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Climate Change – Placentia Flood Wall

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ABSTRACT

Climate change has become a major growing concern in today's society. Climate change also presents profound risk to the integrity of numerous engineered systems and in turn, the global public safety. According to the Canadian Code of Ethics "engineers shall hold paramount the safety, health and welfare of the public and the protection of the environment." Therefore, engineers must assure that existing public infrastructure is capable of withstanding the impacts of climate change.

Established by French colonies in 1963, Placentia is located on Newfoundland's Avalon Peninsula and on the east coast of Placentia Bay. With a, currently rising, population of approximately 4,000 residents the region is the site of present and planned petroleum refineries as well as the soon to be locale for processing ore from the Voisey's Bay nickel-copper-cobalt plant.

Unfortunately, due to the regions low lying location on a flood plain adjacent to the sea the town of Placentia has been face with serious flooding in the past. As a result, is 1993 a sheet pile floodwall structure running parallel to the main beach was constructed. The sheet pile wall is intended to protect the downtown portion of the community from flooding. However, due to present concerns surrounding climate change the question arises whether or not this form of infrastructure is vulnerable to the effects of intensified weather events. Catastrophic failure of the floodwall would flood much of the downtown Placentia.

The following paper will highlight the history of flooding concerns in Placentia and the effects of specific aspects of climate change on the sheet pile flood wall. These aspects include; sea level rise, wind assisted surge waves, and intense rainfall events. The engineering requirements to address such effects will also be presented.

1 INTRODUCTION

Have you ever wondered what it is which forms the foundation for the society in which we live? Infrastructure is a fundamental requirement which allows the Canadian economy to function on a daily basis and continue to grow and develop in order to meet both current and future demands. Defined as the physical components of interrelated systems which provide commodities and services essential to enable, sustain and enhance societal living conditions.[1] Such components include; roads, bridges, water supply, sewers, electrical grids, and telecommunications.

Traditionally, infrastructure has been designed based on historical weather statistics. However due to recent concerns related to climatic changes, which Canadians are currently experiencing, traditional methods are no longer sufficient. According to several studies conducted, recent evidence of climate change includes an increase in the global average air and ocean temperatures, widespread melting of snow and ice, and a rising sea level [2]. As a result, both existing and proposed infrastructure may be susceptible to failure. Professional engineers have an ethical responsibility and standard duty of care to ensure that our infrastructure remains safe and serviceable in the face of climate change.

In August 2005, Engineers Canada formed the Public Infrastructure Engineering Vulnerability committee. The committee is responsible to facilitate and oversee the assessment of infrastructure and climate change [3]. During the assessment, four categories of infrastructure are evaluated to determine the vulnerabilities and then appropriate recommendations are made for each. The four categories of infrastructure assessed by the committee include, water resources, storm water and waste water, roads and associated structures, and buildings.

Water resources infrastructure incorporates a wide variety of structures including water resource systems; particularly potable-water collection and treatment systems, and coastal flood control systems. Clearly, this category of infrastructure is a vital aspect to society since it provides a means of protection and a supply of water services. Disruption or damage to any of these categories of physical infrastructure may result in major impacts on public health, safety and effective functioning. Unfortunately, water resource infrastructures are considered to be vulnerable to the effects of climate change and therefore it is one are the four categories assessed by the committee and will be referenced throughout this case study.

Narrowing in a one particular means of water resources infrastructure – flood walls, a system used to control coastal flooding, will be assessed for the province of Newfoundland. The existing sheet pile wall which was constructed in 1993, running parallel to the main beach in Placentia Bay, Newfoundland, Canada is an essential means of protection to the downtown area of the town. Located in a low lying region adjacent to the sea, the flood wall in Placentia is significantly venerable to climate change and therefore must be assessed to assure its current design is capable of withstanding extreme climate conditions.

2 COASTAL FLOODING

Coastal flooding has long since been a concern in various locations throughout Canada. The issue arises wherever development is undertaken near the coast. Therefore the maritime regions are particularly prone to such events. Two main contributors to flooding are; sea level rise and intensified storm systems. The sea level beneath a storm which is formed around a low pressure system will rise by approximately a centimeter for each milli-bar of pressure [4]. Also, storms are typically associated with high winds which cause tension on the water surface thus creating high waves. Both of these characterises of the ocean during storm situations result in coastal flooding.

