SEALED ENVIRONMENT

Climate Control of Historic House Museums

Submission for HODI Award for Built heritage Conservation

by

Golnaz Karimi

Carleton University
Ottawa, Ontario

PROJECT DESCRIPTION

Horaceville, a nineteenth-century stone masonry historic structure in Kanata, was transformed in the late twentieth century from a farm residence to a public house museum. Today, it exhibits a permanent collection of approximately 5000 historical artifacts including domestic items, furniture, textiles, paintings, library and archival materials, and archaeological specimens from on-site excavations. Exhibiting a collection of artifacts in an older building creates a new life and purpose for the building. However, historic houses were designed with a certain type of construction and systems to provide the required indoor environment for a residence. After being transformed to house museums, the challenge is to find a good balance between preserving the building's historic fabric and providing a stable and museum-quality indoor environment for the occupying artifacts. This research attempts to address/propose appropriate measures and strategies required for the stabilization of Horaceville, and the preservation of both the historic structures and the artifacts housed in them.

It is first necessary to understand and appreciate the historical and cultural context of Horaceville and its significance as Canadian heritage. According to historical records and previous investigations, Hamnett Pinhey, an English merchant, immigrated to Upper Canada in 1820 to take ownership of a military land granted to him for services to the crown. He established one of the first agricultural settlements, called Pinhey's Point, on the Ottawa River.

Throughout the nineteenth century and early twentieth century, Pinhey's settlement developed as a farm complex with log cabins, a stone house (Horaceville), barns, mills, a church, a fort terrace, a powder house, a smoke house, and other related agricultural outbuildings. The estate became one of greater Ottawa's commercial, industrial, religious, and educational settlements. The Ontario Heritage Trust issued a heritage easement in 1988 to conserve the stone house. The City of Ottawa has also designated Horaceville under the Ontario Heritage Act.

To begin researching the site, a survey was conducted of the house museum and its adjacent barn with a 3D laser scanner in collaboration with the Azrieli School of Architecture and Urbanism and the Carleton Immersive Media Studio (CIMS). Multiple scans were taken from the exterior elevations and the interior rooms, corridors, and stairways which measured and collected millions of points in space. Then, the images were stitched together using SCENE, an image processing software, to create a 3D point cloud model of the building and its surrounding landscape. This was then used as a basis to create a 3D building simulation using ArchiCAD to demonstrate the existing condition of the structure with fine detail. This survey can be a base point study for future restoration projects and surveys. Another benefit is the visual and cultural value of the generated 3D model and 2D drawings that can be used for educational and experiential purposes such as creating virtual tours, museum programing, and fly/walkthroughs of the site.

Following the survey, a comprehensive physical assessment of Horaceville was conducted to determine the as-found condition of the building and artifacts. This aimed to understand building's construction via visual inspection and examination of previous condition assessment studies, particularly Julian Smith's 1991 Master Plan Study. It also provided context to reveal performance issues of the structure and to determine whether the building and the artifacts suffer from any environmental causes. The physical condition assessment allowed for visual detection of certain building performance issues, such as pest infestation. However, issues like high indoor relative humidity cannot be assessed visually and require further environmental studies. Various field investigation techniques were used to perform the environmental study to confirm Horaceville's existing issues and determine their sources. A thermal camera was used to detect moisture on the exterior and interior surfaces of the physical fabric. A weather station was used to measure and monitor the relative humidity and temperature in various rooms. A moisture meter was used to detect points of high moisture on the interior side of the building's perimeter walls. These tests were performed multiple times in various climate conditions to collect enough sample data to then analyze and identify potential issues.

The site investigations and environmental studies identified many performance issues in the house museum. Through independent research and consultation with John Ward of the Canadian Conservation Institute, a list of performance issues was prepared and ranked by level of risk. The detected issues include uncontrolled moisture, high relative humidity, inappropriate artifact storage, poor ventilation, deficiencies with the climate control system, and condensation on windows. The majority of these issues relate to the high levels of moisture in the fabric, which can result in gradual deterioration. Understanding the associated risks of the issues can help to determine preventive conservation measures and maintenance strategies. The performance assessment is also a useful guide for short-term and long-term museum planning. In addition, the general advice and preventive conservation strategies from this case study can be used for other Canadian house museums.

In order to stabilize the indoor environment in this house museum, one of the first steps is to manage the moisture levels. Several entries of liquid water were noticed throughout the building envelope. And it was determined that many locations had high moisture levels, which can be a results of various factors.

There are currently no gutters or downspout systems for handling surface rain run-off. Managing the rainwater is one of the most important measures in reducing the unwanted moisture for any historic building. Uncontrolled rainwater saturates the soil around the building and eventually wets the base of the building. The moisture will seep through any cracks in the foundation walls, leading to a damp basement that can increase the level of relative humidity in the entire building. The slopes and grading around the foundation walls also contribute to the high moisture levels in the basement. The ground slopes downward at the south elevation and directs rain and groundwater toward the building, leading to damp masonry walls in the basement and the south wing's central kitchen at grade. Additionally, rising damp appears at the base of the foundation walls and up to about one-and-a-half metres above ground level in the south wing's kitchen walls. The visual evidence of the rising damp is a band of discolouration or physical damage on the surface of internal walls.

