Cost Benefit Analysis of Climate Change Adaptation Strategies for the Acadian Peninsula

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Introduction

A cost benefit analysis (CBA) is an economic based decision support tool used to compare options, projects or scenarios on a monetary basis in order to identify the most advantageous for society as a whole. All the potential outcomes of an option are considered, including social and environmental outcomes, not just the implementation costs, and the net present value of options (NPV) are compared.

We conducted a CBA of adaptation strategies that have been put forward by work groups, the general population, or local stakeholders in three communities of the Acadian Peninsula that have participated in a climate change adaptation process[1]. These communities are Le Goulet, Sainte-Marie-Saint-Raphaël (SMSR), Cap Bateau (CB), Pigeon Hill (PH), Shippagan, and Pointe-Brûlée (Figure 1).

In the Acadian Peninsula, the adaptation process focuses on reducing the risks associated with coastal erosion and flooding. Thus, the strategies that are compared in the CBA are dike construction and beach nourishment in Le Goulet; relocation of homes and construction of erosion control structures in Sainte-Marie-Saint-Raphaël, Cap Bateau, and Pigeon Hill; and changes to zoning regulations in Shippagan and Pointe-Brûlée.

The goal was to estimate the following costs and benefits for each scenario:

- Cost of implementation and any maintenance associated with the adaptation action;
- Cost of any impacts of the adaptation action (e.g. loss of land due to increased erosion on properties adjacent to rock walls, loss of beach);
- Value of the avoided damages from implementation of adaptation actions;
- Social (e.g. value of changed sense of safety, value of ocean vista's or access to the ocean) and environmental (e.g. ecosystem services) non-market cost or benefits resulting from adaptation actions.

We assessed the net present value (NPV) of each scenario for a period of 25, 50 and 100 years. The NPV is the difference between present value flow of benefits and costs over the time horizon and is calculated as follows:

$$NPV = \sum_{t=1}^{T} \frac{Benefits_t}{(1+\rho)^t} - \sum_{t=1}^{T} \frac{Costs_t}{(1+\rho)^t}$$

Where «ρ» is the discount rate and «T» is the number of years in the study period (Tecsult 2008).

A positive NPV is an indication that an option could be beneficial for the community, while a negative NPV indicates the opposite.

[1] For more information on the adaptation work that has been done in the Acadian Peninsula, consult the Regional Service Commission 4 website at : http://www.csrpa.ca/fr/changements-climatiques.

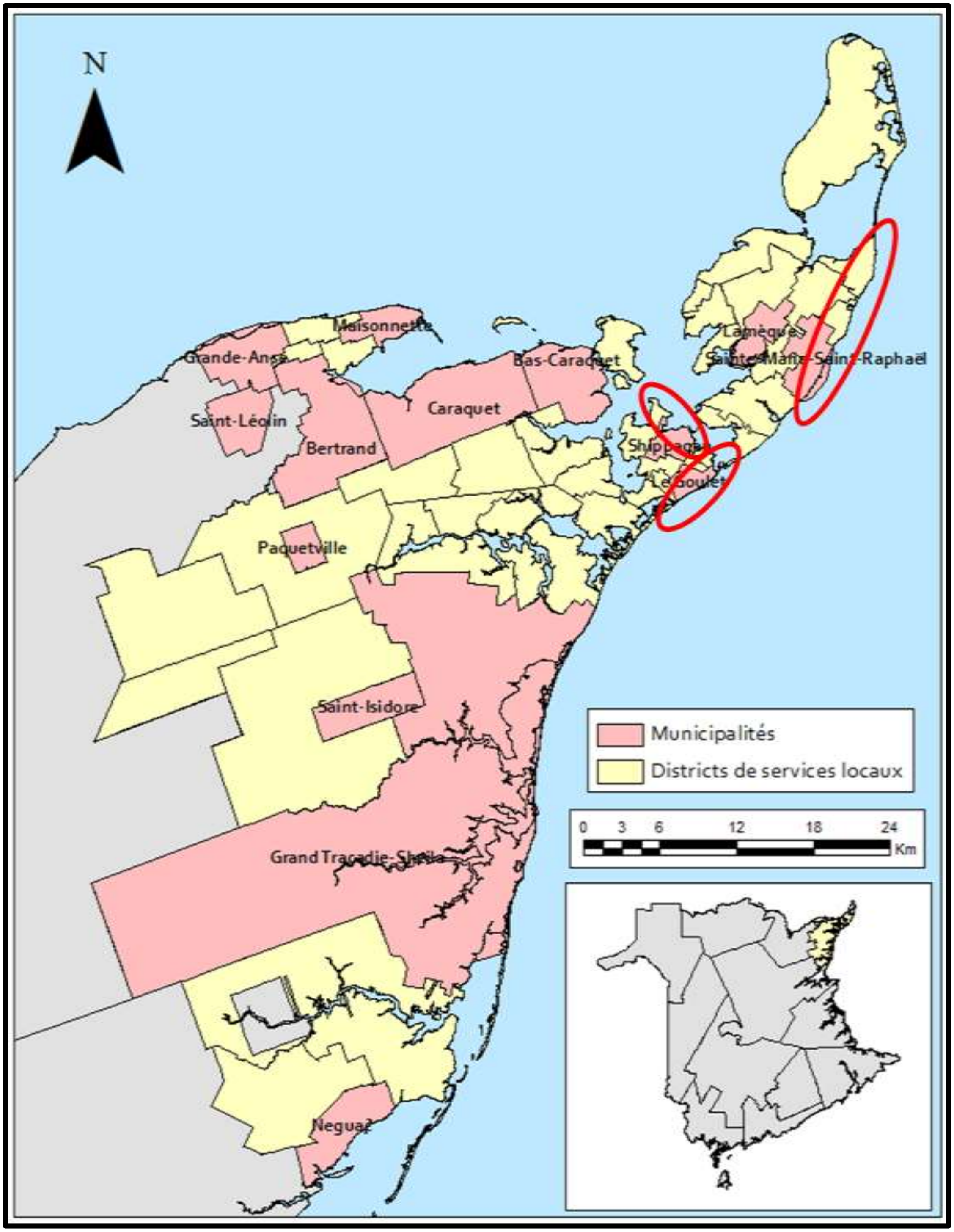

Figure 1. Location of the case study communities: Le Goulet, Sainte-Marie-Saint-Raphaël, Cap Bateau, Pigeon Hill, Shippagan and Pointe-Brûlée

Existing available data to assess costs and benefits included:

- Digital elevation model based on 2009 LiDAR data
- 2009 and 2012 orthophotos
- Erosion scenarios (projected coastline retreat or advance) for 2025, 2055, 2085 and 2100 based on historical rates (shapefiles) (Robichaud et al. 2012; Robichaud et al 2011)
- Flood scenarios (storm surge combined with sea level rise) for 2025, 2055, 2085 and 2100 (Robichaud et al. 2011; Daigle 2014)
- Flood polygons at 10 cm increments from 1.0 to 4.1 m (shapefiles)
- Infrastructure data base (buildings and roads) and associated erosion and flood risk classification (shapefiles) (Robichaud et al. 2012; Robichaud et al. 2011)
- Feasibility and cost estimate of relocation in SMSR, CB and PH (Hébert and Aubé 2015)
- Feasibility and cost estimate of beach nourishment in Le Goulet (Hébert and Aubé 2016)
- Zoning recommendations, including boundaries and conditions of use (e.g. building prohibited or first floor above flood level) (Aubé and Kocyla 2012)

The key steps undertaken were to:

1) Confirm the adaption actions to compare and outline the methods (time horizons, discount rates, flood scenarios and erosion, damage estimation, etc.).
2) Identify economic costs and benefits for each adaptation action (e.g. implementation costs, maintenance costs, avoided damage costs, loss of land, loss of tourist attractions, commercial loss, etc.).
3) Collect data for items identified in step 2.
4) Identify and scope the non-market social and environmental values associated with each adaptation action. The goal was to develop a reasonably complete list of associated non-market values from which priority values would be selected for quantification. For example:
    a) potential environmental impacts (e.g. fish habitat, wetlands, ocean views, beach access and use),
    b) potential social impacts (e.g. disruption to daily life, changing sense of security).
5) Estimate the monetary value of priority non-market elements. This process involved:
    a) developing and validating a questionnaire,
    b) administering the questionnaire (as a door-to-door survey),
    c) data entry,
    d) data analysis.
6) Conduct the market valuation of costs and benefits, where sufficient data was available to support calculations.
7) Calculate the net present value.
8) Perform a sensitivity analysis.

This reports presents the methods that were used to conduct the CBA, including the assumptions, as well as the results. The results are interpreted and discussed, the end goal being to provide useful information for these and other coastal communities, helping them make more informed adaptation decisions.

Costs and Benefits Considered

There are a number of benefits and costs associated with each adaptation scenario. They include market and non-market elements, as listed in Tables 1 to 3. Unfortunately, we were not able to measure some of the market and non-market elements listed due to data limitations.

The benefits that are included in our CBA assessment are the avoided damages to buildings and their content due to flooding, the avoided land and building loss due to erosion, the value people attribute to the fact that properties are protected and to feeling safer, as well as the value people attribute to an increase in coastal recreational opportunities and to maintaining or improving natural coastal habitats for flora and fauna. The costs that are considered include the implementation and maintenance costs of adaptation, un-avoided flood damages to buildings and their content, un-avoided land and building loss due to erosion, as well as the value that people attribute to a loss of ocean view and a reduction in natural coastal habitat (Table 4).

For flood related damages used in Le Goulet and Shippagan, the assessed flood damages (or avoided flood damages) is only a partial assessment and does not include:

- Damages to vehicles
- Damages to public infrastructure (e.g. roads, bridges, water and waste water sewers, etc.)
- Impacts to health
- Psychological trauma
- Clean up costs
- General social or economic disruption
- Emergency measures

Table 1. Benefits and costs of adaptation strategies to reduce the risk of damages due to coastal flooding in Le Goulet

<table>
<tr><th colspan="3">Le Goulet (flooding)</th></tr>
<tr><th>Adaptation method</th><th>Benefits</th><th>Costs</th></tr>
<tr><td>Beach nourishment</td><td>• Maintenance of beach and dunes for habitat and recreation (no more erosion)
• Avoided flood damages
• Increased feeling of safety of citizens</td><td>• Implementation and maintenance costs
• Potential negative impact of implementation on fish and piping plover (trampling and disturbance from machines and silting from sediments deposited)
• Potential false sense of security and increase in infrastructure and citizens at risk
• Flood damages if dune is breached
• Emergency measures response during breach events
• Non market impacts on people during and after breach events (inconvenience of evacuation if evacuated, stress and anxiety, potential missed days of work, potential loss of items of sentimental value)
• Loss of ocean view</td></tr>
<tr><td>Dike</td><td>• Avoided flood damages
• Increased feeling of safety of citizens
• Increased recreation opportunities due to trail on dike</td><td>• Implementation and maintenance costs
• Potential false sense of security and increase in infrastructure and citizens at risk
• Flood damages if dike is breached
• Emergency measures response during breach events
• Non market impacts on people during and after breach events (inconvenience of evacuation if evacuated, stress and anxiety, potential missed days of work, potential loss of items of sentimental value)
• Loss of ocean view
• Beach/land loss to erosion</td></tr>
</table>

Table 2. Benefits and costs of adaptation strategies to reduce the risk of damages due to coastal erosion in Ste-Marie-St-Raphaël, Cap-Bateau and Pigeon Hill

Ste-Marie-St-Raphaël, Cap Bateau, Pigeon Hill (erosion)		
Adaptation method	**Benefits**	**Costs**
Relocation	• Avoided damages (loss of infrastructure) • Increased feeling of safety of citizens • Creation of green space on waterfront (potential increased recreation) • Maintenance of natural coastline • No increase in buildings and citizens at risk	• Relocation costs • Non market costs of moving for people relocated (stress and anxiety, inconvenience of temporary lodging, potential loss of location of sentimental value) • Loss of ocean view for those relocated
Rip-rap	• Avoided damages (loss of land and infrastructure) • Increased feeling of safety of citizens	• Implementation and maintenance costs • Loss of natural coastline (esthetic impact, habitat loss, loss of a source of sediment for regional beaches) • Increased erosion at ends of wall • Potential false sense of security and increase in infrastructure and citizens at risk

Table 3. Benefits and costs of adaptation strategies to reduce the risk of damages due to coastal flooding in Shippagan and Pointe-Brûlée

Shippagan, Pointe-Brûlée (flooding)		
Adaptation method	**Benefits**	**Costs**
Maintenance of retaining wall, rocks and boardwalk	• No erosion • Maintenance of recreational benefits	• Maintenance costs • Artificial coastline (esthetic impact, habitat loss, loss of a source of sediment for regional beaches) • No room for beach to retreat to • Potential false sense of security and increase in infrastructure and citizens at risk • Flood damages when wall is breached • Emergency measures response during breach event • Non market impacts on people during and after breach event (inconvenience of evacuation if evacuated, stress and anxiety, potential missed days of work, potential loss of items of sentimental value)
Zoning regulations	• Avoided damages for new constructions • No increase in buildings and citizens at risk	• Potential increase in building costs for new constructions in accommodation zone to respect conditions • Potential decrease in property values in retreat and accommodation zones

Table 4. Benefits and costs included in the cost benefit analysis of adaptation strategies

Benefits	Costs
• Avoided damages • Property protection • Increased sense of safety • Increased recreation • Habitat improved	• Implementation and maintenance • Flood damages • Lost property value • Ocean view loss • Habitat reduced

Other specific items not included in the CBA:

1) Le Goulet
    a) Beach nourishment
        i) Potential increase in risk to infrastructure and citizens resulting from a false sense of security that leads to increased development in low lying areas behind the protective structure.
    b) Dike
        i) Potential increase in risk to infrastructure and citizens resulting from a false sense of security that leads to increased development in low lying areas behind the protective structure.
2) Shippagan
    a) Zoning regulations
        i) Potential increase in building costs for new construction in the accommodation zone, needed to meet zone requirements
3) SMSR, CB, PH
    a) Relocation
        i) Erosion damage to roads
        ii) Inconvenience and emotional strain of moving
    b) Rip-rap
        i) Erosion damage to roads
        ii) Increased erosion at either end of the rip-rap walls

Methods to Assess Costs and Benefits

Avoided Damages

In the context of the cost benefit analysis, the market benefit of adaptation is equal to the value of the *avoided damage costs* resulting from adaptation. Avoided damage costs occur when adaptation actions result in a measurable reduction in flood or erosion risk. The reduction in risk translates into avoided damage costs. The method employed to estimate the reduction in risk, or in other words, the avoided damage costs is described below.

Avoided Flood Damages

Flood risk results from a combination of the value of potential flood damage and the probability of a flood event occurring (Forster et al. 2008). Since we don't know when a flood will occur and therefore when economic damages will result, we use the predicted probability of flood events to estimate expected annual damages (EAD). This calculation is described by the following mathematical equation:

$$EAD = \sum D_i \times P_i$$

where EAD = expected annual damage

D_i = damage costs for event *i*

P_i = probability for event *i*

To calculate EAD, damage values are estimated across a range of flood probabilities. For any given point in time, EAD can be depicted graphically by relating damage costs to the probability of an event occurring (Figure 2). Figure 2 depicts a hypothetical change in the damage probability relationship as a result of adaptation measures. The dark green shaded area between the curves represents the reduction in damages due to adaptation measures.

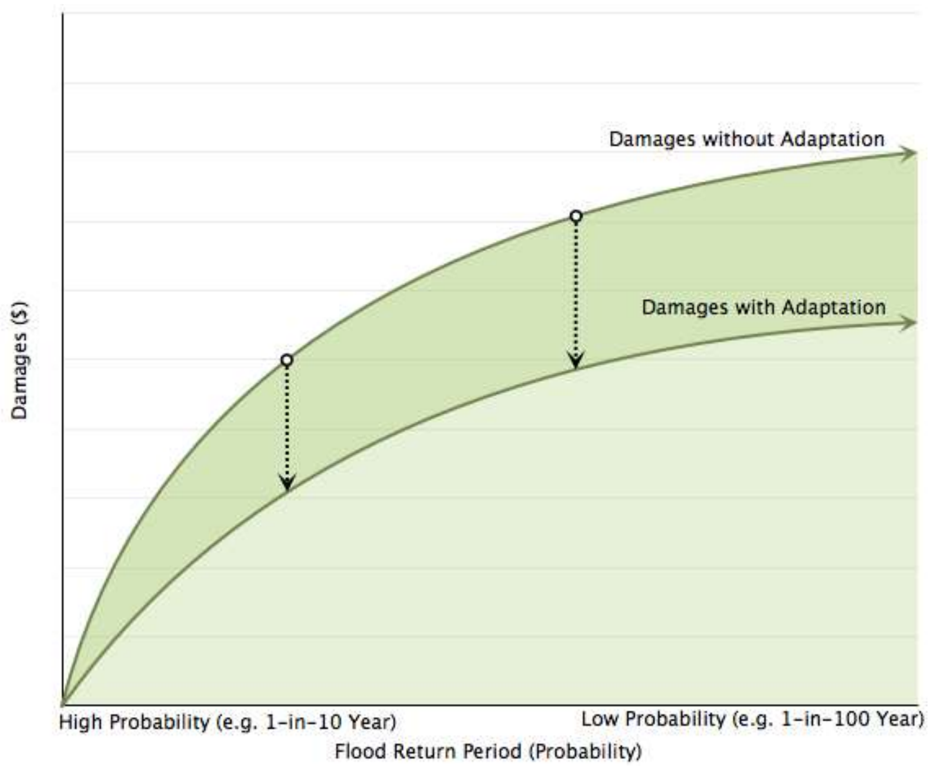

Figure 2. Damage probability relationship

For the current analysis, damage cost values were calculated for buildings and their contents under a range of flood probabilities. Flood damage cost values were calculated for four points in time (2010, 2030, 2050 and 2100), for six flood return periods (1 in 2 year, 1 in 5 year, 1 in 10 year, 1 in 25 year, 1 in 50 year, and 1 in 100 year).

To estimate the damage cost values for each of these times and flood return periods, known building structures expected to be flooded within the communities of Le Goulet and Shippagan were identified using a detailed geospatial database. Key property characteristics for each building were extracted from the database, including: the structure's ground elevation, the structure's assessed value, and the building type.

The damage cost values for each building were estimated using depth damage curves. Depth damage curves relate the depth of flood water to a proportion of the value of a building as a measure of the damage sustained to that building (Wilson et al. 2012). Thus, these curves can be used to estimate anticipated damages to buildings and contents at specified flood depths (for example, according to depth damage curves, a 2-story residential home that is flooded to a depth of x metres will result in damages that cost y percent of the buildings value). Such curves are commonly used to estimate the direct flood costs associated with flooding events (Johnston et al. 2006, Jonkman et al. 2008, and Broekx et al. 2011).

