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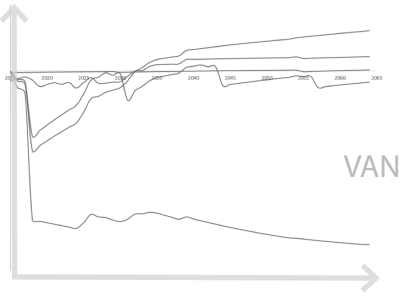

$$\text{VAN} = \sum_{t=1}^{T} \frac{avantages_t}{(1+\rho)^t} - \sum_{t=1}^{T} \frac{coûts_t}{(1+\rho)^t}$$

COST-BENEFIT ANALYSIS OF COASTAL ADAPTATION OPTIONS IN *PERCÉ*

Final Report

March 2016

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COST-BENEFIT ANALYSIS OF COASTAL ADAPTATION OPTIONS IN PERCÉ

PROJECT: ECONOMIC ASSESSMENT OF THE IMPACTS OF CLIMATE CHANGE AND COST-BENEFIT ANALYSIS OF ADAPTATION OPTIONS IN QUEBEC'S COASTAL AREAS

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March 2016

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EXECUTIVE SUMMARY

Few studies to date have focused on the economic assessment of climate change impacts and adaptation options for eastern Quebec's coastal areas. A program of work was therefore initiated by the Economics Working Group of Canada's Climate Change Adaptation Platform, chaired by Natural Resources Canada, to create economic knowledge and tools to help decision-makers in Canada's private and public sectors make better adaptation investment choices and policy decisions. Under this program of work, the research project *Economic Assessment of the Impacts of Climate Change and Cost-Benefit Analysis of Adaptation Options*, targeted coastal areas of Quebec and the Atlantic Provinces.

The Quebec study was conducted by Ouranos and its primary partner, the the Laboratoire de dynamique et de gestion intégrée des zones côtières (LDGIZC) of University of Quebec in Rimouski (UQAR), which has developed a wealth of knowledge about coastal erosion and flooding in Quebec. The objectives of this study aimed to assess the economic impact of erosion due to climate change (CC) in Quebec's maritime regions and to analyze the costs and benefits of various adaptation options for coastal erosion and flooding.

Five sites were subject to cost-benefit analysis (CBA) in this study: Percé, Maria, Carleton-sur-Mer, Îles-de-la-Madeleine and Kamouraska. This report focuses on the coastline of the City of Percé.

Percé is already experiencing significant impacts of climate change, due to sea-level rise, milder winters, loss of ice cover on the Gulf of St. Lawrence and changing storm patterns. In particular, the waterfront boardwalk and the buildings behind it have been subject to repeated damage for several years. It is becoming urgent to implement appropriate mesures to protect the coast, notably to maintain tourism traffic.

Methodological Approach

The purpose of this study is to identify, using cost-benefit analysis, the most beneficial adaptation options for protecting Percé's coastal zone from the impacts of erosion, which are increasing due to climate change. The study relies on future erosion projections provided by UQAR's LDGIZC.

The cost-benefit analysis (CBA) compares the aggregated benefits and costs of technically feasible adaptation options, from an economic point of view. The CBA relies on two indicators to compare the adaptation options to non-intervention: net present value (NPV) and benefit-cost ratio.

The study provides an assessment of the economic, environmental and social impacts as well as the costs of adaptation options. These include preliminary studies, construction and maintenance costs. As for the benefits of adaptation options, most of them stem from avoided costs and from benefits related to the use of the coast, principally by tourists.

The costs and benefits of the various options proposed are discounted at 4% for the study period, from 2015 to 2064. They are assessed from a regional perspective for the entire Gaspésie region.

Study Area

In the City of Percé, 4 segments of the coast were studied and the limits of these segments are presented in Figure A. These segments are Côte Surprise, Anse du Sud, Mont-Joli Sud and Anse du Nord. They were defined and chosen according to their physical characteristics and land use, in addition to the anticipated risks.

Figure A – Location of the study area and the 4 segments under study

Adaptation Options

The technical adaptation options studied, in particular the engineering structures, were drawn from the conceptual study conducted by engineering firm BPR (BPR et al., 2014). These options take into account the hydrodynamic conditions, erosion, sedimentation and geotechnical constraints associated with the segments under study. The adaptation options were designed to avoid all problems of erosion over the next 50 years.

Where possible, more than one option was compared to the non-intervention option. However, planned retreat was the only option considered for two segments composed largely of cliffs. Table A lists the adaptation options studied in each segment.

Table A – Adaptation options considered in each segment

Adaptation options	Côte Surprise	Anse du Sud	Mont-Joli Sud	Anse du Nord
Hard engineering structures		Seawall Rubblemound Riprap		Rubblemound Riprap
Soft engineering structures		Beach replenishment Beach replenishment with groynes		Beach replenishment
Options without coastal structures	Planned retreat		Planned retreat	Planned retreat

The main conclusions drawn for each of the four segments are presented below.

Côte Surprise

The Côte Surprise segment is located southwest of Percé Bay. It is bounded on the west by the cape Blanc and on the east by the rubblemound revetment that begins in front of the Riôtel Hotel. This part of the coast is composed mostly of over 30-meter-high cliffs of sedimentary rock, which have low resistance to erosion. Remote compared to the center of Percé, this segment has few buildings south of the provincial highway. To the west, there is a motel with three buildings each containing 12 units, a restaurant and a pub. In the middle, there is a campsite with 125 pitches. The eastern part has not been built on or developed.

The major issues in this segment are erosion and the possibility of the upper cliff collapsing. Certainly, active cliffs can recede quickly and unpredictably. If nothing is done in the next 50 years, several business assets will be at risk, including the three Motel La Côte Surprise buildings, as well as some thirty camping pitches.

A loss of business income is to be expected for the region, in addition to the loss of buildings and land. The motel units with a view of Rocher Percé and Bonaventure Island, which will be lost due to erosion, will unlikely be replaced with motel units offering an equally beautiful view. The camping pitches, however, could be easily replaced. The

cost-benefit analysis results indicate that non-intervention in this segment would lead to a negative net present value of close to -$560,000 over 50 years.

Given the height of the cliffs, only planned retreat is considered as a technically appropriate adaptation option in this segment. This option involves moving at-risk assets to another part of the property if the area is large enough, which is the case for the Motel La Côte Surprise buildings. The buildings should be moved as soon as they are 5 m from the edge of the cliff, to allow for safe manoeuvring of buildings and equipment. The net present value of planned retreat is about -$401,000. The net discounted benefits of this option total about $160,000 over 50 years compared to the non-intervention option.

A sensitivity analysis shows that the CBA results are robust to an increase in the value of the at-risk assets, and to a decrease in the estimated value of the view of Rocher Percé and Bonaventure Island from the motel units. Furthermore, introducing a safety margin of 4.3 m to prevent building collapse significantly increases the benefit of planned retreat. Finally, the results of the CBA favour planned retreat when the discount rate is decreased to 2% but not when it is increased to 6%.

Therefore in all cases, unless a discount rate of 6% is used, planned retreat is the most economically viable option over a period of 50 years. The benefit-cost ratio of planned retreat compared to non-intervention is 1.4. Planned retreat would therefore generate benefits equivalent to $1.40 for every dollar invested by the society.

In the Côte Surprise segment, the buildings that are exposed have an economic value high enough to justify economically their preservation with planned retreat over a 50-year period. Even if certain calculation assumptions are modified, planned retreat remains the least costly option over 50 years.

Anse du Sud

The Anse du Sud segment is the historic, cultural and economic heart of Percé. This coastal segment, between the Riôtel Hotel and Percé wharf, is threatened by the sea waves, which cause tens of thousands of dollars of damage every year. The main portion of the segment (towards the north) is protected by a concrete seawall that supports the seaside boardwalk. In recent years, ad hoc emergency interventions have

helped to hold the seawall and boardwalk in place, but the seawall is at the end of its useful life and these two infrastructures are extremely vulnerable to storm events.

Without adequate protection, the coastline in the northern part of the segment is expected to be subject to erosion again by 2020 and to retreat by an average of -15 cm per year. Further south, the coast is composed of low rocky cliffs protected by a rubblemound revetment that is in poor condition and poorly calibrated. The observed erosion rate is - 8 cm per year despite existing protection.

In the next few years, a number of business and tourism assets in this segment will be at risk. Hotels and businesses will be directly exposed to erosion within the study period (50 years). Moreover, the seaside boardwalk is predicted to disappear, which would put the tourism character of the City of Percé under serious threat. The central axis formed by the boardwalk and wharf attracts 400,000 visitors every year.

An analysis of the potential impacts of non-intervention shows that the seawall's inability to protect coastal assets could lead to total discounted losses of nearly $705 million over 50 years, mostly due to a decline in tourism traffic in the whole of the Gaspésie region. An online survey conducted among 2,000 Quebecers revealed that if the boardwalk was lost, many people would spend less time in the Gaspésie peninsula or would not go there so often. This change of behaviour would result in a 21% decrease in overnight stays in the Gaspésie region, about 320,000 less each year.

Given the scale of these impacts, five adaptation options have been studied to redevelop and protect the Percé coast: building a seawall, constructing a rubblemound revetment, installing a riprap, and beach replenishment with or without groynes[1]. An analysis of the costs and benefits of each option was conducted, taking into account not only the implementation costs, but also the costs and benefits relating to the economic, environmental and social impacts of implementing these options. The Quebec survey results were used, among other things, to assess how the implementation of each of the five options would affect tourism traffic.

[1] See BPR et al. (2014) for the design and characteristics of the adaptation options that require engineering work.

Among the studied options, the most economically advantageous option is beach replenishment with pebbles. It would provide net benefits discounted at 4% of approximately $773 million over 50 years compared to the non-intervention option (see Figure B). Non-intervention costs ($705 million) would be avoided and it would generate additional net benefits of $68 million. These additional gains would come from a 2% increase in tourism, about 35,000 overnight stays each year.

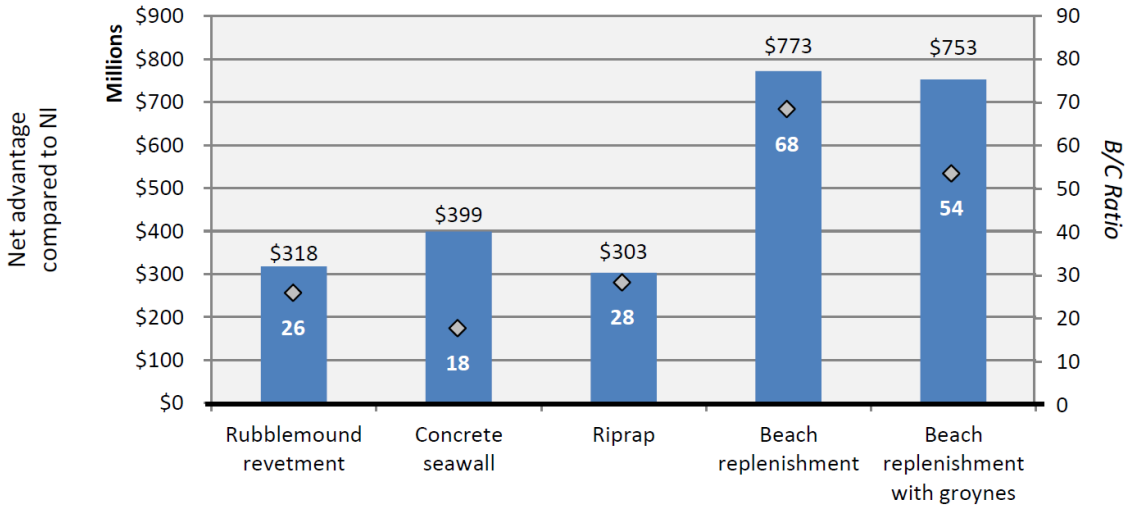

Figure B – Net discounted benefits compared to the non-intervention option in Anse du Sud

Beach replenishment with pebbles also has the highest benefit-cost ratio, with benefits 68 times greater than the costs. Each dollar invested by the society could then generate $68 in benefits. This result is clearly due to significant tourism benefits and to construction costs lower than those of the other options, even though beach replenishment involves high maintenance costs every 12 years. A steady supply of pebbles is indeed essential to ensure the sustainability of this option in the long term and its ability to protect the infrastructures over the next 50 years.

The second most advantageous adaptation option is beach replenishment with T-groynes, which are rock structures built at right angles to the coast and used to keep pebbles in place. The net discounted benefits of this option are in the order of $753 million compared to non-intervention. Although more costly than beach

replenishment without groynes, this option does not require maintenance for the study period. The benefits are 54 times greater than the costs.

Building a new seawall with deflector to better withstand future storm events has discounted benefits of $399 million. This option, like constructing a rubblemound revetment or a riprap[2], are advantageous options compared to non-intervention, but they would not allow maintaining the tourism traffic at the levels of the last few years in the Gaspé peninsula. These results bring to light the importance of taking action. Whatever option is implemented, it will always be more advantageous to protect and develop the Anse du Sud coast than to do nothing.

A sensitivity analysis revealed that the results of the cost-benefit analysis are robust to changes in assumptions. A change in the discount rate affects the results but does not alter the order of preference of the adaptation options. With regard to the assumptions on tourism traffic changes, even the most pessimistic forecasts do not alter the ranking of the options. Beach replenishment with pebbles is still the most economically viable option.

In summary, potential losses in the Anse du Sud segment are high, but the potential economic benefits from the implementation of adaptation options are higher, amounting to hundreds of millions of dollars over 50 years. Beach replenishment is the most beneficial adaptation option, followed closely by beach replenishment with T-shaped groynes.

Mont Joli Sud

The third segment, the portion south of the cape Mont-Joli, is an iconic landscape of Percé. It is composed of 12 to 25-meter-high rocky cliffs. Erosion rates are low, varying from -1 to -10 cm/year, depending on the type of rock. However, some buildings are very near the cliffs and appear to be vulnerable to erosion in the medium to long term. According to erosion rate forecasts, the Frederick-James Villa, located less than 4 m from the edge of the cliff, will be exposed to erosion during the study period. This is a

[2] Riprap is an adaptation option built by dumping of stones of various size with a soft slope in order to absorb and dissipate wave energy before it reaches the shore.

special heritage building in Percé and its presence on Mont-Joli enhances the value of the landscape and view of the Rocher Percé.

The non-intervention option in the Mont-Joli South segment would result in a negative NPV of -$209,470 in 2012 dollars discounted at 4%. This economic loss is essentially the loss of the building's property and heritage value of the Frederick-James Villa totalling over half a million dollars. Discounting plays a major role here, as the building is expected to be lost in 2042 according to the segment's estimated erosion rate.

Over a 50-year time horizon and with a discount rate of 4%, the net present values of non-intervention and planned retreat are almost the same. In other words, planned retreat in the Mont-Joli South segment does not appear to be economically preferable to the non-intervention option.

Sensitivity analyses on the heritage value, discount rate and erosion rate were conducted in an effort to make a distinction between the option of non-intervention and that of planned retreat. The sensitivity analyses of the heritage value and erosion rate could not clearly determine which of these two options is more economically benficial, as the difference between the NPVs of the two options is within the margin of error of the economic analysis. However, a sensitivity analysis combining an increase in the heritage and landscape value of the Frederick-James Villa (20%) and a slight increase in the erosion rate (10%) would favour the planned retreat option compared to non-intervention.

As for variations in the discount rate, the sensitivity analysis showed that the time factor is critical in this segment. Even though the Frederick-James Villa is only at risk in 2042, its preservation would require imminent relocation, as the building is already less than 5 m from the cliff hedge. Therefore, a decision is urgently needed if it is to be preserved for future generations.

Anse du Nord

The fourth segment under study in Percé is Anse du Nord and includes the area between the capes Mont-Joli and Barré. It is a natural-looking pebble beach, a complementary site to Anse du Sud in Percé's tourism offering. While much less visited than the Anse du Sud segment, a few thousand visitors come to Anse du Nord every

year to walk, swim, fish and admire the view of Rocher Percé. It offers a remarkable natural environment that would benefit from development so its beauty could be fully appreciated.

In terms of erosion, the coast of this segment is eroding more quickly than that of the other segments. The projected the erosion rate is estimated at -18 cm/yr. Given the retreat of the shoreline, non-intervention would lead to the loss of land, residential buildings, hotels and businesses. The value of the losses discounted at 4% would amount to $420,000 over 50 years.

Four adaptation options have been assessed to prevent these losses: constructing a rubblemound revetment, installing a riprap, beach replenishment and planned retreat[3].

The results of the CBA show that beach replenishment is the only economically viable option compared to the non-intervention option over a 50-year period. Unlike the other adaptation options, beach replenishment could produce benefits by encouraging the recreational use of the coast ($3.0 million), which amount to more than the cost of the option ($2.1 million). Over the entire period, beach replenishment would result in benefits of $1.3 million compared to non-intervention (Figure C). Given the increased recreational use and protection of assets, each dollar invested in beach replenishment by the society would generate benefits of $1.62.

In comparison, relocating assets would generate a negative net present value of just over -$100,000 compared to the non-intervention option. This means that non-intervention is preferable to moving at-risk assets in this segment. This is due to the high cost of moving buildings in relation to their property assessment value. In the case of planned retreat, each dollar invested would generate benefits of less than one dollar ($0.77).

Providing protection with a riprap, which would cost about the same as beach replenishment, would result in more environmental costs (destruction of capelin spawn) without increasing recreational use value of the coast. With negative net present benefits and a benefit-cost ratio less than 1, this option is not economically justifiable. Finally,

[3] See BPR et al. (2014) for the design and characteristics of the adaptation options that require engineering work.

constructing a rubblemound revetment would constitute the least economically viable option compared to non-intervention (-$4.0 million), because it is costly to implement ($4.4 million) and does not provide indirect benefits such as improved recreational use of the coast.

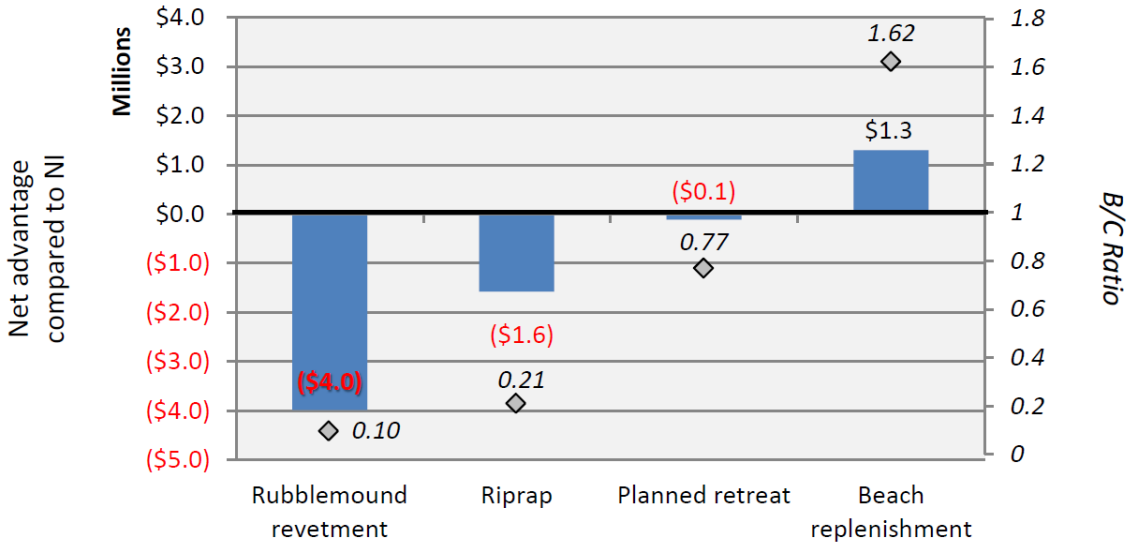

Figure C – Net discounted benefits compared to non-intervention in Anse du Nord

In light of these results, it is clear that the value of the built environment in Anse du Nord that will be at risk between 2015 and 2064 cannot alone justify the implementation of protection mesures such as beach replenishment, rubblemound revetment or riprap. These options must create additional benefits, notably increased recreational use of the coast, to be considered more advantageous than inaction.

The NPV of beach replenishment is not negatively affected when basic assumptions are modified. The sensitivity analyses confirm that beach replenishment is the most economically beneficial option to fight coastal erosion in Anse du Nord, Percé.

Conclusion

The purpose of this cost-benefit analysis was essentially to compare various adaptation options for coastal areas in Percé in order to determine which would be the most economically beneficial. The CBA provides two economic indicators, net present value and benefit-cost ratio, that can help local, regional and national decision-makers choose the options best suited to the challenges that coastal communities will face over the next 50 years.

The results of the CBA clearly indicate that the most economically viable option for society as a whole is beach replenishment with pebbles in both Anse du Sud and Anse du Nord. The benefits of this option outweigh the costs in both cases, as this option favours the development of the coast and improves the tourism offering of Percé, in particular in Anse du Sud.

For the two other segments consisting of rocky cliffs (Côte Surprise and Mont-Joli Sud), planned retreat through the relocation of at-risk buildings is the only option that would preserve Percé's tourism infrastructures and heritage assets. Planned retreat is economically beneficial for Côte Surprise, where buildings are threatened with collapse in the short term.

This option should also be considered for the Mont-Joli Sud segment, where the historic Frederick-James Villa is in jeopardy. Although the CBA indicates that the options of planned retreat and non-intervention are almost equivalent in Mont-Joli Sud, the loss of the Frederick-James Villa would be a strike against Percé's heritage value as well as the beauty of the landscape, two aspects that are difficult to reliably assess in monetary terms.

In conclusion, this cost-benefit analysis has demonstrated that the most economically viable options are those that improve coastal use and the tourism offering while costing less to implement.

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CBA:	Cost-benefit analysis
BAT:	Tourist information centre
CA:	Advisory committee
CC:	Climate Change
CLO:	Local orientation committee
CR:	Regional committee
CT:	Technical committee
LDGIZC :	Laboratoire de dynamique et de gestion intégrée des zones côtières
MAMOT:	Ministère des Affaires municipales et de l'Occupation du territoire
MAPAQ:	Ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec
MCC :	Ministère de la Culture et des Communications
MDELCC:	Ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques
DFO:	Fisheries and Oceans Canada
MRC:	Regional County Municipality
MTQ:	Ministère des Transport du Québec
NI:	Non-intervention
MSL:	Mean sea level
GDP:	Gross domestic product
CON:	Capelin Observers Network
RPPSG (APFSG):	Regroupement des Pêcheurs professionnels du Sud de la Gaspésie
B/C ratio:	Benefit-cost ratio
PR:	Planned retreat
SÉPAQ :	Société des établissements de plein air au Québec
UNB :	University of New Brunswick
UPI :	University of Prince Édward Island
UQAM :	Université du Québec à Montréal
UQAR:	Université du Québec à Rimouski
NPV:	Net present value

SYMBOLS AND UNITS OF MEASUREMENT

mm:	millimetre
cm:	centimetre
m:	metre
km:	kilometre
LN:	linear metre
$:	2012 dollars unless otherwise specified

1 INTRODUCTION

Quebec has over 3,000 km of coastline in the eastern part of its territory. In 2014, this maritime area, which is comprised of Côte-Nord, Bas-Saint-Laurent, Gaspésie, the Îles-de-la-Madeleine, and Anticosti Island had in 2014 a population of 388,000 inhabitants living in 212 municipalities, 110 of which are situated on the coast (ISQ, 2014a). Over one third of the population lives less than 500 m from the shore, and more than 90% live within less than 5 km from the shore (Bourque and Simonet, 2008). In 2013, the gross domestic product (GDP) of the maritime area was $17.1 billion, with the main industries being fisheries, tourism, aluminum production, ground transportation and port facilities transporting mining products (ISQ, 2014b).

These communities are facing an unprecedented transformation of their environment as a result of climate change (CC). By altering the key parameters that underlie coastal processes, climate change threatens the integrity of coastal areas. For example, the maritime storm of December 2010 caused close to $30 million in damage to public infrastructure and some 740 coastal properties along the Estuary and Gulf of St-Lawrence and Chaleur Bay (Quintin C. et al., 2015). In this context, Ouranos set out to analyze the different adaptation options for the erosion and coastal submersion that are threatening Quebec's coastal regions.

This study is part of a research project supported by Natural Resources Canada through the Economics Working Group of Canada's Climate Change Adaptation Platform and Quebec's Green Fund. The project includes an overall economic assessment of the

impact of erosion on the coastline of Quebec's maritime regions, which was published in July 2015 (Bernatchez et al., 2015). It also includes a study on the CC impacts and adaptation options, which could protect the coastal assets and the uses of the coast. Five case studies of coastal municipalities in Quebec were carried out in order to determine the economic viability of different adaptation options to protect the coastline.

This report focuses on the City of Percé. Percé, which had 3,188 inhabitants in 2014 (ISQ, 2014a), is one of the region's major tourist hubs. Its coastal attractions draw thousands of tourists to the Gaspésie region each year. With around 74 km of coast, Percé is unique in terms of its history and its exceptional location. Percé's coastline is directly affected by climate change, which makes it more vulnerable to coastal erosion. As a result, Percé's main tourist attractions are in jeopardy, as are many of its buildings and infrastructures.

The second chapter of this report presents the study area and its main geomorphological, hydro-sedimentary, and socioeconomic characteristics. It provides an overview of the segments under study and the criteria that led to them being chosen. Finally, it describes the coastal issues facing Percé.

The third chapter explains the study's methodological approach. It begins by describing the participatory process used throughout the study, among other things, to identify the issues, impacts and adaptation options. The chapter concludes with an overview of the economic methodology and a summary of the key assumptions used in the specific context of this study.

The next four chapters present, in greater detail, the methodological approach used and the results of the cost-benefit analysis (CBA) undertaken for each of the four segments under study. Each chapter discusses the characteristics and issues particular to that segment and describes the adaptation options considered and their potential impacts. These impacts are quantified, then monetized, in order to carry out a cost-benefit analysis.

The costs and benefits of the various adaptation options considered within a given segment are then compared in order to determine the most beneficial options for that segment. The results of the CBA are presented in detail, and sensitivity analysis is used

to test their robustness. Each chapter concludes with a summary of the most economically advantageous adaptation options.

Finally, the conclusion of the report offers the reader an overall view of all the results obtained for the four segments under study in the City of Percé.

2 CONTEXT OF THE STUDY

This chapter begins with a description of the general characteristics of the study area in the municipality of Percé. The segmentation process applied to the coastline is then explained, as are the general characteristics of the segments chosen for analysis.[4] The chapter concludes with a description of the issues associated with climate change and their impacts on Percé.

2.1 STUDY AREA

The study area chosen in the City of Percé was the village of Percé, which is situated on the southeastern tip of the Gaspé Peninsula. Since the merger in 1970, the village has been an integral part of the city of Percé, which is an amalgamation of 6 rural municipalities located around the historic village (see Figure 2.1). The village of Percé is a major tourist and historical attraction in the region. It is home to an exceptional natural and built heritage, including the emblematic Rocher Percé. Its ability to attract visitors reaches beyond municipal borders.

More specifically, the study area covers the coastline of the village of Percé from Cap Blanc in the west to Cap Barré in the east. Resting on the Bonaventure geological formation, the area covers a little over 4.5 km and has a wide diversity of coasts, which include high, rocky sandstone and conglomerate cliffs, limestone cliffs, and beach terraces. Coves lined with rocky limestone, sandstone, and conglomerate cliffs are

[4] A detailed description of each segment can be found in the separate chapter dedicated to that segment.

characteristic of the coastline of the village of Percé (Figure 2.1) (Bernatchez et al., 2008).

The coastal area under study is home to the majority of the tourism-related infrastructure and is the historic and touristic centre of the city. The geographical positioning of Percé makes it particularly vulnerable to coastal hazards. The village looks out on the Gulf of St. Lawrence, exposing it to high winds coming off the water, which makes for a rigorous coastal dynamic. What is more, the absence of littoral accumulation formations indicates that longshore drift is not a dominant process along the coastline of the village of Percé (Bernatchez et al., 2008). As a result, the sediment lost during storms is rarely recovered and difficult to replace.

To combat these hazards, different steps have been taken to protect the coastline, which has led to the artificialization of certain parts of the coast, especially Anse du Sud and Anse du Nord. Since the early 2000s, the protective infrastructure along the coast has suffered major damage caused by, among other things, the major storm that occurred on December 6, 2010. The damage is so extensive that this protective infrastructure appears to have reached the end of its useful life.

2.2 SEGMENTATION AND SELECTION PROCESS

The coastline of the village of Percé was segmented in such a way that each segment of the coastline would be sufficiently homogenous to apply an adaptation option across it. Clearly, the adaptation options that could be applied to a limestone cliff are not the same as those that could be applied to a pebble beach, for example. The segmentation criteria used were the type of coast, the hydro-sedimentary dynamic, the condition of the coast, protections already in place, and the type of built environment. The segmentation process allowed the village of Percé to be divided into 8 homogenous parts. Figure 2.1 indicates the location of each segment.

Figure 2.1 – Map of the study area

Once the segmentation process was completed, a selection process was undertaken with a view to selecting those segments containing infrastructures that would be at risk during the time horizon of this study, which covers the period 2015- 2064. This first criterion enabled us to eliminate 3 segments from the study: Cap Blanc, SÉPAQ, and Mont-Joli Nord. None of these segments will be under threat over the next 50 years.

For reasons of availability of data, the Côte Surprise-rubblemound and Percé-Centre segments were amalgamated to form the Anse du Sud segment[5]. As a result, the four segments examined in this study are Côte Surprise, Anse du Sud, Mont-Joli Sud and Anse du Nord.

The following section offers a brief description of the geomorphological characteristics of the segments studied, as well as their limits.

2.3 PRESENTATION OF SEGMENTS STUDIED

Côte Surprise

The Côte Surprise segment is comprised of 1,388 m of sandstone and conglomerate cliffs between Cap Blanc and the Riôtel Percé Hotel (see Figure 2.2). The rocky cliff in Côte Surprise is essentially composed of a mix of conglomerates and sandstone more friable than the limestone rocks found in the Cap Blanc area to the west. The cliff in this area is more dynamic, given that the sandstone and conglomerate of which it is made are more sensitive to the cryogenic processes of the freeze-thaw cycle and to wave erosion (Bernatchez et al., 2008).

Therefore, this section of the cliff can collapse suddenly, without any warning. Over time, wave erosion is creating wave-cut notches at the base of the cliff that can reach a depth of several metres. When these notches cave in, they destabilize the talus, which could cause soil collapse at the summit. There are numerous rocky overhangs, as well as signs of falling rock. These materials feed Anse du Sud, longshore drift being in an easterly direction.

[5] While the cost-benefit analysis was carried out, the BPR firm (BPR et al., 2014) undertook a design study to identify different adaptation options for certain segments targeted by the economic analysis. In order to tie the BPR study in with the costing data needs of the economic analysis, the boardwalk and Côte Surprise (rubblemound) segments were amalgamated. In addition to offering recommendations for the Anse du Sud segment in its entirety, BPR's report also provided a preliminary design for protective structures for Anse du Nord.

Figure 2.2 – The Côte Surprise segment

Anse du Sud

The Anse du Sud segment, as shown in Figure 2.3, is adjacent to the Côte Surprise segment, and is made up of two distinct sub-segments. It starts at the Riôtel Percé Hotel and ends at the Percé wharf. This segment of low cliffs of unconsolidated sediment and beach terrace measures 907 m in length.

Figure 2.3 – Anse du Sud segment

The first sub-segment of 275 m is composed of a rocky conglomerate cliff with a height that varies between 6 and 12 m (LDGIZC-UQAR, 2015). In places, the cliff is composed of loose deposits on a rocky base. However, given the low height of the cliff in comparison with those in Côte Surprise, the loose deposit summit covers a larger thickness and the agents of erosion are more active than in neighbouring segments. Because of this, the talus was stabilized with a rubblemound revetment.

The second sub-segment, which measures 633 m, is the centre of the village of Percé. It has been entirely artificialized with a low concrete seawall that protects the seafront boardwalk.

Prior to the installation of the seawall in the 1970s, this section was a pebble beach. Over the years, the seawall has caused the beach to narrow and subside (LDGIZC-

UQAR, 2015). Currently, the beach is narrow (less than 10 m wide) and, at high tide, waves regularly hit the foot of the seawall.

The reduction and subsidence of the beach caused by the seawall make this sub-segment more vulnerable to the repeated attacks of the waves. When a breach occurs in a rigid protective structure, the erosive power of the waves becomes concentrated, which can cause significant erosion.

It should be noted that the wharf itself is not part of this segment, as its rehabilitation is currently the subject of a separate study. However, it is worth pointing out that the wharf acts as a point of convergence, slowing down the sediment transport coming from the cliffs of Côte Surprise in the southwest, and from the cliffs of Mont Joli Sud and Rocher Percé in the northeast (LDGIZC-UQAR, 2015).

Mont-Joli Sud

This section of rocky cliffs, which vary between 12 and 30 m in height, runs along 605 m of active coast. It marks the transition from the beach managed by SÉPAQ and the Mont-Joli cliff (LDGIZC-UQAR, 2015). This segment is characterized by a mix of cliffs of unconsolidated sediment, cliffs of unconsolidated sediment with rocky bases, and rocky cliffs, all of which are eroding more or less quickly, according to their composition. It is a source of sediment for the beach to the west (SEPAQ segment), a large part of which is held back by the wharf (LDGIZC-UQAR, 2015) (see Figure 2.4).

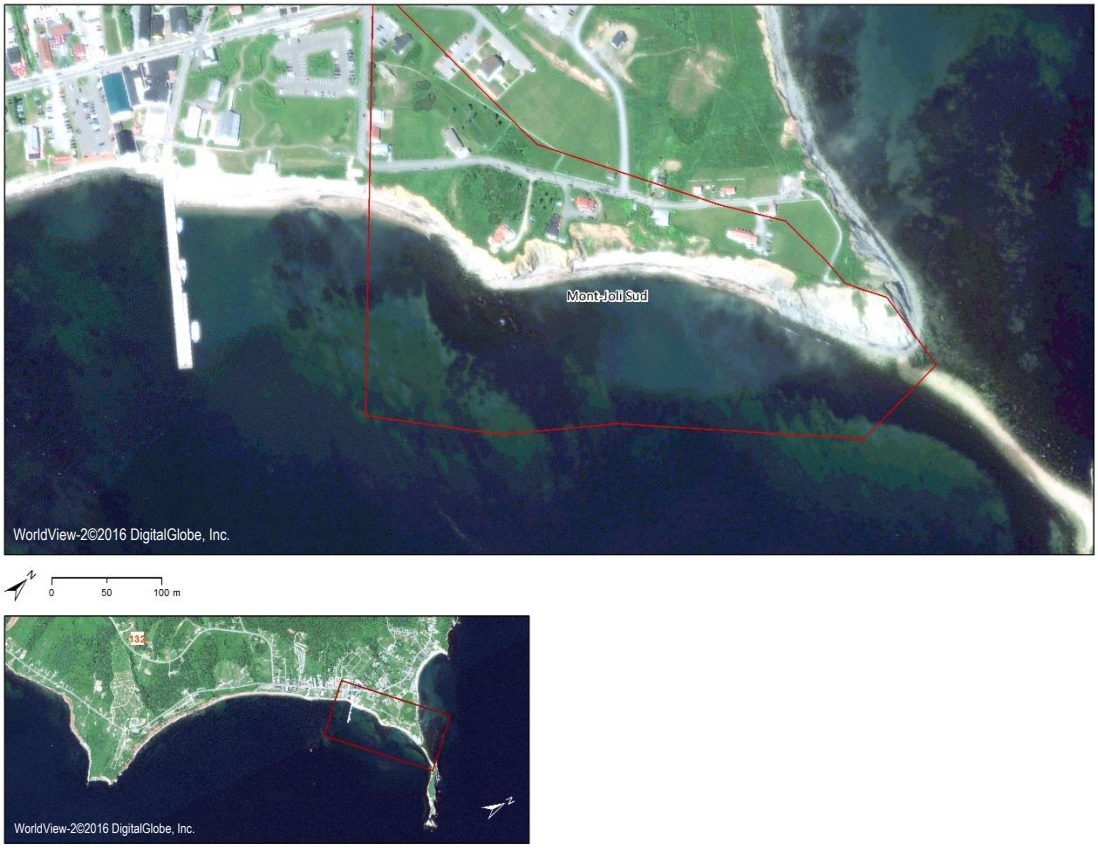


Figure 2.4 – Mont-Joli Sud segment

Because it is a high active cliff, it is difficult to stabilize the talus at the base. Due to its height, the summit continues to erode as a result of weathering, and hydrogeological, gravitational, and cryogenic processes. In this segment, there is a real danger of strike-slip faulting and rock slides, especially in sections where the base of the cliff is eroding more quickly than the top.

Anse du Nord

This area, 415 m in length, is composed of a mixture of coast, beach terraces, embankments, and low cliffs of unconsolidated sediment. The segment is delineated by Biard street to the south and Cap Barré to the north (Figure 2.5). The longshore drift flows towards the northwest with the result that the sediment eroded from the northern coast of Cap Mont-Joli feeds the beach terraces of Anse du Nord. Cap Barré blocks the

longshore drift and marks the end of the hydro-sedimentary cell of Rocher Percé. This allows a beach to accumulate.

Figure 2.5 – Anse du Nord segment

In Anse du Nord, beach maintenance minimizes the impact of storms in terms of coastal erosion and submersion. Over the last two decades, protective structures were put in place to prevent erosion. These structures have caused the beach to subside and its width to be reduced, and have caused end-effect erosion. In fact, the beach in this area has gone from a width varying between 30 and 40 m from the 1930s to the 1970s, to a width of about 15 m during 1990s and 2000s (Bernatchez et al., 2008). What is more, sediment transport from the southeast does not appear to be sufficient to maintain the beach in a future in which climate change is a factor.

2.4 ISSUES ASSOCIATED WITH CLIMATE CHANGE

The coast of Percé is among the coasts most affected by storm waves in all the Gulf of St. Lawrence. This coast is exposed to waves and storms coming from the northeast and southeast, which often result from storm surge conditions. These waves have a fetch length of over 400 km in which to develop. During intense storms, waves in the waters off Percé can exceed 10 metres when they reach the coast. The orientation and composition of the beaches of Percé are typical of beaches shaped by storms.

Percé is situated in a subsidence zone, that is, a zone that is slowly sinking. Additionally, the relative mean sea level is rising, which is causing the height of storm surges to increase, which is turn is causing the waves that reach the base of the cliffs to become more powerful. In the Percé region, the disappearance of the coastline due to erosion is weak, sediment drift from rivers is negligible, and sediment transport is very limited. All of these factors ensure that the rise in sea level causes a flooding of beaches, which results in a reduction in the width of these beaches, regardless of the type of coast. This phenomenon of shrinkage has been observed for years, and the width of beaches having diminished by an average of 54% between 1934 and 2001. The beach terraces having been artificialized with protective structures, the width of the beach has gone from an average of 34 m in 1934 to 10 m in 2001 (a 70% reduction). The beach has disappeared almost entirely in certain places.

The main source of sand input that feeds the beaches comes from the erosion of rocky cliffs. The rocky peaks form barriers to sediment transport, with the result that several coves are without external sediment input. In the sector under study, there is no river to supply the beaches with sediment. What is more, the duration of sea ice cover is decreasing, with the result that winter storms can cause waves to develop during a longer period of the year.

