United States Department of Agriculture	**Natural Conservation Service**	**100 Campus Boulevard Suite 200 Newtown Square, PA 19087-4585**

Subject: Archaeology -- Geophysical Assistance **Date:** 22 August 2003

To: Gus Hughbanks
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USDA - NRCS
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Purpose:
Geophysical field assistance was provided to support cultural resource investigations in Washington.

Participants:
Martha Chaney, Archaeologist, USDA-NRCS, Olympia, WA
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Jim Doolittle, Research Soil Scientist, USDA-NRCS, Newtown Square, PA
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Chuck Natsuhara, Resource Soil Scientist (Western Washington), USDA-NRCS, Puyallup, WA
Tom Riebe, Student Trainee Soil Science, USDA-NRCS, Mount Vernon, WA
Rosemary Regan, Secretary, Mondovi Cemetery, Regan, WA

Activities:
All field activities were completed on 21 to 24 July 2003.

Findings:

1. Interpretations contained in this report are considered preliminary estimates of site conditions. These interpretations do not substitute for direct observations, but rather reduce their number, direct their placement, and supplement their interpretations. Interpretations should be verified by ground-truth observations.

2. The GPR survey of the Pleasant Hill Cemetery resulted in the identification of 10 unmarked gravesites. The GPR confirmed the presence of several burials marked with headstones. However, at several gravesites with headstones, GPR detected no subsurface features. It was assumed that these corpses had been buried in more easily weathered materials. Alternative interpretations are that the corpses were never buried or that only their ashes were interred or dispersed across these marked gravesites. In general, the GPR survey failed to disclose the locations of children's graves. These were apparently too small and/or the corpses were enclosed in more readily weathered materials that were not directly detectable with GPR. In addition the location of the unmarked grave of Richard A. Hutchinson (1853 to 1921) was discovered. Richard Hutchinson deeded the land to the cemetery and was a former Washington State Senator. In general, the GPR survey was favorably received and provided the cemetery's trustees with valuable information.

3. Based on the results of the GPR survey at Pleasant Hill Cemetery, the trustees plan to contact the families of several unmarked gravesites to let them know what we found and offer them the opportunity to erect stones for their family members.

4. EMI and GPR surveys revealed no indications of a former log cabin located near Mud Bay on the lower Elbe Inlet west of Olympia, Washington. It is possible that the structure, if located in the surveyed areas, was either completely removed or left no remnants that were detectable with these geophysical tools. It is also possible, that the relatively coarse EMI and the "wildcat" GPR surveys did not pass directly over measurable structural remnants and remnants were overlooked.

5. At the Mud Bay site, patterns of high apparent conductivity were related to areas of salt-water intrusion along tidal channels. In other coastal areas of Washington, EMI may prove to be a valuable tool for soil and salt-water contamination mapping.

6. At the Mud Bay site, areas of higher apparent conductivity were associated with subsurface tile drains. EMI may assist soil scientists and conservationists located buried drain line and assist wetland determinations.

It was my pleasure to work again in Washington and with members of your fine staff.

With kind regards,

James A. Doolittle
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cc:
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Equipment:
The radar unit is the Subsurface Interface Radar (SIR) System-2000, manufactured by Geophysical Survey Systems, Inc.[1] Morey (1974), Doolittle (1987), and Daniels (1996) have discussed the use and operation of GPR. The SIR System-2000 consists of a digital control unit (DC-2A) with keypad, VGA video screen, and connector panel. A 12-volt battery powers the system. This unit is backpack portable and, with an antenna, requires two people to operate. Antennas with center frequencies of 200 and 400 MHz were used in this study. Hard copies of the radar data were printed in the field on a model T-104 printer.

