# A Coastal Hazard Assessment of the Gabarus Seawall, Cape Breton County, Nova Scotia

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## 1.0 Introduction

On December 7, 2011, an e-mail was sent by The Friends of Gabarus to a number of provincial and federal government departments, municipal governments and I believe various Crown Corporations and agencies.  The e-mail raised several issues, but in particular the residents felt there was a potential for the failure of the Gabarus seawall.  A lack of records relating to ownership and responsibility for the seawall was raised. The residents are looking for action and funding from various levels of government to repair and/or stabilize the seawall.

The Geological Services Branch of the Nova Scotia Department of Natural Resources (DNR) received the e-mail on January 3, 2012, at which time the issue was referred to Philip Finck (geologist) by the division's director Rob Naylor. With permission from the director, geohazards associated with the seawall were assessed during a site visit on January 10th to the 12th, 2012. The results of the technical and geological assessment are outlined in this report.

Readers need to recognize that this report has been prepared for the general public, as an informative tool for government use, and for general scientific applications. As such, this document is not heavily referenced with peer reviewed scientific literature. However, where readers desire additional references to matters discussed in the report the author will provide such references within available time constraints. Digital images prepared by the author and presented in this paper are available with permission from DNR, and given that appropriate reference is made.

## 2.0 Background

Gabarus is a small fishing community located approximately 43 km from Sydney on Route 327 **(Fig. 1).** According to local residents the seawall protecting the harbour was built in sections, the first section being constructed in 1946. Other sections were built in later years with the present seawall being approximately 400 metres long. In 1983 a section of the seawall was damaged with the result being heavy flooding, surge within the harbour, and significant damage to infrastructure associated with the local fishing industry **(Fig. 2)**.

According to Gene Kersey (Friends of Gabarus), local fisherman Earl Sherwood has indicated that repairs following the 1983 damage were carried out by H. (Harold) W. Phillips & Sons, currently located in Mira Gut. As far as the group is aware, there was a federal grant for repairs to local fishing infrastructure and presumably for repair of the seawall.

On December 2, 2010, a severe winter storm corresponding with high tide caused significant over-wash of the seawall, damaged local fishing wharfs and lobster traps, and resulted in severe structural damage to a 75 – 100 metre long section of the seawall. At present the local residents fear that the sea wall may be breached in another large storm, whether a hurricane or winter/spring storm.
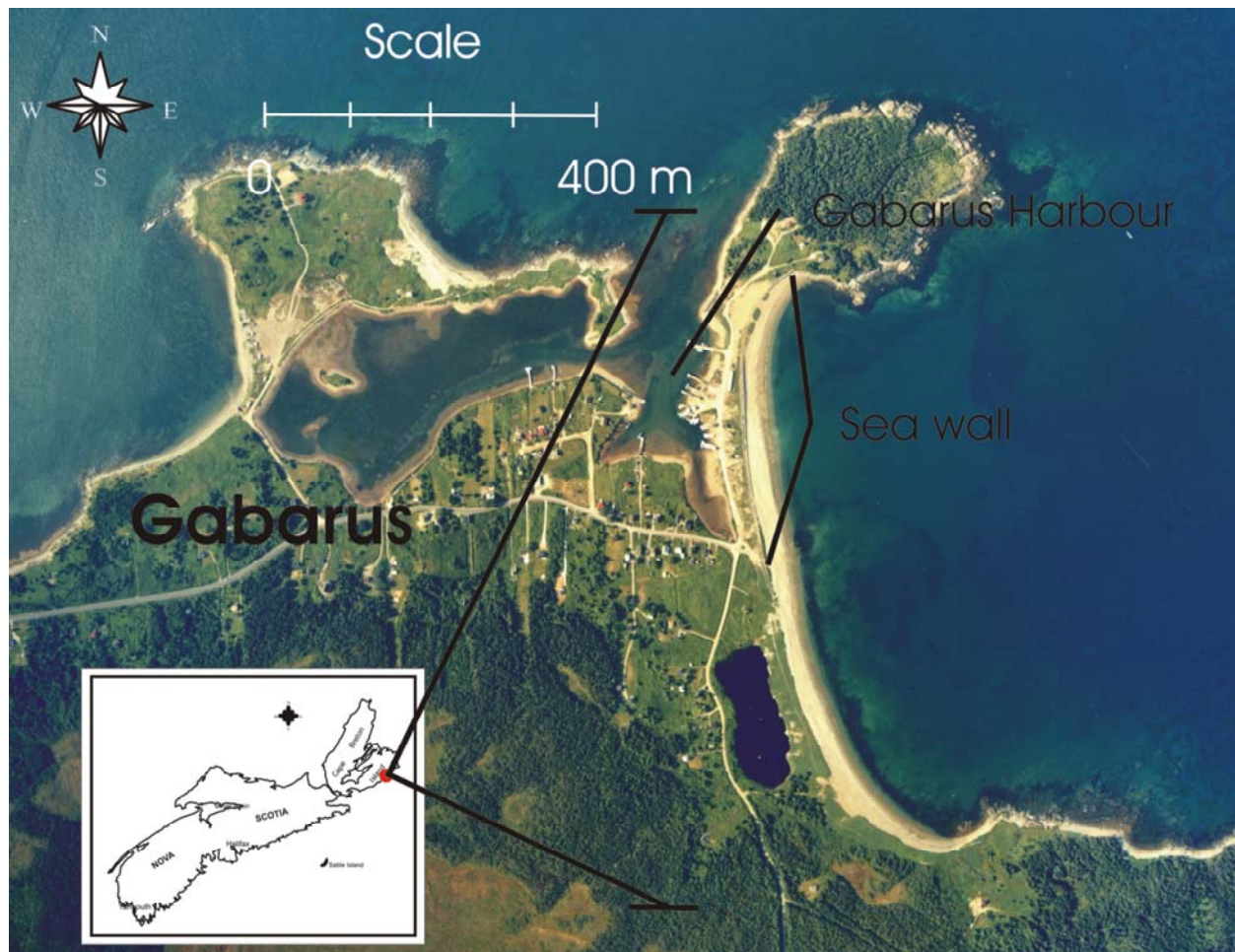
*Figure 1. Map and air photograph showing the location of the community of Gabarus.*

# 3.0 Ratings of Risk

The use of statistical methods of assessing or defining risk is heavily debated and is extremely difficult. In many cases risk is a relative thing that is dependent on the eyes of the beholder. There is also the concept of acceptable risk. Many natural systems are cyclical over decades, centuries, millennia and eons. Phenomena (e.g. hurricanes) relating to climate systems, however, are also highly chaotic, thus making annual, decadal or millennial predictions controversial and (in the author's opinion) subject to large errors.

There is no mathematical or statistical analysis of data used in this report to assign levels of risk. Rather, risk is simply referred to as high, significant, moderate, or low. These assignments of risk by the author are qualitative, though empirical observations (e.g. typical size of hurricanes versus post- tropical storms, storm duration, length of tidal cycles, etc.) are considered in assigning levels of risk. More qualitative factors such as pre-existing damage or historical context are considered. Various levels of risk are defined below. When appropriate and where levels of risk are applied to a specific situation, due diligence may justify a legal analysis as the risk levels may have a correlation with liability.

