United States Department of Agriculture	**Natural Resources Conservation Service**	**c/o USDA Forest Service** **11 Campus Boulevard** **Suite 200** **Newtown Square, PA 19073** (610) 557-4233; FAX: (610) 557-4200

SUBJECT: MGT – Trip Report, ARCH-Geophysical Field Assistance August 6, 2009

TO: Douglas Zehner, State Conservationist File Code: 330-7
USDA, NRCS
344 Merrow Road, Suite A
Tolland, CT 06084-3917

Dr. Nicholas F. Bellantoni
Connecticut State Archaeologist
Connecticut Archaeology Center
2019 Hillside Road, U-1023
University of Connecticut
Storrs, CT 06269-1023

Purpose:
At the request of the Connecticut State Archaeologist and local historians, GPR surveys were conducted at historical sites located in Glastonbury, Middletown, Farmington, Windsor, Ridgefield, Weston and Westport, Connecticut.

Principal Participants:
Nicholas Bellantoni, Connecticut State Archaeologist, Connecticut Archaeology Center, Univ. of Connecticut, Storrs, CT
Jim Doolittle, Research Soil Scientist, USDA-NRCS-NSSC, Newtown Square, PA
Donald Parizek, Soil Scientist, USDA-NRCS, Windsor, CT
John Spalding, Archaeologist, FOSA/ABAS, Glastonbury, CT
Debbie Surabian, Soil Scientist, USDA-NRCS, Tolland, CT

Activities:
All activities were completed during the period of 27 to 30 July 2009.

Summary:
1. At most sites, the use of geophysical techniques provided archaeologists with added insight into subsurface conditions and the presence of archaeological features. All results, however, are interpretative and must be confirmed with ground-truth excavations.

2. At the Glastonbury Site, if present, remnants of former structures lack sufficient contrast with the soil materials to be easily detected with either GPR or EMI. However, anomalous features were detected with each geophysical technique and may be deemed worthy of further attention by archaeologists.

3. At the Green Hill Cemetery Site in Middletown, GPR confirmed the presence of an unknown buried structure immediately in front of three tombs whose walls are in need of restoration. This restoration project would involve some excavation in areas containing these buried features. At the “public cemetery” site, GPR revealed features whose presence and geometry suggested potential unmarked graves.

4. At the Native American Cemetery site in Farmington, GPR appears to have detected the in-filled materials of a known grave shaft, which was excavated in 1767. This interpretation, however, must be tempered with the knowledge that the radar traverse was conducted across a known and marked burial and subsurface reflection patterns were, rightfully or wrongly, instinctively associated with the grave.

5. At the Black Cemetery in Windsor, an analysis of both 2D radar records and 3D pseudo-images revealed no subsurface reflector or spatial pattern that could be unequivocally associated with unmarked graves. If present at this site, graves were not clearly detected with the GPR system and procedures used.

6. At the Casagmo Gardens site in Ridgefield, one GPR survey revealed an area that was interpreted to contain the buried remnants of a former residence.

7. At the Weston site, no subsurface extension to a narrow underground passageway was detected.

8. At the West Parish Meeting House site is Westport, neither GPR or EMI provided a clear indication as to the location of the former structure. Spatial GPR and EMI patterns, however, did agree with one another and reveal the most likely area for the structure.

It was my pleasure to work in Connecticut and to be of assistance to you and your staff.

With kind regards,

James Doolittle
Research Soil Scientist
National Soil Survey Center

cc:
M. Golden, Director, Soils Survey Division, USDA-NRCS, Washington, DC
J. Hempel, Director, National Soil Survey Center (NSSC), USDA-NRCS, Lincoln, NE
L. West, National Leader, Soil Survey Research and Laboratory Staff, NSSC, USDA-NRCS, Lincoln, NE
S. Bridges, National Cultural Resources Specialist/ FPO Ecological Sciences Division, USDA-NRCS, PO Box 2890, Washington, DC 20013
K. Kolesinskas, State Soil Scientist, USDA, NRCS, Tolland, CT
D. Hvizdak, State Soil Scientist/MLRA Office Leader, USDA, NRCS, 451 West Street, Amherst, MA 01002-2995
W. Tuttle, Soil Scientist (Geophysical), NSSC, USDA-NRCS, P.O. Box 974, Federal Building, Room G08, 207 West Main Street, Wilkesboro, NC 28697

Equipment:

The radar unit is the TerraSIRch Subsurface Interface Radar (SIR) System-3000 (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 9 lbs (4.1 kg) and is backpack portable. With an antenna, the SIR-3000 requires two people to operate. Daniels (2004) and Jol (2008) discuss the use and operation of GPR. The 200 and 400 MHz antennas were used in the studies reported in this paper.

The RADAN for Windows (version 6.6) software program (GSSI) was used to process the radar records.[1] Basic processing steps, which were applied to all radar records, included: header editing, setting the initial pulse to time zero, color table and transformation selection, display range gain adjustments. All radar records used to prepare the 3D pseudo-images shown in this report were collectively subjected to signal stacking to improve visualizations and interpretations (see Daniels (2004) and Jol (2008) for discussions of this processing technique).

The use of digital signals and sophisticated signal-processing software, have enabled signal enhancement and improved pattern-recognition on radar records in some soils. Processing algorithms 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). In recent years, an advanced type of GPR data manipulation, known as *amplitude slice-map analysis*, has been used in archaeological investigations (Conyers and Goodman, 1997). For this analysis, a 3D pseudo-image of a small grid area is constructed from the computer analysis and synthesis of a series of closely-spaced, two-dimensional radar records. Amplitude differences within the 3D pseudo-image are analyzed in "*time-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 radar records 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 may 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.

The EM38-MK2-2 meter (Geonics Limited, Mississauga, Ontario) was used at the Glastonbury and Westport sites.[1] This meter requires no ground contact and only one person to operate. The EM38-MK2-2 meter weighs about 2.8 kg (6.2 lbs) and operates at a frequency of 14,500 Hz. The meter has one transmitter coil and two receiver coils. The receiver coils are separated from the transmitter coil at distances of either 1.0 or 0.5 m. This configuration provides nominal penetration depths of 1.5 and 0.75 m (for the 1.0 and 0.5 m coil spacings, respectively) in the vertical dipole orientation, and 0.75 and 0.38 m in the horizontal dipole orientation. The EM38-MK2-2 meter can provide simultaneous measurements of both quadrature-phase (conductivity) and in-phase (susceptibility) components within two depth ranges. Operating procedures for the EM38-MK2-2 meter are described by Geonics Limited (2008).

The coordinates of each EC_a measurement were recorded with a Trimble AgGPS 114 L-band DGPS (differential GPS) antenna (Trimble, Sunnyvale, CA).[1] An Allegro CX field computer (Juniper Systems, North Logan, UT) was used to record and store both EMI and position data.[1] The TrackmakerEM38MK2 software program (Geomar Software Inc., Mississauga, Ontario) was used to record, store, and process EMI and GPS data.[1]

To help summarize the results of the EMI surveys, the SURFER for Windows (version 8.0) software (Golden Software, Inc., Golden, CO) was used to construct the two-dimensional simulations shown in this report.[1] Grids were created using kriging methods with an octant search.

