Title

Final Report of Geophysical Investigations at the Pio Pico Restoration Project, Whittier California

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Final Report of Geophysical Investigations at the Pio Pico Restoration Project, Whittier California

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Geophysical investigations were conducted at four locations within the Pio Pico State Historic Park in Whittier, California. The purpose of the geophysical surveys was to locate and map modern cultural and potential archaeological features for future excavation. Those data could then be integrated with geophysics to produce maps of sensitive archaeological remains to be avoided or excavated prior to park re-development. Field surveys were conducted in March and August, 2001. Three geophysical techniques were employed: ground penetrating radar (GPR), electromagnetic conductivity (EM), and total magnetic field measurement (MAG).

The Site

The Pio Pico adobe is located in Pio Pico State Historic Park in the City of Whittier, California. The State owns 1.2 acres of the site while 2.3 acres of land is leased from the City. According to the survey reports, a rural landscape surrounded the adobe during the historic period when the adobe was built, around 1850. Little of this landscape survives today due to encroachment of the city and on-site development. The site is located on the east bank of the San Gabrielle River about 2 miles south of the Mission San Gabrielle.

The Pio Pico site contains complex soil and geology, as well as a variety of buried archaeological remains. Included are historical features, abundant adobe architecture, and much cultural and geological complexity, related to San Gabriel River terraces, alluvial processes and modern cultural features, including but not limited to sewer and electrical lines. The surveyed area is a little more than 100x100 meters in dimension, and contains a wide range of soil types, vegetation and numerous cultural and landscape changes.

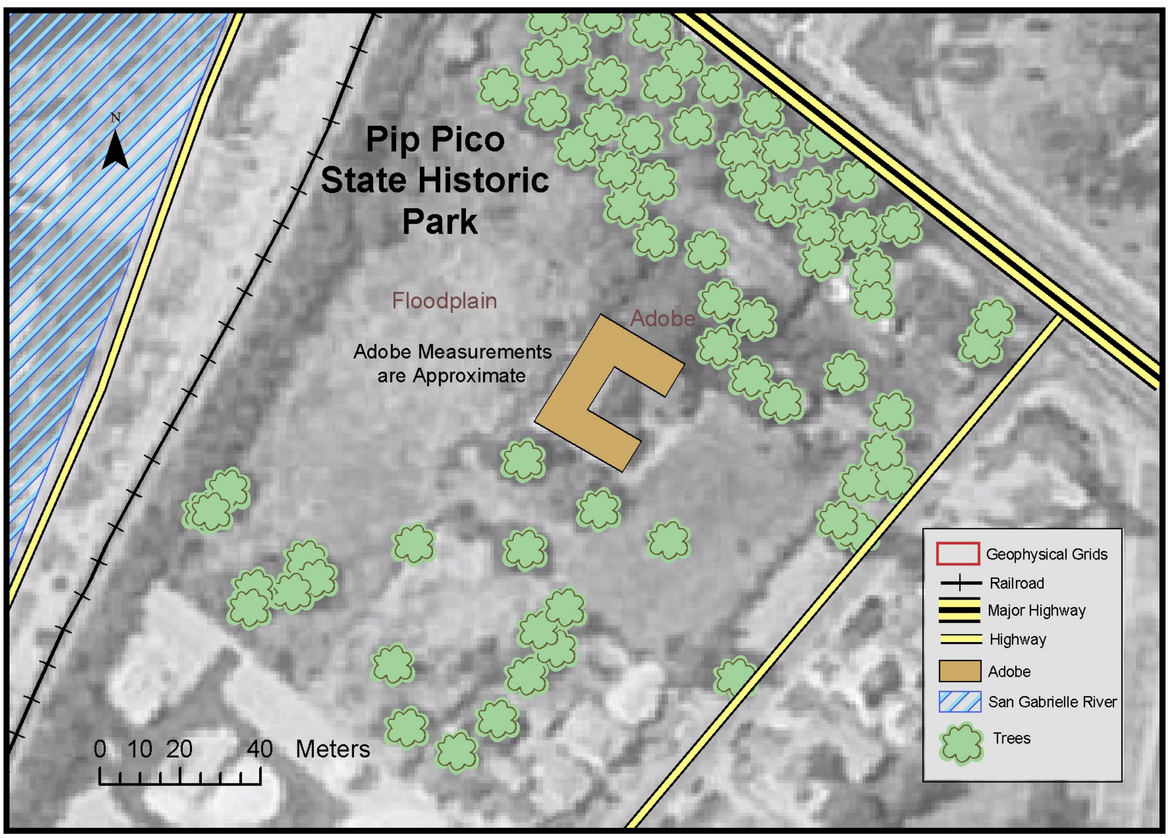


Figure 1
Modern cultural features are sketched in place over an aerial photograph of the Pio Pico State Park.

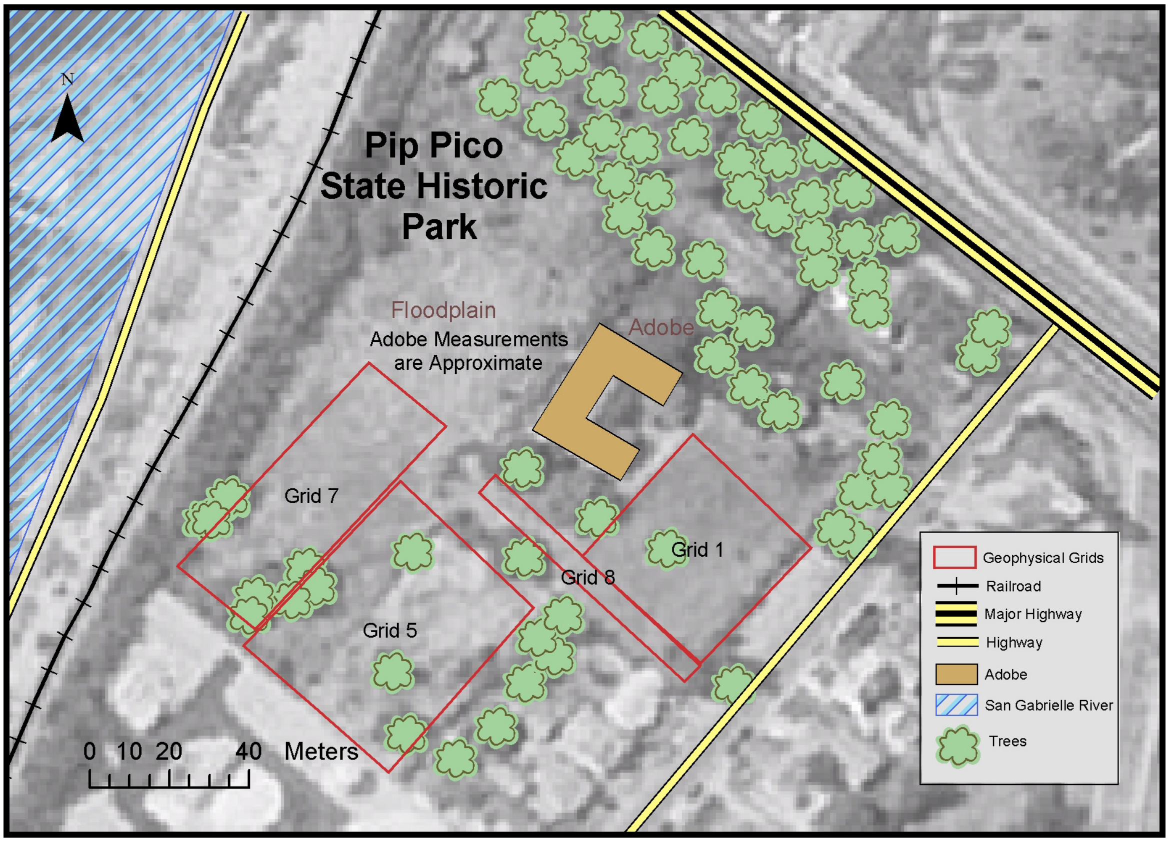


Figure 2
The approximate locations of the geophysical survey grids are mapped on the image.

<u>Grid Measurements</u>
Grid 1 measures 40 m x 40 m.
Grid 5 measures 55 m x 46 m.
Grid 7 measures 25m x 100m.
GPR survey of Grid 7 measures 25m x 40m.
Grid 8 measures 6m x 70m.

Geophysical Techniques

Each geophysical technique has certain advantages and limitations based on the soil types and features to be discerned. Ground penetrating radar, for example, works best in soils that are relatively dry and low in salt and clay content. Radar frequency and equipment selection can sometimes be adjusted for these limitations. In addition, the degree of contrast between buried features and their surrounding physical environment is measured by the radar data. If the archaeological materials are similar physically and chemically to the surrounding environment, they will be difficult to identify with radar. Additional "noise" and varying degrees of clarity in the results of the GPR survey can make interpretation difficult.

Electromagnetic Conductivity (EM) induces a field into the ground and measures its response to changes in the physical and chemical properties in soils and buried features. Data can be collected over a variety of soil types, not being limited to only certain conditions, as is GPR. Buried metal objects, which are very electrically conductive, will highly alter the readings from the surrounding soils, effectively overwhelming the more subtle readings of buried cultural materials.

Magnetics measures subtle variations in the Earth's magnetic filed, which is affected by buried magnetic materials in the ground. Pipes and other recent metallic cultural materials can overwhelm the more subtle magnetic features, in much the same way as in the EM method.

Any one method of geophysical survey may only be analyzing part of the geophysical data that can be recovered. As a result, many researchers are beginning to understand the importance of integrating multiple geophysical databases. Employing other geophysical techniques such as magnetic and geoelectric surveys can assist in providing additional information which can complement GPR. At Pio Pico three types of geophysical surveys, ground penetrating radar (GPR), electromagnetic conductivity (EM) and total magnetic field (MAG), were conducted and integrated using geographic information systems (GIS) technology.

Ground Penetrating Radar (GPR)

Ground-penetrating-radar surveys reflect radar waves off sub-surface features. The velocity of the wave and the amplitude of the reflected waves change depending on the electrical and magnetic properties of the materials through which they pass. Anomalies in the resulting waves are identified, mapped, and studied in three dimensions.

Ground penetrating radar transmits high frequency electromagnetic energy into the ground and measures energy reflected from buried interfaces, such as between soil and rock or wood. GPR is a means for delimiting buried site stratigraphy, and objects or structures that disrupt the natural stratigraphy. In the Pio Pico study area, we used a GPR unit manufactured by GSSI (SIR-2000) with a 400 MHz antenna. Maximum depth of penetration was about 1.5 m. with a resolution to about 20 cm.

GPR data were collected at 16 scans/second as the radar antenna was moved along the ground surface at walking speeds. Grids of data were collected with .5m line spacing. A series of maps of radar reflectivity were produced at various depths, called time-slices. Data were collected within a total time window of 30 (ns) nanoseconds from the surface, and were divided into 7 ns time-slices for display (0-7 ns, 7-14 ns, 14-21 ns, and 21-28 ns), each of which is approximately 30cm. depth. The radar data were gridded with a large search radius to filter out clutter, and to emphasize the largest features.

The time slices were created in a software program that aligns the collected vertical traces in a grid. Then, depth slices are created by averaging a range of values between a specified time range on each trace. The averaged values are then mapped into a XYZ format in which the X and Y values describe position in the grid and the Z represents the averaged value for the range. The XYZ data were then mapped in imaging software to view.

Figures 3-6:
The colors in the image represent the averaged Z values, which are the amplitudes of reflected waves. Mapping the data helps see patterns in the data and identify geologic and cultural features under the surface. The red in the following maps indicates a high reflected amplitudes while the blue and green colors are areas of relatively homogeneous soils.

The GPR survey of grid 7 covers a smaller area than those in the EM and MAG surveys. The entire grid 7 is outlined in red on the maps and the image from the GPR survey is placed correctly in that grid.

The dark rectangle in grid 5 represents a break in the survey data. A wagon was located in that area, blocking access by all geophysical tools.

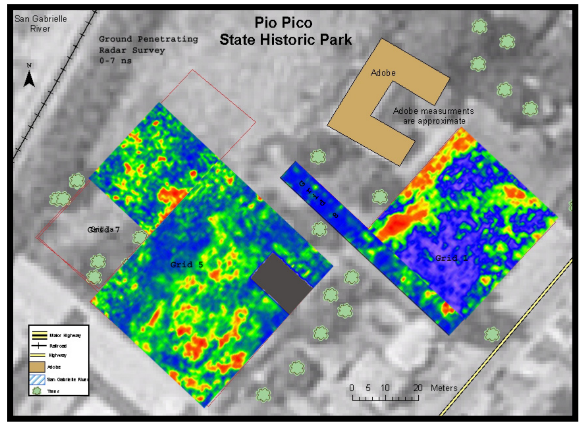


Figure 3
GPR survey results. These images represent horizontal slices of the data between 0-7ns or 0-30 cm.

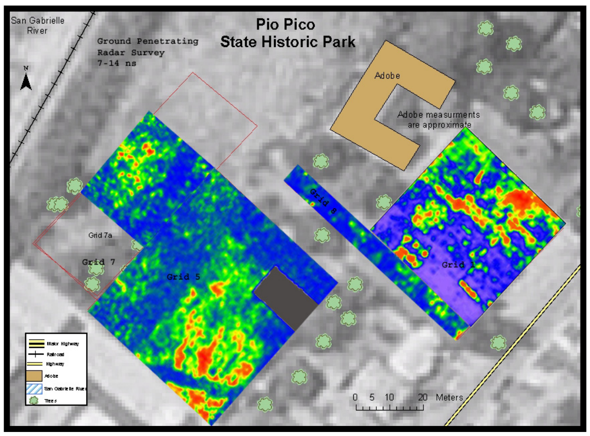
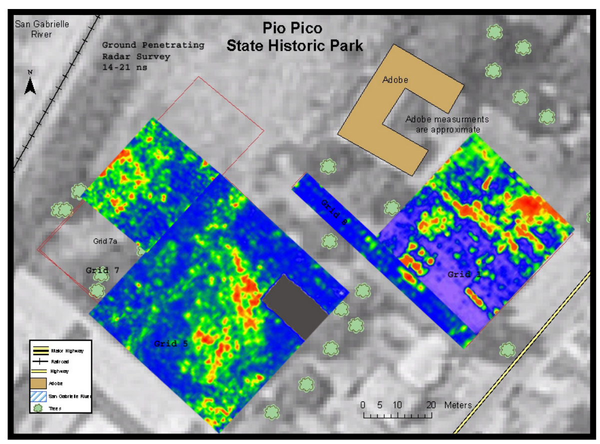


Figure 4
GPR survey results. These images represent horizontal slices of the data between 7-14ns or 30-60 cm.



Figures 5
GPR survey results. These images represent horizontal slices of the data between 14-21 or 60-90 cm.

