Title

Final report of geophysical investigations at three Carrizo Corridor stage stations, Anza Borrego Desert State Park

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FINAL REPORT OF GEOPHYSICAL INVESTIGATIONS AT THREE CARRIZO CORRIDOR STAGE STATIONS, ANZA BORREGO DESERT STATE PARK

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Geophysical investigations were conducted at three Carrizo Corridor Stage Stations within the Anza Borrego Desert State Park to search for buried objects and structures associated with historic occupation of these sites. Field surveys were conducted on March 21-23, 2001 at Carrizo Creek, Palm Spring, and San Felipe Stage Station. Three geophysical techniques were employed: ground penetrating radar (GPR), electromagnetic conductivity (EM), and total magnetic field measurement (MAG).

GEOPHYSICAL TECHNIQUES

Ground Penetrating Radar

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 Carrizo study area, we used a GPR unit manufactured by GSSI (SIR-2000) with a 400 MHz antenna. The wavelength of a 400 MHz antenna in sandy soils, such as those found in the Carrizo area, is about 0.34 m. The near-field zone of the 400 MHz antenna is about 1.5 times this wavelength, therefore the shallowest features separated from the out-going pulse in the Carrizo dataset should be about 50 cm deep. Imaging capabilities in the 0-50 cm depth zone will be more limited than for 50-100 cm depths.

GPR data were collected at 16 scans/seconds as the radar antenna was moved along the ground surface at walking speeds. Grids of data were collected with 0.5 m 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 40 (ns) nanoseconds from the surface, and were divided into 6 ns time-slices for display (0-6 ns, 6-12 ns, 12-18 ns, and 18-24 ns). The radar data were gridded with a large (approximately 1 m) search radius to filter out clutter, and to emphasize the largest features. All radar images were given red colors for reflective materials and blue colors for non-reflective materials.

Electrical Conductivity

Electrical conductivity uses low frequency electromagnetic energy to detect changes in soil electrical properties. It is an effective means for detecting soil moisture content or buried metallic objects. Instruments for measuring electrical conductivity have a transmitting antenna and a receiving antenna separated by some horizontal distance. The antenna separation sets the optimal depth for detection. Metal objects produce a particularly strong signature, since they are efficient conductors of electrical energy. In the Carrizo Corridor study area, we measured electrical conductivity using an instrument manufactured by Geonics, the EM-38, with the sensing element held as close as possible to the ground surface (0-.2 m) and with a maximum detection sensitivity at about 0.4 m beneath the ground surface. Data were collected at 0.4 sec intervals at walking speed along survey tracks. The data were corrected for walking speed (shifted backward along track) and then gridded for display. In the conductivity images, regions of high electrical conductivity are shown with white and red colors, whereas regions with low electrical conductivity are shown with black and blue colors.

Total Magnetic Field

Total magnetic field mapping detects changes in the magnetization of subsurface materials. For example, fire produces a strong magnetization in clay and soils, such as the materials comprising a hearth or kiln. Metals are another class of materials that have a strong magnetic signature. There is a daily variation of ambient magnetic field strength due to the presence of the sun; at local noon an enhanced magnetic field is observed whose amplitude depends on the geomagnetic latitude and on sunspot activity. To remove the solar diurnal variation, measurements were repeated at a fixed station. The data were then corrected for solar daily variations to capture the presence of local magnetized materials. The magnetic sensor was moved in a horizontal plane at about 0.3 m above the site surface. Collecting a grid of magnetic field measurements with 0.5 m line spacing allowed us to produce a two-dimensional map. At the Carrizo study area, magnetic data were collected with a Geometrics 858 cesium vapor total field magnetometer. In the magnetic field images, regions of increased total magnetic field are shown with white and red colors, whereas regions with decreased total magnetic field are shown with black and blue colors.

RESULTS

The geophysical survey grids were designed to test for historic structures or objects at each of the three stage station sites. At each site grids were marked on the ground with corner stakes, and GPS measurements were made to position the grid relative to a site datum. All geophysical data were collected at 0.5 m line spacing. Measuring tapes were placed along the ground surface and control marks were entered into the data at 1 m intervals during the data collection process.

CARRIZO CREEK STAGE STATION

Three grids of geophysical data were collected at the Carrizo Creek Stage Station on March 22, 2001. These grids are shown superimposed on existing site features in Figure 1. The grids are located west of a north-east trending drainage, except for grid 1, which has the drainage gully passing along its eastern edge. A recent erosion gully passes between grids 1 and 2, exposing cobble walls of the stage station buildings. Disturbance of the site was evident; a berm of adobe had been pushed up along the eastern edges of grids 1 and 2, apparently to aid in water catchment during use of the area for cattle ranching (see the yellow line in Figure 1). After the geophysical data collection, archaeological subsurface testing revealed the outline of two structures (labeled A and B in Figure 1) spanning grids 1 and 2, as well as part of a structure in the southern portion of grid 1. The floors of these structures were cobble covered at a depth of about 45 cm (18 inches).

CARRIZO Ground Penetrating Radar

The GPR data were collected and initially processed as a series of vertical slices, for example, grid 1 – line 11 is displayed in Figure 2. This line runs from north to south, 5 m from the eastern edge of the grid. A strong reflector is observed in the line at about 18-20 cm (7-8 inches) and another deeper reflector is seen at 60-70 cm (24-28 inches). Note that although this line lies over the cobble floor of Structure A, nothing in the GPR data suggests the presence of a cobble floor at 18 inches. One explanation may be that the cobble floor lies in the "dead-zone" created by the out-going radar pulse, consistent with the low amplitude character of the radar signal between 20-50 cm.

The time-sliced GPR data for Carrizo Stage Station grids are presented in Figure 3, with each slice representing 25 cm of depth. The outline of the cobble floors for Structure A and B would be expected to appear in the second slice (Figure 3, 25-50 cm) or third slice (Figure 3, 50-75 cm). However, no correlation between the GPR data and the excavated structures in grids 1 and 2 is observed. The adobe berm on the western edge of grid 1 appears as a zone of low GPR reflectivity. Two of the most consistent areas of high GRP reflectivity appear in grid 3: (a) a 2-3 m zone of high reflectivity in the south-west corner, and (b) a patchy 5-10 m zone of high reflectivity at 30 m north, 10 m east from the south-west grid corner.

CARRIZO Electrical Conductivity

The Carrizo Stage Station electrical conductivity data are shown in map view in Figure 4. Note that for the EM data, grid 2 extends westward to the base of the hill at the western edge of the site. The EM data at the Carrizo Stage Station primarily may show the moisture content of the soil, and secondarily the location of metallic objects. The EM data reveal a low conductivity zone associated with the adobe berm in grids 1 and 2, presumably because of its low water content. High conductivity zones are associated with the main north-south drainage, as well as the smaller gullys in the western part of grid 2. A zone of high conductivity in the south-east corner of grid 1 has angular corners and straight sides, following the trend of Structure A. There is some suggestion in these data that a low conductivity feature is associated with Structure A in grid 1 and Structure B in grid 2. In grid 3 high conductivity is found in the south-west corner and along the eastern edge of the grid. Local zones of high and low conductivity are seen at 30 m north, 10 m east from the south-west grid corner, suggestive of metallic objects, as observed on the site surface (Figure 1).

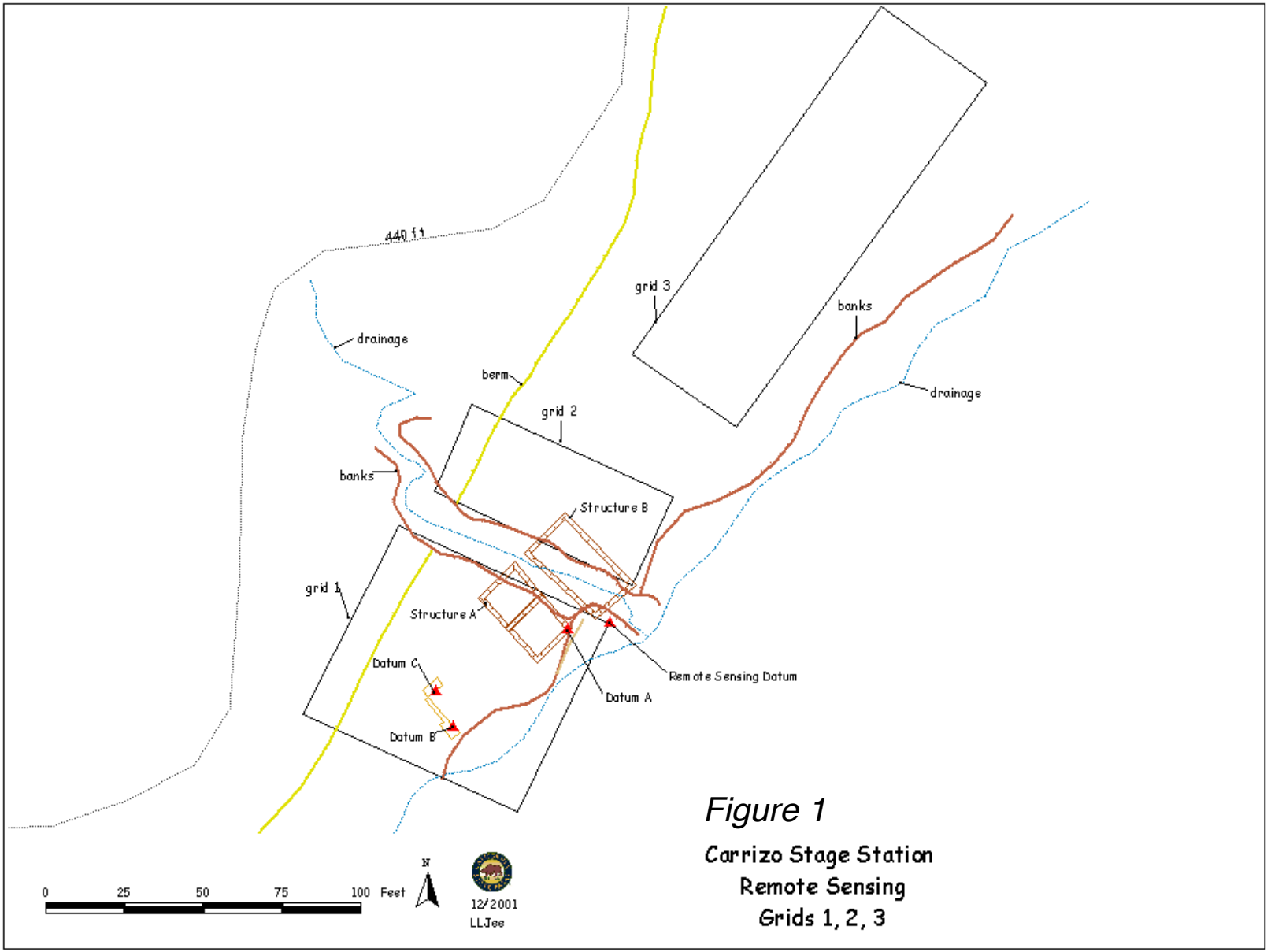


Figure 1

Carrizo Stage Station
Remote Sensing
Grids 1, 2, 3

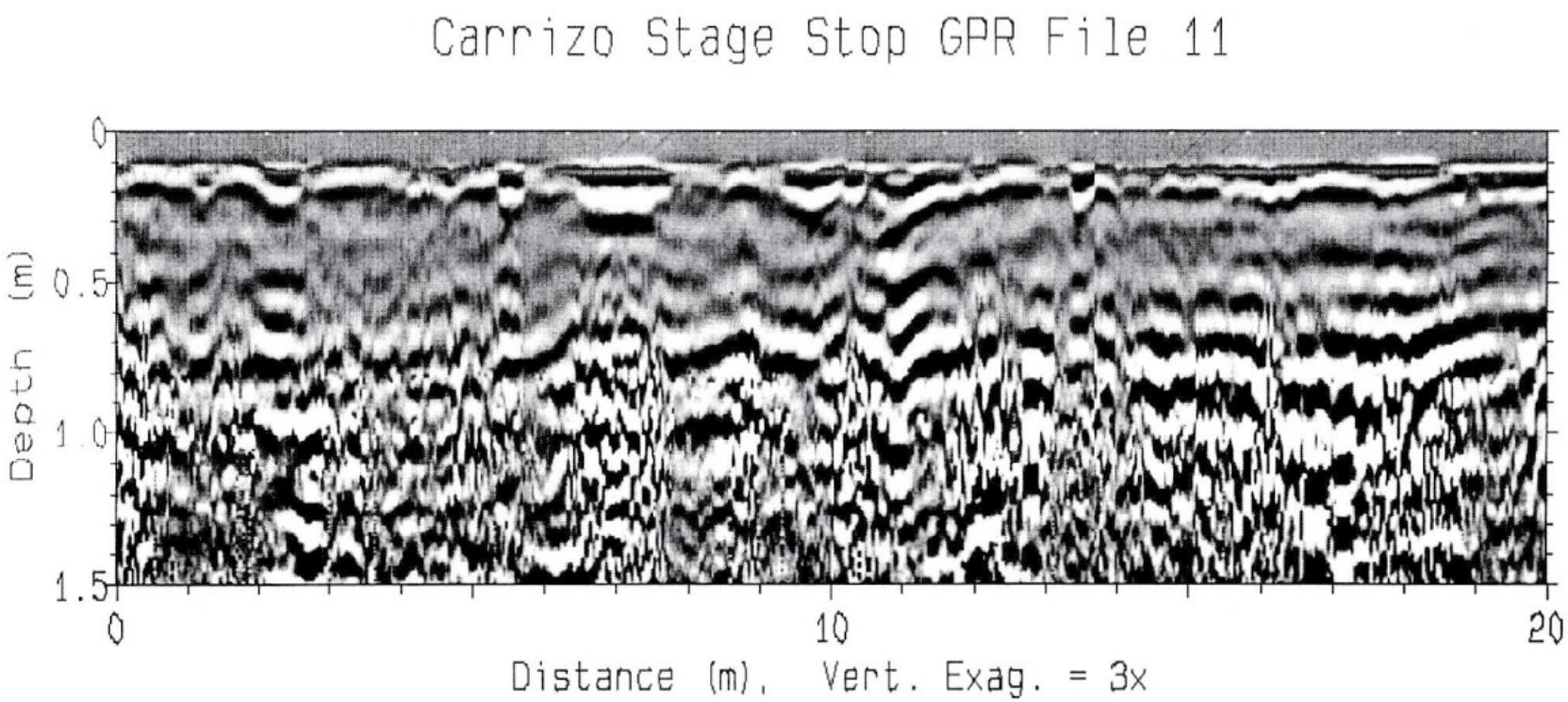


Figure 2. Vertical GPR slice at Carrizo Stage Station Site, Grid 1, Line 11. The profile run from north to south, 5 m from the eastern edge of the grid.

