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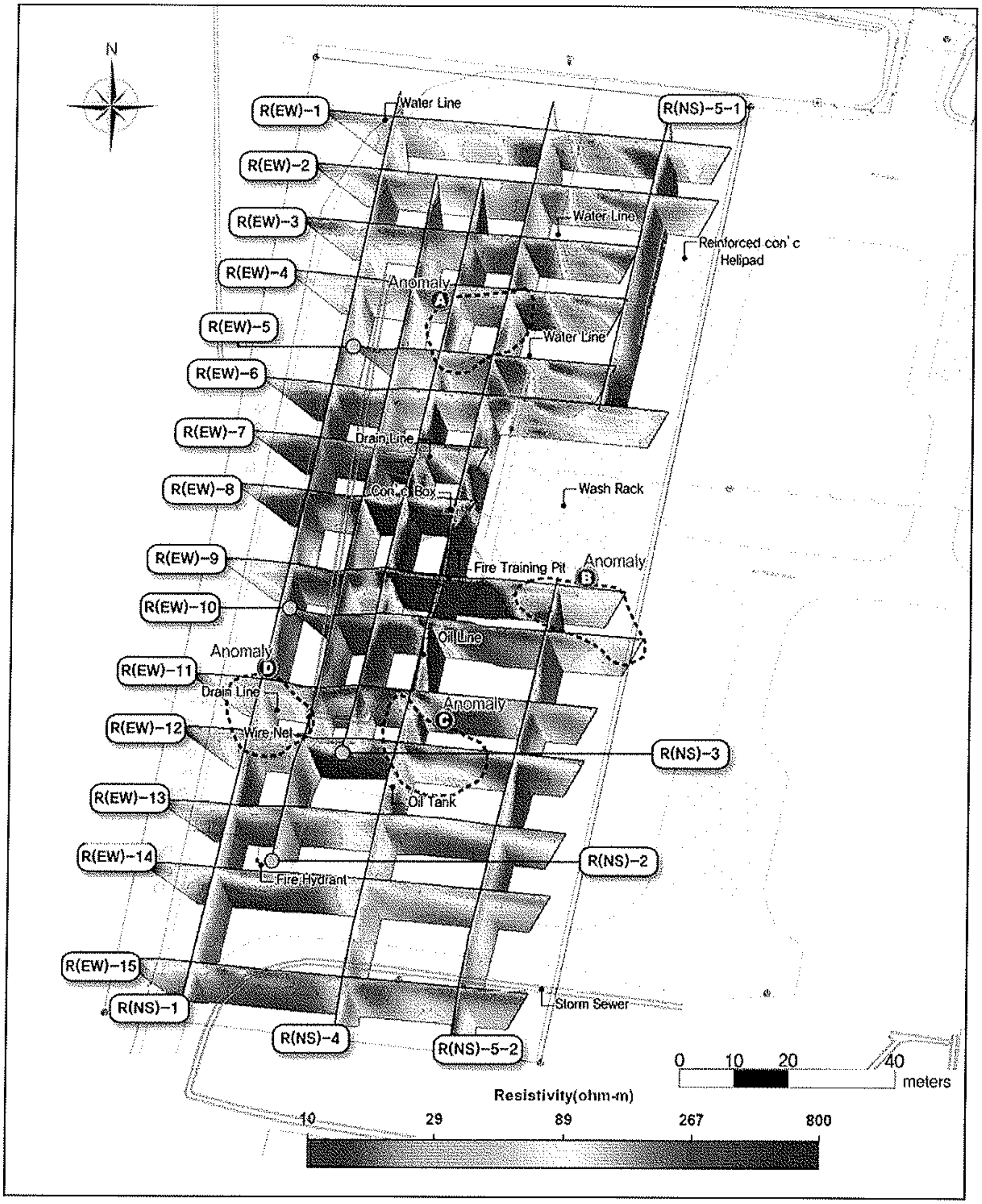
11901 Samuel, Garden Grove, CA 92840-2546

Figure 3-8. ERI Result



4. CONCLUSIONS

The locations where confirmed subsurface anomalies are indicated by the Magnetic Gradiometry, GPR and ERI surveys are shown on Figures 4-1 through 4-3. Figure 4-4 shows the results superimposed. A final interpretation of the data and subsurface anomaly zones are shown on Figure 4-5. The conclusions are summarized as follows:

- The Magnetic Gradiometry survey results indicate five subsurface anomalies.
- The GPR survey results indicate four subsurface anomalies.
- The ERI survey results indicate three subsurface anomalies.
- When the results of the three geophysical surveys are combined, they indicate four anomaly zones, identified as Zones A, B, C and D on Figure 4-5 where foreign objects may be present.
- The subsurface anomalies zones may be attributed to loosely packed soils (disturbance indicative of excavation and backfill), high water content (may be indicative of recent leaks or spills), or buried foreign objects such as steel drums.
- Zone A has the highest probability to contain buried foreign objects, with higher probabilities indicated by darker shades of red.

Figure 4-1. Magnetic Gradiometry Confirmed Subsurface Anomalies

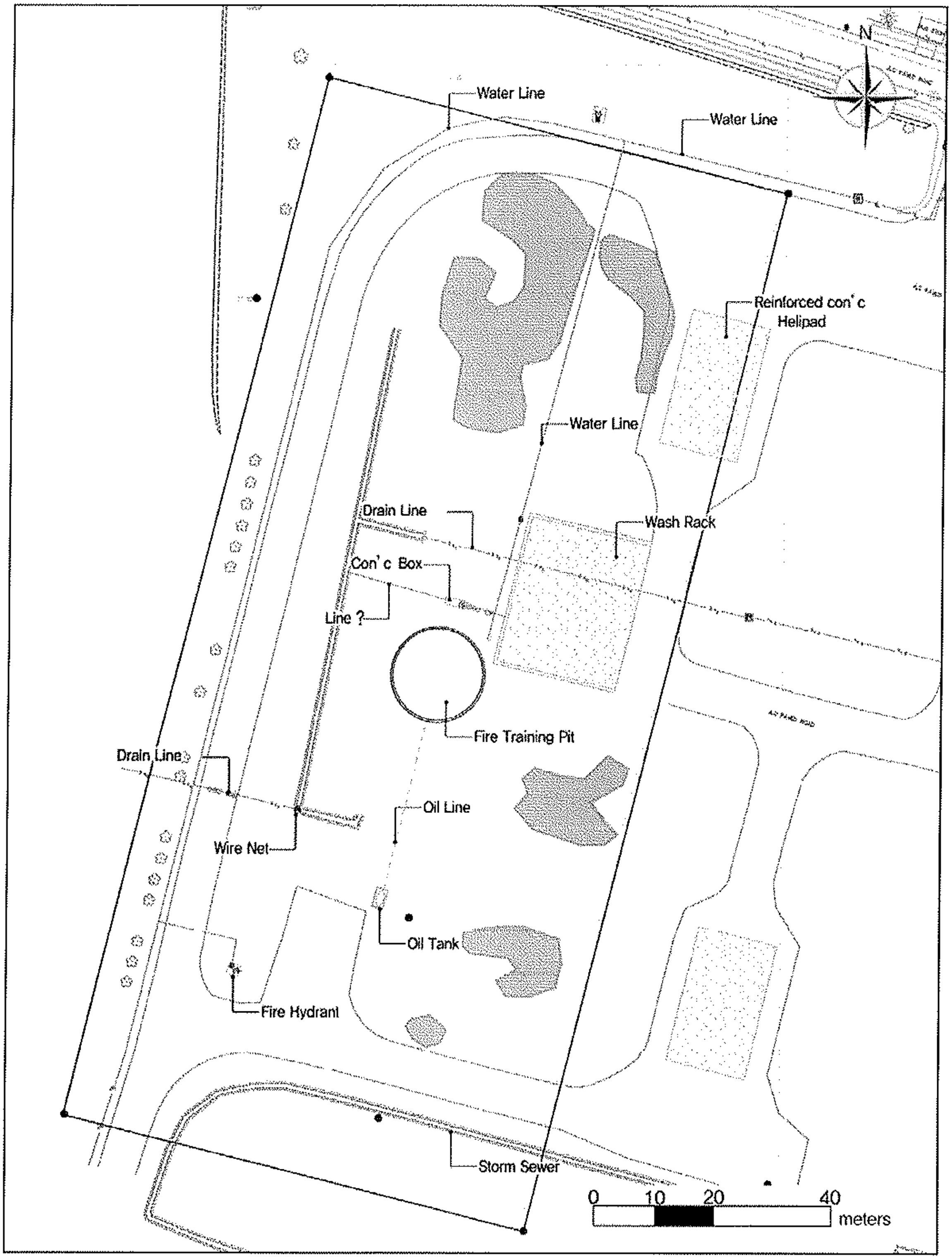


Figure 4-2. GPR Confirmed Subsurface Anomalies

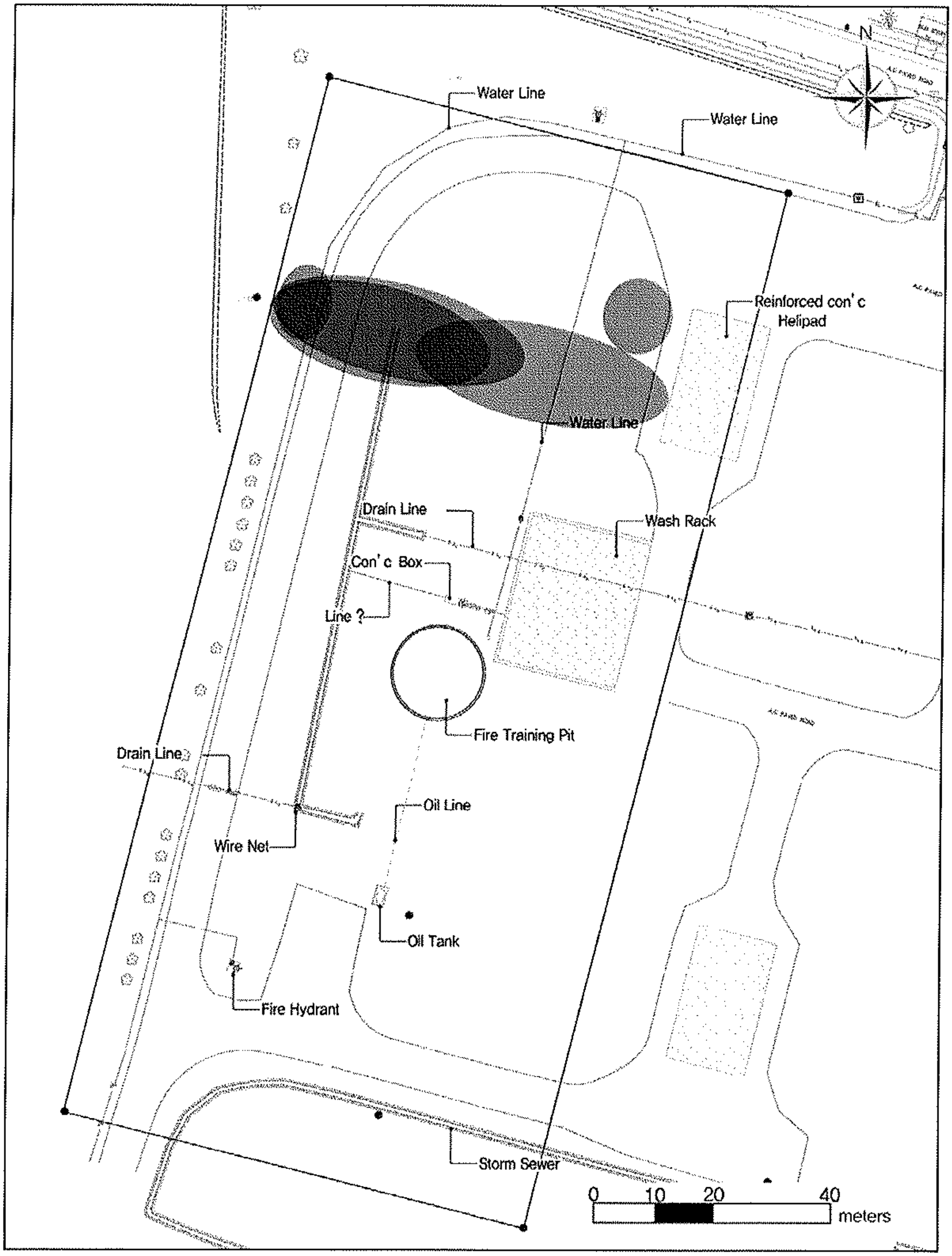


Figure 4-3. ERI Confirmed Subsurface Anomalies

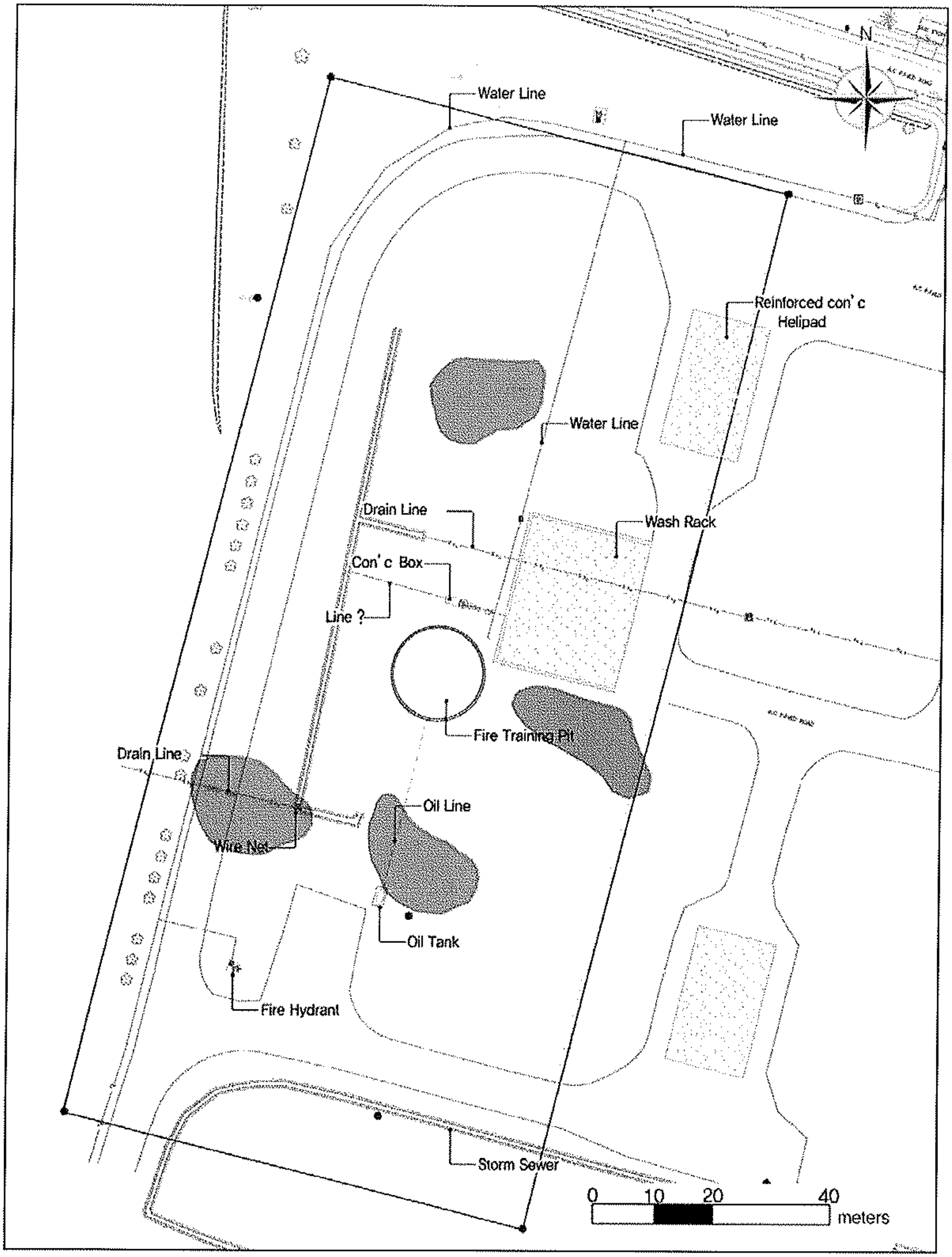


Figure 4-4. Combined Magnetic Gradiometry, GPR and ERI Results

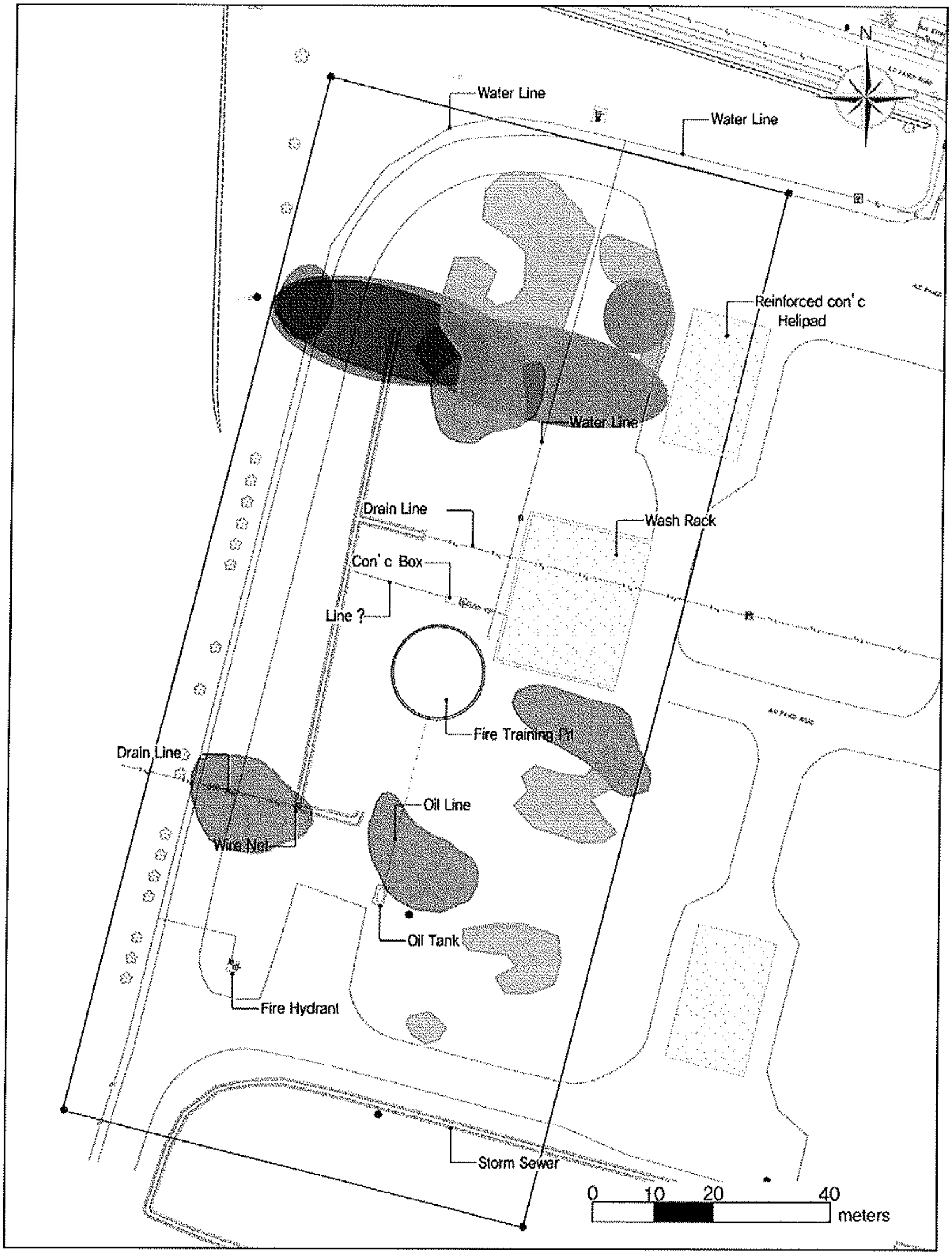
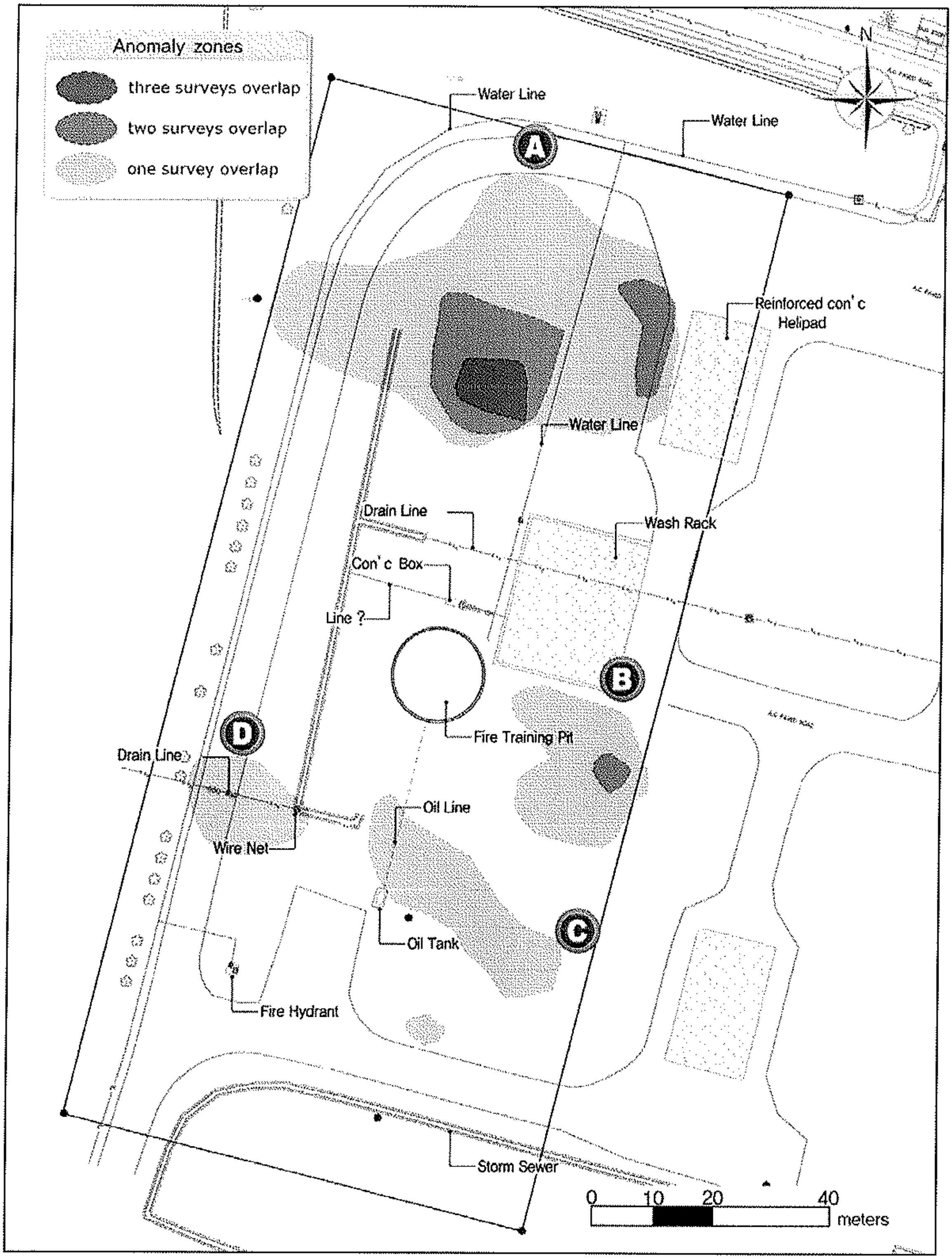


Figure 4-5. Final Interpretation of Subsurface Anomaly Zones



APPENDIX A
GEOPHYSICAL SURVEY INSTRUMENT SPECIFICATIONS

Bartington Instrument Ltd model Grad601 gradiometer
MALÅ GeoScience model ProEx™ Professional Explorer GPR
ABEM Instrument AB model Terrameter LS

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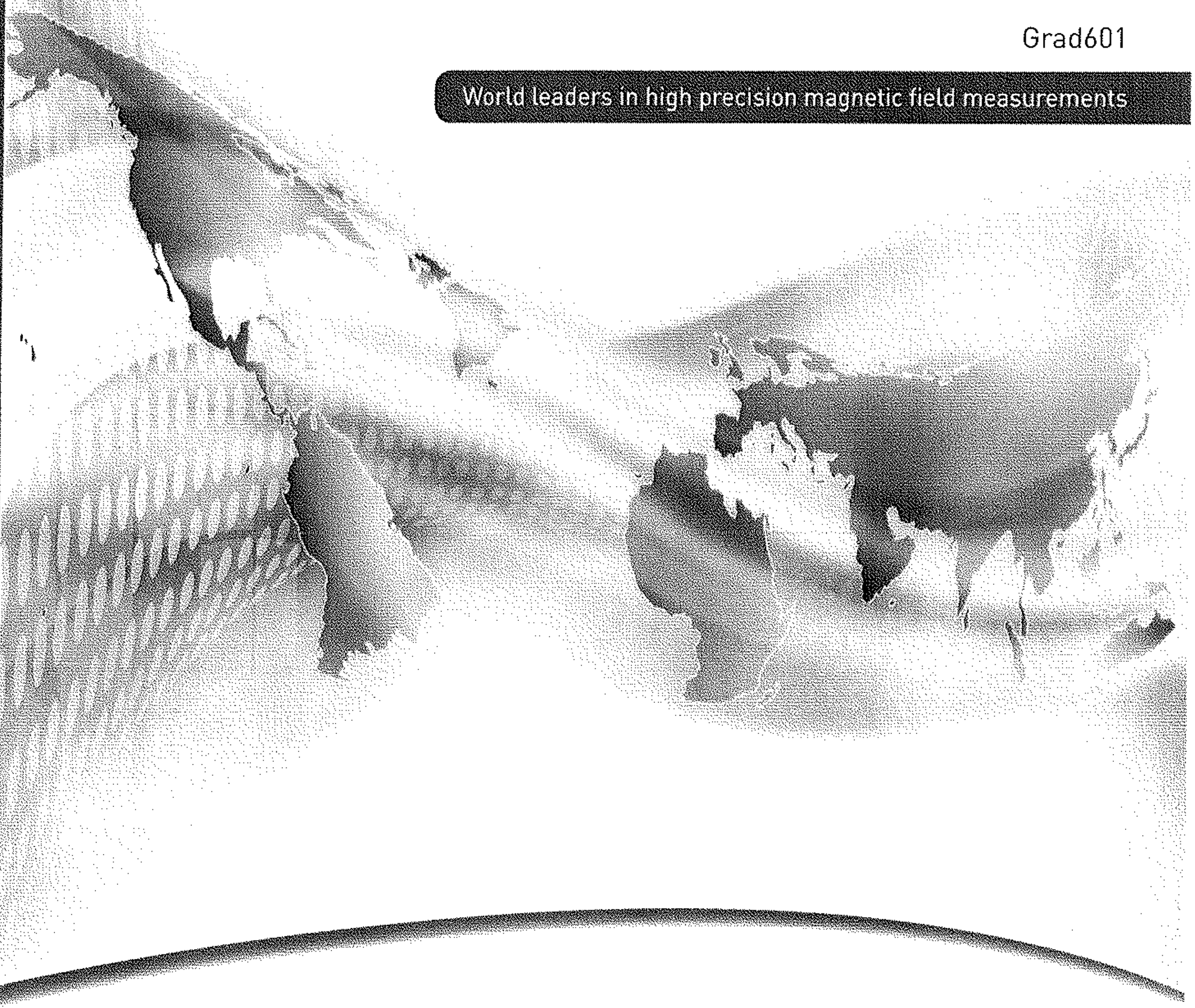
Grad601

World leaders in high precision magnetic field measurements



Grad601

Magnetic Gradiometer System

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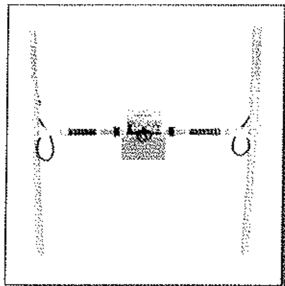
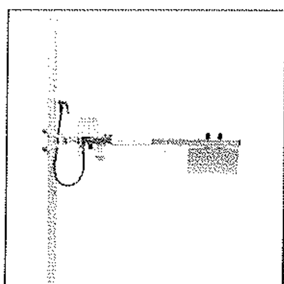
Bartington®
Instruments





Grad601

Magnetic Gradiometer System

The Grad601 is a vertical component fluxgate gradiometer comprising a data logger, battery cassette and either one or two Grad-01-1000L cylindrical sensors mounted on a rigid carrying bar. Each sensor contains two fluxgate magnetometers with one metre vertical separation. The system provides an enhanced depth response compared to a gradiometer with 0.5 metre separation, along with exceptional stability. Calibration of the gradiometer is by simple push-button control, eliminating the uncertainties usually associated with mechanically adjusted instruments.

- The Grad601-1 single sensor version is ideal for the location of pipes, cables, drums and archaeological features.

- The Grad601-2 two sensor version allows geophysical surveys to be completed in about half the time.

Both versions provide linear ranges of 100nT with a resolution of 0.01nT (effective resolution 0.03nT) and 1000nT with a resolution of 0.1nT. A large non-volatile flash memory and fast downloading of data enhance survey efficiency.

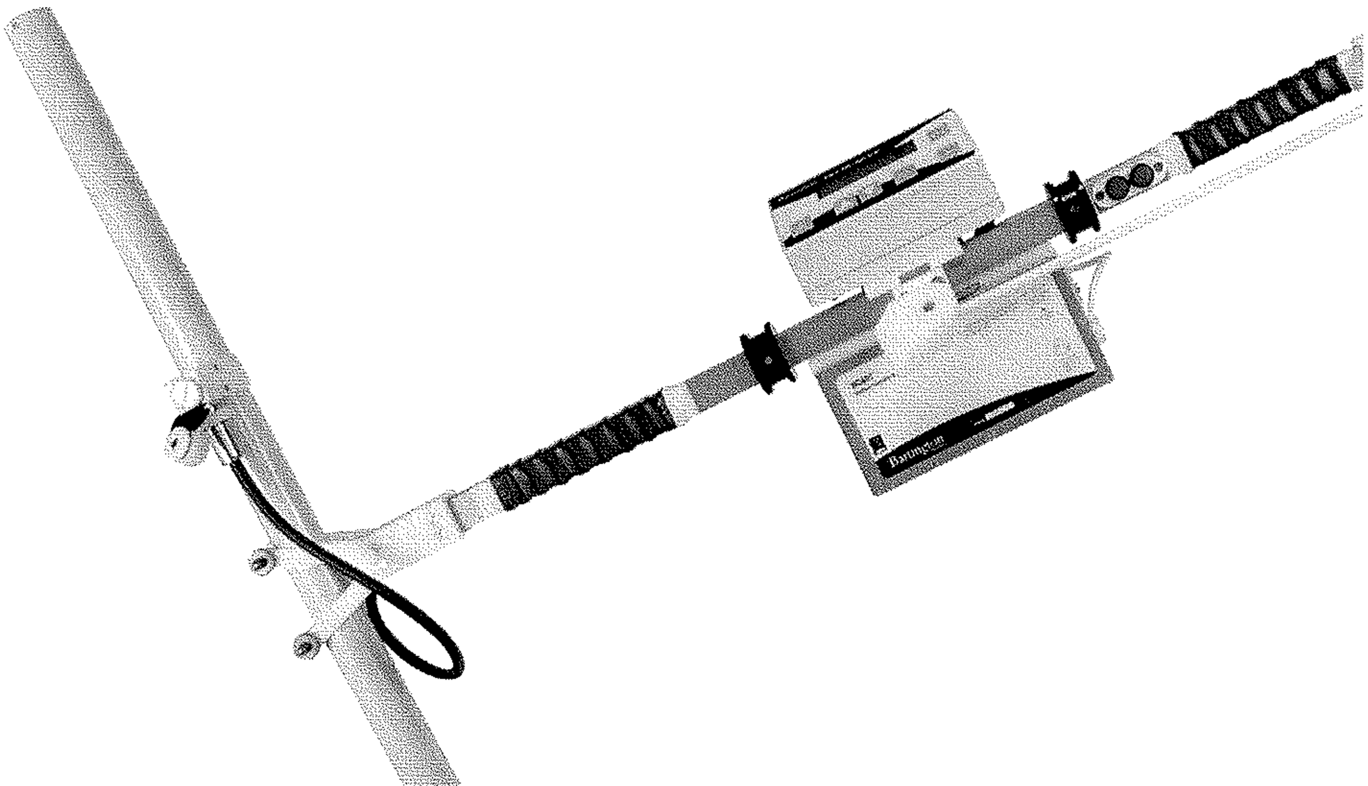
The exceptional temperature stability of the sensors ensures minimal drift during surveys and reduces the need for adjustment. All adjustments are accomplished using a single push-button and audible cueing. Overall system delay is minimal, ensuring negligible data skew. Powerline rejection can be keypad selected for 50Hz or 60Hz, giving >1000:1 reduction.

The instrument operates in either survey or scanning mode. In survey mode, data is logged using continuous or single-shot measurements, while covering the site in parallel or zigzag paths. In scanning mode, the instrument operates as a search tool with an adjustable audio alarm, without logging data. Either mode can be used to locate archaeological features, pipes, cables, waste drums and unexploded ordnance. Survey data are saved in grids of 10, 20, 30 or 40 metre squares.

The non-volatile 256kB flash memory is sufficient, for example, to log 30 grids of 30 x 30 metres with a one metre line separation and a resolution of four readings per metre. Software is provided for downloading data from the data logger to a PC via a RS232 serial or USB interface, and it can save data in any of three formats for subsequent data processing. Downloading a full memory takes less than seven minutes.

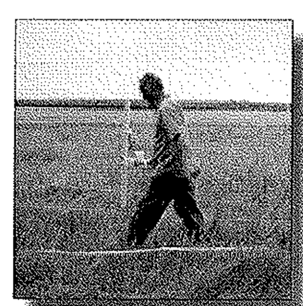
The intelligent data logger measures the gradient using a high sample rate with automatic averaging to smooth the data for each reading. Sample rate can be adjusted to suit the operator's pace.

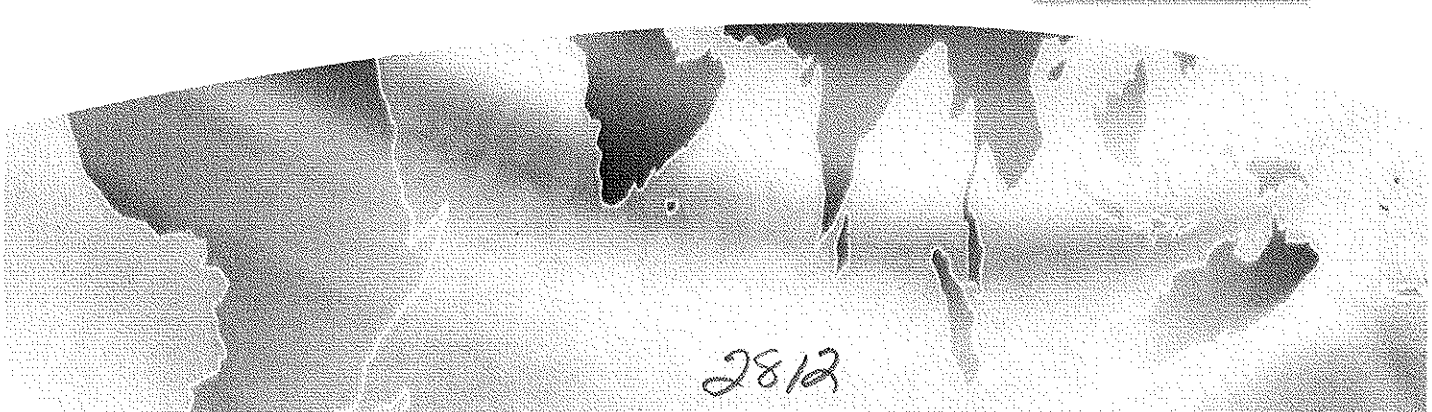
GPS
A version of the logger with an NMEA data output, suitable for use with GPS devices, can be supplied. Contact us for details.



