future increases in employment rate may be more likely to occur in the Aspotogan than elsewhere in the district due to the fact that Hubbards boarders the outskirts of the urban centre of the Halifax Regional Municipality. As was noted in the Integrated Community Sustainability Plan (ICSP), aging populations also contribute to the increases in employment as more people are of working age (Institute for Planning and Design, 2009).

At the time of the 2006 census, the average value of private dwellings rose by 150.6% since 1996, increasing in average value more than all other communities in the Municipality of the District of Chester, except the village Chester itself (Nova Scotia Community Counts, 2011). The increase in property value is likely the combined result of a relatively high population density in the coastal zone (see definition in section 3.1) and a high demand for waterfront property from a significant immigrant population (8.9%) (Nova Scotia Community Counts, 2011).

The economy of the Aspotogan is based on tourism, accommodations, retail, and fisheries and aquaculture. Despite recent declines in tourism (Institute for Planning and Design, 2009), there are many summer rental cottages that reside along the Aspotogan, as well as seasonal private properties, in contrast to the high density of restaurants and gifts shops in Chester village. Otherwise, many of the jobs in the region are seasonal because they are resource-based. There are three seafood businesses in the area, namely Shatford's Lobster Pound Ltd, Granville Gates & Sons Ltd, and Cooke Aquaculture**.** Finally, while the manufacturing company Louisiana Pacific exists beyond the peninsula, it offers year-round employment for many residents of the Aspotogan and the entire municipality (Institute for Planning and Design, 2009).

1.3 Infrastructure

The infrastructure of the Aspotogan peninsula is fairly sparse, with existing structures predominately present along the coast. As mentioned above, the buildings are primarily private homes, with few businesses and municipal structures in between. Many of the oceanfront homes and businesses have built up

rock wall structures for protective purposes. Some structures, like the Hubbards Yacht Club, extend directly onto the water.

There is a public wharf owned by the municipality in Aspotogan, as well as a public boat launch in Blandford. The federal government operates wharves at Mill Cove, Fox Point, Blandford, and Northwest Cove. These wharves have rock walls on the ocean side. Many of the ocean front homes and businesses have private wharves and docks.

The main roadway is Route 329, which connects to Trunk 3 in East River. Off of Route 329 are roadways, both paved and unpaved, that lead to private homes. One of the larger stretches of paved road is the Mill Cove Shore Road, which runs along the Eastern coast of the peninsula. Lining the roadways, are power and telephone lines (personal observation, 2011).

The majority of residents in this area are supplied by well water except for approximately 40 homes that are currently on a central water system at Mill Cove (Lyle Russell, personal communication, November 10, 2011). According to Lyle Russell, assistant engineer for Chester's public works department, permission has been granted to drill 40 wells which will complete the system's decommissioning, by November of 2012 (personal communication, November 10, 2011). The Nova Scotia Utility and Review Board has approved for the municipality to abandon this service due to high levels of fluoride in the water and sparse population (Canadian Legal Information Institute, 2011). There is no major central waste management system on the peninsula. Approximately 65 residents in the Mill Cove area are on a small central system, with the rest of the residents having septic tanks (Lyle Russell, personal communication, November 10, 2011). For storm water drainage, there is a lake culvert at Bayswater beach.

1.4 Politics & Governance

The Aspotogan peninsula, located in the Municipality of the District of Chester, straddles two municipal districts, District One and District Two. District One is represented by Councillor Marshal Hector, and District Two is represented by

Deputy Warden Floyd Shatford. Council meetings are held on a bi-weekly basis and are presided over by Warden Allen Webber.

The authority of the Municipal Council is granted from the province by way of the Municipal Government Act, the purpose of which is as follows:

> (a) give broad authority to councils, including broad authority to pass by-laws, and to respect their right to govern municipalities in whatever ways the councils consider appropriate within the jurisdiction given to them;
>
> (b) enhance the ability of councils to respond to present and future issues in their municipalities; and
>
> (c) recognize that the functions of the municipality are to
>
> (i) provide good government,
>
> (ii) provide services, facilities and other things that, in the opinion of the council, are necessary or desirable for all or part of the municipality, and
>
> (iii) develop and maintain safe and viable communities.
> *1998, c. 18, s. 2* (Government of Nova Scotia, 1998)

The Municipal Government Act achieves this purpose by laying out guidelines for the overall structure of the governance of the municipality as well as outlining specific roles and responsibilities in regards to the every day business of running a municipality. The main tool that is given to the municipalities in order to achieve the above goals is the ability to develop and enforce municipal by-laws.

The municipal council has enacted and is currently enforcing many of these municipal by-laws, but the Land Use By-Law is the most important in regards to dealing with the potential effects of climate change. This is because, even though the roads are going to be affected, they are the responsibility of the province, as are

many of the beaches. Wharfs and other ocean front infrastructure fall largely under the Federal purview and so lands outside of municipal responsibility.

The municipal Sub-Division By-Law is another potential tool that could be used in order to help to plan and prepare for the potential effects of climate change, however the Land-Use By-Law generally overrules it. Section 8 of the Subdivision By-Law clearly states that:

> Where a land use by-law is in effect
>
> (a) all *lots* shall meet the applicable requirements contained in such a by-law; and
>
> (b) Clauses 7(b) and 7(c), and Sections 10, 11,13,14,16 and 18 are inoperative and do not apply unless the land-use by-law permits development on any *lot* created pursuant to these sections and the municipal planning strategy provides for both the *subdivision* and *development* of such lots. (Municipality of the District of Chester, 2000)

Therefore, any changes made to the Land-Use By-Law would supersede the Subdivision By-Law.

While there are many places where governance and planning could help to minimize the effects of climate change, in many cases effective policy exists, it just needs to be applied to risk areas. For example, in Blandford, access to the fire department could be restricted in the event of an emergency (see section 3.3.4). This is not due to a gap in policy or planning, but it is rather an issue that needs to be addressed. The governance section of this report will focus more on the actual policy gaps as opposed to simply areas where issues need to be dealt with using current strategies. It is clear that the strongest potential tool for the Municipality is their control over land use and development. It is also the largest gap in policy, and as such that is what will be focused on in the governance section of this report. Effective development planning going forward is going to be essential in ensuring that the Municipality of the District of Chester remains a viable and vibrant community long into the future.

The Land Use By-Law and the Aspotogan

Currently the Aspotogan peninsula consists of two different zoning areas (Municipality of the District of Chester, 1997). The zoning restrictions and development guidelines for these two areas are all contained within the Municipality of the District of Chester Land Use By-Law. According to the by-law, the vast majority of the peninsula falls under the "General Basic Zone", while a small area on the former site of CFS Mill Cove, now called Mill Cove Park, has its own set of restrictions as laid out in section 6A. Mill Cove Park falls outside of the scope of this project however, as it lies outside of the coastal zone as defined above. This being the case, only the General Basic Zone will be addressed in this report.