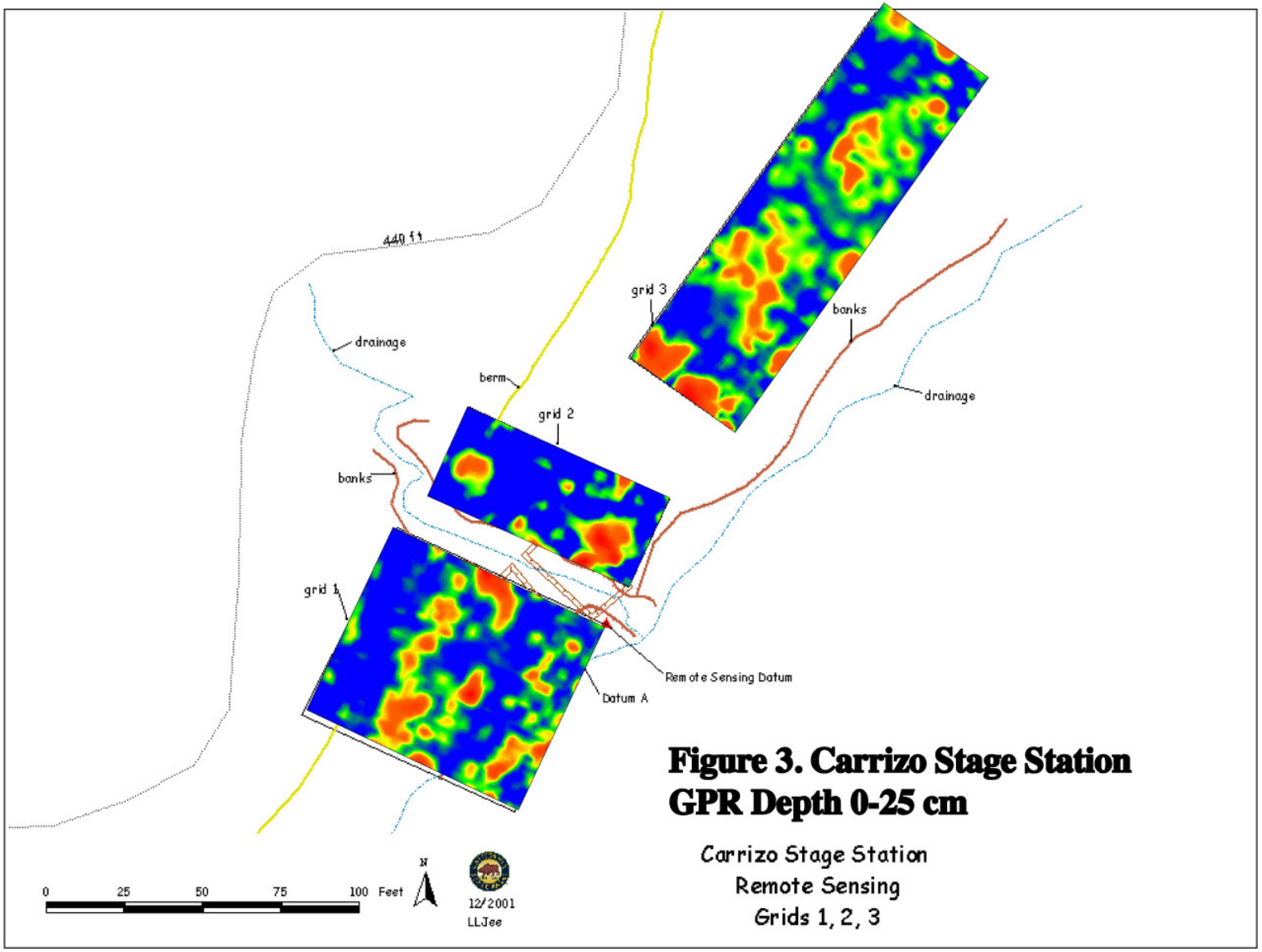
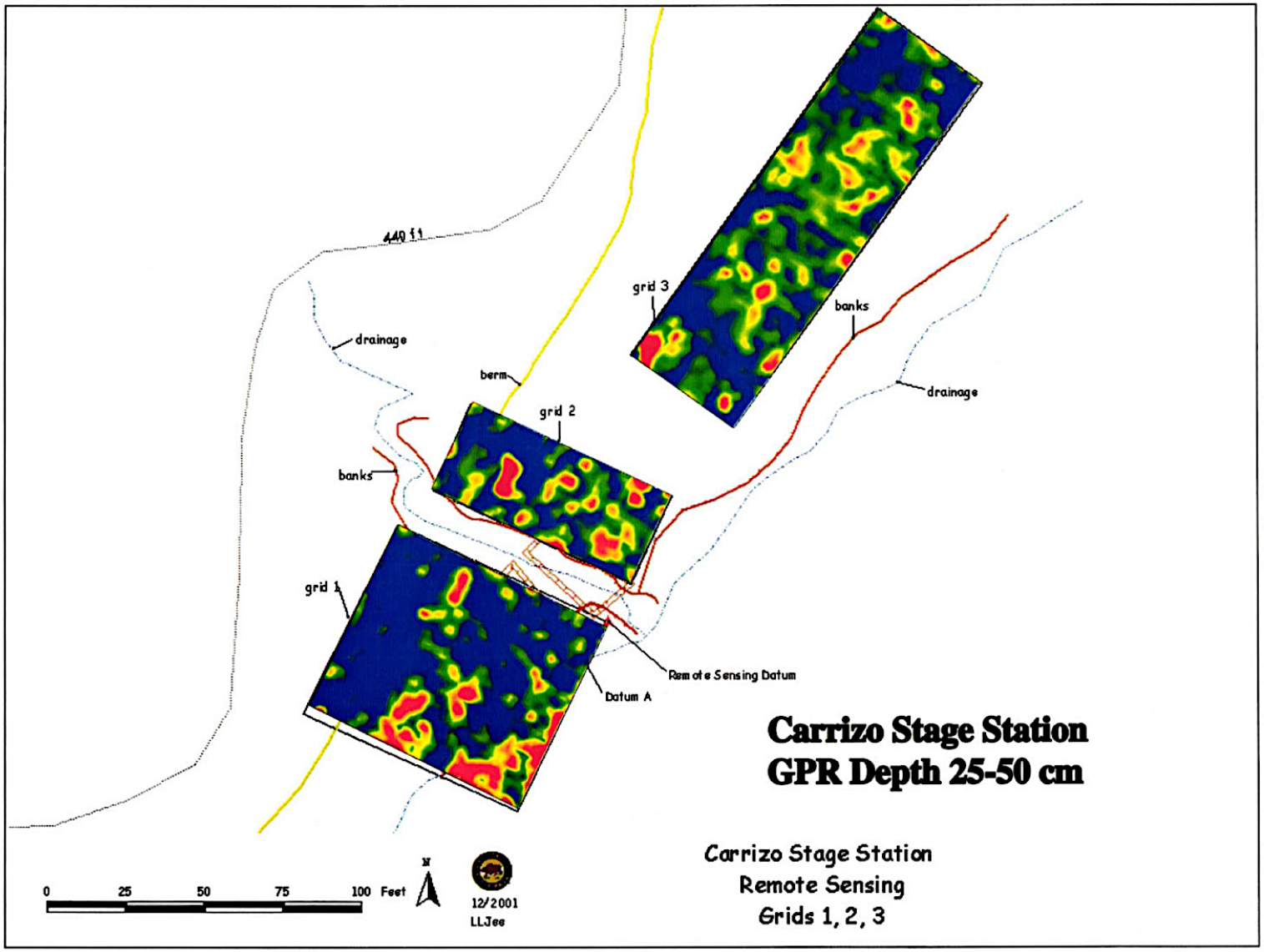
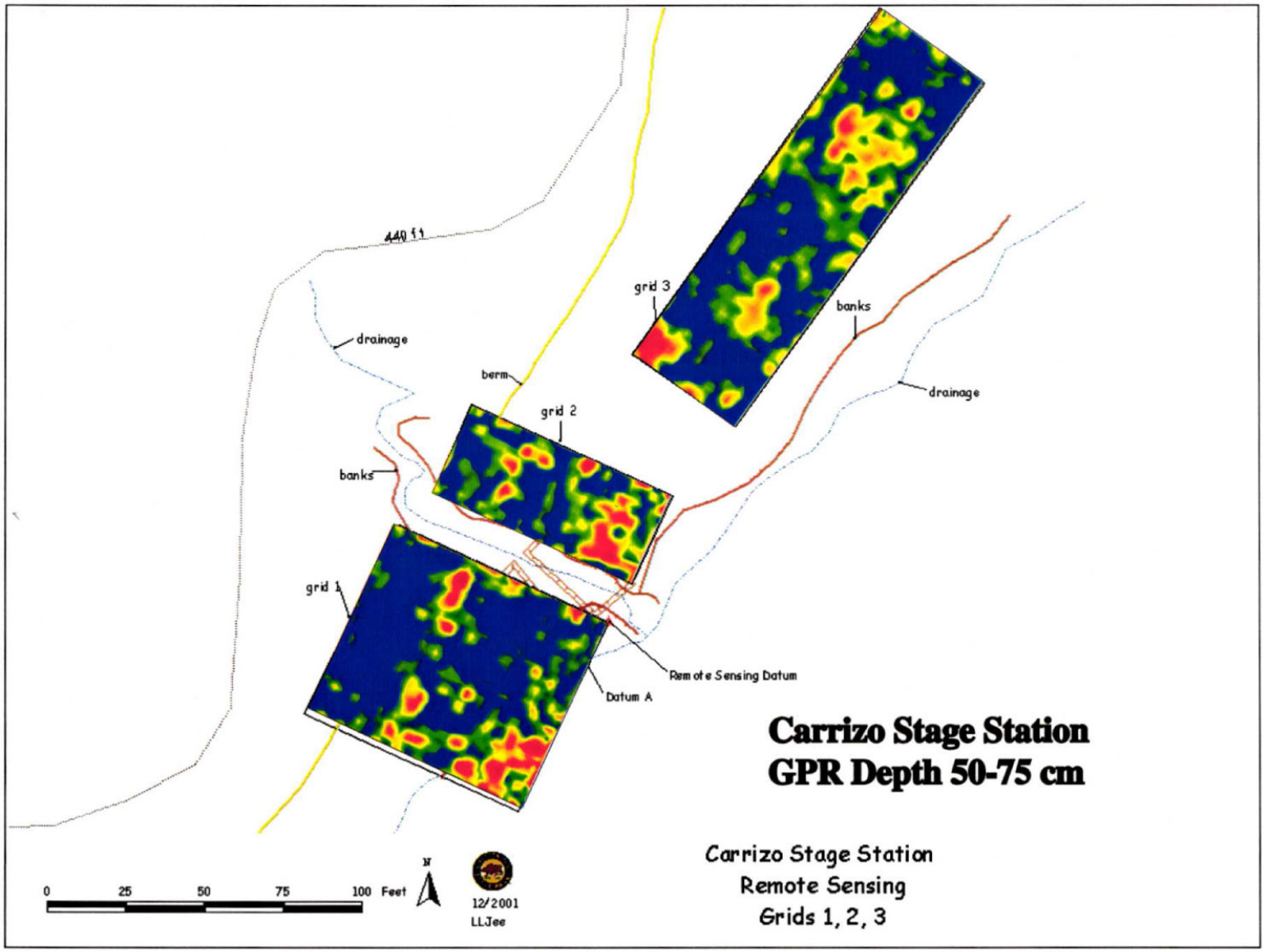
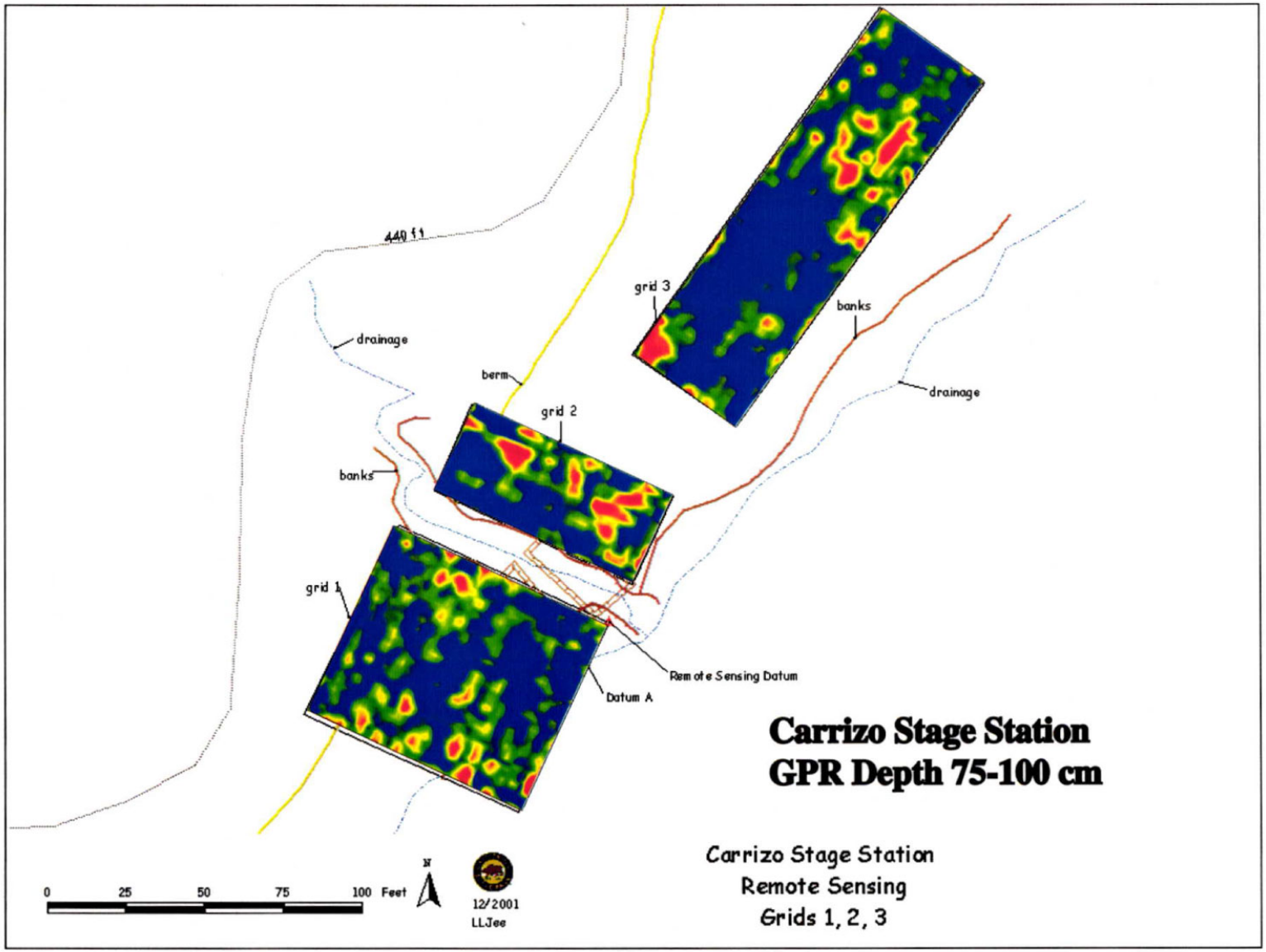


Figure 3. Carrizo Stage Station GPR Depth 0-25 cm


440 ft
grid 3
banks
drainage
berm
grid 2
drainage
banks
grid 1
Remote Sensing Datum
Datum A
Carrizo Stage Station
GPR Depth 25-50 cm
0
25
50
75
100 Feet
N
12/2001
LLJee
Carrizo Stage Station
Remote Sensing
Grids 1, 2, 3


grid 3
banks
drainage
berm
grid 2
drainage
banks
grid 1
Remote Sensing Datum
Datum A
Carrizo Stage Station
GPR Depth 50-75 cm
0
25
50
75
100 Feet
N
12/2001
LLJee
Carrizo Stage Station
Remote Sensing
Grids 1, 2, 3


440 ft
grid 3
banks
drainage
berm
grid 2
drainage
banks
grid 1
Remote Sensing Datum
Datum A
Carrizo Stage Station
GPR Depth 75-100 cm
0
25
50
75
100 Feet
N
12/2001
LLJee
Carrizo Stage Station
Remote Sensing
Grids 1, 2, 3

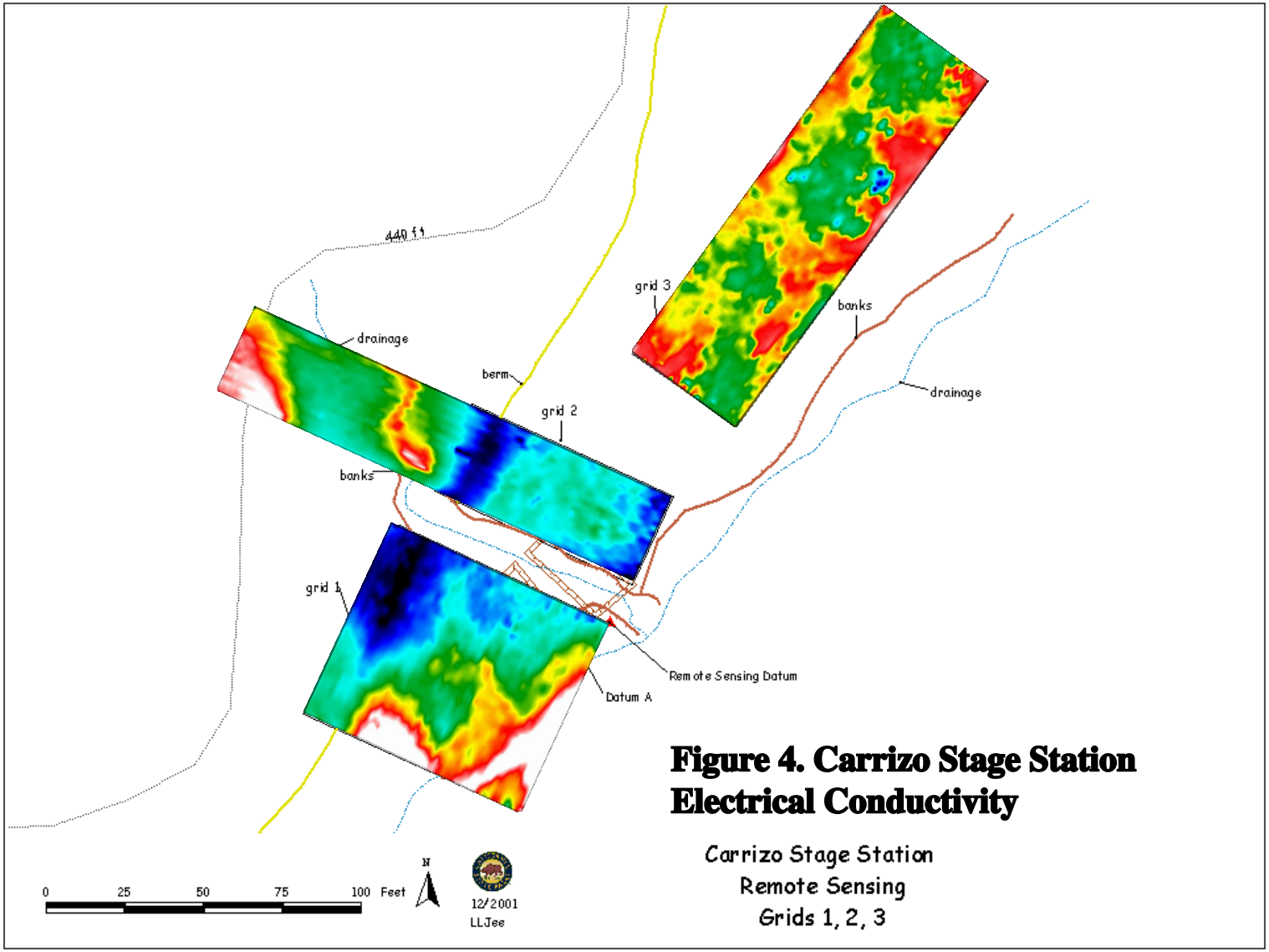


Figure 4. Carrizo Stage Station Electrical Conductivity

Carrizo Stage Station
Remote Sensing
Grids 1, 2, 3

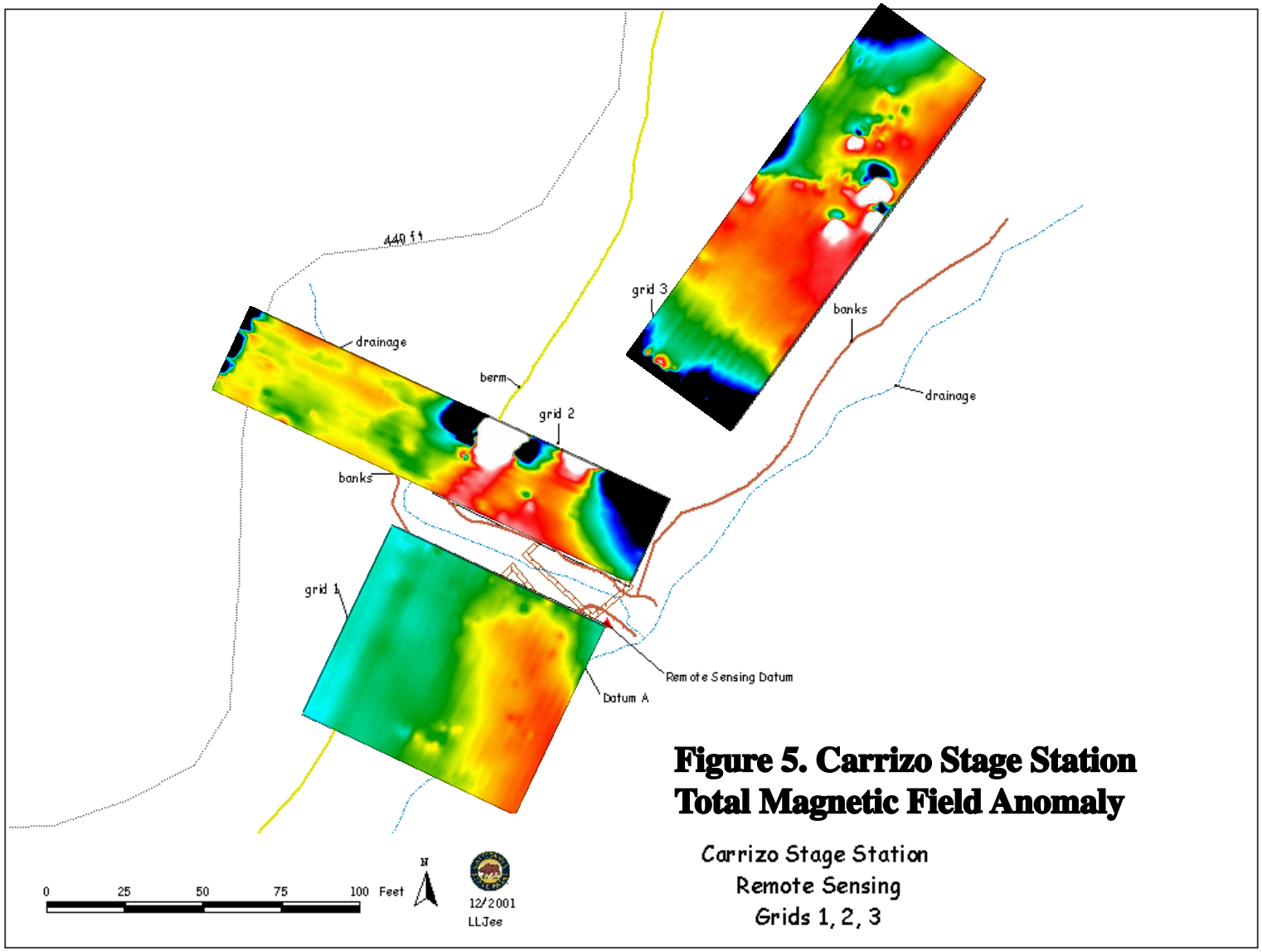


Figure 5. Carrizo Stage Station Total Magnetic Field Anomaly

CARRIZO Magnetometry

The Carrizo Stage Station total magnetic field data are shown in map view in Figure 5. These data primarily show the location of metallic objects and secondarily may indicate the presence of fire. The magnetic field data reveal a linear zone of high magnetic field strength running in a north-south direction through grid 1. This zone of positive magnetic anomaly originates within the area of Structure A, but extends to the south beyond the walls of the structure. One possibility is that the magnetic anomaly results from the presence of fire, either inside or adjacent to Structure A, and from ashes and other fire debris which were transported from the structure. Anomalies displaying alternately high and low magnetic field strength are seen along the northern edge of grid 2, in the south-west corner of grid 3, and at 30 m north, 10 m east from the south-west grid 3 corner. The character of these anomalies suggests that they are associated with metallic objects.

PALM SPRING STAGE STATION

Two grids of geophysical data were collected at the Palm Spring Stage Station site on March 21-22, 2001. Excessive vegetation coverage prevented good MAG and EM data collection on March 21, so after additional vegetation removal, these data were recollected on March 22. The geophysical data grids are shown superimposed on existing site features in Figure 6. The grids are located 20 m west of the stone monument marking this site. A dirt road passes along the southern edge of grid 1. Grid 2 is located in a widened portion of the road used for vehicle parking. Surface metallic objects are noted on the site map. The surface soil within both grids is primarily sand within a dune-like pile. After the geophysical data collection, archaeological subsurface testing was conducted at five locations (STP-1 to 5 in Figure 6). No historic objects or features were discovered in these shovel test pit excavations.

PALM SPRING Ground Penetrating Radar

The time-sliced GPR data for the Palm Spring grids are presented in Figure 7, with each slice representing 33 cm of depth. In grid 1, the western edge of the top slice (0-33 cm) reveals a highly reflective area, perhaps associated with surface salt deposits. At depth, discontinuous patches of high reflectivity appear, primarily in the northern portions of grid 1. A square reflective feature is located in grid 2 at 4 m north, 2 m east (re: the south-west grid corner).

PALM SPRING Electrical Conductivity

The Palm Spring Stage Station electrical conductivity data are shown in map view in Figure 8. EM data are presented only from within grid 1. These EM primarily may show the moisture and salt content of the soil. The EM data reveal a rectangular (10m x 15 m) zone of low conductivity in the north-west portion of the grid. This zone is suggestive of a stage station building in dimensions and shape. Also suggestive is the low conductivity of this zone, which may be associated with adobe walls or wall melt. However, note that the shovel test pits excavated in this zone (STP-1 to 5 on Figure 6) failed to reveal any evidence of an historic structure. High conductivity zones mirror the site topography; they were found in the low-lying areas at the western and eastern edges of the grid, perhaps associated with evaporation of salts.