The coastal dynamic and the erosion sensitivity of the coast have been analyzed by UQAR. The researchers at the Laboratoire de dynamique et de gestion intégrée des zones côtières de l'Université du Québec à Rimouski (Coastal Zone Dynamics and Integrated Management Laboratory of the University of Quebec at Rimouski) (LDGIZC-UQAR) noted that several such studies have been undertaken since the early 2000s. These studies enabled them to calculate the probable shoreline displacement rate for

the coastline of the coastal segments studied. Recent studies show that the speed of shoreline displacement from the 1990s to present will be representative of the future evolution of the shoreline over the coming decades. According to Bernatchez et al. (2008), this period will be characterized by a significant increase in annual average temperatures. This warming has been significant in terms of winter temperatures since the 1980s.

Although Bernatchez and Dugas (2014) noted constraints related to the availability of data on the evolution of the coast of maritime Quebec, LDGIZC-UQAR had access to historic and recent data on coastal evolution (1990 to present). As a result, LDGIZC-UQAR was able to determine probable erosion rates from now to 2065 for the four geomorphological segments studied. These rates are presented and explained in the detailed sections dealing with each individual segment under study.

It is worth noting that, because the coastline of Percé is exposed to storms, the shores could experience significant coastline retreat during just one single storm event. Even the protective structures already in place cannot protect the coastline from the onslaught of these intense storms. However, keeping in mind the difficulty of predicting which segments of the coast could be affected by such storm events in the future, erosion due to storm events was taken into account in the calculation of historic erosion rates.

3 METHODOLOGY

This chapter begins by presenting the consultation process set up by Ouranos in order to ensure the study's relevance for local and regional decision-makers. It then goes on to explain the methodological approach used to conduct the economic analysis and the key assumptions underlying this approach.

3.1 CONSULTATION PROCESS

A cost-benefit analysis requires a good understanding of the economic, environmental and social issues of the area under study, as well as the way in which these issues will be impacted by the proposed actions.

In the context of this project, four committees were established to assist the project team with progress and analysis: a local orientation committee, a regional committee, a technical committee, and an advisory committee. Table 3.1 summarizes the involvement of each of these committees in the various activities carried out.

In every municipality that the study focused on, a local orientation committee composed of stakeholders, government employees, and elected officials was established by the municipality in order to guide the work of the study in terms of local needs and realities.

Table 3.1 – Consultation process and role of committees

Activities		LOC	RC	TC	AC
1	Description of methodological approach				X
2	Validation of biophysical segments	X			
3	Validation of erosion scenarios				X
4	Identification of adaptation options	X	X	X	
5	Identification of impacts of options chosen	X	X		
6	Economic evaluation of costs and benefits	X		X	
7	Cost-benefit analyses: time horizon of 2065				X

LOC: Local orientation committee, RC: Regional committee, TC: Technical committee, AC: Advisory committee

In the case of Percé, the local orientation committee was composed of municipal government employees, regional stakeholders and elected officials. In addition to providing the project team with a great deal of data, the members of the local orientation committee met four times during the course of the study. The first meeting took place at the beginning of the study in order to discuss the objectives and methodology of the CBA, to clearly define the biophysical segments to be studied, and to have a preliminary discussion regarding the possible adaptation options for each segment to be studied.

The second meeting provided an opportunity to discuss the adaptation options chosen for each segment under study, and to identify the potential impacts of these options on the human and biophysical environments.

The third meeting of the local orientation committee aimed to discuss the assumptions used to determine the economic value of certain impacts of the adaptation options. The ability to estimate the value of certain non-market goods with the aid of methods requiring surveys and working sessions with the communities targeted by the study was also addressed. As a result, this meeting enabled certain working hypotheses formulated within the framework of the study to be validated.

Finally, the last meeting was dedicated to presenting the results of the study to the local orientation committee in order to take their comments and suggestions into account when writing the final report. This presentation allowed the members to become familiar with the methodological approach, and to take ownership of these results.

For its part, the regional committee (RC) participated in the identification of potential adaptation options and the impacts these options could have on flora, fauna, infrastructure, and fishing activities. The preliminary results of the study were also discussed with the RC in order to validate certain conclusions.

The five Quebec ministries represented on the regional committee included the ministère de l'Agriculture, des Pêcheries et de l'Alimentation du Québec (MAPAQ), the ministère des Affaires municipales et de l'Occupation du territoire (MAMOT), the ministère du Développement durable, de l'Environnement et de la Lutte contre les changements climatiques (MDDELCC), the ministère de la Culture et des Communications (MCC), and the Ministère des Transports du Québec (MTQ). The committee also included representatives from Fisheries and Oceans Canada (DFO).

As for the technical committee, it was composed of coastal specialists, including two coastal engineers, two geomorphologists, an oceanographer, and some economists. The committee met once at the beginning of the study for a brainstorming session in order to propose adaptation options for the erosion issues facing each segment.

Finally, the advisory committee brought together coastal and cost-benefit analysis specialists, as well as representatives of the organizations that financed the project. The mandate of this committee was to validate the overall research objectives of the project and the methodology adopted to carry out the different steps of the study. The committee met twice over the course of the project.

3.2 ECONOMIC METHODOLOGY

The purpose of this study was to compare various adaptation options to non-intervention in order to determine whether or not it is preferable to intervene, and which option would be the most economically beneficial, taking into consideration all of the costs and the social, economic, and environmental benefits associated with each option.

Cost-benefit analysis (CBA) was used to compare the total net benefits of each adaptation measure for society as a whole. This method has been widely used, notably by different levels of government, for several decades and its modalities are well known to users. CBA analyzes the economic, environmental, and social components of a

project over a given period by estimating the economic value of the project's impact on each of these components. With the help of CBA, it is also possible to compare different adaptation options over time on a common basis with the help of indicators such as net present value (NPV) and benefit-cost ratio (B/C ratio). It is then possible to rank the options studied in terms of their economic performance.

It is important to note that CBA is not a financial analysis. CBA takes the direct and indirect economic, environmental, and social benefits and costs into account, whereas a financial analysis only considers the cash flow of the promoter. As a result, the costs of externalities associated with a project, such as social and environmental impacts, are not included in a financial analysis, while they are included in the scope of a cost-benefit analysis.

A CBA involves six main steps: 1) identification of the adaptation options; 2) identification of the suspected impacts of adaptation options and non-intervention; 3) monetization of negative impacts (costs) and positive impacts (benefits); 4) estimation of implementation costs of adaptation options ; 5) comparison of costs and benefits; 6) sensitivity analysis of the results.

3.2.1 Identification of the adaptation options

In light of the nature of the study area and meetings with local, regional and technical committees, three types of adaptation options were considered for the four segments under study: hard engineering structures, soft engineering structures and options without coastal structure.

Hard structures are classic coastal engineering structures such as seawalls and rubblemound revetments, which profoundly alter the sedimentary dynamic. Soft interventions allow for natural sediment movement, while options without coastal structure aim to reduce exposure of assets to hazards by acting on the assets rather than on their environment. The implementation, costs and technical implications of each option are discussed in more detail in the chapters dedicated to each of the segments under study.

3.2.2 Identification of expected impacts

Economic analysis can begin as soon as adaptation options for a given section of the coastline are chosen. Taking into account that each option requires intervening in a setting where there are already economic and social activities, it is vital to evaluate how these activities will be affected by the proposed option. The same applies to the natural environment, which often gets disrupted by human intervention.

The first group of impacts stems from coastal hazards, namely erosion and its immediate consequences. It involves, among other things, the loss or damage to land and buildings, as well as costs incurred from cleaning up debris, emergency measures and evacuation costs. These impacts are referred to in the scope of this study as the direct impacts of erosion. They are magnified by climate changes.

In addition to impacts directly related to erosion, there are economic, environmental and social impacts associated with adaptation options. Table 3.2 shows positive and negative impacts anticipated for Percé.

It must be pointed out that for the purposes of this economic analysis, only the main medium- and long-term impacts related to the implementation of an adaptation option are considered. Short-term impacts, such as temporary impacts during the construction period, are neither quantified nor estimated. However, all impacts will be taken into account in the environmental impact studies that will be carried out before implementing most of the adaptation options, as required by regulation.

Table 3.2 – All impacts anticipated for Percé

Impacts	Negative Impact	Positive Impact
Related to Erosion	- Loss of land - Damage to land, buildings and infrastructure (public and private) - Loss of waterfront camping sites	
Economic	- Reduction in tourism traffic (depending on the option studied) - Reduction in land value - Disruption to commercial fishing activities - Loss of business revenue	- Increase in tourism traffic (depending on the option studied)
Environmental	- Loss of natural habitats - Loss of spawning sites for fish - Contamination from sanitary discharge	- Improvement to spawning sites for fish
Social	- Loss of the sea view - Damage to the recreational use of the waterfront (depending on the option studied) - Reduction in the quality of life (anxiety, insecurity, etc.) - Damage to the landscape - Deterioration or loss cultural and historical heritage	- Improvement to recreational use of the waterfront (depending on the option studied) - Improved quality of life (security) - Improvement to the landscape

3.2.3 Monetizing expected impacts

Once impacts from adaptation options are identified and quantified, an estimate of their monetary value must be made. Several assessment methods were used in the context of this study, according to the nature of the impacts to be measured and the availability of data.

The method of choice was monetization of impact based on existing market values and real transactions. However, in the case of non-market goods, impacts were indirectly monetized using a related market approach. These included the hedonic pricing method and the travel cost method. Finally, in the absence of data from direct or indirect transactions, the monetization of certain impacts required the use of hypothetical market-based methods such as contingent valuation.

Specific assumptions made in the impact assessment associated with a given adaptation option are presented in the section dealing with each segment under study. However, given the importance of the assumptions related to tourism traffic for this study, they are described below. These assumptions were specifically estimated using, among other things, the results of two surveys conducted in the project.

Assumptions related to tourism traffic

Percé is a very important tourist attraction in Gaspésie; it was thus vital in this economic analysis to take into account the variation in tourism traffic brought on by the condition of facilities along the coastline.

The estimate of changes to tourism traffic is based primarily on an online survey conducted on the Quebec population. This survey was able to collect not only historical data about tourist visits to Gaspésie and Percé, but also information about projected visits based on the various proposed developments along the coastline.

Regarding the number of yearly visits to Gaspésie, extrapolating survey results to the entire population suggests that the people of Quebec spent on average 1.5 million overnight stays each year in Gaspésie during the 2010-2014 period. This historic traffic is consistent with information collected by Tourisme Québec for the Gaspésie region (Tourisme Quebec, 2013)

The investigation also revealed that 63% of tourists that visited Gaspésie also visited Percé during the past five years. This result ties in with the number of visitors exploring Gaspésie estimated in a study led by the Gaspésie Regional Tourism Association (ATR de la Gaspésie) in 2005 being 66% (Groupe OGDS, 2008).

When it comes to the average length of stay in Gaspésie, it adds up to 3.7 nights per visit during the 2010-2014 period. Among the visitors to the Gaspésie region, those that visited Percé during their stay spent on average 7.1 nights in Gaspésie, while 2.4 of those nights were in Percé.

Finally, the survey conducted on tourists visiting Percé in 2014 was able to estimate that tourists spend on average $131 a day, which includes all related travel expenses (accommodation, transportation, activities, etc.).

This information about historical tourism trends is a basis for projected changes to the tourism traffic taking place in the scope of this study and presented in appropriate sections.

3.2.4 Estimating adaptation options costs

In addition to the costs associated with anticipated impacts, a cost-benefit analysis is required to estimate the implementation and maintenance costs of the adaptation options. In general, these costs are calculated based on the cost incurred during similar projects or by consulting with engineers specialized in the design of proposed options. Although these costs were relatively easy to estimate, because they are based on projects already carried out, they remain approximate.

In this case, the costs of adaptation options involving engineering work were estimated by engineering firm BPR as part of a design study of shoreline protection structures for the City of Percé (BPR et al., 2014). For estimating the costs of asset relocation, the moving company Héneault et Gosselin Inc. provided unit costs (per linear metre) according to the type of building facade. These unit costs are consistent with the costs of mobilizing equipment in the Gaspésie region.

3.2.5 Comparing costs and benefits

After estimating the various costs and benefits of each of the adaptation options and of non-intervention, the next step is to calculate the sum of the net benefits over the study period in order to be able to compare the options among themselves. This calculation is based on the fundamental assumptions described below.

Population of interest

For the purposes of the study, the population used to estimate the costs and benefits is the population of the Gaspésie region. The choice of population of interest is generally based on which individuals would benefit the most from the project. Although the population of Percé will surely benefit from the adaptation options proposed for the protection of the coastline, it will not be the only beneficiary. In fact, given the importance of Percé to the Gaspésie region as a magnet for tourism, the entire population of the Gaspésie region should benefit from the improvement of the coastline if the adaptation options lead to an increase in tourism traffic.

Time horizon

The time horizon established for this study is 50 years, i.e. from 2015 to 2064. The choice of this time horizon is based on the lifespan of coastal infrastructure. A 50-year period corresponds to a realistic lifespan for such infrastructure, meaning that the adaptation options considered by the CBA will be capable of protecting the coastline during the entire study period, provided that they are properly maintained.

Discounting

The method used to aggregate the costs and benefits associated with a given adaptation option under the specified time horizon is a discounted cash flow analysis. This method makes it possible to bring the cash flows considered for each of the years in line with a common basis using a discount factor. The formula below is used to estimate the present value of each cash flow:

$$VAN = \frac{f_i}{(1+r)^i}$$

Where:

NPV: net present value
f: Cash flow
i: Period in which the cash flow is observed
r: Discount rate

The discount rate represents the opportunity cost of the funds committed throughout the time horizon considered. A higher discount rate indicates that the value attributed to the future costs and benefits is lower. For this study, the discount rate chosen was 4%. This is the rate recommended by Ouranos in its economic analysis guide (Webster et al., 2008) and used in the regional studies launched by Natural Resources Canada. As the discount rate could influence the results of the CBA, a sensitivity analysis of ±2% was carried out in order to verify whether the results (the NPV) are robust to a change in discount rate.

Another assumption involved the choice of currency, which was the 2012 Canadian dollar. It was chosen due to the availability of economic data for that reference year, especially property values.

The results of the cost-benefit analysis (CBA) are presented in the form of net present value (NPV). An advantage of NPV is that it directly presents the economic loss or gain associated with each option, as well as the scale of that element. The benefit-cost ratio is also used where appropriate to present the results in relative terms, making it possible to favour the least costly options among those with a similar NPV.

3.2.6 Sensitivity analysis of results

Sensitivity analysis allows for an examination of the robustness of the NPV obtained when important assumptions of the analysis vary. The parameters or assumptions tested by a sensitivity analysis are chosen according to the extent to which they may influence the results of the CBA, providing additional information about the potential variability of the results. This can help decision-makers to make better-informed choices.

The next four chapters present the cost-benefit analyses carried out for each of the segments under study, referring to the methods and assumptions described earlier in this section.

4 CÔTE SURPRISE SEGMENT

4.1 GENERAL DESCRIPTION

The Côte Surprise segment is bounded on the western side by Cap Blanc and on the eastern side by the rubblemound revetment that begins in front of the Riôtel Percé Hotel, as illustrated in Figure 4.1. This segment is 1388 m long. It is made up of sandstone cliffs and nonvegetated conglomerate reaching over 30 m in height (LDGIZC-UQAR, 2015). These cliffs are made up of materials that are more friable than the limestone in the Cap Blanc sector, making the cliff walls more vulnerable to erosion.

There are few at-risk buildings in the Côte Surprise segment on the south side of the provincial highway (RN 132). There are a few homes in the western portion and a motel comprised of 3 buildings with 12 units each, a restaurant and a pub. In its central portion, the segment also contains a campground with 125 spaces, around thirty of which are less than 5 m from the cliff. The eastern portion of the segment, to the south of RN 132, is not built up or developed.

4.1.1 Issues

Given the height of the cliffs, this segment is not at risk of flooding, even during storms. However, erosion and the risk of the collapse of the top of the cliff are major issues.

Figure 4.1 – Satellite image of the Côte Surprise segment

Source: LDGIZC-UQAR and MSP

Figure 4.2 – Oblique photograph of a part of the Côte Surprise segment in 2010

In fact, this active cliff segment could retreat suddenly and without warning. Over time, the action of the waves is forming indentations that can reach a depth of several metres at the base of the cliffs. When these indentations collapse, they will destabilize the embankment, causing retreats at the summit. In Figure 4.2, numerous rocky overhangs can be observed, as well as signs of crumbling demonstrated by the large blocks of caved-in conglomerate at the foot of the cliffs.

The estimated average rate of retreat of the top of the cliff between 1963 and 2013 is -0.10 m/yr. Between 2005 and 2012, erosion of the top of the cliff led to a measured average rate of retreat of -0.14 m/yr (LDGIZC-UQAR, 2015). The two LDGIZC monitoring stations measured retreats of -0.20 and -0.30 m in 2011, after the December 2010 storm. In addition, maximum retreats of -0.70 m were measured between 2007 and 2009, showing that significant retreats can occur annually (LDGIZC-UQAR, 2015).

The height of the cliffs is such that it takes more time for erosion of the slope to translate into a retreat of the peak. Thus, an average rate of retreat of -0.10 m per year was selected for this study, given that the cliffs retreat relatively slowly on average. This rate is considered as the probable rate of erosion of the top of the cliff for the study period,

from 2015 to 2064. However, the main danger of this type of shoreline is related to the danger of collapse of the cliffs, which can suddenly damage infrastructure.

4.1.2 Non-intervention option

Without intervention, it is expected that the cliffs will continue to erode at the rate of 10 cm per year. Collapses happen when the weight imposed by the ground, conglomerates and vegetation at the top of the cliff create an imbalance. Thus, to the extent that the shoreline erodes, there will be losses of land and some buildings will find themselves partially overhanging empty space or will collapse. Buildings at risk include the three buildings of Motel La Côte Surprise. It is assumed that they will be demolished when the edge of the cliff reaches them, since they will no longer be safe to use. In fact, even though a collapse of the cliff could happen without warning, the study considers that unsafe conditions will only be achieved when the buildings at risk are found at the limit of the cliff edge. This approach is considered non-interventionist and is called the non-intervention (NI) option.

A sensitivity analysis will be undertaken in order to take into account the impact of the risk of collapse on the economic viability of the option under study. A safety margin that takes into account the possibility that a sudden collapse could occur will be included in this analysis.

4.1.3 Adaptation options

Given the height of the cliffs, it is practically impossible to stop or slow the active erosion processes. Therefore, the only technically feasible option of adaptation for this segment is planned retreat (PR). Planned retreat involves relocating buildings at risk when they are less than 5 m from the edge of the cliff. This margin of 5 m was selected because it allows the buildings to be safely moved.

Relocation can be done on the same land, if there is enough space, or to another piece of land. In the context of this study, relocation on the same land was preferred as long as zoning regulations are respected and the relocated buildings are out of danger up to the end of the study period. According to *Règlement de zonage de Percé numéro 436-2011*, in zone (266-Ct) where Motel La Côte Surprise is located, the minimum front, side, combined side, and rear setbacks are 9 m, 2 m, 6 m and 9 m respectively. Taking into

account municipal regulations and the land area of Motel La Côte Surprise, the three buildings of this motel can be relocated on the existing land.

Considering that the three buildings are already located at less than 5 m from the top of the cliff, they should be relocated immediately. To ensure that they are actually able to be moved, a contractor specializing in structural moving was consulted. This contractor confirmed that it is still possible to move them.

The cost-benefit analysis for the Côte Surprise segment therefore compares the option of planned retreat through relocation of the facilities at risk with the non-intervention option, which would result in the loss of three buildings in 2038, 2047 and 2058 respectively.

4.1.4 Expected impacts

Table 4.1 compares the impacts considered for the two options studied, those being non-intervention (NI) and planned retreat (PR). Apart from the impacts related to erosion, a single direct economic impact is anticipated in the non-intervention option.

Table 4.1 – Comparison of expected impacts

Types of impact	**NI**	**PR**
Impacts related to erosion		
Loss of land	X	X
Loss of commercial buildings	X	
Economic impacts		
Loss of business income	X	

NI: Non-intervention PR: Planned retreat X: Impact expected to be present

Non-intervention involves the loss of the three hotel buildings present in the segment in addition to the loss of thirty campsites by 2064. The residential buildings in the western part of the segment are not exposed during the time horizon considered. In addition, loss of the commercial buildings involves a loss of business income, since certain lost accommodation units will not be able to be replaced by equivalent units under existing conditions.

Planned retreat avoids the loss of the commercial buildings but does not prevent the loss of land, including campgrounds.

No loss of tourist revenues is expected for the two options considered, since it is expected that tourists will not change the length of their stay in Gaspésie due to the loss of the motel or campsites in the Côte Surprise segment. Tourist revenues in the region as a whole will be transferred to other accommodation establishments or campgrounds, but they will not be lost.

4.2 ESTIMATED MONETARY IMPACTS

The monetary estimation of impacts, whether due to inaction or implementing planned retreat, constitutes the next step in the cost-benefit analysis.

4.2.1 Impacts due to erosion

a) Loss of land

Land is expected to be lost each year due to erosion. The area lost is calculated based on the probable rate of erosion provided by UQAR. The economic value of a piece of land is estimated with reference to its assessed value per square metre adjusted to 2012 market conditions (Servitech, 2013)[6]. This value is then multiplied by the area lost each year.

In general, when all the major buildings on a piece of land are considered at risk, the residual value of the land is set at zero since the land is considered to be non-buildable. However, in the case of Motel La Côte Surprise, the land on which the three buildings are found at risk is sufficiently large that the area remaining after the loss of the last building in 2058 will remain buildable. The residual value of the land is therefore not considered to be nil in the non-intervention option.

In the case of planned retreat, it is planned that the three buildings will be moved on the existing land and the annual losses of land due to erosion will continue until 2064.

[6] Taking into account the difference between the value registered on the assessment roll and the market value, the roll data for 2013 represents the market values for July 2011. To translate into 2012 values, the value registered on the roll was multiplied by the adjustment factor provided by the Ministry of Municipal Affairs and Land Occupancy, being 1.25. The adjustment factor is established by considering the median difference between sales completed in Percé and the value entered on the roll to arrive at the values of market conditions in 2012.

For the segment as a whole, the costs associated with the loss of land are $4,010 in 2012 dollars discounted at the rate of 4%. Figure 4.3 illustrates a part of the anticipated land losses as well as the locations of buildings exposed by 2064.

Figure 4.3 – Loss of buildings and land by 2064 for the most exposed part of the Côte Surprise segment

b) Loss of commercial buildings

In the non-intervention option, the retreat of the coastline is expected to reach the three buildings of Motel La Côte Surprise in 2038, 2047 and 2058 respectively. The building furthest west, being the main building, will be the first building affected, while the easternmost will be the last exposed.

The monetary value of the three buildings of Motel La Côte Surprise was estimated with reference to the value of the motel on the assessment roll, being $440,250 in 2012 dollars. This value was divided equally between the three buildings, at $146,750 each.

4.2.2 Economic impacts

a) Loss of rental income from campsites

The loss of rental income from campsites was estimated as zero since the sites lost are likely to be quickly replaced at little cost. In fact, the lost sites are not provided with well or piped water, or electricity services. Given the large number of campgrounds at Percé, the assumption that they will be replaced is considered reasonable.

b) Loss of business income

A cost-benefit analysis does not take into account the income lost by a commercial establishment if it is transferred to another establishment. However, if the income is not fully transferred, then it can be considered that there is a loss for the economy as a whole.

In the case of Motel La Côte Surprise, it is likely that the accommodation units with a view of Rocher Percé and Île Bonaventure which will be lost in the case of non-intervention will not be replaced by units offering equally beautiful views in the other establishments. As the accommodation units with a view of Rocher Percé and Île Bonaventure are generally rented at a higher price, the loss of these units means a loss of commercial revenue for the entire region.

Analysis of unit prices for accommodation at Percé, among others, with the La Normandie and Riôtel Percé Hotels as well as consultation of websites such as TripAdvisor indicates that on average a premium of $32 per night is charged to the customer for a room with a view of the Rocher Percé and Île Bonaventure. This premium reflects the value customers place on the view of this unique landscape.

Motel La Côte Surprise has 36 units that offer a view of Rocher Percé and Île Bonaventure. Assuming that the occupancy rate of these units is equivalent to the average occupancy rate for rooms in Gaspésie as estimated by Tourisme Quebec in 2013, being 82 nights/year, then the loss of income would be about $94,464 per year. Since the three buildings of Motel La Côte Surprise are steadily affected by erosion in the case of non-intervention, the losses of business income were calculated based on the number of units affected from the year when these units are lost.

It should be noted that the loss of rental income from campsites with a view of the Rocher Percé and Île Bonaventure was not estimated, since the analysis of rental prices of these sites did not show a significant difference between a site with and without a view. The services offered to campers on a site are more important than the view in determining the rental price.

4.2.3 Estimated cost of adaptation options

For the Côte Surprise segment, the only option studied is planned retreat. Moving costs were estimated by the moving company Héneault et Gosselin Inc., which made a visit to Percé. The prices given are prices per linear metre depending on the type of building facade. These prices are presented in Table 4.2.

Table 4.2 – Price for moving a building per linear metre

Exterior facade	Transport on road and foundation	Relocation on same land and foundation	Lifting and raising foundations
Vinyl, wood, etc.	$1,410	$1,345	$1,410
Brick and vinyl	$1,575	$1,510	$1,575
Brick	$2,135	$2,070	$2,135

As these are buildings with vinyl and wood facade, the costs of moving each building of Motel La Côte Surprise are estimated at $1,345 per linear metre. Since the buildings are rectangular with dimensions of 20 m x 38 m, 28 m x 13 m and 34 m x 11 m, the cost of relocation on the same land is estimated at about $156,020, $110,290 and $121,050 respectively. When moving the three buildings, costs for disconnecting and reconnecting electricity will be incurred for an amount estimated at $3,250 per building.

It is important to mention that non-intervention also involves a cost of implementation since it assumes that the exposed buildings will be demolished. The cost of demolishing the buildings was estimated at about $54 per square metre[7] and each building has two floors. Therefore, this represents demolition costs of about $86,400, $43,630 and

[7] The demolishing cost per square metre stems from a study completed in 2008 *Analyse avantages-coûts de solutions d'adaptation à l'érosion côtière pour la ville de Sept-Îles*. (Tecsult, 2008). Inflation was factored in using the Canadian consumption price index.

$44,710 for each building respectively. These costs include additional costs of $1,080 per demolition, due to the significant distance between Percé and the Gaspé landfill site, as well as the costs for removal of the foundations, which amount to $3,240. The demolition costs for the three buildings will be incurred in 2038, 2047 and 2058 respectively.

4.2.4 Estimated monetary benefits of options

The proposed adaptation option, planned retreat, has the advantage of preserving three hotel buildings of the Côte Surprise segment, buildings which house motel units that provide a view of Rocher Percé and Île Bonaventure, and avoiding demolition costs. These benefits are in fact the avoided costs related to non-intervention.

4.3 COST-BENEFIT ANALYSIS

This section presents the sum of all costs and benefits for the 50-year study period, that is to say the net present value of the two options, non-intervention and planned retreat.

4.3.1 Calculation of costs over 50 years

All costs related to non-intervention total $559,820 over the 2015-2064 period at a discount rate of 4%. Costs are present as an aggregate, but are available on an annual basis in Appendix 1.

The loss of buildings in 2038, 2047 and 2058 represents the largest part of the costs, to which the costs of demolitions are added. In addition, the loss of the buildings leads to the loss of business income in the following years. Finally, there are losses of land each year depending on the annual rate of erosion.

In the case of planned retreat, the total costs of this option, calculated for 2015-2064 and discounted to their present value at the rate of 4%, are $400,985. The detail of these calculations is presented in Appendix 1.

The most significant costs are incurred in 2015, since the three buildings of Motel La Côte Surprise are located less than 5 m from the coastline. In order to safely undertake the move, planned retreat must take place as quickly as possible. The costs incurred in the following years are related to the annual loss of land.

4.3.2 Calculation of benefits over 50 years

For the Côte Surprise segment, there are no benefits to be calculated. The only benefits related to planned retreat are the avoided costs associated with non-intervention.

4.3.3 Net present value

With reference to the total costs discounted to the present value as previously calculated, the net present values associated with non-intervention and planned retreat are -$559,819 and -$400,986 respectively. Comparing the two options shows that planned retreat offers net present benefits of about $158,830 over 50 years compared to non-intervention. The benefit-cost ratio of planned retreat compared to non-intervention is 1.4. This ratio means that planned retreat provides a benefit to society of $1.40 for each dollar of cost.

Figure 4.4 illustrates, for the period between 2015 and 2064, the cumulative sum of the net present value of planned retreat compared to non-intervention.

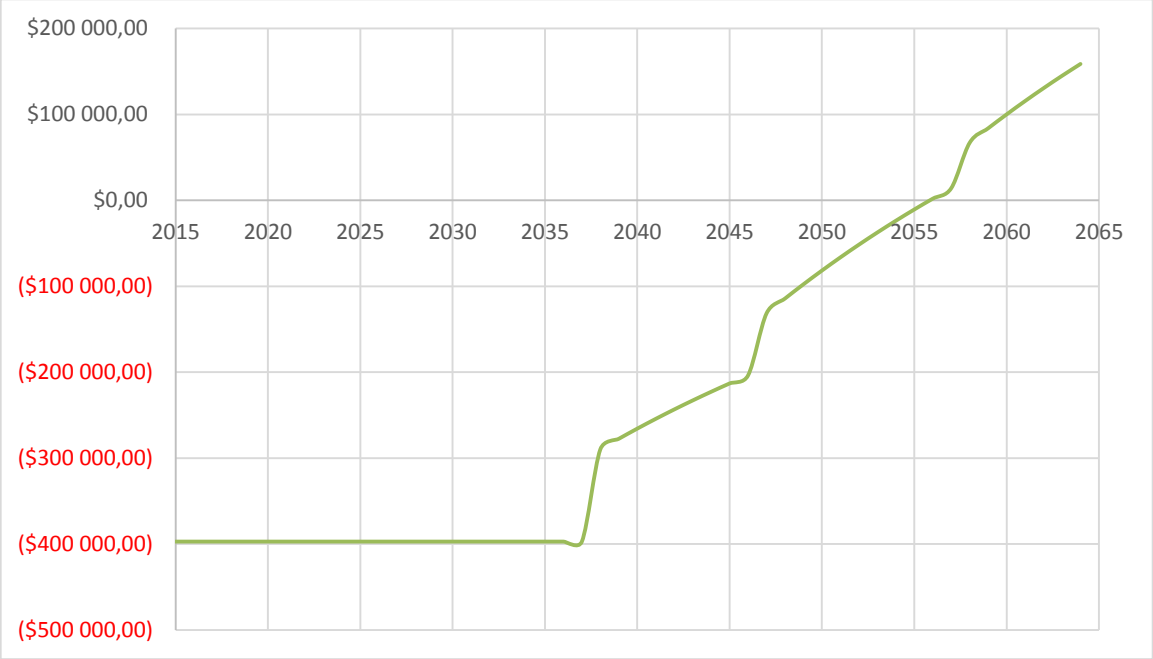


Figure 4.4 – Cumulative value of the net benefits of planned retreat compared to non-intervention between 2015 and 2064

4.3.4 Interpretation of results

As shown in Figure 4.4, the sum of net benefits of planned retreat is positive from 2056, or until the third building of Motel La Côte Surprise is lost in the case of non-intervention. Thus, the analysis shows that it is preferable to move Motel La Côte Surprise now rather than waiting until it is affected by erosion.

In fact, despite the high initial costs of planned retreat, the costs related to non-intervention are higher in the long term. Even if erosion only reaches the buildings of Motel La Côte Surprise in several years, it is more advantageous to intervene quickly to relocate the buildings.

It should be noted that the option of deferring planned retreat to 2038, when the first building will be directly exposed, cannot be envisaged for reasons of safety when moving the buildings.

4.4 SENSITIVITY ANALYSIS

The results of the comparison favour the option of planned retreat based on the assumptions held. In this regard, four assumptions warrant being examined more closely, being the value of the buildings and land, the value of the view for lost units, the safety margin to be retained and the discount rate.

4.4.1 Value of assets based on the assessment roll value

The first variable to be subject to a sensitivity analysis is the value of the assets. The 2013 real estate value assessment roll of the City of Percé was used to estimate the losses of the buildings (Servitech, 2013). Yet, major differences in value were observed in the roll between similar properties, particularly since certain assessments have been contested or did not follow price increases of properties on the market. It must also be pointed out that there have been few real estate transactions in Percé in recent years, which limits the information available to assess the properties. So, for example, according to the expected revenue method generally used to assess a commercial property, the assessed value of Motel La Côte Surprise is underestimated.

Assuming, for example, that the assessed value of Motel La Côte Surprise is underestimated by 20%, the value of the loss of the three buildings would then rise to

$528,300 rather than $440,250. This implies that the total costs of non-intervention discounted to the present value at the rate of 4% over a 50-year period would increase of 5% to reach $586,300 instead of $559,819. This increases the net present benefits of planned retreat compared to non-intervention.

4.4.2 Value of the view of Rocher Percé and Île Bonaventure

A second variable, which influences the results of the analysis, is that of the loss of income from motel units with a view of Rocher Percé and Île Bonaventure. This is based on two assumptions, the premium for rooms with a view ($32) and the occupancy rate (20%). Sensitivity analyses with a premium of 20% less and an occupancy rate 20% lower were conducted.

The results obtained show in both cases a reduction of total costs of non-intervention, discounted to present value, to $485,480, or about 15%. Assuming a simultaneous reduction of both values, being a premium of $25.60 and an occupancy rate of 65 nights per year, the total costs of inaction, discounted to present value, decreases to $426,010, or about 24%. In the three cases considered, planned retreat, whose total costs discounted to present value are $400,986, remains more advantageous than non-intervention over the 2015-2064 time horizon.

4.4.3 Margin of safety against the risk of collapse

Thirdly, the possibility of a collapse must be examined. Indeed, it is highly probably that a sudden retreat event could happen in this type of sandstone and conglomerate cliff. The maximum retreat measured for this type of cliff in this region is 4.3 m and a retreat of this magnitude could happen at any time. This sensitivity analysis therefore considers that any building located less than 4.3 m from the coastline can no longer be used and loses its value in the case of non-intervention.

Use of this margin has the effect of forcing demolition of the two buildings closest to the coastline in 2015, then that of the last building in 2016. This increases the costs of inaction related to erosion and demolition, discounted to present value, to $423,270 over 50 years. In addition, the economic costs associated with the loss of accommodation units with a view of the sea increases considerably, since these costs are in the order of $94,500 per year and begin in 2016. Overall, the costs of non-intervention, discounted

over 50 years, reach $2.7M when demolition of the buildings is moved forward as a safety measure.

Thus, over the 2015-2064 period, the net present benefits of planned retreat compared to non-intervention increases considerably to reach $2.29 million. Planned retreat is therefore clearly more economically advantageous.

4.4.4 Discount rate

By using rates of 2% and 6% rather than 4%, the total costs of planned retreat discounted to present value varies little, since most of the costs are incurred in the first three years. At 2% they increase to $416,140 while at 6% they decrease to $400,025.

On the other hand, the variation of costs in the non-intervention option is more significant. The total discounted costs over 50 years increase to $1,102,330, assuming a discount rate of 2%, while they decrease to $295,750 at the rate of 6%. This represents an increase of 97% and a decrease of about 47% respectively, compared to the total costs discounted over 50 years at the rate of 4%. The decrease at a rate of 6% is sufficient that inaction becomes less costly than planned retreat.

With a lower discount rate, a relatively higher weight is given to future costs and benefits, which favours the solution whose benefits are more spread out over time compared to the initial costs. Conversely, when the discount rate is higher (such as 6%), the average and long-term costs become relatively less significant, which favours inaction to the detriment of planned retreat where most costs are incurred at the beginning of the period.

4.4.5 Summary of the sensitivity analysis

Table 4.4 presents a summary of the results of the sensitivity analyses conducted. As shown in this table, the only case where changes to the basic assumptions influence the choice of the most beneficial option is when the discount rate is increased to 6%. In all other cases analyzed, planned retreat remains the most economically advantageous over a 50-year period, including in the case of applying a margin of safety, which significantly increases the benefits of planned retreat.

The study period is not generally a variable that is the subject of a sensitivity analysis. However, for this segment, the time horizon considered has an effect on the results of the cost-benefit analysis. Since the net cumulative benefits of planned retreat compared to non-intervention become positive only after 2056, a cost-benefit analysis based on a study of 40 years or less would favour inaction.

Table 4.3 – Summary of sensitivity analysis results

Modified assumption	Variation in costs of non-intervention	Variation in costs of planned retreat	Most economically beneficial option
Increase of 20% in the assessed value of the buildings	Increases	Increases	Planned retreat
Reduction of 20% in the premium for the view	Decreases	No change	Planned retreat
Decrease of 20% in the occupancy rate	Decreases	No change	Planned retreat
Decrease of 20% in the premium and occupancy rate	Decreases	No change	Planned retreat
Use of a 4.3 m margin of safety	Increases	No change	Planned retreat
Discount rate of 2%	Increases	Increases	Planned retreat
Discount rate of 6%	Decreases	Decreases	Non-intervention

4.5 CONCLUSION

In the Côte Surprise segment, little infrastructure would be at risk in the short and medium term if the probable rate of erosion is considered. However, over a 50-year period, the exposed buildings have a sufficiently high economic value that preserving them through planned retreat is economically justified. Even when certain assumptions are modified, planned retreat remains the least costly option over 50 years and constitutes a very robust result. The benefit of planned retreat is even greater if a safety margin of 4.3 m is considered, which would protect against collapses of the land.

The use of a shorter calculation time horizon would draw a different conclusion, however. It is nonetheless important to remember that the possibility of moving the buildings decreases year by year and a short-term decision is required.

5 ANSE DU SUD SEGMENT

5.1 GENERAL DESCRIPTION

The Anse du Sud segment begins in front of Motel Le Riôtel and ends at the Percé wharf, which is not part of this analysis. It is at the very centre of Percé's heritage and history, and the seafront boardwalk that runs along it forms a structuring axis. The boundaries of this segment are identified in Figure 5.1.

Tourism, commercial, recreational and residential infrastructures are found throughout the segment. In terms of tourism, there are about 10 hotels and motels south of Highway 132, the largest of which is Hôtel La Normandie. There are also many restaurants and shops as well as a range of recreational activities, like a children's park and a nautical centre for kayak and scuba diving. The segment also includes two buildings that are part of Percé's heritage circuit and a few residential buildings.

Geomorphologically, this 908 m segment can be broken down into two subsegments by type of coast. The first subsegment measures 275 m and consists of low rocky cliffs protected by rubblemound revetment. The second subsegment consists of backfill, which forms the foundation of the boardwalk, itself protected by a concrete seawall built in the 1970s. Figure 5.2 illustrates the seawall's construction, which encroaches on the beach. At the time, rigidification of the coastline was part of a worldwide movement to create seaside boardwalks.

Figure 5.1 – Satellite image of Anse du Sud segment

Source: City of Percé

Figure 5.2 – Construction of Percé's seawall in Anse du Sud in 1974 (SEPAQ area)

Before the seawall and the boardwalk were built, there was a wide pebble beach all along this segment. In earlier times, cod was dried directly on the pebbles (Figure 5.3). Over the years, the protective seawall led to a thinning and a marked drop in the beach due to its reflectivity and its effect on sediments, which are pushed out to sea. The beach is now very narrow (less than 10 m) and waves often strike the foot of the seawall at high tide.

