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2015 Ground-penetrating Radar Survey at the Alamo, Bexar County, Texas

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2015 Ground-penetrating Radar Survey at the Alamo, Bexar County, Texas

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2015 Ground-penetrating Radar Survey at the Alamo, Bexar County, Texas

Antiquities Code of Texas

Permit No. 7485

By

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Austin, TX

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Abstract

A ground-penetrating radar (GPR) investigation was conducted by members of the Archeology Division of the Texas Historical Commission at the Alamo Mission in San Antonio, Texas on December 2, 2015. The purpose of the survey was to determine whether GPR is a suitable technology for mapping subsurface features on the site in advance of future archeological investigations or development. Nine separate GPR grids were surveyed to provide a broad sample of the areas that may retain buried historical features. The General Land Office of Texas owns and manages the Alamo. In compliance with the Antiquities Code of Texas, the work was conducted under Antiquities Permit #7485. Records for this project are curated at the THC's Center for Artifact Research.

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Introduction

A ground-penetrating radar (GPR) investigation was conducted by members of the Archeology Division of the Texas Historical Commission at the Alamo in San Antonio, Texas on December 2, 2015. The purpose of the survey was to determine whether GPR is a suitable technology for mapping subsurface features on the site in advance of future archeological investigations or development. Nine separate GPR grids were surveyed to provide a broad sample of the areas that may retain buried historical features (Figure 1). The General Land Office of Texas owns and manages the Alamo and two GPR grids were also collected over Alamo Plaza, City of San Antonio property. In compliance with the Antiquities Code of Texas, the work was conducted under Antiquities Permit #7485.




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Figure 1. Nine GPR grids collected in and around the Alamo

GPR Methods

GPR data are acquired by transmitting pulses of radar energy into the ground from a surface antenna. Transmitted pulses are reflected off buried objects, features or bedding planes and then detected back at the ground surface with a receiving antenna. When collecting radar reflection data, the surveyor moves surface radar antennas along the ground following transects within a survey grid. The radar data are measured in temporal units called nanoseconds (ns). The resulting data are a series of reflections from each transect that are plotted to create a two-dimensional profile. Each profile is a graphic representation of a vertical face along a particular transect (Figure 2).

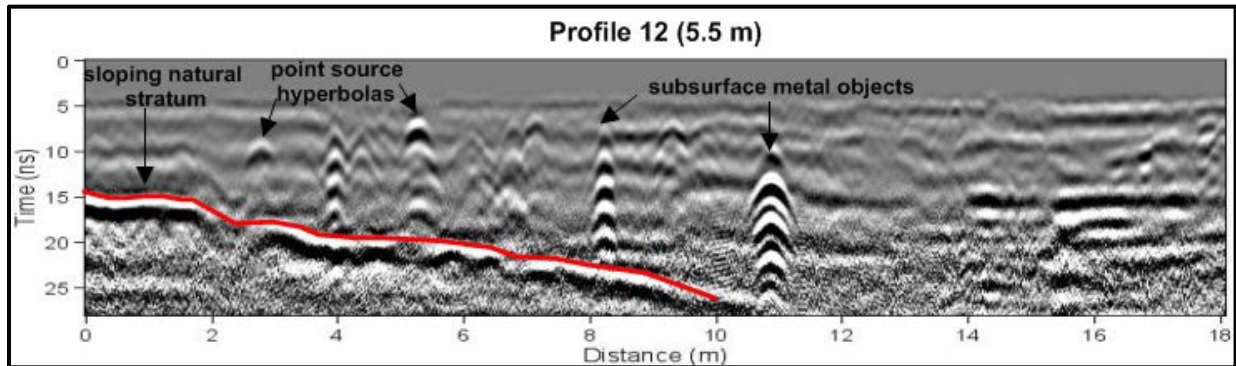


Figure 2. Example of a GPR profile showing hyperbolic reflections resulting from discrete point sources, reflection signature of metal objects, and a sloping planar surface.

The success of GPR surveys in archeology is largely dependent on soil and sediment mineralogy, ground moisture, depth of burial and surface topography and vegetation. Electrically conductive or highly magnetic materials in the ground will quickly dissipate radar energy and prevent its transmission to depth. The best conditions for energy propagation are usually therefore dry sediments and soils. The greater the contrast in electrical (and to some extent magnetic) properties between two materials at an interface, the stronger the reflected signal, and therefore the greater the amplitude of reflected waves (Conyers and Goodman 1997:33-34).

When reflections from buried objects are viewed in two dimensions they often appear as hyperbolic reflections (see Figure 2). These reflections are produced from buried “point sources” such as pipes or large rocks as opposed to planar surfaces such as buried pathways or floors. The wide angle or “footprint” of the radar beam causes the antenna to “see” the object as it moves toward it and continues to “see” it as it moves over and away from the buried object, resulting in a hyperbolic reflection along the transect.

The GPR system used for the Alamo survey was a Geophysical Survey Systems Inc. (GSSI) Subsurface Interface Radar (SIR) 3000 model mounted on a wheeled cart (see Figure 3). The GPR antenna used for the survey was a dual 400 megahertz (MHz) antenna that produces a radar pulse of about 25 cm in wavelength. The 400 MHz frequency antenna is commonly used for archeological investigations since it allows for relatively deep penetration with the ability to resolve small features and objects. Nine survey grids were laid out with various configurations to maximize survey areas while avoiding obstacles (Table 1).



Figure 3. Cart mounted GSSI Sir 3000 GPR with 400 MHz antenna.

All GPR reflection data were collected as 16-bit data, with 512 digital samples defining each reflection trace. The data were frequency-filtered to remove extraneous noise from the reflection traces. Range gains were applied in the field to enhance reflections from deeper within the profiles. All reflection data were first processed into two-dimensional profiles and analyzed as if looking at stratigraphy within a trench or cutbank. Amplitude-slice maps were also generated to aid in interpretation. These maps are analogous to arbitrary excavation levels in standard archeological terminology. Each slice represents successively deeper 20 cm layers in the ground. Often slice 1 is not shown due to its surficial nature. In the pages that follow these slice maps are shown in full color for each survey grid. High amplitude reflections are seen as “warmer” colors, greens, yellows, and reds.