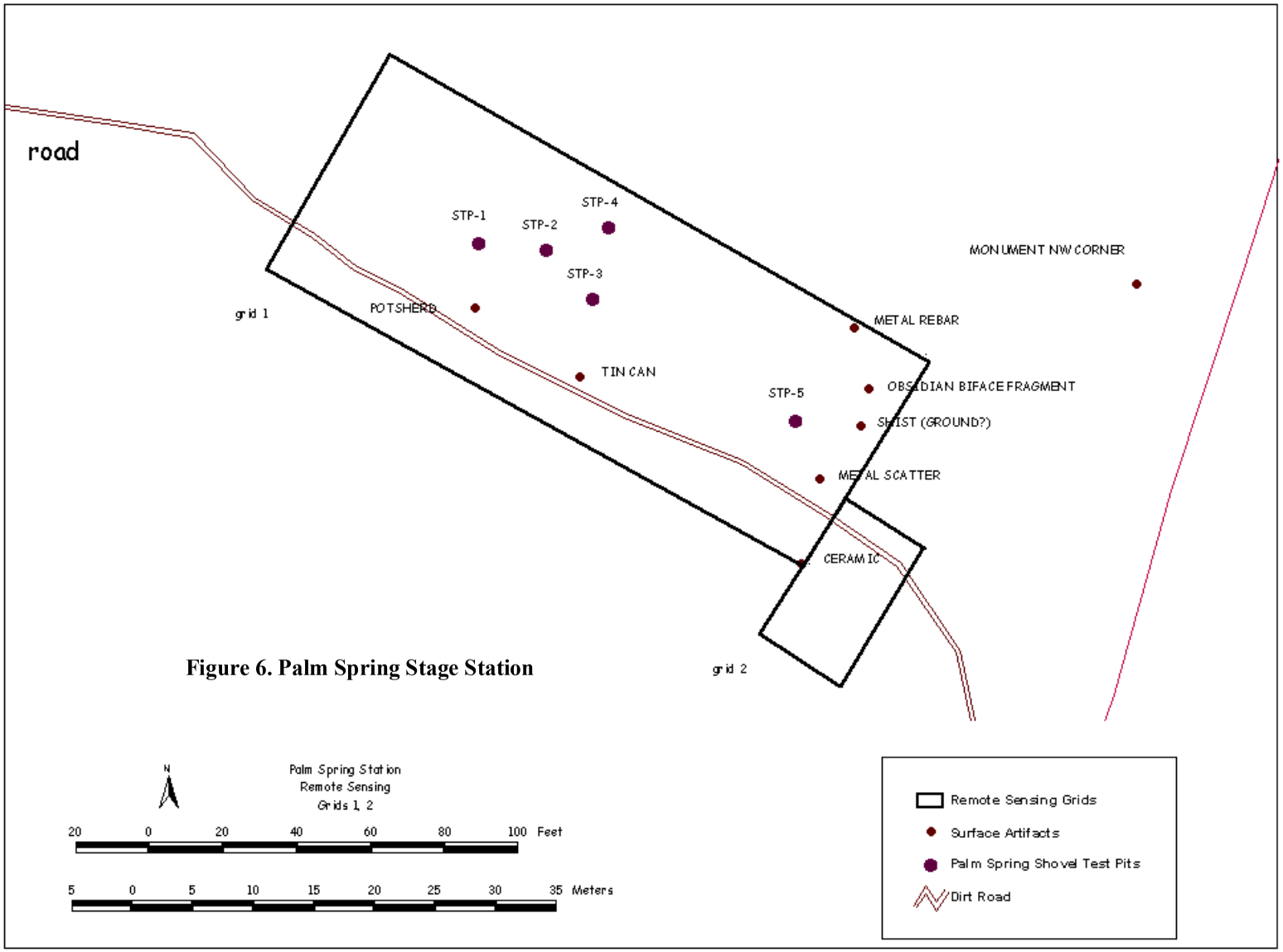


Figure 6. Palm Spring Stage Station

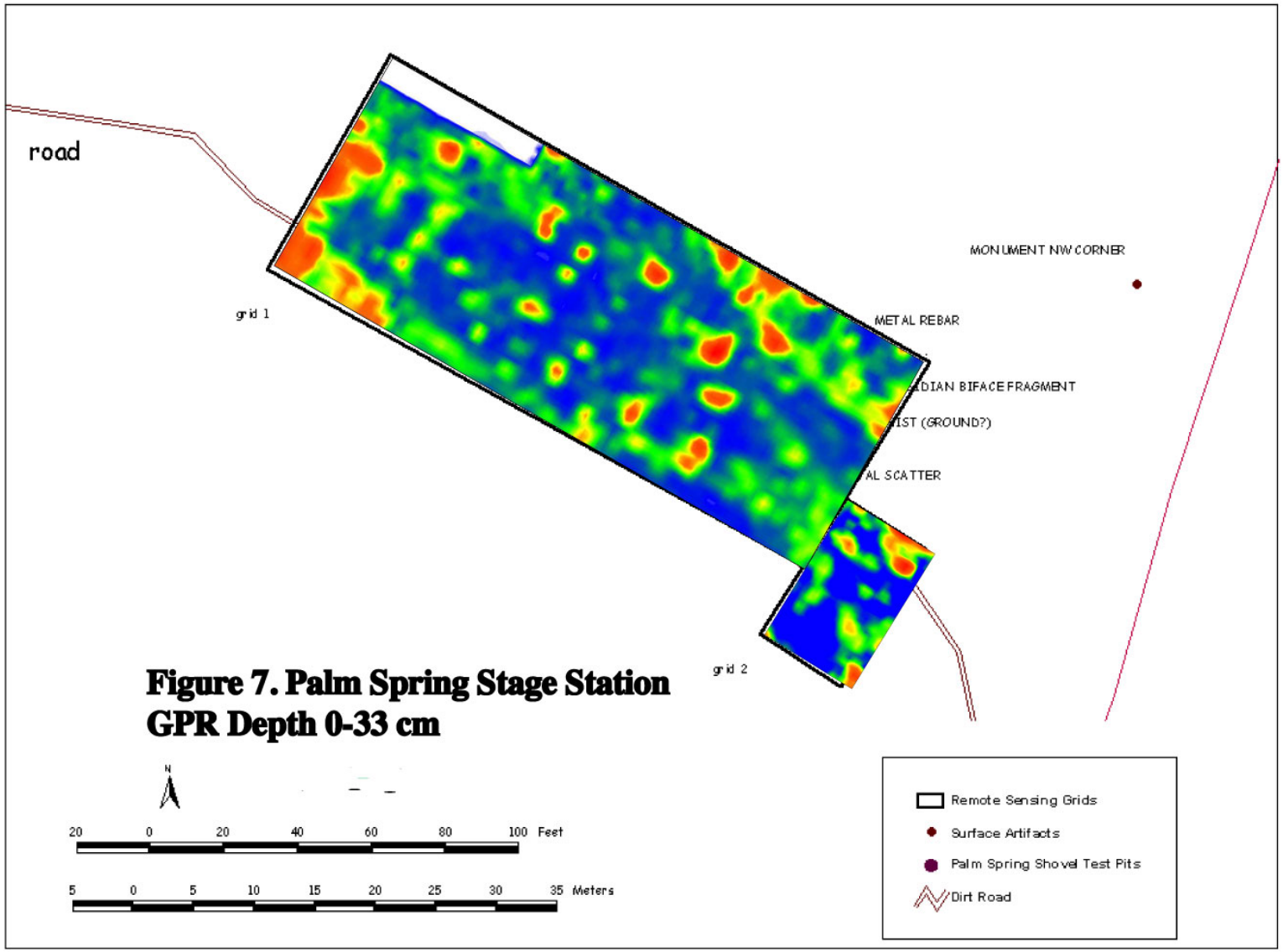
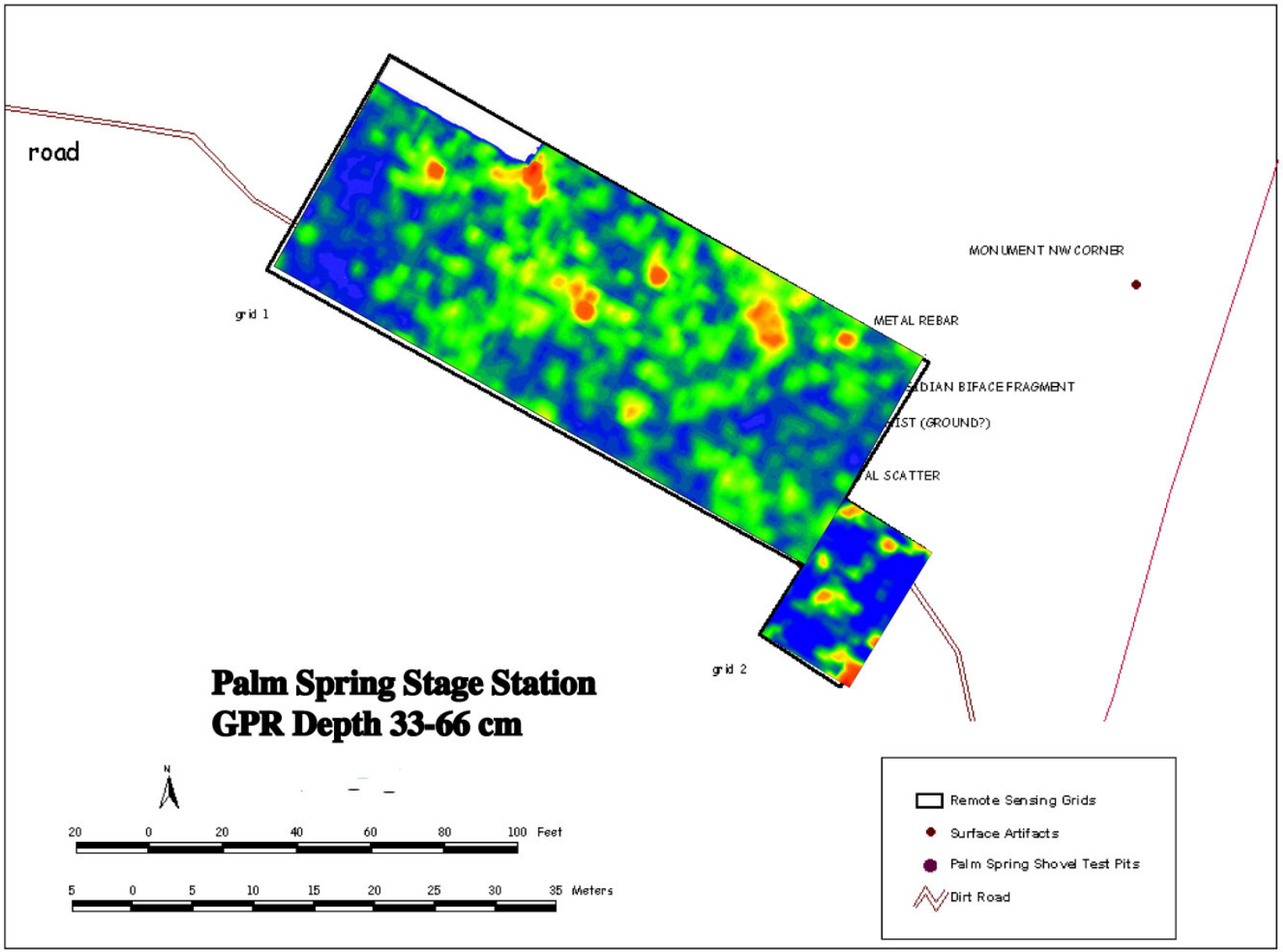
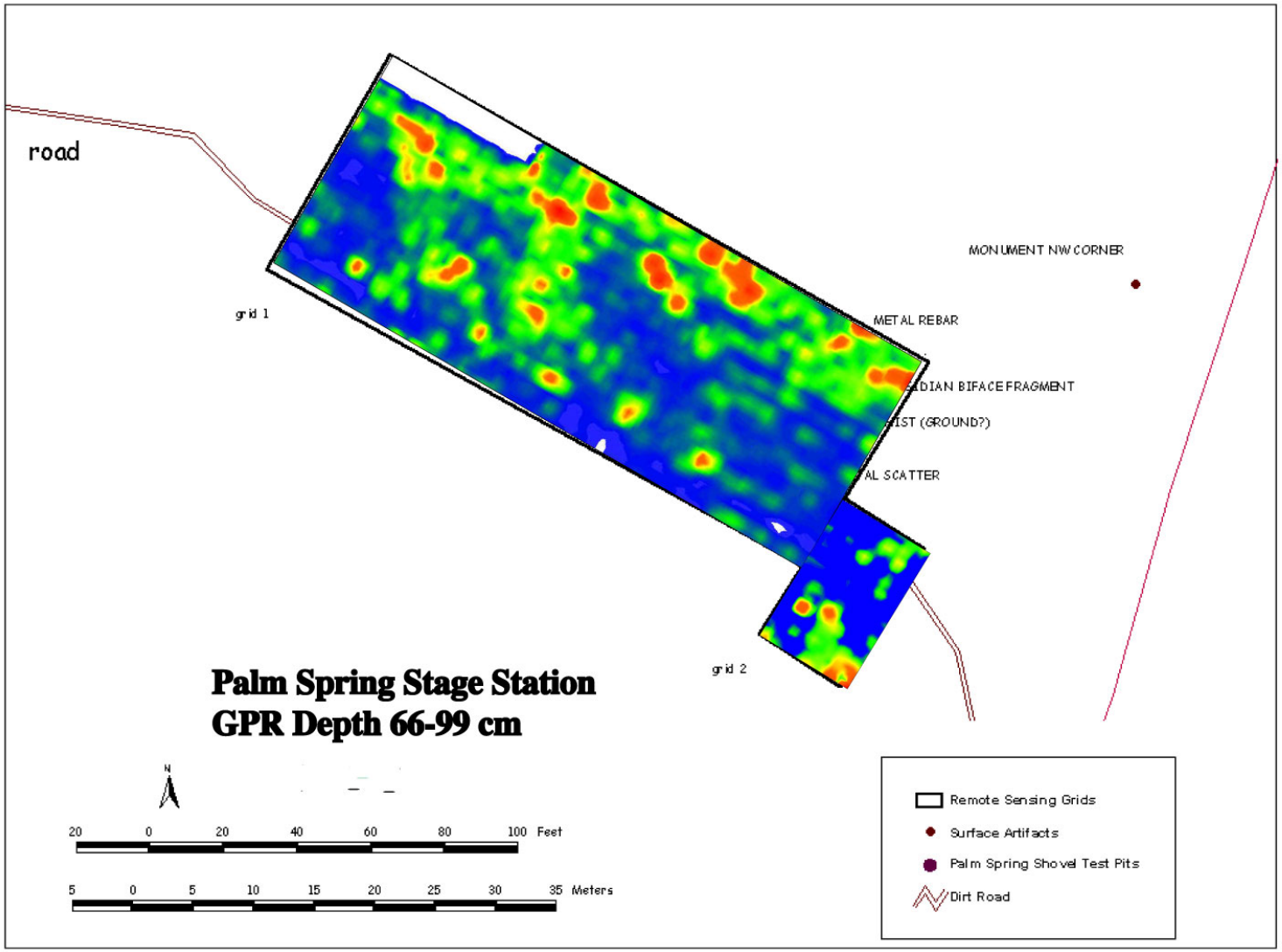


Figure 7. Palm Spring Stage Station
GPR Depth 0-33 cm


road
grid 1
grid 2
MONUMENT NW CORNER
METAL REBAR
EDIAN BIFACE FRAGMENT
IST (GROUND?)
AL SCATTER
Palm Spring Stage Station
GPR Depth 33-66 cm
N
20 0 20 40 60 80 100 Feet
5 0 5 10 15 20 25 30 35 Meters
Remote Sensing Grids
Surface Artifacts
Palm Spring Shovel Test Pits
Dirt Road


road
grid 1
grid 2
MONUMENT NW CORNER
METAL REBAR
DIAN BIFACE FRAGMENT
IST (GROUND?)
AL SCATTER
Palm Spring Stage Station
GPR Depth 66-99 cm
N
20 0 20 40 60 80 100 Feet
5 0 5 10 15 20 25 30 35 Meters
Remote Sensing Grids
Surface Artifacts
Palm Spring Shovel Test Pits
Dirt Road