The RADAN NT (version 3.0) software program developed by Geophysical Survey Systems, Inc., was used to process the radar records.[1] Radar records contained in this report were converted into bitmap images using the Radan to Bitmap Conversion Utility (version 1.4) developed by Geophysical Survey Systems, Inc.[1] Some radar records from Pleasant Hill Cemetery were processed into a three-dimensional image using the 3D QuickDraw for RADAN Windows NT software developed by Geophysical Survey Systems, Inc. [1] Once processed, arbitrary cross-sections and time slices were viewed and selected images saved to files.

The electromagnetic induction meter is the EM38DD, manufactured by Geonics Limited.[1] Geonics Limited (2000) describes the operating procedures for this meter. The EM38DD meter is portable and requires only one person to operate. No ground contact is required with this meter. The EM38DD operates at a frequency of 14,600 Hz. It has effective penetration depths of about 0.75 and 1.5 m in the horizontal and vertical dipole orientations, respectively. The EM38DD meter consists of two EM38 meters bolted together and electronically coupled. One meter acts as a master unit (meter that is positioned in the vertical dipole orientation and having both transmitter and receiver activated) and one meter acts as a slave unit (meter that is positioned in the horizontal dipole orientation with only the receiver switched on).

The Geonics DAS70 Data Acquisition System was used to record and store EMI and GPS data.[1] The acquisition system consists of an EM38DD meter, a Trimble Ag 114 GPS receiver, and an Allegro field computer. With this data acquisition system, the EM38DD meter is keypad operated and measurements can either be automatically or manually triggered.

To help summarize results, the SURFER for Windows (version 8) program, developed by Golden Software, Inc., [1] was used to construct two-dimensional simulations. Grids were created using kriging methods with an octant search.

GPR:
A favorable feature of GPR is its ability to detect soil disturbances and the intrusion of foreign materials. GPR is therefore a useful tool for locating burials (Bevan, 1991; Gracia et al., 2000; King et al., 1993; and Vaughan, 1986). However, results vary with soil conditions. In some soils, rates of signal attenuation are so severe that GPR cannot profile to required depths. In other soils, burials are difficult to distinguish in soils having numerous rock fragments, tree roots, animal burrows or stratified or segmented soil layers. These scattering bodies produce undesired subsurface reflections, which complicate radar records and mask the presence of burials. Under such conditions, burials may be indistinguishable from the background clutter. Even with favorable site conditions (i.e. dry, coarse-textured soils) the detection of a burial is never guaranteed with GPR. The detection of burials is affected by (i) the electromagnetic gradient existing between the feature and the soil, (ii) the size and shape of the buried feature, and (iii) the presence of scattering bodies within the soil (Vickers et al., 1976).

The amount of energy reflected back to an antenna by a buried object is a function of the dielectric gradient existing between the object and the surrounding soil. The greater or more abrupt the difference in dielectric properties, the greater the amount of energy reflected back to the antenna, and the more intense will be the amplitude of reflections on the radar record. At first, most buried objects contrast with the surrounding soil

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

matrix. However, with the passage of time, buried objects decay or weather and become less electrically contrasting with the surrounding soil matrix. For burials, the rate of decay or weathering varies with the materials used to contain the corpse. Corpses may be buried in sacks, body bags, or in wooden, fiberglass, composite, or metal caskets. If a coffin is partially intact, an air-filled void may exist, which is generally detectable with GPR.

The size and depth of a burial affect detection. Large objects reflect more energy and are easier to detect than small objects. In addition, the reflective power of an object decreases proportional to the fourth power of the distance to the object (Bevan and Kenyon, 1975). Most bones are small and generally indistinguishable with GPR (Bevan, 1991; Killam, 1990). 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, which directly surrounds a burial rather than the bones themselves. 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, natural soil-forming processes will erase the signs of disturbances. At the Pleasant View Cemetery, grave shafts were generally not visible with either the 200 or 400 MHz antenna. At some gravesites, there were faint indications of truncated soil horizons. However, as the cemetery represents a sacred or sensitive area, ground-truth verification of interpretations was limited. Interpretations were therefore constrained.