Survey Procedures:

In order to calibrate the GPR and assess site conditions, random GPR traverses were conducted across each site. To collect the data required for the construction of 3D GPR pseudo-images, small survey grids were established across selected areas of most sites. The sizes and dimensions of the grids varied and are listed in Table 2. For each grid, two parallel lines were established across the selected sites. Along each of these parallel lines, survey flags were

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

inserted into the ground at a spacing of 50 cm. A reference line was extended between matching survey flags on opposing sides of the grid using a distance-graduated rope. GPR traverses were conducted along the distance-graduated rope. For each grid, the 400 MHz antenna was towed along the graduated rope, and as it passed each 100-cm graduations, a mark was impressed on the radar record. Following data collection, the reference line was sequentially moved to the next pair of survey flags to repeat the process.

For the EMI surveys, the EM38-MK2-2 meter was operated in the deeper-sensing vertical dipole orientation (VDO). Apparent conductivity data were recorded for both the 50 and 100 cm intercoil spacings. The EM38-MK2-2 meter was operated in the continuous (measurements recorded at a rate of 1/sec) mode. Using the TrackmakerEM38MK2 program, both GPS and EC_a data were simultaneously recorded in the Allegro CX field computer. While surveying, the EM38-MK2-2 meter was held about 5 cm (about 2 inch) above the ground surface and orientated with its long axes parallel to the direction of traverse. Surveys were completed by walking in a random pattern across accessible areas at each site. The EC_a data discussed in this report were not temperature corrected.

Table 2. Basic features of the GPR Grid Sites

Site	Grid Dimensions	Line Spacing	Number of Lines	Antenna	E_r	V (m/S)
Glastonbury	20 x 13 m	50 cm	27	400 MHz	16.2	0.074
Indian Hill Cemetery-Crypt 1	17 x 5.5 m	50 cm	12	400 MHz	16.2	0.074
Indian Hill Cemetery-Crypt 2	12 x 6.5	50 cm	14	400 MHz	16.2	0.074
Indian Hill Cemetery-Public Cemetery	10 x 6m	50 cm	13	400 MHz	6.0	0.122
Farmington-Native American Site	5 x 5 m	50 cm	11	400 MHz	6.0	0.122
Windsor-Palisado Cemetery	20 x 4.5 m	50 cm	10	400 MHz	12.0	0.086
Ridgefield-Casagmo Garden #1	12 x 9 m	50 cm	19	400 MHz	6.0	0.122
Ridgefield-Casagmo Garden #2	14 x 13 m	50 cm	27	400 MHz	6.0	0.122
Wesport Meeting House	32 x 20 m	50 cm	43	400 MHz	6.9	0.113

Ground-penetrating radar:
Ground-penetrating radar is an impulse radar system designed for shallow, subsurface investigations. This system operates by transmitting short pulses of electromagnetic energy into the ground from an antenna. Each pulse consists of a spectrum of frequencies distributed around the center frequency of the transmitting antenna. Whenever a pulse contacts an interface separating layers of differing dielectric permittivity (E_r), a portion of the energy is reflected back to the receiving antenna. The receiving unit amplifies and samples the reflected energy, and converts it into a similarly shaped waveform in a lower frequency range. The processed reflected waveforms are displayed on a video screen and can be stored on a hard disk for future playback, processing, and/or display.

Ground-penetrating radar is a time scaled system. This system measures the time that it takes electromagnetic energy to travel from the antenna to an interface (e.g., bedrock, soil horizon, buried archaeological feature) and back. To convert the travel time into a depth scale, 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 the following equation (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 the equation (Daniels, 2004):

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

Where C is the velocity of propagation in a vacuum (0.298 m/ns). Velocity is typically 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 estimated v and E_r at each site are listed in Table 2. These are ball park estimates which are based on either the depth to a shallowly (50 cm) buried, known reflector or hyperbola matching techniques.

Soils:
The well drained and/or somewhat excessively drained, shallow Hollis, moderately deep Chatfield, and very deep Charlton and Montauk soils formed in till. The very deep, moderately well drained Sutton soils also formed in till. The moderately well drained Ludlow and the well drained Paxton soils formed in loamy lodgment till. They are very deep to bedrock and moderately deep to a densic contact. The very deep, moderately well drained Ninigret and Tisbury soils have, respectively, loamy and silty mantles over sandy and gravelly outwash. The very deep, well drained Haven soils formed in loamy over sandy and gravelly outwash. The very deep well drained Hadley soils formed in silty alluvium. In the upper 1 meter of the soil profile, Hadley averages only 7 % clay. Because of their low clay and soluble salt contents, these soils provide deep penetration and are considered well suited to GPR. However, variations in soil moisture content, and the presence of scattering bodies and contrasting, unpredicted layers will affect penetration depths (http://soils.usda.gov/survey/geography/maps/GPR/index.html). The taxonomic classifications of the aforementioned soils are listed in Table 1.

Table 1. Taxonomic Classification of Soils

Soil Series	Taxonomic Classification
Chatfield	Coarse-loamy, mixed, superactive, mesic Typic Dystrudepts
Charlton	Coarse-loamy, mixed, active, mesic Typic Dystrudepts
Hadley	Coarse-silty, mixed, superactive, nonacid, mesic Typic Udifluvents
Haven	Coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Typic Dystrudepts
Hollis	Loamy, mixed, active, mesic Lithic Dystrudepts
Ludlow	Coarse-loamy, mixed, semiactive, mesic Aquic Dystrudepts
Montauk	Coarse-loamy, mixed, subactive, mesic Oxyaquic Dystrudepts
Ninigret	Coarse-loamy over sandy or sandy-skeletal, mixed, active, mesic Aquic Dystrudepts
Paxton	Coarse-loamy, mixed, active, mesic Oxyaquic Dystrudepts
Sutton	Coarse-loamy, mixed, active, mesic Aquic Dystrudepts
Tisbury	Coarse-silty over sandy or sandy-skeletal, mixed, active, mesic Aquic Dystrudepts

Results:
Ferry Crossing in Glastonbury,
The site (long. 72.62228 W and lat. 41.66692 N) is located near the Connecticut River just west of South Glastonbury. Historical records indicate that early town houses (early 1600s) were built in this area. The property owner had located a "well" in a field and thought that it might indicate the presence of a former structure. Ground-penetrating radar and electromagnetic induction surveys were completed in an attempt to locate buried foundation remnants of former structures. The site is located in a hay land and in an area of Hadley silt loam (105)[2].

[2] Numbers following a soil map unit name is the map unit symbol.

Figure 1. The Glastonbury site was located in a hay land. The cone in the right foreground identifies the site of a former well (Photograph courtesy of John Spaulding).

The results of the EMI survey are shown in Figure 2. Hadley soils have low clay contents, are electrically resistive, and displayed low EC_a. Within the survey area, EC_a was low and largely invariable across most of the site. Apparent conductivity averaged only 9.2 mS/m, with one-half the observations between 8.9 and 9.9 mS/m. However, across this site, EC_a ranged from about -85.3 to 26.7 mS/m. The large range and negative EC_a (see A, B, and C in Figure 2) values suggest the presence of metallic artifacts buried or scattered across the site. The anomalous EMI response at "A" (see Figure 2) was investigated. A shallow excavation near "A" revealed a buried concentration of nails, hinges, and charcoal. The landowner indicated that piles of debris had been, in the past, burned in this and adjoining fields. The EMI survey did reveal the presence of some metallic artifacts, but provided no indication of the location of historical structures within the site. It is inferred that remnant materials from any former structures, if present, are minor in size and extent, and displayed similar conductivity with the soils. If present, these remnants lack sufficient contrast with the soil materials to be easily detected with EMI.

A 20 by 13 m grid was established across a portion of the Glastonbury site, which was suspected to contain remnants of a former barn. Base on oral history, a well was located near a corner of this barn. The well was located (see cone in Figure 1) just outside the grid area. Using the 400 MHz antenna, 27 parallel radar traverses were conducted across the grid area in essentially a southeast-northwest direction. Each traverse line was 20-m long. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of the grid site.