**High Risk –** a term reserved for situations where there is a clear threat to people in the present or near term (days, months or several years) and requires a rapid response or remedial action.

*Figure 2.  Photograph of damage caused when the seawall failed during a late October storm, 1983. Photograph courtesy of Dr. Bob Taylor, GSC Atlantic.*

**Significant Risk –** a term for situations where there is a clear and present threat to significant infrastructure or the natural environment. When relevant, this includes potential but not necessarily probable threats to people over varying time scales.

**Moderate Risk –** a term for situations where there is a threat to infrastructure or the natural environment where a process is occurring (or would be occurring without interference) but at a slow rate that will manifest over a period of several years. It is also used when a process is gradual, may be occurring now, and may or may not increase in severity over time (e.g. gradual shoulder erosion of a road). This term is also used when an event is known to occur: the nature of the event may be cause for considerable concern, but the occurrence of that event is on the scale of years, decades, or centuries and cannot be reliably predicted.

**Low Risk –** an event is possible but is unlikely in the author's opinion. This includes situations where risk cannot be entirely dismissed or the risk is only relevant over such long periods of time that proper planning would reduce or eliminate the risk.

## 3.0 Local Beach Processes

Gabarus Harbour is formed by a series of three gravel-cobble bars that stretch between the mainland and what are in essence three bedrock islands (when considered without the attaching gravel bars). The bars

are composed of material transported by longshore currents and deposited in areas of low energy, anchored by the bedrock islands. These types of bars are common along the shore due to high levels of sediment supply derived from eroding drumlins.

**Figure 3** illustrates the transport of sediment under varying wind conditions along the eastward facing, main bar. The north end of the beach (backed by the sea wall) protects Gabarus Harbour from easterly winds and surges generated by storms and tropical (post-tropical) cyclones. Examination of **Figure 3** reveals a 'double arc' in the longshore profile of the bar. The two arcs correspond closely to the protected – unprotected parts of the bar, with the central apex located near the south end of the seawall. This also corresponds to the location of a possible rip-tide effect.

The south end of the beach, not protected by the seawall, is inferred to be retreating landward at an average rate of 0.3 - 0.5 m/yr. This rate is inferred from the rate of retreat of a bar examined west of the study area and is consistent with the rate of landward retreat of the spit at Dominion Beach. This rate of retreat can be used as a crude approximation of the rate of retreat of the entire bar if the seawall had not been constructed. Applying the rate of retreat to the northern end of the bar allows construction of a model of the present day harbour if there was no seawall. What is particularly important to note is that Rouse (Island) anchors the north end of the bar. If the bar had been allowed to migrate to the west there would have been a moderate risk that it would have blocked the harbour entrance as well as infilling the harbour. There would also be a moderate risk that the bar would have breached at the northern end and then the entire bar would have moved westward to stabilize on the shore of the mainland. Such large scale movements might occur slowly over a period of years but may also occur suddenly. In such a scenario, the bar would overwash and be cut down to an intertidal to sub-tidal height. The new beach would then form along the shoreline at the back of the present day harbour over a period of a few months or years.



***Figure 3.*** *Illustration of general sediment transport in front of the Gabarus Seawall, including the area of the seawall at increased risk of collapse.*

This scenario could be applied to a major seawall breach (or a series of major breaches). Without repair such breaches could compromise the entire bar and seawall. However, this interpretation is highly speculative as end effects of the seawall, width of a breach(s), sediment loss or gain; and many other unanticipated factors would likely influence the behaviour of the natural system.

# 4.0 Sea-level Rise and Sustainability

Sea-level rise may be cited as a major factor leading to the deterioration of the seawall, and as a factor driving the need for repairs. The magnitude of sea-level rise anticipated at Gabarus should also be considered in engineering plans when designing a repair strategy for the seawall. Sea-level rise is also likely to be referred to as a reason why the harbour and community will be increasingly threatened in the future. Thus, this issue needs to be addressed, and specifically with respect to the sustainability of the community, the present seawall, and the sustainability of repairs to the seawall.

The best estimate of changing rates of sea-level rise along the Atlantic coast of Nova Scotia is from a paper published by Gehrels (2005) and shown in **Figure 4**. Note that during the period 1800 – 1910(20) the rate of sea-level rise was 1.6 mm/yr (16 cm/100 yr). In the 1910 to 1920 time interval, the rate of sea-level rise accelerated to 32 cm/100 years, and it has remained constant since that time. This acceleration is a global phenomenon occurring at different times in different regions, but generally occurring between the mid- to late-1800s and 1930.

**Figure 5** shows the rate of global sea-level rise between1993 and late 2011, based on satellite altimetry (used with permission from the University of Colorado). The average rate based on an assumption of a continuous linear rate of rise is approximately 32 cm/100 years. Examination of a GRACE gravity measurement plot of regional sea-level rise near Cape Breton indicates that the regional rate is only one-
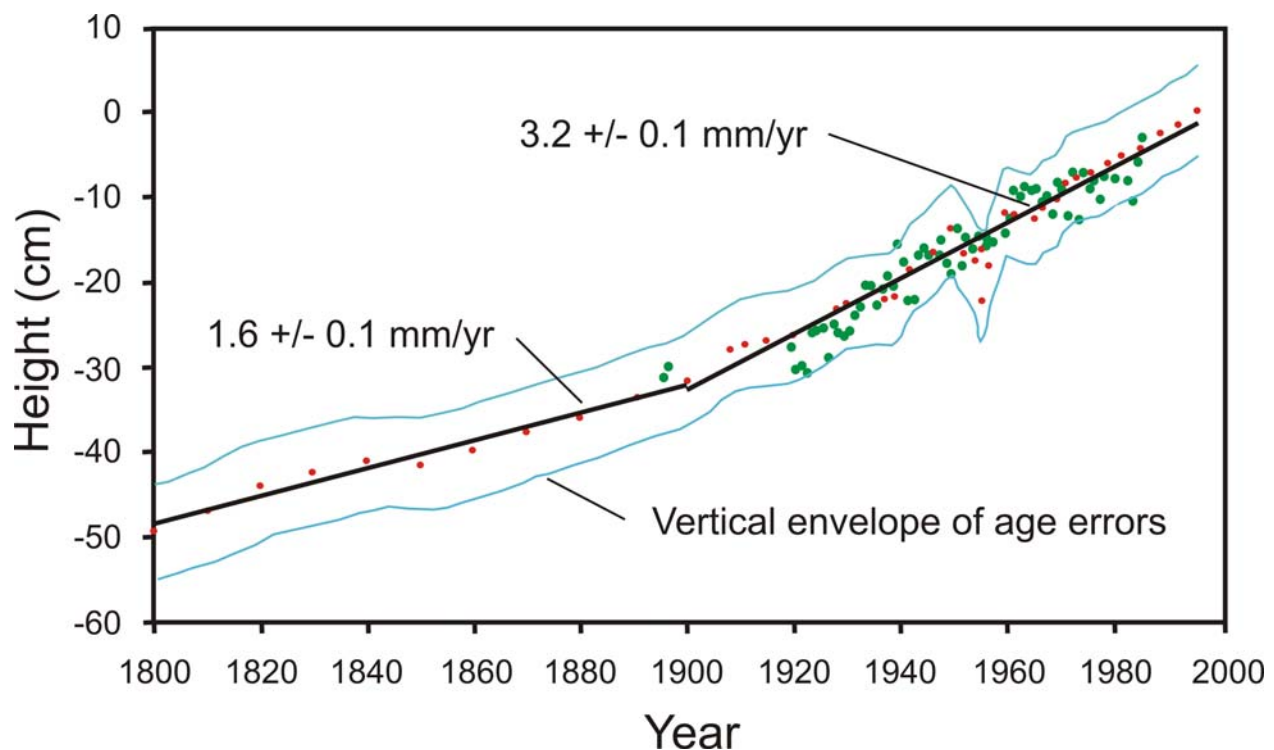