Table 1. GPR Data Collection at the Alamo

GPR/Mag Grid Name	Dimensions (m)	Transect Spacing (m)	# lines	Profiling Direction	(0,0) position	Files	Date
Grid 1	5 – x – 16	0.5	11	E-W	NW	1-11	12-2-15
Grid 2	27 – x – 5	0.5	11	E-W	SE	12-22	12-2-15
Grid 3	8 – x – 14	0.5	17	E-W	SE	23-39	12-2-15
Grid 4	5 – x – 16	0.5	11	E-W	SE	40-50	12-2-15
Grid 5	9-x-23	0.5	20	N-S	SW	51-70	12-2-15
Grid 6	11-x-30	0.5	24	N-S	NE	71-94	12-2-15
Grid 7	6-x-12	0.5	14	E-W	SE	95-108	12-2-15
Grid 8	10-x-11	0.5	22	E-W	NW	109-130	12-2-15
Grid 9	6-x-7	0.5	14	E-W	NW	131-144	12-2-15

Survey Results

Grid 1 Church

One long narrow grid was placed in the nave of the Alamo Church (Figure 4). The results of this grid are shown in Figure 5. Two utility lines are the most obvious features identified (Figures 5 and 6). These lines generally run north-south below the flagstone floor and may be collocated in the same trench. The more shallow is a metal pipe that is likely no more than 15 cm below the floor. The second is a nonmetallic line that is slightly deeper at around 20-25 cm below the floor. There is also a buried feature that may represent another utility at 12 meters (m) along this grid. This feature may also be located in a trench or pit and is located at approximately 20 centimeters below surface (cm bs). There appears to be a soil interface or texture change at 1 m below the floor surface (Figure 6). This may represent the interface between modern construction materials and historic rubble and the intact natural sediments below.

The metal grave monument in the floor, shown in the figure 7 photograph, is visible at the top of the figure 7 GPR results. This monument marks the reburial of human remains that were recovered from the below the floor of the Church near the altar in 1937 during interior renovations (Uecker 2001). Human remains were also found along the south wall of the transept during 1995 excavations by the University of Texas at San Antonio’s Center for Archeological Research (Meissner 1997). Notably, although it is anticipated that additional burials remain below the floor within the Church, none are clearly identifiable in the GPR data.



Figure 4. Survey grid inside the Alamo Church

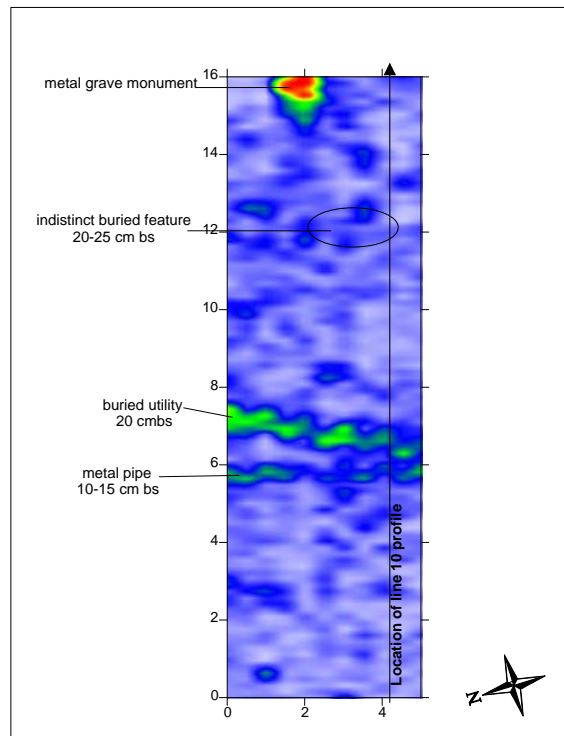


Figure 5. Annotated amplitude slice map of GPR data collected over Grid 1 inside the Alamo Church. This slice shows GPR results at 34 cm below the floor.

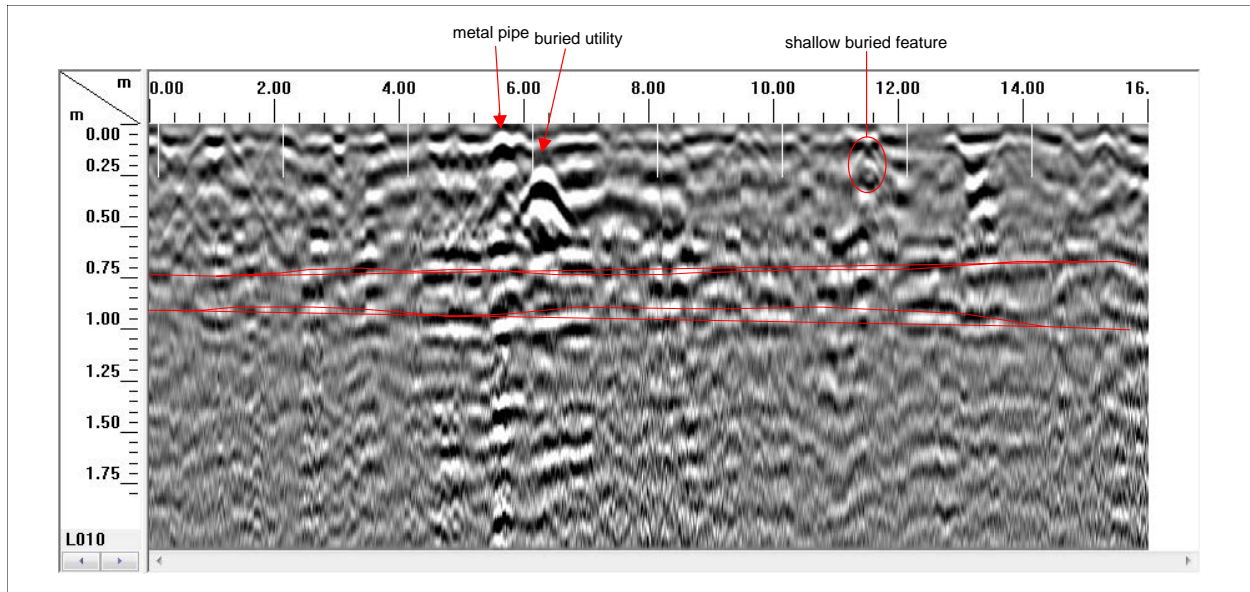


Figure 6. Annotated two-dimensional profile from Line 10, Grid 1.



