United States Department of Agriculture

NRCS

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Subject: MGT – Trip Report - Cultural Resources Geophysical Assistance

August 7, 2012

To: Jay Mar
State Conservationist, NRCS
Tolland, Connecticut

File Code: 330-20-7

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Purpose:
To provide geophysical training and cultural resource assistance to the MLRA Soil Survey Office staff in Tolland, Connecticut. Ground-penetrating radar was used to support six cultural resources projects that are being carried out in cooperation with the Connecticut State Archaeologist, Connecticut Archaeology Center, and University of Connecticut.

Principal Participants:
Adam Aldridge, Student Intern, USDA-NRCS, Tolland, CT
Nicholas Bellantoni, Connecticut State Archaeologist, Connecticut Archaeology Center, University of Connecticut, Storrs, CT
Jennifer Blanchette, Student Intern, USDA-NRCS, Norwich, CT
Andrew Brown, Student Intern, USDA-NRCS, Tolland, CT
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Bruce Greene, Friends of the Office of State Archaeology (FOSA), Storrs, CT
Debbie Surabian, Acting State Soil Scientist, USDA-NRCS, Tolland, CT

Activities:
All activities were completed during the period of July 9-13, 2012.

Summary:
Ground-penetrating radar surveys conducted during this week were productive and highly successful. The following results were obtained:

1. At the Plainville site, GPR revealed the likely location of a refill dry dock on the Farmington Canal.

2. At the Hebrew Farm site in Chesterfield, GPR revealed no coherent trend or architecture that would suggest the presence of buried pipes from a mikvah.

3. At the North Stonington site, GPR confirmed that no major structural features are buried beneath a grassed trail. Ground-penetrating radar charted the course of a trailrace buried beneath the driveway of the North Stonington Historical Society Office.

4. At the West Neck Cemetery, random GPR surveys identified marked and unmarked gravesites. In addition, GPR revealed the locations of several seemingly open spaces that can be used for future burials. If unmarked graves exist in these open areas, they are highly decomposed and beyond the detection limits of the 400 MHz antenna.

5. At the Robinson Burial Grounds, GPR revealed the possible location of a suspected crater known to be the grave of Elisabeth Hall. In addition, GPR is believed to have identified several unmarked graves in the Robinson family plot.

6. The GPR survey revealed no major structural feature beneath the parking area at the North Stamford Congregational Church.

It was the pleasure of Jim Doolittle and the National Soil Survey Center to work in Connecticut and be of assistance to you and your fine staff.

JONATHAN W. HEMPEL
Director
National Soil Survey Center

Attachment (Technical Report)

cc:
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Technical Report

Jim Doolittle

Background:
Ground-penetrating radar (GPR) can be used to identify areas of interest within cultural resource sites, locate buried archaeological features, clear suspected areas so that resources can be directed elsewhere, tests hypothesis, and confirm existing site knowledge. At many sites, the efficacy of cultural resource investigations can be improved through the combined use of GPR and traditional archaeological methods.

Ground-penetrating radar provides for the rapid, noninvasive detection of subsurface anomalies, which, based on additional supporting evidence and disturbance signatures, are identified as potential burials, archaeological structures, or other artifacts. The efficacy of GPR is highly site-specific and success is dependent on favorable soil and site conditions. Results vary with soils and soil properties.

Equipment:
The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (here after referred to as the SIR-3000), manufactured by Geophysical Survey Systems, Inc. (GSSI; Salem, NH).[1] The SIR-3000 consists of a digital control unit (DC-3000) with keypad, SVGA video screen, and connector panel. A 10.8-volt lithium-ion rechargeable battery powers the system. The SIR-3000 weighs about 4.1 kg (9 lbs) and is backpack portable. With an antenna, the SIR-3000 requires two people to operate. Jol (2009) and Daniels (2004) discuss the use and operation of GPR. A 400 MHz antenna was used in the investigations.

The RADAN for Windows (version 6.6) software program (developed by GSSI) was used to process the radar records shown in this report. Processing used included: header editing, setting the initial pulse to time zero, color table and transformation selection, signal stacking, horizontal high pass filtration and range gain adjustments (refer to Jol (2009) and Daniels (2004) for discussions of these techniques).

Calibration of GPR:
Ground-penetrating radar is a time scaled system. The system measures the time that it takes electromagnetic energy to travel from an antenna to an interface (e.g., soil horizon, stratigraphic layer, buried cultural feature) and back. To convert the travel time into a depth scale, either the velocity of pulse propagation or the depth to a reflector must be known. The relationships among depth (D), two-way pulse travel time (T), and velocity of propagation (v) are described in equation [1] (after Daniels, 2004):

$$v = 2D/T \qquad [1]$$

The velocity of propagation is principally affected by the relative dielectric permittivity (E_r) of the profiled material(s) according to equation [2] (after Daniels, 2004):

$$E_r = (C/v)^2 \qquad [2]$$

C is the velocity of light in a vacuum (0.3 m/ns). Typically, velocity is expressed in meters per nanosecond (ns). In soils, the amount and physical state (temperature dependent) of water have the greatest effect on the E_r and v. The dielectric permittivity ranges from 1 for air, to 78 to 88 for water (Cassidy, 2009). Small increments in soil moisture can result in substantial increases in the relative permittivity of soils (Daniels, 2004). Using a 100 MHz antenna, Daniels (2004) observed that the relative

[1] Manufacturer's names are provided for specific information; use does not constitute endorsement.

dielectric permittivity of most dry mineral soil materials is between 2 and 10, while for most wet mineral soil materials, it is between 10 and 30.

No ground-truth verifications of the velocity of propagation were attempted during this study. As a result, depth scales were approximated using hyperbolic velocity matching that was carried out during processing. Hyperbolic velocity matching provided rough estimates of average relative dielectric permittivity and the velocity of propagation at each site. This information was used to depth scale the radar records.

Amplitude Slice Analysis:
In recent years, the use of advanced signal-processing software have enabled the enhancement of radar signals and improved pattern-recognition on radar records in some soils. Some of the signal processing methods used to improve the interpretability of subsurface archaeological features appearing on radar records are discussed by Sciotti et al. (2003) and Conyers and Goodman (1997). One advanced signal processing method that is commonly used in archaeological investigations is *amplitude slice analysis* (Conyers and Goodman, 1997). In this analysis, a three-dimensional (3D) pseudo-image of a small grid area is constructed from the computer analysis and synthesis of a series of closely-spaced, two-dimensional (2D) radar records. Amplitude differences within the 3D pseudo-image are analyzed in "*time-slices*" (or depth-slices) that examine changes within specific depth intervals in the ground (Conyers and Goodman, 1997). In this process, the reflected radar energy is averaged horizontally between adjacent, parallel 2D radar traverses and in specified time (or depth) windows to create a time-slice (or depth-slice) image. Each amplitude time-slice shows the spatial distribution of reflected wave amplitudes, which can indicate changes in soil properties or the presence of subsurface features. In many instances, 3D GPR imaging techniques have been used to distinguish and identify potential targets and to reduce interpretation uncertainties.