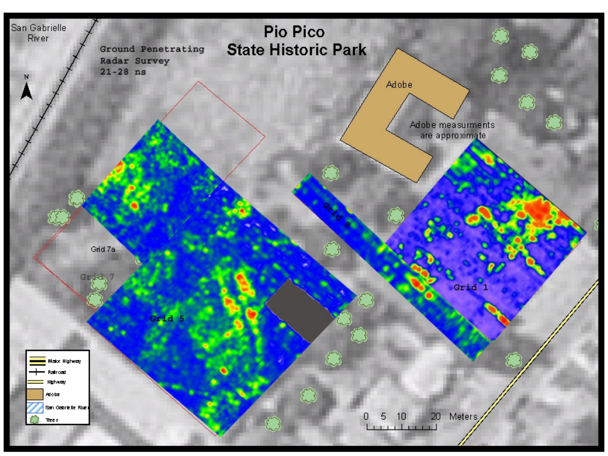


Figure 6

GPR survey results. These images represent horizontal slices of the data between 21-28 ns or 90-120 cm.

Total Magnetic Field (MAG)

Magnetic methods measure small changes in the earth's magnetic field intensity. In addition to identifying objects made of iron, this technique is useful in identifying fired materials and structures such as bricks and kilns. Organic materials that are found in pits or ditches, solid walls, tombs, and roads that exhibit differences in magnetic intensities can also be detected. Magnetic survey results are often "contaminated" by metallic debris and igneous minerals necessitating both filtering and advanced interpretation techniques. Results vary depending on the nature of the soils, the orientation of the buried features, changes in the earth's magnetic fields, depth of burial of features, and the latitude of the study area.

At Pio Pico a Geometrics magnetotometer was used with two sensors located about 1 meter apart vertically. Data were collected continuously in transects 1 meter apart.

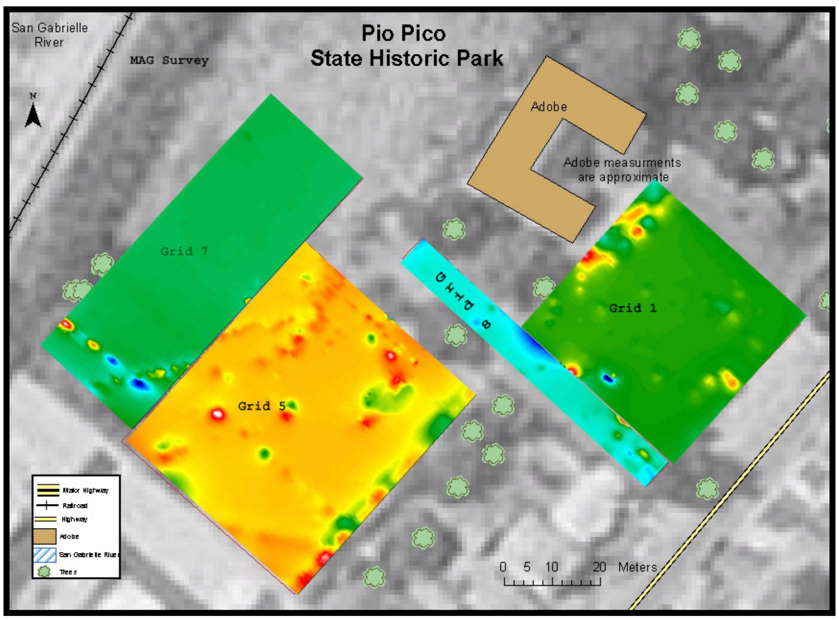


Figure 7
MAG survey images. The metal features are apparent in the images as bright red, yellow and blues that stand out from the background. The image is dominated by the metallic features.

Electromagnetic Conductivity

In Electromagnetic Conductivity, or EM, an electromagnetic field is propagated into the ground from a source on the surface. A second instrument measures the earth's response to that field. The electrical and magnetic properties possessed by a feature determine its conductivity. Highly resistant features, such as stone walls and foundations, often possess low conductivity, dependent on their composition. Low resistivity features, such as moist organic fill, are highly conductive. Anomalies in the survey results suggest the boundaries between media with different properties. This device is complementary to ground penetrating radar because it works well in conductive soils while radar works best in resistant soils.

EM ranges: EM 38 has maximum exploration depth of about 1.5 m with a maximum sensitivity at .4m depth or 40 cm.

The system used was a Geonics EM-38. Data were collected continuously every .4 seconds in transects located 50 cm. apart. A 50 meter transect would on average contain more than 400 individual readings.

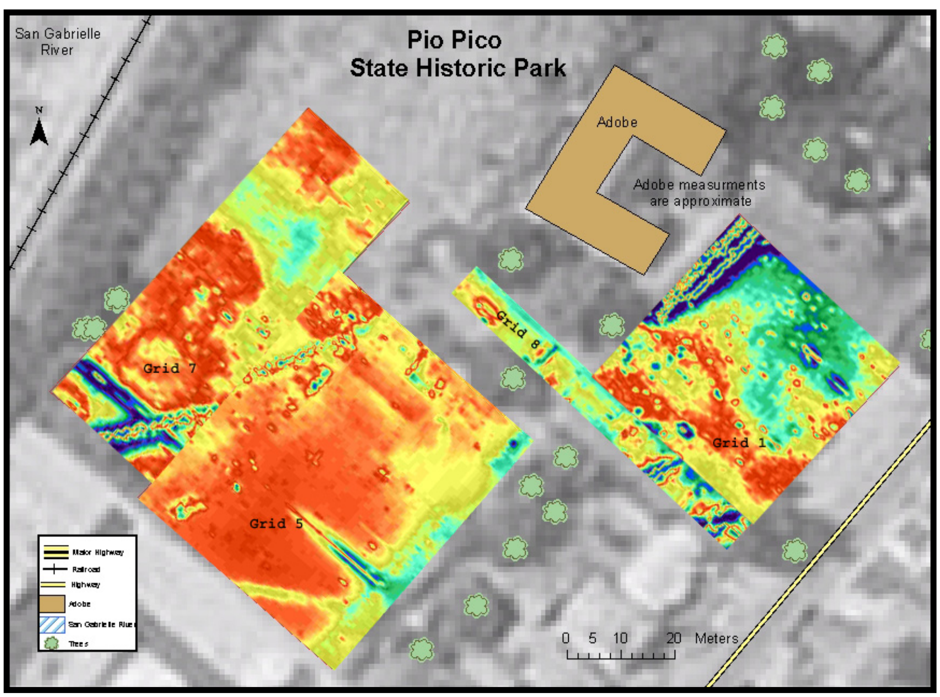


Figure 8 EM survey results. The metal features are still visible but so are other , possibly non-metallic, features. The blue features represent reflections off metal features. The red possibly represents more compacted soils, foundations or asphalt.

Geophysical Integration

The geophysical data collected by GPR, MAG and EM, are processed into a database of XYZ coordinates, with the X and Y defining a coordinate position and the Z value representing a number that describes the characteristics of that point as defined by the particular survey technique. For example, in GPR, the survey returns values that are measurements of the time it takes the radar wave to travel through the earth and return and the amplitude of the waves. Since the three geophysical methods measure different qualities, the z values need to be normalized so they can be integrated together in a meaningful way.

The purpose of collecting data from three different geophysical survey methods is to integrate them together to get a more precise composite image of the sub-surface. The approach used in this analysis weighs each method, MAG, EM and GPR, with a % value in the IDRISI geographic information systems application. For example, depending on the specifics of the survey objectives and the soil composition, the GPR survey could be assigned to represent 50% of the final image while the MAG will represent 30% and the EM only 20%. The final image then, will weigh the results of the GPR survey heavier, but all surveys will be accounted for. For Pio Pico, the metal pipes are clearly identified by all three survey methods. The MAG and EM are better than the GPR in identifying the metal features in the soils. The GPR is better at identifying the non-metallic features at the site. In some cases, the EM and MAG do pick up the non-metallic features somewhat. In the integration process, the metal is weighted less and the non-metallic features are enhanced if more than one survey can identify it.

Each geophysical survey was processed in IDRISI to weight the strengths of each method and standardize the results. Next, the results of all three methods were added together to create a fourth image that better defines geophysically the important features identified by all methods in each grid.

The data was first processed with as little as possible manipulation of the originally collected values. To maintain the integrity of the data set, the mathematical computations and integration were performed on the XYZ data set before the images were produced

The EM and MAG surveys produce results in two dimensions. Depth is not known, but can be estimated based certain parameters for each system. Because of this limitation, the GPR depth slice (labeled 7-14 ns, etc) was used because it correlates closest with the maximum sensitivity range of the other two surveys.

Archaeology

The archaeological data was provided by Herb Dallas for unit 12, located in grid 5. The data were recorded in a unit level book describing location and type of features found as well as soil characteristics and tools used, by level. Each level is 10 cm in depth.

The global positioning data, used to place each grid and the archaeological data into space was of poor quality, and of limited value. In general the archaeological data supports the claim that much of the site contains metallic debris, either from trash deposits or modern electrical and plumbing materials.

Global Positioning System (GPS)

A global positioning system survey was conducted several times to map the coordinates of grid corners, excavation units, and auger test holes. The GPS unit accuracy was not sufficient to accurately map this site. The precise locations of the features mapped needed to be within an accuracy of less than .5 meter, ideally within centimeters. Unfortunately, at best, the survey data is within 2-3 meters. This error is too great to accurately map the features. Consequently, the maps and features are only approximated to their true locations based on measurements, field notes, and the GPS points. The distortion is apparent in the locations of grid corners, auger holes and excavation units in all the maps produced in the report.

Auger Hole Tests

Auger log reports compiled by Herb Dallas were summarized in tables and charts in an effort to understand the soil composition by depth at various locations in grid 1 and grid 5. Only in grids 1 and 5 was there auger hole documentation provided.

Results

Grid 1 Analysis

Grid 1 measures 40 m x 40m. Some auger data as well as the three geophysical survey techniques provide information for this portion of the analysis.

Auger Tests in Grid 1

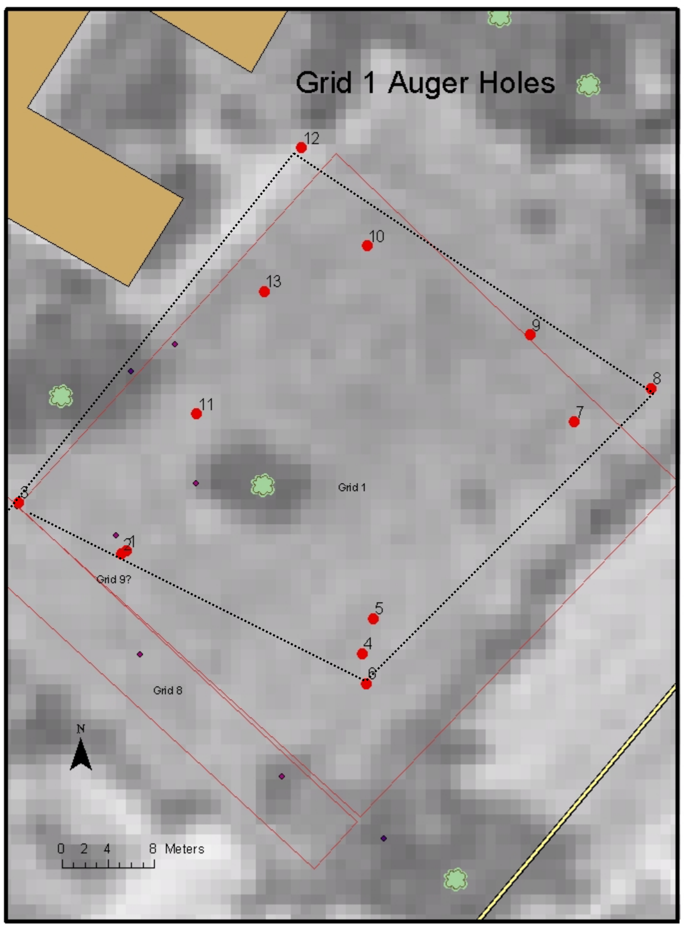


Figure 9
Note that the GPS points that define the grid (dotted lines drawn between GPS points that should define corners) do not match with the grid drawn on the map. Error in the accuracy of the GPS survey is the reason for the inaccuracy of position. The GPS points were collected with 2-3 meter accuracy at best.

Based on the auger data provided by the Herb Dallas, a description of the soil and sediment at various depths is possible.

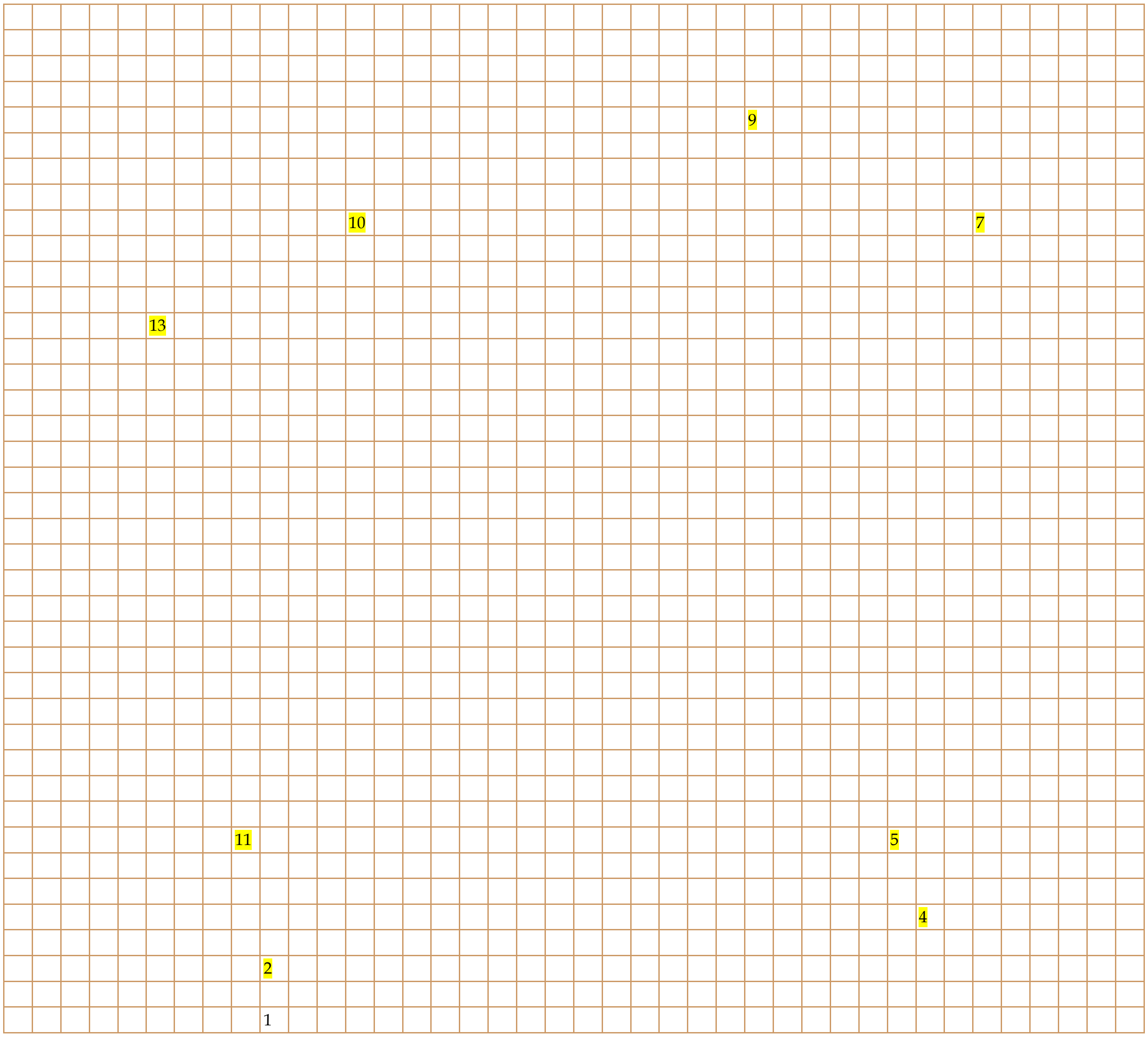


Figure 10
This sketch of grid one illustrates the locations of the auger holes. These auger hole results help describe the soil characteristics of grid 1 at 10 cm depths. This information may indicate which geophysical surveys will be most successful in identifying buried features.

