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APPLIED ANTHROPOLOGY LABORATORIES

Geophysical Field Reconnaissance of a Historic "Colored" Cemetery (CR-06-65) to Support Restoration Efforts by Eagle Scouts from Boy Scouts of America, Thorntown, Indiana

Prepared for:

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AAL Project #17SP001

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Introduction

At the request of the Reece Thompson of Boy Scout Troop 350 the Applied Anthropology Laboratories (AAL) conducted a ground penetrating radar (GPR) survey of the Thorntown historic "Colored" Cemetery in Thorntown, Indiana (Figure 1). The property is bounded on the east by County Road 825 W and surrounded on three sides by agricultural fields, Thorntown, Indiana 46071, in section 34, Township 20N, Range 2W on the first meridian as shown on the Thorntown, Indiana USGS 7.5 minute quadrangle (Figure 2). The survey included approximately 0.3 acres (~1,200 m^2) of level open grass lawn (Figure 3). The project area was relatively dry. Two small rainstorms occurred during survey, but otherwise the weather was sunny and warm. The area surveyed consists of two 20 m x 20 m blocks (Blocks 1 and 2) and one 10 m x 40 m block (Block 4/5) covering the entire extent of the former cemetery. The main purpose of the survey was to prospect for potential buried headstones and possible locations of unmarked graves to aid in the restoration process congruent with DHPA permit to probe for gravestones in the cemetery (CR-06-65). The cemetery has been the subject of one previous geophysical investigation by Oswalt (2013). Oswalt also conducted genealogical research to identify the number of possible community members interred in the cemetery. Through a combination of his records search and magnetic gradiometry analysis he identified at least "38 probable burial shafts" (Oswalt 2013:26), while noting that "this number likely still falls short of the actual number of graves present at the cemetery" (Oswalt 2013:27) (Figure 4). Oswalt surveyed a 30 m (E-W) by 60 m (N-S) area. In relation to the current survey, his grid extends approximately 10 m north, and 10 m south of the GPR grid (Figure 5).

What follows is a summary of the methods used in the field, the post-processing of the data, and then an interpretive summary.

Figure 1: Location of Survey Area within Boone County, Indiana.

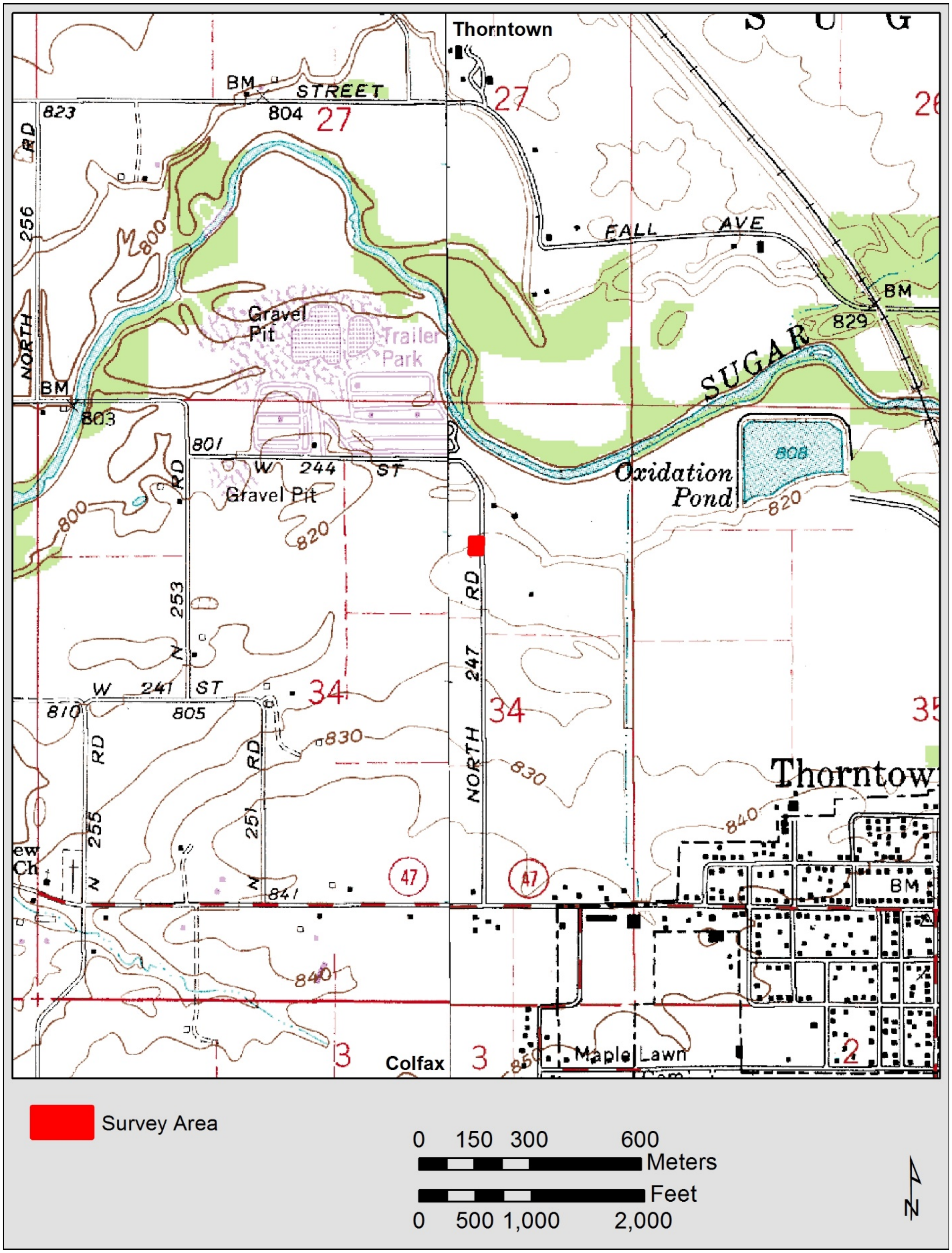

Figure 2: Location of the 17SP001 Project Area over the Thorntown and Colfax, Indiana 7.5 minute USGS quadrangles.

Figure 3: Aerial Photograph of Thorntown "Colored" Cemetery, Thorntown, Indiana.

