Impact of Climate Change on Prince of Wales Fort:
the conservation process and the adaptation strategy

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Abstract

In the early 18th century a massive masonry fortification was built in a Vauban style in the land of polar bears overlooking the immense and glacial Hudson Bay to secure the fur trade for the Hudson's Bay Company. Prince of Wales Fort is a truly unique engineering and architectural achievement, one of the most northern fortifications in the world, and in one of the coldest environments for such a masonry construction. Abandoned after the 1782 French attack, the fort nevertheless survived its first 200 years with a surprising level of integrity with only a few collapsed walls. Repaired in the first half of the 20th century the ramparts were monitored for the following 50 years. But the 21st century is harsh. Repaired walls are doing fine. Other large split-boulder work is doing well too. However ashlar walls that were perfectly plumb less than two decades ago now display serious cracks and bulges. Could this sudden deterioration be related to recent climate changes? Focusing on some of the key elements of the stability of the escarp wall at Prince of Wales Fort, this paper provides an overview of the history of construction and repairs, and a closer look at conservation activities over the last 10 years, including: investigation, monitoring, analysis; emergency stabilization; conservation strategy; and adaptation strategy required to ensure the longevity of the masonry walls in the context of climate change.

Key words: fortification, historic masonry, stone, permafrost, conservation, climate change, adaptation strategy

1.0 Introduction

In the early 18th century a massive masonry fortification was built by the Hudson Bay Company to secure its fur trade on the Esquimo Peninsula across the river from Churchill, Manitoba. Overlooking the immense and glacial Hudson Bay, Prince of Wales Fort is truly a most unique engineering and architectural achievement, one of the most northern fortification in the world, and in one of the coldest environments for such a masonry construction. It took more than 40 years to build and was occupied for only 10 years. Attacked by the French in 1782, it was totally abandoned for more than 150 years and nevertheless came to the 20th century with a surprising level of integrity. Safeguarded by stabilization works in the first half of the 20th century, the walls were essentially under a monitoring regime through the latter part of that century. But the 21st century is harsh. Repaired walls are doing fine and other large split-boulder works are doing well too. However ashlar walls that were perfectly plumb less than two decades ago now display serious cracks and bulges. Could this sudden deterioration be related to recent climate changes, possibly creating a new thermal and moisture regime for the rampart? This question came up, unexpectedly, as the design team was finalizing the working drawings and specifications for the rampart drainage strategy, challenging and potentially compromising the timely delivery of the conservation project.

Focusing on some of the key elements of the stability of the escarp wall at Prince of Wales Fort, this paper provides an overview of the history of construction and repairs and a closer look at
conservation activities over the last 10 years, including the investigation, monitoring, analysis, interim stabilization program, pilot masonry stabilization, and development of the conservation strategy. The paper further presents the revised stability assessment and the adaptation strategy developed in response to the observed changes.

The Parks Canada multi-disciplinary team lead by Cam Elliott, Site Superintendent Wapusk National Parks and Manitoba National Historic Sites, and the supporting architectural and engineering team lead by Lyne Fontaine from the Heritage Conservation Directorate, Public Works and Government Services Canada, have invested considerable efforts and resources to maintain the ramparts’ structural integrity. Capturing the essence of the changes endured by the fortification over the years and the challenging conservation process, this paper presents a story of perseverance and hardship, a story of continuous adaptation.

2.0 History of construction and repairs

Built by Hudson Bay Company in the early 18th century to secure the fur trade in Northern Canada, this masonry work is a commercial fortification, not a military fort like most other fortifications. Yet it was built in accordance with 18th century state of the art fortification principles, in a Vauban style, with massive masonry walls featuring four bastions tied by curtain walls. Most unusual in terms of scale and material for northern construction, the ramparts are almost 13 meters wide, and the escarp walls are more than 5 meters high. Prince of Wales Fort is a unique engineering and architectural achievement.

