Appendix D

GEOPHYSICAL SURVEY REPORT

Report of Geophysical Survey for U.S. Route 301, Section 2
St. Georges Hundred, New Castle County, Delaware
Phase II Archaeological Evaluation of Significance, Survey of Sites at Levels Road

Submitted to:

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December 23, 2010

Project Scope

A geophysical survey and preliminary geomorphology investigation was conducted on 3.48 acres adjacent to Sandy Branch at the Level Road Sites, St. Georges Hundred, New Castle County, Delaware. This investigation included Ground Penetrating Radar (GPR) and Gradiometer/Magnetometer surveys along with hand auger borings to assess stratigraphy in select areas.

Geophysical Surveys

These sites are located on an upland ridge and a slope down to Sandy Branch (Figure 1). The Site Clusters identified by Hunter Research, Inc. were divided into 4 grids for the geophysical surveys. These grids were flagged at 1 m and ½ meter intervals to collected the geophysical data and produce three-dimensional models. The GPR survey was completed using the Geophysical Survey Systems, Inc. 400 MHz antenna and a SIR-3000 Single Channel GPR Data Acquisition System. The magnetometer and gradiometer data was collected using the Geometrics Cesium Vapor G858 Gradiometer. Radan© and MagMapper© software were used to process the geophysical data. ArcMap© Geographical Information Software was used to compile the grids into the geophysical data maps. Each of the four grids are shown on the aerial photograph (Figure 2).

The geophysical grids differ slightly from the artifact site clusters because they were designed to outline the different topographic areas across the site. Geophysical Grid 1 was extended across Site Cluster B and part of Site Cluster A to the break in slope. Grid 3 then covers the remaining portion of Site Cluster A that extends down the slope toward Sandy Branch. Geophysical Grids 2 and 4 extend toward the southeast to cover prehistoric Site Clusters C and D. The grid coordinates start at the northeast corner of each grid with X=0 and Y=0. Then the x-axis extends along the northwest side of the grid and the y-axis extends along the east side of the grid.

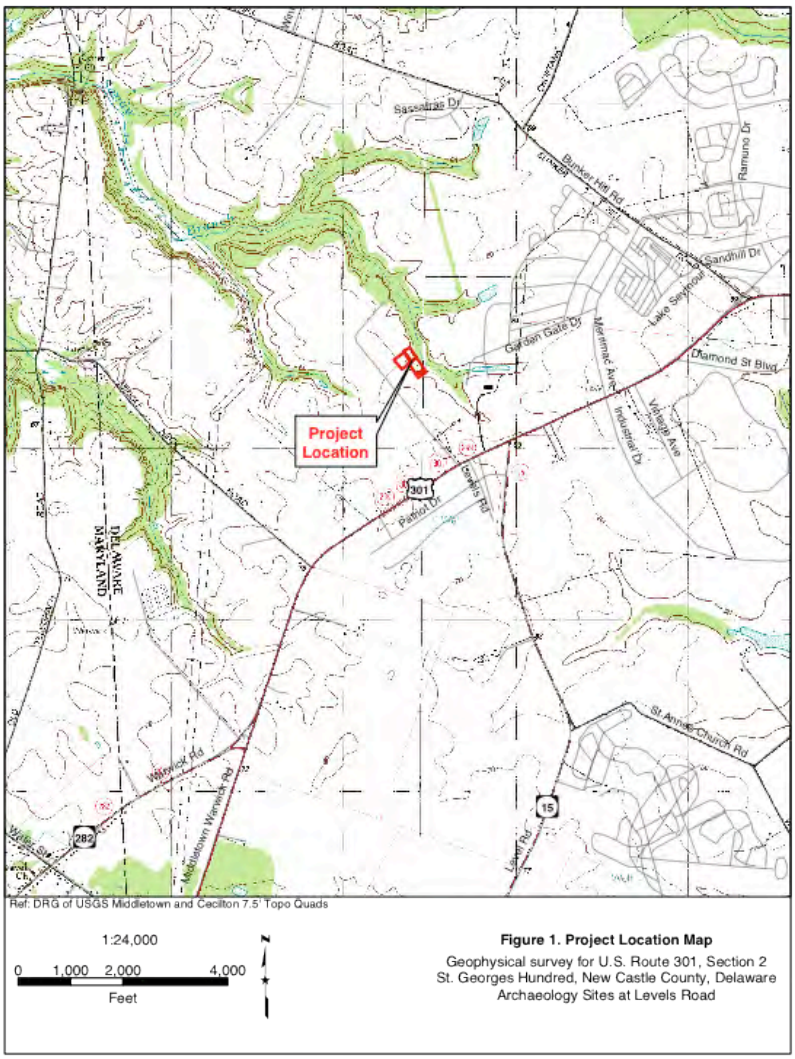

Figure 1. Project Location Map
Geophysical survey for U.S. Route 301, Section 2
St. Georges Hundred, New Castle County, Delaware
Archaeology Sites at Levels Road

