

Coastal Erosion in Daniel's Harbour

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ABSTRACT

Daniel's Harbour is a small town located on the Northern Peninsula of Newfoundland. It received its name following a storm prior to 1821 that forced a man, Daniel Riggins, to seek shelter for his boat and family that he was moving from Labrador to Bonne Bay. Upon arriving at the harbour, Daniel was faced with a decision, whether to try and find shelter in the nook, that appeared rather uninviting, or to brave the stormy conditions. Having no choice, Daniel tried and to his satisfaction, saved his family and his boat with the shelter that it provided. From that point on the area became known as Daniel's Harbour.

Daniel's Harbour, while considered a mining town for seventeen years, remains a traditional Newfoundland fishing community, with a natural rock wall protecting the small harbour. However, this protection has come into question in recent years as steep cliffs within the community have fallen due to landslides. In April of 2007, and again in June and May of 08 and 09, this community, with a population near 300, were devastated as residents watched helplessly as a home and other smaller structures fell into the water below.

In the years since these disasters several homes have been condemned and studies have been performed to bring to light the causes of the slides. In many cases the studies have identified coastal erosion and weak underlying soil within the area as the two main causes.

The following report will highlight the effect coastal erosion can have on areas like Daniel's Harbour, identify possible techniques and methods to reduce its affect, and discuss the challenges that remain following coastal erosion within the area of Daniels Harbour.

1 INTRODUCTION

The small community of Daniel's Harbour is located on the Northern Peninsula of Newfoundland, with an estimated population of nearly 265 people. History indicates the town was first settled prior to 1821 as a fishing ground, similar to many of the settlements in Newfoundland at the time. Although mining of zinc-rich ore became popular during the mid seventies lasting just over fifteen years, the town of Daniel's Harbour has remained a traditional Newfoundland fishing community.

Throughout its history Daniel's Harbour has been protected by a natural rock wall. However due to the combination of coastal erosion of the weak underlying soil and the increased soil saturation within the area this protection has come into question in recent years. As a result of these contributing factors, devastating landslides have occurred along the coastal cliffs located on the northern side of the town. Occurrences in 2006, 07, 08 and again in 09 have lead to the destruction and abandonment of homes and other nearby structures, temporary and permanent re-routing of roads, and other inconveniences for the town's residents.



Figure 1: Results of Landslide in 2007

Since coastal regions are amongst the most populated environments on the earth, with areas containing much higher populations than that of Daniel's Harbour, it is imperative that management techniques and the engineering responses to coastal erosion be analyzed to learn from previous applications in hope of determining the best methods to cope with coastal erosion in these areas.

2 COASTAL EROSION

Erosion is the modification of landforms by the wearing away of rock and soil. In coastal areas, this natural process is caused by a number of factors that can have varying effects on shorelines. In general the agents of coastal erosion consist of wind, water and ice, with the most devastating effects cause by wave-action along the shore. In areas where sedimentary material is scarce and waves move material away from the coast, erosion dominates [4]. In Newfoundland in particular, sea-level rise,

wave action, storm surge and human activities are the main factors that impact coastal areas, where approximately 90% of the province's population call home [6].

Waves and storms, sea-level rise and human interference are all factors that affect the stability of coastal regions. A wave's ability to induce erosion depends ultimately on wind climate. An increase in the wind speed leads to an increase in wave energy. Greater wave energy and the resulting increase in wave length allow the wave to transport larger particulate and larger volumes of sediment to be disturbed and displaced [3]. The overall erosion effects of waves can be accelerated by storm surges which expose higher land elevations to more energetic wave conditions. The overall impact of a storm is influenced by the timing, track, meteorological conditions, local characteristics of the area and the angle at which waves reach the shoreline [6].

As a result of the changing sea-level, erosion may occur depending on the rate and direction of the change. In general, if the rate of sea-level rise exceeds the rate of sediment supply, erosion can occur. This is becoming of particular interest in Newfoundland as the sea-level is currently rising across most of the island. These changes in sea-level have been caused in part by human interactions. Manmade structures such as sea walls can cause water tables to rise and increase wave turbulence in the area if improperly designed. However, human interference can provide protection from erosion. By constructing shore-parallel structures, such as a breakwater, wave energy can be decreased and the overall impact of erosion in the area can be reduced.