The fort was built over a period of 40 years by a small team, typically around 50 men. They lived in unbearably harsh conditions in this rigorous climate and had many other duties, such as hunting, fishing, firewood, trading. With only one supply boat per year coming from England they essentially had to rely on the food they could grow, fish, hunt or trade for. Firewood was far distance as away: there are few or no trees around the bay. Previous explorers had deemed this environment unsuitable for any European settlement. Yet these men had to build in this remote location, land of polar bears and permafrost, a masonry fort with rudimentary lifting equipment, one horse or an ox. The construction of Prince of Wales Fort is truly a story of perseverance and incredible hardship.

Figure 1. Prince of Wales Fort, National Historic Sites of Canada, Churchill, Manitoba, July 2000

Figure 2 & 3: Prince of Wales Fort is situated on the western shore of Hudson Bay at the mouth of the Churchill River about 1000 km north of Winnipeg. Churchill is the polar bear capital of the world as well as the beluga capital of the world.
Using mostly quartz wacke, a stone harder than granite, the fort was built in two phases.

Figure 4&5: The first phase of construction (1730 to 1740) included a 25-foot wide and 10-foot high rampart with masonry walls built with large split boulders and clay mortar, and with wooden gabions filled with sand as the parapet. The escarp wall was 9 feet wide at the foundation and 6 feet at the top. On the right, the right flank of the NE bastion in June 1989.

Figure 6&7: The second phase (1740 to 1772) featured a 40 foot wide rampart with casement rooms built in the bastions, a stone parapet, and an ashlar outer wythe. The split boulder face stones were taken down, cut into ashlar stone and reset using lime mortars as seen on the right, at the NW bastion.

Several reasons triggered the second phase. The initial rampart was not wide enough to accommodate the recoil of the cannons and more working surface was required in the bastions. Furthermore, the wooden gabions were deteriorating and would not resist enemy attack; there was a need for a stone parapet, which would add significant load on the escarp wall. A stronger escarp wall was required. The builders first peeled off the split-boulder facestones in the upper section and reset them. But soon this approach was found to be insufficient, and they went into a major rebuilding. About three-quarters of the front section of the escarp walls were rebuilt as an ashlar wall with a reinforced core using lime mortars. Work was done with excellent craftsmanship and tight joints. However the lime mortar, typically requiring months to cure, has likely never set properly because of the frost. The rebuilding also resulted in a lack of proper keying of the face stones into the core wall.

In August 1782, Prince of Wales Fort was attacked by three French warship under the command of Admiral Comte de La Perouse. Faced with as many as 300 soldiers and sailors, Samuel Hearne and his 39 men, essentially traders and tradesmen, badly outnumbered, surrendered immediately. The French spiked the 42 cannons, burned the buildings, and blew up casements, including the powder magazine. The fort was damaged and basically neutralized. Hearne returned the following year, but decided to abandon the fort.
Prince of Wales Fort was rediscovered at the turn of the 20th century and its historic value recognised as “one of the most important fortresses of the Western Hemisphere” (1). Designated a National Historic Site of Canada in 1920, it was acquired by Parks Branch in 1922.

![Image](image1.png)

Figure 8&9: As shown on these 1910’s and 1930’s photographs, despite the siege and more than 150 years total neglect most of the rampart had survived surprisingly well considering the damage inflicted by the attack, the harsh climate and the total lack of maintenance and repair for all these years.

The reasons for the designation of PWF as a national historic site are as follows:
1) It commemorates PWF’s role in the 18th century French-English rivalry for control of the territory and resources around Hudson Bay. Fundamental to this commemoration is the role of the fur trade and its participants; and
2) The ruin that is Prince of Wales Fort is both of national historic and architectural significance.

![Image](image2.png)

Figure 10 & 11: In the 1930’s and in the 1950’s, the federal government undertook a stabilization project. The bulk of the work was to reset fallen face stones of the escarp wall with concrete back-up and coping as seen on the left at the SW bastion. Ashlar sections exposed to SW sun radiation had suffered most extensive damage. On the right the SE bastion salient angle which had retained its structural integrity and required minimal work.

