White Paper Report

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THE PRESERVATION SOCIETY OF NEWPORT COUNTY

WHITE PAPER
FEASIBILITY STUDY FOR THE USE OF GEOTHERMAL CLIMATE MODIFICATION AT THE BREAKERS

Introduction

The project was to study the potential of an aquifer beneath The Breakers in Newport, Rhode Island (Figure 1) to be used as a passive heating and cooling system. The Breakers is a historic house museum owned and managed by The Preservation Society of Newport County. The house was designed in the late 19th century to be heated and cooled using convection. A sub-basement beneath the main basement receives air that is tempered as it travels under the south side terrace. Pierced openings in the sub-basement connect to ducts which lead to rooms on the first and second floors. During cold months, radiators heat this tempered air, which then rises to the upper floors. During the summer attic skylights are opened, so that the warm air rises and pulls cooler air from under the terrace to the sub-basement and then to the associated rooms.

An Institute of Museum and Library Services Climate Assessment grant in 2008 allowed the Preservation Society to hire a climate engineer and preservation architect to survey the interior environments at its 10 historic properties. Their report became the basis of individual climate mitigation plans for each property, which we are implementing as resources become available. Finding the most efficient but least expensive means of providing heating/ventilation/air conditioning (HVAC) for The Breakers' 138,300 square feet of space (three floors, mezzanine, attic, and basement) is particularly challenging. The expense and complexity of conventional climate modification systems are prohibitive and unsustainable for a building as large as The Breakers. Our hope was that an aquifer known to run beneath the structure would provide at least a partial solution.

The original project scope was to drill a single test hole in order to measure the capacity of the aquifer to be used in designing a sustainable climate control system, such as coupled heat exchangers and/or HVAC units, to further modify the environment at The Breakers. In order to implement a viable system, we knew we would need, at a minimum, a water flow rate of 30 gallons per minute (gpm) and a water temperature as close to 52° F as possible.

The project goal was to protect both the structure and its valuable historic collections from the debilitating effects of humidity and temperature extremes, and to provide a more amenable climate for the over 300,000 people each year who visit The Breakers by: 1) lowering the high relative humidity in the summer and fall; and 2) lowering summer temperatures by providing circulating, filtered cool air.

Description of Project Activities

Preliminary Research on Geology

The project geologist was Christopher Covel, P.G\C.G. of Covel & Associates. He investigated the nature of the rock by examining the cliffs on the ocean side of the property (Figure 2). The cliff face shows the different layers of the rock—schist, conglomerate, competent bedrock, and slate—and how they are folded and fractured. An old hand-pump well head was found at the edge of the cliffs, with water running out of the fractures in the rock nearby (Figure 3). The axis of the main fault line through The Breakers property extends out into the water, exactly in line with a well known surf spot at Ruggles Avenue (Figure 4). By touring the site, one can visualize as well the network of fractures that emanate from the main fault. This network of fractures has the potential to hold water.

Identification of the Drilling Site

Very Low Frequency (VLF) testing was employed to identify the exact locations of water-bearing structures. The radio waves can penetrate water and the earth's surface. They can be used to identify water-bearing fractures but cannot predict specific well yields, which can only be determined by drilling and testing. As the VLF waves sweep over a site, they conduct more electromagnetic energy along a hydraulically conductive water-bearing fracture. A secondary electromagnetic field is also created, from which can be determined whether there is salt in the water—a very important capability as salt water would contaminate the system.

The process involved laying out geophysical data lines perpendicular to the trend of the fault and walking with the instrument periodically to gather data as the fault is crossed (Figure 5). Several replicate lines were tested as this ensures repeatability. The project geologist laid out approximately 1,300 meters of VLF geophysical line and collected data along the designated paths. The relative strengths of the current were recorded and the data presented in graph form (Current Density Profiles) and in color-coded cross section maps.   High current density indicates the presence of water and is shown by hotter red areas on the maps as opposed to non-water-bearing structures in cooler blues.   The relative wetness of the site and the angle of the fault are clearly visible (Figures 6, 7).

Possible targets for non-salt-contaminated water-bearing structures were identified and project geologist Christopher Covel and his associate Blair May, the Preservation Society director of properties Curt Genga, and consulting engineer William Wladyka, P.E. met to discuss the project and the potential results. Subsequent meetings were held with the Preservation Society director of gardens and grounds Jeff Curtis and well-driller Joel Russell of Russell Water Wells to discuss the impact on the historic landscape (Figure 8).

Drilling

Joel Russell and his team arrived with the drill rig on Monday, January 17, 2011 (Figure 9). Bad weather kept them from setting up and beginning drilling until Wednesday, January 19 (Figures 10, 11). The area was taped off and kept secure during the drilling process. They drilled seven feet of overburden, one foot of decomposed bedrock, and then into competent bedrock. They then installed 20 feet of eight-inch casing and grouted it into place to keep the bedrock borehole from being contaminated by the fine materials in the upper layer.