Features

- Electronic adjustment
- Selectable 0.01nT or 0.1nT resolution
- 125k readings
- Low power – 24 hour operation
- Survey and Scan modes
- 1 to 4 lines/m
- 1 to 8 readings/m along each line (4 max on 40m grids)
- Fast download – 6.5 minutes max





Accessories

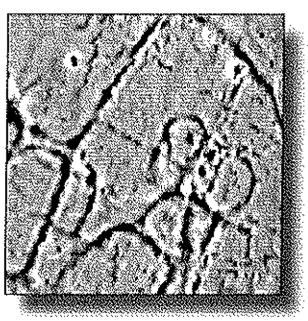
Each gradiometer system is supplied in a universal rugged carrying case, with cut-outs for either a single or dual system, together with the following accessories:

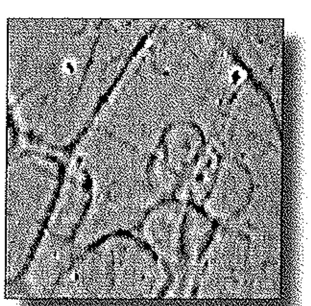
- Carrying harness with spare rings (Grad601-2 only)
- Mains adaptor: 110V-240V/47-63Hz, charging current 1.25A maximum
- In-car charger: regulated 12V-24V DC-DC, 2A current rating, short circuit protected, automatic thermal and overload cut-off
- 9-pin serial cable and USB adaptor
- Downloading software on CD
- Grad601 Operation Manual on CD

The Grad601-2 carrying harness provided for the dual gradiometer system relieves the operator's arms of the weight of the gradiometer, while enhancing the operator's ability to use the instrument. A water-filled bag in the back of the harness counter balances the gradiometer.

The harness can be adjusted to fit the operator and enables the gradiometer to be positioned at the required carrying height. The dual gradiometer bar sits in quick release swivel mounts on the abdominal spacer bar to assist in keeping the sensor vertical. The spacer is attached to the harness by shock absorbing rubber rings.

Grad601 (1m vertical sensor spacing)





Same site surveyed using a gradiometer with 0.5 m vertical sensor spacing

Software

Most users will find that processing and interpretation of survey results is greatly simplified if graphical mapping software is used. The typical graphical image plots shown here indicate how detected features can be clearly identified.

ArcheoSurveyor by DW Consulting
This is a fully featured and powerful graphical imaging application specifically designed for archaeological geophysics. ArcheoSurveyor can read data directly from the Grad601 Gradiometer (and other commonly used survey instruments) via the serial/USB connection. The user can then apply a wide variety of data filters and algorithms (e.g. clip, destripe, destagger, etc.) to enhance the clarity of any magnetic anomalies.

ArcheoSurveyorLite is a 'lite' version of this graphical mapping software, providing the user with the majority of functions needed to process instrument data. There is a simple upgrade path to the full version when further features become necessary.

ArcheoSurveyor and ArcheoSurveyorLite can be purchased from Bartington Instruments or DW Consulting.

Grad601 Download Utility
This utility is supplied free of charge and allows survey data to be downloaded to a Windows® PC. Several file formats (including 'xyz', 'z data' and 'spreadsheet mode') are available, and are compatible with most common mapping software packages (e.g. Surfer, Geoplot).

These plots illustrate how the 1m vertical spacing of the sensors on the Grad601 provides an increased depth of response compared to a 0.5m spacing gradiometer.

Specifications

Environmental Specification	
Rating	IP65
Operating temperature	-20°C to +70°C

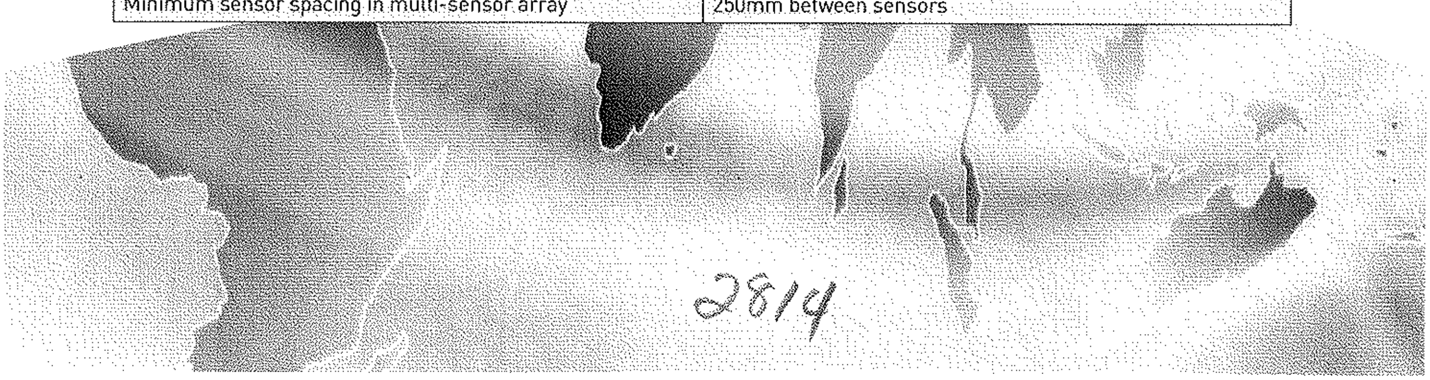
Mechanical Specification	
	Weight
Grad601-1 Single Gradiometer	2.9kg
Grad601-2 Dual Gradiometer	4.3kg
Harness with abdominal spacer and balance weight	1.6kg
Carrying case for either system (dimensions 1250 x 280 x 260mm)	9.85kg (empty) 15.75kg (full)

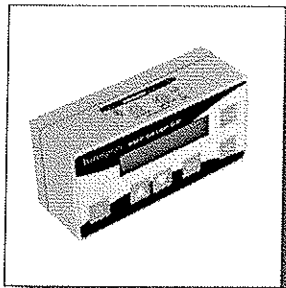
Optional alternative arrangements	
With some additional parts, the Grad601 can be used as either a dual sensor system (for best survey speed) or single sensor system (for confined spaces)	
Conversion:	Additional parts required:
Grad601-2 dual to Grad601-1 single system	Grad601-1 support beam including BC601 battery cassette extension cable
Grad601-1 single to Grad601-2 dual system	Grad601-2 support beam, Grad-01-1000L Sensor

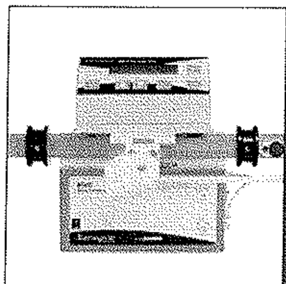
Grad-01-1000L Sensor

The Grad-01-1000L is a high stability fluxgate gradient sensor with a 1m separation between the sensing elements and an effective sensitivity of 0.03nT/m. The exceptional temperature stability of this sensor ensures minimal drift during surveys and reduces the need for adjustment to a minimum. Each sensor contains electronics and non-volatile memory for calibration data storage and can be operated independently, over long cables, if required.

Specification - Grad-01-1000L Fluxgate Gradiometer Sensor	
Sensor element spacing	1m
Gradient range	±100nT/m or ± 1000nT/m full-scale
Bandwidth	DC to 14Hz with -40dB 50Hz/60Hz rejection
Sensitivity	0.03nT/m (max effective)
Accuracy	±2%
Maximum ambient field	±100μT
Drift	<1nT in 24 hours
Dimensions	38mm diameter x 1050mm in length
Weight	0.83kg
Connector	12-way Tajimi R04-R12M
Power supply current	60mA
Minimum sensor spacing in multi-sensor array	250mm between sensors







DL601 Data Logger

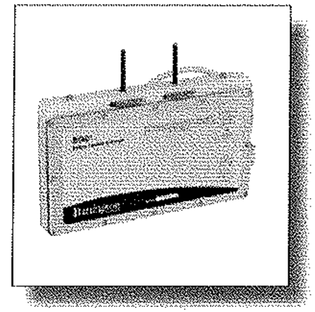
The data logger has a simple six-key control panel for menu-selected operation and liquid crystal display (LCD). External push-buttons are provided for optional use during survey operations.

Specification - DL601 Data Logger	
Sensors	1 or 2 Grad-01-1000L Gradiometers
Gradient ranges	±100nT and ±1000nT
Resolution	0.01nT on ±100nT range* 0.1nT on ±1000nT range
Attenuation	-20dB 50Hz/60Hz rejection
Control delay	27ms
Controls	ON/OFF switch, keypad and external switch
Display	2 rows x 20 characters LCD
Display update rate	Operation dependent
Gradiometer adjustment	Automatic via keypad
Data logging memory	125k data points non-volatile
Data output	RS232 interface USB converter supplied NMEA output version available **
Audio output	Variable rate bleeper
Dimensions (H x W x D)	160 x 80 x 60mm
Weight	0.49kg
Connectors: Grad-01-1000L RS232 output battery external switch	 Two 12-way Tajimi R04-R12F 9-way D type 1-way 62GB type 3-way series 712 subminiature
Power supply requirements	9-18V DC, 45mA (max)

* Effective resolution with Grad-01-1000L Sensor is 0.03nT/m.

** NMEA output for GPS logging, contact Bartington Instruments for details.

BC601 Battery Cassette



This Lithium Ion type of battery is housed in a sealed cassette which also contains the automatically terminating charging circuitry. The battery is charged by the mains adaptor supplied, or any isolated 9-18V DC supply (at 1.2A minimum) in 6 to 8 hours. One charge will operate the system for up to 24 hours with two gradiometer sensors, or 36 hours with one gradiometer. A push-button charge indicator is provided.

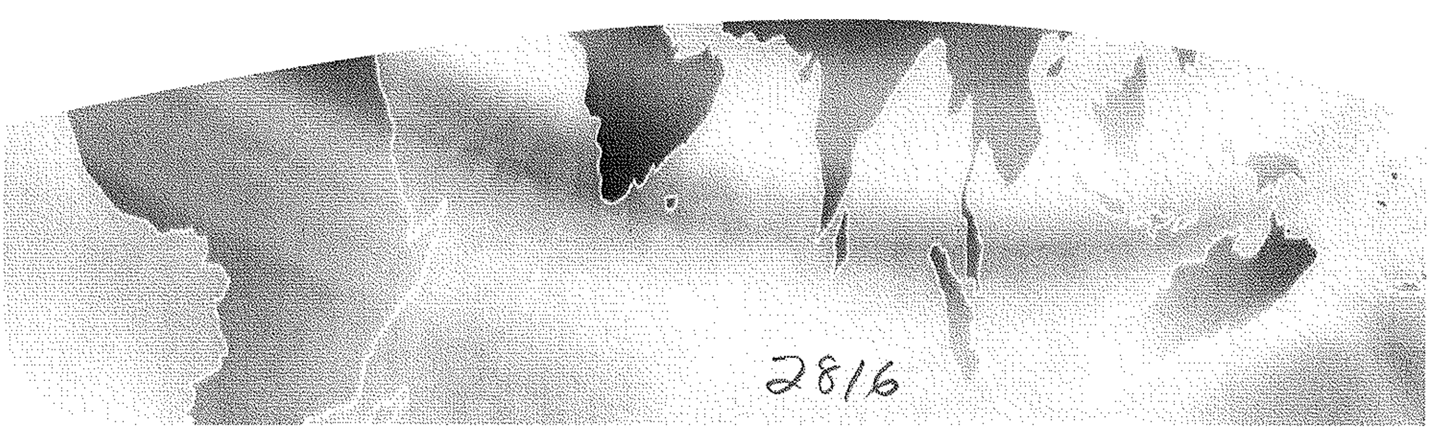
Specification - BC601 Battery Cassette	
Battery	12V 4Ah Lithium Ion
Battery charging	6 to 8 hours with mains adaptor supplied (automatic termination)
Indicators	Red LED lit when charging, off when complete
Fuse	2A 20mm anti-surge internal
Dimensions (H x W x D)	120 x 210 x 25mm
Weight	0.91kg including battery
Connectors: charger input output	 2.1mm socket 2-way 62GB type on 250mm cable

Grad601 Carrying Bar

The appropriate carrying bar is supplied for each configuration. The gradiometers are attached at the ends of the carrying bar by quick release clamps.

The data logger and battery cassette are normally left attached to the carrying bar. All cables are routed through the carrying bar.

Green and red push-buttons are provided on the carrying bar as alternatives to the keypad ENTER and ESC keys, for synchronising the data collection, interruption during surveys and for setting up. The auxiliary push-button sub-assembly, which is easily replaced, is conveniently located near the operator's hand, and reduces excessive wear of the most frequently used keys.



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DS1800/14

For further reading, please refer to a paper entitled: 'A high-stability fluxgate magnetic gradiometer for shallow geophysical survey applications' by G. Bartington and C.E. Chapman. Published online 4 November 2003 and available at the Wiley Online Library: www.onlinelibrary.wiley.com

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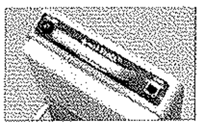
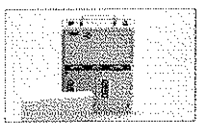
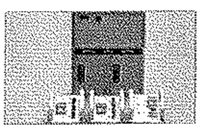


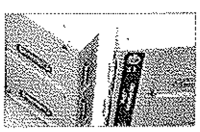
Ethernet communications 100Mbit/s



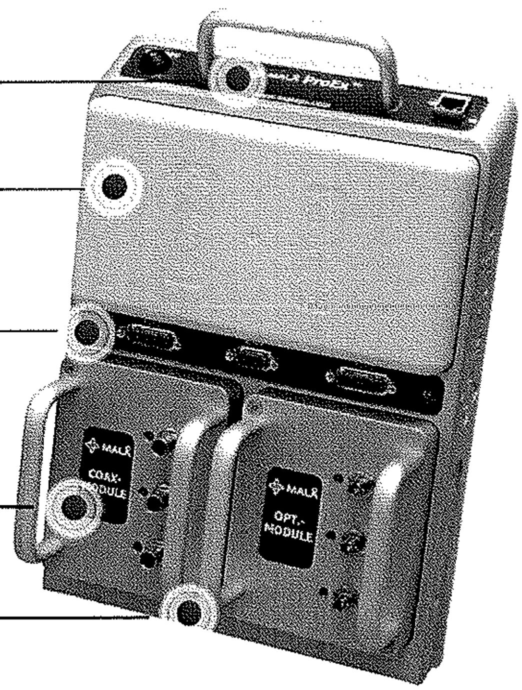
Battery or external 12V power supply



Antenna modules



Expansion unit



MALÅ Professional Explorer (ProEx™)

The most versatile GPR unit on the market

The MALÅ Professional Explorer (ProEx™) System is a modular, full-range Ground Penetrating Radar (GPR) system designed to meet the needs of the advanced professional user. At the heart of this system is the MALÅ ProEx Control Unit. Designed on a completely new technical platform, the MALÅ ProEx is the most versatile control unit in the MALÅ Geoscience range and replaces the World famous RAMAC/GPR CUII as the new high-end full range system.

GPR offers a practical, reliable and most importantly non-destructive solution for subsurface geophysical and geotechnical investigations.

The MALÅ ProEx Control Unit is fully compatible with broad range of antennas from MALÅ Geoscience and offers a flexible and versatile approach to detecting subsurface targets and geological layers accurately, efficiently and in real-time.

MALÅ Geoscience's modular design approach offers you a flexible and affordable choice to system configuration. You need only to invest in what you need today; however, as your needs change, so can your MALÅ GPR system.

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Main Applications

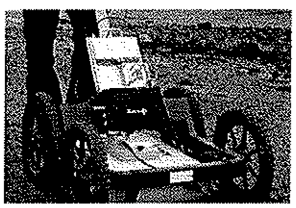
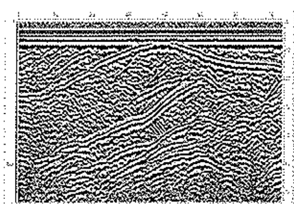
Whatever your application is, the MALÅ ProEx can assist in providing solutions to your subsurface investigation needs in areas such as:

- Archeology & Forensics
- Borehole
- Concrete NDT & Civil Engineering
- Environmental
- Geological/Mining
- Ice & Snow Measurements
- Research
- Road & Transportation
- Utility Detection & Mapping
- And more!

Specific Features

MALÅ Geoscience is renowned for its innovative designs and the tradition continues with this third-generation digital control unit. The MALÅ ProEx boasts a list of practical features rolled into one rugged design suitable for advanced and professional users.

- Modular Design
- Dual hardware channel (4 data channels)
- Multi-channel: max. 8 antennas (16 data channels) as optional
- Supports all antennas from MALÅ Geoscience
- Supports array configurations
- Ethernet communication
- Pulse Repetition Frequency (PRF): 100 KHz (upgradeable)
- 100 KHz PRF per hardware channel

System Configuration

The MALÅ ProEx is a modular digital radar control unit with multi-channel functionality. The unit is designed for two hardware channels (4 data channels) and by adding antenna modules this allows connection of two separate antennas for simultaneous data collection whilst also providing a third "virtual antenna". As an option, the available MALÅ ProEx Expansion Unit can be added to expanded the system to eight hardware channels (16 data channels) and operate up to eight individual antennas.

A choice of three antenna modules (optical, high frequency and coax) allows the user to connect any MALÅ antenna in various configurations, for single, dual or multi-antenna operation. Thus enabling a wide range of advanced measurements to be carried out.

Technical Specification

Power supply: Li-Ion 12V battery
Operating time: 5 h nominal, depending on configuration
Operating temp: -20° to +50°C / 0° to 120 °F
Environmental: IP65
Dimensions: 32.5 x 22.2 x 4.2 cm
Weight: 1.9 kg
Antennas: The MALÅ ProEx is fully compatible with the entire range of MALÅ Geoscience antennas, the MALÅ XV Monitor data acquisition platform and the MALÅ GroundVision 2[1] acquisition software.

[1] Requires a notebook PC

See our webpage for latest information

MALÅ
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Terrameter LS

- Imaging system measuring Resistivity, IP and SP.
- High reliability, safety and robustness under harsh field conditions.
- Easy to use with multi-lingual graphical user interface on sunlight readable colour LCD.
- On-site capabilities for data QA, system diagnostics and fault tolerance.
- Superior quality in data acquisition with powerful transmitter and high dynamic range multi-channel receiver.
- Open communication platform for data exchange, Internet and remote diagnostics (TCP/IP, USB).

ABEM

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Technical Specifications: **Terrameter LS**

Receiver

No. of Channels	4 – 12 input (+ 2 for Tx monitoring)
Isolation	All channels are Galvanically isolated
Input Voltage Range	+ / - 600 V
Input Impedance	200 MOhm, 20 MOhm and 300 kOhm
Precision	0.1 %
Accuracy	0.2 %
Resolution	3 nV at 1 sec integration
Linearity	0.005 %
Range	Operator selected range of measurement + /- 5 V, 20 MOhm + / - 5 V 200 MOhm + / - 600 V 300 kOhm
Flat Frequency Response	better than 1 % up to 300 Hz

Measuring

Resistivity	YES, Full waveform recorded
SP	YES, Full waveform recorded
IP	YES, Full waveform recorded
Dynamic Averaging	24 bit A/D conversion
Data Sampling Rate	30 kHz
Cycle time	from 0.1sec to 30 sec User selectable
IP Windows	Arbitrary windows flexibility configured to powerline frequencies

Transmitter

Output power	250 W
Current transmission	True Current Transmitter
Output Current Accuracy	better than 0.4 %
Maximum Output Current	2500 mA
Maximum Output Voltage	+ / - 600 V 1200 V peak to peak
Instant Polarity Changer	YES
Accuracy	0.4 %
Precision	0.1 %
Self Diagnostics	Temperature, Power dissipation Monitoring
Safety	Emergency Interrupter easily accessible

Tx Monitor

Voltage	+/- 600 V
Current	+/- 2500 mA
Full wave from monitored	
Accuracy	0.2 %
Precision	0.1 %

General

Casing	Rugged Aluminum case meets IEC IP 66
Computer	Embedded ARM 9, 200 MHz
GPS	20 channels SirFstarIII chip
Display	8,4" Active TFT LCD, full colour, Daylight visible
I / O ports	2 x KPT 32 p for imaging, AUX 2 x USB, RJ45 for LAN
Service point	Accessible through Internet Multifuncion connector
Memory Capacity	More than 1 500 000 readings
Power	Internal NiMH 12 V power pack or Optional External 12 VDC battery
Dimensions (W x L x H)	39 x 21 x 32 cm
Weight	12 kg

Software & Communication

Terrameter LS is controlled using the incorporated Firmware. It has a Graphical User Interface that is easy to follow in all its aspects. Clear and instructive graphics assists the user in the operation of the instrument.

For enhanced Data Quality Control in the field it is possible to display the measured Multi-Electrode Resistivity Imaging data in near real time as a pseudo section. Thanks to access points as USB and RJ 45 (for LAN) transfer of data to other computers is extremely simple.

For full inversion of data external software is required. Most common today is RES2DINVor RES3DINV. This program supports data formats provided with the help of the Terrameter LS software.

Multi-Electrode Survey Systems for 2D & 3D for Resistivity, IP & SP Imaging & Monitoring

Switching matrix	Internal 10 X 64
Roll-a-Long	YES full coverage, both 2 & 3D
All 84 take-outs	in a Standard cable array are active for roll-a-long
Array types Default	Multiple Gradient, Dipole-Dipole, Pole-Dipole, Wenner etc.
Take-outs internal	64 inline + 3 remote electrodes
Expandable	through Multiconnector up to 16320 electrodes. Unlimited number via Interconnect cable.

The switch matrix is divided into four blocks for effective use of all receiver channels available.

Electrode Test	YES, Focus One and Pair

SAS LOG 300 logging unit (optional)

Measures both long and short Normal configuration. A lateral configuration is also included. A fluid resistivity cell, a temperature sensor and a water level indicator make it a complete electrical logging device. Refer to the separate leaflet for more details.

FIELD EQUIPMENT IMAGING

Consult your local ABEM distributor for full details of the various configurations available for you. A hint G30-2D = 30 m depth & 2D software.

Terrameter LS Imaging G30-2D	**33 3002 01**
Terrameter LS Imaging G70-2D	**33 3002 02**
Terrameter LS Imaging G140-2D	**33 3002 03**
Terrameter LS Imaging G200-2D	**33 3002 04**
Terrameter LS Imaging G275-2D	**33 3002 05**
Terrameter LS Imaging G30-3D	**33 3002 06**
Terrameter LS Imaging G70-3D	**33 3002 07**
Terrameter LS Imaging G140-3D	**33 3002 08**
Terrameter LS Imaging G200-3D	**33 3002 09**
Terrameter LS Imaging G275-3D	**33 3002 10**

With reservations for changes; our products undergo continuous development

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Telephone +46 8 54 88 300
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sales@abem.se
www.abem.se

Your Distributor

2821

APPENDIX B
GPR 2-DIMENSIONAL SECTIONS AND ERI VERTICAL CROSS SECTIONS

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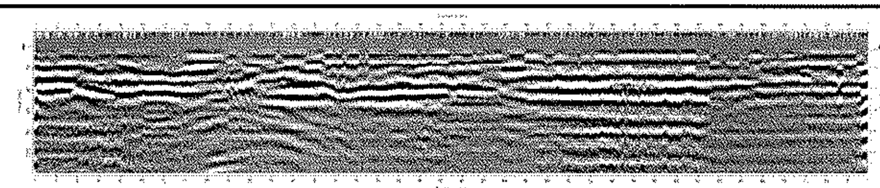
1. 100MHz GPR 2D sections

E-1



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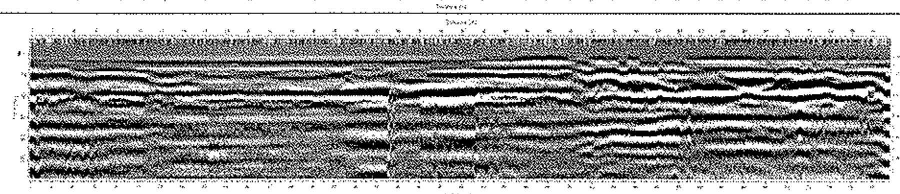

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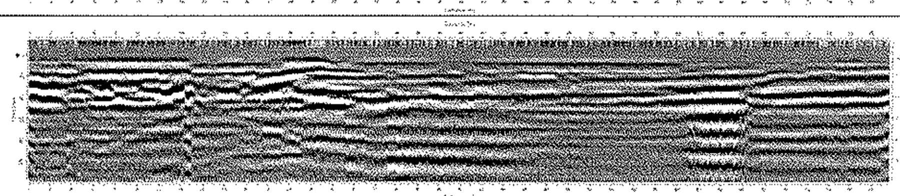

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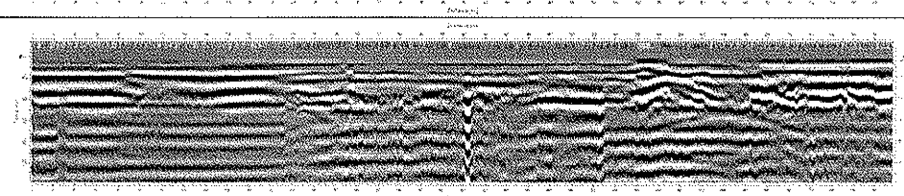

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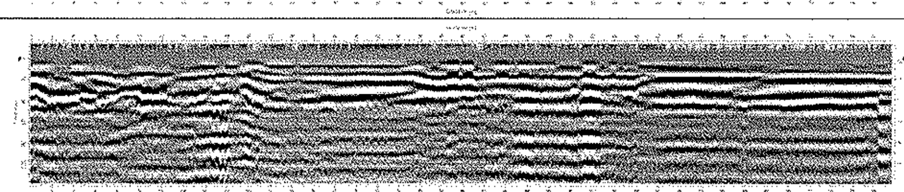
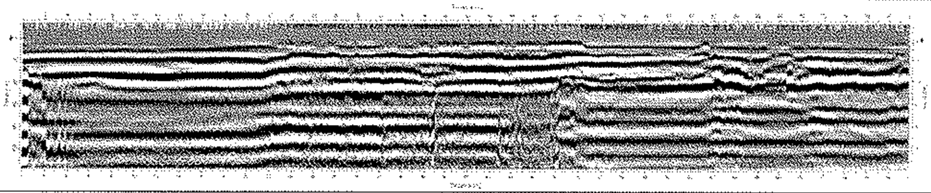
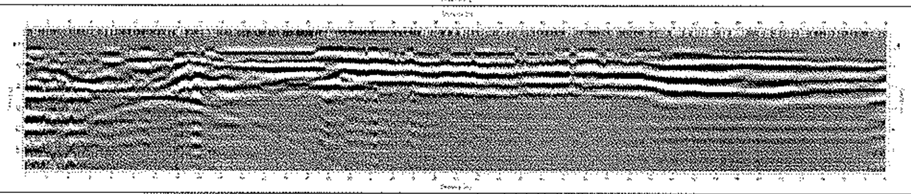
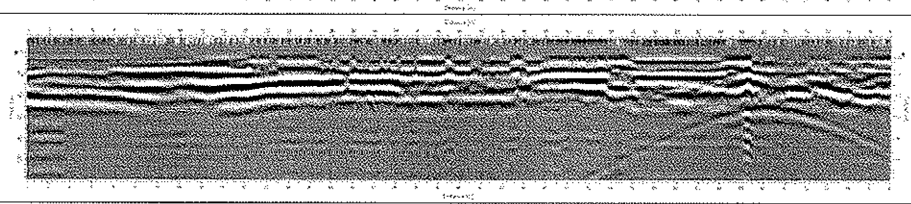
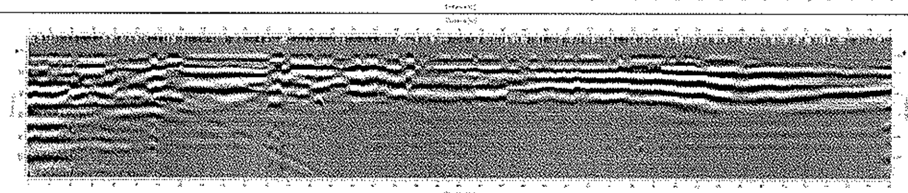
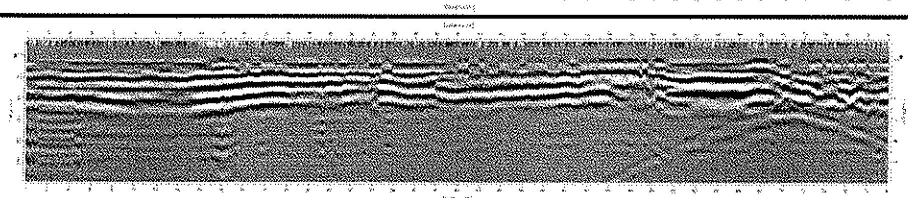
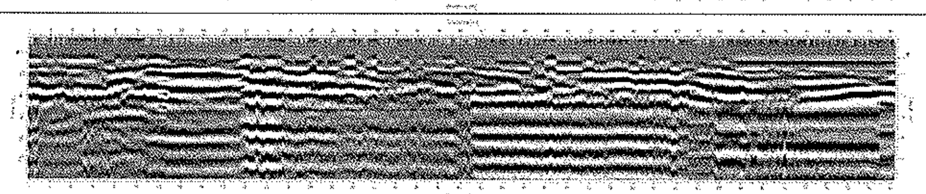
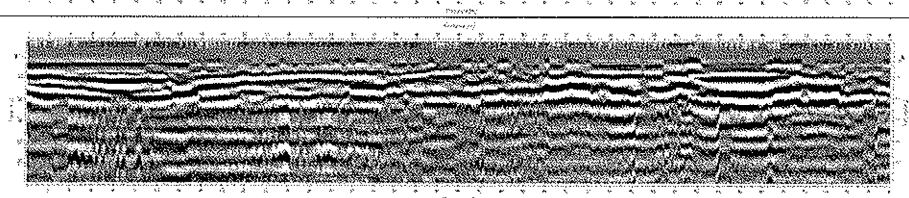
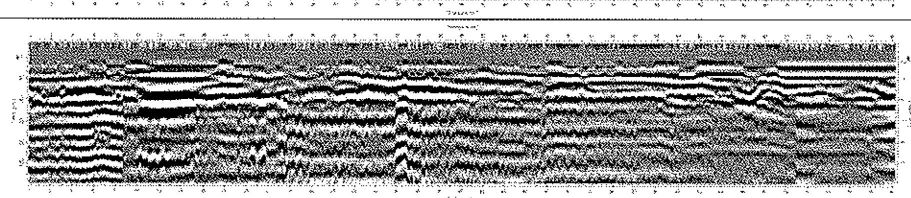
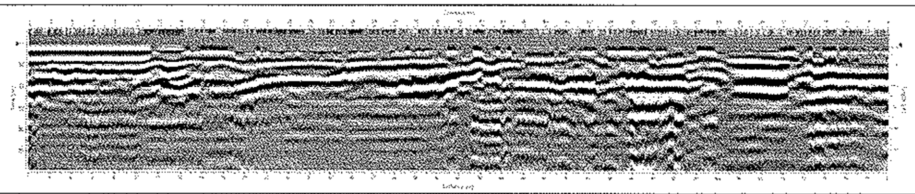
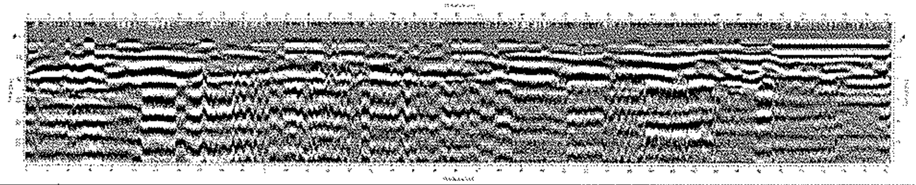
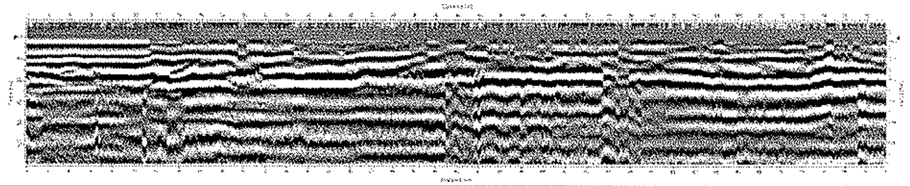
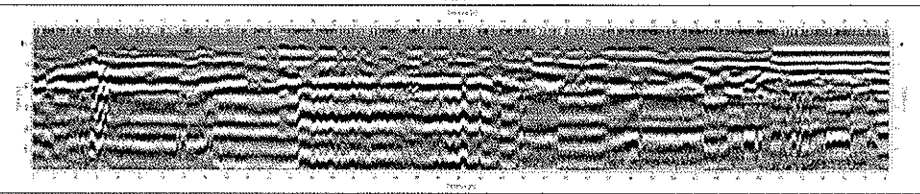
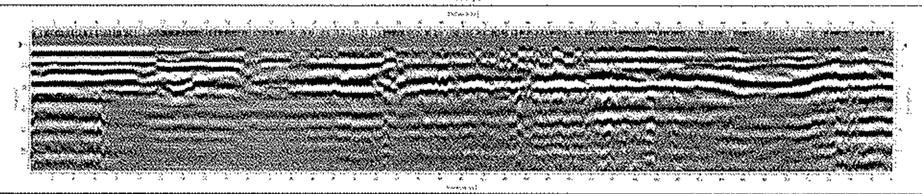
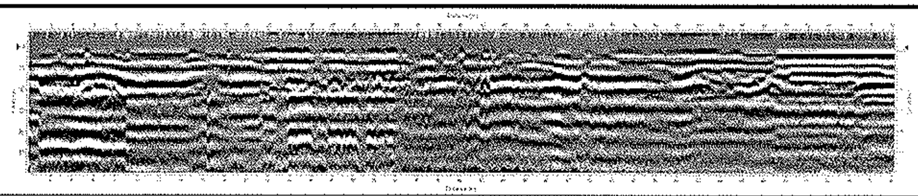
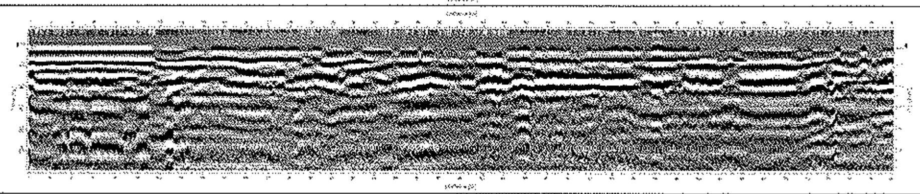
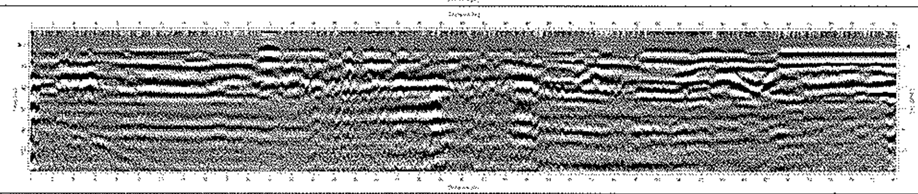
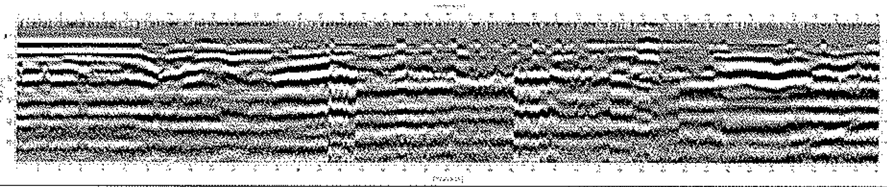
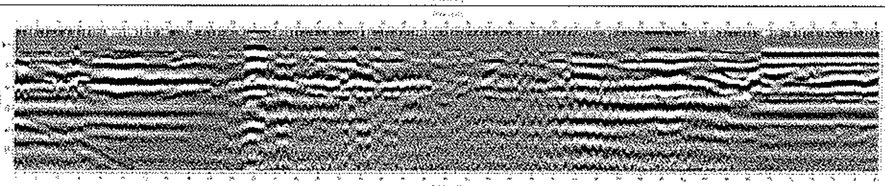
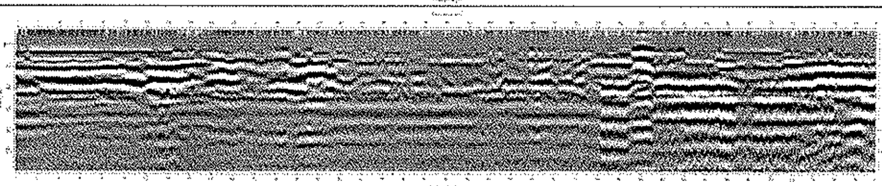
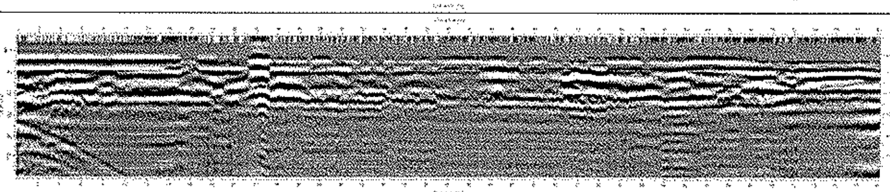
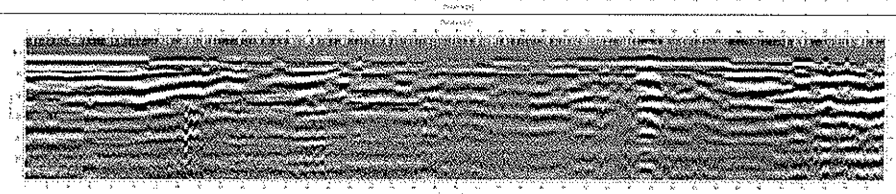
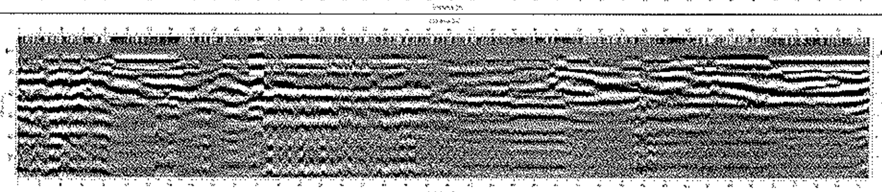
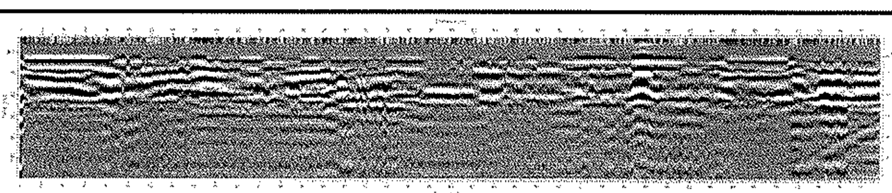
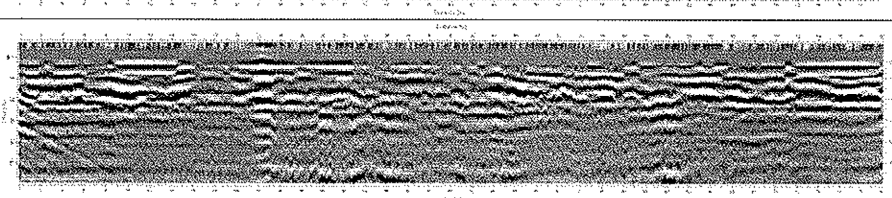
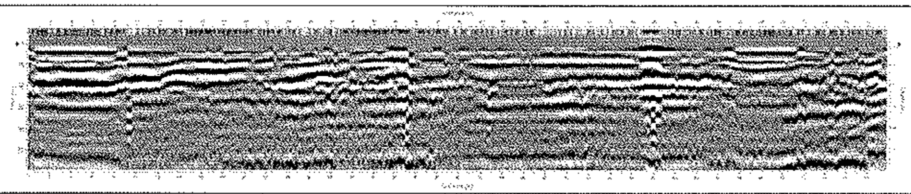
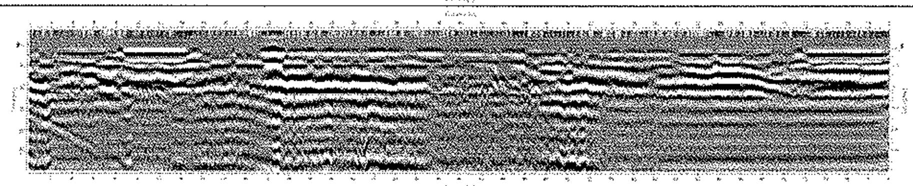
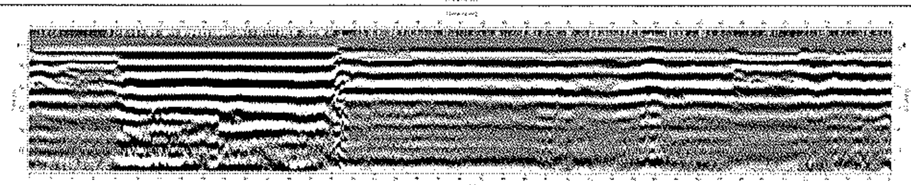
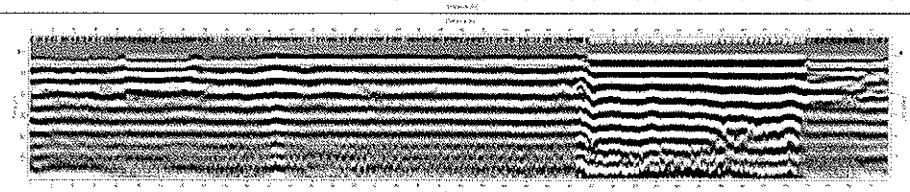
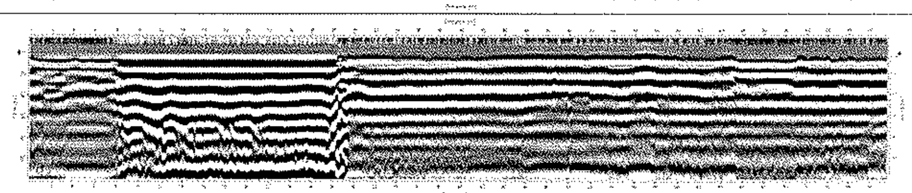
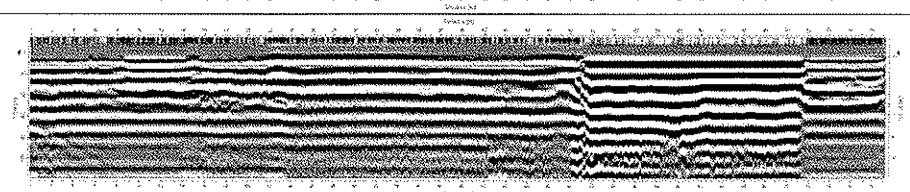
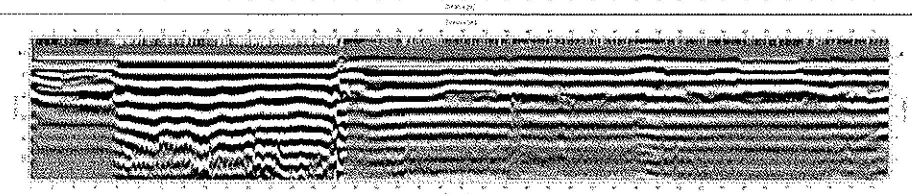
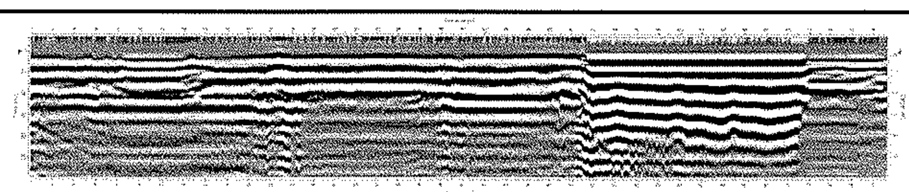