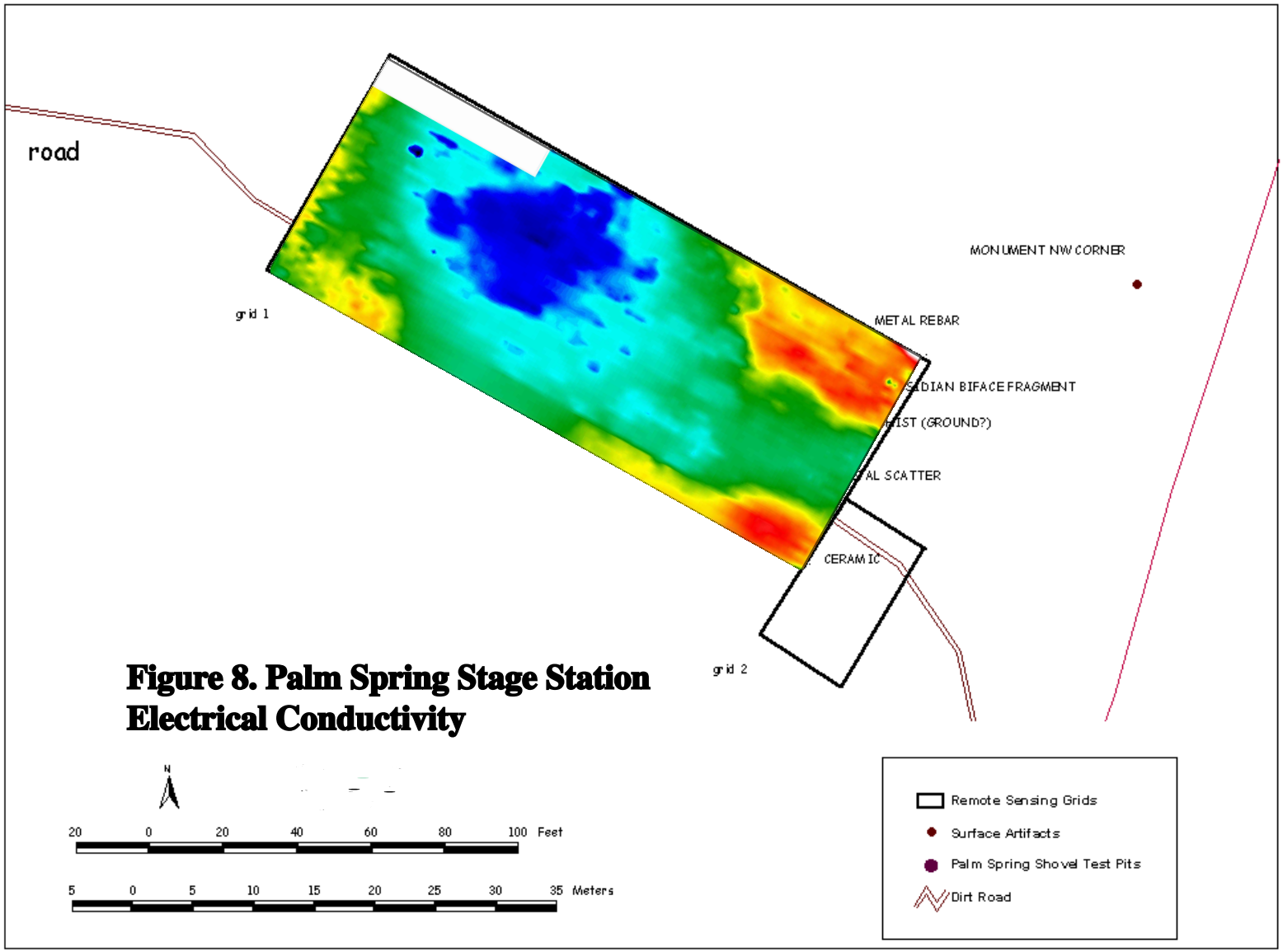


Figure 8. Palm Spring Stage Station Electrical Conductivity

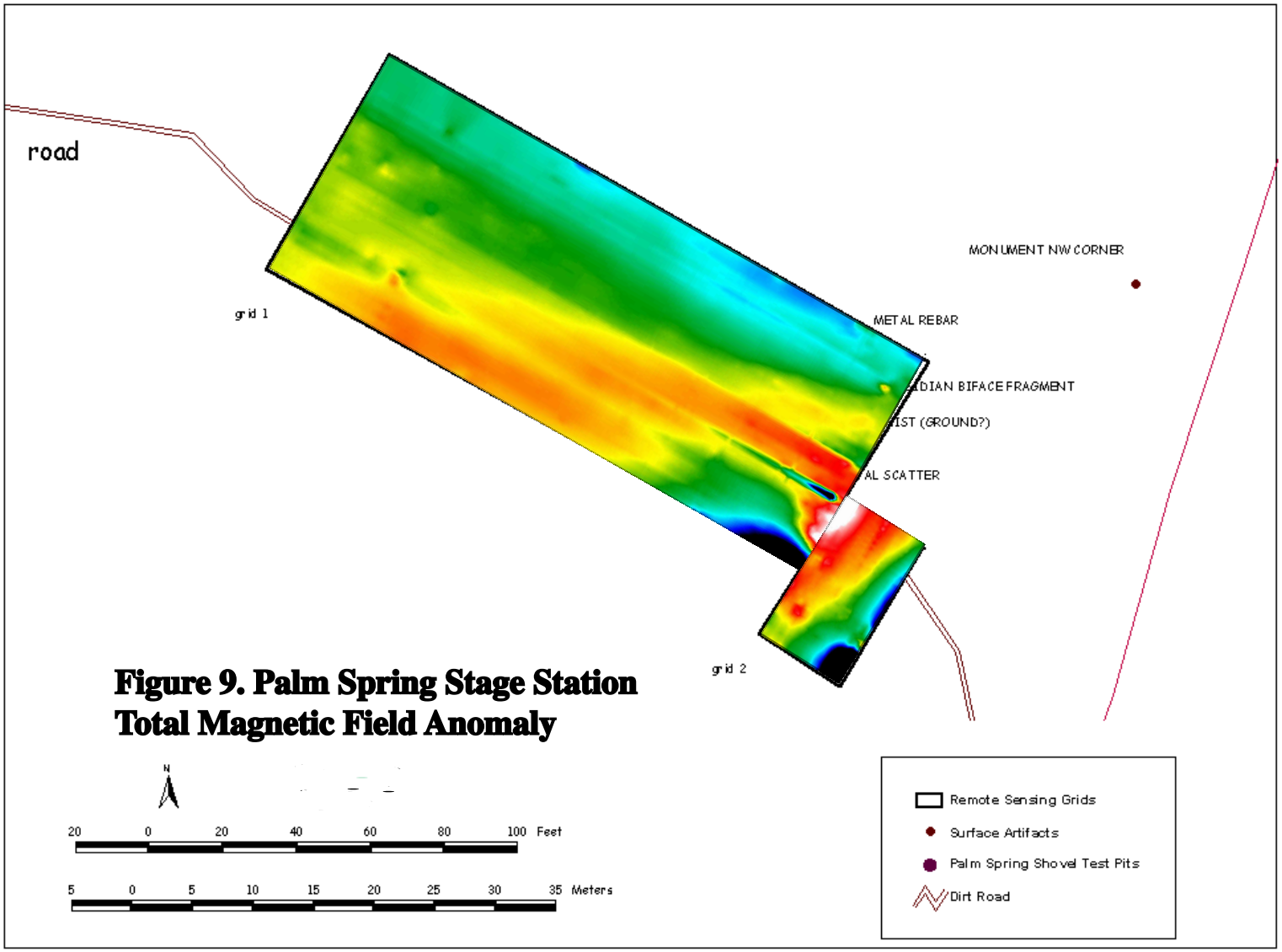


Figure 9. Palm Spring Stage Station Total Magnetic Field Anomaly

PALM SPRING Magnetometry

The Palm Spring Stage Station total magnetic field data are shown in map view in Figure 9. These total magnetic field data show the location of metallic objects and may also indicate soil magnetic properties. The magnetic field data reveal a linear zone of high magnetic field strength running in an east-west direction through grid 1. This zone of positive magnetic anomaly may be associated with the presence of fire, or other modification of the soil magnetic properties. Strong anomalies displaying alternately high and low magnetic field strength are seen along the eastern edge of grid 1, at its boundary with grid 2. These data are consistent with the presence of metallic objects, as noted on the site map in Figure 6. A strong, rectangular magnetic anomaly is located in the south-west corner of grid 2, at 4 m north, 2 m east from the south-west corner. This anomaly may be associated with a metallic object or a fire pit.

SAN FELIPE STAGE STATION

Two grids of geophysical data were collected at the San Felipe Stage Station site on March 23, 2001. The geophysical data grids are shown superimposed on existing site features in Figure 10. The grids are located south of the San Felipe Creek. Surface metallic objects are noted on the site map, as is a stone foundation wall in the north-west corner of grid 1. The surface soil within both grids is primarily sandy alluvium No archaeological subsurface testing has been conducted yet within these geophysical survey grids.

SAN FELIPE Ground Penetrating Radar

The time-sliced GPR data for the San Felipe grids are presented in Figure 11, with each slice representing a 33 cm depth interval. In the top slice (0-33 cm) of grid 1, many of the prominent high reflectivity anomalies are associated with the roots of trees or large shrubs (for instance 15 m north, 30 m east from the south-west corner). Within the second slice (33-66 cm), however, a prominent crescent-shaped reflector occurs in the north-east corner of grid 1. GPR for the lowest slice (66-99 cm) may have a low signal-to-noise, since reflection features are predominantly elongated along the direction of data collection. The data for grid 2 show prominent but discontinuous reflectors in the grid's northern portion.

SAN FELIPE Electrical Conductivity

The San Felipe Stage Station electrical conductivity data are shown in map view in Figure 12. These EM data primarily may show the moisture and salt content of the soil. The EM data for grid 1 reveal three separate zones of high conductivity at the: (a) grid center, (b) southern edge, and (c) north-east corner. These high conductivity zones do not mirror site topography. In grid 2, there is a low conductivity zone, with linear edges, in the northern portion of the grid. This zone is suggestive of a stage station building in shape. Also, suggestive is the low conductivity, which may be associated with adobe walls or wall melt.

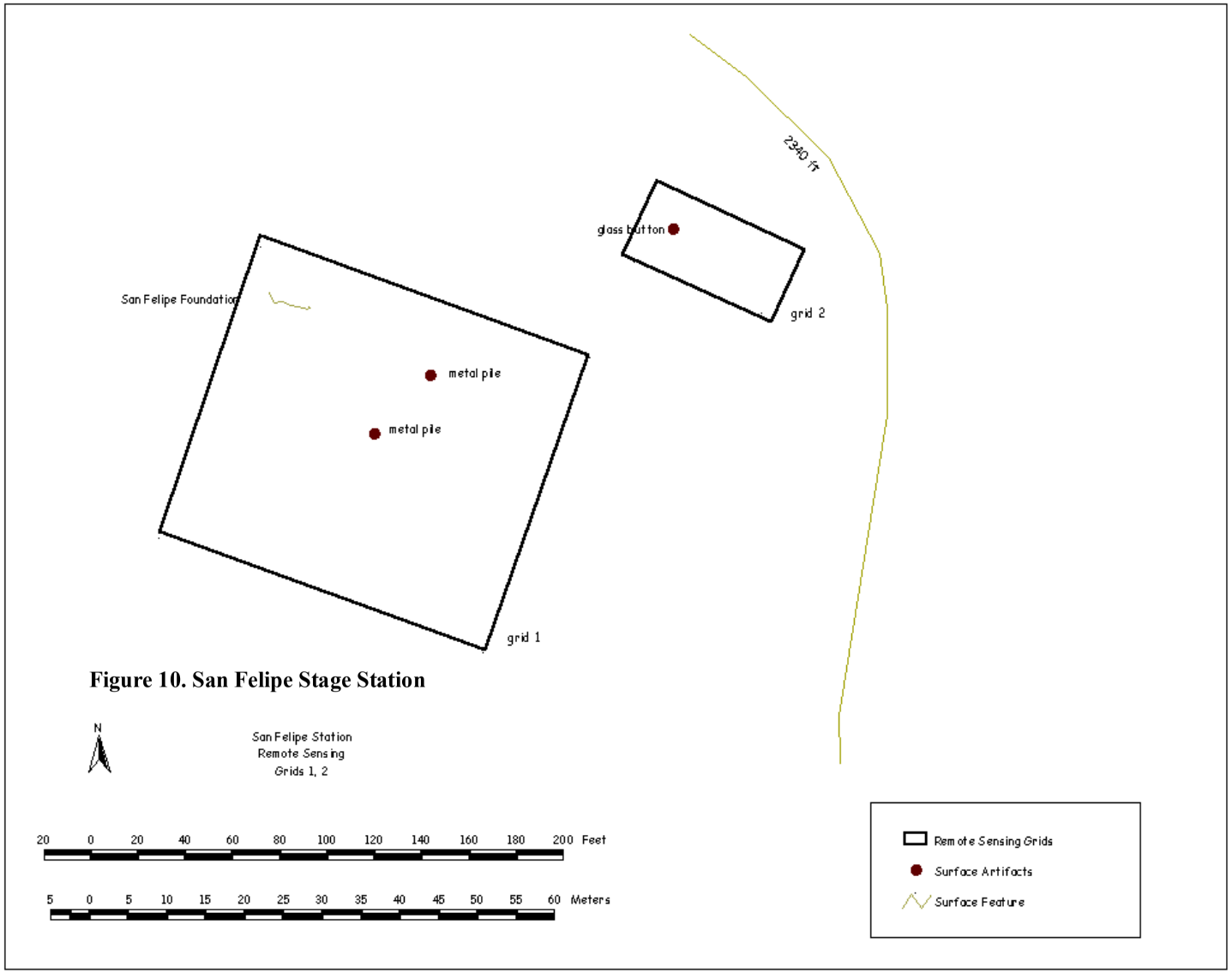


Figure 10. San Felipe Stage Station

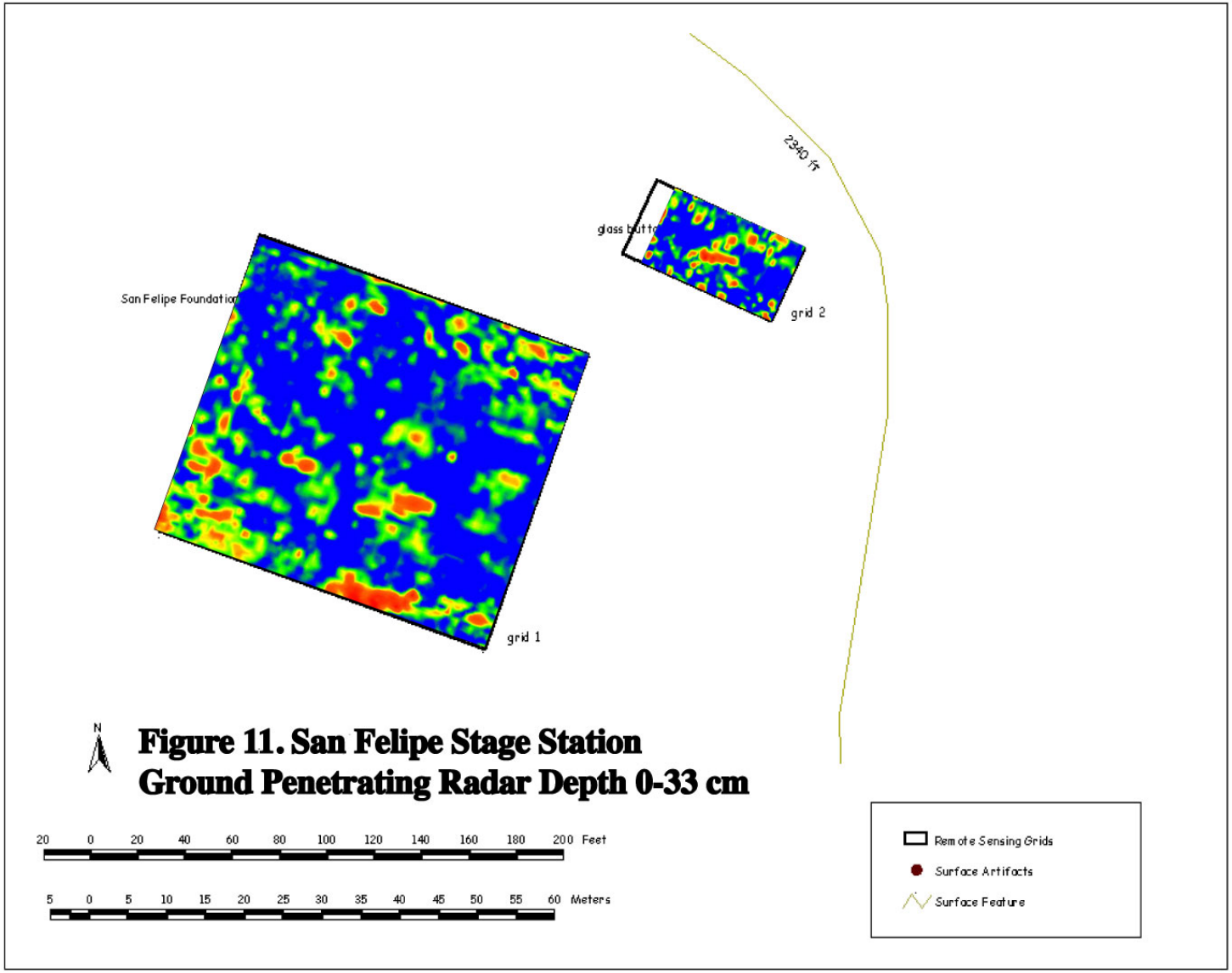
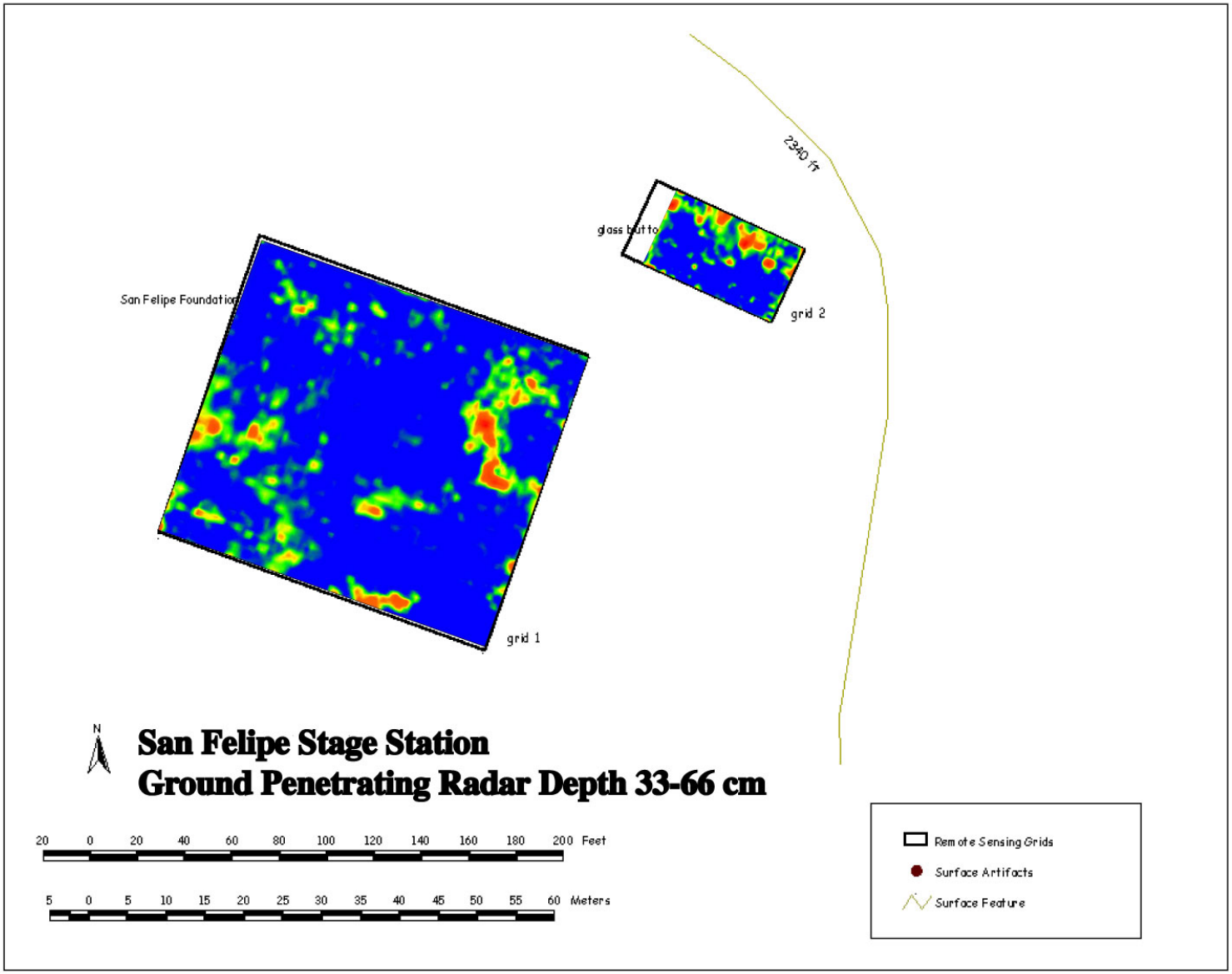
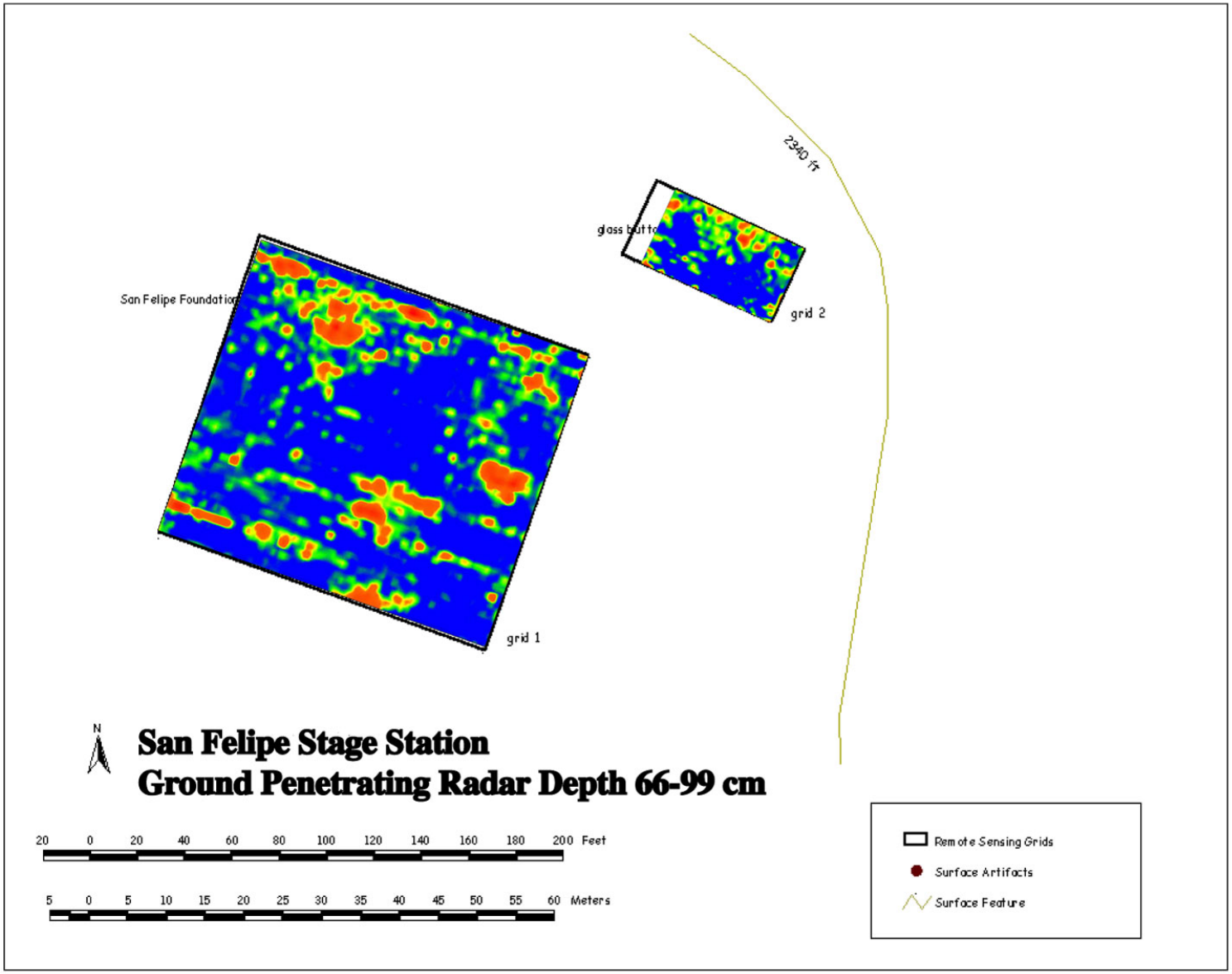


Figure 11. San Felipe Stage Station
Ground Penetrating Radar Depth 0-33 cm


2340 ft
glass butto
grid 2
San Felipe Foundatio
grid 1
N
San Felipe Stage Station
Ground Penetrating Radar Depth 33-66 cm
20 0 20 40 60 80 100 120 140 160 180 200 Feet
5 0 5 10 15 20 25 30 35 40 45 50 55 60 Meters
Remote Sensing Grids
Surface Artifacts
Surface Feature


2340 ft
glass butte
San Felipe Foundation
grid 2
grid 1
N
San Felipe Stage Station
Ground Penetrating Radar Depth 66-99 cm
20 0 20 40 60 80 100 120 140 160 180 200 Feet
5 0 5 10 15 20 25 30 35 40 45 50 55 60 Meters
Remote Sensing Grids
Surface Artifacts
Surface Feature