Located in a permafrost area with an average temperature of –2 Celsius, the fort is fortunately built on bedrock or dense granular material, thus permafrost condition does not affect significantly the bearing capacity of the foundations. However the period without significant frost is about two months, allowing 6 to 8 weeks for construction at the fort. The implementation of the conservation activities is further challenged due to the lack of services in Churchill. Supplies and materials must be specified, purchased, transported and stored so they are available for use during the summer work period. This requires a logistical trail beginning a year or more in advance of the work.

The second half of the 20th century shifted to monitoring. Some cracks were observed in the 1970’s on the escarp walls and tell-tales were installed. In the 1980’s a photogrammetry program was initiated for the south front and NW corner sections of the escarp walls. In 1989 the engineers of the Heritage Conservation Program identified three areas of concern. Unfortunately funding was not available to address the unstable sections.
3.0 Defining the conservation strategy

The collapse of twelve stones of the SE bastion acted as a wake-up call. An investigation, monitoring and analysis program was initiated in 1999 to understand the causes of the collapse and deterioration of the escarp masonry walls. The work of the multi-disciplinary team included the:

- detailed structural history;
- archaeological investigation on the rampart (occupation layer very close to the surface);
- geotechnical investigation, including percolation in soil; characterization of the soil (mostly granular material, some silt);
- testing of stone properties: very hard (more than 180Mpa) and impervious;
- investigation of the core wall with fibrescope: extensive cavities found in the wall, in particular in the bulged areas; large boulder construction observed in the core, suggesting dry-masonry assembly;
- monitoring the moisture and thermal regime of the rampart, boreholes in the fill and installation of temperature and moisture probes: no evidence of permafrost in the fill is found; temperature in the fill fluctuates below and above freezing point; and
- investigation of the hidden face of the escarp wall: large boulder construction set in clay mortar.

The diagnosis reached in 2000 was that there was a moisture problem in the wall combined with the rigorous frost action. More specifically there is no drainage system on the rampart, i.e. the water percolates through the rampart and infiltrates the masonry walls. In addition there is an absence of keystones tying the facestones to the core wall. The excessive moisture at freezing temperatures results in the **frost jacking** of the face stones, a typical cause of masonry disorder in Canada. Thus there was a need to keep the wall as dry as possible.

In August 1997 an imminent danger of collapse was identified in these areas, in particular for the right face of the SE bastion, where the face stones had moved outward by about 140 mm over a period of 9 years, resulting in an exponential pattern of deformation, and thus in a very critical situation. The wall was in the process of collapse.

In October 1997, a more than 100km/hr wind storm triggered the collapse of twelve face stones on the south face of the SE Bastion. The “architectural significance of the ruin that is Prince of Wales Fort”, as stated in the commemorative intent, generated a debate that extended over several weeks. It was decided to maintain the integrity of the rampart and rebuild the collapsed section. Three of the most threatened areas were shored and the fallen stones were re-erected during the winter 1998.

The July 2000 team meeting included Prof. Ramiro Sofronie (centre) and Juhanni Pentimikko (right) from ISCARSAH (ICOMOS structure committee). The outcome of the meeting was as follows:

- Drainage on the rampart is top priority
- Minimum intervention for masonry walls; dismantling & rebuilding should be a last resort
- Masonry stabilization by anchor should be investigated.
While archaeological investigation and monitoring continued, a new funding uncertainty arose in early 2002. The long-term conservation was postponed. More trusses were installed in winter 2002 in areas of the SE Bastion and South curtain wall. Trusses are anchored to the bedrock. Drilling the boreholes where anchors are grouted requires a lot of water because of the hardness of the stone, raising questions about the feasibility of drilling into the masonry walls.

4.0 New evidences of masonry deterioration at the fort

As the initial phase of the conservation project was initiated between 2003 and 2006, some new evidence of deterioration became apparent. The core of the escarp wall was more deteriorated than expected. In some areas the movement of the facestones appeared to be accelerating.

During the masonry stabilization project the core wall, in particular the front part of the core, was found to be more deteriorated. Cutting back up to 200 mm of either the back of the facestone or the front of the core stone was required to reset a profile that would be reasonably vertical. This need to cut back to reinstate a profile that would be close to the original profile confirms the extent of movement and instability of the core wall.