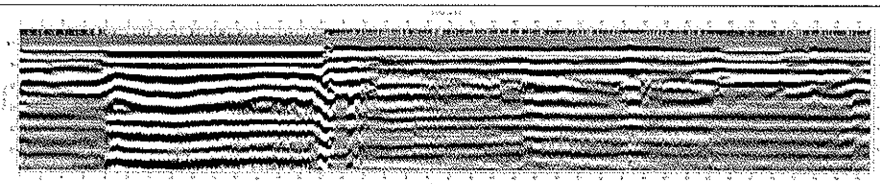
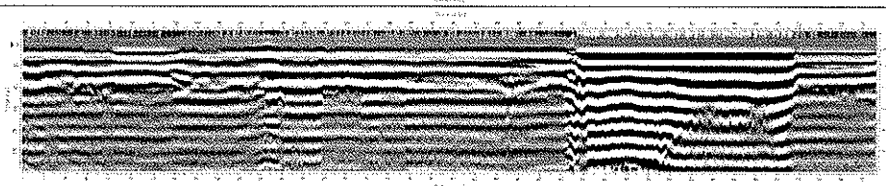
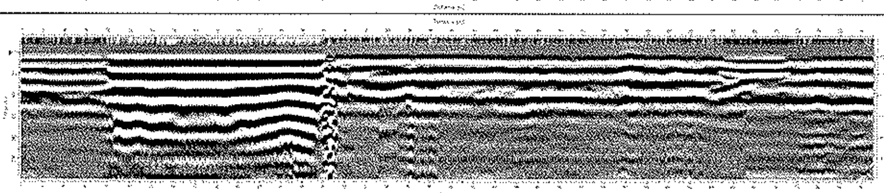
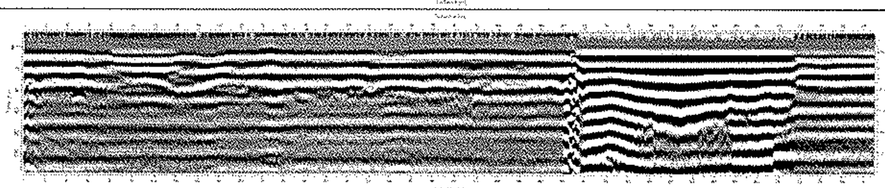
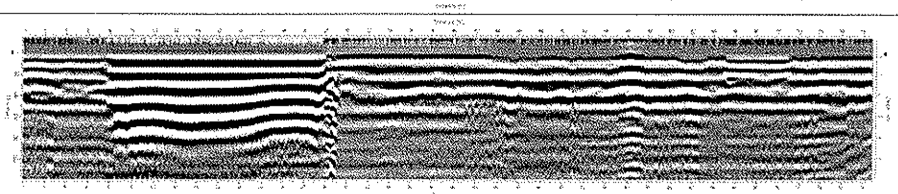
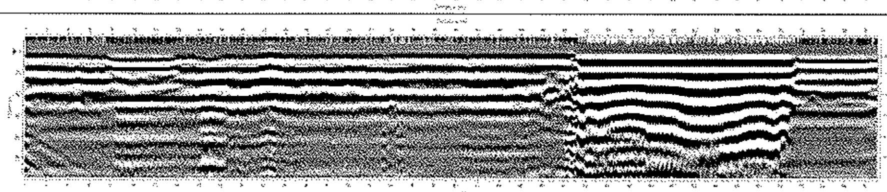
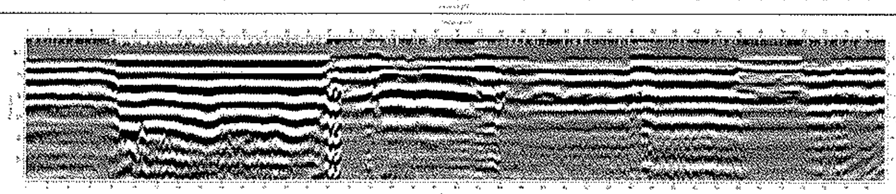
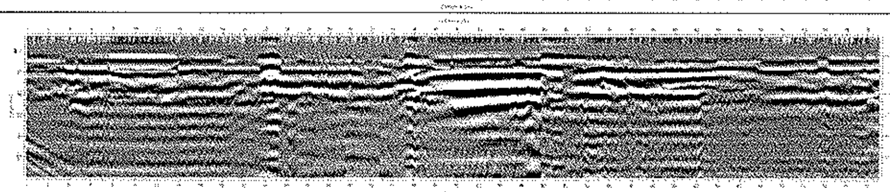
W-6	
E-7	
W-8	
E-9	
W-10	
E-11	
W-12	
E-13	

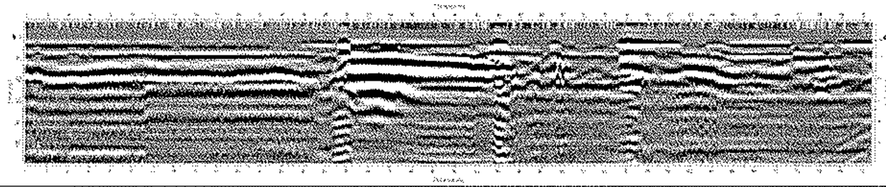
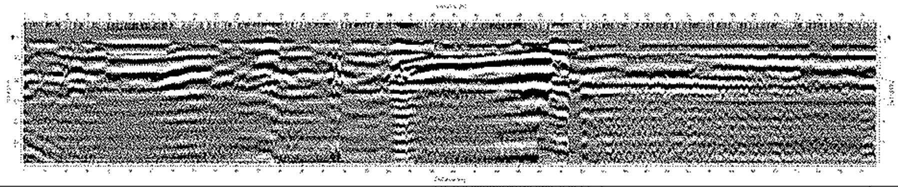
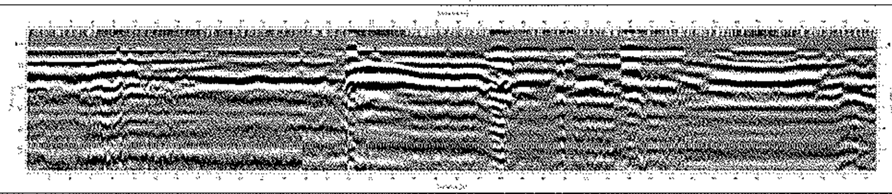
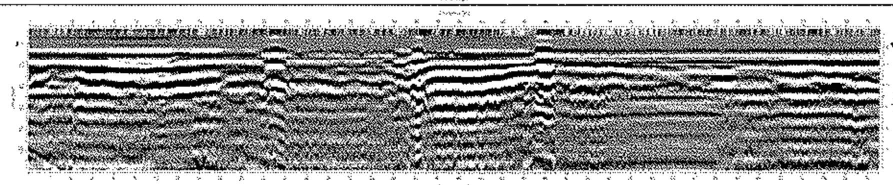
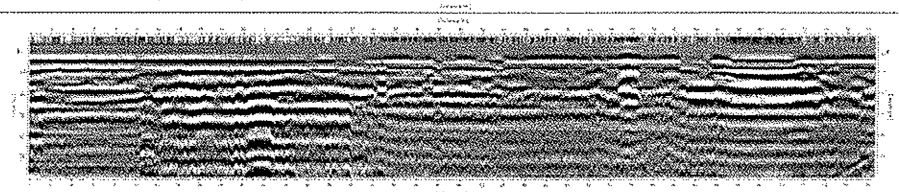
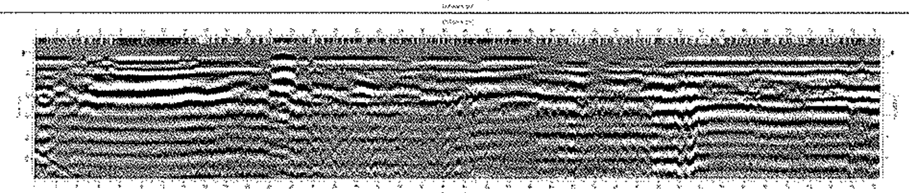
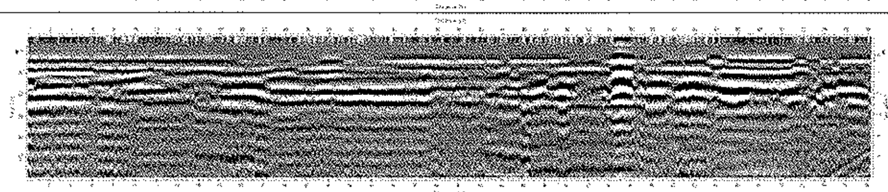
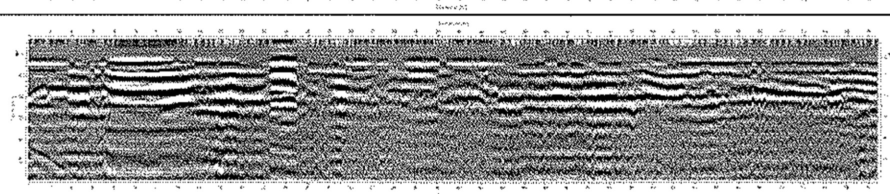
W-14	
E-15	
W-16	
E-17	
W-18	

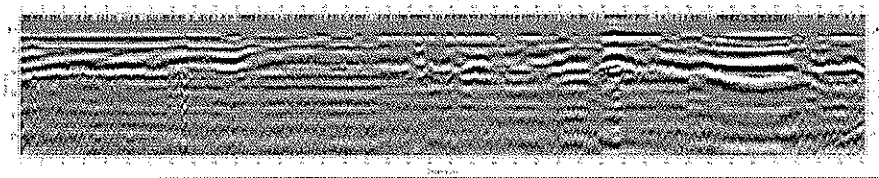
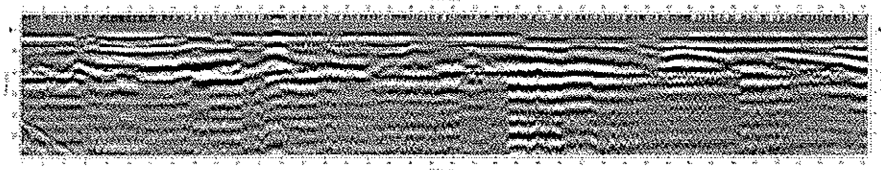
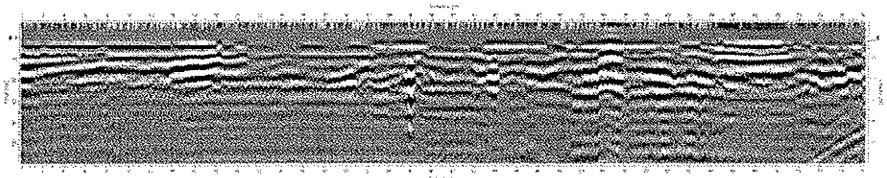
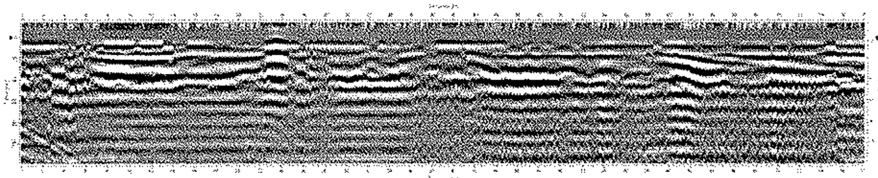
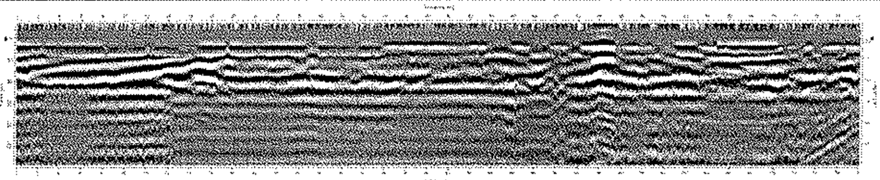
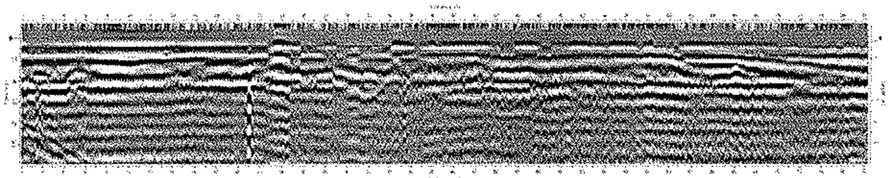
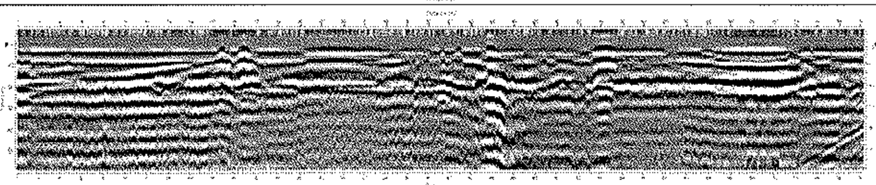
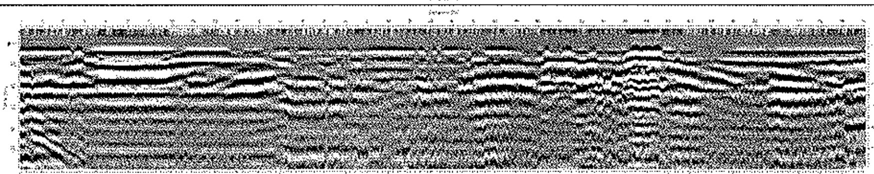
E-19	
W-20	
E-21	

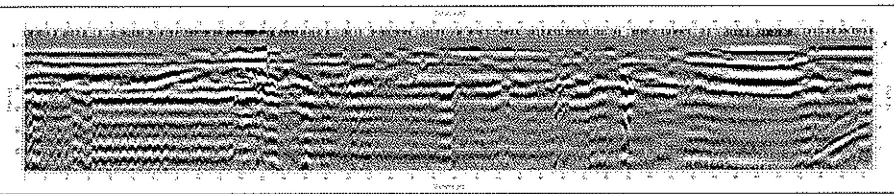
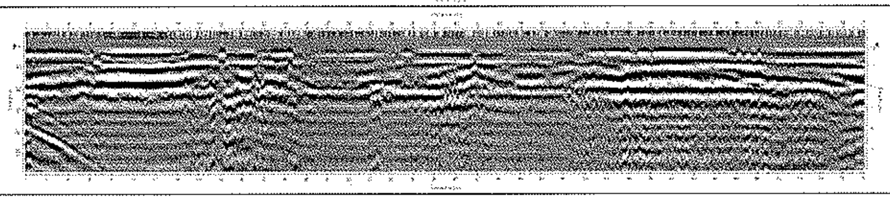
W-22	
E-23	
W-24	
E-25	
W-26	
E-27	
W-28	
E-29	

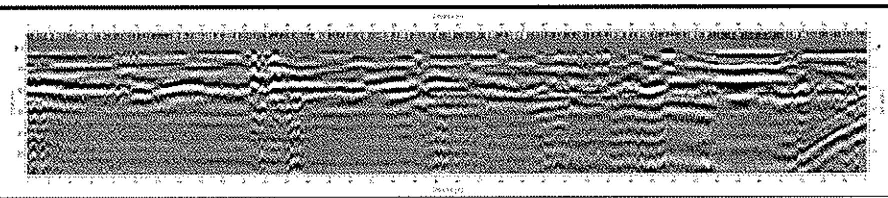
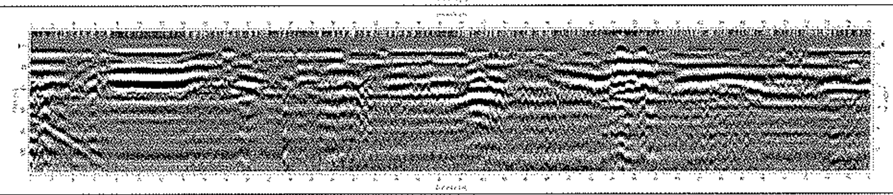
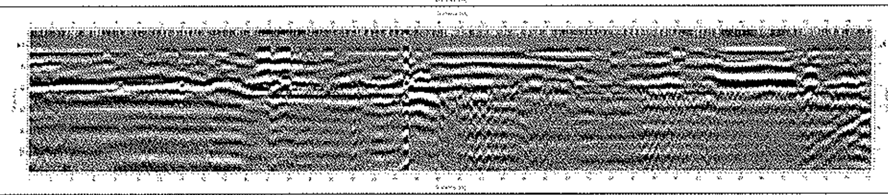
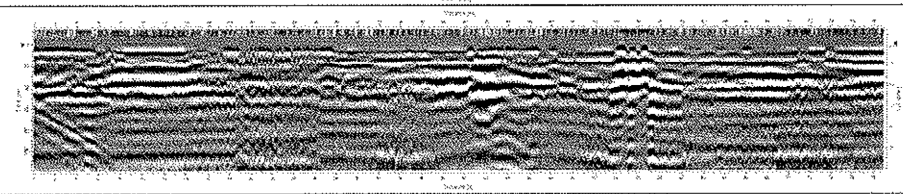
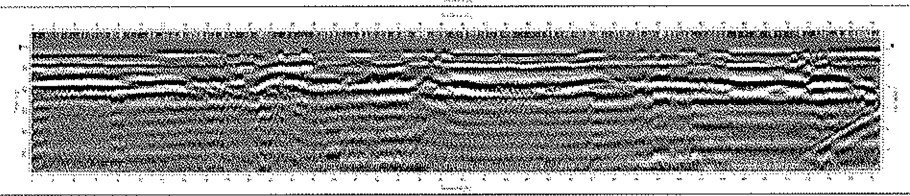
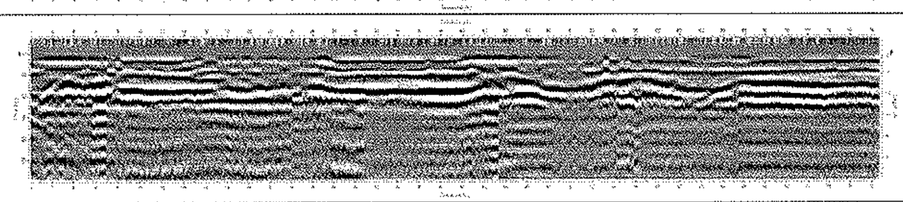
W-30	
E-31	
W-32	
E-33	
W-34	
E-35	
W-36	
E-37	

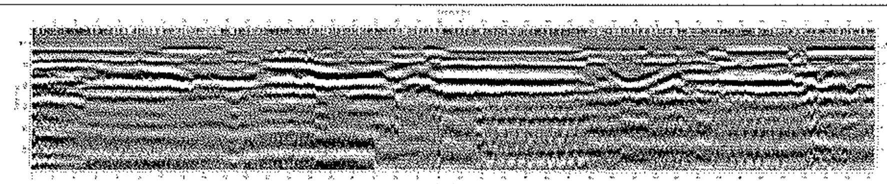
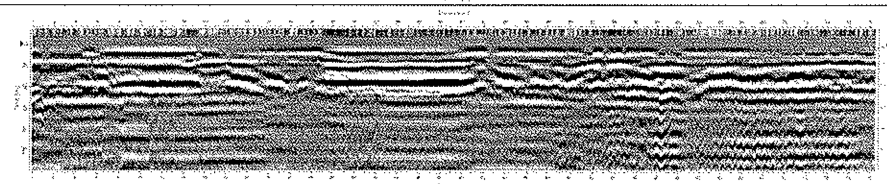
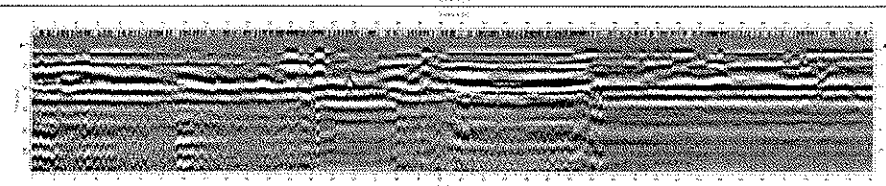
W-38	
E-39	
W-40	
E-41	
W-42	
E-43	
W-44	
E-45	

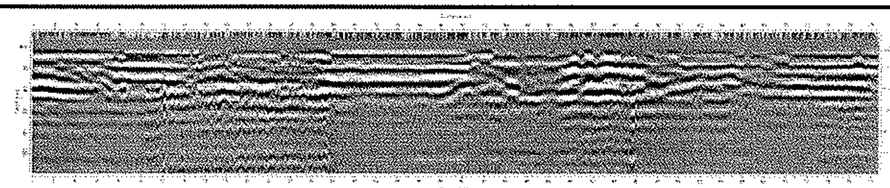
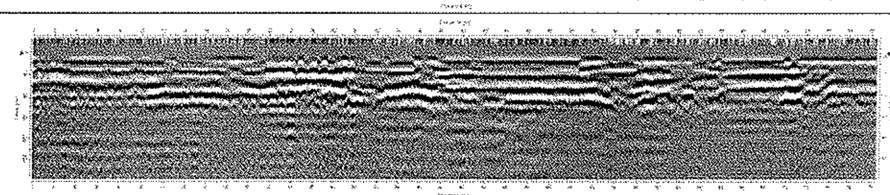
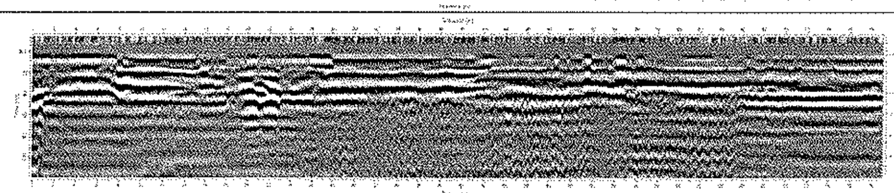
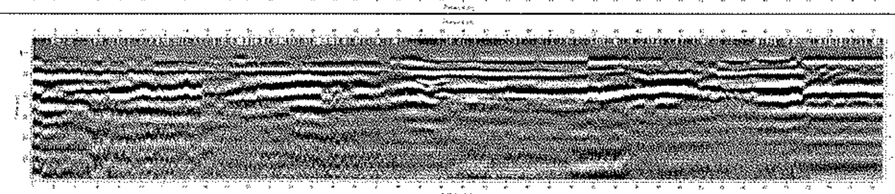
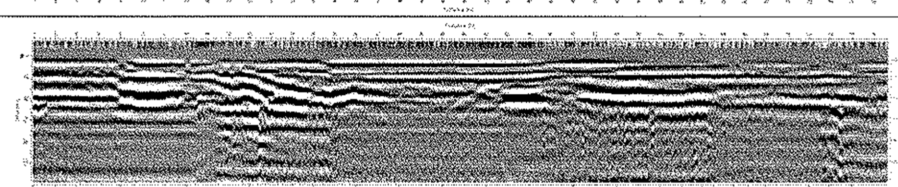
W-46	
E-47	
W-48	
E-49	
W-50	
E-51	
W-52	
E-53	

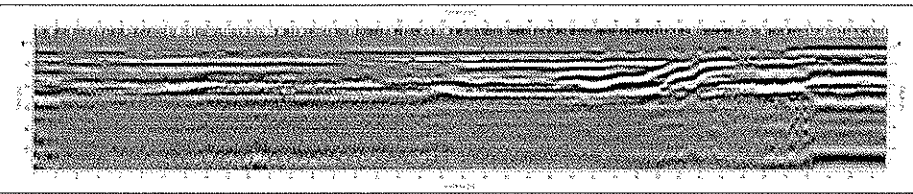
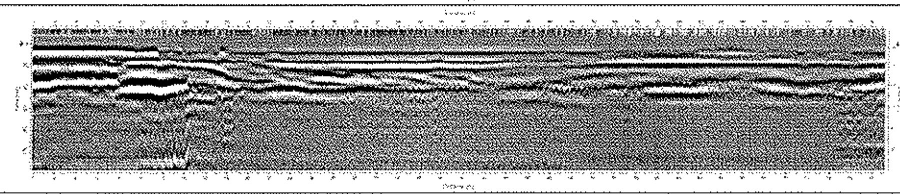
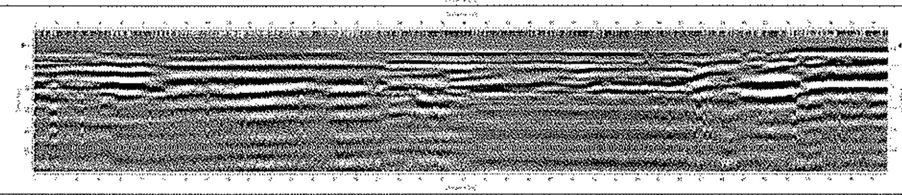
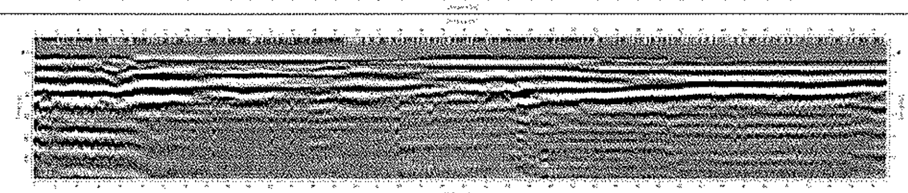
W-54	
E-55	
W-53	
E-57	
W-58	
E-59	
W-60	
E-61	

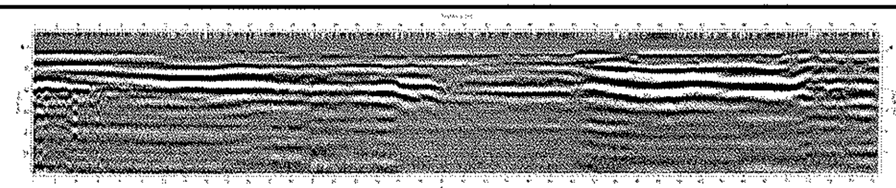
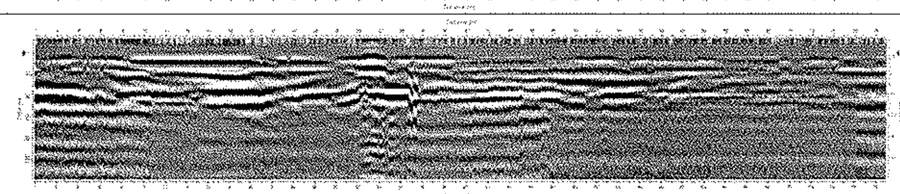
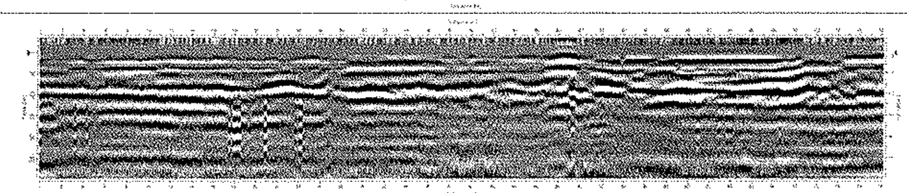
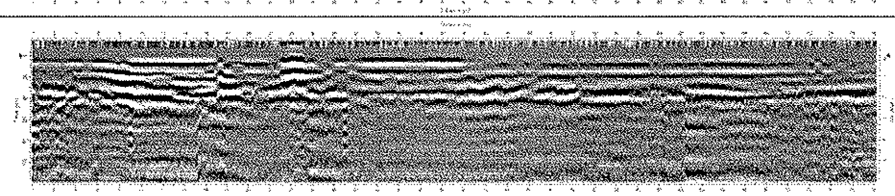
W-62	
E-63	