Figure 7. Monument in the floor of the Alamo Church. Visible in figure 5 GPR results.

Grid 2

Grid 2 was designed as a long, narrow grid over the flagstone surface just north of the grassy *campo santo* area in front of the Alamo complex (Figures 1 and 8). Figure 9 shows the amplitude slice maps created from the GPR results. The indication of archeological features within this grid is minimal. The annotated slice maps in figure 9 provide a summary of the most apparent results, many of which reflect a complex and dynamic construction and development history of the Alamo Complex.

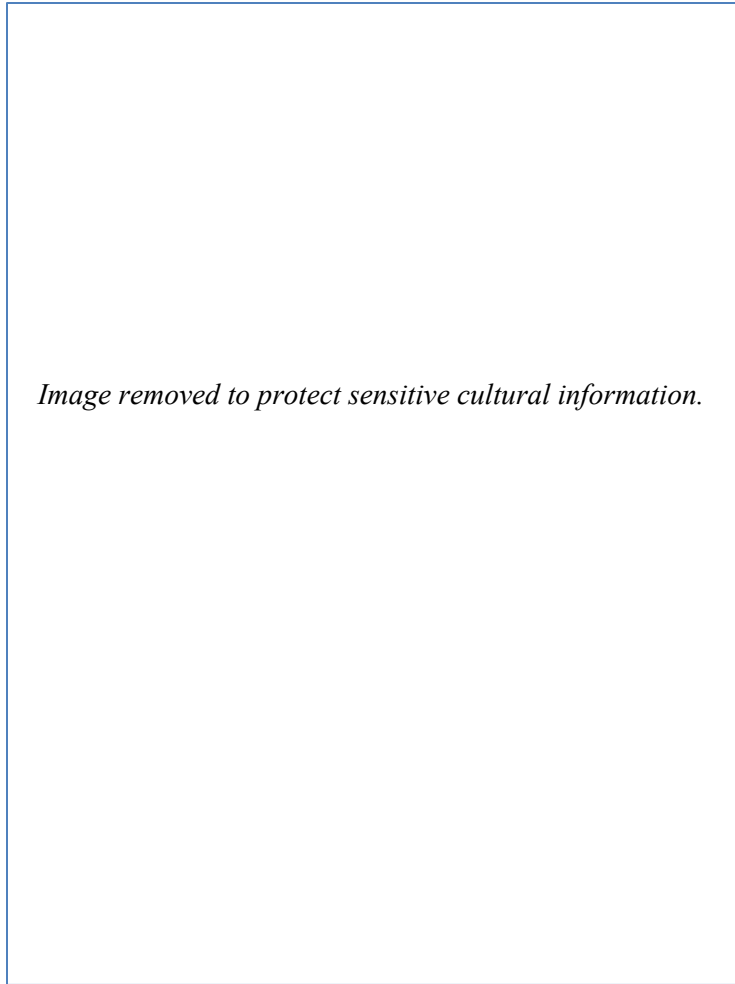


Figure 8. Location of GPR Grid 2.

A wire mesh, possibly no more than a 4-inch pattern, is visible under the flagstone in the two-dimensional profiles shown in figure 10. The mesh extends the length of the grid in the northern half (see figure 9). In the first three lines it extends from 0-6 meters, then constricts back to 3 m in lines 4-6. At line 7 it extends to the length of the grid. The wire mesh in lines 1-3 seems to have a buckle or dip and at approximately 2-3 meters (Figure 10). A utility line is present across the grid at 1 meter and the buckled wire may be representative of utility trenching and subsequent replacement of the mesh.

There appears to be another utility trench or large buried feature across the grid between 17-19 meters. This feature is approximately 60 cm below the surface and may be archeological. A second possible archeological feature is located between 2-4 meters. Both of these features have a clustered, rubble appearance in the GPR profile images (Figure 10).

Two shallow buried utilities are visible in the grid, one at 18 meters and another crossing the grid at 10 meters (figure 9).

A highly reflective surface that undulates between 10-20cm bs extends across much of the grid but terminates in a distinct line that runs diagonal to the grid (Figure 9). This feature may reflect prior paving and likely could be answered by an analysis of old landscaping and paving plans.

This interpretation highlights the most apparent buried features within this survey grid. Additional analysis would likely yield additional buried features. If these features are ever ground-truthed, the results should be used to extrapolate additional information from the rest of the two-dimensional profiles.

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Figure 9. Annotated amplitude slice maps of GPR data collected over Grid 2.

