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PILOT CONSERVATION PROJECT STRATEGY DEVELOPMENT REPORT

Presqu'ile Point Lighthouse
Brighton, Ontario

Prepared for: Presqu'ile Point Lighthouse Preservation Society
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NOTE: ISSUED FOR COSTING PURPOSES - SECTION YET TO BE COMPLETED

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Dave Sharp; Presqu'ile Point Lighthouse Preservation Society

1.0 INTRODUCTION

1.1 During a meeting held at Presqu'ile Provincial Park on Wednesday 4th May 2016 between representatives of Ontario Parks, Presqu'ile Point Lighthouse Preservation Society (PPLPS), PJ Materials Consultants Ltd (PJMC) and Shoalts Engineering (SE) [the latter two firms being referred to jointly hereafter as *the Consultants*], there was general agreement that there was insufficient information available to reliably design a Conservation Strategy[1] and go out to tender for the work - particularly in view of the differing opinions that have been expressed regarding the most appropriate methods and materials that should be used.

.1 In particular, concerns were raised that, in the event that the existing wood cladding remains in place until the conservation work begins, there is a strong possibility that subsequently revealed conditions could prove more challenging than otherwise envisaged - and the actual cost of the project could escalate beyond a reasonable pre-project committed budget.

.2 It was therefore determined that the Consultants should develop and implement a comprehensive strategy to carry out a Pilot Conservation Strategy which could more reliably identify the extent of hidden conditions, develop an appropriate final conservation strategy and estimate the potential cost for the work. It should be noted that it is proposed that the Pilot Conservation Project be limited at this stage to the masonry components.

1.2 This report has been developed to serve as a working document and action plan for those proposed to be involved in the project. Comprehensive information is included so the historical background can be documented and the reasoning behind some of the recommended components of the project can be better understood.

2.0 BACKGROUND & LIGHTHOUSE HISTORY

2.1 Presqu'ile Point Lighthouse is located at the south-eastern tip of the Presqu'ile Peninsula, the latter extending into Lake Ontario from the northern boundaries of the Presqu'ile Provincial Park, near Brighton, Ontario. (See Figure 1)

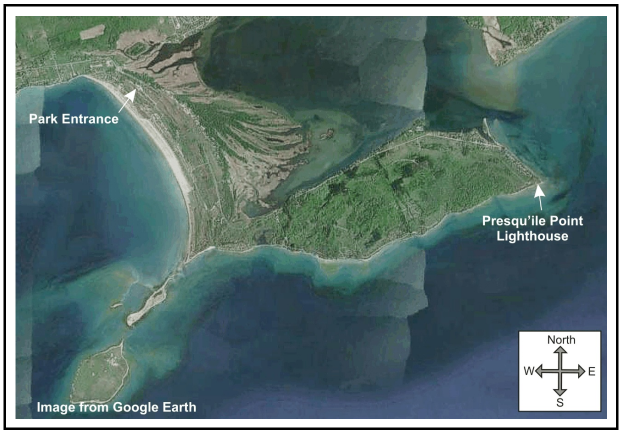

Figure 1: The Presqu'ile Peninsula.

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[1] The Parks Canada publication *Standards & Guidelines for Historic Places in Canada* confirms that the term "Conservation" can include restoration, preservation, or rehabilitation.

2.2 The tower, which is now the second oldest surviving lighthouse in Ontario, was constructed from locally quarried and fabricated limestone circa 1837-1841. It has been reported that the tower was built on a 30-foot (9-m) square stone foundation constructed to be 5-ft 3-in (1.6-m) below grade and founded on bedrock. From the square foundation, the tower was constructed as a tapering octagonal shaft rising from an ornamental pedestal to a height of 69-ft (21-m), where it was flared outward to a diameter of 17-ft (5.2-m). It is reported that the walls of the shaft are 6-ft (1.8-m) thick at its base and 2ft 6-in (0.76-m) at its upper level. The interior cylindrical core space is reported to have a relatively constant almost 12-ft (3.6-m) diameter. The exterior surfaces of the masonry were apparently whitewashed to improve visibility.

