COST-BENEFIT ANALYSIS OF COASTAL ADAPTATION OPTIONS IN PERCÉ

Executive Summary
March 2016
This study was supported by the Economics Working Group of Canada's Climate Change Adaptation Platform, chaired by Natural Resources Canada. It also received funding from Quebec's Green Fund as part of the 2013-2020 Climate Change Action Plan.

Many people contributed to this study, in particular Pascal Bernatchez and his team at the Laboratoire de dynamique et de gestion intégrée des zones côtières (LDGIZC) of Université du Québec à Rimouski (UQAR), who shared with Ouranos their experience and in-depth knowledge of the hydro-sedimentary processes of Quebec’s coasts.

We wish to thank the City of Percé for the exceptional collaboration of the various stakeholders with the project team. In particular, we would like to acknowledge the invaluable assistance of Mayor André Boudreau, Félix Caron, Lisa-Marie Gagnon and Ghislain Pitre.

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Finally, we would like to thank you to all the organizations and firms that provided essential data for the study, especially the Regroupement des pêcheurs professionnels du sud de la Gaspésie, Pesca Environnement, BPR (TetraTech) and W.F. Baird & Associates Coastal Engineers.
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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
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 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 building behind it have been subject to repeated damage for several years. It is becoming urgent to implement appropriate measures 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 cost-benefit ratio (C/B 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 SITE**

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.

**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.

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 that begins in front of the Riótel Hotel. This part of the coast is composed mostly of over 30-metre-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

**Tableau A - Adaptation options considered in each segment**

<table>
<thead>
<tr>
<th>Adaptation options</th>
<th>Côte Surprise</th>
<th>Anse du Sud</th>
<th>Mont-Joli Sud</th>
<th>Anse du Nord</th>
</tr>
</thead>
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<tr>
<td>Hard engineering structures</td>
<td>Seawall</td>
<td>Rubblemound</td>
<td>Riprap</td>
<td>Rubblemound</td>
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<td>Riprap</td>
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<td>Soft engineering structures</td>
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<tr>
<td>Options without coastal structures</td>
<td>Planned retreat</td>
<td>Planned retreat</td>
<td>Planned retreat</td>
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</table>
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 $1.44 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 wall and boardwalk in place, but the wall 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 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 wall’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 were lost, many people would spend less time in the Gaspésie region 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, installing a riprap, and beach replenishment with or without groynes. 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.

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.

Beach replenishment with pebbles also has the best benefit-cost ratio, with benefits 68 times greater than the costs. So, each dollar invested by the society could 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 measure 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 offers discounted benefits of $399 million. This measure, like constructing a rubblemound or

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1 See BPR et al. (2014) for the design and characteristics of these adaptation options.
a riprap\textsuperscript{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 Gaspésie region. 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.

\textbf{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 fairly 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 projections, the Frederick-James Villa, located less than 4 m from the edge of the cliff, will be

\textsuperscript{2}Riprap is an adaptation option 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.

\textbf{Figure B - Net discounted benefits compared to the non-intervention option in Anse du Sud}

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.

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exposed to erosion during the study period. This is a special heritage building in Percé and its presence on Mont-Joli enhances the value of the landscape and view of 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 projected 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 beneficial, 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, which covers 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 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, installing a riprap, beach replenishment and planned retreat.

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 compared 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 a negative net present benefits and a benefit-cost ratio less than 1, this option is not economically justifiable. Finally, constructing a rubblemound 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.

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 measures such as beach replenishment, rubblemound or riprap. These options must generate additional benefits, notably increased

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$Figure C -$ Net present benefits compared to non-intervention in Anse du Nord

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3 See BPR et al. (2014) for the design and characteristics of the adaptation options that require engineering work.
recreational use of the coast, to be considered more advantageous than inaction.

The sensitivity analyses show that the NPV of beach replenishment is robust. These 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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<thead>
<tr>
<th>Acronym</th>
<th>Description</th>
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<tbody>
<tr>
<td>CBA</td>
<td>Cost-benefit analysis</td>
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<tr>
<td>CC</td>
<td>Climate change</td>
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<td>LDGIZC</td>
<td>Laboratoire de dynamique et de gestion intégrée des zones côtières</td>
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<td>MAMOT</td>
<td>Ministère des Affaires municipales et de l’Occupation du territoire</td>
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<td>MAPAQ</td>
<td>Ministère de l’Agriculture, des Pêcheries et de l’Alimentation du Québec</td>
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<td>Ministère de la Culture et des Communications</td>
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<td>Ministère du Développement durable, de l’Environnement et de la Lutte contre les changements climatiques</td>
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<td>NPV</td>
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