To date, limited work has been done in Canada on developing depth damage curves.[2] For the purpose of this analysis, detailed damage curves from the United States based Hazus model were employed (FEMA 2016). The damage cost assessment drew on a database of over 50 depth damage curves, each defining a unique depth damage relationship for a range of building types (e.g. residential structures, industrial harbour structures, university structures, police stations, mobile homes, nursing homes, etc.). Two types of curves were utilized, one focused on structures, and one focused on contents.

The value of a flooded structure was assumed to be the assessed value of the property parcel on which the structure is located. If multiple structures exist on the same property parcel, the assessed value was divided among all the property structures, proportional to the area of each structure's footprint. A flood depth at each building structure was established by calculating the difference between the flood depth and the ground elevation at the location of the building structure. Flood depths used are based on projections of local sea level rise and storm return periods from Daigle (2014) (Appendix 1). Depth damage curves for structures and contents were then applied to the building structures according to the estimated flood depths.

Once the depth damage curves were applied to the flooded structures, total damage estimates were determined by summing all individual structure and content damage estimates. This was done for each flood return period. The results become points on the damage probability curve (Figure 2) and the area under the curve the EAD estimate. For the current project, the area under the curve was approximated using the trapezoidal rule. The area is equal to the avoided damage costs resulting from adaptation.

Avoided Erosion Damages

In the communities of Sainte-Marie-Saint-Raphaël, Cap-Bateau and Pigeon Hill coastal erosion is the primary risk. In this case, the assessment was based on changes in shoreline over time. Estimates of future shoreline were integrated with the detailed property parcel data. This allowed us to determine,

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[2] Hazus Canada is currently working on establishing a series of Canadian specific damage curves. For more information, see: www.hazuscanada.ca.

for each coastal property, the amount of land that would be eroded from 2012 to 2025, from 2025 to 2055, from 2055 to 2085, and from 2085 to 2100.

Lost property value from erosion was assumed to be proportional to the percent of land lost over each time period. In other words, erosion damages were measured by estimating the percent of land lost and multiplying by the assessed property value. Typically for real estate assets land and buildings are treated separately. However, in the case of coastal erosion, land is actually disappearing and is essentially "eroding" the market value of the property over time as the remaining usefulness of the property decreases. The assessment assumes a linear relationship between land lost and value lost. In reality this relationship would be non-linear with more value being lost as the remaining amount of land associated with a property decreases and would spike once the shoreline encroaches on the structures. However, given data limitations, the linear assumption was used as a means to approximate the lost values over all impacted properties within the three communities.

The sum of all lost property values is the cost of doing nothing. When certain adaptation measures are taken, these lost property values can be interpreted as avoided erosion damages. In the case of the rip-rap scenario, a total of 61 properties were protected. These specific properties were identified and treated as an avoided cost. In the relocation scenario, the land is still lost and therefore still a cost. However, the damage to the structures of relocated homes are saved and are accounted for as an avoided cost.

Implementation and Maintenance Costs

Note that scenarios are described in more detail in the Results section.

Dike scenario in Le Goulet

No prior designs or cost estimates for a dike existed, so we produced a design and cost estimates especially for this CBA. First, the position of the dike was delineated, to outline the natural contours of the saltmarshes that are between the village and the beach, as much as possible. The dike would be located somewhat inland, behind the saltmarshes, to limit the loss and degradation of coastal habitat. Our design assumes that the dike would be contained within municipal limits. In reality, it is possible that to fully protect the village from flooding, the dike would have to extend outside of municipal limits, but to simplify, we assumed that it would not. The total length of the dike is 4 620 m.

The profile of the dike is based on sea dike and coastal engineering guidelines from the BC Ministry of Environment and the U. S. Army Corps of Engineers (Ausenco Sandwell 2011; USACE 2002). The dike has a 16 m wide base and 4 m wide crest, with 1:3 slopes. Total elevation is 3.5 m, based on the 50 year flood in 2055 at HHWLT (Daigle 2014), including a freeboard of 0.6 m. Since the average elevation of the ground is 1.5 m, the height of the dike is 2 m relative to the ground.

The dike would be made from piled sandstone of two grade types, a standard grade (B) and a high grade (A). The high grade sandstone is for the top of the dike, to enable the construction of a gravel trail. There would also be sealing material inside, to prevent water from seeping through. Aboiteaux and culverts would be installed to enable surface drainage. Furthermore, accesses for roads would be built were the dike crosses them (chemin de la côte, rue Basile Roussel and rue du Havre).

Implementation cost estimates include materials, transportation and construction costs, engineering costs, as well as an amount for unexpected costs (Table 5). They were estimated with the help of a local consulting engineer (B. Comeau, Roy Consultants, personal communication, 2015). They include the following:

1) Materials, transportation and installation
    a) Sandstone volumes of 3.5 m^3/m for (A) at \$20/$m^3$and 16.5 m^3/m for (B) at \$15/m^3
    b) Sealing material at \$150/m
2) Site accessibility
    a) For approximately 50% of the length of the dike, access to construction site would be limited. For instance, on private properties, only one truck could pass at a time, increasing transportation time. We estimate that these delays would amount to a cost equivalent to 25% of material, transportation and installation costs.
3) Drainage
    a) 9 roads or streets would require culverts at \$15 000/unit
    b) 8 aboiteaux would be installed in the dike at \$12 000/unit
4) Road accesses
    a) Accesses would be built for the chemin de la Côte, rue Basile Roussel and rue du Havre
    b) Road access slopes would be 8%, so 25 m ((3.5-1.5)/8%) would be built on each side of the dike at \$100/m (P. Robichaud, CSRPA, personal communication, 2014)
5) Engineering costs
    a) 10% of total costs
6) Unexpected costs
    a) Due to the relative uncertainty level of the project, estimated at 20 % of total costs

Ongoing annual maintenance costs are assumed to be 1% of implementation costs.

Table 5. Detailed implementation cost of the dike scenario at present value

Description	Cost
Sandstone A	$ 323 400
Sandstone B	$ 1 143 450
Sealant	$ 69 300
Accessibility	$ 192 019
Culverts	$ 135 000
Aboiteaux	$ 96 000
Road access	$ 15 000
Engineering (10%)	$ 197 417
Unexpected (20%)	$ 394 834
Total	$ 2 320 419

Beach nourishment scenario in Le Goulet

The beach nourishment scenario costs are based on prior assessments conducted for Le Goulet (Hébert and Aubé 2015). Average beach profiles based on 2014 and 2015 elevation data for 17 beach transects were used to estimate the volume of sediment that would be required to obtain the desired dune and beach profiles (Hébert and Aubé 2016). There are two desired dune and beach profiles, one that would be built in 2016 to protect against the 50 year storm in 2050 at HHWLT in 2050, and one that would be built in 2055, to protect against the 50 year storm at HHWLT in 2100 (for details, refer to Hébert and Aubé 2016).

The sediments used would be those obtained from dredging that is soon to be conducted in the Le Goulet fishing port as part of major port infrastructure upgrades. Based on nourishment conducted in 2014, sediment transportation and placement costs are estimated at $\$10/m^3$. Regular re-nourishment is required and would be conducted every 10 years, at 25% of the initial volume (Table 6). These choices are arbitrary, as it is impossible to estimate the volume of sediments that would be lost and when the beach would need to be replenished, due to a lack of data. Engineering costs are assumed to be 10%, and unexpected costs to be 20% of implementation and maintenance costs. There would be additional costs to build temporary access roads to transport the sediments on the beach, but these are unknown at the moment and were not included.

Table 6. Detailed costs of beach nourishment at present value

Year	Description	Beach profile	Volume (m^3)	Costs
2015	New nourishment	2050 profile	30264	$ 302 640
2025	Maintenance	25% of 2050 profile	7566	$ 75 660
2035	Maintenance	25% of 2050 profile	7566	$ 75 660
2045	Maintenance	25% of 2050 profile	7566	$ 75 660
2055	New nourishment	2100 profile	98260	$ 982 600
2065	Maintenance	25% of 2100 profile	24565	$ 245 650
2075	Maintenance	25% of 2100 profile	24565	$ 245 650
2085	Maintenance	25% of 2100 profile	24565	$ 245 650
2095	Maintenance	25% of 2100 profile	24565	$ 245 650
Sub-total				$ 2 494 820
Engineering (10%)				$ 249 482
Unexpected (20%)				$ 498 964
Total				$ **3 243 266**

Relocation scenario in SMSR, CB and PH

Average relocation costs in SMSR, CB and PH were estimated to be $94 250 per house in a feasibility study conducted in 2014-2015 (Hébert and Aubé 2015). This includes: new lot, foundation, well and septic system; electrical and plumbing de-connection and re-connection; house relocation and service wire management; temporary lodging accommodations; and decommissioning of old well, septic system and foundation.

Rip-rap scenario in SMSR, CB and PH

No prior designs or cost estimates for rip-rap existed, however, location and length is based on areas where the erosion risk to residences is highest as described in Hébert and Aubé (2015). A total of 1 337 m of erosion control structures made of armour stone would be built at a cost of $1 000/m, as reported for similar work that was done in PH by the New Brunswick Department of Transportation (D. LeBlanc, NBDT, personal communication, 2014). These costs include materials, transportation and installation. Unexpected costs of 15% of implementation costs are also included (Table 7). No ongoing maintenance would be required, but the life expectancy of the structures is assumed to be 25 years, after which they need to be completely rebuilt.

Table 7. Detailed implementation costs of rip-rap at present value

Sector	Community	Length (m)	Cost
1	SMSR	413	$ 413 000
2	SMSR	222	$ 222 000
3	CB	112	$ 112 000
4	CB	184	$ 184 000
5	PH	62	$ 62 000
6	PH	344	$ 344 000
Sub-total		1337	$ 1 337 000
Unexpected costs (15%)			$ 200 550
Total			$ 1 537 550

Non-market Valuation

We conducted a specific study to estimate the value, in monetary terms, of potential environmental and social outcomes (non-market outcomes) of adaptation strategies. The study consisted of a door-to-door survey and utilized the stated preference approach. Contingent valuation (willingness to pay to stay), choice experiments (trade-offs in protection, recreational opportunities, natural coastal habitat, ocean view, and increase in property taxes) and Likart scales were used. The results enabled us to attribute a monetary value to the value people place on knowing their community is protected (protective value of adaptation), how much they value feeling safer, and the value they place on changes in coastal recreational opportunities, natural coastal habitats for flora and fauna, and a loss of ocean view (for detailed methods and results, see Appendix 2).

People's willingness to pay for repairs or protection was used as a proxy for sense of safety and is valued at $10 170 per household, based on the contingent valuation results. The choice experiment results are used for the other non-market elements. They consist in the marginal willingness to pay per household over a five year period for the number of properties protected, an improvement or a reduction of natural coastal habitat, a change in the range of available coastal recreational opportunities from none to Fishing, Swimming, Walking, Picnic and Observation (FSWPO), and an improvement or a loss in ocean view (Table 8).

Table 8. Marginal willingness to pay (mWTP) per household for five years for properties protected, habitat, recreation and ocean view based on choice experiment results. Fishing (F), Swimming (S), Walking (W), Picnic and Observation (PO).

Attribute	Level	mWTP
No. of properties protected	50	$0.41
	100	$0.39
	200	$0.36
	400	$0.29
	600	$0.23
	1000	$0.10
Habitat	Improved	$36.03
	Reduced	-$6.14
Recreation available	FSWPO	$124.53
	SWPO	$51.03
	WPO	$25.00
	W	-$16.42
	None	-$56.39
Ocean view	Improved	$46.05
	Lost	-$98.38

Results

Le Goulet

Population: 817
Number of households: 334 [3]
Number of properties assumed at risk: 143

[3] Statistics Canada (2011). Census Profile

Description of the area: A sandy beach coastline stretching over 5 km along the Gulf of St. Lawrence. The natural dunes and beach provide a protective barrier against storm surge flooding.

Issue: Shoreline erosion and storm surge flooding. Erosion of dunes and beach is increasing the risk of flooding. Flooding could significantly increase by 2100 and a large proportion of Le Goulet is already at risk.

Status quo: No adaptation action is taken and flood occurs periodically causing a range of flood damages.

Adaptation scenarios: Dike construction, beach nourishment and beach nourishment with breach (Table 9).

Table 9. Overview of adaptation scenarios for Le Goulet

Adaptation Scenario		Description	Benefits	Costs

1	Dike construction	• Height of dike would be high enough to protect all properties from flooding
		• Based on 50 year storm in 2050 at HHWLT = 2.6 ± 0.3 m plus a freeboard of 0.6 m for a total of 3.5 m
			• Avoided damage costs from flooding to buildings and content
			• Non-market value gains:
			  ○ Recreation: WPO
			  ○ Protection value of adaptation
			  ○ Increased sense of safety
				• Initial construction cost of dike
				• Ongoing annual maintenance cost of dike, assumed to be 1% of total construction cost
				• Non-market value loses:
				  ○ Habitat reduced
				  ○ Ocean view lost

2	Beach nourishment	• Height of beach dune designed to be phased in over time, but in all years would be high enough to protect all properties from flooding
		• Based on 50 year storm in 2050 at HHWLT = 2.6 ± 0.3 m and 50 year storm in 2100 at HHWLT = 3.0 ± 0.6 m
		• No breach of the dune occurs
			• Avoided damage costs from flooding
			• Non-market value gains:
			  ○ Protection value of adaptation
			  ○ Increased sense of safety
				• Initial cost of building up beach dune
				• Ongoing cost to replenish beach dune
				• Non-market value losses:
				  ○ Ocean view lost

3	Beach nourishment with breach	• Same as scenario 2, but dune is breached by a 100 year return storm in 2054	• Same as Scenario 2	• Scenario 2 plus cost of breach (flood damages and dune repair)

Scenario 1 Dike construction

A dike would be constructed along and behind the coastal wetlands within municipal limits (Figure 3). The dike would be 4620 m in length, with a 16 m wide base and 4 m crest, and 1:3 slopes (Figure 4) (Ausenco Sandwell 2011; USACE 2002). The elevation of the dike would be 3.5 m (CGVD28), based on the 50 year flood at higher high water large tide (HHWLT) in 2055 (2.6 m)[4], plus the margin of error (Daigle 2014), plus a 0.6 m freeboard. The height of the dike relative to the ground would be 2 m. The dike would be made of piled sandstone, with a layer of sealing material to prevent water from seeping through. Aboiteaux and culverts would be installed for surface water drainage and accesses would be built for roads were the dike crosses them (chemin de la côte, rue Basile Roussel and rue du Havre). Also, a gravel trail would be built on the crest. The slopes would be covered with native plants for a natural look and low maintenance.

We are assuming that the height of the dike would be sufficient to prevent flooding from storm surges up to the 100 year storm at HHWLT in 2100 (3.03 ± 0.68 m), based on 2014 sea-level rise and flood projections for the area (Daigle 2014) and that no bigger storms occur. The dike would therefore result in avoided flood damages to buildings and content (Table 10) and an increase in the sense of safety for the households at risk. It would result in the protection of 143 properties to which a protection value of adaptation can be applied at the community level.

Table 10. Estimated avoided flood damages as measured by expected annual damage

Year	Present value
2010	$2 592
2030	$7 050
2050	$13 718
2100	$176 282

The gravel trail on top of the dike would provide additional recreational opportunities (Walking, Picnic and Observation) for the community, but the height of the dike would block the view of the ocean. Although care would be taken in locating the dike outside of the coastal wetlands, the wetlands cannot be avoided entirely, so some wetland area would be lost or degraded. Initial construction costs of the dike are estimated to be $2 566 240 and ongoing maintenance costs 1% of this amount, at an inflation rate of 2%.

[4] This flood scenario is the scenario that was chosen as the reference for land use planning by a community work group and recommended to the community council (reference).

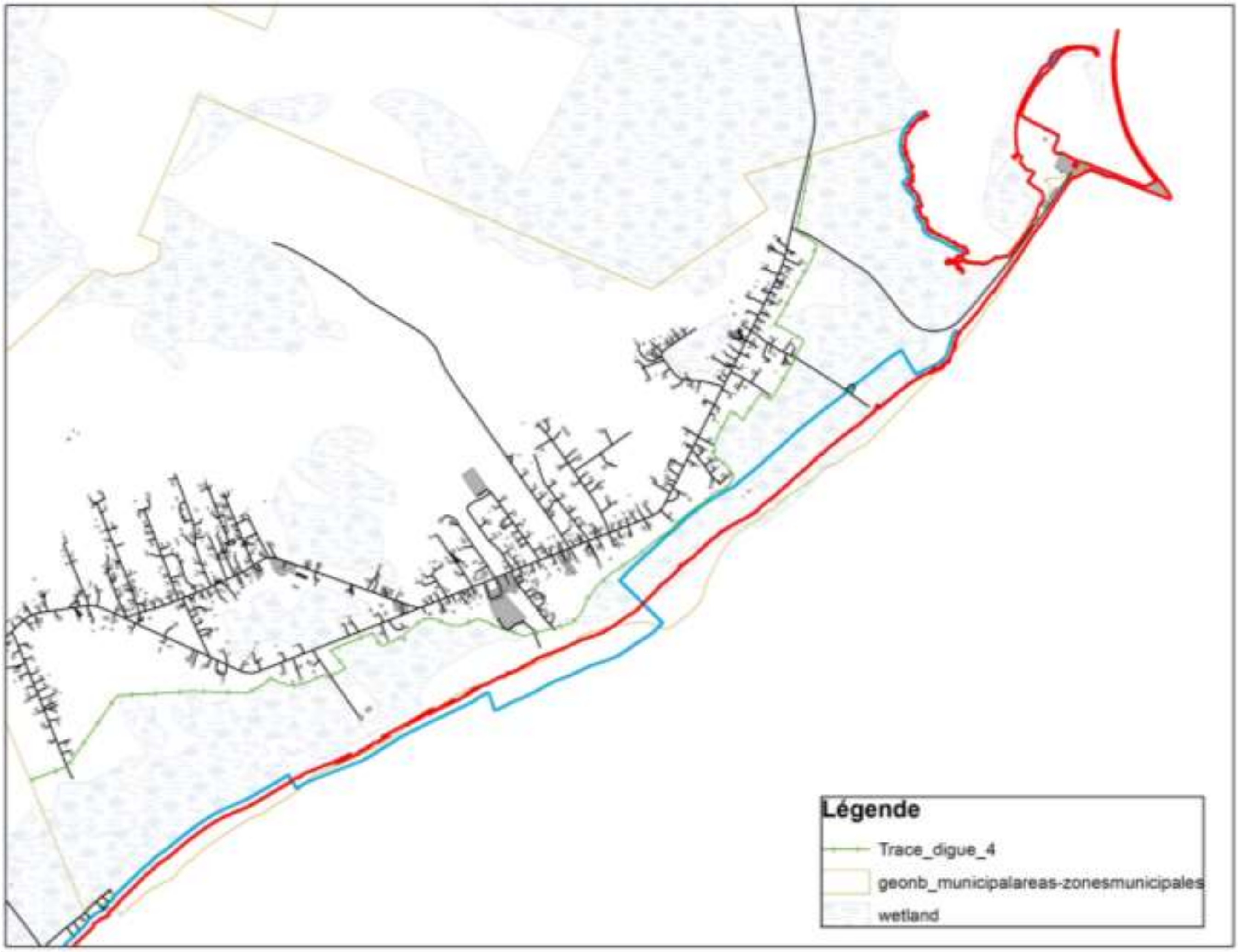

Figure 3. Hypothetical location of the dike in green. The red line represents the 2012 position of the coastline and the blue line the projected position of the coastline for 2100.