Under the General Basic Zone, there are some restrictions on the development of commercial properties. Schedule "C" of the Municipal Land Use By-Law outlines the types of commercial uses that are subject to the successful finalizing of a development agreement between the developer and the municipality. As far as private residential dwellings are concerned, however, no development permit is necessary (Municipality of the District of Chester, 1997). There are no building restrictions beyond those laid out by the province, which does a thorough job of laying out *how* a building should be built. When it comes to *where* buildings can be built however, the provincial building code for the most part defers to "*the authority having jurisdiction"* (Government of Nova Scotia, 2011). In this case, the authority having jurisdiction is the Municipality of the District of Chester, and in the General Basic Zone, there are no significant building restrictions whatsoever. This lack of building regulation is simultaneously the largest legislative gap in how the municipality will be able to deal with climate change as well as the largest opportunity.

2.0 Climate & expected changes

Regardless of whether or not one believes that human activity is to blame, there can be little doubt that the climate is changing. According to the Municipality of the District of Chester (Institute for Planning and Design, 2009), sea level rise is expected to increase between 55 and 95 cm in the next 98 years. If one then takes into consideration the potential for storm surge on top of that initial sea level rise, in severe weather events the water level could go as high as 2.67 meters (Halifax Regional Municipality, 2010). These estimates are by no means infallible, however it is clear that the question is no longer *if* the climate is changing, but *by how much.*

One of the leading reports on climate change is the IPCC Fourth Assessment Report published in 2007. Aside from sea level rise, the report lists increased storm activity and severity, an increase in tidal ranges, and changes in precipitation and wind patterns (IPCC, 2007). All of these factors will have a particularly pronounced effect on the coastal regions of the world, and Nova Scotia is no exception.

Recent events in Nova Scotia's meteorological history serve to illustrate the kinds of effects that can be expected as weather grows more severe and sea level continues to rise. Events like Hurricane Juan, White Juan, and, more recently Hurricane Noel, all act as potent reminders of the effects that extreme weather can have on an unprepared coastline. See Table 2-1 for a summary of the Aspotogan climate as it stands today, and what can be expected in the future. Table 2-2 shows these climate change expectations in relation to their expected impacts.

Table 2-1 (a): The climate as it stands today[1]

Average Temperature Range (°C)	18.4 to -5.9
Average Annual Precipitation (m)	1.52
Tidal Range (m)	1.5-2
# of days annually with >10mm precipitation	52

Table 2-1 (b): Expected changes (IPCC, 2007)

Temperature (°C)	Increase of 2-4 degrees
Precipitation	Increase in frequency and severity of storms
Tidal Range	Increase of approximately 1m
Weather Patters	Precipitation and wind patterns will change

Table 2-2: Possible impacts

Impact	Sea Level Rise	Storm Surge	Storms	Precipitation	Temperature
Extreme Weather Events			✔	✔	✔
Flooding	✔	✔		✔	
Seawater Intrusion	✔	✔		✔	✔
Erosion	✔	✔	✔	✔	
Coastline Migration	✔	✔			
Loss of habitat/ biodiversity	✔			✔	✔

[1] Temperature and precipitation information courtesy of http://www.theweathernetwork.com/statistics/summary/cl8204453/cans0027

3.0 Vulnerabilities

3.1 Coastal Zone

Due to the seaside location of the Aspotogan, the greatest climate change impacts to the region will be those that are marine and related to ocean circulation. Therefore, the area of the Aspotogan that will be most affected by climate change is the area closest to the coast, or the coastal zone. For the purposes of this study, the coastal zone can be generally described as extending from the high water mark to a minimum of 100 meters (m) inland (Figure 3-1). The coastal zone also includes the first 10 m of elevation, and thus the boundary may be extended up to a maximum of one kilometer inland in order to accommodate elevation, or significant features or structures.

The first 10 m of elevation have been specified due to the risk of these areas to the direct impacts climate change. Based on an average tidal range of 4 m, and an estimated maximum sea level rise of 95 centimeters, the first 5 m of elevation are at risk of permanent flooding. Due to the risk of storm surges, the following 5 m of elevation are at risk of occasional flooding. These two areas of elevation have been made visible in all maps in this report (Figure 3-1).

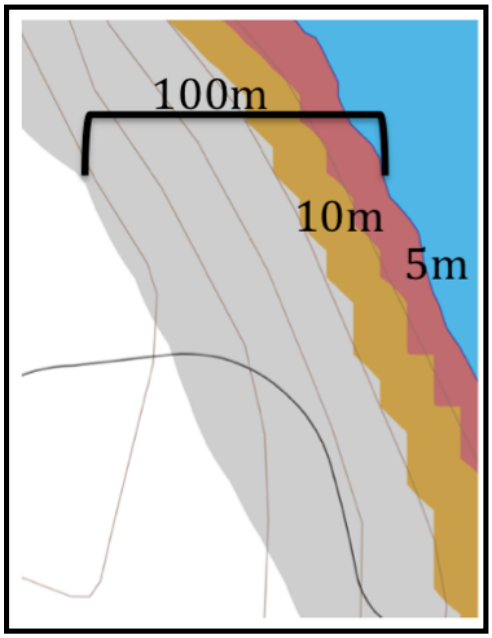

Figure 3-1. Coastal zone delineations. Symbolized in grey for first 100m inland from high water mark. Elevations of 0-5m shown in pink and 5-10m shown in orange.

3.2 Vulnerability

Before determining the vulnerability of an area to climate change, it is necessary to define 'vulnerability'. The body of literature on climate change presents several variations, however, for the purposes of this paper, vulnerability will be defined in accordance with the IPCC (2007) as:

> The degree to which a system is susceptible to, and unable to cope with adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity.

In other words, the degree of vulnerability is equal to the degree of risk, minus the degree of adaptation. As there is no longer a debate as to the existence of climate change, it is important to foster adaptive capacity by identifying vulnerabilities and employing potential coping solutions, such as adaptations.

In the case of the Aspotogan, climate change forces can create vulnerabilities in natural systems, infrastructure systems, social and economic systems. In many ways, vulnerability in one of these systems will cause weakness in others (*e.g.* poor emergency response planning is a governance vulnerability and can cause social systems to be vulnerable). If left without adaptation, these systems will each experience climate change impacts that compound to create especially vulnerable areas.

In the following pages, impacts and vulnerabilities relevant to the Aspotogan peninsula will be discussed in terms of biophysical, infrastructure and socioeconomic systems. This will be followed in section 3.3 by maps and a description of anticipated impacts in five priority vulnerable areas of the Aspotogan peninsula. Finally, governance and planning systems will be examined in light of these vulnerabilities.

3.2.1 Biophysical Impacts & Vulnerability

According to the GIS analysis, some areas of the Aspotogan, such as Fox Point, Mill Cove, Blandford, and Bayswater, are vulnerable to sea level rise because of the low-lying coast. The Intergovernmental Panel on Climate Change has categorized sea level rise as the most hazardous impact of climate change in coastal

zones (Intergovernmental Panel on Climate Change, 1996). Several impacts are related to this rise in sea level, and may:

> (i) inundate and displace wetlands and lowlands, (ii) erode shorelines, (iii) exacerbate coastal storm flooding, (iv) increase the salinity of estuaries and threaten freshwater aquifers and otherwise impair water quality, (v) alter tidal ranges in rivers and bays, (vi) alter sediment deposition patterns, and (vii) decrease the amount of light reaching water bottoms (Intergovernmental Panel on Climate Change, 1990a, p. 6-1).