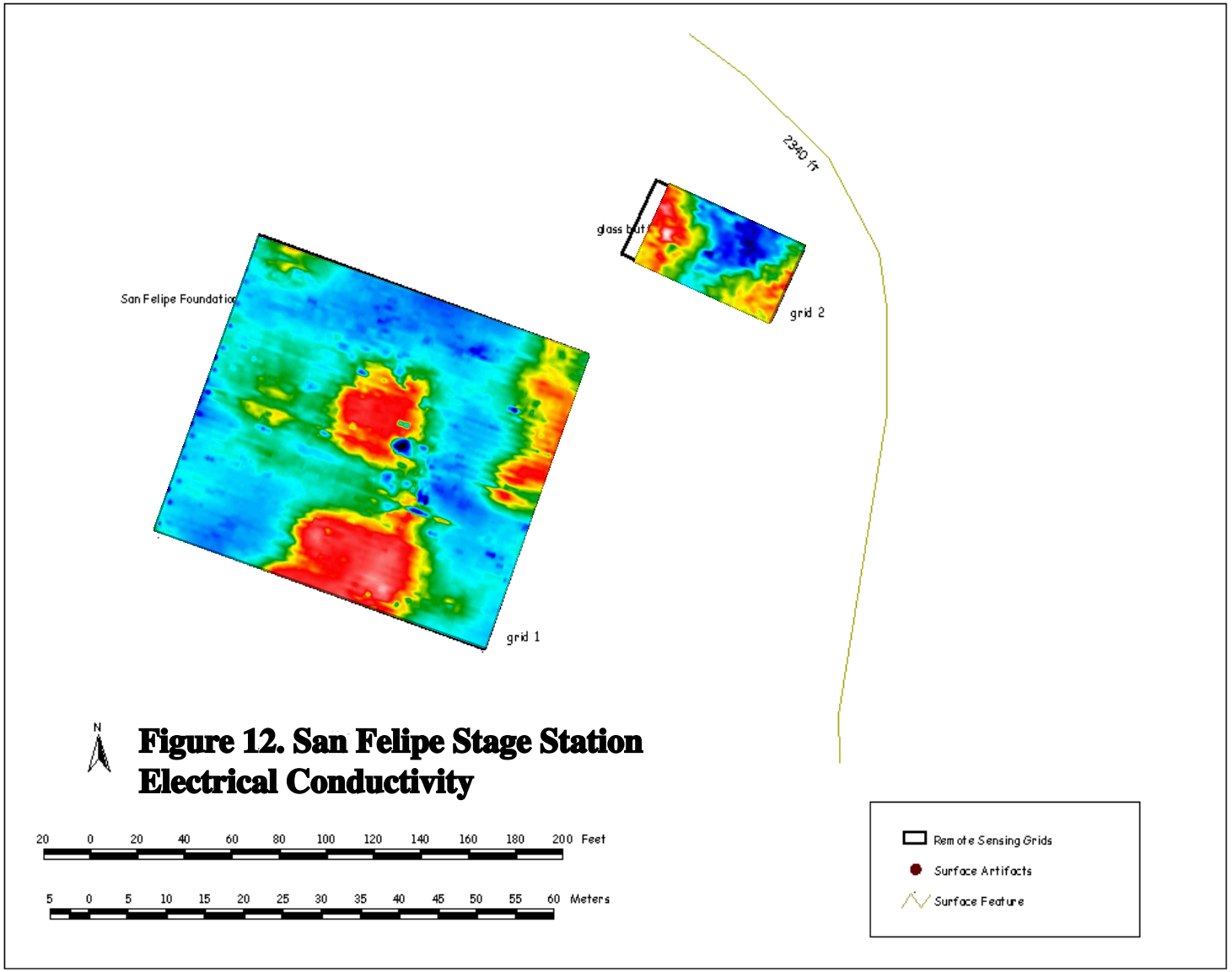


Figure 12. San Felipe Stage Station Electrical Conductivity

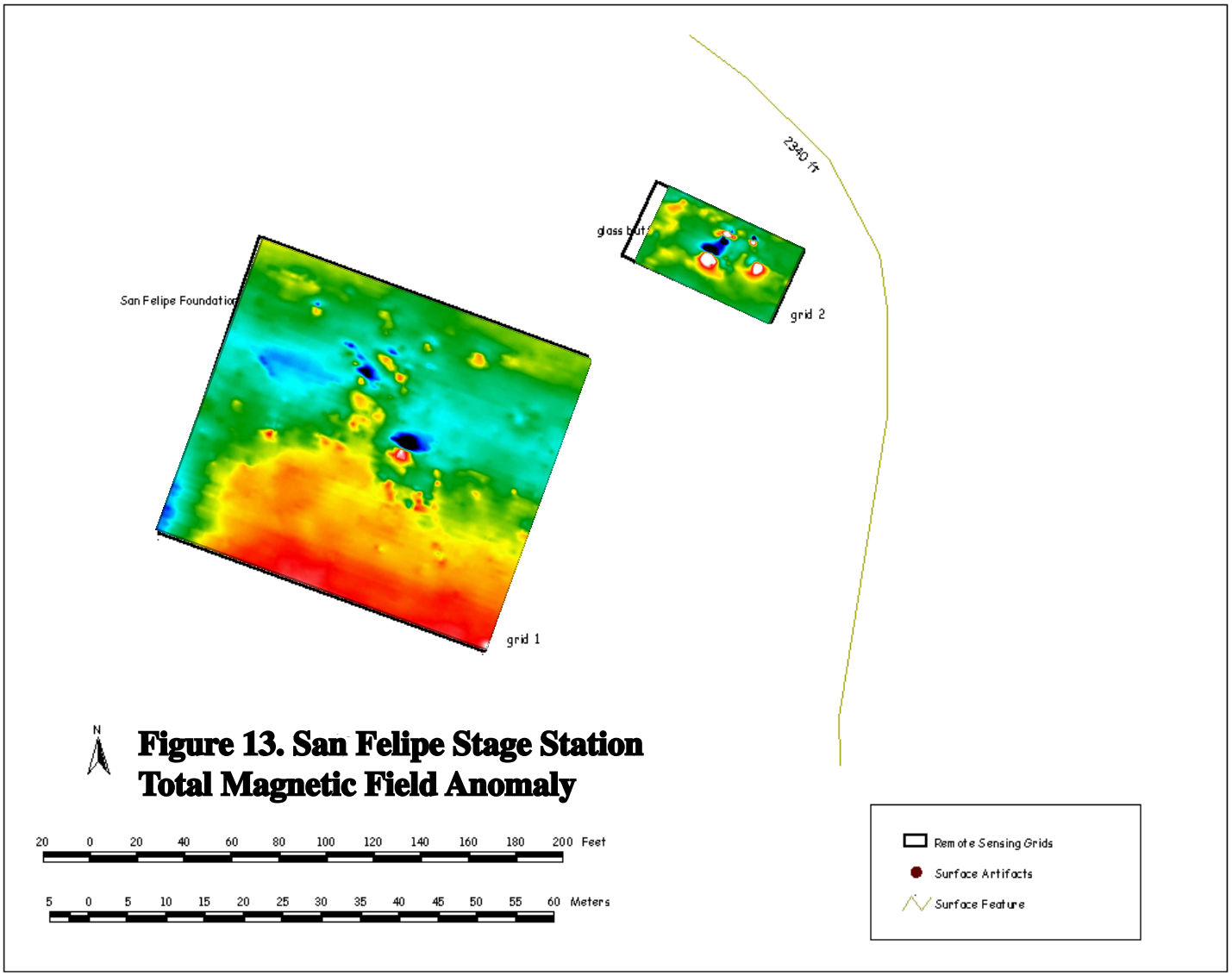


Figure 13. San Felipe Stage Station Total Magnetic Field Anomaly

SAN FELIPE Magnetometry

The San Felipe Stage Station total magnetic field data are shown in map view in Figure 13. These total magnetic field data show the location of metallic objects and may indicate soil magnetic properties. The magnetic field data reveal a bi-modal distribution of magnetic field strength, with low magnetization in the northern portion of the grid, and high magnetization in the southern portion of the grid. Strong localized anomalies displaying alternately high and low magnetic field strength are seen in the center of the grid, consistent with the presence of metallic objects, as noted on the site map in Figure 10. Several strong local magnetic anomalies are also seen within grid 2, probably associated with metallic objects.

SUMMARY

At three Carrizo Corridor Stage Station sites within Anza Borrego Desert State Park, we have used ground penetrating radar, electrical conductivity, and magnetic survey techniques in an effort to image buried objects and structures.

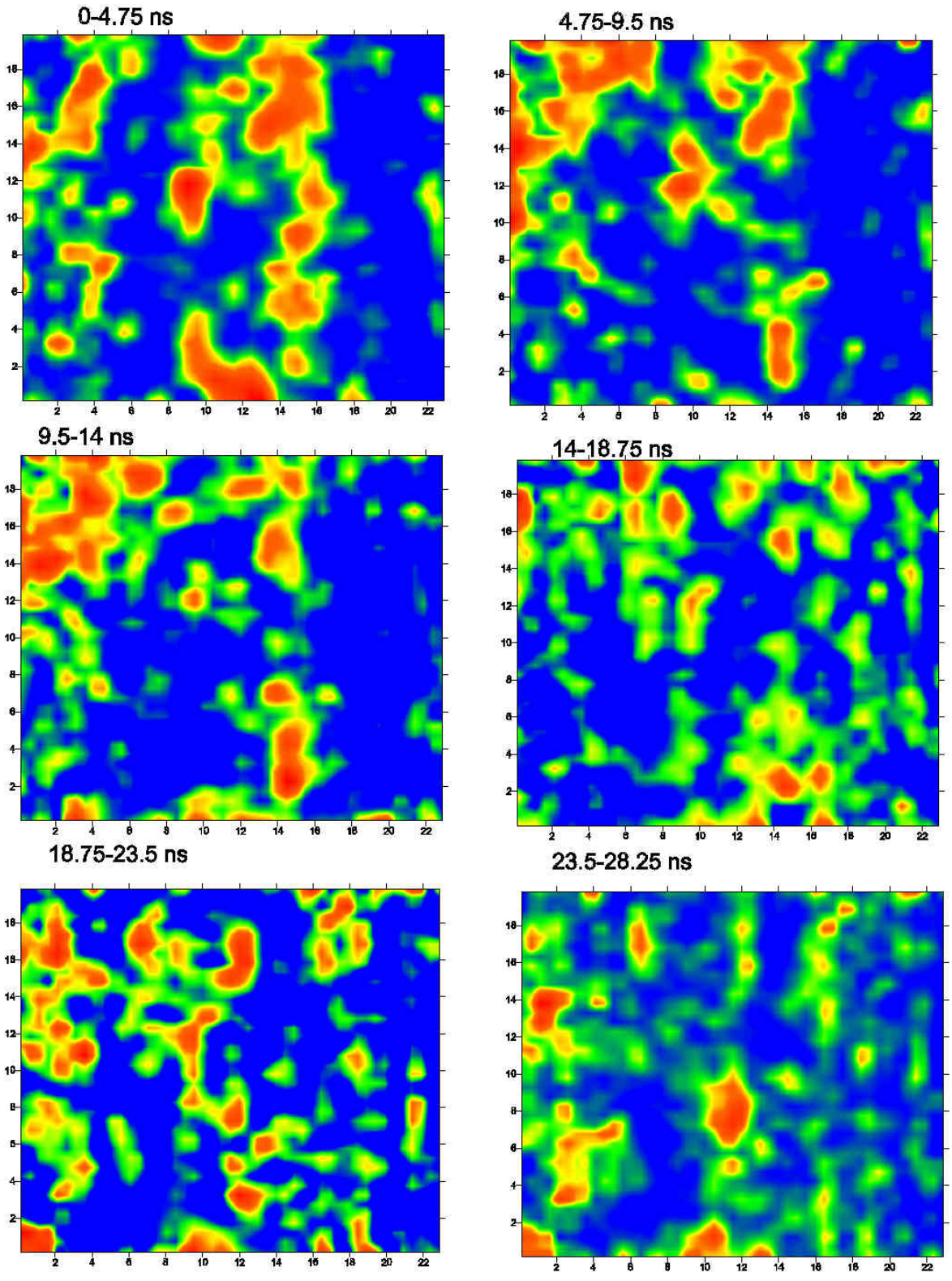
At the Carrizo Stage Station site the outlines of Structure A and B, as defined by test excavation, are suggested in the EM data by a low conductivity feature. A magnetic anomaly within and adjacent to Structure A may be suggestive of a fire feature. Other geophysical anomalies at the Carrizo Stage site are associated with metallic objects within grids 2 and 3. The feature within grid 3 at 30 m north, 10 m east (re: south-west corner) may deserve further investigation as it appears in the all three techniques, as discussed above. It may be associated with a well feature known from historic accounts of the site.

At the Palm Spring Stage Station site, no historic objects or structures have been found by test excavations to date. The outline of a structure is suggested in the EM data by a low conductivity feature in the north-west portion of grid 1. Further testing of this feature may be warranted. A GPR and MAG anomaly within grid 2 (4 m north, 2 m east from the south-west corner) may be a fire pit or metallic object at > 66 cm depth. Other anomalies are associated with metallic objects at the boundary between grids 1 and 2.

At the San Felipe Stage Station site a structure is suggested in the EM data by a low conductivity feature in the northern portion of grid 2. Associated metallic objects are seen in the grid 2 MAG data. A coincident GPR reflector and EM high conductivity anomaly is seen in the north-east corner of grid 1. This feature may be worthy of subsurface testing. Additional anomalies are associated with metallic objects near the central portion of grid 1.