Three horizontal time-sliced images of the grid site (for location, see Figure 2) are shown in Figure 3. These horizontal time- or depth-sliced images were extracted from the 3D pseudo image of the grid site at depths of 50, 100 and 150 cm. In the 50-cm depth slice, while high-amplitude (colored white or black) reflections are scattered across the northern ¾ of the grid site (In Figure 3, lower portion of the depth-sliced image). No identifiable spatial patterns can be seen on this depth-slice that would suggest the locations of former structures or contrasting layers of occupational history. In the 100- and 150-cm slices, two conspicuous, anomalous areas (*A & B*) have been identified. These anomalous areas are rather large and persist vertically through the remaining depth column of the 3D pseudo image. Because of their size, prominence and persistence with depth, these subsurface features may be deemed worthy of further attention by archaeologists.

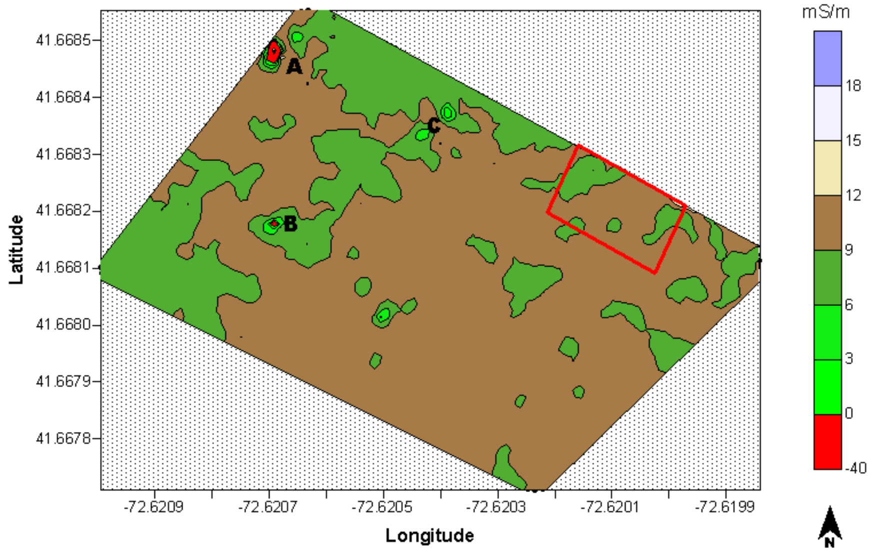

Figure 2. Spatial distribution of EC_a collected with the EM38-MK2-2 meter operated in the vertical dipole orientation (VDO) at the Glastonbury site. The approximate location of the GPR Grid is outlined in red; the locations of "cultural" anomalies are identified by letters.

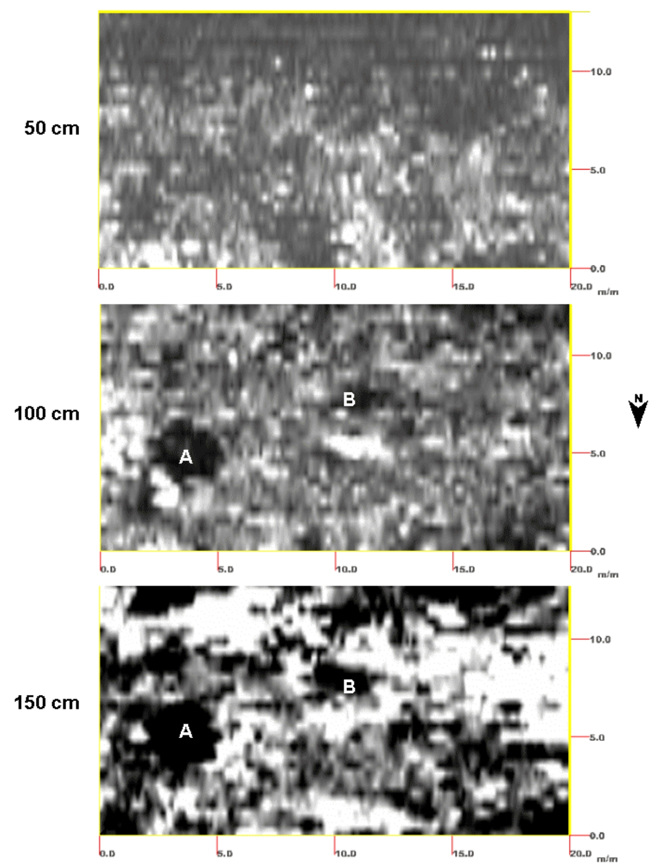

Figure 3. Three, time- or depth-sliced images of the Glastonbury GPR Grid Site with horizontal slices graphically removed at depths of 0, 100, and 150 cm. Views are from directly overhead of the grid area looking down. Depth persistent spatial patterns are indicated by the letters "A" and "B".

Middletown
Indian Hill Cemetery is located on a grassy knoll in Middletown, between Vine, Wallingford and Butternut Streets. Restoration of the side walls of three, large family crypts has been proposed, but design architects anticipate the need for excavating the area immediately in front of the crypts (see Figure 4) in order to install subsurface drains. A large (about 2 by 2 m) tablet occupies the center of this proposed area (see Figure 4). Ground-penetrating radar was used to help verify that no unmarked graves or subsurface archaeological features were present in the area immediately in front of the tombs. The site (long. 72.6634 W and lat. 41.5558 N) is located in an area of Paxton and Montauk fine sandy loams, 8 to 15 percent slopes (84C).

Because of the large tablet in the front of the crypts, the survey site (see Figure 4) was divided into two separate grid areas. Grids were 17 by 5.5 m (*A*, near road) and 12 by 6.5 m (*B*, near crypts) in size. Using the 400 MHz antenna, 12 and 14 parallel radar traverses were conducted across grid areas *A* and *B*, respectively, in essentially a north-south direction. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of each grid site.

Figure 5 contains four time-sliced images, two for each grid area (*A*, upper plots; *B*, lower plots). Also shown in Figure 5 is the general location of the large tablet (large, dark-colored square), which separates the two grid areas. In Figure 5, the crypts are located to the immediate east (just below) of the lower plots. The two sets of horizontal depth-sliced images were extracted from the 3D pseudo images of the two grid areas at depths of 75 and 100 cm. All depth-sliced images have central portions, which are bisected in an east-west direction by a high-amplitude, linear reflector. Probings revealed a firm (concrete or stone) interface at a depth of about 70 cm. This linear, artificial feature splits in the lower depth sliced images into a herringbone pattern. A similar, but less well-expressed pattern can be visualized in the upper plot as well. However, the pattern in the upper plot is more ambiguous (does this suggest greater damage or weathering?) and conjectural. Radar surveys revealed the presence of an unknown, buried structural feature, which definitely will need to be considered if the side walls to these tombs are restored.

Figure 4. The "Crypt" study site at the Indian Hill Cemetery, Middletown, Connecticut. (Photograph courtesy of John Spaulding).