In addition, its negative impacts are associated with the expected increase of storm frequency and intensity, and, therefore, storm surges (see also Table 2-2) (Vasseur & Catto, 2008).

A storm surge has been defined as "the difference between the observed water level during the storm and the level the tide would normally rise to in the absence of storm activity " (Forbes, 2004, as cited in Vasseur, L., & Catto, N. R, (2008, p. 131). Past storms and storm surges have indicated that coastal areas exposed to open seas that experience such events are highly vulnerable. For instance, in Chester, Hurricane Noel not only caused infrastructure damages, but also deposited flotsam and jetsam along the coast (Chesterns, 2007). Along with this, the wave analysis conducted by METOC Halifax showed 10 metre sig-waves along the Atlantic coast of Nova Scotia ("Hurricane Noel Damage to Nova Scotia", 2007) during this particular storm event. Storm urges could potentially damage important landing wharfs and docks areas (*e.g.* Fox Point Harbour, Mill Cove harbour, Granville Gates fish plant, and the municipal wharf), and could produce fishing-related waste from such damages. This could contribute to coastal environment degradation (Chiappone, White, Swanson, & Miller, 2002).

Coastal erosion, another side effect of sea level rises and storm surge, represents a menace to coastal zones. Vasseur et al. (2008) highlighted that erosion occurs mainly in sensitive coastlines, such as sand dunes, sand and pebbles gravel beaches, as well as in weak consolidated bedrocks and unconsolidated sediments.

To evaluate how vulnerable the coast would be to this natural phenomenon, it is necessary to determine the soil and shore composition. In the Aspotogan peninsula, three types of coastal contours exist: rocky, boulder and cobble shores, sandy beach, and a mix of rocky and sandy beach. Nonetheless, it is difficult to appropriately estimate the magnitude of coastal erosion in rocky shores, mainly because of the minimal research on slowly changing rocky coasts (Trenhaile, 2002). Yet, what it is certain is that these coastal contours cause perilous implications when linked to coastal developments. For example, in an event of storm surge, waves can place rocks from the subtidal zone to either intertidal zones or in the coast (O'Carroll, 2010). This causes the blocking of access to relevant infrastructures and also to auxiliary roads that lead to private man-made structures (see section 3.2.3).

The literature indicates that resistant bedrock, such as granite, does not erode rapidly, compared to other types of rock (Nova Scotia Museum of Natural History, n.d., (a)). In open sea zones, due to the constant exposure to wave action and strong winds (Nova Scotia Museum of Natural History, n.d.,(g)), and the projections related to extreme climate conditions (Field et al., 2007), even granite rock coastal zones could experience accelerated erosion.

In the Aspotogan, "sandy shores form through the deposition of sand resulting from the erosion of glacial till and bedrock in the area of occurrence" (Nova Scotia Museum of Natural History, n.d., (h), p.411). In terms of vulnerabilities, coastal zones composed of soft sediments, such as sandy shores, could suffer serious biophysical impacts if they are unable to retreat. The natural process of retreating, also termed as inland migration, is related with the seasonal variation of the sand distribution along the coast as a result of wind and wave action (Nova Scotia Museum of Natural History, n.d., (h)). Sand is transported from the beach to shallow waters during winter and, *vice versa* during summer (Nova Scotia Museum of Natural History, n.d., (h)). However, the strong Aeolian forces and wave action could create an unbalance in this natural process and could enhance deposition of the sand on the beach, which would accelerate the pace of retreat. The sum of the expected changes (increase in the number and/or intensity of storms, and increment in sea level rise) will intensify coastal dynamics, and translate to a higher

rate of cliff and land erosion and landward migration of sandy coasts (O'Carroll, 2010).

The blockage inhibiting the inland migration of beaches is principally correlated to human infrastructure, such as roads or protection structures. These structures are the main cause of coastal squeeze. Coastal squeeze denotes the loss of the intertidal zone due to the combination of two factors: (i) rising seas that narrow shoreline zones and (ii) infrastructures that limit the coastal retreat (O'Carroll, 2010). Finally, in terms of species diversity, Kont et al. (2003) underline that there is not a strategy that can prevent sea level rise or protect the coastal richness. The authors state that: "one must accept that global climate change causes some ecosystems to transform or disappear and some new one to appear" (p. 12).

Flooding, or inundation, is one of the major direct physical effects of sea level rise. Biologically speaking, coastal flooding intensifies shoreline retreat (Intergovernmental Panel of Climate Change, 1990a). The "mean water level upon which the tides, waves and storm surges can attack beaches, bluffs, embayments and barrier islands of the world's coastlines" (Intergovernmental Panel of Climate Change, 1990a, ch. 6, p.6-8).

3.2.2 Infrastructure Impacts & Vulnerability

Flooding causes concern for infrastructure in low-lying areas because of the effects of increased precipitation and storm surge. Flooding can cause a variety of impacts to coastal infrastructure. These impacts include road washout, building and wharf damage, storm water draining issues, saltwater intrusions, and the backup of septic systems. In addition to washout, roads are also vulnerable to the effects of erosion. With increased moisture in soils, sediment can fall onto roadways, damaging or closing them (Canadian Council of Professional Engineers, 2009). According to councilor Floyd Shatford, roadways such as the Mill Cove Shore Road have already seen these effects during storms: boulders have fallen onto the roadway and the tides have washed out sections of the road.

Storm water drainage systems have been generally designed with past weather events in mind. Given the expectation of increased variability in precipitation and increasingly intense storm events, drainage systems will have difficulty in handling an increased capacity of storm water (Mortimer & Walker, 2007). The incapacity of the system can lead to flooding (Canadian Council of Professional Engineers, 2009). Storm water drainage in coastal areas also has the potential to be affected by the backflow of water due to incoming tides. This causes water to be pushed backwards, potentially causing further flooding. With expected sea level rise, this could increasingly cause problems (Cardno Ltd, 2011). Geoff Macdonald, planning director for the municipality, noted that tidal action causes water to backflow into the culvert at Bayswater (personal communication, September 23, 2011).

Salt-water intrusion is an impact that can affect well water. It occurs as a result of the movement of saltwater into freshwater aquifers which renders the water unfit for human consumption. The intrusion occurs as a result of the water table being drawn down, especially when done rapidly, or due to an inflow of water. The effect is expected to be compounded by sea level rise in aquifers present along the coast (Vasseur & Catto, 2007). A schematic of a coastal aquifer can be found in Figure 3-2. The figure shows the susceptibility of intrusion by either low levels of groundwater or high levels of salt water. Although granite substratum is not as porous as sand, for instance, the rock is still able to collect groundwater within the fractures. Aquifers within crystalline rock fractures are susceptible to salt water intrusion where the openings in the fractures extend into the ocean (Barlow, 2003).

A further issue with the elevation of the water table due to sea level rise is the potential to cause septic systems to cease to function. The change in the water table influences the system's capacity to pump. A further concerning issue is the potential for groundwater to become contaminated due to the submersion of the septic system. If the septic system is placed in a zone expected to be impacted by erosion there is the potential for the system to become exposed (Titus et al., 2009). In addition, when the ground is saturated, soil has a decreased ability to filter

sewage effluent (Cole, 2008). The other possible complication, according to Lyle Russell, is that sewage treatment bacteria are killed by increases in salinity (personal communication, November 10, 2011).