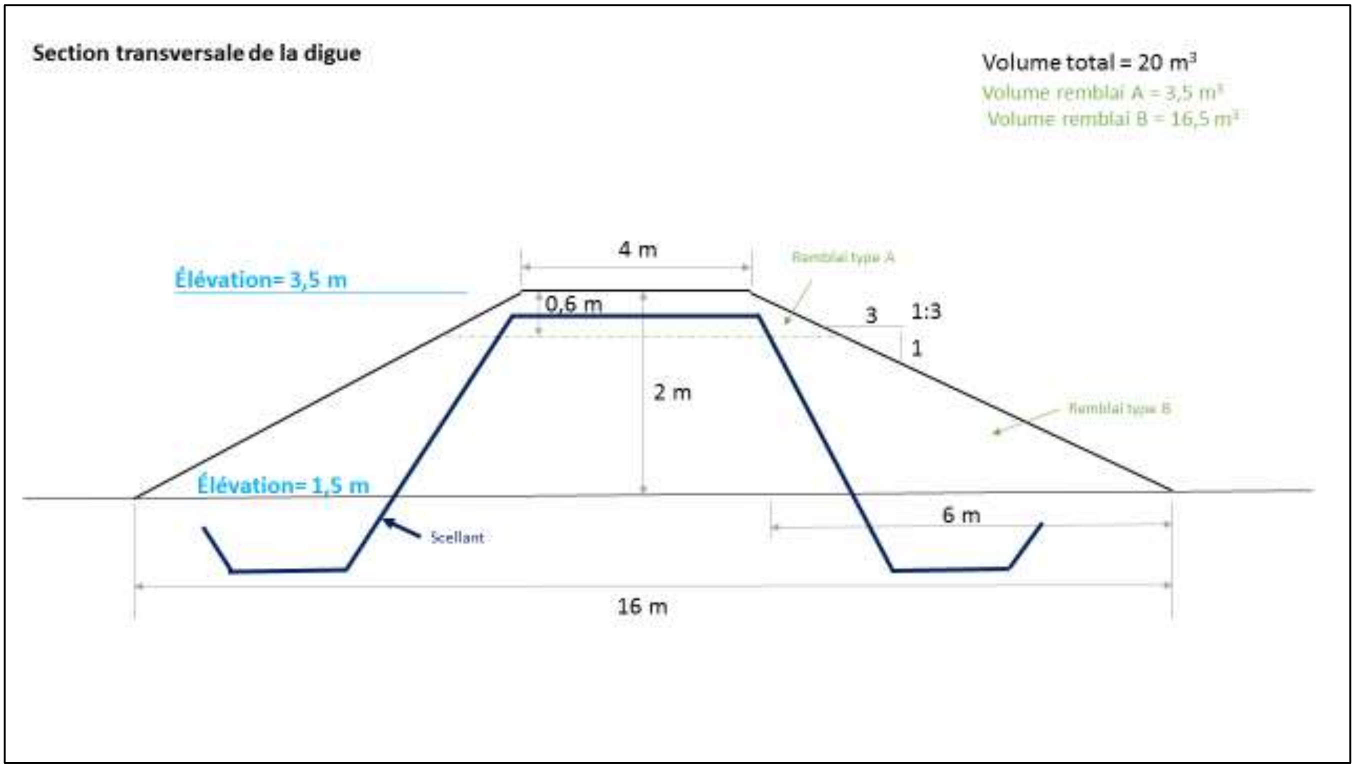

Figure 4. Hypothetical dike profile

Scenario 2 Beach nourishment

Sediments would be brought in and deposited on the beach and the dunes to create a beach profile that would prevent flooding from storm surges from up to the 100 year storm at HHWLT in 2100 (3.03 ± 0.68 m), based on 2014 sea-level rise and flood projections for the area (Daigle 2014). We assume that no bigger storms occur. The dune would first be built to an elevation of 2.9 m, the height of the 50 year storm at HHWLT in 2050 (Figure 5). Regular sediment replenishments would occur every ten years henceforth. In 2055, the dune would be built up to reach 3.6 m, the height of the 50 year storm in 2100 (Figure 6). We estimate that 30 264 m^3 of sediments would be needed to build the 2050 profile and 98 260 m^3 to build the 2100 profile. Including replenishments of 25% every ten years, a total of 249 482 m^3 would be required (Hébert and Aubé 2016).

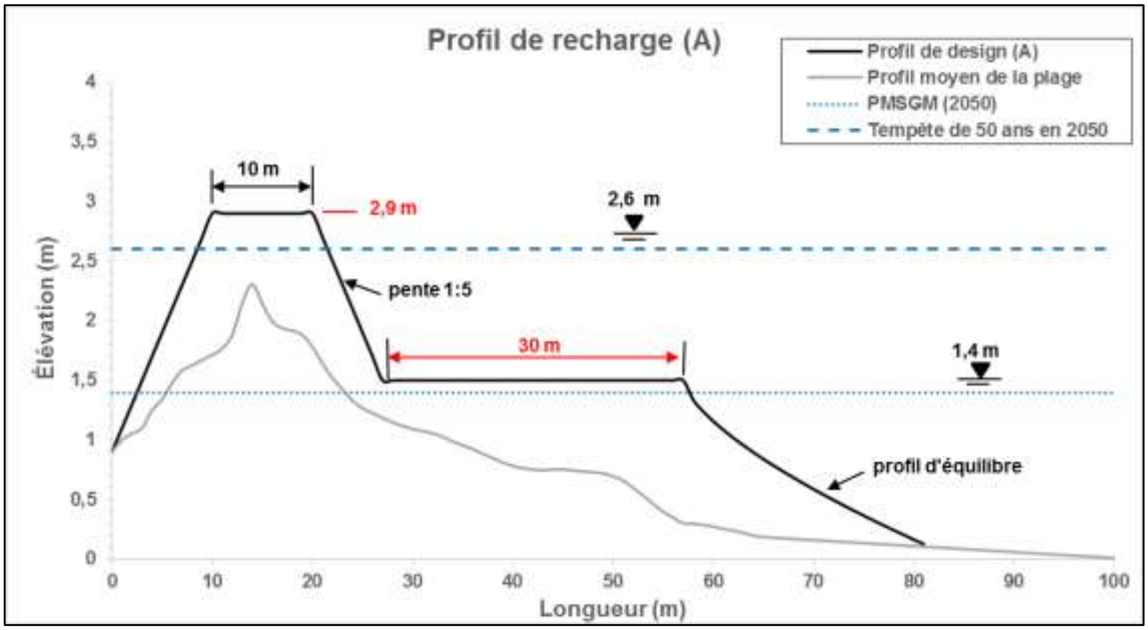

Figure 5. Hypothetical beach profile that would be built during the first phase of beach nourishment. Dune elevation is 2.9 m with a 10 m crest and 1:5 slopes. The dry beach is 30 m wide. Average profile shown is hypothetical and used for illustration purposes only (from Hébert and Aubé 2016).

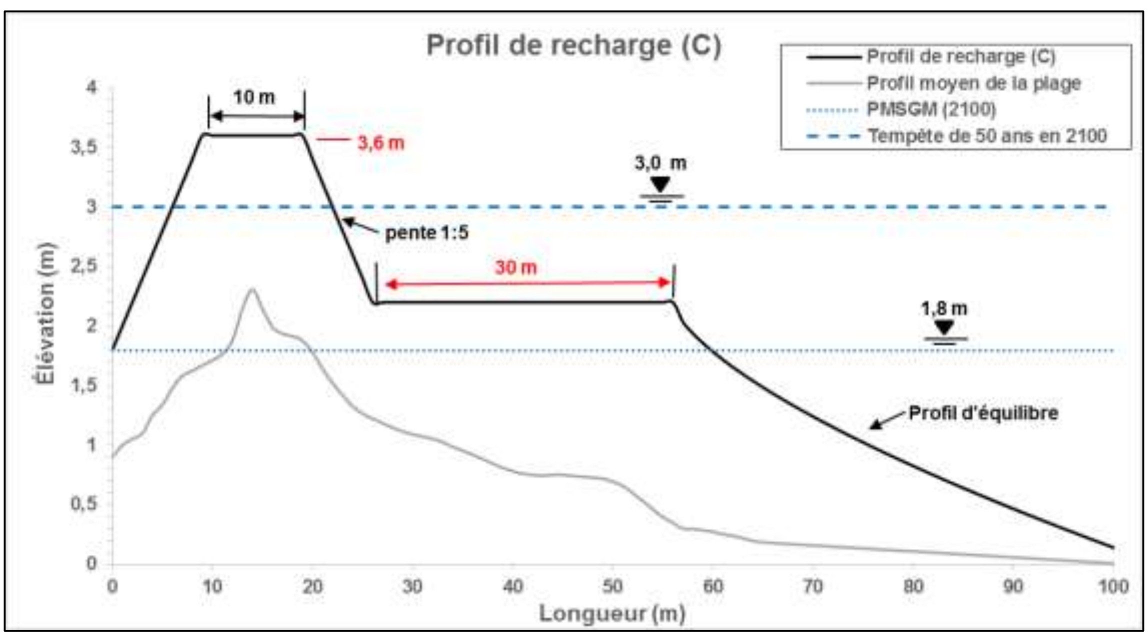

Figure 6. Hypothetical beach profile that would be built in 2055. Dune elevation is 3.6 m with a 10 m crest and 1:5 slopes. The dry beach is 30 m wide. Average profile shown is hypothetical and used for illustration purposes only (from Hébert and Aubé 2016).

Estimated implementation costs are presented in Table 11.

Table 11. Estimated beach nourishment implementation costs

Year	Present value	Future value
2016	$302 640	$302 640
2025	$75 660	$79 134
2035	$75 660	$83 180
2045	$75 660	$87 434
2055	$982 600	$1 193 584
2065	$245 650	$313 656
2075	$245 650	$329 697
2085	$245 650	$346 557
2095	$245 650	$364 280
2105	$245 650	$382 910
2115	$245 650	$402 492
Inflation rate	0,50%	

We are assuming that no flooding of the community would occur, resulting in avoided flood damages to buildings and contents, an increase in the sense of safety for the households at risk and a protection value of adaptation that applies to 143 properties at the community level. Our estimates of avoided flood damages are the same as those for scenario 1. Beach nourishment would not result in coastal habitat reduction, but would result in the loss of ocean view.

Scenario 3 Beach nourishment with breach

This scenario is a variant of scenario 2. It considers the realistic hypothesis that a severe storm could erode the beach and dunes enough to create a breach resulting in a flood. All the benefits and costs of scenario 2 apply, but the costs of flood damages and dune repair following a one-time breach event are also considered. We assume that the breach event would occur in 2054 during a 100 year storm and that the extent and depth of the flood would be the same as if no beach nourishment had occurred. Estimated cost of the breach is presented in Table 12.

Table 12. Estimated costs of a one-time breach event of the nourished beach

	Present value	Future value
Flood damage in 2054	$400 926	$652 848
Dune repair costs	$26 000	$42 337
Total cost of breach	$426 926	$695 185

For all scenarios, a discount rate of 3% and a general inflation rate of 1% (1.01 based on current rates, Statistics Canada, CANSIM table 326-0020) are used in the net present value (NPV) calculations. Based on our non-market valuation study, sense of safety is valued at $10 170 per property at risk (143). The protection value of adaptation is $0.39 per property at risk per household for 5 years. The coastal recreational opportunities of Walking, Picnic and Observation (WPO) are valued at $25 per household per year for 5 years. Reduced habitat is valued at -$6.14 and lost ocean view at -$98.38 per household per year for 5 years.

Net present values

Benefits and costs were projected for 25 years, 50 years and 100 years (Tables 13 to 15). The NPV of the dike scenario is highly negative compared to the status quo, for all time projections. Beach nourishment, on the other hand, has a positive NPV for all time projections, even when a breach is considered. The assumed benefits of these two adaptation strategies are almost identical, but the implementation and maintenance costs of the dike scenario are much higher than those of beach nourishment. Note that for all scenarios, the increased sense of safety is a significant benefit, even more than the avoided damages.

Table 13. Net present value of adaptation scenarios for Le Goulet when benefits and costs are projected over 25 years (2016-2041)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Flood damages	$85 578	**-$85 578**
Scenario 1: Dike	Avoided flood damages	$85 578	Construction costs	$2 566 420	
	Non-market recreation benefit (WPO)	$40 160	Ongoing maintenance	$535 754	
	Increased sense of safety	$1 454 310	Habitat reduced	$9 863	
	Protection value of adaptation	$89 589	Ocean view lost	$158 037	
	Total benefits	$1 669 636	**Total costs**	$3 270 074	**-$1 600 438**
Scenario 2: Beach nourishment	Avoided flood damages	$85 578	Nourishment and maintenance	$410 726	
	Increased sense of safety	$1 454 310	Ocean view lost	$158 037	
	Protection value of adaptation	$89 589			
	Total benefits	$1 629 476	**Total costs**	$568 763	**$1 060 713**
Scenario 3: Beach nourishment with breach	Avoided flood damages	$85 578	Nourishment and maintenance	$410 726	
	Increased sense of safety	$1 454 310	Breach cost (flood damage + repairs)	$0	
	Protection value of adaptation	$89 589	Ocean view lost	$158 037	
	Total benefits	$1 629 476	**Total costs**	$568 763	**$1 060 713**

Table 14. Net present value of adaptation scenarios for Le Goulet when benefits and costs are projected over 50 years (2016-2066)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Flood damages	$219 228	**-$219 228**
Scenario 1: Dike	Avoided flood damages	$219 228	Construction costs	$2 566 420	
	Non-market recreation benefit (WPO)	$40 160	Ongoing maintenance	$975 266	
	Increased sense of safety	$1 454 310	Habitat reduced	$9 863	
	Protection value of adaptation	$89 589	Ocean view lost	$158 037	
	Total benefits	$1 803 287	**Total costs**	$3 709 586	**-$1 906 300**
Scenario 2: Beach nourishment	Avoided flood damages	$219 228	Nourishment and maintenance	$898 401	
	Increased sense of safety	$1 454 310	Ocean view lost	$158 037	
	Protection value of adaptation	$89 589			
	Total benefits	$1 763 127	**Total costs**	$1 056 437	**$706 689**
Scenario 3: Beach nourishment with breach	Avoided flood damages	$219 228	Nourishment and maintenance	$898 401	
	Increased sense of safety	$1 454 310	Breach cost (flood damage + repairs)	$226 092	
	Protection value of adaptation	$89 589	Ocean view lost	$158 037	
	Total benefits	$1 763 127	**Total costs**	$1 282 530	**$480 597**

Table 15. Net present value of adaptation scenarios for Le Goulet when benefits and costs are projected over 100 years (2016-2116)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Flood damages	$819 062	**-$819 062**
Scenario 1: Dike	Avoided flood damages	$819 062	Construction costs	$2 566 420	
	Non-market recreation benefit (WPO)	$40 160	Ongoing maintenance	$1 589 499	
	Increased sense of safety	$1 454 310	Habitat reduced	$9 863	
	Protection value of adaptation	$89 589	Ocean view lost	$158 037	
	Total benefits	$2 403 121	**Total costs**	$4 323 819	**-$1 920 698**
Scenario 2: Beach nourishment	Avoided flood damages	$819 062	Nourishment and maintenance	$1 085 534	
	Increased sense of safety	$1 454 310	Ocean view lost	$158 037	
	Protection value of adaptation	$89 589			
	Total benefits	$2 362 961	**Total costs**	$1 243 570	**$1 119 391**
Scenario 3: Beach nourishment with breach	Avoided flood damages	$819 062	Nourishment and maintenance	$1 085 534	
	Increased sense of safety	$1 454 310	Breach cost (flood damage + repairs)	$226 092	
	Protection value of adaptation	$89 589	Ocean view lost	$158 037	
	Total benefits	$2 362 961	**Total costs**	$1 469 663	**$893 298**

Sensitivity Analysis

As a sensitivity analysis, we increased the flood levels by including the upper bound of the margin of error associated with our projected water levels (Appendix 1). This results in higher flood damages, or avoided flood damages, but does not change the overall results (Appendix 3). Beach nourishment, even when a breach is considered, still seems more advantageous than building a dike. The NPV of the dike scenario, however, becomes less negative than the status quo when benefits and costs are projected for 50 years, and positive when they are projected for 100 years. Also, avoided flood damages become the most significant benefit for both scenarios over 100 years.

Sainte-Marie-Saint-Raphaël (SMSR), Cap-Bateau (CB), Pigeon Hill (PH)

Population:[5] 1,720
Number of households: 784
Number of properties assumed at risk: 259

Description of the area: The municipality of SMSR and the local service districts of CB and PH are located on Lamèque Island facing the Gulf of St. Lawrence. This stretch of coastline is largely cliffs of soft, easily erodible earth and sandstone.

Issue: Erosion is the key concern. Some residents lost approximately 9 m of land from a storm in December 2010. In PH, four houses have been moved since 2000 due to erosion, three of which were relocated outside the community.

Status quo: No action is taken, buildings[6] and land are lost due to erosion.

Adaptation scenarios: Relocation of homes most at risk, erosion control structures for properties most at risk (Table 16)

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[5] Statistics Canada (2011). Census Profile

[6] Owners of these buildings could relocate them on their own before they are lost. Since only 3 of the 24 residences identified for relocation had an assessed value greater than $95,000, the cost of relocating a home, however, it is unlikely that they would chose to do so.

Table 16. Overview of adaptation scenarios for SMSR, CB and PH

Adaptation Scenario		Description	Benefits	Costs
1	Relocation of homes at risk	• 24 homes are relocated away from the erosion risk • Relocation is done in 2 phases: 17 homes moved immediately, 7 additional homes moved in 2025 • Properties become communal green spaces	• Avoided damage costs to infrastructure (70% of the assessed value of relocated homes) • Non-market value gains: ○ Recreation improves to FSWPO ○ Habitat Improves ○ Protection value of adaptation ○ Increased sense of safety	• Lost property values • Cost of relocation • Non-market value losses: ○ Ocean view lost for those relocated
2	Construction of erosion control structures	• 1.3 km of rip-rap are installed • Rip-rap is assumed to completely stop current erosion and shoreline remains constant over the time horizon • Life span of rip-rap is 25 years then needs to be rebuilt	• Avoided damage costs to infrastructure • Avoided lost property values • Non-market value gains: ○ Protection value of adaptation ○ Increased sense of safety	• Cost of installing rip-rap • Maintenance cost equal to installation cost of riprap occur every 25 years to maintain erosion control • Non-market value losses: ○ Habitat reduced

Scenario 1 Relocation of homes at risk

A planned relocation program would be implemented in two phases to relocate the residences that are the most at risk within the communities, on lots outside of the risk areas, as described in Hébert and Aubé (2015). Residences that are considered the most at risk are those located within 20 m (± 5 m) of the 2012 coastline or the projected 2025 coastline. There are 24 such residences, 17 immediately at risk that would be relocated during the first phase in 2016, and 7 that would be relocated during the second phase in 2025. Average estimated cost of relocation per house is $94 250 (Hébert and Aubé 2015). Total relocation costs are presented in Table 17. Relocation would result in the protection of 24 properties to which a protection value of adaptation can be applied at the community level. The abandoned properties (land) would be designated as communal green space and therefore improve coastal recreational opportunities to Fishing, Swimming, Walking, Picnic and Observation, as well as improve coastal habitat. Sense of safety would increase for those relocated, but they would lose their ocean view. Damages to relocated buildings would be avoided at an assumed value of 70% of the property value (Table 18). Yet, erosion would continue and land loss would occur on the abandoned lots, as well as other properties, resulting in lost property values (Table 19).