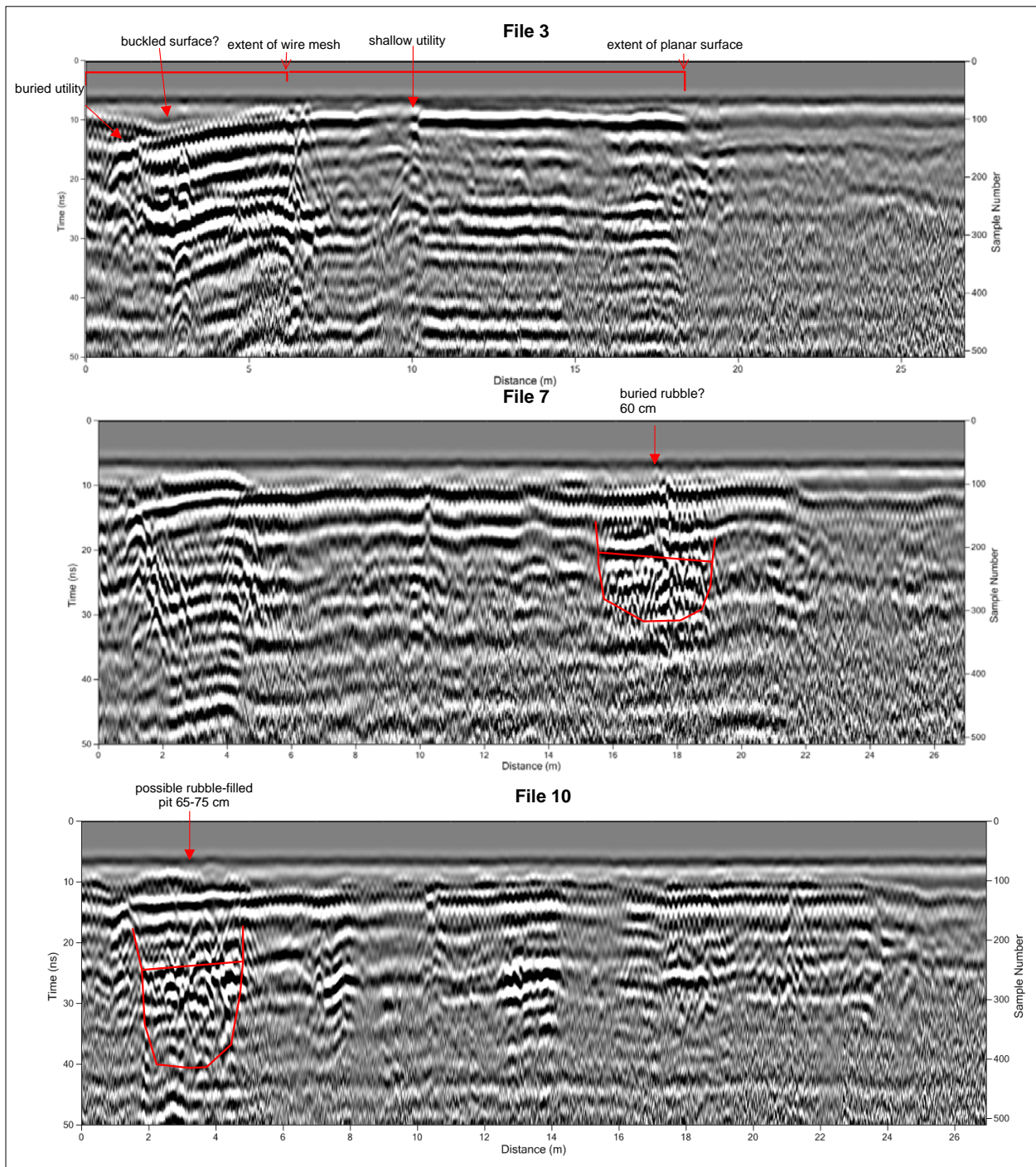


Figure 10. Two-dimensional profiles collected over lines 3, 7, and 10 in Grid 2.

Grid 3

Grid 3 was a small grid collected over the grassy *campo santo* area directly in front of the Alamo (Figure 11). This area was chosen to determine if GPR could map the graves that are suspected to be present in this location. The grassy area had been watered the night before and was nearly saturated during the

morning of our survey. Moisture retention in clayey matrix negatively affects the propagation of electromagnetic waves in the ground. This is because the ground conductivity (moisture in clay is highly conductive) allows a portion of the radar wave to be conducted away, leaving very little of the remaining signal to reflect off of buried objects and eventually be recorded back at the surface. As a result of these conditions, very little useful reflection data is present below 50 cm in this grid.

The sprinkler system lines criss-cross this grid and many are visible in the shallow GPR slice results from this survey. Figure 12 shows three sprinkler or electrical lines running roughly north-south within the grid, labeled A, B, and C, as well as the location of the line 10 transect which crosses all of three utilities. Their reflections are also clearly visible in the profile of line 10 (see figure 13).

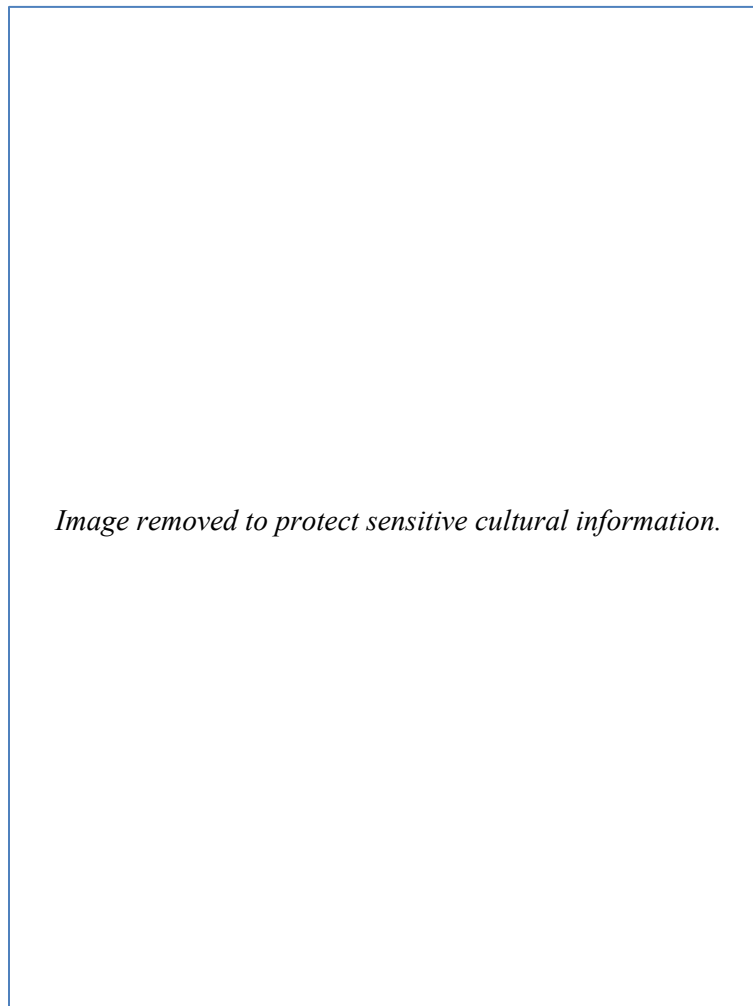


Figure 11. GPR survey grid over the grassy *campo santo* area.