Deteriorated mortar joints were observed at the base of all exterior walls close to grade. Water and moisture penetrates thorough deteriorated mortar joints and saturates the masonry walls, leading to a reduction in the thermal performance of the walls. Also, sections of the walls have been repointed over the years with cement-based mortars, which restricts the breathability of the fabric

A single-season monitoring program was undertaken with a weather station to measure the temperature and relative humidity (RH) inside the house museum. The data collection started in September and was performed once a month for four months in the morning at various rooms of the house. All three levels of the building had consistently high RH levels, predominantly over 50% in all rooms. The basement had the highest RH levels, never going below 60% likely due to damp foundation walls. The high level of RH can easily facilitate the growth of mold and other fungi on organic materials such as wood, paint, and paper. The outstanding challenge for most house museums is to find an appropriate level of RH for the best preservation of the content as well as the historic structure. RH is not an agent of deterioration, but an improper level can threaten the historic structure and the collection.

Additionally, a relatively high level of RH fluctuations was observed within a short period of time during the monitoring season. For example, the RH in the west wing's attic space fluctuated between 45% and 73% during the four-month observation period. A rapid change in RH causes the moisture contents of organic materials to change sharply, which in turn causes their size to alter, resulting in cracking of their surfaces. Currently, the east and west wings' attics are used for artifact storage. These attic spaces are poorly ventilated with high temperatures in cooling seasons and low temperatures in heating seasons. The temperature ranges result in high RH fluctuations that can be threatening to the stored historic artifacts.

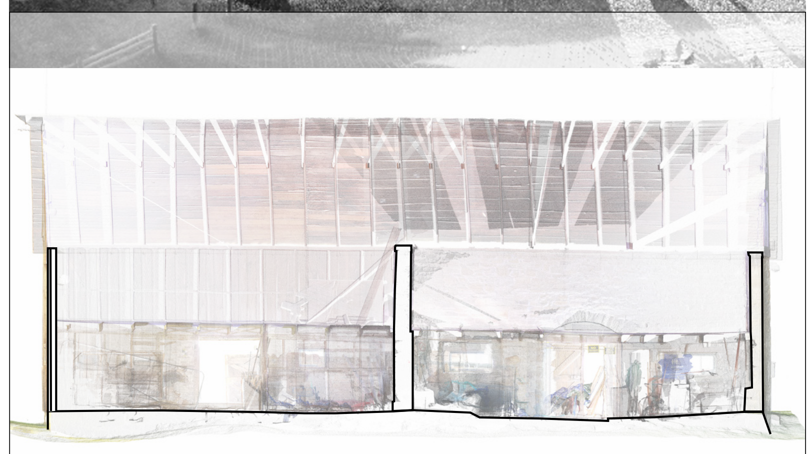
In terms of addressing some of the indicated issues, the highest priority climate control recommendation is to reduce the moisture problem at the source. Installing a roof water collection system with gutters and downspouts can help with directing the water to a storm water system with a perimeter drainage system at the subsurface level. The next necessary intervention is lowering and sloping the grades in a manner that will direct water away from the foundations, and help reduce the rising damp around the south side of the building. Also, vegetation close to the north wall must be trimmed or relocated away from the building to help with air circulation around the building. Furthermore, the air flow and ventilation should be increased in the basement and the kitchen, which is located on the south side, to dry the walls. Regular maintenance is required for early detection of any source of damage. Examining the masonry walls is an important part of the regular maintenance program. Decayed stones should be replaced with a matching unit. Also, any cement-based mortars should be removed and repointed with appropriate formulated mortars to increase breathability.

Mitigating the basement's moisture problems will automatically reduce the high RH in the building. However, a suitable monitoring system with temperature and RH sensors should be installed inside the exhibition rooms to collect a full year of data to ensure safe levels of RH. The existing climate control system should be equipped with a humidistat-controlled digital device instead of a thermostat. It is generally acknowledged that controlling the RH is more effective than controlling the temperature. When humidity rises above a certain level, such as 50% during the heating season, the heating system is activated to heat the room, which results in a decrease in the RH level. Also, the ventilation system should be controlled by humidity or dew point sensors so that it operates only when the air outside is dryer than inside. A modified use of conventional climate control systems can assist in keeping the winter and summer humidity at preferred levels.

This study also highlighted a need for additional artifact storage at Horaceville as well as improved conditions for their long-term preservation. Three options were proposed. In the end, the option that involved the rehabilitation of an existing vacant historic structure, the barn adjacent to the house museum, was suggested in favour of a new construction. The storage facility will be assembled inside the vacant timber section of the barn with a set back from the existing shell to preserve the barn's exterior fabric. The gap between the new and old structures will be an integral part of the proposal and carries several functions; it will allow air to circulate between the two structures to reduce harmful moisture and provide future access to the existing fabric. The gap will also be used as a utility space during and after construction. The new facility will be a three-storey rectangular container-type structure constructed with modular structural building components. It will provide forty square metres of space on each floor connected by perimeter stairs located in the space between the old and new structures. The first two floors of the new storage facility will contain storage spaces for artifacts, and the third floor will offer a multi-purpose room planned for artifact preparation, examination and research. The storage facility's multi-purpose room is intended to be available all year round for the museum and conservation related activities. The storage areas are based on Pinhey's Point Foundation's storage needs assessment conducted by Lundholm Associates in 2015. The first level will contain a compact storage system with wide shelves for heavy and large artifacts such as furniture pieces. The lighter and smaller items like framed artifacts and archival materials will be arranged on specialized compact storage system on the second level.