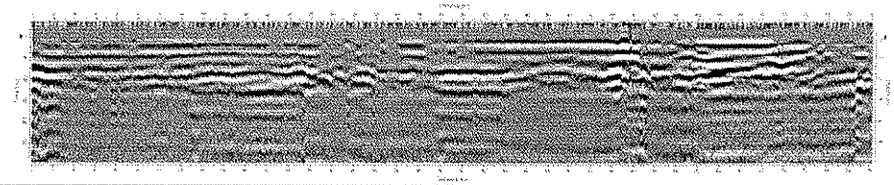
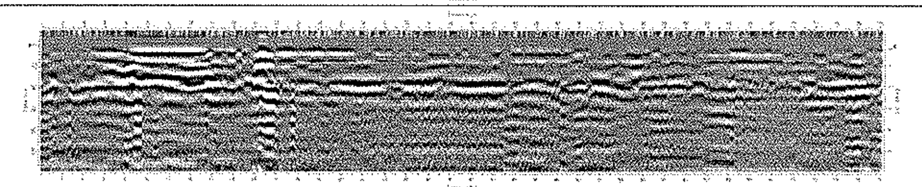
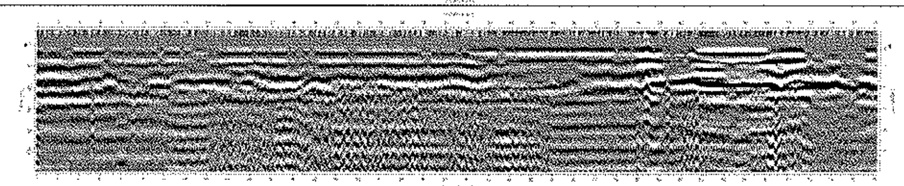
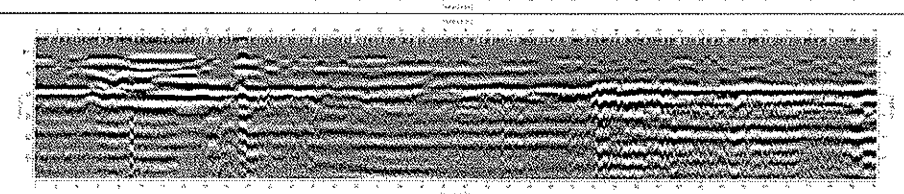
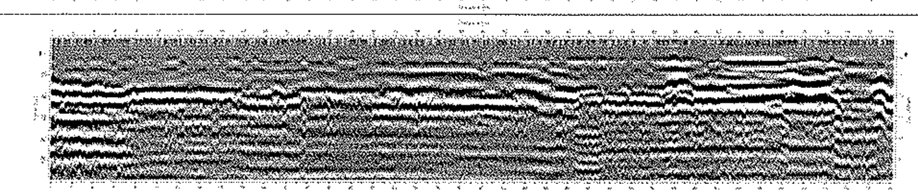
W-64	
E-65	
W-66	
E-67	
W-68	
E-69	

W-70	
E-71	
W-72	

E-73	
W-74	
E-75	
W-76	
E-77	

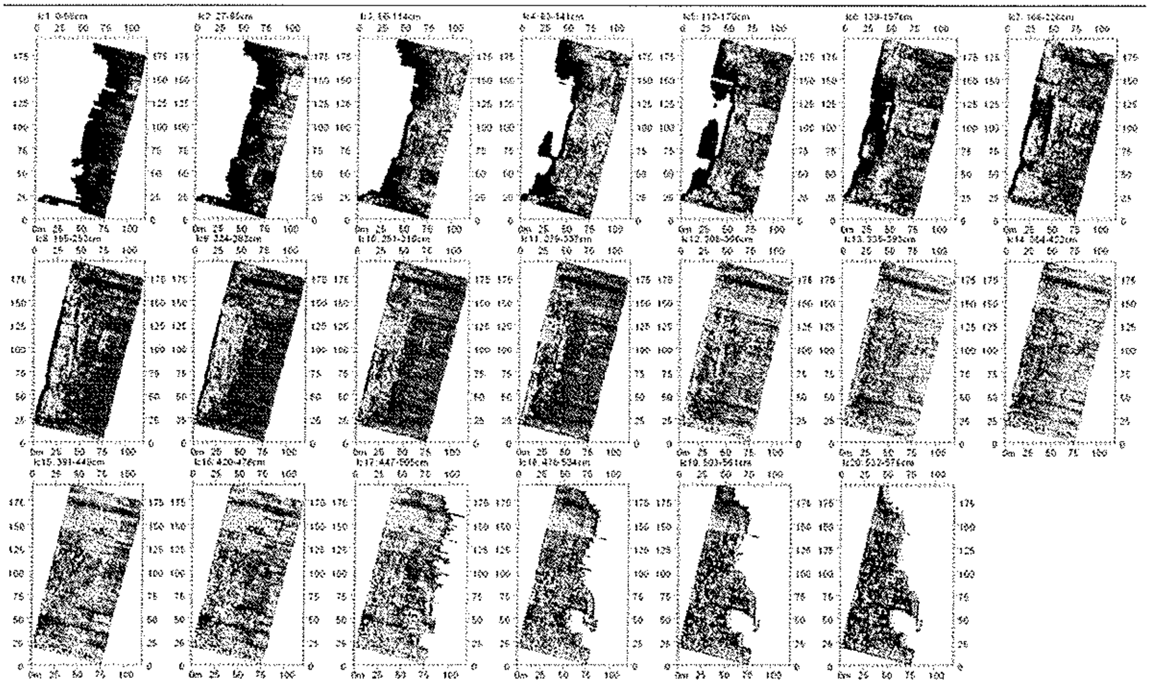
W-78	
E-79	
W-80	
E-81	

W-82	
E-83	
W-84	
E-85	

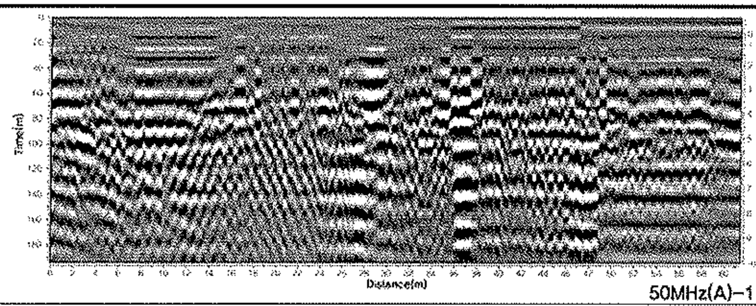
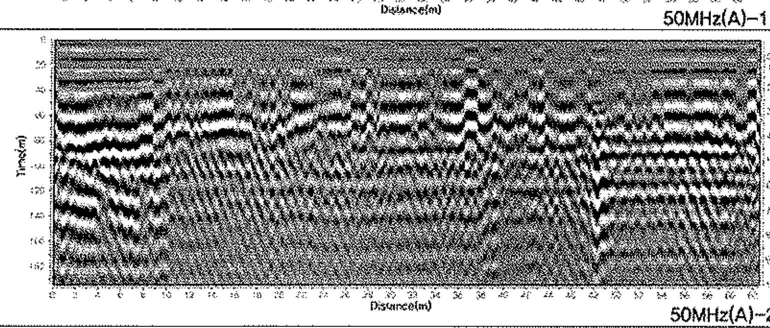
W-86	
E-87	
W-88	
E-89	
W-90	

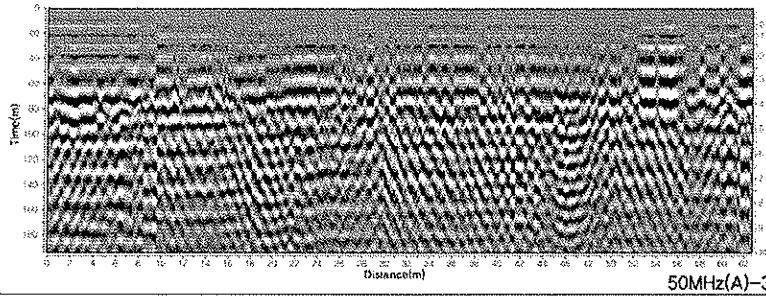
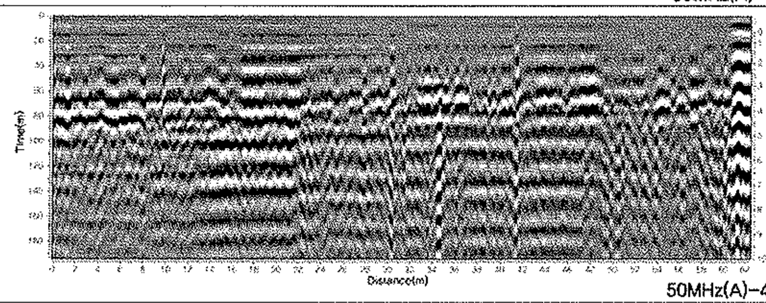
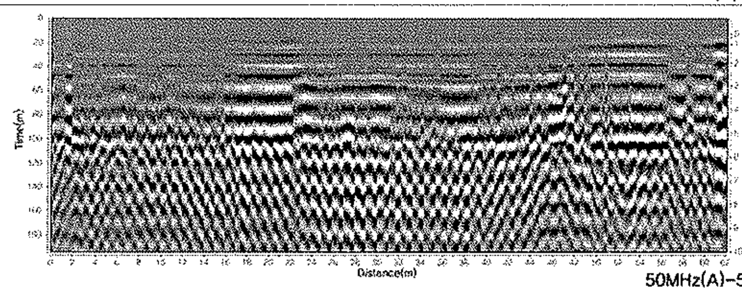
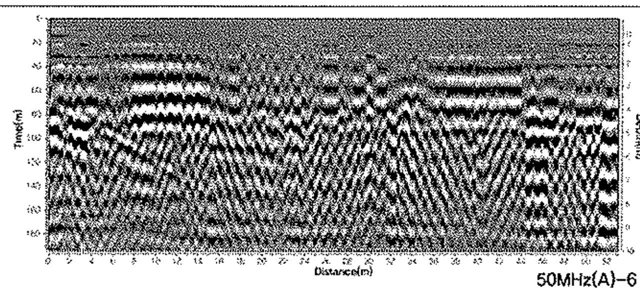
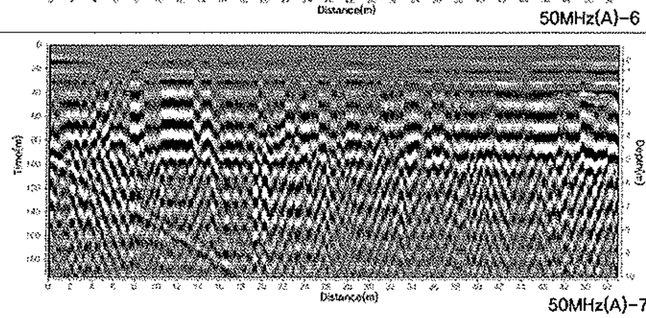
2. GPR 3D sections

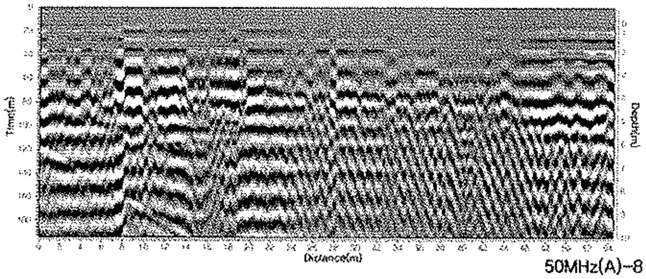
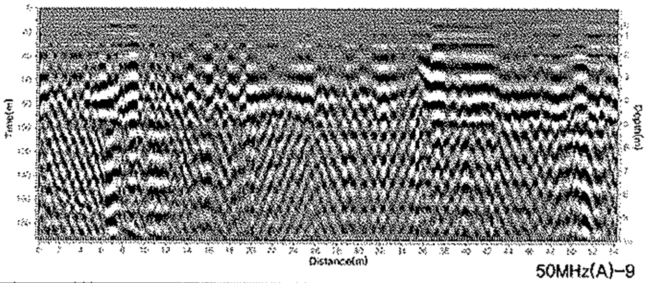
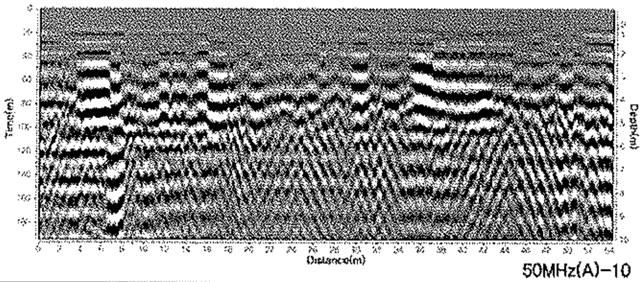
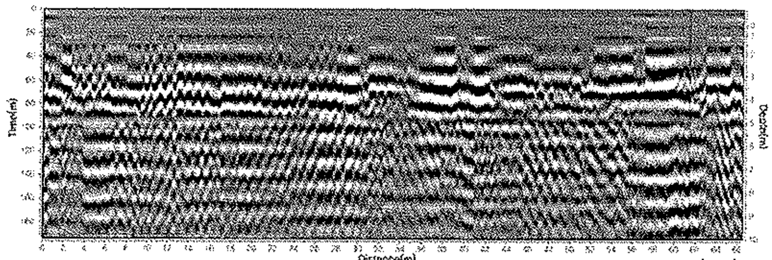
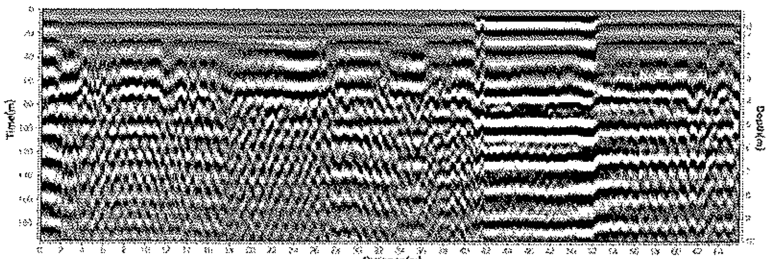
Horizontal slice images

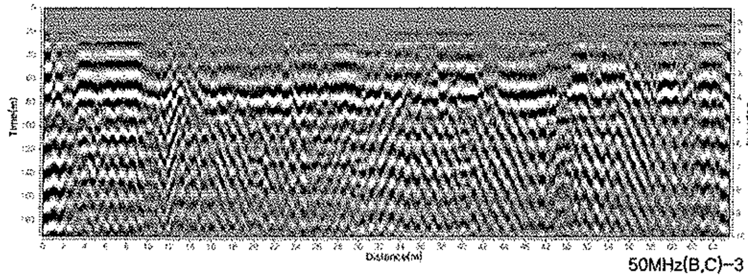
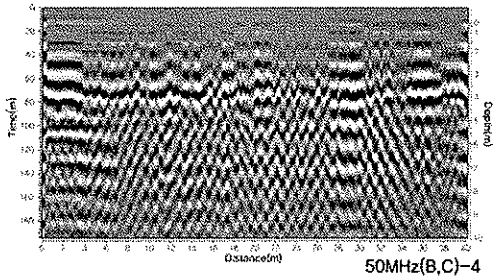
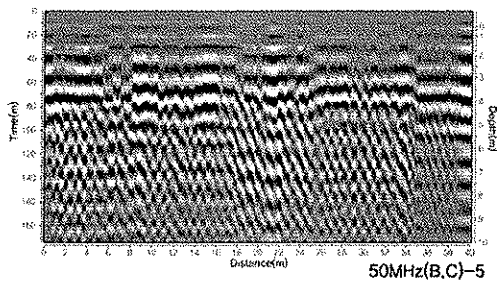
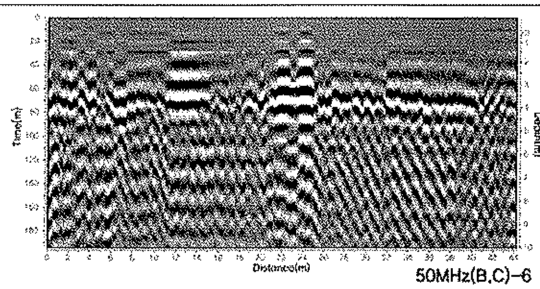
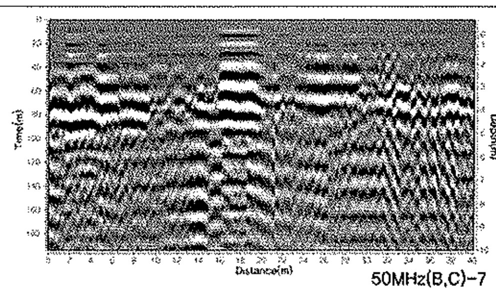


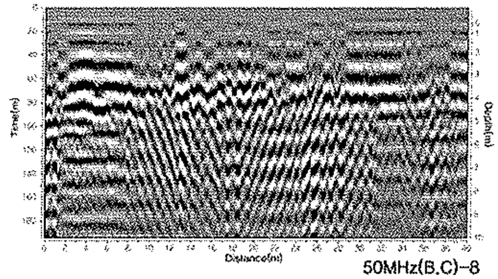
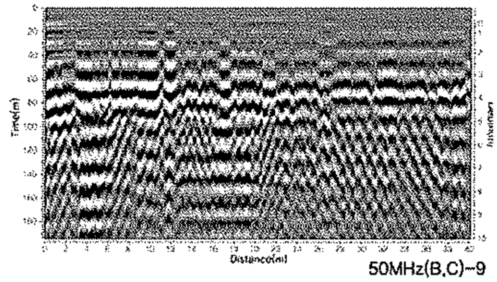
3. 50MHz GPR 2D sections

50MHz(A)-1	
50MHz(A)-2	

50MHz(A)-3	
50MHz(A)-4	
50MHz(A)-5	
50MHz(A)-6	
50MHz(A)-7	

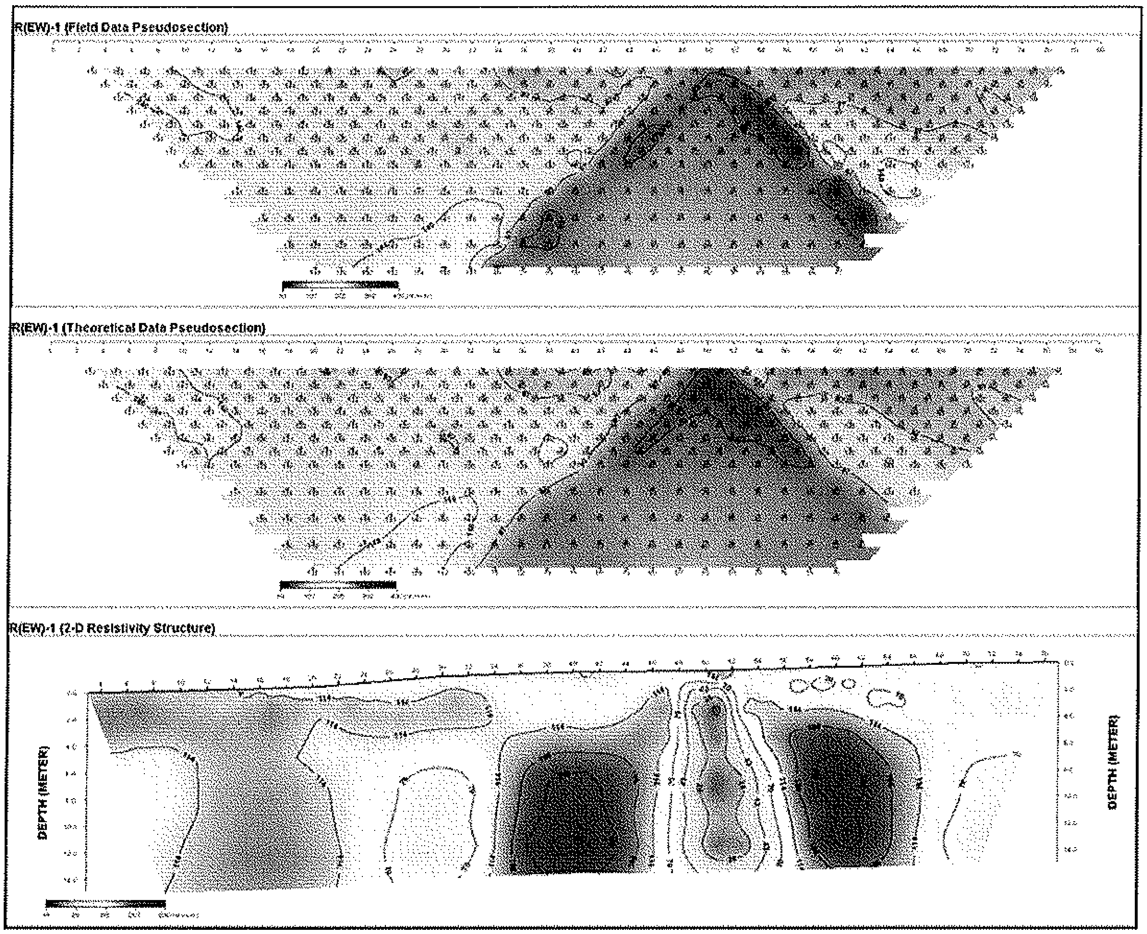
50MHz(A)-8	 50MHz(A)–8
50MHz(A)-9	 50MHz(A)–9
50MHz(A)-10	 50MHz(A)–10
50MHz(B,C)-1	 50MHz(B,C)–1
50MHz(B,C)-2	 50MHz(B,C)–2

50MHz(B,C)-3	
50MHz(B,C)-4	
50MHz(B,C)-5	
50MHz(B,C)-6	
50MHz(B,C)-7	

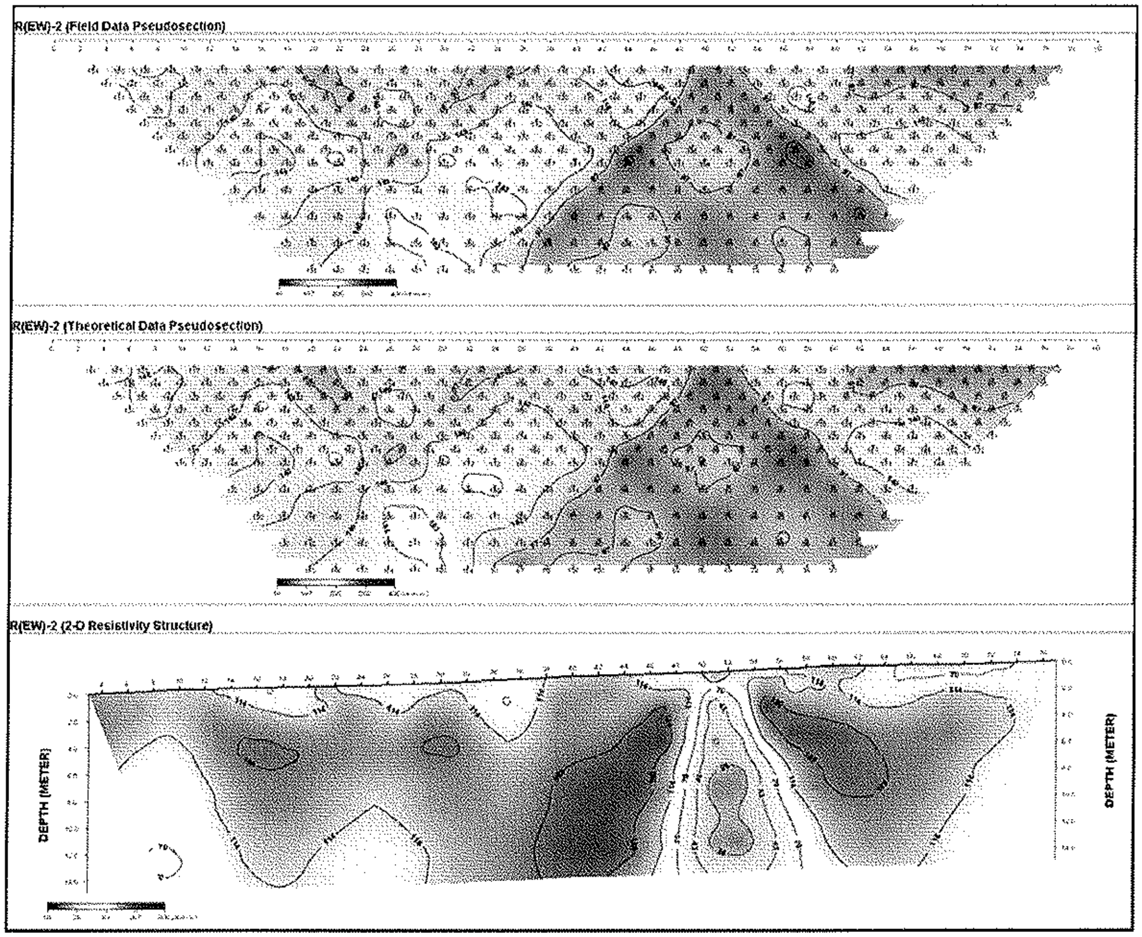
50MHz(B,C)-8	
50MHz(B,C)-9	

DC Resistivity survey sections

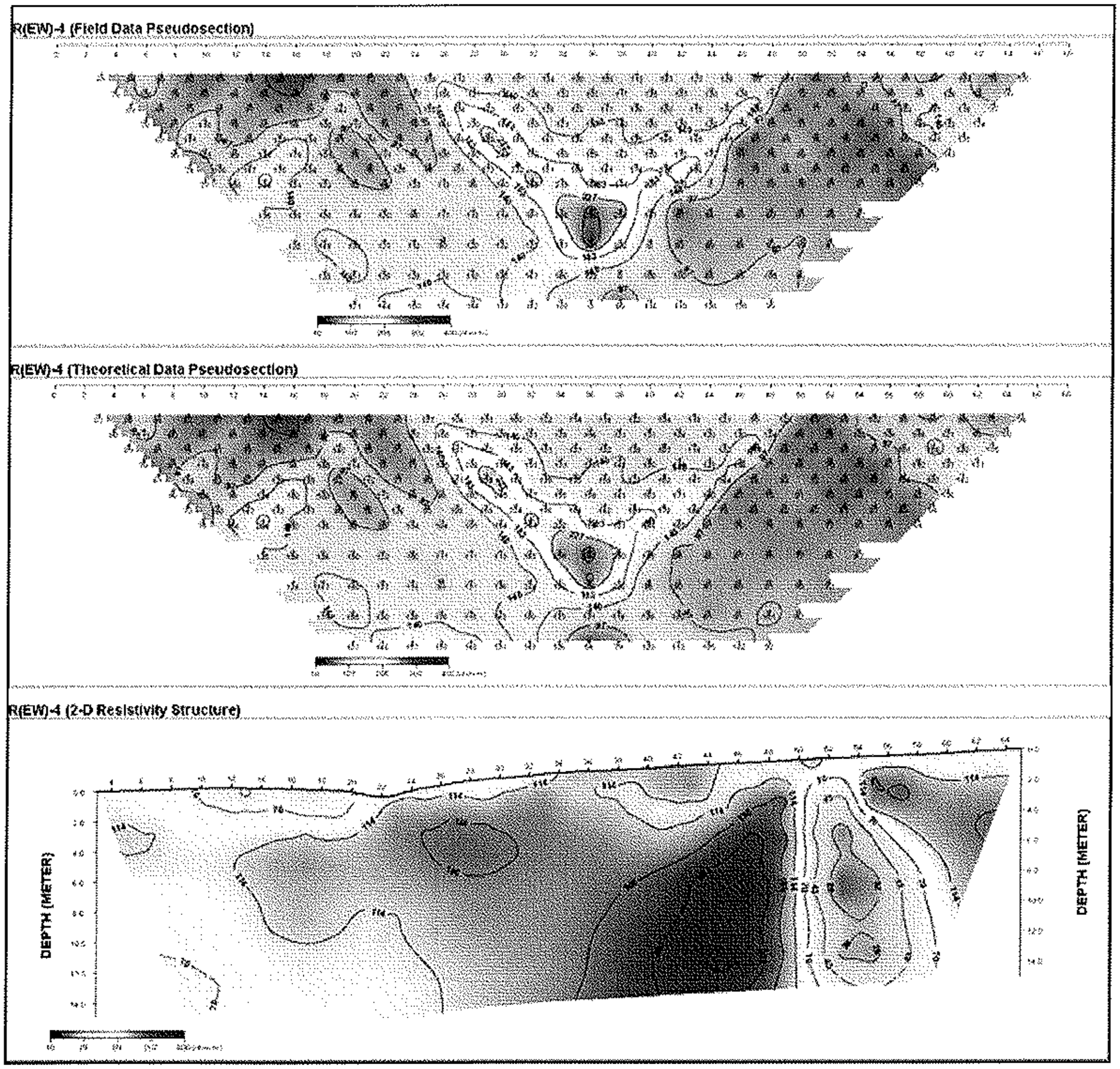
R(EW)-1



R(EW)-2


R(EW)-2 (Field Data Pseudosection)
R(EW)-2 (Theoretical Data Pseudosection)
R(EW)-2 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-4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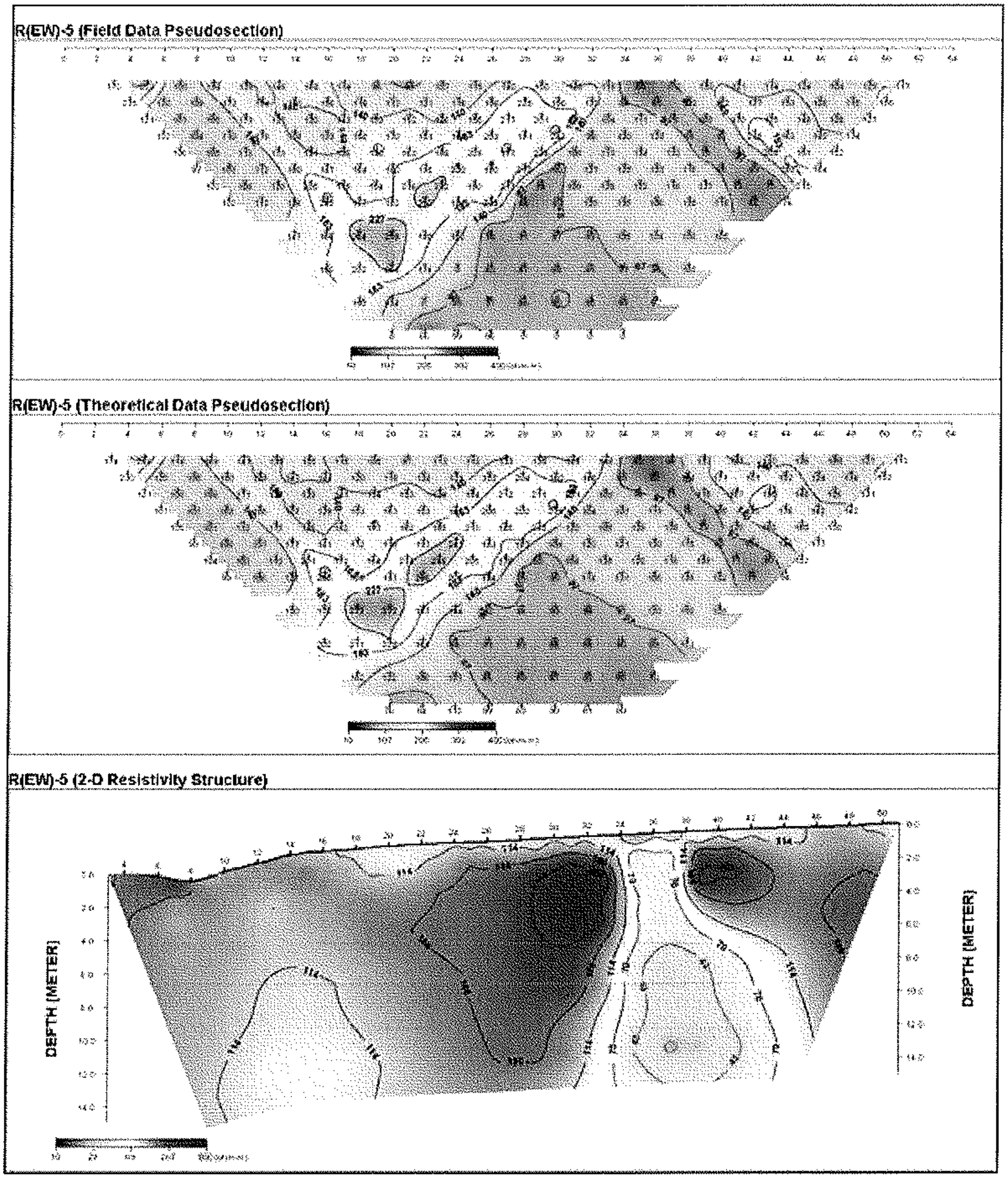
R(EW)-4 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-5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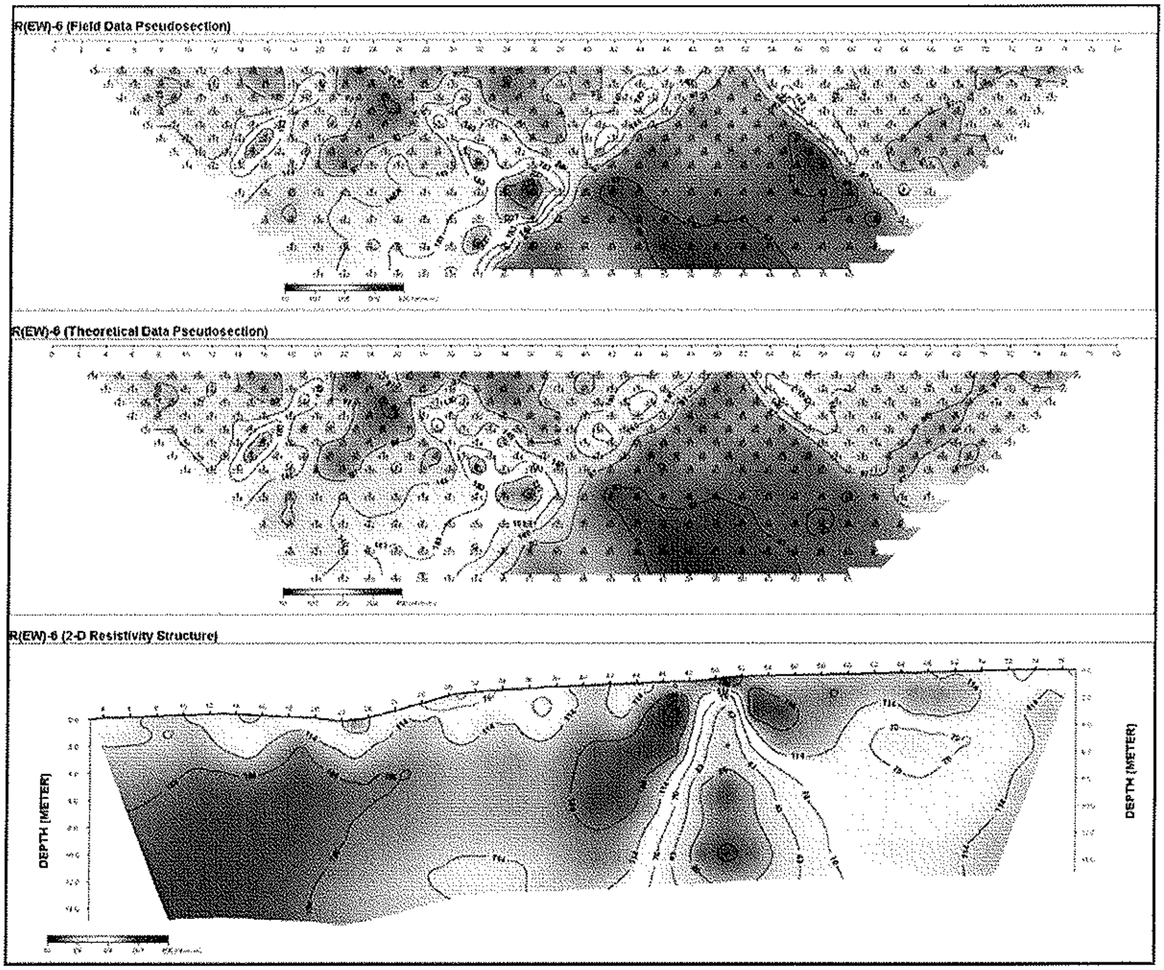
R(EW)-5 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-6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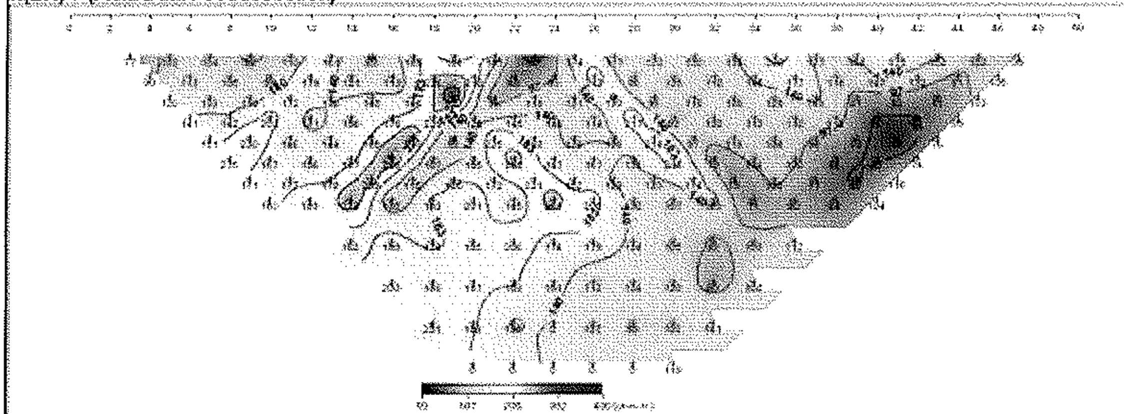
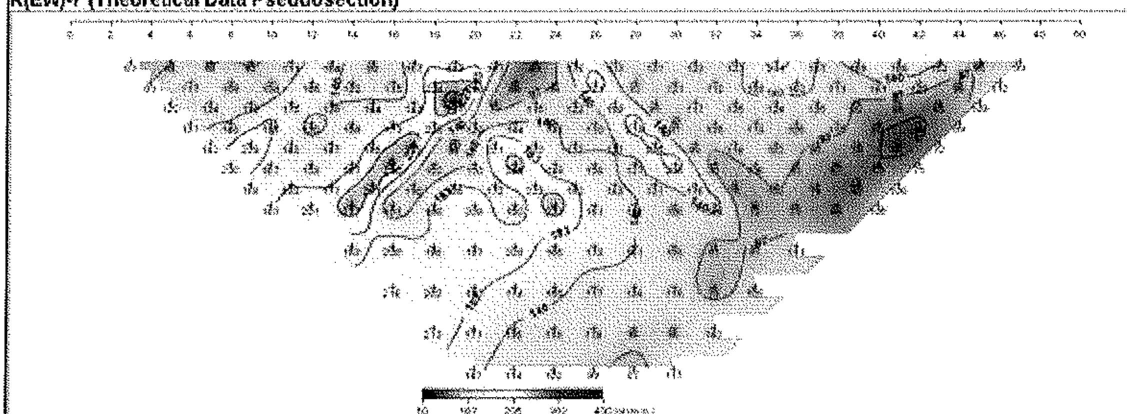
DEPTH (METER)
DEPTH (METER)