Pleasant View Cemetery:
The cemetery is located in Section 3, T. 25 N., R. 38 E. near Mondovi, Washington. The cemetery is located in an area that has been mapped as Hanning silt loam, 0 to 7 percent slopes (Stockman, 1981). The very deep and deep, well drained Hanning soil formed in loess on uplands. Hanning is a member of the fine-silty, mixed, superactive, mesic Pachic Argixerolls family.

<u>Survey Procedures:</u>
A 10-m survey line with reference points spaced at 1-m intervals was laid out across fifteen cemetery plots. All lines were orientated in a north-south direction. While burial practices change with time, it was assumed that coffins would be orientated with their long axis orientated in an east-west direction and buried at a depth of 1- to 2-m. Radar traverses were conducted orthogonal to the assumed orientation of the graves. In addition, a grid was established across the larger Hamilton family plot. The dimensions of this grid were 18- by 19-m. Survey lines were 18-m long, orientated in a north-south direction, and spaced 1 m apart. Along each line reference marks were spaced at 2-m intervals. Pulling the 200 MHz antenna along 20 equally spaced (1-m) survey lines completed the GPR survey. The surveys was conducted by pulling the antenna in a back and forth manner along survey lines. Along each line, as the antenna was towed passed a reference point, a vertical mark was impressed on the radar record.

At the Pleasant Hill Cemetery, calibration trials were conducted with both the 200 and 400 MHz antennas. Radar records recorded with the 400 MHz antenna were more depth restricted and contained higher levels of background noise. The 200 MHz antenna detected several known burials that were not discerned with the 400 MHz antenna. Because of these results, the 200 MHz antenna was used for the investigation of the Pleasant Hill Cemetery. The radar's scanning time was set to 40 nanoseconds (ns). The soil was dry at the time of this investigation. Based on tabled values and assuming a velocity of propagation of about 0.10 m/ns and a dielectric permittivity of 9 for dry, loamy soil, a scanning time of 40 ns provided an observation depth of about 2.0 m.

<u>Results:</u>
Radar records collected with the 200 MHz antenna were of good interpretative quality. Although most burials were deeper than 1 m, several burials were observed on radar records at comparatively shallow depths (< 60 cm). The GPR confirmed several burials marked with headstones. However, some burials were not detected with GPR over known, marked gravesites. It was assumed that these corpses had been buried in more easily weathered materials. Alternative interpretations are that the corpses were never buried or that only their ashes were interred or dispersed across these marked gravesites. The GPR survey resulted in the identification of 10 unmarked graves. In general, the GPR survey failed to disclose the locations of children's graves. These were

apparently too small and/or the corpses were enclosed in more readily weathered materials that were not directly detectable with GPR. In addition the location of the unmarked grave of Richard A. Hutchinson (1853 to 1921) was discovered. Richard Hutchinson deeded the land to the cemetery and was a prominent Washington State Senator. Richard A. Hutchinson was also prominent in mining and was on the railroad commission.