The geologist logged the borehole through the entire process, examining and documenting the material for size, color, and texture; listening to the sound of the drill, as the sound of the bit is different depending upon whether it is in solid bedrock or a degraded fracture; and correlating the actual drilling with the VLF maps. At 301 feet the project geologist terminated the drilling because all the VLF-identified water features had been passed.

Estimates suggested an initial recovery rate of 4.5 gpm, far less than the 30 gpm required for the type of very low-tech heat exchange process we were considering. After discussion among the Preservation Society staff and the geologist, we decided to drill a second borehole, as it would be less expensive to do with the drill rig already on site. The two boreholes would then be hydro-fractured and the water tested for recovery rate, temperature, and quality. Hydro-fracturing is a method whereby water pumped at high pressure is used to open up cracks in the ground around the borehole and so provide more water. It was the considered opinion of the project geologist and the driller that the combined output of the boreholes after hydro-fracturing could be 30 gpm with the possibility of adding a third borehole.

Drill Target #2 was drilled on the northwest border of the property (Figure 12). Eight-inch casing was used, but for cost savings the borehole was drilled at six inches rather than eight. The borehole was drilled to 362 feet before it passed out of the water-bearing zone and drilling was terminated. Again, the delivery rate was similar to Drill Target #1 at 5 gpm, giving a combined total of 9.5 gpm, still short of our goal of 30 gpm.

Hydro-Fracturing

Under the direction of the project geologist and well driller, each borehole was subsequently hydro-fractured, requiring a water truck and a truck outfitted with a compressor and pump (Figures 13, 14). An expandable plug, called a “packer” (Figure 15), was lowered into each borehole and inflated just above the water-bearing zone. Water was then pumped at high pressure through an integral pipe (Figure 16). This was repeated at each zone. The pressure, which fractures the web of water-bearing zones further, could go as high as 3,000 pounds per square inch (psi) and the process used over 15,000 gallons of water.

Analysis and Evaluation

Hydro-fracturing Drill Target #1 caused the yield to go from 4.5 to 7.5 gpm, and for Drill Target #2 the yield rose from 5 to 10 gpm, for a total yield of 17.5 gpm, significantly closer to our goal of 30 gpm (Figures 17, 18). The water volumes identified are considered to be very conservative numbers that can be counted on continuously. The addition of two boreholes (one north of Drill Target #1 and one south of Drill Target #2), bringing the total to four, would very much increase the probability that we could achieve at least 30 gpm, the lower estimate of our need for the most sustainable system (Figures 17, 18).

The water was tested for temperature, pH, conductivity, volatile organic compounds and semi-volatile organic compounds, and for dissolved metals and hardness (Figure 19). We found the water has a temperature average of 55.2° F—close enough to our target of 52° F—and has a nearly neutral pH, is free of volatile organic compounds and semi-volatile organic compounds, and contains a minimal amount of sodium chloride, making it suitable for the system proposed.

The project had an impact on the landscape, as the vehicles were heavy and the project overall was intrusive. However, after cleanup, landscaping, and seeding, very little evidence of disturbance remains (Figures 20-23).

Conclusion and Evaluation

The project was an important one to the Preservation Society. Climate modification for all 10 of our historic houses is a vital part of our preventive conservation planning and this is our first opportunity to address a part of it using natural resources and the potential for a sustainable, low impact system.

Initial results show a water flow rate below that needed for the simplest direct heat exchange process we would like to use. Drilling two additional boreholes has the potential to increase the rate to the desired 30 gpm. The current rate will, however, be useful for providing tempered water to a more sophisticated dehumidification system.

Drilling a second test borehole and hydro-fracturing came at a high and unanticipated financial cost to the Preservation Society. We were unsuccessful in attracting outside funding for what was perceived as a somewhat risky project. However, the leadership at the Preservation Society was confident in the project's potential for success and decided to fund the additional work from general operating reserves. The total final cost for this feasibility study was $83,931.17, to which the Preservation Society contributed $56,083.17.

At the end of the project, it was very clear that having the geologist on site throughout was vital. There were project management issues and decisions that only he was competent to make.

Continuation of the Project

The next step is to determine the maximum utility of the aquifer. This will require a period of planning and modeling by the consulting engineer. A network of piping for the boreholes, including supply, injection, and sentinel boreholes, will need to be designed and appropriate pumps and heat exchanges identified. An architect will need to be consulted for building penetrations. Further, a cost/benefit analysis must be undertaken to determine complexity of the project, whether there could reasonably be some heat benefit as well as cooling, and to gauge what the institutional commitment is to a more complex system than direct heat exchange.

