Special Publication SJ99-SP5

FINAL REPORT

SURFACE ELECTRICAL RESISTIVITY MEASUREMENTS OF THE UPPER FLORIDAN AQUIFER IN THE TITUSVILLE AREA

SJRWMD CONTRACT NUMBER 98H321

Prepared For:

St. Johns River Water Management District
Palatka, Florida

AUGUST 1999

SDII GLOBAL

SDII Global Corporation
Main Office
7381 114th Ave. North
Suite 405B
Largo, Florida 33773
727.544.5020
Fax 727.546.6282

August 10, 1999

Dr. David Toth, P.G.
St. Johns River Water Management District
P.O. Box 1429
Palatka, FL 32178

Subject: FINAL REPORT-SURFACE ELECTRICAL RESISTIVITY MEASUREMENTS OF THE UPPER FLORIDAN AQUIFER IN THE TITUSVILLE AREA
SDII Project No. 1010997
SJRWMD Contract Number 98H321

Dear Mr. Toth:

SDII Global Corporation (SDII) is pleased to submit the final report for the above referenced project. The purpose of the investigation was to utilize surface electrical resistivity measurements to help determine the thickness of the fresh water layer within the Upper Floridan aquifer in the Titusville, Florida area.

SDII appreciates the opportunity to have assisted St. Johns River Water Management District on this project. If you have any questions or comments about the report, please contact us.

Sincerely,

SDII GLOBAL CORPORATION

Michael J. Wightman, V.P.
Florida Professional Geologist Number 1423

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

1.0 EXECUTIVE SUMMARY

An audio magnetotelluric (AMT) survey was performed at 14 sites in the Titusville area. The survey was conducted over a 3 day period in December, 1998. The AMT method is a geophysical technique, which through ground surface based measurement, enables description of the vertical distribution (one-dimensional layering) of formation electrical resistivity. Accordingly, AMT soundings provide a gross approximation of an electrical log as performed in a borehole without the significant expense of drilling, completing and logging such a borehole. In comparison of AMT soundings to electric logs, the minimum thickness of an interval that can be resolved is several orders of magnitude larger than what can be resolved by electric logs. The confidence in the conclusions from AMT findings can be increased when water quality and lithologic information from nearby wells is available.

The AMT survey was conducted at four locations in the Titusville area. At one of the locations, Bent Oak Golf Course, the objective of the survey was to determine where the thickness of the fresh water layer in the Upper Floridan aquifer is the greatest. At the other three locations, the objective was to determine the thickness of the fresh water layer in the Upper Floridan aquifer. At the Bent Oak Golf Course the maximum estimated thickness for the fresh-water saturated Upper Floridan aquifer was approximately 45 m. The calculated resistance of the freshwater layer from the AMT survey did not correlate well with the electrical log results from a nearby well. However, because of the effects of nearby sources of interference, the absolute values of the AMT-derived resistivities were not reliable.

At the Lundy Drive site, an apparent drop in apparent resistivity was observed at a depth of 50 to 60 meters. This correlates to a fresh-water saturated thickness of the Upper Floridan aquifer of 15 to 25 m. It is expected that a decline in water quality (increasing chlorides) occurs within this depth range. Similar to the Bent Oak Golf Course site, the AMT-derived resistivities for the suspected fresh-water saturated layer were lower than what would have been expected. As with the Bent Oak site, it is suspected that the absolute values of the calculated resistivities were also effected by cultural interference. At the remaining sites, Astronaut High School and Garden Street Water Treatment Plant, the AMT sounding data were not interpretable due to the effects of interference.

2.0 INTRODUCTION

2.1 Introduction

The Upper Floridan aquifer in the Titusville area contains a layer of fresh water (less than 25 mg/l chlorides) which overlies a layer of saline water with a chloride concentration in excess of 2,000 mg/l. The fresh water layer is less than 100 feet (ft) in thickness (SJRWMD, personal communication). The City of Titusville is considering the development of another well field in the surficial aquifer in the Titusville area. The confining layer between the surficial aquifer and the Floridan aquifer is either thin or absent in this region. For that reason, the City desires to locate the well field in the area where the fresh water layer in the Floridan aquifer is the thickest.

Geophysical investigations have been previously performed in the Titusville area for the purpose of characterizing the water quality within the Upper Floridan Aquifer (Blackhawk, 1991 and SDII, 1994). These investigations were conducted using Time-Domain Electromagnetics (TDEM). Results from the TDEM surveys located the depth of the interface for saline water. The TDEM surveys could not infer information on the water quality above the saline interface because this layer contained sediments above the Floridan aquifer. This investigation was conducted under the supervision of Dr. David Toth of the St. Johns River Water Management District (SJRWMD).