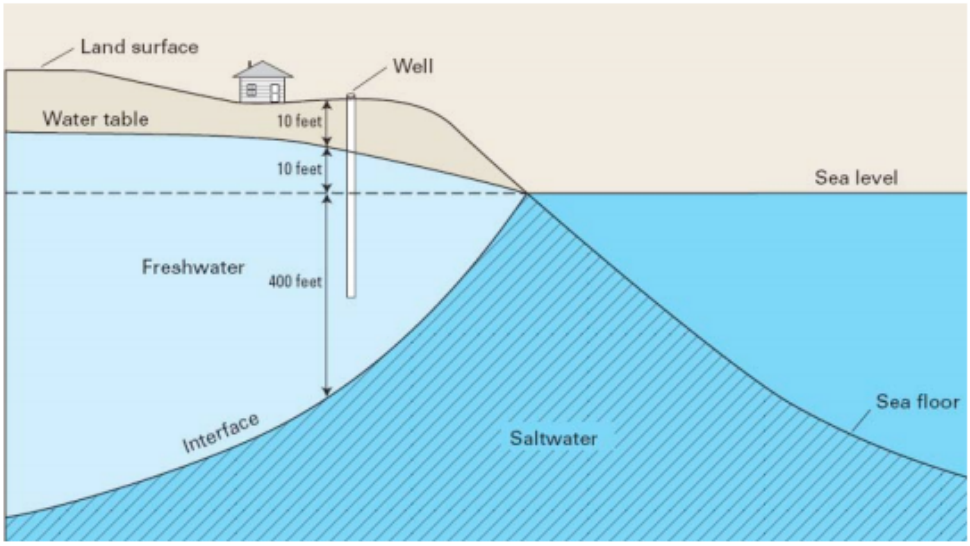

Figure 3-2. A coastal aquifer is susceptible to salt water intrusion due to sea level rise. Reprinted from "Ground water in freshwater-saltwater environments of the Atlantic coast (p. 15)" by P. Barlow, 2003, Denver, CO: Library of Congress. Copyright 2003 by the US Geological Survey.

Strong wind events are able to cause damage to infrastructure. Winds cause the blow-down of power lines, leaving residents without power. Power systems are generally built to operate in stable weather, and their structures are often not suited for high winds (Kezunovic, Dobson & Dong, 2008). They can also cause structural damage to buildings, especially though the shattering of windows and the damaging of roofs (Canadian Council of Professional Engineers, 2009). Winds that are able to blow down trees create the potential for trees to fall onto roadways, affecting the road's accessibility, or the potential to fall onto buildings.

3.2.3 Socioeconomic Impacts & Vulnerability

The most thorough impact that climate change will have on socioeconomic systems in the Aspotogan is the impact on private property. As waterfront property in the Aspotogan continues to increase in value (Nova Scotia Community Counts,

2011), there is a growing abundance of homes and businesses directly on the coast. As such, the homes of most current and future residents are likely to be damaged or become unsafe due to storms, flooding, and coastal erosion. Without careful structural and development planning, this may deter new residents from the area, and thus will weaken the economy of the municipality through a reduced tax base (Municipality of the District of Chester, personal communication, 2011) and lack of population turnover (Allen Webber, personal communication, November 10, 2011). As was mentioned, many of the oceanfront properties are seasonal homes and rental cottages. As they are not occupied year-round, it will be difficult to prepare the structures for the impacts of a storm, or monitor long-term impacts on the property such as sea level rise. If the summer weather trends become unseasonable, repairs and a drop in tourism may make these properties unprofitable and weaken the economy. Moreover, some of the largest coastal private properties belong to marine businesses with wharves, boats, and equipment, and are equally likely to suffer damages or losses in extreme events. As these businesses are essential to many of the residents, this would not only have an impact on the local economy but also on the welfare of the people of the Aspotogan.

Secondly, there are specific social vulnerabilities associated with the age of residents and the area's remoteness. As the resident population continues to age, there is a greater need for access to medical services and a reduced ability for emergency preparedness. Communities on the Aspotogan peninsula are frequently fed by no-exit roads. This creates added vulnerability should these roads become impassable, because emergency response vehicles would not be able to reach residents nor would the residents be able to evacuate. Even in non-emergencies, a cycle of damages and repairs to the road infrastructure would limit the ability for residents to commute to their place of employment or for business to commute to certain addresses.

These vulnerabilities can be categorized separately as private investment, maritime small business, seasonal tourism economy, demographics, or remoteness, and are highly connected within a socioeconomic system.

3.3 Priority Vulnerable Areas

According to our GIS data analysis, communications with municipal staff, and observations *in situ*, five areas have been categorized as vulnerable zones in the context of climate change impacts. The commonality of these areas is that they all encompass the same type of erodible substrate and are all equally exposed to winds and wave action. However, some exceptional vulnerabilities exist, and are described in more detail for each section. The five priority vulnerability areas are pictured in Figure 3-3.