Grid 1
40m x 40 m

Auger Holes
1 = 40 S, 11 E
2 = 38 S, 11 E
4 = 35 S, 33 E
5 = 32 S, 32 E
7 = 7 S, 35 E
9 = 4.5 S, 27 E
10 = 8 S, 13 E
11 = 32 S, 9 E
13 = 12 S, 6 E

Overview of Soil Analysis in Grid 1 by Depth

Summary:
In the top layers the soil is dark brown, sandy silt. As depth increases soil gets dryer, sandier, lighter in color, and more compact, turning to clay in some locations. At 10-20 cm. asphalt is consistently found throughout the grid. Most cultural features were found between 30-40 cm.

Tables 1-10 summarize the auger hole test results by depth. A general description of the soil composition at 10 centimeter depths follows.

Detail of Auger Hole Results by Depth

Depth	**Auger Hole**	**Soil Characteristics (from auger logs)**	**Cultural Evidence**
0-10 cm	1	Dark brown, sandy silt	Small amount of brick
	2	Dark brown , sandy silt; 3-5% gravel content; grass, roots	
	4	Dark brown, sandy silt; grass roots	
	5	Moist, dark brown, sandy silt; grass and duff	
	7	Dark brown sandy, silt; 3-5% gravel content; small root and grass	
	9	Dark brown sandy, silt; grass, roots	
	10	Moist, dark brown sandy silt; grass; roots	
	11	Dark brown, sandy silt; 3-5% gravel content, grass, roots	1 piece of asphalt
	13	Dark brown sandy silt; 5% gravel content	

Table 1
General description of layer 0-10 cm in Grid 1:
Dark brown sandy silt, moist, 3-5% gravel content; some grass and roots; few cultural artifacts consisting of only brick and asphalt.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
10-20 cm	1	Dark brown, sandy silt	Paper, brick
	2	Dark brown , sandy silt; 3-5% gravel content; large cobble	Lots of asphalt
	4	Dark brown, sandy silt	Asphalt
	5	Moist, dark brown, sandy silt	Asphalt
	7	Dark brown sandy, silt; 3-5% gravel content	1 asphalt chunk
	9	Dark brown sandy, silt; a few pebbles; 3-5% gravel content	1 small fleck of charcoal
	10	Moist, dark brown sandy silt; 3-5% gravel content	1 fleck of asphalt, small fleck of charcoal, 1 piece of brick
	11	Dark brown, sandy silt; 3-5% gravel content	1 piece of asphalt
	13	Dark brown sandy silt; 5% gravel content	Brick piece, small amount of mortar, bone

Table 2
General description of layer 10-20 cm in Grid 1:
Continuation of dark brown sandy silt, 3-5% gravel content. Asphalt consistently found in layers at this depth. Some bone and charcoal.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
20-30 cm	1	Soil is more compact, sandy, and dry	Bone, asphalt
	2	Sandier soil,	Small flecks of asphalt
	4	Sandier soil, roots	Small asphalt pieces
	5	Change in soil to silty sand – same color; roots	Asphalt
	7	Dark brown sandy, silt; 3-5% gravel content	Asphalt
	9	Sandier Soil, less compact	
	10	Moist, dark brown sandy silt; 3-5% gravel content	1 piece of metal, 1 piece of brick, 1 ceramic fragment, 1 fleck asphalt
	11	Soil become less compact and sandier	1 piece of clear glass
	13	Dark brown sandy silt; 5% gravel content	Cut bone, cement

Table 3
General description of layer 20-30 cm in Grid 1:
Drier sandier soil than in the upper 20 cm, more compact soil. Asphalt still dominates cultural features.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
30-40 cm	1	Soil is more compact, sandy, and dry	Metal pieces
	2	Lighter, grey and more compact soil	Small metal fragments
	4	Sandier soil	Small asphalt pieces
	5	Silty sand; roots	Snail shell
	7	Clay soil with red color	Asphalt, plastic or mica, square nail
	9	Sandier Soil, less compact	1 piece of embossed, aqua glass, 1 piece of charcoal, 1 chert flake
	10	Sandier soil	1 piece of bone
	11	Soil become less compact and sandier	1 piece of brick
	13	Dark brown sandy silt; 5% gravel content	Small amount of asphalt

Table 4
General description of layer 30-40 cm in Grid 1:
Drier, sandier soil than in upper 20 cm, more compact soil. More cultural features identified in this stratum. Metal, bone glass, charcoal, brick and asphalt are among the artifacts.

Depth	**Auger Hole**	**Soil Characteristics (from auger logs)**	**Cultural Evidence**
40-50 cm	1	Soil is more compact, sandy, and dry	1 piece of ceramic with maker's mark
	2	Lighter, grey and more compact soil	White ceramic fragment
	4	Sandier soil	Brick, bone
	5	Silty sand; roots	
	7	Sandier soil, larger pebbles	Cement, wire nail, staple
	9	Sandier Soil, less compact	Small flecks of asphalt
	10	Sandier soil	1 piece of asphalt, 1 piece of brick
	11	Soil increasing in clay content	
	13	Dark brown sandy silt; 5% gravel content	

Table 5
General description of layer 40-50 cm in Grid 1:
Moving to more clay content of soil. Some ceramics, but fewer overall cultural feature or artifacts were identified.

Depth	**Auger Hole**	**Soil Characteristics (from auger logs)**	**Cultural Evidence**
50-60 cm	1	Soil is more compact, sandy, and dry	Lots of plastic, some metal, string
	2	Lighter, grey and more compact soil	
	4	Sandy soil	Asphalt, mortar
	5	Silty sand	
	7	Sandy soil, larger pebbles	Charcoal, mortar, brick
	9	Sandy Soil, less compact	
	10	Sandier soil	
	11	Soil is mostly sand, lighter in color, and dry	
	13	Sandier soil	

Table 6
General description of layer 50-60 cm in Grid 1:
This layer consists of more sandy soils and dry. Very few cultural features or artifacts were found.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
60-70 cm	1	Very sandy	Lots of plastic
	2	Lighter, grey and more compact soil	
	4	Sandy soil	
	5	Silty sand	
	7	Light tan sandy soil	Aphalt, mortar
	9	Soil slightly lighter in color	Small flecks of charcoal and asphalt
	10	Sandier soil, more compact, some roots	1 piece of asphalt
	11	Dry, light tan soil with small amount of clay content	
	13	Sandy soil	

Table 7
General description of layer 60-70 cm in Grid 1:
This layer consists of more sandy soils and dry. Very few cultural features or artifacts were found.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
70-80 cm	1	Very sandy	Electric fuse, plastic, string
	2	Lighter, grey and more compact soil	Small flecks of charcoal, small pieces of metal, steel wool scrub pad material, wood
	4	Sandy soil	
	5	Silty sand	
	7	Dry, yellow soil	bone
	9	Soil slightly lighter in color	1 small piece of clear glass, flecks of charcoal
	10	Sandier soil, more compact, some roots	
	11	Dry, light tan soil with small amount of clay content; more compact	
	13	Sandy soil	

Table 8
General description of layer 70-80 cm in Grid 1:
Dry, sandy soil dominates this stratum. There are some cultural features identified.

Depth	**Auger Hole**	**Soil Characteristics (from auger logs)**	**Cultural Evidence**
80-90 cm	1	Tan, dry sand	Plastic, metal
	2	Light, grey, compacted soil	Plastic, aluminum, foil, string, metal
	4	Sandy soil	
	5	Silty sand	
	7	Sandier soil	
	9	Sandier soil	1 piece of purple glass
	10	Sandier soil, more compact	
	11	Dry, light tan soil with small amount of clay content; more compact; root	
	13	Sandy soil	

Table 9
General description of layer 80-90 cm in Grid 1:
Dry sandy soil increasing in compactness as depth increases. Some cultural features are identified and are probably part of electrical and plumbing debris.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
90-100 cm	1	Tan, dry sand	Glass, plastic
	2	Light, grey, compacted soil	Lots of metal fragments, wood, plastic
	4	Drier soil	
	5	Silty sand	
	7	Sandy soil	
	9	Sandy soil	Flecks of charcoal
	10	Sandier soil, more compact	
	11	Soil of increasing compaction	1 piece of clear glass
	13	Sandy soil	Small piece of brick

Table 10
General description of layer 90-100 cm in Grid 1:
Dry sandy soil increasing in compactness as depth increases. Some cultural features are identified.

Overview by Auger Hole

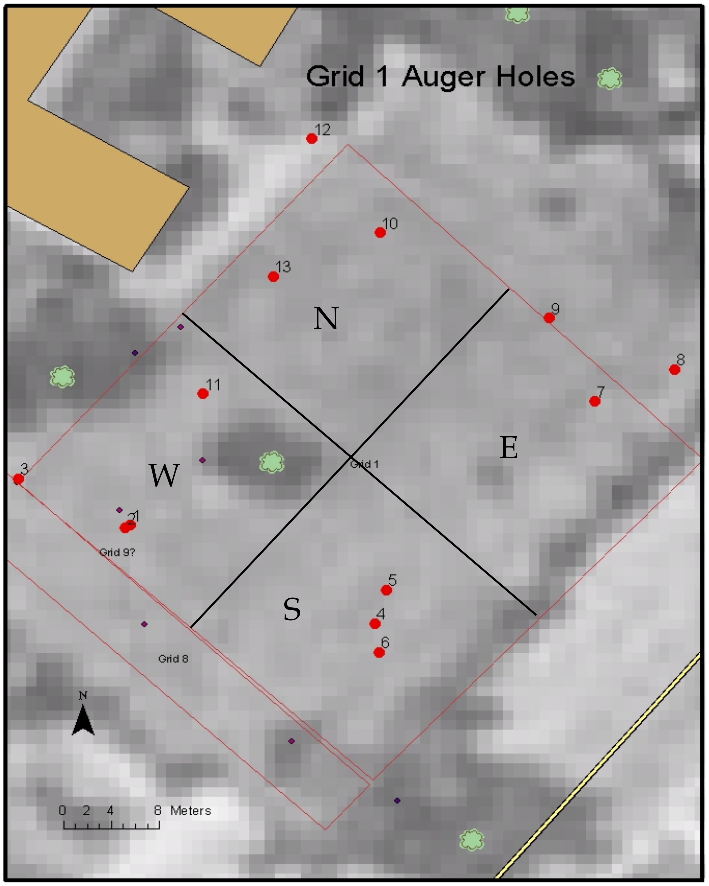


Figure 11
This map shows the GPS plotted auger holes. Grid 1 is divided into quadrants to illustrate the divisions described in the following summary of auger hole results. The analysis is by necessity very general.

Due to the inaccuracy of the GPS survey points of auger holds and grid corners, the precision of the descriptions must be approximated and generalized by quadrant.

W quadrant: described by auger holes 1, 2 and 11. Deeper cultural features include electrical fuses, plastic, string, and metal at 50-100cm. Pipes were located in this area of site. The abundance of cultural materials is probably due to modern plumbing and electrical materials.

Auger hole 1: 10/10 layers contained cultural features. Dark brown sandy silt, increases in sand and dryness to about 100 cm. Modern cultural materials were found throughout.

Auger hole 2: 8/10 layers contained modern cultural materials. Dark brown sandy silt, increases in sand and dryness to 100 cm. Metal fragments, wood and plastic were found to 110 cm.

Auger hole 11: 5/10 layers contained cultural features. Dark brown sandy silt, increasingly more compact and sandier to 50 cm, increasing slightly in clay and dryness. More compact at 90-100 cm. Very few cultural materials.

S quadrant: described by auger holes 4 and 5. No cultural materials or features were found below 60 cm.

Auger hole 4: 5/10 layers contained cultural features. Dark brown sandy silt, increases in sand and dryness to 100 cm. No cultural mataerials were found deeper than 60 cm. Very few cultural artifacts below the asphalt layer.

Auger hole 5: 2/10 layers contained cultural artifacts. Dark brown sandy silt changing to silty sand at 20 cm. Below the asphalt layers to 30 cm, no cultural materials were found.

N quadrant: Very few cultural materials were identified by auger tests. Auger holes 10 and 13 describe this area of grid.

Auger hole 10: 5/10 layers contained cultural materials. Dark brown sandy sandy silt, increasingly more sandy and compact with less moisture as depth increases. No cultural features deeper than 70 cm. Most artifacts were found between 10-50 cm.

Auger hole 13: 4/10 layers contained many artifacts. Dark brown sandy silt, 5% gravel content to 50 cm. Soil increases in sand content to 100cm. and then more clay to 120 cm. Very few cultural materials found at depth.

E quadrant: Some cultural materials were found in Auger holes 7 and 9..

Auger hole 7: 7/10 layers contained modern artifacts. Dark brown sandy silt to 30 cm. Then red clay soil, and below that sandier, lighter soil to 70 cm. Dry yellow soil increasing in sand content to 100 cm.

Auger hole 9: 7/10 layers contained artifacts. Dark brown sandy silt, increases in sand and dryness, lighter in color as depth increases.

Summary:
Based on this soil information, the GPR should be the best type of survey tool to because the soils were resistant and dry. The abundance of metal objects no doubt dominated the data in the EM and MAG surveys. The site is littered with metallic debris that shows up on both these surveys.