Table 17. Relocation costs (PV = present value, FV = future value)

	Cost
Immediate relocation	$1 602 250
2025 relocation PV	$659 750
2025 relocation FV	$721 559

Table 18. Avoided damages to relocated buildings

	Present value
Building structure value – immediate	$530 810
Building structure value – 2025	$264 460

Table 19. Lost property values from eroded land

Years	Present value	Future value
2012 to 2025	$653 582	$714 813
2025 to 2055	$1 516 178	$2 235 032
2055 to 2085	$1 427 323	$2 835 940
2085 to 2100	$646 529	$1 491 364

Scenario 2 Construction of erosion control structures

The shoreline would be armoured with rocks (rip-rap) to prevent erosion of the properties that were identified as being at risk in the relocation feasibility study (Hébert and Aubé 2015). Some properties in between would also be protected, to prevent them from being subject to increased erosion due to end of wall effects (Figure 7). Note that we are uncertain of the feasibility and effectiveness of this technique on the sections of the coastline consisting in sandstone cliffs, but are assuming that it can be applied everywhere and that it would completely stop erosion. A total of 1337 m of rip-rap would be installed on six separate sections of coastline to protect 61 properties. Total estimated implementation costs is $1 537 550. We are assuming that the rip-rap requires no maintenance, but that it needs to be entirely re-built every 25 years (Table 20). The rip-rap would stop erosion and result in avoided land loss and damages to buildings on the properties protected and an increase in sense of safety. A protection value of adaptation can be applied to 61 properties at the community level. Ocean view would be maintained, but coastal habitat would be reduced.

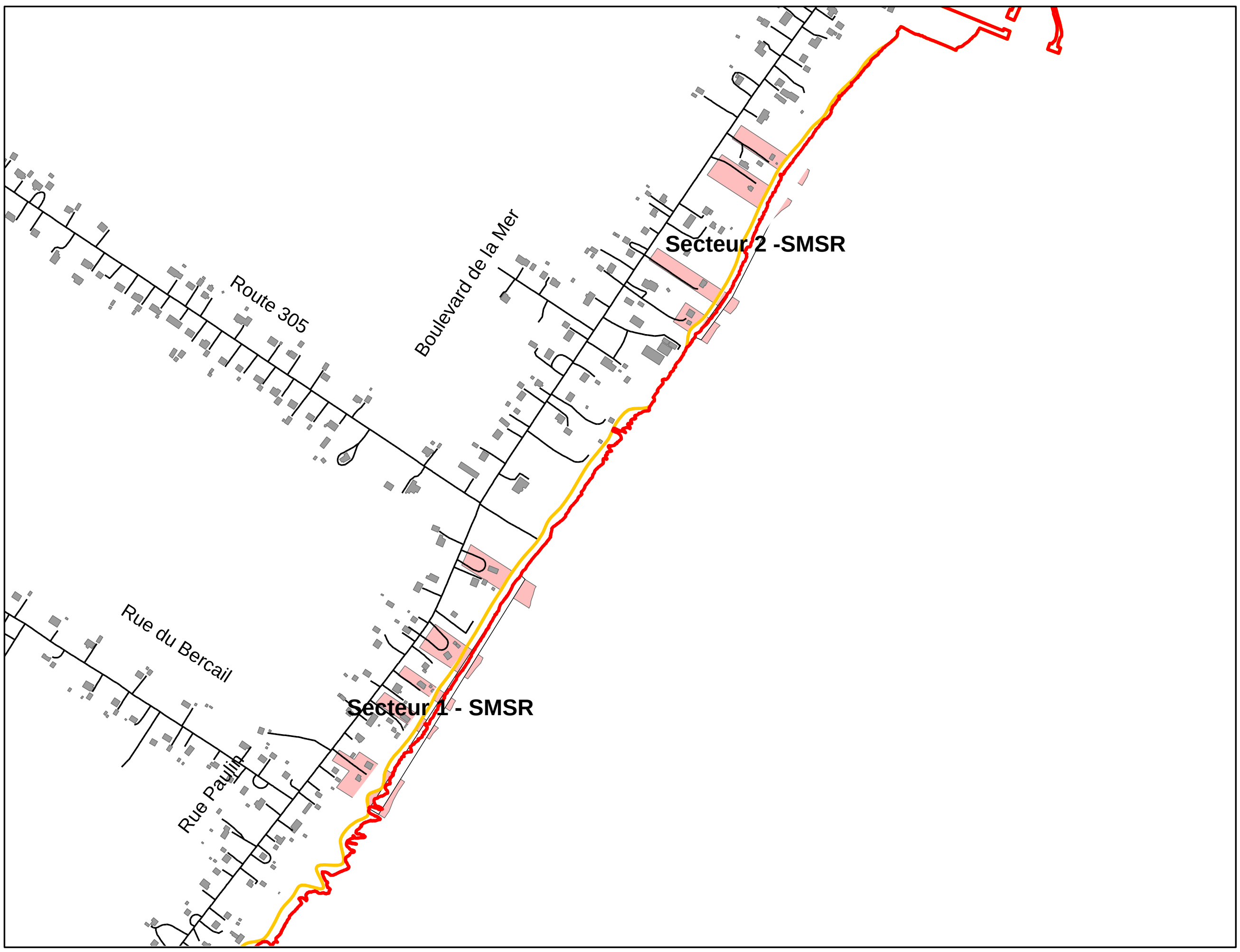

Figure 7. Sections of coastline that would be armoured with rip-rap in SMSR shown in crosshatching. Red line represents 2012 coastline, yellow line projected position of 2025 coastline. Properties with residences at risk are in pink.

Table 20. Costs of re-building rip-rap considering inflation (5%)

Year	Cost
2041	$1 741 730
2066	$1 975 597
2091	$2 235 033

For all scenarios, a discount rate of 3% and a general inflation rate of 1% (1.01 based on current rates, Statistics Canada, CANSIM table 326-0020) are used in the net present value (NPV) calculations. Based on our non-market valuation study, sense of safety is valued at $10 170 per property protected (61) or relocated (24). The protection value of adaptation is $0.41 per property protected or relocated per household for 5 years. The coastal recreational opportunities of Swimming, Walking, Picnic and Observation (SWPO) are valued at $51.03 per household per year for 5 years. Improved habitat is valued at $36.03, while reduced habitat is valued at -$6.14 per household per year for 5 years. Finally, lost ocean view is valued at -$98.38 per property relocated per year for 5 years.

Net present values

Benefits and costs were projected for 25 years, 50 years and 100 years (Tables 21 to 23). Both the rip-rap and the relocation scenarios are more negative than the status quo, even for the 100 year projection. Implementation costs are just too high relative to the value and number of properties protected, and non-market benefits considered do not compensate for this. The rip-rap scenario is initially less negative than the relocation scenario because it protects more properties for similar implementation costs, but over 100 years, the continuing costs of maintaining the rip-rap make the two options seem equally unattractive. It would have been interesting to consider the potential impact of higher erosion rates on the results, since available erosion scenarios are conservative[7], but coastline projections are not available for higher erosion rates, so we did not conduct a sensitivity analysis for this case.

[7] Available erosion scenarios are conservative because they are based on historical erosion rates and do not account for increased erosion due to rising sea levels.

Table 21. Net present value of adaptation scenarios for SMSR, CB and PH when benefits and costs are projected over 25 years (2016-2041)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Lost property values	$547 844	**-$547 844**
Scenario 1: Rip-rap	Avoided lost property values	$275 658	Construction and maintenance costs	$1 537 550	
	Increased sense of safety	$620 370	Habitat reduced	$23 152	
	Protection value of adaptation	$94 305	Lost property values	$272 187	
	Total benefits	$990 333	**Total costs**	$1 832 889	**-$842 556**
Scenario 2: Relocation	Avoided damages to buildings	$754 702	Lost property values	$547 844	
	Recreation SWPO	$192 419	Immediate relocation	$1 602 250	
	Habitat improved	$135 858	2025 relocation	$553 015	
	Increased sense of safety	$244 080	Ocean view lost	$11 356	
	Protection value of adaptation	$37 104			
	Total benefits	$1 364 162	**Total costs**	$2 714 465	**-$1 350 303**

Table 22. Net present value of adaptation scenarios for SMSR, CB and PH when benefits and costs are projected over 50 years (2016-2066)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Lost property values	$1 253 564	**-$1 253 564**
Scenario 1: Rip-rap	Avoided lost property values	$636 447	Construction and maintenance costs	$2 369 410	
	Increased sense of safety	$620 370	Habitat reduced	$23 152	
	Protection value of adaptation	$94 305	Lost property values	$617 117	
	Total benefits	$1 351 122	**Total costs**	$3 009 679	**-$1 658 557**
Scenario 2: Relocation	Avoided damages to buildings	$754 702	Lost property values	$1 253 564	
	Recreation SWPO	$192 419	Immediate relocation	$1 602 250	
	Habitat improved	$135 858	2025 relocation	$553 015	
	Increased sense of safety	$244 080	Ocean view lost	$11 356	
	Protection value of adaptation	$37 104			
	Total benefits	$1 364 162	**Total costs**	$3 420 184	**-$2 056 022**

Table 23. Net present value of adaptation scenarios for SMSR, CB and PH when benefits and costs are projected over 100 years (2016-2116)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Lost property values	$1 747 006	**-$1 747 006**
Scenario 1: Rip-rap	Avoided lost property values	$834 820	Construction and maintenance costs	$3 063 554	
	Increased sense of safety	$620 370	Habitat reduced	$23 152	
	Protection value of adaptation	$94 305	Lost property values	$912 186	
	Total benefits	$1 549 495	**Total costs**	$3 998 891	**-$2 449 396**
Scenario 2: Relocation	Avoided damages to buildings	$754 702	Lost property values	$1 747 006	
	Recreation SWPO	$192 419	Immediate relocation	$1 602 250	
	Habitat improved	$135 858	2025 relocation	$553 015	
	Increased sense of safety	$244 080	Ocean view lost	$11 356	
	Protection value of adaptation	$37 104			
	Total benefits	$1 364 162	**Total costs**	$3 913 626	**-$2 549 464**

Shippagan and Pointe-Brûlée

Population:[8] 2833
Number of households: 1360
Number of properties assumed at risk: 393

Description of the area: Most urbanized of the cases, lots of critical infrastructure in flood risk areas**.** Does not face the Gulf of St. Lawrence, but the more sheltered Bay of Shippagan. Most of the coastline within Shippagan city limits is artificialized with rip-rap and wooden retaining walls. There is also a 2 km boardwalk.

Issue: Storm surge flooding**.** Flooding could significantly increase by 2100.

Status quo: No action is taken and floods occur periodically causing a range of damages.

Adaptation scenarios: Zoning for future development with and without an impact on existing property values (Table 24)

Table 24. Overview of adaptation scenarios for Shippagan and Pointe-Brûlée

Adaptation Scenario		Description	Benefits	Costs
1	Establishment of a "retreat zone" and an "accommodation zone" with reduction in existing property values	• Existing retaining wall, rocks and boardwalk are maintained indefinitely • A "retreat zone" and an "accommodation zone" are established in the zoning regulations	• Non-market value gains: ○ Protection value of adaptation for future properties ○ Increased sense of safety ○ Loss of recreation avoided	• Flood damage costs • Ongoing annual maintenance cost of retaining wall • Non-market value losses: ○ Habitat reduced ○ Impact of zoning on existing property values within defined risk zones
2	Scenario 1 with no impact on existing property values	• Same as scenario 1	• Same as scenario 1	• Flood damage costs • Ongoing annual maintenance cost of retaining wall • Non-market value losses: ○ Habitat reduced

[8] Statistics Canada (2011). Census Profile

Scenario 1 Zoning with reduction in existing property values

Zoning regulations are adopted to establish a retreat zone and an accommodation zone. The retreat zone would be a relatively small area delimited by coastal wetlands and the projected position of the coastline for 2100. No new development would be permitted in this zone. The accommodation zone would consist in the area at risk of flooding from the 100 year storm at HHWLT in 2055 (Aubé and Kocyla 2012). New buildings constructed in this zone and newly renovated buildings would have to be adapted[9] to minimize risk of damage from flooding. We assume that existing retaining wall, rocks and boardwalk would be maintained indefinitely. Loss of recreational opportunities would be avoided and future properties and renovated properties would be protected from damages. Sense of safety would also increase. Nonetheless, flood damages to non-renovated buildings and content would occur (Table 25). Annual costs of maintaining the retaining wall and boardwalk are assumed to be 1% of the original construction costs and amount to $19 628. Furthermore, maintaining the wall and boardwalk would result in a reduction in habitat. Finally, we assume that zoning would result in a 5% decrease in property values within defined risk zones (see Appendix 4 for details), a total cost of $2 871 170.

Table 25. Estimated flood damages for Shippagan and Pointe-Brûlée measured by expected annual damages

Year	Present value
2010	$184 423
2030	$278 731
2050	$448 819
2100	$1 900 353

Estimates of future buildings protected by the adoption of new zoning regulations are based on 10 year historical Shippagan and Pointe-Brûlée building permit data (from 2006 to 2015) (Benjamin Kocyla, Regional Service Commission 4, personal communication, 2016) (Figure 8). The average number of permits within the accommodation zone is 4.6 per year in Pointe-Brûlée and 3.1 per year in Shippagan (Figure 8). Of those, 73% are for major renovations of existing buildings (based on the overall area average). We therefore assume that 7.7 buildings are protected each year (2.08 are new buildings, 5.62 are newly protected existing buildings through major renovations) and that this trend continues for the time horizons projected. However, in the 100 year time horizon major renovations were only considered to result in new protection until 2085 at which point, it was assumed that all existing building stock had been renovated and updated for flood protection. To estimate damages to future new buildings and avoided damages to future renovated buildings, we used the average estimated flood damages (Table 25) per building at risk.

[9] Living space would have to be above flood level (Aubé and Kocyla 2012).

Figure 8. Number of building permits for major renovations and new constructions in Shippagan and Pointe-Brûlée from 2006 to 2015 (Benjamin Kocyla, Regional Service Commission 4, personal communication, 2016)

Scenario 2 Zoning with no reduction in existing property values

This scenario is a variant of scenario 1. It considers the reasonable hypothesis that zoning regulations would have no impact on existing property values (see Appendix 4 for details). All the benefits and costs of scenario 1 apply, except for the reduction in existing property values in the defined risk zones.

For all scenarios, a discount rate of 3% and a general inflation rate of 1% (1.01 based on current rates, Statistics Canada, CANSIM table 326-0020) are used in the net present value (NPV) calculations. Based on our non-market valuation study, sense of safety is valued at $10 170 per future property protected. The protection value of adaptation is valued at $0.36, $0.29 or $0.23 per future property protected per household per year for 5 years. The avoided loss of coastal recreational opportunities of Walking, Picnic and Observation (WPO) is valued at $56.39 and reduced habitat is valued at -$6.14 per household per year for 5 years.

Net present values

Benefits and costs were projected for 25 years, 50 years and 100 years (Tables 27 to 29). Because of avoided future damages, the zoning scenarios have a higher NPV than the status quo. Their NPV is nonetheless negative for the 25 and 50 year projections. They are positive for the 100 year projection, by which time, according to our assumptions, all existing buildings will have been renovated and will thus be protected. Of course the zoning scenario with no reduction in existing property values has a higher NPV than the one with a reduction.

Sensitivity Analysis

As for the Le Goulet case, for the sensitivity analysis, we increased the flood levels by including the upper bound of the margin of error associated with our projected water levels (Appendix 1). This results in higher flood damages, or avoided flood damages, but does not change the overall results (Appendix 5).

Table 27. Net present value of adaptation scenarios for Shippagan and Pointe-Brûlée when benefits and costs are projected over 25 years (2016-2041)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo	Recreation benefits	$368 847	Flood damages	$4 396 530	
			Future damage	$310 723	
			Retaining wall maintenance	$391 706	
			Habitat reduced	$40 162	
	Total benefits	$368 847	**Total costs**	$5 139 120	**-$4 770 273**
Scenario 1: Change to zoning	Increased sense of safety	$1 562 767	Flood damages	$3 569 718	
	Protection value of adaptation for future properties	$454 469	Retaining wall maintenance	$391 706	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$1 137 535	Impact on property values in risk zone	$2 871 170	
	Total benefits	$3 523 618	**Total costs**	$6 872 755	**-$3 349 137**
Scenario 2: Change to zoning with no impact on property values	Increased sense of safety	$1 562 767	Flood damages	$3 569 718	
	Protection value of adaptation for future properties	$454 469	Retaining wall maintenance	$391 706	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$1 137 535			
	Total benefits	$3 523 618	**Total costs**	$4 001 585	**-$477 967**

Table 28. Net present value of adaptation scenarios for Shippagan and Pointe-Brûlée when benefits and costs are projected over 50 years (2016-2066)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo	Recreation benefits	$368 847	Flood damages	$9 014 568	
			Future damage	$1 256 731	
			Retaining wall maintenance	$631 624	
			Habitat reduced	$40 162	
	Total benefits	$368 847	**Total costs**	$10 943 085	**-$10 574 238**
Scenario 1: Change to zoning	Increased sense of safety	$2 519 957	Flood damages	$9 014 568	
	Protection value of adaptation for future properties	$730 303	Retaining wall maintenance	$631 624	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$4 596 477	Impact on property values in risk zones	$2 871 170	
	Total benefits	$8 215 584	**Total costs**	$12 557 524	**-$4 341 939**
Scenario 2: Change to zoning with no impact on property values	Increased sense of safety	$2 519 957	Flood damages	$9 014 568	
	Protection value of adaptation for future properties	$730 303	Retaining wall maintenance	$631 624	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$4 596 477			
	Total benefits	$8 215 584	**Total costs**	$9 686 354	**-$1 470 769**

Table 29. Net present value of adaptation scenarios for Shippagan and Pointe-Brûlée when benefits and costs are projected over 100 years (2016-2116)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo	Recreation benefits	$368 847	Flood damages	$18 310 046	
			Future damage	$5 235 580	
			Retaining wall maintenance	$868 579	
			Habitat reduced	$40 162	
	Total benefits	$368 847	**Total costs**	$24 454 367	**-$24 085 520**
Scenario 1: Change to zoning	Increased sense of safety	$3 465 325	Flood damages	$6 098 028	
	Protection value of adaptation for future properties	$904 162	Retaining wall maintenance	$868 579	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$10 965 192	Impact on property values in zones	$2 871 170	
	Total benefits	$15 703 526	**Total costs**	$9 877 939	**$ 5 825 587**
Scenario 2: Change to zoning with no impact on property values	Increased sense of safety	$3 465 325	Flood damages	$6 098 028	
	Protection value of adaptation for future properties	$904 162	Retaining wall maintenance	$868 579	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$10 965 192			
	Total benefits	$15 703 526	**Total costs**	$7 006 769	**$8 696 757**

Conclusion

The key steps of the study were successfully completed: economic costs and benefits were identified and measured for each adaptation scenario; a non-market valuation study was conducted to assess priority non-market elements; and the NPV of adaptation scenarios were calculated and compared.