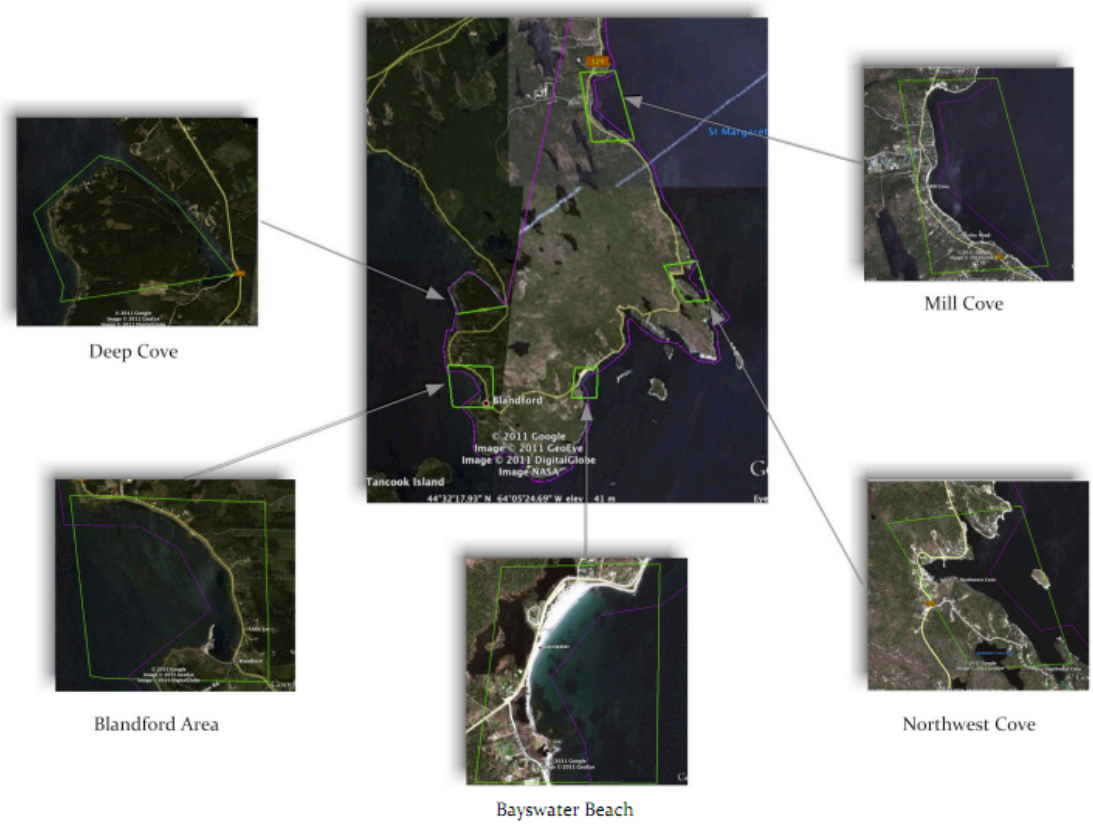

Figure 3-3. The five priority vulnerable areas of the Aspotogan

3.3.1 Fox Point to Mill Cove Rd

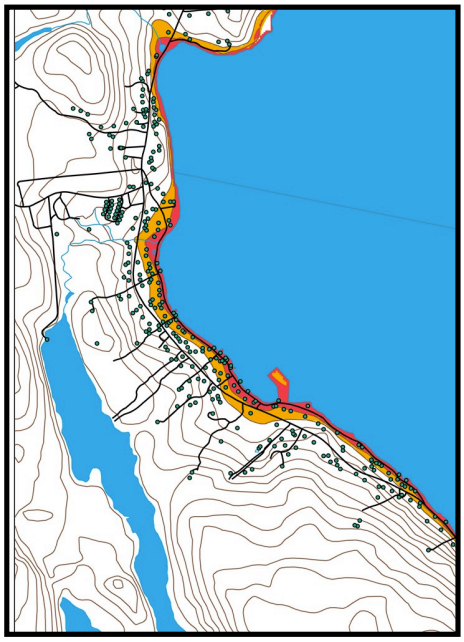

Figure 3-4. Fox Point to Mill Cove

The Fox Point to Mill Cove area poses a vulnerability due to its lack of natural protection (*e.g.* islands), leaving the area exposed to wave action and strong wind forces. The increase in frequency and intensity of storms and storm surge could potentially cause major damages to the surrounding coastal infrastructure, which could trigger coastal degradation due to the fishing-related and infrastructure waste. In particular, the area has a low lying road, the Mill Cove Shore Road, which is lined with transmission lines, vulnerable to flooding and blow downs, respectively. The Fox Point Beach parking lot and beach ramp pose vulnerability due to their exposure, as do the public and private wharves. Small maritime businesses, such as Shatford's lobster and private ocean front homes are exposed to the ocean, leaving the potential for building damage, as well as impacts to their septic and well water systems. The area also has small, pocket sandy beaches, which could be squeezed due to the lack of space to retreat. Highway 329 and the expected sea level rise will impede the beaches from migrating back inland, putting the beaches in risk of disappearing. The vulnerable zone is pictured in Figure 3-4.

3.3.2 Leeward point to Northwest Cove

Leeward Point is a new development destined for this area with six lots currently for sale. The area for this development is almost entirely contained within the 0-5 m pink zone at the top right-hand corner of Figure 3-5. As it is still undeveloped, this area encompasses a green belt of forest that acts as a natural coastal protection against sea level rise and storm surges. However, the

development project will put this protection at risk by cutting down the trees. The forest belt also serves as a soil net to diminish coastal erosion as it is a terrain where the sediments are prone to erode. According to the literature, granite cliffs do not erode rapidly. However, in the case of Leeward Point, its granite cliffs are exposed directly to ocean open waters, and to strong wave action. Consequently, it experiences continual water friction between the base of the cliffs and the ocean water. This area is also vulnerable because of its seasonal tourism economy. Toward Northwest Cove, there are several summer homes between the road and the water and private wharves adjacent to the ocean.

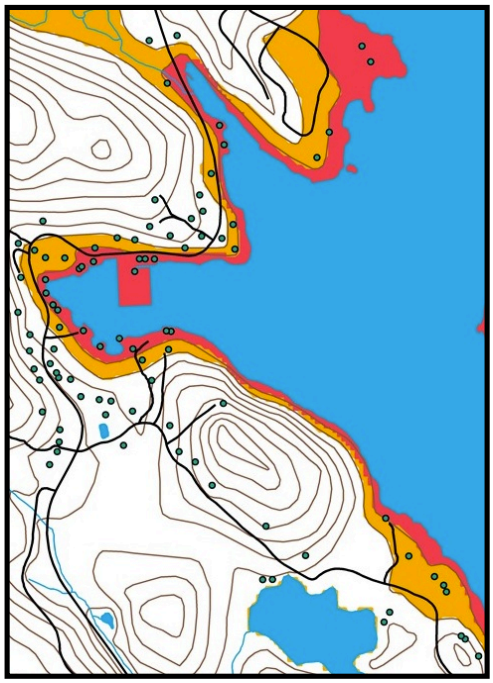

Figure 3-5. Leeward Point to Northwest Cove

3.3.3.Bayswater

The major vulnerability in this zone is related to the negative biological implications that sea level rise and storm surges may have on Bayswater beach. The natural beach migration process, which to date has occurred at a regular pace, will be blocked due to the presence of Route 329. This impediment will cause the beach to be squeezed and could cause the disappearance of the sole recreational coastal area of Bayswater, and one of the main sandy beaches of the Aspotogan. The lake culvert, which transports

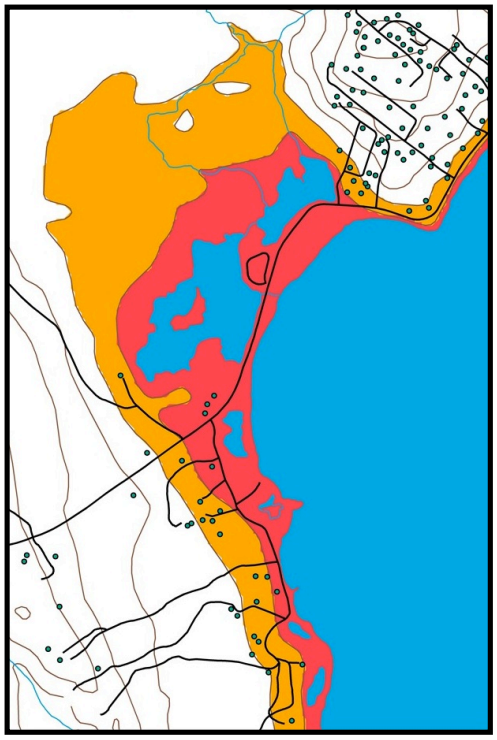

Figure 3-6. Bayswater Beach

water from the lake to the ocean during flooding events, will likely increase flooding during a storm event. Storms and storms surges are predicted to be stronger and more frequent, thus, the influx of the water could cause backflow into the culvert. This would alter the salinity of the fresh water pond, species assemblages, and biodiversity in the pond. As pictured in Figure 3-6, the pond is presently directly behind Route 329 so, in the event that the pond floods due to backlog, the road way could be washed out from both the ocean and pond sides. Along with Route 329, Backman Road also poses a vulnerability. The road is lined with houses and power lines. If this road is washed out, the residents do not have any alternate exit. These residents are particularly vulnerable due to their remoteness. Additionally, flooding in this area puts the seasonal tourism economy at risk.