Appendix 1: Images

Figure 1: The Breakers, west front

Figure 2: At the cliff on the east side of the site, geologist Christopher Covel indicates a typical fracture in a layer of conglomerate. This is the type of feature that holds and transmits underground water.

Figure 3: An old well head (at arrow), probably hand-pumped, is found abutting The Breakers on Cliff Walk. Different layers and rock can be seen on the cliffside: overburden, schist, conglomerate, and slate. The schist layer is very wet.

Figure 4: A north-south fault running through the site extends into the ocean, creating a well known surf spot at Ruggles Avenue.

Figure 5: Markers indicate one of the lines laid out for gathering VHF data. The geologist walks the line with the ABEM WADI instrument which gathers data relative to the behavior of the radio waves at water- and non water-bearing underground structures.

Figure 6: Geologist Christopher Covel shows a cross-section map of a water-bearing feature to Preservation Society staff Curt Genga, Director of Properties, and Jeff Curtis, Director of Gardens and Grounds, and consulting engineer William Wladyka.

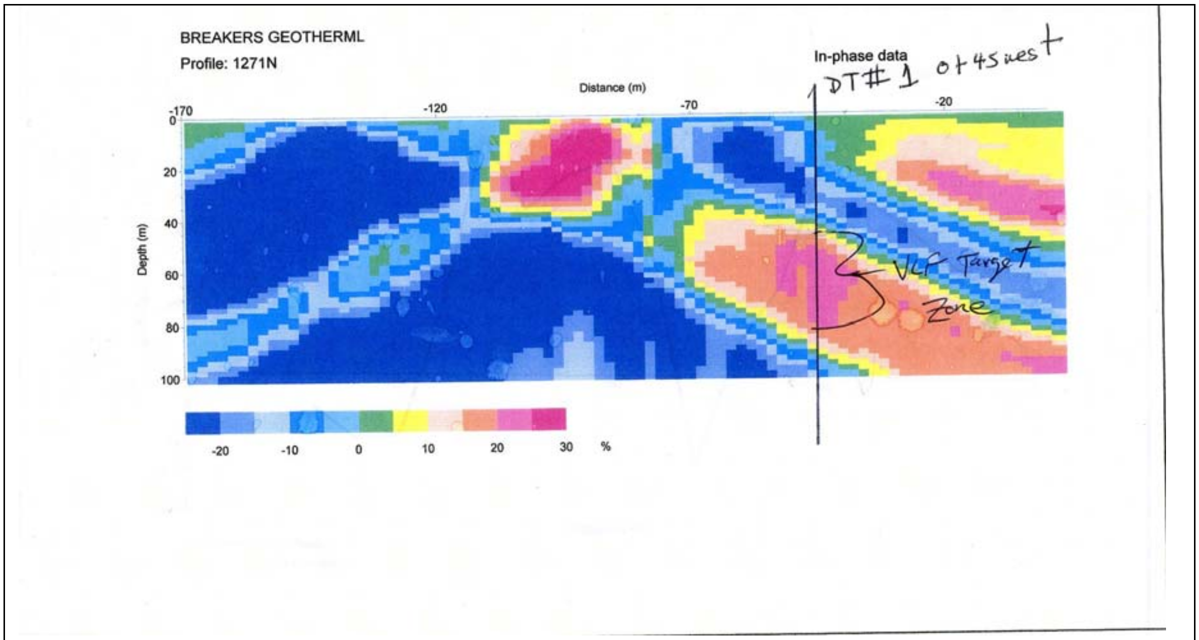

Figure 7: Derived from the VLF data, a computer generated cross-section shows the water-bearing zone and its depth for Drill Target #1.

Figure 8: Meeting of geologist and well driller with Preservation Society staff to discuss well locations and impact

Figure 9: Drill rig arrives at The Breakers

Figure 10: Drilling underway at Drill Target #1. Note hay bales to contain drill slurry. Eventually, a containment pit had to be dug.

Figure 11: Adding drill rod

Figure 12: Drilling Target #2 in winter conditions.

Figure 13: Setting up for hydro-fracturing. Truck is fitted out with a crane and pumps/compressor

Figure 14: Water for the hydro-fracturing is supplied by a tanker truck.

Figure 15: An expandable plug (“packer”) is inflated in the hole at each fracture zone to seal it while compressed air and water is injected through the pipe.

Figure 16: Well driller Joel Russell manages the hydro-fracturing operation.

Figure 17: Chris Covel and Joel Russell perform initial rating of gallons per minute.

Figure 18: 48-hour drawdown pump test in operation. Pumped water was discharged into drains in the maintenance drive.

Figure 19: Water sampling for laboratory analysis.

Figure 20: Drill site was marked then leveled and seeded over.

Figure 21: Drill rig path to Drill Target #2.

Figure 22: Path cleaned up and seeded.

Figure 23: Drill Target #2 well was left raised above the ground.