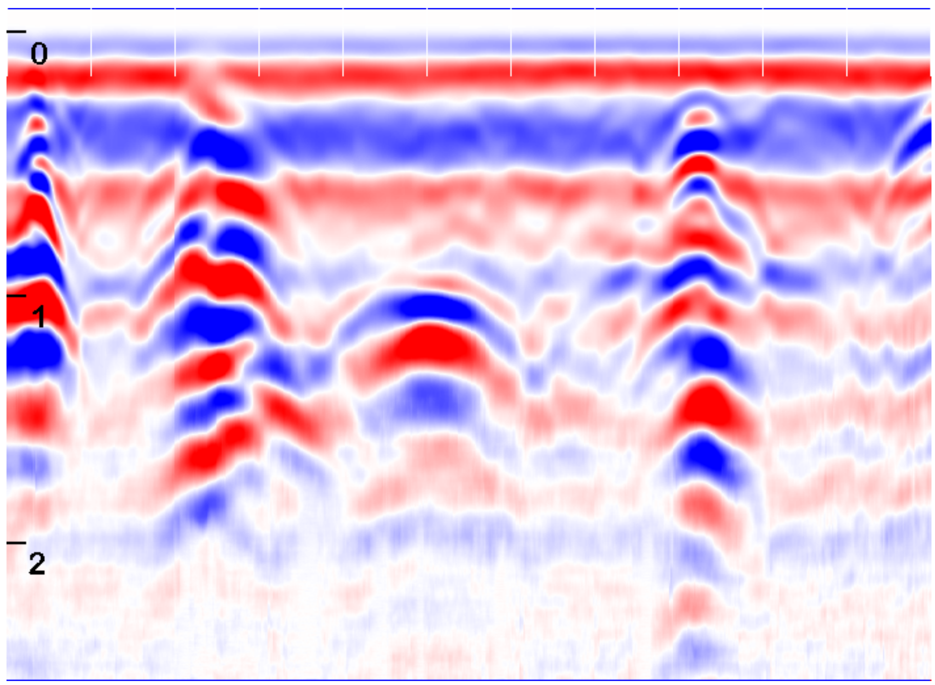

Figure 1. A representative radar record showing characteristic reflections from gravesites within the Pleasant Hill Cemetery.

Figure 1 is a representative radar record from the cemetery. The short, white, vertical lines at the top of the radar record represent equally spaced (1-m) reference points along the radar traverse. The vertical scale along the left-hand margin is a depth scale that is based on a velocity of pulse propagation of 0.10 m/ns. Note that the depth scale in Figure 1 is exaggerated relative to the horizontal scale by a factor of about 7.8.

In Figure 1, several hyperbolic reflectors and their associated, reverberated signals are evident. Three of these reflectors occur at shallow depths ranging from about 25 to 30 cm. These reflectors produce reflections that reverberate with depth. These reverberations suggest metallic objects. In addition, the shapes of these reflections do vary with depth and suggest superimposed or multiple reflecting surfaces. In the middle of the radar traverse (reference position 5m (measured from left side)) the conspicuous, hyperbolic reflector at a depth of about 1-m is believed to represent a burial. During the course of the surveys, additional hyperbolic reflectors were identified. Generally, these reflectors were aligned in an east-west orientation and occurred at a similar depth. Aligned and repeated patterns on adjoining radar records suggest burials. Many were at an estimated depth of about 1 m. Some corresponded with headstones, others with unmarked sites. These hyperbolic reflectors, while prominent, did vary in size, shape, and amplitude. Some larger reflectors appeared to consist of two or more, superimposed reflectors, which suggested multiple, closely spaced burials. While most radar records contained hyperbolic reflectors, no or scant indications of grave shafts were evident above these reflectors. The absence of a noticeable grave shaft was attributed to fairly homogenous soil horizons.

Three-dimensional interpretations of GPR data have been used to identify burials, middens, and other cultural features (Conyers and Goodman, 1997, Whiting et. al, 2000). In the past, the use of 3-D images has been restricted because of the time required to conduct fieldwork over limited areas and the lack of satisfactory signal-processing software. The recent development of sophisticated signal-processing software has enabled signal enhancement and improved pattern- recognition on radar records.