PRESERVING CULTURAL HERITAGE

DOCUMENTATION



Survey results from a 3D scanner

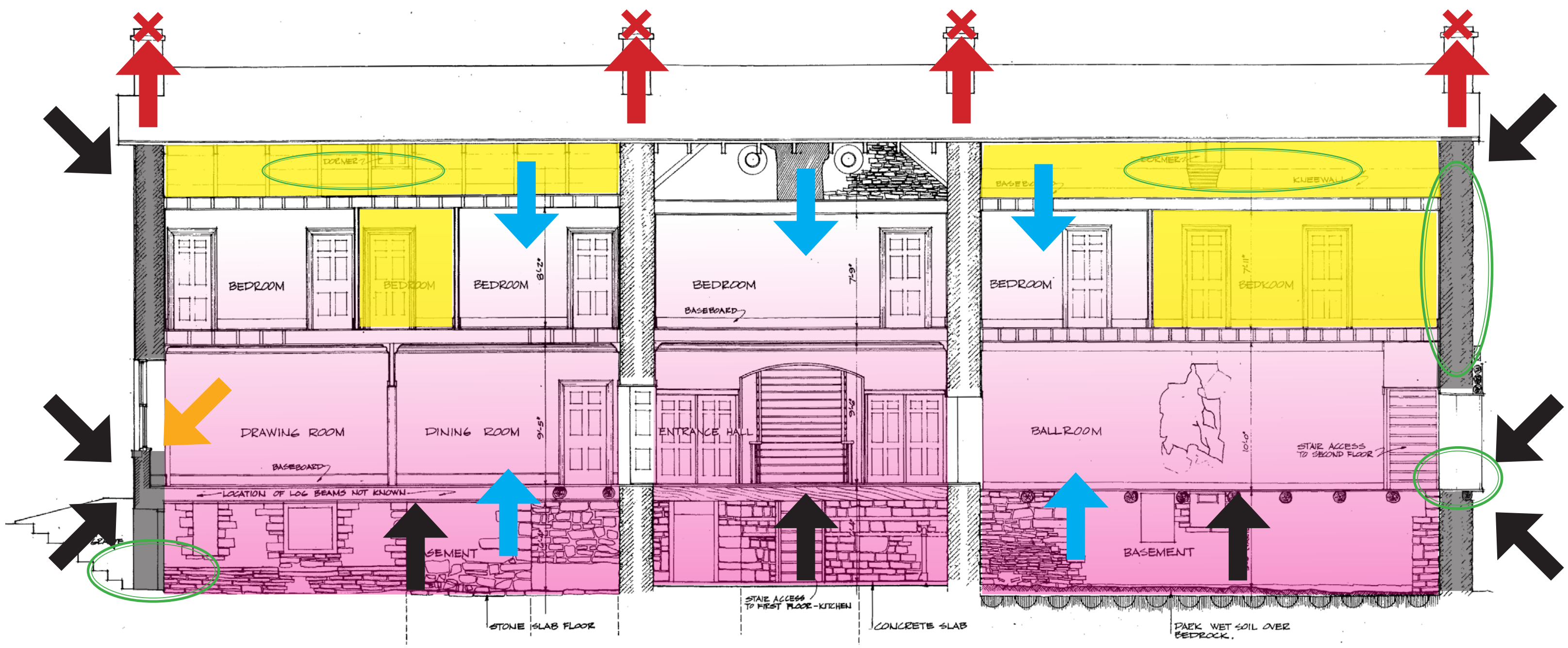
CONDITION AUDIT

CONDITION ASSESSMENT OF THE HOUSE MUSEUM

High risk

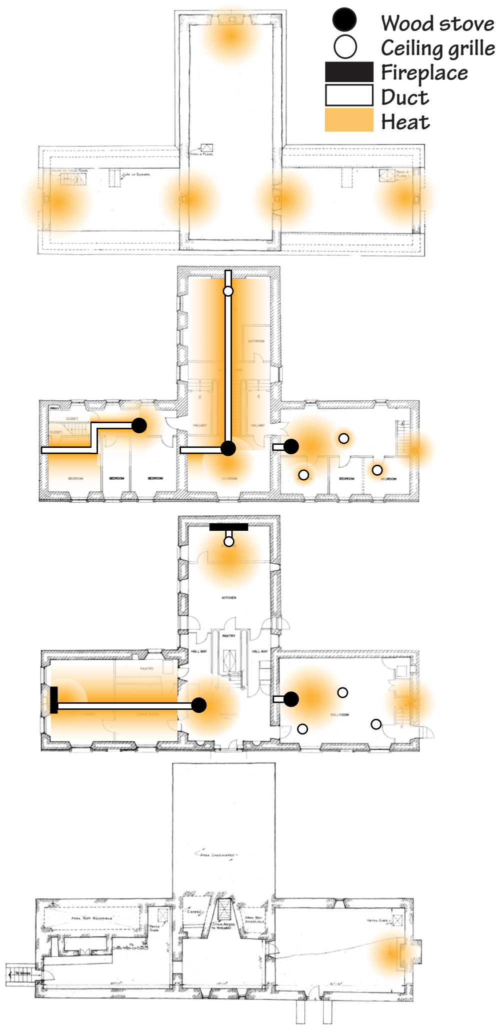
1. Uncontrolled moisture
2. High relative humidity
3. Inappropriate artifact storage
4. Poor ventilation
5. Issues with climate control system
6. Pest infestation
7. Condensation on windows