Figure 1. U.S. Geological Survey 7.5 Minute Topographic Quadrangle showing the project location.

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Magnetometer and GPR data was collected for Gird 1 at one meter spacing as proposed for the historic clusters. This spacing was selected to target larger structures rather than smaller dispersed prehistoric features. A large relatively homogenous rectangular anomaly of low magnetometer values was recorded in the NE corner of Grid 1 (Appendix 1.5). This large anomaly will be referred to hereafter as the "Grid 1 Rectangular Anomaly". Two areas of Grid 1 were selected for a magnetometer survey at ½ m spacing

to collect higher resolution data. The area around Site Cluster B along the western corner of Grid 1 and the Grid 1 Rectangular Anomaly were re-surveyed with the gradiometer at this ½ m spacing. These are shown on the interpreted color contour map of the magnetometer data (Appendix 1.3). The Grid 1 Rectangular Anomaly is evident in the ½ m spacing sub-grid (X=0-35, Y=0-45) and there are some distinct anomalies within this higher resolution data.

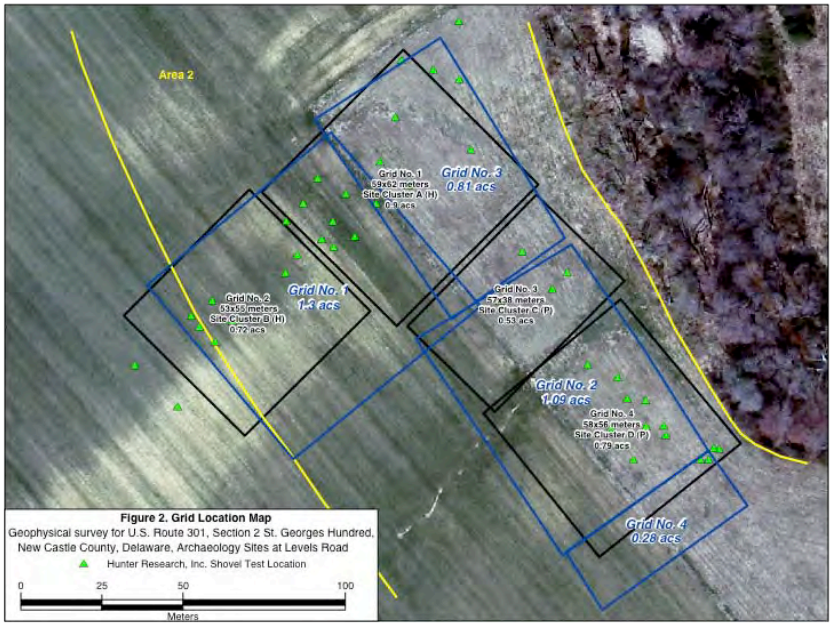

Figure 2. Geophysical grid locations (blue text and rectangles) relative to Site Clusters A through D.

It was decided to continue running the rest of the historic Site Cluster A (Geophysical Grid 3) at ½ m spacing to collect higher resolution data and see more detail in the anomalies along the slope down to Sandy Branch. Data from both of the other prehistoric clusters were collected at ½ m line spacing as was proposed in the research design.

The Radan© software is used to produce a 3-dimensional (3-D) model of the geophysical data. GPR anomalies can be evaluated by selecting horizontal slices through the 3-D model of each grid at different depths. These horizontal slices show the radar reflections returned over a particular thickness of the 3-D model. It is our understanding that Hunter Research was targeting features along the interface between the plow zone and the underlying undisturbed sediment. These features reportedly have the potential to extend several feet into the undisturbed soil below the profile. To target these features we selected two depths, 30 cm and 45 cm for interpreting the GPR data. A relatively thin 5cm slice of vertical data was chosen for each depth. A 5 cm slice includes radar reflections 2.5 cm above and below the selected depth. This decision was based on an initial review of the data where it was determined that many of the anomalies or GPR reflections were limited to a particular depth.