*Figure 4. Historical reconstruction of the rate and observed amount of sea-level rise along the eastern shore of mainland Nova Scotia. Green dots indicate tide gauge data from Halifax. Modified from Gehrels et al., 2005.*
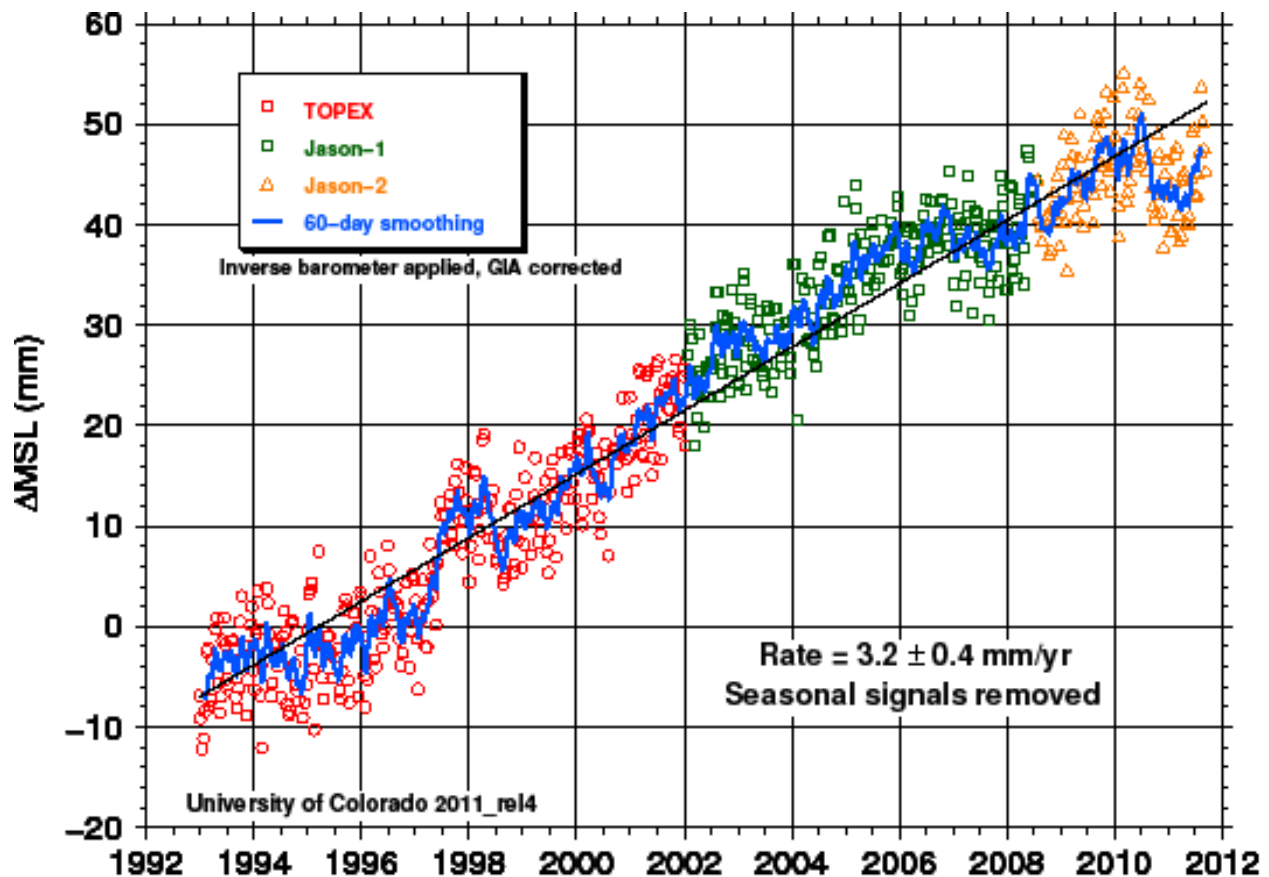
*Figure 5.*  *Average global sea-level rise between 1993 and late 2011, as measured by satellite. Figure reproduced with permission from the University of Colorado.*

half of the global rates (i.e. ~ 16 cm/100 years). This is consistent with the rate of rise from Gehrels (2005), since the GRACE satellite-based methodology does not measure the contribution of crustal subsidence to the observed sea-level rise, which is in the order of 17 cm/100 years as measured at Halifax. It is important to note that the rate of global average sea-level rise **(Figure 5)** has decelerated dramatically to approximately 29 cm/100 years since 2000 – 2003, if the data are regressed as two separate rates with an inflection point around 2000 – 2003. Note that the use of a 'global average' rate of sea-level rise is controversial and its utility is questioned. It is the author's opinion that calculating an average rate of global sea-level rise from regional rates that vary dramatically and are influenced by regional factors such as ENSO (la Nina and El Nino) and Pacific Decadal Oscillation, among others, is misleading.

To put sea-level rise in a local perspective with respect to eastern and south-eastern Cape Breton Island, local tide gauge records from North Sydney were examined between the mid-1970s and 2011 **(Figure 6).**  The data were smoothed using a 30 day box smoothing average to remove the effects of lunar cycles on the tide data. A 365 day box smoothing average was also applied to remove the yearly variation in tide gauge data caused by thermal expansion and contraction of the southern hemisphere oceans during summer and winter months, respectively. Note that prior to the mid-1970s the tide data from North Sydney are considered by the author as too fragmented to be useful.