GPR Survey Results for Grid 1

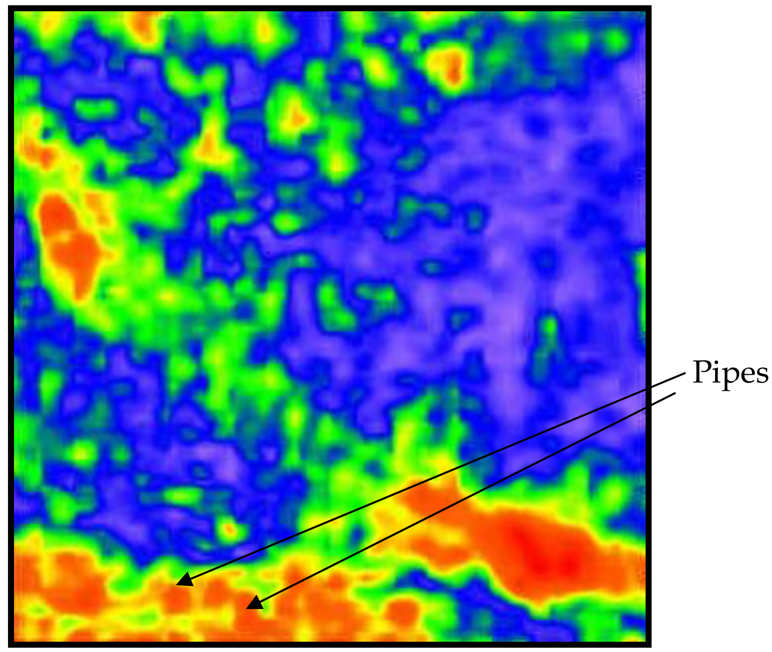


Figure 12
This image is of the GPR survey data for the 0-7 ns, or 0 – 30 cm depth. The pipes are apparent in the lower left corner.

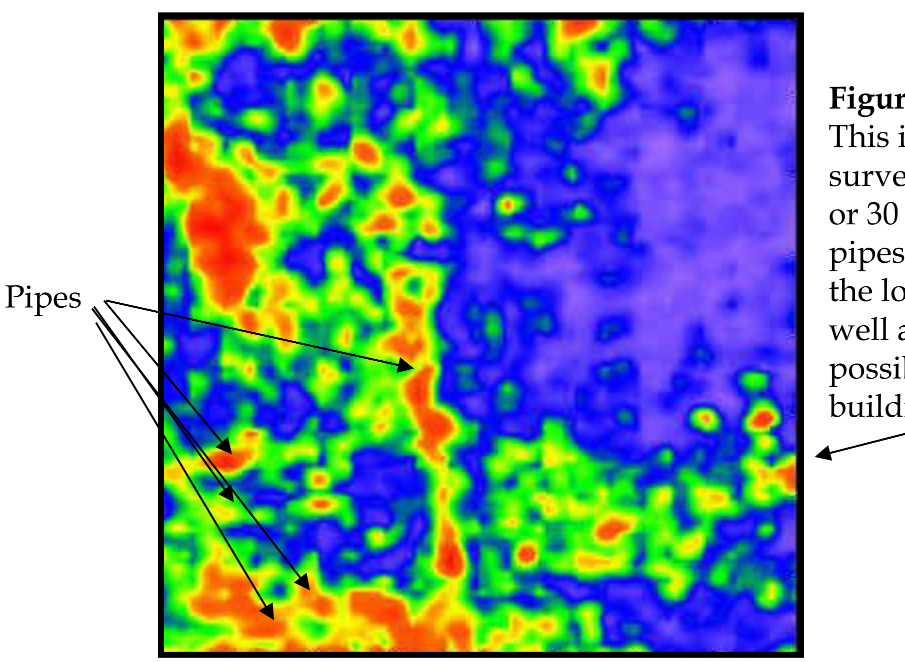


Figure 13
This image is of the GPR survey data for the 7-14ns, or 30 – 60 cm depth. The pipes are still apparent in the lower left corner as well as in the center. The possible foundation of a building is located here.

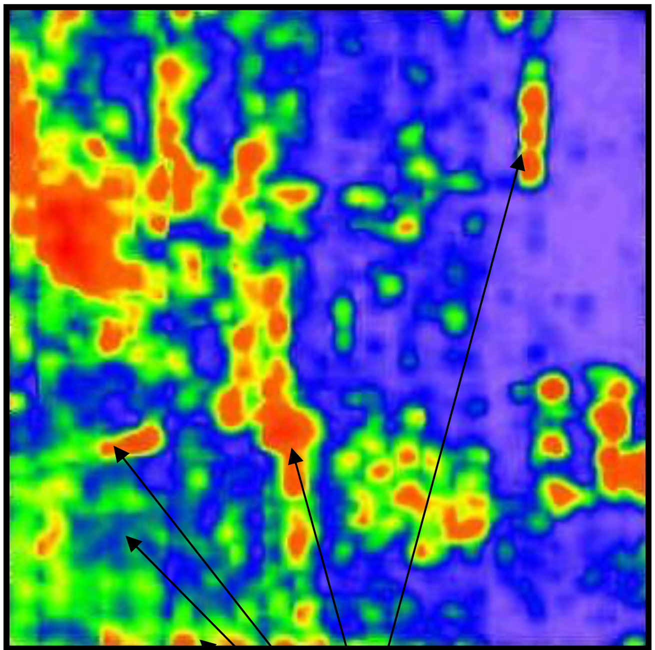


Figure 14
This image is of the GPR survey data for the 14-21 ns, or 60 – 90 cm depth. The pipes are fading with depth in the lower left corner. The pipes running n/s in the image are more apparent.

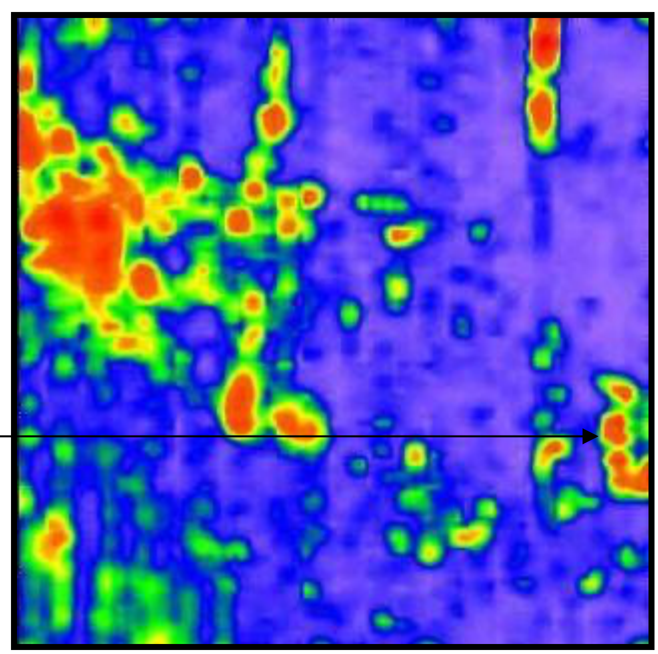


Figure 15
This image is of the GPR survey data for the 21-28 ns, or 90 – 120 cm depth. Most of the pipes have faded. But the possible foundation of the building is quite clear.

MAG Survey Results for Grid 1

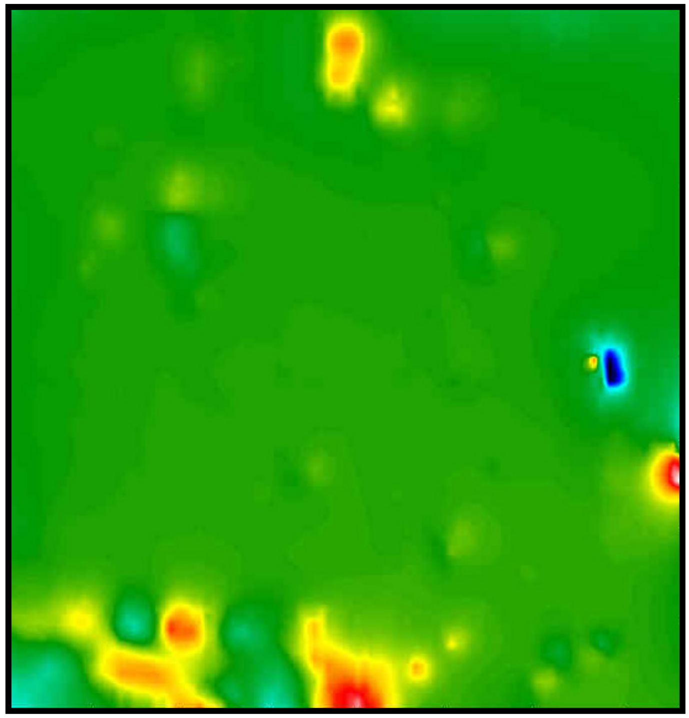
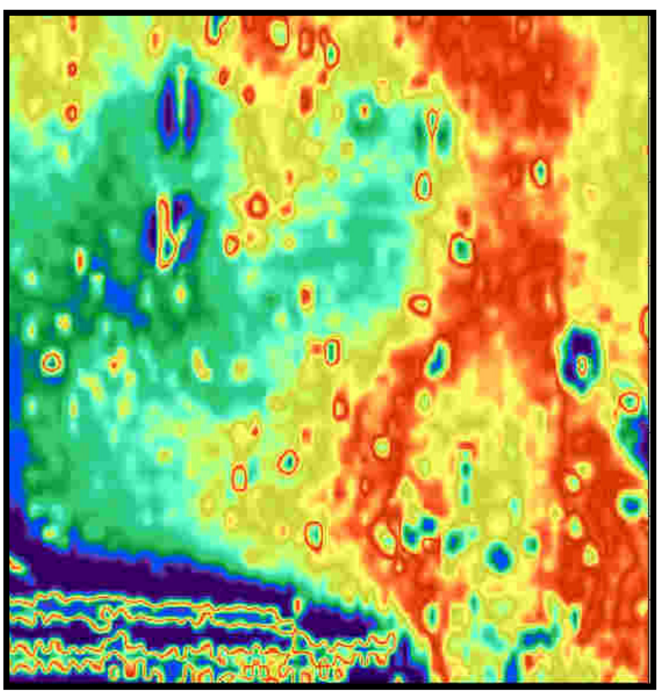


Figure 16
The pipes are easily distinguished in the lower left in red and yellow. Another interesting feature in red occurs on the right. This feature is identified in all three surveys.



EM Survey Results for Grid 1

Figure 17
This EM grid 1 data set was processed to enhance the features identified. Note the pipes in the lower left and the blue feature on the right side, which corresponds to that in the Mag data.

Integration

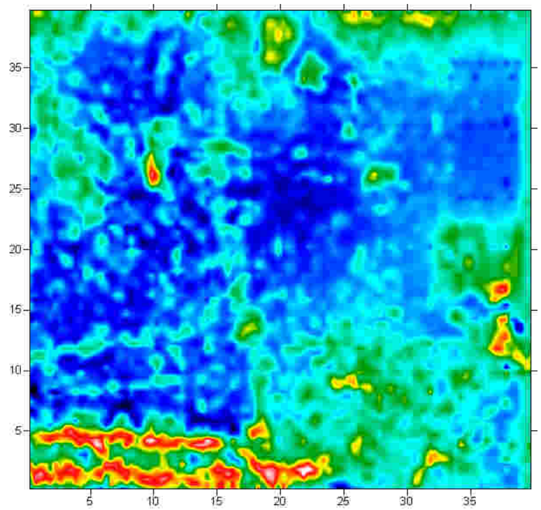


Figure 18
Integrating the GPR, EM and MAG surveys results in this image. Notice the clarity of the pipes as well as the feature to the right. It is likely a buried house foundation with some metallic debris in it.

Interpretation

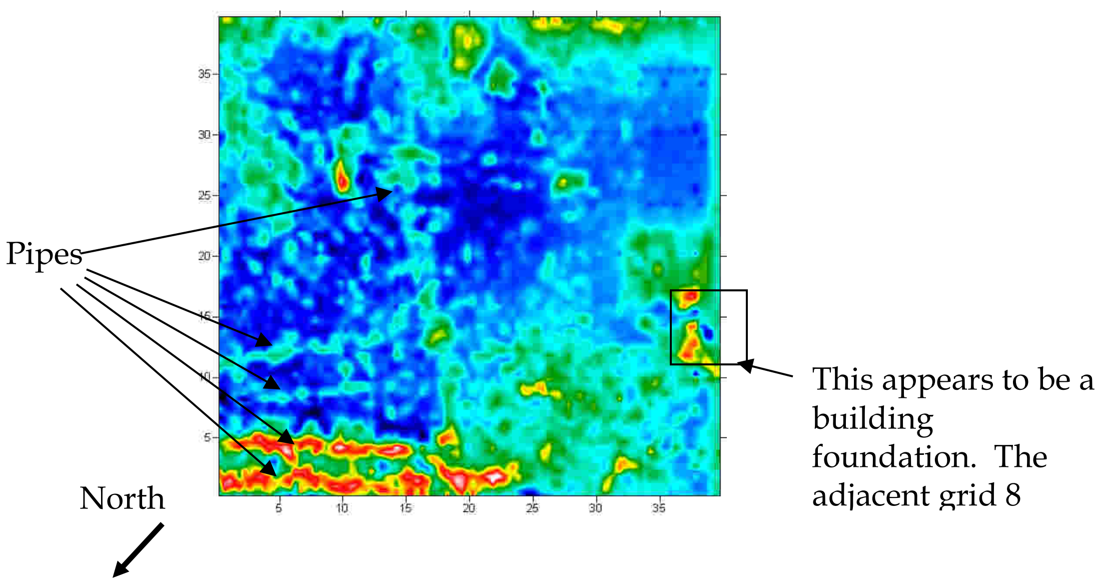


Figure 19
Annotated integrated Grid 1: The north quadrant contains abundant modern plumbing and electrical material. The east quadrant contained the most useful types of cultural artifacts such as bone, mortar, charcoal, brick, and a nail. The presence of asphalt may be the denser material that is seen throughout this grid as "background".

