The Applicability of Ground Penetrating Radar (GPR) and Geographic Information Systems (GIS) in Mormon Nauvoo, Illinois

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Introduction
At its height in the early 1840s, the Mormon metropolis of Nauvoo, Illinois boasted a population of nearly 12,000, rivalling Chicago as the state’s largest city. It is estimated the inhabitants of the city built no fewer than 300 brick edifices, 250 wood-frame buildings, and 1,500 log structures (Cannon 1991; Flanders 1975; Givens 1990; Lammius and Hallwas 1996, Leonard 2002). After the Mormons were forcefully exiled from the place in 1846, however, the city’s buildings slowly deteriorated until only a relatively small number of original Mormon structures were still standing. Beginning in the 1960s, The Church of Jesus Christ of Latter-day Saints began investing vast resources in the restoration of the city in an attempt to create a veritable “Williamsburg of the Midwest.” A significant part of this restoration effort has involved extensive archaeological excavations, which have uncovered the foundations of a number of original Mormon structures, several of which have since been reconstructed. More recent restoration-related activities in Nauvoo, however, have not considered the city’s vast submerged archaeological resources prior to initiating construction. The unfortunate result has been the unnecessary disturbance of a number of the city’s archaeological sites (Pykles 2010). The work presented here seeks to help rectify this situation and assist in the preservation of Nauvoo’s buried cultural resources.

Objectives
• Test the effectiveness of Ground Penetrating Radar (GPR) in the historic city of Nauvoo, Illinois;
• Locate and record the location of buried foundations and related features on specific city lots by utilizing Ground Penetrating Radar (GPR) technology;
• Create a geo-spatial map using Geographic Information System (GIS) software that illustrates the location of buried resources on specific lots within, and in relation to, the city’s present landscape.

Methodology: Ground Penetrating Radar (GPR)
GPR is a non-invasive technology that works by emitting light pulses into the ground. Based on the speed and geometry of their return, computer processing can reveal subsurface anomalies. GPR has been used effectively to locate buried cultural features (e.g. walls, water pipes), previous disturbances of the ground (e.g. roads, pits), and geological features related to sediment deposition (Conyers 2004).

For GPR to be most effective, the soil needs to have low clay content and low moisture levels. In the area of Nauvoo, Illinois, high clay and moisture levels are common due to the proximity to the Mississippi River. As such, it was contestable whether the technology would work in this area. It was suspected that the relatively shallow depth of the foundations (a few inches to 3 feet in depth) would compensate for the combined effects of clay and moisture content.

Results
During the summer of 2009, the Alvah L. Tippets property, located in the southwest corner of block 106, lot 4, was surveyed using GPR. The outline of a foundation became visible at just 5 feet in depth. A very pronounced reflection was seen in the eastern half of the foundation appearing at a depth of about 3.5 feet (Figure 1). This is likely a cellar or half-cellar due to its vertical continuation (Figure 2). This feature disappears around 8.5 feet in depth (Figure 3).

Ground truthing is customary to validate the findings of the GPR survey. One test pit was excavated directly over the detected western foundation wall of the Tippets site (Figure 4). This is the material typically used for foundations in the area. A second test pit was excavated in the center of the suspected cellar. Bricks were found at the bottom of this pit, verifying that the structure was a brick house (Figure 5). A number of other artifacts were also found, supporting the interpretation of the anomaly as a cellar feature (Figure 6).

Comparing scans of the cellar feature during times of low moisture and high moisture levels. Illustrates the deleterious effects of the presence of water on the GPR results (Figure 7). The same result is visible in scans of the foundation walls (Figure 8).

Conclusion
This study has proven the utility of GPR to detect buried cultural features from the historic Mormon period in Nauvoo. It has also demonstrated the limitations the environment can impose on such work. Specifically, the presence of high levels of moisture in the soil can seriously reduce the quality of the radar imaging.

Methodology: Geographic Information Systems (GIS)
GIS allows researchers to incorporate various kinds of spatial data into multi-layered maps, where each layer represents a different set of spatial data. For the creation of a GIS database of historic Mormon Nauvoo, Illinois, the digital organization of property records was a necessity (Table 1).

Following digital entry of the Nauvoo property records, the composition of the geo-database began by geo-referencing an 1846 map of Nauvoo (Figure 9) to a 2005 aerial photograph of the area (Figure 10) to ensure the city and all streets were correctly aligned.

The historic map was digitized to create individual blocks and lots for the subdivisions of the city (Figure 11). The database of property records was then referenced to subdivide any lots into separate property divisions based on owners. The data from the property record database (Table 1) was then joined to the geo-database, which made symbolizing these properties in unique ways possible. These subdivisions are color-coded based on the type of structure that once existed on the property. For example, a property subdivision that had a brick house on it is coded red while a property that had a frame house is coded green (Figure 12) Joining the property record database to the geo-database also linked additional information (i.e. property owner, direction the structure faced, the municipal subdivision in which the property is located) to each specific color coded property. The resulting geo-database allows for the easy access and manipulation of this spatial data.

Significance
GPR and GIS technologies are not only important tools for archaeologists who wish to locate places to excavate, but also for developers who are building on historic properties. GIS databases such as this one will make it possible to anticipate potential buried foundations on properties that are being developed so that priceless cultural information is not lost. These technologies are also very useful for people looking to restore historic properties. The geo-database of Nauvoo makes it possible to determine where historic houses were located in the city and who owned them. The ability to easily access this information can also aid genealogists and others involved in researching the history of Nauvoo. Overall, the work presented here has the potential to fill a significant gap in our knowledge and understanding of historic Nauvoo by revealing and recording important spatial information about the archaeological resources in the city. Beyond its contribution to knowledge, this research can also serve as a fundamental tool for the preservation of Nauvoo’s finite archaeological heritage for future generations.

Future Work
As additional GPR surveys in Nauvoo are completed, the resulting images can be added to the GIS database allowing future researchers, developers, and other interested individuals access to the geo-referenced radar data at the click of a mouse.

Acknowledgements
Special thanks to R. W. Rollenger for data collection and fieldwork. Thanks to the Alvah L. Tippets family for their permission to access their property. Special thanks to M. Pentrich for providing the site plan of the Alvah L. Tippets property.

Table 1

<table>
<thead>
<tr>
<th>Property Record Database</th>
<th>Geo-Database</th>
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<tbody>
<tr>
<td>Block 106, Lot 4</td>
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<tr>
<td>1846 Map</td>
<td>Aerial Photograph</td>
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<tr>
<td>May 2009</td>
<td>June 2009</td>
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<tr>
<td>Ground Penetrating Radar</td>
<td>Ground Penetrating Radar</td>
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<tr>
<td>GIS</td>
<td>GIS</td>
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<tr>
<td>Top, west-to-east profile (crossing center of GPR site) surveyed in May 2009, under relatively dry conditions; Bottom, approximately same profile surveyed in June 2009 after rain</td>
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</tbody>
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Figure 1
Figure 2
Figure 3
Figure 4
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Figure 9
Figure 10
Figure 11
Figure 12