The gradiometer consists of two magnetometer sensors vertically separated to measure changes in the magnetic field at different heights above the ground surface. The MagMapper© Software allows us to review and interpret data from each magnetometer sensor and the difference in the data collected from each sensor or the gradient (change) in magnetometer readings with distance from the ground surface. After reviewing the data collected from each sensor and the gradient data between the two sensors, it was determined that the sensor closest to the ground surface provided the most appropriate visualization of the magnetometer data collected from the site. This is the data shown on our maps and used to interpret the anomalies recorded during the survey. Thus, it is magnetometer data that is used for the interpretation of anomalies. The magnetometer data is shown in a color contour map and on shaded relief maps (Appendices 1.3 and 1.4).

The MagMapper© software determines the upper and lower values of the magnetometer data from each grid and sets the color ramp using these values. The anomalies within each grid are best shown on images that use the color ramp set by the MagMapper© software. Therefore we did not normalize the four grids to a single color ramp. This causes a change in the color contour map along the boundary between grids. There was also a precipitation event between collecting data for northern half of Grid 2 and the other grids that could have affected the magnetometer values. The high and low magnetometer values for the color ramp of each grid are listed in Table 1. You will note that the Grid 2 data was actually collected from three sub grids as listed on Table 1.

Anomaly Identification

Thirty-eight anomalies were picked as potentially related to cultural features from the geophysical data. These anomalies are labeled and shown on the magnetometer maps and the maps of the GPR slices at 30 and 45 cm (Appendix 1). The labeled anomalies are shown on the color contour magnetometer map with the two ½ m sub-grids overlaid on Grid 1 (Appendix 1.3). The map showing the 1 m spacing survey for Grid 1 is also included to show the difference in resolution between the ½ m and 1 m spacing survey (Appendix 1.5). The Grid 1 Rectangular Anomaly (blue) is easily recognized on this 1 m spacing map. A shaded relief map of the magnetometer data is included in Appendix 1.4. The shaded relief map shows a different perspective of the magnetometer anomalies.

The geophysical data was examined to identify circular and square anomalies that would not occur by natural processes and thus indicate a potential cultural feature. We also looked for paths and linear sets of anomalies. This technique was used for the entire survey area. The geophysical data was then closely examined in areas with known artifact clusters for anomalies that could be related to cultural activities. Finally, the edge of the upland surface or planted field was examined at the break in slope for anomalies that could represent cultural features. This was the methodology used to identify the 38 anomalies shown on our maps.

Grid Number	X Minimum (m)	X Maximum (m)	Y Minimum (m)	Y Maximum (m)	Color Ramp Minimum (nanotesla)	Color Ramp Maximum (nanotesla)
1 (1m)	0	74	0	70	51834	51918
1 (1/2m)	0	35	0	45	51833	51869
1 (1/2m)	60	74	0	40	51860	51880
2	0	47	0	40	51872	51896
2	48	57	0	40	36972	51906
2	0	57	40	80	44838	51910
3	0	45	0	75	51803	51871
4	0	55	0	20	51875	51921

Table 1. Range for high and low magnetometer values for each grid or section of each grid.

Note that many of the anomalies could be related to natural changes in sediment across the site. As an example, a linear series of anomalies was initially identified on the shaded relief magnetometer data extending across Grid 2 along coordinates X=12.2m and Y=0-33m (Appendix 1.4). These anomalies appeared to be possible postholes for a fence line. Personnel from Hunter Research, Inc. opened up a unit across several of these anomalies and recorded large pieces of limonite. Concentrations or pieces of limonite at the site are recorded as an anomaly in the magnetometer data because of its high iron content. Another anomaly we initially identified was also excavated and determined to be the contact between sediment consisting of sand and a cobble bed (with limonite cobbles) possibly representing an older channel deposit. Anomaly A-35 has a very high magnetic signature and could represent a concentration of limonite. However, it was selected for further testing because it is such distinct anomaly in this data set and we could not exclude it as a possible cultural feature.