R(EW)-7

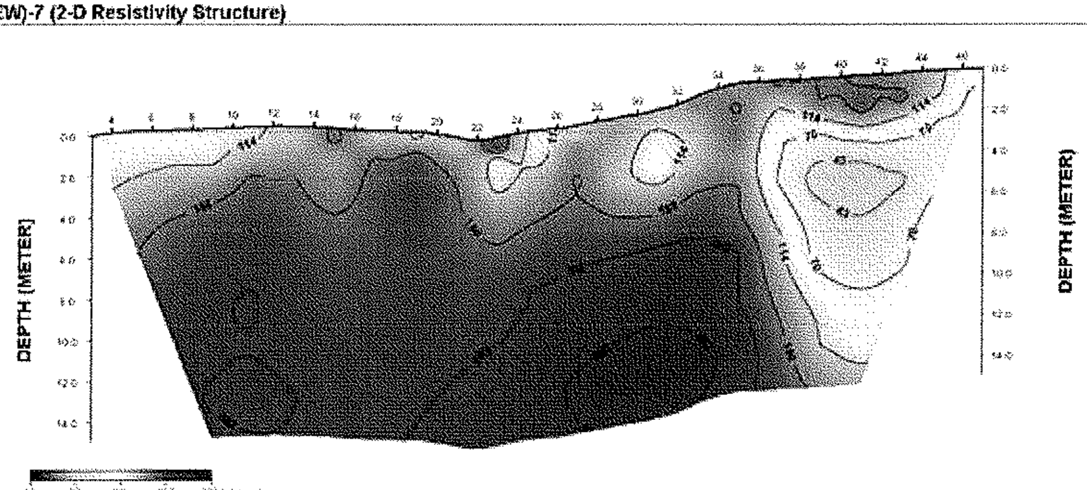
R(EW)-7 (Field Data Pseudosection)



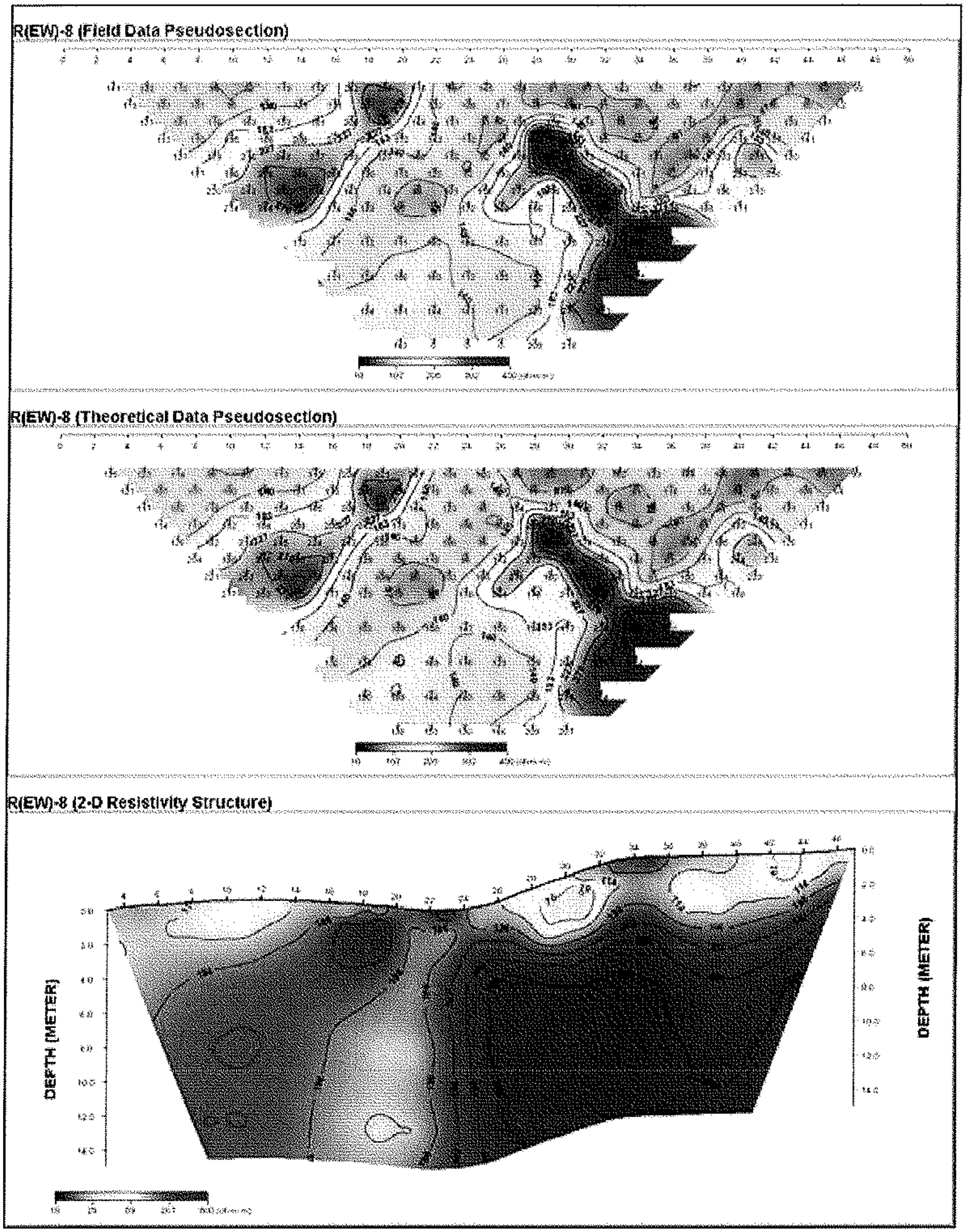
R(EW)-7 (Theoretical Data Pseudosection)



R(EW)-7 (2-D Resistivity Structure)



R(EW)-8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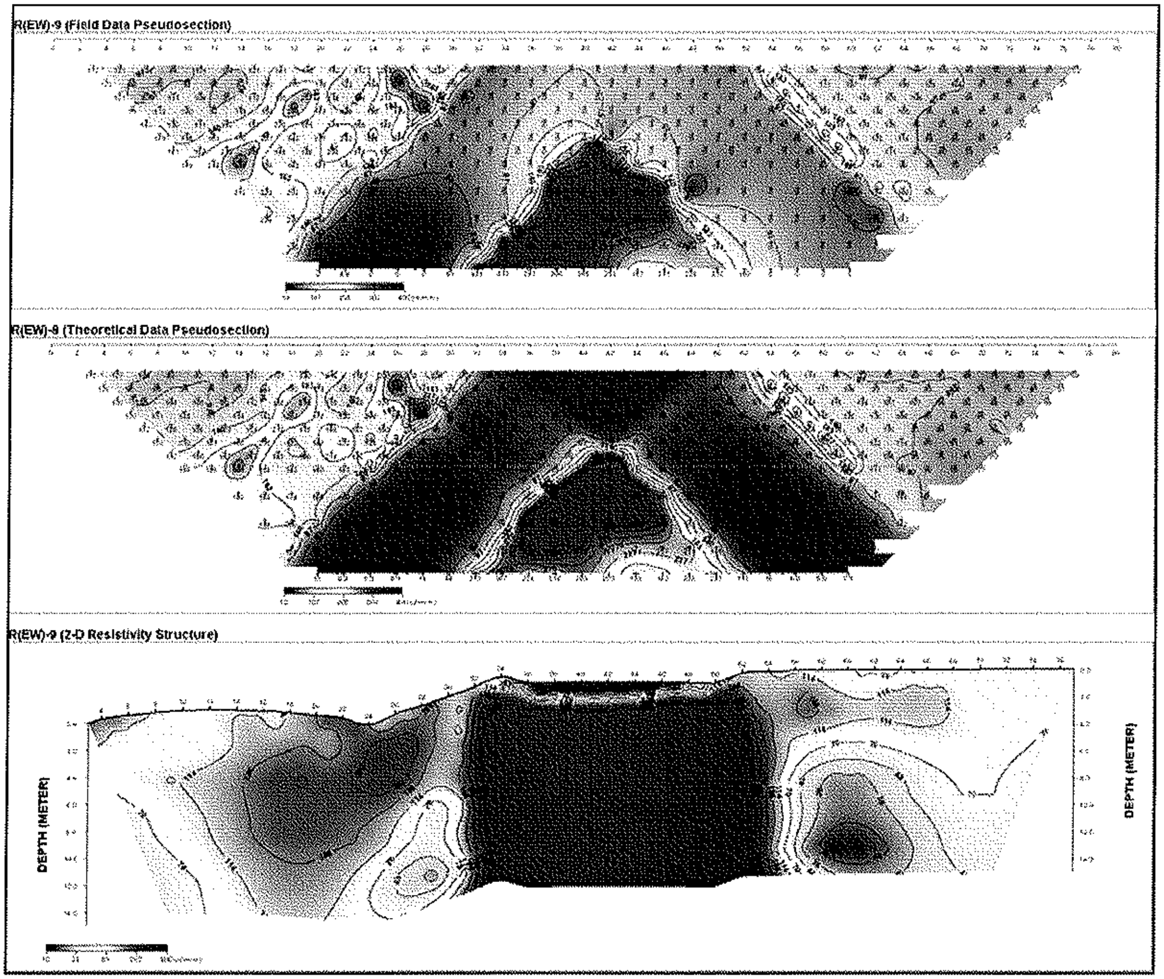
R(EW)-8 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-9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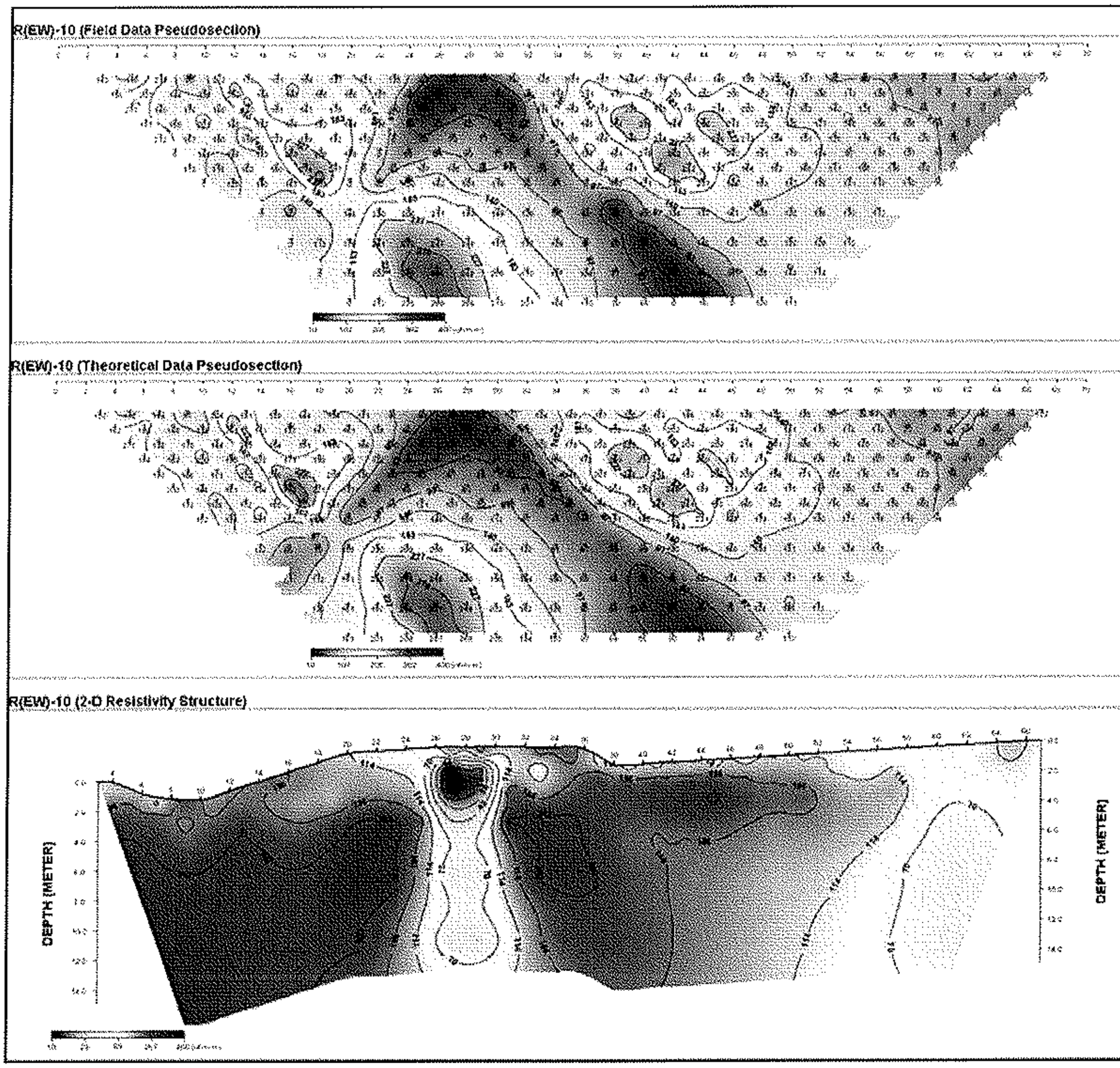
R(EW)-9 (Theoretical Data Pseudosection)
R(EW)-9 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-10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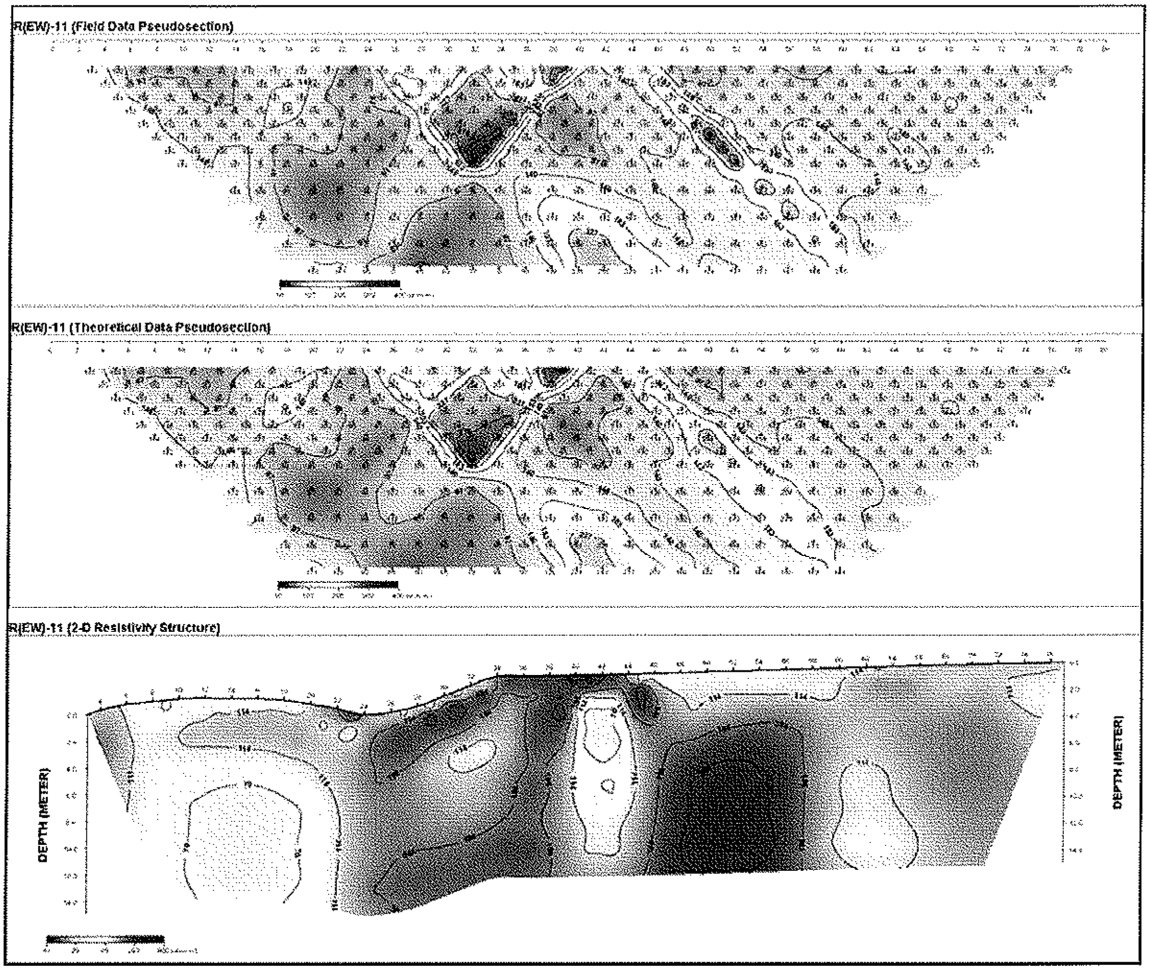
R(EW)-10 (Theoretical Data Pseudosection)
R(EW)-10 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-11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R(EW)-11 (2-D Resistivity Structure)
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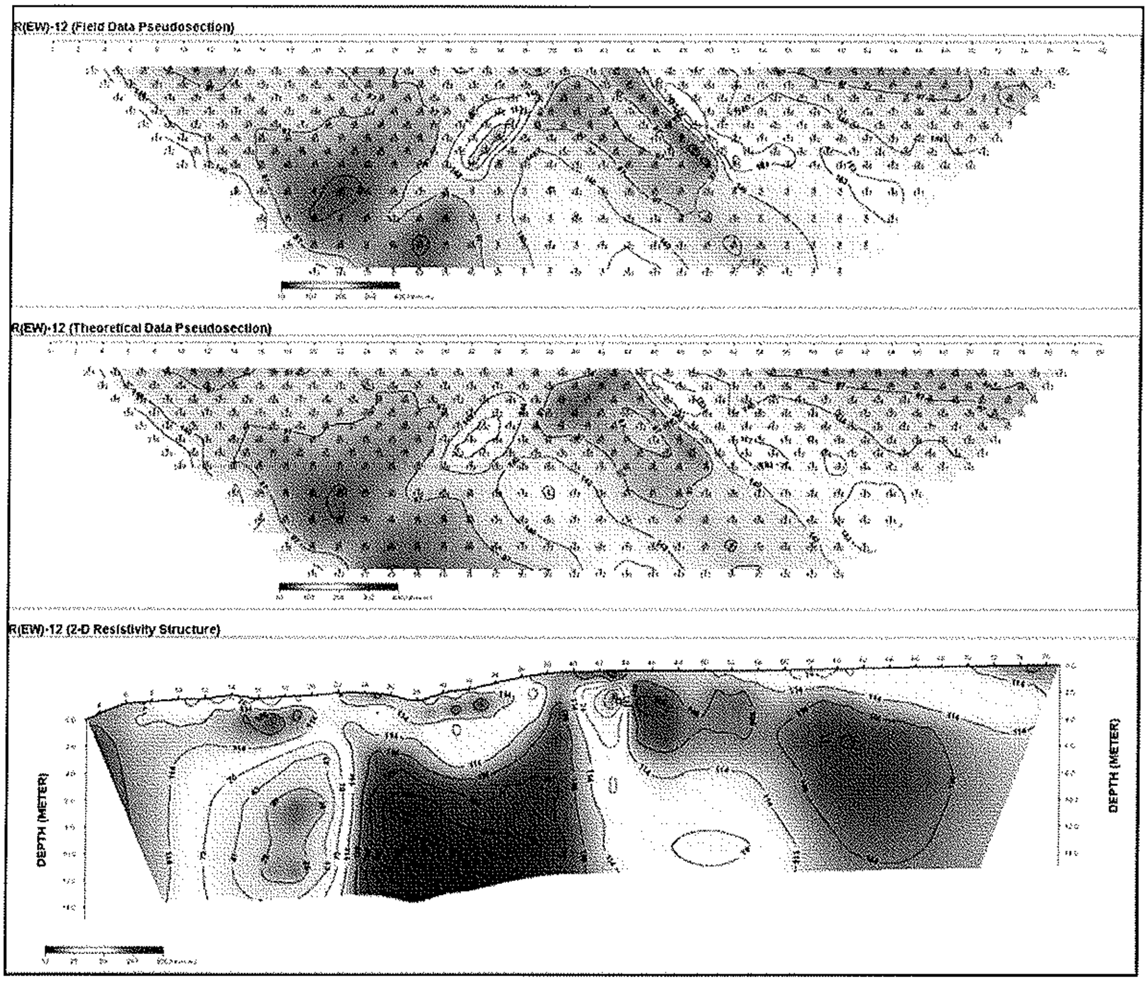
DEPTH (METER)

R(EW)-12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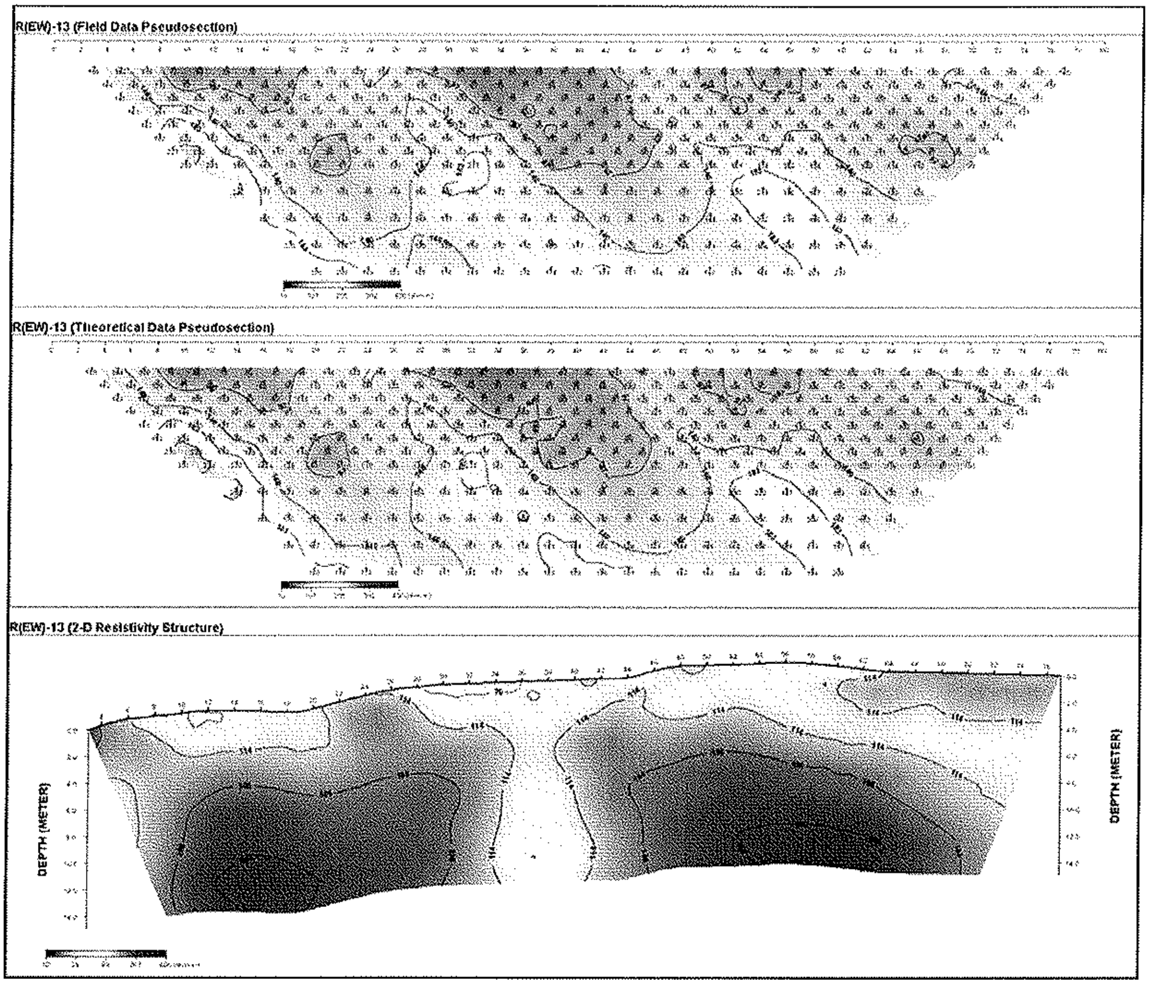
R(EW)-12 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-13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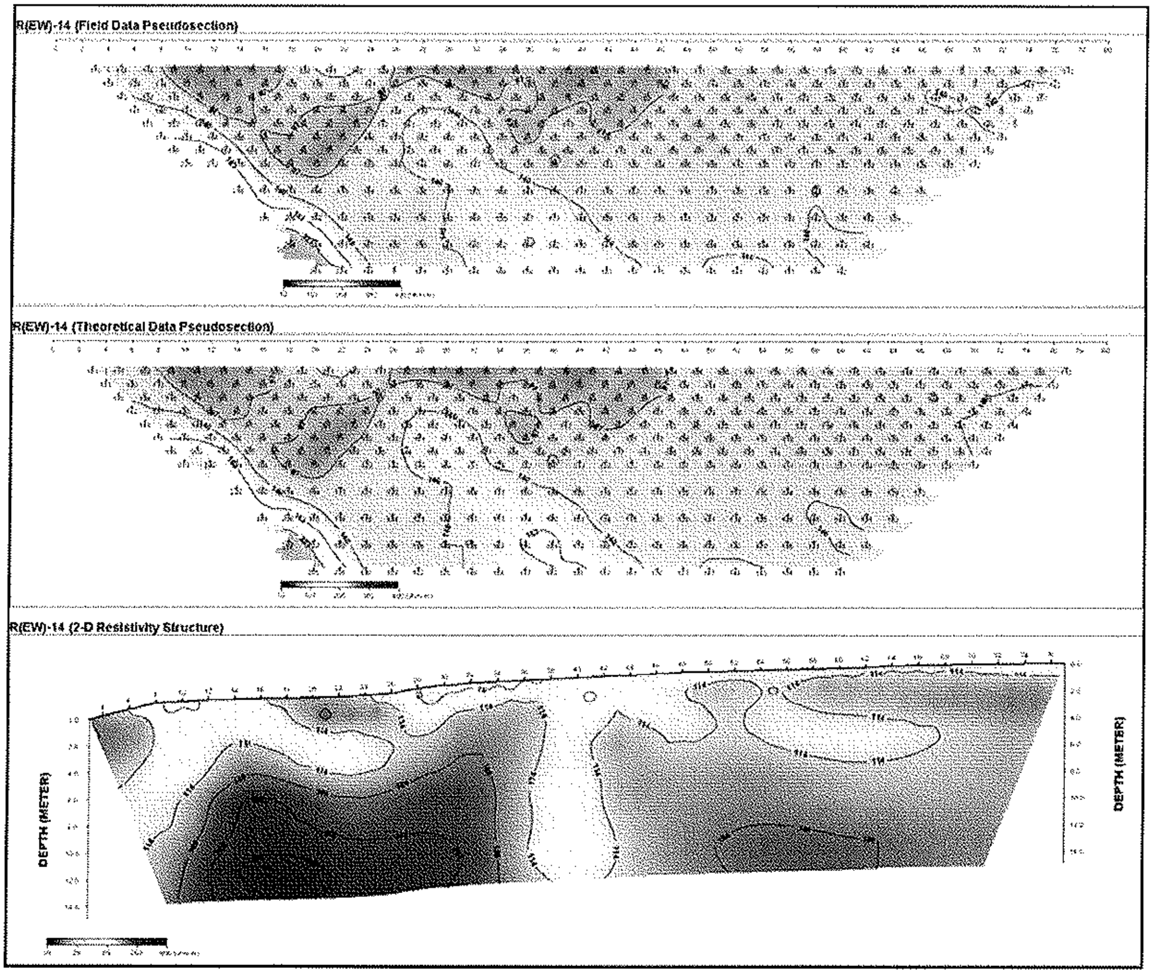
R(EW)-13 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-14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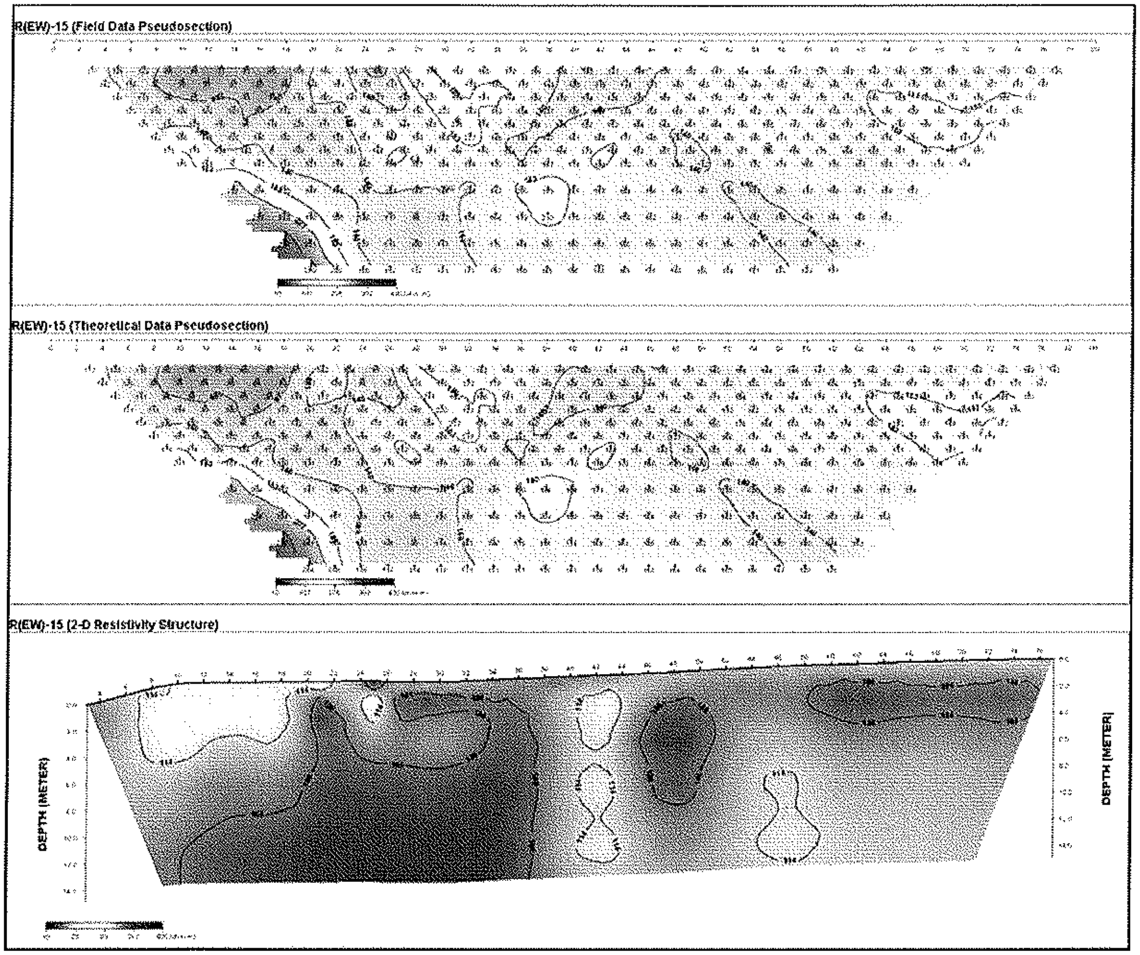
R(EW)-14 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(EW)-15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R(EW)-15 (2-D Resistivity Structure)
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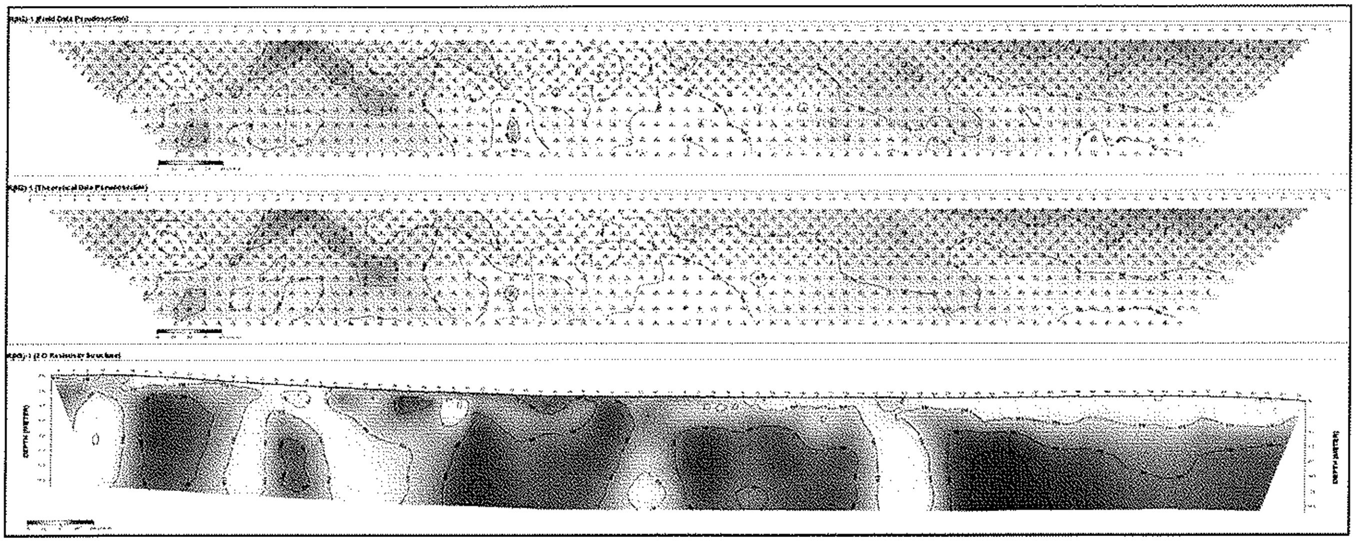
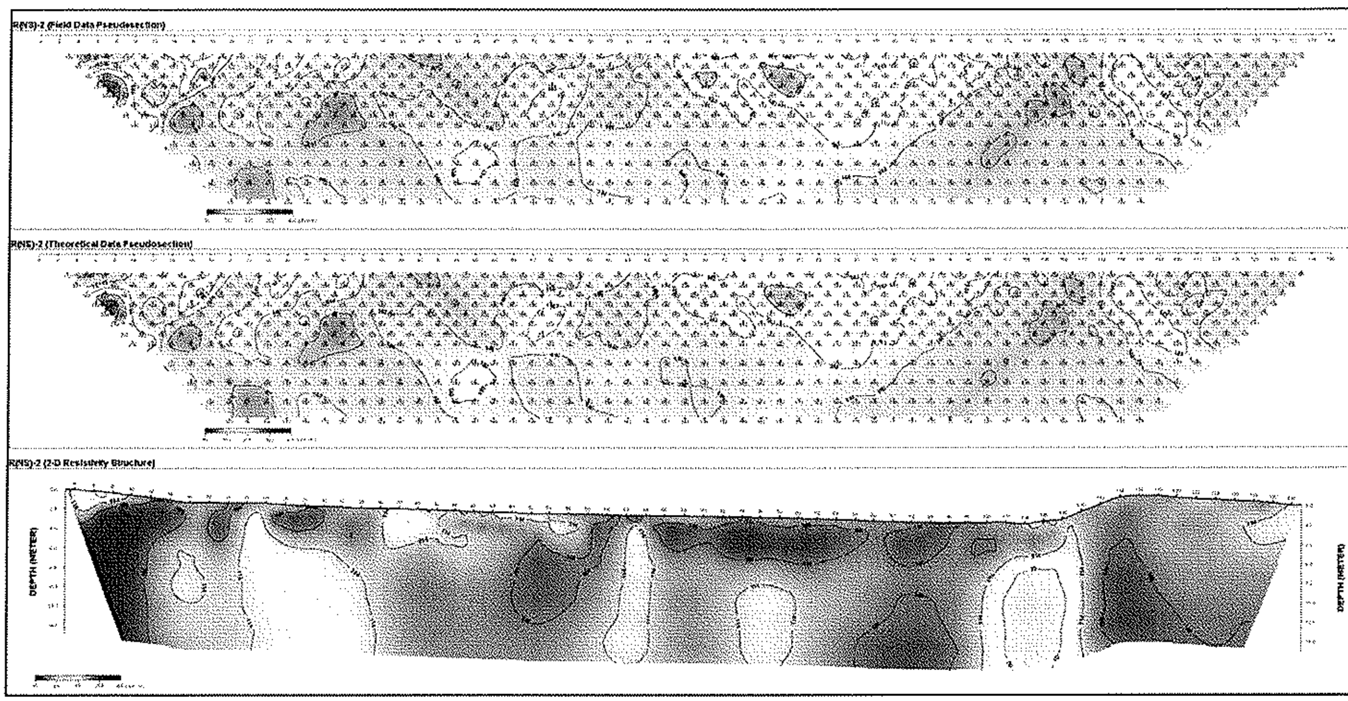
DEPTH (METER)