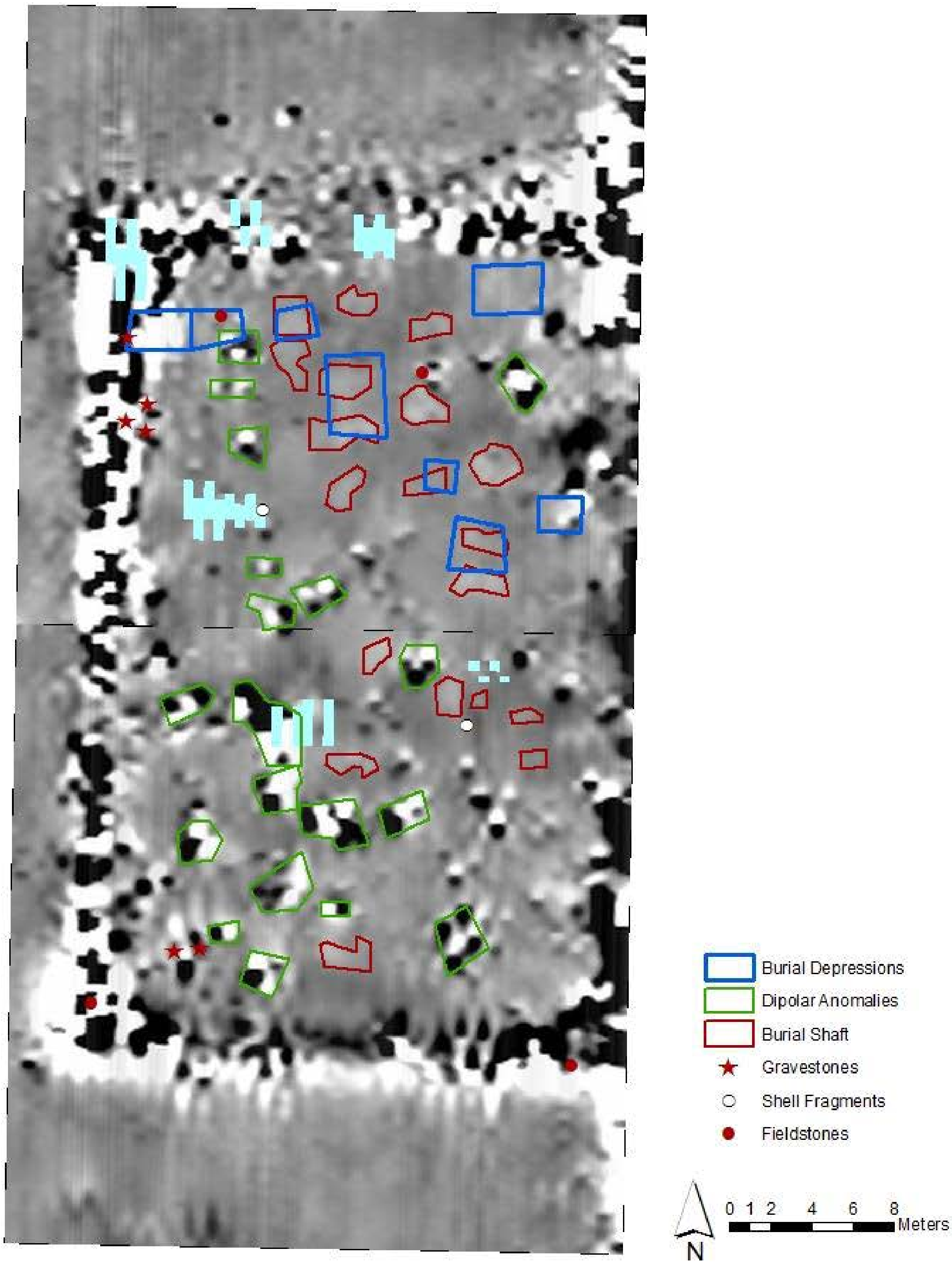

Figure 4: Oswalt's (2013:39) Final Interpretation of the Cemetery

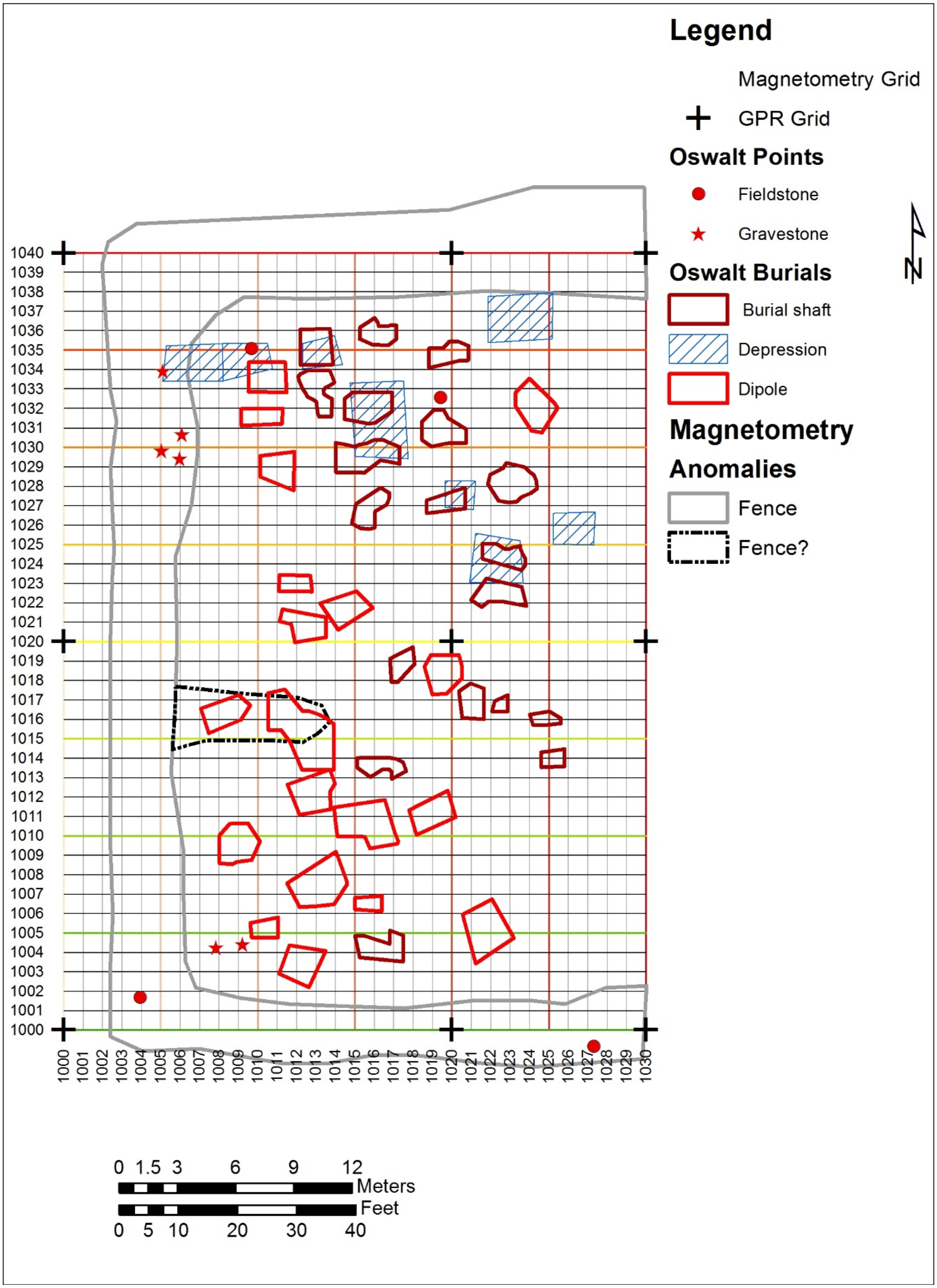

Figure 5: Oswalt's Results over 17SP001 Grid. Note: Fence and possible fence outlines are my interpretation of Oswalt's output images.

Figure 6: Survey Blocks over Aerial Photograph

Methods

Upon arrival, a grid origin was located in the southwest corner of the current cemetery parcel, 50 cm east of the nearest row of corn and 1 m north of the nearest row on the southern edge of the parcel. The grid was aligned to the orientation of the north-south corn rows, bearing ~5°. This origin point was assigned the coordinates of 1000 N 1000 E (metric). The parcel as currently in grass is not a right angle along the southern boundary. At grid 1020 E the corn is 2.26 m south of the base line. It should also be noted that the extent of the cultivation has changed in recent years according to the aerial photograph in Figure 6. The parcel was measured to extend approximately 46 m north-south, and 30 m east-west. The parcel was divided into six survey blocks. Blocks 1 and 2 are 20 m x 20 m blocks (see Figure 6) along the 1000 E line. Block 3 was designated from the 1040 N line to the 1046 N line from 1000 E to 1020 E. Block 4 was designated as a 20 m x 10 m block bounded by 1000 and 1020 N, and 1020 and 1030 E. Block 5 was designated as the 20 m x 10 m block immediately north of Block 4. Block 6 was designated as the 6 m x 10 m block in the northeast corner of the parcel. Blocks 3 and 6 (6 m x 10 m) were not surveyed due to time limits and being outside the original marked boundaries of the cemetery.

Blocks 1, 2, and 4/5 were surveyed in parallel, north-south transects spaced 50 cm apart. Blocks 4 and 5 were surveyed as a single 40 m x 10 m unit to expedite field time. As a result, three different sets of transects were surveyed covering 400 m^2 each. Each Block was stored as a separate project in the data logger, and they were each processed separately in the lab.

While each block was process separately, they were processed using the same steps. All initial processing was conducted in RADAN 7. After processing all profiles, amplitude slices were exported as a CSV file for analysis in ArcGIS 10.5 (ESRI 2017). An amplitude slice was exported for each 10 cm level down to an estimated depth of 100 cm. Depth estimates are the result of a velocity analysis using the “migration” tool in RADAN. This allows the estimation of depth from the hyperbolas that appear around point reflections in the profile. As a result of the velocity analysis it is estimated that the relative dielectric permativity (RDP), or the resistance of the matrix to the transmission of the radar waves, was near 24.4. With this parameter an object detected at 26.61 ns is approximately 0.81 m below ground surface.

Each profile was subjected to the following processing steps, in order. First, all profiles are time zero corrected to the peak of the direct wave to more accurately reflect the location of the surface within the profile. Second, a full-pass background removal was performed. Next three FIR filters are applied simultaneously: Stacking (triangle, length =7), High Pass (100 MHz), and Low Pass (600 MHz). Fourth, a range gain was applied (18, 18, 49, 61, 72, 68, 62, 57, 50, 42, 32, 18). The output of this four-step processing was used in all interpretations. The amplitude slice exports were imported into ArcGIS 10.5 to allow greater control over the interpolation algorithms used in creating surfaces. However, RADAN exports all points in its own interpolated surface. To correct for this, the interpolated points created by RADAN (i.e., not in the original data) must be removed from the point shapefile before running a new interpolation. The query used in selecting interpolated data for removal is found in Appendix A. The remaining point data (the original transects only) was interpolated in ArcMap Spatial Analyst, Kriging interpolation tool. Before selecting an algorithm to characterize the spatial relationships in the data, Geostatistical Analyst extension was used to explore which models best fit the data. The best fit of the relationships in the data was the Exponential model with a nugget of 11831882.40525468, a major range of 0.5511874133093224, a partial sill of 126317029.27669072, and a lag size of 0.0688984266636653. These parameters were used in the Kriging tool to create raster (pixel surfaces) datasets representing the amplitude slices. These parameters provide the best visualization, and the most accurate characterization of the relationships among data points over distance. The same parameters were used in all interpolations.

To arrive at the below interpretations the amplitude slices (in RADAN and ArcGIS) were examined extensively throughout all depths (especially the top 1-1.5 m), and all profiles were examined in at least two times. Field interpretations of the major features were recorded in field notes. Any potential anomalies were checked against neighboring profiles to enable characterization of the nature of the anomaly, and rule out anomalies caused by reflections of shallow or surface anomalies. Of particular importance when searching for graves is the identification of disruptions in the normal horizons (different layers) of the soil column. For 19th century graves, lacking vaults and non-perishable coffins, sometimes the only remnant signature is a subtle disruption of the soil column, a lack of reflection. A major complication of the analysis was the presence of several large trees with extensive root systems.

Results

Here I present the summary of the results of the analysis of the amplitude slices then a summary of the results of the profile analyses. Identification of possible headstones (a specific request of Mr. Thompson) was complicated for this analysis by the high number of tree roots and possible glacial cobbles in the A horizon (topsoil).

Amplitude Slices

The amplitude slices for each 10 cm slice to a depth of 1 m are presented below in Figure 7 through Figure 15. Beginning in the 11 cm to 20 cm slice, the extensive tree root networks are clearly visible, masking much variation in the subsurface. Each slice was examined for approximately rectangular anomalies that approximated the size and orientation of potential grave shafts (i.e., 1 m x 2 m, oriented east-west). Several potential grave shafts appear in the 1-10 cm and 11-15 cm slices revealing the likely structure of the cemetery. It becomes clear that there are two clusters of burials, one north, and one south. These clusters are associated with, but much more extensive than, the extant standing stones in the northwest and southwest, respectively, of the cemetery plot. The fence is also evident, especially in the 51-60 cm slice, and the 91-100 cm slice presents a suggestion of an eastern boundary fence at approximately the 1020.5 E line. This may be an artifact of the seam on the western boundary of Block 4/5, especially as probable graves from both geophysical surveys are outside this area, and the magnetometry failed to identify this fence (given the magnetic nature of iron in the possible fence, the absence of this anomaly in Oswalt's survey indicates this boundary is not real).

The interpretation of the slices involved creation of a polygon shapefile for the grave-like anomalies in the slices. Polygons were only traced for the 1-10 cm and 11-20 cm slices as these seemed to capture most of the areas indicated by deeper slices (with some notable exceptions discussed below). These polygons are presented in Figure 17 below. Approximately 45 potential graves (some anomalies incorporate the area of more than one grave shaft) are indicated in this analysis. This is slightly more than Oswalt's 38 potential graves, but the pattern is largely the same (c.f., Figure 5).

Profile Analysis

Next, all profiles were examined multiple times (at least twice systematically), and the coordinates of each horizon disruption (indicating a possible excavation through the normally developing soil profiles, and thus a possible grave) was recorded. The coordinates were then independently converted into a point shapefile to represent possible graves. The results of mapping the horizon disruptions is presented in Figure 18. Examination of the point anomalies looking for horizon disruptions across approximately 2 m (4 profiles) results in the identification of possible grave shafts represented by the horizon disruptions. These disruptions were also examined against slice anomalies that indicated root activity or other, non-burial activity. The resulting possible grave shafts are shown in Figure 19. At least 40 graves are indicated, largely overlapping with the slice anomalies from 1-20 cm (Figure 20).