The instability of the core became a major concern for the masonry stabilization team. Safety became the paramount element of the masonry stabilization project. A full time resident engineer was assigned to the project. Parks Canada restoration masons executed the masonry work. Every possible measure to mitigate risk was implemented to ensure safety on this challenging masonry construction site.
In retrospect, after gaining a better understanding of the core wall composition and condition, looking back at the 18th century construction of the ashlar escarp wall provides some relevant explanation of the degradation of the core. The core wall was initially built with large boulders set in clay mortar. Subsequently the front section was dismantled and rebuilt with lime mortar and ashlar facestones. Over the years, the lime mortar has lost its compressive strength and its structural integrity. The core stones, losing also their stability, then seek alternate load paths, sliding and rolling, creating an internal disorder in the masonry wall and resulting in excessive pressure on the facestones. The facestones are particularly vulnerable to this excessive lateral pressure because of the lack of keystones tying the facestones to the core. This lack of keystones is a result of the process of rebuilding the face of the wall in the 18th century.

Furthermore, the extreme hardness of the quartz wacke made stone cutting a very difficult task. Consequently, the back faces of these stones have an irregular shape, and a limited bearing surface. This limited bearing surface allows for easier rotation of the facestones, and reduces the capacity of the facestones to resist lateral loads. Therefore, the revised 18th century concept and craftsmanship of these walls embedded a few critical weak points such as heavy split boulders relying on lime mortar for their stability, lack of keystones, and reduced bearing surfaces. In other words, the appearance of a perfect masonry assembly, and despite the incredible hardship that went into the construction of such a massive construction, these sensitive features made the escarp walls vulnerable to the deterioration of the lime mortar in the front core.

As the masonry stabilization progressed, several areas of the escarp walls continued to display more outward displacements of the facestones. The most puzzling area was the North curtain wall where a perfect alignment had been observed in the 20th century and was now showing significant cracking and bulging. This unexpected development of cracks and deformation prompted many questions. Why would a wall that had been performing so well over more than 270 years so suddenly display major evidence of instability? Could the recent climatic changes observed in particular in the Northern part of Canada in recent years have affected the structural integrity of these 18th century walls?

Figure 14, 15, & 16: As the team finalized the design for the rampart drainage for the SE front area, a major acceleration of cracking and bulging of the north wall was observed. Trusses had to be installed in 2006. The North wall had always been stable up to the 1990’s. What could be the explanation of this sudden development of displacement of the face stones?

This question deserved some serious consideration, in particular as the implementation of a drainage system on the top of the ramparts was about to be implemented. Indeed this drainage concept involved the installation of some additional load on the rampart. New material on the rampart was required to create the appropriate drainage slope and prevent uplifting of the membrane system. What would be the impact of this additional loading on the stability of the escarp walls?
At that point it became clear that there was a need for a reassessment and validation of the 2000 diagnosis before finalizing the design of the membrane system. There was a need for understanding the impact of climate change on the stability of the masonry walls.

5.0 Looking into the past to understand the present

In search of a link between the climate change and the performance of the masonry walls, we looked into the past to understand the present. Patterns of deterioration in the previous century were observed and results of the monitoring of the rampart temperature were reviewed. Three key conclusions emerged from this analysis:

1. Apparent good performance of the original split boulder construction

   Interestingly, it would appear that in the long term the split boulder walls, the original type of masonry assembly, outperformed the ashlar masonry. These walls are mostly located in the NE bastion and on the East curtain wall. While most of the split boulder walls face north and east, some sections are facing west and south. There are no records of repairs or reconstruction for some sections, suggesting that the original 18th century construction is still in place.

   Figure 17: The good performance of the split boulder walls could be attributed to several factors:

   1) Clay mortar was used and would be less susceptible to degradation and erosion under frost action, and thus the masonry assembly would be more stable.

   2) The strong batter of the split boulder walls would allow for better confinement and would counteract more effectively excessive lateral pressure that could have occurred.

   3) The large size of the split boulder would typically result in the use of less mortar and a more direct load transfer from stone to stone.

