A Non-Invasive Archaeological Investigation at the Gladstone Savanna Neighborhood Preserve and Gloster Park

Ground Penetrating Radar and Light Detection and Ranging Survey of the Gladstone Shops of the St. Paul and Duluth Railroad

PREPARED FOR:

THE CITY OF MAPLEWOOD

BY:

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INTRODUCTION

Archaeo-Physics, LLC was contracted by the City of Maplewood to perform a non-invasive archaeological investigation at the Gladstone Savanna Neighborhood Preserve and Gloster Park. The investigation consisted of ground penetrating radar (GPR) and light detection and ranging (LiDAR) investigations at the location of the Gladstone shops of the St. Paul and Duluth railroad. Construction of the Gladstone shops and roundhouse was started in 1887 and the site was utilized for the remainder of the 19th and into the early 20th century. The roundhouse was demolished sometime around WWI, and some of the associated shops remained standing until 1979. After demolition the site was buried beneath a layer of homogeneous sandy fill. The primary objective of the investigation was to assess the integrity of buried archaeological resources prior to potential impacts to the site associated with remediation of contaminated soils and grading.

The GPR investigation was performed by David Maki, of Archaeo-Physics. Data collection took place over the period spanning 8-14 June, 2012. LiDAR analysis was conducted using data provided by the State of Minnesota High-Resolution Elevation Mapping Project (State of Minnesota, 2012). LiDAR data from Gladstone Savanna area were made available to the public on 2 October, 2012.

METHODS AND SURVEY DESIGN

A brief description of the methods and survey design parameters utilized during the investigation is presented below. A more comprehensive introduction to ground penetrating radar survey methods as applied to archaeology can be found in Clark (1996), Conyers and Goodman (1997), Johnson (2006), Gaffney and Gator (2003) and Conyers (2012). Analysis of airborne laser scanning data for use in archaeological studies is discussed in several recent publications by Bennett, et. al. (2012), Challis, et. al. (2011), Gallagher and Josephs (2008), Hesse (2010), and Riley et. al. (2010).

Ground Penetrating Radar Survey

The GPR functions by sending high frequency electromagnetic waves into the ground from a transmitter antenna. Some of these waves are reflected back to the surface as they encounter abrupt vertical changes in the dielectric permittivity or electrical conductivity of the matrix through which they are traveling and are detected by a receiver antenna (note: diffuse vertical changes in these properties do not produce significant reflections). The amplitude and two-way travel time of these reflections are recorded and used to construct a two-dimensional plot of horizontal distance versus travel time. Data collected in the field are stored for later analysis, and may be viewed as two-dimensional profiles in real-time during data collection.
GPR data are traditionally examined as profile maps depicting individual transects. Time-slicing is a technique for constructing plan view maps of an area at specific depths. Time (or depth) slicing not only makes interpretation of data in the horizontal plane much more intuitive, but also allows us to isolate specific depth slices (or more properly, the two-way travel times of reflected waves) for examination. GPR data were examined and analyzed as both profile maps and as plan view time-slice maps. Time data were converted to depth data (depth-slices) by using an estimated wave velocity of 0.10 m per nanosecond.

The GPR survey grid was established at the site using an electronic total station. This grid had maximum dimensions of 150 x 180 meters, and encompassed a total area of 14,500 m² (Figure 1). The UTM coordinates of key points on the GPR survey grid were recorded using a Trimble GEO XH global positioning system (GPS). These data were used to geo-reference the GPR data imagery.

GPR survey was conducted using a Sensors & Software pulseEKKO 1000 radar system (Figure 2). A center frequency of 450 MHz was used. GPR data were collected in linear transects spaced 1.0 m apart, with a GPR trace collected every 0.05 m along each transect, resulting in an overall data sample density of 20 samples per square meter.

GPR data processing proceeded as follows: (1) The length of each individual GPR transect was normalized to its correct value; (2) Data were re-sampled to a consistent sampling interval down each GPR transect; (3) The zero-point in the time domain (time-zero) was defined as the point at which the signal amplitude exceeded 5% of the maximum signal amplitude. This time-zero point was set consistently in each individual GPR trace; (4) A 3 point low-pass smoothing filter was applied in the time-domain; (5) 2-D GPR profiles were converted to depth-slices by calculating the average-amplitude of the reflected signal within 5.56 cm thick windows; (6) Average amplitude data were exported as a 3-D data volume after normalizing each datum by the mean value at that depth; (7) A spherical 3-D low-pass Gaussian smoothing filter (0.75 m radius) was applied; (8) Data were displayed as grey-scale images at a range of positive four and negative two standard deviations (σ) from the mean value; (9) Depth slice images were assembled into an animated sequence and compared with LiDAR imagery from the site.

LiDAR Data Analysis

Light detection and ranging (LiDAR) is fast emerging as a cost-effective method of archaeological reconnaissance and assessment. Airborne LiDAR surveys illuminate the earth's surface with pulses of light and measure the time it takes for reflections to arrive back at the aircraft. Location information is provided by an onboard GPS system. Time data are converted to
distance, enabling calculation of the elevation of the target. Reflections occur from trees, vegetation, buildings, the ground surface, and other surface phenomena. After careful parsing of this information, it is possible to construct an extremely accurate digital elevation model representing the surface of the earth.