In summary, there are two main clusters of probable graves, one primarily in the southern portions of Blocks 1 and 4, and another in the northern portions of Blocks 2 and 5 (Figure 20). This pattern largely follows that interpreted by Oswalt (Figure 21). Oswalt has possible grave shafts mapped in the clusters of roots between 1013 – 1018 N, and 1020 – 1024 N. While the GPR indicated some possible horizon disruptions between 1020 N and 1024 N, these do not form linear arrangements, and are potentially caused by deflection of the radar signal by the dense roots. The Oswalt graves between 1013 N and 1018 N seem to fit better with what I interpret as a possible fence (see Figure 5) in his data, and a place of several very strong point reflections in the GPR data. These points have reflections similar to what is expected from metal, factoring into my interpretation of Oswalt's data. The current survey cannot rule out graves in this area of Block 1, but the anomalies do not match either the expected shape and orientation of graves, or the radar data.

In examining Figure 21, a gap in the pattern of regular rows of graves in the GPR interpretation in the northwestern section of Block 5 is filled by a surface depression mapped by Oswalt. Re-examining the amplitude slices, there are subtle hints of linear anomalies the size of grave shafts present. Further, there were isolated horizon disruptions (see Figure 18) in this gap that were excluded from the original grave interpretation (see Figure 19) due to a lack of visible disruption in neighboring profiles. Re-examining the slices, especially the 61-70 cm and 81-90 cm slices (see Figure 12, and Figure 14) indicates the depression may be related to settling of older grave shafts after the disintegration of the coffin. The strongest such indication is in the 81-90 cm slice between Oswalt's surface depression and a 1-10 cm slice anomaly. Thus there are likely three additional graves (1034.07 N, 1036.17 N, and 1037.22 N on the 1021.8 E line) beyond the 46 mapped in Figure 20.

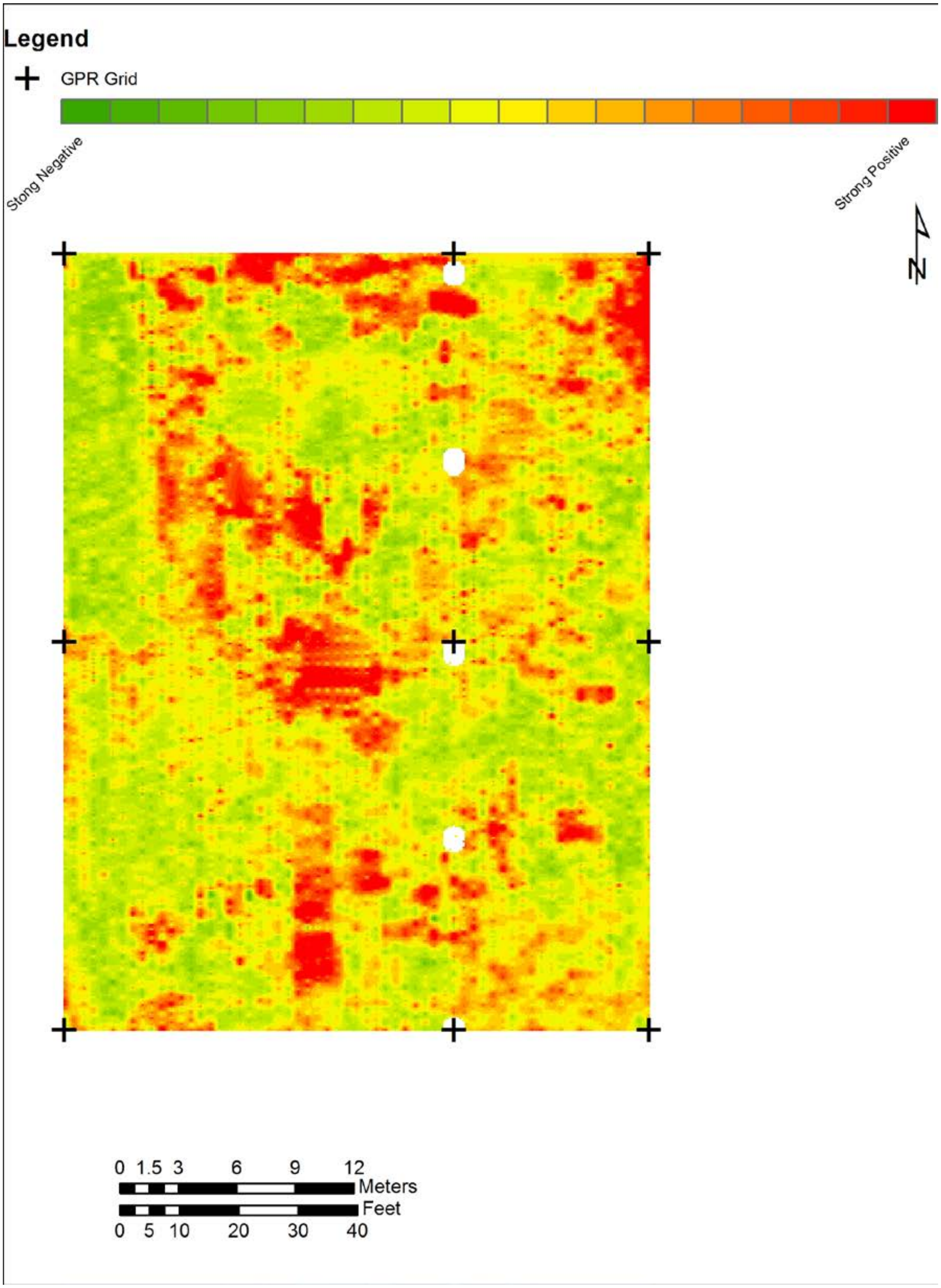

Figure 7: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 1-10 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

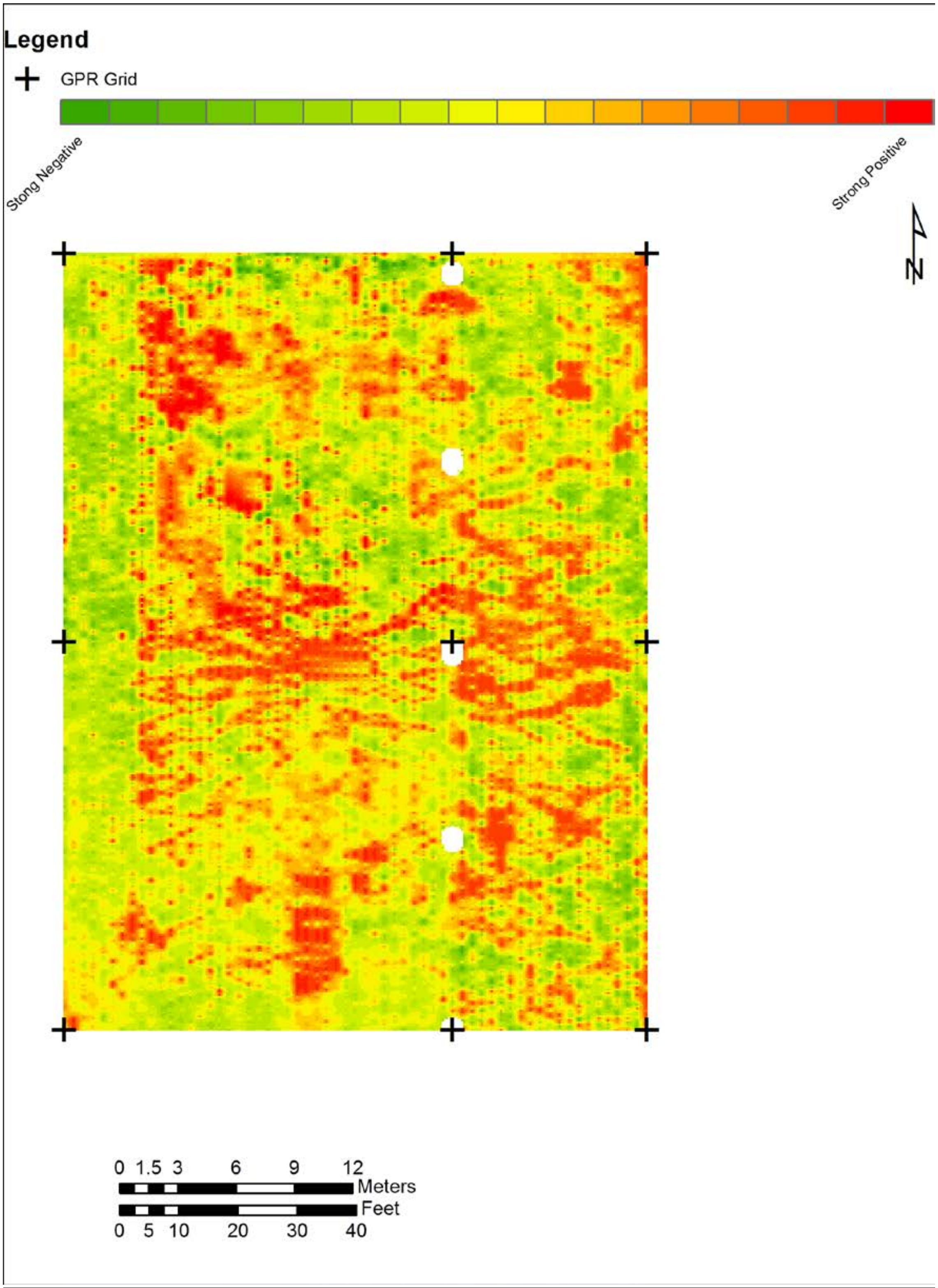

Figure 8: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 11-20 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