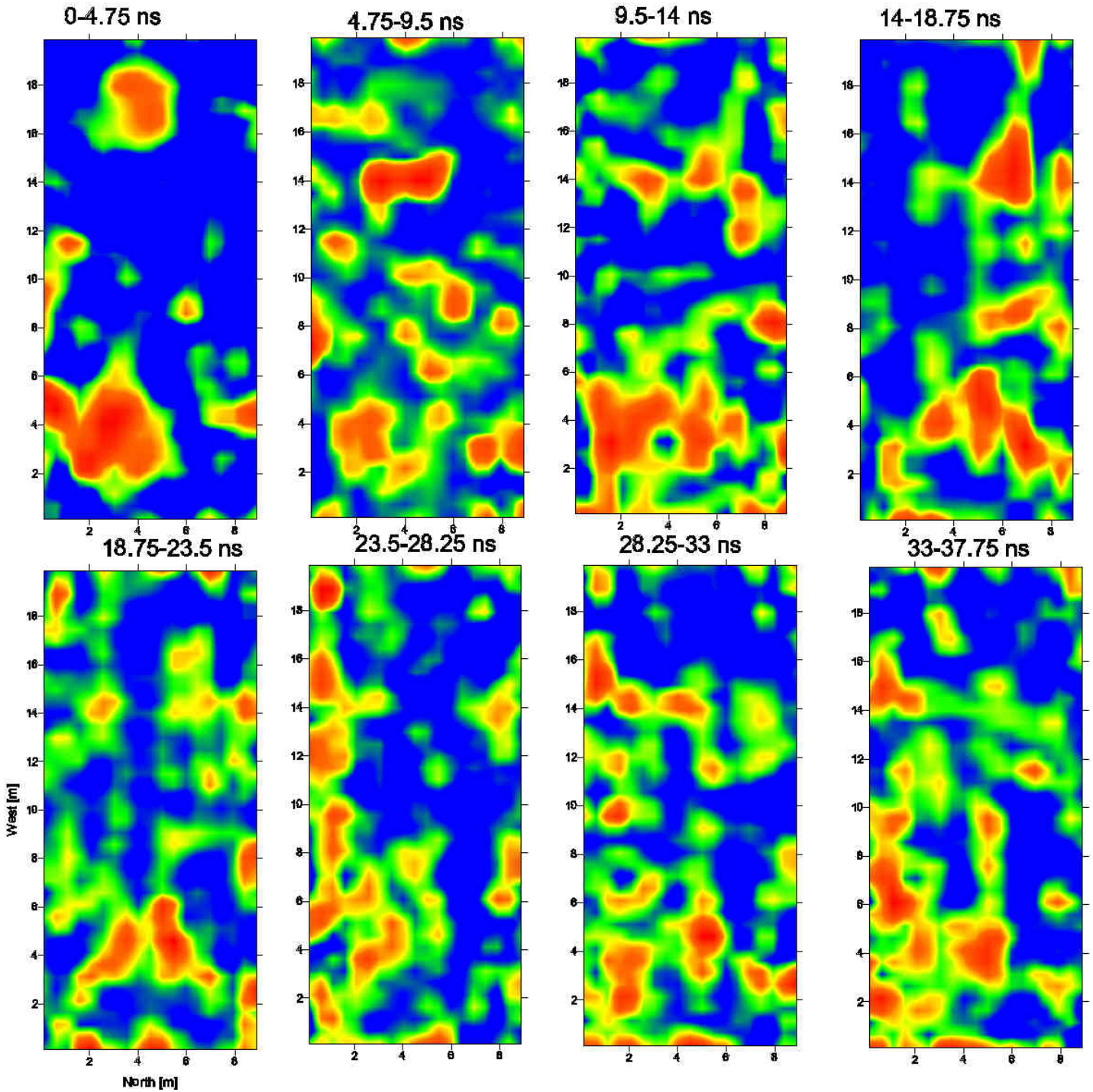
APPENDIX- 1

GEOPHYSICAL SURVEY GRIDS



Carrizo Stage Station Grid 1 GPR Slices 1-6

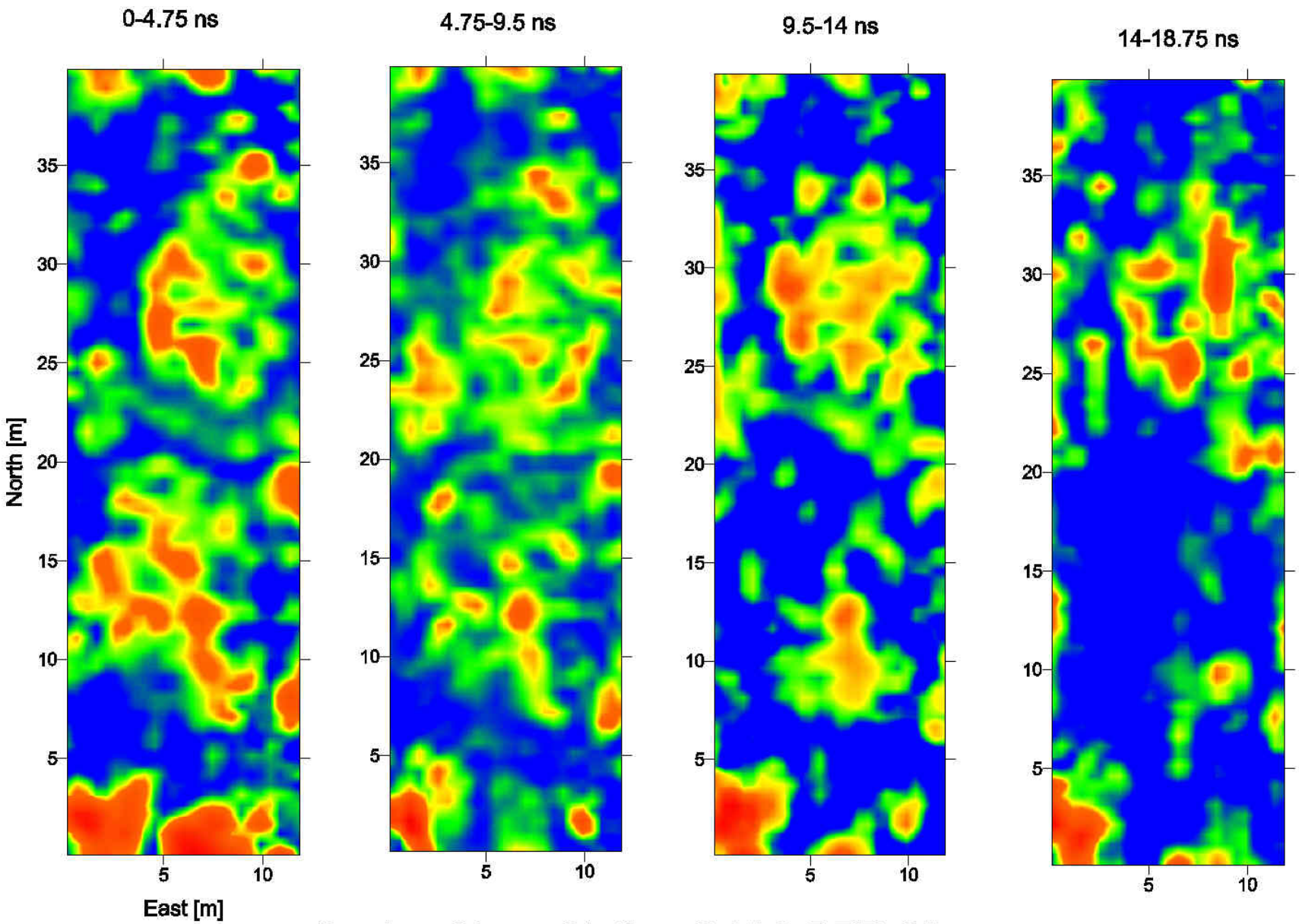
LBC 3/22/01



Carrizo Stage Station

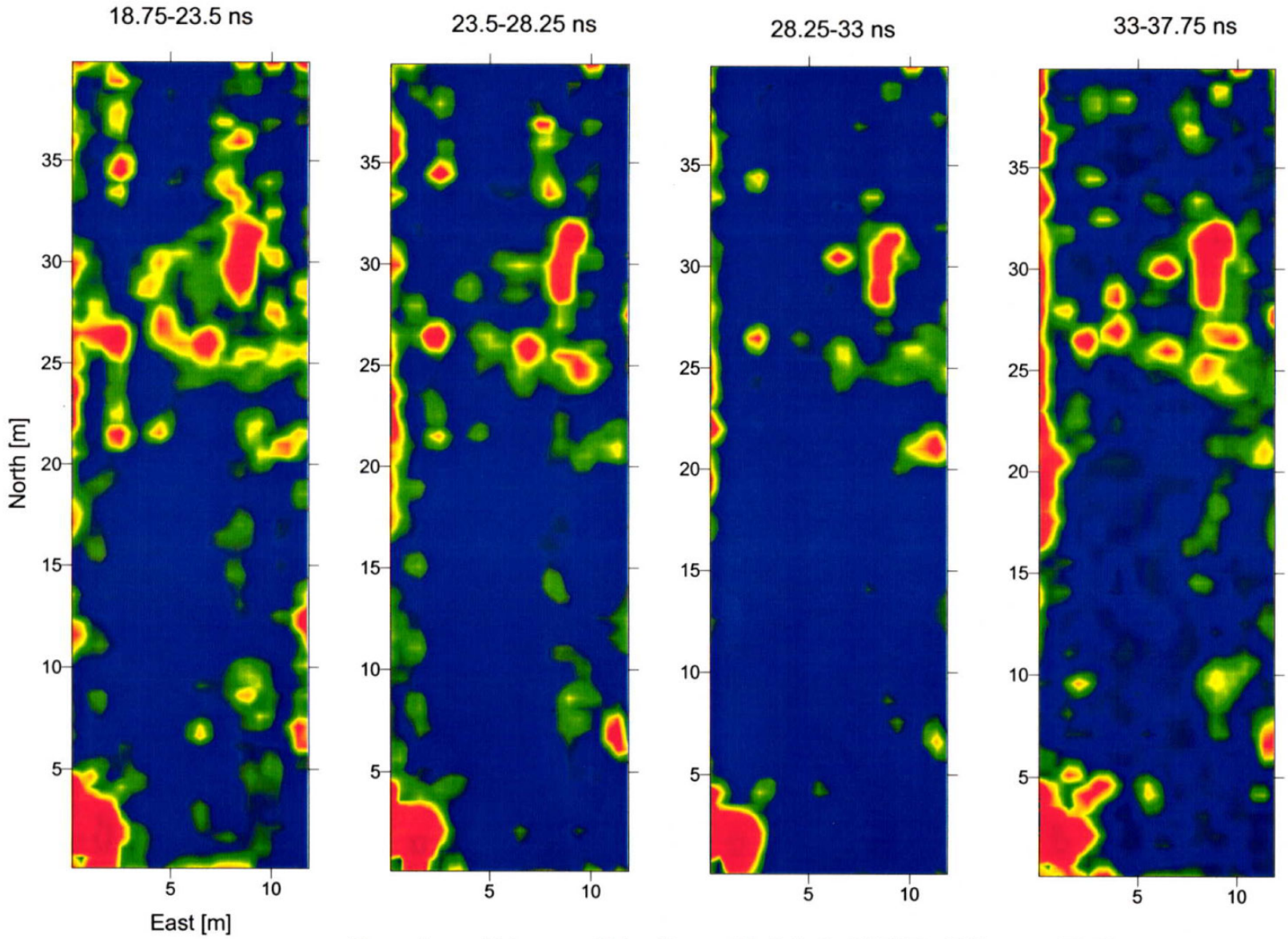
Grid 2 GPR Slices 1-8

LBC 3/22/01



Carrizo Stage Station Grid 3 GPR Slices 1 - 4

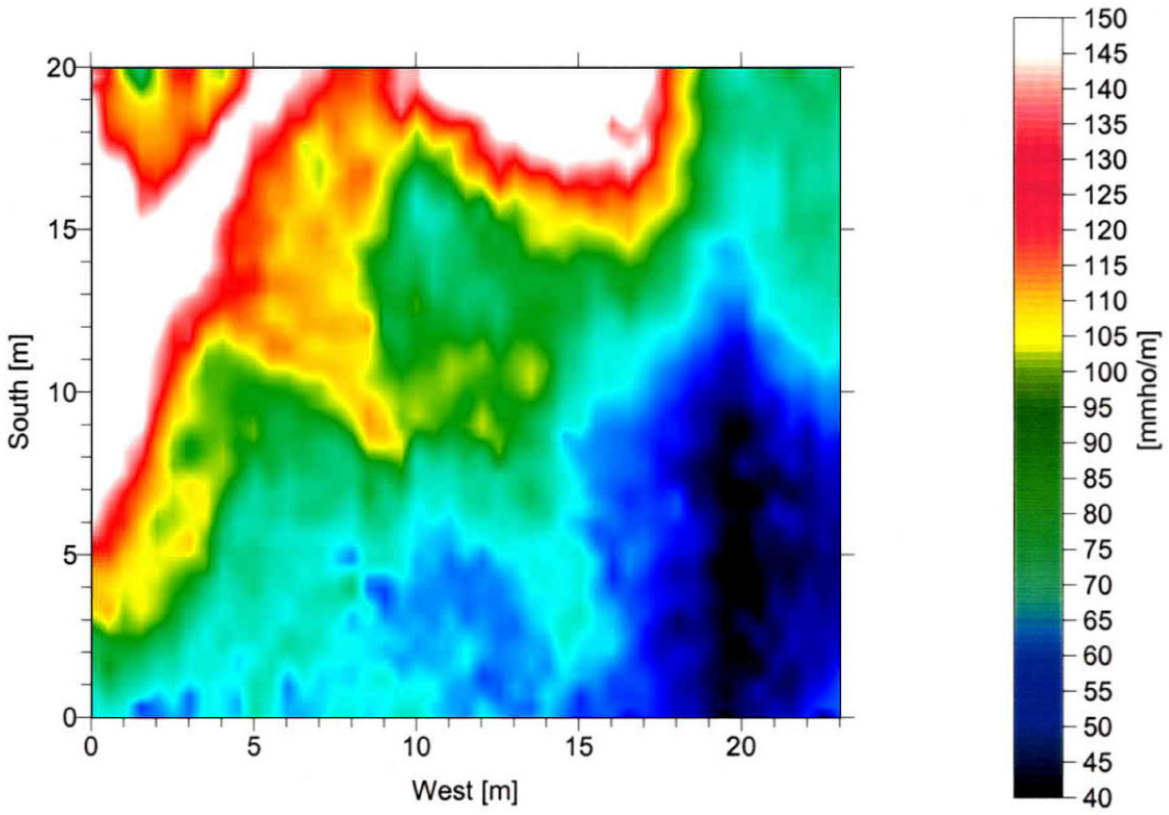
LBC 3/22/01



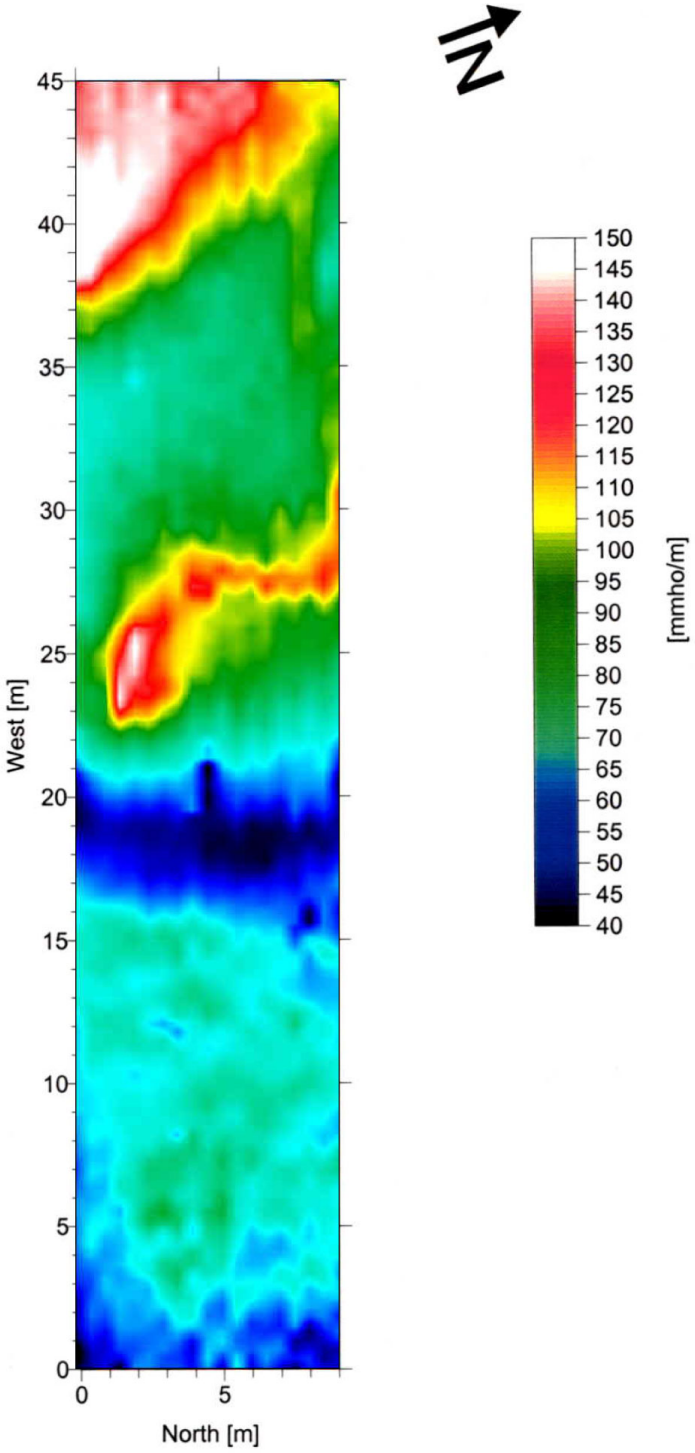
Carrizo Stage Station Grid 3 GPR Slices 5-8

LBC 3/22/01

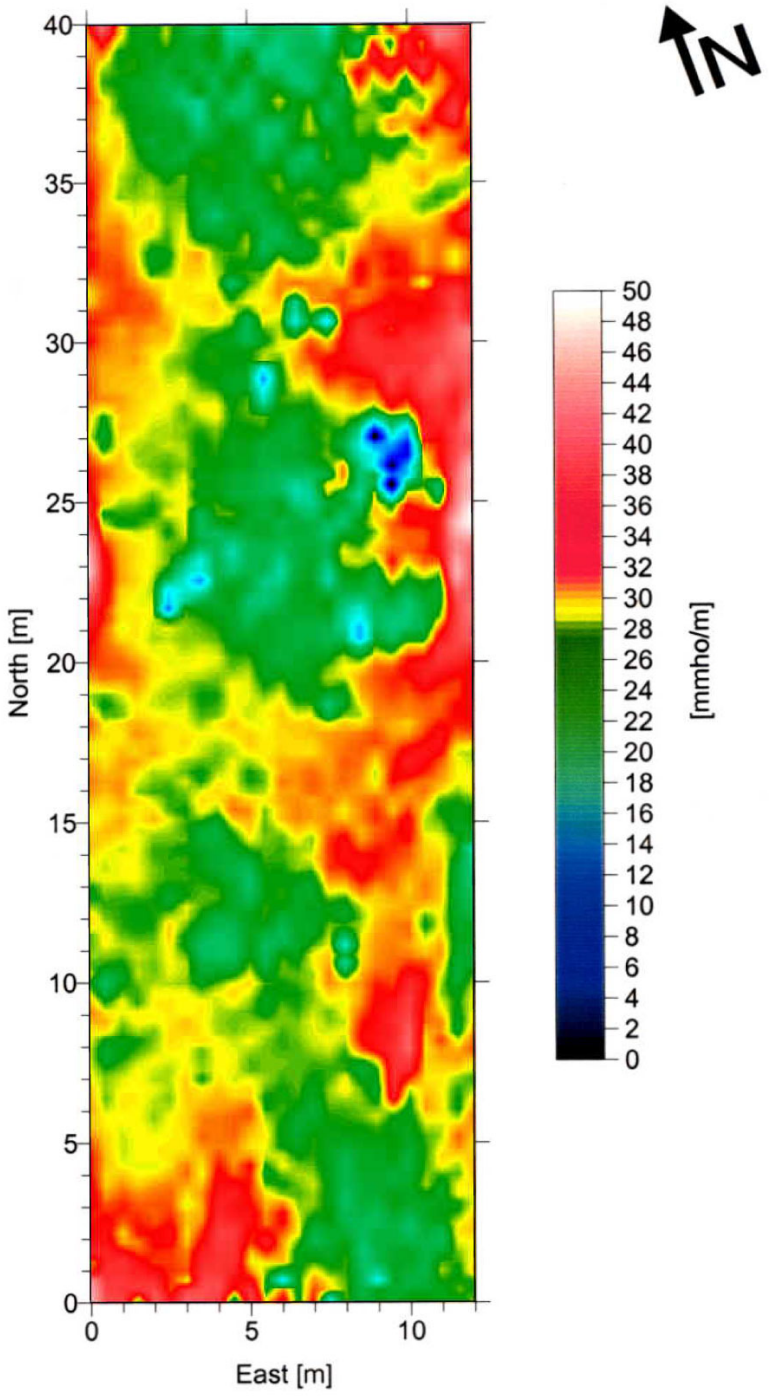
Carrizo Creek Stage Station - Grid 1
Electrical Conductivity
03/22/01



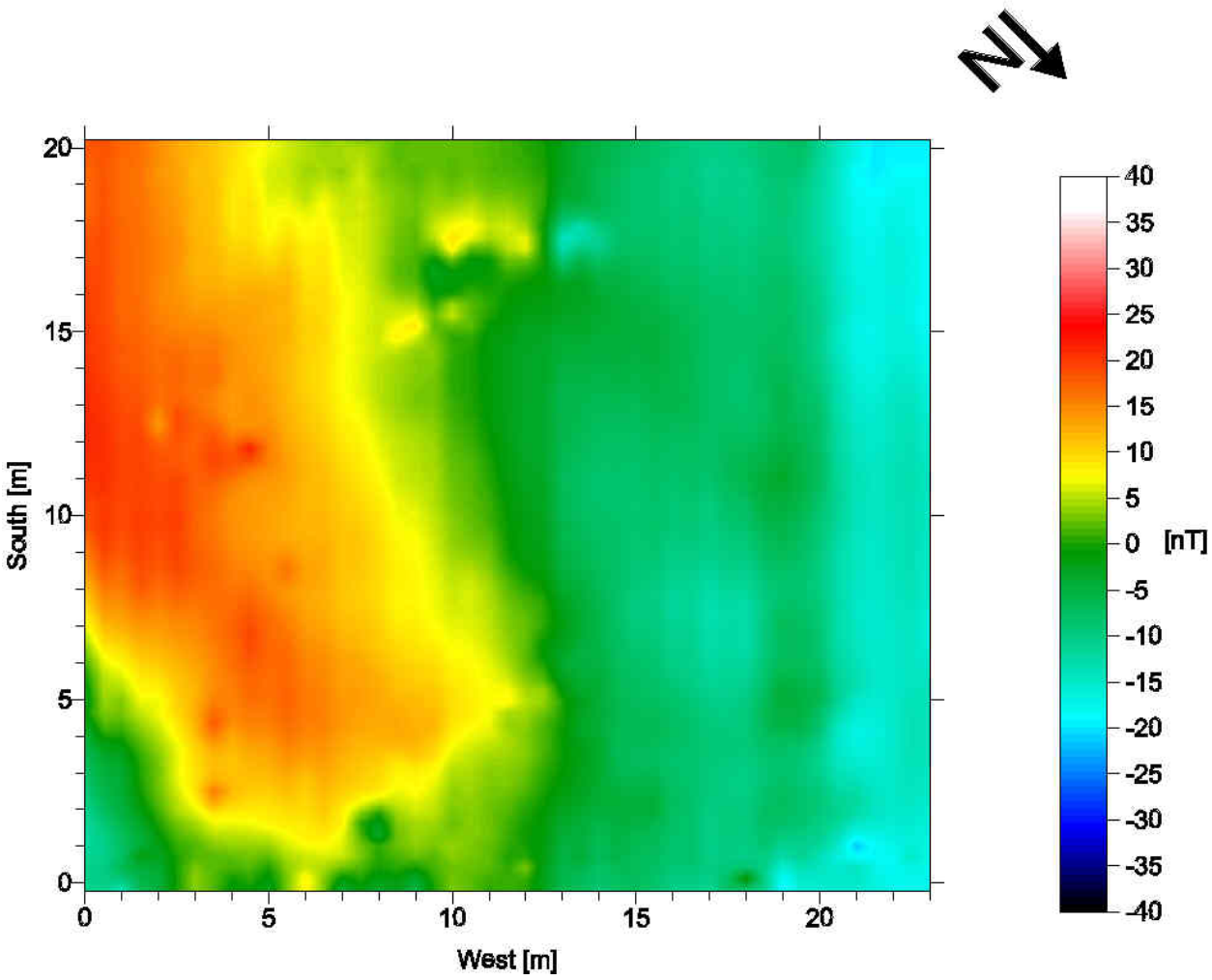
Carrizo Creek Stage Station - Grid 2
Electrical Conductivity
03/22/01



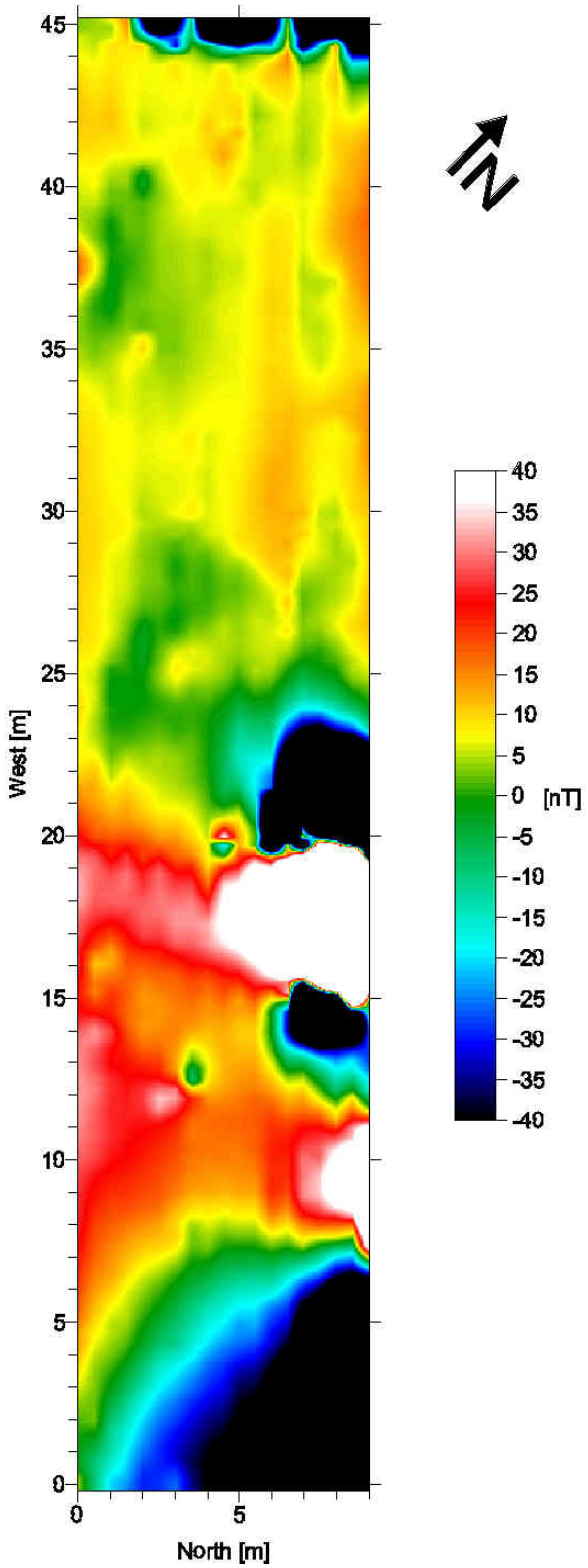
Carrizo Creek Stage Station - Grid 3
Electrical Conductivity
03/22/01