Flooding presents a concern for both public safety and property damage. Storms have been reported across Newfoundland, from the Northern Peninsula to the Avalon since 1755. Reports indicate property damage to sheds, bridges, homes, telephone poles and railway tracks, culverts, and water supplies. All damages range from hundreds to millions of dollars loss. The most significant property damage reported occurred in 1929 on the Burin Peninsula. A tsunami, produced by an earthquake on the grand banks measuring 7.2 on the Richter scale, cause local sea levels to rise between 3 and 7 m. At which time the damages were estimated to be approximately one million dollars and even more significant than property damage, there were 28 live lost. [5]

Due to the destructive nature of coastal flooding, flood risk maps have been created to reduce the amount of flood damage. The figure below indicates the locations across Newfoundland and Labrador which are at risk of coastal flooding.

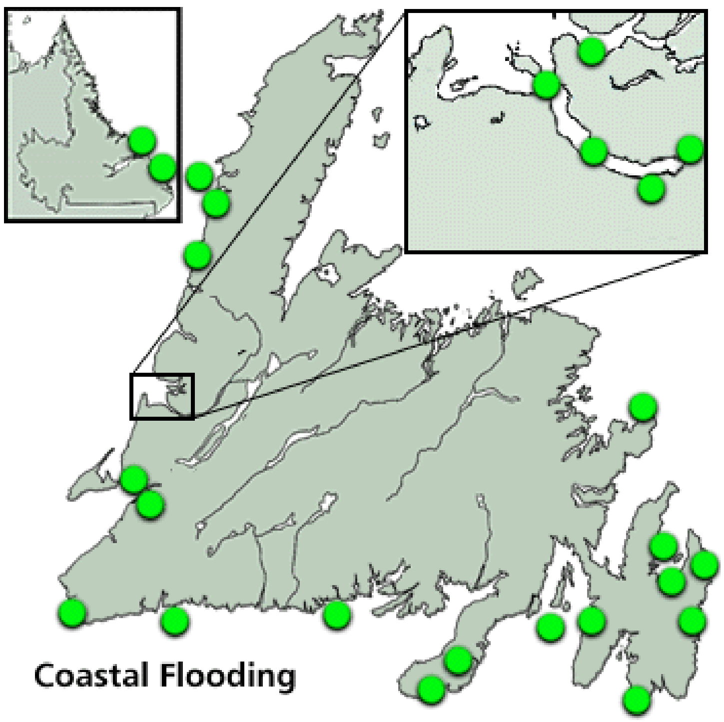

Figure 1: Areas of Coastal Flooding

The most common means of engineered infrastructure, if correctly designed, which offers a means of protection against flooding is known as a flood wall. A flood wall is a vertical barrier which is constructed along the shore. The wall is designed to prohibit the passage of water during intensified weather systems which result in high waves or even during periods of high water levels.

3 PLACENTIA

The town of Placentia is one of the oldest locations in Newfoundland. Embedded within the town are the communities of Placentia, Dunville, Jerseyside, Freshwater, and Argentina. The average population to date is approximately 4000 and is expected to climb due to the local labour opportunities in Long Harbour at the VALE Nickel Processing Plant. [6]. Figure one below illustrates the coastal location of the town and the low lying characteristics.

Figure 2: The Town of Placentia

The majority of the town of Placentia lies near sea level and therefore the foundation of all the existing structures are below the marine limit. As a result, coastal flooding has continued to present itself as an on-going problem in the area. Placentia has been flooded more than 10 times in the past 100 years. The first recorded flooding event was issued by letter in 1775. The British garrison officers reported to the Royal Engineers in St. Johns that a depth of up to four feet of water was in every house. [7]