Low risk

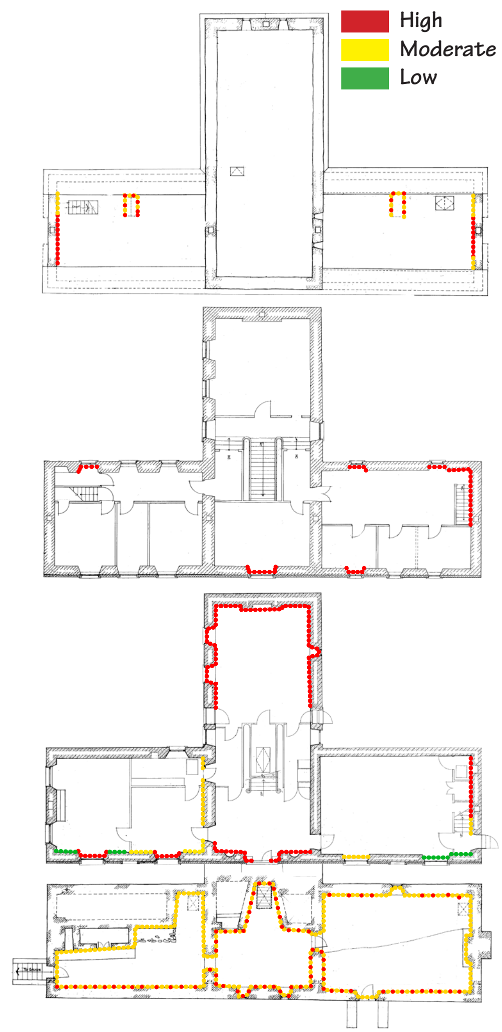


Performance issues

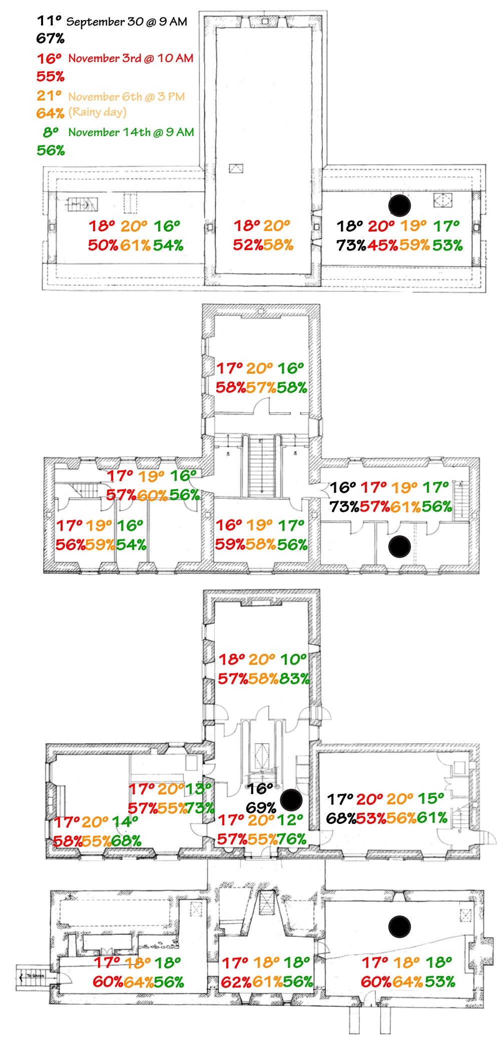
ENVIRONMENTAL STUDY



analysis of 1850's heating system



moisture test



humidity test

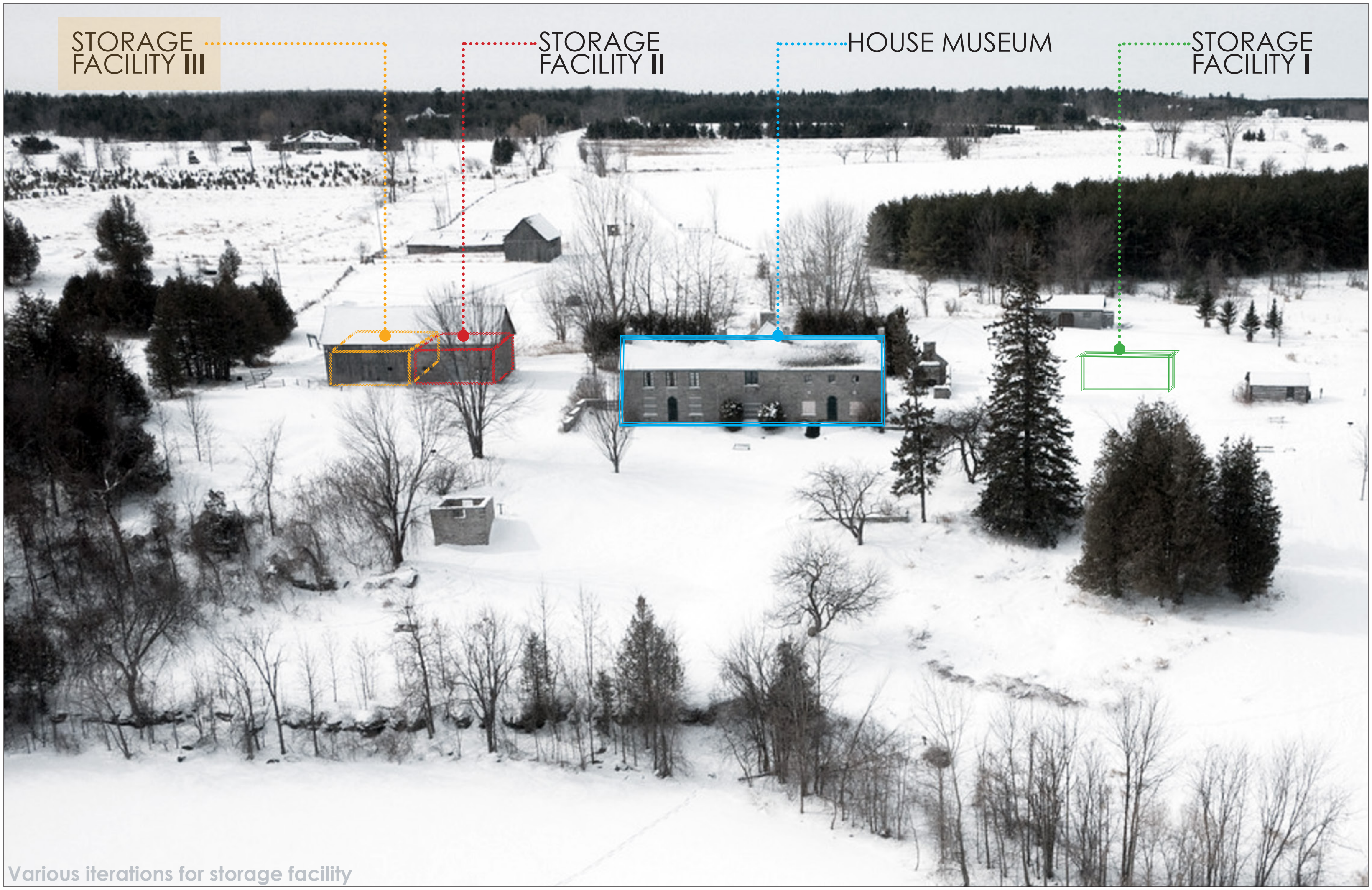