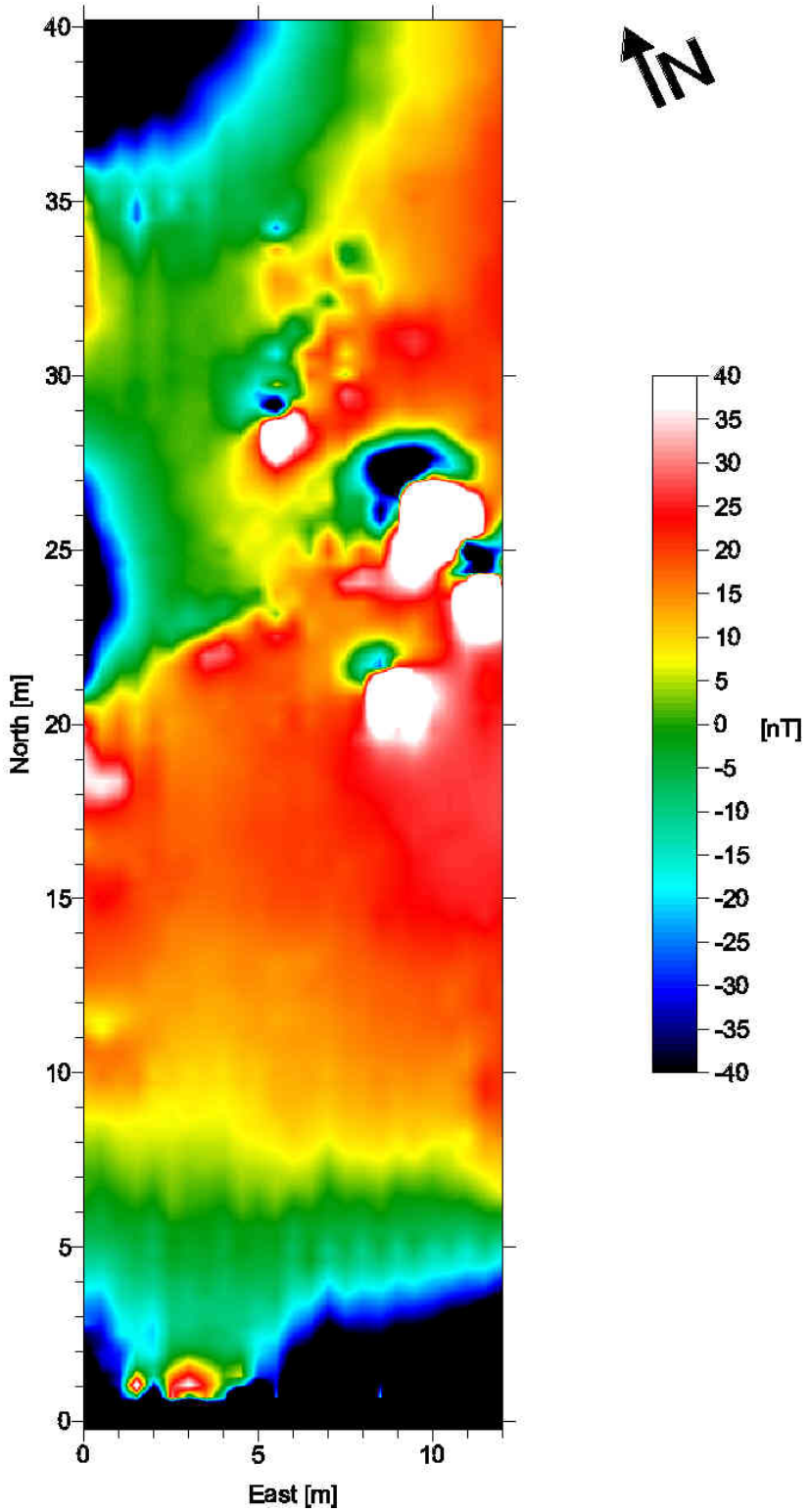
Carrizo Creek Stage Station - Grid1
Total Field Magnetic Anomaly

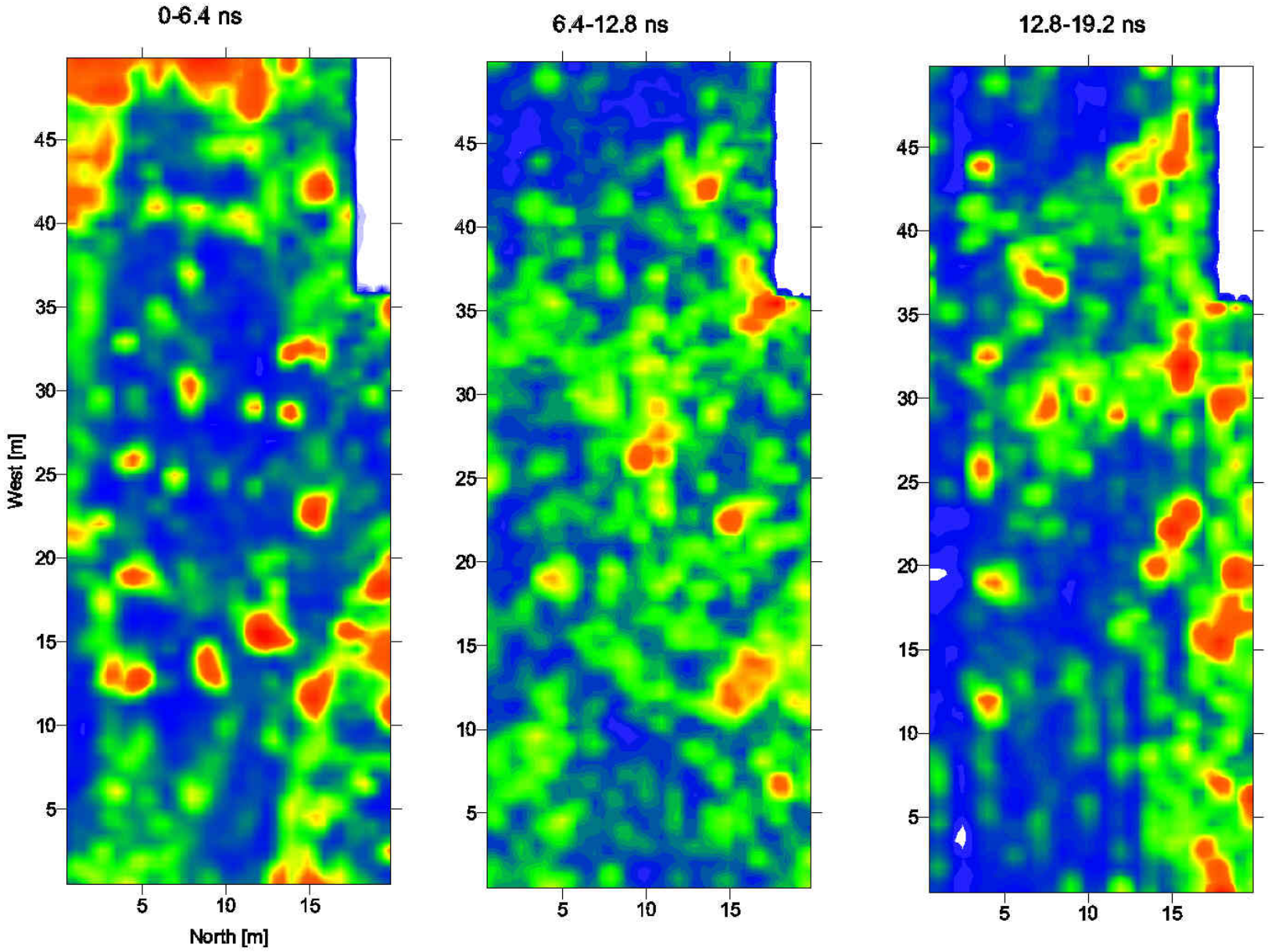


Carrizo Creek Stage Station - Grid2
Total Field Magnetic Anomaly



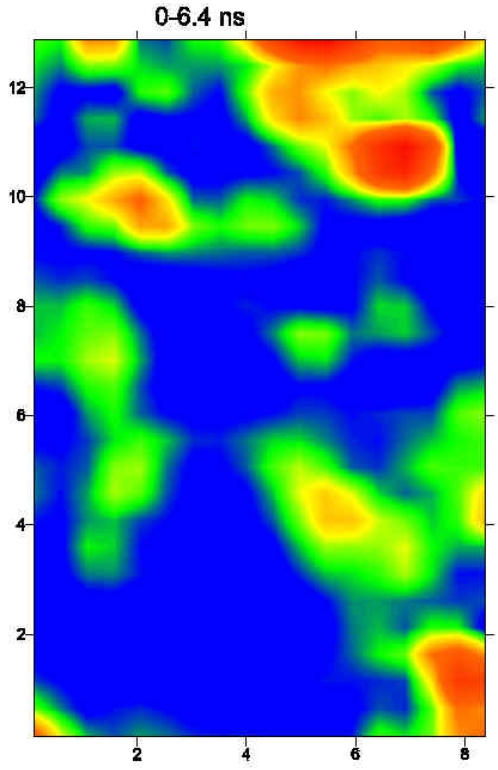
Carrizo Creek Stage Station - Grid3
Total Field Magnetic Anomaly

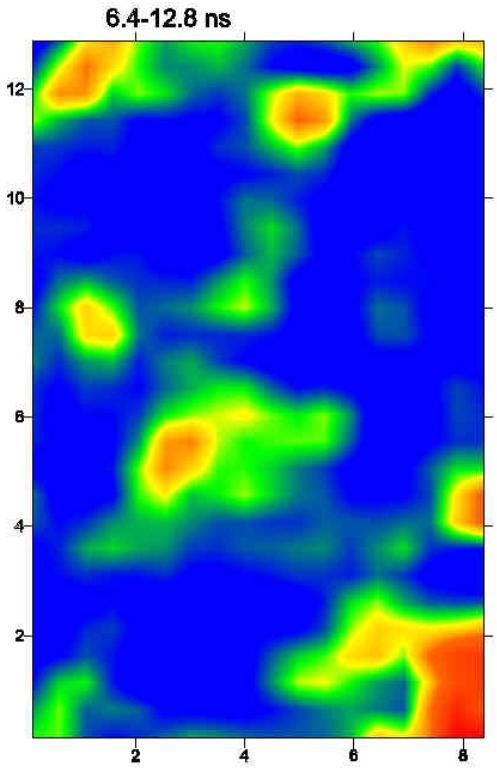


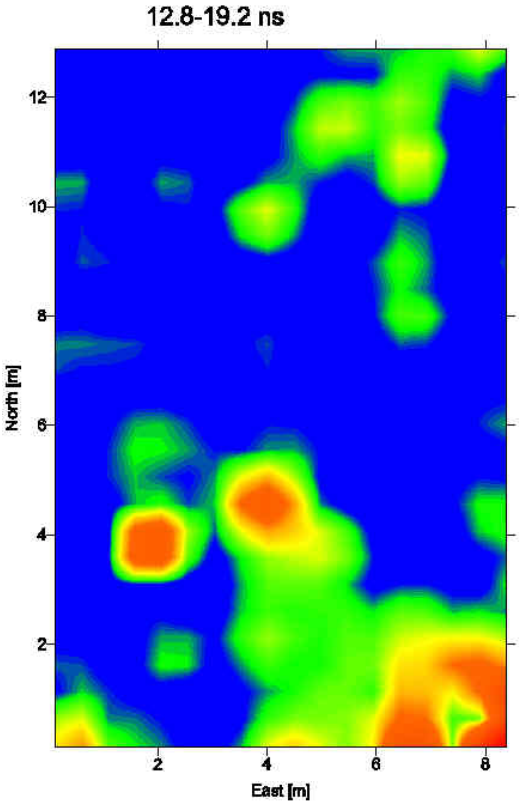


Palm Springs Stage Station - Grid 1 GPR Slices

LBC 3/21/01



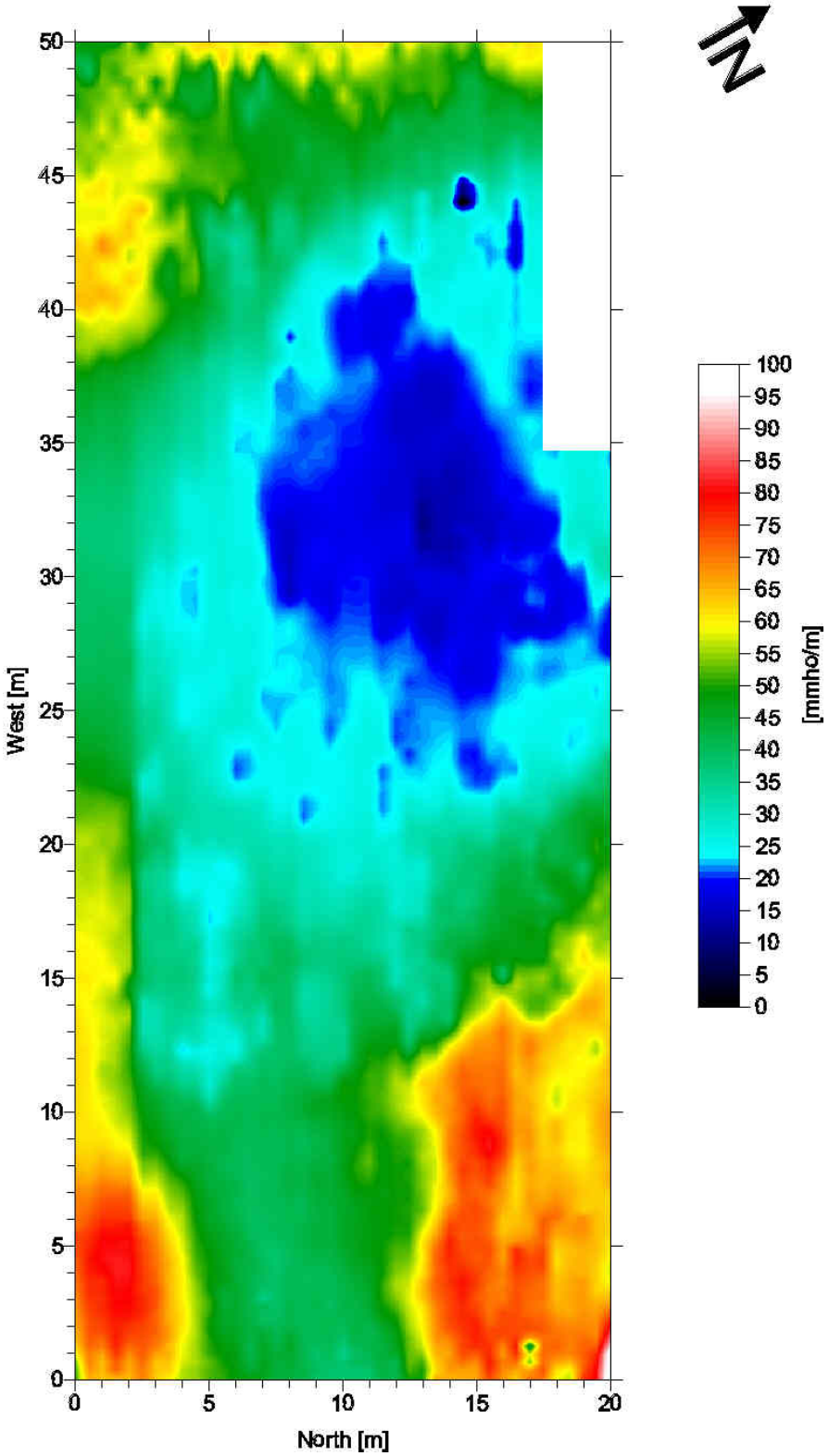




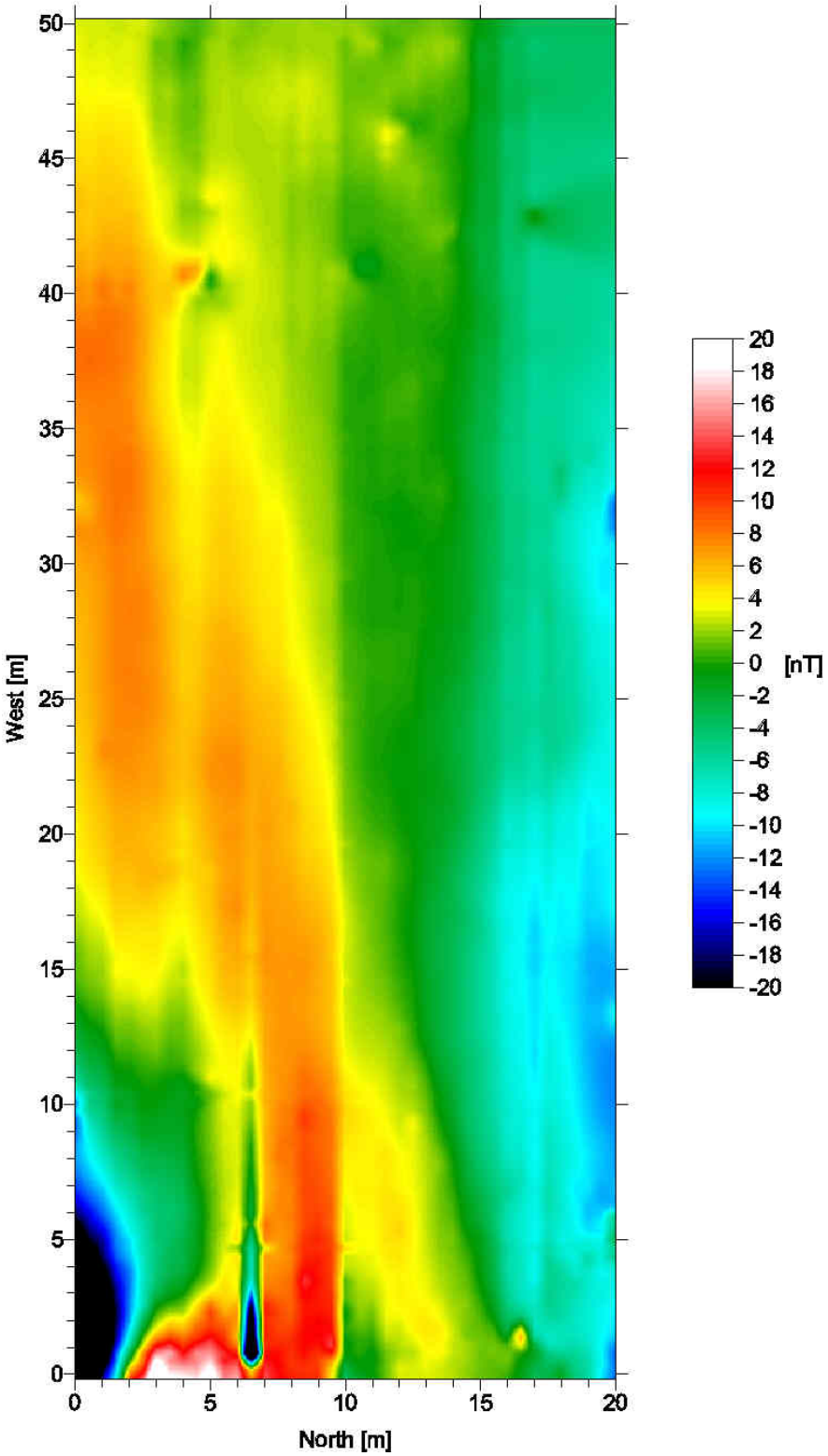
Palm Springs Stage Station
Grid 2 GPR Slices