2.3 The tower was constructed under the supervision of contractor John Laird to a design by government engineer Nicol Hugh Baird. From an architectural perspective, which has no doubt also impacted the tower's performance, a primary feature of the design was the inclusion of lancet (tall pointed arch) windows in the Gothic style.

2.4 An "oil room" was constructed as a shallow pit under the first floor; today, the pit contains considerable debris that is scheduled for removal. The tower's five wooden floor decks are connected by ladder-type wooden stairs; the upper floor has a lathed and plastered interior wall and a coved ceiling, while the remaining lower interior rubble walls are stuccoed. (It has been hypothesised within a recent report that the upper floor wall may have required re-plastering due to deterioration of the originally applied stucco from the effects of early moisture infiltration.) Both historic and more recently painted graffiti adorns the interior surfaces at all levels.

2.5 It is understood that the original lantern had an octagonal, birdcage style framework with small multi-panes of glass in each panel. It was topped by an 'ogee' (double-curved profile) dome. The lantern was removed in 1966 and an airport beacon installed on a buoy structure.

2.6 It is reported that, shortly after erection of its metal roof and lantern, leakage was experienced into the masonry and the interior at the upper levels; apparently the leakage was through sheet metal and coping joints. Deteriorated joints and interior plasterwork were subsequently reported, together with cracking of the exterior masonry.

.1 Apparently, various attempts at remedial work were made over the next few decades but, presumably, these were unsuccessful. In any event a Marine & Fisheries Inspection Report, issued in 1894, criticized the poor quality of stone, pointing material and workmanship used to construct the tower. Claiming it to be unsafe, the report recommended that the tower be ".... repaired by surrounding (it) with iron bands and planking and shingling the sides ...." In 1895, a further Inspection Report noted that the work had been completed - however, it should be noted that inspections/investigations carried out in more recent times have not been able to verify that the "iron bands" were in fact installed.

2.7 Several investigations have been carried out over the last thirty plus years, including an engineering study carried out during 2014. In no particular order of importance, some of the conclusions or relevant comments resulting from the investigations can be summarised as follows:-

.1 It is reported that the shingled cladding was applied over 2-in x 4-in (50-mm x 100-mm) horizontal girts. However, an image extracted from a 2014 investigation report by the consultant team Scheinman and Silburn indicates that varying conditions are likely to exist beneath the shingles. [See Photograph 1.]

Photo. 1: An image extracted from a 2014 investigation report by Scheinman and Silburn which illustrates varying conditions within an area where shingles were removed to reveal underlying woodwork.

.2 Timber lintels were observed to be badly decayed.

.3 The timber support structure was considered to be in a reasonably good condition, although some debris from boring insects was observed.

.4 Mortar joints were observed to vary in width but were generally quite wide.

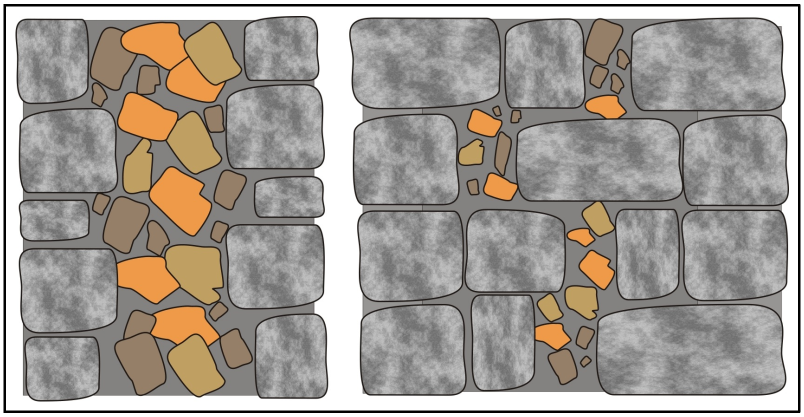
.5 One author of a report observed that the extent of sand in the "basement" indicates a considerable amount of mortar binder had been "washed" from the joints and core.