Source: City of Percé

Figure 5.3 – Cod drying on pebble beach in Percé

5.1.1 Issues

This segment is primarily exposed to storm events from the east and southeast that can produce significant surges, that is, a sea level higher than the forecast astronomical tide level due to an atmospheric depression. In addition, the 500-km fetch in the Gulf of St. Lawrence results in storm waves about 10 metres high (Savard et al., 2008). Faced with these storm events, the coast is particularly vulnerable at the narrowest points of the beach.

Because the southern subsegment consists of low cliffs, certain areas of which are made up of superficial deposits on a rocky base, the coastline is receding fairly steadily. Although the rubblemound revetment partially stabilizes the slope, the cliff's loose/sandy lithological composition means the low cliff is bare and actively eroding. From 1992 to 2013, the average annual rate of erosion was -8 cm/year (LDGIZC-UQAR, 2015). Projections suggest that erosion will progress at the same rate as recently. The probable rate of retreat for this subsegment is then estimated at -8 cm/year.

The northern subsegment is eroding differently. The presence of the seawall anchored the shoreline and no retreat has been observed since it was built. However, the seawall has made the beach smaller and lower, making the structure vulnerable to the repeated impact of waves. This vulnerability is exacerbated by the fact that the seawall has reached the end of its useful life. Storm events in the past few years have shown the infrastructure's inability to withstand the sea's repeated assaults. So although the coast is not receding every year, this segment is nonetheless threatened by punctual erosion retreat due to occasional storm events.

In fact, storms in 2005, 2010, 2014 and 2015 substantially damaged the seawall and the boardwalk. The December 2010 storm destroyed the seawall in certain areas of the segment, allowing waves to then erode the properties behind the seawall.[8] In certain areas, particularly near Hôtel La Normandie, erosion has reached up to 7 metres (Figure 5.4). The damages forced authorities to carry out over $600,000 in major emergency work to add rubblemound revetments and bypasses for safe access to the pedestrian walkway.

The seawall is at the end of its useful life and this repair work is but a stopgap measure. Erosion is expected to resume in the boardwalk subsegment. The estimated rate of retreat will be at least -15 cm/year, which was the average annual rate of retreat between 1948 and 1963, before the wall was built. This is a highly conservative assumption, as the beach was wider in those days and was therefore more effective in protecting the shore. The future expected climate will lead to less ice to protect the coast and more storms with surges and waves that can erode the coastline by several metres.

[8] When a breach opens up in a rigid protective structure, the erosive power of the waves is concentrated and the resulting erosion can be significant.

Source: City of Percé

Figure 5.4 – Damage caused by the December 2010 storm

Given the importance of the boardwalk and other infrastructures in this segment in the Percé region's tourism offering, it is essential that this segment be protected. In the medium and long terms, Percé can only remain an esteemed, recognized and competitive destination if its coastal environment continues to reflect the wealth and quality of its natural environment and its heritage.

5.1.2 Non-intervention Option

Without intervention, it is assumed that the infrastructures in this segment will be maintained through occasional repairs as storms occur. However, despite these repairs, the protective infrastructures will continue to deteriorate until the end of their useful life. Despite the gradual nature of this deterioration assumption, the infrastructures may become damaged beyond repair by a major storm, especially since the work carried out in 2011 was intended only to allow for tourism to resume until a new structure could be built.

One basic assumption of this analysis is that without intervention, the seawall in Anse du Sud will no longer prevent erosion in 2020, at the end of its useful life. This assumption was retained because the seawall was built in the early 1970s with an estimated useful life of 50 years. Given recent storm events, this assumption may even be optimistic.

For the purposes of the CBA, it is projected that the unprotected coast will once again be subjected to an average annual rate of retreat of -15 cm from 2021 to 2064. Without intervention, properties will begin to gradually erode and certain infrastructures will be at risk as early as 2021. The exposed buildings will be demolished when the coastline reaches them, as they will no longer be safe.

Collapse of the seawall will lead to destruction of the boardwalk it supports. The economic loss resulting from the disappearance of this popular tourism infrastructure has thus been factored into the analysis as from 2021.

5.1.3 Adaptation Options

At the same time as this study, the City of Percé hired the engineering firm BPR and partners to carry out a preliminary design study on options for rebuilding the retaining seawall and boardwalk (BPR et al., 2014). The adaptation options under study take into account the hydrodynamic constraints, erosion, sedimentation processes and geomorphology of the Anse du Sud segment. These options were designed to avoid erosion over the next 50 years

To ensure the complementarity of the two studies, the cost-benefit analysis is based on the options identified and designed by BPR. The BPR study analyzed the adaptation options for the entire Anse du Sud segment without differentiating between the two subsegments described above. As a result, the same approach was used for the cost-benefit analysis. They were studied jointly since the City of Percé plans to extend the boardwalk all the way to Môtel Le Riôtel.

The adaptation options studied in this analysis are beach replenishment with pebbles, with or without groynes, as well as rubblemound revetment, riprap, and a seawall with deflector.

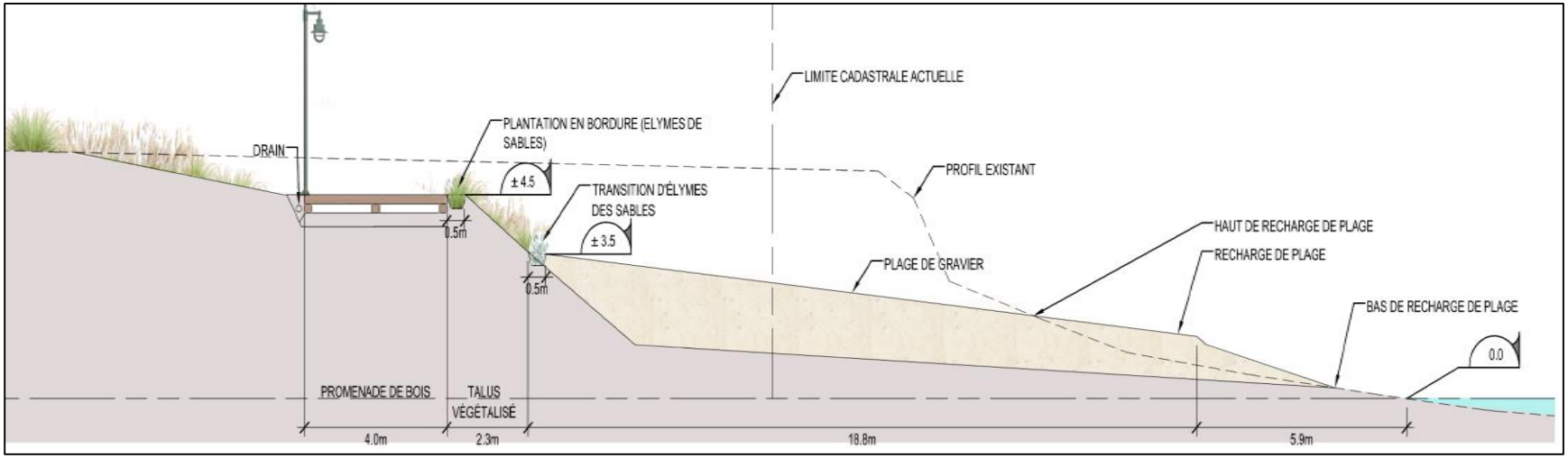
a) Beach replenishment[9] (BR)

Beach replenishment is a coastal protection based on the principle of returning the beach to the historical morphological conditions which existed in Percé. Given the intensity of the waves hitting the Percé shores, the replenishment must be carried out using relatively coarse materials with a median diameter (D_{50}) ranging from 20 to 40 mm. This type of material is similar to the pebbles found on the beaches north of the wharf and in Anse du Nord and is well suited to natural dynamics. In terms of size, the average elevation of the crest for the replenishment would be 2 m above mean sea level (MSL), which is 1 to 3 m lower than the highest portion of the current seawall. Its width would vary between 12 and 15 m (see Figures 5.5a and 5.5b).

It is more difficult to protect the area near the wharf, as the wave energy there is too high for replenishment to stabilize the beach in the medium term. The especially deep waters in the area allow waves to conserve all their energy and to break directly on the wharf, resulting in hydrodynamic conditions too strong for a beach. The proposed option is a rubblemound revetment with a crest 4 or 5 m above MSL, provided submerged riprap (or riprap berm) is placed in front of the rubblemound revetment some 40 m into the sea in order to reduce water depth and slow the waves. Figure 5.5c shows the protection proposed for transects 18, 19 and 20 located south of the wharf. This type de protection is also required for the other adaptation options.

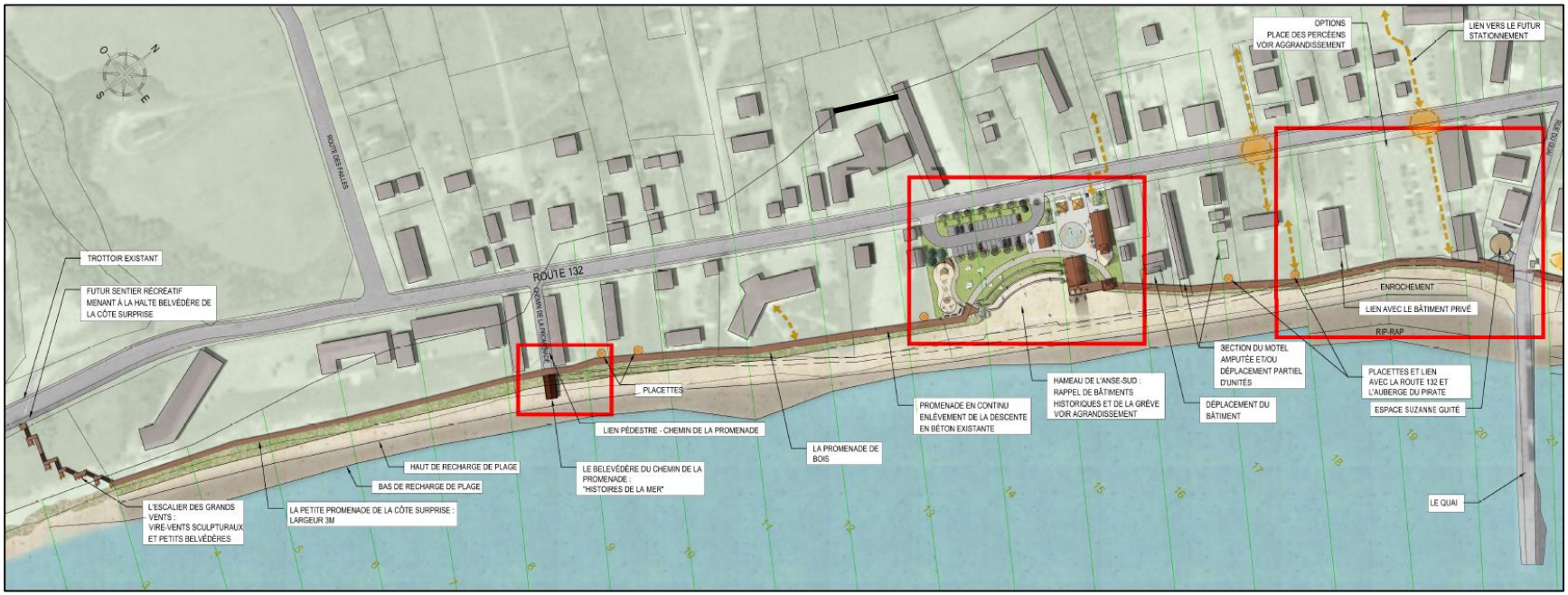
Finally, the beach replenishment option (with or without groynes) involves displacing a few buildings in order to provide the space needed to achieve an equilibrium slope near the wharf.

[9] The design is intended to resist water levels with a 50-year recurrence and assumes that water levels will increase by more than 40 cm over 50 years due to climate change.



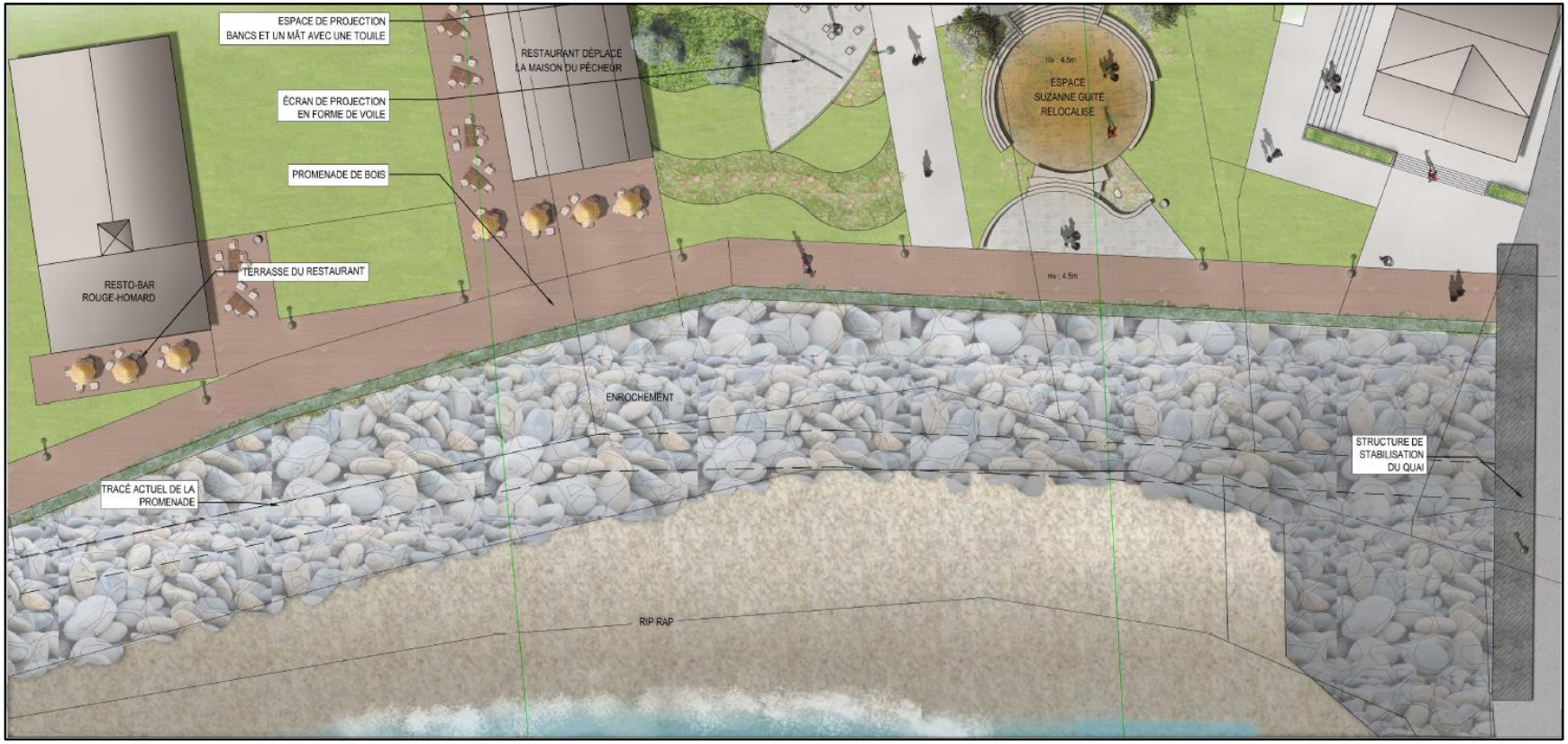
Source: BPR et al. (2014).

Figure 5.5a – Cross-section of beach replenishment for Anse du Sud (transect 13)



Source: BPR et al. (2014)

Figure 5.5b – General plan for the Anse du Sud boardwalk with the beach replenishment option

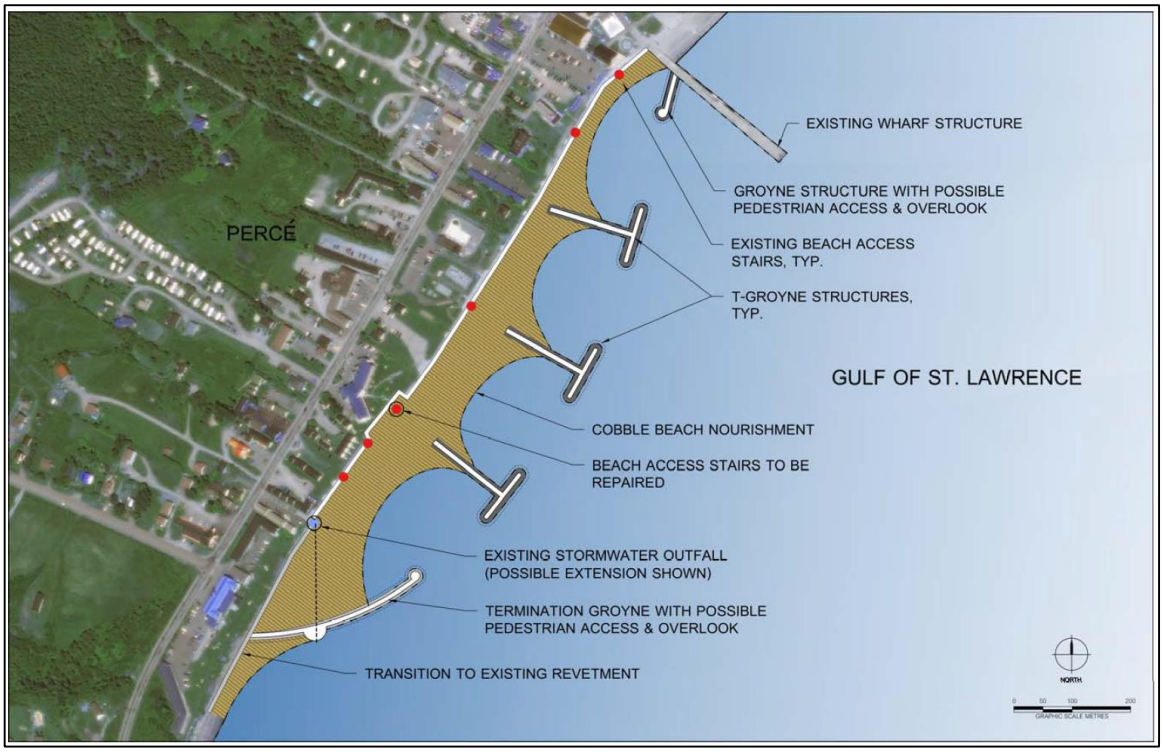


Source : BPR et al. (2014)

Figure 5.5c – View of transects 18, 19 and 20 south of the wharf, requiring hard engineering protection, namely a rubblemound revetment or a riprap berm

b) Beach replenishment with groynes (BRG)

This option is similar to beach replenishment without groynes. The pebble used is the same as that for the replenishment described above, but with the addition of T-groynes. Groynes are rock structures[10] that are built at a perpendicular angle to the beach and that reach out some 20 m into the water. These groynes create beach cells that help keep pebbles on the beach during storm events. This option eliminates the need for periodic replenishment to maintain the beach slope over the medium or long term. Figure 5.6 shows a simulation of beach replenishment with groynes in Anse du Sud.



Source: Baird (2014).

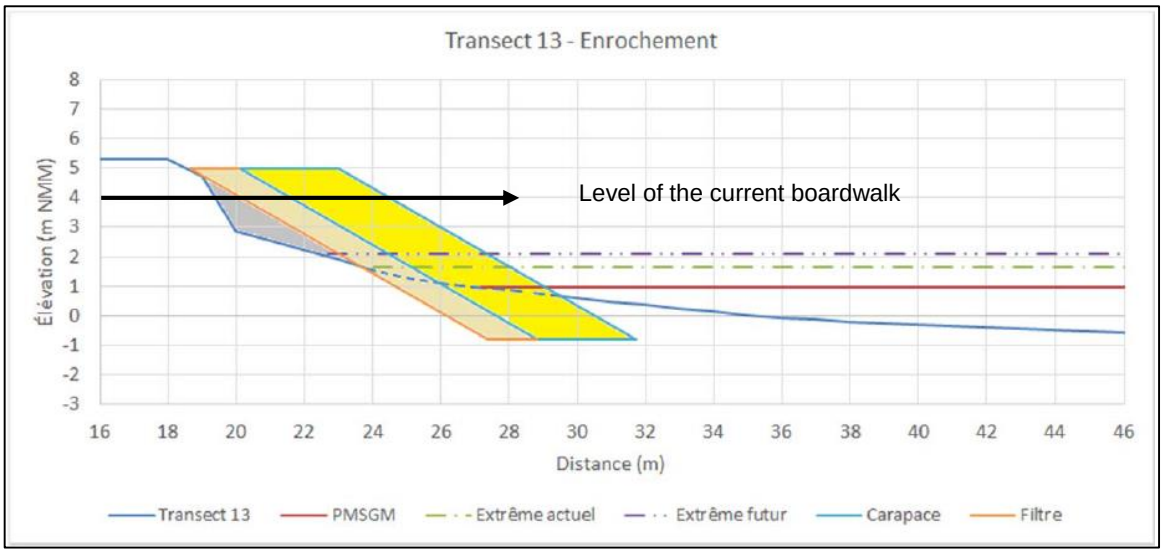
Figure 5.6 – Simulation of beach replenishment with groynes in Anse du Sud

c) Rubblemound revetment (R):

This protection option uses conventional rubblemound revetment with a slope of about 67% or of 1 m in height by 1.5 m in width. Depending on the design used,[11] crest height for the rubblemound revetment is 5 m above MSL for the entire segment, i.e., about 1 m

[10] Rocks from 50 to 1,500 kg may be used. A detailed design study is needed to determine the optimal rock size.
[11] The design criteria for rubblemound height are based on 2% overflow for a 50-year storm event (BRP, 2014).

higher than the current seawall (Figure 5.7). In front of the wharf, the seawall's elevation could reach close to 7 m above MSL unless a riprap berm is installed on the sea floor.

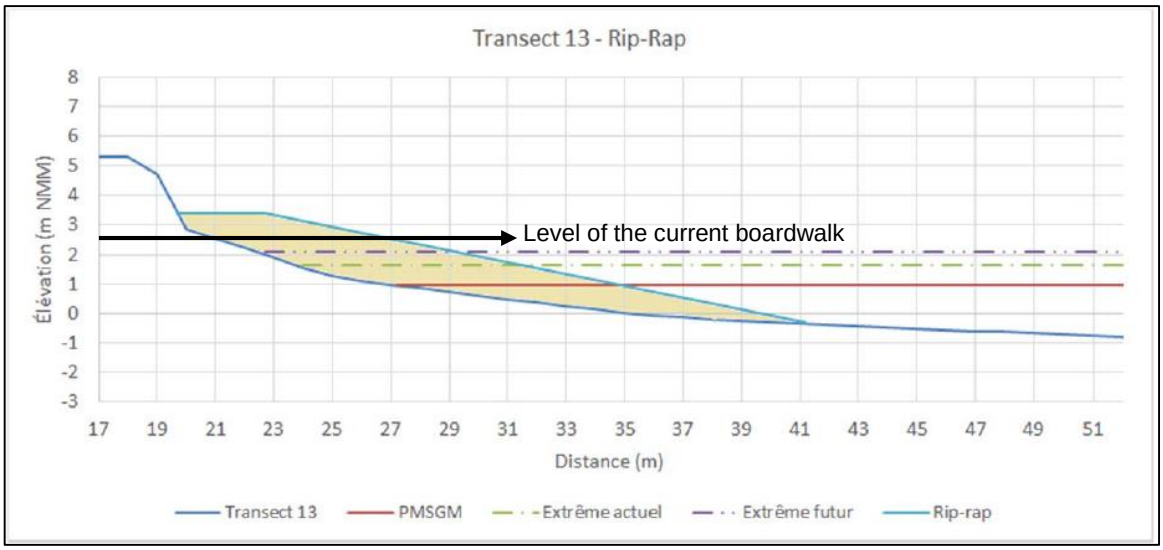


Source: BPR et al. (2014)

Figure 5.7 – Cross-section of rubblemound revetment option for Anse du Sud (transect 13)

d) Riprap (RR)

Riprap consists of quarry stones of varying sizes deposited in bulk on the coast with a slope of 20% or 1 m in height by 5 m in width. This slope, which is gentler than with conventional rubblemound revetment, absorbs and diffuses wave energy before it reaches the shoreline. Thanks to this slope, there is less runup with a riprap than with a rubblemound revetment when waves hit. As a result, the crest can be lower for riprap than for rubblemound revetment. For Anse du Sud, the average height of the riprap crest is 3.5 m above MSL. This is about 1 m lower than the current boardwalk, creating a height difference that could be filled with vegetation.



Source: BPR et al. (2014).

Figure 5.8 – Cross-section of the riprap option for Anse du Sud (transect 13)

e) Seawall with deflector (CW) and riprap berm

The seawall with deflector was not proposed by BPR and its partners. This option has been included in this report to assess the viability of replacing the current seawall with a similar infrastructure adapted to the new weather conditions. The design criteria and costs stem from information obtained for comparable local structures built in the past few years.

When refering to existing structures and calculations completed by BPR engineers (BPR et al., 2014), a seawall that is 4.3 m above MSL, or 30 cm higher than the current seawall, lined with a pre-coastal riprap berm would be required to absorb waves and prevent overtopping. As with the other options, the berm would involve encroaching on the pre-coastal area by about 40 m. Without it, the seawall would have to be 7.5 m above MSL near the wharf, 3.5 m higher than the current seawall, and would completely block the view along the boardwalk. Given the importance of tourism in Percé, a berm-less wall was automatically ruled out. Use of a deflector also allows to reduce the seawall's height by 0.85 m (with the berm).

Source: Chadwick (2009).

Figure 5.9 – Illustration of a seawall with deflector on a gravel beach

5.1.4 Anticipated Impacts

The Anse du Sud segment possesses an extremely rich natural and built environments. The actions taken must not only protect the coast, but also be designed to reduce any negative impact on its natural and anthropic environment. As such, two types of impact are considered in this study. On the one hand, there are the direct impacts of erosion associated with non-intervention, since the current seawall is at the end of its useful life. On the other hand, there are the indirect economic, environmental and social impacts associated both with implementing the proposed adaptation options and with non-intervention. Table 5.1 presents the range of anticipated impacts based on the various options.

Erosion impacts concern only the non-intervention option and may include significant damage to protective structures, loss of property, and loss or damage to commercial buildings and infrastructure. In fact, only abandoning the existing protective infrastructures would lead to these consequences, since each adaptation option would protect threatened buildings, properties and infrastructure. This type of impact has occurred in the past and affected the boardwalk, the urban furniture along the coast, the sewer system under the current boardwalk, and the town's public spaces, such as Espace Suzanne-Guité.

Table 5.1 – Anticipated impacts of adaptation options and non-intervention option on the Anse du Sud segment

Type of impact	NI	BN	BNG	RR	R	SW
Impacts due to erosion						
Loss of property	X					
Loss or damage to commercial buildings	X					
Loss or damage to public infrastructure	X					
Economic impacts						
Change in tourism traffic	X	X	X	X	X	X
Loss of business revenues	X					
Disruption of commercial fishing activities		X	X	X	X	X
Environmental impacts						
Changes to natural habitats		X	X	X	X	X
Disturbance of fish spawning grounds			X	X	X	X
Contamination by sewage	X					
Social impacts						
Change in landscape		X	X	X	X	X
Changes to coastal access	X	X	X	X		
Quality of life (anxiety, insecurity, disruption)	X					

NI: Non-intervention; BN: Beach replenishment; BNG: Beach replenishment with groynes; RR: Riprap; R: Rubblemound revetment; SW: Seawall; X: presence of anticipated impacts

In terms of the potential economic impacts, some may concern tourism, business revenues and commercial fishing activities. Coastal development is closely tied to the quality of touristic experience in Percé, where the waterfront is one of the main touristic attraction. Anse du Sud is the nerve centre of the tourist–sea connection, which means any change to the environment may affect its quality. A change in the segment's amenities would affect the quality of the tourism offering, which in turn would impact the number of visitors to Percé and even the Gaspésie region, according to the survey carried out by Ouranos.

Without intervention, business revenue is expected to decline due to loss of or damage to the buildings of some businesses. The adaptation options can prevent such losses.

Finally, Anse du Sud is an important fishing area in the region, particularly for the coast's Northern lobster fishery (RPPSG, 2014). Coastal changes resulting from protective

structures or beach replenishment may encroach on the habitat of adult lobster and affect the productivity of the local lobster fishery, a fact considered in the analysis.

There are three types of environmental impacts. First, the sea floor of Anse du Sud provides natural habitats ideal for the development of lobster as well as other animal and plant species. As these habitats may be affected by some of the proposed development and structures, their potential impact has been factored into the analysis. Second, a number of observers have reported that capelin are spawning on the beaches of Percé and the encroachment of certain options may be detrimental to that process. Although a detailed study will be needed to identify the spawning sites more accurately, our analysis has taken this potential impact into consideration.

Thirdly, one of the anticipated environmental impacts of the non-intervention option comes from the possible contamination from sewer effluent. In fact, the sewer system along the boardwalk has been damaged by storm events in the past and will likely be so again. When this happens, wastewater is discharged into the sea. All the proposed adaptation options includes to move the sewer system. The cost of moving the system is also included in the non-intervention option to ensure that the boardwalk's disappearance does not lead to sewage dumping into the sea.

Three social impacts are presented in Table 5.1. First, transforming the Percé seaside will affect the Percé landscape and access to the coast. For some people, the changes related to the various adaptation options will be beneficial, while others might perceive them as negative. In all cases, the changes affect the value users place on the coast. Since most who use the Anse du Sud coast are tourists, social impact is considered through changes to tourism traffic. It is understood that a variation in the value of the coast will be reflected in tourism traffic. Tourists who appreciate the changes to the landscape and coastal access can be expected to modify their travel behaviour accordingly, while tourists who do not like the changes could reduce the length of their stay.[12]

[12] The omission of variations in the value of the coast for residents should not affect the results of the study, or the choice of the most advantageous adaptation option, because very few residents visit Anse du Sud compared to the number of tourists.

Finally, residents who live close to the Anse du Sud coast may experience great insecurity and stress when storm events occur, resulting in deterioration of their quality of life, as documented for the Côte-Nord region (Séguin-Aubé, 2013). An improvement in shore protection may mitigate this negative impact and improve quality of life by the sea.

5.2 ESTIMATED MONETARY IMPACTS

This section describes the methodological approach used to estimate all costs and benefits associated with the impacts identified earlier. Data sources and assumptions are also explained.

5.2.1 Impacts due to erosion

Anticipated losses due to erosion vary from one subsegment to the next because of the range of probable erosion scenarios provided by UQAR.

For the southern subsegment, as the sector is currently protected by rubblemound revetment and retreating at a rate of -8 cm/year, a 4-m strip of land will be lost along the coast over the 50-year study period, corresponding to about 1,100 m^2. Moreover, one building belonging to Motel Le Riôtel (the most southerly) as well as Motel Fleur de Lys will be threatened before the end of the study period. These losses are estimated using the property and building values of the 2014 real estate assessment roll, adjusted to 2012 dollars.

For the northern subsegment, corresponding to the existing boardwalk, no erosion is expected until 2020, as the retaining seawall will continue to keep the shoreline stable until the end of the seawall's useful life. However, this assumption entails annual repairs, as are currently being carried out.[13] From 2020 onward, it is assumed that the seawall will be lost. Erosion will then resume, affecting a strip of land about 6.75 m wide, as well as certain portions of buildings, including Restaurant la Morutière and Motel La Normandie. A total of 4,746 m^2 of land is expected to be lost by 2064. Figure 5.10 shows losses from the anticipated erosion of the boardwalk subsegment.

[13] This assumption is conservative, as an extreme event may extensively damage the structure and require far more repairs.

Figure 5.10 – Map of retreat expected by 2064 for the boardwalk subsegment of Percé. The red strip represents the area that will be lost, ranging from 6.5 to 8.5 m in width.

The collapse of the seawall implies that the boardwalk will be neither functional nor safe, as it is attached to the seawall structure. Furthermore, rebuilding a new wall-less boardwalk would mean encroaching on seaside properties. Consequently, because the boardwalk will have to be dismantled, and it will no longer be possible to stroll along the waterfront to admire the Rocher Percé and Bonaventure Island. Loss of the seawall will also expose the sewer pipes currently beneath the boardwalk. This sewer system must be moved and rebuilt.

All impacts associated with erosion under the non-intervention option, combined with dismantling the seawall and moving the sewer pipes, represent a total discounted cost of about $730,000 over 50 years, at a 4% discount rate. Other types of impact, like the change in the tourism traffic, are estimated in the next section.

5.2.2 Economic impacts

The options to develop the coast must both protect the shoreline and respect the waterfront's historical and environmental nature as well as its tourism value. The proposed options entail a number of economic impacts, positive and negative.

With over 400,000 visitors a year (SEGMA, 2013), the Percé boardwalk and wharf are intricately connected and represent a place of exchange, entertainment and cultural sharing. The boardwalk and view from this pedestrian amenity are the area's key attractions, as are visits to Bonaventure Island and the Rocher Percé.

a) Change in property value

Over the time horizon studied, a 4 to 8.5 m strip of land will be lost to erosion. The properties cannot be declared non-buildable because they are 75 m in depth on average, which means existing buildings can be moved on the same lot, even if it is partially reduced or reconfigured. As a result, in Anse du Sud, no change in property value is taken into consideration, only lost business revenues from fewer seaview accommodation units.

b) Change in tourism traffic

Non-intervention option

Given the importance of Anse du Sud attractions to the Percé tourism offering, the impact analysis must include the impacts of deterioration in coastal amenities on tourism traffic in Percé and the Gaspésie region. The anticipated change in travel behaviour was estimated using an online survey as part of this project.

Without intervention, the seawall's gradual deterioration will lead to the loss of access to the boardwalk by 2020 and possibly to a change in tourism traffic. The survey of about 2,000 Quebecers allowed evaluating how respondents would modify their travel behavior to future conditions.

Since this study is looking at the entire Gaspésie region rather than just Percé, the survey addressed changes to tourism traffic for the Gaspésie region. The analysis was given a regional perspective because Percé is a strategic component of the regional tourism offering, which means that any changes to the Percé coast could affect both the

number of tourists who choose to visit the Gaspésie region and the total number of days spent there.

Not all tourists expect to change their plans to visit the Gaspésie region on account of changes to the Percé coast. For example, tourists may decide to visit the Gaspésie region anyway without going to Percé or may spend less time there. They would then spend more time in other Gaspésie municipalities, such that there would be no economic loss to the region as a whole. The clientele would transfer from one municipality to another in the study area.

Based on all responses, the survey results suggest that the number of nights spent in the Gaspésie region would fall by 21% if the seawall and boardwalk were to be destroyed in 2020. This decline represents approximately 300,000 nights per year for the region.

Adaptation options

As opposed to the non-intervention option, any adaptation option that would maintain or improve the infrastructure in Anse du Sud should have a positive impact on tourism traffic compared with the current situation.[14] For example, beach replenishment would eliminate the current frontier between the boardwalk and the seashore and give tourists beach access, where they could take walks. This would enhance the tourism experience, making Percé more attractive and increasing the number of visitors to the Gaspésie region. Likewise, the adaptation options may affect the length of time that visitors stay by increasing the number of nights spent in the region. The following paragraphs describe the impact of the proposed actions on tourism traffic, based on the survey results.

Table 5.2 shows the variation in tourism traffic for the Gaspésie region for each adaptation option under consideration, according to the results of the online survey conducted in spring 2015.

As stated in the previous section, the non-intervention option would have a major impact on tourism traffic in the Gaspésie region by cutting over 300,000 nights (21%) from the

[14] The current or historic situation was established by asking 2,000 respondents about their tourists habits to Percé and the Gaspésie region from 2010 to 2014 and extrapolating their responses to the Quebec's entire population.

total number per year. Although certain adaptation options would negatively affect the number of tourists in comparison with historic figures, the impact would be lesser than without intervention. This might be because rubblemound revetment, riprap or a seawall with deflector would lead to disappearance of the Anse du Sud beach. Conversely, beach replenishment with or without groynes would increase tourism traffic to the Gaspésie region by about 2%, or 30,000 additional nights per year over historic tourist numbers.

Table 5.2 – Variation in tourism traffic in the Gaspésie region

Adaptation options	Number of nights spent in Gaspésie	Variation in the number of nights compared to historic numbers
Historic numbers	1,524,546	
Non-intervention	1,205,020	-319,526
Rubblemound revetment	1,370,168	-154,378
Riprap	1,362,603	-161,943
Seawall	1,406,455	-118,091
Beach replenishment	1,559,294	34,748
Beach replenishment with groynes	1,550,190	25,644

To estimate the monetary value of higher or lower tourism traffic for each option, the anticipated variation in nights was multiplied by the average daily spending by tourists. This expense was estimated using an August 2014 survey conducted in Anse du Nord to collect data on how much respondents spent while visiting Gaspésie, among other information. By weighting the answers based on the types and cost of local accommodation, the average daily expense was estimated at $131 per tourist.[15]

Table 5.3 presents the annual value of the change in tourism traffic for each adaptation option.

[15] Daily spending is based on a 4-night, 5-day stay, which is the average stay among the tourists interviewed during the survey.

Table 5.3 – Annual economic gain or loss by adaptation option and corresponding assumptions on tourism traffic

Adaptation option	Impact on annual tourism	Annual economic variation
Beach replenishment	34,748	$4,274,289
Beach replenishment with groynes	25,644	$3,363,414
Rubblemound revetment	- 154,378	-$20,116,296
Seawall with deflector	- 118,091	-$15,195,273
Riprap	- 161,943	-$21,017,495
Non-intervention	- 319,526	-$41,665,451

The non-intervention option will lead to a significant loss of more than $41 million per year for the region. Hard engineering structures (seawall, rubblemound revetment and riprap) would also negatively affect tourism traffic and related spending, but to a lesser degree than the non-intervention option, in the order of $15 million to $21 million.

Beach replenishment with or without groynes, however, would lead to annual gains of close to $4 million. Although this may seem marginal compared with the impact of the non-intervention option, the cumulative impact of more visitors over a 50-year period would exceed $60 million.[16] In addition, beach replenishment with or without groynes would prevent the loss of tourism revenues associated with the non-intervention option, i.e., $700 million over 50 years.

c) Loss of business revenue

Cost-benefit analyses do not factor in revenues lost by a business if these are transferred to another business. However, if revenues are only partly transferred, the entire economy is considered to have sustained a loss. The primary commercial loss considered is that of accommodations with a view of Rocher Percé and Bonaventure Island.

Without intervention, erosion will affect certain commercial buildings (La Normandie, Le Riôtel and Fleur de Lys motels), which will lose several accommodation units with a view of Rocher Percé and Bonaventure Island. Since access to this view is limited, the losses

[16] At a discount rate of 4%.

will probably not be replaced by units with as nice a view at other establishments. Because seaview accommodation units are usually rented at a higher price than others, the loss of units will translate to a loss of business revenue for the entire region.

Based on the number of buildings potentially threatened by erosion from 2015 to 2064, it is estimated that three motels (La Normandie, Le Riôtel and Fleur de Lys) will lose a total of 41 accommodation units with a view of Rocher Percé and Bonaventure Island.

The premium that clients are willing to pay for a sea view was estimated using an analysis of the price of accommodation units in Percé for the La Normandie and Le Riôtel Percé Hotels and by consulting websites specializing in hotel room rental. The analysis indicates that, on average, clients pay $32 more per day for a view of Rocher Percé and Bonaventure Island.