PERFORMANCE FAILURES

PREVENTIVE CONSERVATION

REHABILITATION

MAINTENANCE

CONSERVATION PROCESS



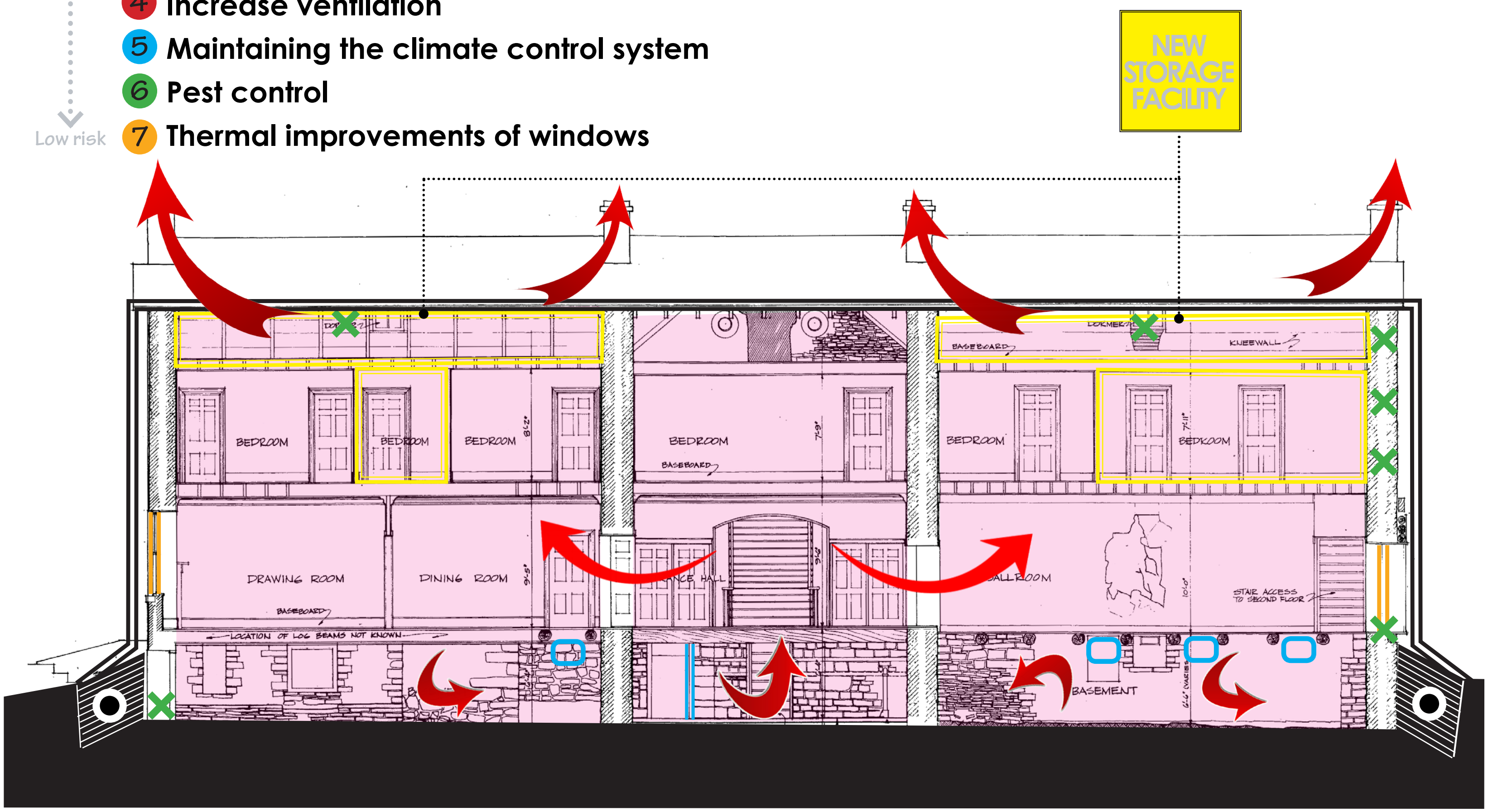
Various iterations for storage facility

CLIMATE CONTROL INTERVENTIONS FOR HORACEVILLE

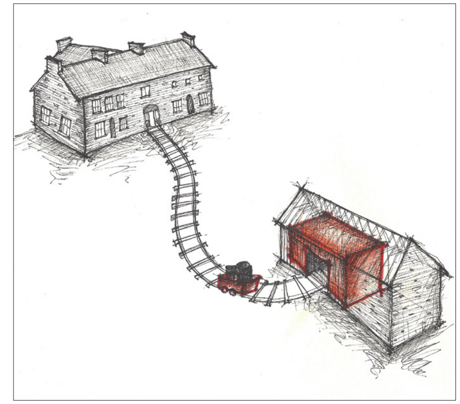