R(NS)-1



2855

R(NS)-2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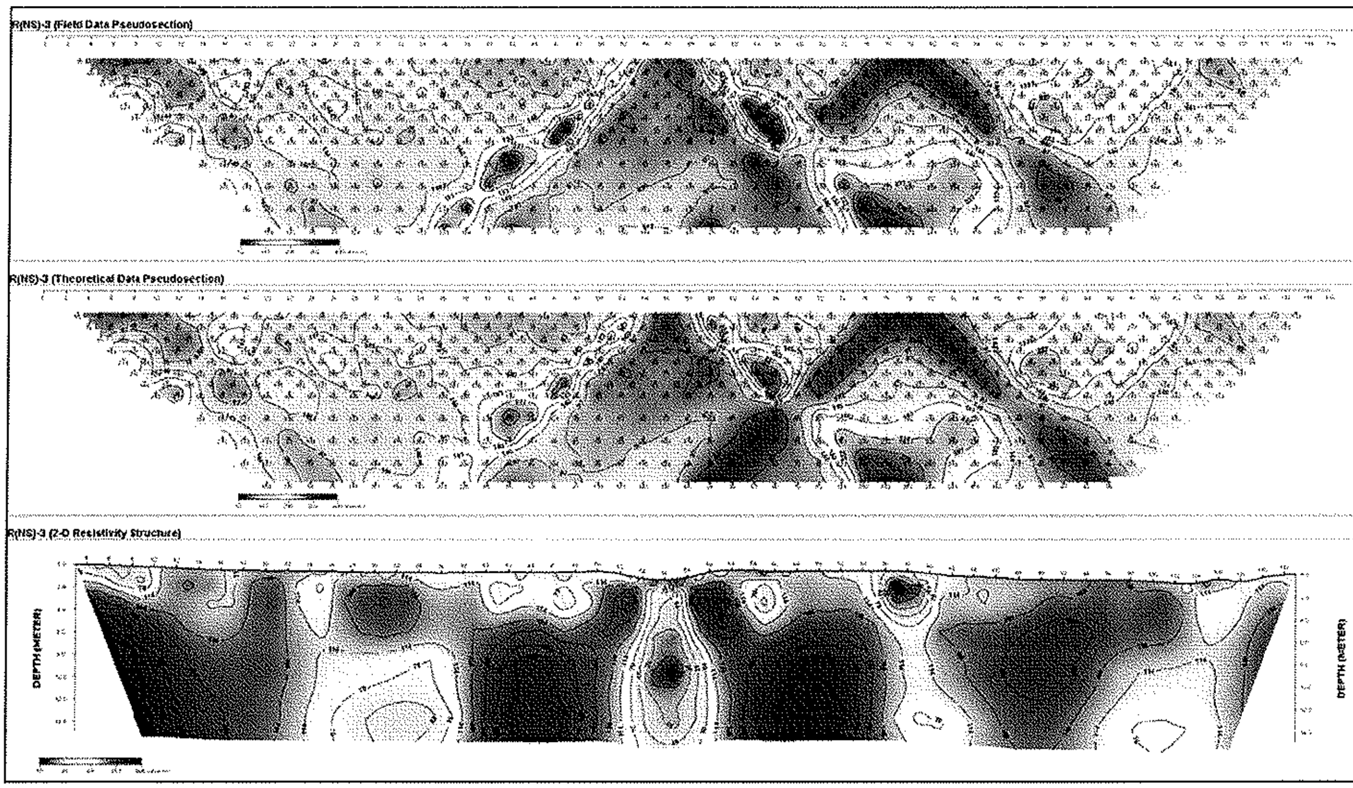
R(NS)-2 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

2856

R(NS)-3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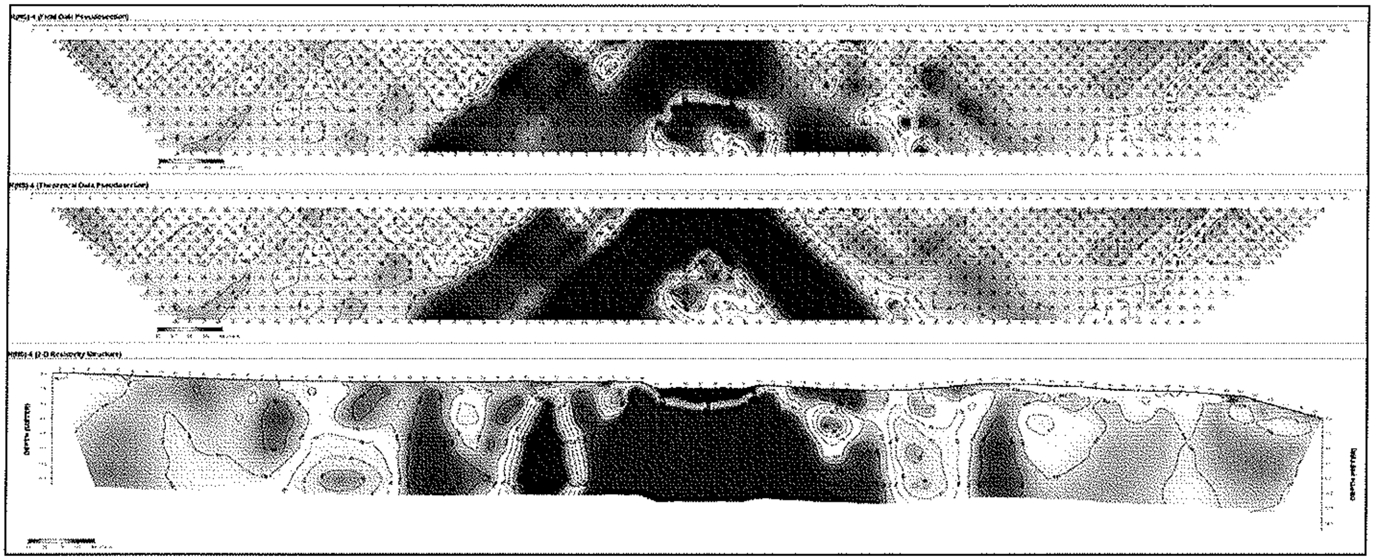
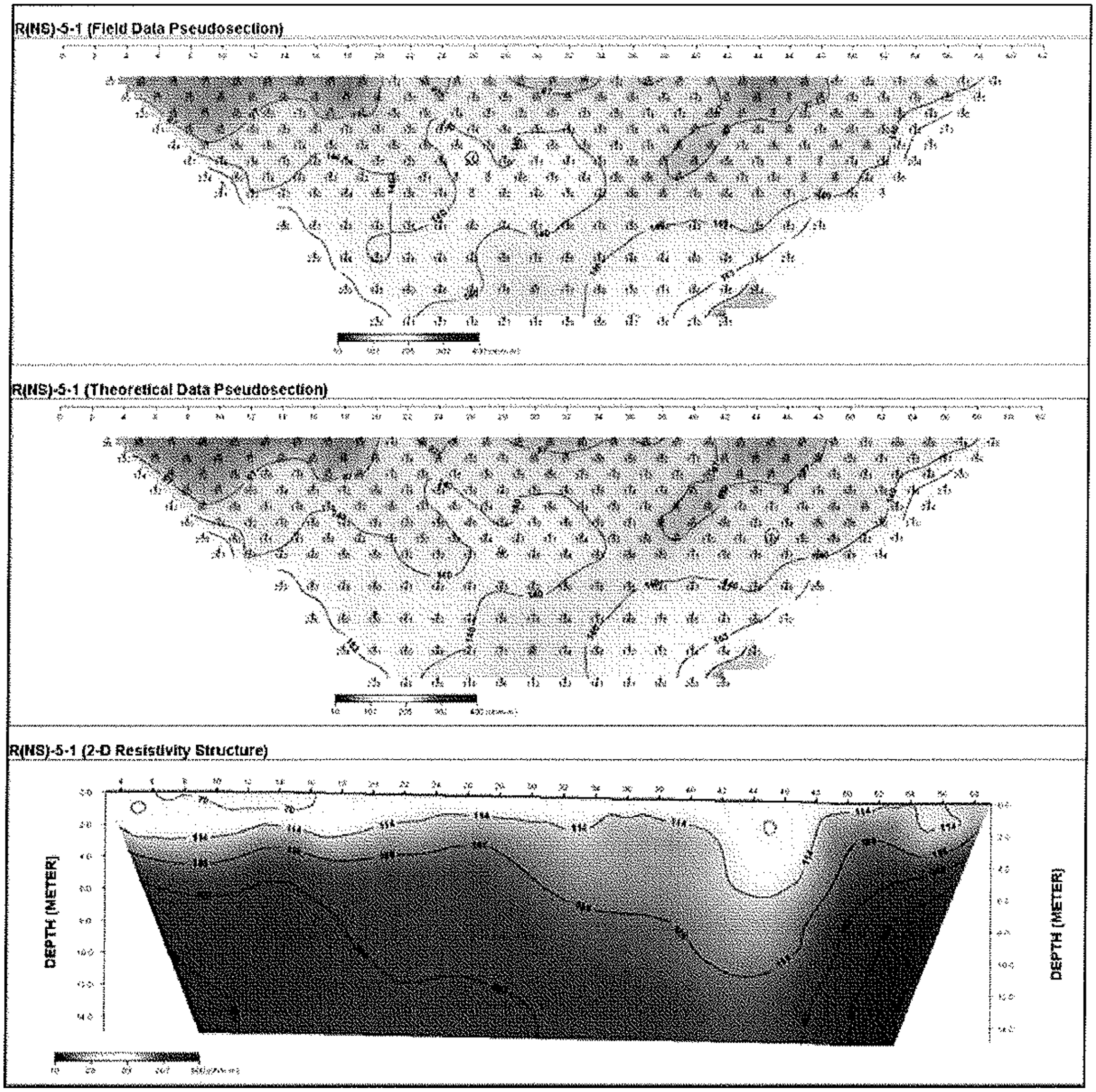
R(NS)-3 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

2857

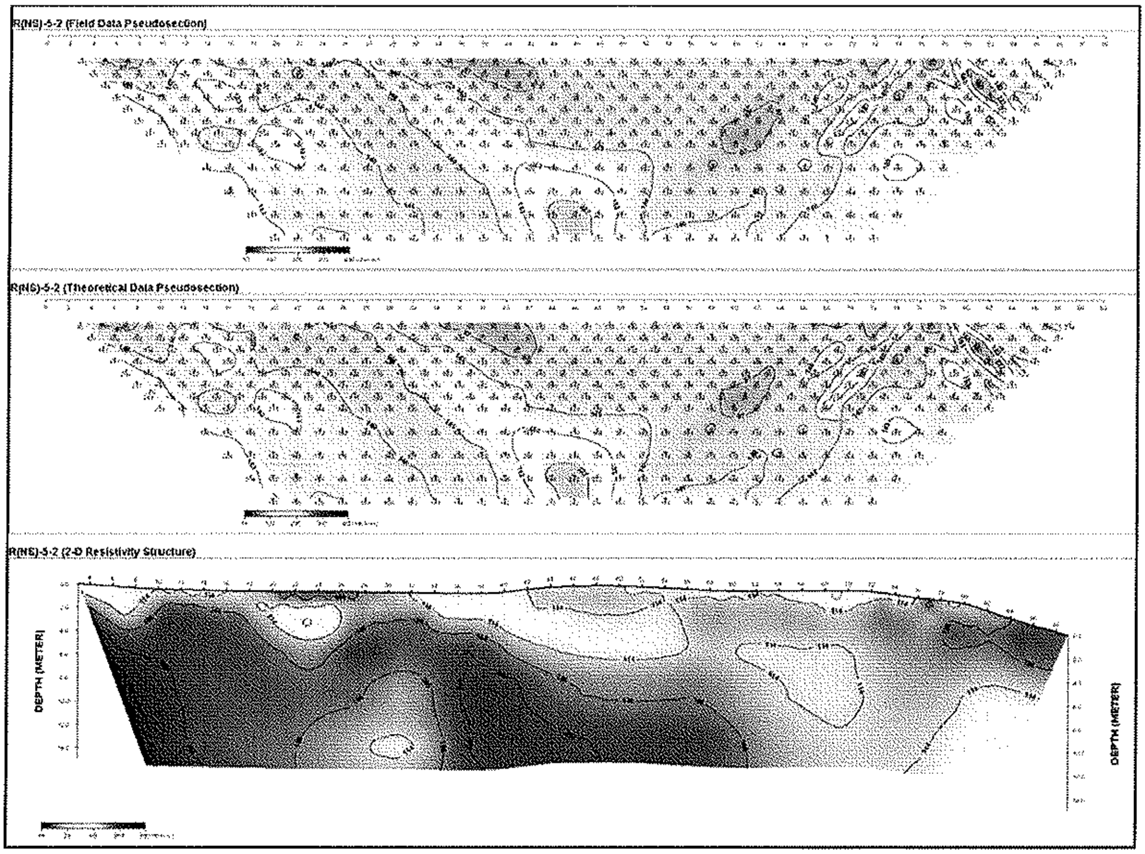
R(NS)-4



R(NS)-5


R(NS)-5-1 (Field Data Pseudosection)
R(NS)-5-1 (Theoretical Data Pseudosection)
R(NS)-5-1 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

R(NS)-5


R(NS)-5-2 (Field Data Pseudosection)
R(NS)-5-2 (Theoretical Data Pseudosection)
R(NS)-5-2 (2-D Resistivity Structure)
DEPTH (METER)
DEPTH (METER)

APPENDIX C
FIELDWORK PHOTOGRAPHS

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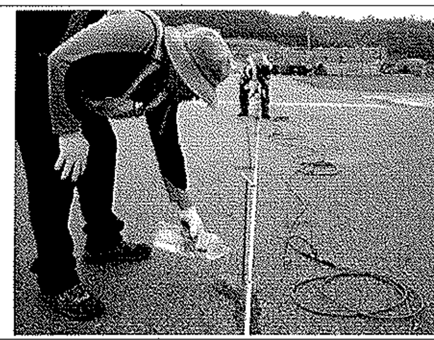
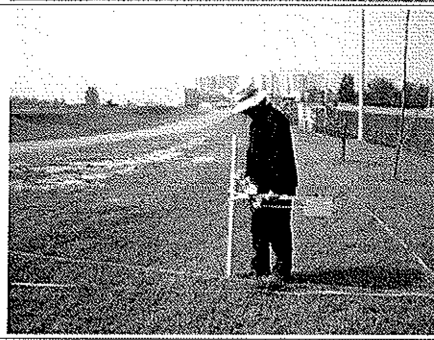
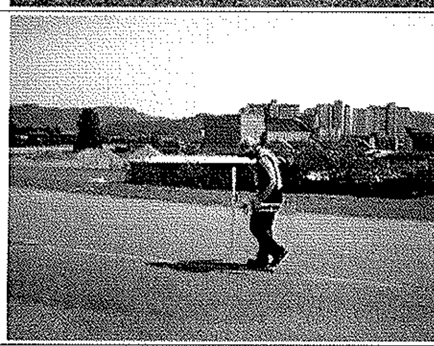
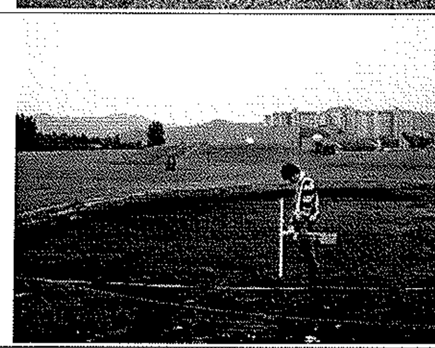


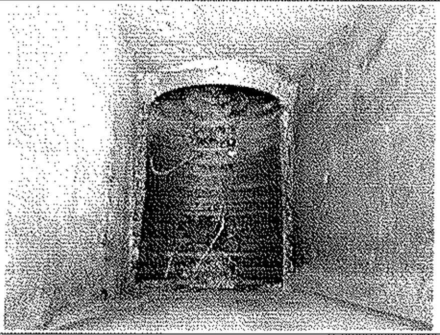


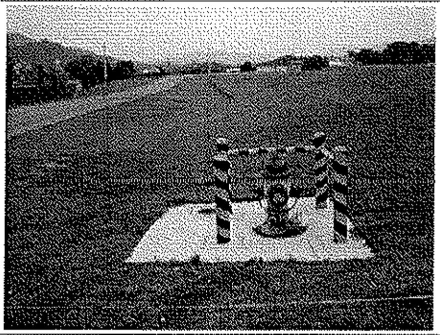


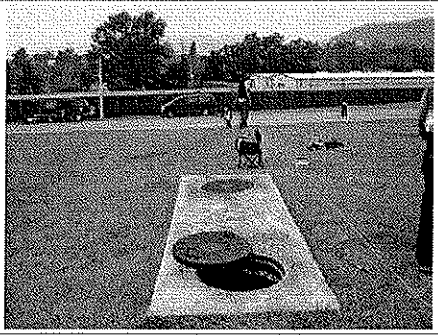








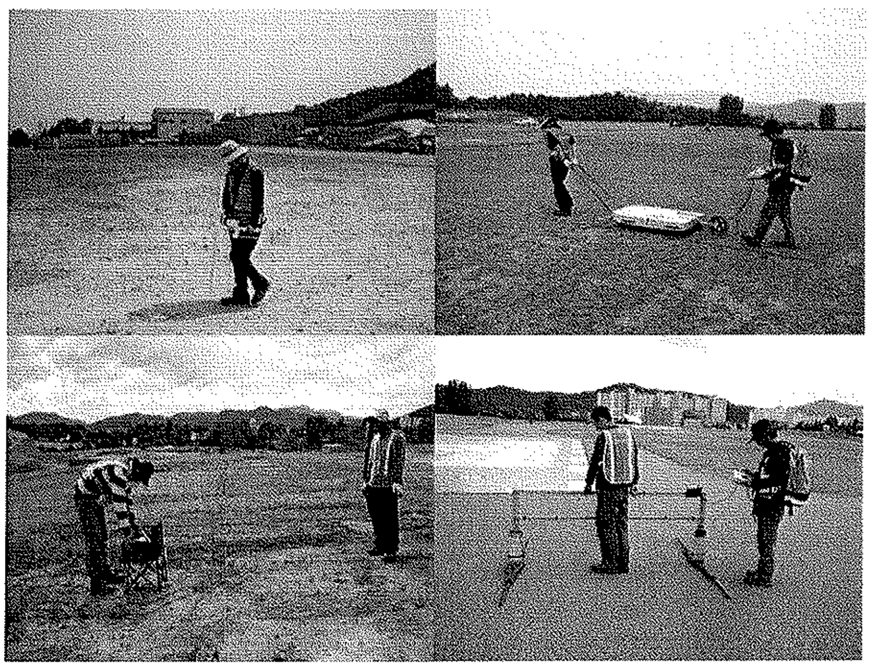


APPENDIX II. GEOPHYSICAL REPORT OF PHASE II/IIB- HELIPAD, LANDFARM AND AREA D INCLUDING SLOPE AREA and RECYCLING YARD- CAMP CARROLL

US Army Corps of Engineers
Far East District®

PHASE II AND IIB GEOPHYSICAL SURVEY REPORT

Camp Carroll
U.S. Army Garrison Daegu, Republic of Korea



July 20, 2011

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EXECUTIVE SUMMARY

This report presents the results of geophysical surveys conducted for the Phase II (Area D and Landfarm) and Phase IIB (Helipad) sites located on Camp Carroll, Republic of Korea (ROK). The surveyed areas are located in southeastern portion of Camp Carroll where disposal and burial of hazardous material and waste allegedly occurred between the years 1977 and 1982 (Figure ES-1). The purpose of the survey was to identify and locate foreign objects, especially steel drums and delimit the approximate vertical and horizontal coordinates of the burial. Geophysical survey of the western half of the Helipad site had been completed during Phase I and the results were provided in the Phase I (Helipad) Site Geophysical Survey Report.

Geophysical Survey Procedure

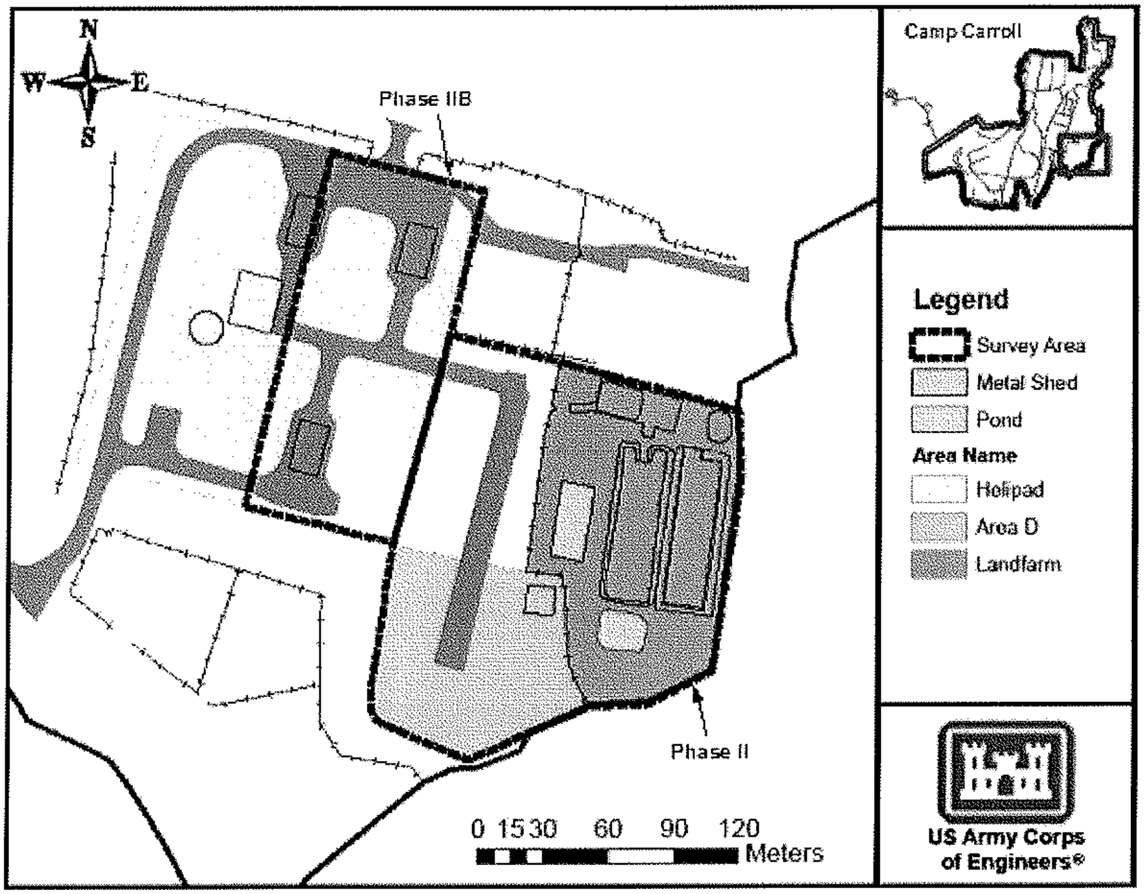
The Area D survey area measures approximately 180 m from north to south and from about 52 m to 130 m east to west. The Landfarm survey area measures approximately 150 m from north to south and 100 m east to west. The Phase IIB Helipad survey area measures approximately 170 m from north to south and 72 m east to west. The geophysical survey was conducted using three non-intrusive techniques: magnetic gradiometry, ground penetrating radar (GPR), and electrical resistivity imaging (ERI).

The magnetic gradiometry survey utilized a grid system with north-south and east-west running gridlines at 1 m intervals. Including endpoints, this resulted in 12,719 intersections points in Area D, 7,607 points for the Landfarm and 12,420 intersections points in the Phase IIB Helipad site. Magnetic readings were taken at each of the intersection points using a Bartington Instrument Ltd (United Kingdom) model Grad601 gradiometer.

The GPR survey was conducted using a MALÅ GeoScience (Sweden) model ProExTM Professional Explorer GPR. The survey utilized 2 m interval transects in the east-west direction, resulting in 93 transects for Area D, 121 transects for the Landfarm and 84 transects for the Helipad site. An input frequency of 100 megahertz (MHz) was initially selected. After completion of the survey at 100 MHz, a second survey was conducted at locations where anomalies were detected using an input frequency of 50 MHz. The lower frequency provides deeper coverage but at a slightly lower resolution.

The ERI survey was conducted using an ABEM Instrument AB (Sweden) model Terrameter LS direct current resistivity meter. The survey was conducted along 19 transects for Area D, 16 for the Landarm and 14 transects for the Helipad.

Figure ES-1. Camp Carroll Phase II and IIB Geophysical Survey Location Map



Survey Results

The survey results were combined and a final interpretation of the data and subsurface anomaly zones are shown on Figure ES-2. The results are summarized as follows:

Phase II Area D Site

- The magnetic gradiometry survey results indicate four areas of subsurface anomalies.
- The GPR survey results indicate three subsurface anomalies, mostly towards the southern portion of the site.
- The ERI survey results indicate seven subsurface anomaly zones.

Phase II Landfarm Site

- The magnetic gradiometry survey results indicate two areas of subsurface anomalies.
- The GPR survey results indicate six subsurface anomalies.
- The ERI survey results indicate four subsurface anomaly zones.

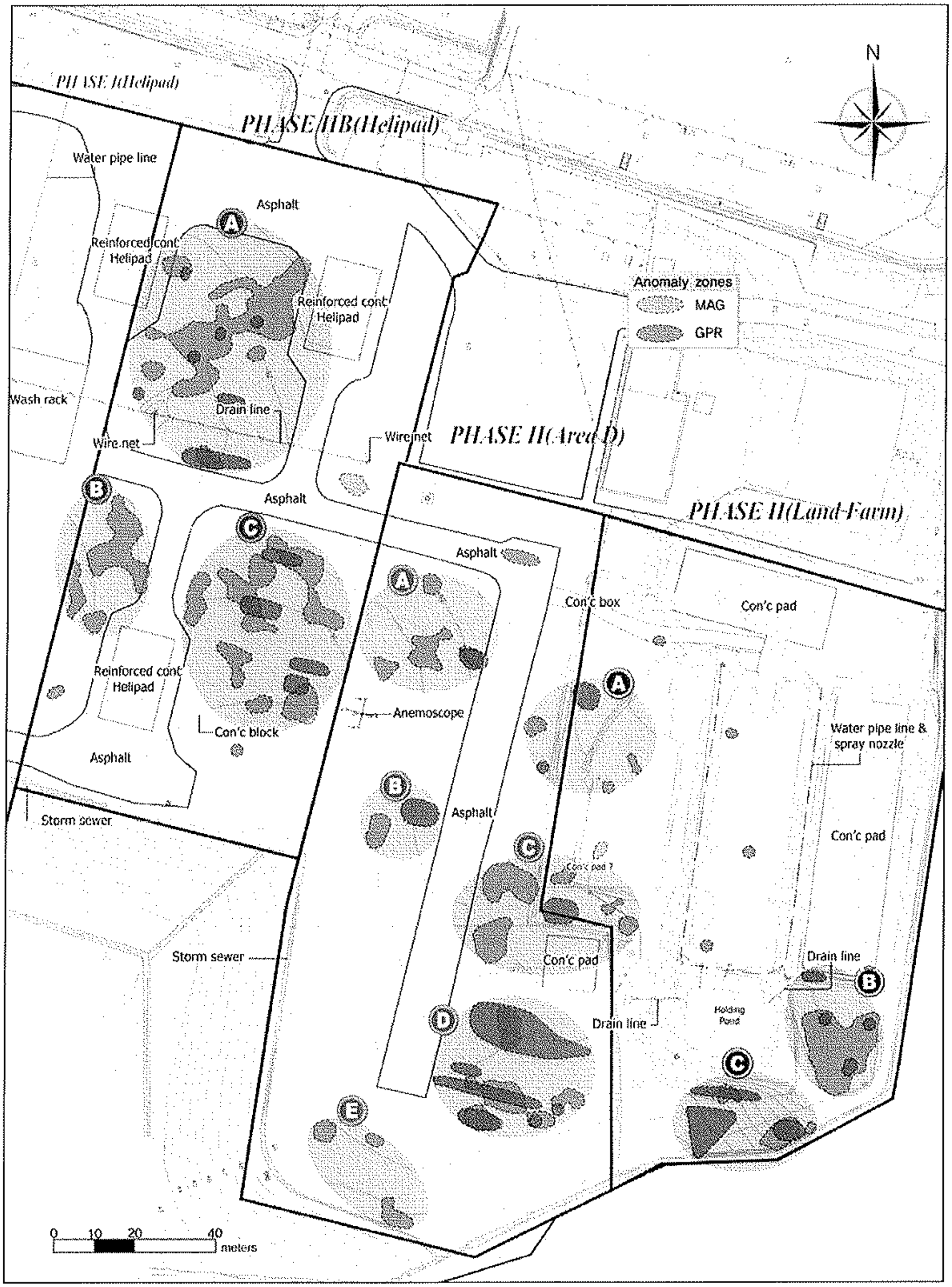
Phase IIB Helipad Site

- The magnetic gradiometry survey results indicate three areas of subsurface anomalies.
- The GPR survey results indicate six subsurface anomalies.
- The ERI survey results indicate six subsurface anomaly zones.

Conclusions

The subsurface anomalies identified by the ERI survey is attributed to geologic features and do not indicate the presence of buried foreign objects. The combined results of the magnetic gradiometry and GPR surveys shown on Figure ES-2 indicate 11 anomaly zones where the probability for the presence of buried foreign objects are the highest. There are four such anomalies in the Area D site, three in the Landfarm site and three in the Phase IIB Helipad site. The subsurface anomalies zones may be attributed to loosely packed soils possibly indicating excavation and backfill; high liquid content, which may be indicative of recent leaks or spills; or buried foreign objects such as steel drums.

Figure ES-2. Final Interpretation of Subsurface Anomaly Zones



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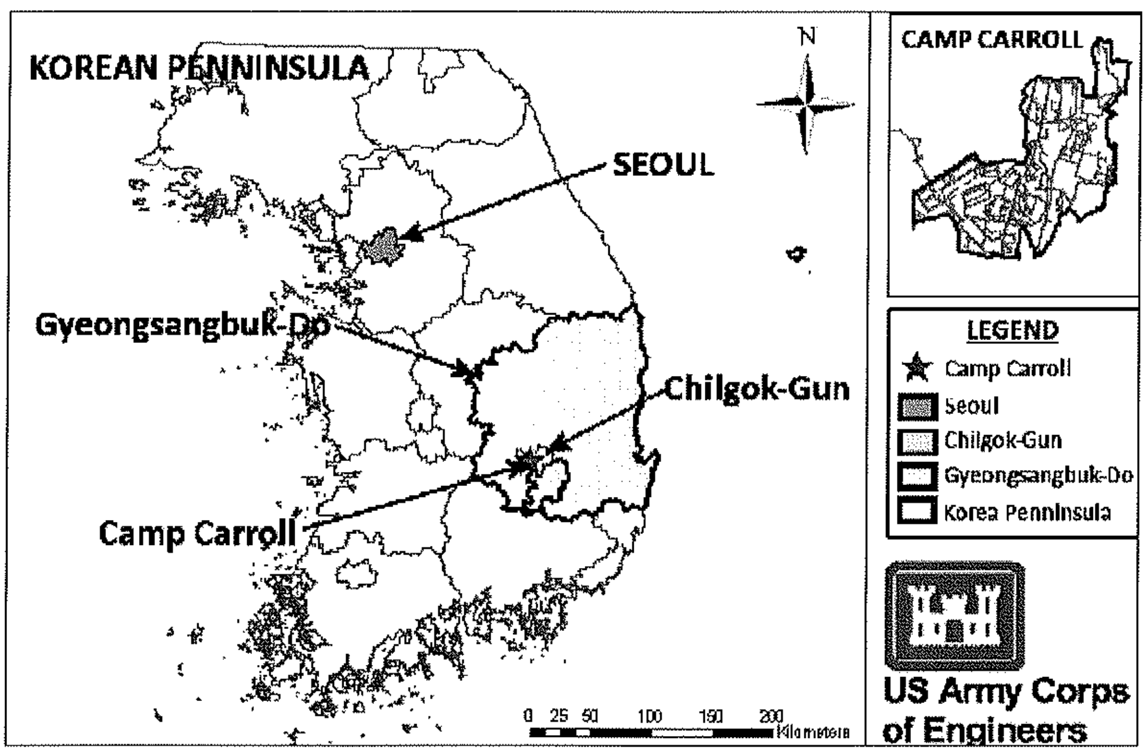
1. INTRODUCTION

This report presents the results of geophysical surveys that were conducted for the Phase II (Area D and Landfarm) and IIB (Helipad) sites located on Camp Carroll, Republic of Korea (ROK). The purpose of the geophysical survey was to locate potential foreign objects, especially steel drums, which may have been buried in the area. The survey will also delimit the approximate vertical and horizontal coordinates of subsurface anomalies that indicate the possible presence of foreign objects. A geophysical survey has been completed for the western one-half of the Helipad site during Phase I of this project and the results are provided in the Phase I (Helipad) Site Geophysical Survey Report.