3.3.4 Blandford

The superficial geology of Blandford encompasses till shore as part of its coastal geology characteristics. The combination of till shore, and a low-lying coast make this zone vulnerable to cope with sea level rise and its impacts. This area is a highly vulnerable zone to storm surge. The wave and tidal forces could bring sparse rocks from the subtidal zone to both the intertidal zones and the coast. This would limit the ability for vital services such as the Blandford Volunteer Fire Department to reach private houses. The fire department is located off of Route 329 on a road with no alternate exit, posing a vulnerability for emergency response if the route is washed out. A lack of access to the homes in the area could occur due to their remoteness and cause enhanced issues due to the older age of the residents in these homes. The Granville Gates & Sons fish plant is vulnerable to coastal impacts due to

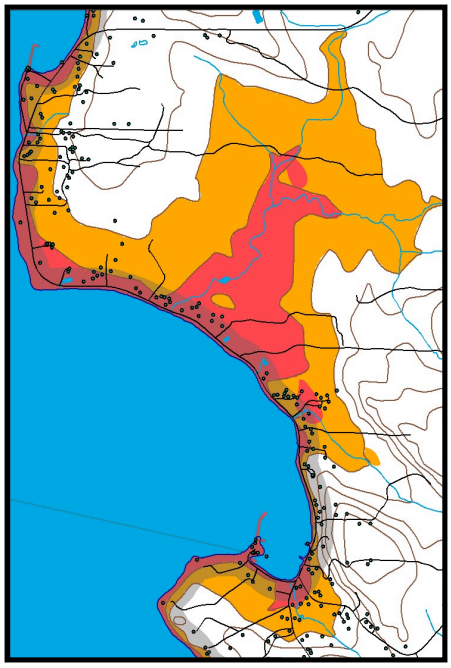

Figure 3-7. Blandford

its low-lying location next to the ocean and its prominent wharf structure. The significant area covered by this business could dramatically add to the surrounding area's fishing-related litter in an event of storm and storm surges. The coastal zone at risk is highlighted in Figure 3-7.

3.3.5 Deep Cove

There is a sparse vegetation belt that could disappear due to sea level rise, and more frequent storm surges. By removing these natural and potential protective barriers, the rate of coastal erosion could increase. This area has many poorly constructed private docks, which could easily break down in the event of a storm. This could produce litter before, during, and after storms and storm surges, and would limit the resident's access to the water. As visible in Figure 3-8, this area has areas of high elevation. However, the homes and roads are situated at the bottom of the elevation, exposed to the ocean. As the Upper Blandford Road approaches Deep Cove, there are areas that are directly next to the coast.

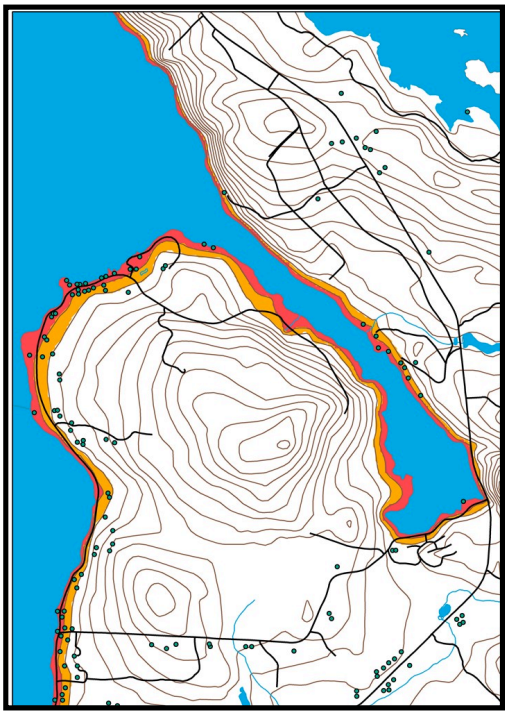

Figure 3-8. ∫Deep Cove

4.0 Adaptations

4.1 Biophysical

Seawalls, revetments, and bulkheads are among the hard structures that have being designed to protect coastal zones from the direct effects of waves and storm tides (Intergovernmental Panel of Climate Change, 1990b), and also to reduce the slouching of sea cliffs that support the beach (Komar, 1998). Although it is an

expensive adaptation strategy, hard structures have been used in areas where there is not more space to retreat or relocate (Komar, 1998). The IPCC stated the following benefits associated with building hard protecting structures: (i) prevention of physical damage to property as a result of waves and flooding; (ii) prevention of loss of (economic) production and income; (iii) prevention of land loss through erosion; and (iv) the prevention of loss of natural resources (environmental and recreational)" (IPCC, 1990b, p.152).

According to the IPCC, beach nourishment or beach replenishment has been described as the action of " dredging sand from back bays, navigation channels, or offshore, or excavating material from a land-based source and placing it on the beach" (IPCC, 1990b, p.5). Beach nourishment is a "soft" technique that has been widely used worldwide (Hanson et al., 2002; Davison, Nicholls, & Leatherman, 1992). The effectiveness of this technique is that it enhances and rebuilds the natural habitats of sandy beaches without compromising its aesthetic (Nordstrom, 2005). A good example of this soft option was evidenced in the sandy beaches of Miami, Florida, where beach nourishment had a positive outcome in expanding the sandy surface of the beach (Komar, 1998). In terms of cost, beach nourishment has been categorized as an expensive soft technique (Esteves, & Finkl, 1998), mainly because it requires continue filling of the beach area to make it a long-time effective measure. However, "the economic benefits to a community can exceed the costs" (Houston, 1996, as cited in Komar, 1998).

Finally, the last adaptation suggested to cope with sea level rise is afforestation or reforestation. This soft option consists of "the direct human-induced conversion of non-forest to forest land through planting, seeding, and and/or the human-induced promotion of natural seed sources" (Nabuurs et al., 2007, p.550). In tropical countries, this soft measure has been used to protect low-lying coastal areas from tidal surges, as well as to provide shelter to wildlife and communities during typhoons events (Saenger & Siddiqi, 1993).

4.2 Infrastructure

Preventative and protective measures can be taken to adapt coastal infrastructure to climate change. These measures would involve strengthening or elevation the coastline through structures such as rock walls to protect the coastline from the effects of sea level rise and storm surge (Rosenzweig et al., 2011). Retreat approaches can also be taken which would involve moving the vulnerability altogether out of the zone at risk (Parlee, 2004). These types of approaches can be applied to all coastal infrastructures but there are also adaptation options that exist for specific infrastructure components.

Roads can be adapted to diminish the effects from flooding. This can be accomplished through improving the drainage system, including the diminishment of overland flow and increasing the road's permeability (OCCIAR, 2010). Roads can be paved with more porous asphalt, such as permeable interlocking concrete pavement (US Environmental Protection Agency, 2009). Paving roads to be more sloped can help with water runoff (Culp, 2009), and increasing road elevation can offer protection from sea level rise (Meyer, Amekudzi, & O'Hare, 2009).