The changes induced by coastal erosion take place over a wide range of durations. Erosion may occur in response to short-term events such as storm surges or the long term interaction of the shore with waves, tides and wind that can eventually wear away the coast. As a result shorelines are constantly changing with highly varied forms. On rocky coasts, for example, constant wave pounding and weathering play a major role in the degrading of the existing rock. The ease with which this occurs depends on the characteristics of the parent material.

2.1 Effects of Coastal Erosion

In today's world the consequences of coastal erosion have become more and more disastrous due to the increasing population, buildings, transport and utility infrastructure that reside along the coast. As a result, coastal erosion poses a significant risk that can result in damages that can be physical, such as injury or loss of lives, ruined properties, or economic, social, and cultural in terms of interrupting the use of the coastline [3].

In some cases coastal erosion has led to the instability of existing structures and the need to take precautionary measures with homes and businesses, abandoning them in fear of further repercussions. In the more extreme cases mass movements of unconsolidated material under the influence of gravity, also known as landslides, can occur. This type of movement can strike almost anywhere in the world with catastrophic results, damaging property, destroying roads, homes, bridges, and at times cause injury or loss of life [4]. With the down slope land movement associated with landslides, any structures located in the affected area are destroyed.

The possible economic impacts coastal erosion can have on a development are endless. Not only can erosion cause the loss of property, it can also drive the initial and construction costs for projects upwards. For situations where coastal erosion is a concern, special specifications or requirements may need to be met to eliminate the possibility of future problems that may result due to further eroding of the coast.

2.2 Management of Coastal Erosion

Reducing the potential for coastal erosion can play a vital role in diminishing the negative effects this natural process can have on existing coastal zones. Shore protection projects can moderate the long-term effects erosion can have on shorelines, providing wider buffer zones between the land and sea. Consequently, this protection can reduce damage that may result from storm surge waves and flooding [1]. In general there are three basic approaches to management and engineering response for shore protection.

The first of the three basic approaches is the protection method. This category is divided according to the application of hard or soft engineered solutions to defend vulnerable areas, especially populated centres, economic activities and natural resources [7]. In terms of hard engineered solutions, this method is further subdivided into armouring and shoreline stabilization. Armouring refers to the use of seawalls, bulkheads, and protective revetments for cliffs and dikes. The relatively high cost for this approach is justified when erosion is effecting low areas of substantial human investment. Shoreline stabilization on the other hand uses near shore breakwaters, groins, and wetlands to moderate coastal sediment transport processes to reduce the local erosion rate [1]. An application of this approach is used when erosion due to diminished sediment supply becomes a major problem. The design used for this approach must be carefully constructed as improper functionality has lead to adverse environmental impacts. Soft protection provides coastal defence by supplementing natural processes and enhancing the natural environments. These solutions are reversible in most cases and allow a wider range of coastal management options to be available to future generations [7]. An example of this approach is beach nourishment. This requires loose sediment material to be place on the beach as underwater mounds. Due to several constraints that exist with many projects, this soft alternative solution has become the most common alternative for shore protection [1].

By elevating structures, flood proofing, zoning restrictions, changing land use or construction methods one can accommodate or adapt to coastal erosion or flooding of an area. The adaption or accommodation approach is the next method in the management and engineering response for shore protection [1]. Although it is rather difficult to achieve due to the permanent nature of erosion, accommodation can be achieved by physically changing an environment to accommodate increased erosion through advanced planning. The two most common examples of this method are the alteration of zoning and building codes to reduce damage cause by erosion. For example building codes could specify the minimum floor elevations or modified drainage that should be used in areas where surging water and high winds are expected.