Imagery constructed from high-resolution LiDAR data is useful for detecting topographic patterning that may be associated with archaeological features. Geophysical data processing methods may be employed to reduce noise and enhance the visibility of subtle features. Data are typically presented as shaded relief images in which a digital elevation model is illuminated by an inclined light source from different angles. Careful processing and display of LiDAR data can reveal topographic patterning not readily perceptible to the naked eye at ground level.

It should be noted that although LiDAR imaging is an effective method of visualizing archaeological landscapes, the technology can only detect features with topographic expression. Thus LiDAR is not an exclusive investigatory technique, but may be included as part of a comprehensive research design that also includes methods of detecting subsurface features that lack surface expression.
Figure 1: Location of the GPR survey area. The GPR grid is outlined in black. The background image was created from LiDAR data that contain full discrete return information. This includes the response from the ground and near surface vegetation (grey-scale), as well as the response from trees, brush, buildings, and telephone poles (reds and yellows).
Figure 2. Ground penetrating radar data collection at Gladstone Savanna.

RESULTS AND INTERPRETATIONS

Initial interpretations offered in this section are limited to those anomalies thought most likely to be of archaeological interest. The purpose of these initial interpretations is to serve as a starting point for discussion and ongoing interpretation; it should be considered likely that some interpretations may be in error, and quite certain that features of interest exist which have not been interpreted or even detected.

Geophysical Results

Full results from of the geophysical investigation are available for download and viewing at the following URL: [http://www.archaeophysics.com/gladstone/index.html](http://www.archaeophysics.com/gladstone/index.html)

The interactive graphics presented at this URL allow viewers to dynamically view and compare the LiDAR and GPR data. Interactive graphics, project imagery, and project data may be downloaded at the bottom of the page.
LiDAR data from Gladstone Savanna are presented as shaded-relief images in Figures 3 and 4. In these figures each image is illuminated from a different horizontal azimuth. Representative GPR depth slices are presented in Figure 5. Combined LiDAR and GPR survey results are presented in Figure 6. Archaeological interpretations of the LiDAR and GPR data are offered in Figure 7. GPS points used to geo-reference the GPR data are presented in Figure 8. It should be noted that the initial interpretations offered in Figure 7 are limited to those anomalies thought most likely to be of archaeological interest. Because anomalies suspected to represent archaeological features vary in their strength and definition, grading into ambiguity, no attempt is made to interpret every anomaly.
Figure 3: Bare-earth LiDAR shaded-relief imagery. The illumination inclination is 45 degrees. The illumination azimuth varies by image. (a) 45 degrees; (b) 135 degrees.
Figure 4: Bare-earth LiDAR shaded-relief imagery. The illumination inclination is 45 degrees. The illumination azimuth varies by image. (c) 225 degrees; (c) 315 degrees.
Figure 5: Representative average-amplitude GPR depth slice images.
Figure 5: GPR depth slice from 75 cm below surface overlaid on a shaded-relief LiDAR image (illumination azimuth 45 degrees).
Figure 6: Archaeological interpretations.
points used for geo-referencing the GPR survey grid

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Figure 7: Points used to geo-reference the GPR survey grid.
CONCLUSIONS

A geophysical investigation at Gladstone Savanna has mapped buried archaeological resources associated with Gladstone Shops and roundhouse. The Gladstone Shops date to the late 19th / early 20th century and belonged to the St. Paul and Duluth Railroad. Buried foundation walls appear clearly in the GPR data from between 50 cm and 100 cm below surface, with images from approximately 75 cm being most well-defined. In portions of the site covered by GPR survey the structure foundations appear to have good integrity, although in some cases foundations appear to have been damaged by utility trenches and site demolition.

The roundhouse is well-defined in the GPR data. In areas not covered by the GPR survey topographic patterning associated with the roundhouse is visible in the LiDAR data. Much of this patterning is not apparent to the eye at ground level. The central turntable of the roundhouse is not visible in the GPR data suggesting its mechanical components have been removed. A circular depression marking the location of the turntable is clearly visible on the ground surface and in LiDAR data. Roads, R.R. tracks, spurs, and features of unknown origin are visible in the LiDAR data in areas not covered by the GPR survey. This suggests these areas also contain intact archaeological resources.

A comparison of GPR data and historic maps suggest the area of contaminated soil is located over the eastern wall of the machine shop. Foundation walls first appear at about 30 cm below surface in this area, but are most well-defined at a depth of approximately 75 cm below surface. Guidance from a professional archaeologist is recommended during soil removal.

The LiDAR and GPR data complemented each other and provided a more thorough understanding of buried resources at this historic archaeological site than either method alone would have. Clarity in the GPR imagery was likely due to the relative transparency of homogenous sand at this site and the high dielectric contrast of between this and the buried foundations. Excellent resolution of the roundhouse was obtained from the LiDAR data despite its location beneath tree canopy. This is due to the relatively high data sample density (8 per square meter) of the airborne laser scanning data.
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