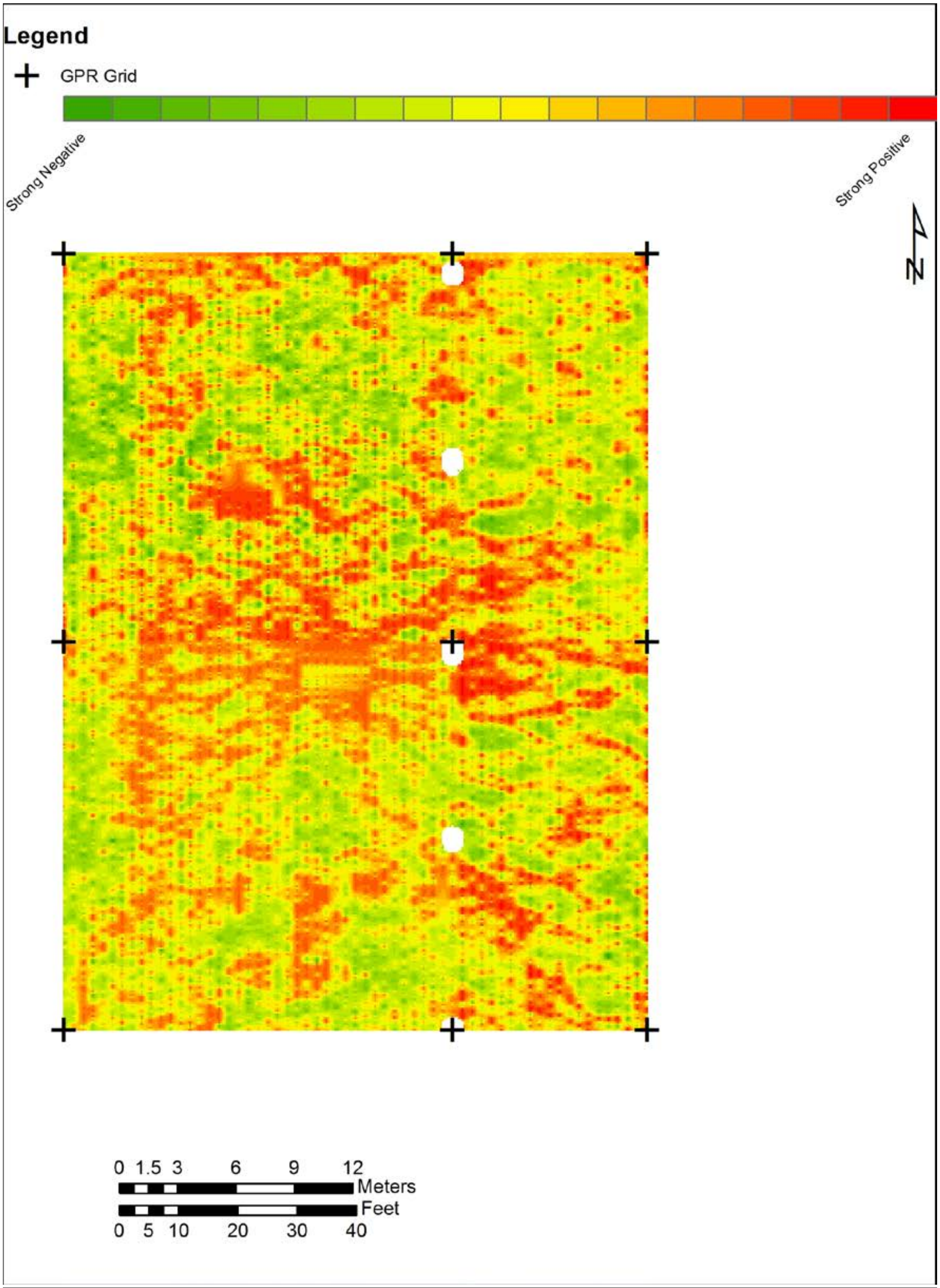

Figure 9: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 21-30 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

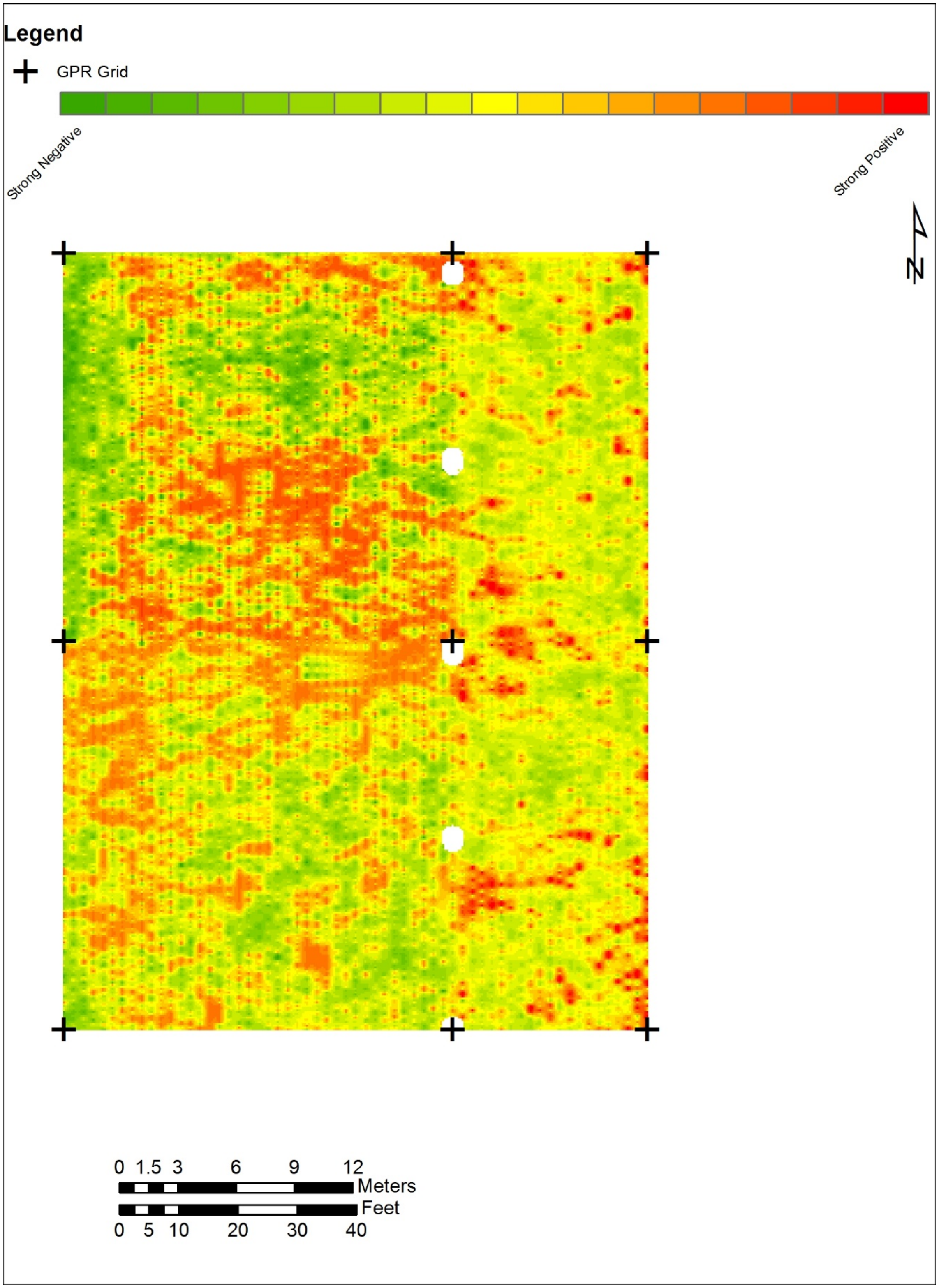

Figure 10: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 31-40 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

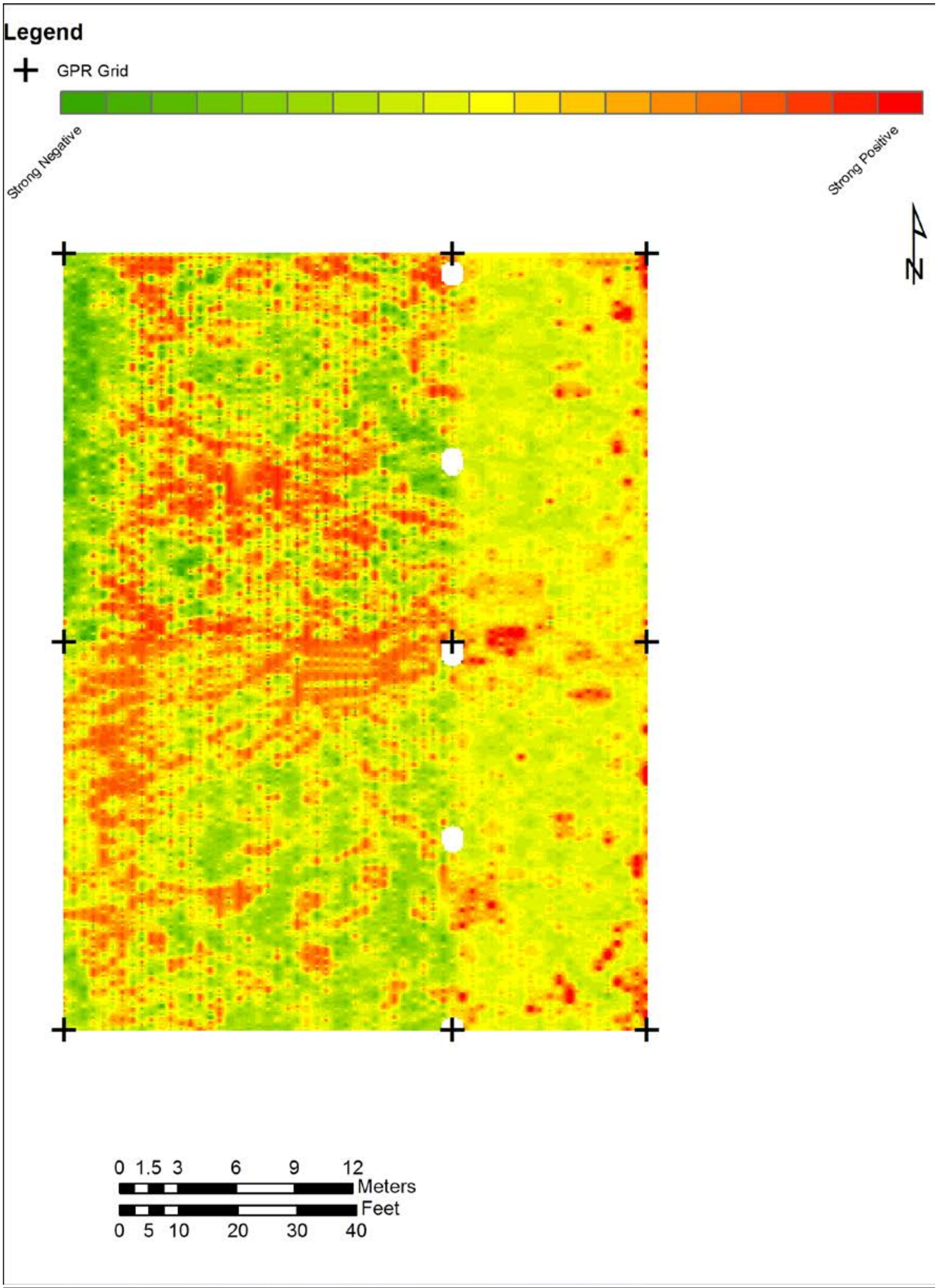

Figure 11: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 41-50 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

