Canadian Archaeological Association
Association canadienne d'archéologie

Ground-Penetrating Radar (GPR)
Recommended Data Collection Procedures for Locating Unmarked Graves

The following recommendations elaborate on GPR as part of Step 7 (Subsurface Remote Sensing Fieldwork) of the CAA Remote Sensing Pathways Guide. We recommend that readers familiarize themselves with the Pathways Guide before reading this document.

Ground-penetrating Radar (GPR) is a form of remote sensing that is commonly used to locate unmarked burials in cemeteries. It works by sending electromagnetic (EM) waves into the ground at different frequencies. Soil layers and objects below the surface can reflect these waves, returning them to the GPR to be recorded. The time it takes returning waves to reach the GPR allows us to estimate their depth. Different soils and objects will reflect the waves differently back to the antennae, allowing for visualization of the subsurface. This document considers how to collect GPR data when searching for burials. The CAA is developing separate guidance on how to interpret probable burials in GPR results.

GPR scanning is non-invasive; it does not disturb or damage the subsurface. It is widely used in industrial contexts for the detection of buried pipes, cables, foundations and other buried infrastructure. Its use in the location of burials is a specialized application that requires a specific method and experience in identifying grave shaft reflections. When a grave is dug, the soil density and compaction may change; under good conditions, the GPR signal will reflect differently over the grave shaft. Interpreting these signals as graves takes specialist knowledge and experience; archaeologists have been working on refining the use of GPR to detect graves for many years. While GPR cannot provide 100% certainty of a burial, graves can be identified with confidence, especially in formal cemeteries given optimal soil conditions. Its application is less developed in informal or clandestine burials and certain soils (particularly clay) can make grave detection challenging. Negative results in GPR does not ensure that no graves are present; it implies further work is needed.

There are a number of considerations when undertaking a GPR survey to locate unmarked graves.

1) Planning

GPR survey can be time-consuming. We estimate that a crew of 3 technicians can conduct intensive survey (see Step 6, below) of about 500 – 1000 m^2 in one day, depending on conditions. Such surveys require permissions, access, and the development of agreements on scheduling, deliverables, timelines, training and, if required, budgets. Depending on the jurisdiction, permits may also be required. Communities often require specific protocols to be followed including necessary ceremonies, timeframes, and rules about comportment and behaviour when working with ancestors.

2) Reconnaissance and Site Preparation

The area of assessment should be thoroughly investigated prior to conducting a GPR survey. The site should be mapped and its background geology assessed. Landscape features, areas of interest, potential obstacles, and survey grids should be located on the ground and incorporated within a spatial data management system (GIS), which allows the integration, analysis and visualization of multiple forms of spatial data. GPR units work best when in direct contact with the ground, and this may require the removal of low vegetation and mowing.

3) GPR Survey: Preliminary Steps

GPR surveys should begin with an assessment of the background geology by collecting line data in undisturbed areas (i.e. with no burials or other disturbances). The speed at which the radar waves travel through the ground varies with soil type, and should be established in order to convert the GPR responses into depths. If velocity cannot be measured directly, common velocities of subsurface sediments can be estimated. Most GPR user guides provide this information.

4) GPR Survey: Prospection

There are two basic forms of GPR survey: prospection and investigation. In both cases, we recommend an antenna frequency between 250 and 500 MHz. Higher frequencies are sometimes used to investigate a known burial that is very near the surface (within 50 cm), but lower frequencies are more useful for locating unmarked graves. Prospection involves roaming over a target area looking for signals in the GPR display; this can be very useful for confirming that probable graves exist within a large area. When a response indicating a target of interest, in this case a possible grave, is identified, the operator scans the area repeatedly to confirm the identification. Likely graves are then flagged and mapped. Ideally prospection data would be captured as either screen grabs from the display or stored as compilations of lines or traces. Prospection can be assisted by the use of GPS built into GPR, although the precision of such instruments are rarely smaller than ±1m. In this mode, the GPR can be moved across a wide area relatively quickly to assess the likelihood of graves on a landscape. Prospection is a preliminary step in the GPR survey, and should be followed by more detailed investigations.

5) GPR Survey: Investigation

GPR results are most definitive when collected in patterns as grids. Grids should be located to completely cover areas of interest. Multiple grids are usually necessary for a study location. The Working Group's collective experience, along with the existing archaeology geophysics literature, suggests that grids with data collection lines run at

25 cm intervals and with 2 cm step sizes are necessary to provide sufficient data saturation to locate burials when using frequencies between 250-500 MHz. Spacing the GPR lines evenly and close together ensures overlap between the lines and covers the full area. Burials are usually most visible in GPR when the survey crosses the grave perpendicular to its length. As the grave orientation cannot be assumed for clandestine burials, best practice is to collect lines in perpendicular directions (X and Y) across the grid to increase both the signal density and the chances of crossing the short axis of a grave. When working in a cemetery context where general orientation is known, collecting data only along the axis perpendicular to grave length may be sufficient.