Grid 5 Analysis

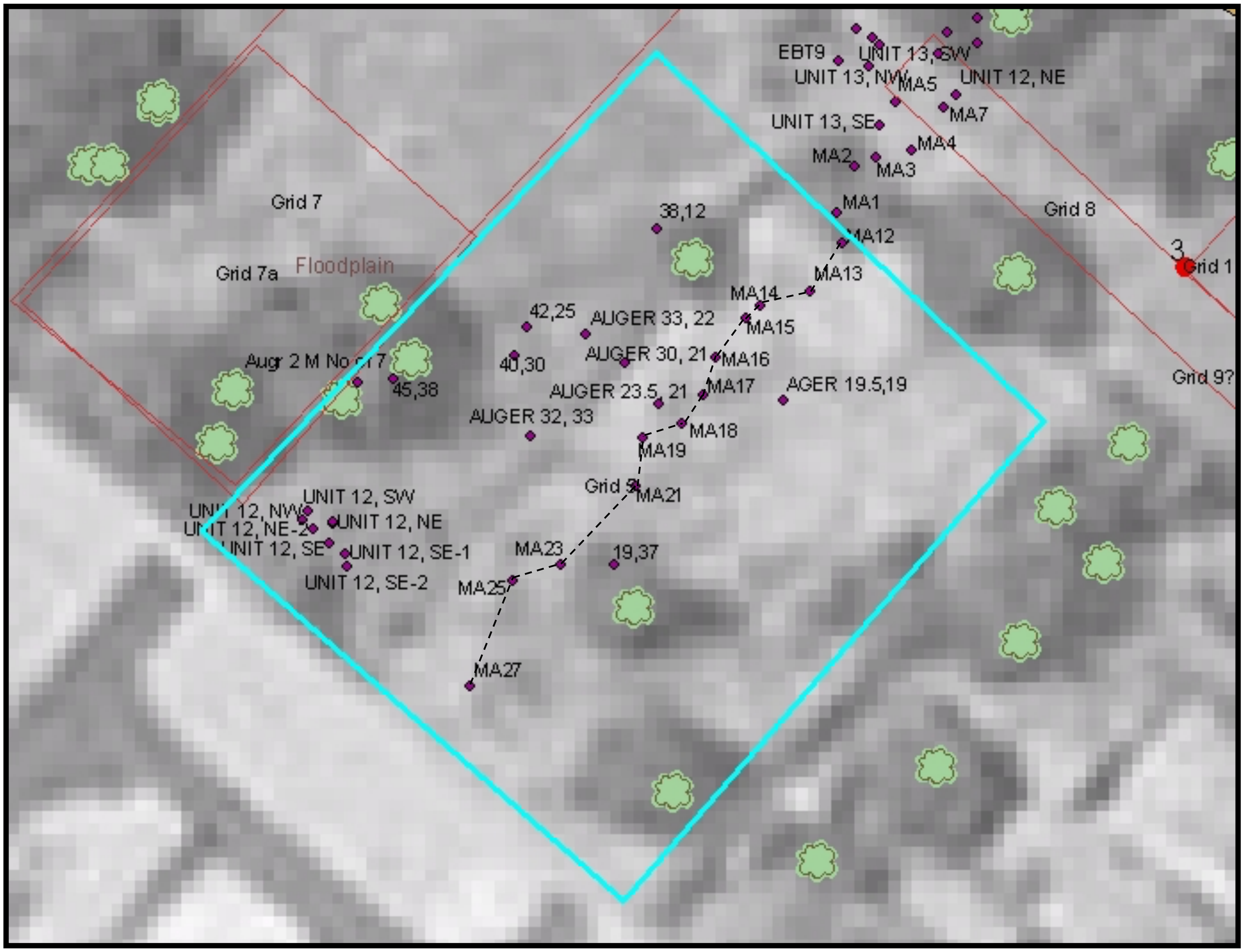


Figure 20
Auger Hole Tests in Grid 5

Grid 5 measures 55 x 46 meters and runs adjacent to grid 7. A wagon restricted the EM and GPR surveys. There is a rectangle of uncollected data in the images displayed as a black or blurry rectangle in the geophysical maps where the wagon was located.

Again, the inaccuracy of the GPS point locations is obvious. According to the documentation provided by Herb Dallas, the MA series of auger holes were placed 3 meters apart in a straight line. The map above shows the points as plotted using the GPS tool to determine location. The dotted line is drawn in to help illustrate the MA series of auger holes. The MA series of auger holes that are located within grid 5 are summarized in tables 11-20. The other auger holes mentioned on this map have no accompanying documentation, so the results cannot be used in the analysis for this report.

Unit 12 does have archaeological documentation and is included in this analysis. In the provided archaeological reports, however, a unit 12-A and unit 10 are referenced. There is no locational information provided by the GPS points for a unit 12-A or unit 10. Consequently, neither unit could be analyzed.

Overview of Soil Analysis for Grid 5 by depth

Summary:
Generally, this grid is characterized by loose light tan, silty sand with about 10% gravel content decreasing with depth. There is fairly uniform soil composition by depth across grid according to auger tests. These auger holes, however, do not cover the entire grid. They are placed only along one line through the center, which corresponds to the edge of the river terrace.

Detail of Auger Hole Results for Grid 5 by Depth

Depth	**Auger Hole**	**Soil Characteristics (from auger logs)**	**Cultural Evidence**
0-10 cm	MA12	Loose, light tan silty sand	Glass; metal plastic
	MA13	Tan sand with low silt content; very compact on surface; no gravel	glass
	MA14	Gray silty sand, loosely compact	Brownware and earthware sherds
	MA15	Loose, light tan silty sand	
	MA16	Loose, light tan silty sand	glass
	MA17	Loose, light tan silty sand	Glass, plastic,, brick
	MA18	Loose, light tan silty sand	
	MA19	Loose, light tan silty sand	Glass, plastic
	MA21	Loose, light tan silty sand	glass
	MA23	Loose, light tan silty sand	Green glass
	MA25	Loose, light tan silty sand	Brick, mortar, glass
	MA27	Loose, light tan silty sand	Charcoal, brick, glass

Table 11
General description of layer 0-10 cm in Grid 5:
Loose, light tan, silty sand, glass found throughout and well as other misc. cultural features.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
10-20 cm	MA12	Sandier soil; more compaction	Glass; plastic
	MA13	Tan sand with low silt content	glass
	MA14	tan silty sand	glass
	MA15	Loose, light tan silty sand	Brownware, brick, bone
	MA16	Loose, light tan silty sand	Possible bone
	MA17	Loose, light tan silty sand	Bone
	MA18	Loose, light tan silty sand	Bone
	MA19	Loose, light tan silty sand	Bone
	MA21	Loose, light tan silty sand	Small flecks of charcoal
	MA23	Loose, light tan silty sand	Green glass
	MA25	Loose, light tan silty sand	Brick
	MA27	Loose, light tan silty sand	Charcoal flecks, cement

Table 12
General description of layer 10-20 cm in Grid 5:
Loose, light tan, silty sand, Misc. cultural features found throughout.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
20-30 cm	MA12	Orange/brown sandy silt; less gravel content	
	MA13	Tan sand with low silt content	
	MA14	Orange/brown sandy silt	Brownware sherds
	MA15	Loose, light tan silty sand	Bone, glass
	MA16	Loose, light tan silty sand; less silt	bone
	MA17	Loose, light tan silty sand	Green glass, bone, small amount of charcoal
	MA18	Loose, light tan silty sand	
	MA19	Loose, light tan silty sand	
	MA21	Loose, light tan silty sand	Small flecks of charcoal
	MA23	Grey sandy silt	Green glass
	MA25	Light grey sandy silt; 3% gravel	
	MA27	Loose, light tan silty sand	Glass, cement, brownware

Table 13
General description of layer 20-30 cm in Grid 1:
Loose, light tan, silty sand, Misc. cultural features found throughout.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
30-40 cm	MA12	Moister soil; decrease in gravel	
	MA13	Tan sand with low silt content	
	MA14	Orange/brown sandy silt	Brownware sherd
	MA15	Loose, light tan silty sand	Nail, bone
	MA16	Loose, light tan silty sand	
	MA17	Loose, light tan silty sand	
	MA18	Loose, light tan silty sand	Fabric, small tooth, bone
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand, 5% gravel	Small flecks of charcoal
	MA23	Grey sandy silt; 3% gravel; roots	
	MA25	Light grey sandy silt; 2% gravel	
	MA27	Loose, light tan silty sand	

Table 14
General description of layer 30-40 cm in Grid 5:
Loose, light tan, silty sand, Misc. cultural features found throughout.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
40-50 cm	MA12	Orange/brown sandy silt; less gravel content	
	MA13	Tan sand with low silt content	
	MA14	Orange/brown sandy silt with white inclusions	
	MA15	Orange/brown sandy silt	bone
	MA16	Loose, light tan silty sand	
	MA17	Loose, light tan silty sand	
	MA18	Loose, light tan silty sand	
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand	
	MA23	Grey sandy silt; 3% gravel; roots	Small flecks of charcoal
	MA25	Light grey sandy silt; 2% gravel	Small flecks of charcoal
	MA27	Light gray sandy silty	Small flecks of charcoal

Table 15
General description of layer 40-50 cm in Grid 5:
Loose, light tan, silty sand. Decrese in cultural features, limited only to charcoal and bone. Notice the location of auger holes MA 23, MA 25, and MA 27 (figure 20). The charcoal flecks were found in the same general area at the same depth.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
50-60 cm	MA12	Orange /brown sandy silt	
	MA13	Tan sand with low silt content	
	MA14	Brown/orange clayey sand	
	MA15	Brown/orange clayey sand	bone
	MA16	Loose, light tan silty sand	
	MA17	Loose, light tan silty sand	
	MA18	Loose, light tan silty sand	
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand	Small flecks of charcoal
	MA23	Grey sandy silt; 1% gravel; roots	Small flecks of charcoal
	MA25	Light grey sandy silt; 2% gravel	Small flecks of charcoal
	MA27	Light gray sandy silt	Small flecks of charcoal

Table 16
General description of layer 50-60 cm in Grid 5:
Charcoal still consistently found at the south end of the string of auger holes. The soil is sandy silt at the southern and middle auger holes, but turns to clay at the northern end.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
60-70 cm	MA12	Brown/orange clayey sand	plastic
	MA13	Tan sand with low silt content	
	MA14	Brown/orange clayey sand	
	MA15	Brown/orange clayey sand	
	MA16	Soil change to red/brown sandy silt with lumps of clay	wood
	MA17	Loose, light tan silty sand	
	MA18	Loose, light tan silty sand	
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand	Small flecks of charcoal
	MA23	Grey sandy silt; 1% gravel; roots	Small flecks of charcoal
	MA25	Light grey sandy silt; 2% gravel	Small flecks of charcoal
	MA27	Light gray sandy silt	

Table 17
General description of layer 60-70 cm in Grid 1:
Continuing same trend as in 50-60 cm. depth.

Depth	**Auger Hole**	**Soil Characteristics (from auger logs)**	**Cultural Evidence**
70-80 cm	MA12	Brown/orange clayey sand	
	MA13	Tan sand with low silt content	
	MA14	Brown/orange clayey sand	
	MA15	Brown/orange clayey sand	
	MA16	Soil change to red/brown sandy silt with lumps of clay	
	MA17	Dark tan, sandy silt, increase in gravel to 15%	
	MA18	Loose, light tan silty sand; 5% gravel	
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand	
	MA23	Grey sandy silt; 1% gravel; roots	
	MA25	Light grey sandy silt; 2% gravel	Small flecks of charcoal
	MA27	Light gray sandy silt	

Table 18
General description of layer 70-80 cm in Grid 5:
Very few cultural features found at this depth. Same soil trends as above.

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
80-90 cm	MA12	Brown/orange clayey sand	
	MA13	Tan sand with low silt content	
	MA14	Brown/orange clayey sand	
	MA15	Brown/orange clayey sand	
	MA16	Soil change to red/brown sandy silt with lumps of clay	
	MA17	Dark tan, sandy silt, increase in gravel to 15%	
	MA18	Loose, light tan silty sand; 5% gravel	
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand	
	MA23	Grey sandy silt; 1% gravel; roots	
	MA25	Light grey sandy silt; 2% gravel	
	MA27	Light gray sandy silt	

Table 19
General description of layer 80-90 cm in Grid 5:

Depth	Auger Hole	Soil Characteristics (from auger logs)	Cultural Evidence
90-100 cm	MA12		
	MA13	Tan sand with low silt content	
	MA14	Brown/orange clayey sand	
	MA15		
	MA16	Soil change to red/brown sandy silt with lumps of clay	
	MA17	Dark tan, sandy silt, gravel 10%	
	MA18	Dark tan, sandy silt, increase in gravel to 15%	bone
	MA19	Loose, light tan silty sand	
	MA21	Light grey silty sand	Blue glass
	MA23	Grey sandy silt; 1% gravel; roots	
	MA25	Light grey sandy silt; 2% gravel	
	MA27	Light gray sandy silt	

Table 20
General description of layer 90-100 cm in Grid 5:

Geophysical Surveys for Grid 5

GPR Results

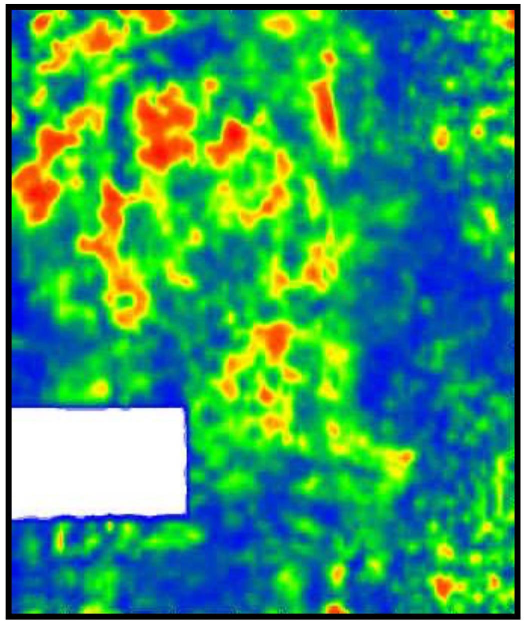


Figure 20
GPR image of grid 5. This slice represents 0-7 ns, or 0-30 cm. depth.

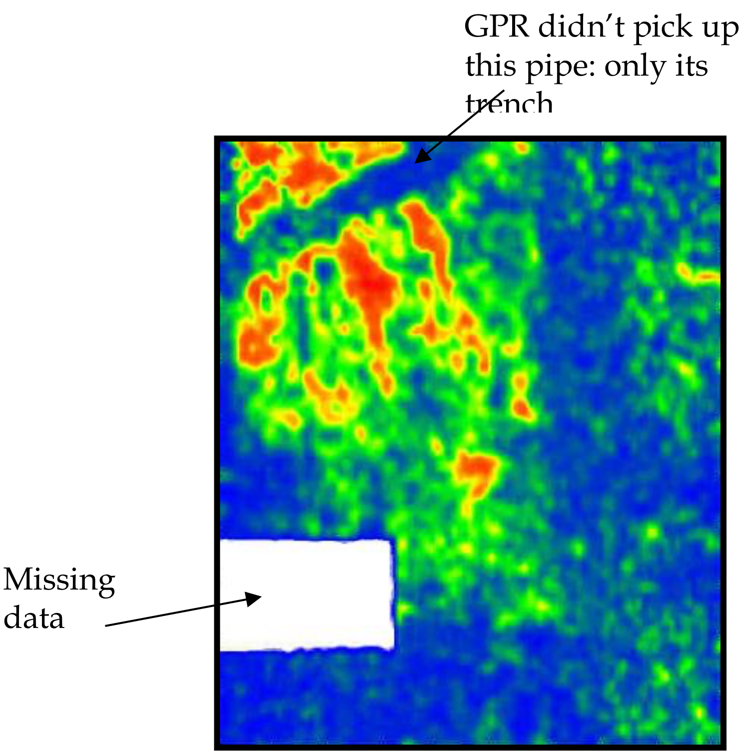


Figure 21
GPR image of grid 5. This slice represents 7-14 ns, or 30-60 cm. depth. This slice is used in the integration process because the other surveys reach maximum sensitivity at this approximate depth.