.6 One author of a report concluded that the timber banding is essential to maintain the stability of the structure ".... as the tower itself cannot be made structurally independent of the banding ...." (However, the Consultants have yet to see conclusive evidence that these claims are justified.) Only one author believed that the cladding could be removed to expose the stone masonry.

Photo 2: This stone unit, which was apparently removed from the interior masonry, appears to be a very dense, tough but brittle limestone.

.7 Various report authors have commented that the dimension stone used for the lighthouse masonry was an inferior local shore stone. However, the Consultants have yet to see evidence of poor quality; although the stone units observed within the interior appeared to be fabricated from a very tough, dense, fine-grained but brittle, limestone that - if face-bedded - could have the propensity to crack under an "over-loaded" condition. [See Photograph 2.] In view of this, it seems more likely to the Consultants that the initial deterioration was primarily caused by the use of inferior, on-site produced bedding and pointing mortars.

.8 The author of another report has indicated that the nature of the construction of a mortar filled core and the lack of through wall bonding seems to have led to ".... failure in the form of major cracking and, possibly, the almost complete disengagement of the outer wythe of stone, at least at the south and south west elevations ...." Once more, it should be noted that the Consultants have yet to see any evidence which justifies a claim that the latter hidden condition currently exists.



Figures 2 and 3: Not-to-scale schematic illustration of a typical vertical section through a traditional mass masonry wall (left) and the likely make-up of the lighthouse masonry assembly (right).

.9 It should also be noted that it is highly unlikely there is an outer and inner wythe with a distinct central core that is comparable to most traditional mass masonry walls constructed using natural stone. In fact, human nature and the likely construction economies at that time would tend to indicate that - unlike for thinner walls (18-in to 24-in/450 to 600-mm thick range) - small off-cuts of stone and rubble pieces would most likely not have been used as the only materials between the exterior and interior wythes. However, small pieces of rubble may have been used to fill the gaps between larger units used across the tower's thicker masonry assembly, resulting in a series of inter-connected "compartments" rather than a continuous central core. [See Figure 2 & 3 on Page 4 for schematic illustrations of these differences.] (Notwithstanding this, a more pronounced core may have been constructed at the upper levels where the wall sections are somewhat thinner.) This theory tends to be justified by the fact that the original specifications required ".... one or two courses of a header stone for every two stretchers ...." and that headers were to be ".... not less than 3x their own thickness...." (Some authors have indicated that the specifications were unlikely to have been followed, but once more, the Consultants have not seen any evidence of this.)

.10 The most recent study, which made small openings through the cladding, has reported the presence of cracks that appeared to propagate from the "point" of the lancet windows. Most authors of previous reports have hypothesised that the design of the window openings and their stacked locations created "the least line of resistance" for the development of stresses generated by gravity loads. In support of these reported observations, it should be noted that, on several previous projects, the Consultants have observed that cracks can be caused when there are no lintels above the openings - or the lintels are not long enough to otherwise "spread" gravity loads away from the window jambs into a greater mass of masonry. The Consultants have been able to successfully correct these deficiencies in the past by the installation of hidden semi-flexible steel reinforcement grouted into slots cut within horizontal joints above the openings.

.11 The most recent report has hypothesised that metal cladding at the base of the tower was probably installed during the 1980s to replace badly damaged shingles with a more durable material. [See Photograph 3.]

.12 Except for some observed loose stones, the foundations were considered by the most recent study to be "impressive" and "amazingly intact". [See Photograph 3] This tends to justify the Consultants' belief, expressed earlier, that past problems have most likely been linked to poor mortar, rather than the quality of the stone. However, concerns have been expressed within the most recent report regarding the concrete "capping" of the corner "shoulders" which are in a poor condition.