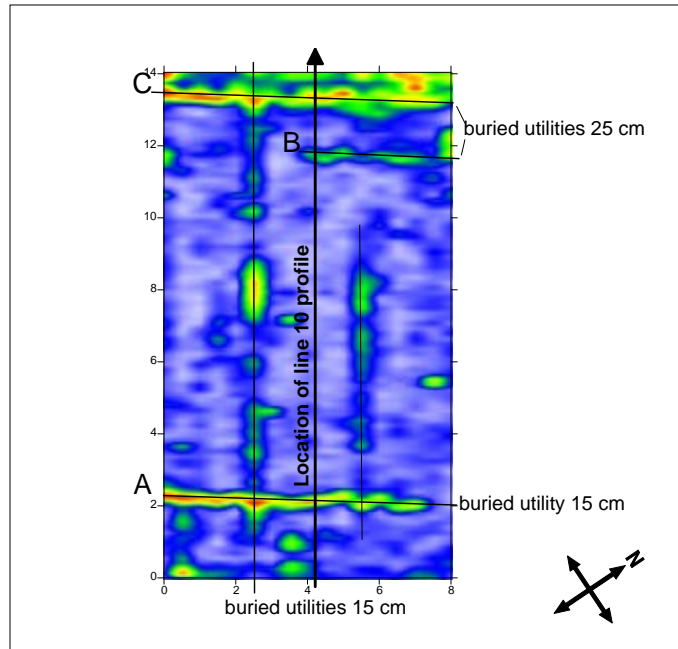


Figure 12. Grid 3 GPR slice map showing three shallowly buried utility lines A, B, and C below the grass.

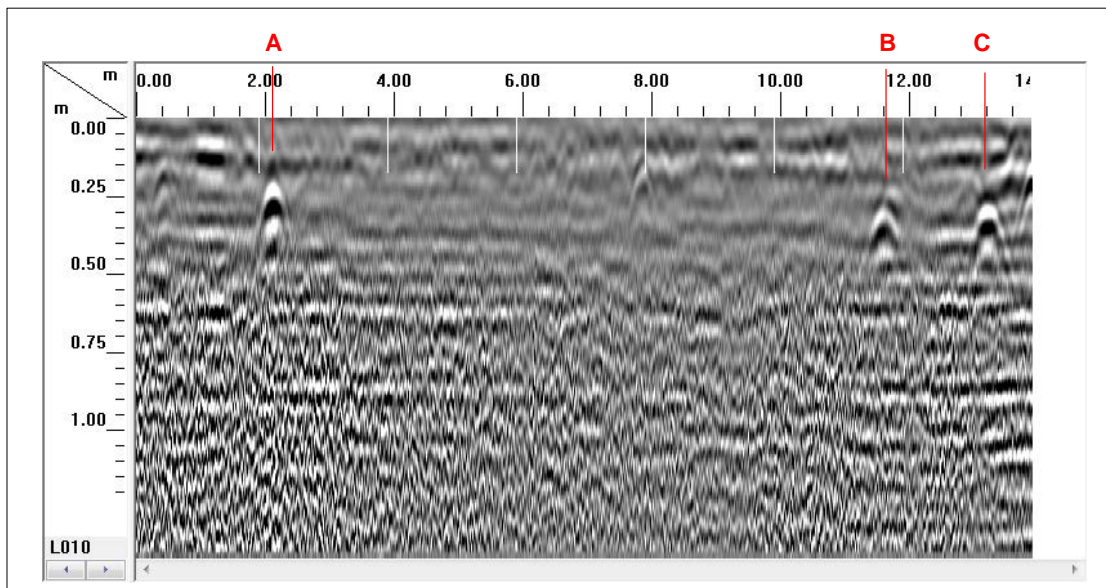


Figure 13. Two-dimensional profile of showing the three buried utilities that are visible in figure 12.

Grid 4

This long narrow grid was placed over the flagstone in front of the Alamo Church just south of the grassy *campo santo* area (Figure 14). The most notable features in the GPR results are shallow pipes and some possible voids or pits which may be historical (Figure 15). Again, wire mesh appears to be present in portions of the grid just below the flagstone surface.

In profile 4 it appears that fill has been added in locations to level the ground surface (Figure 16). Figure 15 includes several locations of GPR anomalies that may represent archeological features. These include a buried feature with a clustered or rubble appearance between 4-6 meters and approximately 75 cm deep in the northern portion of the grid (Feature 4 in figure 15, circled in figure 16). Features such as this would be worth a careful examination of previous records to determine whether trenching or other ground disturbance is known in this area prior to archeological investigation or ground-truthing. Feature 1 is a high amplitude reflection at approximately 50 cm deep and may represent a series of buried objects or point sources. Feature 2 is more indistinct and may be a pit or old trench into the substrate below the street. Feature 3 is a small anomaly at approximately 35 cm deep that may not be archeological. Feature 5 has the appearance in profile of a planar surface, potentially bounded on the west by a linear feature or buried utility.



Figure 14. Location of GPR Grid 4.

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Figure 15. Grid 4 slice maps show the locations of at least two buried utilities, A and B, and several other buried features of interest (1-5).