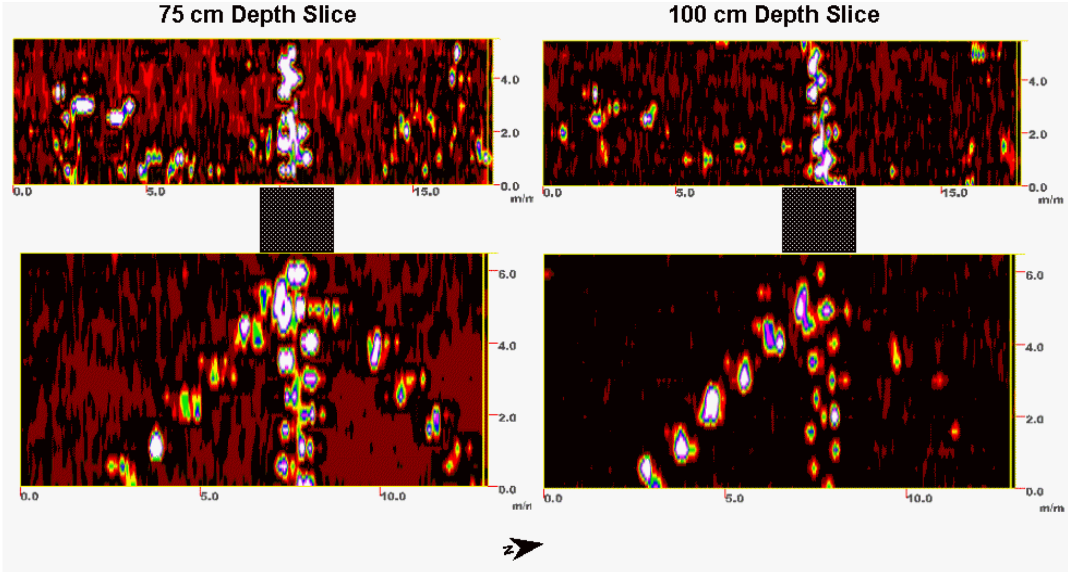

Figure 5. Two, time or depth slice images of the two Crypt Grid Sites with horizontal slices graphically removed at depths of 75 and 100 cm. Views are from directly overhead of the grid area looking down. Rectangular block in center of each depth-slice set represents the tablet shown in Figure 4. Crypts are located along the bottom of this plot.

In the southwestern portion of the Indian Hill Cemetery, in a section known as the "Public Cemetery" (next to the *Grand Army of the Republic* lot), a relatively open area has several marked graves, but other, unmarked graves could be present. Cemetery officials wish to confirm whether this open area contains unmarked graves. If not, this open area can be used for additional burials. The site (long. 72.6636 W and lat. 41.5540 N) is located in an area of Ludlow silt loam, 2 to 15 percent slopes, extremely stony (42C).

Figure 6. The "Public Cemetery" study site at the Indian Hill Cemetery, Middletown, Connecticut. (Photograph courtesy of John Spaulding).

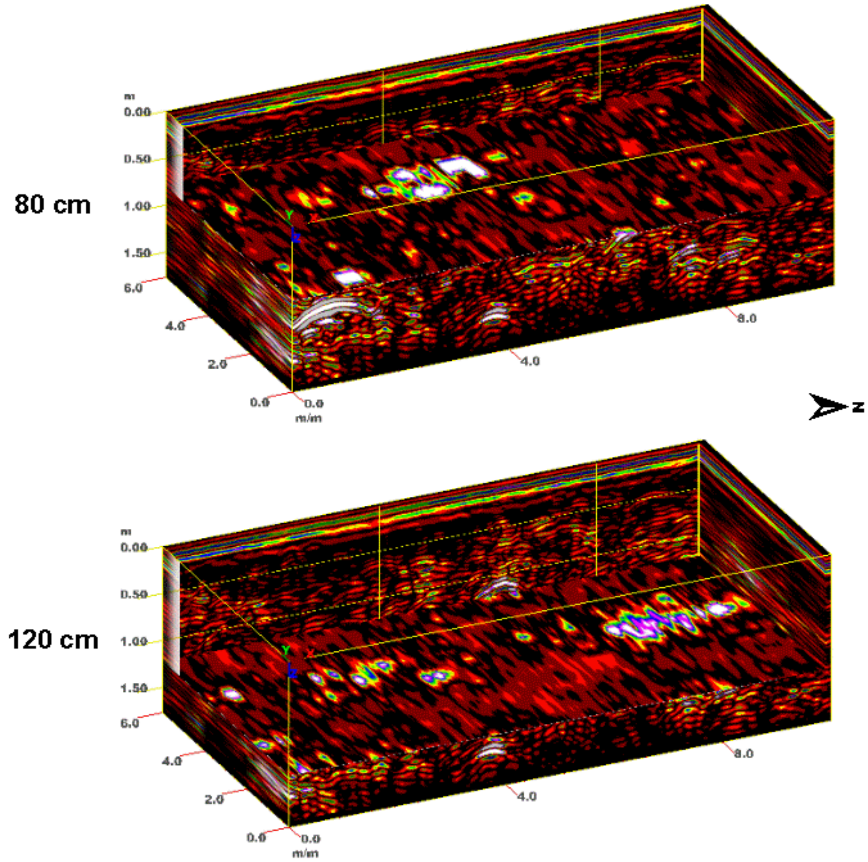

Figure 7. Two 3D Pseudo-images of the Public Cemetery Site in the Indian Hill Cemetery, with inset cubes graphically removed at depths of 80 and 120 cm. The north-south trending spatial patterns in the central portion of this grid area suggest possible unmarked graves.

A 10 by 6 m grid was established across the Public Cemetery site. Using the 400 MHz antenna, 13 parallel radar traverses were conducted across the grid area in essentially a north-south direction. Each traverse line was 10-m long. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of the grid site.

Figure 7 contains 2, 3D pseudo-images of the surveyed portion of the *Public Cemetery*. In each pseudo images a 9.9 by 5.9 inset cube has been graphically removed to depths of 80 (upper image) or 120 (lower image) cm. In each of these pseudo-images a distinct pattern of high-amplitude reflections stretches across the entire length (X=10 m) of the surveyed area near the Y = 4 m line. Features along this line are unclear and highly segmented, but most features appear to have longer linear extents in an east-west orientation. While the identities of these features are unknown, their presence and geometry do suggest potential unmarked grave sites.

<u>Farmington:</u>
The site (long. 72.8620 W and lat. 41.7221 N) is located in Farmington, Connecticut. The site is located on public lands and contains the graves of Native Americans. The cemetery dates back to the early 1700s and contains several headstones (see Figure 8), but a greater number of unmarked burials are suspected at this site. The site is located in an area of Hinckley gravelly sandy loam, 15 to 45 percent slopes (38E). The wooded nature of this site limited the execution and scope of the GPR survey. Several random GPR traverses were conducted across the site. Based on the location of a known burial (circa 1767), a small, 5 by 5 m grid was constructed. Using the 400 MHz antenna, 11 parallel radar traverses were conducted across grid area in essentially a north-south direction. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of the grid site.