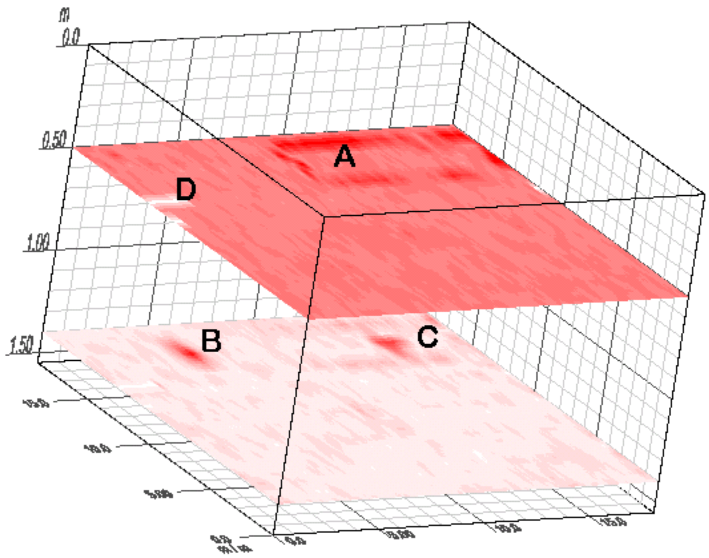

Figure 2. 3D time-sliced radar images of the Hutchinson Family Plot showing the probable burial (see B) of Washington's State Senator Richard A. Hutchinson.

Figure 2 contain a 3D block diagram of the Huntington Family Plot. The dimensions of the grid area are 18 by 19 m. In Figure 2, all units of measurement are expressed in meters. The origin is located in the southeast corner of the grid. Two horizontal "time slices" have been made across the cube at depths of about 0.5 and 1.4 m. These depths were based on an assumed signal propagation velocity of 0.010 m/ns through the soil. The shallower (0.5 m) slice reveals a conspicuous rectangular pattern (see "A" in Figure 2) in the northwest portion of the grid area. This area appears to correspond to lines of border stones that enclose a large family obelisk. Plotting errors have resulted in the absence of imagery at "D" in Figure 2. Two noticeable linear reflectors (see "B" and "C" in Figure 2) are evident on the deeper (1.4 m) slice. These higher amplitude (dark red colors) reflections occur at a uniform depth on adjoining radar records and are aligned in an east-west direction. These pattern suggest burials. It is believed that the unmarked burial at "B" is that of former Washington's State Senator Richard A. Hutchinson.

Mud Bay:
Archaeology students from South Puget Sound Community College are excavating the site of a Squaxin Island Tribe village on Mud Bay, lower Elbe Inlet, and west of Olympia, Washington. The site is located on land that is the home of Washington's Secretary of State, Ralph Munro. Numerous artifacts have been unearthed at this site. The Squaxin Island Tribe and the Washington State Office of Archaeology and Historic Preservation are assisting with the archaeological investigation.

The purpose of the geophysical investigation was to locate the site of a former log cabin. Other than an old picture and some cursory notes, the exact location of this former homestead is unknown and no remnants of this structure have been found.

The selected sites were located in two open fields near Mud Bay and in the southeast quarter of Section 12, T. 18 N., R. 3 W. Both sites are located in areas that have been mapped as Bellingham silty clay loam (Pringle, 1990). The very deep, poorly drained Bellingham soil formed in alluvium and lacustrine sediments. Bellingham is a member of the fine, mixed, superactive, nonacid, mesic Vertic Endoaquepts family. Because of Bellingham's high clay content and cation exchange capacity, depth of GPR penetration was anticipated to be restricted. Because of the large size of each site, a reconnaissance survey was completed with EMI.

<u>Survey Procedures:</u>
Survey procedures were simplified to expedite fieldwork. Two parallel sets of lines were laid out on opposite sides of each field. These lines defined the perimeter of a rectangular grid area. Along each of the lines, survey flags were inserted in the ground at intervals of 3-m. These flags served as grid line end points and provided ground control. Walking at a fairly uniform pace between similarly numbered flags on opposing parallel lines in a back and forth pattern across each grid area with an EM38DD meter and the DAS70 data acquisition system completed a survey. The EM38DD meter was operated in the continuous mode with measurements recorded at 1-sec intervals. The instrument was orientated with its long axis parallel to the direction of traverse and held about 3 inches above the ground.

At each site, "wild-cat" surveys were completed with the GPR system using a 200 MHz antenna.