Assuming that the occupancy rate of these 41 units is the same as that of hotel rooms in the Gaspésie region as established by Tourisme Québec in 2013 (Tourisme Québec, 2015), that is, 82 nights a year, the loss of units represents some $107,625 in lost revenues per year. As erosion affects motel buildings at different points in time in the non-intervention option, loss of business revenue was calculated based on the number of units affected and the point at which these units will become unusable.

d) Disruption of commercial fishing activity

Underwater surveys have shown that the sea floor in Anse du Sud is home to a wide range of substrates, mostly blocks and rocks as well as parent rock, whose interstices are buried in sand and gravel (RPPSG, 2014). Such diversity is favourable to the development of various animal and plant species and is particularly ideal for the Northern lobster (*Homarus americanus*) at every stage of growth. Juvenile lobster in the shelter phase find homes in rock fissures, interstices and cracks away from the seaweed, which is an ideal habitat for juveniles in the emergent phase as well as adolescents and adults because it is rich in food, especially as eelgrass areas[17] are abundant with organism they eat.

[17] Herbaceous marine plant with rhizomal growth found in temperate coastal areas; it has long, ribbon-like leaves and grows in dense colonies (OQLF, 2013).

Thanks to the quality of the natural environment, lobster fishing is particularly productive in Anse du Sud and, in season, numerous lobster traps can be seen near the coastline. In the Anse du Sud area (zone 20A4), six fishing licences are currently granted, one of which also allows fishing in Anse du Nord. In 2013, licenced fishers caught 73,540 kg in lobster, with a market value of $707,501. Anse du Sud is at the heart of this area and is particularly favourable for lobstering.

Licence buy-back is used to estimate the cost of compensation for loss of commercial fishing revenue. Economically, the option is effective because it allows licence holders who can still fish in the affected zone to maintain or increase their harvest rate. Licence holders who agree to sell their licence are compensated for the loss at market price. However, buy-out of the fishing licences means potential job losses, which have been factored into this analysis.

Given the productivity of the fishery in Anse du Sud, two fishing licences will have to be bought out for $350,000 each in order to maintain the harvest rate of other licence holders in the fishing zone. This buy-out will lead to the loss of five jobs over the study period, according to information gathered from fishers. The impact on fishing is considered the same for all adaptation options. In fact, it is believed that even a minor encroachment may have the same effect on the resource as major changes to the coastline.[18] The licences would be bought out before the work begins.

5.2.3 Environmental impacts

The three main environmental impacts considered in this study concern changes to natural habitats, disturbance of fish spawning grounds, and contamination by sewage water.

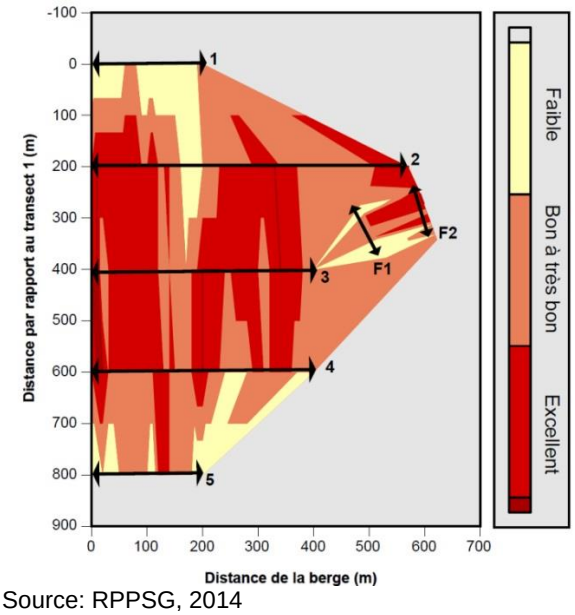
a) Changes to natural habitats

To better understand the milieu's biodiversity, a preliminary characterization of the sea floor was conducted in this segment (RPPSG, 2014). The characterization identified

[18] Coastal encroachment could vary from 6,000 m^2 with the construction of a wall to more than 27,000 m^2 in the case of beach replenishment, according to estimates based on the preliminary concepts. However, the expected coastal encroachment will be determined by the environmental and social impact study required before any adaptation options are carried out, as will the way in which losses resulting from changes to the fishing zone should be compensated. The impact study may use a different approach to determining the impact of options on the fishing zone than the current analysis.

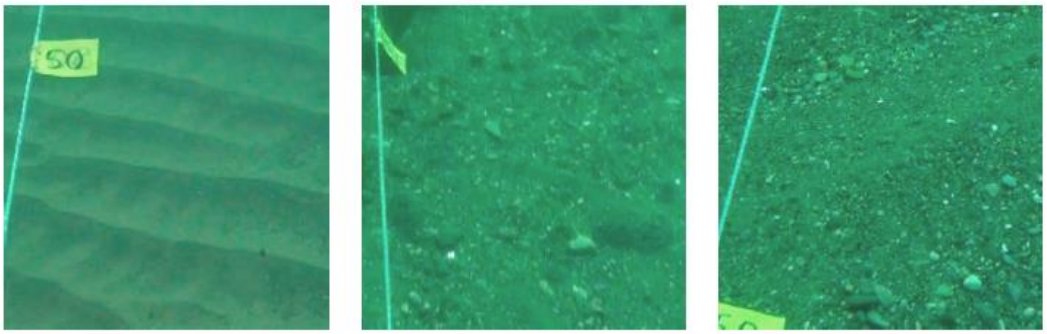
zones favourable to lobster development at every stage of growth. Figure 5.11 summarizes the quality of lobster habitat in Anse du Sud, between transect 1 along the Percé wharf and transect 5, 800 m farther south in front of Motel Le Riôtel. The results of the analysis show that the area closer to the wharf (the first half between transects 1 and 2) provides a habitat ranging in quality from poor to good. The substrate is essentially sandy and free of plant life (Figures 5.12). This type of sea floor is not among the most favourable to lobster, according to the St. Lawrence Global Observatory (SLGO, 2015).

However, the environment becomes more favourable to lobster as we move southward away from the wharf. The images taken along transect 3, halfway between the wharf and Motel Le Riôtel, accurately represent the type of sea floor favourable to lobster establishment and growth (Figure 5.13). Nearing the end of the site, very close to transect 5, the milieu becomes less favourable. Overall, with the exception of the segment's far ends, the natural environment in Percé's Anse du Sud appears to be especially favourable to lobster of all sizes due to its heterogeneity.



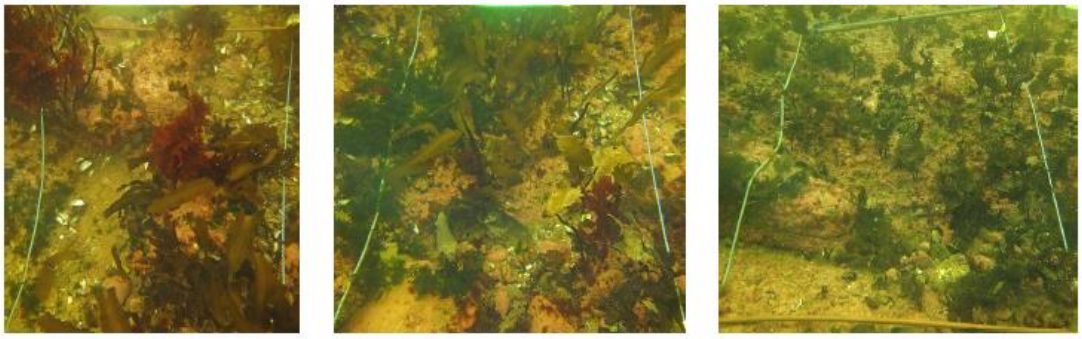
Source: RPPSG, 2014

Figure 5.11 – Quality of lobster habitat in the surveyed area of Anse du Sud



Source: (RPPSG, 2014)

Figure 5.12 – Photographs of the 50 m, 100 m and 150 m quadras for transect 1



Source: (RPPSG, 2014)

Figure 5.13 – Photographs of the 50 m, 100 m and 150 m quadras of transect 3

The sea floor in Anse du Sud is varied and provides an environment that is generally favourable to many organisms in addition to Northern lobster. A number of invertebrates specific to rocky floors have been identified, such as green sea urchins, mussels, starfish and brittle stars. Numerous species of macroalgae, like sea cabbage, are also found there. In short, any project to protect the coast in this area will either directly or indirectly alter the natural environment of Anse du Sud. These changes will translate to a loss of habitat affecting several species of algae, marine wildlife and, inevitably, lobster at every stage of development.

All of the adaptation options involve encroaching on the aquatic milieu, but the value of this rich habitat is hard to quantify. A wide range of complex economic methods can be used to assign a monetary value to ecosystem services, from the cost of compensation to stated or revealed preference approaches. The buy-out of lobstering licences

described in the previous section does not fully reflect the value of the habitat's ecosystem services. To assess this habitat as a whole, the cost of replacement was evaluated based on the encroachment area, that is, the cost of reproducing the area of lost habitat in another location. Table 5.4. shows the expected widths and areas of encroachment based on the technical profiles provided by BPR et al. (2014). The length of the area considered in this study is 908 m. In order, the seawall results in the least encroachment, with a riprap berm being installed only on 150 m,[19] followed by rubblemound revetment, riprap and replenishment (with or without groynes). The encroachment areas shown in Table 5.4 were rounded off to the nearest hundred.

Although this analysis assumes that the lost habitat area will be replaced, only an environmental impact study can determine whether these structures can be built and under which conditions. The cost of the studies, development and monitoring was nonetheless estimated. Based on estimates provided by the Department of Fisheries and Oceans (DFO) and the Regroupement des pêcheurs professionnels du sud de la Gaspésie (RPPSG), a development that includes four artificial reefs over a total area of 2,400 m^2 would cost approximately $120,000, that is, an average of $60,000 for the studies and development and $60,000 for monitoring over two years. Monitoring is very important to ensure that the artificial reefs are populated by various plant and animal species at every stage of development.

Table 5.4 – Encroachment on sea floor by option

Adaptation option	Width of encroachment (Distance at low tide line)	Area of encroachment (Distance x length of zone)
Replenishment	30 m	27,300 m^2
Replenishment with groynes	30 m	27,300 m^2
Riprap	15 m	13,700 m^2
Rubblemound revetment without berm	7 m	6,400 m^2
Seawall with deflector	40 m (berm)	6,000 m^2

[19] According to the transect cross sections in the BPR study, the berm would be installed over about 150 m near the wharf rather than along the segment's entire length.

The cost of replacing lost habitat with an equivalent area of artificial reefs was calculated for each adaptation option using Table 5.4 above. The discounted cost of lost habitat is $1,176,335, $588,165, $274,480 and $259,105 respectively for beach replenishment (with and without groynes), riprap, rubblemound revetment and the seawall.

The groynes built for beach replenishment, the riprap and the riprap berm in front of the seawall near the wharf may well become favorable environments to certain plant and animal life, including the Northern lobster. However, no design criteria specific to habitat creation were included in the adaptation options. For now, the benefits of creating potential habitats have not been quantified, which means the potential environmental benefits of certain options may have been underestimated. The recommendations of the environmental and social impact study may better harmonize the natural environment and structure design.

b) Disturbance of fish spawning grounds

According to the Capelin Observers Network (CON), capelin spawning was noted in Percé (Percé district) in May or June of 2005, 2007, 2009, 2010 and 2011 (DFO, 2015). The DFO confirmed that in 2011, spawning was observed in Percé, more specifically in Anse du Sud and near Anse-à-Beaufils, whereas in 2012 the fish reportedly spawned near Barachois and Prével (Grégoire, Sirois and Chevrier, pers. com.). No observation was reported in 2013 or 2014 (DFO, 2015).

Capelin is a key species at the bottom of the food chain in the marine ecosystem of the northern Gulf of St. Lawrence. It is essential prey for cod and many other fish (black halibut, Canadian plaice, salmon), blue whales, dolphins and certain marine birds, including the Northern gannet, a large colony of which lives on Bonaventure Island.

All adaptation options result in loss of potential capelin spawning grounds with the exception of beach replenishment, which does not significantly alter the substrate and the connectivity of the spawning environment. However, beach replenishment with groynes will prevent circulation to a certain extent, while rubblemound revetment, riprap and a berm would make the substrate less favourable for capelin.

To compensate for the loss of a potential spawning environment, beach replenishment could be carried out in an area where the capelin have spawned before, but where the

beach has deteriorated over time. Certain beaches in Barachois and Anse-à-Beaufils experienced marked thinning from 1934 to 2001 and would be ideal for beach replenishment (Bernatchez et al., 2008). Maintenance of that replenishment must also be taken into account to ensure that this compensatory measure can be maintained for the entire study period.

Of the 908 m of coast that will be redeveloped, roughly half is identified as favourable for capelin spawning, i.e., the beach's particle-size distribution is sufficiently fine and homogeneous. Compensation of an equivalent area elsewhere in the town of Percé would require 8,700 m^3 of sand at a cost of $15 par m^3. When mobilization expenses (5%), contingency expenses (20%) and engineering and monitoring fees (20%) are factored in, the discounted cost of compensation for loss of capelin spawning grounds is approximately $176,000. In addition, maintenance is expected to be required four times over the 2015-2064 time horizon, at a discounted cost of $72,295. As with the construction of artificial reefs, an environmental and social impact study must confirm that this mitigation option can be applied.

c) Contamination by sewage

Given the current condition of the protective installations, an extreme event storm striking the Percé coast may cause major damage to the sewer system under the boardwalk. This occurred during the storm of 2010. The damage punctured the sewer system, causing effluent to pour into the sea and pollute the shores for a period of time. However, after consulting environmental experts, it was agreed that the dilution capacity in Anse du Sud is high enough to prevent such an incident from having a significant environmental impact (Castonguay and Bélanger, 2014). Although no damage has been included for such an event, the plan is to move the sewer pipes whatever the adaptation option considered.

5.2.4 Social impacts

Of the three social impacts identified above, coastal access and changes to the landscape are addressed in this section from a more global perspective of changes to the coastline. The constraints related to the estimation of the changes in quality of life are also discussed.

a) Changes to the coastline

As the situation stands, the boardwalk is the main component that influences coastal use value, as the seawall creates a well-defined border between land and sea. By transforming the coastline and the boundaries between land and sea, the various adaptation options will change the use of the coast and its value. Moreover, changes to the landscape will affect the value of Percé's visual equity by modifying views of the sea, Rocher Percé and Bonaventure Island. Figure 5.14 allows for comparison of the Percé landscape after adaptation options implemented.

In the context of this analysis, surveys were used to indirectly estimate the value associated with the different changes. It was assumed that gains or losses will be reflected in a variation in the number of tourists visiting Percé, since Anse du Sud is primarily frequented by tourists. The improvement or deterioration of the landscape and coastal access is expected to lead to higher or lower tourist traffic in Percé and the Gaspésie region, or to a longer or shorter average stay. The assumptions concerning variations in tourism traffic by adaptation option were presented earlier in this section (see Section 5.2.2, Economic Impacts).

It is important to note that the Percé landscape is even known to Quebecers who have never visited the region. As a result, use value does not capture the value that non-tourists may place on this landscape. The lack of data prevented the quantification of the impact of changes in landscape and coastal access for residents. However, as far fewer residents than tourists use Anse du Sud, the monetary estimate of the variation in use value for residents would be very low in comparison with that for tourists.

Figure 5.14 – Visual simulations of the five adaptation options under study, developed by WSP/Ouranos.

b) Quality of life

The impacts on quality of life considered in this study are related to anxiety, insecurity and the inconvenience of living in a setting where there is a risk of disaster. In Anse du Sud, most buildings are motels, hotels or recreational infrastructures that operate essentially in the summertime. As such, the impact of fall and winter storm events is quite limited. However, there are a few private homes in Anse du Sud, and their owners must live with the threat of a major storm that may damage their property. This risk will be even greater once the retaining seawall collapses.

Because the monetary cost of reducing insecurity is hard to evaluate, a more in-depth study on the risk aversion of residents and business owners would be required to determine this cost. For this analysis, it was decided that this impact would be addressed only from a qualitative perspective by stressing that all adaptation options in the study should improve quality of life for residents and business owners by reducing insecurity over non-intervention.

5.2.5 Estimated cost of adaptation options

The cost of each adaptation option was assessed based on the preliminary design by BPR and its partners hired by the City of Percé. All structures are designed to protect the coast for the duration of the study period.

Presented in Table 5.5, the total cost of executing each option includes the cost of studies, construction, coastal amenities, and maintenance. The beach replenishment and riprap options involve moving certain buildings and expropriating a few properties, and these costs are also factored into construction costs.

A comparison of the discounted costs from 2015 to 2064 shows that the seawall with deflector is the most expensive option at $24,675 per linear metre. The discounted cost is lower for the other options studied: $13,230, $12,540, $10,315 and $10,335 per linear metre respectively for replenishment with groynes, rubblemound revetment, riprap and replenishment without groynes. Although adding T-groynes to beach replenishment for stabilization purposes doubles the cost of construction materials, it eliminates the need for maintenance.

In terms of maintenance costs, the beach replenishment option is the most costly because it requires partial replenishment every 10 years. This maintenance involves adding a volume equal to 25% of the initial quantity of material. When groynes are built, there is no need for maintenance replenishment because the sediments are stabilized by the groynes inside the beach cells they create. Riprap must be partially nourished three times over 50 years, each time with about 17% of the initial quantity of material. Finally, rubblemound revetment and the seawall require no maintenance over 50 years.

Table 5.5 – Cost of adaptation options examined in the study, discounted at 4% over 50 years

Adaptation options	Construction costs	Landscaping and coastal amenities	Maintenance costs[20]	Total discounted cost
Beach replenishment with pebbles	$5,358,905	$3,397,995	$626,555	$9,383,455
Beach replenishment with pebbles and groynes	$8,614,515	$3,397,995		$12,012,510
Rubblemound revetment	$7,989,915	$3,397,995		$11,387,910
Riprap	$5,345,890	$3,397,995	$620,960	$9,364,840
Seawall with deflector	$19,008,725	$3,397,995		$22,406,720

5.3 COST-BENEFIT ANALYSIS

This section presents all estimated costs and benefits over a 50-year time horizon for non-intervention as well as for each adaptation option. Costs and benefits are compared in order to calculate the net present value (NPV). Table 5.6 in Section 5.3.3 provides a summary of the costs, benefits and NPV of each option. Finally, the results are interpreted to compare each option's economic viability.

[20] In addition to the material, maintenance costs include mobilisation costs (5%), contingency costs (20%) as well as engineering and surveillance costs (20%).

5.3.1 Calculation of costs over 50 years

This section addresses the total costs of the non-intervention option and the costs of implementing each of the adaptation options. All costs presented for the study period (2015–2064) are discounted at 4%.

a) Cost of the non-intervention option

The main costs of the non-intervention option are losses and expenses stemming from erosion, costs to repair the seawall until it is dismantled, and the reduced number of tourists.

The discounted economic loss from property erosion as of 2021 and from partial loss of the four buildings to be affected by 2064 is $219,225 for the period ranging from 2015 to 2064. It will cost an estimated $198,500 to move the sewer pipes when the boardwalk is dismantled in 2020 and to maintain the seawall until the end of its useful life. The cost of dismantling the current seawall and demolishing the affected buildings is just over $310,000. Add to this another $158,000 for the economic loss associated with fewer seaview accommodation units and related income. Finally, fewer tourists beginning in 2021 will lead to a loss of just over $41.7 million per year until the end of the study period. In the aggregate, the 4% discounted cost of non-intervention represents $704.6 million over the considered time horizon. Appendix 2 shows the annual costs.

b) Cost of beach replenishment

The cost of beach replenishment includes $873,580 in engineering and environmental studies.[21] Expenses will be incurred in 2016 for the engineering design while expenses for the environmental and social impact study will be distributed equally over 2016 and 2017. Construction will take place in 2018 at the discounted cost of approximately $7.88 million. This sum includes the cost of moving three buildings, expropriating portions of property, moving the sewer system, and developing the seaside. Replenishment will have to be maintained every 10 years at a cost of roughly $626,555 over 50 years. The total cost of construction, maintenance and development is thus close to $9.4 million.

[21] All costs are discounted at 4%, except annualized costs.

Other costs include the anticipated loss in commercial fishing revenues and environmental costs from loss of natural habitats. As stated earlier, the mitigation measures in this analysis are the buy-out of fishing licences and the creation of artificial reefs. The discounted cost of these compensatory options is about $2.1 million over a 50-year time horizon.

According to the survey of Quebec residents, beach replenishment will have a positive effect on tourism traffic in Percé and the Gaspésie region. This benefit is presented in detail in section 4.3.2.

The aggregate cost of beach replenishment in Anse du Sud is therefore $11.5 million over 50 years using a 4% discount rate. Refer to Appendix 2 for the annualized cost of beach replenishment for the 2015-2064 time horizon.

c) Cost of beach replenishment with groynes

The cost of beach replenishment with groynes resembles that without groynes. However, there are three key differences. First, the studies and construction are more costly. The environmental impact and engineering studies account for close to $1.4 million, to be invested in 2016 and 2017. Construction costs are $10.6 million, with materials twice as expensive per linear metre as for beach replenishment alone. However, groynes eliminate the need to periodically nourish the beach and the cost of this maintenance.

The cost of the negative economic, environmental and social impacts are the same as for beach replenishment without groynes, except for the compensation for destroying capelin spawning grounds. Groynes are expected to make capelin spawning more difficult. The proposed compensation for capelin spawning grounds is to restore an eroded beach to meet capelin spawning needs. The total discounted cost of this compensation is estimated at $248,295. This sum includes engineering fees and maintenance costs every 10 years. Overall, the discounted cost of pebble beach replenishment with groynes is approximately $14.3 million over 50 years. See Appendix 2 for the annualized costs from 2015 to 2064.

d) Cost of riprap

The cost of the riprap option includes preliminary studies, implementation, coastal amenities and landscaping, and maintenance. Riprap is slightly more advantageous than

beach replenishment as regards to maintenance because it requires three interventions instead of four over the study period. Development costs are the same for all adaptation options. In total, the discounted cost of the riprap option is about $9.4 million over the 2015–2064 period.

Economic costs include the loss of business revenue for the fishery, compensated by the buy-out of two commercial fishing licences. Based on the survey, tourism is expected to suffer an economic loss of $21 million per year, as tourists find riprap a less attractive option than beach replenishment with or without groynes.

In terms of environmental impacts, the cost of creating artificial reefs to compensate for the loss of natural habitat is $588,165, given the area lost. In addition, changes to the substrate will directly affect the potential for capelin spawning. The cost of nourishing an eroded beach in Percé with sand or pebbles and maintaining it is estimated at $248,295 over 50 years. The total discounted cost of all environmental impacts is approximately $836,460.

The total discounted cost of the riprap is $401.3 million, given the significant decline in tourism revenues. However, this loss is less than that expected if no action is taken. Refer to Appendix 2 for the annualized costs of the riprap option.

e) Cost of rubblemound revetment

The cost of rubblemound revetment includes the cost of preliminary studies (10%), mobilization (5%), rock purchase, transportation and installation, and engineering fees (10%). Expenses to demolish the existing seawall and rock structure were also added, at $410,000 and $22,225 respectively. Finally, the cost of coastal amenities and landscaping are included (with a 20 % contingency cost). In total, the discounted cost of the rubblemound revetment option is $11.4 million from 2015 to 2064.

The economic impacts of rubblemound revetment include lost revenues in the commercial fishery and a decrease in tourism traffic. Lost fishery revenues are of the same order as those estimated for other options: $894,675. Rubblemound revetment is expected to reduce tourism traffic to the Gaspésie region, according to the survey. The decline in tourism revenues is estimated at around $20 million per year compared with

historical levels. Over 50 years, this drop represents an appreciable $373.5 million for the entire region.

The environmental impacts considered for the rubblemound revetment option are compensations for the loss of capelin spawning grounds and the loss of natural habitat due to encroachment in the sea. The present value of both compensations is estimated respectively at $248,290 and $274,480 from 2015 to 2064.

In the aggregate, the discounted cost of rubblemound revetment is estimated at roughly $386.3 million. Refer to Appendix 2 for the annualized cost of rubblemound revetment for the 2015–2064 period.

f) Cost of seawall with deflector

The cost of building a seawall with deflector and berm includes the same components as listed above for rubblemound revetment. However, it costs significantly more to build the seawall than the rubblemound revetment. The total discounted cost is about $22.4 million from 2015 to 2064 for construction of a seawall with deflector and berm, representing a discounted cost of $24,680 per linear metre.

In terms of economic impacts, the construction of the seawall would lead to lost commercial fishery and tourism revenues, the latter due to a decrease in tourism traffic. Fishing would be mainly affected by the presence of the berm, which would encroach up to 40 m into the pre-coastal area along 150 m of the segment. Compensation for lost revenues in the lobster fishery totals $894,675 (present value), while the total anticipated loss for tourism is in the order of $282 million over the study period. As with rubblemound revetment and riprap, the seawall will not keep tourism traffic at its historical level, but should result in lower revenue losses compared to the non-intervention option.

As regards to the environmental impacts of building a riprap berm near the wharf, in front of the seawall, the compensation for lost natural habitat is estimated at $259,105. The berm is also expected to be prejudicial to capelin spawning grounds; the discounted cost of replacing these grounds is $248,295 from 2015 to 2064.

In total, the discounted cost of this adaptation option is estimated at about $306 million for the 2015–2064 period. Refer to Appendix 2 for the annualized cost of the seawall option with deflector and berm over the 2015–2064 time horizon.

5.3.2 Calculation of benefits over 50 years

This section assesses the benefits of all the adaptation options in the study over the 2015-2064 time horizon. Avoidance of the losses associated with non-intervention is not counted as a benefit of the adaptation options in order to avoid double-counting. However, it should be stressed that all the adaptation options studied will prevent loss of property, buildings and seaview accommodation units.

The quantified and monetized benefits all relate to an increase in tourism. The survey of Quebec residents showed that only beach replenishment with or without groynes could have a positive impact on tourism traffic compared to historical figures (i.e., the last five years). One potential explanation for this fact is that no other option restores access to the beach in Anse du Sud. In other words, coastal use is not improved by the seawall, rubblemound revetment or riprap options.

a) Benefits of beach replenishment with and without groynes

The survey showed that beach replenishment would have a favourable impact on tourism in the Gaspésie region. More specifically, survey responses suggest the number of tourists that visit the region would grow by about 2%, representing about 35,000 additional nights. Based on average daily spending by tourists in Gaspésie, this is expected to translate into economic gains of $4.3 million per year. Over the 2015-2064 time horizon, this influx of additional revenues represents a discounted economic benefit of close to $79.4 million.

As for replenishment with groynes, this option would also generate substantial tourism gains, but slightly less than replenishment without groynes. This would represent about 26,000 additional nights per year, or $3.4 million annually. Over the entire study period, the economic benefit is in the order of $62.4 million.

The annual benefits related to beach replenishment with and without groynes are presented in Appendix 3.

5.3.3 Net present value

This section examines the net present value (NPV) of the costs and benefits for each adaptation option in Table 5.6.

Because no benefit is associated with the non-intervention option and its cost is heavy in terms of lost tourism revenues, the non-intervention option has a negative NPV. The NPV for non-intervention is -$705 million over the study period. In comparison with non-intervention, the NPV is higher for all adaptation options. In fact, the NPV for the rubblemound revetment, riprap and seawall options is also negative: however, although they involve no direct benefits, their cost is lower.

The two options with a positive NPV are beach replenishment with or without groynes, since both lead to increased tourism. Benefits exceed total costs, such that the NPV for replenishment without groynes is approximately $68 million while the NPV for beach replenishment with groynes is $48 million.

In addition to presenting the NPV for non-intervention and for each adaptation option, Table 5.6 shows the main categories of costs and benefits used to calculate NPV. The economic impacts category, which includes gains and losses associated with changes in tourism traffic, has an enormous impact on NPV, both positive and negative. This component ranges from -$704 million to $78 million. Figure 5.15 illustrates and compares the costs and benefits of each adaptation option.

When the non-intervention option is compared with the results for every adaptation option, it becomes clear that non-intervention must be ruled out as an option. All the options examined in this study have benefits that outweigh costs, when the averted costs of non-intervention are treated as benefits. NPV for non-intervention ranges from $303 million for riprap to $773 million for beach replenishment.

Figure 5.16 illustrates net cumulative benefits compared to non-intervention, discounted at 4% over the 2015–2064 period.

Table 5.6 – Discounted costs and benefits for adaptation options in Anse du Sud

Net present value and impacts	Non-intervention	Beach replenishment	Beach replenishment with groynes	Rubblemound revetment	Riprap	Seawall with deflector
Erosion	($219,224)	- $	- $	- $	- $	- $
Average annual damage	($198,496)	- $	- $	- $	- $	- $
Cost of options	($311,327)	($9,383,457)	($12,012,511)	($11,387,909)	($9,364,838)	($22,406,721)
Economic impacts	($703,872,066)	$78,463,410	$61,551,754	($374,381,495)	($391,113,497)	($283,015,900)
Environmental impacts	- $	($1,176,334)	($1,424,626)	($522,770)	($836,459)	($507,397)
NPV (benefits or net cost)	($704,601,113)	$67,903,620	$48,114,617	($386,292,174)	($401,314,794)	($305,930,018)
NPV compared with non-intervention		$772,504,733	$752,715,730	$318,308,939	$303,286,319	$398,671,095

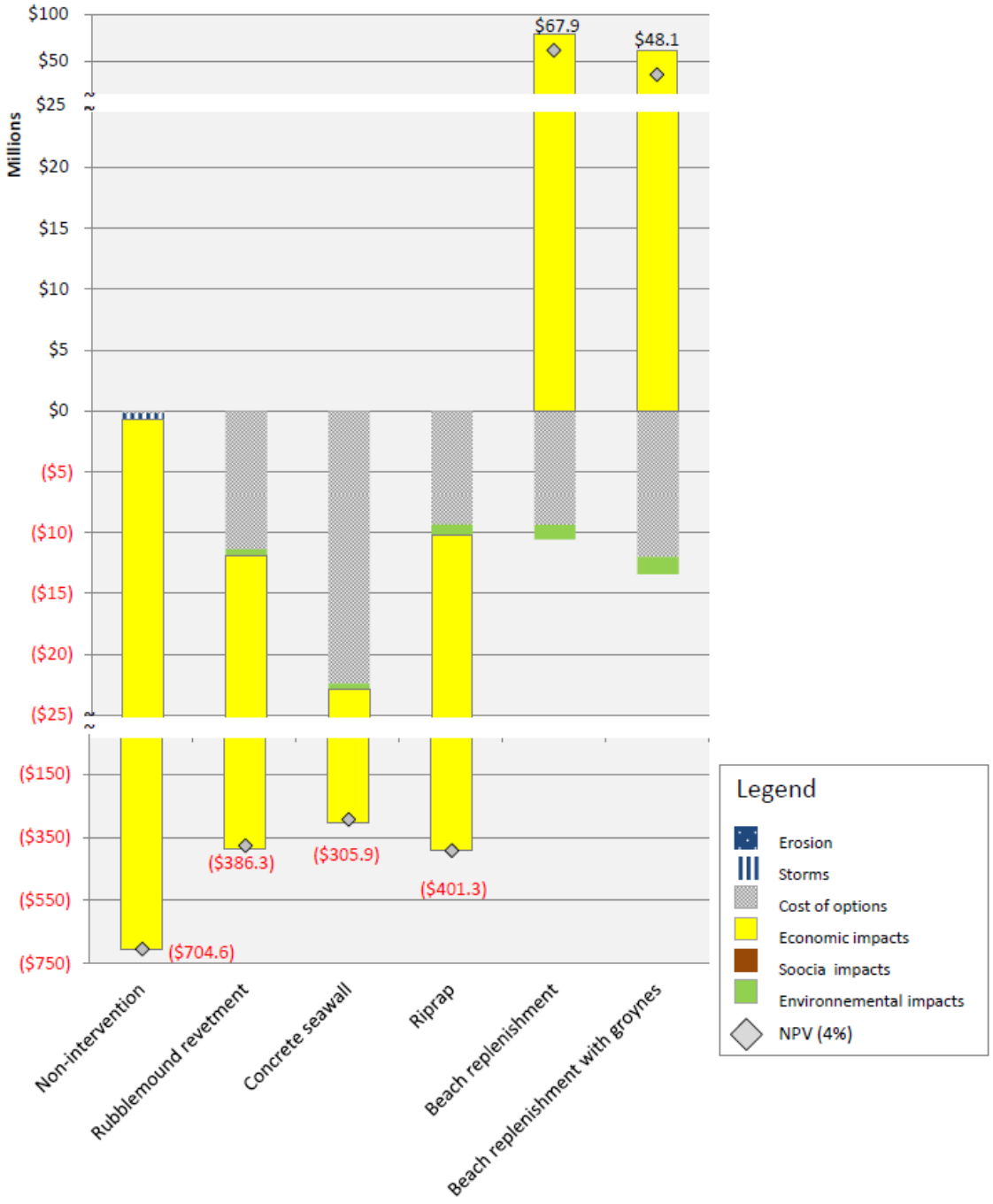


Figure 5.15 – Breakdown of costs and benefits by option ($M)

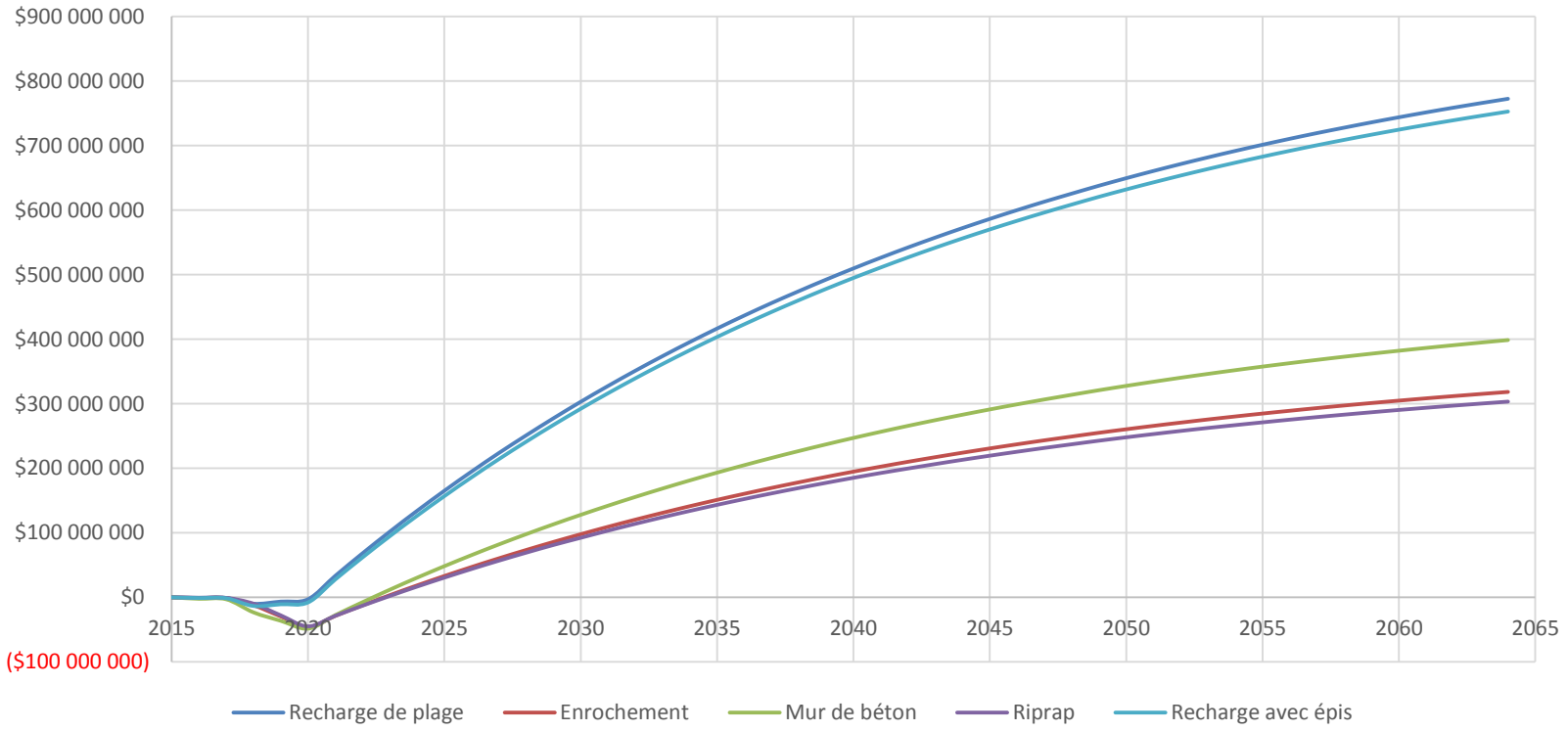


Figure 5.16 – Cumulative value of the net benefits compared to non-intervention from 2015 to 2064

Figure 5.16 shows the point at which an option becomes more beneficial than non-intervention option. Accordingly, beach replenishment with and without groynes becomes more beneficial than non-intervention in 2021. This profitability stems from a combination of lower construction costs and significant economic benefits from accrued tourism traffic. The other options (riprap, rubblemound revetment and the seawall) become more beneficial than non-intervention beginning in 2023.

5.3.4 Interpretation of results

As shown in Figure 5.17, all adaptation options represent a net economic gain for the Gaspésie population compared with the non-intervention option. However, the extent of that gain varies from one option to the next.

Beach replenishment with pebbles is the most economically advantageous option. This is clearly the result of significant tourism gains and relatively low construction costs, even if the solution involves high maintenance costs every 12 years. The beach must be nourished regularly with additional pebbles in order to maintain the solution's long-term integrity and its ability to protect infrastructures over the next 50 years.

The second most viable option is beach replenishment with T-groynes. This option's net discounted benefit over non-intervention is about $753 million. This option is more expensive to build than replenishment without groynes, but requires no maintenance over the study period.

Building a new seawall with deflector to better withstand storm events entails a net discounted benefit of $399 million. Although the seawall, rubblemound revetment and riprap options are more beneficial than non-intervention, they will not maintain the level of tourism traffic in Gaspésie from recent years. These results highlight the importance of taking action. The fact remains that regardless of the option considered, it is always more beneficial to protect and develop the Anse du Sud coast than to do nothing at all.

Finally, the benefit-cost ratios in Figure 5.17 show that beach replenishment with pebbles is also the most beneficial option based on this indicator. The ratio for this option $68 in benefits for every dollar invested. The ratio for beach replenishment with groynes is somewhat lower, but is nonetheless $54 in benefits for every dollar in cost.

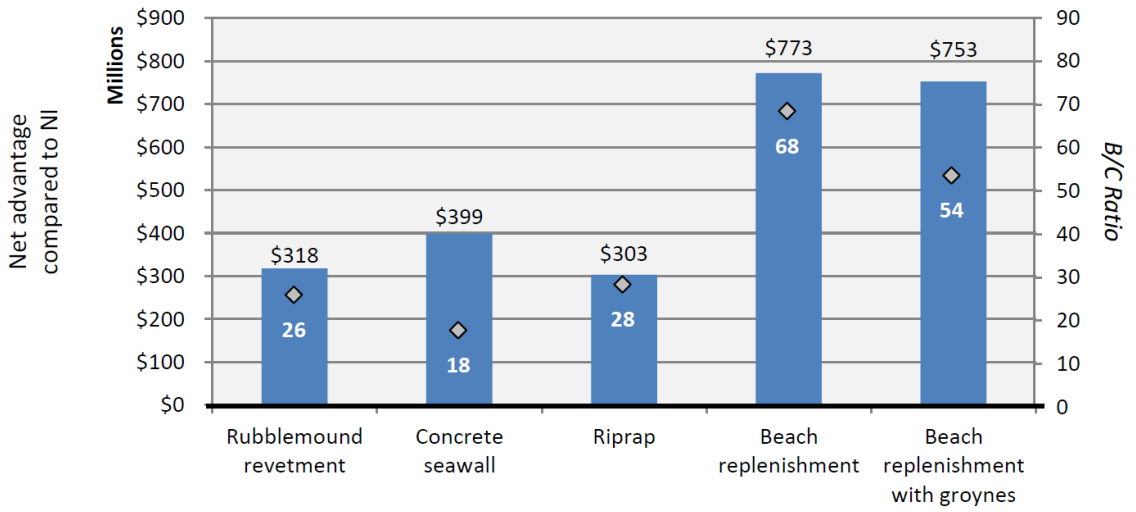


Figure 5.17 – Net benefits of adaptation options and benefit-cost ratio

5.4 SENSITIVITY ANALYSIS

This section presents the net present value (NPV) when key assumptions in the analysis are modified to test the robustness of NPV. The main assumptions that were modified concern the discount rate and the effect of adaptation options on tourism traffic. Table 5.7 presents the parameters modified for the sensitivity analyses.