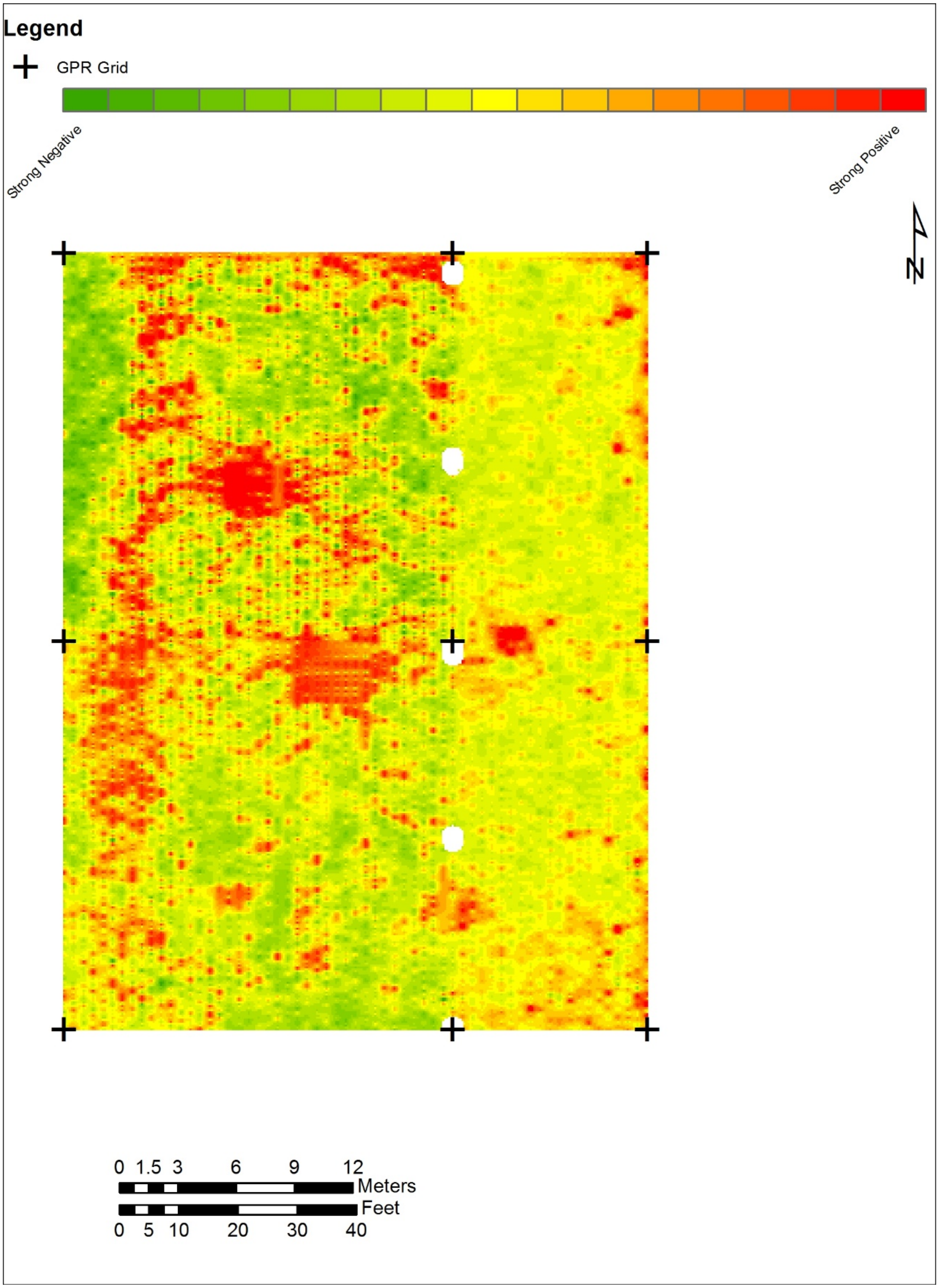

Figure 12: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 51-60 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

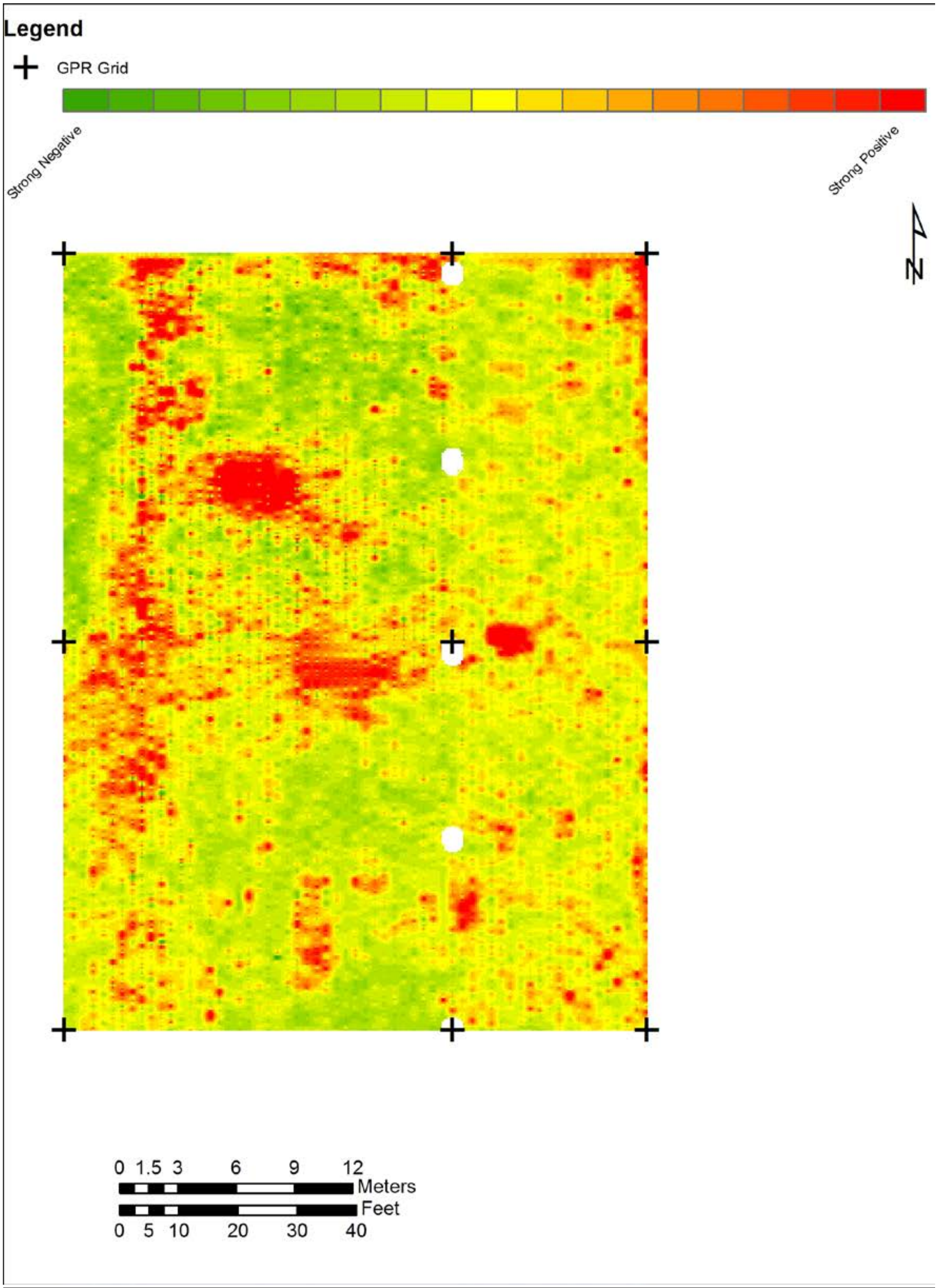

Figure 13: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 61-70 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

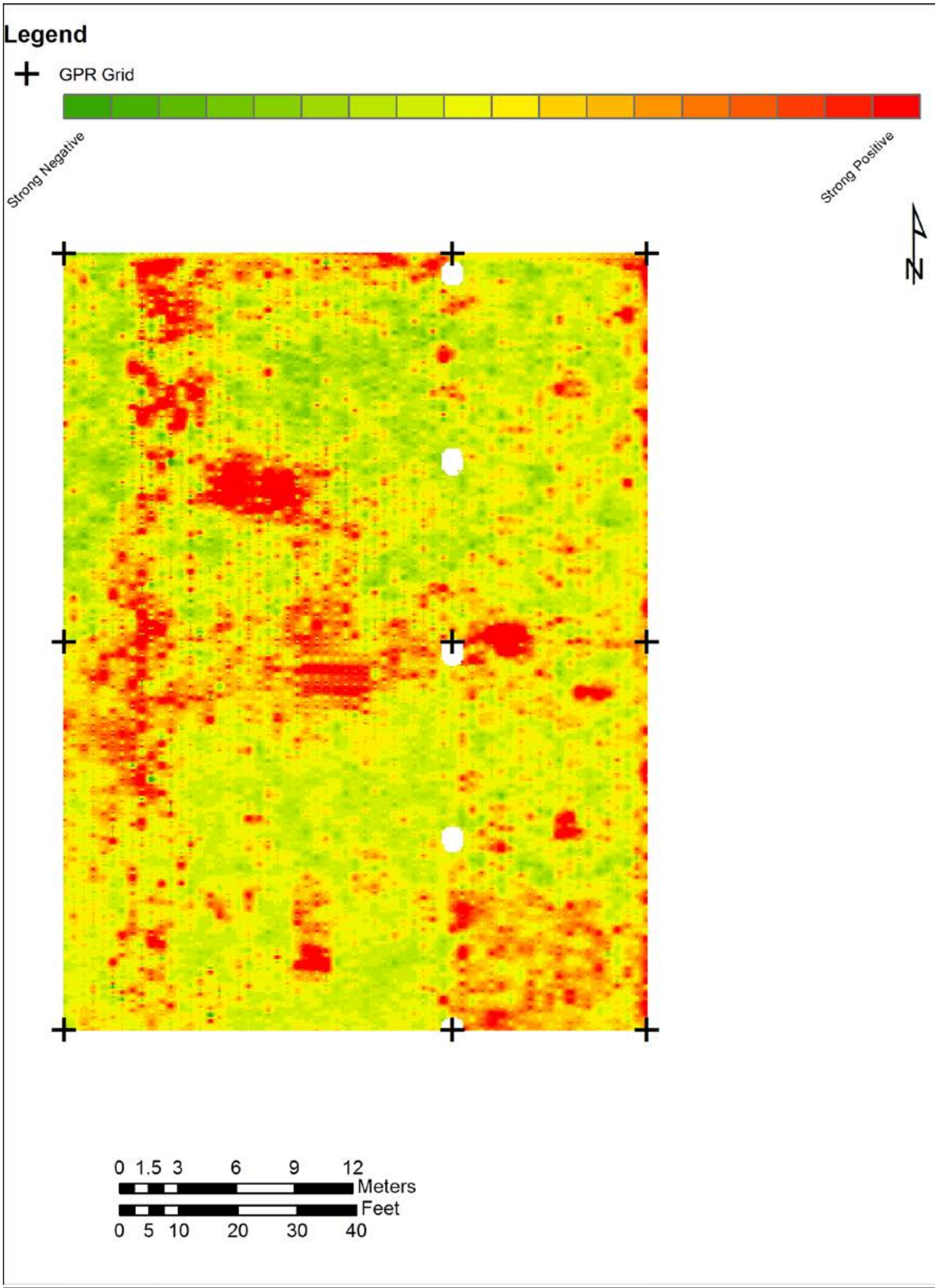

Figure 14: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 71-80 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