<u>Results:</u>
Mud Flat Site:
At this site, 1519 measurements were recorded with the EM38DD meter in both the horizontal and vertical dipole orientations. Within this site, apparent conductivity ranged from 0.0 to 101.8 mS/m. With the EM38DD meter, apparent conductivity increased and became more variable with increasing depth. In the shallower-sensing, horizontal dipole orientation, apparent conductivity averaged about 7.0 mS/m with a standard deviation of about 4.6 mS/m. One-half the observations had values of apparent conductivity between about 5.1 and 8.3 mS/m. In the deeper-sensing, vertical dipole orientation, apparent conductivity averaged 14.8 mS/m with a standard deviation of about 8.4 mS/m. One-half the observations had values of apparent conductivity between about 11.1 and 15.8 mS/m. The increased conductivity with increasing depth was attributed to greater moisture, clay, and soluble salt contents at lower soil depths.

Figure 3 shows the spatial distribution of apparent conductivity measured with the EM38DD meter at the Mud Flat site. Apparent conductivity was generally low and invariable across most of this site. Conspicuously higher values of apparent conductivity were recorded in the southwest portion (lower left-hand corner of Figure 3) of the site. These values increase with increasing soil depth (measurements recorded in the deeper sensing (0 to 1.5 m) vertical dipole orientation are higher than those recorded in the shallower-sensing (0 to 0.75 m) horizontal dipole orientation). This portion of the site bordered a tidal channel to Mud Bay and the higher apparent conductivity reflects salt-water intrusion. In other coastal areas of Washington, EMI may prove to be a valuable tool for soil and salt-water contamination mapping. In Figure 3, the approximate location of a subsurface tile drain is indicated in each map by a blue-segmented line. In general, apparent conductivity is higher along most portions of this line. The linear pattern of high apparent conductivity assisted the identification of this drain line.

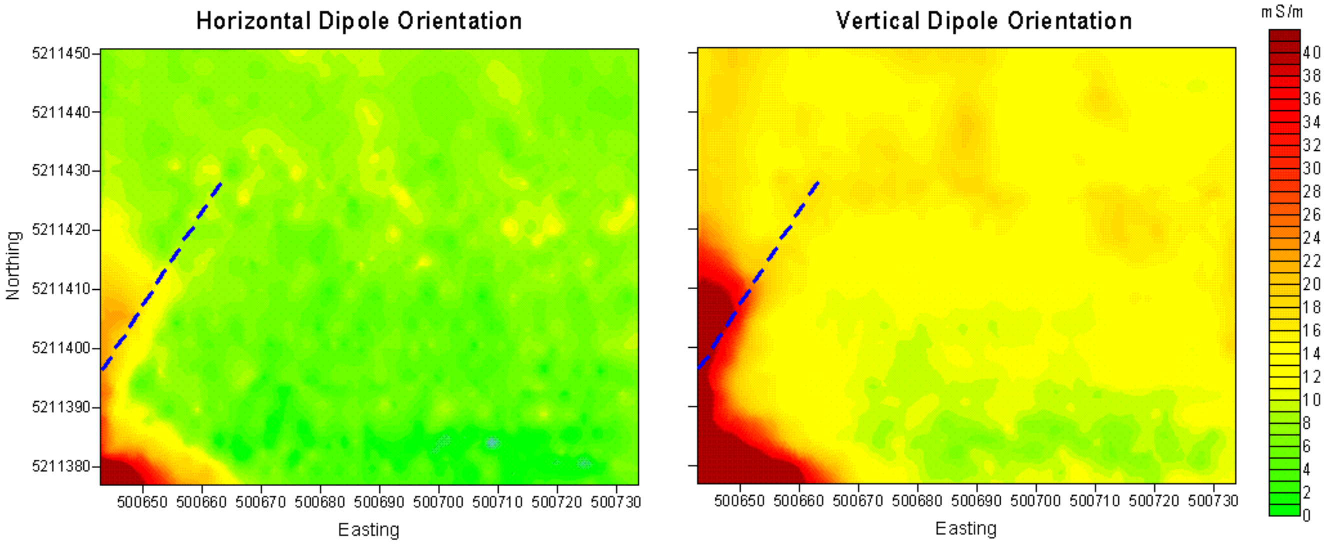

Figure 3. Spatial patterns of apparent conductivity within the Mud Flat Site.