Table 5.7 – Sensitivity analyses

Parameter	Variation
Discount rate	± 2%
Effect of adaptation options on tourism traffic	Confidence intervals at 95%

For every variation in Table 5.7, the resulting modification has been quantified in terms of cost and benefits.

5.4.1 Discount rate

The use of a lower discount rate gives greater weight to impacts that happen later in the 50-year considered time horizon. Conversely, using a higher rate increases the relative

value of initial costs and reduces the value of costs and benefits incurred later in time. Table 5.8 illustrates the values obtained with a 2% and 6% discount rate.

Table 5.8 – Results with a 2% and 6% discount rate

Adaptation options		Discount rate	
		2%	**6%**
Non-intervention	NPV	($1,098,771,131)	($479,604,989)
Beach replenishment	NPV	$107,809,543	$45,127,189
	Net benefits compared to non-intervention	$1,206,580,674	$524,732,177
Beach replenishment with groynes	NPV	$79,423,874	$30,358,445
	Net benefits compared to non-intervention	$1,178,195,005	$509,963,434
Rubblemound revetment	NPV	($580,331,703)	($274,253,530)
	Net benefits compared to non-intervention	$518,439,428	$205,351,458
Riprap	NPV	($604,258,246)	($284,187,712)
	Net benefits compared to non-intervention	$494,512,885	$195,417,277
Seawall	NPV	($453,314,789)	($220,560,436)
	Net benefits compared to non-intervention	$645,456,341	$259,044,553

Table 5.8 shows the scope of variations resulting from changes to the discount rate. With a 2% rate, the NPV for beach replenishment with or without groynes increases while the NPV for the seawall, rubblemound revetment, riprap and non-intervention decline. The reverse happens when the discount rate increases from 4% to 6%.

Even with a 6% discount rate, which benefits non-intervention by giving less weight to tourism losses after 2020, every option studied is still more advantageous than non-intervention. Beach replenishment remains the most economically viable option, whatever the discount rate.

5.4.2 Effect of adaptation options on tourism traffic

As stated earlier, the effect of the adaptation options on tourism traffic was ascertained through a province-wide Internet survey of 2,000 respondents age 18 and older. Despite the reasonable sample size and a survey methodology that aimed to minimize bias (including bias in assumptions), the results of the survey nonetheless entail a degree of uncertainty that must be taken into account.

To test the sensitivity of cost-benefit analysis (CBA) results to the inherent uncertainty of survey estimates, we used confidence intervals at 95% of the estimate obtained for variations in tourism traffic. Table 4.9 shows the range of confidence intervals for tourism estimates obtained in the survey for every option and for non-intervention.

Table 5.9 – Confidence intervals for number of tourists based on survey

Options	Nbr of nights per year	Confidence intervals (95%)	
		Lower threshold	Upper threshold
Non-intervention (after 2020)	1,205,020	968,736	1,441,304
Beach replenishment	1,559,294	1,317,886	1,800,702
Beach replenishment with groynes	1,550,190	1,304,689	1,795,691
Rubblemound revetment	1,370,168	1,131,836	1,608,500
Riprap	1,362,603	1,124,487	1,600,718
Seawall	1,406,455	1,163,517	1,649,392

At the lower threshold of the confidence intervals, none of the adaptation options increases tourism beyond historic levels. Conversely, at the upper threshold, all adaptation options increase annual tourism beyond historic levels. Only non-intervention reduces the number of expected nights per year. These results show that extrapolating survey results can substantially influence the number of estimated nights that visitors plan to stay in the Gaspésie region depending on the adaptation option studied.

However, in all cases, non-intervention leads to a decline in visitors that is significantly greater than that anticipated for all the options studied.[22]

Sensitivity analyses for the tourism variable show that the results are sensitive to this variable. However, as indicated in Table 5.10, the most beneficial option, beach replenishment without groynes, remains the most advantageous option for Anse du Sud and all the options in the study are preferable to non-intervention.

Table 5.10 – Variation in NPV of each option according to variations in tourism traffic

Options	Benchmark NPV	Confidence intervals (95%)	
		Lower threshold	Upper threshold
Non-intervention	($704,601,113)	($1,228,016,631)	($181,185,311)
Beach replenishment	$67,903,620	($519,951,433)	$655,758,673
Beach replenishment with groynes	$48,114,617	($549,706,885)	$645,936,120
Rubblemound revetment	($386,292,174)	($966,657,715)	$194,072,430
Riprap	($401,314,794)	($981,152,975)	$178,522,137
Seawall	($305,930,018)	($897,509,376)	$285,649,965

Although the cost of implementation exceeds benefits for all adaptation options at the lower threshold of the confidence interval, the discounted cost of every option is less than that of non-intervention. This means that failure to take action would lead to much higher tourism losses than those expected with the proposed adaptation options, making beach replenishment without groynes the least costly option.

At the opposite end of the spectrum (the upper threshold of confidence intervals), every adaptation option increases tourism beyond historic levels. Thus, all options lead to a positive NPV and are substantially more beneficial than non-intervention.

[22] Equality tests (t-tests) were conducted between the estimated tourism traffic for each option. In every case, the assumption of equality among tourism traffic is rejected at a confidence level of 1% for each option in comparison with non-intervention.

5.5 CONCLUSION

The tourism activities in Anse du Sud make this segment of Percé a key one. While there is considerable potential for loss, the potential for economic gains through adaptation are of even greater magnitude. More specifically, the increased tourism resulting from changes to the coastline may translate to net gains worth several millions of dollars, whereas non-intervention would result in losses of the same order.

Among all adaptation options, beach replenishment is most economically beneficial option. It remains the most advantageous choice, even when the discount rate or the tourism variable is modified. This outcome is attributable to the option's low construction cost combined with its capacity to attract tourists. This conclusion can be considered robust.

6 MONT-JOLI SUD SEGMENT

6.1 GENERAL DESCRIPTION

The Mont-Joli Sud segment consists of high rocky cliffs in the southern portion of Cap Mont-Joli. In the east, it begins with the start of the rocky cliff right next to the beach administered by SÉPAQ and ends at the southern tip of Cap Mont-Joli (see Figure 6.1). This 605-m segment is made up of alternating high rocky cliffs and loose rock cliffs ranging from 12 m to 25 m in height (LDGIZC-UQAR, 2015).

The rate of retreat has been relatively stable for the past 50 years in this area. Erosion does not appear to have accelerated in past decades despite higher temperatures, less ice cover and the higher sea level. In fact, there is no statistical difference between the rates of retreat for the 1963–1992 and 1993–2013 periods (LDGIZC-UQAR, 2015).

The probable rates of retreat used are from the 1993–2013 period and vary between -0.01 m and -0.10 m per year based on cliff composition (LDGIZC-UQAR, 2015). These rates are relatively low; no marked acceleration is anticipated over the study period. At this pace, property losses along the coast will be roughly -0.5 m to -5 m over 50 years.

Source: LDGIZC-UQAR and MSP

Figure 6.1 – Oblique photograph of a portion of the Mont-Joli segment in 2010

6.1.1 Issues

The issue in this segment is the proximity of buildings to the cliff's edge. One such building is the Frederick-James Villa, an important heritage building that was used as an international summer school by Université Laval. The other buildings near the cliff's edge are five small summer cottages (beach cottages), two residential buildings and one 19-room historic building (Wexford Manor).

The Frederick-James Villa holds a crucial place in Percé's landscape and built heritage. Its exceptional location on Cap Canon overlooking the sea, its magnificent view of the Rocher Percé and its Neo-Queen Anne architecture certainly make it Percé's foremost heritage home (CBCQ, 2006).

The height of the cliffs in this area makes it extremely difficult to prevent or slow active erosion processes. It might be possible to stabilize the loose portion of the cliff with a talus to slow erosion. However, the buildings at risk between 2015 and 2064 are not located in this area of the segment. The only option considered for this segment is planned retreat.

Figure 6.2 – Satellite image of the Mont-Joli Sud segment

6.1.2 Non-intervention option

If the infrastructures are neither protected nor moved and the cliff continues to recede at the same pace as during the 1993–2013 period, certain buildings at the cliff's edge will gradually be threatened and lost. Without intervention, it is expected that at-risk buildings will be demolished when the coast reaches them, as they will no longer be safe to use or move.

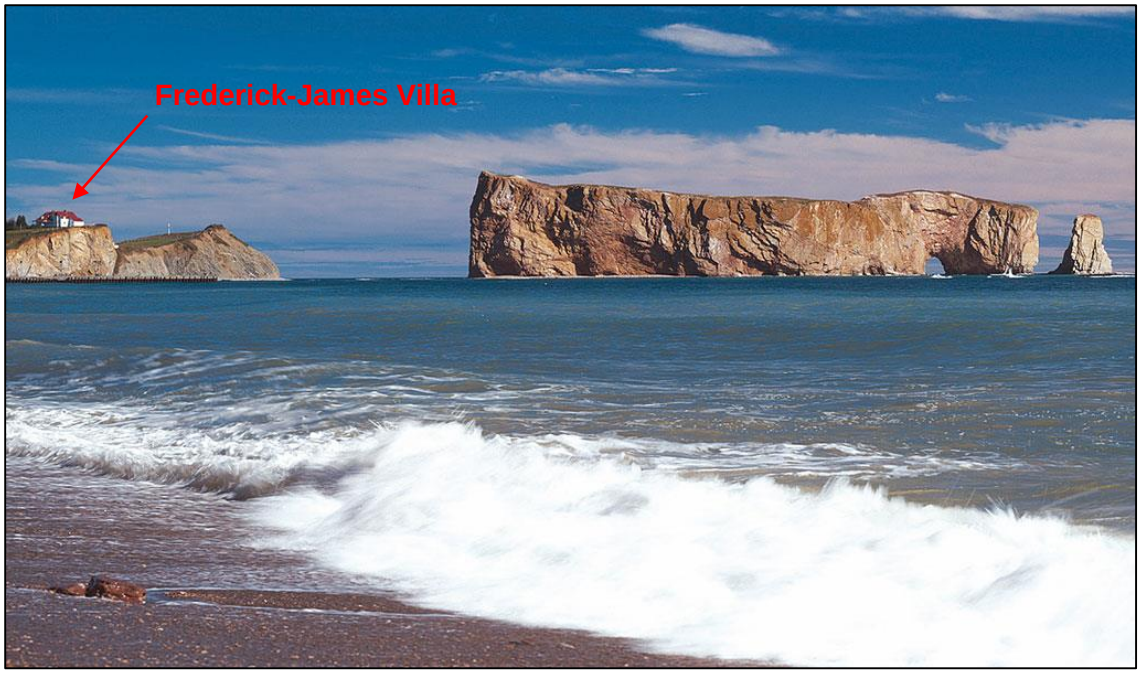
6.1.3 Adaptation options

Planned retreat consists of moving an at-risk building when it less than 5 m from the cliff's edge. The building can be moved elsewhere on the same property, if the property is large enough, or to another property. Moving the building elsewhere on the same property is preferred provided zoning by-laws are respected and the buildings moved are out of danger until the end of the study period. According to *Règlement de zonage de Percé 436-2011*, for zone 230-Cn where the at-risk buildings in the Mont-Joli Sud segment are located, the minimum front, side, combined side, and rear setbacks are 3 m, 2 m, 6 m and 9 m respectively. Given these constraints and the cliff's expected retreat over 50 years, all at-risk buildings in this segment can be moved elsewhere on their current lot.

6.1.4 Expected impacts

Cap Mont-Joli is a landscape emblematic of Percé. The presence of historic buildings, particularly the Frederick-James Villa, gives perspective to the grandiose proportions of the Rocher Percé. Cap Mont-Joli and its heritage buildings are frequently photographed together as in Figure 6.3.

Beyond the landscape and heritage aspects, the potential impacts are limited given the few infrastructures. In particular, no environmental impact is expected to the extent that both options examined anticipate that the coast will recede without affecting the milieu.Table 6.1 compares the expected impacts of both options studied as part of this cost-benefit analysis.



Source: adapted from bonjourquebec.com

Figure 6.3 – Photograph of Rocher Percé and Cap Mont-Joli

Table 6.1 – Anticipated impacts of non-intervention and planned retreat for the Mont-Joli Sud segment

Type of impact	NI	PR
Impacts due to erosion		
Loss of property	X	X
Loss of buildings	X	
Economic impacts		
Loss of business revenue	X	
Social impacts		
Loss of historical and cultural heritage	X	
Change in landscape	X	X

NI: Non-intervention PR: Planned retreat X: presence of anticipated impacts

The main potential impacts from erosion involve the loss of buildings. They also include property loss as erosion advances, in both options under consideration.

The only potential economic impact is the decline in business revenue associated with the loss of accommodation units with a view of the ocean and Rocher Percé. However, because the coast's probable rate of retreat is very slow, neither option will lead to the loss of such accommodation units. Loss of business revenue only becomes likely if a faster rate of retreat is assumed in the sensitivity analyses.

Finally, a loss in heritage and cultural value is expected given that erosion will affect the Frederick-James Villa during the study period. In addition, moving the building or potentially losing it to erosion would represent a loss in terms of the quality of Percé's landscape as well as its natural and built environment.

6.2 ESTIMATED MONETARY IMPACTS

6.2.1 Impacts of erosion

a) Loss of property

Property loss from erosion is expected to occur every year with both the non-intervention and planned retreat options. The lost area was calculated using the erosion rates provided by UQAR. It was then monetized using the real estate property value per square metre published in the 2013 municipal property assessment roll (Servitech, 2013). Given the time lag between assessment and publication of the assessment roll, data on the roll represent market values as of July 2011. The data were adjusted to 2012 dollars by multiplying them by 1.25, the adjustment factor proposed by the Ministère des Affaires municipales et de l'Occupation du territoire.[23]

Figure 6.4 illustrates property loss and at-risk buildings by 2064.

[23] The adjustment factor uses the median variance between sales in Percé and the value indicated on the property assessment roll to determine the value based on 2012 market conditions.

Figure 6.4 – Loss of buildings and property by 2064 for the Mont-Joli Sud segment

For the entire segment, the cost of property loss is $14,895 in 2012 dollars, at a 4% discount rate over the 50-year study period.

b) Loss of buildings

Based on the study's probable erosion scenarios, only the Frederick-James Villa will be at risk by 2064. There should be no risk to the other buildings in the next 50 years. Although the beach cottages are very close to the cliff's edge, the projected rate of retreat is so low that these structures will only be threatened in 2065, a year after the study period ends. However, the cliffside access to the cottages will probably become unusable before 2065.

Under these circumstances, a decision was made not to consider these cottages as threatened during the study period to ensure consistency among the analyses. However, considering the buildings' proximity, a sensitivity analysis of erosion rates was conducted to determine whether the threat to these additional buildings would alter which of the adaptation options would be the most economically advantageous.

Without intervention, the Frederick-James Villa is expected to be lost in 2042 at a cost of $77,278, discounted at 4%. The building's assessed value does not factor in its heritage or cultural value.

6.2.2 Economic impacts

In this segment, the only building that will be exposed during the study period is the Frederick James Villa. The property on which this villa sits is large enough that the building could be moved to another location on the property, which remains permissible for development despite the current exposure of the building to erosion. Therefore, no loss of value has been considered with regard to this land.

Since no hotels will be exposed from now until the end of the study period, no commercial loss due to the loss of accommodation units with a view of the ocean has been included. However, this potential impact was taken into account in the sensitivity analyze of the erosion rate, since an increase in the rate of retreat would cause some cottages on the beach to be exposed during the study period.

It should be noted that since the Frederick-James Villa is no longer used as an international summer school, no loss due to this economic activity was included in this analysis.

6.2.3 Environmental impacts

With regard to the environment, there is no impact anticipated. Given the absence of direct intervention on the coast, there would be no perturbation of natural areas due to planned retreat involving the relocation of buildings.

6.2.4 Social impacts

The non-intervention option would lead to negative social impacts due to the disappearance of the Frederick-James Villa, with its cultural and historic heritage value as well as the quality of the landscape of Percé. Planned retreat would have a lesser impact since it would allow the Villa to be saved, but it would still entail a change to the quality of the Percé landscape.

It is extremely difficult to determine the value of the Frederick-James Villa with respect to the visual, heritage, and cultural environment of Percé. However, this building, owned by Heritage Canada, is recognized as a heritage building of great value:

> *"Its location on Cape Canon, the uniqueness of its architecture in the Percé landscape, and the fact that its history is closely linked to that of American painter Frederick James are all elements that contribute to the importance of this magnificent property of exceptional heritage value."* (Patri-Arch, 2008)

The Commission des biens culturels du Québec even stated, in a 2006 report, that a building of such value should be designated as a heritage property to be protected individually (CBCQ, 2006).

Beyond the heritage value of the building, the entire landscape of Percé would be significantly changed if the Frederick-James Villa were lost. For visitors walking along the Anse du Sud Boardwalk, the Villa is a means of enjoying the magnificence of the Rocher Percé. This particular attribute is very hard to quantify by any means other than a survey comparing, for example, the value accorded to a photograph with and without the Villa. It was not possible to include such an evaluation in this study.

Beyond the qualitative appreciation of the building's exceptional heritage and scenic value, it is difficult to assign an economic value to it. However, recent real estate transactions carried out on land in Percé have made it possible to obtain an approximation of its heritage value.

In September 2014, two important heritage buildings associated with the Charles Robin fish company, located along the Anse du Sud Boardwalk, were listed for sale. These buildings, built in the 1830s, bear witness to the prosperous cod-fishing period that characterized Percé at the beginning of the 19th century. In this way, these buildings can be compared to the Frederick-James Villa due to their historical, heritage, and visual importance to the built environment of Percé. An inventory of the built heritage of the natural surroundings of Percé carried out by Patri-Arch (2008) identifies these buildings having a "superior heritage value".

These two buildings were purchased simultaneously for a sum of $600,000 when the real estate value adjusted to 2012 market conditions was a total of $433,625 ($188,125,

$154,000, and $161,500 for the Pirate building, the Bell House, and the land, respectively) (Gélinas, 2014; Servitech, 2013). According to the media, the buyer wanted to ensure that these historic buildings would be preserved and that "Percé would return to its previous splendour and that UNESCO would include it in its list of world heritage sites" (Gélinas, 2014).

In light of their condition at the time of purchase, the buildings will require extensive repair, in line with strict architectural constraints imposed by the Québec Ministère de la Culture et des Communications. The cost of these renovations will be at least as high as the purchase price (Haroun, 2014). Thus, considering that the purchase price was $600 000, from which the real estate value of the land, $161 500, is subtracted, and that the expected cost of renovation is around $600,000, the buyer will have invested at least $1,038,500 in these two historic buildings once they are restored. This sum is slightly over 3 times the value of the two buildings as listed in the assessment roll and we can consider it to reflect both the value of the buildings and the minimum heritage and scenic value associated with these buildings.

By applying the same ratio to the Frederick-James Villa, the value of the building would be around $546,000, which is $366,125 greater than the 2012 valuation. In this analysis, it is assumed that the difference between the value listed in the assessment roll and the supposed market value is equal to the heritage, cultural, and scenic value of the villa. Since the Frederick-James Villa will be exposed in 2042, the social loss is estimated at $126,980 in 2012 dollars, discounted at a rate of 4%.

Finally, anxiety due to uncertainly for the owners of buildings on Cap Mont-Joli could not be quantified despite its negative impact on quality of life. This negative impact could be attenuated by planned retreat, positively affecting the net present value (NPV) of this option. However, this was not taken into account in calculating the NPV due to a lack of data.

6.3 ESTIMATED COST OF ADAPTATION OPTIONS

For the southern Mont-Joli section, the only option studied was planned retreat. Therefore, the only costs presented in this section are those related to moving the

building. According to the moving company Héneault et Gosselin Inc., the cost of moving this type of building on the same piece of land is around $1,345 per linear metre.

Thus, considering the dimensions of the Frederick-James Villa, the cost of moving it is estimated at slightly over $200,000. Since the villa is less than 5 m from the cliff, for safety's sake, it should be moved as soon as possible. This means it is assumed that the cost of moving will incur in 2015.

It should be noted that the non-intervention option also entails a cost associated with the demolition of the Frederick-James Villa when it becomes exposed to erosion in 2042. This cost would be $5,210, discounted in 2012 dollars.

6.4 COST-BENEFIT ANALYSIS

This section presents the sum of all costs and the benefits from 2015 to 2064 which were used to estimate the net present value of both non-intervention and planned retreat.

6.4.1 Calculation of costs over 50 years

The total cost of the options includes the costs related to erosion, the costs of the options themselves, as well as the costs associated with the economic, environmental, and social impacts. The aggregated costs are presented in Table 6.2, but they are available on an annual basis in Appendix 4.

Table 6.2 – Total costs of non-intervention and planned retreat, discounted at 4%

Costs	Non-intervention	Planned retreat
Erosion	$77,278	$14,895
Costs of the option	$5,210	$201,827
Social impacts	$126,978	-
NPV	$209,466	$216,722

In the case of non-intervention, the principal costs would arise in 2042 with the loss of the Frederick-James Villa and its heritage and scenic value. Given the long-term horizon

of this loss, the choice of discount rate has a significant influence on the actualized costs. For that reason, a sensitivity analysis of the discount rate was performed.

The principal costs for the planned retreat would arise at the beginning of the period, in 2015, since the villa is less than 5 m from the edge of the cliff. The relocation should be planned in 2015, which means that the discount rate chosen does not have a large influence on the NPV of this option.

6.4.2 Calculation of benefits over 50 years

In the case of the Mont-Joli Sud segment, no direct benefit was identified. The only potential benefits of planned retreat correspond to the avoidance of the costs of inaction.

6.4.3 Net present value

Since the two options studied entail only costs, the net present values of non-intervention and planned retreat are -$209,467 and -$216,721, respectively. The estimate of the NPV of planned retreat compared to the option of non-intervention is slightly negative, at -$7,254. The benefit-cost ratio of planned retreat compared to non-intervention is 0.96.

Figure 6.5 illustrates the cumulative sum of the net costs of non-intervention actualized at a rate of 4% over the 2015-2064 period. This graph shows that planned retreat does not become more beneficial than inaction over the course of the study period, since the sum remains negative. However, the cumulative sum reaches almost zero beginning in 2042, the year in which the Frederick-James Villa will be exposed, based on the probable erosion rates of this segment.

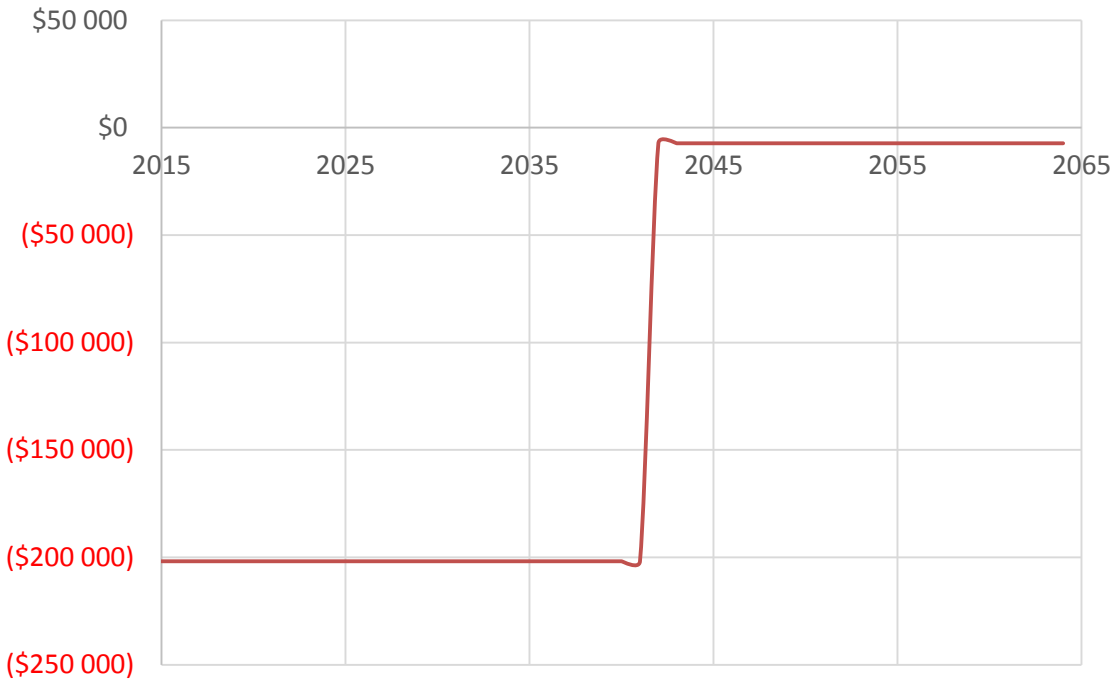


Figure 6.5 – Cumulative value the net costs of planned retreat compared to non-intervention, 2015-2064

6.4.4 Interpretation of results

Over a time horizon of 50 years, with a discount rate of 4%, non-intervention and planned retreat produce net present values that are almost equivalent. Although non-intervention may seem slightly more advantageous than planned retreat (by around $7,000), this advantage is considered to be within the margin of error of the analysis. In fact, the comparative NPV is so close to zero that a slight variation in any of the parameters could reverse the results of the analysis. For example, a slight acceleration of erosion could alter the results sufficiently to make planned retreat the optimal choice. The following sensitivity analyses make it clearer which parameters could influence the results of this CBA in one direction or the other and whether it is possible to conclude that one of the options is superior.

6.5 SENSITIVITY ANALYSIS

The parameters on the basis of which the sensitivity analyses were carried out are the heritage and scenic value of the Frederick-James Villa, the erosion rate, and the

discount rate. The assumptions made are less certain for these parameters, meaning that these parameters may have a more significant influence on the results of the CBA.

6.5.1 Heritage and scenic value

The estimate of the heritage and scenic value of the Frederick-James Villa is based on a single real estate transaction in Percé, that of the two Robin buildings (the Bell House and the Pirate building). This estimate is based on the assumption that the heritage value of the Robin buildings is equivalent to that of the Frederick-James Villa. However, the assessment carried out as part of the inventory of the built heritage of Percé identifies the heritage value of the Robin buildings as “superior,” while the Frederick-James Villa is identified as having an “exceptional” heritage value (Patri-Arch, 2008). Although this terminology is qualitative, it reflects a difference in the heritage value of these buildings.

Moreover, the visual value of the Frederick-James Villa to the Percé landscape was only partially considered through the heritage value. However, this visual value is undeniable, since the building is found in numerous photographs of the Rocher Percé.

Considering these elements, an increase in the heritage and scenic value of 20% was included in the sensitivity analysis. This increase changes the heritage and scenic value from $366,125 to $439,350. The NPV of planned retreat relative to non-intervention then becomes positive, at slightly over $18,000. This comparative advantage is relatively minor considering the incertitude associated with the analysis. It is therefore impossible to state with certainty that planned retreat is clearly a more advantageous option than inaction, based on this modification alone.

6.5.2 Erosion rate

The probable erosion rates used for this segment varied from -1 cm to -10 cm per year. However, rates of retreat of up to -80 cm per year have been observed between 2005 and 2012 based on LDGZC distance markers. It is therefore possible that the true rates of retreat over the next 50 years could be higher than what was assumed in this CBA.

To study the effect of a more rapid retreat of the coastline, it was assumed that the erosion rates could be 10% greater. With this assumption, two of the five cottages on the

beach would be exposed in 2063 and 2064, respectively, while the James Villa would be exposed in 2040 rather than in 2042.

The exposure of the two cottages on the beach would be accompanied by a loss of the view of the sea for two accommodation units. According to the evaluation of the Percé accommodation market, an accommodation unit with a view of the sea can be rented for $32 per night more than a unit without a view. This additional value represents a minimal estimate of the value that people give to a view of the sea. The occupation rate of these two accommodation units was estimated using the average occupation rate of rooms in Gaspésie from Tourisme Québec for 2013, which is 82 nights per year. The economic loss associated with the exposure of two cottages on the beach is thus estimated at $5,248. In the sensitivity analysis, this economic loss is accounted for starting from the time when each of the buildings is considered lost.

By increasing the erosion rate by 10%, the NPV of non-intervention changes from -$209,467 to -$240,404, while the NPV of planned retreat changes from -$216,721 to -$227,265. Furthermore, the NPV of planned retreat relative to non-intervention becomes positive and reaches over $13,000. However, this NPV is not sufficient to consider planned retreat preferable to inaction, since it is within the margin of error of the analysis.

6.5.3 Discount rate

Table 6.4 shows the variations in costs and results obtained using discount rates of 2% and 6%. This table demonstrates that the discount rate has a significant effect on the option NPV. Using a discount rate of 2% makes planned retreat more advantageous than non-intervention, while a discount rate of 6% has the opposite effect.

The variations observed in the results are explained by the fact that a low discount rate increases the impact of future cash flows, making the expected loss in 2042 due to the exposure of the Frederick-James Villa larger. Inversely, using a higher discount rate reduces the weight of future impacts. The absence of robust conclusions for the analysis means that neither planned retreat nor non-intervention has a clear advantage. However, when one considers assets of a communal nature such has a heritage property whose conservation is important for future generations, economic theory

suggests using a lower discount rate, which would give the advantage to planned retreat.

Table 6.3 – Variations in costs and in NPV with discount rates of 2% and 6%

Option considered	Variations	Discount rate	
		2%	6%
Non-intervention	Costs associated with erosion	$126,416	$48,594
	Cost of the option	$8,801	$3,115
	Social costs	$214,499	$75,923
	NPV	($349,716)	($127 632)
Planned retreat	Costs associated with erosion	$21,034	$11,294
	Cost of the option	$201,827	$201,827
	NPV	($222,861)	($213 121)

6.6 CONCLUSION

In general, the two options studied seem to result in similar NPVs over the time horizon studied, at a discount rate of 4%. The sensitivity analyses modifying one parameter at a time did not make it possible to determine whether one of the two options is more advantageous from an economic standpoint. However, a sensitivity analysis that combined an increased heritage and scenic value of the Frederick-James Villa (20%), a slight increase in the erosion rate (10%), and a discount rate of 4% would lead to the conclusion that planned retreat is more advantageous than non-intervention.

The sensitivity analysis on the discount rate demonstrated that the time factor is critical in this segment. Furthermore, even if the Frederick-James Villa becomes threatened only in 2042, its preservation requires imminent relocation since the building is already located less than 5 metres from the coastline. This means that a decision should be made very soon if it the Frederick-James Villa is to be preserved for future generations.

7 ANSE DU NORD SEGMENT

7.1 GENERAL DESCRIPTION

The Anse du Nord segment is bordered on the south by Biard Street and on the north by the old Coopérative des Pêcheurs (Fishers' Cooperative) building, which today houses municipal public services. The Anse du Nord sector is the second most important location for tourism in Percé. It is complementary to Anse du Sud and contains tourism, commercial, and residential infrastructures. It includes, among other things, a small campground for recreational vehicles, a general store, the Bleu-Blanc-Rouge, Trois Sœurs, and Rocher Percé hotel/motels, and two restaurants.

From a tourism point of view, Anse du Nord is particularly popular due to its pebble beach, which has kept its natural appearance, as well as its view of the Rocher Percé and Cape Barré. Cape Barré is recognized as an element of Percé's natural heritage. The Anse du Nord coast is mainly used for walking, picnics, observing marine mammals, and fishing for mackerel and striped bass.

Despite these many attractions, tourism traffic at Anse du Nord is much lower than at Anse du Sud, since access is more limited and the site has not been the subject of promotion comparable to that of Anse du Sud. In the south, the pebble beach is accessible at the end of Biard Street via a wooden staircase, the structure of which rests on a concrete base. In the north, the City of Percé has created a small park that

essentially serves as an informal parking area that makes it possible to reach the pebble beach via a natural slope down to the beach[24].

A study on the usage of the coast, conducted by Ouranos in August 2014, estimated the total tourism traffic at around 3,500 visits between the months of June and October (Ouranos, 2014). In comparison with the hundreds of thousands of visits annually of the wharf and the boardwalk, Anse du Nord attracts few tourists despite the quality of its natural environment and the views it offers of the sea and the Rocher Percé.

In geomorphological terms, this sector is composed of alternating flat beach coastline, embankments, and low loose soil or sandy cliffs (LDGIZC-UQAR, 2015). The longshore drift heads in a northerly direction and drags sediments eroded from the north coast of the Mont-Joli cape towards Anse du Nord (LDGIZC-UQAR, 2015). The presence of Cape Barré acts as an impediment to the longshore drift and marks the end of the Rocher Percé hydro-sedimentary cell. The presence of Cape Barré leads to deposits at the beach (see Figure 7.1). A major stream flows into the northern portion of the segment right before the City of Percé municipal building.

Historically, the Anse du Nord beach had a wharf used for fishing boats and tourist excursions to the Rocher Percé and Bonaventure Island. In fact, at the time, the Percé wharf was located on the Anse du Nord side (see Figure 7.2). The historical photograph below shows that the longshore drift indeed travelled from the south to the north, from the Mont-Joli cape toward Cape Barré. This image also shows that, at the time, most of the buildings built near the coast had foundations resting on stilts and were essentially used for the fishing activities that were practiced in the region.

The Anse du Nord coastline remained relatively natural until the 1970s, when protective infrastructure was erected. The banks were consolidated at that time with the construction of concrete steps (see Figure 6.3). Other protective options along certain portions of the segment further increased the rigidity of the coastline. Over time, some waterfront property owners built protective seawalls and rubblemound revetment to slow the erosion of their land.

[24] The City of Percé plans to move the local nautical club to Anse du Nord, which could increase tourism traffic in this segment. However, this CBA does not take this move into consideration, since it assumes a status quo situation in terms of economic activity.

Figure 7.1 – Satellite image of the Anse du Nord segment

Source: Ville de Percé

Figure 7.2 – Historical photograph of Anse du Nord

Source: LDGIZC-UQAR and MSP

Figure 7.3 – Oblique photograph of a portion of the coast protected by concrete steps in 2010

7.1.1 Issues

The presence of a relatively large beach minimizes the impact of storms on the erosion of the low cliffs further back on the beach. However, the construction of protective structures and embankments in recent years has contributed to a lowering and narrowing of the beaches where they are located. Since the 1960s, the width of the beach has been reduced by over 20 m (Bernatchez et al., 2008). The partial artificialization of the coastline has also provoked *lateral scarring* on unprotected portions of the coast (see Figure 7.4).

Source: LDGIZC-UQAR et MSP

Figure 7.4 – Lateral scouring from a protective seawall on the adjacent land in a portion of the Anse du Nord segment in 2010

Deposits from the south do not appear to be sufficient to maintain the beach in its current condition. An even greater increase in the rigidity of the coastline could worsen the situation. Artificialization throughout the sector would eventually lead to the disappearance of the beach over time, in a similar way to what has occurred in the Anse du Sud segment after the construction of the seawall.

In terms of retreat, the narrowing and lowering of the beach have not resulted in a significant retreat of the coastline between 1993 and 2013. The construction of different

protective structures, such as the concrete steps, has kept the shoreline fixed, up to a certain point. The average rate of retreat across the entire segment is around -3 cm per year, but the rates measured at different points along the coast are fairly heterogeneous (LDGIZC-UQAR, 2015). The portions that are still natural tend to retreat more rapidly due to the lateral scouring caused by other structures. For example, in the portion between the Auberge Les Trois Sœurs' low wooden seawall and the embankment of the municipal garage, the coastline retreated 3.96 m between 2007 and 2009 (LDGIZC-UQAR, 2015).

7.1.2 Non-intervention option

The non-intervention option consists of leaving the protective structures in place. This option rests on the assumption that the current structures are not of the right size and that even if maintained, they will not slow the retreat of the coastline. This approach would foster both a return to a natural coast in the medium term and a return to a natural rate of retreat in the segment, leading to a new equilibrium for the beach.

The erosion rate applied is equal to the average rate measured in the natural sections of the segment between 1993 and 2013. The assumption is therefore made that, without intervention, the Anse du Nord coast would change at a rate of -18 cm per year (LDGIZC-UQAR, 2015). In fact, despite the fact that the retreat of the coastline would probably occur during storm events, it is assumed that the coast will gradually retreat year after year.

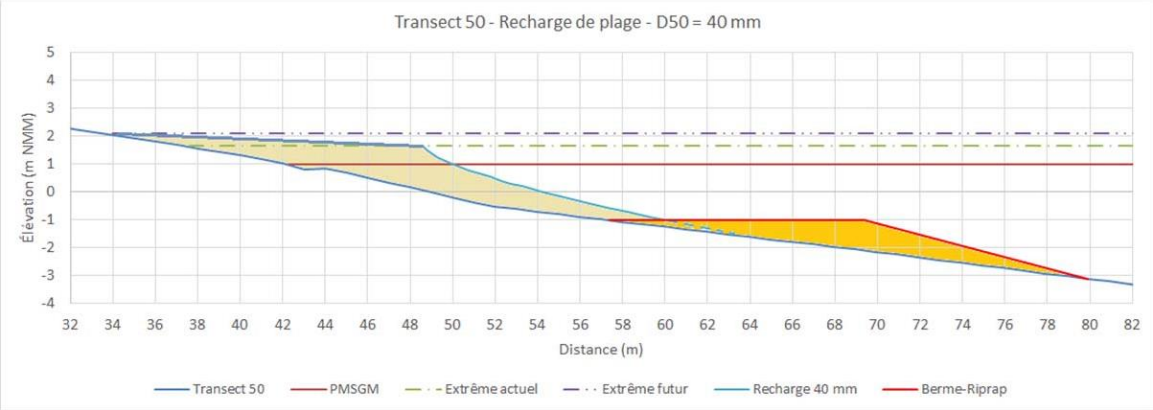
7.1.3 Adaptation options

In parallel with the present study, the City of Percé hired engineering consulting firm BPR and its collaborators to carry out a preliminary design study of possible solutions to protect the embankments in Anse du Sud and Anse du Nord. The adaptation options under study take into account the hydrodynamic constraints, erosion, sedimentation processes and the geomorphology of the Anse du Sud segment. These options were designed to avoid erosion over the next 50 years. In the spirit of complementarity between the two studies, the present study drew on the identification and design of solutions carried out by BPR in order to conduct its comparison of possible options from an economic point of view.

The options studied in this analysis were beach replenishment with pebbles, rubblemound revetment, riprap and planned retreat.

a) Beach replenishment[25] (BR)

Protection by beach replenishment is based on the principle of maintaining the geomorphological conditions of the beach of Anse du Nord. Taking into account the intensity of the waves that hit the shores of Percé, the replenishment would have to be carried out using relatively coarse materials. This type of material is typical of the pebbles found on the beach of Anse du Nord. The median diameters D_{50} considered range from 20 to 40 mm. The average elevation of the ridge of the replenishment would be 2 m in relation to the mean sea level (MSL) and would have an average width of between 12 and 15 m (see Figure 7.5).