Photo. 3: Illustration of the metal cladding at the base of the tower above the stone foundations.

.13 A structural analysis reported within the 2014 engineering study by the consultant team Scheinman and Silburn indicated that the tower was considered to be stable in its present configuration under all conditions except for a severe seismic event - pointing out that the location of the tower had not been prone to such events and that one had not been experienced since the tower was constructed. The engineering study then reported that, in the event that the timber structure and cladding were removed, certain structural reinforcement installation techniques would be necessary to assure the tower's ongoing stability for seismic event resistance. However, it is the Consultants' opinion that these recommendations have been based on certain assumptions regarding the unproven beneficial effects that have been provided by the timber framework. Further, the structural analysis was carried out assuming an unconsolidated rubble core and essentially independent interior and exterior wythes - the latter considered to potentially have become disengaged at some locations. These assumptions lead directly to the recommendation that the walls require extensive reinforcing; however, it is the Consultants' opinion that the suppositions have yet to be proven.

3.0 SUMMARY OF THE CURRENT SITUATION

3.1 Based on the background information detailed above, it can be determined that, although a considerable amount of deterioration of the currently hidden masonry has no doubt occurred, further investigation is required to establish its realistic condition today. This is essential if potential conservation strategy options are to be considered that can assure a durable, stable condition can be achieved for the long term. The potential condition of the inner core and its actual make-up also needs to be much better understood.

3.2 There is no doubt that, over the years, the cladding has reduced the degree of moisture saturation that the hidden masonry would otherwise have experienced. However, it is also evident that the cladding has prevented optimal natural drying of the masonry where the latter has been exposed to the reported moisture infiltration. It is therefore considered to be logical that these areas of masonry will have experienced considerably more wetting cycles than drying cycles for decades - and will continue to remain moist until sufficiently exposed to a drying regime. It also follows that accelerated and progressive deterioration must continue to occur until this condition is corrected and that this cannot be effectively achieved while the cladding remains in place.

.1 In the event that it is determined that the cladding should be temporarily removed, but re-erected after the primary conservation work has been carried out, it also follows that - if the current vulnerability of the masonry is to be corrected - a drying condition will require to be artificially created. It also follows that, to ensure that the cladding remains more effectively watertight than it has been in the past, a regular monitoring and maintenance programme will require to be funded and in place.

3.3 The Consultants believe that an effective Conservation Strategy must include stabilizing and consolidating the masonry assembly utilizing hidden semi-flexible stainless steel helical masonry ties and low pressure injection techniques, the latter preferably using a lightweight, low strength cellular foamed cement grout to inject into hidden voids. As indicated earlier, a further essential component should be the installation of semi-flexible rods above window openings so that the negative crack-inducing "stacking" effect of the openings can be reduced or negated.[2] These techniques are proposed since they have been proven on many previous historic projects to offer their stabilizing effects without dramatically changing the ability of structures to accommodate naturally occurring movement from temperature change, wind-loading, etc. A further benefit is that the techniques also would not change the appearance of the original stone tower, providing a critical advantage in the event that it is determined the tower should be restored without re-erection of the timber framework and cladding.

.1 The Consultants also believe that the efficient use of non-destructive testing techniques (discussed later) - as well as the establishment of the stabilization/consolidation techniques needed for the effective development of technical specifications for the Primary Conservation Project - can only be reliably assured by completely exposing the exterior surfaces of the tower's masonry.

.2 Removal of the cladding also provides the added benefit that hidden conditions would be revealed, resulting in a better understanding of the full extent of the deterioration and thereby the development of a conservation strategy that can be reliably costed without the potential for escalation.

3.4 Based on the above, it is recommended that scaffolding be erected to completely encapsulate the tower and thereby facilitate cladding removal work to reveal the exterior stone masonry. Work on the interior should also be included within the Pilot Conservation work.