The average rate of sea-level rise at North Sydney is 29 cm/100 years.  This is entirely consistent with global rates of sea-level rise, work by Gehrels (2005), the Halifax tide gauge data, and measured crustal
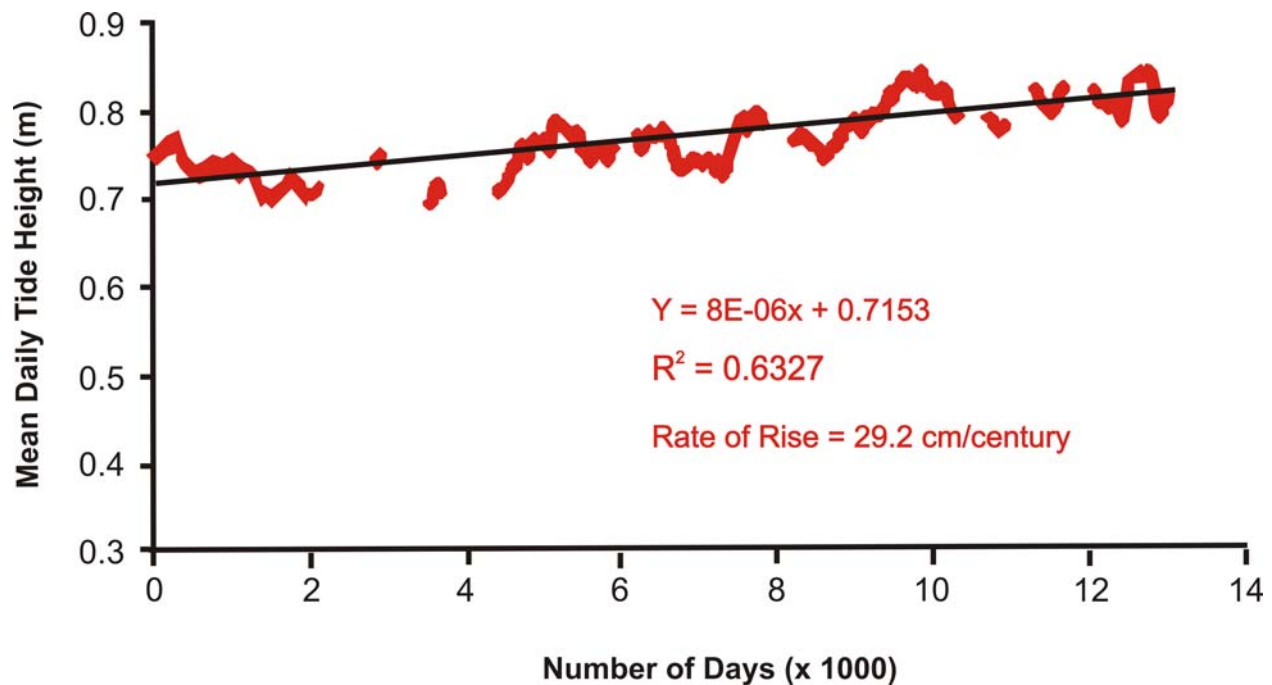
*Figure 6*. *Tide gauge data from North Sydney between the mid-1970s and 2011. Lunar and seasonal yearly variations were removed using a box smoothing technique. Data are from the Canadian Hydrographic Survey.*

subsidence, given large standard deviations around the average for some of these methods. Note that there has been no acceleration in the rate of sea-level rise since the beginning of modern satellite measurements in 1993.

Based on an examination of the peer reviewed literature, the author concludes that sea-level rise at Gabarus will remain at approximately 30 cm/100 years for the foreseeable future **(Figs. 4, 5 and 6).** Thus, with appropriate repairs, the community of Gabarus, the seawall, and the harbour infrastructure will be sustainable in the future with respect to the <u>low risk</u> associated with the issue of sea-level rise in this area.

# 5.0 Intermediate- to Short-term Factors Influencing Back-harbour Flooding and Infrastructure Damage

Past, present and future eustatic and isostatic changes in sea level, and how they relate to apparent sea-level rise (or fall), were discussed in Section 4. Sea-level rise has and will affect harbour flooding levels over time periods of many decades to centuries. Sea-level change is a long term process, however, and in the author's opinion a low risk process, and will not be discussed further in this section. There are additional intermediate- to short-term parameters that affect the potential for and magnitude of harbour flooding, and these will be discussed below.

## 5.1 Storms

In this section the varying nature of tropical cyclones or hurricanes (e.g. Juan), post-tropical storms (e.g. Noel), and late fall, winter and spring storms are briefly discussed in relation to their potential impacts on Gabarus Harbour.

5.1.1 Tropical Cyclones (Hurricanes)

Overview.  The difference between hurricanes, post-tropical storms, and the general term `storm', is somewhat esoteric. A hurricane is a tropical cyclone with winds of 121 km/hr or greater. Post-tropical storms and regular fall/winter storms often have winds that exceed hurricane force, but are not considered to be hurricanes for many reasons not relevant to this report. Tropical cyclones or hurricanes that impact Maritime Canada typically move rapidly, impact suddenly, and may depart an area in the time frame of an hour. Similarly, the associated storm surge may arrive as one or more individual surges that build rapidly and subside equally quickly. Because of this people will often report that property damage was caused by only a couple of waves. Storm surges and large waves that occur an hour or so before and after a high tide usually cause far less damage than hurricanes arriving at or near high tide. Because of this time constraint the risk of damage to marine infrastructure is localized and reduced. Damaging wind directions typically vary from southeast to northeast, depending on what side of the head wall a community is located on when the hurricane makes landfall. Thus harbours, bays or shorelines that are exposed to these wind directions typically suffer the most wave damage.

Relevance.  The seawall at Gabarus is aligned roughly north – south along the top of the bar **(Fig. 3)** and is directly exposed to the east. There are two headlands at either end of the bar that offer only limited protection to the north and south ends of the bar from northeast and southeast winds respectively.  With respect to tropical cyclones the highest winds are encountered along the north and east sides of the cyclone's headwall. Thus, a hurricane making landfall west of Gabarus would likely be a worse-case scenario for the village and protecting seawall. However, hurricanes that pass just offshore of Nova Scotia may produce very large storm surges with accompanying large ocean swells. An example is Hurricane Bill that passed south of Nova Scotia on August 23, 2009.  Such a hurricane, passing south of Nova Scotia, could be particularly damaging to the seawall if the surge and accompanying ocean swells struck during high tide.

5.1.2 Post-tropical Storms (Extra-tropical Cyclones)

Overview.  These storms may have hurricane force winds, large surges and accompanying large ocean swells. The difference between a post-tropical storm and a hurricane is that the storm has started to lose or has lost some meteorological characteristics typical of a tropical cyclone. An example is post-tropical storm Noel that struck Nova Scotia on the evening of November 3rd and the early morning of November 4th, 2007. The important distinction between a post-tropical storm and a hurricane, relevant to this discussion, is that post-tropical storms commonly affect larger areas than a hurricane in Nova Scotia. Thus, the probability of an individual area being hit by such an event is much higher than during a hurricane. Of equal or greater importance is that because of its size, the length of time that an area experiences tropical storm levels is longer (i.e. several hours). Thus, the probability of the storm surge and high surf conditions occurring across a high tide is greatly increased. Given the nature of post-tropical storms, the major wind directions may be different than commonly experienced during a hurricane. During Noel, winds west of Halifax blew strongly from the south-southeast and hauled around gradually to near southwest. Areas of shoreline that are commonly sheltered from hurricanes were exposed to 'hurricane' type conditions. This is why access roads, sections of shoreline, and Conrad's Road across the top of Queensland Beach (Halifax County) was destroyed by Noel.