Study Sites:
Farmington Canal Dry Dock:
The Farmington Canal, which was used between 1828 and 1847, is the longest canal ever built in New England. The canal stretched 87 miles between New Haven, Connecticut, and Northampton, Massachusetts. A former dry dock is believed to be located in a residential area (41.6747 N latitude, 72.8611 W longitude) along Norton Place in Plainville, Connecticut. The site is located in an area of Merrimac sandy loam, 0 to 3 percent slopes (34A). The very deep (> 150 cm), somewhat excessively drained Merrimac soils formed in sandy outwash. Ground-penetrating radar was used to identify remnants of this former dry dock.

Hebrew Farmers Site:
The Hebrew Farmers Site (41.4272 N latitude, 72.2156 W longitude) is located in a wooded area near the intersection of Routes 85 and 161 in Montville, Connecticut. The site is located in an area of Canton and Charlton soils, 3 to 8 percent slopes, very stony (61B). The very deep, well drained Canton and Charlton soils formed in a loamy till. For Canton soils, this loamy mantle is underlain by sandy till. Charlton soils lack this underlying layer of sandy till. The focus of the GPR surveys was to identify buried pipelines extending from the structural remains of a mikvah's foundation.

North Stonington Historical Society Trailrace:
The site (41.4415 N latitude, 71.8816 W longitude) is located on Wyassup Road in North Stonington, Connecticut. The site is located in an area of Hinckley gravelly sandy loam, 3 to 15 percent slopes (38C). The very deep, excessively drained Hinckley soils formed in sandy glaciofluvial materials. Ground-penetrating radar was used to detect potential cultural remnants buried beneath a grassed trail and to identify the extent of a buried trailrace in front of the North Stonington Historical Society's office.

West Neck Cemetery:
The West Neck Cemetery (41.3096 N latitude, 72.1291 W longitude) is located along Great West Neck Road in Waterford, Connecticut. The cemetery is located in an area of Woodbridge fine sandy loam, 3 to 8 percent slopes (45B). The moderately well drained loamy Woodbridge soils formed in lodgement till. Woodbridge soils are very deep to bedrock and moderately deep (50 to 100 cm) to a densic contact.

The West Neck Cemetery was founded in the 1850s. The cemetery association has records of 474 burials; however, approximately 20 of these burials have no headstones. The purpose of the GPR survey is to indentify unmarked graves and provide the cemetery association with the locations of any open spaces that can be used for future burials. Random GPR traverses were conducted across eight areas of the cemetery.

Robinson Burying Ground:
The Robinson Burying Ground (41.3368 N latitude, 71.9078 W longitude) is located near the intersection of Water and Broad Streets in Stonington, Connecticut. The site is located in an area of Agawam fine sandy loam, 3 to 8 percent slopes (29B). The very deep, well drained Agawam soils formed in sandy, water deposited materials.

The Robinson Burying Ground was established in the mid- to late-1770s. During the Battle of Stonington (August 10-13, 1814), a British shell was reported to have landed in the burial grounds where it created a large crater. Elisabeth Hall died during the battle and was hurriedly buried, on her bed, in this crater. Ground-penetrating radar was used to locate this crater. In addition, headstones for the immediate family of Captain Thomas Robinson are missing and the Burying Grounds Association wishes to identify the locations of these burials.

North Stamford Congregational Church:
The North Stamford Congregational Church is located on Cascade Road in Stamford, Connecticut. The site is located in an area of Canton and Charlton soils, 8 to 15 percent slopes, very stony (61C). An 18 by 8 m grid was established across a small, paved, parking area (41.1386 N latitude, 73.5429 W longitude) that is adjacent to the Stone House that is along Cascade Road. The purpose of this GPR survey was to identify remnants of buried structures and possible buried feature related to Native Americans.

Table 1 lists the taxonomic classifications of the aforementioned soils. These soils are well suited to deep exploration depths with GPR because of favorable soil properties (low clay, moisture and soluble salt contents).

Table 1. Taxonomic classification of the soils identified in the study sites.

Soil Series	Taxonomic Classification
Agawam	Coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudept
Canton	Coarse-loamy over sandy or sandy-skeletal, mixed, semiactive, mesic Typic Dystrudepts
Charlton	Coarse-loamy, mixed, active, mesic Typic Dystrudepts
Hinckley	Sandy-skeletal, mixed, mesic Typic Udorthents
Merrimac	Sandy, mixed, mesic Typic Dystrudepts
Woodbridge	Coarse-loamy, mixed, active, mesic Aquic Dystrudepts

Survey Procedures:
Random or *wild-cat* surveys were conducted across accessible areas at most sites. Areas of dense vegetation were avoided.

Survey grids were established at the Hebrew Farm, Robinson Burying Grounds, and North Stamford Congregational Church sites. Survey grids are required for the construction of 3D-GPR pseudo-images.

At each of the grid sites, two parallel survey lines were laid out and served as grid axis lines. Along these two parallel axis lines, survey flags were inserted into the ground at a spacing of 50 cm. A distance-graduated rope was stretched between matching survey flags on these two axis lines, which were located on opposing sides of the grid area. The 400 MHz antenna was towed along the graduated rope and, as it passed each 100-cm graduation, a mark was impressed on the radar record. Following data collection along the line, the distance-graduated rope was sequentially displaced 50-cm to the next pair of survey flags to repeat the process.

Results:

Farmington Canal- Plainville

Random GPR surveys were conducted between to two houses along the east side of Norton Place. The survey area is located to the immediate east of where Norton Place makes a noticeable bend to the west. These GPR surveys revealed a 7-meter wide zone of dissimilar radar reflection patterns. This anomalous pattern was observed to extend away from the first house (southern-most) in a north-northwest direction, beneath the adjoining paved driveway and towards a tree-covered depression located between the two houses. On the radar records collected over this site, most areas contained subsurface planar reflectors that suggest stratification common to the glacial outwash sediments of Merrimac soils. The anomalous area lacked these sub-horizontal reflectors and was composed of numerous, chaotically arranged point reflectors (see Figure 1). Because of the sites location and the information supplied by local historians, it is believed that these anomalous reflections represent debris used to refill a previously excavated area that served as a dry dock on the Farmington Canal.