The results of the CBA indicate that the beach nourishment strategy may be worth pursuing for the community of Le Goulet. For SMSR, CB and PH it seems that the status quo is better than the costly strategies of rip-rap and relocation. Finally, for Shippagan and Pointe-Brûlée, the results indicate that zoning regulations to protect future development could be quite advantageous over the long term (Table 30).

Table 30. Overview of net present values of adaptation scenarios when benefits and costs are projected over25, 50 and 100 years

Community	Scenario	Time horizon (years)		
		100	50	25
Le Goulet	Status quo	-$819 062	-$219 228	-$85 578
	1: Dike	-$1 920 698	-$1 906 300	-$1 600 438
	2: Beach nourishment	**$1 119 391**	**$706 689**	**$1 060 713**
	3: Beach nourishment with breach in 2054	**$893 298**	**$480 597**	**$1 060 713**
SMSR, CB, PH	Status quo	-$1 747 006	-$1 253 564	-$547 844
	1: Rip-rap	-$2 449 396	-$1 658 557	-$842 556
	2: Relocation	-$2 549 464	-$2 056 022	-$1 350 303
Shippagan and Pointe-Brûlée	Status quo	-$24 085 520	-$10 574 238	-$4 770 273
	1: Change to zoning	**$5 825 587**	-$4 341 939	-$3 349 137
	2: Change to zoning (no impact on property values)	**$8 696 757**	-$1 470 769	-$477 967

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Appendix 1. Flood Levels Used to Estimate Avoided Damages for Le Goulet, Shippagan and Pointe-Brûlée

Flood scenarios for Le Goulet used to estimate avoided damages, based on higher high water mean tide (HHWMT) (the average from all the higher high waters) in meters (CGVD28). HHWMT projections from Robichaud et al. (2011), return periods and surge residuals from Daigle (2014).

Return period	2010		2030		2050		2100	
1-Year	0.99	± 0.20	1.12	± 0.27	1.24	± 0.34	1.68	± 0.58
2-Year	1.07	± 0.20	1.20	± 0.27	1.32	± 0.34	1.76	± 0.58
5-Year	1.19	± 0.20	1.32	± 0.27	1.44	± 0.34	1.88	± 0.58
10-Year	1.37	± 0.20	1.50	± 0.27	1.62	± 0.34	2.06	± 0.58
25-Year	1.51	± 0.20	1.64	± 0.27	1.76	± 0.34	2.20	± 0.58
50-Year	1.63	± 0.20	1.76	± 0.27	1.88	± 0.34	2.32	± 0.58
100-Year	1.74	± 0.20	1.87	± 0.27	1.99	± 0.34	2.43	± 0.58

	2010		2030		2050		2100	
HHWMT	0.4		0.53	±0.07	0.65	±0.14	1.09	±0.38

Flood scenarios for Shippagan and Pointe-Brûlée used to estimate avoided damages, based on HHWMT in meters (CGVD28). HHWMT projections from Robichaud et al. (2011), return periods and surge residuals from Daigle (2014).

Return period	2010		2030		2050		2100	
1-Year	1.29	± 0.20	1.41	± 0.27	1.53	± 0.34	1.96	± 0.58
2-Year	1.37	± 0.20	1.49	± 0.27	1.61	± 0.34	2.04	± 0.58
5-Year	1.49	± 0.20	1.61	± 0.27	1.73	± 0.34	2.16	± 0.58
10-Year	1.67	± 0.20	1.79	± 0.27	1.91	± 0.34	2.34	± 0.58
25-Year	1.81	± 0.20	1.93	± 0.27	2.05	± 0.34	2.48	± 0.58
50-Year	1.93	± 0.20	2.05	± 0.27	2.17	± 0.34	2.60	± 0.58
100-Year	2.04	± 0.20	2.16	± 0.27	2.28	± 0.34	2.71	± 0.58

	2010		2030		2050		2100	
HHWMT	0.7		0.82	±0.07	0.94	±0.14	1.37	±0.38

Appendix 2. Non-market valuation study

Introduction

The goal of the non-market valuation study was to estimate the value, in monetary terms, of potential environmental and social outcomes (non-market outcomes) of adaptation strategies that were being compared in the cost benefit analysis (CBA). The inclusion of non-market value in any cost benefit analysis is a well established practice in economics and research highlights excluding them results in the inefficient allocation of resources (Hanley and Spash 1993).

The stated preference approach (survey) was chosen for the study, since sufficient data to conduct a revealed preference study (i.e.no residential market data, no local parking or entrance fees to trails or beaches) was not available. Furthermore, the stated preference approach is the only approach that can be applied to estimate the non-use value of ecosystems or habitats.

While somewhat constrained by time and budget, a targeted local survey was preferable to a value transfer approach. Limited research have been conducted measuring the type of non-market values that have be expressed by local residents and no studies were found for small rural coastal communities in eastern Canada. Important non-market values to measure included feeling safe from personal risk or risk to property in relation to erosion or flooding, emotional attachment to a home or property, esthetic appeal and ecological value of natural coastlines or natural coastal habitats, esthetic appeal of ocean views, and recreational values of coastal areas.

Methods

Potential non-market outcomes were first identified for each case and possible valuation approaches were considered (Tables 1 to 4). We reduced and reworked the list of non-market elements to measure based on feasible valuation approaches. For instance, non-market impacts of flooding on people during and after events are too difficult to measure without a recent event, so they were not assessed. The non-market values that were assessed in the study are:

1) willingness to pay for protection or repairs to stay (this value can be used as a measure of the value of safety or of attachment to property);
2) protection value of adaptation (the value in doing something to help those at risk);
3) value of coastal recreational opportunities (fishing, swimming, walking, picnic and observation);
4) ecological value of coastal habitats; and
5) esthetic value of an ocean view.

Table 1. Preliminary non-market outcomes identified for Le Goulet

Le Goulet (flooding)		
Adaptation method	**Benefits**	**Costs**
Beach nourishment	• maintenance of beach and dunes for habitat and recreation (no more erosion) • increased feeling of safety of citizens	• potential negative impact of implementation on fish and piping plover (trampling and disturbance from machines and silting from sediments deposited) • non market impacts on people during and after breach events (inconvenience of evacuation if evacuated, stress and anxiety, potential missed days of work, potential loss of items of sentimental value)
Dike	• increased feeling of safety of citizens • increased recreation opportunities due to trail on dyke	• loss of ocean view • beach loss to erosion • non market impacts on people during and after breach events (inconvenience of evacuation if evacuated, stress and anxiety, potential missed days of work, potential loss of items of sentimental value)

Table 2. Preliminary non-market outcomes identified for SMSR, CB and PH

Ste-Marie-St-Raphaël, Cap Bateau, Pigeon Hill (erosion)		
Adaptation method	**Benefits**	**Costs**
Relocation • Houses at risk are moved or demolished, regulation adopted to designate land as green space, no residential use permitted	• Increased feeling of safety of citizens • Creation of green space on waterfront (potential increased recreation) • Maintenance of natural coastline	• Non market costs of moving for people relocated (stress and anxiety, inconvenience of temporary lodging, potential loss of location of sentimental value) • Loss of ocean view for those relocated
Rock wall	• Increased feeling of safety of citizens	• Loss of natural coastline (esthetic impact, habitat loss, loss of a source of sediment for regional beaches) • Increased erosion at ends of wall

Table 3. Preliminary non-market outcomes identified for Shippagan and Pointe-Brûlée

Shippagan (flooding)		
Adaptation method	**Benefits**	**Costs**
Wall • Maintenance of retaining wall, rocks and boardwalk	• Maintenance of recreational benefits	• Artificial coastline (esthetic impact, habitat loss, loss of a source of sediment for regional beaches) • No room for beach to retreat to • Non-market impacts on people during and after breach event (inconvenience of evacuation if evacuated, stress and anxiety, potential missed days of work, potential loss of items of sentimental value)
Zoning regulations • No new construction in limited retreat area, first floor above flood height in larger accommodation zone for new constructions and renovations of existing buildings		

Table 4. Overview of benefits and costs and possible valuation approaches considered

Benefit / Cost to Estimate	Approach	Possible Alternative Approach
• Cost of stress, anxiety, and sentimental loss associated with relocating a home	• WTA compensation for home relocation. This would be closed ended, single or dichotomous choice.	• WTP to invest in hazard protection or for damage repairs - What is the most you would be willing to invest in flood / erosion control before you would relocate? - What is the most amount of damage you would be willing to repair before you would relocate?
• Value associated with feeling safe	• Estimate private investment in voluntary erosion / flood control measures. This would act as a conservative proxy for value residents place on perceived safety.	
• Value of maintaining natural beach and dune habitats	• Choice experiment describing attributes: recreation, habitat, protection from damages, cost required to maintain beach and dunes.	
• Value of a natural coastline vs hardened protection	• Choice experiment describing attributes: aesthetic impact, habitat, loss of sediment source for regional beaches, waterfront greenspace, recreation)	• WTP to support relocation of residents at risk from erosion and support the maintenance of a natural coastline for recreation
• Sense of fear and anxiety associated with storm events	• Likart scale to assess average residents level of anxiety	

Willingness to pay to stay was assessed by the contingent valuation method. The other values were assessed through a choice experiment where trade-offs in number of properties, recreational opportunities, natural coastal habitat, ocean view, and increase in property taxes were measured.

Survey considerations:

- Given survey fatigue in all three case study locations a broader regional assessment was preferred.

- Reference to specific adaptation measures (e.g. rip-rap versus dune nourishment) could generate bias responses as many residents already have strong perceptions about what adaptation solutions will or will not work
- Estimating general benefit/costs values in relation to erosion and flooding concerns for the Acadian Peninsula region would support application of results to further community case studies in the future.

We chose to conduct the survey in coastal communities at risk where some information on flood and/or erosion risk was available (GIS data) (to be able to classify respondents as being in or outside of a risk zone) and little or no surveying had occurred in the past.

Communities targeted were Le Goulet, Pointe-Sauvage, Chiasson-Savoy, Pointe-Brûlée, Haut-Shippagan, Pointe-Alexandre, Pokesudie, Inkerman Centre, Pointe à Bouleau, Val Comeau, Ste-Marie-St-Raphaël, Cap Bateau, and Pigeon Hill (Table 5). Sample targets were set for each community, based on a 90% confidence interval (Table 6).

Table 5. Communities targeted by the survey, with number of total residences and estimated residences in risk zones

Community	**Risk zone**		**Number of residences**	**Number of at risk residences**
	Flooding	**Erosion**		
Le Goulet	x		383	226
Pointe-Sauvage	x		38	30
Chiasson-Savoy	x		226	150
Pointe-Brûlée	x		431	431
Haut-Shippagan	x		153	120
Pointe-Alexandre	x		137	60
Pokesudie	x		117	100
Inkerman Centre	x		431	259
Pointe à Bouleau	x		89	70
Val Comeau	x		345	175
Ste-Marie-St-Raphaël		x	441	24
Cap Bateau		x	119	14
Pigeon Hill		x	122	24

Table 6. Target sample details by community based on at risk proportion by community, or proportion of entire population at risk (66%) in targeted communities

Community	**Target Sample (@ 90%) - proportional**			**Target Sample (@ 90%) - 66% at risk**		
	Number of residences	**Not at risk**	**At risk**	**Number of residences**	**Not at risk**	**At risk**
Le Goulet	31	13	19	31	10	21
Pointe-Sauvage	3	1	2	3	1	2
Chiasson-Savoy	19	6	12	19	6	12
Pointe-Brûlée	35	0	35	35	12	24
Haut-Shippagan	13	3	10	13	4	8
Pointe-Alexandre	11	6	5	11	4	8
Pokesudie	10	1	8	10	3	6
Inkerman Centre	35	14	21	35	12	24
Pointe à Bouleau	7	2	6	7	2	5
Val Comeau	28	14	14	28	9	19
Ste-Marie-St-Raphaël	36	34	2	36	12	24
Cap Bateau	10	9	1	10	3	7
Pigeon Hill	10	8	2	10	3	7
Total	249	111	138	249	83	166

The questionnaire was developed, translated in French, and tested in a residential area with risks of coastal flooding and erosion in a community not targeted by the survey (n= 16). For the test, follow up questions on the questionnaire's difficulty, question wording and understanding were asked. Adjustments were then made to the amounts proposed in the contingent valuation question. An attribute was removed for the choice experiment (provides protection from erosion or flooding). Levels for the number of homes and properties protected, as well as property tax increase were adjusted in the choice experiment. Finally, the wording and format of some of the protest screen questions were adjusted.

The final questionnaire was comprised of the following:

1) Pre-interview section with
   a) Introductory script about the survey and the implications of participating (confidentiality, etc.)
   b) List of points to note regarding location (adjacent to the coast, in an identified flood risk zone, in an identified erosion risk zone, community, address)

2) Introductory questions on :
   a) Property (own or rent, primary or secondary, time lived at location)
   b) Concern about sea level rise and extreme weather
   c) Opinion on seriousness of climate change as a threat
   d) Opinion on financial responsibility of private land owners to protect their own property
   e) Opinion on greatest hazard concern for the community
   f) Opinion on overall condition of recreational opportunities, coastal habitat for flora and fauna, and ocean vistas, in the community

   to help interpret contingent valuation and choice experiment (identify factors affecting results, screen for protest bids).

3) Questions on opinion on individual exposure to flood and erosion risk (at risk zone only) :
   a) Belief that property will be affected over the next 10 years
   b) Likart scale on anxiety related to storm events
   c) Investment in flood or erosion defense (goal and amount)

4) Questions on of how much respondent is willing to spend on protection or repairs to stay (double-bounded contingent valuation):

«[Note for interviewer: for OWNERS only, systematically cycle through each bid value as you move from house to house. <u>Record the value used along with responses</u>.]

Studies suggest that the rate of flooding and erosion will increase in the future. Suppose your property is exposed to increased damages on a regular basis. As a result of these damages, over the next 10 years you are required to spend **[5,000$ / 10,000$ / 20,000$ / 30,000$ / 50,000$]** on installation and maintenance of private protection measures and/or damage repairs. These costs would be over and above any investments you've already made to date. Would you:

OPTION A	**OPTION B**
Move to avoid the costs	Accept the costs to be able to stay at this location

[1] OPTION A

[0] OPTION B

What if the damages required you to spend **[…]** over the next 10 years?

[IF OPTION A] What if the damages required you to spend **[2,500$ / 5,000$ / 10,000$ / 15,000$ / 25,000$]** over the next 10 years?		**[IF OPTION B]** What if the damages required you to spend **[10,000$ / 20,000$ / 40,000$ / 60,000$ / 100,000$]** over the next 10 years?	
OPTION Aa Move to avoid the costs	**OPTION Ab** Accept the costs to be able to stay at this location	**OPTION Ba** Move to avoid the costs	**OPTION Bb** Accept the costs to be able to stay at this location

[1] OPTION Aa **OR** OPTION Ba

[0] OPTION Ab **OR** OPTION Bb»

and follow up questions to :

a) better capture lower and higher amounts of willingness to pay
b) screen for uncertainty
c) screen protest bids

5) Choice experiment questions based on the following attributes and levels (Table 7):

Attributes	Levels
Number of homes and properties protected	0 50 100 200 400 600 1000
Impact on natural habitat for coastal flora and fauna	• Improved habitat • Reduced habitat • No change
Available recreation opportunities	• No recreation • Walking • Walking, picnic, and observation facilities • Swimming, walking, picnic, observation facilities • Fishing (e.g. striped bass, clams, quahogs), swimming, walking, picnic, observation facilities • No change
Impact on ocean vista	• Improved ocean view • Lost ocean view • No change
Annual increase in property taxes (or rent) for the next 5 years	\$0 \$25 \$50 \$75 \$100 \$150 \$200

The attributes and levels result in 1,944 ($6^3 * 3^2$) unique alternatives. Since it is not feasible for respondents to choose from this many alternatives, we used the computer program SAS to generate an orthogonal main effects fractional factorial design with 36 alternatives (Kuhfeld, 2010). These alternatives were optimally grouped into 6 blocks, each containing 6 choice sets. The choice sets each contained a single alternative alongside an option representing the status quo. Such binary choice sets have been shown to be more incentive compatible, under certain conditions, than sets containing more alternatives (Vossler, Doyon, & Rondeau, 2012).

Introductory script and questions:

«Suppose that your municipality and the provincial government are holding a referendum on whether or not to enact an adaptation plan to protect vulnerable portions of your community's coast. The plan could utilize any combination of the strategies mentioned earlier, such as beach nourishment, dune restoration, hardened protection or relocation. To cover the cost of the plan, property taxes would be increased for a period of 5 years, after which they would return to their current level. In other words, if accepted by the majority, the adaptation plan would be implemented and everyone's property taxes would temporarily increase.

- *While this is a hypothetical scenario:*
    - *Try to imagine how you would feel if faced with this decision today and answer as honestly as possible since your choices will inform the development of a coastal adaptation plan.*
    - *The PROPOSED PLAN scenarios are based on actual considerations for communities in the Acadian Peninsula.*
- *Property taxes would be a short-term increase to cover the costs associated with the adaptation plan.*
- *[IF RENTER] Note, that their rent would increase since their landlord's property taxes would increase.*
- *The CURRENT SITUATION means your community would continue to face increasing risk and damages from flood and erosion, but your property taxes (or rent) would not increase.*
- *Consider the scenario on each card independently of the others.*

If you had to vote on these two options, would you vote for the PROPOSED PLAN or the CURRENT SITUATION? Note, for the current situation there is no change to the taxes (or rent) you would have to pay.

[1] PROPOSED PLAN

[0] CURRENT SITUATION»

Respondents answered these questions for 6 different choice sets. Then answered follow up questions to:

a) identify factors affecting results
b) screen for uncertainty
c) screen protest bids

6) Socio-economic questions :
   a) Gender
   b) Age group
   c) Number of people in household
   d) Education level
   e) Employment status
   f) Annual household income

to compare the sample to the population and identify factors that affect results.