2. Ashlar masonry walls exposed to more sun radiation have deteriorated more rapidly.

   As seen on figure 18, historic performance of the ashlar masonry correlates with extent of sun radiation.

   Figure 18: Warmer areas have deteriorated more rapidly than colder areas

   1) most historic collapses observed at the turn of the 20th century occurred in south west exposure areas (shaded areas).

   2) the SW salient angle, exposed to more sun radiation on both faces, was the most damaged.

   3) the North curtain wall, the wall with the least sun exposure, performed best up the later part of the 20th century.
3. Temperature in the rampart is a function of the extent of solar radiation affecting the walls located in close proximity.

The thermal regime of the rampart is complex. Churchill is located in a zone of discontinuous permafrost and has an average annual temperature given as –2 degrees Celsius in the 20th century. Suspecting permafrost conditions in the rampart, a temperature monitoring program was started in 1999 to understand the main characteristics of this thermal regime. No permafrost condition was observed in any location. The temperature fluctuates between –1 Celsius and +1 Celsius at the deepest location (4.5 metres below the surface of the rampart). Temperature varies more widely at probes located closer to the surface. Higher temperatures are recorded where the probes are located close to a wall that is exposed to more sun.

No temperature monitoring program has been set up yet for the masonry walls. The rampart temperature monitoring results provide, by extension, an indication of the pattern of temperature fluctuation in the walls. It can be assumed that the temperature in the masonry walls typically fluctuates more widely than the temperature in the soil.

The temperature in the rampart can be significantly affected by solar exposure. Solar radiation penetrates not only the surface of the rampart but also the sides of the ramparts, i.e. through the escarp walls or the courtyard walls. The sun being typically much lower in the North (Churchill being located at the 58th parallel), the solar energy transfer can be quite significant through the rampart walls. This sensitivity to sunshine has been confirmed by the results of the temperature monitoring.

The temperature differential is the most significant in the North curtain rampart. In the summer, the difference in the temperature between the probes installed along the north escarp wall and the probes installed along the south courtyard wall can be as much as 5 degrees Celsius. Part of this significant difference could be explained by the fact that the courtyard wall is not as massive as the escarp wall, thus allowing for a more direct transfer of the solar energy to the soil. As expected, the difference in the winter is not as significant, because of the reduced number of hours of solar radiation in the winter, and possibly because of the snow accumulation along the walls, acting as an insulator.

Thus looking into the past performance of the wall and the results of the temperature monitoring program suggests that the ashar masonry walls would be more vulnerable to potential increase of temperature. It seems that colder areas have performed better in the past, possibly because there were fewer freeze-thaw cycles that would damage the lime mortar, and also possibly because the temperature in the wall may have remained below zero for most of the year.

6.0 Impact of climate change on the masonry walls

Figure 18 & 19: In 1999 a monitoring program was set up to record moisture and temperature in the rampart. More than 30 temperature probes were set up in 11 boreholes at various locations in the rampart. The results improved the understanding of the complex thermal regime in the rampart. New moisture probes were installed in 2006. The monitoring has demonstrated the significant impact of solar radiation on the temperature of the rampart.
In light of these observations on the historic performance of the ashlar masonry walls and border line conditions of the thermal regime in the rampart, the impact of climate change could be an important factor in the acceleration of the distress in the ashlar masonry walls observed recently. The ramifications of climate change could be numerous: increase in precipitation observed in the North; increase in temperature, also well documented to be more acute in the North; and possible increase of the freeze-thaw cycles in the walls. How would these changes affect the structural integrity of the walls?

There has been significant evidence of temperature change in the last decade, for example:
1) The 1990’s were the warmest decade on record
2) From 1971 to 2001 the mean summer temperature has increased by 0.94C
3) From 1996 on the mean annual temperature anomaly has increased by up to 3 degrees per year
4) From 1930 to 1990 there were only 17 positive anomalies, i.e. less than 3 per decade; from 1990 to 2000, there were 6 positive anomalies, thus a two-fold increase in the last decade of the 20th century.