2.2 Purpose

The purpose of the investigation is to determine where the fresh water layer in the Upper Floridan aquifer is the thickest in the Titusville area. The investigation was performed using an audio magnetotelluric (AMT) electrical resistivity system, the Geometrics Strategem EH4.

2.3 Scope of Work

SDII implemented the following scope of work to complete this investigation:

- Mobilize to the project site and perform the AMT geophysical investigation in the four areas of the project site specified by SJRWMD personnel;

- Analyze the geophysical data to determine the presence and thickness of the fresh water layer within the Upper Floridan aqufier;

- Demobilize and prepare a final report that summarizes the geophysical methods, field procedures and results of the investigation.

2.4 Site Description

The project area consisted of four sites around or near Titusville, Florida. The four sites were at the Bent Oak Golf Course (Figure 1), near Astronaut High School and Lundy Drive (Figure 2) and near the City of Titusville water treatment plant (Figure 3). Bent Oak Golf Course is a municipal golf course that is surrounded by residential housing. A brackish surface water body is present to the west of the site area. Nine soundings (Soundings 1-9) were performed at the golf course (Figure 1).

Two soundings (Soundings 10-11) were performed at the Astronaut High School site (Figure 2). The soundings were performed in an open field north of the high school. Two soundings (Soundings 12-13) were performed at the Lundy Drive site (Figure 2). The soundings were conducted in an undeveloped field south of the drive. Residential housing was present north of the sounding locations. One sounding (Sounding 14) was performed in an open field area north of the Garden Street water treatment plant (Figure 3). Overhead powerlines were present in the vicinity of each of the four sites.

The hydrogeologic conditions in the Titusville area have previously been evaluated using surficial geophysical methods. Time domain electromagnetic (TDEM) soundings were performed in 1991 in the area of Astronaut High School site (Blackhawk, 1991) and 10.5 km south of Bent Oak Golf Course site (SDII, 1994). The approximate location of the Blackhawk (1991) TDEM Sounding is provided on Figure 2; the location of the SDII (1994) TDEM Sounding is approximately 7 km south of the Blackhawk sounding and is not shown. Results from the Blackhawk (1991) investigation indicated a two-layer model where the depth to the salt-water saturated Floridan Aquifer was 181 feet (ft) below mean sea level (msl). The layer above the saltwater saturated layer had a resistivity of 30 Ohm-meters (Ohm-m). The layer above the salt-water saturated layer contained sediments from both the Hawthorn Group and Upper Floridan aquifer. Accordingly, it was not possible to infer water quality in the Upper Floridan aquifer from the TDEM data (Blackhawk, 1991).

In the SDII (1994) investigation, a two-layer subsurface model for the TDEM data was also developed. The contact between the two layers, however, was within the sediments of the Hawthorn Group and not at the hydrostratigraphic contact between the Hawthorn Group sediments and the top of the Floridan Aquifer. Accordingly, it was not possible to infer the water quality in the Upper Floridan aquifer at the project site (SDII, 1994).

TDEM soundings were also performed at two sites (Sites 8 and 9) approximately 6 and 9 km, respectively, north of Astronaut High School (Blackhawk, 1991). The location of these soundings is not shown. Similar to the results at the TDEM sounding at Astronaut High School, a two-layer model was determined. The depth to the salt-water saturated Floridan aquifer was 168 ft below msl and 182 ft below msl for Sites 8 and 9, respectively. For both the soundings, the layer above the salt-water saturated layer contained sediments from both the Hawthorn Group and Upper Floridan aquifer. Accordingly, it was not possible to infer water quality in the Upper Floridan aquifer from the TDEM data (Blackhawk, 1991).

Electrical logs and water quality information are available from two wells which are in the vicinity of the project sites. This information was supplied by SJRWMD. As part of this investigation, a test well and BR1661 were constructed. First, a test hole was drilled to the top of the Floridan aquifer, geophysically logged and then plugged in March, 1999. Then the surficial aquifer well, BR1661, was constructed. BR1661 is 61 ft deep. . The test well and BR1661 were constructed approximately 1,500 ft southeast of Sounding 7 and 800 ft southeast of Sounding 9 (Figure 1). The 64-inch electrical (long-normal) log indicated that formation resistivity exceeded 200 Ohm-m for the upper 60 ft (18 m) and ranged from approximately 200 Ohm-m to 120 Ohm-m to the termination depth of the well at 111 ft (34 m). Depth to the top of the Floridan Aquifer was approximately 98 ft (30 m).