To adapt storm water infrastructure, their capacity can be increased. This can be accomplished through increasing the size of the culverts, reducing storm water entrance speed, and through the creation of retention ponds. A depressed area can be used as a place to divert water to during a storm even for water to be stored temporarily when draining is not a feasibility (Waters, Watt, Marsalek, & Anderson, 2003). Backflow control valves can be used to decrease the backflow of seawater into the drainage system (Cardno Ltd, 2011).

If septic tanks in the coastal zone are particularly vulnerable, an extended sewage system may want to be considered so that the sewage pumping can take place at higher ground and away from the coastal zone. Further, a mounds-based septic system can be adopted in areas where the water table is expected to increase. In this type of system, sand mounds are constructed and they contain perforated drainage pipes that sit on top of gravel. Sewage is pumped from the septic tank up into the drainage pump. This makes sewage pumping effective even with a high water table (Titus et al., 2009).

If salt water is to intrude into ground water systems, a potential adaptation is to invest into increased treatment of the water so that water of lower quality can be used. This can be done to desalinize water affected by salt-water intrusion or to treat water whose quality has been reduced through increases in precipitation (Association of Metropolitan Water Agencies, 2009). Groundwater can be artificially recharged to avoid the intrusion of salt water, and this can be accomplished through storing rain and storm water **(**Hull & Titus, 1986). As coastal aquifers can be affected from salt-water intrusion, there may be an advantage in investing in a central water system, whose water supply is isolated from the ocean.

4.3 Socioeconomic

In the short term, homes, businesses and private properties will need to be dissuaded from being built directly on the coast, and those that already exist need to be protected from storm surges during extreme weather events. One such method is to reinforce the shoreline with a seawall or boulders. Examples exist in the Aspotogan, such as the work done by Shatford's Lobster Pound Ltd after they suffered damages from Hurricane Juan, and the foundation of the Hubbards Sailing Club. While these are viable solutions likely to overcome occasional high wind and wave action, they are likely not the most effective solutions for the long term, due to the added wave height and prolonged wave action that will exist in a few decades from now.

There are two alternatives for new developments and for renovations: setbacks, both vertical and horizontal, and rolling easements. For homes that exist near rocky, boulder shores, and backing onto elevation (e.g. Deep Cove, Blandford), set backs can allow a home to be maintained in relatively the same area, and occupy relatively the same footprint, while still being protected from both short and long term climate change impacts. This is typically desirable for development projects, because the design can incorporate a vertical stratification of multiple elevations, and therefore multiple homes can share an oceanfront view. This has successfully been demonstrated in Deep Cove at The Anchorage development. Otherwise, where there are soft, easily erodible sediments and/or naturally shallow shorelines (e.g.

Mill Cove, Bayswater), it is more likely that coastal migration will occur, and less likely that storm surge will occur (see section 4.1). In this case, set backs could detract from the natural progression of the shoreline, and would likely be impractical. Rolling easements, as defined by Titus (1998), alternatively "allow construction near to the shore, but require the property owner to recognize nature's right of way to advance inland as sea level rises" (p. 1316), and can be done by placing the structure on pilings (See Figure 4-1). This may likely be a more desirable option for the municipality as a whole, as it will not require the government to reestablish baselines and property lines, and therefore will have less of an impact on property values.

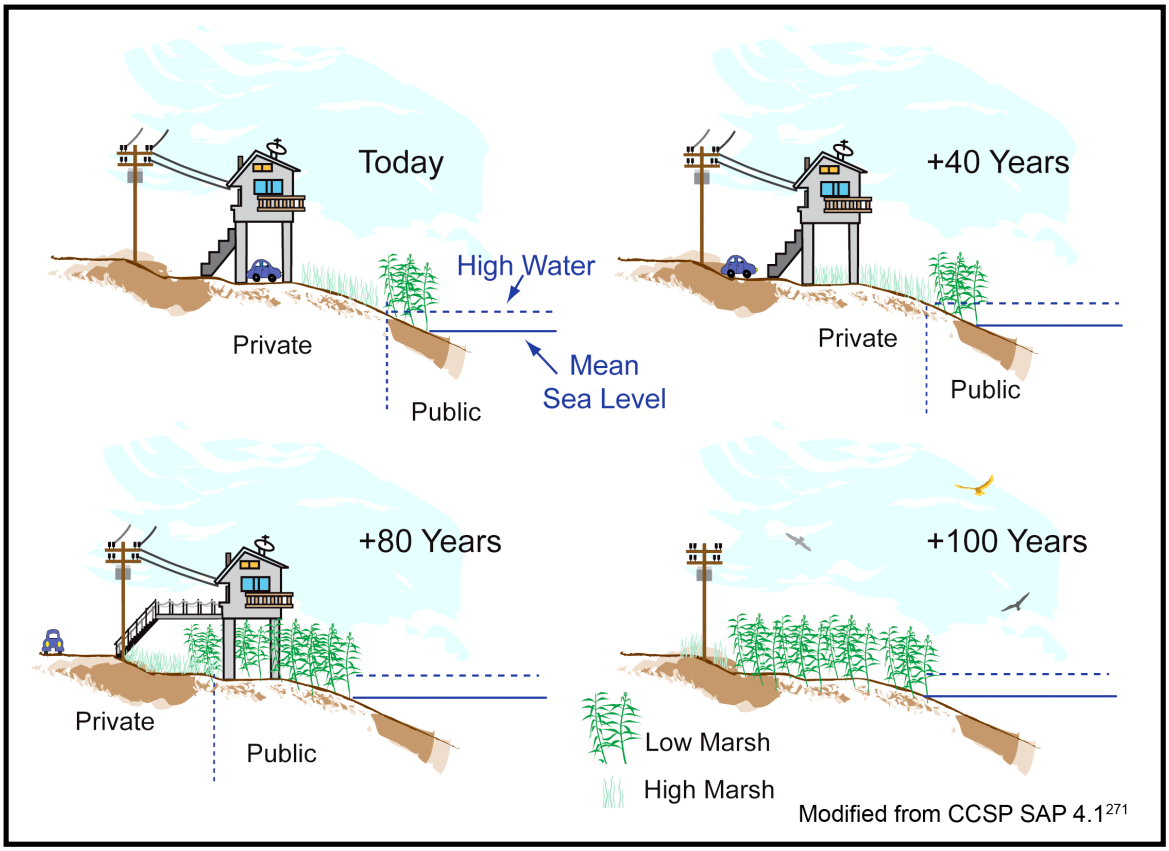

Figure 4-1. Rolling easements. This type of building structure on pilings allows the marsh to migrate inland as sea level rise takes place, beginning in 40 years hence. In 80 years, an extension of the boardwalk is necessary but the house is still able to be occupied. After 100 years, the land can still return to a natural state. Modified from Titus et al. (1998), retrieved from: http://www.globalchange.gov/publications/reports /scientific-assessments/ us-impacts/full-report/climate-change-impacts-by-sector/ecosystems

In the medium term, due to the broad risks posed to the marine environment and coastal development, certain coastal-bound industries such as the family-owned

fishing businesses may be unable to adapt, and unemployment may increase. However, the job market can be diversified in order for the community to become less dependent of the coast. For example, there are opportunities with renewable energy (Institute for Planning and Design, 2009), which could not only create jobs but would also help to mitigate future climate change. Additionally, some level of adaptation may come in the form of climate change insurance. While there are concerns about the industry's ability to cope with the costs of increased extreme weather events, there are policies already in place (Allianz Group & WWF, 2006) and, as climate change grows in general acceptance, the market for such a product grows too (Mills, 2009).