LBC 3/21/01

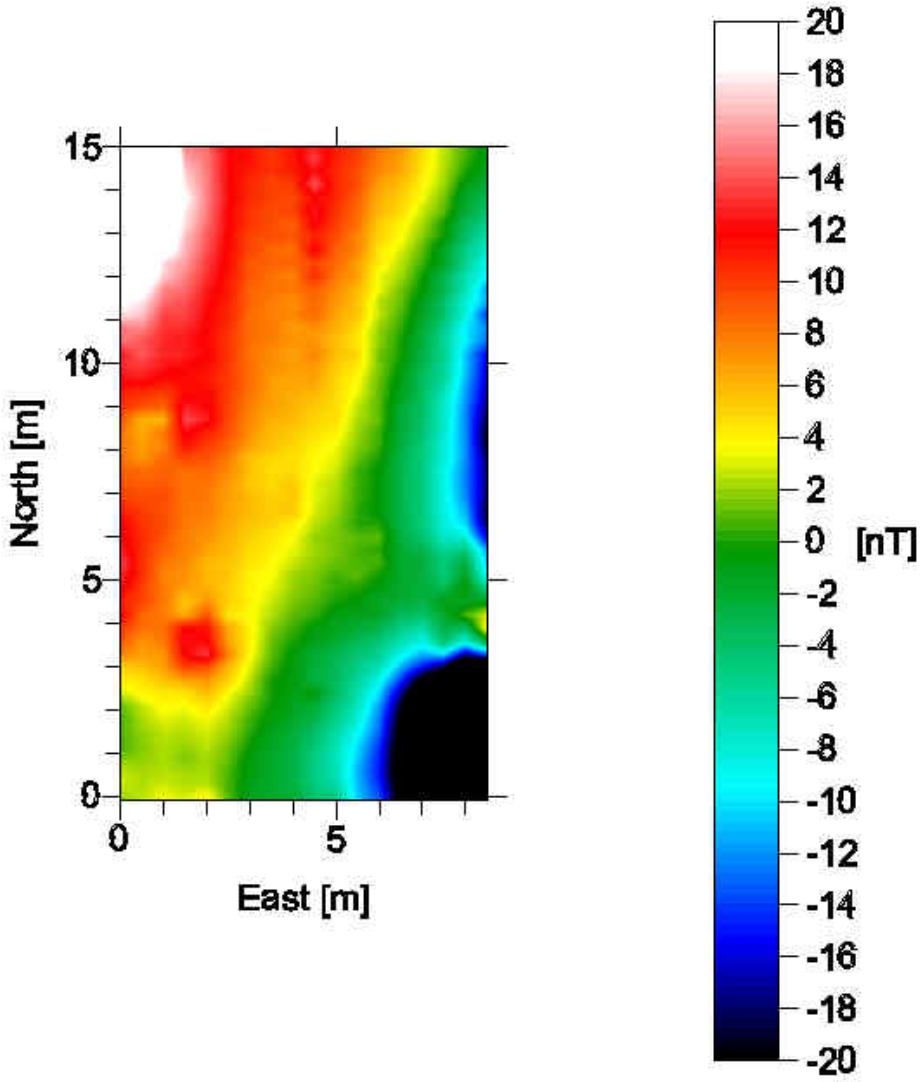
Palm Spring Stage Station - Grid 1
Electrical Conductivity
03/22/01



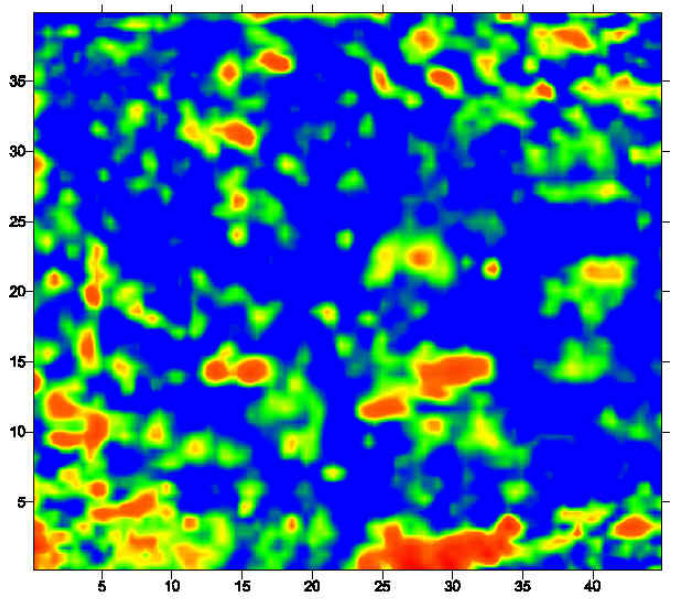
Palm Spring Stage Station - Grid 1
Total Field Magnetic Anomaly



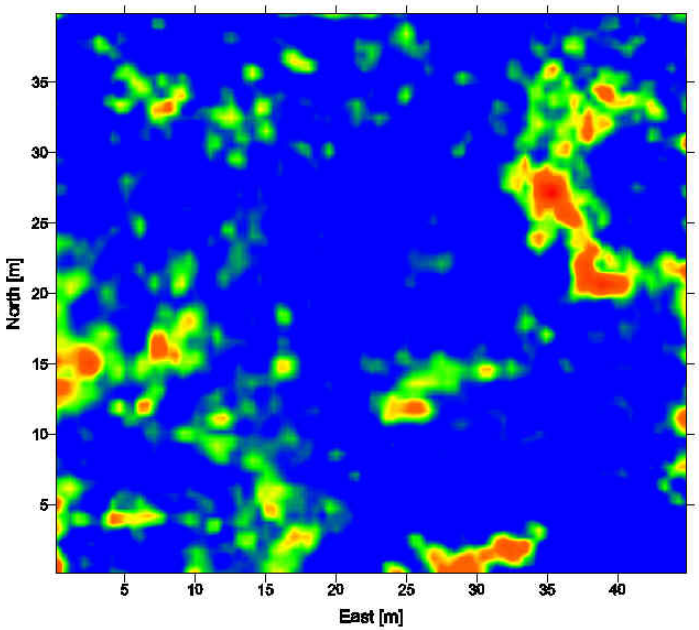
Palm Spring Stage Station - Grid 2
Total Field Magnetic Anomaly



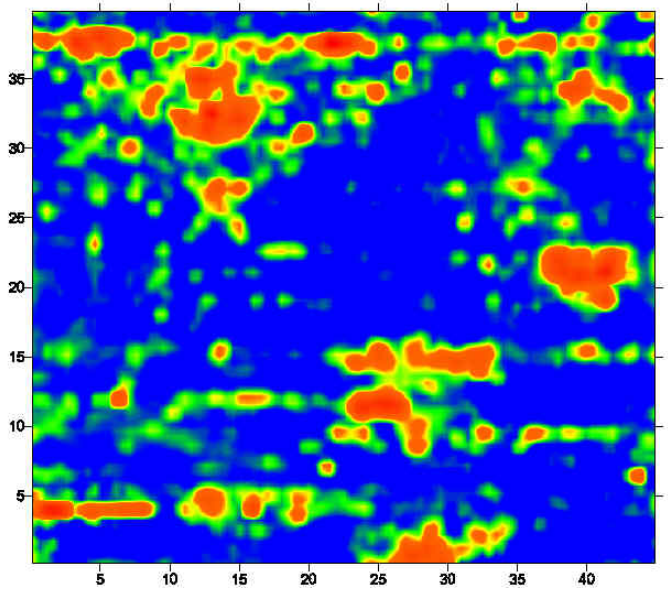
0-6.33 ns



6.33-12.66 ns

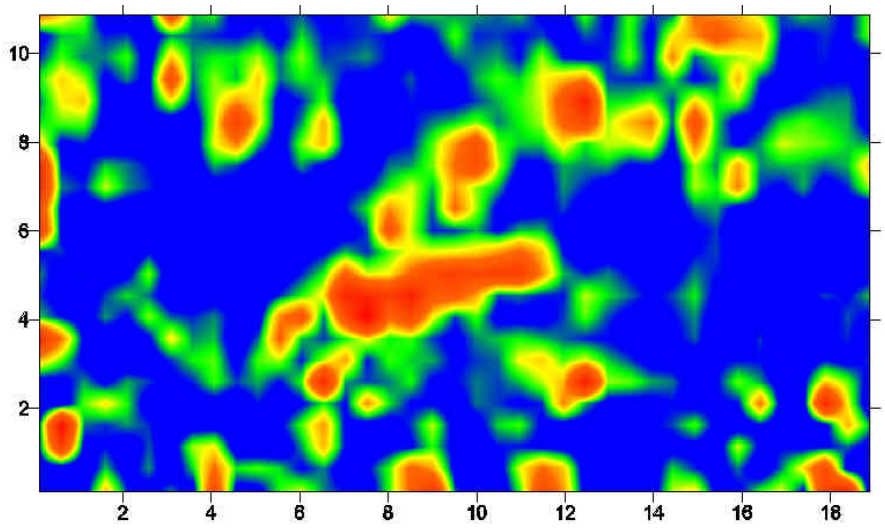


12.66-19 ns

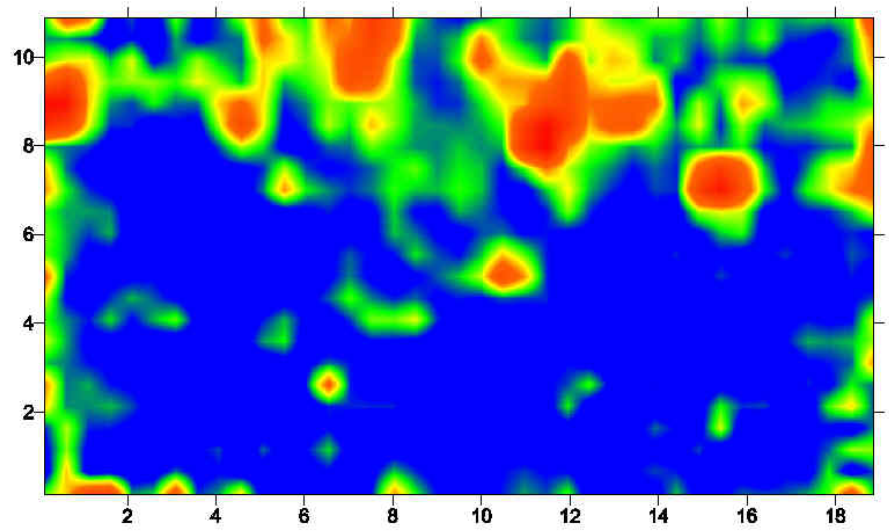


San Felipe Stage Station
Grid 1 GPR Slices

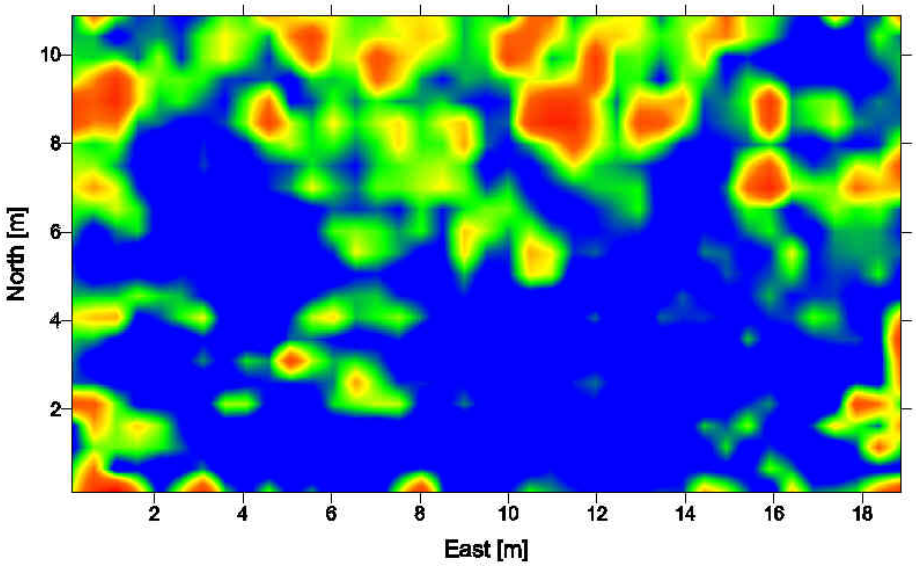
LBC 3/23/01



0-6.33 ns



6.33-12.66 ns

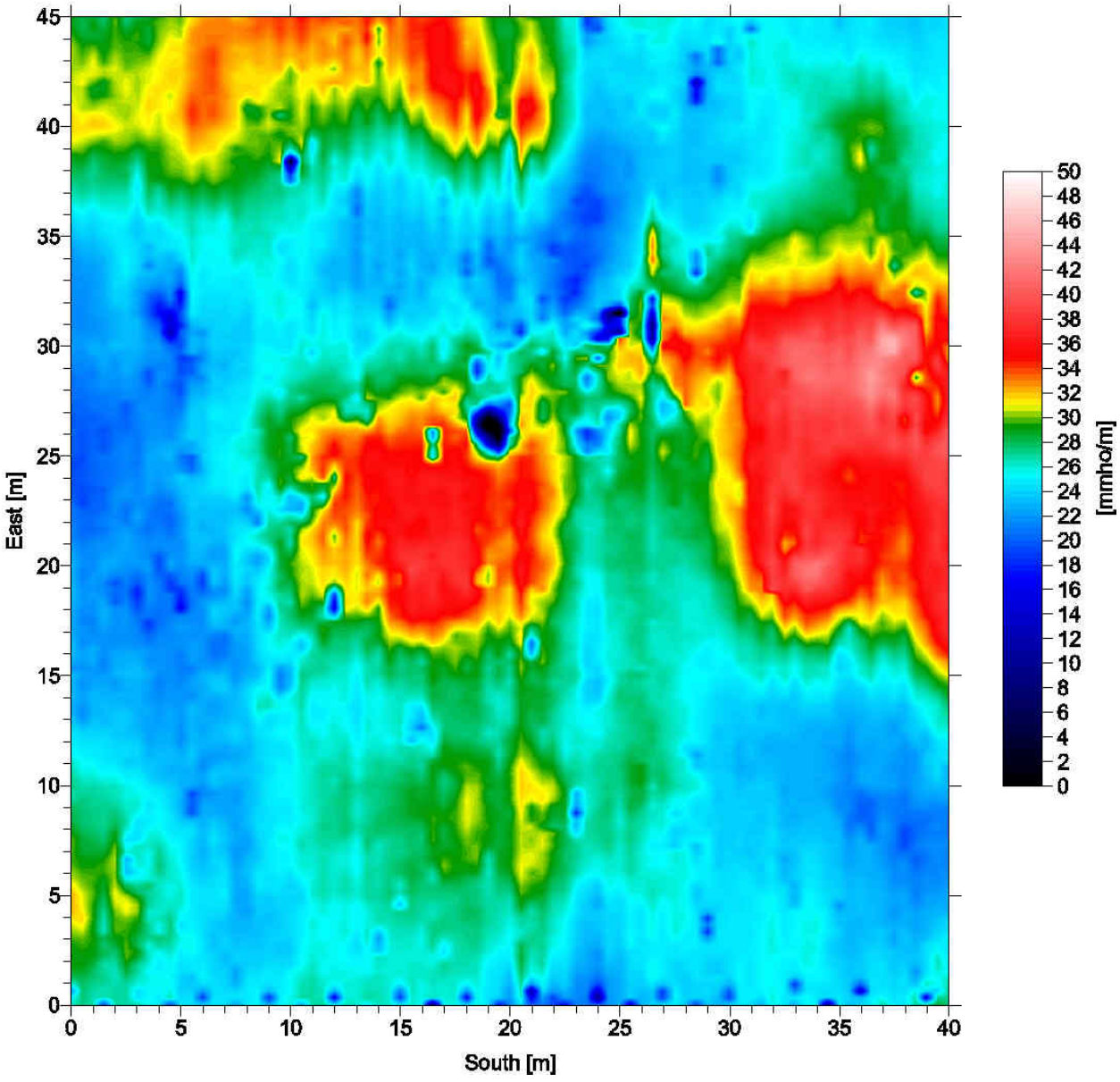


12.66-19 ns

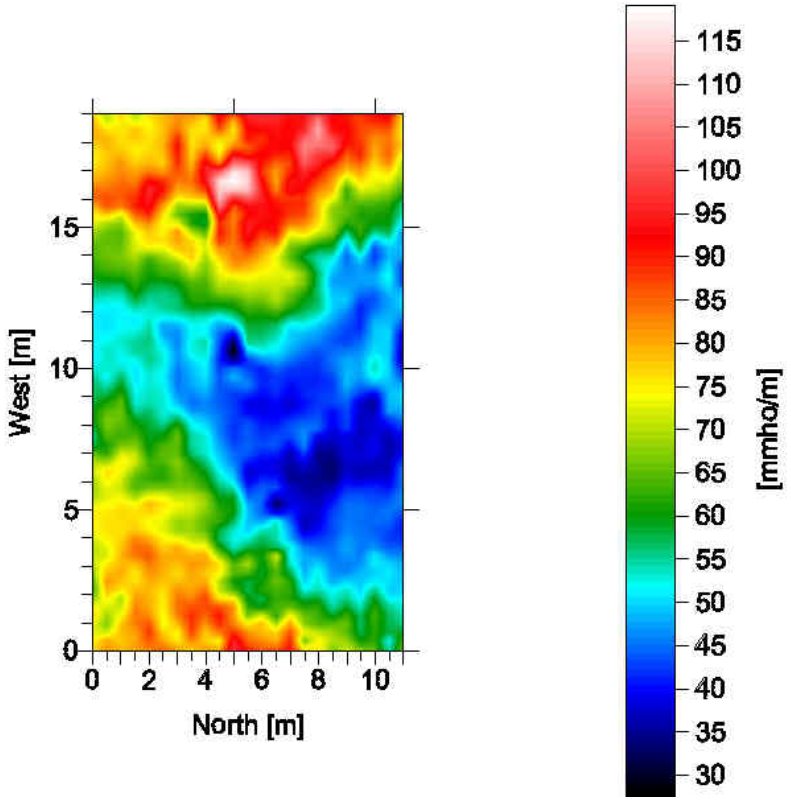
San Felipe Stage Station Grid 2 GPR slices

LBC 3/23/01

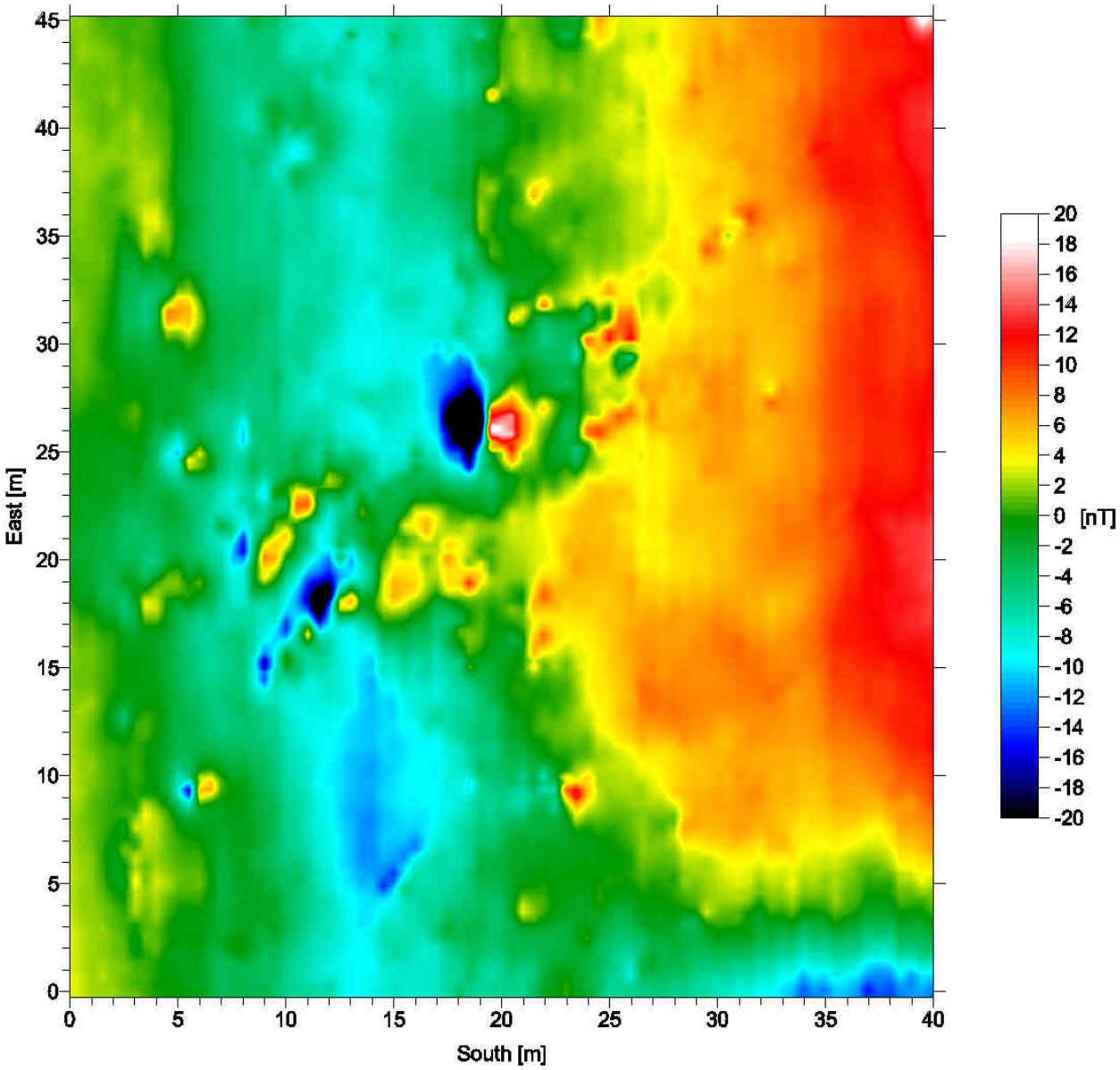
San Filipe Stage Station - Grid1
Electrical Conductivity (EM38)



San Filipe Stage Station - Grid 2
Electrical Conductivity (EM38)
03/23/01



San Felipe Stage Station - Grid 1
Total Field Magnetic Anomaly
03/23/01



San Felipe Stage Station - Grid 2
Total Field Magnetic Anomaly