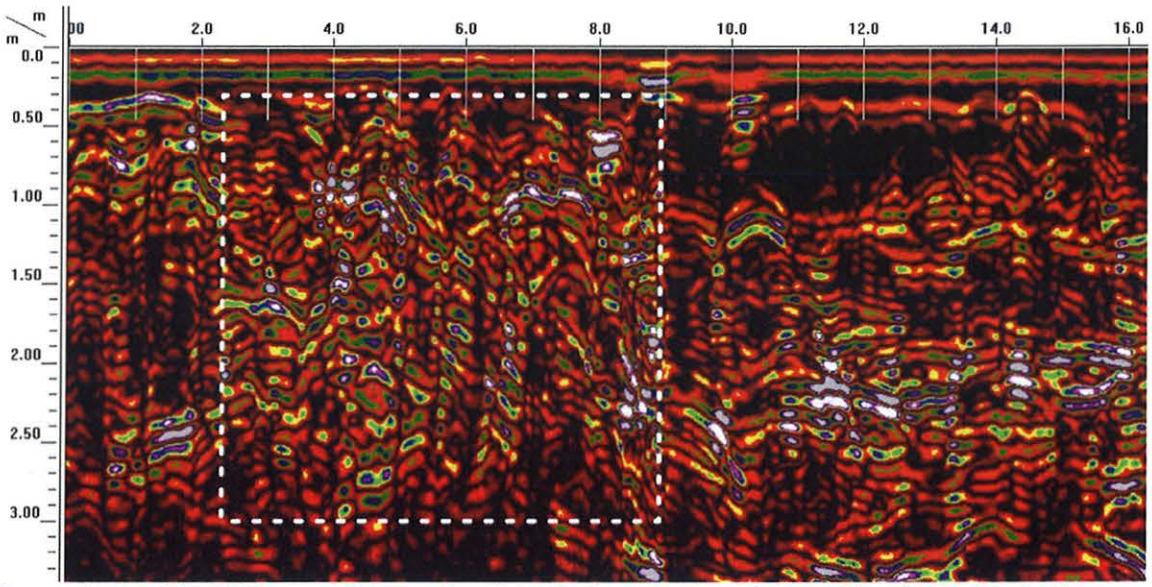

Figure 1. On this GPR record from the site of a former Farmington Canal dry dock, the area enclosed by the segmented lines has a different radar signature indicating dissimilar materials. This area is suspected to represent an infilled dry dock. All scales are in meters.

Hebrew Farm, Chesterfield:

The site represents the location of a rural synagogue and mikvah (ritual bath house) used by a small community of Jewish farmers. In the 1880s, these Jewish farmers had emigrated from Russia to New York City in order to escape persecution and violence. By 1890, some of these immigrants had moved to Chesterfield, where they established a small community. Their synagogue and mikvah, which are on the National Register of Historic Places, were largely abandoned by the early 1930s. A mikvah is a bathing facility used by Orthodox Jews to take ritual purification and cleansing baths on certain occasions. The

focus of the GPR surveys was the area surrounding the structural remains of the mikvah's foundation. Several pipes are exposed along the sidewalls of the mikvah and knowledge of their geometry, connectivity and direction of flow is desired.

The site is located in an area of Canton and Charlton soils. Canton and Charlton soils have optimal properties (e.g., low conductivity, low clay contents) for deep exploration with GPR. However, the glacial till contains numerous point objects (e.g., stones and cobbles, tree roots), which can be easily confused with a buried pipe that is cross orthogonal to its long axis. As a result, random GPR traverses provided inconclusive evidence supporting the locations of buried pipes.

Figure 2. Completing a grid survey at the Hebrew Farm site. The structural remains of a mikvah are on the left. An exposed pipe is adjacent to the 400 MHz antenna that is being towed along the ground surface.

A small grid (3 by 2 m) was setup to the immediate south of the mikvah and the area was surveyed with GPR (Figure 2). Figure 3 contains two 3D pseudo-images of the grid site. The left-hand image is a solid cube; the right-hand image has been *time* or *depth-sliced* with the upper 84 cm of the soil removed.

In Figure 3, both pseudo-images reveal a major subsurface interface at depths ranging from 75 to 1 m in the sidewalls of the cubes. While the identity of this subsurface interface was not verified, its high amplitude (colored white and grey) reflections do signify an abrupt boundary that separates highly contrasting materials. My best guess would be that this interface represents the presence of a layer of dense till. In Figure 3, the arrow on the right-hand pseudo-image represents the approximate location of an exposed standing pipe. A noticeable right-angle reflection pattern is evident on this pseudo-image in the area immediately in front (to the south) of this pipe. However, this pattern is abruptly truncated with no discernible continuing trend. No further indications of a pipeline were observed on animated time-sliced images of this 3D cube.

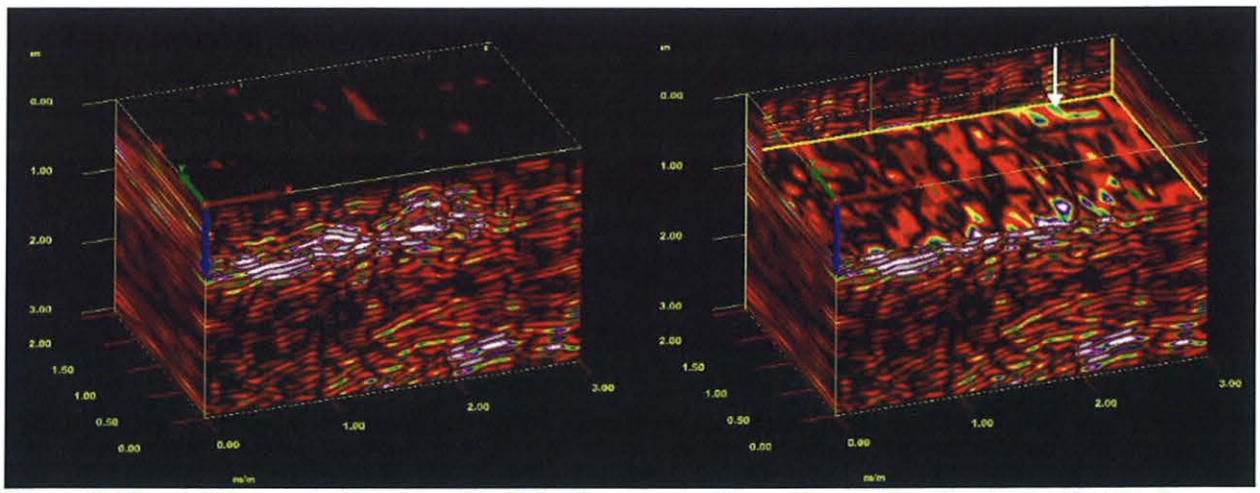

Figure 3. These 3D pseudo images of the 3 by 2 meters grid are from the mikvah site that is shown in Figure 2. A solid image (left) and an image with the upper 84 cm removed (right). Arrow on the right-hand image indicates the approximate location of an exposed pipe.

Several subsurface point anomalies that appeared on 2D radar records collected in other portions of the site were hand excavated. These probes revealed the presence of rock fragments, but no buried cultural features. In general, there is no coherent trend or architecture evident on the radar records and pseudo-images that would suggest the presence of buried pipes.

North Stonington site:

This investigation focused on the detection of buried structures along a grassed trail (Figure 4) and a buried trailrace near the North Stonington Historical Society Office. A race conveys water for industrial applications (e.g., water wheel, turbine). The race that brings water from a mill pond to a water wheel is called a headrace; the race that carries water away from a water wheel is referred to as a trailrace.

A radar traverse (Figure 5) that was conducted along the grassed trail adjacent to the trailrace revealed no major subsurface, artificial structural features. Numerous point reflections (appearing as hyperbolas) suggest the presence of larger rock fragments, but some could represent buried artifacts. Several hyperbolas have a sequence of multiples extending vertically downwards beneath the initial hyperbolas. This is a form of noise that can be used to identify metallic objects. A fairly noticeable zone of weaker amplitude reflections has been enclosed by segmented lines in Figure 3. This zone is located in front of the white barn shown in Figure 4. Because of this zone's spatial location, the weaker amplitude signals suggest possible GPR signal attenuation caused by discarded solutions.