Relevance.  The risk of wind and wave damage (distinct from deep ocean swells) to the seawall at Gabarus is reduced due to the eastward facing direction of the seawall. This is simply a function of typical post-tropical wind directions as described above. However, the increased potential (see above) for the storm surge with accompanying large swells to strike or last across a high tide increases the risk of flooding and damage to infrastructure behind the seawall. In addition, there is significant potential for

breaching of the seawall, given its present lack of structural integrity and the recent damage in February 2010.

5.1.3 Seasonal Storms

Overview. Seasonal storms are often referred to as northeasters, southeast gales or spring storms. These storms may have accompanying large storm surges, battering swells and high winds nearing tropical cyclone strength. They last for several hours, thus increasing the potential to strike across a high tide. Such storms are particularly damaging in areas where there are high erosion rates and where coastal sea ice is a factor.

Relevance. The February storm of 2010 that caused significant damage to the Gabarus seawall is typical of such an event. This is highly significant for Gabarus as it demonstrates that the harbour and seawall are not only at moderate risk from a hurricane or post-tropical storm (which are relatively rare events), but are at significant risk from far more common 'winter storms'. Such gales and storms, though varying in intensity, are a yearly event. Given the present damage to the seawall, a large storm or gale may cause the seawall to fail. The presence of armour stone behind the seawall may prevent waves from penetrating behind the seawall. Alternatively, the boulders could quickly be undercut as they lie on sand and gravel, be displaced, and allow wave egress. It is not possible to offer an opinion on which scenario is more likely or if a combination of the processes may occur. However, it is noteworthy to point out that a limited amount of armouring placed in front of the seawall (the seaward side) appears to have remained in place for a significant number of years.

5.1.4 Long Term Variations in Storm Intensity, Frequency and Damage

Overview. Early hurricane studies during the 1990s to mid-2000s generally concluded that the frequency and size of hurricanes were increasing and the cause was due to global warming (e.g. Webster et al, 2005). More recent papers (and newer data and analysis) have reached a consensus that there is no presently measurable correlation or causality between global warming and incorrectly reported increases in hurricane frequency or intensity (e.g. Maue, 2011). The National Oceans and Atmospheric Administration (NOAA) states that "as our understanding of tropical cyclones had developed, analysis techniques at the National Hurricane Center changed over the years," (authors insertion: i.e. satellites) "and led to biases in the historical database……." (http://www.aoml.noaa.gov/hrd/hurdat/). The frequencies of hurricanes and named storms in the database are erroneous because the database fails to account for increased hurricane detection due to the advent of satellites. A better measure of trends in hurricane strength and frequency over time is given by the number and intensity of land-falling hurricanes, as these statistics are little affected by satellite observations. In these data there is no increase in intensity or frequency of hurricanes (NOAA, 2012). This is also true with respect to the number of named tropical storms and hurricanes impacting the Atlantic Provinces (**Fig. 7**). This result is consistent with US landing hurricane and named storm data, which shows no increase in frequency or magnitude of tropical cyclones and named storms. It is also consistent with 2012 *in press* research on global storm frequency

Further, initial studies examining hurricane damage suggested that the cost of damages from hurricanes was increasing due to global warming. These studies were fundamentally flawed as they did not generally correct for inflation, greater numbers of coastal properties, increased per unit value of the properties above the inflation adjusted base line, and the NOAA database was incorrect (Pielke Jr., 2008). There is general consensus in the literature (except in insurance company funded studies), that there has been no increase in properly normalized hurricane losses as a function of global warming.
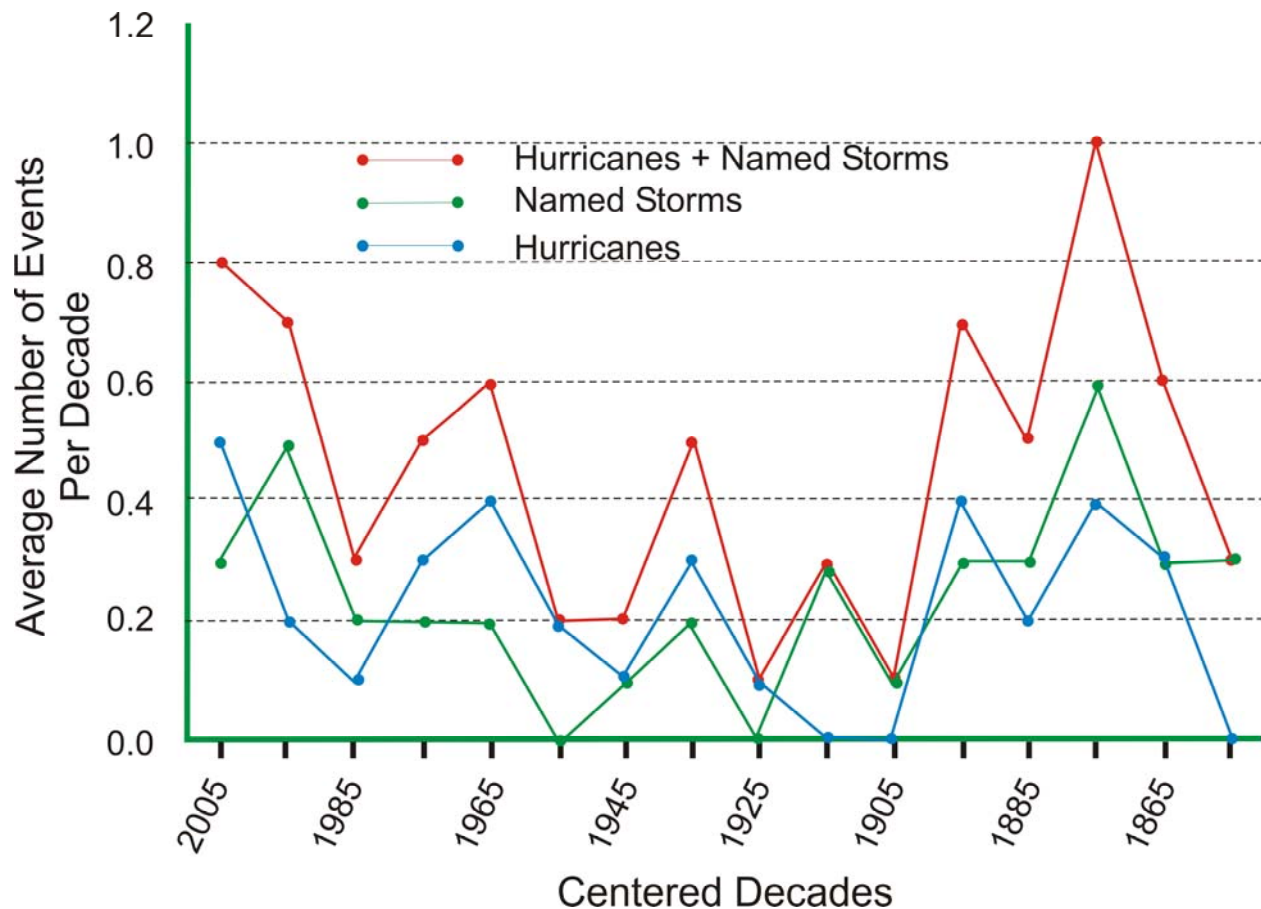
**Figure 7.** *Frequency of named storms and hurricanes making landfall in the Atlantic Provinces be-tween 1951 and 2010, inclusive. Raw data from the National Oceans and Atmospheric Administration (NOAA) hurricane database, 1951 – 2012.*

Relevance. With respect to the village of Gabarus, Gabarus Harbour, and the seawall, there is no evidence to suggest that infrastructure maintenance costs or long term risk will increase over time with respect to named storms, tropical and post-tropical cyclones. Such claims in similar situations are based on conclusions from erroneous literature. There is low risk.