There has also been a significant increase of precipitation in recent years. This is of particular concern because lime mortar is known to be vulnerable to frost action when saturation level is high. The higher the saturation level, the more extensive the freeze-thaw damage could be. The annual precipitation prescribed in the building code for Churchill, an average of the previous 30 years, shows limited changes over the period of 1975 to 1995. When comparing the annual precipitation records of recent years to the 2000 prescription, 2000 to 2006 records indicate an average increase of 33%, the year 2005 shows an increase of almost 80%.

Figure 21 Coincidental changes?
There has been significant evidence of climate change over the last decade in Churchill: increased temperature, increased precipitation, possible wind increase and freeze-thaw cycle increase as well. Meanwhile the north wall, the escarp wall that had performed very well over the last centuries, has suddenly started to show suddenly serious signs of deterioration

Figure 22 To be frozen or not to be?
The impact of these changes on the integrity of the walls is a complex subject. At this point one general explanation has emerged: the wall with northern exposure would have remained essentially frozen for most of the year throughout the past centuries, allowing the mortar temperature to go beyond the thawing point only for a few weeks in a typical year. This would have resulted in a reduced degradation of the mortar. The recent climate change would have resulted in more extensive thawing periods and more deterioration of the lime mortar. In a way, this poorly cured 18th century lime mortar may actually own its survival in this rigorous climate to its almost year round frozen state for centuries. Consequently the changing climatic conditions could represent a significant threat to the stability of the North wall. Shoring trusses had to be installed in fall 2006.
Understanding the evolution of mechanical properties of a lime mortar going through multiple cycle of freeze-thaw cycles is the subject of cryogenesis, a very complex domain, and not so well understood and explored for lime mortar.

Facing this new evidence a revised diagnosis was required. In essence:

1) Cracking and bulging of ashlar masonry walls is caused not only by frost jacking of the facestones but also by excessive lateral pressure on the facestones from the unstable front core; the front core was rebuilt with lime mortar in the 18th century.

2) The ashlar masonry does not behave like a dry masonry assembly as originally assumed because of the extensive cavities and the large size of the boulders. In this type of masonry the load transfer is from one stone to another. The lime mortar is key in transferring some of the load. The deterioration of the lime mortar creates internal disorder in the front core and results in excessive lateral pressure on the facestones.

3) The increased precipitation results in increased moisture content in the mortar and aggravates deterioration of the lime mortar.

4) The process of deterioration of the ashlar masonry appears to have accelerated in the recent years and has resulted in an unstable condition of the core wall.

5) Given the deteriorating condition of the ashlar masonry walls, load restrictions would have to be applied on the rampart along the parapet.

7.0 Adaptation strategy

A membrane system was required more than ever given the observed increased precipitation. Yet this intervention was under load restriction, requiring a major revision to the proposed drainage system. The installation of the membrane required significant amount of levelling material and of ballast material, causing undesired weight on the rampart along the parapet. Excavation on the surface of the rampart was not an option because of the presence of the 18th century archaeological vestiges a few centimetres below the surface. An adaptation strategy was required. Geofoam was used as a substitute to the levelling soil. A system of wiremesh anchored down by the weight of the canons and helical anchors was used to secure the membrane layers against the wind uplifting loads.
While this adaptation strategy may look in retrospect relatively simple, the design process was not so simple as it required major changes just a few months prior construction on a remote site. The main design revisions had to be done in a few weeks. The system had to be reversible, i.e. it would have the very least negative impact on the archaeological vestiges below the surface of the rampart. Every layer of the system was assessed to ensure not only its appropriateness, but also the feasibility of an installation on the shore of Hudson Bay a few months later.

There was considerable discussion around the geofoam. While the geofoam is only 1% of the weight of the soil, there were questions, and still are, on the actual impact that this light and insulating material could have on the thermal regime of the rampart. Designing the anchoring system for the membrane to resist the ferocious wind of Hudson Bay was challenging as there was limited information on the actual pull out capacity of these anchors in a sandy gravel material.

In short, climate change had a major impact on this conservation project which had to be realigned a few months prior to construction, a major achievement for a site where construction is typically planned well in advance to secure timely delivery of material and proper arrangements for all resources.