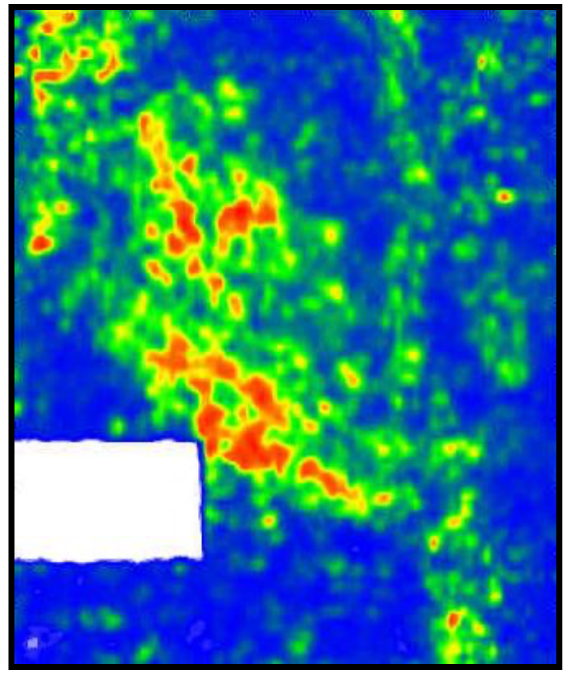


Figure 22
GPR image of grid 5. This slice represents 14-21 ns, or 60-90 cm. depth.

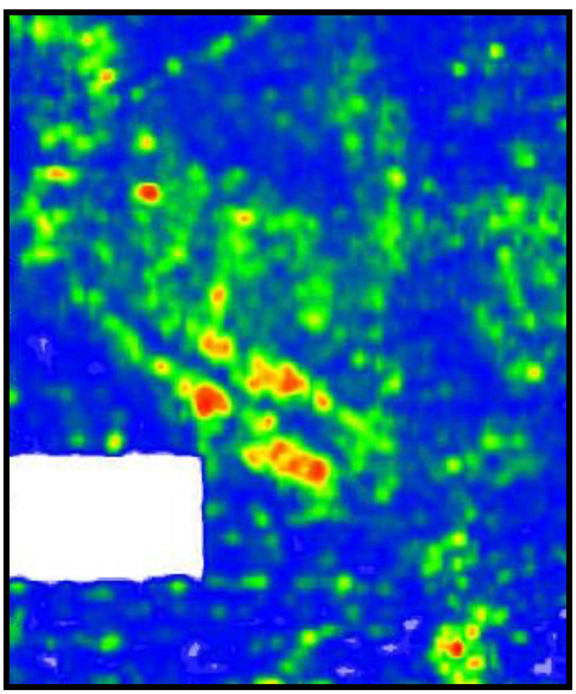


Figure 23
GPR image of grid 5. This slice represents 21-28 ns, or 90-120 cm. depth.

MAG Results

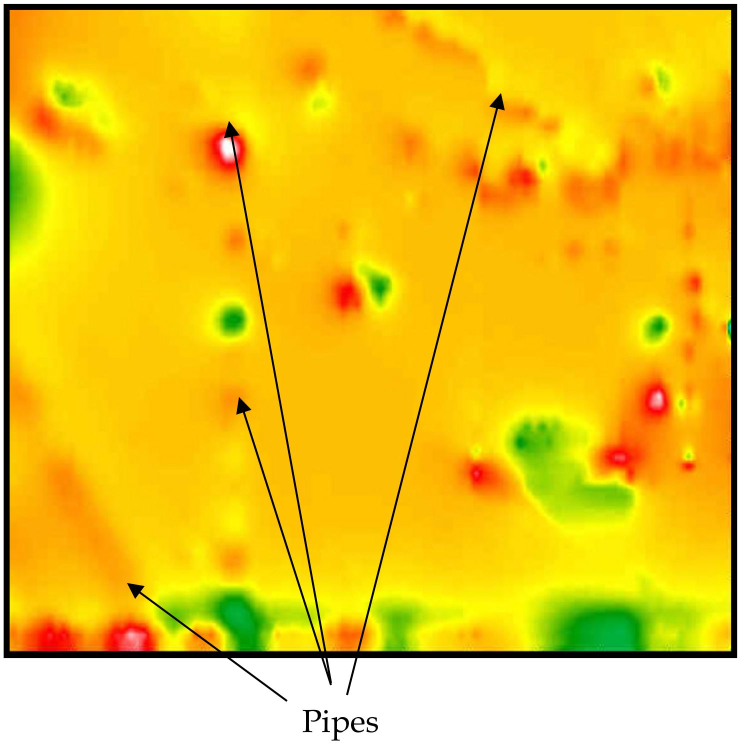


Figure 24
The green and red features on this survey are significant and probably represent metallic features. A few pipes are visible.

EM Results

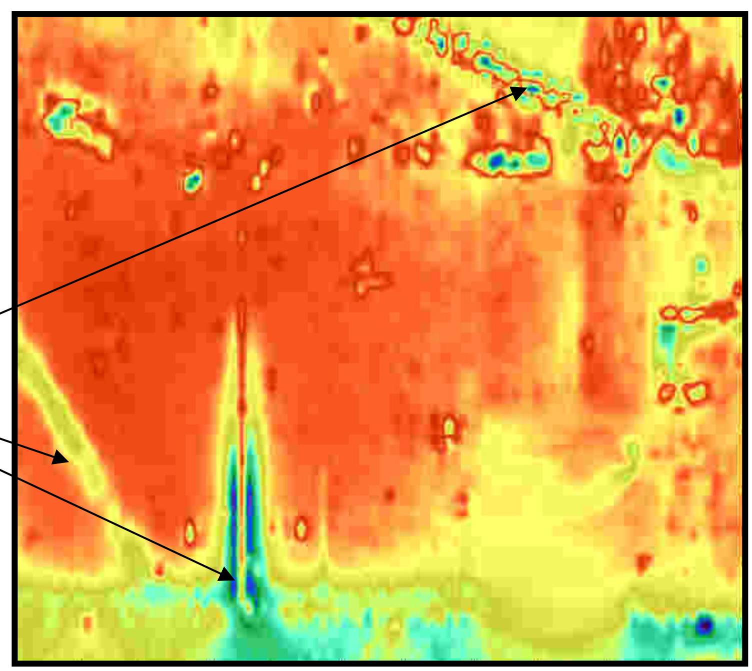
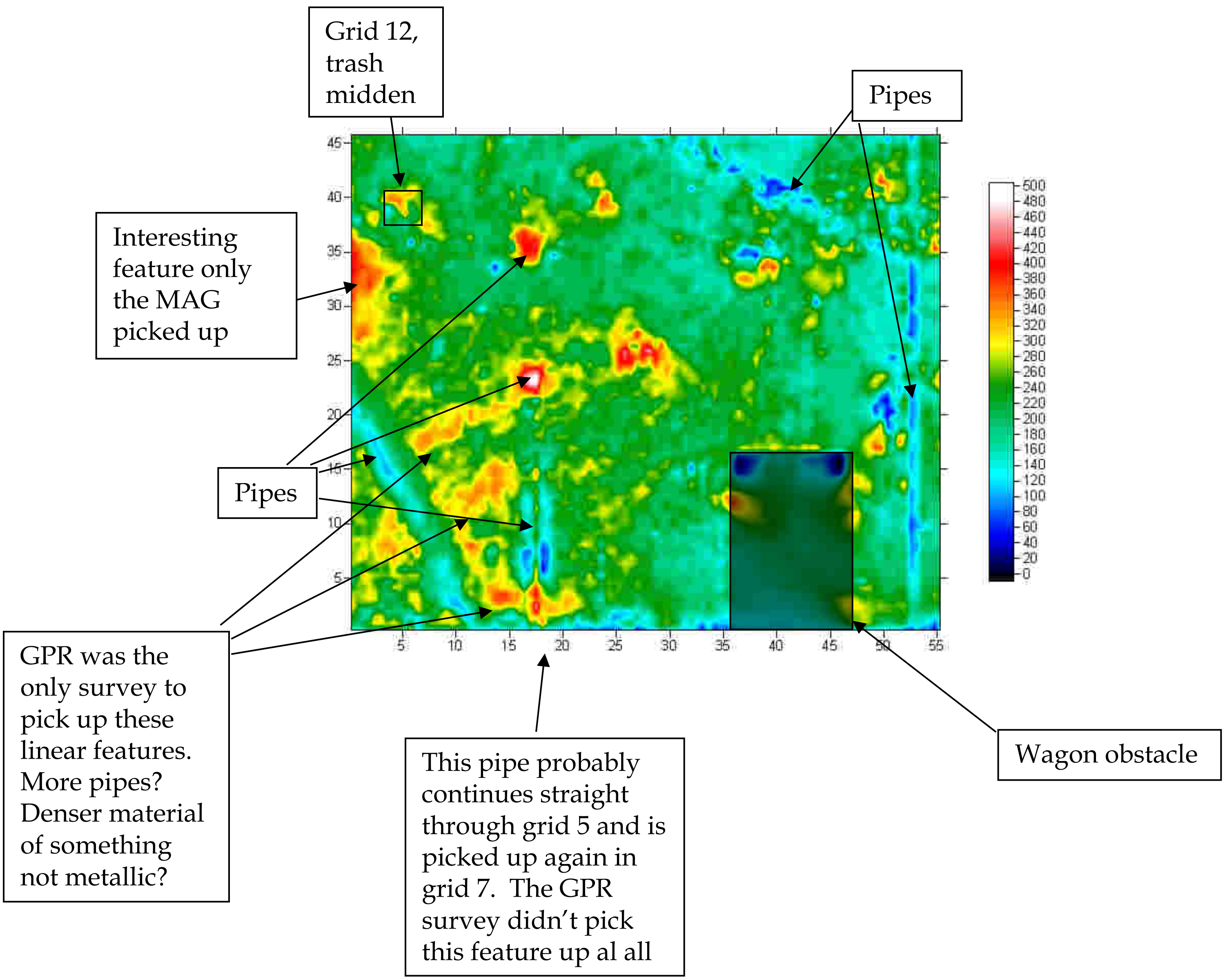


Figure 25
The EM data displayed here has already been processed to highlight features. Notice the pipes.

Integration

Figure 26
This is the image created by integrating the EM, MAG and GPR geophysical surveys in a geographic information system. On this image, some features only one survey picked up clearly, while other features, all surveys picked up. The strength of one survey or one or more combined is illustrated by higher values on the color scale included in the legend. White is the most visible feature, with red, orange, and yellow following. Blue pipes are strong features as well, but have been weighted less in this analysis to limit skewing the image in favor of the strong metallic response.



Summary	Soil	Debitage	Groundstone	Lithic Tools	Pottery	Shell	Bone	Charcoal	Disturbance	Historic Glass	Historic Metal	Historic Ceramic	Other
Surface													
0-10 cm	Dry	basalt				x	Mammal, bird	x	x	Clear milk, Lt. green	civic	x	Insulator Burned wood post; newspaper; mortar, plaster; bricks
10-20 cm	Dry									x	x	x	Increase in artifacts
20-30 cm	Dry						x	x		Seamed molded bottles	x	x	gasket
30-40 cm				Maybe prehistoric		Abalone shell, snail	Small mammal	Small-med fragments	rodent	Clear, green brown, milk, cobalt	Light bulbs, metal molding	Stoneware	Gasket; fabric
40-50 cm	Dry					clam	Machine cut	Scattered throughout level					
50-60 cm	Dry						Some burned, some not	Scattered throughout level	Stream or rodents	Clear, brown, blue	x	x	Trash deposit; Most artifacts metal
60-70 cm	Dry						Some burned; machine cut	Scattered throughout level	roots	Cobalt, brown, clear, window	x	x	Trash deposit; button, paint cans; red bead
70-80 cm							Small mammal, fish, large mammal, bird	Scattered throughout level	roots	Blue, clear, green, brown	lots	x	Trash deposit; button;
80-90 cm	Dry								roots	clear	x		Cement planter, brick
90-100 cm	Dry									x	x		

Table 21
Summary table derived from Unit Level Book for unit 12 located in grid 5, by H. Dallas

Summary:
Glass is consistently found at all depths. This is an area of trash middens and the glass, ceramic and metal debris is preserved in the sandy soils. The grid shows up on the integrated geophysical map (see figure 26).

Grid 7

There was no auger point data provided to use for a soil analysis of grid 7. The total grid size measures 100 m. x 25 m. and lies adjacent to grid 5. The GPR survey only covers a partial area of Grid 7, extending for 40 m. in the center of the larger grid (figure 31). The EM and the MAG surveyed the entire grid.