Lastly, there is the potential for small communities such as those of the Aspotogan to form a community-based and operated monitoring system. Because there are often many private properties that go unattended regularly, these properties would potentially be unprepared for sudden weather events, and/or may undergo gradual changes that would go otherwise unnoticed. A system of community monitoring could be as simple as documenting and distributing perceived changes in watermarks and erosion patterns, and properly protecting homes and structures when storms are approaching. Not only would this serve to make the community more aware of the pace of change in their own community, but would also serve as an information base for new incoming residents that may be concerned about local risks of sea level rise, etc.

4.4 Overall governance and planning adaptations (summary)

As it stands, there are very few restrictions on building along the shores of the Aspotogan peninsula. In some ways this could be viewed as a positive; the lack of building restrictions could serve as incentive for people to come and settle in the area, however it could cause many problems as well. Unregulated building along the shoreline brings with it the risk that in the relatively near future the effects of climate change will start to affect these coastal dwellings, and in the event of a disaster, the burden could fall on the municipality if they have done nothing to discourage near shore building.

As mentioned above, the entire coastal region of the Aspotogan peninsula falls under the General Basic Area, and this classification means that there are very few restrictions in regards to where on their lots people can build. When one looks at the shoreline it becomes clear that current pattern of building favours sites close to the mean high water mark, and there is no reason to suspect that if this is left unchecked it will not continue. This could result in the construction of dwellings that are exposed to an unnecessary level of risk. As it stands there are very few rules to prevent this from happening. This situation needs to change.

In order to properly illustrate the current gaps in the Land-Use By-Law, a similar document must be examined in order to see where changes could be made. In this case, the Halifax Regional Municipality's (HRM) Land Use By-Law can serve as an example as to where stricter rules could be put into place.

Within the Municipality of the District of Chester, and more specifically on the Aspotogan Peninsula, there is no specific policy in place to deal with properties in Coastal Areas. This could prove troublesome in the future and can be rectified with minimal expense to the Municipality. Other areas of the province have successfully implemented coastal policies in an attempt to minimize building directly on the shoreline. HRM, for example, has developed section 14QB of their Land-Use By-Law to deal specifically with potential lots in the coastal zone. They have established setbacks, elevation requirements, planning requirements, and other

(1) No development permit shall be issued for any dwelling on a lot abutting the coast of the Atlantic Ocean, including its inlets, bays and harbours, within a 2.5m elevation above the ordinary high water mark.

(2) Subsection (1) does not apply to:

(a) any residential accessory structures, marine dependant uses, open space uses, parking lots and temporary uses permitted in accordance with this by-law; and

(b) lands within the area designated on the Generalized Future Land Use Map in the Regional Municipal Planning Strategy as Harbour.

(3) Notwithstanding subsection (1), any existing dwelling situated less than the required elevation may expand provided that such expansion does not further reduce the existing elevation.

(4) Every application for a development permit for a building or structure to be erected pursuant to this section, shall be accompanied by plans drawn to an appropriate scale showing the required elevations, contours and lot grading information to determine that the proposed building or structure will meet the requirements of this section.

Figure 4-2. COASTAL AREAS RC-Jun 27/06;E-Aug 26/06)

guidelines in order to retain some modicum of control over their coastal lots (Halifax Regional Municipality, 2011). (See Figure 4-2 for the text of Section 14QB of the HRM Land-Use By-Law)

While the Municipality of the District of Chester has a fair amount of control over commercial development, there is a large gap when it comes to residential construction. By establishing appropriate horizontal and vertical set backs when it comes to new development, the District of Chester could ensure that houses built today will continue to be viable dwellings for the people of the Municipality of the District of Chester for years to come.

The second large gap in the Chester Land Use by-Law is the fact that the entire study area falls under only one zone. Aside from commercial and residential, this does little to control the types of dwellings that are built within the coastal zone. In comparison, the HRM has no less than 39 different types of zone into which developments can be classified (Halifax Regional Municipality, 2011. 16[1]). While 39 zones may be excessive for the Municipality of the District of Chester, it shows that much the same way there are many different variations of 'commercial' uses for lands, having different classes of residential zones can be useful as well. Different zones allow for different rules, and the rules can change depending on the demands of the people wishing to develop. By definition, a single-family dwelling will have different needs than a two family dwelling or a townhouse. As it stands, the General Basic Area treats all three of these areas in the same way, with little or no regulation.

R-1 Single Family Dwelling Zone

R-2 Two Family Dwelling Zone

R-2P General Residential Zone

R-2T Townhouse Zone

R-2AM General Residential Conversion Zone

R-3 Low-Rise Apartment Zone

R-4 Multiple Dwelling Zone

RC-1 Neighbourhood Commercial Zone

C-1 Local Business Zone

C-2A Minor Commercial Zone

C-2B Highway Commercial Zone

C-2 General Business Zone

Figure 4-4. Examples of potential Zones

Different zones also allow for different types of permitting structures. By having different types of zones, the municipality

could keep the Aspotogan attractive to potential new arrivals by keeping the restrictions on some types of dwelling low, while simultaneously ensuring safe, controlled development by requiring permits for others. See figure 4-4 for examples of current HRM zones that may be useful to consider for the Municipality of the District of Chester. Definitions of these zones can be found on pages 38-71 of the HRM Land Use By-Law (Halifax Regional Municipality, 2011).

Having different zones could also act as a revenue generator for the municipality, as it is common for municipalities to charge a fee development permits as well as for applications to make a variance from the current zoning classification (Halifax Regional Municipality, 2011. 19A[1])

While there may be other incidental gaps in the current governance structure as it pertains to the Aspotogan Peninsula, the largest is by far and away the lack of appropriate zoning regulations for the coastal region. With the development of more specific and rigid restrictions to development in the Coastal Zone as well as more appropriate matrix of zones throughout the region, the District of the Municipality of Chester could not only open up a new revenue streams through permitting and zone variance applications, but they could also ensure that any new developments that do begin on the Aspotogan happen in a way that ensures they are safe, and prepared to deal with the challenges of a changing climate.

Conclusion

In conclusion, while there are definitely areas of the Aspotogan that are vulnerable, there are also numerous ways to reduce that vulnerability. It is important to realise that even though the situation may seem dire, there is still time. Through the use of a variety of aforementioned adaptation measures, as well as the modification of the Land Use By-Law the majority of the identified vulnerabilities can be effectively managed. Climate change is happening, but there is no reason that, with the right adaptation measures, the Aspotogan peninsula cannot continue to be a viable and vibrant place to live for generations to come.

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