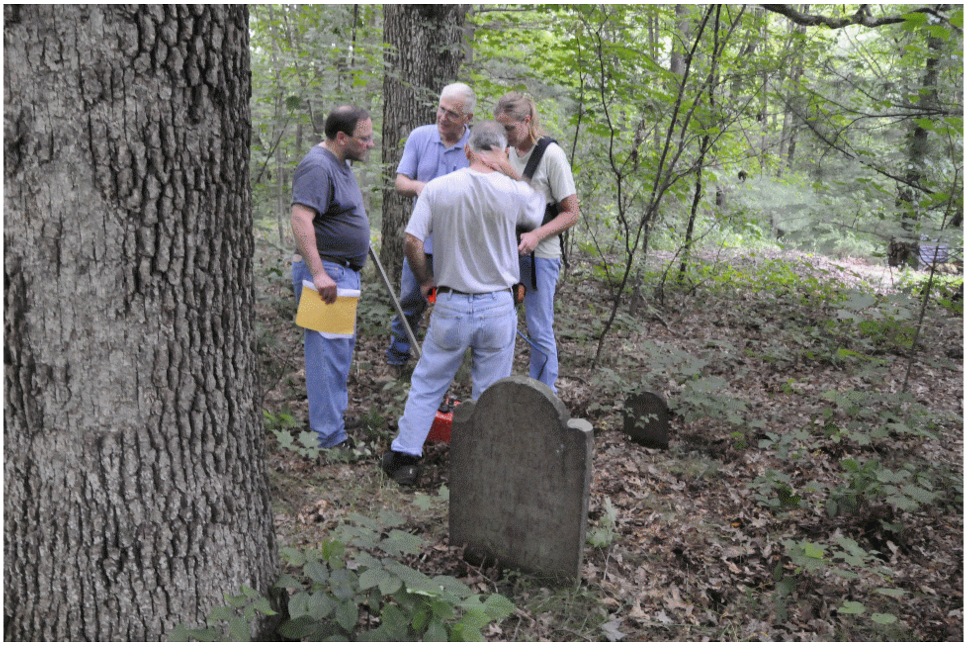

Figure 8. Dense vegetation at the Native American Cemetery Site in Farmington limited the use of GPR.

Figure 9 is a 2D radar record that was collected orthogonal to the long axis of a known (marked) grave site. In Figure 9, the horizontal and depth scales are in meters. The approximate location of the grave has been enclosed in a rectangle. Hinckley soils are composed on stratified deposits of sands and gravels. These stratifications are manifested in planar reflections of different amplitudes on radar records. What is most significant and impressive on this radar record is that the mixed materials used to refill the excavated grave cavity are seemingly apparent in the upper 60 cm of this radar record. If this interpretation is correct, natural soil-forming processes have not erased disturbance signatures dating back to 1767. This interpretation, however, must be tempered with the knowledge that the radar traverse was conducted across a known and marked burial and subsurface reflection patterns were, rightfully or wrongly, instinctively associated with the grave.

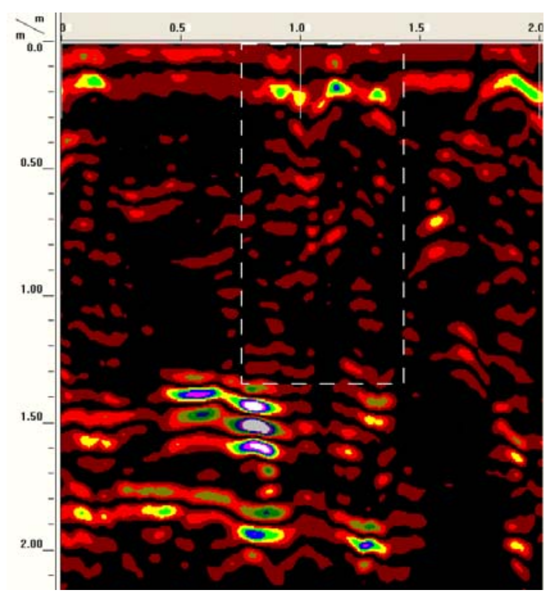

Figure 9. This 2D radar record was collected at the Farmington Site. The rectangle marks the approximate location of a known burial.

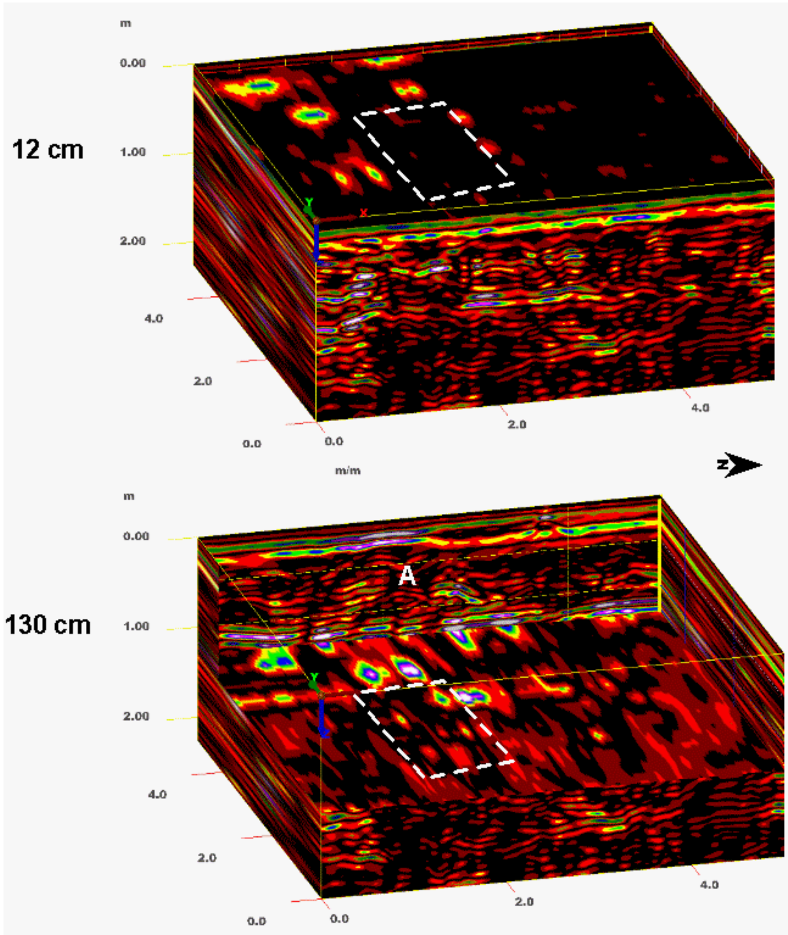

Figure 10. Two 3D Pseudo-images of a known grave within the Farmington Site, with inset cubes graphically removed at depths of 12 and 130 cm

Figure 10 contains 2, 3D pseudo-images from a small grid area established at the Farmington Site. This survey area included a known (marked) gravesite. In each pseudo image, a 4.9 by 4.9 inset cube has been graphically removed to depths of 12 (upper image) or 130 (lower image) cm. A rectangle formed by white-colored dashed lines marks the approximate location of the grave. In the 3D pseudo image with the base of the inset cube at a depth of 12 cm (upper image), the grave site is enclosed by high-amplitude reflections and the in-filled grave shaft is seemingly clear of reflections. In the 3D pseudo image with the base of the inset cube at a depth of 130 cm (lower image), high-amplitude reflections mark the approximate location of the headstone (top (west) of rectangle). The grave shaft is characterized by low-amplitude (black and red colored) reflections with sporadic higher-amplitude point reflections. Without knowledge of the gravesite, these patterns may have been dismissed or overlooked.

<u>Windsor - Palisado Cemetery:</u>
The site (long. 72.63919 W and lat. 41.85936 N) is located in Palisado Cemetery, which is off of Palisado Avenue in Windsor, Connecticut. The site is known to contain the headstones of several Black Americans, but a greater number of unmarked burials are suspected at this site. The site is located in an area of Merrimac sandy loam, 0 to 3 percent slopes (34A), however the soil examined near the site was classified as Haven. The thickness of the loamy solum and the depth to sandy and gravelly outwash ranges from about 45 to 90 cm. This contact provides a high-amplitude reflector that was easily identified and traced laterally on radar records.