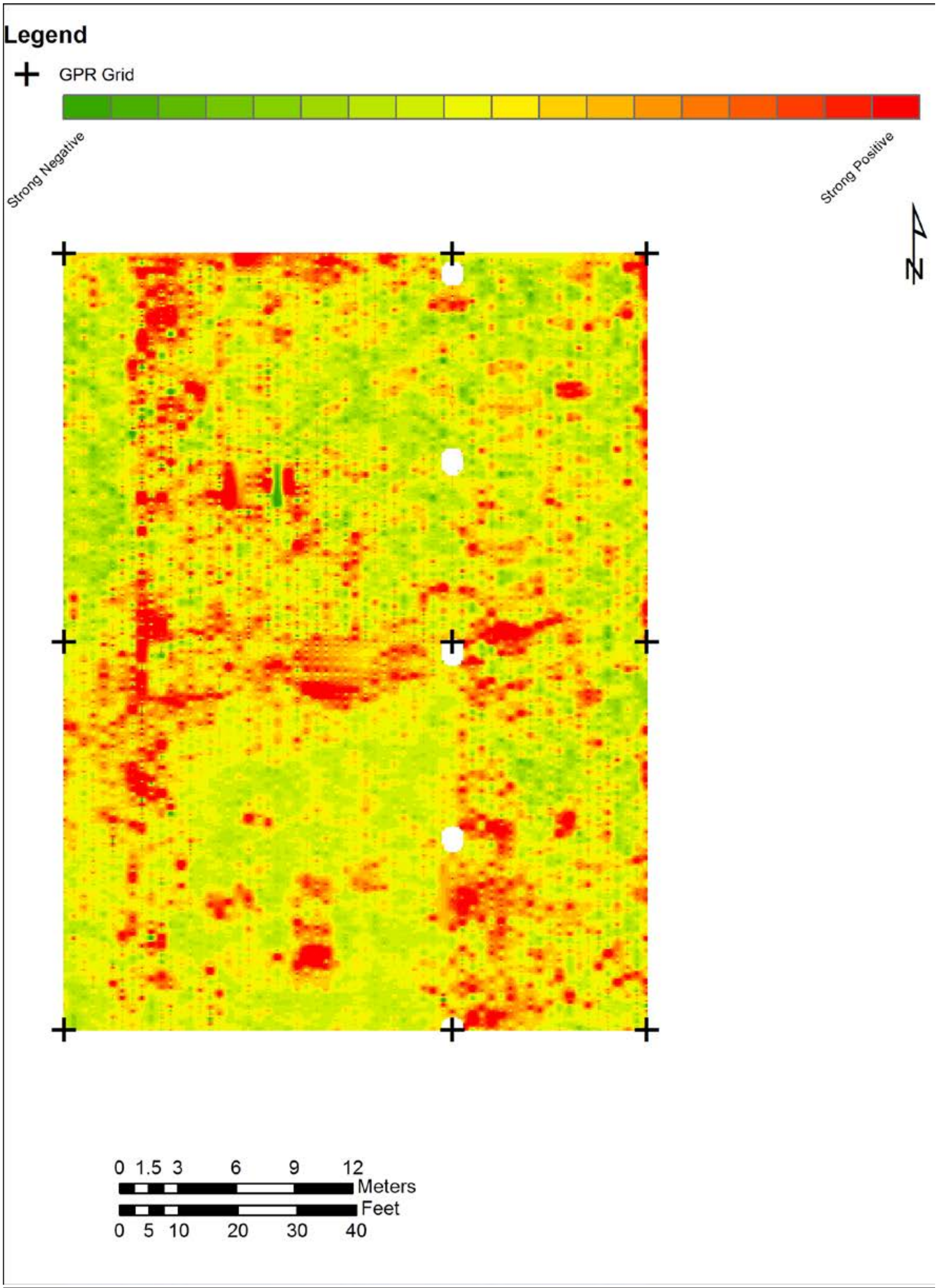

Figure 15: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 81-90 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

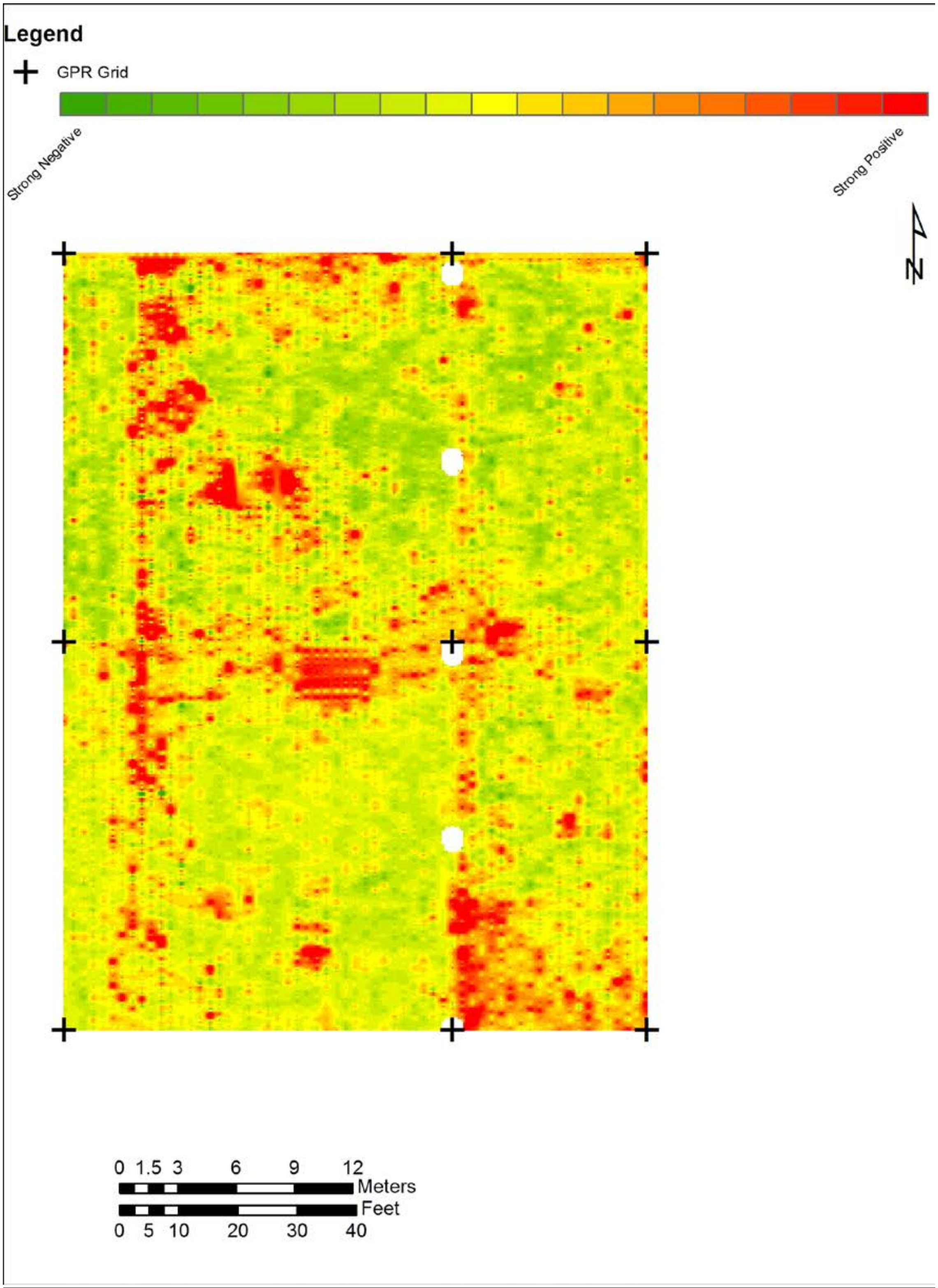

Figure 16: Amplitude Slice Produced by Kriging Interpolation in ArcGIS 10.5 from Exported RADAN 7 Processed Data for 91-100 cm below surface. Amplitude slices represent the most intense signal value from within the slice thickness, either positive, or negative. See Figure 5 for more detailed coordinates within the GPR grid block corners.