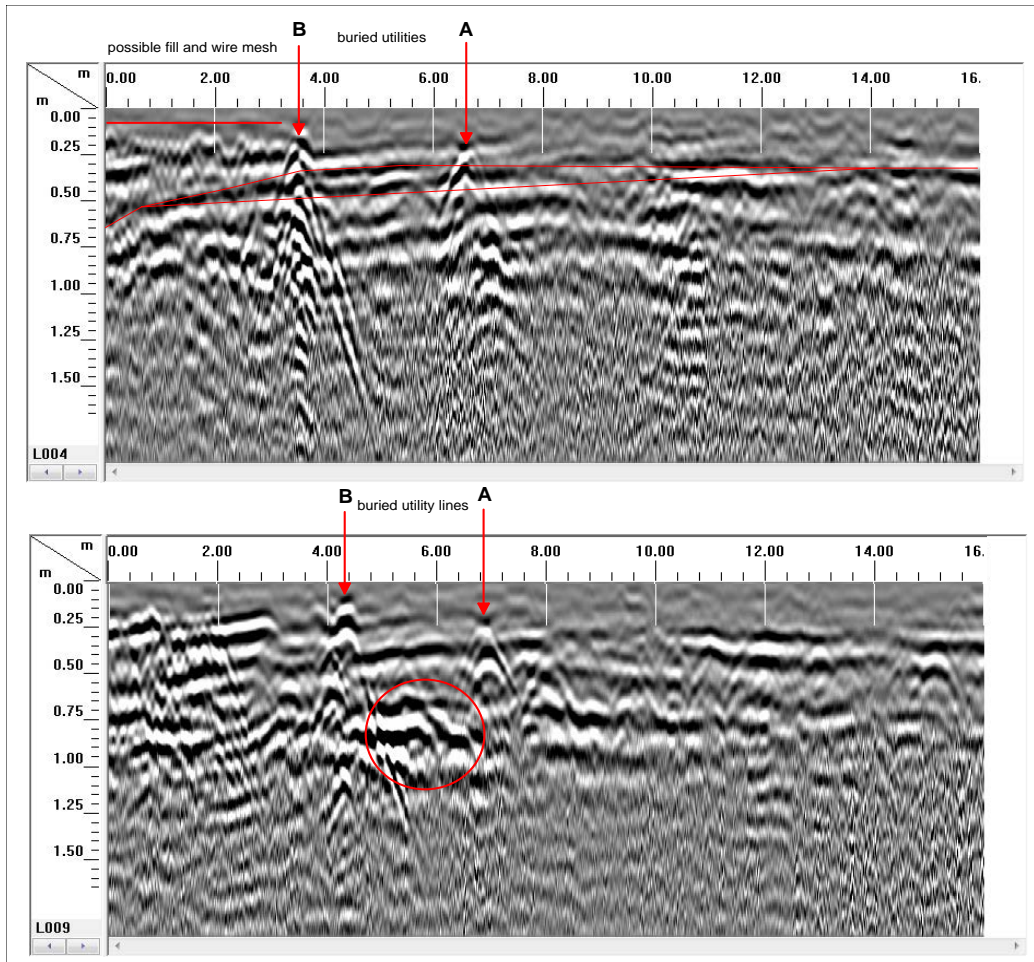


Figure 16. Two-dimensional profiles of lines 4 and 9 show the locations of buried utility lines and wire mesh in Grid 4.

Grid 5

Grid 5 was collected on City of San Antonio property, over the flagstone surface of the Alamo Plaza street southwest of the Church (Figures 1 and 17). Previous archeological investigations in Alamo Plaza have documented rebar under the flagstone street surface. Below this, there is a layer of modern street base, an old asphalt street surface, and another layer of road base (Uecker 2001). The rebar is clearly visible in profile throughout the grid (Figure 19). The amplitude slice maps resulting from the Grid 5 survey highlight several buried utilities and one interesting buried feature that may be archeological at approximately 50-75 cm deep (Feature 1 in Figure 18).

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Figure 17. Location of Grid 5 survey area in Alamo Plaza.

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Figure 18. Grid 5 GPR results indicating the location of several buried utilities and one buried feature (Feature 1).