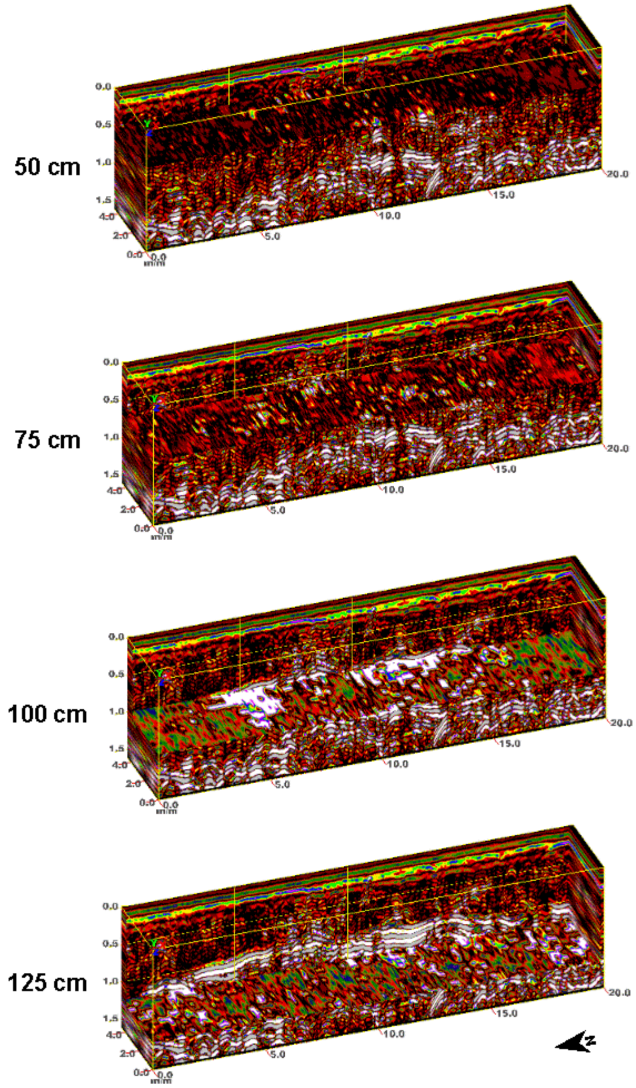

Figure 10. Four 3D Pseudo-images of a the Palisado Cemetery Site in Windsor, with inset cubes graphically removed at depths of 50, 75, 100 and 125 cm

Based on the location of marked graves, a small, 20 by 4.5 m grid was constructed in an open area of the cemetery. Using the 400 MHz antenna, 10 parallel radar traverses were conducted across the grid area in essentially a north-south direction. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of the grid site.

Figure 10 contains four 3D pseudo-images of the Palisado Cemetery Site. In the pseudo images, a 19.9 by 4.4 m inset cube has been graphically removed to depths of 50, 75, 100 and 125 cm. Along the side walls of the 3D cube, the contact of the loamy surficial deposits with the underlying sands and gravels is identified by high-amplitude (white colored) planar reflections. The solum lacks high-amplitude planar reflectors, but contains low- to moderate-amplitude point reflectors. The identities of these reflectors are unknown, some may represent graves others larger rock fragments or soil discontinuities. In the 75 cm cutout cube, several high-amplitude, linear reflectors are identifiable, but could not be tracked with slight (20 cm) increases in soil depth. For the inset cubes that have their base at 100 and 125 cm, the underlying coarser textured outwash deposits have been penetrated. While seemingly more continuous in the sidewalls of the cubes, these strata appear not extensive in 3D. An analysis of both 2D radar records and 3D pseudo-images revealed no reflector or spatial pattern that can be unequivocally associated with unmarked grave sites. If present, graves were not detected with the GPR system and procedures used.

<u>Ridgefield</u> - Casagmo Gardens

The site (long. 73.4987 W and lat. 41.28708 N) is located on the lawns of Casagmo Gardens off of Olcott Way in Ridgefield, Connecticut. The site is located in an area of Paxton-Urban land complex, 3 to 8 percent slopes (284B). Dr. Bellantoni, members of the Ridgefield Historical District Committee, the Town Historian, and a local landscape architect had earlier assessed the remains of the gardens. As many of the garden walls were exposed after the rather dense vegetation was cleared and removed from the site, the use of GPR to locate these walls was deemed unnecessary. Two GPR grid surveys were conducted in an attempt to locate buried structural remnants, which could be associated with a former residence.

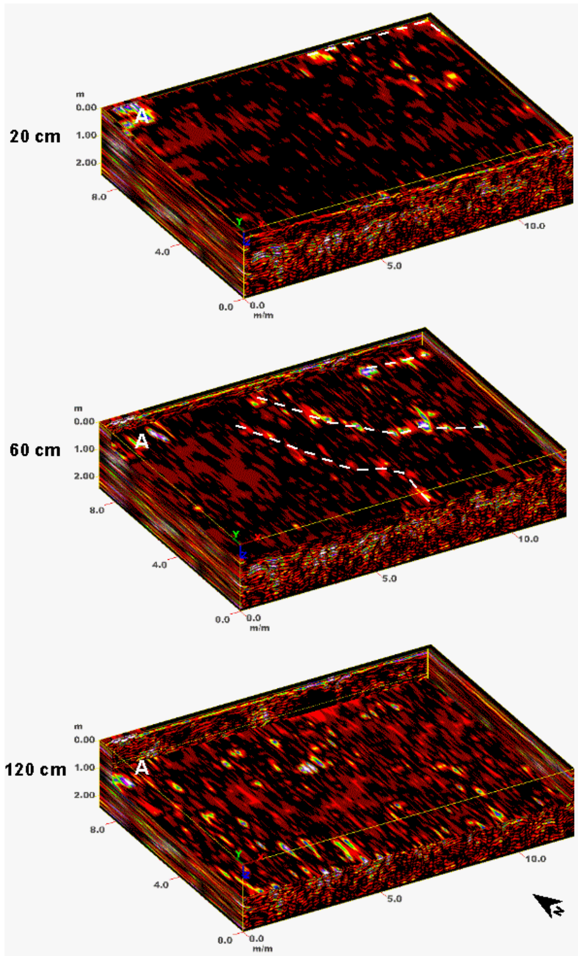

Figure 11. Three 3D Pseudo-images of Grid A in the Casagmo Gardens Site (Ridgefield), with inset cubes graphically removed at depths of 20, 60 and 120 cm.

Two separate grid areas were established across the lawns to the south of the gardens. The dimensions of the grids were 12 by 9 m (*A*, nearest the gardens) and 14 by 13 m (*B*, to the south, partially crossing Olcott Way) in size. Using the 400 MHz antenna, 19 and 27 parallel radar traverses were conducted across grid areas *A* and *B*, respectively, in essentially a north-south direction. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of each grid site.

Grid A extended northward from a line, which connects the southeast corner of a square, concrete well cover and the northwest corner of a park bench. Figure 11 contains three 3D pseudo-images of this grid site. In the pseudo images, an 11.9 by 8.9 inset cube has been graphically removed to depths of 20, 60 and 120 cm. The concrete well cover is located adjacent to the southwest (upper-left; see "A") corner of the grid. Reflections in this corner of the pseudo-images are attributable to this feature. In the pseudo images with bases at depths of 20 and 60 cm, white-colored segmented lines have been used to connect seemingly linear patterns of high-amplitude reflections. These patterns, however, are restricted in depth and form no coherent geometric pattern, which would suggest remnants of a former structure. The pseudo-image with its base at a depth of 120 provides widely dispersed and chaotic patterns of high-amplitude reflections. This pattern can be associated with the underlying till fabric.