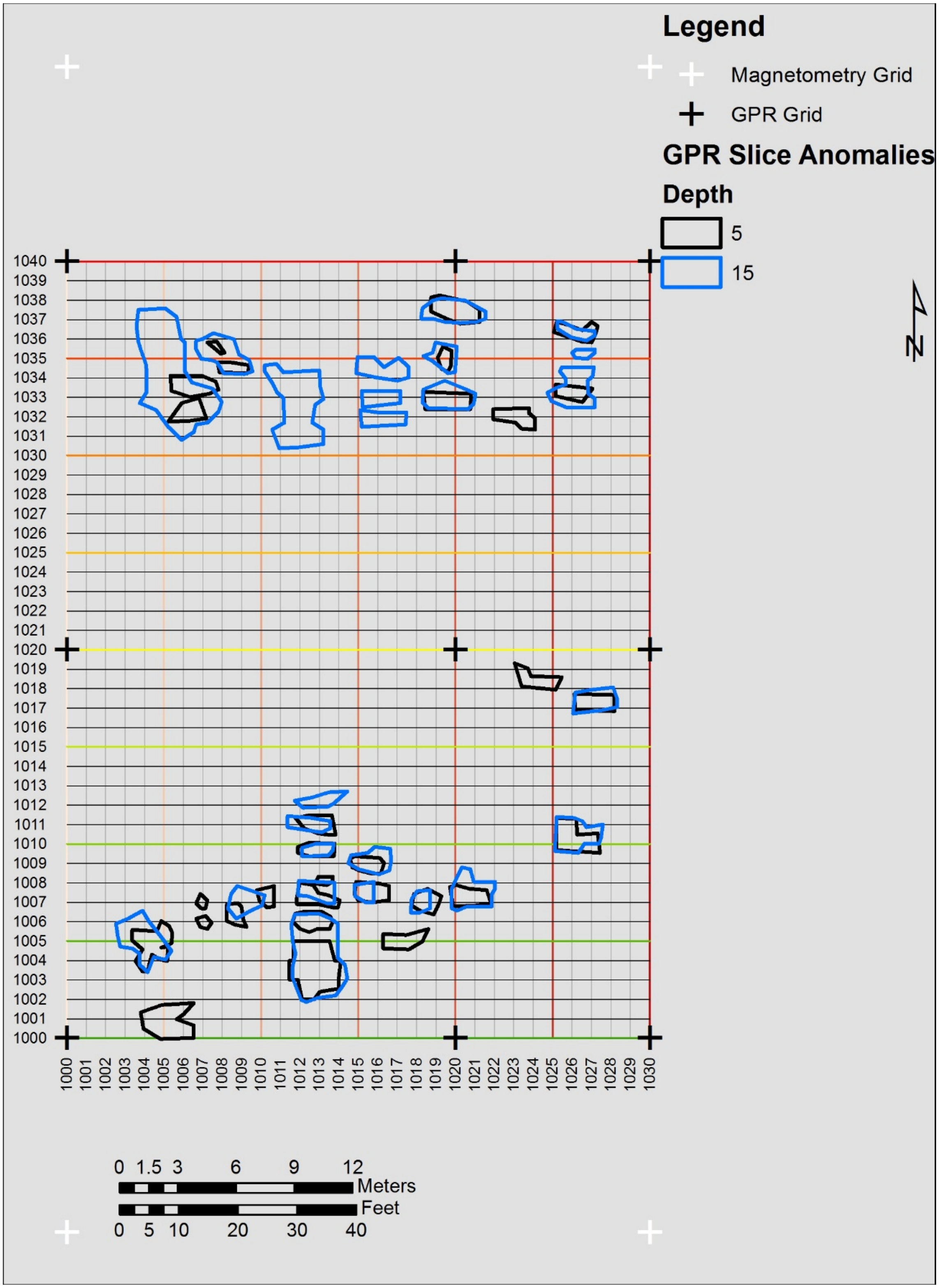

Figure 17: GPR Amplitude Slice Anomalies representing potential Grave shafts.

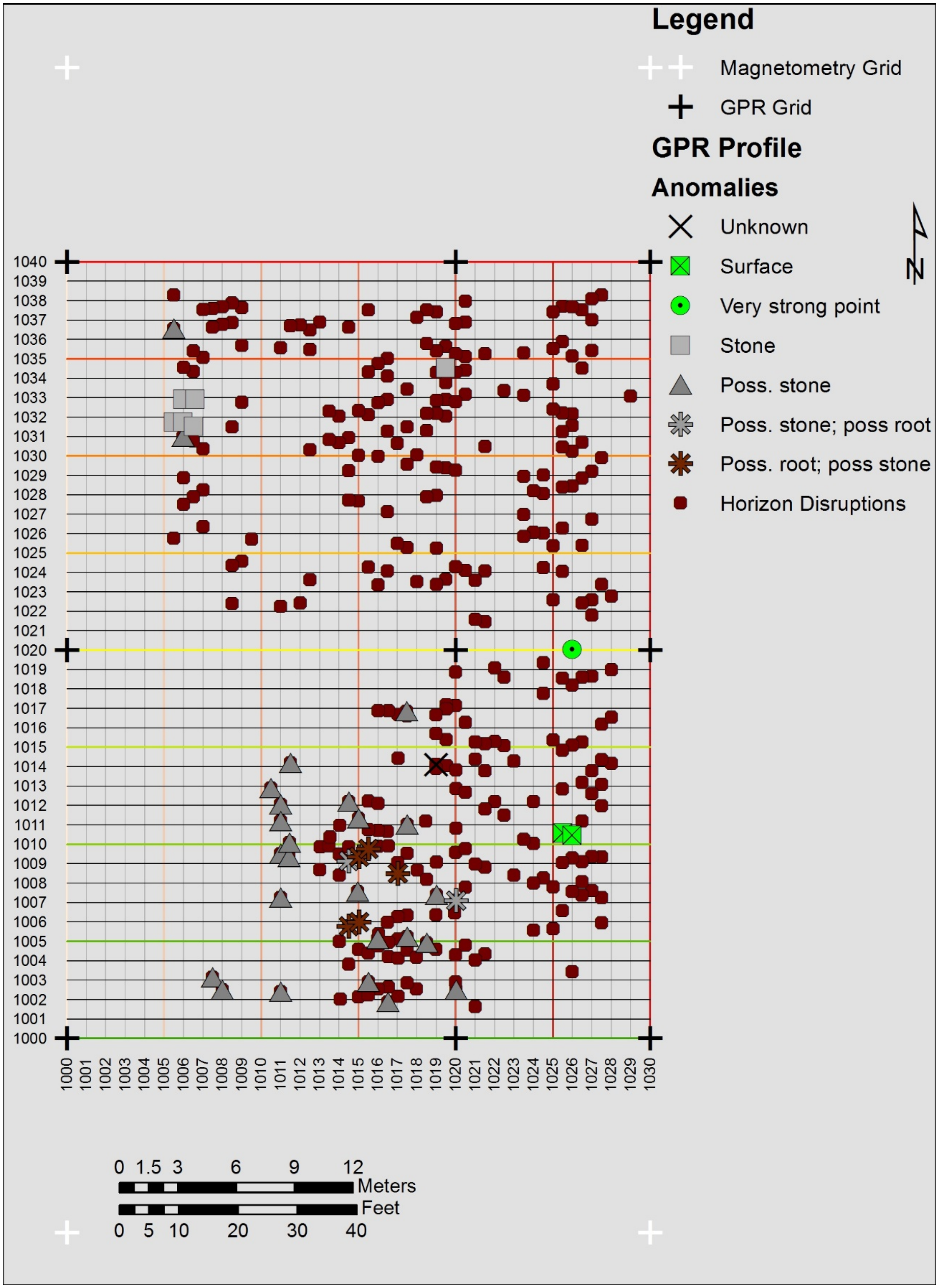

Figure 18: Location of all Point Anomalies extracted from GPR Profiles in RADAN 7.