Homestead Site:
At this site, 1117 measurements were recorded with the EM38DD meter in both the horizontal and vertical dipole orientations. Within this site, apparent conductivity ranged from 0.0 to 23.2 mS/m. With the EM38DD meter, apparent conductivity increased and became slightly more variable with increasing depth. In the shallower-sensing, horizontal dipole orientation, apparent conductivity averaged about 7.0 mS/m with a standard deviation of about 1.6 mS/m. One-half the observations had values of apparent conductivity between about 6.0 and 8.0 mS/m. In the deeper-sensing, vertical dipole orientation, apparent conductivity averaged 14.7 mS/m with a standard deviation of about 2.0 mS/m. One-half the observations had values of apparent conductivity between about 13.3 and 15.9 mS/m. The increased conductivity with increasing depth was attributed to greater moisture and clay contents at lower soil depths. No areas of salt-water contamination were detected with EMI at this site.

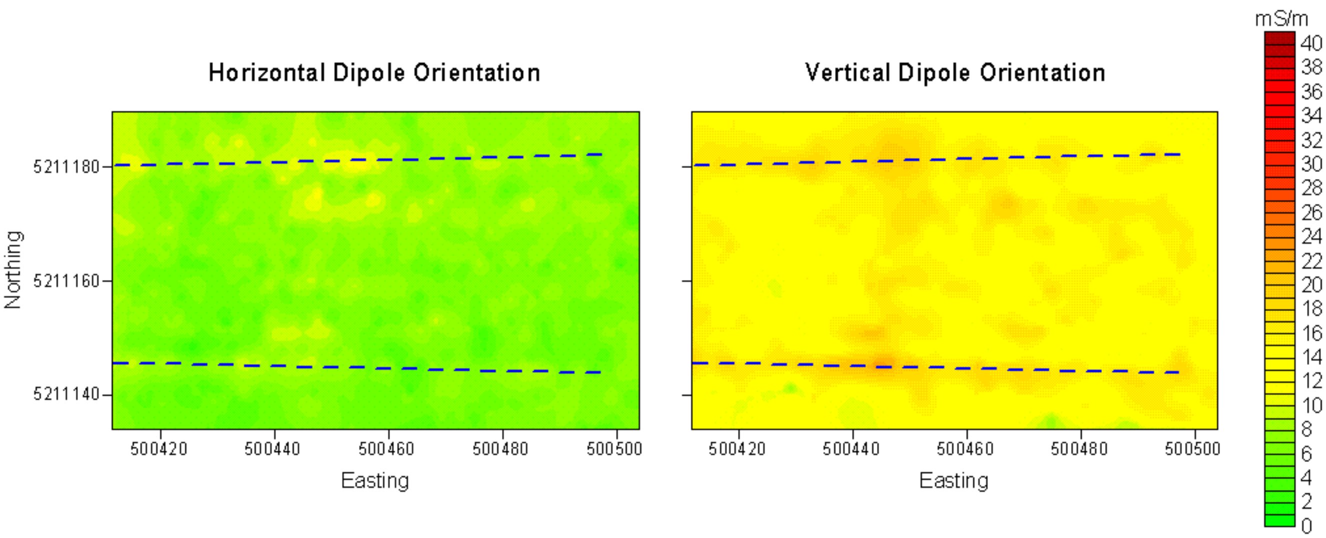

Figure 4. Spatial patterns of apparent conductivity within the Homestead Site.

Figure 4 shows the spatial distribution of apparent conductivity measured with the EM38DD meter at the Homestead site. Apparent conductivity was low and invariable across this site. In Figure 4, very weakly expressed, linear patterns of higher apparent conductivity are evident in each plot. Blue, segmented lines have been used to help show the approximate locations of these features. Their expression and orientation suggest buried drainage tiles.