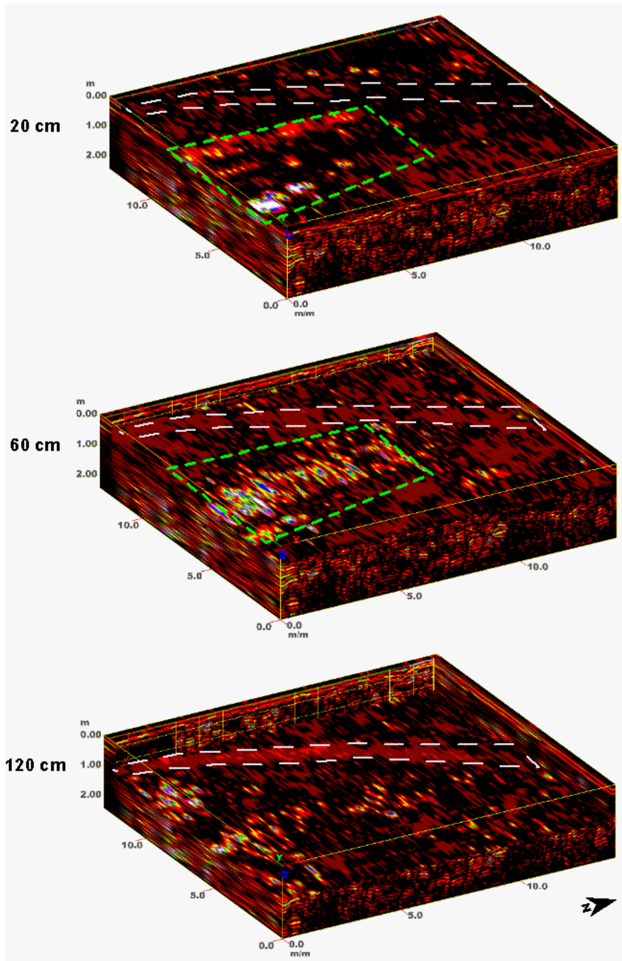

Figure 12. Three 3D Pseudo-images of Grid B in the Casagmo Gardens Site (Ridgefield), with inset cubes graphically removed at depths of 20, 60 and 120 cm.

Grid B extended across an open area to the south of Grid A. The northern most base line of this grid extended eastward from 2 m off of the southeast corner of the northernmost of two stone pillars. Figure 12 contains three 3D pseudo-images of this grid site. In the pseudo images, a 13.9 by 12.9 inset cube has been graphically removed to depths of 20, 60 and 120 cm. In each pseudo image, segmented white lines have been drawn to approximate the general location of Olcott Way. A relatively large area of high-amplitude, linear spatial patterns, which can be traced vertically with increasing soil depth, has been enclosed by green-colored segmented lines. Though not outlined on the pseudo-image with the inset cube removed to a depth of 120 cm, spatial patterns are present that support some continuation of the feature(s) outlined in the other pseudo-images. This area is likely to contain remnants of a former structure.

<u>Weston Ice House Site</u>:
An old, abandoned ice house in Weston, Connecticut, has a peculiar, walled passageway at one end. This narrow passageway is underground, leads nowhere, and has no obvious function. The landowner wishes to know if this passageway has been sealed and actually continues underground, possibly to a nearby residence. During the 1800s, the *Underground Railroad* was known to be active in this area and, as a consequence, the purpose of this peculiar structure is questioned. The Site 1 (long. 73.3781 W and lat. 41.24886 N) is located in a residential area off of

Ladder Hill Road. The site is located within a delineation of Hollis-Chatfield-Rock outcrop complex, 15 to 45 percent slopes (75E).

Radom radar traverse were conducted across this site, and into the nearby yards of neighbors. The ice house site is covered with rather dense vegetation, which limited the scope of the radar survey. A 200 MHz antenna was used in this investigation.

Figure 13 contains a portion of a radar record, which traversed the buried passageway. The approximate position of the subterranean passageway has been approximated by a rectangle, which is formed by segmented white-colored lines. The sidewalls of the passageway are evident in this record. The GPR investigation revealed no further extension of the passageway than that which is evident below ground. A tunnel, which extends from the ice house into nearby residences, was not detected with GPR.

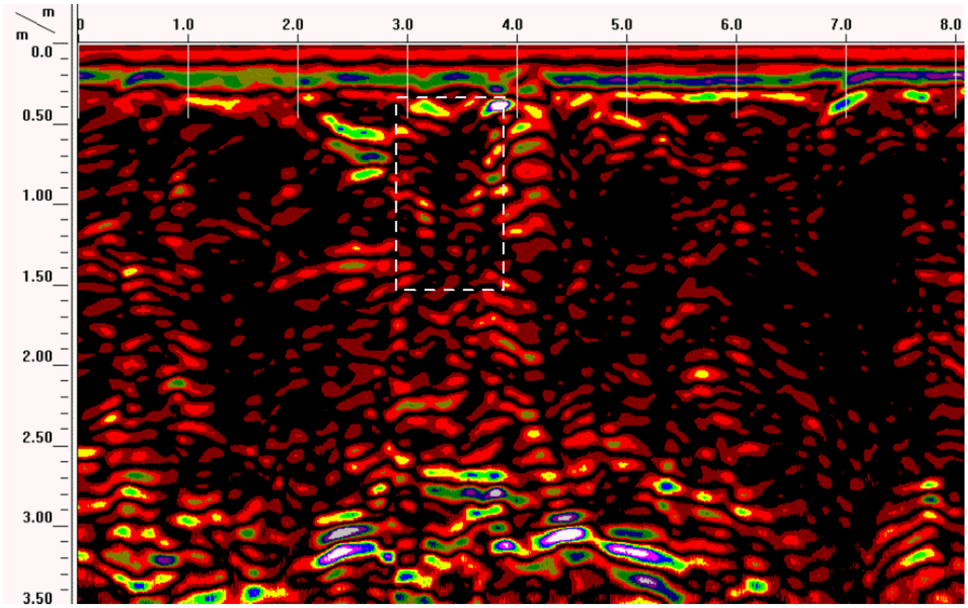

Figure 13. This 2D radar record was collected at the Weston Site. The rectangle marks the approximate location of a known subterranean passageway.

Westport Parrish Meeting House:

The purpose of this survey was to try to identify the exact location of the West Parish Meeting House, which was the original seat of Westport's town government and also served as the Green's Farms Congregational Church. The meeting house/church and its surrounding structures were burned to the ground by advancing British soldiers on July 8, 1779. The site (long. 73.3308 W and lat. 41.12736 N) is located on the town-owned Green's Farms (West Parish) Colonial Church Historic Property off of Greens Farms Road in Westport, Connecticut. The site is largely located within a delineation of Sutton fine sandy loam on 3 to 6 % slopes (50B). The eastern portion of the site is in an area of Urban-land Charlton-Chatfield complex, rocky, on 3 to 15 % slopes. The site slopes northward into a lower-lying area of Ninigret and Tinsbury soils on 0 to 5 % slopes.

In order for a larger portion of the site to be surveyed, a reconnaissance EMI survey was conducted. The results of the EMI survey are shown in Figure 14. Charlton, Chatfield, Sutton, Ninigret and Tinsbury soils have low clay contents, are electrically resistive, and displayed low EC_a. Variations in EC_a across the site are associated with changes in soil moisture contents. As soil moisture contents increase so does EC_a. The general spatial trend is for EC_a to increase northward across the study site as slopes descend into a wetter area of Ninigret and Tinsbury soils (see Figure 14). Within the survey area, EC_a averaged only 4.0 mS/m, with one-half the observations between 2.9 and 5.1 mS/m. However, across this site, EC_a ranged from about -48.7 to 10.8 mS/m. The large range and negative EC_a values suggest the presence of metallic artifacts buried or scattered across the site.