High risk

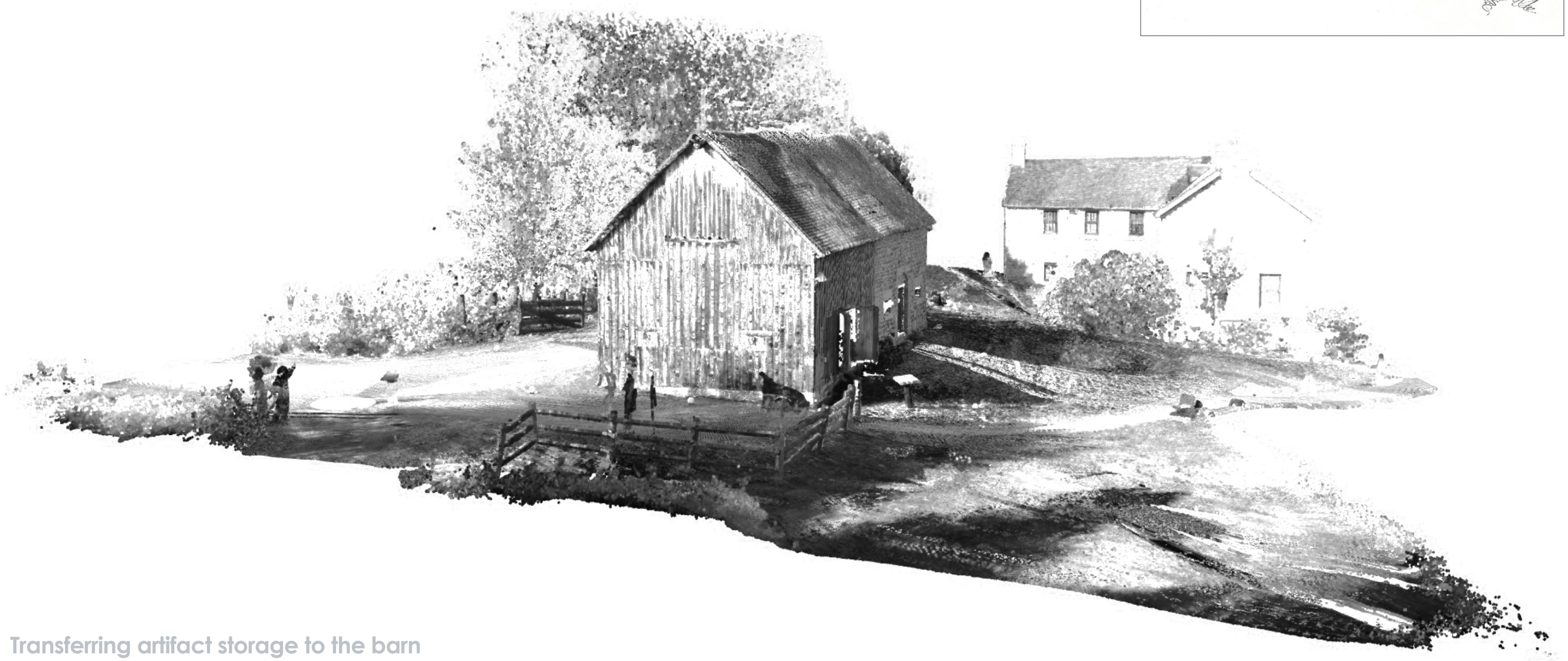
1 Controlling moisture
2 Monitoring relative humidity
3 New artifact storage facility
4 Increase ventilation
5 Maintaining the climate control system
6 Pest control
7 Thermal improvements of windows