Summary:

The EMI and GPR surveys revealed no indication of remnants of any former structure within the selected fields. It is probable that the structure, if located in these fields, were either completely removed or left no remnants that were detectable with these geophysical tools. It is also possible, that the coarse EMI and the "wildcat" GPR surveys did not pass directly over detectable structural remnants and that these features, if present, were overlooked.

Apparent conductivity was generally low and invariable across most of the surveyed areas. For areas that had been mapped as a fine-textured soil belonging to a superactive cation exchange activity class, the measured apparent conductivity are unexpectedly low and do not appear to reflected the classification of Bellingham soil (fine, mixed, superactive, nonacid, mesic Vertic Endoaquepts). However, little work has been completed with geophysical techniques by the National Soil Survey Center in areas influenced by volcanic materials and the measured results may be more common than anticipated.

References:

Bevan, B. W. 1991. The search for graves. Geophysics 56(9): 1310-1319.

Bevan, B. and J. Kenyon. 1975. Ground-probing radar for historical archaeology. MASCA (Museum Applied Science Center for Archaeology) University of Pennsylvania, Philadelphia. Newsletter 11(2): 2-7.

Conyers, L. B., and D. Goodman. 1997. Ground-penetrating Radar; an introduction for archaeologists. AltaMira Press, Walnut Creek, CA.

Daniels, D. J. 1996. Surface-Penetrating Radar. The Institute of Electrical Engineers, London, United Kingdom.

Doolittle, J. A. 1987. Using ground-penetrating radar to increase the quality and efficiency of soil surveys. 11-32 pp. IN: Reybold, W. U. and G. W. Peterson (eds.) Soil Survey Techniques, Soil Science Society of America. Special Publication No. 20.

Geonics Limited. 2000. EM38DD ground conductivity meter: Dual dipole version operating manual. Geonics Ltd., Mississauga, Ontario.

Gracia, V. P., J. A. Canas, L. G. Pujades, J. Clapes, O. Caselles, F. Garcia, and R. Osorio. 2000. GPR survey to confirm the location of ancient structures under Valencian Cathedral (Spain). Journal of Applied Geophysics 43: 167-174.

Killam, E. W. 1990. The detection of human remains. Charles C. Thomas Publisher, Springfield, Illinois.

King, J. A., B. W. Bevan, and R. J. Hurry. 1993. The reliability of geophysical surveys at historic-period cemeteries: An example from plains Cemetery, Mechanicsville, Maryland. 1993. Historical Archaeology 27(3): 4-16.

Morey, R. M. 1974. Continuous subsurface profiling by impulse radar. 212-232 pp. IN: Proceedings, ASCE Engineering Foundation Conference on Subsurface Exploration for Underground Excavations and Heavy Construction, held at Henniker, New Hampshire. Aug. 11-16, 1974.

Pringle, R. F. 1990. Soil Survey of Thurston County, Washington. USDA – Soil Conservation Service and Washington State Department of Natural Resources and Washington State University Agricultural Research Center. US Government Printing Office, Washington, DC.

Stockman, D. 1981. Soil Survey of Lincoln County, Washington. USDA – Soil Conservation Service and Washington State University Agricultural Research Center. US Government Printing Office, Washington, DC.

Vaughan, C. J. 1986. Ground-penetrating radar surveys in archaeological investigations. Geophysics 51(3): 595-604.

Vickers, R., L. Dolphin, and D. Johnson. 1976. Archaeological investigations at Chaco Canyon using subsurface radar. 81-101 pp. IN: Remote Sensing Experiments in Cultural Resource Studies, assembled by Thomas R. Lyons, Chaco Center, USDI-NPS and University of New Mexico.

Whiting, B. M. D., McFarland. D. P., S. Hackenberger. 2000. Preliminary results of three-dimensional GPR-based study of a prehistoric site in Barbados, West Indies. 260-267 pp. IN: (Noon, D. ed.) Proceedings Eight International Conference on Ground-Penetrating Radar. May 23 to 26, 2000, Goldcoast, Queensland, Australia. The University of Queensland.