Figure 4. This grassed trail, which is adjacent to the trailrace (in bushes to right), was surveyed with GPR at the North Stonington site.

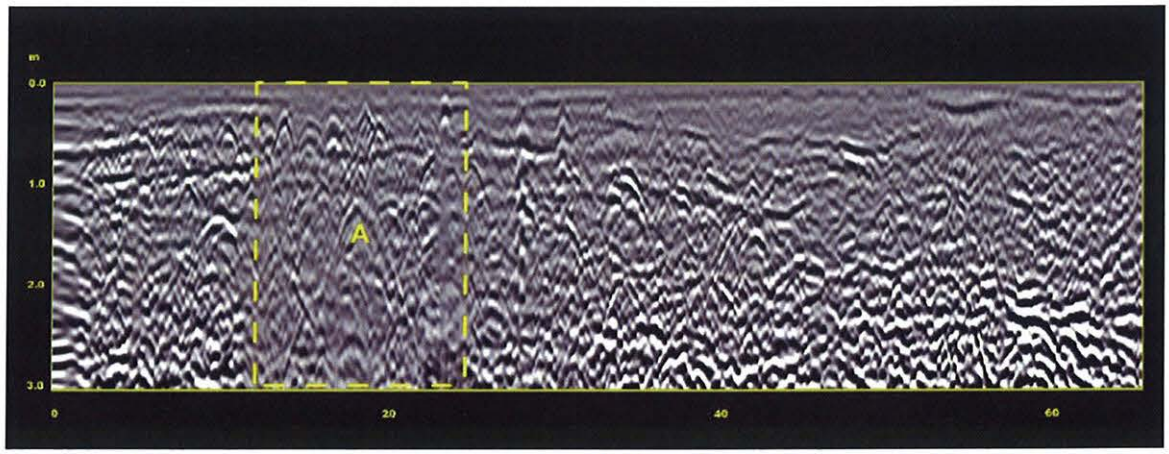

Figure 5. In this radar record from the grassed trail at the North Stonington site, a zone of weaker amplitude reflections is enclosed by segmented, yellow-colored lines. All measurements are in meters.

Radar surveys were also conducted over the buried portion of the trailrace that is located in front of the house. The radar record shown in Figure 6 was collected adjacent to the driveway and close to an exposed portion of the trailrace. On this radar record, the buried trailrace has been enclosed by white colored, segmented lines. The presence of two sequences of banded reflections with a polarity reversal indicates the top and bottom surfaces of an intact portion of the trailrace. The trailrace was mapped with GPR beneath the driveway in front of the house to Wyassup Road where the signature was lost.

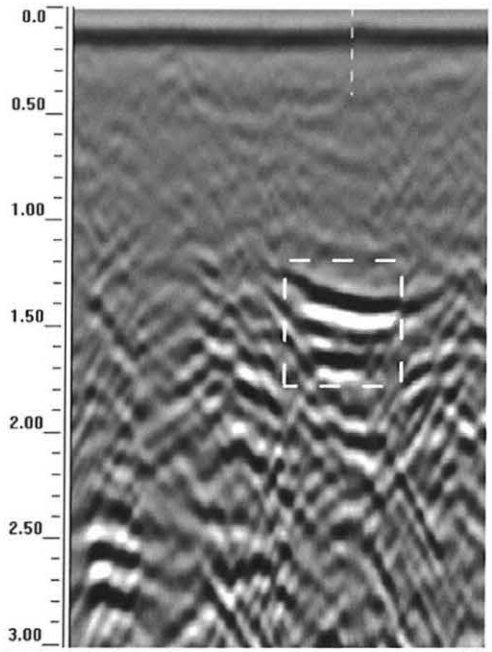

Figure 6. An intact portion of the buried trailrace has been enclosed by white-colored, segmented lines on this radar record.

West Neck Cemetery:

A series of wildcat surveys were completed in an attempt to locate unmarked graves and to identify open areas within this cemetery. Even with favorable soil conditions (e.g., dry, coarse-textured soils) the detection unmarked graves with the GPR cannot be guaranteed. The detection of unmarked graves is affected by the electromagnetic gradient existing between a burial and the soil; the size, shape, and orientation of the burial; and the presence of scattering bodies within the soil (Vickers et al., 1976).

The amount of energy reflected back to an antenna by burial is a function of the dielectric gradient that exists between the buried feature and the soil. The greater and more abrupt the difference in electromagnetic properties, the greater the amount of energy reflected back to the antenna, and the more intense (and noticeable) will be the amplitude of the image recorded on the radar record. Initially, burials contrast with the surrounding soil matrix. However, with the passage of time, burials decay or weather and become less electrically contrasting with the surrounding soil matrix. For burials, the degree of preservation depends on the genetic age and health of the deceased as well as duration of burial (Killam, 1990). Other factors influencing the degree of preservation include soil type, moisture content, temperature, flora and fauna (Killam, 1990). Corpses deteriorate more rapidly in highly acidic soils than in neutral or alkaline soils (Mellett, 1992). Rodriquez and Bass (1985) noted a direct correlation between rates of decomposition or preservation and soil type, soil temperature, or depth of burial.

The size, orientation, and depth to a buried feature affect detection. Large objects reflect more energy and are easier to detect than small objects. Small, shallowly-buried features will be missed, unless located directly beneath the aperture of the radar antenna. With GPR surveys that cover extensive areas, the detection of small buried features is often considered fortuitous. Mellett (1992) discussed the fortuitous detection of a corpse. Small, deeply buried features are often more difficult to discern than large, shallowly buried features on radar records as the reflective power of an object decreases with the fourth power of the distance to the object (Bevan and Kenyon, 1975).

Bevan (1991) noted that it is more likely that GPR will detect the disturbed soil within a grave shaft, a partially or totally intact coffin, or the chemically altered soil materials that directly surrounds a burial rather than the bones themselves. Killam (1990) believes that most bones are too small and not directly detectable with GPR. Killam (1990) noted that the disruption of soil horizons makes most graves detectable. However, in soils that lack contrasting horizons or geologic strata, the detection of a grave shaft is improbable. In addition, with the passage of time, the signs of disturbances are erased by natural soil-forming processes.

Multiple wildcat surveys were completed across different sites located within the West Neck Cemetery. The first set of traverses was conducted at the end of an alleyway between lot numbers 7 and 8, near the cemetery's northern border wall. Headstones for Joseph Ross Hendrahand and Marcus Hendrahand (deceased 1860) are present in this alleyway (see Figure 7). The GPR survey revealed no anomalies that could be associated with a burial around either of these headstones. Burials of this age may be difficult to detect due to decay and weathering, and a reduction in contrast between the burial and the surrounding undisturbed soil matrix. The survey did reveal an anomaly associated with a burial behind the Petrow headstone in the alleyway between lots 7 and 8 (see Figure 7). The placement of this burial is considered unusual since burials today are typically placed in front of the headstone.