This application of GPR generally uses unidirectional data collection within grids rather than Z-pattern (aka zig-zag). Unidirectional collection is especially important over long distances (+5m) to reduce signal noise from errors in odometer calibration and uneven terrain. The grid should be square or rectangular, laid out using non-metallic tape measures or other survey tools. Large metal objects on the surface, such as fences, can create noise in the GPR signal.

Wherever possible, and especially on sloping terrain, the GPR should be equipped with high-precision, real-time kinematic positioning (RTK) GPS, or such data should be collected on the grid control points (corners or axes origins). This allows data to be to be correctly located on the landscape, and corrected for slope, which greatly clarifies reflective patterns.

The CAA is developing further detailed guidance on technical settings, but we recommend the following general principles: use multiple stacking to reduce noise on the signal at maximum depth; apply the minimal filters necessary to visualize grave signals in the GPR (deWOW, gain, high and low band filters, background filtering of the air wave).

It is often helpful to use rectangular survey grids to avoid confusing their orientation during processing. Maximum grid sizes are debated, but we have collected data in grids as large as 50m x 50m with success. It is common to use much smaller grids to avoid obstacles and to ease processing/interpretation.

6) Data Collection Protocols

Accurate field notes are essential to avoid mistakes. While each prospection line or grid line is recorded automatically by the GPR unit, we recommend compiling an additional log of grid lines, their direction, length, and orientation as a back up. Precise and accurate data for the spatial locations of GPR lines and grids, and their relationship to one another, is essential to interpretation. GPR software compiles a composite 3D map of the reflected EM signal (amplitude maps) by combining separate GPR lines together. Errors of line orientation, length, start and end points, etc. will create errors in the GPR outputs. If photographs are appropriate, a photo log should list the subject of each image along with an identifier (such as photo file number). Field notes should be secured and copied as paper or digital back ups if appropriate, depending on how they are collected.

7) Outputs

GPR surveys should produce a final report and a series of archival files. The latter include records of each prospection line and grid as a field note log, such as shown in Figure 1.

These files represent the primary field record of any survey. The GPR lines and grids themselves should be stored securely and with identifiable file/folder names as GPR output files often have similar names. With these elements in place (field logs, site maps, GPR results), the work of identifying graves in GPR can proceed and any potential identifications can be located accurately on the landscape.

A successful field survey will allow for correct data assembly and processing, leading to accurate interpretation of the GPR results and the greatest chance of identifying possible graves.

Sketch or digital maps should be compiled locating all the surface and control point data, such as shown in Figure 2.