The survey was conducted during August and September 2015, mostly during the day, but some evenings and weekends. Printed questionnaires were used, at risk and not at risk zones were delimited and targets for at risk versus not at risk were set prior to going in. Surveyors had printed maps and sometimes a list of addresses to guide them. Interviews were conducted face to face, with the surveyor reading the questions and writing the respondent's answers on the printed questionnaire.

Targeted areas or streets were systematically covered with surveyors going door to door until they reached targets or ran out of time. Addresses where surveyors knocked were noted, as well as presence or absence and willingness of occupant to participate.

Results

A total of 338 people were approached, of which 223 responded (66%). Thus we did not succeed in reaching our ideal target of 249 responses (Table 8).

Demographics

Residents of coastal communities in the Acadian Peninsula was the target population for the survey (Table 9). The survey sample is comparable to this population (Figures 1 to 5), except for age. The age of the survey sample is skewed toward older age groups. Depending on the model specification, the statistical analysis found age was significant in some cases and not in others. Given the limited influence of age on the results, no adjustments were made. Most noteworthy is the fact that income characteristics are very similar.

Table 8. Number of respondents per community targeted

Community	Target	Actual	At risk
Le Goulet	31	27	14
Pointe-Sauvage	3	0	0
Chiasson-Savoy	19	21	15
Pointe-Brûlée	35	30	30
Haut-Shippagan	13	11	6
Pointe-Alexandre	11	7	4
Pokesudie	10	10	7
Inkerman Centre	35	35	22
Pointe à Bouleau	7	0	0
Val Comeau	28	25	13
Ste-Marie-St-Raphaël	36	35	9
Cap Bateau	10	10	3
Pigeon Hill	10	12	6
Total	249	223	129

Table 9. Communities included in the coastal Acadian Peninsula population (population data from Statistics Canada 2012)

Community	Population
Alnwich parish	5922
Bas-Caraquet	1380
Bertrand	1137
Caraquet	4169
Caraquet Parish	1382
Grande-Anse	738
Lamèque	1432
Le Goulet	817
Maisonnette	573
Néguac	1678
New Bandon Parish	1195
Sainte-Marie-Saint-Raphaël	955
Shippagan	2603
Shippagan Parish	5032
Tracadie[1]	16100
Total	45113

[1] Tracadie-Sheila, Saumarez parish, Inkerman parish

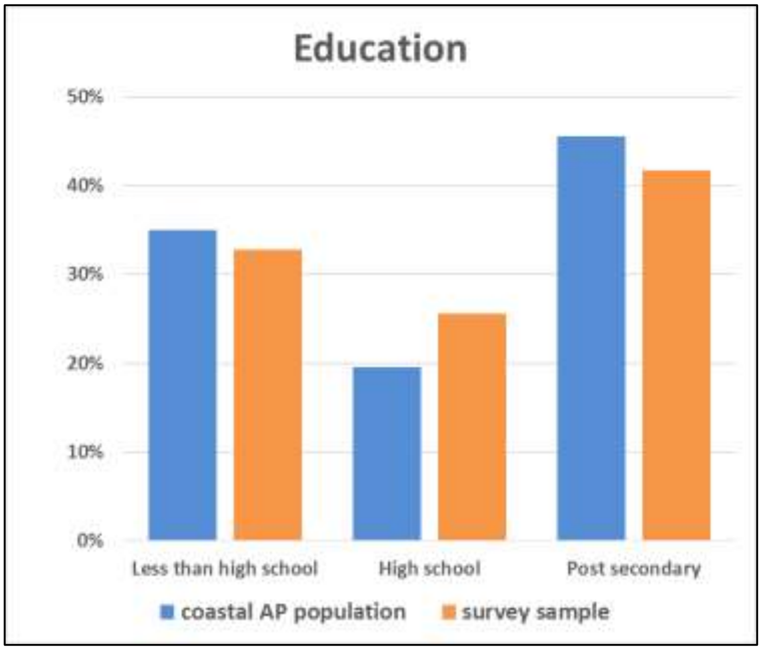

Figure 3. Education level in the coastal Acadian Peninsula population[10] (Statistics Canada 2013) and survey sample

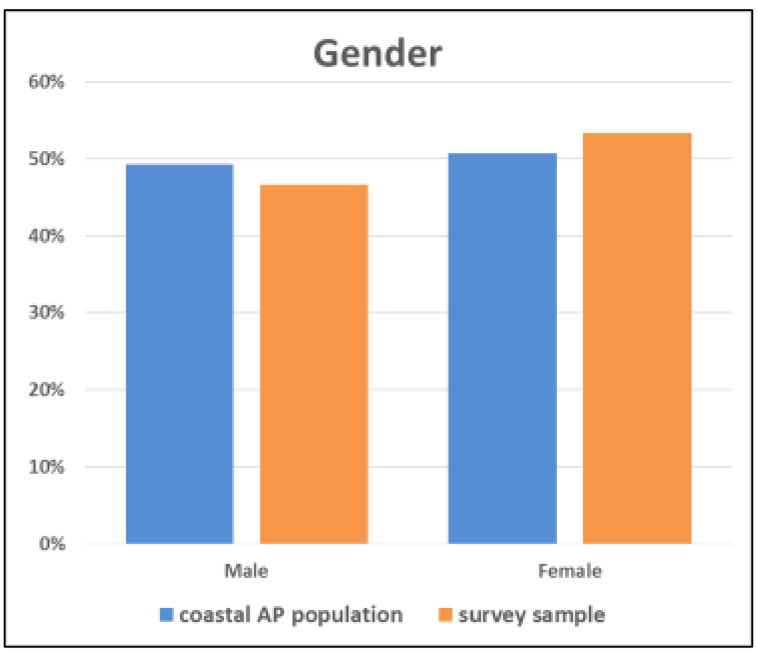

Figure 4. Gender distribution in the coastal Acadian Peninsula population (Statistics Canada 2012) and survey sample

[10] Education data for Le Goulet, Bas-Caraquet, Shippagan (parish) and Caraquet (parish) are from Statistics Canada (2006). The age group is 25 to 64 years.

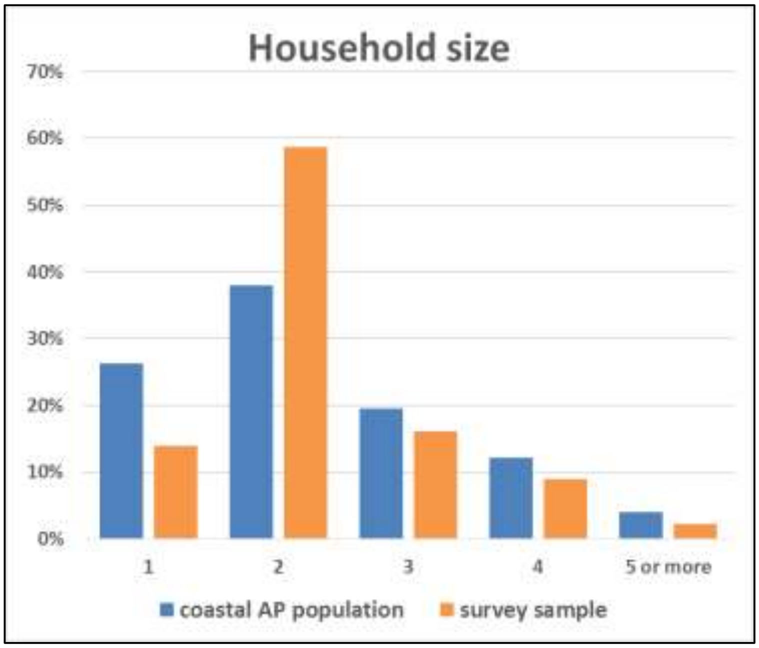

Figure 5. Household size in the coastal Acadian Peninsula population (Statistics Canada 2012) and survey sample

Property characteristics

Most properties (65%) were adjacent to the coast, 50% were in an area at risk of flooding, and 8% in an area at risk of erosion. Almost all the respondents were owners, only 6% being tenants. Owners were in their primary residence for the majority (91%) (Figure 6). Most respondents had lived in the residence for more than 10 years (Figure 7).

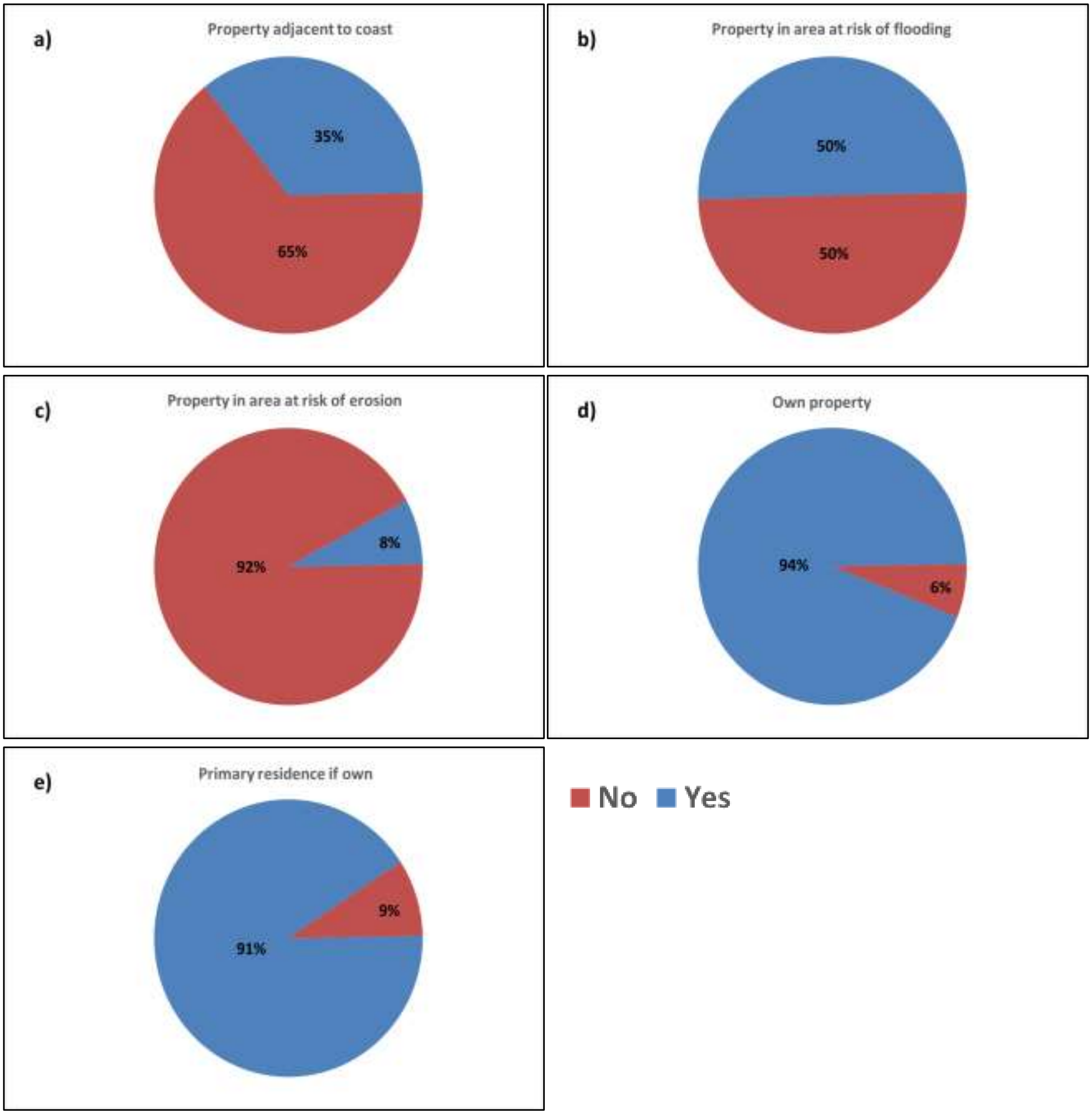

Figure 6. Property characteristics : a) adjacent to coast, b) in area at risk of flooding, c) in area at risk of erosion, d) ownership, e) primary residence.

Figure 7. Number of years lived in current location/property.

General concerns related to climate change and opinions on the quality of recreational opportunities, coastal habitat and ocean vistas

Respondents were either somewhat concerned or very concerned that sea level rise and increased extreme weather will cause greater damage in the Acadian Peninsula. 54% believe that climate change is a serious threat to their community; 55% believe that private land owners have some financial responsibility in protecting their own properties against flood and erosion damages; and 56% believe that flooding and erosion are the hazards of greatest concern for their community (Figure 8).

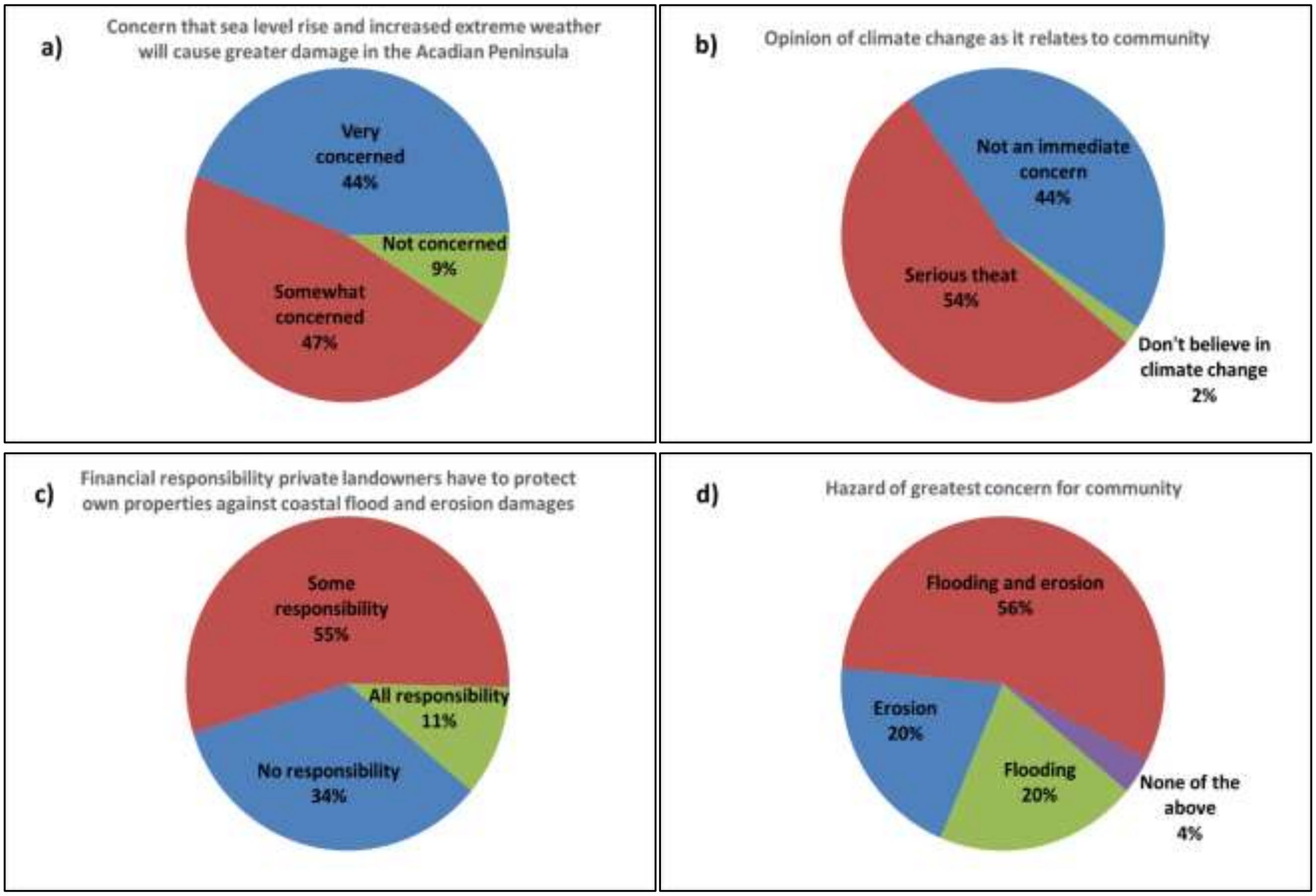

Figure 8. Opinion of respondents on: a) concern that sea level rise and increased extreme weather will cause greater damage in the Acadian Peninsula, b) climate change as it relates to community, c) financial responsibility private landowners have to protect own properties against flood and erosion damages and d) hazard of greatest concern for community.

29% of respondents thought that it was very likely that their property could be affected by flooding or erosion over the next 10 years, while 57% thought it somewhat likely (Figure 9).

40% felt that the condition of coastal recreational opportunities in their community were good; 44% that coastal habitat for flora and fauna in their community was good; and 63% that ocean vistas were very good in their community (Figure 9).

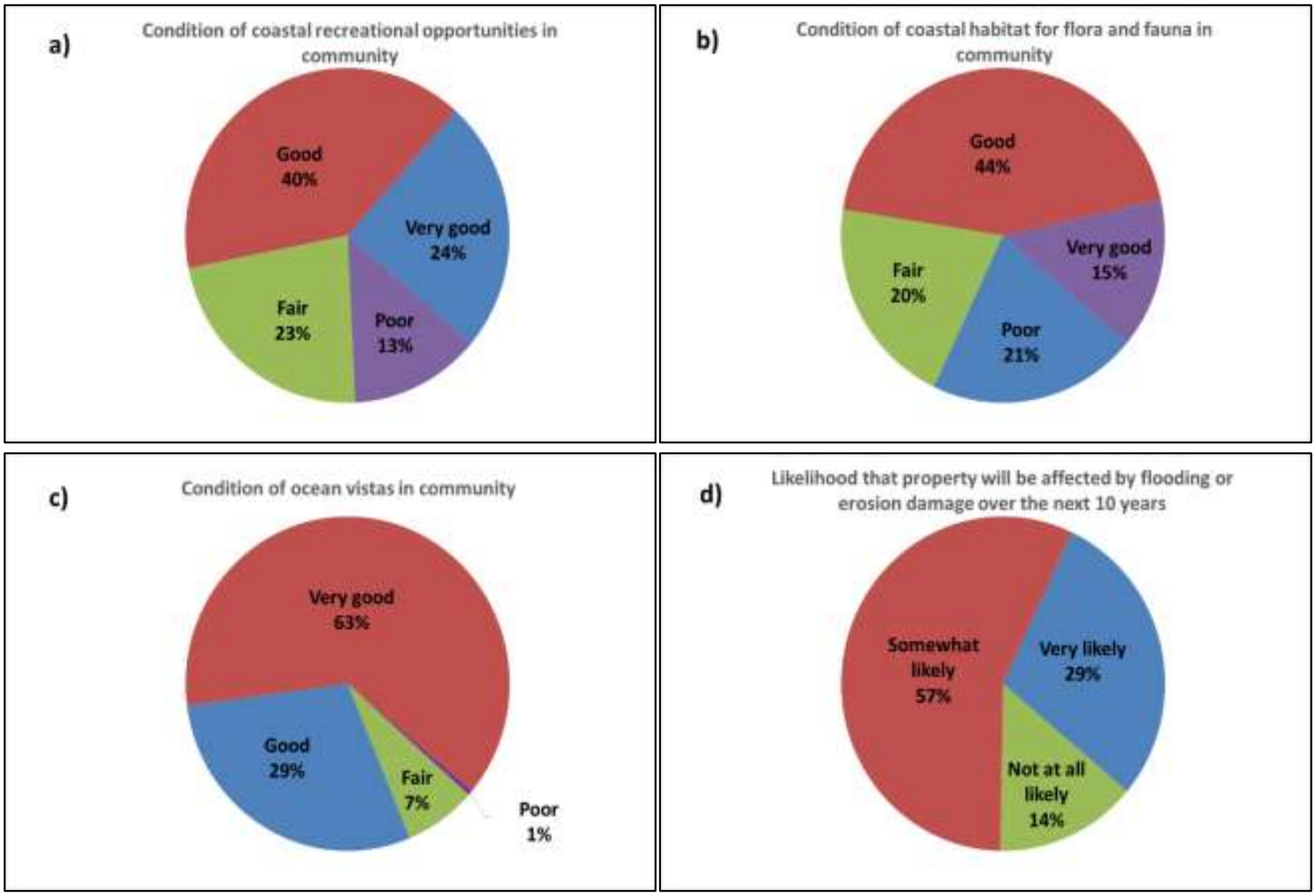

Figure 9. Opinion of respondents on: a) condition of coastal recreational opportunities in community, b) condition of coastal habitat for flora and fauna in community, c) condition of ocean vistas in community and d) likelihood that property will be affected by flooding or erosion damage over the next 10 years.