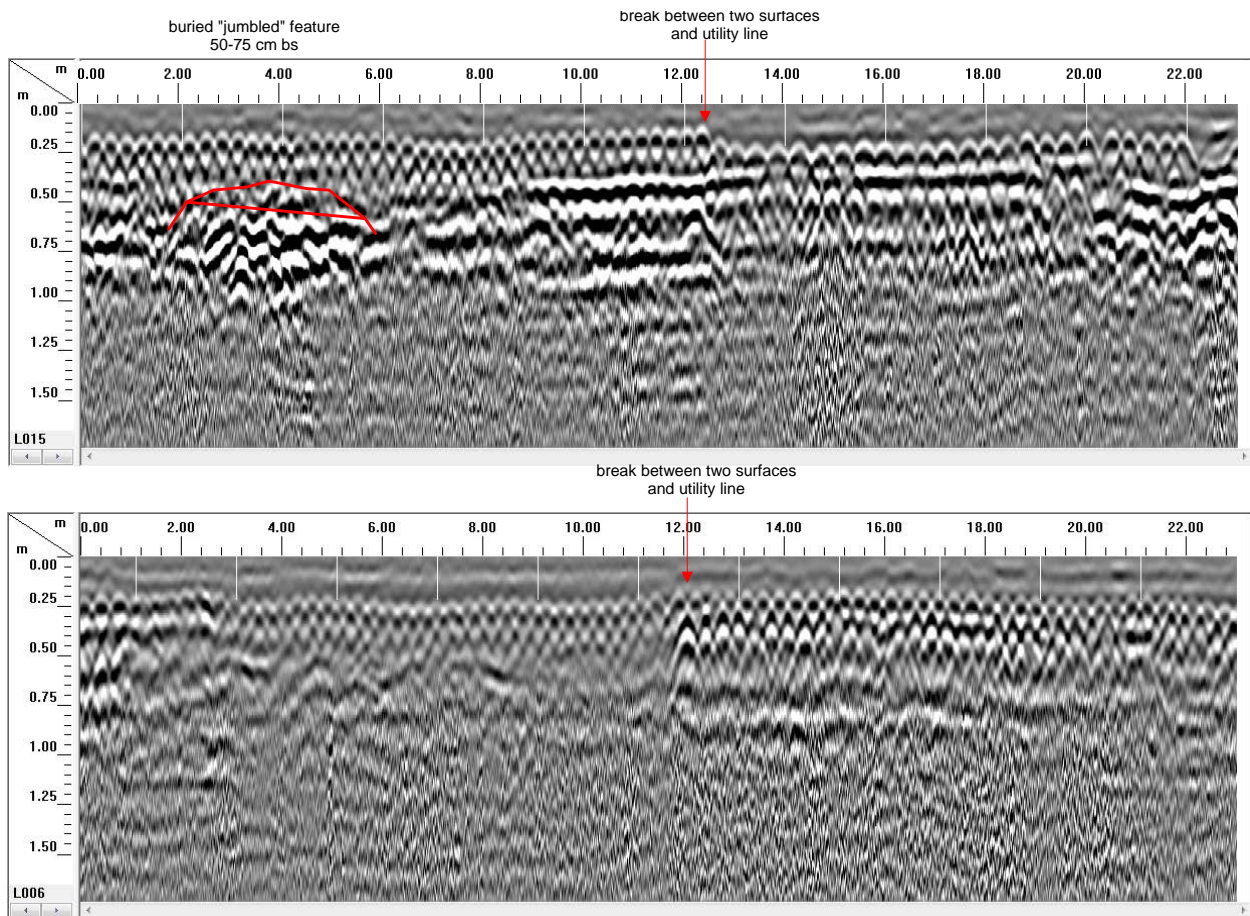


Figure 19. Two-dimensional profiles of lines 6 and 15 over Grid 5. Note the buried feature below 50 cm in line 15.

Grid 6

This grid was also placed over the flagstone street of Alamo Plaza in front of the Long Barrack on City of San Antonio property. The most apparent features in this grid are three utility lines and the location of a 1995 archeological excavation (Figure 20). The utility line that crosses the grid from top to bottom at 5.5 m is almost certainly metallic, given the way it “rings” through the entire profile. The 1995 excavation area is clearly visible in the bottom right portion of the grid as nearly a perfect square. This excavation was conducted by St. Mary’s University and called the Alamo Wells Project (Uecker 2001). It was designed to target a hypothesized well in Alamo Plaza and the treasure that it was rumored to contain. Early geophysical techniques were employed to prospect for the location of the well. These techniques were lacking in the resolution that is now possible for archeological purposes and as such interpretation of the data and identification of buried archeological features was imprecise. An industrial stone saw was used to incise the square hole in the flagstone for the 1995 investigation; no well was identified.

Two other buried features are noted on the slice maps for Grid 6 (Figure 20). The first is located near the top of the Slice 3 at approximately 60 cm bs, this feature appears to be related to a buried interface that

extends across a good portion of this grid as seen in Figure 21. A second buried feature is noted in figure 20 on Slice 4 near the bottom left. This feature is also visible in profile in Line 6 in Figure 21. It has a somewhat clustered appearance and is located at approximately 50-60 cm bs. This feature may be archeological in nature.

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Figure 20. GPR slice maps from Grid 6. Linear features are all buried utilities.

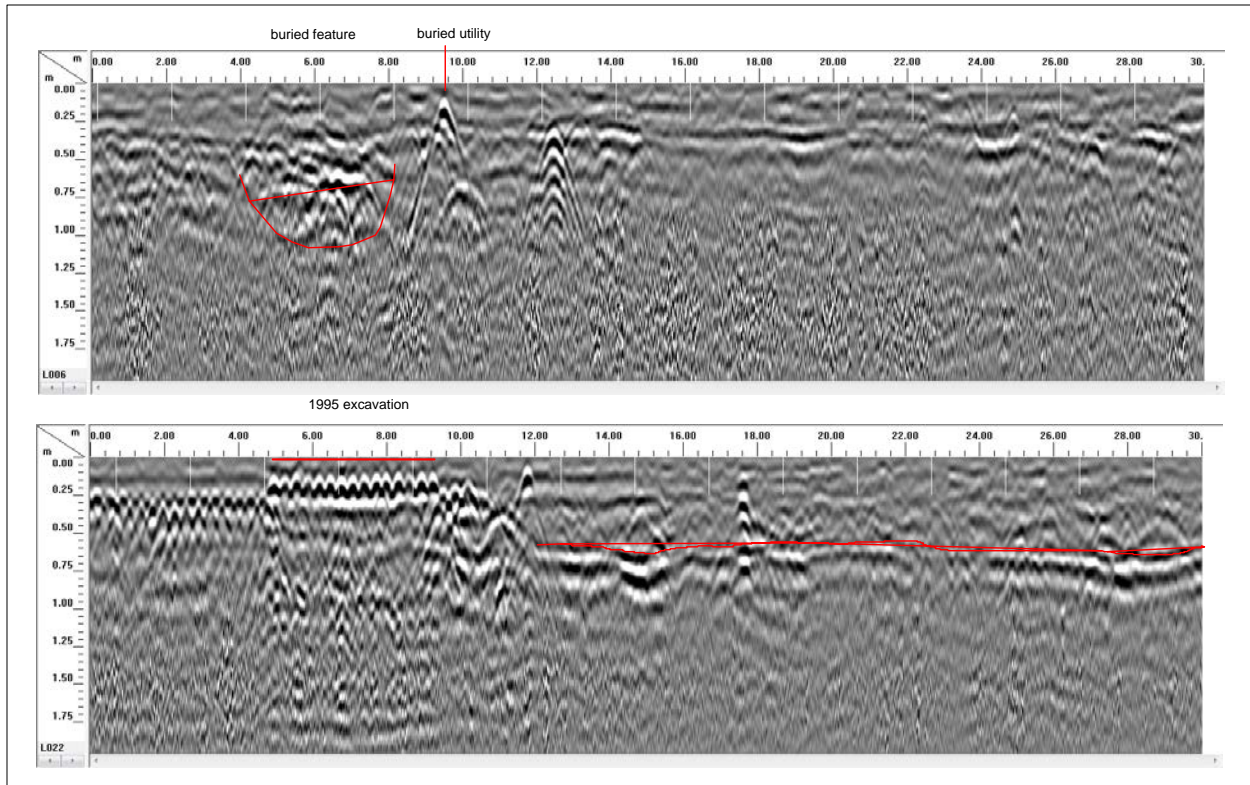


Figure 21. Two-dimensional profiles of lines 6 and 22 over Grid 6.