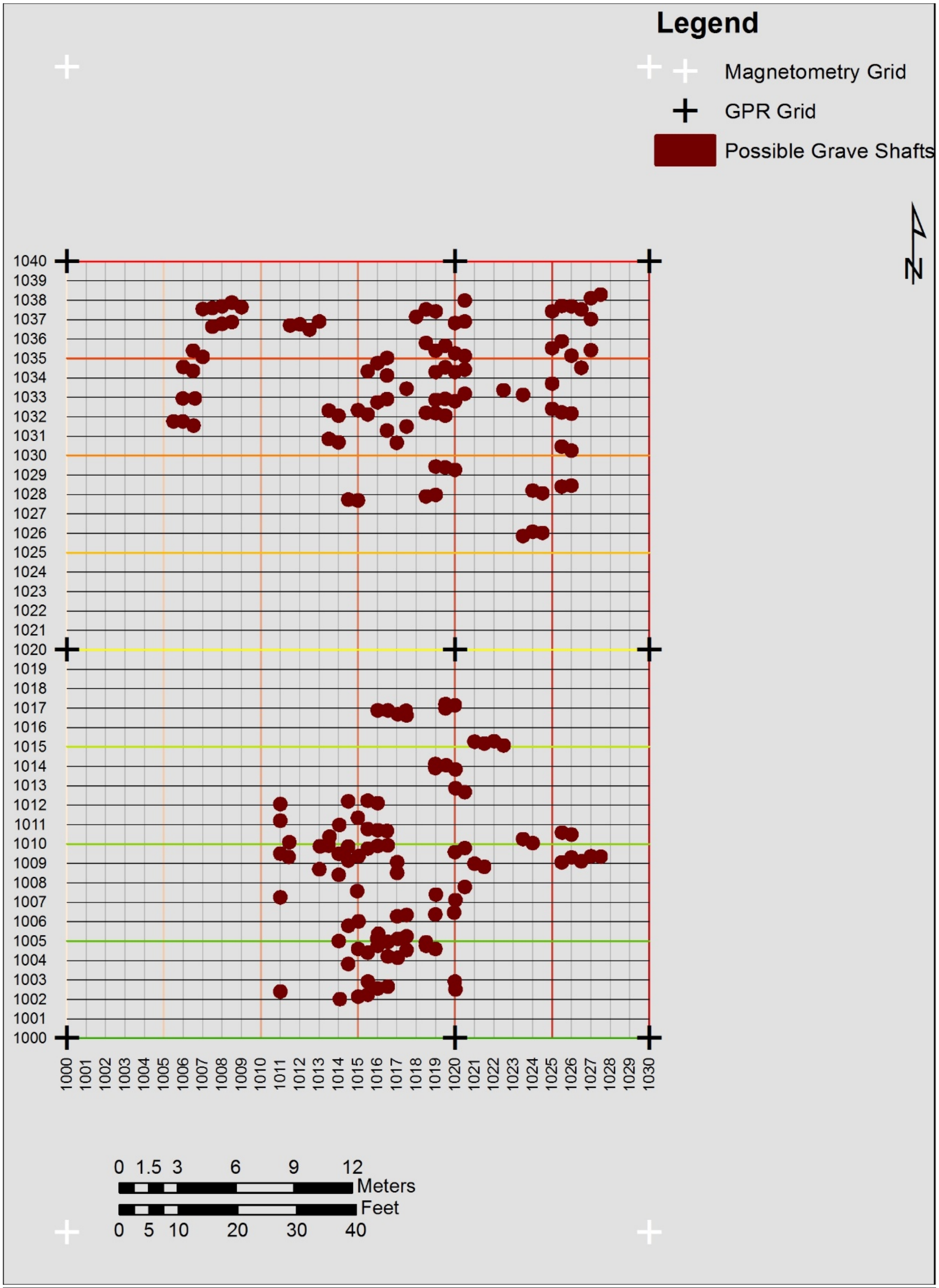

Figure 19: Possible Grave Shafts indicated in GPR Profiles

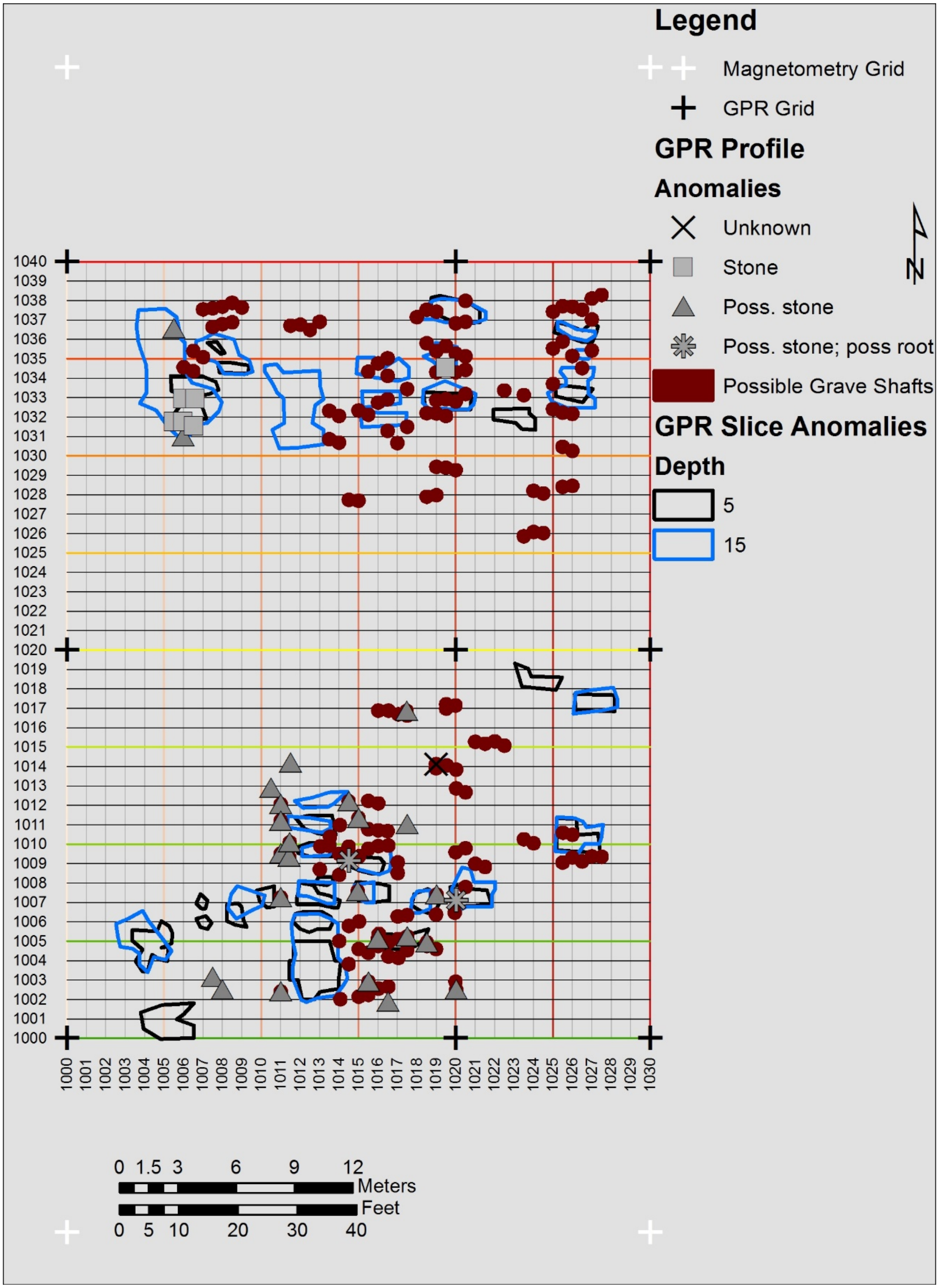

Figure 20: Composite GPR indicated Grave Anomalies.

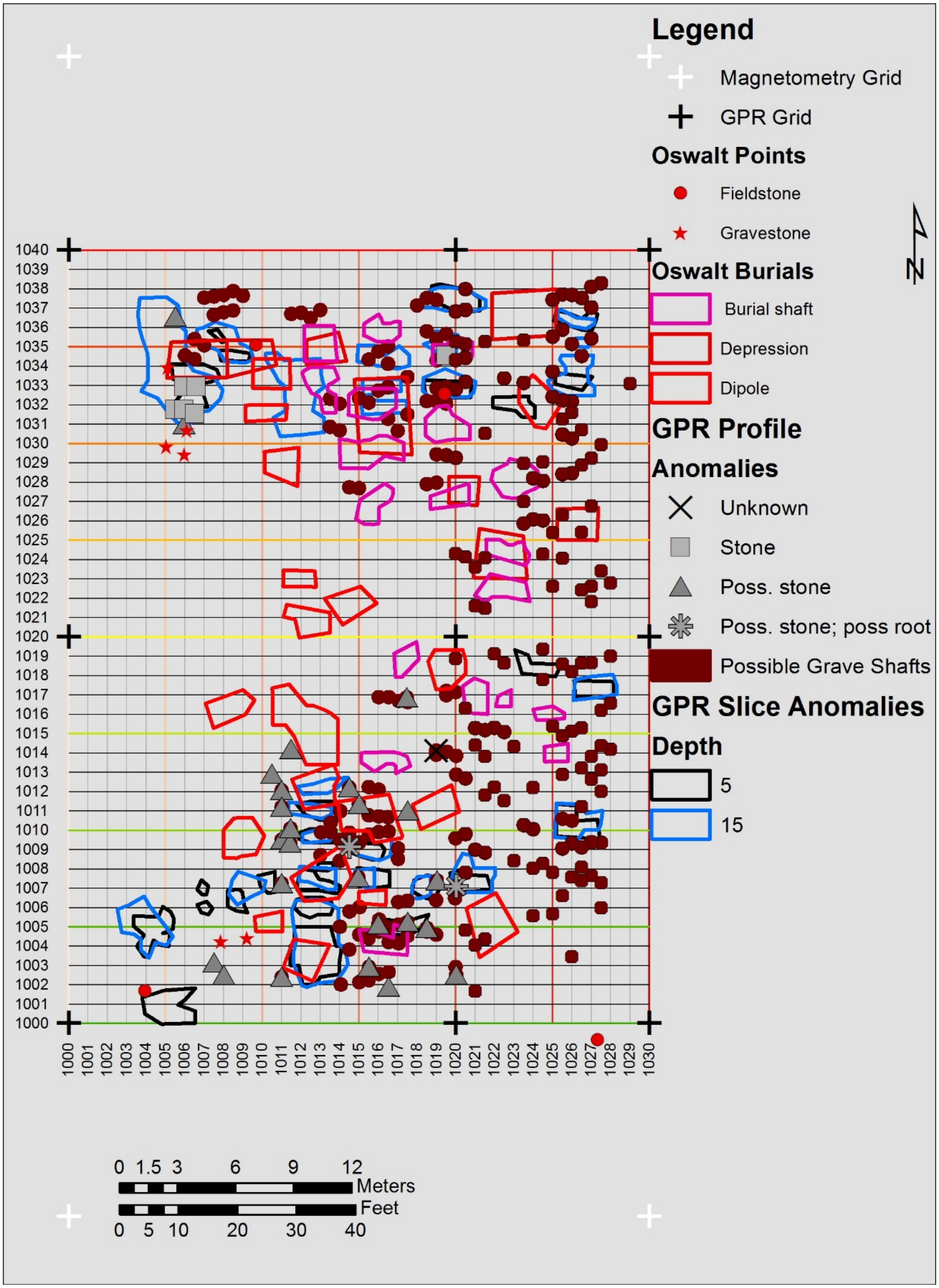

Figure 21: Combined map of magnetometry and GPR potential grave anomalies. Note that the georeferencing of Oswalt's maps onto the current grid is approximate, and there potentially some errors in the locations of the surface mapped (e.g., stones, depressions) features in Oswalt's maps relative to the geophysical data.

Conclusion

The GPR indicates approximately 46-49 interments in the "Colored" Cemetery in Thorntown, Indiana. These graves constitute two clusters. The norther cluster contains 26-29 possible interment in the northern sections of Blocks 2 and 5. The southern cluster contains up to 20 possible interments in the southern portions of Blocks 1 and 4. The results of the GPR survey agree well with and supplement the results of the magnetic gradiometry survey conducted by Oswalt (2013). The combined results of both geophysical surveys indicates a substantial burial population, far exceeding the half dozen extant gravestones and markers. It is hoped that the included maps and grids will aid Reece in locating any remnant stones marking these previously unknown gravesites. However, it is also possible (as noted by Oswalt 2013:24) that no permanent, non-perishable markers were ever present at these now unmarked gravesites.

Works Cited

ESRI

2017 ArcGIS Desktop 10.5.1. Version 10.5.1.7333.

GSSI

2012 RAdar Data ANalyzer for Windows. Version 7.4.16.12090.

Oswalt, Adam

2013 Increased Visibility: Near-Surface Remote Sensing at Thorntown's Colored Cemetery. Unpublished undergraduate thesis, Department of Anthropology, IUPUI, Indianapolis.

Appendix A:

Block 1 query:

("X" > 1000.0001 AND "X" < 1000.46) Or ("X" > 1000.54 AND "X" < 1001) OR("X" > 1001.05 AND "X" < 1001.48) OR("X" > 1001.491 AND "X" < 1002) OR("X" > 1002.0401 AND "X" < 1002.509) OR("X" > 1002.511 AND "X" < 1002.979)OR("X" > 1002.981 AND "X" < 1003.528)OR("X" > 1003.531 AND "X" < 1003.999)OR("X" > 1004.001 AND "X" < 1004.469)OR("X" > 1004.472 AND "X" < 1005.01)OR("X" > 1005.021 AND "X" < 1005.489)OR("X" > 1005.491 AND "X" < 1006.038)OR("X" > 1006.041 AND "X" < 1006.499)OR("X" > 1006.511 AND "X" < 1006.979)OR("X" > 1006.981 AND "X" < 1007.528) OR("X" > 1007.531 AND "X" < 1007.999)OR("X" > 1008.001 AND "X" < 1008.469) OR ("X" > 1008.472 AND "X" < 1009.01)OR("X" > 1009.021 AND "X" < 1009.489)OR("X" > 1009.491 AND "X" < 1010.038)OR("X" > 1010.040 AND "X" < 1010.509)OR("X" > 1010.511 AND "X" < 1010.979)OR("X" > 1010.981 AND "X" < 1011.5289)OR("X" > 1011.531 AND "X" < 1011.999) OR("X" > 1012.001 AND "X" < 1012.469)OR("X" > 1012.472 AND "X" < 1013.019) OR ("X" > 1013.021 AND "X" < 1013.489) OR ("X" > 1013.491 AND "X" < 1014.038) OR ("X" > 1014.04 AND "X" < 1014.509) OR ("X" > 1014.511 AND "X" < 1014.979) OR ("X" > 1014.981 AND "X" < 1015.528) OR ("X" > 1015.531 AND "X" < 1015.999) OR ("X" > 1016.001 AND "X" < 1016.469) OR ("X" > 1016.472 AND "X" < 1017.019) OR ("X" > 1017.021 AND "X" < 1017.489) OR ("X" > 1017.491 AND "X" < 1018.038) OR ("X" > 1018.04 AND "X" < 1018.509) OR ("X" > 1018.511 AND "X" < 1018.979) OR ("X" > 1018.981 AND "X" < 1019.528) OR ("X" > 1019.531 AND "X" < 1020)

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