4.0 PROPOSED PILOT CONSERVATION PROJECT STRATEGY

4.1 The following Pilot Conservation Project Strategy is proposed, with the recommendation that it be implemented and carried out at the earliest opportunity. It should be noted that it is anticipated that the investigations will take place over several weeks.

4.2 Prior to the implementation of the Pilot Conservation Project, if information is not already available, the interior decorations, such as plaster, stucco and paint, should be analysed for harmful substances. The results should be provided to all parties involved in the project so that appropriate procedures for the safe removal and disposal of materials can be included.

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[2] The Consultants have successfully used all of these techniques on several heritage conservation projects including National Historic Sites such as Fredericton City Hall, Halifax's Dingle Tower and the twin towers of Guelph's Basilica of Our Lady Immaculate.

4.3 An on-site pre-start-up meeting took place recently with the contractor who will carry out the Pilot Pilot Conservation Project. Ontario Parks' governing rules, regulations and guidelines to be followed when work is carried out at the site were explained to the Contractors, as well as the limitations that will be imposed on "construction" traffic to and from the tower location through the park. The means by which non-compliant shipments must be transported along the shoreline by barge were also explained, together with the need for special procedures to remove and dispose of materials without contamination of the site and lake were also discussed.

.1 The agreed requirements should be confirmed in writing prior to pilot project start-up, together with environmental, health and safety, and security strategies and policies.

4.4 Under the supervision of PJMC, the current condition of the tower should be recorded using a remotely controlled unmanned aerial vehicle (UAV or drone).

.1 The inspections would be carried out in compliance with a valid Transport Canada Special Flight Operations Certificate and Commercial Liability Insurance coverage would be in place; copies of appropriate documents will be provided in advance of the inspection.

.2 Barricades should be temporarily erected to prevent public access to the tower vicinity. (It is anticipated that the inspection should take less than one hour.)

.3 Upon completion of the inspection, a high definition video would be made available to Ontario Parks and PPLPS, as well as other interested parties. It is envisaged that, some time in the future, the video would be made available for viewing by the general public within the on-site Lighthouse Centre.

4.5 A purpose-designed scaffold system should be erected around the tower to provide safe access to all levels, including the roof. A shop drawing should first be provided by the scaffold company; the drawing should be stamped by a Professional Engineer licenced to practice in the Province of Ontario.

.1 The scaffold system should conform to the requirements of the latest edition of CAN/CSA-Z797 - *Code of Practice for Access Scaffold* and be erected so as to be independent of the timber framework and cladding when completed. Platforms should be installed at all levels with front-boards and back-boards. Access to each level should be provided by ladders through closeable hatches. The scaffold system should be enclosed with debris netting designed to prevent fall of debris; the netting system should also be designed to remain durable and effective under any weather condition for an extended period. The system should also be designed with an enclosed hoist system to facilitate transportation of the shingle/cladding materials to grade level. The perimeter base of the scaffold system should include hoarding which should be designed to prevent unauthorised access to the scaffold. The hoarding should include door access designed to be secured by padlock.

.2 The scaffold system should be designed and maintained to be protected from potential lightning strikes.

.3 The scaffold should be designed and erected so that it can be completely enclosed with plywood should it subsequently be determined that a conditioning process component is required within the Primary Conservation Project to artificially create a drying environment.

.4 The scaffold contractor should be responsible for the maintenance of the system during the pilot project and register as the "Constructor" with the Ministry of Labour, until it is handed over to the Contractor of Record for the primary project.

4.6 Under the supervision of SE, beginning from the top of the tower, the shingled cladding and the metal cladding should be completely removed to reveal the original stone masonry.

.1 In the event that it is subsequently determined that the shingled cladding should not be replaced, a structural analysis should be carried out to verify adequate stability of the freestanding tower, so that the timber framework can be removed during the primary conservation work.