However, late fall, winter and spring storms will continue to cause significant damage to coastal infrastructure. This is particularly true were there are significant increases in the value of coastal properties, the number of coastal properties, and where long-term erosion is now putting fixed location infrastructure at risk. Areas where winter ice has become less frequent in recent years, or where the ice moves on and off the shore more frequently, may experience significant erosion.  However, this trend over the last decade or two cannot be assumed to be a longer term phenomenon. The re-occurrence of severe winter cold in Nova Scotia with associated increases in the coastal ice pack is quite probable, as major ocean indices vary in and out of synchronicity over time.

## 5.2 Currents

Overview.  The effects of a current and a breaking wave on infrastructure are not intuitively similar. However, in both cases there is a physical and significant movement or displacement of water. When a wave breaks there is an obvious translocation of water at various rates of acceleration. Thus a breaking

wave hits an object with a large horizontal force, since it involves the components of mass and acceleration. A current has the same effect. When there is a significant differential water height, this produces a strong current flowing from the area of high water to the area of low water.

Relevance. Overtopping of the seawall and western storm ridge at Gabarus Harbour floods the harbour. A strong current forms, acting with considerable force on objects (infrastructure) and debris in the path of the moving water. Strong currents can compromise wharfs and other stationary infrastructure. This in turn produces debris that impacts other infrastructure with the result being a cascade effect of ever increasing damage (**Figure 2**). There is significant risk to boats, fishing gear and stationary infrastructure due to currents formed by 'harbour flooding'.

## 5.3 Surges and Tides

Overview. Storm surges arrive as a moving wave, increasing until a peak height is reached and then decreasing. There may be more than one surge (wave) and the time between the first arrival of the surge wave and the end of the surge wave varies. There are no tide data available for Gabarus Harbour. However, at North Sydney, the nearest tide station, the tide range is in the order of ± 1.4 metres. At Halifax the storm surge associated with Hurricane Juan was approximately 1.5 metres (http://www.ec.gc.ca/ouragans-hurricanes/default.asp?.lang+en&n=BAAEAC12-1).

Relevance. If a 1.5 metre surge occurred at Gabarus at high tide, the maximum water level could reach 2.9 metres above chart datum. Under such a scenario the harbour would likely fill slowly as the surge approached and tide rose. However, at Gabarus large amounts of water would flood over the seawall on the east side of the harbour **(Fig. 8)** and over the low storm ridge **(Fig. 9)** on the west side of the harbour caused by waves and wave run-up. This could dramatically increase the water height in the harbour. This is because the actual harbour entrance is narrow and shallow, potentially preventing the extra water from quickly flowing out of the harbour.

The author has not undertaken research on maximum storm surges recorded historically at North Sydney. Readers need to recognize that storm surge records for North Sydney may have little predictive capacity for Gabarus. This is because the coastline orientation and setting are different. In addition, since Gabarus is 43 kilometres from Sydney, surge conditions may be very different. There is a moderate risk of a Hurricane Juan event at Gabarus, simply because of the rare nature of a large hurricane or even post-tropical storm event hitting a specific location. However, given the historical record of high water levels, flooding and infrastructure damage from what are presumed to be 'lesser events' (e.g. 1983, 2006, 2010), there is significant risk of dramatic damage to boats, wharfs and fishing gear in the harbour. This is, of course, exacerbated by the potential scenario of a failure of the seawall, allowing waves and water to rush through, further damaging infrastructure. If the seawall disintegrated, then variably sized pieces of the creosote sea wall would become 'floating projectiles'. If this was to happen, the debris, in the form of marine collisions, would represent a high risk to other infrastructure.

## 5.4 Waves, Wave Height and Wave Run-up

Overview. Waves are typically considered as a major factor influencing erosion, flooding and infrastructure damage near coastlines. The reason why breaking waves are damaging was discussed in section 5.2, above. Water depth across the foreshore is an important factor in relation to breaking waves. When a wave enters shallow water its height (H) increases and its wavelength (L) decreases. The front of the wave slows down and the back of the wave, still travelling at a faster speed, starts to catch up (i.e. decreases) as the base of the wave drags on the bottom. Its steepness (the ratio of H/L) increases until the wave becomes unstable and it forms a breaker. This happens when the height of a wave (measured

*Figure 8. Water overtopping the Gabarus seawall due to wave run-up.*



*Figure 9. A 1.5 m high cobble, gravel and sand storm ridge on the west side of Gabarus Harbour.*

from trough to crest) is about 78% of the water depth (i.e. H = 0.78D).

Relevance. The foreshore seaward of the seawall at Gabarus is relatively shallow. Because of this, even if it is high tide and there was to be a 1.5 metre storm surge, there is a limiting of the height of waves impacting the shoreline. This is because the waves break and lose energy before they reach the seawall **(Fig. 10)** and continue landward and over the seawall due to wave run-up **(Fig. 11)**.



*Figure 10. Breaking waves dissipating energy before striking the Gabarus seawall.*



*Figure 11. Wave run-up on the sediment buildup at the north end of the Gabarus seawall, with resulting overtopping and flooding behind the seawall.*

The breaking of a wave seaward of the seawall is an important factor influencing the relatively long-term stability of the seawall. The maximum theoretical height of a wave hitting a vertical structure, if the maximum depth of water is known, can be calculated. So too can the actual 'overtopping' height of the structure (the height required to prevent the wave from overtopping the structure).  However, of more importance at Gabarus is the build up of the wedge shaped sand and gravel deposits against and immediately seaward side of the seawall **(Fig. 12)**. Even though the waves break seaward of the seawall, the inrushing water rushes landward up the ramp of sediment and overtops the seawall. This action is referred to as wave run-up. This is a significant issue that enhances the risk of flooding behind the seawall in the main harbour (refer to section 5.3).

On a point of land northwest of the harbour there was a former government constructed concrete and creosote breakwater **(Fig. 13 top)**. This breakwater has deteriorated **(Fig. 13 bottom)** and no longer offers shelter to the area of the western storm ridge. This likely allows increased overtopping of the bar in this area, thus exacerbating flooding of the harbour during storm events.

# 6.0 Seawall Assessment and Damage

A specific assessment of the structural integrity of the seawall is an engineering issue, not a geological question. However, from an engineering geology perspective the author is able to offer a number of observations and comments.