1.1 Site Description and Background

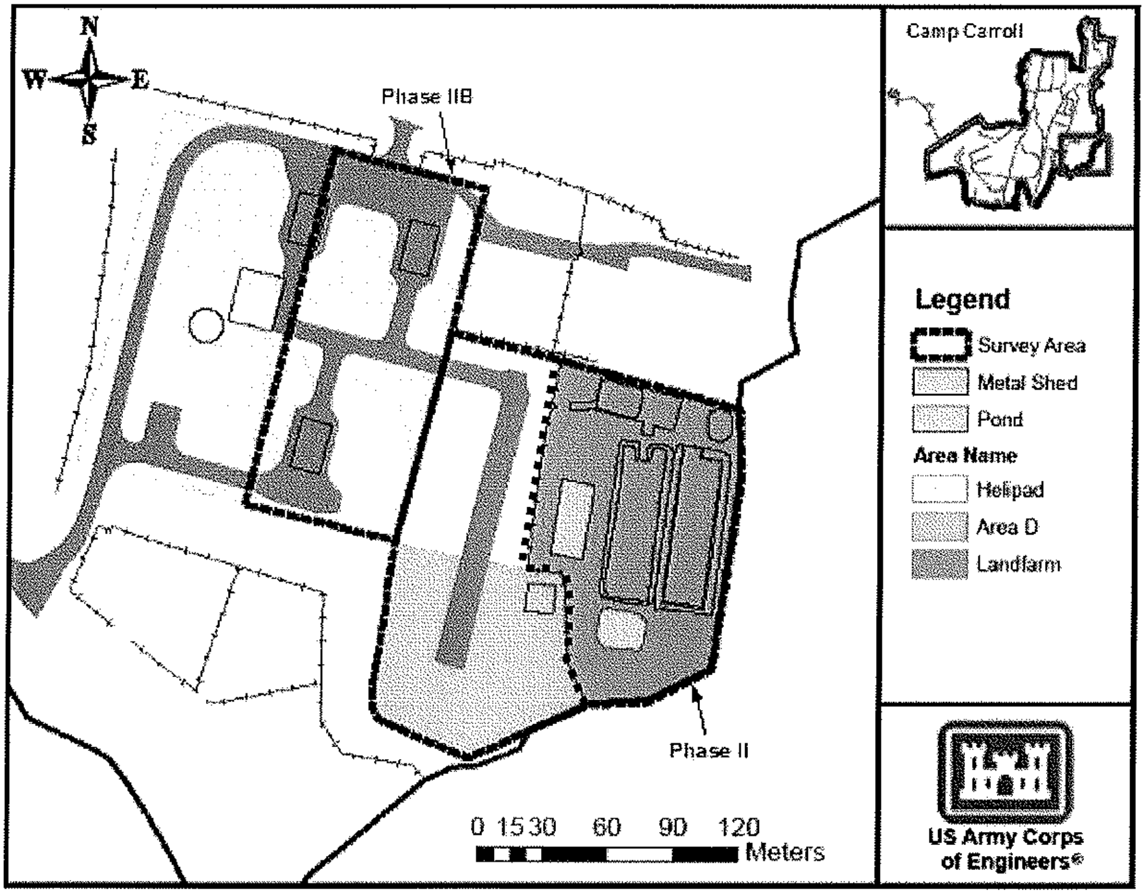
U.S. Army Garrison (USAG) Daegu Camp Carroll (Camp Carroll) is located in Chilgok-Gun, Gyeongsanbuk-Do, adjacent to the village of Waegwan in the south-central portion of the ROK. The general location of the camp is shown on Figure 1-1. Urban areas bound Camp Carroll on the northwest, west and southwest. Hilly, forested areas bound the base on the north and east. Agricultural fields (mostly rice paddies) border the camp on the northeast and the south. The Naktong River flows from north to south approximately 0.5 kilometers west of Camp Carroll.

Figure 1-1. USAG Daegu Camp Carroll Location Map



The location and general layout of the Phase II Area D and Landfarm sites and the Phase IIB Helipad site are shown on Figure 1-2. Disposal and burial of hazardous material and waste, some in 55-gallon drums, reportedly occurred during the period between the years 1977 and 1982.

Figure 1-2. Phase II and IIB Geophysical Survey Location Map



The Phase II and IIB sites are mostly flat with a slight down slope to the southeast. The grounds in the area are mostly unpaved and covered with grass. Main physical feature at the sites include the helipad, several concrete pads, asphalt taxiways, metal shed, holding pond and the landfarm cells. There are also numerous underground utilities and other features at the site that could interfere with survey instrument reading, including water and sewer lines, concrete pad, aboveground and underground drain line.

1.2 Geophysical Survey Methodologies

The geophysical survey was conducted using three non-intrusive techniques: magnetic gradiometry, ground penetrating radar (GPR), and electrical resistivity imaging (ERI). Three separate techniques were employed for the survey in order to ensure optimum coverage and the ability to identify and locate subsurface anomalies. The following sections provide brief descriptions of each technique, along with some of the strengths and limitations assoiated with each technique.

1.2.1 Magnetic Gradiometry

Magnetic gradiometry is a more refined technique under the broader category of magnetic geophysical survey. Magnetic surveying in general is a passive method based on the measurement of localized perturbations to the Earth's magnetic field caused by the presence of buried ferrous targets. Magnetic gradiometry determines the vertical gradient of the magnetic field, and are more sensitive to small or weakly magnetic targets than the typical single sensor, total field magnetometer. The limitation with magnetic survey techniques is that they will not identify non-magnetic materials, such as glass, plastics, wood, and non-ferrous metals such as copper and aluminum.

Typically, data is collected in a systematic manner across a field site and then presented as a contoured map in units of nanotesla (nT) or nT per meter (nT/m), which can be interpreted to produce a map of the subsurface. The amplitude and shape of an individual anomaly will reflect the dimensions, orientation and magnetic susceptibility of the buried target.

1.2.2 Ground Penetrating Radar

In GPR surveys, electromagnetic waves of frequencies between 50MHz and 2.5GHz (microwave band of the radio spectrum) are transmitted into the ground. This energy is reflected back to the surface when it encounters significant contrasts in dielectric properties. The amount of energy reflected is dependent on the contrast in electrical properties encountered by the radio waves. A receiver measures the variation in the strength of the reflected signals with time. The resulting profile is called a "scan." Multiple scans generated by traversing the antenna across the ground surface are used to build 2D vertical cross sections (radargrams) of the subsurface.

The advantage of GPR is that it can be used in a variety of media, including rock, soil, ice, fresh water, pavements and structures. Also, because GPR is sensitive to differences in dielectric properties, it can be used to detect non-ferrous objects, changes in material, and voids and cracks. The limitation with GPR is that signal resolution is dependent on the input signal frequency. Higher frequencies provide higher resolution, but higher frequencies provide less penetration depth. Lower frequencies penetrate deeper into the ground but provides less resolution and hence less accuracy. Another potential limitation with GPR is that the difference between dielectric constants of different materials or layers may be too small to classify, and interpretation of data is less straightforward than magnetic techniques.

1.2.3 Electrical Resistivity Imaging

ERI, also called electrical resistivity tomography (ERT) measures ground resistance by introducing an electric current into the subsurface via two grounded electrodes. The current passing through the ground sets up a distribution of electrical potential in the subsurface. The difference in electrical potential is measured using a second set of electrodes. The transmitting and receiving electrode pairs are referred to as dipoles. Using Ohm's law, this voltage can be converted into a resistance reading in units of ohm-meters (ohm-m) for the ground between the two potential electrodes. By varying the unit length of the dipoles as well as the distance between them, the horizontal and vertical distribution of electrical properties can be recorded.

To build a vertical cross-sectional image of ground resistance, a string of connected electrodes are deployed along a straight line with an inter-electrode spacing of *a*. Once the resistance measurements have been made, the line is re-surveyed with an inter-electrode spacing of 2*a*, 3*a*, 4*a*, etc. For example, if a = 1 m (the initial spacing between the electrodes is 1 m), the next survey along the same line would be conducted for electrodes spaced at 2 m, followed by a survey with electrodes spaced at 3 m, etc. Each increase in the inter-electrode spacing increases the effective depth of the survey. The vertical cross sections are combined to generate a fence diagram output.

2. GEOPHYSICAL SURVEY PROCEDURE

This section provides a description of the field procedures and instrumentation used during the Phase II and IIB geophysical survey. The specifications of the instruments are provided in Appendix A for reference. The results of the survey are presented in Section 3.

The Phase II Area D survey site measures approximately 180 m from north to south and from about 52 m to 130 m east to west. The Landfarm site measures approximately 150 m from north to south and 100 m east to west. The Phase IIB Helipad survey area measures approximately 170 m from north to south and 72 m east to west.

2.1 Magnetic Gradiometry Survey

The magnetic gradiometry survey was conducted using a Bartington Instrument Ltd (United Kingdom) model Grad601 gradiometer equipped with a single Grad-01-1000L high stability fluxgate gradient sensor. The data generated was recording using a DL601 Data Logger.

The magnetic gradiometry survey utilized a grid system with north-south and east-west running gridlines at 1 m intervals. The survey sites are shown on Figure 2-1. Including endpoints, this resulted in 12,719 intersections points in Area D, 7,607 points in the Landfarm site and 12,420 intersections points in the Phase IIB Helipad site. Magnetic readings were taken at each of the intersection points

2.2 GPR Survey

The GPR survey was conducted using a MALÅ GeoScience (Sweden) model ProEx™ Professional Explorer GPR. Based on site geology, soil type, subsurface conditions and the anticipated depth of buried materials at 5 m to 6 m below ground surface (bgs), an input frequency of 100 megahertz (MHz) was selected to provide the highest resolution. After completion of the survey at 100 MHz, a second survey was conducted using an input frequency of 50 MHz. The lower frequency provides deeper coverage but at a slightly lower resolution.

The initial survey using the 100 MHz antenna was conducted utilizing 2 m interval transects in the east-west direction as shown on Figure 2-2. The resultant number of transects in the Area D site was 93; 121 transects in the Landfarm site; and 84 transects in the Phase IIB Helipad site. The length of the transects ranged from about 9 m to 90 m. The 50 MHz antenna survey utilized 4 m to 5 m interval transects, also in the east-west direction (Figure 2-3). There were 18 transects in the Area D site; 59 transects in the Landfarm site; and 23 transects in the Phase IIB Helipad site. The lengths of the transects for the 50 MHz survey ranged from 9 m to 105 m.

2.3 ERI Survey

The ERI survey was conducted using an ABEM Instrument AB (Sweden) model Terrameter LS direct current resistivity meter. The survey was conducted along transects shown on Figure 2-4: 19 for the Area D, 16 for the Landfarm, and 14 for the Phase IIB Helipad site.

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Figure 2-1. Phase II and IIB Magnetic Gradiometry Survey Sites

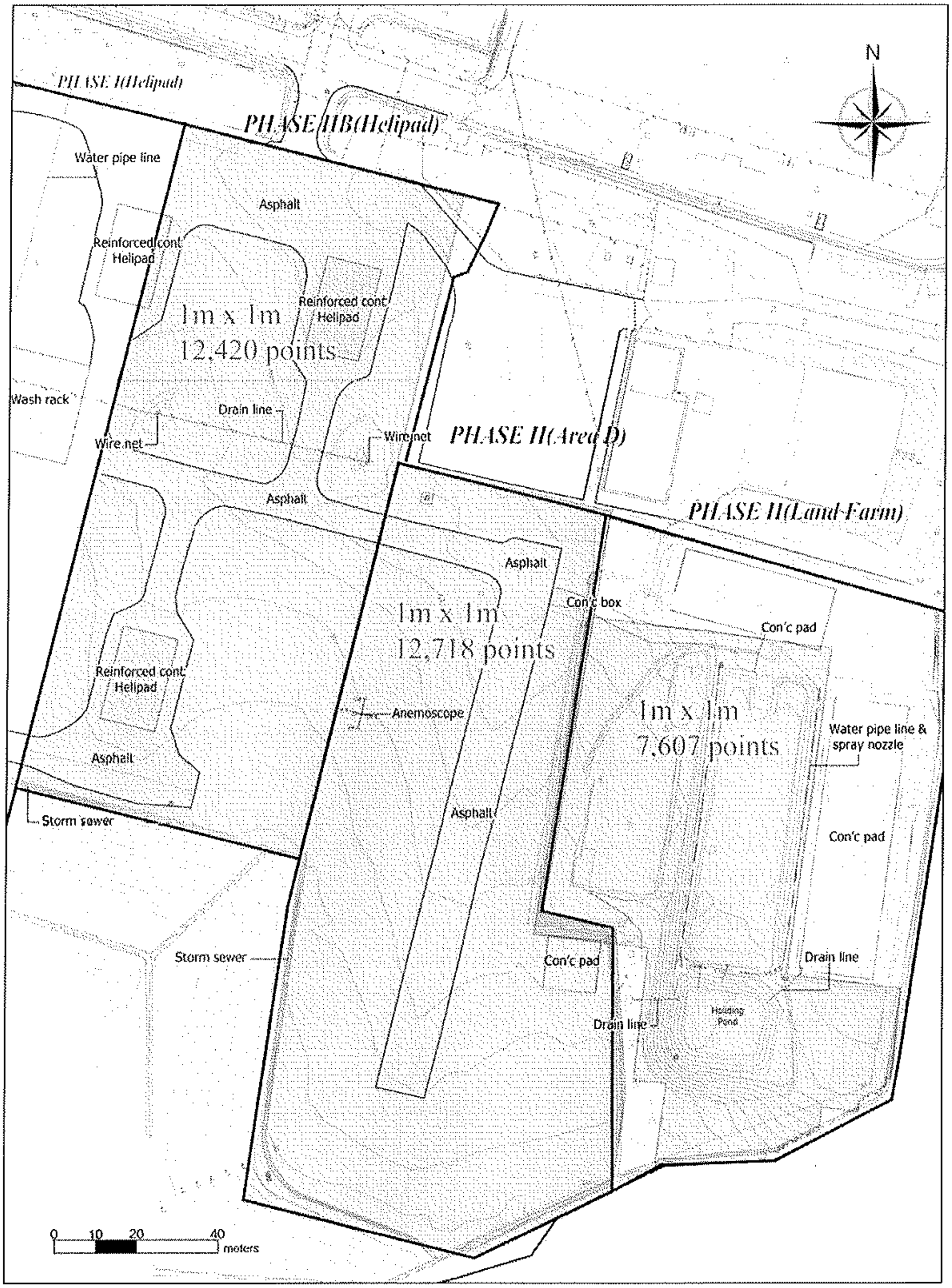

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Figure 2-2. 100 MHz GPR Survey Transects

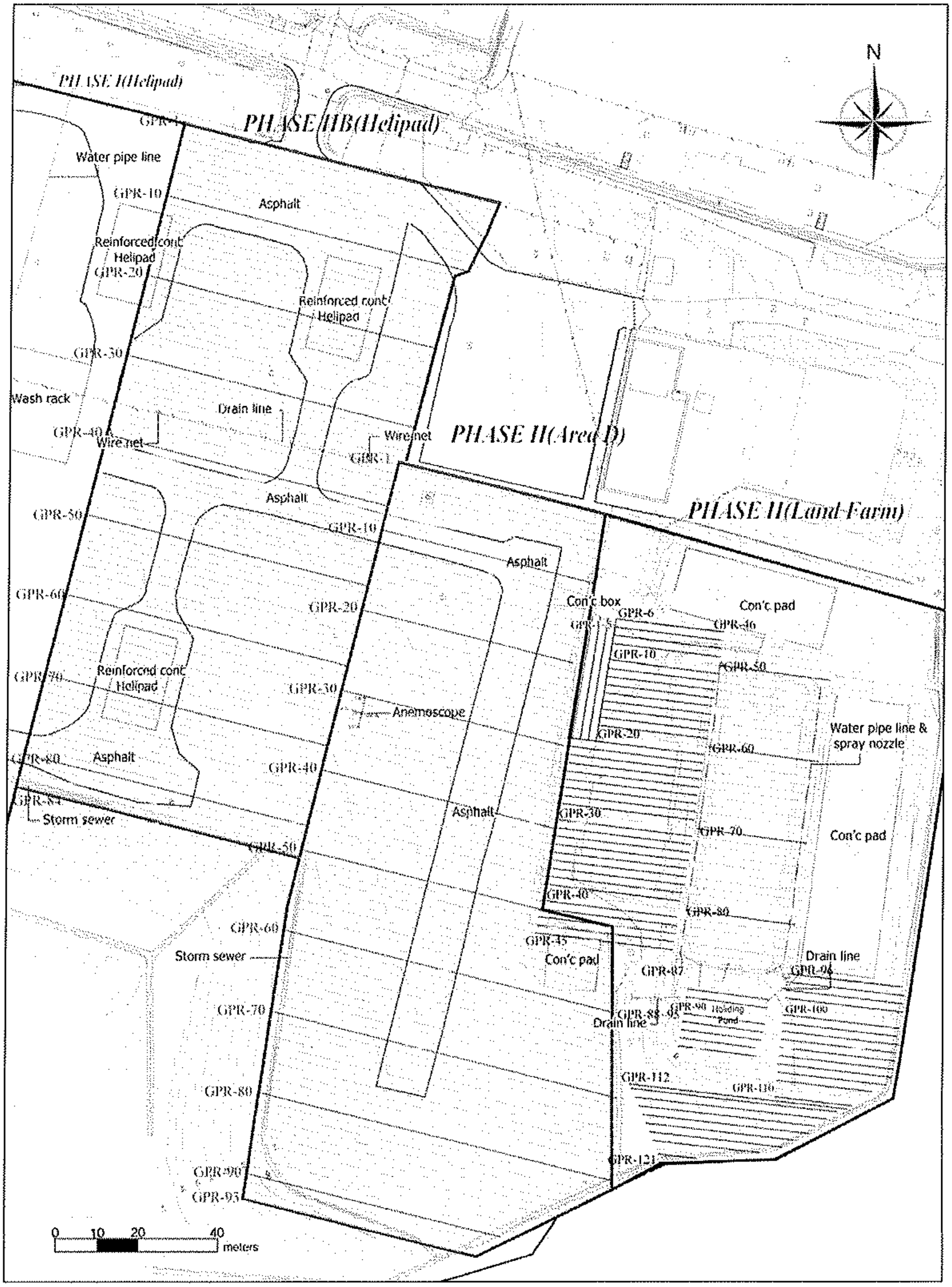

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Figure 2-3. 50 MHz GPR Survey Transects

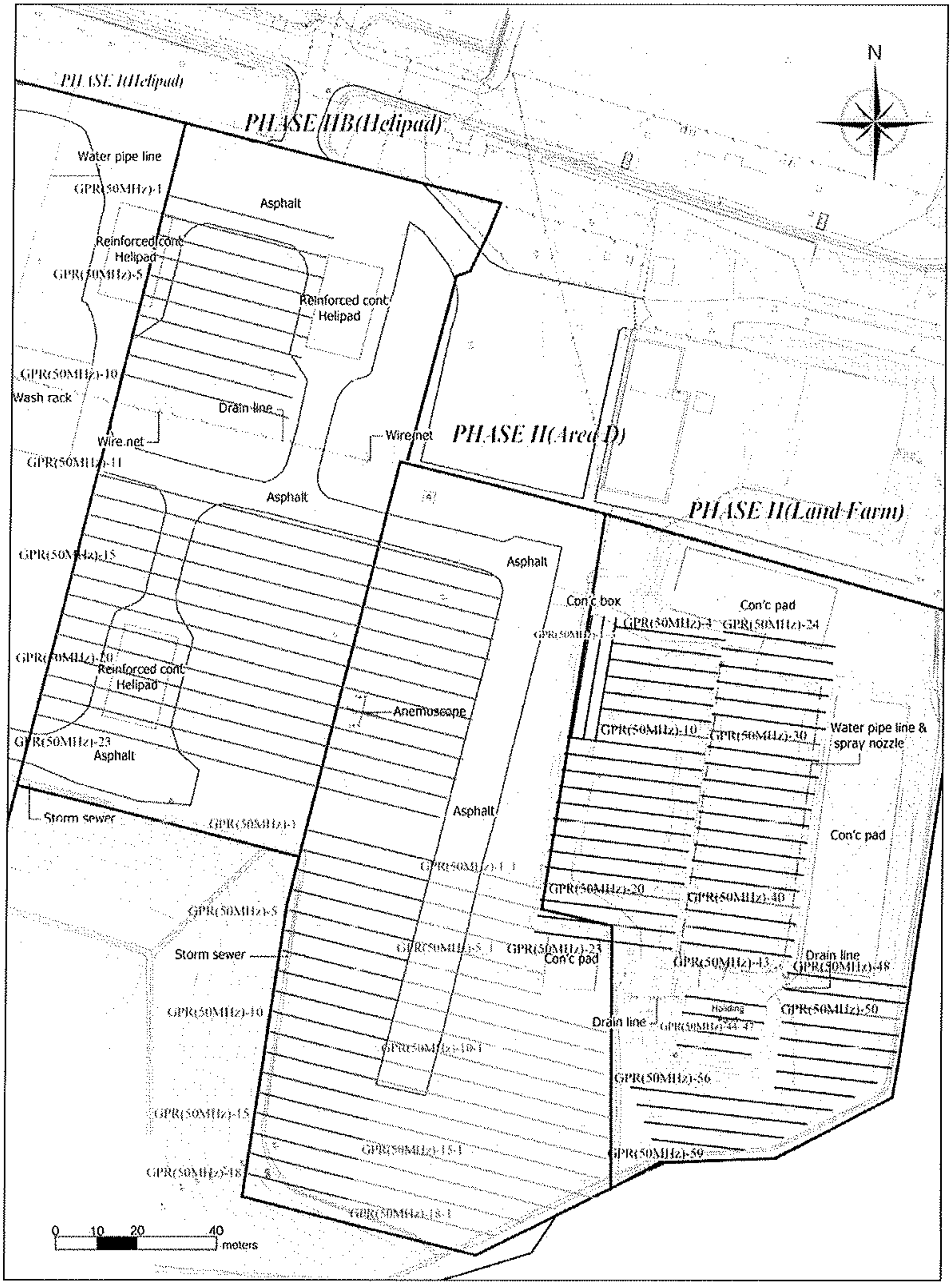

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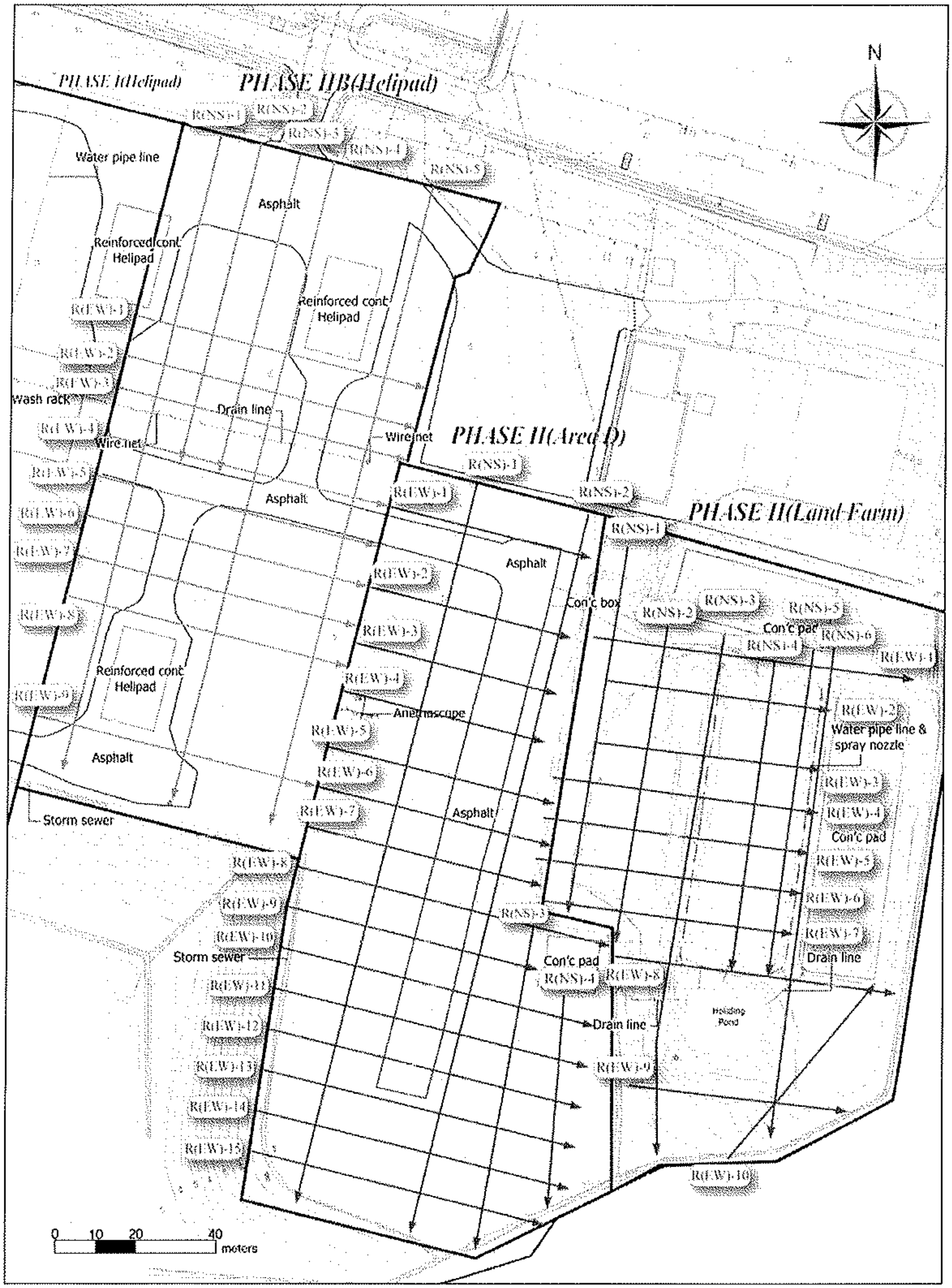
Figure 2-4. ERI Survey Transects



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3. GEOPHYSICAL SURVEY RESULTS

This section provides a brief summary of the geophysical survey results and summaries. The 2-dimentional sections from the GPR survey and vertical cross section output from the ERI survey are provided in Appendix B. Photographs documenting field survey activities are provided in Appendix C. Raw data output from the survey instruments will be provided in electronic format. The raw data files are incorporated by reference as part of this report.

3.1 Magnetic Gradiometry Result

The magnetic gradiometry survey result is presented as a single diagram on Figure 3-1. The result is summarized as follows:

- Magnetic field in the area averages in the 400 nT/m to 500 nT/m range.
- The red and green colored areas on Figure 3-1 indicate the possible presence of buried conductive materials.
- Locations with concrete cover (helipad, concrete pads), metallic objects on or above the ground surface (anemometer, utility poles), and buried metallic objects (water lines, storm and sanitary sewer lines) also present as red or green.
- There are several individual anomalies not associated with the known objects listed above. The individual anomalies are grouped into zones as shown on Figure 3-1:
    - Four for the Area D site
    - Two for the Landfarm site
    - Three for the Phase IIB Helipad site
- The depth of the anomalies is estimated to be within the first 5 m bgs.

Figure 3-1. Magnetic Gradiometry Survey Result

3.2 GPR Result

The GPR survey result using the 100 MHz input signal frequency is presented as a series of 2D vertical cross sectional radargrams. Examples of the 2D radargrams for the Area D, Landfarm and Phase IIB Helipad sites are shown on Figures 3-2 through 3-4, respectively. Complete radargrams for the survey are provided in Appendix B. The 50 MHz survey did not identify any additional subsurface anomalies.

The 2D radargrams are combined to produce plane view diagrams as shown on Figures 3-5 through 3-7. The 2D radargrams have more details and can reveal smaller objects, while the plane view diagrams provide a broader picture of the anomalies. Strong reflected signals caused by known objects (helipad, concrete pad, concrete block, anemometer, asphalt etc.) were excluded. The result is summarized as follows:

- The areas colored red indicate strong signal reflection, which could be cause by foreign objects or dense geologic strata.
- Several smaller anomalies shown as irregular red colored points had signals that indicate boulders within the soil stratum.
- Most of the anomalies that indicate the possible presence of foreign objects occurred at a depth of about 4.0 m bgs.
- The 2D radargrams showed a number of anomalies, which may be attributed to small conductive objects or rocks and boulder. The number of anomalies in each survey site is as follows:
    - 3 for the Area D site
    - 3 for the Landfarm site
    - 2 for the Phase IIB Helipad site
- The plane view diagrams indicate that subsurface anomalies are most likely attributed to geological features such as changes in stratum and bedrock.

Figure 3-2. 100 MHz GPR 2D Radargrams for Area D Site

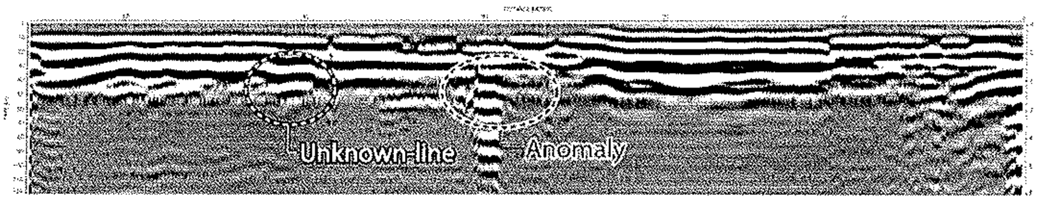
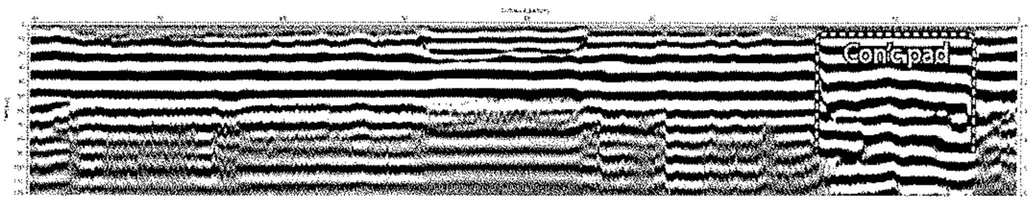
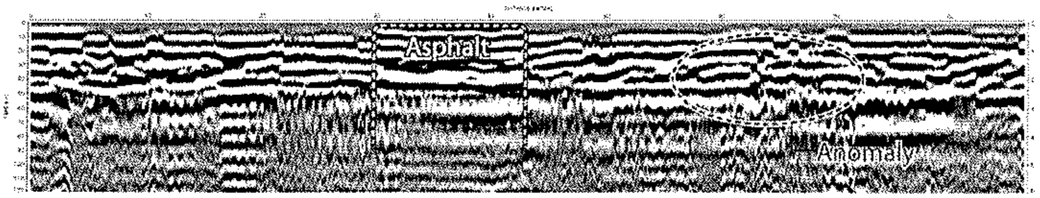
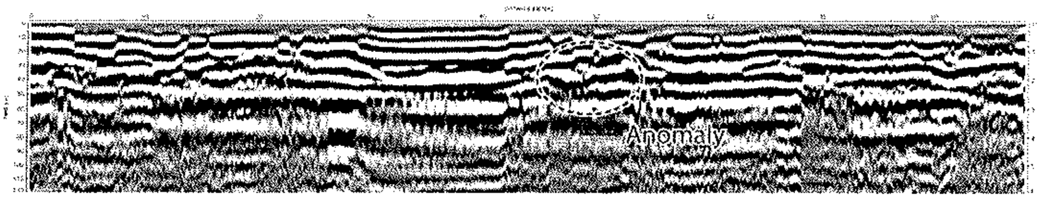
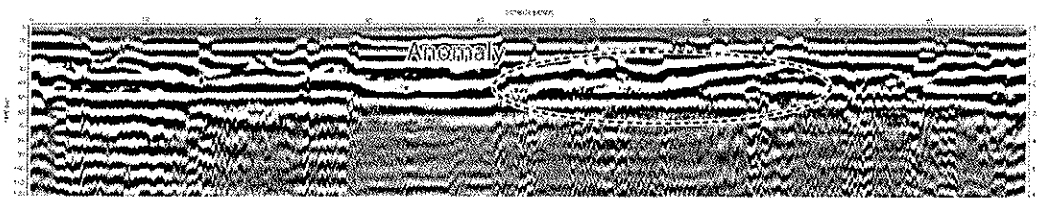
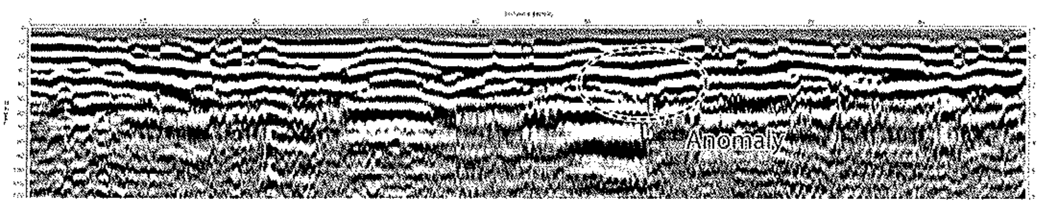
100 MHz - 22	
100 MHz - 54	
100 MHz - 67	
100 MHz - 71	
100 MHz - 73	
100 MHz - 77	