Source: BPR et al. (2014).

Figure 7.5 – Cross-section of the beach replenishment option for Anse du Nord

For the middle portion of Anse du Nord, the slope of the bank and the depth of the water require the installation of a stone berm at the foot of the beach replenishment in order to ensure stability and reduce the number of pebbles needed. Employing the beach replenishment option in Anse du Nord also involves the displacement of the Havre-de-la-Nuit camping building in order to set the shoreline in such a way as to create an equilibrium slope with the beach in the sector further south.

[25] The beach replenishment option was designed to resist water levels with a recurrence period of 50 years, taking into account a rise in water levels due to climate change of +40 cm over 50 years (BPR et al., 2014).

b) Rubblemound revetment (R)

This option consists of a classic rubblemound revetment protection with a slope of approximately 67% or of a height of one metre and a width of 1.5 m. According to the design criteria[26], the elevation of the crest of the rubblemound revetment would be situated at 5 m above the MSL across the entire segment (Figure 7.6).

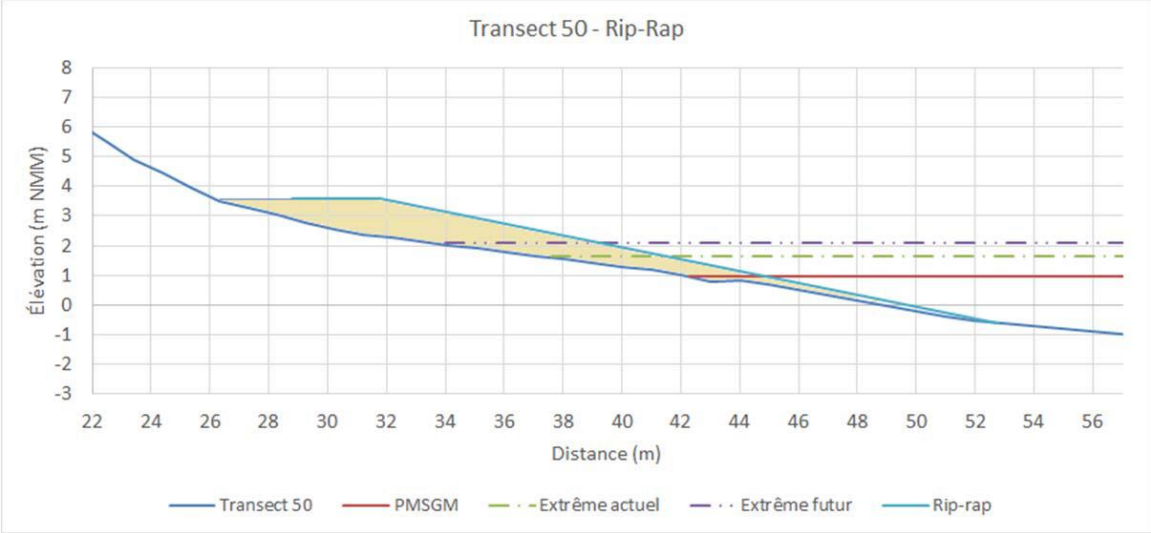
Source: BPR et al. (2014).

Figure 7.6 – Cross-section of the rubblemound revetment option for Anse du Nord (transect 50)

c) Riprap (RR)

Protection by riprap is based on the same principle as protection by rubblemound revetment except that the stone used has a much wider spread in grain size than the armour stone used in a classic rubblemound revetment. The riprap is designed to have a much more moderate slope – around 20%, or one metre high and 5 metres wide – than that of the rubblemound revetment. A more moderate slope allows for the reduction of wave runup during storm events. As a result, the required elevation of the crest of the riprap is much lower than that required for a classic rubblemound revetment. In the case of Anse du Nord, the average elevation of the crest of the riprap would be around 3.5 m above MSL.

[26] The design criteria for the height of the rubblemound are based on 2% rate of overtopping over a recurrence period of 50 years (BPR et al., 2014).



Source: BPR et al. (2014)

Figure 7.7 – Cross-section of the riprap option in Anse du Nord (transect 50)

d) Planned retreat (PR)

Planned retreat is defined as the relocation of at-risk buildings as soon as they become situated within 5 m of the coastline. The building can be moved to a different location on the same plot property if the property is large enough, otherwise it can be moved to a different property. Moving the building on the same property is preferred, as long as zoning laws are respected and the relocated buildings will be out of danger until the end of the time period of this study. According to the *Règlement de zonage de Percé numéro 436-2011*, the minimum front, side, combined side, and rear setbacks for this segment are 3-15 m, 2-4 m, 6-9 m and 9 m respectively.

7.1.4 Expected impacts

The anticipated impacts for the Anse du Nord segment are numerous and diverse. The segment is fairly densely built and is home to a number of hotels, stores, and restaurants. While it is less visited than Anse du Sud, this segment has undeniable tourism potential, with its pebble beach and stunning view of Rocher Percé and the sea. In this sense, interventions along the coastline could have an impact on the recreational use of the coastline by enhancing or reducing the quality of the recreational experience. Table 7.1 presents the anticipated impacts of non-intervention and of the four options studied in the guise of this CBA.

Table 7.1 – Impacts of adaptation options for the Anse du Nord segment

Types of impacts	NI	PR	BN	RR	R
Impacts caused by erosion					
Loss of land	X	X			
Damage to or loss of residential buildings	X				
Damage to commercial buildings	X				
Damage to public infrastructure	X				
Economic impacts					
Changes to tourist traffic					
Loss of commercial revenue	X				
Disruption of commercial fishing activities					
Environmental impacts					
Changes to natural habitats					
Disturbance of fish spawning grounds				X	
Social impacts					
Changes to the coast and its recreational use			X		
Improved quality of life (security, tranquillity, etc.)			X	X	X

NI: Non-intervention; PR: Planned retreat; BN: Beach replenishment; RR: Riprap; R: Rubblemound revetment
X: presence of anticipated impact

Impacts caused by erosion almost only occur in the case of non-intervention, that is, in situations in which already-existing protective infrastructures are left as they already are. However, as planned retreat does not slow erosion, loss of land is also associated with this option. All other potential options examined stop erosion, thereby eliminating potential damage to infrastructure.

The main economic impacts affect tourism traffic, commercial revenue from housing with a view on the ocean, and, potentially, commercial fishing activities.

Anse du Nord occupies an important place in the tourism offering of Percé, albeit a less significant one than Anse du Sud. A major modification of the layout of the coastline in this sector in combination with improved access to the pebble beach and tourist activities could have a considerable impact on Percé's ability to attract visitors. This could also translate into an increase in the number of tourists visiting Percé, and specifically, into longer durations of stays.

Additionally, when certain establishments are exposed to erosion, the loss of accommodation units that will occur will result in less rooms with a sea view being available, which will result in a loss of commercial revenues associated to the premium for a room with a view.

Anse du Nord is also an important fishing zone for the Percé area. Depending on how the adaptation options are designed, their realization could modify lobster habitats situated on the shoreface of the segment. This disturbance could affect areas favourable to lobster development, thereby affecting the productivity of lobstering in the affected areas. The potential impacts on this economic activity are discussed in further detail in section 7.2.2.

As for environmental impacts, these are largely related to the encroachment of the rubblemound revetment on the coastline. This encroachment could destroy capelin spawning grounds. On the other hand, other options could improve the habitat by creating a variety of interstices between the rocky materials used. However, these gains are not taken into account in this analysis.

As far as social impacts are concerned, there are two of them. The transformation of the Percé seaside will directly affect the ways in which residents and tourists visit and use the coastline. Incidentally, the value assigned to the use of the coastline could be modified by any of the possible options.

Finally, for residents who live close to the Anse du Nord coast, fall and winter storms can be cause for great insecurity and stress, which affects their quality of life. An improvement in shore protection could help mitigate this negative effect and improve quality of life by the sea.

7.2 ESTIMATED MONETARY IMPACTS

7.2.1 Impacts of erosion

The monetary estimate of costs related to erosion allows us to put a price on the issues related to the infrastructure and lands at risk. All costs presented in the paragraphs below are associated with non-intervention or planned retreat options, as all the other adaptation options allow to curb erosion.

a) Loss of land

The probable rate of erosion being -18 cm per year in the Anse du Nord segment, yearly loss of land to erosion are anticipated. The total loss of surface area is illustrated in Figure 7.8. As land is chiselled away by erosion, the value of this land diminishes proportionally. The economic value of a plot of land is estimated in reference to its assessed value in 2012 dollars[27].

For the entire segment, the costs associated with loss of land are $44,225 in 2012 dollars discounted at a rate of 4% over the 50-year study period. These costs are the same for non-intervention as they are for planned retreat.

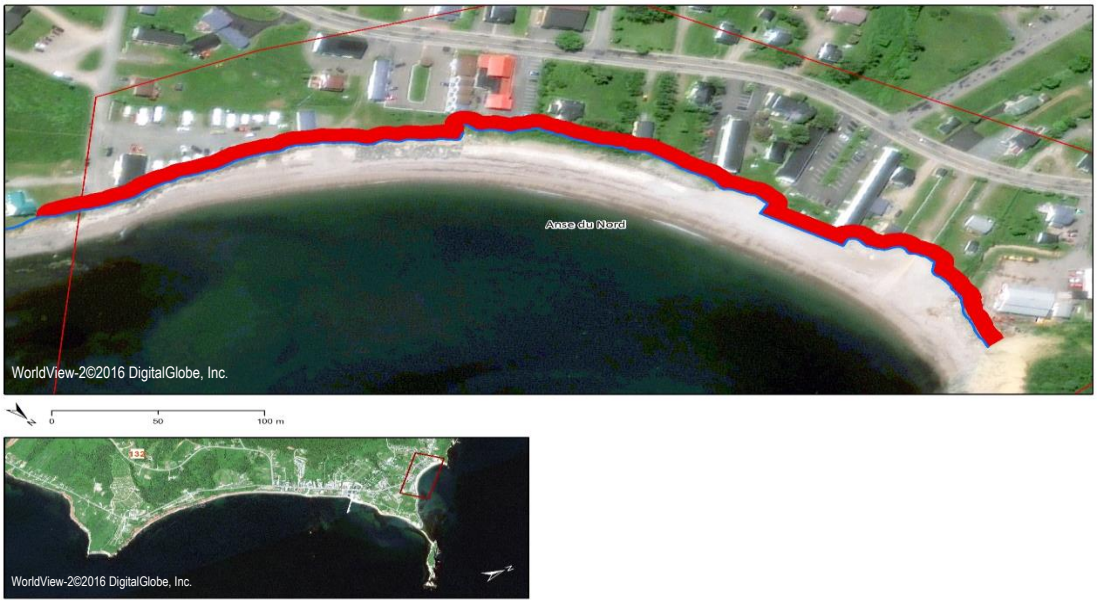


Figure 7.8 – Cartography of anticipated loss for the time horizon of 2064 for the Anse du Nord segment

b) Loss of residential buildings

In total, three residential buildings situated on two different lots will be exposed from now to 2064. The southernmost lot has two buildings: a secondary building that would be lost

[27] Given the discrepancy between the assessment roll and market value, the data in the 2013 roll represents July 2011 market values. In order to transform these into 2012 values, the value indicated in the roll was multiplied by 1.25, the adjustment factor suggested by the ministère des Affaires municipales et de l'Occupation du territoire. This adjustment factor was established by taking into account the median deviation between sales made in Percé and the values indicated in the roll to bring the values in line with the 2012 market.

in 2048, and a main building that would be exposed in 2049. The northernmost lot contains two residences, only one of which will be affected in 2048.

The value of properties that will be lost was estimated by referring to the Percé assessment roll, adjusting to reflect 2012 property values. When a property includes two buildings, half of its assessed value is attributed to each building when one of the buildings is lost. The total value of loss of residential buildings discounted at 4% comes to $54,125.

In examining the planned retreat option, it was established that three at-risk residential buildings could be moved to new spots on the same plot of land while still respecting the applicable zoning by-law.

c) Loss of commercial buildings

All commercial buildings exposed during the study period are hotel establishments, with the exception of a reception building for a campground which also serves as a bar-restaurant. They will be affected between 2036 and 2051.

Some affected buildings are part of hotel complexes that include 3 or 4 buildings. In these cases, the value of a lost building was estimated by taking into consideration the number of accommodation units in this building compared to the total number of available units in the hotel complex. This means that if a lost building has one-third of the accommodation units of a hotel complex, then the value of this building equals one-third of the total value of the hotel complex specified in the assessment role.

Since the hotel buildings of Anse du Nord are built perpendicular to the coastline, not all of the accommodation units are affected when a building is exposed. For example, for the Auberge Les Trois Sœurs for which two buildings are exposed, only 10 accommodation units are actually at risk, although these two buildings include a total of 38 accommodation units. Thus, the proportion of the total value of each building lost was assessed based on the number of accommodation units actually at risk.

The total value of exposed commercial buildings was estimated at $121,435 at the discount rate of 4% over a 50-year time horizon. As part of planned retreat, it was

established that all the commercial buildings at risk, except one, could be moved on the same land while complying with the applicable zoning regulation.

d) Damage to Public Infrastructure

The public infrastructure in the segment includes the municipal garage and a small municipal park. According to erosion projections, the municipal garage will not be affected by erosion and the municipal park does not contain any infrastructure at risk. Only the land will be eroded by the sea and this part was accounted for in the losses of land.

7.2.2 Economic impacts

a) Changes to tourism traffic

The interventions envisaged on the Anse du Nord coastline could promote better harmony between the tourist, recreational and natural uses of Percé. The charm of Anse du Nord is its natural character. As a result, improvement of its attributes by developments consistent with the site's nature could result in an increase in the number of visitors and the duration of recreational and tourist activities on the site.

However, the adaptation options considered for Anse du Nord do not include recreational and tourist improvements that could promote growth of tourist traffic, such as a footpath or lookout. The options focus on protection of the shoreline and assets at risk. As a result, it is assumed in this analysis that the adaptation options will have no quantifiable impact on tourism traffic at Percé or Gaspésie.

b) Loss of business income

A cost-benefit analysis does not take into account the income lost by a commercial establishment if it is transferred to another establishment. However, if the income is not fully transferred, then it can be considered that there is a loss for the economy as a whole.

In the case of the Auberge Les Trois Sœurs and the Bleu Blanc Rouge motel, some buildings will be affected by erosion in the case of non-intervention. Therefore, it is likely that the accommodation units with a view of the sea which will be lost will not be able to be replaced by units offering similarly beautiful views in the other establishments. There

is a limited number of this type of unit due to the opportunities for having a view of the sea. Thus, accommodation units with a view of the sea are usually rented at a higher price than those without this view.

The loss of units that offer a view of the sea means a loss of business income for the entire region. Analysis of unit prices for accommodation at Percé, among others, with the La Normandie and Riôtel Percé Hotels as well as websites such as TripAdvisor, indicates that on average a premium of $32 per night is charged to the customer for a unit with a view of the sea. This premium reflects the minimum value customers place on the view of this unique landscape.

The exposed buildings of the Auberge Les Trois Sœurs and the Bleu Blanc Rouge motel include 41 units that offer a view of the sea. Of these units, only 13 will be exposed by 2064. Assuming that the occupancy rate of these units is equivalent to the average occupancy rate for rooms in Gaspésie as estimated by Tourisme Quebec in 2013, being 82 nights/year, then the loss of 13 units represents an amount of about $34,125 per year. It should be remembered that the buildings will be affected at different times by erosion in the non-intervention option. Therefore, losses of business income were calculated based on the number of units affected and the time from which these units will no longer be usable.

c) Disturbance to commercial fishing activities

The main commercial fishing activity in this sector is American lobster fishing. Intervention in the environment would potentially disturb the lobster habitat by sedimentation and change the seabed due to encroachment. Ultimately, depending on the extent of encroachment, the productivity of lobster fishing could be reduced in this sector.

However, fishing traps are set relatively far away from the Anse du Nord shore. It could be deduced that the quality of the lobster habitat is probably better a little further offshore than near the coastline. This assumption was confirmed by the summary characterization of the seabed conducted for the project by the Pesca Environnement company:

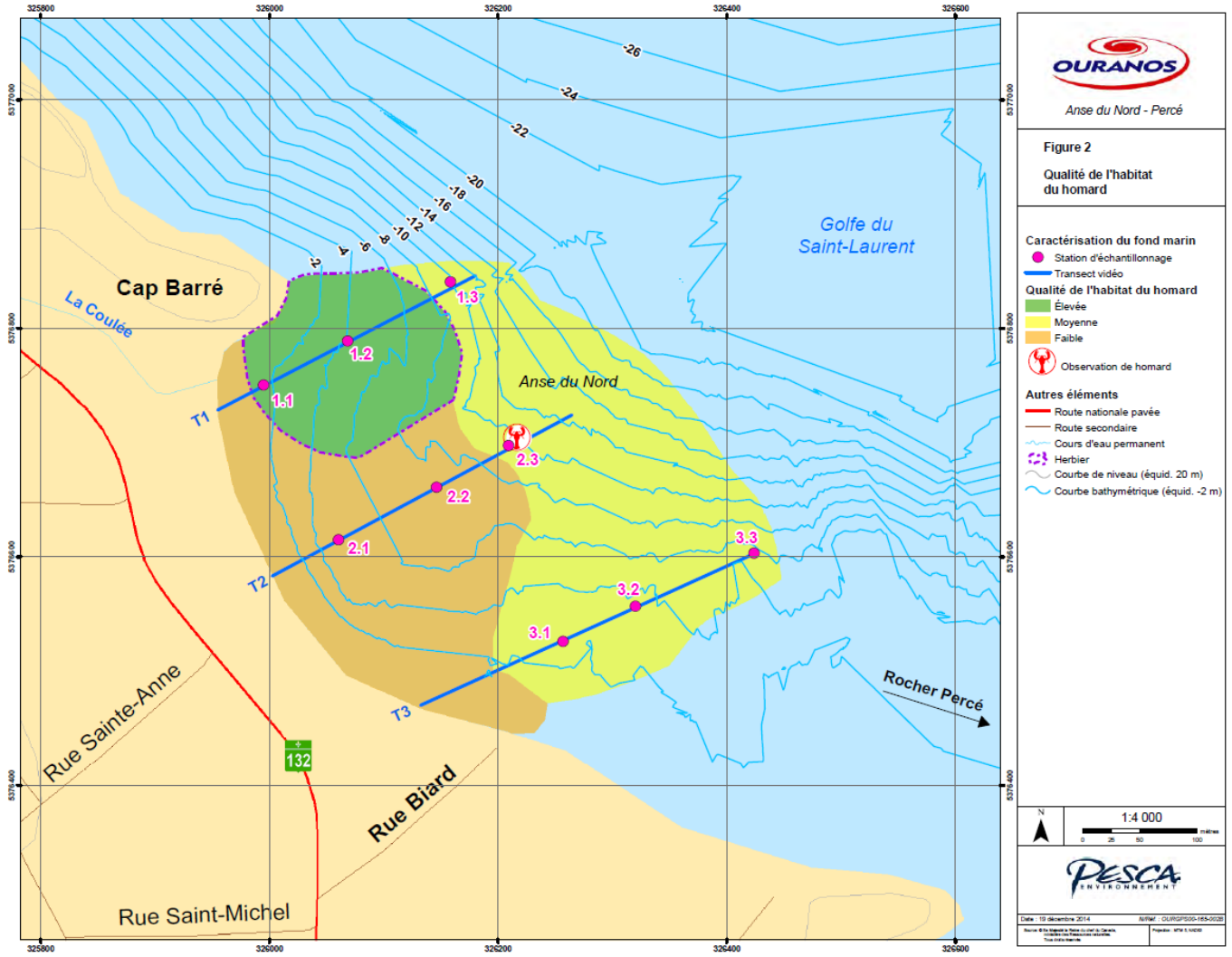
> *"The quality of the lobster habitat along the Anse du Nord beach is weak. The seabed is dominated by sand and gravel, with the presence of a few pebbles. There is little algae. The seabed has little shelter for juvenile and adult lobster. Individuals at the post larvae stage can find refuge, but risk being dislodged by waves, tides and currents, which churn surface sediments." (Castonguay and Bélanger, 2014, p. 7)*

Figure 7.9 illustrates the quality of the lobster habitat in Anse du Nord. The immediate area contiguous with Cap Barré has a high quality habitat. Indeed, as can be seen in Figure 7.10, the seabed in this region is rocky and covered by rich marine flora. This type of seabed is favourable for lobster at all stages of development.

By contrast, in the southernmost region, the quality of the lobster habitat diminishes as the seabed becomes more gravelly and devoid of vegetation. The first 100 metres from the shore are particularly inhospitable for lobster within the entire southern portion of the segment.

In this context, it is assumed that the adaptation options envisaged should not disturb commercial lobster fishing, since the area for intervention within the segment is not a favourable environment for the American lobster's life cycle. The encroachment of beach replenishment should not substantially modify the seabed type (see Figure 7.11). Furthermore, the proposed submerged rock berm to reduce wave energy along with beach replenishment could improve the lobster habitat by creating gaps where they could take refuge.

It is important to point out that this assumption is based on a summary characterization of the seabed and that an environmental and social impact study will be required to detail the potential impacts on commercial fishing.



Source: Castonguay and Bélanger (2014)

Figure 7.9 – Quality of the lobster habitat in the sector surveyed of Anse du Nord

Source: Castonguay and Bélanger (2014)

Figure 7.10 – High quality lobster habitat, section 1

Source: Castonguay and Bélanger (2014)

Figure 7.11 – Low quality lobster habitat, section 2

7.2.3 Environmental impacts

a) Changes to natural habitats

As illustrated in the preceding section, the seabed in this sector is mainly composed of pebbles, sand and gravel. Depending on the preliminary design for the works proposed by BPR, encroachment by beach replenishment will not substantially change the existing characteristics of the seabed.

Also, placing riprap or rubblemound revetment would not lead to significant encroachment that would change the substrate of Anse du Nord. As a result, no impact on natural habitats was taken into account in this analysis.

b) Disruption of capelin spawning sites

According to the report from the Pesca Environnement company (Castonguay and Bélanger, 2014), the Anse du Nord is a beach frequented by capelin, a small pelagic fish that migrates to the coast to spawn on the beaches or on favourable seabeds. If the work is carried out in May or June, the capelin spawn could be disturbed. However, provided that the work is done outside this period, only the riprap would have a permanent impact on capelin spawn since the coast's granulometry would no longer be favourable to spawning.

Capelin is a key species of the ecosystem in the north of the Gulf of St. Lawrence, being a species at the bottom of the marine food chain. It is an essential prey for cod and several other fish (Greenland halibut, Canadian plaice, salmon), whales, dolphins and certain sea birds, including the Northern gannet, which is grouped into a large colony on Île Bonaventure.

To compensate for the loss of an environment favourable to capelin, beach replenishment is planned in an area where the capelin has already spawned, but where the beach has deteriorated over the years. Certain beaches of Barachois or Anse-à-Beaufils have seen marked thinning between 1934 and 2001 and would be locations favourable to beach replenishment (Bernatchez *et al.*, 2008). Maintenance of the replenishment also needs to be taken into account in order for this compensatory option to endure.

The 536 m of shoreline at Anse du Nord are likely to be capelin spawning grounds. The area affected would be equivalent to the area covered by the beach replenishment, which requires 11,800 m^3 of pebbles. Consequently, it was estimated that the same quantity of sand would be needed to recreate a beach of the same surface area in the area of Percé. Given that the price of sand is $15 per m^3 and adding costs for mobilization (5%), contingencies (20%), engineering (10%) and supervision (10%), the discounted cost for compensation for the loss of capelin spawning area amounts to about $230,000. In addition, it is assumed that maintenance costs will be incurred 4 times during the 2015-2064 time horizon for a discounted cost of $98,054. The need to make such compensation should be confirmed as part of an environmental and social impact study.

7.2.4 Social impacts

The social impacts identified relate to recreational use of the coastline and quality of life. The next sections describe how these impacts are handled in the cost-benefit analysis.

a) Changes to recreational use of the coastline

By transforming the Anse du Nord coastline, it is highly likely that the recreational use of the coast will be modified. The non-intervention option assumes that the coast will retain its natural character, since no intervention is planned. In doing so, the beach is expected to be maintained and the use of the coast should not be significantly altered by this option. This assumption also applies to the planned retreat option.

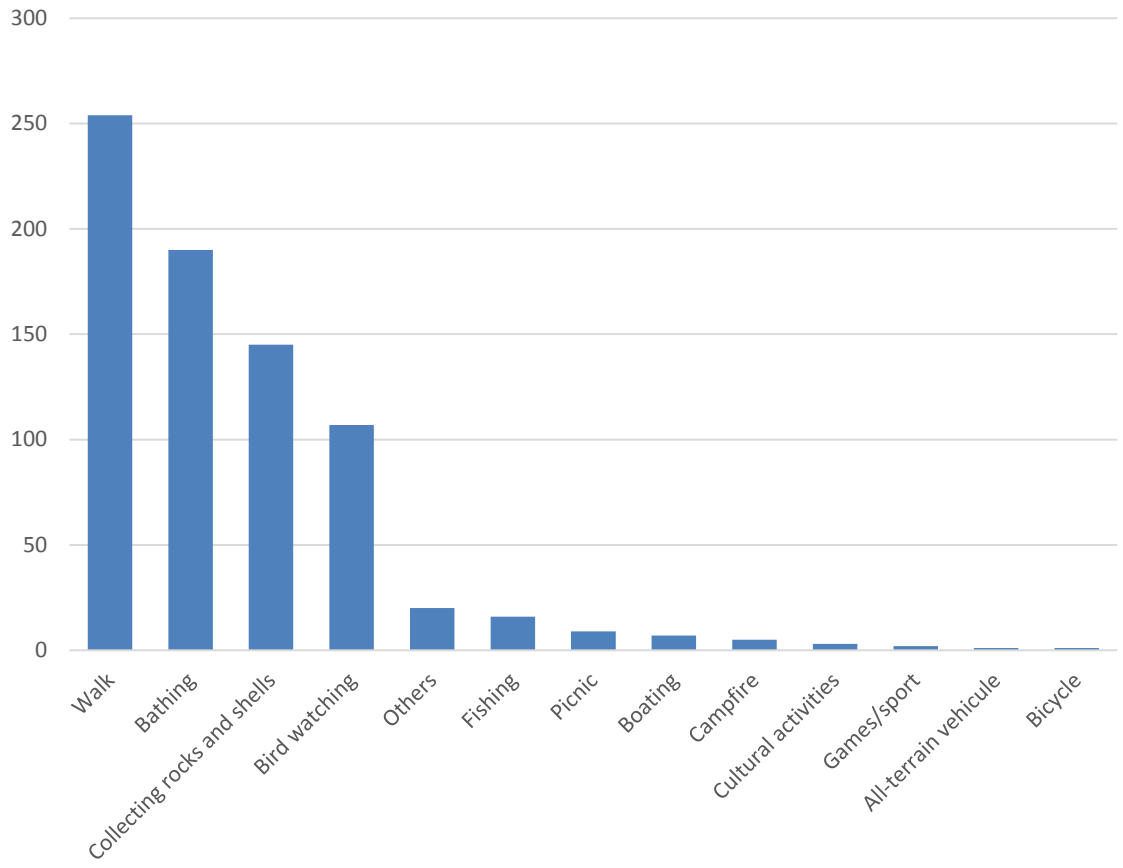
On the other hand, for the other options considered, potential gains and losses could occur in terms of time spent on the beach and the value given to the coast by users.

A survey conducted for Ouranos in August 2014 on the use made of the coast allows a certain number of observations to be made on the uses of the shoreline in Anse du Nord[28]. All data presented in this section come from internal databases from this survey (Ouranos, 2014).

[28] Survey conducted by Pesca Environnement on behalf of Ouranos in Anse du Nord in August 2014.

First, it was noted that Anse du Nord is frequented much less than Anse du Sud. The estimated tourist traffic for 2014 is around 3,500 people, while there are over 300,000 visitors to Anse du Sud.

Figure 7.12 shows the distribution of activities on the beach of Anse du Nord. Users of this segment, mainly tourists, typically use the beach for walking, swimming, collecting agates and bird watching. These activities are representative of activities on the beaches of Gaspésie. Furthermore, these activities, with the exception of walking, require a beach and a rich natural environment that are home to birds that are interesting to watch.



Source: Results of database analysis for the survey on use of the coast in Anse du Nord conducted in 2014, analysis conducted by Ouranos.

Figure 7.12 – Main activities carried out on the beach of Anse du Nord

In order to assess the value of the coastline's recreational use, survey respondents were asked about the amount they would be willing to pay to have access to the site as well

as the expenses incurred to use the site, essentially being the value of the time spent at the site.

On average, the 329 respondents said they would be ready to pay $3.29 per day to have access to Anse du Nord. This average takes into consideration that 177 respondents said they would not be prepared to pay since Anse du Nord is a natural environment to which access should remain free or else that they were lodging in Anse du Nord and therefore they had already paid to have access to the beach.

Regarding the time spent on the Anse du Nord beach, each visitor spent two hours on average, considering all the visits made on the site during a stay. Given that the average salary in Quebec in 2012 was $22.06 (Statistics Canada, 2014), the value of the time spent at Anse du Nord was estimated at $43.38 per visitor on average. Finally, since tourist traffic estimated from the survey is 3,427 visitors per year and the total use value of the coast is on average $46.67 per visitor, the recreational use value of Anse du Nord was established at about $160,000 per year for the purposes of the analysis.

It is expected that each adaptation option will affect the recreational use of the coast differently. Since the survey did not specifically ask visitors about how the value placed on use of the coast would be changed in the event of implementating each option, the following assumptions were made in the analysis. These assumptions are based on the results obtained from a survey conducted across Quebec for Anse du Sud.

Rubblemound revetment will allow the beach to continue being used as it is currently, both as a place for walking and collecting of agates. Over time, the width of the beach will narrow, but this should not affect activities during the study period. It is therefore assumed that the value of use of the coast will not be changed by this development.

Regarding beach replenishment, this should allow the recreational use of the Anse du Nord to be improved, by favouring a pebble beach compatible with what is currently found in this segment. Making the shoreline uniform by removing incongruous structures should improve the natural character of the site and incidentally increase the total value placed on use of the coast. In this perspective, it is assumed that the use value given per visit could double.

Finally, given that the top layer of riprap can be built up with finer material that is suitable for walking, it is assumed that the use value of the coast will be the same as for rubblemound revetment, planned retreat and the non-intervention option.

b) Quality of life

Impacts on quality of life are related to anxiety, insecurity and the inconvenience of living in an environment where there is a risk of a disaster. In the Anse du Nord, most of the exposed buildings are motels, hotels, a campground and restaurants. From this, the impact of the fall and winter high tides remains somewhat limited since the hotel establishments are all closed in the fall and winter. However, some private residences are located along the Anse du Nord and their owners have to live with the risk that a major storm could damage their property.

Unfortunately, under this cost-benefit analysis, the value given to the reduction of this insecurity was not estimated. A deeper study of risk aversion of residents and merchants would be necessary to properly quantify the value of these items.

7.2.5 Estimated cost of adaptation options

The non-intervention option includes the costs for demolition of residential and commercial buildings when they become at-risk. These costs amount to $29,960 at the discount rate of 4% from 2015 to 2064.

The cost of implementing each of the adaptation options was estimated from the preliminary design by the BPR consulting engineering firm and its collaborators hired by the City of Percé (see Table 6.2). Construction costs include costs of 5% for mobilization, 20% for contingencies, 10% for engineering and 10% for jobsite supervision. These costs also include moving certain buildings when necessary. All the works are designed to protect the coast throughout the study period.

The discounted construction cost for beach replenishment is $1.5 million while the discounted construction cost of riprap is $1.4 million. Regarding rubblemound revetment, the discounted construction costs are higher than those for beach replenishment or for riprap and reach $2.4 million. Planned retreat represents the least costly option, with its discounted costs amounting to some $410,000.

For maintenance frequency and costs, the option of beach replenishment requires partial replenishment every 10 years. The volume required for these maintenance activities equals 25% of the initial replenishment material. Riprap, meanwhile, needs partial replenishment equivalent to 50% of the initial quantity of material every 13 years, or 3 times over the next 50 years. Finally, rubblemound revetment does not require any maintenance.

Table 7.2 presents the discounted costs of implementing the different adaptation options under study.

Table 7.2 – Costs for implementing adaptation options under study, discounted at the rate of 4% over 50 years

Adaptation options	Study and construction costs	Maintenance costs[29]	Discounted total cost
Beach replenishment	$1,665,771	$424,905	$2,090,616
Planned retreat	$407,104	-	$407,104
Rubblemound revetment	$4,404,206	-	$4,444,513
Riprap	$1,436,605	$235,221	$1,671,826

7.3 COST-BENEFIT ANALYSIS

This section presents all the estimated costs and benefits over a 50-year time horizon for non-intervention and each of the adaptation options considered. Table 7.3 in Section 7.3.3 provides a summary of the costs, benefits and NPV of each option. The results are then interpreted to compare the economic viability of the different options

7.3.1 Calculation of costs over 50 years

The total costs of non-intervention and implementation of each adaptation option are presented in this section in 2012 dollars discounted at a rate of 4% over the 2015-2064 time horizon.

[29] In addition to the material, maintenance costs include the costs for mobilization (5%), contingencies (20%) as well as engineering and supervisory costs (20%).

a) Cost of non-intervention

The first cost item concerns the costs related to erosion. The discounted economic losses associated with the fact that the land will erode and that 8 buildings will be affected by 2064 amounts to close to $220,000 for the 2015-2064 period.

Demolition costs of affected buildings must be added, since these buildings must be destroyed once the erosion reaches them. These discounted costs amount to $29,958. Finally, non-intervention involves the loss of business income in the order of $170,400.

In total, the discounted costs related to inaction are around $420,150 on the time horizon considered. Annual costs related to non-intervention are presented in Appendix 4.

b) Cost of beach replenishment

The costs for beach replenishment include preparatory studies, construction and maintenance costs for a total of $2.1 million. This option does not include additional costs, since no negative impacts are expected following its implementation. Annual costs related to beach replenishment over the 2015-2064 time horizon are presented in Appendix 5.

c) Cost of planned retreat

The costs of planned retreat come from the need to relocate eight buildings between 2015 and 2026. Moving costs amount to $407,104 in discounted dollars. To these costs are added the economic loss of a piece of land which becomes non-buildable and which incurs a discounted cost of $88,784. In addition, the costs relating to the loss of land due to erosion are in the order of $38,952.

Thus, the total costs for planned retreat are $534,840 and the annual costs over the 2015-2064 period are presented in Appendix 5.

d) Cost of rubblemound revetment

The cost of the rubblemound revetment option includes costs associated with the preliminary studies, mobilization (5%), rock purchase, transportation and installation, and engineering fees (10%). In total, the discounted cost of rubblemound revetment is

$4.4 million for the period extending from 2015 to 2064. Refer to Appendix 5 for discounted annualized costs.

e) Cost of riprap

Riprap protection requires an initial investment of $1.44 million. Over the study period, riprap maintenance represents a cost of $235,221. Overall, the discounted cost of this option from 2015 to 2064 is $1.67 million.

The discounted cost of restoring a deteriorated beach that meets capelin spawning criteria must also be added. The discounted cost of this compensation has been estimated at $326,821.

The total discounted cost of riprap is almost $2.0 million; see Appendix 5 for the annualized costs associated with this option.

7.3.2 Calculation of benefits over 50 years

This section assesses all the benefits of each adaptation option in the study over the 2015–2064 time horizon. Avoidance of the losses associated with non-intervention is not counted as a benefit of the adaptation options in order to avoid double-counting. The sole benefit of protecting the coast in Anse du Nord is an increase in the value of the coast's recreational use resulting from beach replenishment.

Benefits of beach replenishment

As stated earlier, beach replenishment should enhance the perceived value of the Anse du Nord coast among users. Assuming that the value of the coast's recreational use doubles, it is estimated that beach replenishment would lead to a benefit of $159,955 per year from the first year onward. Over the study period, this represents a discounted economic benefit of just under $3 million.

Given the importance of this benefit, we conducted a sensitivity analysis for the main assumptions used to calculate the value of the coast's recreational use for the beach replenishment option.

7.3.3 Net present value

This section presents the net present value (NPV) for the costs and benefits of each adaptation option and of non-intervention. In addition, Table 7.3 compares the NPV for every option to the NPV for non-intervention to determine whether any options are more advantageous than non-intervention. Finally, Figure 7.13 breaks down the various components of the NPV.

The non-intervention option has a negative NPV as no benefit is associated with it. The NPV for non-intervention is -$0.4 million over the study period. Only the NPV for beach replenishment is positive at $0.9 million. As planned retreat, rubblemound revetment and riprap provide no specific benefits, their NPV is negative and estimated at -$0.1 million, -$4 million and -$1.6 million respectively.

When the NPV for each adaptation option is compared with non-intervention, only beach replenishment has a positive NPV of approximately $1.3 million. In other words, although planned retreat, rubblemound revetment and riprap would avert certain costs, they are not economically advantageous options.

Table 7.3 and Figure 7.13 show that in most cases, the cost of measures is the factor with the greatest impact on the NPV. With beach replenishment, the social benefit of increased recreational use of the coast is also a significant factor.

The cost of erosion is relatively low given the type and number of threatened buildings. This is due partly to the fact that the buildings are only threatened from 2036 onward and partly to the fact that the assessed value of hotels appears to be quite low in Percé. The effect of assessed value was therefore examined as part of a sensitivity analysis.