Likart scale results of reaction to approaching storm

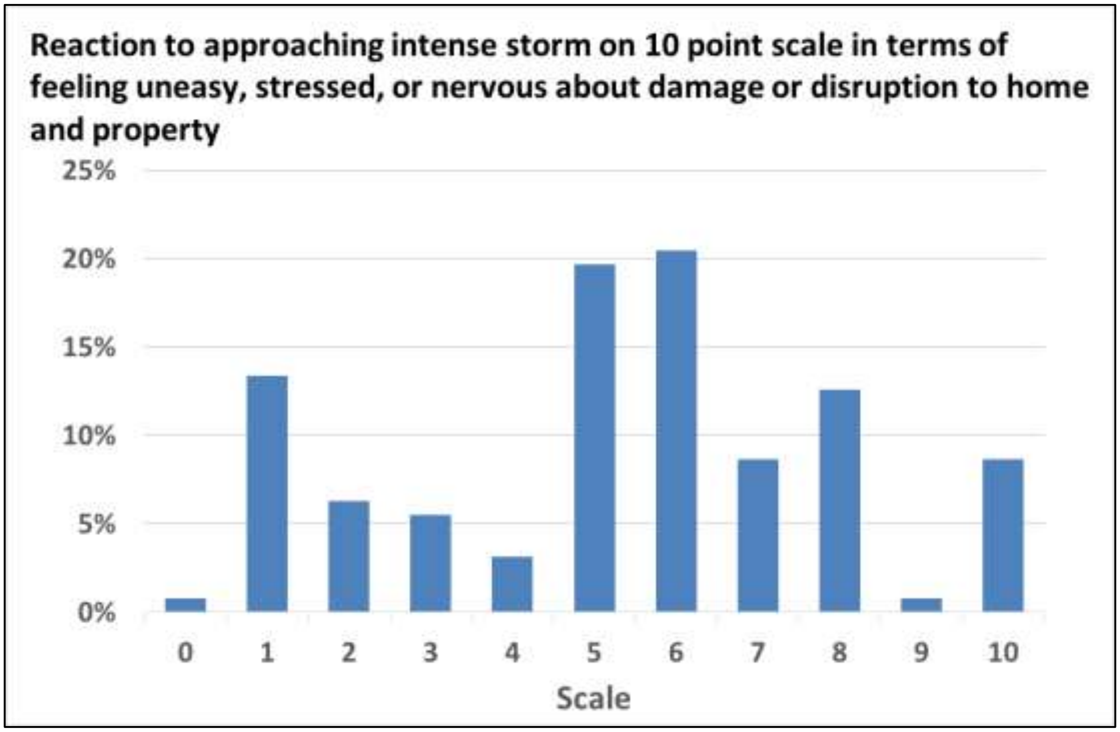

Figure 10. Reaction of respondents to approaching intense storm on a 10 point scale in terms of feeling uneasy, stressed, or nervous about damage or disruption to home and property.

Investment in flood or erosion defense

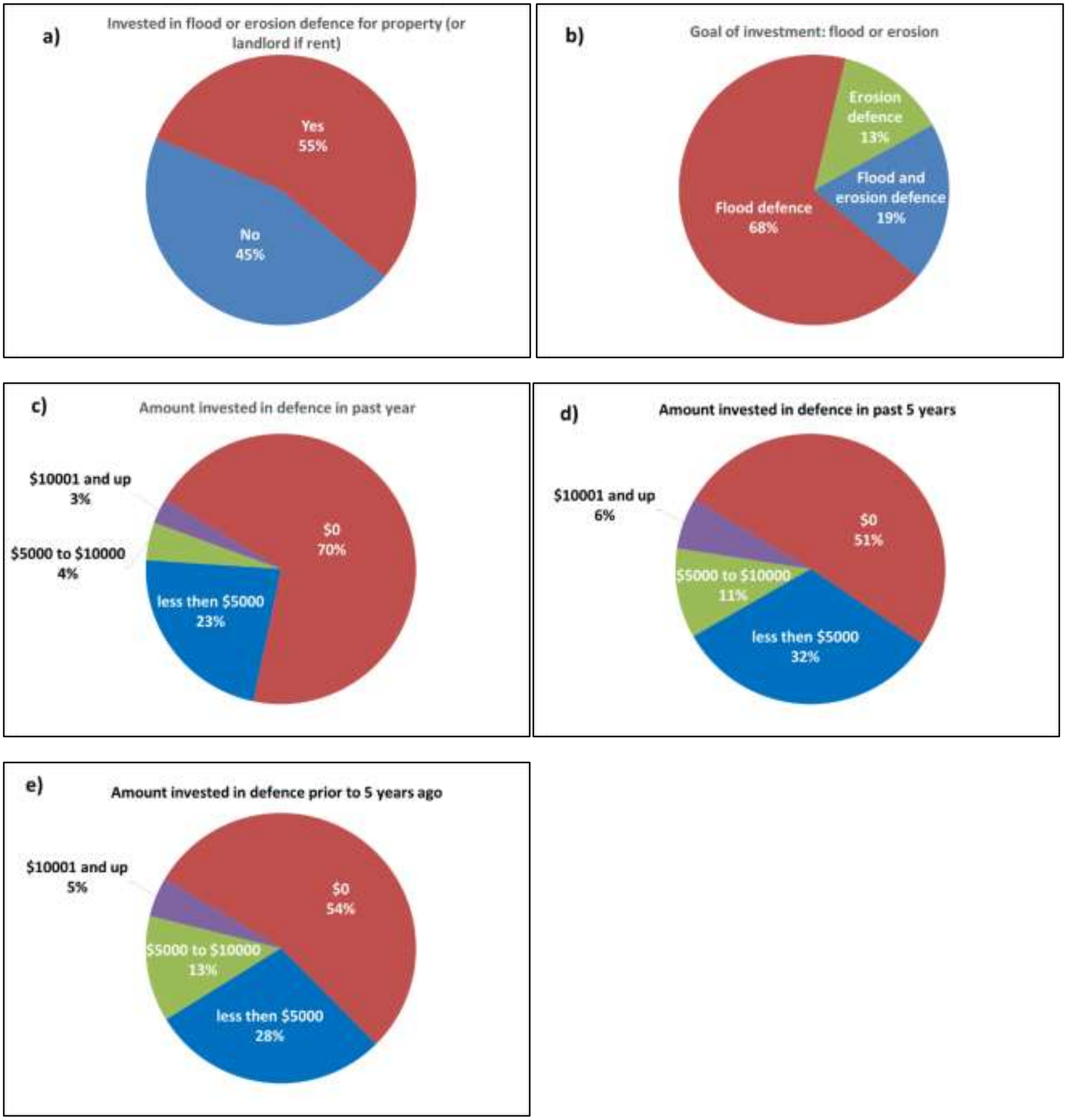

Figure 11. Respondents that have a) invested in flood or erosion defence, b) goal of investment, amount invested c) in past year, d) in past 5 years and e) prior to 5 years ago.

Contingent valuation results (Willingness to pay protection or repairs costs over the next 10 years to maintain living in their current home)

This question was designed to determine how large damage or protection costs would have to be before a homeowner would decide to move. Following is the willingness to pay over the next 10 years in order to maintain living at the current location (Table 10).

Table 10. Willingness to pay damage costs over the next 10 years.

	WTP over 10 years	95% CI Lower Bound	95% CI Upper Bound
Results adjusted for uncertainty	$10,170	$2,001	$18,339
Results unadjusted for uncertainty	$24,980	$19,277	$30,683

A series of model specifications where tested (interval, bivariate probit, random effects). Models of best fit were determined using log likelihood, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) statistics. The interval model was chosen as the best model. It is also one of the most common models used for contingent valuation.

Explanatory variables were also systematically examined to determine the influence of other factors on a respondent's willingness to pay over the next 10 years in order to maintain living in their current home. Below are the interval models (one adjusted, the other unadjusted for uncertainty) with explanatory variables significantly different from 0 at the 10% level.

- **Unadjusted for uncertainty:** Respondents answers were not adjusted according to their level of uncertainty (Table 11).
- **Adjusted for uncertainty:** Respondents who indicated they were very uncertain or uncertain that they would choose to stay if they had to pay damage costs were recoded as not willing to stay (Table 12).

Table 11. Interval model with protests removed and unadjusted for uncertainty

Variable	Coefficient	Standard Error	p-value
Constant	72767.46	17005.54	0.000
Primary Residence	-17950.79	7923.673	0.023
Defence spending in the last 5 years	1.8745	0.931163	0.044
Age	-599.7346	250.5061	0.017
n	84		

When results are unadjusted for uncertainty, primary residence, age, and having spent money on defense measures within the last 5 years were the significant explanatory variables. For each dollar spent on defense in past 5 years, WTP increases by $1.87. For each year of age, WTP decreases by $599.73. Interestingly, the results suggest that if the residence was the respondent's primary residence, WTP decreases by $17,950.79. At first glance this seems counter intuitive. However, we hypothesize that there are systematic differences in risk exposure between primary and secondary residences:

- Secondary residences (i.e. cottages) are typically closer to the coast line and therefore more at risk. Whereas primary residences are likely set further back from the coast.
- Secondary residents are not around year round and may have stronger preferences for additional assurances / peace of mind.
- Primary residents may feel that they shouldn't have to protect seasonal properties

We ran a number of cross tabulations of the survey data to test these theories and any systematic difference between seasonal and primary properties and found a number of supporting results:

- Seasonal residences much more likely to be coastal properties
- Seasonal respondents had a higher income
- Seasonal respondents had a higher education
- Seasonal residences have spent less time in the community on average
- Seasonal residences had a lower assessed value
- Seasonal residences more likely to have invested in flood/erosion defense measures and reported higher total defense expenditures on average
- Seasonal residences more likely to believe that they will be impacted by future flood or erosion
- Seasonal residences more likely to believe that landowners have financial responsibility to protect own properties
- No real difference in starting values for CVM exercise (so we reject the possible explanation that seasonal residences WTP was larger because the starting values with which they were presented were larger)

Table 12. Interval model with protests removed and adjusted for uncertainty

Variable	Coefficient	Standard Error	p-value
Constant	-8407.385	174.3155	0.309
Defence spending in the last 5 years	2.906243	1.079805	0.007
Income	331.0549	131.1867	0.012
n	84		

When adjusted for uncertainty, results were more intuitive, having spent money on defense measures within the last 5 years and income being the significant explanatory variables.

- For each dollar spent on defense in past 5 years, WTP increases by $2.91
- For each additional $1000 increase of income, WTP increases by $331.05

Other relevant statistics:

- Average assessed value of at risk homes surveyed was $76,440.
- Average assessed value of at risk homes who have invested in defence was $80,070
- WTP damage costs ranges from 13% to 33% of assessed property values.
- Average actual expenditures over the last 5 years was $3,663
- Average actual expenditures between 5 and 10 years ago was $7,780
- Given this supporting information, it is likely that the maximum willingness to pay damage costs is closer to unadjusted estimates.

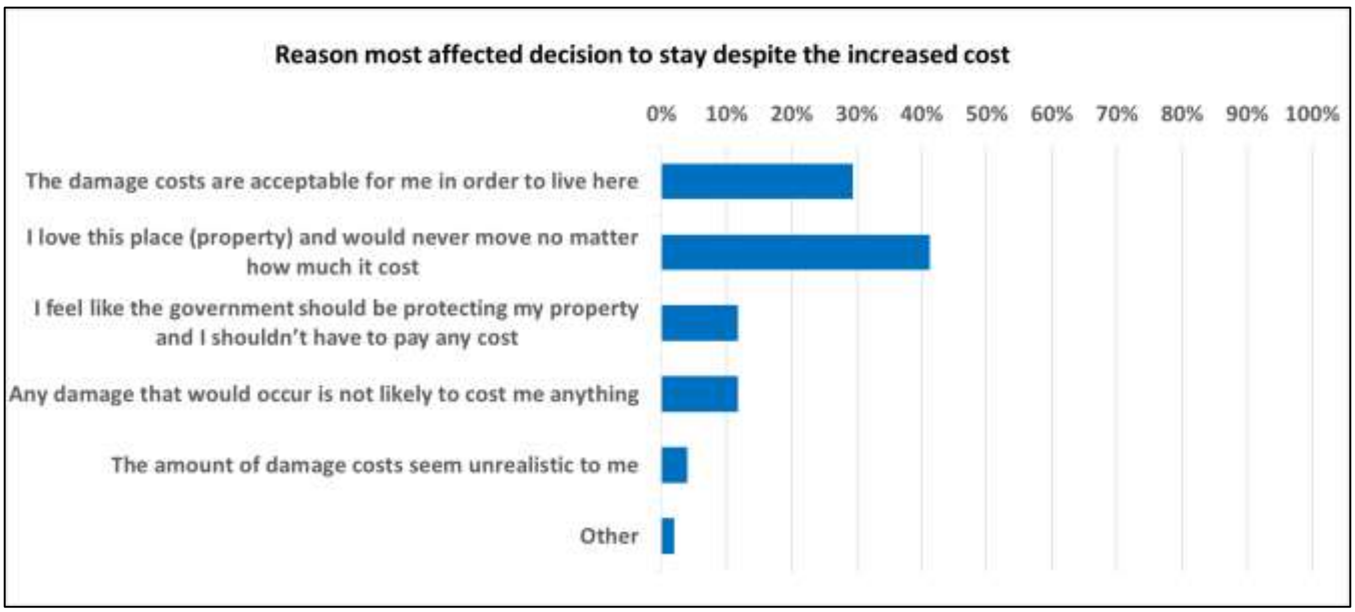

Figure 13. Reason that most affected the decision to stay despite the increased cost

Choice experiment results (Willingness to choose adaptation over the status quo (i.e. do nothing))

To assess the choice experiment results two model specifications where tested: conditional logit and latent class. The latent class model is a more complex specification that groups respondents into different classes based on common attributes and preferences. However, the latent class model found no clearly distinguishable classes (or groups). We also tried the random parameters logit model, but could not get it to converge. Therefore, the more commonly used conditional logit model was chosen (Table 13).

Table 13. Conditional logit model with protests removed and adjusted for uncertainty

	Variable	Coefficient	Standard Error	p-value
1	ASC	1.071	0.463	0.021
2	ASC_ErosionZone	0.472	0.244	0.053
3	ASC_ResPrime	-0.436	0.193	0.024
4	ASC_ResponsibilityNo	0.592	0.149	0.000
5	ASC_CondAllIndex	-0.083	0.035	0.018
6	properties_num	0.004	0.001	0.000
7	properties_num2	0.000	0.000	0.000
8	habitat_imp_d	0.322	0.167	0.054
9	habitat_red_d	-0.060	0.163	**0.713**
10	recreation_fswpo_d	1.134	0.256	0.000
11	recreation_swpo_d	0.456	0.231	0.048
12	recreation_wpo_d	0.210	0.227	**0.354**
13	recreation_walk_d	-0.149	0.226	**0.511**
14	recreation_none_d	-0.516	0.234	0.028
15	view_imp_d	0.415	0.164	0.012
16	view_lost_d	-0.890	0.167	0.000
17	cost_num	-0.009	0.001	0.000
	n	2232		

Insignificant if *p-value* is over 0.1

Notes on regression outputs:

1) Alternative specific constant (ASC). All else equal people are more likely to choose Alternative instead of the Status Quo
2) Interaction of erosion zone indicator with ASC. Those in erosion zone more likely to choose Alternative instead of Status Quo.
3) Interaction of prime residence indicator with ASC. Those with residence as prime residence less likely to choose Alternative instead of Status Quo.

4) Interaction of private landowners have no financial responsibility to protect properties indicator with ASC. Those thinking that they have no financial responsibility are more likely to choose Alternative instead of Status Quo.
5) Interaction of sum of condition Likart scores with ASC. Those believing current condition of attributes are good are less likely to choose Alternative instead of Status quo (why take a risk on changing a good thing).
6) Linear properties protected variable. Preference is having more properties protected.
7) Quadratic properties protected variable. People prefer having more properties protected, but ***with diminishing marginal utility***. This is a very good sign that results are following actual preferences.
8) Improved habitat variable (base is no change). People prefer improved habitat vs. status quo.
9) Reduced habitat variable (base is no change). Insignificantly different from no change, but hints that people dislike reduced habitat.
10) Fishing, swimming, walking, picnic, & observation recreation variable (base is no change). People prefer fishing, swimming, walking, picnic, & observation recreation
11) Swimming, walking, picnic, & observation recreation variable (base is no change). People prefer swimming, walking, picnic, & observation recreation.
12) Walking, picnic, & observation recreation variable (base is no change). Insignificant, but hints that people prefer walking, picnic, & observation recreation.
13) Walking only recreation variable (base is no change). Insignificant, but hints that people dislike having walking only.
14) No recreation (base is no change). People dislike no recreation.
15) Improved ocean view variable (base is no change). People prefer improved ocean view.
16) Lost ocean view variable (base is no change). People dislike lost ocean views.
17) Linear cost variable. People prefer to pay less.

For the choice experiment results, we are interested in how respondents traded off different attributes given the cost associated with the alternative (or adaptation) scenario. The model compares these trade-offs to determine a marginal willingness to pay for each attribute. The following table summarises these marginal WTP using the conditional logit model with protests removed and responses adjusted for uncertainty (Table 14).