Although the issue of coastal flooding existed for several years it wasn't until 1960 that a breakwater system was constructed in the town. The purpose of the breakwater was to provide protection against flooding but it was unsuccessful, and flooding continued throughout the 1970s and early 1980s. As a result the original breakwater structure was replaced with creosote-stone wall. Again, this structure was proven unsuccessful during storm events. Coastal flooding continued as the water travelled through the channel under the Lift Bridge, and washed over the community from the lagoon. Finally, in 1992 and 1993, Government extended the breakwater and installing a steel rampart; backside flood wall, around the southeast side of the community as shown in the figure below. [7]

3.1 Placentia Flood Wall

As result of past flooding events in Placentia a flood wall was constructed around the southeast side of the community in 1992 and 1993 as shown in the figure below

Figure 3: Steel Sheet Pile Wall around Southeast Side of the Community

The flood wall in Placentia was constructed of steel sheet pile with a top elevation of 2.2 m. each of the steel sheet piles of the wall were driven into the water and founded good soil and bedrock material. The wall runs parallel to and between the main beach and a road on the downtown peninsula portion of the town. Aesthetically designed, the wall includes a publicly accessible and maintained boardwalk spanning the top. Since the flood wall construction there has been no flooding to date. However, the flood plain is still considered at risk to flooding and with potentially more severe storms in the near future due to climate change this infrastructure must be assessed to determine its flood resisting ability.

At the time of the design of the floodwall, in 1992, a typical high tide was 1.2m under calm conditions. Luckily for residences, aside from occasional spay, there has been no waves which have overtopped the wall. However, since construction, the wall has experience continuous wave and tide action and has not under gone any regular maintenance. Therefore it is possible that corrosion to the wall may compromise its flood protection ability. Also, the height of the wall may not be sufficient for higher tides and storm induced waves. The figure below illustrates an example of high tide acting on the sheet pile flood wall in Placentia on December 23, 2010. From the location of the wall where the waves strike and the puddle of water landside of the wall it is noted that under current conditions the wall is barely high enough to prevent flooding.

Figure 4: Sheet Pile Flood Wall in Placentia on December 23, 2010

3.2 Current Climate

The climate in Eastern Newfoundland is classified as mid-boreal. Mid-boreal climate is known to be relatively cool with seasonally consistent precipitation and humid regions. Newfoundland's climate is controlled by the westerly winds of the mid-latitude Northern Hemisphere, and the proximity of the relatively cold waters of the Labrador Current system of the Atlantic Ocean. In February the mean temperature of the ocean's surface is less than zero degrees Celsius along the majority of the coastline. Mesoclimatc and microclimatic regimes are created in many locations within Newfoundland due to local factors, such as topography and the prevalence of onshore and offshore breezes. [8]

All four seasons are experienced within Newfoundland. On the Avalon Peninsula, summers are short, cool and wet. Winters are moderately mild and wet. Spring is normally long while autumn is short. The mean annual precipitation throughout the Avalon varies from 1500 to 1650 mm. [7]

In the low-lying region of Placentia Bay, the exposed coastline allows for a rather significant fetch. Fetch is a term referred to as the length of water over which a given wind blows. Therefore the southwesterly winds which are common in Placentia control the coastal conditions. Strong southwesterly winds are associated with many of the major storms and hurricanes during the summer and autumn, which generally pass over the region from southwest to northeast.

3.3 Climate Change

Climate change is a fast growing concern in todays' society due to the outcome which will result in long term changes in weather patterns. Climate change is believed to be the result of the depletion of the ozone layer as a result of emissions of greenhouse gases. The activities undertaken on a daily basis by the global population add to the amount of greenhouse gases emitted. Such activities include transportation, manufacturing and production of goods, and disposal of waste.

Ultimately, climate change will result in intensified weather systems which will lead to strong winds and high precipitation in areas. Since waves are created by the tension created on the water surface from wind, wave heights will also be increased and therefore areas located near the sea will become at risk of flooding. Areas such as Placentia, which is already prone to flooding, will have an increased risk.