Table 7.3 – Discounted costs and benefits for adaptation options in Anse du Nord

Discounted costs and benefits	Non-intervention	Beach replenishment	Rubblemound revetment	Riprap	Planned retreat
Erosion	($219,783)	- $	- $	- $	($38 952)
Cost of measures	($29,958)	($2,090,616)	($4,404,206)	($1,671,826)	($407,204)
Economic impacts	($170,406)	- $	- $	- $	($88,784)
Environmental impacts	- $	- $	- $	($326,821)	- $
Social impacts	- $	$2,969,768	- $	- $	- $
NPV (net benefits or costs)	($420,147)	$879,152	($4,404,206)	($1,998,647)	($534,840)
NPV compared with non-intervention		$1,299,299	($3,984,059)	($1,578,500)	($114,693)

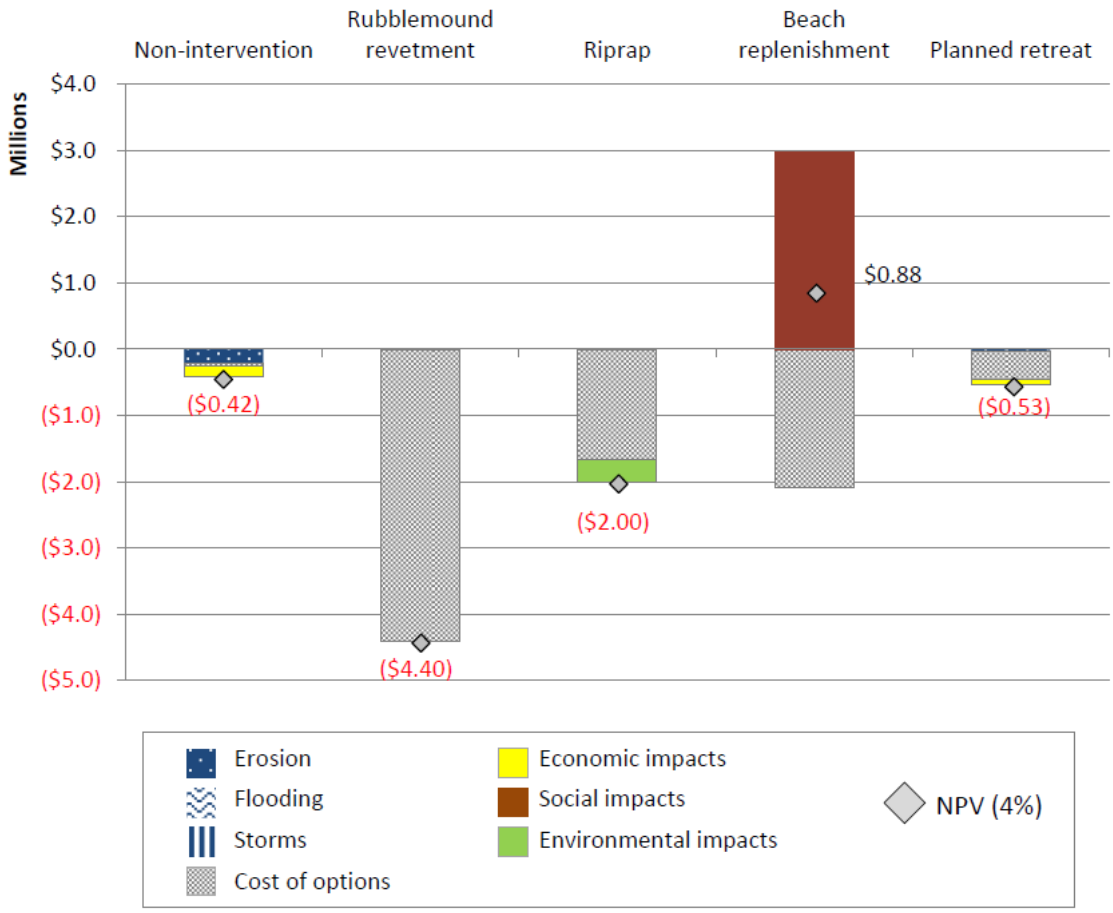


Figure 7.13 – Breakdown of costs and benefits by option and for non-intervention ($M)

Figure 7.14 illustrates net cumulative benefits compared to non-intervention discounted at 4% over the 2015–2064 period. The chart shows the point at which an option becomes more beneficial than non-intervention. For Anse du Nord, none of the adaptation options is advantageous at the outset of the study period due to the high construction costs, whereas losses from erosion happen later on. Only beach replenishment becomes more advantageous than non-intervention as of 2036, that is, as the gains associated with the coast's recreational use compound and offset the initial investments.

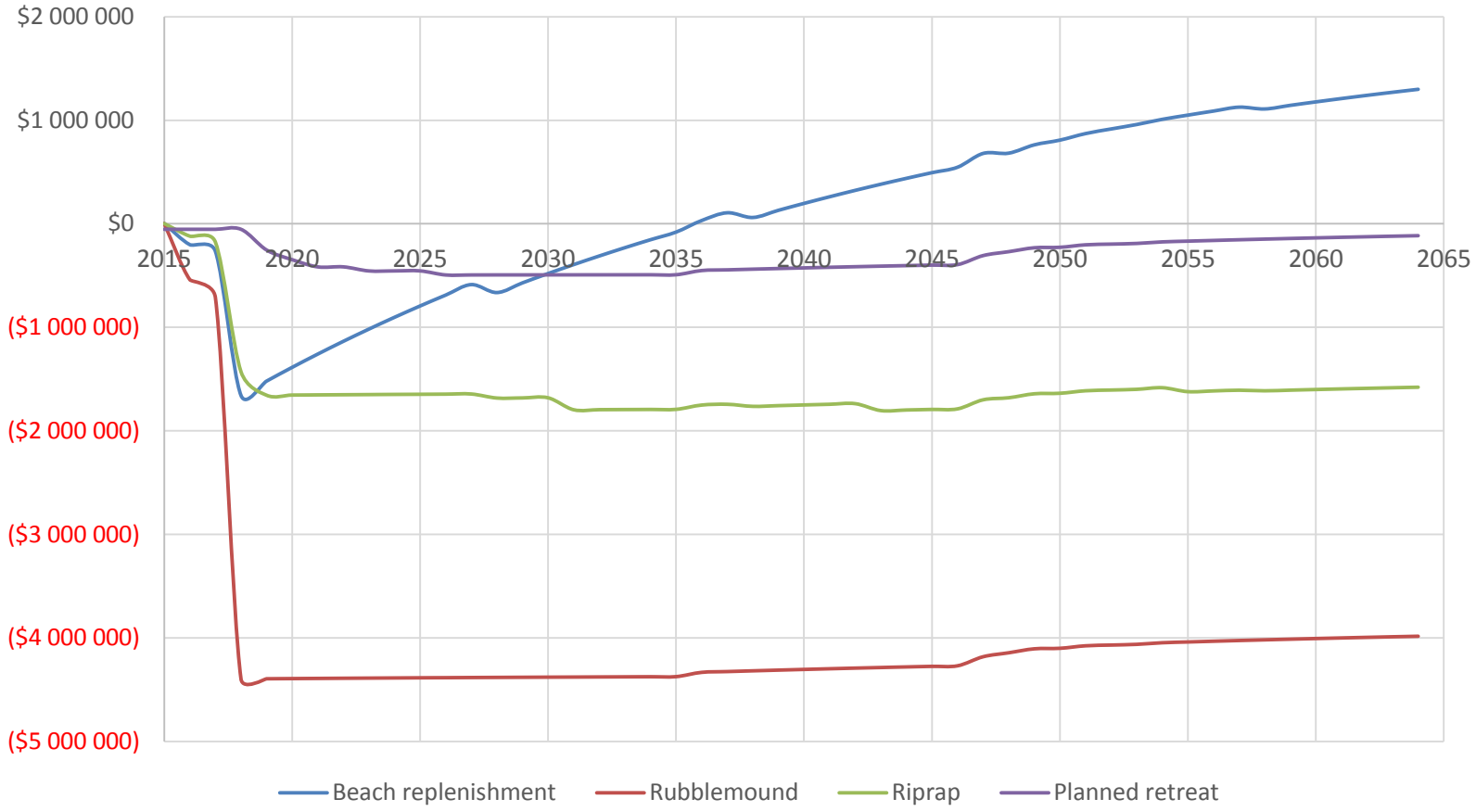


Figure 7.14 – Cumulative value of the net discounted benefits compared with non-intervention from 2015 to 2064.

7.3.4 Interpretation of results

As indicated in Figure 7.15, beach replenishment alone shows a net economic gain for the Gaspésie region over the non-intervention option, with a net benefit in the order of $1.3 million. This outcome is due to the expected increase in coastal use, which offsets the construction costs and the relatively high cost of maintenance every ten years. The pebbles must be topped up regularly in order to maintain the long-term integrity of the option and its capacity to protect infrastructures over the next 50 years.

Rubblemound revetment and riprap would not lead to net economic gains for the Gaspésie region. High construction costs, in particular for the rubblemound revetment option, undermine the feasibility of these options, especially as they generate no direct benefit. The net costs compared to non-intervention are in the order of -$4 million for rubblemound revetment and -$1.6 million for riprap.

Planned retreat is also a less viable option than inaction, but to a lesser degree than rubblemound revetment or riprap. In short, the benefits of preserving threatened buildings do not offset the high cost of moving them. The net costs of this option compared to non-intervention are in the order of -$0.1 million.

Finally, the benefit-cost ratios in Figure 7.15 show that beach replenishment with pebbles is also the most beneficial option based on this indicator. The ratio for this option is $1.62 in benefits for every dollar invested. For all other options, the ratio is less than one, which means costs exceed benefits.

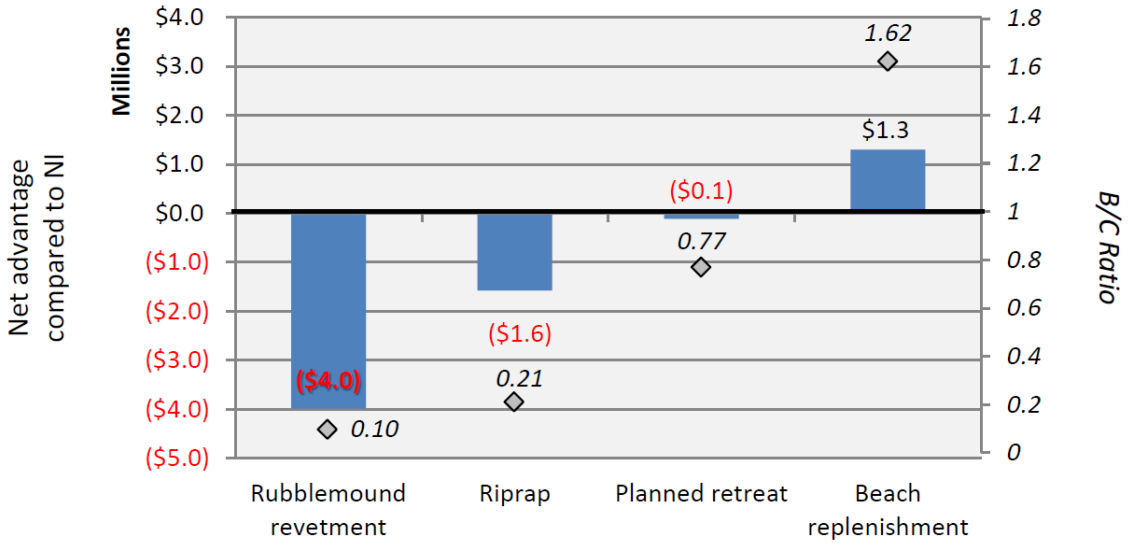


Figure 7.15 – Net benefits or costs of adaptation options and benefit-cost ratio

7.4 SENSITIVITY ANALYSIS

The purpose of the sensitivity analysis is to test the robustness of the NPV when critical assumptions in the cost-benefit analysis are modified. This section presents the NPV values obtained when certain assumptions are altered. The tested assumptions concern the discount rate, the assessed value of hotel buildings, and the value of the coast's recreational use. Table 7.4 presents the variations used in the sensitivity analyses.

Table 7.4 – Sensitivity analyses

Parameter	Variation
Discount rate	± 2%
Assessed value of hotel buildings	+ 20%
Value of the coast's recreational use	Identification of critical value

7.4.1 Discount rate

The use of a lower discount rate gives greater weight to impacts that happen later in the 50-year time horizon. Conversely, using a higher rate heightens the relative value of initial costs and lessens the value of costs and benefits incurred later in time. Table 7.5 illustrates the values obtained with a 2% and 6% discount rate.

At a rate of 2%, the NPV for beach replenishment increases while those for other options and for non-intervention decline. At this rate, the most beneficial option is still beach replenishment, but planned retreat also becomes more beneficial than non-intervention.

At a rate of 6%, the NPV for beach replenishment declines while those for rubblemound revetment, riprap, planned retreat and non-intervention increase. The most beneficial option at this rate remains beach replenishment.

In short, the economic viability of beach replenishment is robust to variations in the discount rate.

Table 7.5 – Impact of varying discount rates of 2% and 6%

Adaptation options		Discount rate	
		2%	**6%**
Non-intervention	NPV	($781,723)	($235,899)
Beach replenishment	NPV	$2,067,096	$225,119
	Net benefits compared with non-intervention	$2,848,819	$461,018
Planned retreat	NPV	($601,352)	($481,640)
	Net benefits compared with non-intervention	$180,370	$245,741
Rubblemound revetment	NPV	($4,642,885)	($4,282,690)
	Net benefits compared with non-intervention	($3,861,162)	($3,946,791)
Riprap	NPV	($2,305,271)	($1,788,639)
	Net benefits compared with non-intervention	($1,523,548)	($1,552,740)

7.4.2 Variation in the assessed value

The property assessment roll published by the City of Percé in 2013 was used to estimate property and building losses. Significant differences in the roll were observed from one property to the next as certain assessments were disputed and did not follow the increases in property market value, among other reasons. It should also be noted that there have been few real estate transactions in Percé in the past few years, a fact that limits the information available for property assessment.

Based on the expected revenues method that is generally accepted for assessing the value of a business, we can assume that the assessed value of motels in Anse du Nord is probably underestimated. That is why a sensitivity analysis was conducted based on a 20% increase in the assessed value of threatened buildings in Anse du Nord.

Applying a 20% increase in the value of the Percé property assessment roll, particularly in Anse du Nord, the loss of the properties and the eight buildings affected would be valued at $846,697 rather than a non-discounted $705,581. This means the total cost of non-intervention would increase by 11% to approximately $464,103 discounted at 4% over 50 years. As this increase in the value of lost property and buildings is relatively low, it has little impact on the results of the analysis. The optimal option continues to be beach replenishment.

7.4.3 Variation in the assumptions as to the use value of the coast

It is difficult to accurately assess the value of a coast's recreational use. Given that value of recreational use is an important variable when choosing the optimal option for Anse du Nord, a sensitivity analysis was carried out in order to determine the minimum value of coastal use required for beach replenishment to be more economically advantageous than non-intervention.

Keeping all other assumptions constant, the analysis indicates that the minimum value at which beach replenishment becomes the most beneficial option is $89,972 per year for a total discounted value of $1.67 million.

Assuming that tourism traffic estimated in 2014 remain steady at 3,427 visitors a year in Anse du Nord, this means that every visitor would have to attach an additional use value

of $26.30 to use of the Anse du Nord coast after beach replenishment. The value would thus increase on average from $46.67 per visitor to $73. In terms of time spent on the beach in Anse du Nord, this enhanced value represents just over one hour more spent in Anse du Nord per trip.

Thus for any use value higher than $73, beach replenishment is more advantageous than non-intervention.

7.5 CONCLUSION

The Anse du Nord segment offers an exceptional natural environment that few enjoy and that would benefit from development.

Economically, the value of the built environment that will be threatened by 2064 is too low to warrant protective options like beach replenishment, rubblemound revetment or riprap. These options must lead to more benefits in terms of recreational use in order for any of the options considered to be more feasible than non-intervention.

Beach replenishment is the only adaptation option that both protects the coast and increases its value as a natural milieu.

The economic viability of beach replenishment was shown to be robust in all sensitivity analyses. This cost-benefit analysis indicates that beach replenishment is the most economically beneficial option to counter coastal erosion in Anse du Nord in Percé.

8 GENERAL CONCLUSION

The purpose of this cost-benefit analysis was essentially to compare various adaptation options for the coastal environment in order to determine the most economically beneficial for Percé. The CBA provides two economic indicators, net present value and benefit-cost ratio, that can help local, regional and national decision-makers choose the options best suited to the challenges that coastal communities will face over the next 50 years.

The results of the cost-benefit analysis clearly indicate that the most economically feasible option for society as a whole is beach replenishment with pebbles in both Anse du Sud and Anse du Nord. The benefits of this option outweigh the costs in both cases, as the option favour the development of the coast and improves the tourism offering of Percé, particularly in Anse du Sud.

For the two other segments consisting of rocky cliffs (Côte Surprise and Mont-Joli Sud), planned retreat through the relocation of at-risk buildings is the only option that would preserve Percé's tourism infrastructures and heritage assets. Planned retreat is economically beneficial for the Côte Surprise segment, where buildings are threatened with collapse in the short term.

This option must also be considered for the Mont-Joli Sud segment, where the historic Frederick-James Villa is in jeopardy. Although the CBA indicates that the options of planned retreat and non-intervention are almost equivalent in the Mont-Joli Sud segment, the loss of the Frederick-James Villa would be a strike against Percé's heritage

value as well as the beauty of the landscape, two aspects that are difficult to reliably assess in monetary terms.

Figure 8.1 summarizes the analysis results by presenting the net present value for each option in comparison with non-intervention. All positive results confirm that the option is preferable to non-intervention. The benefit-cost ratios are also shown so that the scope of the anticipated benefit can be compared with the cost. Any ratio higher than one means that the value of the benefit is greater than one dollar for every dollar invested.

In conclusion, this cost-benefit analysis has demonstrated that the most economically viable options are those that improve coastal use and the tourism offering while costing less to build.

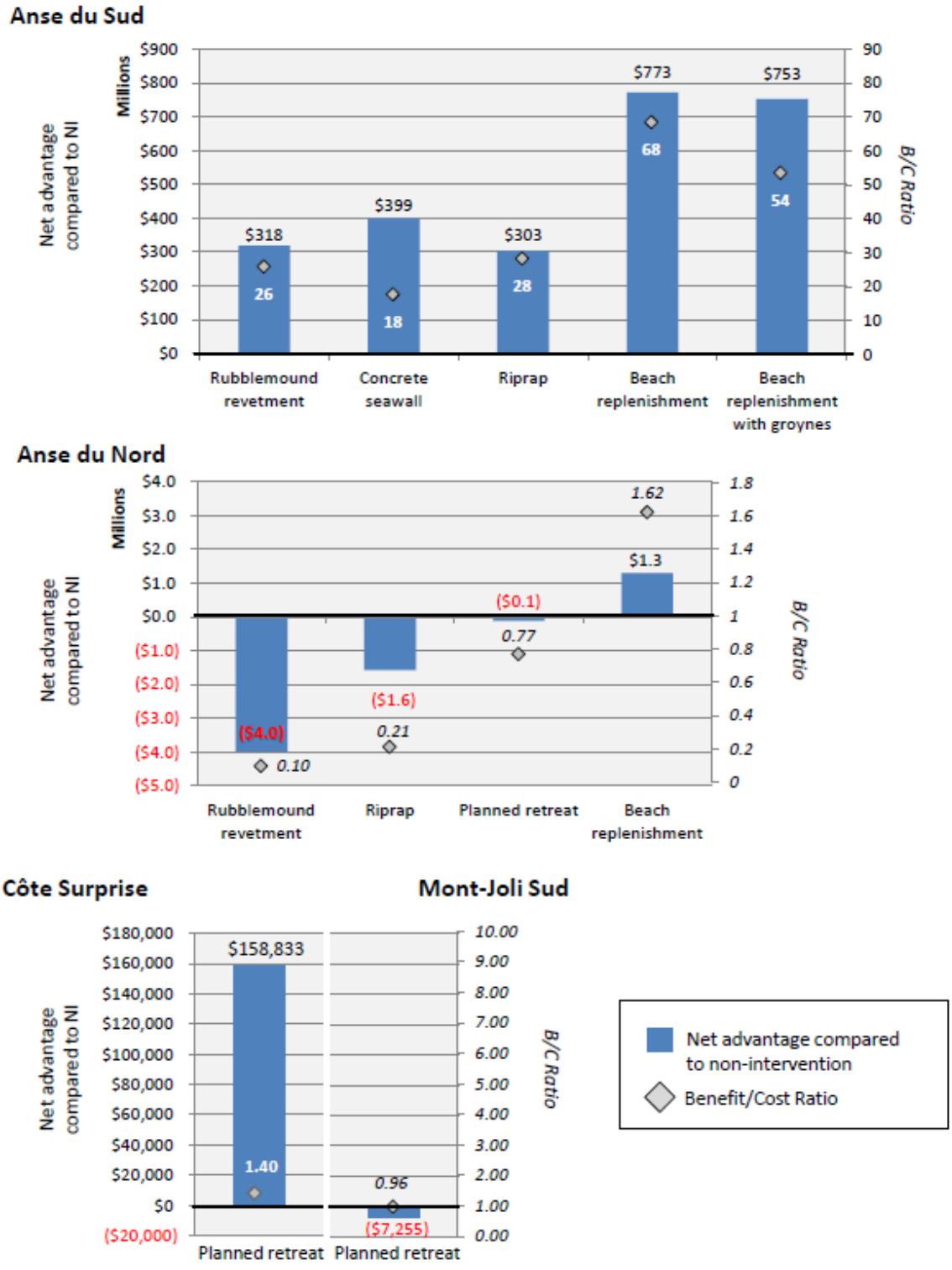


Figure 8.1 – NPV compared with non-intervention and benefit-cost ratio for the 4 segments in Percé

9 GLOSSARY

Beach replenishment: soft engineering option to erosion hazard involving the artificial addition of sediment (sand or gravel) of suitable quality to a beach area that has a sediment deficit in order to widen the beach and increase the dissipating capacity of the shore. This method requires frequent replenishment.

Benefit-cost ratio: indicator used within the cost-benefit analysis built by dividing the discounted stream of benefits by the discounted stream of costs of a program, project or activity.

Cost-benefit analysis (CBA): economic evaluation of a program, project or activity consisting of comparing various options, in which direct and indirect impacts are quantified in common monetary units (discounted).

End-toe effect or lateral scouring: geographical process by which the waves' energy that are hitting a rigid and impermeable structure, like a seawall or rubblemound revetment, is reoriented towards the extremities of the structure, which in turn can accelerate the erosion of the neighbouring littoral zones.

Eustatic adjustment: net variation of the mean sea level (relative to the continents assumed stable) caused by the ocean's thermal variations, the ice sheet meltdown and glacial/deglacial dynamics.

Fetch: length of water over which a given wind blows without meeting any obstacle from its origin point to its end point; the longer the fetch, the more important is the wave height; on the contrary, at a position sheltered by a coast (or under a wind originating from the land and going seaward), the wave height is small, even though the wind is powerful, because the fetch is shorter.

Flooding (coastal): natural phenomena of inundation by the sea occurring when the water elevates above the superior limit of the shoreline or of the protection structure.

Flood proofing: adaptation option to flooding hazard consisting of rising buildings above the extreme water levels in order to reduce or eliminate damages caused by flooding events.

Geodetic zero: an altitude benchmark based on the three-dimensional positioning of a point in a given geodetic system, itself dependent on a projection of the earth's surface; in North America, the most common geodetic benchmark systems are WGS84 (*World Geodetic System*), used by the worldwide GPS system, and NAD83 (*North American Datum*).

Gross domestic product (GDP): measure of growth expressing the total value added of goods and services produced in a given year and region.

Groyne: rigid structure made out of stone or wood, built out at an angle from the shore to protect the shore from erosion by currents, tides, and waves and to trap sediment.

Hydrographic zero (also chart datum): the common benchmark for measuring sea depth (or benchmark plane for charted depths) on a nautical chart as well as for tide predictions**.**

Isostatic adjustment: also called post-glacial rebound, a phenomena that uplifts the continent following the glacial meltdown, because terrestrial masses that were formerly compressed under the weight of continental ice sheet are raising during the post-glacial period.

Littoral or longshore drift: a geographical process that consists of the transportation of sediments (clay, silt, sand and shingle) along a coast at an angle to the shoreline, which is dependent on prevailing wind direction and swash and backwash; term referred to for both the current and the transportation (transit) of sediments.

Mean (relative) sea level (MSL): mean level of the ocean's surface, by reference to a vertical datum sufficiently stable (a standardised geodetic reference point); this level is generally considered as the difference between eustatic level (measure of the sea level relative to the continents assumed stables) and isostatic level (see isostatic rebound).

Median diameter (D_{50}): Particle Size Distribution D50 is also known as the median diameter or the medium value of the particle size distribution, it is the value of the particle diameter at 50% in the cumulative distribution. It is one of an important parameter characterizing particle size. For example, if D50=5.8 um, then 50% of the particles in the sample are larger than 5.8 um, and 50% smaller than 5.8 um. D50 is usually used to represent the particle size of group of particles.

Net present value (NPV): indicator used within the cost-benefit analysis built by calculating the difference between the discounted benefits and costs arising from the implementation of a project or a program. Discounting is the operation used to bring future costs and benefits occurring at different periods to their present value.

Non-intervention (NI): reference option based on limited or no intervention to protect or reduce the risk of flooding and erosion on infrastructures in the study area leading to an accumulation of erosion and flooding damages over time.

Planned retreat: Adaptation option to erosion and flooding consisting of the relocation of buildings at risk to secure areas. Thresholds used to trigger the intervention are the followings: when the building is closer than 5 meters of the shoreline or when the elevation of the ground floor is inferior to the 20 year extreme water-level.

Return period: probability of having an extreme water level occurrence. For example, a 20-year return period means the extreme water level would occur on average once within the next 20 years. Return periods can also be expressed as an annual probability. A 20-year return period has a 5% probability of occurring every year.

Riprap: adaptation option against erosion built by dumping a layer of stones of various size with a soft slope in order to absorb and dissipate wave energy before it reaches the shore.

Runup: The advance of water up the foreshore of a beach or structure, following the breaking of a wave; its height depends on the significant wave height, their period and the inclination and morphology of the intertidal zone over which the waves break.

Submersion: natural flooding by the sea that happens when the upper edge of the wash exceeds the upper level of the shoreline or the protective structure.

Subsidence (geological): a slow downward shift of the lithosphere (the continent) resulting in a progressive deposit of sediments relative to a vertical datum such as a constant water depth.

Surge: an abnormally high level at high tide or low level at low tide due to unusual weather conditions like an atmospheric depression, storm or hurricane, the effects of which are compounded with those of the astronomical tides (those induced by the moon and the sun).

Revegetation: a method of protecting against erosion by planting vegetation suited to the coastal environment, the roots of which retain sediment; this may take the form of bundles of soil and plants or the planting of plants and bushes with deep, dense root systems along the coast (e.g.,

rose bushes, raspberry bushes, dune grasses). However, this method can be damaged by bad weather and trampling under foot.

Zero geodetic: vertical reference based on the three dimensions positioning of a point in a selected geodetic datum system, the later depending of a given projection of the Earth surface; in North America, the most popular datum systems are WGS84 (world geodetic system), notably used by the worldwide GPS system, and the NAD83 (North American datum).

Zero relative chart datum: also called hydrographic zero, it consists in the vertical reference level to measure water depth on the hydrographic charts, which also applies for tides predictions.

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APPENDIX 1
ANNUALIZED COSTS OF ADAPTATION OPTIONS OVER THE 2015-2064 PERIOD IN CÔTE SURPRISE

NON-INTERVENTION OPTION

Year	Erosion (costs per year)	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	-$172	$0	$0	$0	$0	-$172
2016	-$166	$0	$0	$0	$0	-$166
2017	-$160	$0	$0	$0	$0	-$160
2018	-$154	$0	$0	$0	$0	-$154
2019	-$148	$0	$0	$0	$0	-$148
2020	-$142	$0	$0	$0	$0	-$142
2021	-$137	$0	$0	$0	$0	-$137
2022	-$131	$0	$0	$0	$0	-$131
2023	-$126	$0	$0	$0	$0	-$126
2024	-$121	$0	$0	$0	$0	-$121
2025	-$116	$0	$0	$0	$0	-$116
2026	-$112	$0	$0	$0	$0	-$112
2027	-$108	$0	$0	$0	$0	-$108
2028	-$103	$0	$0	$0	$0	-$103
2029	-$99	$0	$0	$0	$0	-$99
2030	-$95	$0	$0	$0	$0	-$95
2031	-$92	$0	$0	$0	$0	-$92
2032	-$88	$0	$0	$0	$0	-$88
2033	-$85	$0	$0	$0	$0	-$85
2034	-$81	$0	$0	$0	$0	-$81
2035	-$78	$0	$0	$0	$0	-$78
2036	-$75	$0	$0	$0	$0	-$75
2037	-$72	$0	$0	$0	$0	-$72
2038	-$59,610	-$35,042	-$12,781	$0	$0	-$107,433
2039	-$67	$0	-$12,289	$0	$0	-$12,356
2040	-$64	$0	-$11,817	$0	$0	-$11,881
2041	-$62	$0	-$11,362	$0	$0	-$11,424
2042	-$59	$0	-$10,925	$0	$0	-$10,984
2043	-$57	$0	-$10,505	$0	$0	-$10,562
2044	-$55	$0	-$10,101	$0	$0	-$10,155
2045	-$52	$0	-$9,712	$0	$0	-$9,765
2046	-$50	$0	-$9,339	$0	$0	-$9,389
2047	-$41,881	-$12,433	-$17,959	$0	$0	-$72,273
2048	-$47	$0	-$17,269	$0	$0	-$17,315
2049	-$45	$0	-$16,604	$0	$0	-$16,649
2050	-$43	$0	-$15,966	$0	$0	-$16,009
2051	-$41	$0	-$15,352	$0	$0	-$15,393
2052	-$40	$0	-$14,761	$0	$0	-$14,801
2053	-$38	$0	-$14,193	$0	$0	-$14,232
2054	-$37	$0	-$13,648	$0	$0	-$13,684
2055	-$35	$0	-$13,123	$0	$0	-$13,158
2056	-$34	$0	-$12,618	$0	$0	-$12,652
2057	-$33	$0	-$12,133	$0	$0	-$12,165
2058	-$27,205	-$8,276	-$17,499	$0	$0	-$52,980
2059	-$30	$0	-$16,826	$0	$0	-$16,856
2060	-$29	$0	-$16,179	$0	$0	-$16,208
2061	-$28	$0	-$15,557	$0	$0	-$15,584
2062	-$27	$0	-$14,958	$0	$0	-$14,985
2063	-$26	$0	-$14,383	$0	$0	-$14,409
2064	-$25	$0	-$13,830	$0	$0	-$13,854
TOTAL	**-$132,381**	**-$55,751**	**-$371,687**	**$0**	**$0**	**-$559,819**

PLANNED RETREAT

Year	Erosion (costs per year)	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	-$172	-$397,152	$0	$0	$0	-$397,324
2016	-$166	$0	$0	$0	$0	-$166
2017	-$160	$0	$0	$0	$0	-$160
2018	-$154	$0	$0	$0	$0	-$154
2019	-$148	$0	$0	$0	$0	-$148
2020	-$142	$0	$0	$0	$0	-$142
2021	-$137	$0	$0	$0	$0	-$137
2022	-$131	$0	$0	$0	$0	-$131
2023	-$126	$0	$0	$0	$0	-$126
2024	-$121	$0	$0	$0	$0	-$121
2025	-$116	$0	$0	$0	$0	-$116
2026	-$112	$0	$0	$0	$0	-$112
2027	-$108	$0	$0	$0	$0	-$108
2028	-$103	$0	$0	$0	$0	-$103
2029	-$99	$0	$0	$0	$0	-$99
2030	-$95	$0	$0	$0	$0	-$95
2031	-$92	$0	$0	$0	$0	-$92
2032	-$88	$0	$0	$0	$0	-$88
2033	-$85	$0	$0	$0	$0	-$85
2034	-$81	$0	$0	$0	$0	-$81
2035	-$78	$0	$0	$0	$0	-$78
2036	-$75	$0	$0	$0	$0	-$75
2037	-$72	$0	$0	$0	$0	-$72
2038	-$69	$0	$0	$0	$0	-$69
2039	-$67	$0	$0	$0	$0	-$67
2040	-$64	$0	$0	$0	$0	-$64
2041	-$62	$0	$0	$0	$0	-$62
2042	-$59	$0	$0	$0	$0	-$59
2043	-$57	$0	$0	$0	$0	-$57
2044	-$55	$0	$0	$0	$0	-$55
2045	-$52	$0	$0	$0	$0	-$52
2046	-$50	$0	$0	$0	$0	-$50
2047	-$48	$0	$0	$0	$0	-$48
2048	-$47	$0	$0	$0	$0	-$47
2049	-$45	$0	$0	$0	$0	-$45
2050	-$43	$0	$0	$0	$0	-$43
2051	-$41	$0	$0	$0	$0	-$41
2052	-$40	$0	$0	$0	$0	-$40
2053	-$38	$0	$0	$0	$0	-$38
2054	-$37	$0	$0	$0	$0	-$37
2055	-$35	$0	$0	$0	$0	-$35
2056	-$34	$0	$0	$0	$0	-$34
2057	-$33	$0	$0	$0	$0	-$33
2058	-$31	$0	$0	$0	$0	-$31
2059	-$30	$0	$0	$0	$0	-$30
2060	-$29	$0	$0	$0	$0	-$29
2061	-$28	$0	$0	$0	$0	-$28
2062	-$27	$0	$0	$0	$0	-$27
2063	-$26	$0	$0	$0	$0	-$26
2064	-$25	$0	$0	$0	$0	-$25
TOTAL	-$3,835	-$397,152	$0	$0	$0	**-$400,986**

APPENDIX 2
ANNUALIZED COSTS OF ADAPTATION OPTIONS OVER THE 2015-2064 IN ANSE DU SUD

NON-INTERVENTION OPTION

Year	Erosion (costs per year)	Damages Infrastructures	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total Costs
2015	-$1,749	-$29,813	$0	$0	$0	$0	-$31,563
2016	-$1,737	-$28,667	$0	$0	$0	$0	-$30,404
2017	-$1,778	-$27,564	$0	$0	$0	$0	-$29,342
2018	-$1,799	-$26,504	$0	$0	$0	$0	-$28,303
2019	-$1,812	-$25,485	$0	$0	$0	$0	-$27,297
2020	-$1,787	-$60,464	-$286,647	$0	$0	$0	-$348,898
2021	-$1,748	$0	$0	-$32,928,811	$0	$0	-$32,930,559
2022	-$1,711	$0	$0	-$31,662,318	$0	$0	-$31,664,029
2023	-$1,673	$0	$0	-$30,444,537	$0	$0	-$30,446,210
2024	-$1,634	$0	$0	-$29,273,593	$0	$0	-$29,275,227
2025	-$1,590	$0	$0	-$28,147,686	$0	$0	-$28,149,275
2026	-$1,534	$0	$0	-$27,065,082	$0	$0	-$27,066,616
2027	-$1,482	$0	$0	-$26,024,118	$0	$0	-$26,025,600
2028	-$1,431	$0	$0	-$25,023,190	$0	$0	-$25,024,620
2029	-$1,377	$0	$0	-$24,060,760	$0	$0	-$24,062,137
2030	-$1,331	$0	$0	-$23,135,346	$0	$0	-$23,136,677
2031	-$1,289	$0	$0	-$22,245,525	$0	$0	-$22,246,814
2032	-$1,248	$0	$0	-$21,389,928	$0	$0	-$21,391,176
2033	-$1,209	$0	$0	-$20,567,238	$0	$0	-$20,568,447
2034	-$1,168	$0	$0	-$19,776,191	$0	$0	-$19,777,359
2035	-$1,128	$0	$0	-$19,015,568	$0	$0	-$19,016,696
2036	-$1,088	$0	$0	-$18,284,200	$0	$0	-$18,285,287
2037	-$1,050	$0	$0	-$17,580,961	$0	$0	-$17,582,011
2038	-$1,023	$0	$0	-$16,904,771	$0	$0	-$16,905,794
2039	-$995	$0	$0	-$16,254,587	$0	$0	-$16,255,582
2040	-$959	$0	$0	-$15,629,411	$0	$0	-$15,630,369
2041	-$925	$0	$0	-$15,028,279	$0	$0	-$15,029,204
2042	-$893	$0	$0	-$14,450,269	$0	$0	-$14,451,162
2043	-$870	$0	$0	-$13,894,489	$0	$0	-$13,895,359
2044	-$849	$0	$0	-$13,360,086	$0	$0	-$13,360,935
2045	-$827	$0	$0	-$12,846,236	$0	$0	-$12,847,063
2046	-$806	$0	$0	-$12,352,150	$0	$0	-$12,352,957
2047	-$784	$0	$0	-$11,877,068	$0	$0	-$11,877,852
2048	-$763	$0	$0	-$11,420,257	$0	$0	-$11,421,020
2049	-$125,661	$0	-$13,559	-$10,990,702	$0	$0	-$11,129,923
2050	-$637	$0	$0	-$10,567,983	$0	$0	-$10,568,620
2051	-$618	$0	$0	-$10,161,522	$0	$0	-$10,162,141
2052	-$595	$0	$0	-$9,770,694	$0	$0	-$9,771,290
2053	-$571	$0	$0	-$9,394,899	$0	$0	-$9,395,470
2054	-$549	$0	$0	-$9,033,556	$0	$0	-$9,034,105
2055	-$529	$0	$0	-$8,686,112	$0	$0	-$8,686,641
2056	-$8,526	$0	-$2,007	-$8,356,237	$0	$0	-$8,366,770
2057	-$472	$0	$0	-$8,034,843	$0	$0	-$8,035,315
2058	-$449	$0	$0	-$7,725,810	$0	$0	-$7,726,259
2059	-$428	$0	$0	-$7,428,664	$0	$0	-$7,429,092
2060	-$409	$0	$0	-$7,142,946	$0	$0	-$7,143,355
2061	-$396	$0	$0	-$6,868,217	$0	$0	-$6,868,613
2062	-$80	$0	$0	-$6,604,055	$0	$0	-$6,604,135
2063	-$77	$0	$0	-$6,350,053	$0	$0	-$6,350,130
2064	-$35,182	$0	-$9,113	-$6,113,119	$0	$0	-$6,157,414
TOTAL	**-$219,224**	**-$198,496**	**-$311,327**	**-$703,872,066**	**$0**	**$0**	**-$704,601,113**

BEACH REPLENISHMENT

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total Costs
2015	$0	$0	$0	$0	$0
2016	-$661,545	$0	$0	$0	-$661,545
2017	-$212,034	$0	$0	$0	-$212,034
2018	-$7,883,323	-$634,743	-$605,407	$0	-$9,123,473
2019	$0	-$11,967	-$291,061	$0	-$303,028
2020	$0	-$11,507	-$279,866	$0	-$291,373
2021	$0	-$11,064	$0	$0	-$11,064
2022	$0	-$10,639	$0	$0	-$10,639
2023	$0	-$10,230	$0	$0	-$10,230
2024	$0	-$9,836	$0	$0	-$9,836
2025	$0	-$9,458	$0	$0	-$9,458
2026	$0	-$9,094	$0	$0	-$9,094
2027	$0	-$8,744	$0	$0	-$8,744
2028	-$256,756	-$8,408	$0	$0	-$265,164
2029	$0	-$8,085	$0	$0	-$8,085
2030	$0	-$7,774	$0	$0	-$7,774
2031	$0	-$7,475	$0	$0	-$7,475
2032	$0	-$7,187	$0	$0	-$7,187
2033	$0	-$6,911	$0	$0	-$6,911
2034	$0	-$6,645	$0	$0	-$6,645
2035	$0	-$6,389	$0	$0	-$6,389
2036	$0	-$6,144	$0	$0	-$6,144
2037	$0	-$5,907	$0	$0	-$5,907
2038	-$173,455	-$5,680	$0	$0	-$179,135
2039	$0	-$5,462	$0	$0	-$5,462
2040	$0	-$5,252	$0	$0	-$5,252
2041	$0	-$5,050	$0	$0	-$5,050
2042	$0	-$4,855	$0	$0	-$4,855
2043	$0	-$4,669	$0	$0	-$4,669
2044	$0	-$4,489	$0	$0	-$4,489
2045	$0	-$4,316	$0	$0	-$4,316
2046	$0	-$4,150	$0	$0	-$4,150
2047	$0	-$3,991	$0	$0	-$3,991
2048	-$117,180	-$3,837	$0	$0	-$121,018
2049	$0	-$3,690	$0	$0	-$3,690
2050	$0	-$3,548	$0	$0	-$3,548
2051	$0	-$3,411	$0	$0	-$3,411
2052	$0	-$3,280	$0	$0	-$3,280
2053	$0	-$3,154	$0	$0	-$3,154
2054	$0	-$3,033	$0	$0	-$3,033
2055	$0	-$2,916	$0	$0	-$2,916
2056	$0	-$2,804	$0	$0	-$2,804
2057	$0	-$2,696	$0	$0	-$2,696
2058	-$79,163	-$2,592	$0	$0	-$81,755
2059	$0	-$2,493	$0	$0	-$2,493
2060	$0	-$2,397	$0	$0	-$2,397
2061	$0	-$2,305	$0	$0	-$2,305
2062	$0	-$2,216	$0	$0	-$2,216
2063	$0	-$2,131	$0	$0	-$2,131
2064	$0	-$2,049	$0	$0	-$2,049
TOTAL	**$9,383,457**	**-$894,673**	**$1,176,334**	**$0**	**-$11,454,463**