These anomalies can be tested with slot trenches or plow zone stripping with the backhoe. Rectangles are drawn across anomalies A-37 and A-38 that represent a linear set of radar reflections and through anomaly A-32 that occurs at one of the artifact clusters. In most cases it can be determined whether an anomaly represents a cultural feature or a geologic deposit with slot trenches or plow zone stripping across a portion of the target.

Field Testing with Hand Augers

Several hand auger borings were drilled along across Grids 1 and 3 to assess the sedimentology of areas with higher and lower magnetic signatures. One set of hand auger borings was drilled at Grid 3 into an area of low magnetic values (X=33.25, Y=64.85, boring B-1) and an adjacent area of high magnetic values (X=37.40, Y=65.62, boring B-2). The plow zone had a consistent sedimentology of silty sand (sandy loam) across the site. At boring B-1 the sub-plow zone sediment was clayey, sandy silt (silty loam). In contrast the sub-plow zone sediment at boring B-2 was silty, clayey sand with some cobbles (sandy loam). This indicates that the areas with a high percentage of sand have a higher magnetic signature. This is attributed to the likely presence of heavy minerals in the sand such as ilmenite and magnetite.

The second set of borings was collected along the northern edge of Grid 1 where areas of

high and low magnetometer readings were recorded. Boring B-3 (X=19, Y=1) was drilled into an area of low magnetometer values. The sediment below the plow zone in boring B-3 consisted of sandy, clayey silt (silt loam). Boring B-4 (X=33, Y=1) was drilled into an area of higher magnetometer values. The sediment below the plow zone in boring B-4 consisted of silty, clayey sand (sandy loam). The higher magnetometer values measured at boring B-4 are attributed to higher sand concentration.

The third set of hand auger borings was drilled into a linear anomaly that crosses the northern portion of Grid 1. This anomaly is represented by a lighter ridge on the shaded relief magnetometer map (Appendix 1.4). Boring B-5 (X=20, Y=18.3) was drilled into the lighter linear ridge representing a higher magnetometer reading. The sediment below the plow zone consisted of silty, medium to coarse sand (sand to loamy sand). Boring B-6 (X=20.5, Y=15) was drilled into the darker shadow north of the ridge that represents a lower magnetometer reading. The sediment below the plow zone consisted of sandy, clayey silt. Again, the higher sand concentration is attributed to the higher magnetometer values measured at boring B-5.

One final boring (B-7) was drilled into an isolated high magnetometer value on both the color contour and shaded relief maps at X=11.8 and Y=12.8 (see anomaly A-23 on Appendices 1.3 and 1.4). Several pieces of metal were recorded in this boring at a depth of 20 cm. This metal is located in the vicinity of a set of anomalies identified within the Grid 1 Rectangular Anomaly.

Anomaly Descriptions

The following is a description of the 38 anomalies identified as targets for features possibly related to cultural activity at the site. The anomaly identification table is intended to indicate the anomaly location and the specific sets of geophysical data that were used to identify each anomaly (Table 2). Comments on factors contributing to the anomaly selection are listed in Table 3. The grid coordinates in Table 2 can be used to locate the anomalies in the field using the grid flags and corner stakes. Note these coordinates are in meters from X=0, Y=0 in the northeast corner of each grid. The coordinates listed in Table 2 target the center of each anomaly.

Anomaly	Grid #	X (m) Coordinate	Y (m) Coordinate	Mag. Color	Mag. Shaded	GPR 30cm	GPR 45 cm
1	4	22.4	8.8-5.3	x	x		x
2	2	42.25	4.25	x	x		x
3	4 & 2	(G-4) 45.0	(G-4) 0.0	x	x		x
4	2	41.0	65.0	x	x		x
5a	2	9.5	63.0				x
5b	2	6.3	61.0			x	x
5c	2	9.2	64.0		x	x	
6	2	17.2	43.3	x	x		
7	2	6.3	43.4				x
8a	2	22	28.8		x	x	x
8b	2	18.2	32.5		x	x	x(?)
9	2	34.6	34.5	x	x		
10	2	37.4	26.7			x	x