**Figure 14**, showing the damage to the seawall in 1983, provides a cross-section view of the seawall. It was constructed out of creosote timber with a rectangular cross section, with a raised wall on the
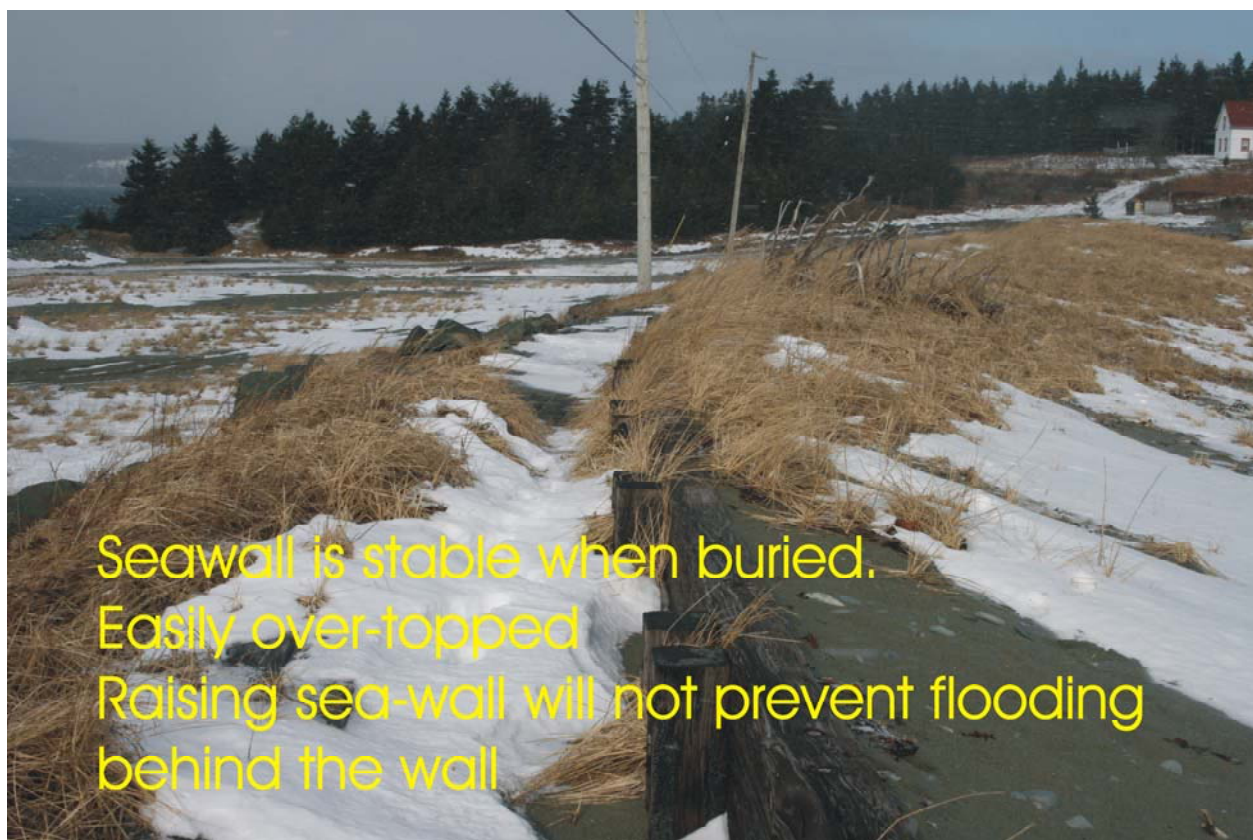


*Figure 12. Sediment build up against and over the north end of the Gabarus seawall.*

*Figure 13. Historical concrete breakwater showing deterioration (bottom) with present day enhanced deterioration (top).*

*Figure 14. 1983 photograph of damage to the seawall at Gabarus. Photo by Bob Taylor, GSC Atlantic.*

seaward side. It was ballasted with stone. It appears that it was simply placed on top of what was then the top of the beach (probably on wash over). In **Figure 14** it appears that the seawall was pushed landward, likely by the force of breaking wave impacts. The seawall ruptured, at which point the southern end rolled over on the back side exposing the base of the structure.

The photograph shows that the structure was not undercut in the front. It simply wasn't heavy enough to remain stationary, and once it started to move the structure was not strong enough perpendicular to the length of the seawall to prevent it from rupturing. An alternative failure mechanism may have been vertical lift from wave impact and a concomitant twisting or rolling of the structure. If this occurred the wall simply twisted and broke apart with the concomitant landward movement of the seawall. In either case the force of the waves exceeded the mass of the seawall.

Armour stone has subsequently been placed against the back side (landward) of the seawall to prevent it from moving landward. This appears to have been successful. However, over the last several years, where sediment is not piled against the front of the seawall, the seawall has tipped and bulged outward toward the water (**Figs. 15 and 16**). The back of the seawall has separated from its position against the backing armour stone. In **Figure 16** a small amount of armour stone is visible, presumably placed in front of the seawall in an attempt to keep the north end of the wall from collapsing.

It is critical to note that where the seawall has tipped and bulged outward, it has in fact twisted and rolled (**Fig. 14**). As was discussed in relation to the 1983 failure, this is the same failure mechanism that occurred in 1983, only this time the movement is seaward rather than landward.

It is also apparent that the movement is more damaging than previously discussed in this report. Looking at **Figure 17** one sees that the entire front of the seawall over a distance of 75+ meters has separated from the top, back and bottom of the seawall. This indicates that not only may the seawall rupture, but in the process (unlike in 1983) it is twisting itself apart, and this dramatically increases the hazard due to the potential for floating debris (see Section 5.3 above).

*Figure 15.* Severe deterioration of the Gabarus seawall.