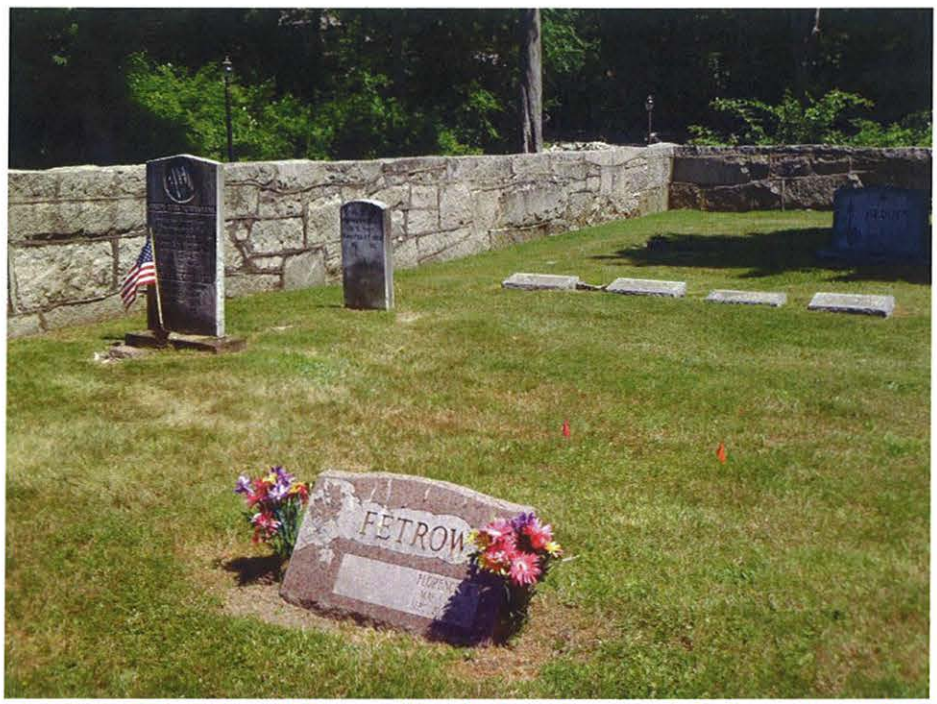

Figure 7. Headstones of Joseph and Marcus Hendrahand are located along the wall of the West Neck Cemetery. An anomaly suspected to be a burial has been flagged behind the Petrow headstone in the right-foreground.

Multiple radar traverses were completed across lots 3, 4, 12, and 13. These GPR survey revealed a relatively large area of seemingly natural, undisturbed soil materials; a number of graves that are properly marked; a new headstone that has no occupants (see Figure 8), and one very shallow, near-surface anomaly. A flag was placed at the location of this anomaly and a hard object close to the surface was contacted by the flag. This anomaly may be investigated further by the State Archaeologist.

Figure 8. A view of lots 3, 4, 12 and 13 from the southeast corner of lot 13 with an arrow identifying a more recent headstone with no evidence of a burial (left-hand image). A close-up of this headstone in lot 12 (right-hand image).

The second GPR survey is located in lot numbers 45 and 54. The GPR revealed an area of natural, undisturbed soils, a number of graves that are properly marked, a grave that was either offset from the headstone or unmarked, and one anomaly.

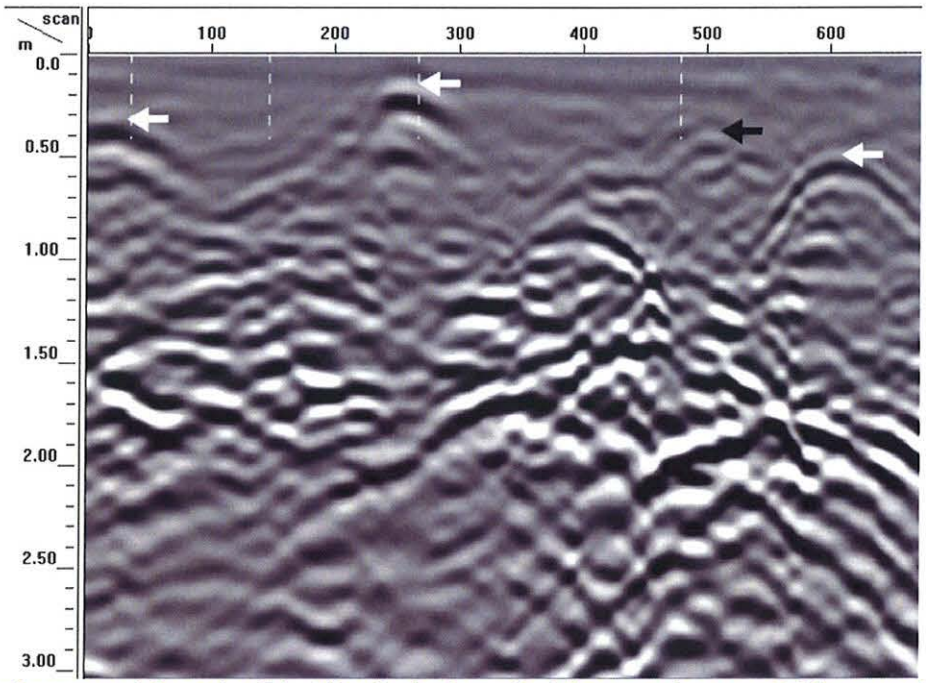

Figure 9. A radar record from lot 54. The dashed vertical lines at the top of this record represent the antenna passing next to a headstone. White arrows indicate hyperbolas from burials. Black arrow indicated a weaker hyperbola from a suspected burial.

Figure 9 is a radar record from this survey area. On the radar record shown in Figure 9, white-colored arrows identify hyperbolas associated with burials. The black colored arrow indicates a weaker hyperbola that may represent a burial. Deeper hyperbolas are associated with larger rock fragments found in the lodgment till of Woodbridge soils. In Figure 9, the arrow on the extreme right identifies a burial that is

offset from a headstone (approximate positions of headstones are identified by the segmented, white-colored, vertical lines at the top of the radar record). This suspected burial was identified in the field with two red flags. An anomaly was also flagged in front of the line of headstones in the alleyway between lots 44 and 45. This anomaly may be investigated further by the State Archaeologist.

The third survey area comprises lots 46 and 55. Radar traverses conducted over these lots revealed an area of natural undisturbed soils and a number of marked graves.

The fourth survey is located in lot numbers 47 and 56. Radar traverses conducted over these lots revealed an area of seemingly natural, undisturbed soils, a number of properly marked graves, and two anomalies. The two anomalies were flagged on the west side of lot number 47 close to the road. These anomalies may be investigated further by the State Archaeologist.