Low risk



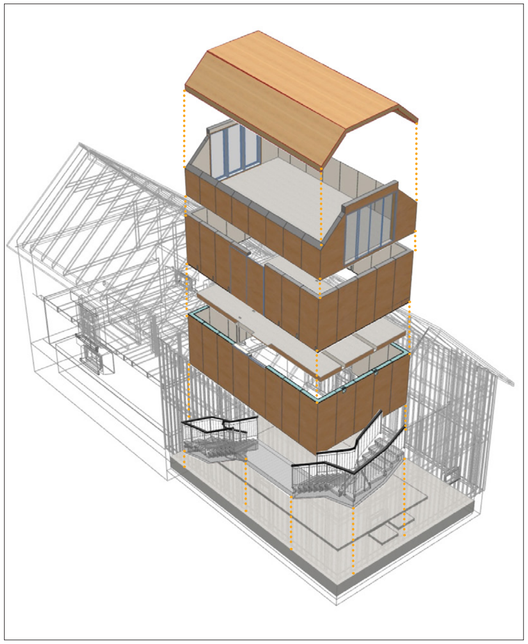
NEW ARTIFACT STORAGE





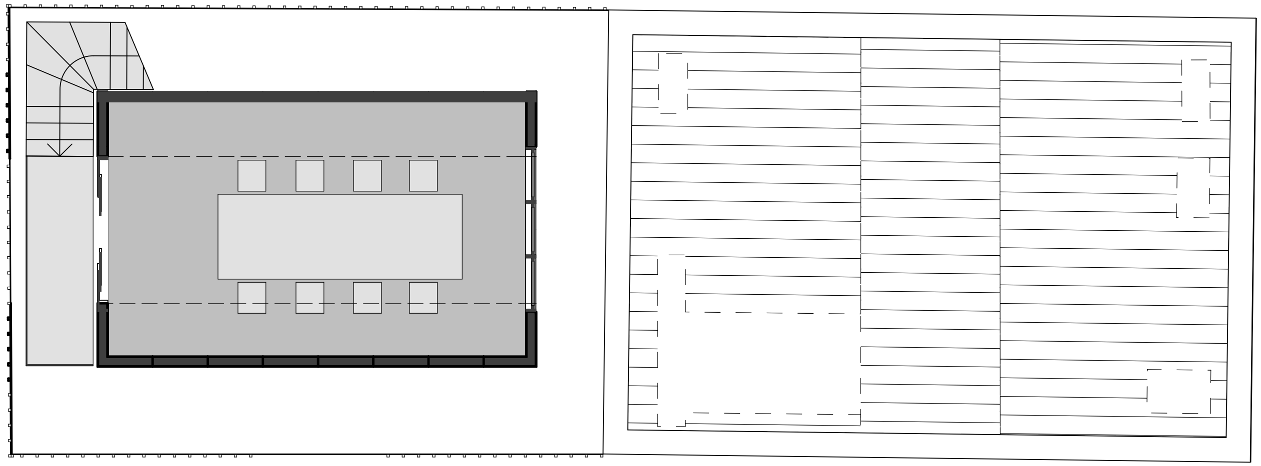
Transferring artifact storage to the barn

REHABILITATING THE BARN

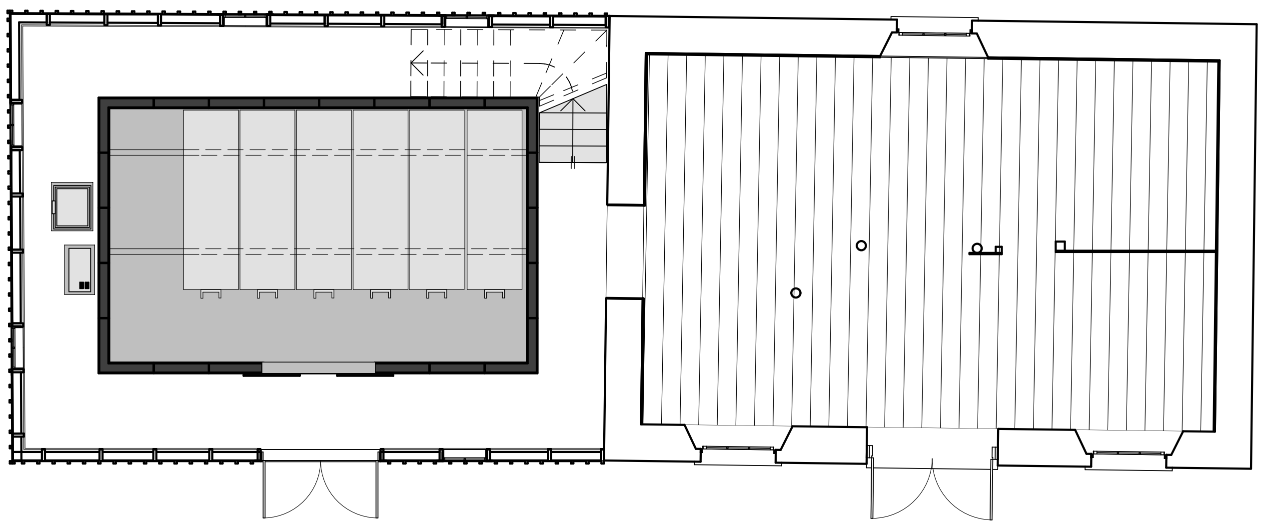


The new structure assembled inside the existing fabric

PLANS



FIRST FLOOR
Artifact storage



THIRD FLOOR
Multi-purpose room

CIRCULATION THROUGH THE BARN

Circulation between the old and new structures

PRESERVING THE VIEWS

The barn existing roof structure

The proposed multi-purpose room with views of historic structure

SUPPLEMENTARY INFORMATION

INDOOR CLIMATE CLASSIFICATION

CCI published an environmental guideline in 1979 for Canadian museums, art museums, and archives. The guideline promoted specific environmental norms intended both for new construction and renovation projects. The optimum temperature set point for storage and exhibition areas was outlined as 21˚C ± 1.5˚C, and the RH set point was defined as 47% to 53% with 2% daily fluctuations (Lafontaine, 1979). Conservators found that the ideal climate for the artifacts housed in historic houses in colder climates are not the ideal climate for the building, and maintaining 50% RH can have a negative impact on the building envelope, such as formation of condensation within wall cavities (Kerschner, 1992).