Figure 3-3. 100 MHz GPR 2D Radargrams for Landfarm Site

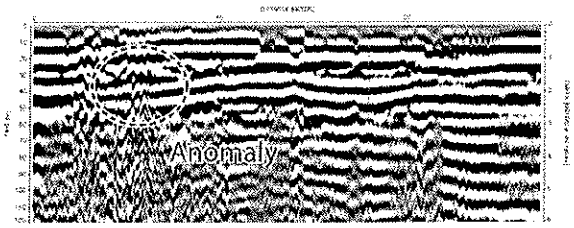
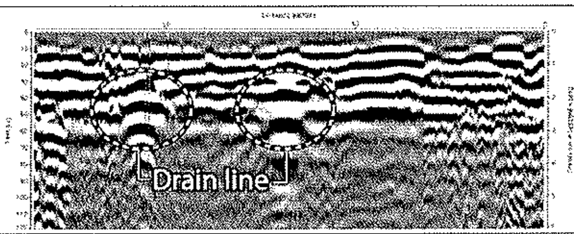
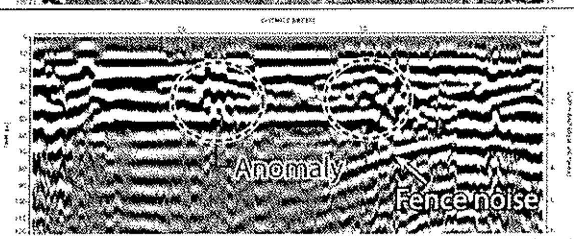
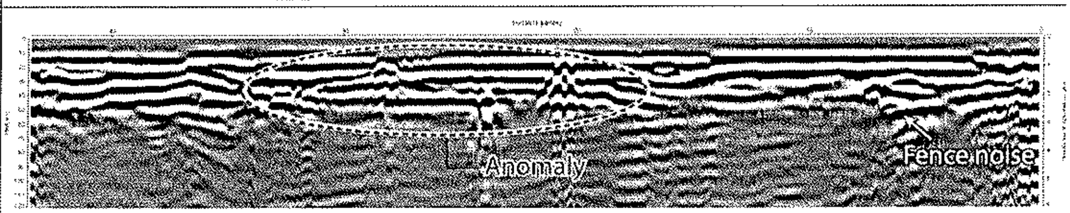
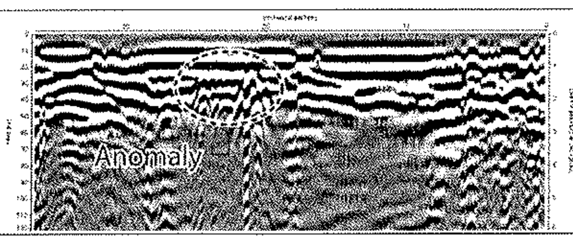
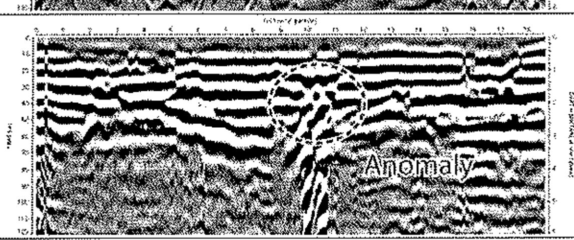
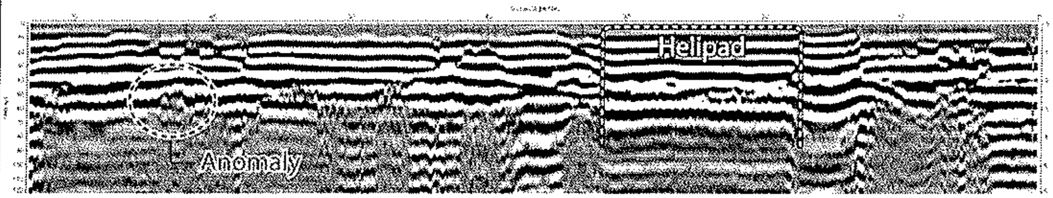
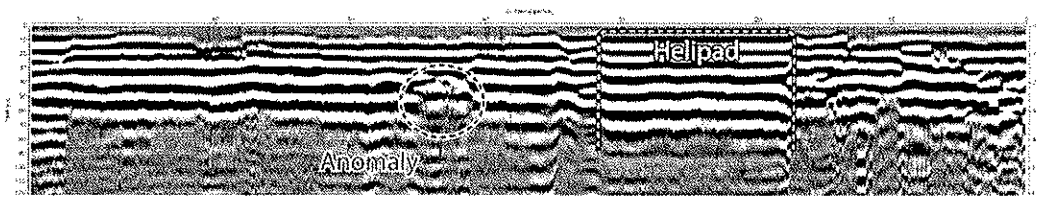
100 MHz - 84	
100 MHz - 87	
100 MHz - 101	
100 MHz - 115	
100 MHz - 117	
100 MHz - 120	

Figure 3-4. 100 MHz GPR 2D Radargrams for Helipad Site

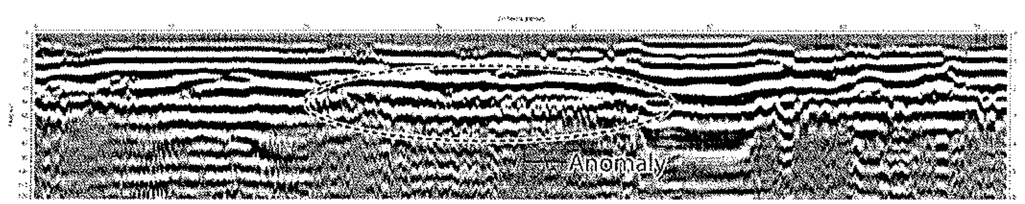
100 MHz - 18



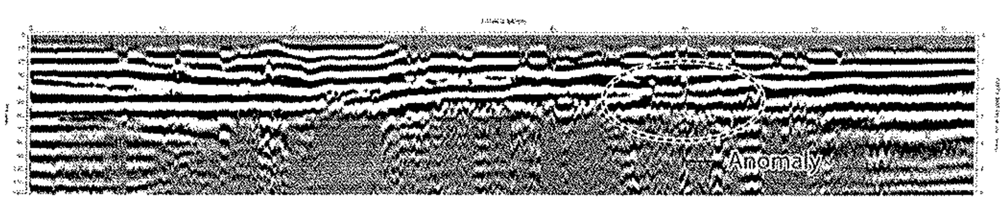
100 MHz - 22



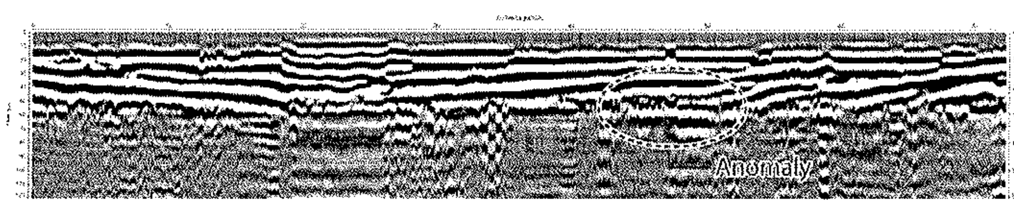
100 MHz - 39



100 MHz - 49



100 MHz - 55



100 MHz - 64

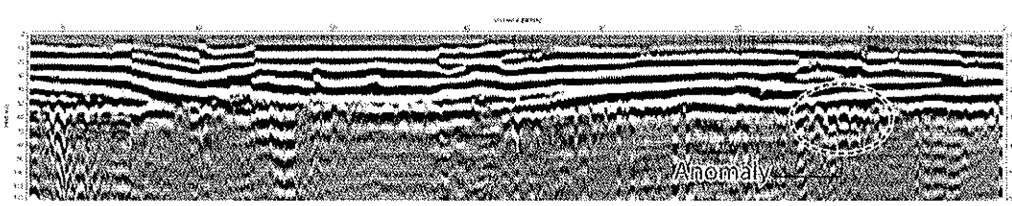


Figure 3-5. 100 MHz GPR 1.89 m to 2.51 m bgs Result

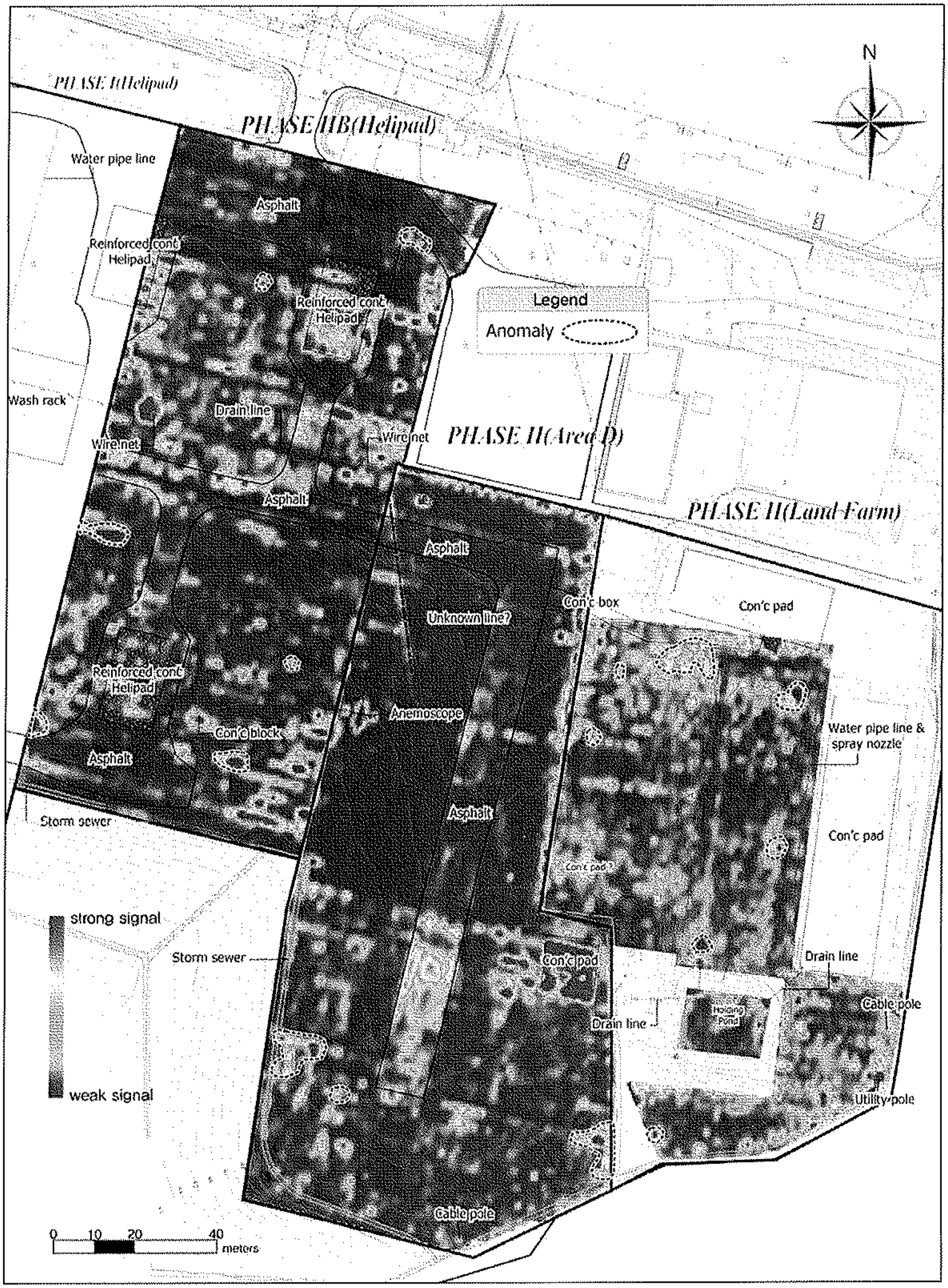


Figure 3-6. 100 MHz GPR 3.38 m to 4.06 m bgs Result

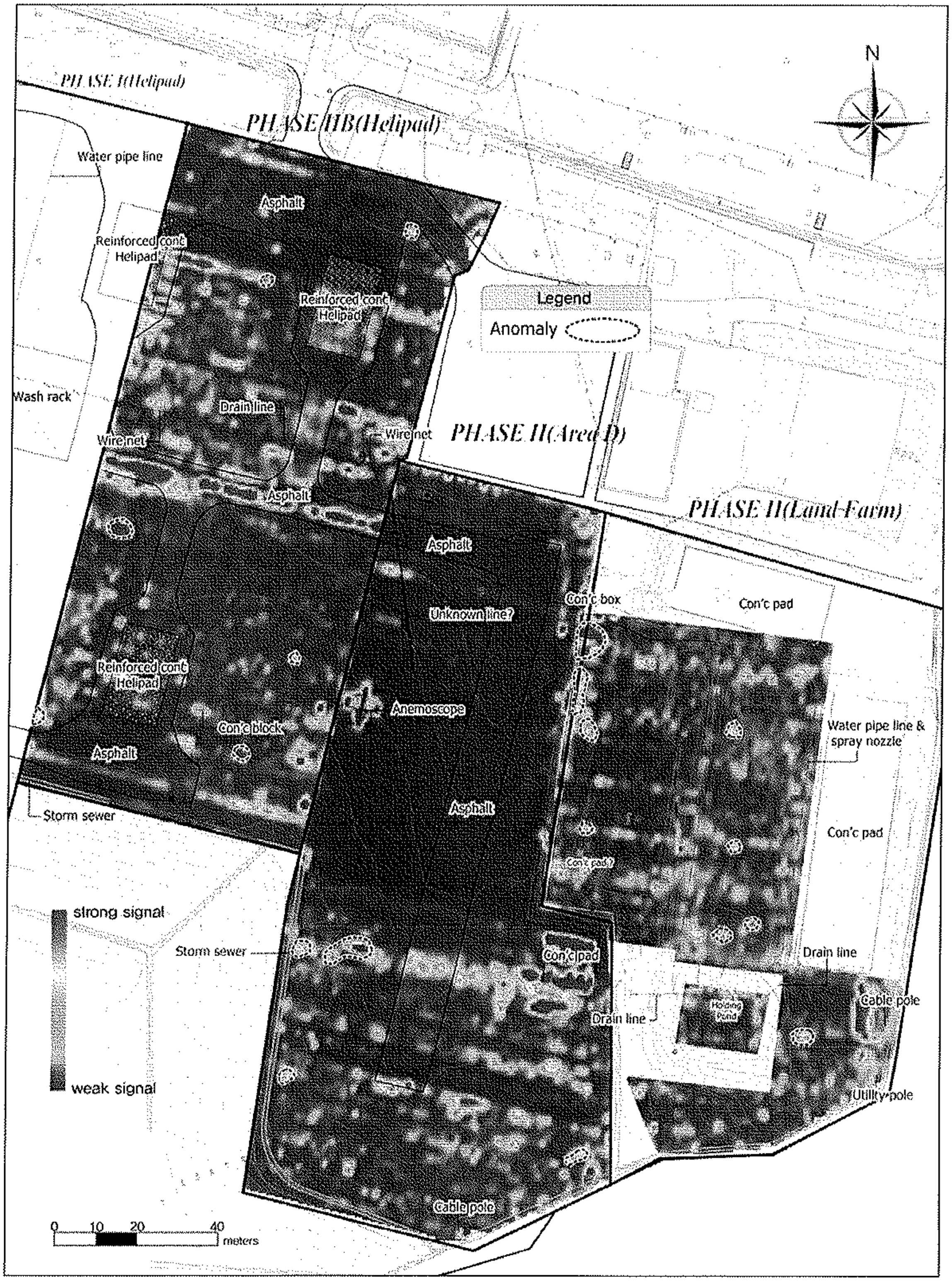


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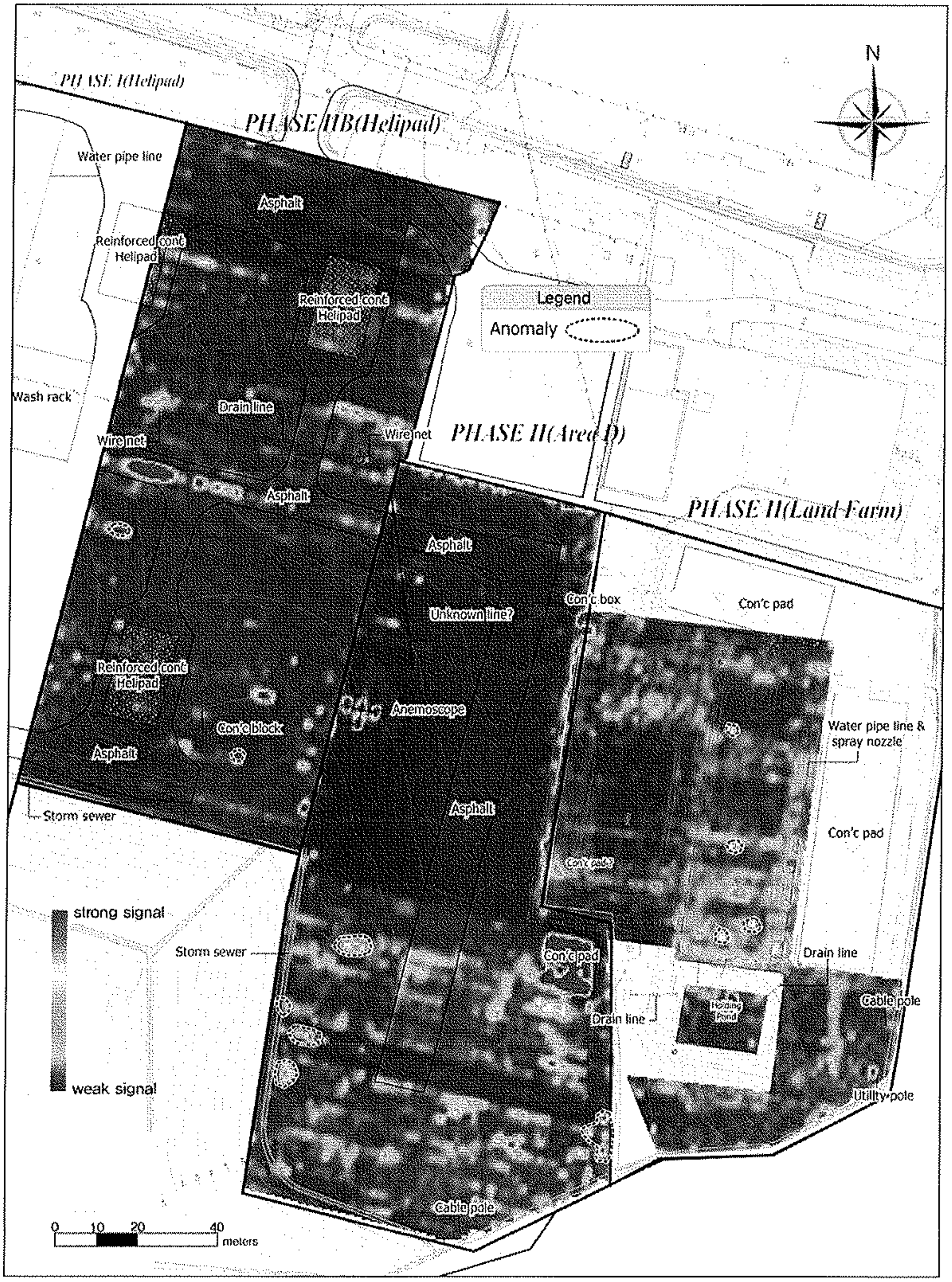
Figure 3-7. 100 MHz GPR 4.59 m to 5.63 m bgs Result

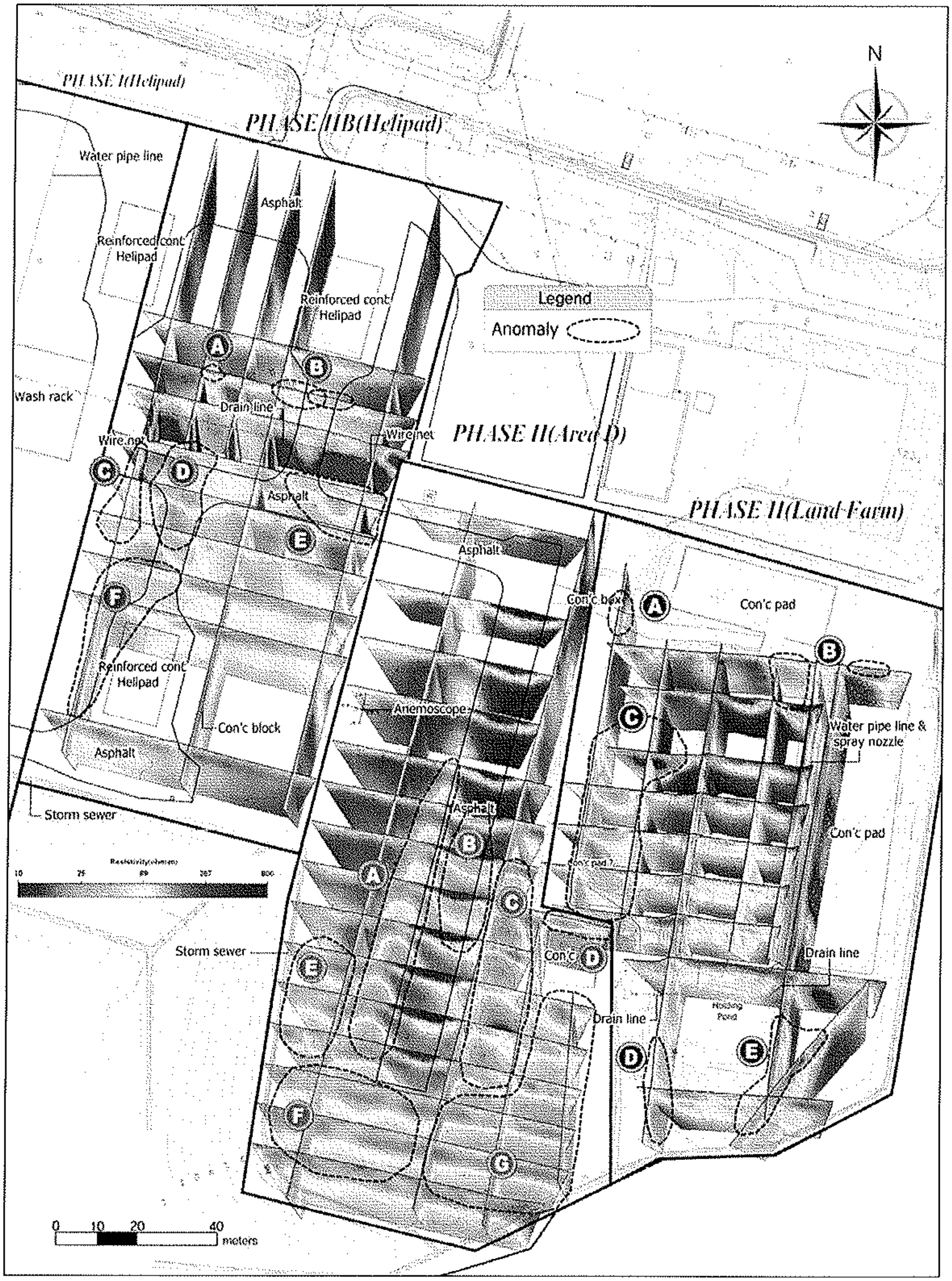


3.3 ERI Results

The ERI survey result is presented as a Fence diagram on Figure 3-8. The result is summarized as follows:

- The ground resistivity in the area ranges from about 90 ohm-m to 300 ohm-m.
- Conductive materials such as buried water pipes show low resistivity as would be expected.
- Locations with low resistivity anomalies (less than 70 ohm-m) are shown in blue and green.
- The Area D site has seven low-resistivity anomalies tentatively identified as follows:
    - Anomalies B and C occurs approximately between 2 m and 10 m bgs
    - Anomalies A, D, E, F and G occurs approximately between 4 m and 12 m bgs
- The Landfarm site has five low-resistivity anomalies tentatively identified as follows:
    - Anomalies B, C and E occurs approximately between 0.5 m and 10 m bgs
    - Anomalies A and D occurs approximately between 4 m and 12 m bgs
- The Phase IIB Helipad site has six low-resistivity anomalies tentatively identified as follows:
    - Anomalies A, C and D occurs approximately between 1 m and 5 m bgs
    - Anomalies B, E and F occurs approximately between 4 m and 12 m bgs

Figure 3-8. ERI Survey Result



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4. CONCLUSIONS

The locations where confirmed subsurface anomalies are indicated by the magnetic gradiometry, GPR and ERI surveys are shown on Figures 4-1 through 4-3. Figure 4-4 shows the results from the three survey superimposed. The anomalies identified by the ERI survey are attributed to subsurface geologic features such as changes in strata, fracture zones in the bedrock and the groundwater table. A final interpretation of the data and subsurface anomaly zones are shown on Figure 4-5. The conclusions are summarized as follows:

Phase II Area D Site

- The magnetic gradiometry survey results indicate four areas of subsurface anomalies.
- The GPR survey results indicate three subsurface anomalies, mostly towards the southern portion of the site.

Phase II Landfarm Site

- The magnetic gradiometry survey results indicate two areas of subsurface anomalies.
- The GPR survey results indicate six subsurface anomalies.

Phase IIB Helipad Site

- The magnetic gradiometry survey results indicate three areas of subsurface anomalies.
- The GPR survey results indicate six subsurface anomalies.

The combined results of the magnetic gradiometry and GPR surveys indicate 11 anomaly zones shown on Figure 4-5 where the probability for the presence of buried foreign objects are the highest. There are four such anomalies in the Area D site, three in the Landfarm site and three in the Phase IIB Helipad site. The subsurface anomalies zones may be attributed to loosely packed soils possibly indicating excavation and backfill; high liquid content, which may be indicative of recent leaks or spills; or buried foreign objects such as steel drums.

Figure 4-1. Magnetic Gradiometry Confirmed Subsurface Anomalies

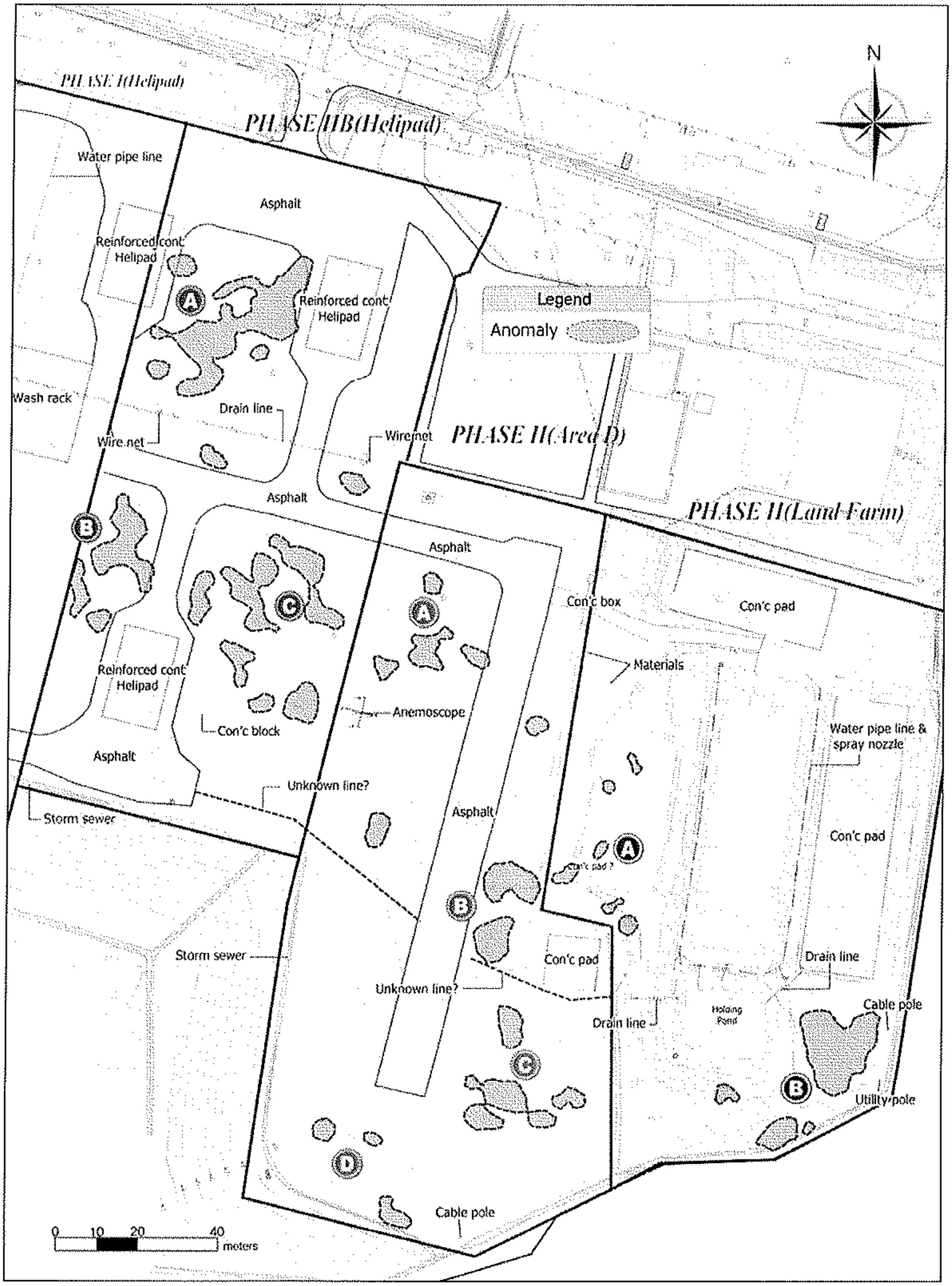


Figure 4-2. GPR Confirmed Subsurface Anomalies

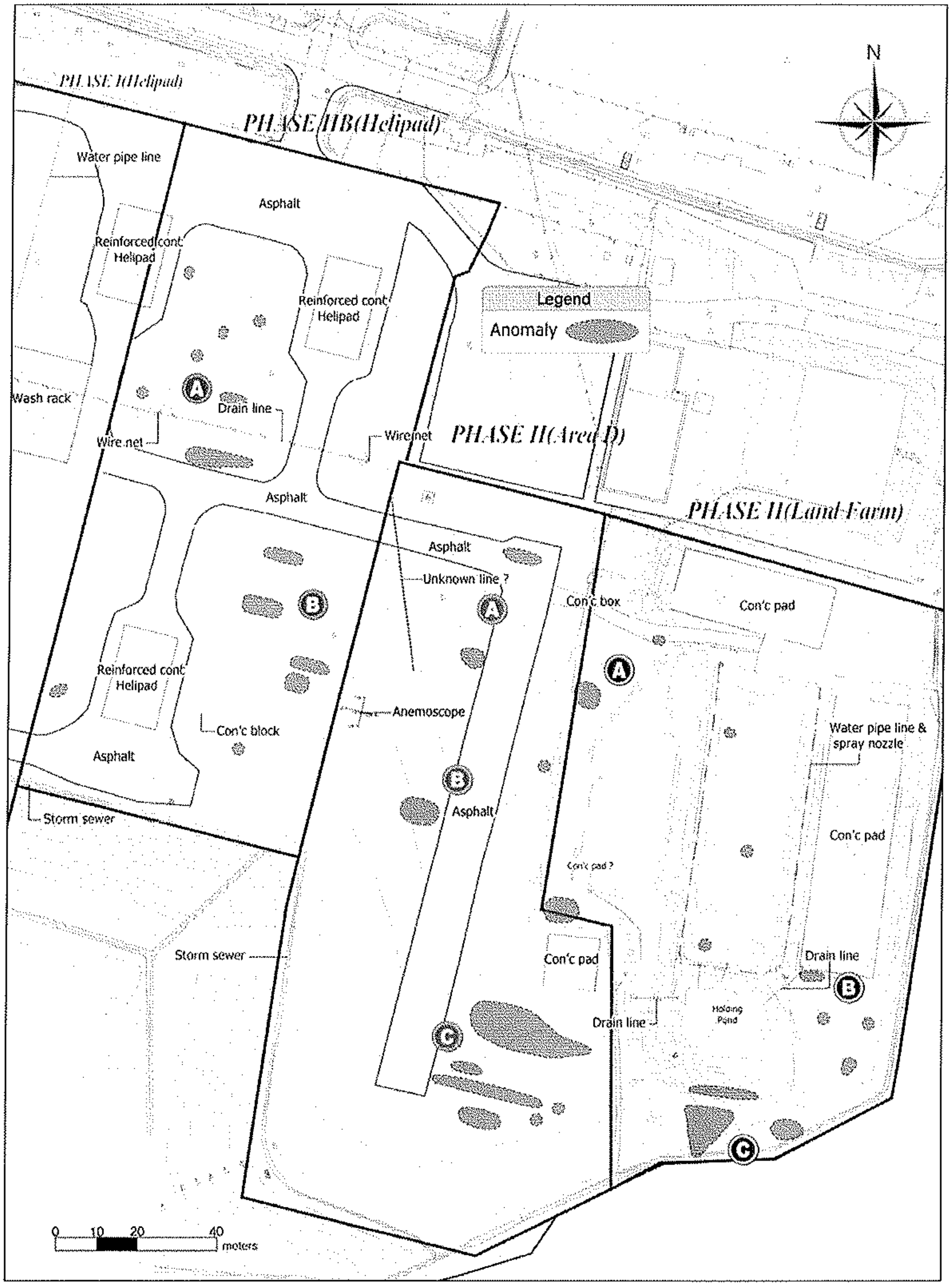
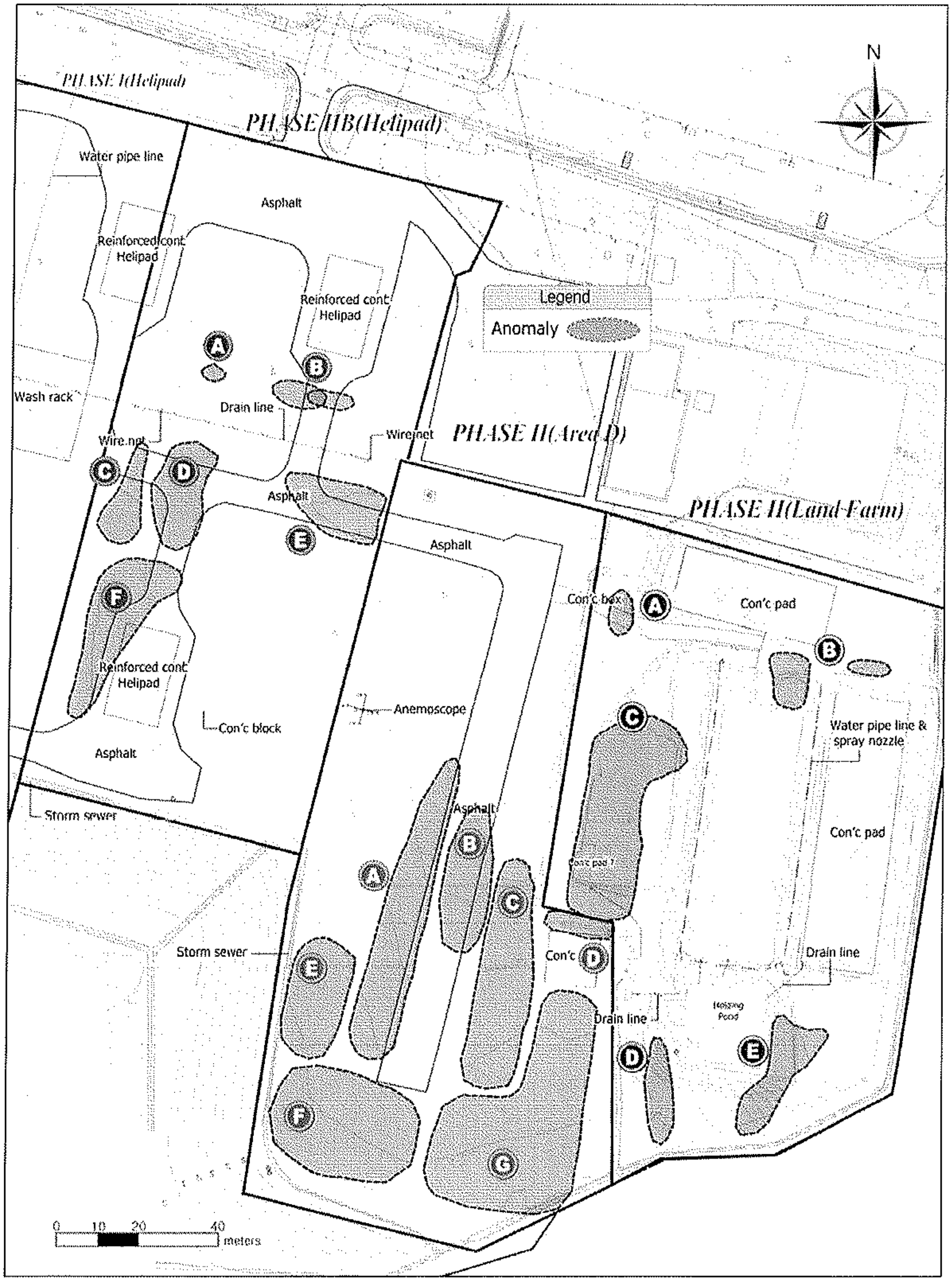


Figure 4-3. ERI Confirmed Subsurface Anomalies



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