Table 14. Results of the marginal WTP using the conditional logit model with protests removed and responses adjusted for uncertainty

Attribute	Level	mWTP	S.E.	LB 95% CI	UB 95 % CI
No. of properties protected	50	$0.41	$0.10	$0.22	$0.60
	100	$0.39	$0.09	$0.21	$0.57
	200	$0.36	$0.08	$0.20	$0.52
	400	$0.29	$0.07	$0.16	$0.42
	600	$0.23	$0.05	$0.13	$0.32
	1000	$0.10	$0.03	$0.05	$0.15
Habitat	Improved	$36.03	$19.07	-$1.34	$73.40
	Reduced	-$6.14	$18.34	-$42.08	$29.80
Recreation available	FSWPO	$124.53	$32.58	$60.68	$188.38
	SWPO	$51.03	$26.96	-$1.80	$103.87
	WPO	$25.00	$25.85	-$25.67	$75.67
	Walk	-$16.42	$25.56	-$66.52	$33.67
	None	-$56.39	$27.01	-$109.33	-$3.46
Ocean view	Improved	$46.05	$19.25	$8.33	$83.78
	Lost	-$98.38	$22.14	-$141.77	-$54.99

As can be seen in Table 14:

- No. of properties protected shows diminishing marginal willingness to pay (i.e. the more properties that are protected the lower the amount people are willing to pay to protect an additional property. NOTE: mWTP here is for a single property, to estimate the value of the attribute level we multiply mWTP by the number of properties protected (e.g. 50 x $0.41 = $20.50)
- People value improvements to habitat at $36, but losing habitat reduces value by $6.
- Recreation values are as compared to the status quo. Respondents seeing having walking only as a loss of recreation opportunity (i.e. that is the status quo of “no change” meant current recreation opportunities include more than just walking). Therefore, this represents lost recreation value of $16. Loosing all recreation opportunities reduces values by $56.
- Improving ocean views increase value by $46, however, if the view is lost the lost value ($98) is more than double the improved value.

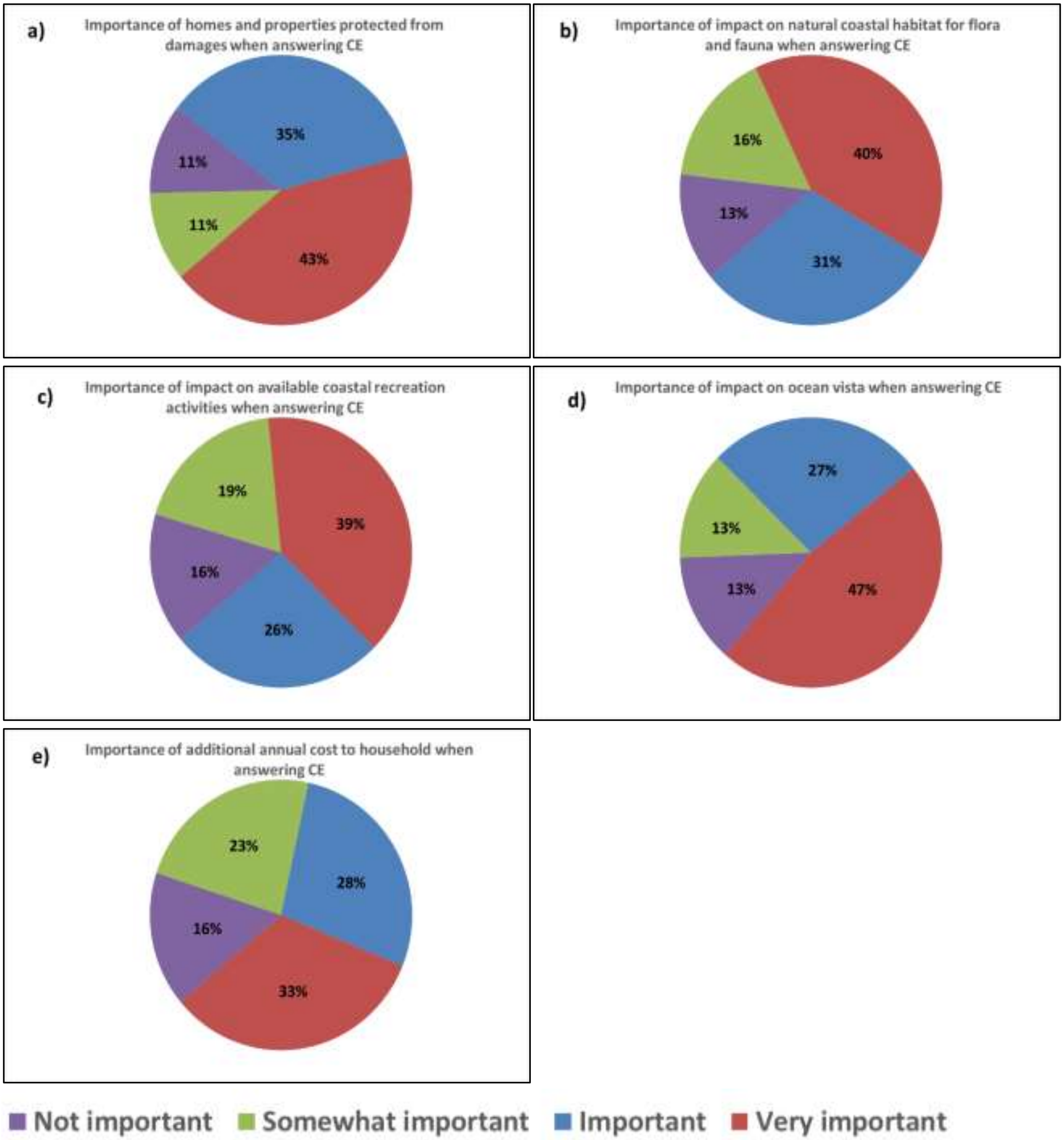

Figure 14. Relative importance of attributes when answering: a) number of homes and properties protected from damages, b) impact on natural coastal habitat for flora and fauna, C) impact on available coastal recreation activities, d) impact on ocean vista and e) additional annual cost to household.

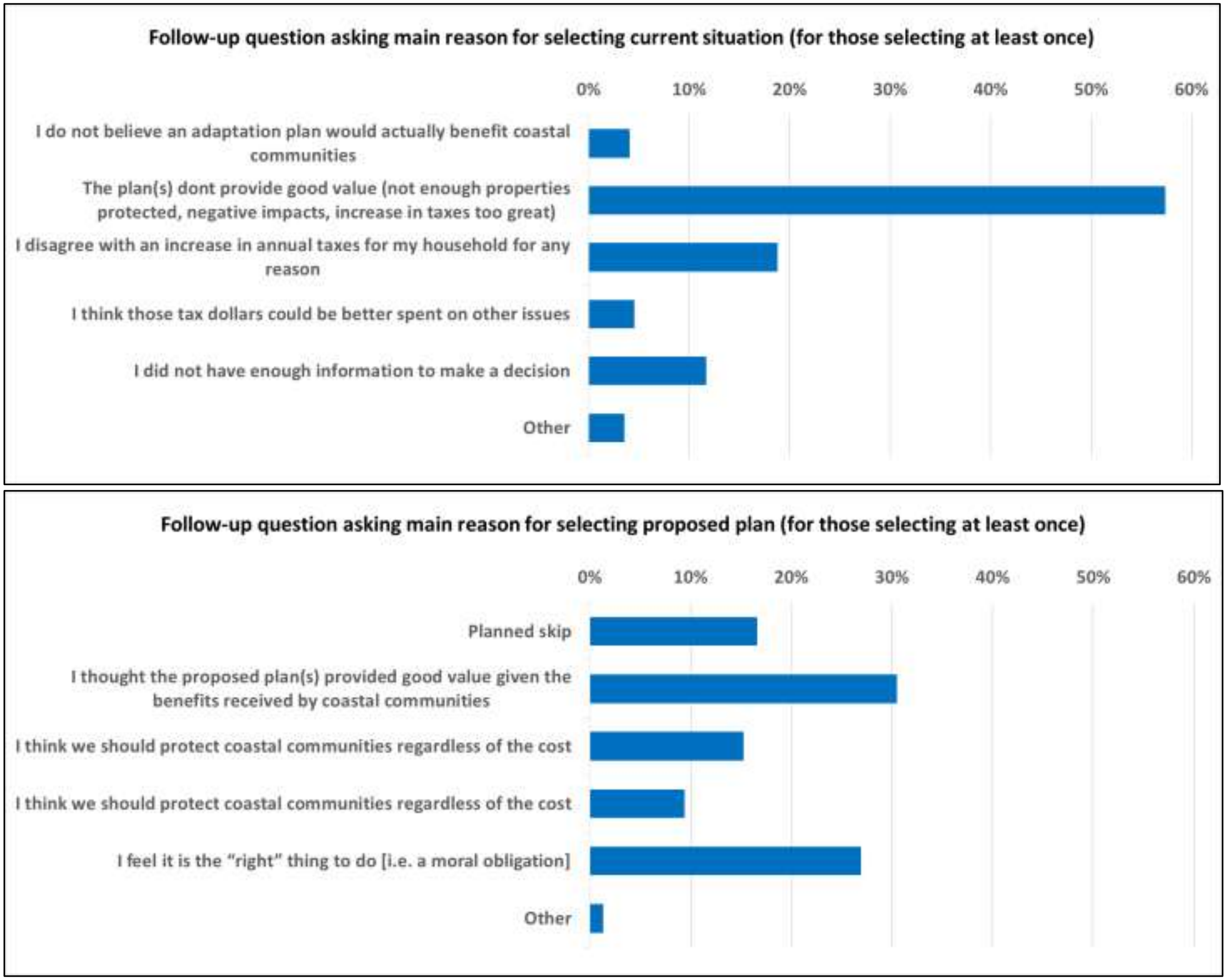

Figure 15. Follow-up question asking main reason for selecting current situation or proposed plan.

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Appendix 3. Sensitivity analysis for Le Goulet, NPV calculations based on upper bound flood levels (HHWMT + margin of error)

Cost and benefits projected for 25 years (upper bound flood levels)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Flood damages	$424 973	**-$424 973**
Scenario 1: Dike	Avoided flood damages	$424 973	Construction costs	$2 566 420	
	Non-market recreation benefit (WPO)	$40 160	Ongoing maintenance	$535 754	
	Increased sense of safety	$1 484 820	Habitat reduced	$9 863	
	Protection value of adaptation	$91 468	Ocean view lost	$158 037	
	Total benefits	$2 041 420	**Total costs**	$3 270 074	**-$1 228 654**
Scenario 2: Beach nourishment	Avoided flood damages	$424 973	Nourishment and maintenance	$410 726	
	Increased sense of safety	$1 484 820	Ocean view lost	$158 037	
	Protection value of adaptation	$91 468			
	Total benefits	$2 001 261	**Total costs**	$568 763	**$1 432 498**
Scenario 3: Beach nourishment with breach	Avoided flood damages	$424 973	Nourishment and maintenance	$410 726	
	Increased sense of safety	$1 484 820	Breach cost (flood damage + repairs)	$0	
	Protection value of adaptation	$91 468	Ocean view lost	$158 037	
	Total benefits	$2 001 261	**Total costs**	$568 763	**$1 432 498**

Cost and benefits projected for 50 years (upper bound flood levels)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Flood damages	$1 276 498	**-$1 276 498**
Scenario 1: Dike	Avoided flood damages	$1 276 498	Construction costs	$2 566 420	
	Non-market recreation benefit (WPO)	$40 160	Ongoing maintenance	$975 266	
	Increased sense of safety	$1 484 820	Habitat reduced	$9 863	
	Protection value of adaptation	$91 468	Ocean view lost	$158 037	
	Total benefits	$2 892 946	**Total costs**	$3 709 586	**-$816 641**
Scenario 2: Beach nourishment	Avoided flood damages	$1 276 498	Nourishment and maintenance	$898 401	
	Increased sense of safety	$1 484 820	Ocean view lost	$158 037	
	Protection value of adaptation	$91 468			
	Total benefits	$2 852 786	**Total costs**	$1 056 437	**$1 796 648**
Scenario 3: Beach nourishment with breach	Avoided flood damages	$1 276 498	Nourishment and maintenance	$898 401	
	Increased sense of safety	$1 484 820	Breach cost (flood damage + repairs)	$226 092	
	Protection value of adaptation	$91 468	Ocean view lost	$158 037	
	Total benefits	$2 852 786	**Total costs**	$1 282 530	**$1 570 256**

Cost and benefits projected for 100 years (upper bound flood levels)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo			Flood damages	$5 621 006	**-$5 621 006**
Scenario 1: Dike	Avoided flood damages	$5 621 006	Construction costs	$2 566 420	
	Non-market recreation benefit (WPO)	$40 160	Ongoing maintenance	$1 589 499	
	Increased sense of safety	$1 484 820	Habitat reduced	$9 863	
	Protection value of adaptation	$91 468	Ocean view lost	$158 037	
	Total benefits	$7 237 454	**Total costs**	$4 323 819	**$2 913 635**
Scenario 2: Beach nourishment	Avoided flood damages	$5 621 006	Nourishment and maintenance	$1 085 534	
	Increased sense of safety	$1 484 820	Ocean view lost	$158 037	
	Protection value of adaptation	$91 468			
	Total benefits	$7 197 294	**Total costs**	$1 243 570	**$5 953 723**
Scenario 3: Beach nourishment with breach	Avoided flood damages	$5 621 006	Nourishment and maintenance	$1 085 534	
	Increased sense of safety	$1 484 820	Breach cost (flood damage + repairs)	$226 092	
	Protection value of adaptation	$91 468	Ocean view lost	$158 037	
	Total benefits	$7 197 294	**Total costs**	$1 469 663	**$5 727 631**

Appendix 4. Discussion of potential impact of zoning on existing property values

The economic literature highlights the impact that being in a hazard zone has on property values. The research shows that the impact depends on the degree to which information about the hazard is available when a property is purchased (Samarasinghe and Sharp 2010). When new information becomes available, it sends a signal to the market which results in a price adjustment. Assuming the establishment of the retreat and accommodation zoning policy sends such a signal to the housing market in Shippagan and Pointe-Brulée, we would expect to see a price adjustment that reflects the associated risk. Empirical literature reports a range of potential impacts:

- Bin et al. (2008a) – North Carolina – property values were 11% lower relative to a similar property without risk
- Bin et al. (2008b) – North Carolina – property values were 7.8% lower in a 100 year flood zone and 6.2% lower in a 500 year flood zone relative to similar properties outside the flood zones
- Carbone et al. (2006) – Florida – After Hurricane Andrew the rate of house price increases dropped by 20 to 30%
- Fridgen and Shultz (1999) – Minnesota – property values were 8% lower in the 100 year flood risk zone relative to similar properties outside the flood zone
- Samarasinghe and Sharp (2010) – New Zealand – property values were 6.2% lower in the flood plain relative to similar properties outside the flood plain
- Bin and Kruse (2006) – North Carolina – properties were 5 to 10 % lower if located within a flood zone, all these the same

There are a number of uncertainties associated with the degree to which the real estate market would be impacted by the establishment of the zoning areas. First, whether or not this is actually a cost depends on the degree to which the current real estate market is unaware of these risks. If the market is already aware, then existing market values should already account for this effect. The only way to determine this is through a detailed statistical assessment of property sales in and outside of the proposed zoning areas, which was outside the scope of this research project. Second, the impacts noted by existing literature are based on specifically quantifiable risk zone (e.g. the current 100 year flood zone). The zoning areas proposed are somewhat different than this, since they are based on future potential risks. Therefore, the actual impact depends on how the new zoning information is framed by the city and interpreted by the market. If framed as an preventative measure of potential future risks, then the market may interpret this as a positive proactive measure, in which case we wouldn't expect to see a price adjustment, or possibly a price adjustment much less than what has been shown in the literature. To account for this uncertainty, two scenarios are provided (1) with a price adjustment of 5%, and (2) with no price adjustment.

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Appendix 5. Sensitivity analysis for Shippagan, NPV calculations based on upper bound flood levels (HHWMT + margin of error)

Cost and benefits projected for 25 years (upper bound flood levels)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo	Recreation benefits	$368 847	Flood damages	$10 628 963	
			Future damage	$805 892	
			Retaining wall maintenance	$391 706	
			Habitat reduced	$40 162	
	Total benefits	$368 847	**Total costs**	$11 866 722	**-$11 497 875**
Scenario 1: Change to zoning	Increased sense of safety	$1 562 767	Flood damages	$8 484 908	
	Protection value of adaptation for future properties	$454 469	Retaining wall maintenance	$391 706	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$2 949 947	Impact on property values in risk zone	$2 871 170	
	Total benefits	$5 336 030	**Total costs**	$11 787 945	**-$6 451 915**
Scenario 2: Change to zoning with no impact on property values	Increased sense of safety	$1 562 767	Flood damages	$8 484 908	
	Protection value of adaptation for future properties	$454 469	Retaining wall maintenance	$391 706	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$2 949 947			
	Total benefits	$5 336 030	**Total costs**	$8 916 775	**-$3 580 745**

Cost and benefits projected for 50 years (upper bound flood levels)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo	Recreation benefits	$368 847	Flood damages	$25 091 925	
			Future damage	$3 799 605	
			Retaining wall maintenance	$631 624	
			Habitat reduced	$40 162	
	Total benefits	$368 847	**Total costs**	$29 563 316	**-$29 194 469**
Scenario 1: Change to zoning	Increased sense of safety	$2 519 957	Flood damages	$25 091 925	
	Protection value of adaptation for future properties	$730 303	Retaining wall maintenance	$631 624	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$13 895 947	Impact on property values in risk zone	$2 871 170	
	Total benefits	$17 515 054	**Total costs**	$28 634 881	**-$11 119 827**
Scenario 2: Change to zoning with no impact on property values	Increased sense of safety	$2 519 957	Flood damages	$25 091 925	
	Protection value of adaptation for future properties	$730 303	Retaining wall maintenance	$631 624	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$13 895 947			
	Total benefits	$17 515 054	**Total costs**	$25 763 711	**-$8 248 657**

Cost and benefits projected for 100 years (upper bound flood levels)

Scenario	Benefit	PV	Cost	PV	NPV (Benefits - Costs)
Status quo	Recreation benefits	$368 847	Flood damages	$59 767 888	
			Future damage	$18 910 991	
			Retaining wall maintenance	$868 579	
			Habitat reduced	$40 162	
	Total benefits	$368 847	**Total costs**	$79 587 620	**-$79 218 773**
Scenario 1: Change to zoning	Increased sense of safety	$3 465 325	Flood damages	$16 383 803	
	Protection value of adaptation for future properties	$904 162	Retaining wall maintenance	$868 579	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$36 846 672	Impact on property values in risk zone	$2 871 170	
	Total benefits	$41 585 006	**Total costs**	$20 163 714	**$21 421 293**
Scenario 2: Change to zoning with no impact on property values	Increased sense of safety	$3 465 325	Flood damages	$16 383 803	
	Protection value of adaptation for future properties	$904 162	Retaining wall maintenance	$868 579	
	Recreation benefits	$368 847	Habitat reduced	$40 162	
	Avoided future damage	$36 846 672			
	Total benefits	$41 585 006	**Total costs**	$17 292 544	**$24 292 463**