Grid 7

Grid 7 was located in the grassy area near a flag pole southwest of the Alamo (Figure 1). Again, due to evening irrigation of the lawn, this area was nearly saturated during the survey. Results indicate the location of at least one of these sprinkler lines but very little else of note. Other linear features are present that likely represent other buried utilities (Figure 21). Below 24 ns very little reflection data was recorded due to system noise and ground conductivity. It is anticipated that recent fill and disturbance in this area may extend to at least 18 inches below surface, if so, the current survey may not have been able to collect useful reflection data below this zone of disturbance. If future development is planned for this area and additional GPR work is conducted, it is recommended that the sprinkler system be turned off for a couple of days prior to allow for the ground to dry. This would greatly enhance the ability to transmit electromagnetic waves to depth.

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Figure 22. Amplitude slice maps from Grid 7. Linear features are likely buried utilities.

Grid 8

Grid 8 was placed east of the current acequia within the Alamo complex (Figure 23). This grid was placed to attempt to detect prior configurations of the historic period acequia. Again, the ground was moist in this grid due to evening watering. One irrigation line is visible but no indication of the acequia can be interpreted from the GPR results (Figure 24).



Figure 23. Photo of Grid 8 location facing northwest. Acequia runs across the photo in the background.

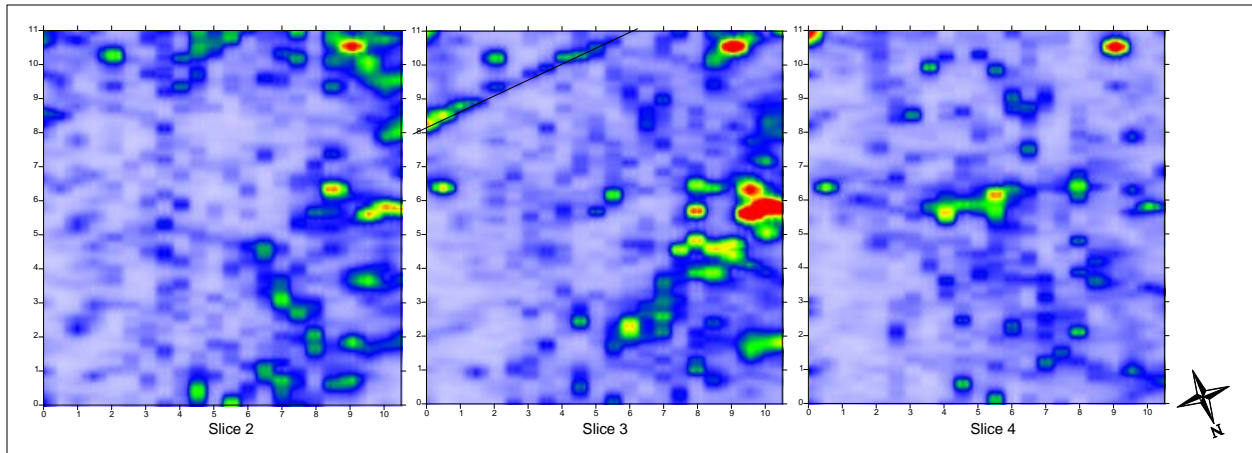


Figure 24. GPR slice maps from Grid 8. Linear feature is likely a buried utility line.

Grid 9

Grid 9 was also placed to prospect for old acequia configurations (see figure 1). This grid was far too small to resolve patterns beyond the irrigation lines that criss-crossed this grid (Figure 25). Several sprinkler valves were located at the surface near the center of this small confined survey area.

On March 1, 2016 representatives of the THC returned to the Alamo grounds to test the shallow subsurface conditions near Grid 9 to determine the depth of recent fill over the intact surface. One small shovel wide trench was excavated just north of Grid 9. The trench was 1 meter long, oriented north-south, and was excavated to 18 inches without encountering intact sediments. The observed fill was mixed, dark, clayey sediment with limestone gravels.

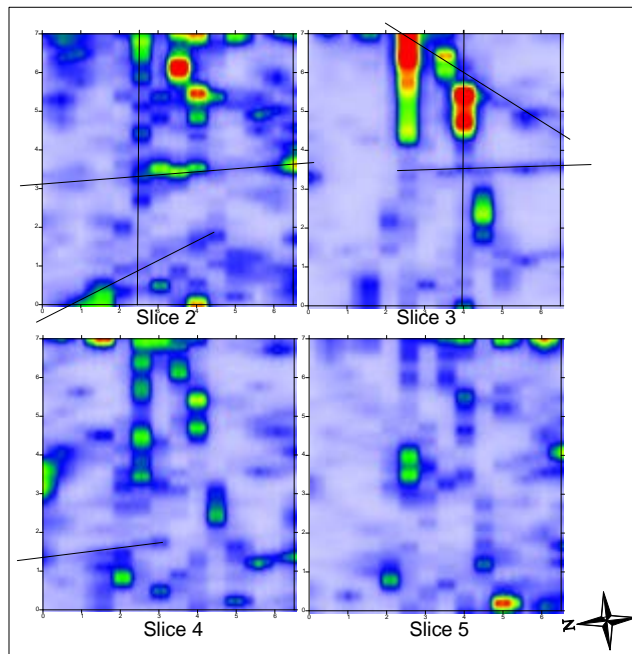


Figure 25. GPR slice map results from Grid 9. Linear features are likely buried utility lines.

Conclusions

The Texas Historical Commission's 2015 GPR survey at the Alamo was intended to serve as a test to determine the efficacy and success of modern GPR methods and equipment in the specific conditions presented at the historical site. The results indicate that GPR can be quite successful at resolving buried features at the Alamo, particularly below the flagstone surfaces. In several of the areas sampled by this project, however, the dynamic construction and development history of the Alamo grounds results in very complex GPR data. Without specific questions or areas of inquiry, the interpretation of these data could become overwhelming and will benefit from a more project-directed approach. Despite this, GPR could be an immensely useful tool for planning and development of the site in the future. An attempt has been made to summarize and annotate some of the more prominent features identified during this investigation. Many more features exist in these datasets, and a detailed study should be undertaken of previous utility work and construction development where records exist to assist further analysis.

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