.2 Alternatively, if it is subsequently decided that the shingled cladding should be replaced, a structural evaluation should be carried out to determine if additional work is required to enable the timber framework to be re-utilised.

.3 Separate determinations for appropriate action will be required should the metal bands that were reported to have been installed become located.

4.7 As the masonry is revealed, ongoing determinations will be made regarding the need for any emergency work to ensure adequate safety and structural integrity, including rebuilding, tie installations, etc.

4.8 Following a review of the exposed masonry, determinations should be made with regard to locations where interior work will be carried out. Determinations should also be made at this time with regard to similar locations within the interior, and appropriate plasterwork should then be removed to accommodate the investigations/trials.

.1 Since drilling for the installation of ties and grout injection tubes should take place through joints, rather than stone - it should be particularly noted that at least the partial removal of plasterwork will be critical, although localised areas adorned with historical graffiti should be preserved pending a decision regarding appropriate action.

4.9 Ground penetrating radar (GPR) evaluations should then be carried out by PJMC on both the interior and exterior walls.

.1 GPR is a non-destructive test method which incorporates radar antennas that emit very short, precisely timed pulses of radio frequency energy into the structure under test. The pulses are emitted from a scanning head when connected odometer wheels are moved over a temporary 24-in x 24-in (600-mm x 600-mm) test grid at 4-in (100-mm) spacings on an 'X' & 'Y' axis (See Photographs 4 & 5 from a previous project). Part of the energy subsequently echoes back to the surface to be analysed by a computer, which records how "loud" the signal is and how long it takes to return to the antenna. A computer software program is then used to analyse the raw data and generate the results and images. (See Photograph 6.)

Photo. 4 (left): Scanning a location using Ground Penetrating Radar. Photo. 5 (upper right) The scanning head moved over a temporary grid. Photo 6. (Lower right): A typical scan of a grid slice visually interpreted by the computer.

.2 The data generated by the GPR should then be reviewed and an assessment made regarding the severity and extent of voidage within the masonry assembly. In particular the assessment should study the uniformity or differences between voids within the upper, middle and lower levels of masonry so that a determination can be made regarding the likely extent of consolidation work (grouting) that will subsequently be carried out during the primary conservation project.

4.10 While the GPR testing is underway, trial installations of helical stainless steel masonry tie should be carried out by the manufacturer's technical representative. The objective of the trials should be to establish the diameter and potential length of ties, as well as any practical limitations for their installation. This information is essential for the efficient development of specifications and realistic competitive bidding for the primary work.

.1 A series of pilot holes should first be drilled through mortar joints (See Photo 7). The masonry ties illustrated by Photograph 8 should then be installed into the pilot holes using a purpose designed "dry-set" installation tool (See Photo 9).Testing of ties can then be achieved by securing a direct tensile pull-off testing device over the protruding ends and applying axial loads (See Photo10 with inset image). The information from the tests will facilitate the establishment of more reliable cost estimates for the subsequent primary work. Locations for tie installations can also be selected so that information provided by the GPR tests can be verified.

Photo.7 : (Left) Installing a stainless steel helical masonry tie. Photo. 8: (Second from left) An illustration of a stainless steel helical masonry tie. Photo. 9 : (Centre) Installation of a tie within a pilot hole. Photo. 10: (Right with inset image.) Testing an installed tie using a pull-off testing device to apply an axial load.

4.11 Following the establishment of appropriate locations, low pressure grouting trials should be carried with the objective of determining the procedures and calculating potential volumes of grout that could be required for the primary conservation work.

.1 It is recommended that a cellular foamed cement grout be used, principally because of its lightweight, low strength properties - as well as its ability to absorb stress. These properties, together with the grout's ability to deform considerably under load at a constant yield stress, assist in the redistribution or prevention of otherwise damaging point load stresses. Generally, densities of about 45-50 pcf (700-800 Kg/m^3) produce a stable hardened material which will typically produce desirable 28-day compressive strengths between 450-750 psi (3.0-5.0 MPa).