BEACH REPLENISHMENT WITH GROYNES

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total Costs
2015	$0	$0	$0	$0	$0
2016	-$1,063,443	$0	$0	$0	-$1,063,443
2017	-$340,847	$0	-$15,202	$0	-$356,050
2018	-$10,608,221	-$634,743	-$766,202	$0	-$12,009,166
2019	$0	-$11,967	-$291,061	$0	-$303,028
2020	$0	-$11,507	-$279,866	$0	-$291,373
2021	$0	-$11,064	$0	$0	-$11,064
2022	$0	-$10,639	$0	$0	-$10,639
2023	$0	-$10,230	$0	$0	-$10,230
2024	$0	-$9,836	$0	$0	-$9,836
2025	$0	-$9,458	$0	$0	-$9,458
2026	$0	-$9,094	$0	$0	-$9,094
2027	$0	-$8,744	$0	$0	-$8,744
2028	$0	-$8,408	-$29,626	$0	-$38,034
2029	$0	-$8,085	$0	$0	-$8,085
2030	$0	-$7,774	$0	$0	-$7,774
2031	$0	-$7,475	$0	$0	-$7,475
2032	$0	-$7,187	$0	$0	-$7,187
2033	$0	-$6,911	$0	$0	-$6,911
2034	$0	-$6,645	$0	$0	-$6,645
2035	$0	-$6,389	$0	$0	-$6,389
2036	$0	-$6,144	$0	$0	-$6,144
2037	$0	-$5,907	$0	$0	-$5,907
2038	$0	-$5,680	-$20,014	$0	-$25,694
2039	$0	-$5,462	$0	$0	-$5,462
2040	$0	-$5,252	$0	$0	-$5,252
2041	$0	-$5,050	$0	$0	-$5,050
2042	$0	-$4,855	$0	$0	-$4,855
2043	$0	-$4,669	$0	$0	-$4,669
2044	$0	-$4,489	$0	$0	-$4,489
2045	$0	-$4,316	$0	$0	-$4,316
2046	$0	-$4,150	$0	$0	-$4,150
2047	$0	-$3,991	$0	$0	-$3,991
2048	$0	-$3,837	-$13,521	$0	-$17,358
2049	$0	-$3,690	$0	$0	-$3,690
2050	$0	-$3,548	$0	$0	-$3,548
2051	$0	-$3,411	$0	$0	-$3,411
2052	$0	-$3,280	$0	$0	-$3,280
2053	$0	-$3,154	$0	$0	-$3,154
2054	$0	-$3,033	$0	$0	-$3,033
2055	$0	-$2,916	$0	$0	-$2,916
2056	$0	-$2,804	$0	$0	-$2,804
2057	$0	-$2,696	$0	$0	-$2,696
2058	$0	-$2,592	-$9,134	$0	-$11,727
2059	$0	-$2,493	$0	$0	-$2,493
2060	$0	-$2,397	$0	$0	-$2,397
2061	$0	-$2,305	$0	$0	-$2,305
2062	$0	-$2,216	$0	$0	-$2,216
2063	$0	-$2,131	$0	$0	-$2,131
2064	$0	-$2,049	$0	$0	-$2,049
TOTAL	**-$12,012,511**	**-$894,673**	**-$1,424,626**	**$0**	**-$14,331,810**

RIPRAP

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total Costs
2015	$0.00	$0.00	$0.00	$0.00	$0.00
2016	-$659,938	$0	$0	$0	-$659,938
2017	-$211,519	$0	-$15,202	$0	-$226,721
2018	-$7,872,425	-$634,743	-$463,499	$0	-$8,970,667
2019	$0	-$17,977,810	-$145,530	$0	-$18,123,341
2020	$0	-$17,286,356	-$139,933	$0	-$17,426,289
2021	$0	-$16,621,496	$0	$0	-$16,621,496
2022	$0	-$15,982,208	$0	$0	-$15,982,208
2023	$0	-$15,367,508	$0	$0	-$15,367,508
2024	$0	-$14,776,450	$0	$0	-$14,776,450
2025	$0	-$14,208,125	$0	$0	-$14,208,125
2026	$0	-$13,661,658	$0	$0	-$13,661,658
2027	$0	-$13,136,210	$0	$0	-$13,136,210
2028	$0	-$12,630,971	-$29,626	$0	-$12,660,597
2029	$0	-$12,145,164	$0	$0	-$12,145,164
2030	-$308,210	-$11,678,043	$0	$0	-$11,986,253
2031	$0	-$11,228,887	$0	$0	-$11,228,887
2032	$0	-$10,797,007	$0	$0	-$10,797,007
2033	$0	-$10,381,737	$0	$0	-$10,381,737
2034	$0	-$9,982,440	$0	$0	-$9,982,440
2035	$0	-$9,598,500	$0	$0	-$9,598,500
2036	$0	-$9,229,327	$0	$0	-$9,229,327
2037	$0	-$8,874,353	$0	$0	-$8,874,353
2038	$0	-$8,533,031	-$20,014	$0	-$8,553,046
2039	$0	-$8,204,838	$0	$0	-$8,204,838
2040	$0	-$7,889,267	$0	$0	-$7,889,267
2041	$0	-$7,585,834	$0	$0	-$7,585,834
2042	-$192,507	-$7,294,071	$0	$0	-$7,486,578
2043	$0	-$7,013,530	$0	$0	-$7,013,530
2044	$0	-$6,743,779	$0	$0	-$6,743,779
2045	$0	-$6,484,403	$0	$0	-$6,484,403
2046	$0	-$6,235,003	$0	$0	-$6,235,003
2047	$0	-$5,995,195	$0	$0	-$5,995,195
2048	$0	-$5,764,610	-$13,521	$0	-$5,778,131
2049	$0	-$5,542,895	$0	$0	-$5,542,895
2050	$0	-$5,329,706	$0	$0	-$5,329,706
2051	$0	-$5,124,718	$0	$0	-$5,124,718
2052	$0	-$4,927,613	$0	$0	-$4,927,613
2053	$0	-$4,738,089	$0	$0	-$4,738,089
2054	-$120,239	-$4,555,855	$0	$0	-$4,676,095
2055	$0	-$4,380,630	$0	$0	-$4,380,630
2056	$0	-$4,212,144	$0	$0	-$4,212,144
2057	$0	-$4,050,139	$0	$0	-$4,050,139
2058	$0	-$3,894,364	-$9,134	$0	-$3,903,498
2059	$0	-$3,744,581	$0	$0	-$3,744,581
2060	$0	-$3,600,559	$0	$0	-$3,600,559
2061	$0	-$3,462,076	$0	$0	-$3,462,076
2062	$0	-$3,328,919	$0	$0	-$3,328,919
2063	$0	-$3,200,883	$0	$0	-$3,200,883
2064	$0	-$3,077,773	$0	$0	-$3,077,773
TOTAL	**-$9,364,838**	**-$391,113,497**	**-$836,459**	**$0**	**-$401,314,794**

RUBBLEMOUND REVETMENT

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Somme des coûts
2015	$0	$0	$0	$0	$0
2016	-$931,579	$0	$0	$0	-$931,579
2017	-$298,583	$0	-$15,202	$0	-$313,786
2018	-$10,157,747	-$634,743	-$302,057	$0	-$11,094,547
2019	$0	-$17,207,462	-$67,914	$0	-$17,275,376
2020	$0	-$16,545,636	-$65,302	$0	-$16,610,938
2021	$0	-$15,909,266	$0	$0	-$15,909,266
2022	$0	-$15,297,371	$0	$0	-$15,297,371
2023	$0	-$14,709,010	$0	$0	-$14,709,010
2024	$0	-$14,143,279	$0	$0	-$14,143,279
2025	$0	-$13,599,307	$0	$0	-$13,599,307
2026	$0	-$13,076,257	$0	$0	-$13,076,257
2027	$0	-$12,573,324	$0	$0	-$12,573,324
2028	$0	-$12,089,734	-$29,626	$0	-$12,119,360
2029	$0	-$11,624,745	$0	$0	-$11,624,745
2030	$0	-$11,177,639	$0	$0	-$11,177,639
2031	$0	-$10,747,730	$0	$0	-$10,747,730
2032	$0	-$10,334,356	$0	$0	-$10,334,356
2033	$0	-$9,936,880	$0	$0	-$9,936,880
2034	$0	-$9,554,693	$0	$0	-$9,554,693
2035	$0	-$9,187,204	$0	$0	-$9,187,204
2036	$0	-$8,833,850	$0	$0	-$8,833,850
2037	$0	-$8,494,087	$0	$0	-$8,494,087
2038	$0	-$8,167,391	-$20,014	$0	-$8,187,405
2039	$0	-$7,853,261	$0	$0	-$7,853,261
2040	$0	-$7,551,212	$0	$0	-$7,551,212
2041	$0	-$7,260,781	$0	$0	-$7,260,781
2042	$0	-$6,981,520	$0	$0	-$6,981,520
2043	$0	-$6,713,000	$0	$0	-$6,713,000
2044	$0	-$6,454,808	$0	$0	-$6,454,808
2045	$0	-$6,206,546	$0	$0	-$6,206,546
2046	$0	-$5,967,833	$0	$0	-$5,967,833
2047	$0	-$5,738,301	$0	$0	-$5,738,301
2048	$0	-$5,517,597	-$13,521	$0	-$5,531,118
2049	$0	-$5,305,382	$0	$0	-$5,305,382
2050	$0	-$5,101,329	$0	$0	-$5,101,329
2051	$0	-$4,905,124	$0	$0	-$4,905,124
2052	$0	-$4,716,465	$0	$0	-$4,716,465
2053	$0	-$4,535,062	$0	$0	-$4,535,062
2054	$0	-$4,360,637	$0	$0	-$4,360,637
2055	$0	-$4,192,920	$0	$0	-$4,192,920
2056	$0	-$4,031,654	$0	$0	-$4,031,654
2057	$0	-$3,876,590	$0	$0	-$3,876,590
2058	$0	-$3,727,491	-$9,134	$0	-$3,736,625
2059	$0	-$3,584,126	$0	$0	-$3,584,126
2060	$0	-$3,446,275	$0	$0	-$3,446,275
2061	$0	-$3,313,726	$0	$0	-$3,313,726
2062	$0	-$3,186,275	$0	$0	-$3,186,275
2063	$0	-$3,063,726	$0	$0	-$3,063,726
2064	$0	-$2,945,890	$0	$0	-$2,945,890
TOTAL	**-$11,387,909**	**-$374,381,495**	**-$522,770**	**$0**	**-$386,292,174**

SEAWALL WITH DEFLECTOR AND RIPRAP BERM

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total Costs
2015	$0	$0	$0	$0	$0
2016	-$2,291,827	$0	$0	$0	-$2,291,827
2017	-$734,560	$0	-$15,202	$0	-$749,762
2018	-$19,380,334	-$634,743	-$294,145	$0	-$20,309,222
2019	$0	-$13,000,950	-$64,110	$0	-$13,065,061
2020	$0	-$12,500,914	-$61,645	$0	-$12,562,558
2021	$0	-$12,020,109	$0	$0	-$12,020,109
2022	$0	-$11,557,797	$0	$0	-$11,557,797
2023	$0	-$11,113,267	$0	$0	-$11,113,267
2024	$0	-$10,685,833	$0	$0	-$10,685,833
2025	$0	-$10,274,840	$0	$0	-$10,274,840
2026	$0	-$9,879,654	$0	$0	-$9,879,654
2027	$0	-$9,499,667	$0	$0	-$9,499,667
2028	$0	-$9,134,295	-$29,626	$0	-$9,163,921
2029	$0	-$8,782,976	$0	$0	-$8,782,976
2030	$0	-$8,445,169	$0	$0	-$8,445,169
2031	$0	-$8,120,355	$0	$0	-$8,120,355
2032	$0	-$7,808,034	$0	$0	-$7,808,034
2033	$0	-$7,507,725	$0	$0	-$7,507,725
2034	$0	-$7,218,966	$0	$0	-$7,218,966
2035	$0	-$6,941,314	$0	$0	-$6,941,314
2036	$0	-$6,674,340	$0	$0	-$6,674,340
2037	$0	-$6,417,635	$0	$0	-$6,417,635
2038	$0	-$6,170,803	-$20,014	$0	-$6,190,817
2039	$0	-$5,933,464	$0	$0	-$5,933,464
2040	$0	-$5,705,254	$0	$0	-$5,705,254
2041	$0	-$5,485,821	$0	$0	-$5,485,821
2042	$0	-$5,274,828	$0	$0	-$5,274,828
2043	$0	-$5,071,950	$0	$0	-$5,071,950
2044	$0	-$4,876,875	$0	$0	-$4,876,875
2045	$0	-$4,689,303	$0	$0	-$4,689,303
2046	$0	-$4,508,945	$0	$0	-$4,508,945
2047	$0	-$4,335,524	$0	$0	-$4,335,524
2048	$0	-$4,168,773	-$13,521	$0	-$4,182,294
2049	$0	-$4,008,436	$0	$0	-$4,008,436
2050	$0	-$3,854,265	$0	$0	-$3,854,265
2051	$0	-$3,706,024	$0	$0	-$3,706,024
2052	$0	-$3,563,485	$0	$0	-$3,563,485
2053	$0	-$3,426,428	$0	$0	-$3,426,428
2054	$0	-$3,294,642	$0	$0	-$3,294,642
2055	$0	-$3,167,925	$0	$0	-$3,167,925
2056	$0	-$3,046,082	$0	$0	-$3,046,082
2057	$0	-$2,928,925	$0	$0	-$2,928,925
2058	$0	-$2,816,274	-$9,134	$0	-$2,825,408
2059	$0	-$2,707,956	$0	$0	-$2,707,956
2060	$0	-$2,603,803	$0	$0	-$2,603,803
2061	$0	-$2,503,657	$0	$0	-$2,503,657
2062	$0	-$2,407,363	$0	$0	-$2,407,363
2063	$0	-$2,314,772	$0	$0	-$2,314,772
2064	$0	-$2,225,742	$0	$0	-$2,225,742
TOTAL	**-$22,406,721**	**-$283,015,900**	**-$507,397**	**$0**	**-$305,930,018**

APPENDIX 3
ANNUALIZED BENEFITS FOR ADAPTATION OPTIONS OVER THE 2015-2064 PERIOD IN ANSE-DU-SUD

TOURISM TRAFFIC

Year	Beach Nourishment	Beach nourishment with groynes
2015	$0	$0
2016	$0	$0
2017	$0	$0
2018	$0	$0
2019	$3,653,680	$2,875,060
2020	$3,513,154	$2,764,481
2021	$3,378,033	$2,658,155
2022	$3,248,109	$2,555,918
2023	$3,123,181	$2,457,614
2024	$3,003,059	$2,363,090
2025	$2,887,557	$2,272,202
2026	$2,776,497	$2,184,810
2027	$2,669,708	$2,100,779
2028	$2,567,027	$2,019,979
2029	$2,468,296	$1,942,288
2030	$2,373,361	$1,867,584
2031	$2,282,078	$1,795,754
2032	$2,194,306	$1,726,687
2033	$2,109,909	$1,660,276
2034	$2,028,759	$1,596,419
2035	$1,950,730	$1,535,018
2036	$1,875,702	$1,475,979
2037	$1,803,559	$1,419,211
2038	$1,734,192	$1,364,626
2039	$1,667,492	$1,312,140
2040	$1,603,358	$1,261,673
2041	$1,541,690	$1,213,147
2042	$1,482,394	$1,166,488
2043	$1,425,379	$1,121,623
2044	$1,370,557	$1,078,483
2045	$1,317,843	$1,037,003
2046	$1,267,157	$997,119
2047	$1,218,420	$958,768
2048	$1,171,558	$921,892
2049	$1,126,498	$886,435
2050	$1,083,171	$852,341
2051	$1,041,511	$819,559
2052	$1,001,453	$788,037
2053	$962,935	$757,728
2054	$925,899	$728,585
2055	$890,288	$700,562
2056	$856,046	$673,618
2057	$823,121	$647,709
2058	$791,462	$622,797
2059	$761,022	$598,844
2060	$731,752	$575,811
2061	$703,607	$553,665
2062	$676,545	$532,370
2063	$650,524	$511,894
2064	$625,504	$492,206
TOTAL	**$79,358,083**	**$62,446,427**

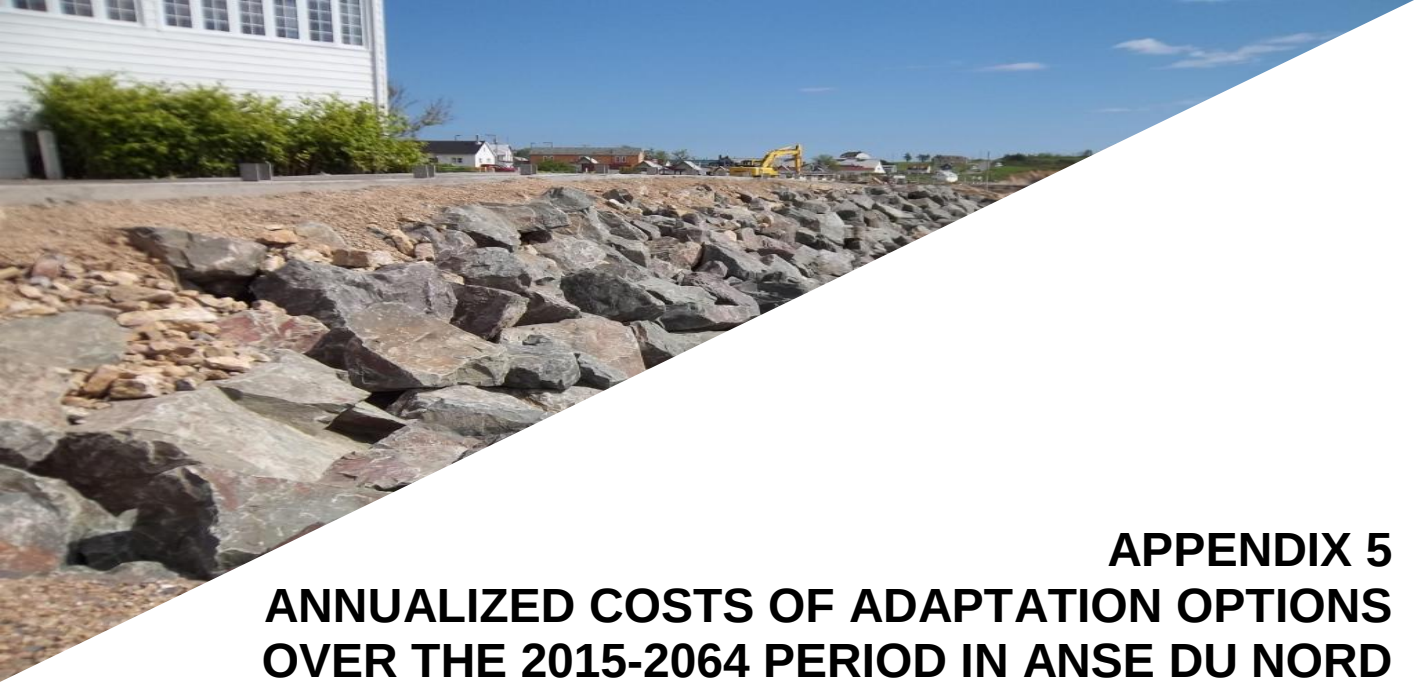
APPENDIX 4
ANNUALIZED COSTS OF ADAPTATION OPTIONS OVER THE 2015-2064 PERIOD IN MONT JOLI

NON-INTERVENTION OPTION

Year	Erosion (costs per year)	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	-$732	$0	$0	$0	$0	-$732
2016	-$702	$0	$0	$0	$0	-$702
2017	-$669	$0	$0	$0	$0	-$669
2018	-$640	$0	$0	$0	$0	-$640
2019	-$613	$0	$0	$0	$0	-$613
2020	-$586	$0	$0	$0	$0	-$586
2021	-$553	$0	$0	$0	$0	-$553
2022	-$526	$0	$0	$0	$0	-$526
2023	-$500	$0	$0	$0	$0	-$500
2024	-$477	$0	$0	$0	$0	-$477
2025	-$458	$0	$0	$0	$0	-$458
2026	-$439	$0	$0	$0	$0	-$439
2027	-$420	$0	$0	$0	$0	-$420
2028	-$402	$0	$0	$0	$0	-$402
2029	-$385	$0	$0	$0	$0	-$385
2030	-$370	$0	$0	$0	$0	-$370
2031	-$353	$0	$0	$0	$0	-$353
2032	-$337	$0	$0	$0	$0	-$337
2033	-$322	$0	$0	$0	$0	-$322
2034	-$308	$0	$0	$0	$0	-$308
2035	-$293	$0	$0	$0	$0	-$293
2036	-$281	$0	$0	$0	$0	-$281
2037	-$269	$0	$0	$0	$0	-$269
2038	-$258	$0	$0	$0	$0	-$258
2039	-$248	$0	$0	$0	$0	-$248
2040	-$238	$0	$0	$0	$0	-$238
2041	-$228	$0	$0	$0	$0	-$228
2042	-$62,602	-$5,210	$0	$0	-$126,978	-$194,791
2043	-$210	$0	$0	$0	$0	-$210
2044	-$201	$0	$0	$0	$0	-$201
2045	-$191	$0	$0	$0	$0	-$191
2046	-$183	$0	$0	$0	$0	-$183
2047	-$175	$0	$0	$0	$0	-$175
2048	-$168	$0	$0	$0	$0	-$168
2049	-$161	$0	$0	$0	$0	-$161
2050	-$155	$0	$0	$0	$0	-$155
2051	-$149	$0	$0	$0	$0	-$149
2052	-$143	$0	$0	$0	$0	-$143
2053	-$137	$0	$0	$0	$0	-$137
2054	-$132	$0	$0	$0	$0	-$132
2055	-$127	$0	$0	$0	$0	-$127
2056	-$122	$0	$0	$0	$0	-$122
2057	-$117	$0	$0	$0	$0	-$117
2058	-$112	$0	$0	$0	$0	-$112
2059	-$108	$0	$0	$0	$0	-$108
2060	-$104	$0	$0	$0	$0	-$104
2061	-$100	$0	$0	$0	$0	-$100
2062	-$96	$0	$0	$0	$0	-$96
2063	-$92	$0	$0	$0	$0	-$92
2064	-$88	$0	$0	$0	$0	-$88
TOTAL	**-$77,278**	**-$5,210**	**$0**	**$0**	**-$126,978**	**-$209,467**

PLANNED RETREAT

Year	Erosion (costs per year)	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	-$732	-$201,827	$0	$0	$0	-$202,559
2016	-$702	$0	$0	$0	$0	-$702
2017	-$669	$0	$0	$0	$0	-$669
2018	-$640	$0	$0	$0	$0	-$640
2019	-$613	$0	$0	$0	$0	-$613
2020	-$586	$0	$0	$0	$0	-$586
2021	-$553	$0	$0	$0	$0	-$553
2022	-$526	$0	$0	$0	$0	-$526
2023	-$500	$0	$0	$0	$0	-$500
2024	-$477	$0	$0	$0	$0	-$477
2025	-$458	$0	$0	$0	$0	-$458
2026	-$439	$0	$0	$0	$0	-$439
2027	-$420	$0	$0	$0	$0	-$420
2028	-$402	$0	$0	$0	$0	-$402
2029	-$385	$0	$0	$0	$0	-$385
2030	-$370	$0	$0	$0	$0	-$370
2031	-$353	$0	$0	$0	$0	-$353
2032	-$337	$0	$0	$0	$0	-$337
2033	-$322	$0	$0	$0	$0	-$322
2034	-$308	$0	$0	$0	$0	-$308
2035	-$293	$0	$0	$0	$0	-$293
2036	-$281	$0	$0	$0	$0	-$281
2037	-$269	$0	$0	$0	$0	-$269
2038	-$258	$0	$0	$0	$0	-$258
2039	-$248	$0	$0	$0	$0	-$248
2040	-$238	$0	$0	$0	$0	-$238
2041	-$228	$0	$0	$0	$0	-$228
2042	-$219	$0	$0	$0	$0	-$219
2043	-$210	$0	$0	$0	$0	-$210
2044	-$201	$0	$0	$0	$0	-$201
2045	-$191	$0	$0	$0	$0	-$191
2046	-$183	$0	$0	$0	$0	-$183
2047	-$175	$0	$0	$0	$0	-$175
2048	-$168	$0	$0	$0	$0	-$168
2049	-$161	$0	$0	$0	$0	-$161
2050	-$155	$0	$0	$0	$0	-$155
2051	-$149	$0	$0	$0	$0	-$149
2052	-$143	$0	$0	$0	$0	-$143
2053	-$137	$0	$0	$0	$0	-$137
2054	-$132	$0	$0	$0	$0	-$132
2055	-$127	$0	$0	$0	$0	-$127
2056	-$122	$0	$0	$0	$0	-$122
2057	-$117	$0	$0	$0	$0	-$117
2058	-$112	$0	$0	$0	$0	-$112
2059	-$108	$0	$0	$0	$0	-$108
2060	-$104	$0	$0	$0	$0	-$104
2061	-$100	$0	$0	$0	$0	-$100
2062	-$96	$0	$0	$0	$0	-$96
2063	-$92	$0	$0	$0	$0	-$92
2064	-$88	$0	$0	$0	$0	-$88
TOTAL	**-$14,895**	**-$201,827**	**$0**	**$0**	**$0**	**-$216,721**



APPENDIX 5
ANNUALIZED COSTS OF ADAPTATION OPTIONS OVER THE 2015-2064 PERIOD IN ANSE DU NORD

NON-INTERVENTIO OPTION

Year	Erosion (costs per year)	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	-$2,029	$0	$0	$0	$0	-$2,029
2016	-$1,953	$0	$0	$0	$0	-$1,953
2017	-$1,880	$0	$0	$0	$0	-$1,880
2018	-$1,809	$0	$0	$0	$0	-$1,809
2019	-$1,743	$0	$0	$0	$0	-$1,743
2020	-$1,681	$0	$0	$0	$0	-$1,681
2021	-$1,621	$0	$0	$0	$0	-$1,621
2022	-$1,561	$0	$0	$0	$0	-$1,561
2023	-$1,503	$0	$0	$0	$0	-$1,503
2024	-$1,449	$0	$0	$0	$0	-$1,449
2025	-$1,395	$0	$0	$0	$0	-$1,395
2026	-$1,342	$0	$0	$0	$0	-$1,342
2027	-$1,292	$0	$0	$0	$0	-$1,292
2028	-$1,243	$0	$0	$0	$0	-$1,243
2029	-$1,192	$0	$0	$0	$0	-$1,192
2030	-$1,144	$0	$0	$0	$0	-$1,144
2031	-$1,099	$0	$0	$0	$0	-$1,099
2032	-$1,056	$0	$0	$0	$0	-$1,056
2033	-$1,014	$0	$0	$0	$0	-$1,014
2034	-$974	$0	$0	$0	$0	-$974
2035	-$937	$0	$0	$0	$0	-$937
2036	-$27,752	-$6,680	-$6,912	$0	$0	-$41,344
2037	-$865	$0	-$6,646	$0	$0	-$7,511
2038	-$830	$0	-$6,390	$0	$0	-$7,221
2039	-$798	$0	-$6,145	$0	$0	-$6,943
2040	-$767	$0	-$5,908	$0	$0	-$6,675
2041	-$737	$0	-$5,681	$0	$0	-$6,418
2042	-$708	$0	-$5,463	$0	$0	-$6,171
2043	-$680	$0	-$5,252	$0	$0	-$5,933
2044	-$654	$0	-$5,050	$0	$0	-$5,705
2045	-$629	$0	-$4,856	$0	$0	-$5,485
2046	-$606	$0	-$4,669	$0	$0	-$5,276
2047	-$75,867	-$6,540	-$5,238	$0	$0	-$87,645
2048	-$28,173	-$5,031	-$5,037	$0	$0	-$38,240
2049	-$26,831	-$6,402	-$4,843	$0	$0	-$38,076
2050	-$415	$0	-$4,657	$0	$0	-$5,072
2051	-$14,067	-$3,130	-$7,036	$0	$0	-$24,234
2052	-$383	$0	-$6,766	$0	$0	-$7,149
2053	-$370	$0	-$6,505	$0	$0	-$6,875
2054	-$5,875	-$2,175	-$7,392	$0	$0	-$15,443
2055	-$333	$0	-$7,108	$0	$0	-$7,441
2056	-$327	$0	-$6,835	$0	$0	-$7,162
2057	-$315	$0	-$6,572	$0	$0	-$6,887
2058	-$302	$0	-$6,319	$0	$0	-$6,621
2059	-$290	$0	-$6,076	$0	$0	-$6,367
2060	-$279	$0	-$5,842	$0	$0	-$6,121
2061	-$268	$0	-$5,618	$0	$0	-$5,886
2062	-$257	$0	-$5,402	$0	$0	-$5,659
2063	-$251	$0	-$5,194	$0	$0	-$5,445
2064	-$235	$0	-$4,994	$0	$0	-$5,229
TOTAL	**-$219,783**	**-$29,958**	**-$170,406**	**$0**	**$0**	**-$420,147**

BEACH REPLENISHMENT

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	$0	$0	$0	$0	$0
2016	-$205,628	$0	$0	$0	-$205,628
2017	-$65,907	$0	$0	$0	-$65,907
2018	-$1,394,177	$0	$0	$0	-$1,394,177
2019	$0	$0	$0	$0	$0
2020	$0	$0	$0	$0	$0
2021	$0	$0	$0	$0	$0
2022	$0	$0	$0	$0	$0
2023	$0	$0	$0	$0	$0
2024	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0
2026	$0	$0	$0	$0	$0
2027	$0	$0	$0	$0	$0
2028	-$174,122	$0	$0	$0	-$174,122
2029	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0
2031	$0	$0	$0	$0	$0
2032	$0	$0	$0	$0	$0
2033	$0	$0	$0	$0	$0
2034	$0	$0	$0	$0	$0
2035	$0	$0	$0	$0	$0
2036	$0	$0	$0	$0	$0
2037	$0	$0	$0	$0	$0
2038	-$117,631	$0	$0	$0	-$117,631
2039	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0
2041	$0	$0	$0	$0	$0
2042	$0	$0	$0	$0	$0
2043	$0	$0	$0	$0	$0
2044	$0	$0	$0	$0	$0
2045	$0	$0	$0	$0	$0
2046	$0	$0	$0	$0	$0
2047	$0	$0	$0	$0	$0
2048	-$79,467	$0	$0	$0	-$79,467
2049	$0	$0	$0	$0	$0
2050	$0	$0	$0	$0	$0
2051	$0	$0	$0	$0	$0
2052	$0	$0	$0	$0	$0
2053	$0	$0	$0	$0	$0
2054	$0	$0	$0	$0	$0
2055	$0	$0	$0	$0	$0
2056	$0	$0	$0	$0	$0
2057	$0	$0	$0	$0	$0
2058	-$53,685	$0	$0	$0	-$53,685
2059	$0	$0	$0	$0	$0
2060	$0	$0	$0	$0	$0
2061	$0	$0	$0	$0	$0
2062	$0	$0	$0	$0	$0
2063	$0	$0	$0	$0	$0
2064	$0	$0	$0	$0	$0
TOTAL	**-$2,090,616**	**$0**	**$0**	**$0**	**-$2,090,616**

RUBBLEMOUND REVETMENT

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	$0	$0	$0	$0	$0
2016	-$543,689	$0	$0	$0	-$543,689
2017	-$174,259	$0	$0	$0	-$174,259
2018	-$3,686,257	$0	$0	$0	-$3,686,257
2019	$0	$0	$0	$0	$0
2020	$0	$0	$0	$0	$0
2021	$0	$0	$0	$0	$0
2022	$0	$0	$0	$0	$0
2023	$0	$0	$0	$0	$0
2024	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0
2026	$0	$0	$0	$0	$0
2027	$0	$0	$0	$0	$0
2028	$0	$0	$0	$0	$0
2029	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0
2031	$0	$0	$0	$0	$0
2032	$0	$0	$0	$0	$0
2033	$0	$0	$0	$0	$0
2034	$0	$0	$0	$0	$0
2035	$0	$0	$0	$0	$0
2036	$0	$0	$0	$0	$0
2037	$0	$0	$0	$0	$0
2038	$0	$0	$0	$0	$0
2039	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0
2041	$0	$0	$0	$0	$0
2042	$0	$0	$0	$0	$0
2043	$0	$0	$0	$0	$0
2044	$0	$0	$0	$0	$0
2045	$0	$0	$0	$0	$0
2046	$0	$0	$0	$0	$0
2047	$0	$0	$0	$0	$0
2048	$0	$0	$0	$0	$0
2049	$0	$0	$0	$0	$0
2050	$0	$0	$0	$0	$0
2051	$0	$0	$0	$0	$0
2052	$0	$0	$0	$0	$0
2053	$0	$0	$0	$0	$0
2054	$0	$0	$0	$0	$0
2055	$0	$0	$0	$0	$0
2056	$0	$0	$0	$0	$0
2057	$0	$0	$0	$0	$0
2058	$0	$0	$0	$0	$0
2059	$0	$0	$0	$0	$0
2060	$0	$0	$0	$0	$0
2061	$0	$0	$0	$0	$0
2062	$0	$0	$0	$0	$0
2063	$0	$0	$0	$0	$0
2064	$0	$0	$0	$0	$0
TOTAL	**-$4,404,206**	**$0**	**$0**	**$0**	**-$4,404,206**

RIPRAP

Year	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	$0	$0	$0	$0	$0
2016	-$123,304	$0	$0	$0	-$123,304
2017	-$59,281	$0	$0	$0	-$59,281
2018	-$1,254,020	$0	$0	$0	-$1,254,020
2019	$0	$0	-$228,766	$0	-$228,766
2020	$0	$0	$0	$0	$0
2021	$0	$0	$0	$0	$0
2022	$0	$0	$0	$0	$0
2023	$0	$0	$0	$0	$0
2024	$0	$0	$0	$0	$0
2025	$0	$0	$0	$0	$0
2026	$0	$0	$0	$0	$0
2027	$0	$0	$0	$0	$0
2028	$0	$0	-$40,182	$0	-$40,182
2029	$0	$0	$0	$0	$0
2030	$0	$0	$0	$0	$0
2031	-$116,751	$0	$0	$0	-$116,751
2032	$0	$0	$0	$0	$0
2033	$0	$0	$0	$0	$0
2034	$0	$0	$0	$0	$0
2035	$0	$0	$0	$0	$0
2036	$0	$0	$0	$0	$0
2037	$0	$0	$0	$0	$0
2038	$0	$0	-$27,146	$0	-$27,146
2039	$0	$0	$0	$0	$0
2040	$0	$0	$0	$0	$0
2041	$0	$0	$0	$0	$0
2042	$0	$0	$0	$0	$0
2043	-$72,923	$0	$0	$0	-$72,923
2044	$0	$0	$0	$0	$0
2045	$0	$0	$0	$0	$0
2046	$0	$0	$0	$0	$0
2047	$0	$0	$0	$0	$0
2048	$0	$0	-$18,339	$0	-$18,339
2049	$0	$0	$0	$0	$0
2050	$0	$0	$0	$0	$0
2051	$0	$0	$0	$0	$0
2052	$0	$0	$0	$0	$0
2053	$0	$0	$0	$0	$0
2054	$0	$0	$0	$0	$0
2055	-$45,547	$0	$0	$0	-$45,547
2056	$0	$0	$0	$0	$0
2057	$0	$0	$0	$0	$0
2058	$0	$0	-$12,389	$0	-$12,389
2059	$0	$0	$0	$0	$0
2060	$0	$0	$0	$0	$0
2061	$0	$0	$0	$0	$0
2062	$0	$0	$0	$0	$0
2063	$0	$0	$0	$0	$0
2064	$0	$0	$0	$0	$0
TOTAL	**-$1,671,826**	**$0**	**-$326,821**	**$0**	**-$1,998,647**

PLANNED RETREAT

Year	Erosion (costs per year)	Costs of Adaptation Measures	Economic Impacts	Environmental Impacts	Social Impacts	Total costs
2015	-$2,029	-$53,020	$0	$0	$0	-$55,049
2016	-$1,953	$0	$0	$0	$0	-$1,953
2017	-$1,880	$0	$0	$0	$0	-$1,880
2018	-$1,809	$0	$0	$0	$0	-$1,809
2019	-$1,743	-$111,341	-$88,784	$0	$0	-$201,869
2020	-$1,350	-$93,791	$0	$0	$0	-$95,142
2021	-$1,621	-$69,543	$0	$0	$0	-$71,164
2022	-$1,256	$0	$0	$0	$0	-$1,256
2023	-$1,210	-$39,724	$0	$0	$0	-$40,934
2024	-$1,167	$0	$0	$0	$0	-$1,167
2025	-$1,124	$0	$0	$0	$0	-$1,124
2026	-$1,081	-$39,684	$0	$0	$0	-$40,765
2027	-$1,041	$0	$0	$0	$0	-$1,041
2028	-$1,002	$0	$0	$0	$0	-$1,002
2029	-$961	$0	$0	$0	$0	-$961
2030	-$921	$0	$0	$0	$0	-$921
2031	-$885	$0	$0	$0	$0	-$885
2032	-$850	$0	$0	$0	$0	-$850
2033	-$817	$0	$0	$0	$0	-$817
2034	-$784	$0	$0	$0	$0	-$784
2035	-$754	$0	$0	$0	$0	-$754
2036	-$724	$0	$0	$0	$0	-$724
2037	-$696	$0	$0	$0	$0	-$696
2038	-$668	$0	$0	$0	$0	-$668
2039	-$643	$0	$0	$0	$0	-$643
2040	-$618	$0	$0	$0	$0	-$618
2041	-$593	$0	$0	$0	$0	-$593
2042	-$570	$0	$0	$0	$0	-$570
2043	-$548	$0	$0	$0	$0	-$548
2044	-$527	$0	$0	$0	$0	-$527
2045	-$506	$0	$0	$0	$0	-$506
2046	-$488	$0	$0	$0	$0	-$488
2047	-$466	$0	$0	$0	$0	-$466
2048	-$449	$0	$0	$0	$0	-$449
2049	-$432	$0	$0	$0	$0	-$432
2050	-$415	$0	$0	$0	$0	-$415
2051	-$399	$0	$0	$0	$0	-$399
2052	-$383	$0	$0	$0	$0	-$383
2053	-$370	$0	$0	$0	$0	-$370
2054	-$361	$0	$0	$0	$0	-$361
2055	-$333	$0	$0	$0	$0	-$333
2056	-$327	$0	$0	$0	$0	-$327
2057	-$315	$0	$0	$0	$0	-$315
2058	-$302	$0	$0	$0	$0	-$302
2059	-$290	$0	$0	$0	$0	-$290
2060	-$279	$0	$0	$0	$0	-$279
2061	-$268	$0	$0	$0	$0	-$268
2062	-$257	$0	$0	$0	$0	-$257
2063	-$251	$0	$0	$0	$0	-$251
2064	-$235	$0	$0	$0	$0	-$235
TOTAL	**-$38,952**	**-$407,104**	**-$88,784**	**$0**	**$0**	**-$534,840**