A radar record from these lots is shown in Figure 10. The radar record clearly indicates an area with a relatively thick (120 to 150 cm) homogenous cap of low amplitude signals over a substratum of high amplitude signals. The overlying low amplitude material is believed to represent an eolian cap. The underlying high amplitude material is believed to represent till. However, this scenario is atypical for the Woodbridge soil that has been mapped across the cemetery. Woodbridge soils form in till and have densic materials commonly at depths of 50 through 100 centimeters. Within the suspected eolian cap, weakly expressed, low amplitude hyperbolas are believed to principally represent inhomogeneities in the soil (e.g., differences in soil density, moisture or clay contents). However, older, more weathered or decomposed, unmarked burials cannot be ruled out as they also could produce weak, low amplitude reflections on radar records. If unmarked burials are presence in this area, remains will be scant, very poorly preserved, and difficult to discern.

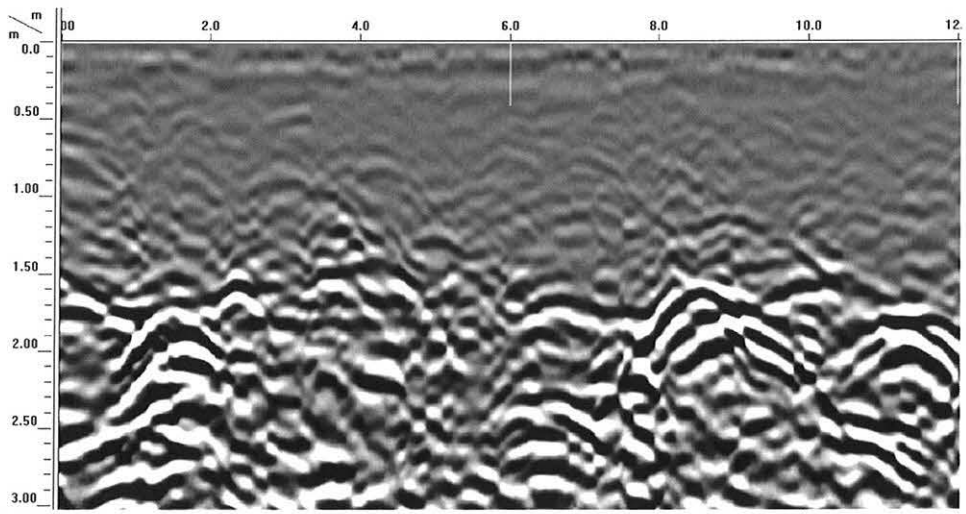

Figure 10. This radar record was collected from lots 47 and 56. Note the general absence of high-amplitude reflectors in the upper part of the radar record. All scales are in meters.

The fifth survey area is located in lots 38 and 42. The GPR survey of these lots revealed an area of seemingly undisturbed soil materials and three properly marked graves. The radar record in Figure 11 is from this survey area. The radar traversed passed near two headstones (approximate positions of headstones are identified by the two segmented, white-colored, vertical lines at the top of the radar record). However, the distorted hyperbolas suggest an overlapping of reflections from three (and perhaps four) closely spaced burials.

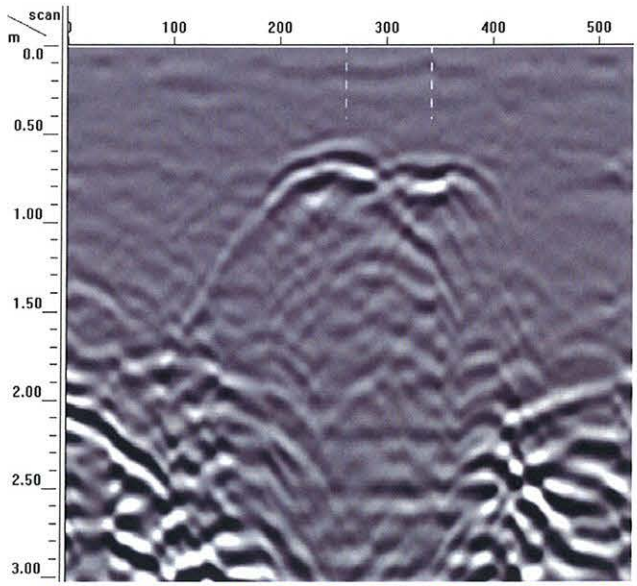

Figure 11. This radar record was collected behind two headstones in lot 38 or 42. Distorted hyperbolas suggest the presence of more than two closely spaced burials.

The sixth survey is located in lot 26. The survey revealed an area of seemingly undisturbed soil materials and one identified burial set behind two headstones.

The seventh survey is located in lot 68. The survey revealed three possible unmarked graves in the center of the lot. This area may be investigated further by the State Archaeologist.

Robinson Burial Grounds:

This investigation focused on the detection of a filled bomb crater in the middle of the cemetery and unmarked graves in the Robinson family plot near the cemetery's entrance. Historical records document that during the battle of Stonington in 1814, a British cannon shell fell into the cemetery and created a large crater. Elisabeth Hall died during the battle and was carried in her bed from her house on Trumbull Street to the burial grounds, where she was buried on her bed in the crater.

Several reconnaissance GPR traverses were conducted across the cemetery. A feature that looks like a carter was detected in a relatively open area in the middle of the burial grounds. A small grid (5 by 6 m) was constructed in this open area (see Figure 12) and a GPR grid surveyed was completed.

A representative radar record from this grid site is shown in Figure 13. On this radar record, all scales are expressed in meter. While not verified by excavation, the imagery does suggest a refilled bomb crater, which would agree with the historical accounts. The crater is about 4 to 5 meters wide and extends to a depth of about 2 meters.

Figure 14 contains four time- or depth-sliced, 3D pseudo-images of the crater grid site. In each image, the view is from directly overhead. Distances are expressed in meters. Other than what is believed to be slight spatial variability in soil properties, no noteworthy features are evident on the 0 and 50 cm depth-slice images. However, in the 100 and 150 cm depth-slice images, the suspected refilled crater can be identified by an area of low amplitude reflections. The low amplitudes are associated with relatively homogenous materials used to fill the crater. This area has been highlighted with an eclipse in both the 100 and 150 cm depth-slice images.

Figure 12. A small 6 by 5 m grid was setup in the middle of The Robinson Burial Grounds. Survey flags indicate the ends of radar traverse lines that were space at 50 cm intervals.