.2 A further benefit to be gained when cellular grout is used is that considerably less water is required to produce a given volume of grout and therefore less water is pumped into the core.

.3 A high speed cement grout mixer should be used to mix neat cement and water at approximately 0.45 w/c ratio. A thixotropic admixture, required to provide grout gelling, cohesive properties and thereby minimize grout loss through open joints, should then be added to the mixture and further mixing carried out.

.4 The mixture should then be transferred to a conventional horizontal spiral blade mortar mixer. Foaming equipment should then be utilized for the development of a cellular foam which should then be blended (folded) into the mixed cement grout. (See Photographs 11 & 12 for illustrations of the type of recommended equipment and materials.)

Photo 11: (Left) Equipment and materials for generating foam. Photo 12: (Right) Equipment set up for producing foamed grout.

.5 After adjustments of the volume of foam required for the desired density range, the blended cellular foam grout should then be transferred into a pump and injected into the masonry through tubes inserted into pre-drilled 12-inch (300-mm) minimum deep holes installed at 24-in (600-mm) centres through mortar joints. (See Photograph 13 for an example installation.) Open joints which could facilitate grout leakage should be temporarily plugged as work proceeds using a hydraulic cement mortar. Return valves should be fitted at the end of nozzles and the pump pressure controlled to be approximately 5-psi (345-mbar) above the observed pump pressure when flow is unrestricted.

Photo. 13: Using low pressure to inject the cellular foamed cement grout into a traditional mass masonry wall. (Dingle Tower, Halifax)

.6 The grout injection work for the pilot conservation work will be carried out by a prequalified masonry contractor with proven experience in grouting historic masonry walls using cellular foamed cement grout.

4.12 Under the supervision of PJMC, the condition of the walls should be evaluated for moisture levels. A series of sensors that measure both relative humidity and moisture should be installed into the walls at various locations, connected to data loggers and set to record measurements every four hours. (See Photograph 14) Data from the sensors should then be evaluated over time to assess the levels of moisture at various locations and determine whether the masonry has the ability to naturally dry to a reasonable level, or whether the Primary Conservation Strategy will require a conditioning component.

Photo. 14: Example of installed sensors set to monitor moisture conditions within a tower's masonry assembly.

4.13 At the conclusion of the pilot project, the information provided by the investigations, tests and trials should be deliberated and Primary Conservation Strategy options identified and costed.

.1 The Primary Conservation Strategy options should also consider the actions required for non-masonry components, such as wooden platforms, stairs, etc., as well as the need to strengthen window openings.

.2 The development of a Conservation Philosophy should then be agreed, based on whether the timber framework should be removed and the masonry structure restored to a durable, stable condition - or whether new shingled cladding should be installed to "preserve" the tower's current appearance. In the latter event, it seems highly likely that consolidation and stabilization work will still be required - although the extent of this will depend upon the results of the study.

.3 Should it is decided that new shingled cladding will be installed, the exact condition of the masonry at that time should first be comprehensively recorded using photographs and videography.

5.0 PILOT CONSERVATION PROJECT PROPOSALS

5.1 Firm quotations have been obtained from the Contractors which confirm the Pilot Conservation Project cost to be

6.0 CONCLUSIONS

6.1 Although the cost for carrying out the proposed pilot conservation project may appear to be excessive, it should be recognised that, in reality, the vast majority of the items would in any event be required to be included within the primary conservation work.

6.2 In forming opinions and providing past recommendations for conservation of the tower, many assumptions have been made by previous investigators which, as yet, remain unproven. The recommended Pilot Conservation Project Strategy is considered by the Consultants to be essential if not critical for the development of Conservation Strategy options that are realistic, and which can be reliably costed for implementation within an agreed budget without an unreasonable risk of escalation.

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