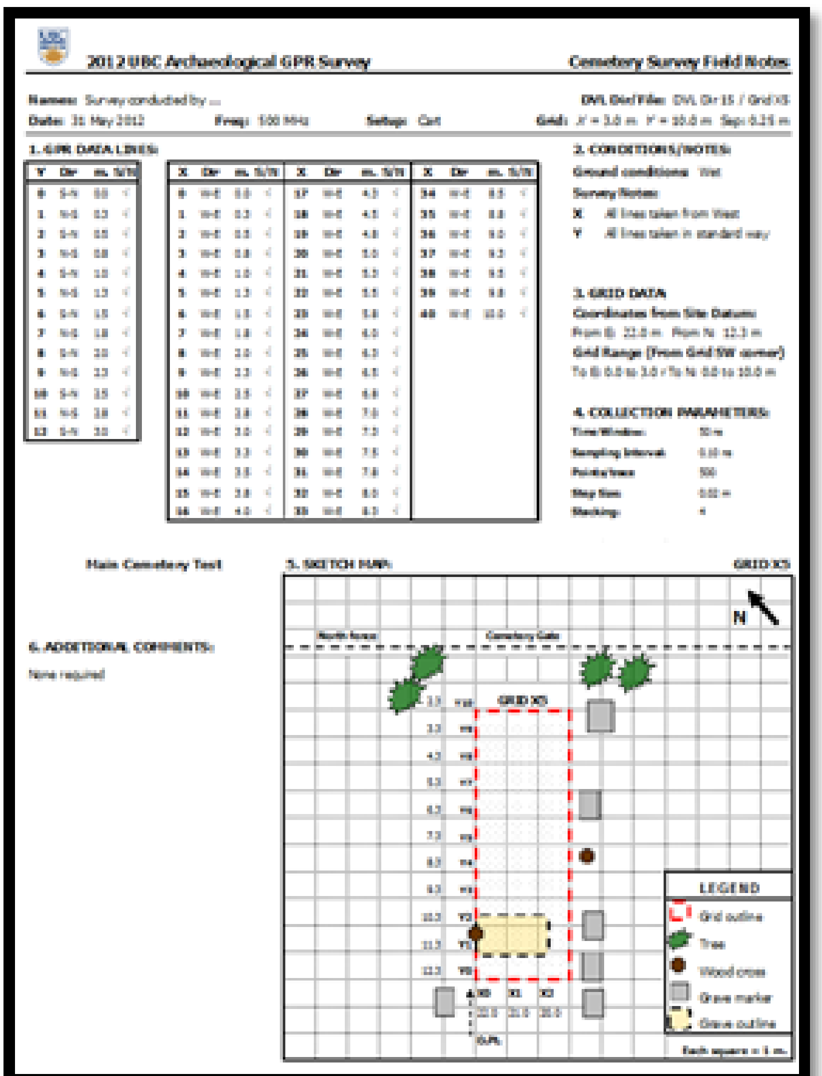

Figure 1. Example GPR Field Notes Log

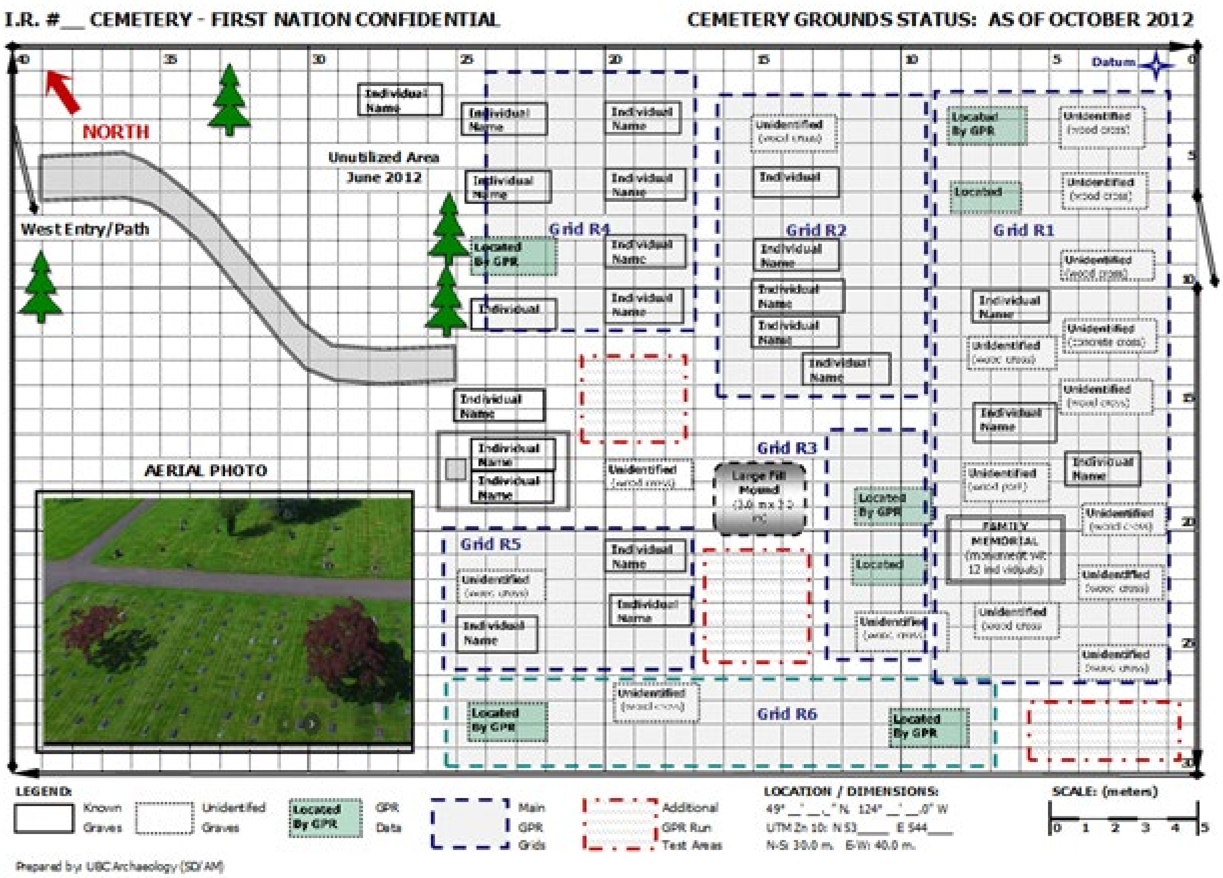

Figure 2. Example GPR Project Grid Map

Authors:

Andrew Martindale, Steve Daniel, William Wadsworth, Eric Simons, and Colin Grier on behalf of the CAA Working Group on Unmarked Graves.

Acknowledgements:

Many thanks to Alistair James P.Eng., Evan Ulmer P.Eng., Dylan Antunes P.Eng., and Dr. Jonathan Fowler for their helpful comments on an earlier draft.