*Figure 16.* Outward collapse of the seawall, with armour stone placed to prevent further tipping (?) and/or erosion behind the north end of the structure.
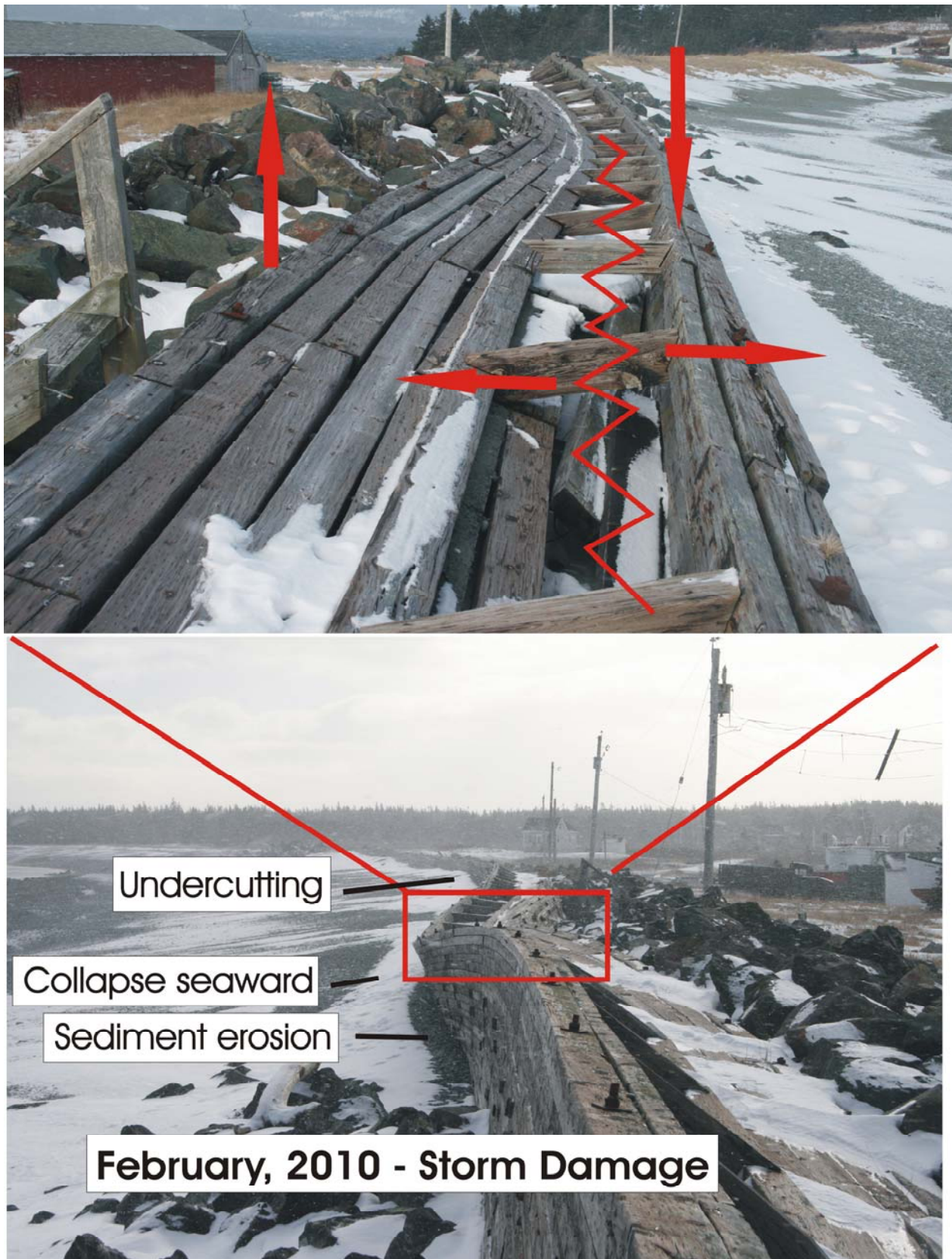
*Figure 17.  Rolling and twisting of the seawall is causing severe damage.*

In the 1983 breach large amounts of floating debris were generated by the failure of fishermen's wharfs. **Figure 2** shows the extent of the damage and debris in the 1983 breach.

# 7.0 Risks to People and Property

The following statement should not be quoted in part, in isolation or out of context with respect to the discussion below. If done so it would be a misrepresentation of the author's opinion. It is the author's opinion that there is a <u>low hazard</u> to 'life and limb' at Gabarus due to a small breach in the seawall during typical seasonal storms. There is one home located in a low area on the northwest side of the inner harbour that could be flooded or cut-off by road from the main highway. There is a <u>low risk</u> of the house being submerged or floating away.

It is anticipated that the previous two paragraphs and conclusion may be contentious with respect to the local community. However, note that it is the author's opinion that 'loss of life or limb' cannot be discounted in the case of a severe storm. A direct hit or near miss from a Category 1 or 2 hurricane would certainly damage or destroy the seawall.

Elsewhere in the community, in the event of a small breach in the seawall during typical seasonal storms, there are several houses where flooding may reach the foundations or surround the homes. Similarly, there is a <u>low risk</u> of the homes being submerged or floating away. In many areas in Nova Scotia, except where the topography is low and extends a considerable distance inland (e.g. the Truro area), or where significant flooding could occur due to breaches in dykes (Annapolis), the risk to people's lives is low. When the author says the risk is low, this is also a relative term. Compare for example coastal villages in Nova Scotia to areas such as Galveston, Texas, where category 5 hurricanes are possible, the topography is barely above sea level, and it extends for miles inland. In addition, in such an area there are many thousands of homes. In comparison, in Nova Scotia if the ocean comes to your front door, many people can simply walk out the back door up the hill.

In Sections 4 and 5, it was concluded that there is <u>significant risk</u> to wharfs, boats and fishing gear from flooding, currents and waves overtopping the seawall. However, there is a perspective here that should be considered. Given past experience it is clear that wharfs are not high enough to remain above anticipated flood levels. Nor has recent construction raised the level of the wharfs or buildings above flood levels that are certain to occur. Further, given the experience in 1983, it is obvious that the type of wharf construction is unlikely to survive a re-occurrence of a similar event. In addition, there is a practice of storing lobster traps on the wharfs, which would be underwater given another 1983 event. In addition, many of these wharfs, given the conditions to be expected, are not only too low, but are not built strong enough to prevent loss of the wharf and traps.

The practice of storing fishing boats on the shoreline and behind the seawall is problematic, given the history of flooding in Gabarus Harbour. Severe flooding will generate large amounts of debris that may puncture the hulls. Even where the hulls are elevated debris and current could easily knock the supports out from under the boats. This risk is increased given the state of the seawall.

# 8.0 Conclusions

The conclusions from this report are presented below.

There is a real and <u>significant hazard</u> of the seawall failing in more than one location and over various lengths in response to a seasonal storm, named tropical or post-tropical storm or hurricane.

It is the author's opinion that there is a <u>low hazard</u> with respect to loss of life and limb at Gabarus as a result of storm events similar to those experienced recently in the past (e.g. northeasters).

In the event of a large storm or hurricane, the hazard with respect to a loss of life and limb cannot be adequately assessed (at least not by this author), and may only be advised by further research.

Even with repairs to the seawall, if a Hurricane Juan type of event hit Gabarus, there is <u>significant risk</u> of an almost total loss of wharfs, fishing gear and boats.

Undercutting and possibly back pressure has caused the seawall to bulge seaward along parts of the northern end of the seawall.

Undercutting has caused the seaward side of the seawall to twist, drop down and forward (seaward). A 75 m to 100 m section is severely compromised as the front of the seawall has split from the top, back, and bottom of the structure.

Heavy wave action, possibly in concert with long-term deterioration of the structure, has broken the top front wave break of the seawall and pushed it back (landwards) along sections of the seawall.

There are numerous nuts and washers missing from bolts that presumably compromise the integrity of parts of the seawall as well as long-term deterioration of the iron bolts and spikes in the structure.

It is the author's professional opinion that sea-level rise at Gabarus will remain at a rate of approximately 30 cm/100 years for the foreseeable future.

With appropriate repairs (see below), the community of Gabarus, the seawall, and the harbour infrastructure will be sustainable in the future specifically with respect to the <u>low risk</u> associated with the issue of sea-level rise in this specific area.

Fishermen should consider increasing both the height and strength of their wharfs to account for the last 100 years of sea-level rise and to continue to build for sea-level rise on a generational basis. They should also consider alternative locations for lobster trap and boat storage.

The design of the fishing infrastructure is inadequate given the past and future risks identified in this report.

Lobster traps stored on the wharfs will be lost in the event of a 1983 type of event.

The storage of boats on land at Gabarus Harbour, even if the seawall is repaired, represents a <u>moderate to significant risk</u>, particularly given the replacement costs.

## 9.0 References

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