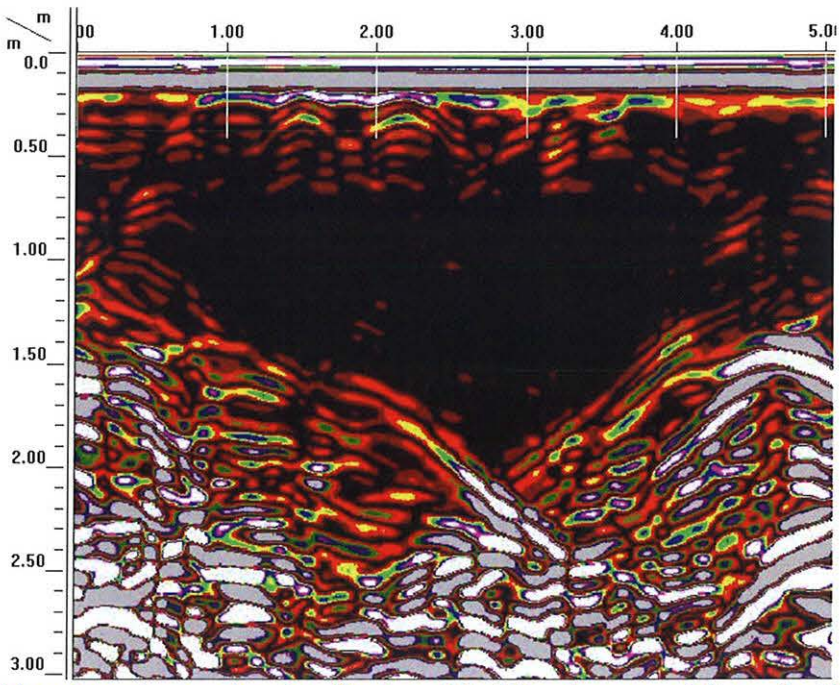

Figure 13. A filled bomb crater can be visualized on this 2D radar record from the Robinson Burial Grounds.

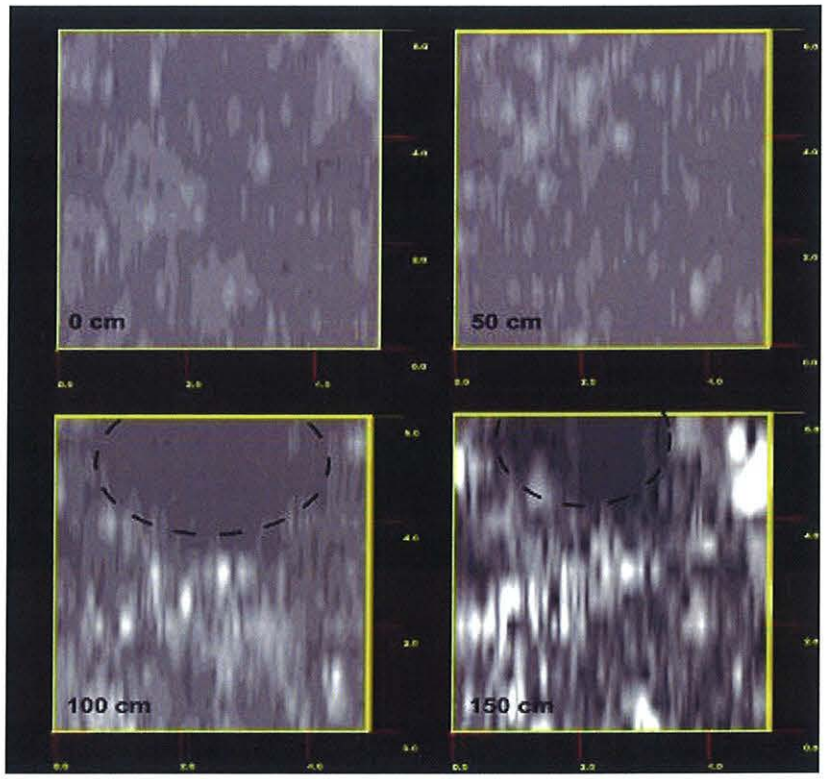

Figure 14. These time-sliced, 3D pseudo-images were constructed from radar data collected at the suspected crater site within the Robinson Burial Grounds.

Next, an 11 by 3 meter grid was established in the southwest corner of the burial grounds in the open area immediately to the north of the ground's entrance (Figure 15). This area represents the Thomas Robinson family plot. While there is a headstone for Captain Thomas Robinson, there are no headstones for his wife, his two sons and their wives. The purpose of this GPR grid survey was to identify unmarked graves in the Robinson family plot.

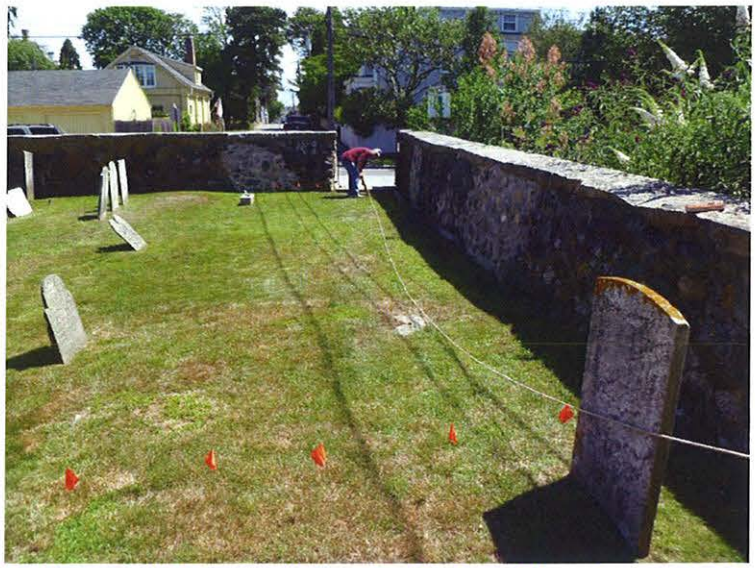

Figure 15. View of the Thomas Robinson plot and grid site. The entrance to the Robinson Burial Grounds is seen in the upper center of this image.

Figure 16 contains four time- or depth-sliced 3D pseudo-images of the Robinson family plot grid. In each image, the view is from directly overhead. Distances are expressed in meters. At a depth of about 100 cm, three, possibly four linear features occur near the northern (lower left) portion of the plot. These linear features have an east-west orientation and occur in the area that is closest to the large headstone shown in the right foreground of Figure 15.