Anomaly	Grid #	X (m) Coordinate	Y (m) Coordinate	Mag. Color	Mag. Shaded	GPR 30cm	GPR 45 cm
11	2	8.0-8.7	14.5-4.2			x	x
12	2	10.0	2.0			x	x
12	2	7.3	1.4			x	x
13	3	2.9	68.7		x	x	x
13a	3	7.8	69.5	x	x		
14	3	6.1	35.2	x	x	x	x
15	3	6.4	25.5	x	x	x	x
16	3	14.6	23.4	x	x		x
17	3	32.3	29.5			x	x
18a	3	22.0	13.5		x	x	x
18b	3	25.0	11.5			x	x
19a	3	34.0	7.0			x	x
19b	3	29.2	7.0	x	x	x	x
20	3	42.1	20.0	x	x	x	x
21	1	15.0	6.0	x	x		
22	1	9.3	9.5	x	x		
23	1	12.5	15.0	x	x		
24	1	16.0	29.0	x			
25	1	21.3	35.2	x		x	x
26	1	25.0	39.5	x			
27	1	24.8	29.2	x		x	x
28	1	24.2	23.5	x			
29	1	24.0	19.7	x			
30	1	31.8	32.2	x			
31	1	30.2	4.1			x	x
32	1	65.4	24.1	x	x		
33	1	63.7	34.0	x	x	x	x
34	1	70.3	30.2	x	x		x
35	2	53	4	x	x		x
36	2	37.5	9.4		x	x	
37	3	7.0	57.0			x	
38	1	11.0	58.0			x	x

Table 2. Anomaly location and geophysical data set used to identify each anomaly.

Anomaly	Comments for Each Anomaly
1	Located in area where several prehistoric artifacts were recorded along the eastern edge of the upland surface. Lower area includes portion of circular pattern noted on shaded relief map. Also includes a contrast in values on color magnetometer map. GPR reflections are noted in upper portion of the anomaly at a depth of 45 cm.
2	Located along the eastern edge of the upland surface. Targets an area that crosses a distinct change in magnetometer readings and some low amplitude GPR reflections at a depth of 45 cm.
3	Located in area where several prehistoric artifacts were recorded along the eastern edge of the upland surface. Very distinct area of low magnetometer values on both Grids 2 and 4.
4	Located west of where several prehistoric artifacts were recorded along the edge of the upland surface. Area of low magnetometer values within a terrain of high magnetometer values. High amplitude GPR reflections encircle the anomaly area at a depth of 45 cm.

Anomaly	Comments for Each Anomaly
5a, b & c	Three areas of higher amplitude GPR reflections at depths of 30 and 45 cm within an area of low magnetometer values on/or adjacent to the flood plain of Sandy Branch. The western area intersects what appears to be a linear path of GPR anomalies that extends to the north toward A-7 on the 45 cm map.
6	Localized area of very high magnetometer values. Not observed on GPR maps. Could indicate area of limonite or historic deposit of metallic artifacts.
7	Rectangle drawn across a linear north-south trending set of GPR reflections observed on the 45 cm map. Note this appears to parallel a linear north-south trending concentration of artifact locations. These occur at the base of the toe slope.
8a & b	Two areas of lower magnetometer values and an area of GPR reflections where the amplitude of the reflections increases with depth. This is located along what appears on the aerial photo to be a swale or perhaps the base of a rise along the slope down to Sandy Branch. The high amplitude GPR reflections in the larger area could be a natural geologic deposit. The smaller circular area is in an interesting set of anomalies clearly seen on the shaded relief map.
9	A very localized source of high magnetometer values possibly representing a limonite concentration or historic artifact.
10	Very high amplitude reflectors on the GPR maps. GPR reflections could be related to broader geologic feature.
11	Branching linear trails of GPR reflections. Preliminary field data indicated a filled linear depression.
12	GPR reflections branching out in a circular geometry between A-11 and A-13. Possibly representing a split in a trail or an outline of a structure.
13	Linear pattern of GPR anomalies extending from A-12 toward Sandy Branch.
13a	Anomaly added at last minute, not on GIS maps. Very high magnetometer values from a point source a few meters west of A-13. There is a point source GPR reflection on the 30 and 45 cm maps just south of this anomaly that could be associated with the high magnetic signature.
14	Anomaly of low magnetometer values on the color and shaded relief maps and high amplitude GPR reflections on the 45 cm map. Possible intersection of several linear GPR anomalies that extend to the south.
15	Slightly arcuate set of GPR reflections that correspond to higher magnetometer values. Several point sources of varying magnetometer values are evident on the shaded relief map.
16	Rectangular area of low magnetometer readings notched into the southern edge of the ravine. Initial testing of this feature indicated possible cultural origin. Scattering of GPR reflections across this area on the 45 cm map. Note rectangle drawn on these maps is centered over the eastern edge of the possible feature to identify what is causing the changes in magnetometer values.
17	Area of low amplitude reflections on the 30 cm and 45 cm GPR maps. These are located in the center of artifact cluster A.
18a & b	Two sets of GPR reflections on both the 30 and 45 cm maps along the ravine the crosses the northern corner of Grid 3. This area is associated with recorded artifacts.
19a & b	Another set of GPR reflections on both the 30 and 45 cm maps along the ravine that crosses the northern corner of Grid 3. 19b (eastern) coincides with a high magnetometer value.
20	This anomaly crosses the eastern edge of the Grid 1 Rectangular Anomaly. Note this anomaly is not apparent on color magnetometer map presented here as it was identified on Grid 3 and Grid 1 covers up the edge of this grid.
21 & 22	There are several anomalies in the magnetometer data in the northeastern corner of Grid 1 that could represent some type of cultural feature(s). This is also where a concentration of artifacts was recorded. Features 20 through 23 attempts to bisect these anomalies in order to determine their source. Anomalies 21 and 22 cut across areas of higher and lower magnetometer values in an attempt to delineate the edge of possible cultural features.