Another significant impact of climate change is the sea level rise. The amount of sea level rise has been increasing in the past years as the amount of greenhouse gases released increases and it is expected to continue. There are two major processes of climate change which will result in sea level rise. First, as climate change increases the temperatures of the oceans, the water will begin to expand and result in sea level rise. A second contributor to sea level rise is the melting of glaciers and ice caps. Melting of ice and glaciers will add water to the ocean and also contribute to sea level rise. Sea level rise also presents itself as an increased risk for flooding in coastal areas, especially low lying areas, such as Placentia.

Evidently, climate change will have a wide range of impacts on coastal environments and infrastructure. For Newfoundland, projections to the year 2050, impacts include coastal erosion, increased frequency and magnitude of storm events, storm surges, wetland and coastal plain flooding. The most concerning impact for Placentia due to its location is flooding and whether the existing flood wall will be able to withstand such changes.

3.4 Environmental Assessment

Assessment studies have been undertaken by the Public Infrastructure Engineering Vulnerability Committee to and the following climate and climate-related projections were obtained. [7]

Table 1 Sea State Elevations

Climate Event for Flood Wall	Current Levels	Predicted for 2050	Predicted Change
Sea Level Elevation	0 m	0.15 m	+0.15 m
Storm Surge Wave Elevation	5.0 m	5.25 m	+0.25 m
Sea Level Elevation and Storm Surge	5.0 m	5.30 m	+0.30 m

It is noted that from the results above, the steel sheet pile wall, located 2.2 m above sea level elevation of 0 m, in Placentia is not able to withstand neither the current nor predicted climate events for the sea level elevation during a storm surge. However, due to the presence of the lift bridge, incoming waves tend to loose significant energy and therefore high waves reaching the flood wall are not of concern but instead high tides resulting from these tides are of concern. As previously stated, the high tide was approximately 1.2 m during the time of construction and is assumed to have increased since then therefore the next step in the assessment should be to be to monitor the current wave heights which are reaching the wall and determine a prediction based on the information gathered.

Also, noted from the table above under non storm conditions, if properly maintained the wall can withstand the sea level elevations predicted for 2050. [7]

The assessment undertaken by the committee also revealed that little to no maintenance has been performed on the steel sheet pile wall in Placentia since it had been constructed in the early 1990s. Discoloration of the wall in areas of dry and wet splash zone can be visually observed upon inspection.

4 CONCLUSION

Upon assessment of the Placentia steel sheet pile flood wall, it was determined from the data collected by the Public Infrastructure Engineering Vulnerability Committee that the flood wall should continue to provide protection against coastal flooding during non-storm surge conditions since a change of only +0.15 m was predicted and the current elevation of the wall is 2.2 m. However, both the current and predicted data for the storm surge elevations indicate that the wall is unable to provide protection against flooding, which is not the case. Due to the location of the lift bridge the waves lose energy prior to contact with the floodwall, therefore the current data from the assessment is not reliable and it is recommended that further studies be completed to determine the exact wave heights which are currently reaching the wall and from there the correct predictions can be made.

Also, due to the discoloration noted on the wall, the steel should be tested by means of anode testing to determine the extent of corrosion in order to assure the resisting capacity of the wall. Corrosion is a serious concern of steel structures in marine environments because if unmonitored it can lead to sudden unexpected failure and thus flooding of the town. To date the town has neglected to perform any monitoring or maintenance to the wall. It is recommended that the wall be monitored on a regular basis by competent individuals to assure its integrity is not compromised.

As a result of the geographic location of Newfoundland and its numerous coastal communities, it is recommended that each of the areas indicated on the flood risk areas shown is figure 1 above adopt a means of protection to flooding. The flood wall is a simple means of infrastructure which, if properly designed, is capable of protecting these areas. For areas in which a means of protection currently exists, it is recommended that the infrastructure be assessed to assure it is capable, similar to the case of the steel sheet pile flood wall in Placentia.

Also it is significant to note that once a means of protection against flooding is in place it must be monitored by capable and competent individuals. Even if a flood wall is designed to such an elevation which will prevent water to pass over it, the wall is still able to fail if it is not monitored. Such failure can occur unexpectedly. Two of the most common materials used for the construction of a flood wall are steel or timber. In marine environments both these materials are prone to decline in structural integrity. Steel is acceptable to corrosion while timber is often attacked by marine organisms and rot.

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