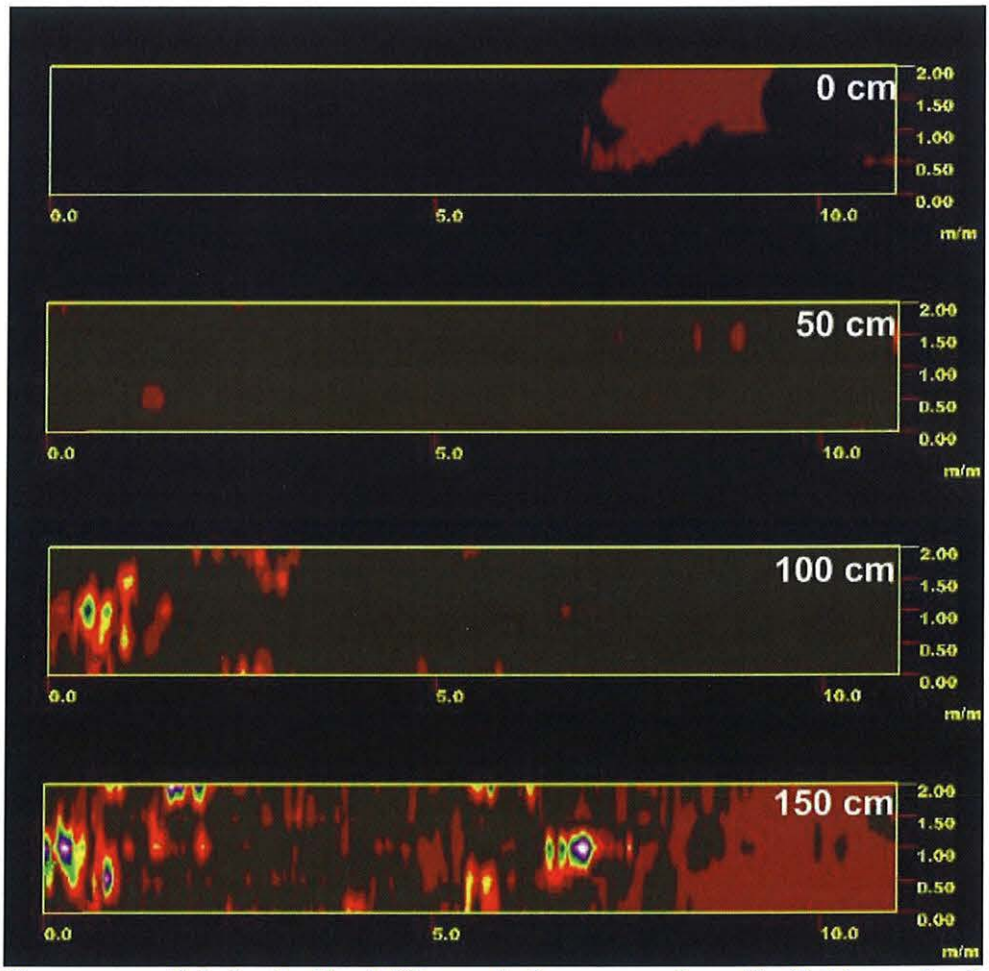

Figure 16. These sequential, depth-sliced, 3D pseudo-images are from the Robinson family plot. The views are from directly overhead. Distances are in meters.

North Stamford Congregational Church:

An 18 by 8 m grid was established across a small, paved, parking area that is adjacent to the Stone House located along Cascade Road. The purpose of this GPR survey was to identify remnants of buried structures and possible buried feature related to Native Americans.

Figure 17 is a 2D radar record that was collected nearest to Cascade road. The traverse was conducted from north (left) to south (right). The survey was conducted in an area of Canton and Charlton soils. The high amplitude reflections that occur at depths greater than about 150 cm represent contrasting glacial materials or possibly bedrock. Across the top of this radar record, a continuous, slightly wavy, subsurface interface is apparent at depths of generally less than 50 cm. Near the northern end (left) of this traverse, this layer appears to plunge to depths of about 75 cm and an additional high amplitude interface is present nearer the soil surface. Weakly expressed low-amplitude hyperbolas are evident in the upper part of the

radar record. Some may represent buried artifacts, others may represent minor soil inhomogeneities or rock fragments, but without ground-truth verification, their identities are unknown.

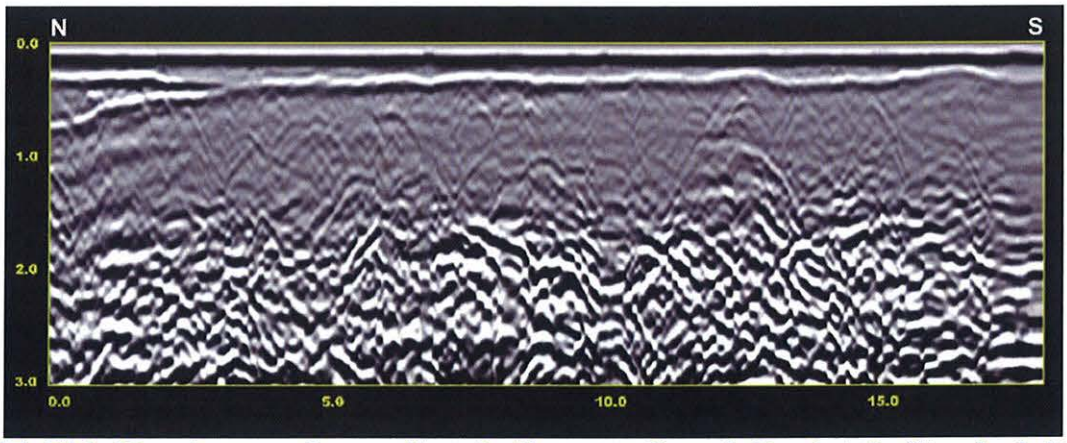

Figure 17. This 2D radar record was collected adjacent to Cascade Road at the Stamford site.

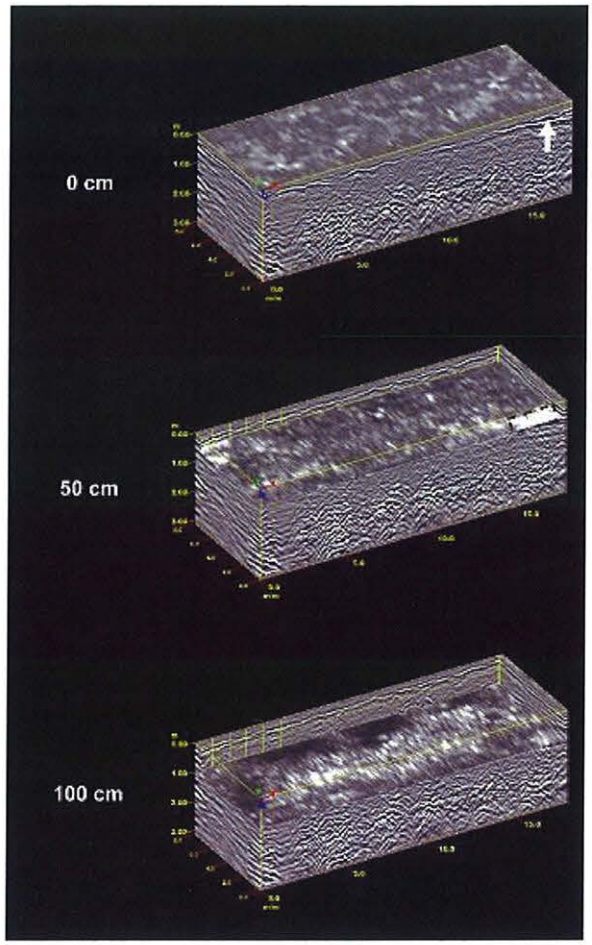

Figure 18. These 3D, time-sliced pseudo-images are from the Stamford site. An arrow in the 0 cm depth-slice identifies the layer enclosed in a cube in the 50 cm depth-sliced image.

Figure 18 contains three, 3D pseudo-images of the grid site. The upper image shows an intact cube. The middle and lower images have the upper 50 and 100 cm of earthen materials removed, respectively. Cascade Road is located immediately in front and parallels the right foreground of each pseudo image. The arrow in the upper image indicated an anomalous layer that has been identified by the rectangle (constructed of black colored segmented lines) in the 50 cm depth-sliced image. This is the same layer shown in the upper left-hand corner of the radar record shown in Figure 17. The rather rectangular geometry of this feature suggests an artificial rather than natural feature.

The GPR survey revealed no major structural feature beneath the parking area at the North Stamford Congregational Church.

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