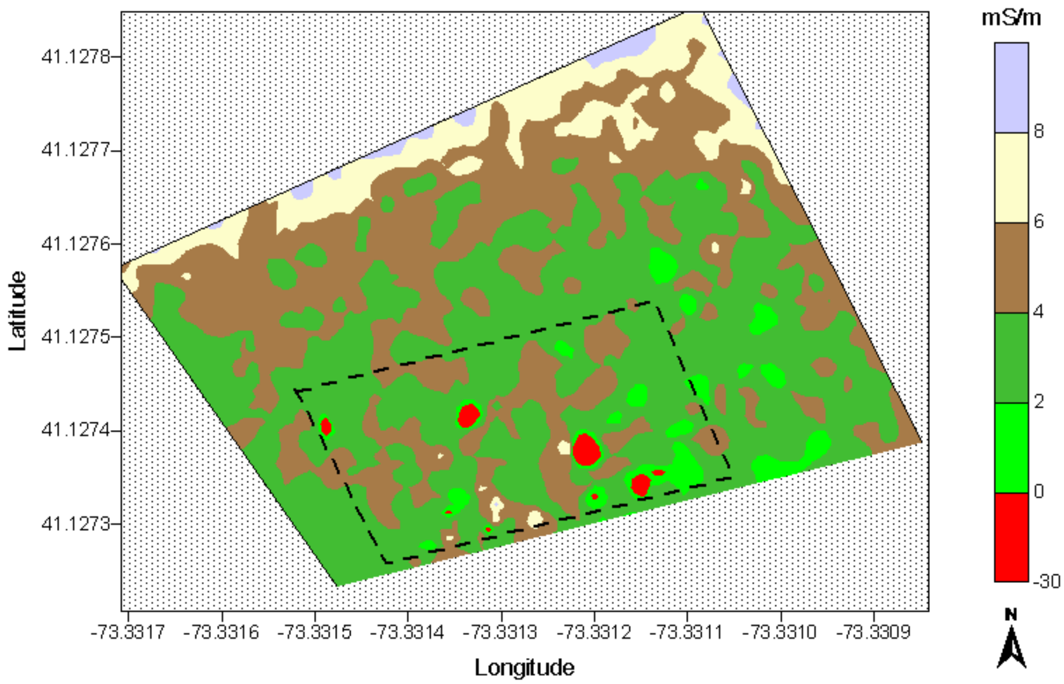

Figure 14. Spatial distribution of EC_a collected with the EM38-MK2-2 meter operated in the vertical dipole orientation (VDO) at the Westport site. The approximate location of the GPR Grid is outlined in black. All negative and anomalous EMI responses are confined within the GPR grid.

In Figure 14, the location of the GPR grid site is shown as a rectangle formed by segmented black-colored lines. As evident in Figure 14, all of the anomalous EC_a measurements are confined within the GPR grid. Negative EC_a values are attributed to metallic artifacts. The map of spatial EC_a patterns suggests that the most likely site of the Meeting House is within the central portion of the GPR grid.

A 32 by 20 m grid was established across a portion of the Westport site (see Figure 14 for approximate location), which was suspected to contain remnants of the former meeting house. Using the 400 MHz antenna, 43 parallel radar traverses were conducted across the grid area in essentially an east-west direction. Each traverse line was 32-m long. The distance between each traverse line was 50 cm. The traverse lines were used to construct a 3D pseudo-image of the grid site.

Three horizontal time- or depth-sliced images of the 32 by 20 m grid site are shown in Figure 15. Though subtle, an area with low signal amplitudes has been identified by a rectangle formed by segmented, black-colored lines is shown in each image. A rather subdues color palette was needed to reveal this pattern. Along the northern border to this rectangular area, unwanted interference and signal noise created the dark linear pattern between the 12 and 16 m distance marks.

The significance of this rectangular area, if any, is unknown, but the geometry of this area suggests a large rectangular feature. This rectangular area closely corresponds with an area suspected to have cultural anomalies based on the EMI survey (see Figure 14). Based on rather faint GPR reflection patterns, which are supported by the results of the EMI survey, the outlined area suggests a location that is promising for the former meeting house.

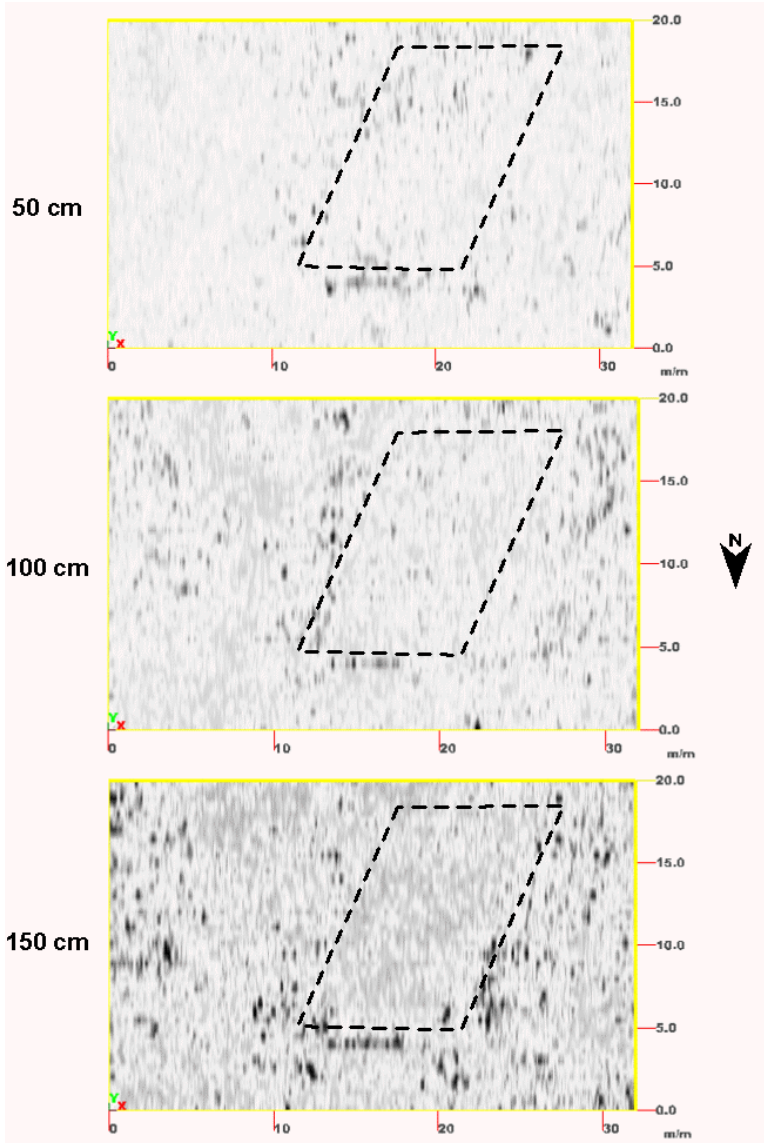

Figure 15 Three, time or depth slice images of the Westport Site with horizontal slices graphically removed at depths of 50, 100 and 150 cm. Views are from directly overhead of the grid area looking down. The rectangular block in each slice identifies an area with a low concentration of high-amplitude reflections (colored black).

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