GPR results

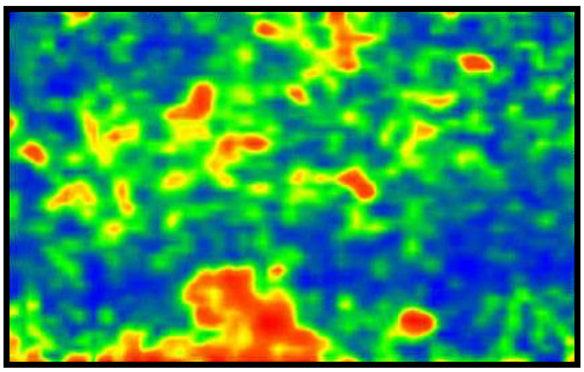


Figure 27
GPR grid 7
0-7 ns

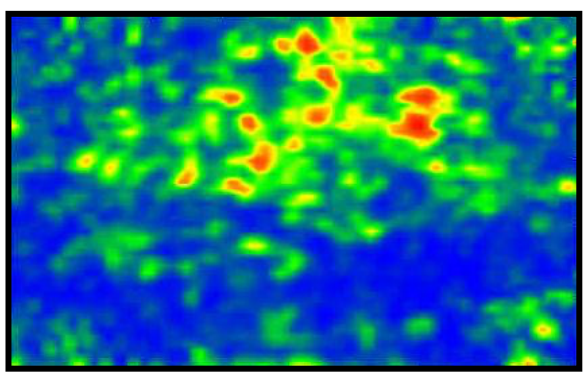


Figure 28
GPR grid 7
7-14 ns

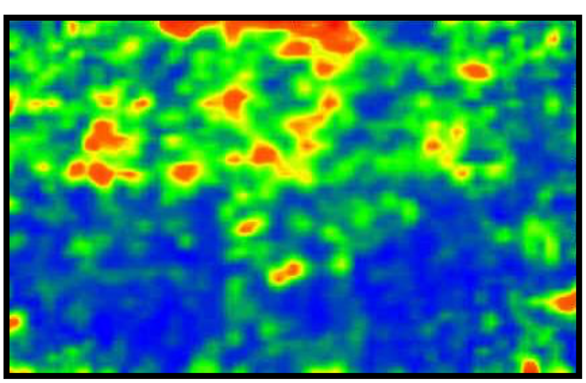


Figure 29
GPR Grid 7
14-21 ns

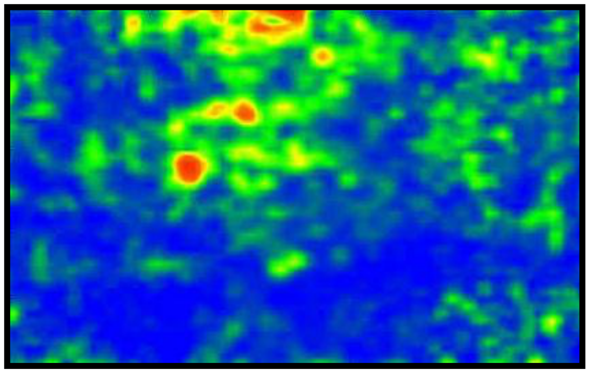


Figure 30
GPR Grid 7
21-28 ns

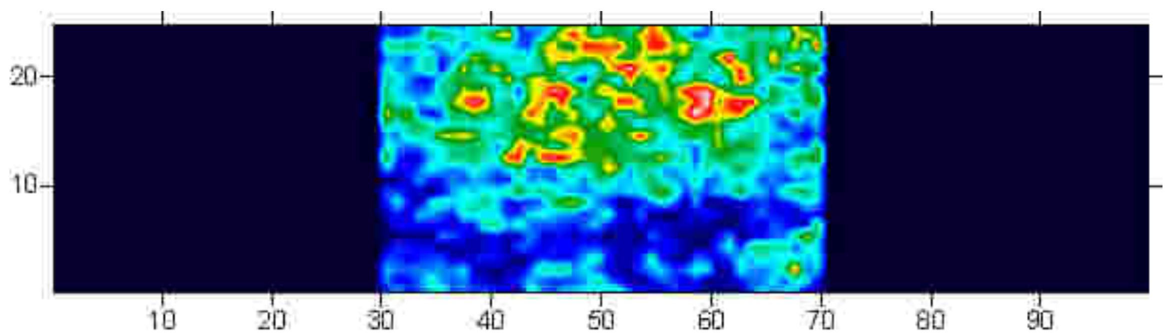


Figure 31
GPR Grid 7
7-14 ns
This GPR image is represents 30-60 cm in depth, to correlate with the EM and MAG images. The grid is placed in the correct position in the larger grid 7 extent. Both the EM and MAG surveys covered 100 m. length, the GPR survey only 40 m. This is the image that will be used to integrate the EM, MAG and GPR surveys in the analysis.

MAG results

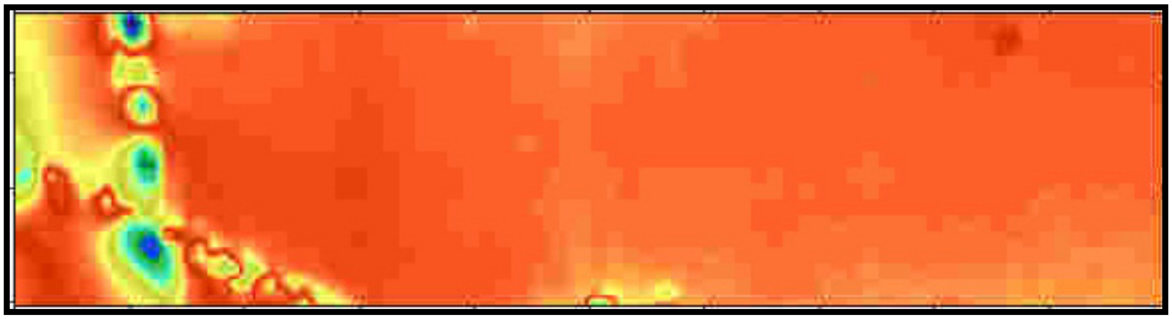


Figure 32
This image of the MAG survey results shows the pipes clearly in the side of the grid. Again, the pipes dominate the image and other less magnetic features are difficult to see without further processing.

EM Results

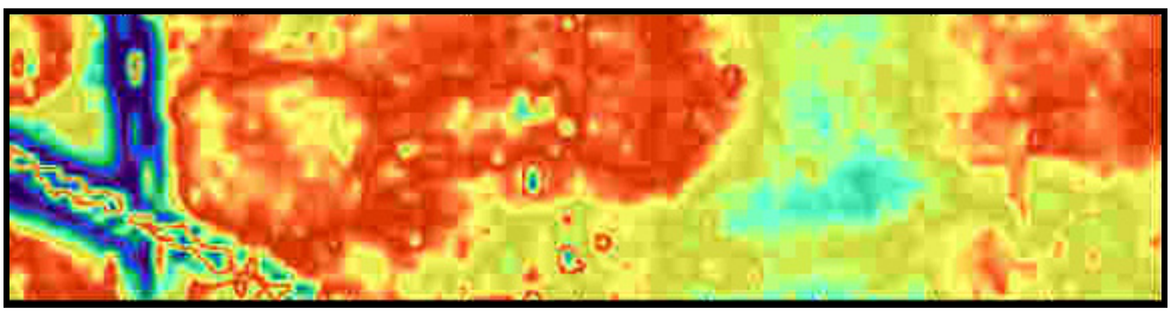


Figure 33
Like the MAG results, this image of the EM survey results shows the pipes in the left. Some other features are also apparent the in center of the grid. The GPR (figure 31) also picks up these features.

Integrated MAG, GPR, EM

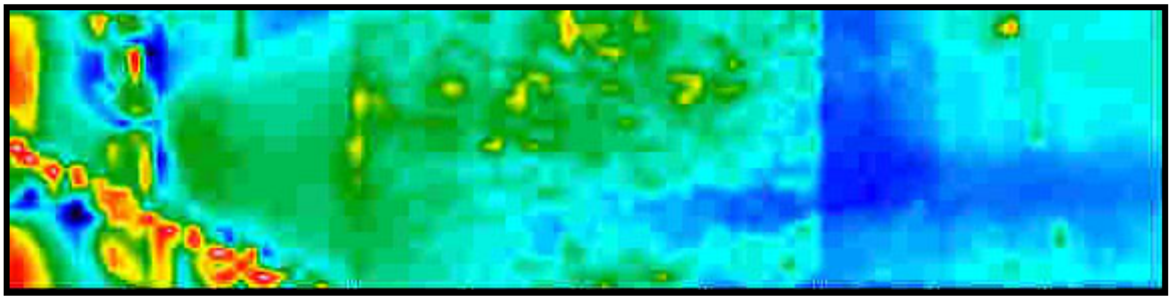


Figure 34
The integration of all the EM, MAG and GPR surveys produces this image. Note that all three surveys are integrated together only in the center section due to the different size survey grids. The MAG and EM are integrated together on both sides of the grid.

Interpretation of Grid 7

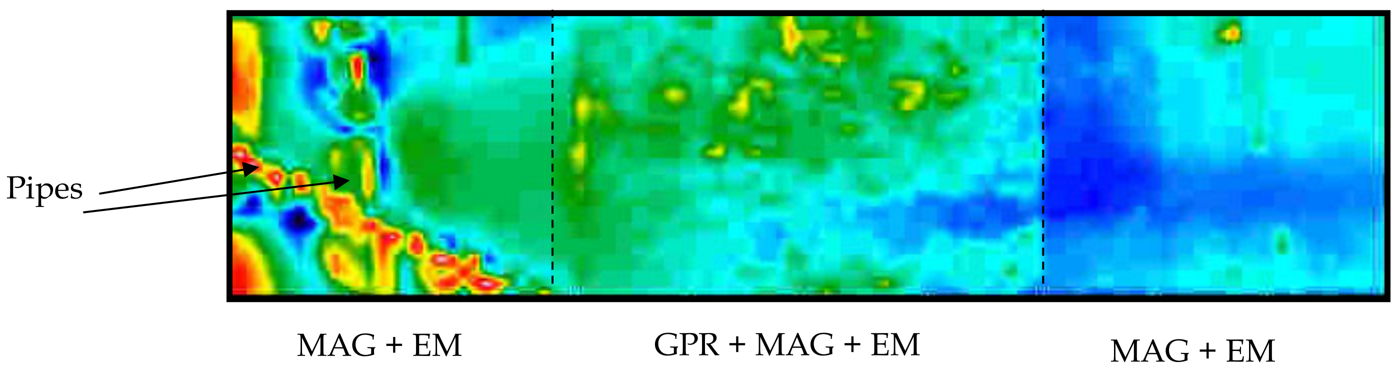


Figure 35
Annotated Grid 7, Integrated EM, MAG and GPR
The pipes in grid 7 are continuations of the pipes noted in grid 5.

Grid 8

Unit 13 is possibly located in a portion of grid 8. The GPS points are inaccurately documented and the accuracy of the point location is not adequate to determine exactly where the unit is located.

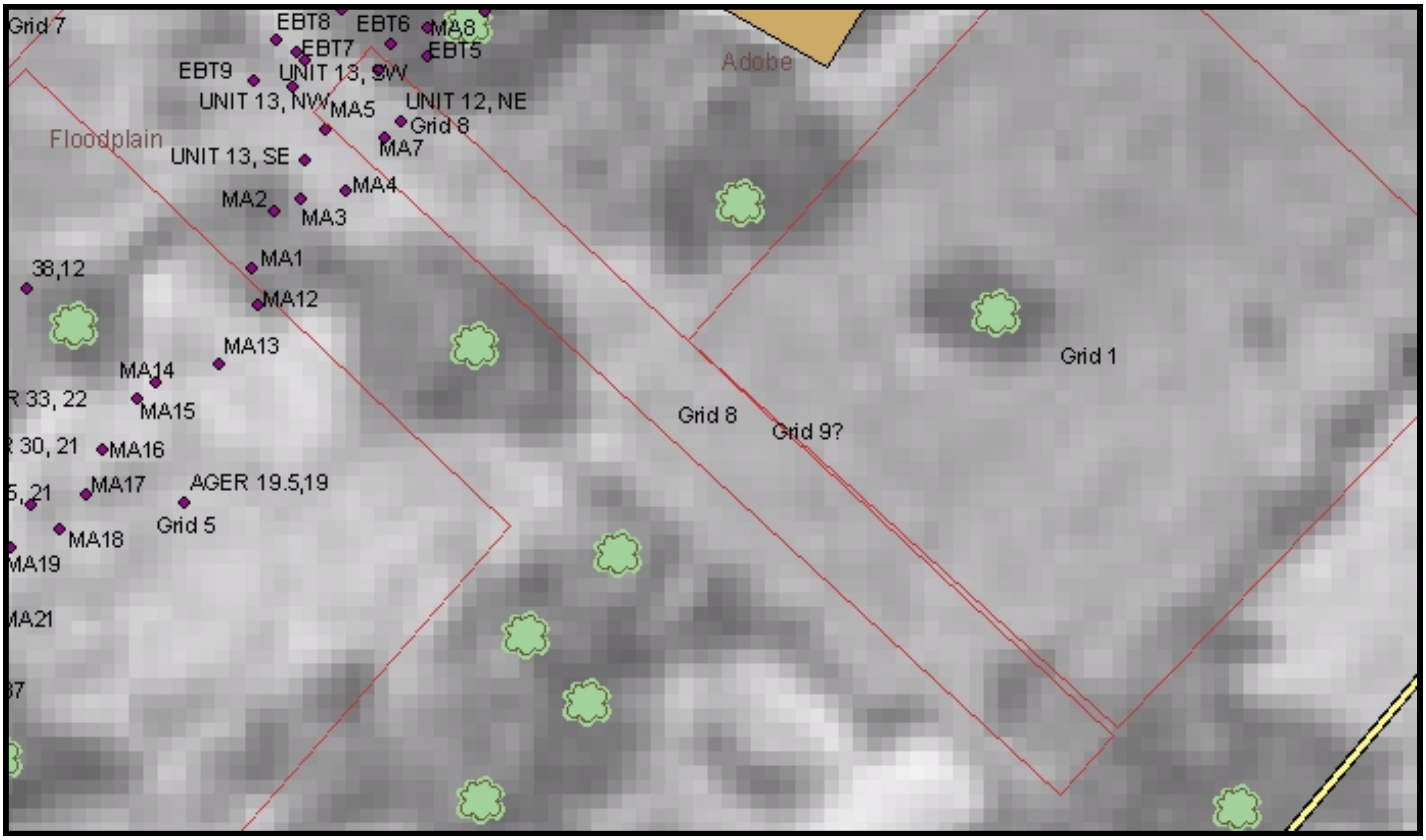


Figure 36
Position of grid 8 and GPS point locations of the auger holes and archaeological excavation unit 13.