An integral part of the conservation design is the moisture monitoring program that was set up in 2006 using time domain reflectometry (TDR) and frequency domain reflectometry (FDR). Moisture probes were installed below the membrane as well as in area where there is no membrane. This monitoring was set up to monitor the impact of the installation of the membrane on the moisture content in the rampart, more specifically to determine the extent of the moisture reduction that would take place and how effective the application of a membrane would be.

The combined results of the wall movement monitoring and the moisture and temperature monitoring should yield valuable information on the actual performance of the drainage interventions. It will be particularly interesting to compare the results between different sections where the surface of the rampart was completely covered by a membrane like in the SE bastion, or partially covered to various extent in other areas. As the implementation of the membrane system progresses every year, the rampart drainage system can be adjusted, and eventually, if necessary, in sections already done can be modified.

8.0 Conclusions

The Prince of Wales Fort escarp walls have undergone major changes in almost 300 years of existence. They were first built with clay mortar and large split boulders. This original masonry assembly still survives behind the ashlar facestones. The front part of the escarp was subsequently rebuilt in the 18th century with precisely cut stone and with what would have been then a good quality
lime mortar. This new assembly was the pride of the Fort’s enduring and perseverant masons. “Stronger and more secure” they said in the 18th century.

The fort was abandoned for more than 150 years. The ashlar walls have endured excessive moisture infiltration over centuries with no protection, and despite a few local collapses, the walls were still standing proudly on the shore of Hudson Bay at the turn of the 20th century. Recognised for their historic value, the ramparts were preserved a few decades later.

Silently and discretely a regime of change began settling progressively into the rampart in the later part of the 20th century. At the turn of the 21st century the beautiful ashlar walls are now facing a major challenge as the remaining frozen lime mortar has entered into a new thermal and moisture regime. Evidence of this change has appeared, some very abruptly and unexpectedly.

In response to the climate change an adaptation strategy is being implemented to mitigate the degradation of the mortar and reduce the frost jacking action. While there is no control over the temperature, the moisture content in the wall can be reduced, and can mitigate the accelerated changes. Will it be sufficient, time and history will tell. This adaptation story will eventually be part of the history of the fort, a story of perseverance.

The uncertainty of future climatic conditions for design is a new concept for existing and new construction as well. The impact of this new uncertainty on built heritage resources is yet to be fully understood. Historic structures have performed over years, decades, and centuries. This new uncertain dimension of the climate will call for considerable judgement on the part of the custodians and professionals mandated to safeguard these assets for future generations.

At Prince of Wales Fort, the impact of climate change was initially totally dismissed, likely because of the overall impressive performance of the masonry assembly in such a rigorous climate, and also because of the absence of permafrost in the rampart. Here are a few lessons learned:

1) The key lesson: expect the unexpected.
2) The impact of climate change can surface late in the project; look for its subtle evidence.
3) As custodians and conservators, we have no control over climate change, so the best strategy is to adapt to climate change.
4) Monitoring is key, the sooner the better. Baseline reading should be established as soon as possible.
5) Climate change is bringing out a heritage of loss and, perhaps, this heritage of loss is part of the conservation process and a legacy to future generations.
6) We ought to save as much as possible, but be prepared to lose some. Aim at safeguarding the character defining elements that embodied the values that are being protected.
7) Persevere: the cultural resources have persisted, so should we.

In closing, there is a real need to tell the stories of how the response to climate change is managed for cultural resources. Numerous cultural resources will be facing the impact of climate change in the upcoming decades. There is a need to share expertise and learn from these experiences, for better or for worse. In sharing the story of Prince of Wales Fort and its continuous battle to survive changes, we hope that the heritage conservation community will learn as much as we did.

You are more than welcome to communicate with us and visit the fort. In discovering the fort the visitors will view the 21st century contribution made by Parks Canada to enable the historic resource to persist and to form the basis for communicating the story. It’s an investment in the past to allow this amazing story of perseverance to continue into the future, rain or shine, cold or warm.

9.0 References