In 1979, the Royal Ontario Museum (ROM) classified five levels of sensitivity for the museum's collection. The type of artifacts determined the required environmental conditions including the temperature and RH ranges that would be safe for the buildings and the artifacts. According to ROM's publication, most artifacts that belong to a house museum are safe under stable conditions of 35% to 50% RH (ROM, 1979), which is also suitable for the conservation of the buildings.

Later, the American Society of Heating, Refrigerating, and Air-Conditioning Engineers (ASHRAE) Handbook (2007) broadly describes the performance targets and specifications for museums, libraries, and archives. ASHRAE classified five groups of temperature and humidity specifications for the collections in accordance with the best knowledge available at the time. The five classes of museum's indoor climate include: AA, A, B, C, and D. Class AA is called a precision class and it is considered to consume very high levels of energy to operate. The set point for this class is 50% RH with no seasonal changes that consequently will put historic buildings at high risk of condensation. Class A is also a precision control with lower energy consumption and it allows some seasonal changes with 50% RH set point ±10%. Classes B and C are the most feasible options for historic buildings. The class B RH is set at 50% with ±10% fluctuations with a setback during winter temperatures. The C class only prevents high-risk extremes and allows the RH to fluctuate between 25% and 75% throughout the year. Class D only controls dampness and has limited potential for environmental improvements and keeps the RH below 75%.

BUILDING CLASSIFICATION

ASHRAE's five classes of environmental controls for museums was described in the previous section. The classified temperature and humidity requirements are provided by HVAC systems. The optimal HVAC system maintains the specified temperature, RH, air circulation, and air filtration with minimum risk of damage to the collection. Maintaining the preservation environment also depends on the building envelope, which plays an important role in controlling the moisture through the fabric. ASHRAE (2007) recommends integrating heavy insulation, vapour barriers, and controls of openings for building envelope design to help with controlling the preservation environment, however, historic structures similar to Horaceville are generally not compatible with such measures.

The tolerance of a building in a given environment is dependent on the local climate as well as the moisture and thermal performance of that building (ASHRAE, 2007). Conrad (1995) classified buildings into six categories based on their type of structure and tolerance of the environmental elements. The building classification is as followed:

• Class 1 buildings provide D class of control, and have no potential for environmental improvements. Examples are open structures such as sawmills and bridges.

• Class 2 buildings can be ventilated and provide class C or D control. Examples are sheathed post-and-beam structures such as cabins and barns.

• Class 3 buildings require low-level heating. Summer exhaust ventilation can be implemented to afford C or D class of control. Examples are uninsulated masonry structures, wooden structures with framed and sided walls and single-glazed windows such as a rough framed house.

• Class 4 buildings can support a basic HVAC system to provide B, C, or D class of control. Examples are heavy masonry or farmed structures with composite plastered walls and storm windows such as finished historic houses or churches.

• Class 5 buildings can support complete HVAC systems to provide AA, A, or B class of control. Examples are newly built structures with insulated walls, vapour barriers, and double-glazed windows.

• Class 6 structures are specifically built to support precision controlled heating, cooling, and RH control systems. Examples are double-wall constructions with insulated and sealed walls such as storage vaults.

HORACEVILLE INDOOR CLIMATE AND BUILDING CLASSIFICATIONS

In order to evaluate a house museum's environmental limitations and possibilities a full year monitoring program is required to comprehensively understand the thermal and vapour characteristics of the building and its response to the outdoor environment. A heavy masonry construction with interior plaster walls such as Horaceville can retain and release a certain amount of moisture during each season. This study accomplished a single-season monitoring program to record the ranges of indoor RH. Due to thesis time limitations, the data was recorded between the months of September and December. During the monitoring period, the measured indoor RH was consistently higher than the outdoor RH, and on the span of these four months the indoor temperature changed ±10˚C with 30% RH fluctuations. Based on previous discussions and the single-season monitoring, Horaceville classifies as a class 4 building and can safely afford a C class of control in Ottawa's cold winter climate.

Horaceville is open to the public from May through August and has limited access in winter. From discussions with the building's custodian, it can be assumed that during the winter months the house museum temperature is kept at 18˚C with no specific moisture control actions. Heating buildings without adding levels of moisture can result in extremely low levels of RH such as 5% to15% (Kerschner, 1992).

By allowing the temperature to drop down during the closing season, the RH will remain at acceptable levels. The challenge is that the building should remain a certain temperature and needs to be heated even when it is unoccupied because it contains a water system and the pipes cannot be left to freeze. The temperature should be low enough to keep the RH at an adequate level for the artifacts. Low levels of RH can be detrimental to the long-term preservation of artifacts; certain artifacts such as paintings on canvas are extremely sensitive to RH fluctuations and must be kept in rooms with narrower ranges of RH and away from exterior walls (Kerschner, 1992). However, the building has no vapour barrier and it is impossible to maintain the 50% RH in the winter months. Any such attempts will cause condensation inside the walls, specifically around the windows, due to cold surfaces.