GPR results

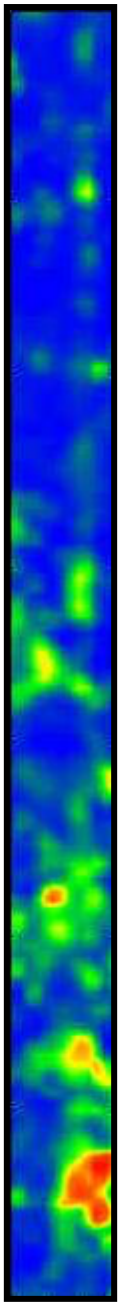


Figure 37
GPR grid 8
0-7 ns or 0-30 cm depth

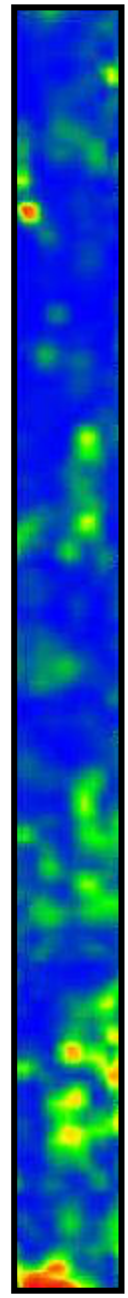


Figure 38
GPR grid 8
7-14 ns or 30-60 cm. depth

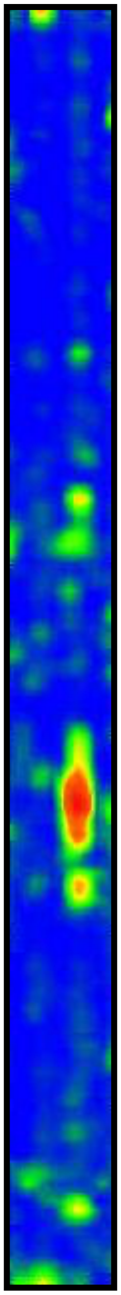


Figure 39
GPR grid 8
14--21 ns or 60-90 cm depth

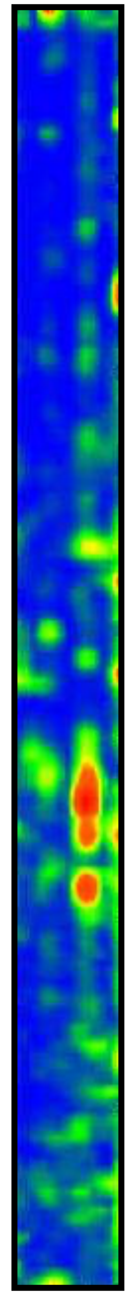


Figure 40
GPR grid 8
21--28 ns or 90-120 cm depth

In figures 39 and 40, the red linear feature at 60 to 120 cm depth is a continuation of the feature identified the adjacent grid 1 (figure 19). This is the feature that the GPR picks up much more clearly than the EM and MAG surveys. It is possibly the other side to the building foundation.

MAG

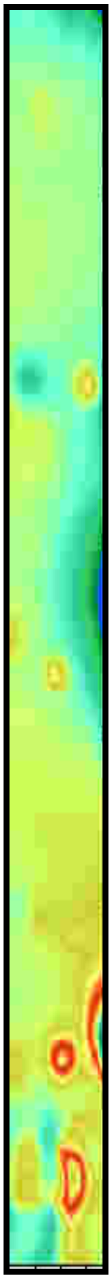


Figure 41
MAG survey results for grid 8

EM

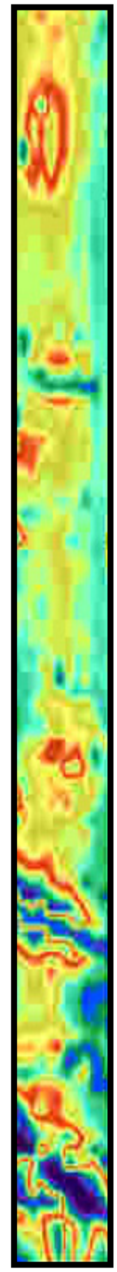


Figure 42
EM survey results for grid 8

Integrated Grid 8

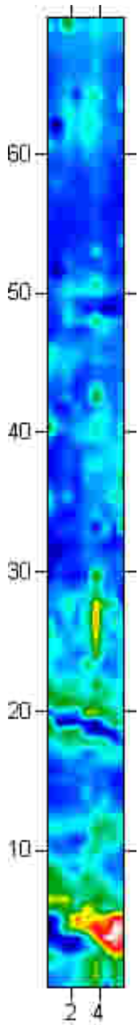
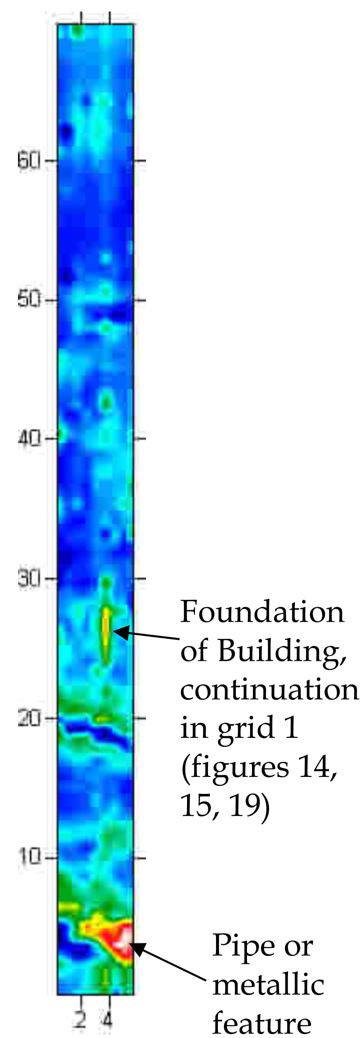


Figure 43
This image represents the integrated GPR, EM, and MAG survey results.

Interpretation

Figure 44
Annotated grid 8. The survey results of the integrated image of GPR, MAG, and EM.



Final Integrated Map of the Pio Pico Site

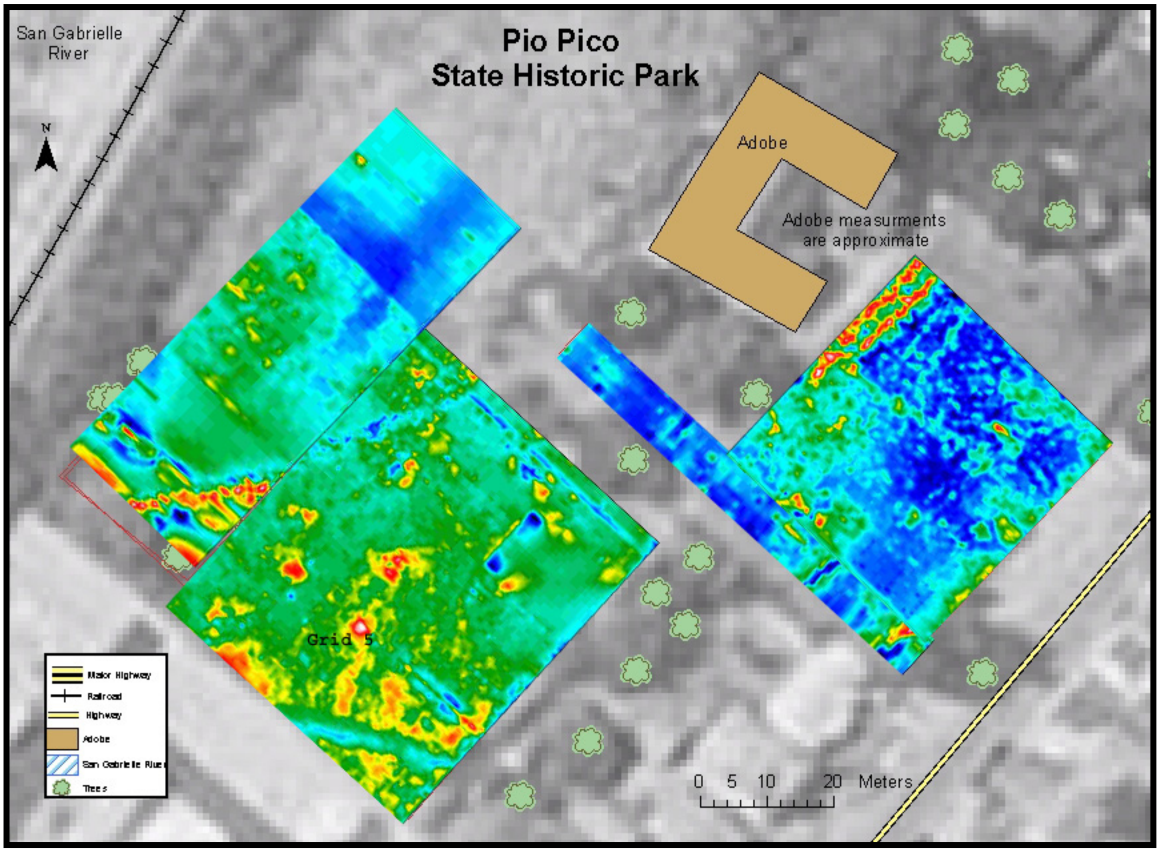


Figure 45
Map of site with Integrated Geophysical Surveys

The area encompassing the Pio Pico site has seen a great deal of disturbance such as pipes, paving, and dumping of garbage and building materials, all of which is evident in the geophysical survey results conducted of grids 1, 5, 7, and 8. In some cases (EM and MAG surveys), the data was overwhelmed with metallic features, overpowering the evidence of the non-metallic features. The GPR was the best device to find non-metallic features at Pio Pico.

Archaeologically, the surveys (mainly GPR) found the building foundation located between grids 1 and 5 and was able to pinpoint the depth of the feature at about 90 cm. (figures 14,15, 19, 46). The trash midden excavated from grid 5 was also identified in the surveys (figure 26.) Based on the soil and archaeological information available, as well as the geophysical survey analysis, the cultural features are generally located at the 30-40 cm. depth throughout the site.

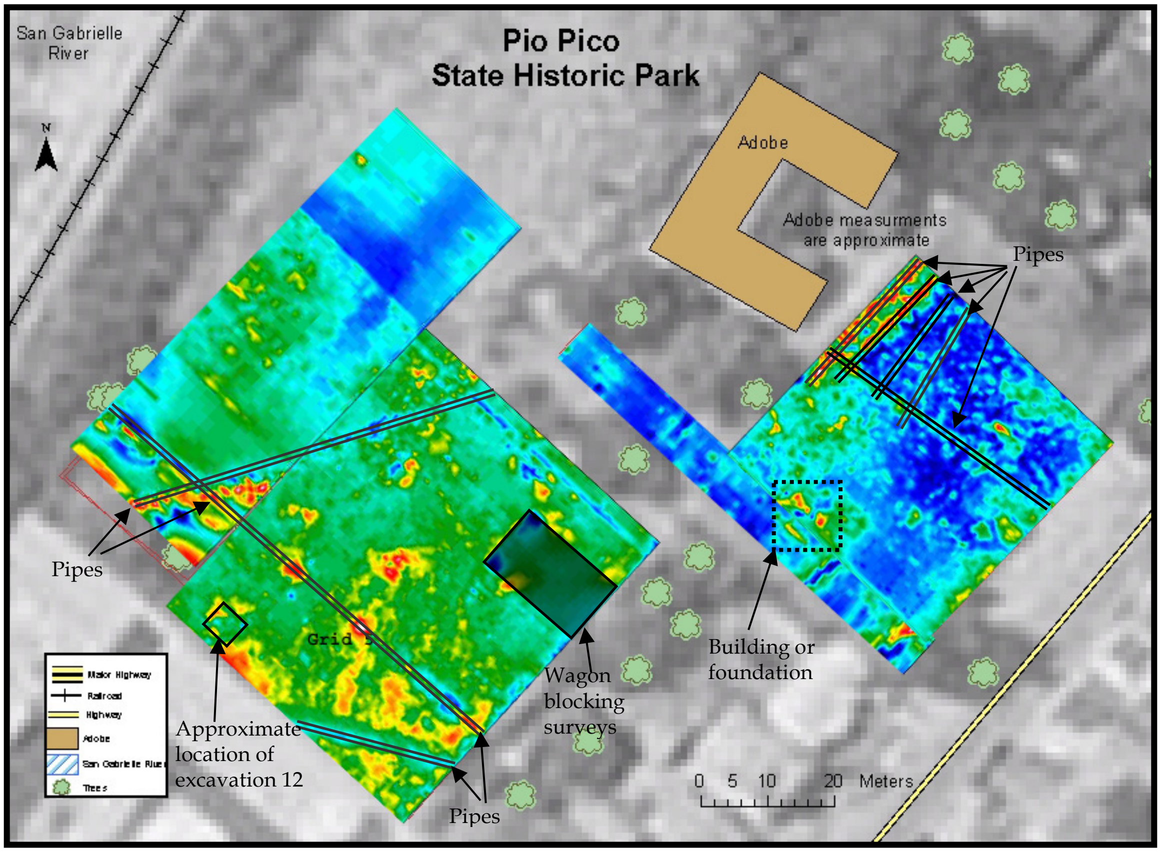


Figure 46
In the dry, sandy soils that characterize Pio Pico, the GPR survey is best at picking out the non-metallic features. The foundation in between grid 1 and grid 8 was displayed best with the GPR and is diffused somewhat in this integrated image. Most of the pipes were clearly identified in all of the geophysical surveys (particularly the EM and MAG) and dominated the survey results. Metal scraps in the trash middens and scattered throughout the site were also easliy identified.

Ideally, the geophysical surveys, GPR, EM, and MAG, would be analyzed individually and processed to emphasize the strengths of each technique and then integrated together. The result would produce an image that represented the best of all surveys. It is possible in a GIS to exclude, or diminish the importance of, those features that either overwhelm the data set or are not of interest to the research. In this way, the MAG, EM and GPR surveys can be combined to highlight those features of interest. The addition of the soil characteristics and archaeological data to the geophysical survey results would contribute to the interpretation of the entire site. At Pio Pico, however, only in grid 5 were all the components available for a thorough analysis. Grid 1 had all three geophysical survey data and some soil analysis but no archaeological information. Grid 7 only had geophysical data, while grid 8 had some soil data as well as geophysical data, but no archaeology. Furthermore, the locations of the grid boundaries as well as auger holes and archaeology excavations are approximated due to the inaccuracy of the GPS point locations.

Despite the lack of consistent and auger hole and archaeological information and inaccurate GPS point locations, using a GIS as a tool to integrate the geophysical survey results at Pio Pico was an useful exercise. The method provided comprehensive images of the subsurface features and produced maps in which the potentially sensitive archaeological remains were identified to be avoided or excavated prior to park re-development.

The integrated geophysical approach was capable of mapping numerous pipes and other recent disturbance in the Pio Pico grids. The Mag and EM data were especially useful in this regard. GPR maps discovered one large house foundation in Grid 1, and at least two midden deposits in Grids 5 and 7, which were not identified by the other two methods. The GPR maps alone however could not pick up many of the pipes, and often could only produce images of the pipe trenches, and not the pipes themselves.

In summary, the Pio Pico geophysics mapped a great deal of recent cultural disturbance to the site, including excavations for pipes and other ground disturbances related to dumping of trash and excavation materials. The archaeological data supports the geophysical data in that most tests uncovered a great deal of recent trash including plastic garbage, bricks, asphalt and metal. Often this was mixed in with older artifacts including brownware ceramics and older glass, which is likely 19th century. This data by itself shows the amount of mixing and disturbance to the site.

Archaeological discoveries made by the geophysics include the two middens, both of which are in the old floodplain of the San Gabriel River, just below the river terrace scarp. The only structural feature is the house foundation in Grid 1, which has not yet been tested by excavations or augers.

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