Anomaly	Comments for Each Anomaly
23	This anomaly includes the high magnetometer values associated with the pieces of iron found in hand auger-boring B-7 and cuts across the center of a possible feature.
24	Area of lower magnetometer values with a point source higher magnetometer value along edge of feature.
25 & 26	Areas of lower magnetometer values in the southwest corner of the Grid 1 Rectangular Anomaly.
27, 28 & 29	A linear set of low magnetometer value point sources that extend along the west edge of the Grid 1 Rectangular Anomaly. Possibly related to the edge of a structure?
30	A low magnetometer anomaly just to the west of the Grid 1 Rectangular Anomaly.
31	A circular to square pattern of GPR reflectors along the northern edge of Grid 1.
32, 33 & 34	Anomalies 32, 33 and 34 are all located along the western edge of the Phase 1B Testing Area where a concentration of historic artifacts was recorded. This appears to be an area of relatively high background magnetometer values with several areas of low magnetometer values. Anomaly 33 shows GPR reflectors at both 30 and 45 cm. Anomaly 34 shows a distinct GPR reflector at 45 cm. These anomalies do not appear to have a natural origin and could be related to cultural activities.
35	This anomaly could very well be a natural geologic feature such as an accumulation of limonite or a sand/gravel bar containing a concentration of magnetic minerals. However it is very distinct feature at the site with a localized area of high magnetometer values surrounded by sediment with a low magnetic signature. A slot trench across this feature (plow zone stripping with the backhoe) would quickly determine the characteristic of this unusual anomaly.
36	This anomaly consists of set of adjacent high and low magnetometer values shown on the shaded relief map. The color contour map shows that they are located in a trough of low magnetometer values that probably represent silty sediment. GPR reflections occur on the 30 cm map directly north and west of this magnetometer anomaly.
37 & 38	These rectangles are oriented to bisect a linear northeast/southwest trending set of reflections on the GPR maps. A-37 is observed on the 30 cm map and A-38 is best represented on the 45 cm map. A several artifacts were recorded in the vicinity of these anomalies.

Table 3. Comments on the selection of each anomaly and their characteristics.

Summary of Geophysical Survey

Overall the results of this geophysical investigation provided some very good data showing anomalies identifying the location of possible cultural features. There are complicating geologic conditions such as the abundance of limonite and changes in terrain that will result in some of the anomalies to be natural occurring features. However, a significant proportion of these anomalies are likely to be related to cultural activity within the study area.

The Grid 1 Rectangular Anomaly correlates to the high concentration of artifacts in Site Cluster A and does not appear to be related geologic processes. The high-resolution data collected across Site Cluster A identified many anomalies that if investigated, could determine the cultural significance of this large feature.

The three anomalies identified along the eastern edge of Grid 1 within Site Cluster B are also good targets for potential cultural features. Anomalies along the eastern edge of the site within Site Clusters C and D appear to represent trails or paths and anomaly patterns that could be related to possible structures and other cultural features.

Appendix 1
Ground Penetrating Radar and Magnetometer Data
Showing the Anomaly Locations