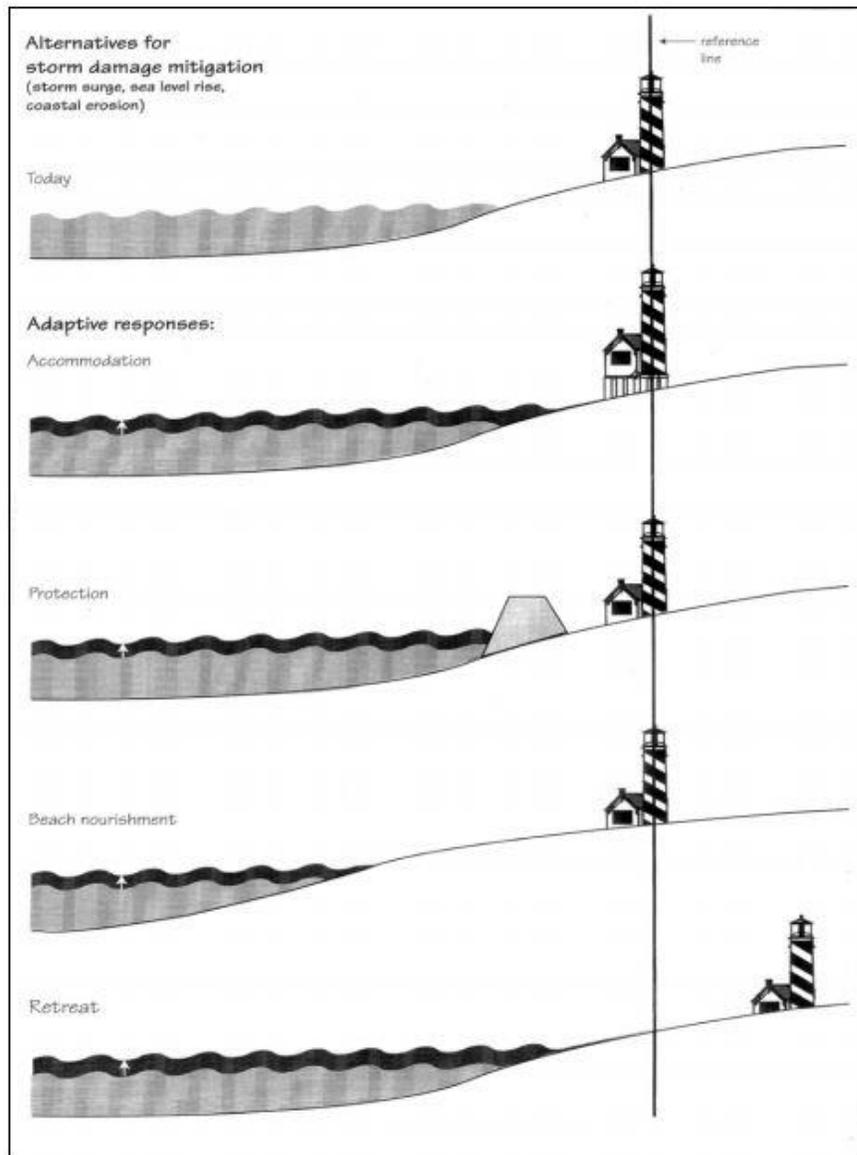


Figure 3: Alternatives for Shoreline Protection

The final of the three alternatives for shoreline protection is the retreat method. This method requires advanced planning and acceptance that some coastal zones may be lost due to erosion. One example of this application is the enforcing of setback limits. Limiting construction close to the shoreline can reduce the risk of erosion by limiting the potential effects [7]. This is usually enforced by Governmental efforts through the acquisition of land, land-use restrictions, prohibiting reconstruction of property damaged by storms and reduction of subsidies and incentives for development in vulnerable areas. Another option included within the retreat method is the allowing of developments on the condition that it will be abandoned if necessary. This option gives the government a more limited role and forces liability on the investors [8].

3 DANIEL'S HARBOUR

The small community of Daniel's Harbour located on the Great Northern Peninsula, western Newfoundland, is situated on a coastal platform, which extends from an elevation close to sea level to approximately 25 metres. While many of the occupants live on the low-lying ground adjacent to the harbour, several residences are located to the north, at an elevation close to the community's peak level. Included in this area is a portion of the Northern Peninsula highway with 14 structures located on the coastward side of the road [5].

The bedrock geology of the area along the coastline north of the community has no significant amount of bedrock noted, including the areas affected by the landslides. This area has been heavily influenced by glaciations and its noted effects. The sediments that were exposed by the landslide are glacial and post glacial. The lower portion of the visible sediment is a very compact layer having a silt-clay matrix, containing pebbles and boulders up to about 50 centimetres in diameter. Above this layer is the top of the glacial sediment, which is sharp and flat due to eroding of the surface by the sea. Overlying the flat surface is a loose sand and gravel unit composed of a mixture of rock types, many of which were rounded [5].

3.1 Landslides

At 7:30 am on October 20, 2006 the first of a series of landslides took place on the coastal cliffs on the northern side of the town of Daniel's Harbour. The volume of the material that was involved was estimated at 20 – 30,000 cubic metres covering an approximate area of 1000 square metres, with the closest structure within 10 metres from the top of the slope. The cliffs in the area consisted of unconsolidated material and no significant rainfall had been recorded in the area prior to the landslide. A relatively large percentage of the material fell into the ocean and further landslides occurred over the days that followed leading to the evacuation of properties in the surrounding areas [2].



Figure 4: 2006 Landslide in Daniel's Harbour

The first landslide in 2006 served notice to the members of the Daniel's Harbour community of the potential risks that existed due in large part to the combination of coastal erosion and the weak underlying clay that existed in the area. This potential for disaster was confirmed shortly after, when a second landslide struck in April of 2007. In this instance, the slides took place over a five day period

and resulted in the loss of one home and several outbuildings, evacuation of seven houses and the temporary re-routing of the Northern Peninsula Highway. When finished, the landslide of 2007 involved a much greater area than the previous slide of 2006 [2]. This slide covered an area of approximately 5250 square metres, spanning 105 metres wide and extending 50 metres inland. It was characterized by a 15-20 metre vertical face and its debris was a combination of natural material from the eroded cliff face and the remnants of buildings and associated debris [5].



Figure 5: House which Topped over following the 2007 Landslide

Just over a year after the devastating landslide that occurred in 2007, a smaller slide occurred just 400 metres south of the 2007 affected area. In June 2008, a movement of earth approximately 20 metres in width and containing a vertical exposure of 7 metres slide a fair distance onto the beach below. The affected cliff was somewhat lower than the area to the north and extended 15 metres above sea level. The landslide at the time left similar sediment material to that of the north exposed, although the uppermost sand and gravel layers were largely absent [2]. In the year that followed another small landslide occurred approximately 2 kilometres south of the site of the major landslide in 2007. Its impacted area stretched nearly 75 metres in length and resulted in the loss of 2 metres from the cliff edge.

3.2 Engineering Response

Following the events of the 2007 landslides that struck Daniel's Harbour a preliminary analysis of the area was completed by the Department of Natural Resources. Within this analysis the history of the area, geotechnical conditions and effects of the landslides that occurred in 2006 and 07 were taken into consideration. Due to the severity of the landslides and the unpredictability of future events it was recommended that all properties currently located west of the present highway be immediately designated as unfit for occupation. The area to the west of the dotted line in the figure below was designated as a Landslide Hazard Area and that no further development would be permitted within its boundaries. A more detail site investigation was also recommended for completion in hopes of determining all the factors that contributed to the landslides occurrences [5].



Figure 6: Location of the Landslide Hazard Zone

In the months that followed, further investigation was conducted into the existing conditions at Daniel's Harbour. As a result, safety zones that had been enforced on the area following the preliminary analysis were extended to include an additional 23 properties from the 10 previously impacted when the zones were first established.

4 CONCLUSION

The occurrences of landslides in Daniel's Harbour are a clear illustration of just one of the many issues associated with coastal erosion. Due to the uncertainty in predicting its future effects, it is imperative that the proper management and protection techniques be put in place to reduce, if not eliminate, the negative effects erosion can have on coastal areas.

In Daniel's Harbour the landslides of 2007 alone, resulted in \$6.5 million in claims to the Federal Government under the Disaster Financial Assistance Arrangements Program. However, since the establishment of the Landslide Hazard Area and other prevention techniques, the disastrous effects of the landslides that followed have been greatly reduced.

Ultimately, the town of Daniel's Harbour, in conjunction with Engineering Consultants, believe that the current management techniques established are the best methods for dealing with coastal erosion in the area. Through consistent monitoring and a dynamic hazard area, the effects of any future events can be negated.

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