Monitor well BR1572 occurs in the area of the Astronaut High School site (Figure 2). Lithologic logs indicate that the limerock (likely associated with the Floridan Aquifer) occurs at an approximate depth of 114 ft below land surface (bls, 35 m). The limerock was overlain by an interbedded sequence of sand, rock and shell. Fluid resistivity logs and water quality data indicate that chloride concentrations in the ground water exceed 250 mg/l at a depth between 180 to 200 ft (55 to 61 m) bls. Formation resistivity for the fresh-water saturated limestones (based on the 64-inch electrical long-normal log) ranged from 25 to 125 Ohm-m. Geophysical logs for both the test well associated with BR1661 and BR1572 are provided as Appendix 1.

A global positioning system (GPS) was used to determine the position of each of the soundings. The GPS positions were differentially corrected to provide a sub one-meter accuracy. GPS data was collected and corrected by SJRWMD personnel. The latitude and longitude position of each of the sounding locations is provided in Table 1.

TABLE 1
SOUNDING LOCATIONS
SURFACE RESITIVITY MEASUREMENTS
TITUSVILLE AREA[1/]

Bent Oak Golf Course	Latitude	Longitude
Sounding 1	283915.460	805238.380
Sounding 2	283913.945	805233.535
Sounding 3	283915.434	805229.357
Sounding 4	283918.779	805235.510
Sounding 5	283918.494	805223.205
Sounding 6	283921.280	805218.456
Sounding 7	283923.456	805212.931
Sounding 8	283920.984	805208.209
Sounding 9	283921.393	805204.911
Astronaut High School		
Sounding 10	283735.420	805056.069
Sounding 11	283738.751	805057.254
Lundy Drive		
Sounding 12	283735.525	805044.082
Sounding 13	283734.899	805040.338
Garden Street Water Treatment Plant		
Sounding 14	283707.133	805018.467

1/ All measurements in WGS-84 datum

3.0 METHODOLOGY

3.1 Equipment and Principles

3.1.1 Magnetotellurics

The audio frequency magnetotelluric (AMT) method uses both natural and man-made electromagnetic (EM) signals to infer the electrical resistivity structure of the earth. The Geometrics Strategem EH4 (Strategem) system was used for this investigation. The Stratagem is capable of measuring the electrical resistivity of the earth in a continuous sounding from depths of a few meters to depths greater than 1 kilometer.

AMT systems are used to determine the electrical impedance of the earth's surface using a series of simultaneous measurements of local variations in the earth's magnetic (H) and electrical (E) fields. Measurements can be collected over a wide frequency range from 0.1 to 10^5 Hertz (Hz). The field measurements are collected over a period of several minutes. The field data are processed in the frequency domain using Fourier transformation. From the processing, impedance is calculated for each of the particular frequencies. The calculated impedances are then interpreted (inverted) in terms of electrical resistivity versus depth. Higher frequency data is influenced by shallow or nearby electrical features. Deeper more remote features influence lower frequency data. In field settings where rapid lateral changes in the earth's resistivity do not occur, the resistivity sounding is a reasonable estimate of the geoelectric layering of the earth (Geometrics, 1998).

Natural sources of electromagnetic fields above a frequency of 1 Hertz (Hz) are created by world-wide thunderstorm activity. Natural sources below 1 Hz are created by current systems in the magnetosphere of the earth. In the high frequency range (above 1 Hz) natural sources are typically weak and a controlled EM transmitter can be used to improve the quality of data.

The Strategem system consists of two main components; a transmitter and a receiver. The receiver acquires data over a frequency range of 100 kHz to 11.7 Hz. For this study a transmitter with a moment unit of 400 amps per m^2 was used. The transmitter has a frequency range of 400 Hz to 32 kHz. This transmitter is typically used in environments where the average resistivity is less than 500 Ohm-m. For site conditions such as those in the Titusville area, the transmitter is placed 200 to 300 meters from the receiver. The receiver consists of the Strategem console (the data acquisition device) which is attached to a set of grounded electrodes and magnetic field sensors. The electrodes are set in an "X-direction" and "Y-direction" fashion where the Y direction is 90 degrees offset from the X direction. Each set of electrodes creates an electrical dipole and a measurement of the earth's resistivity (E field) is made. Maximum dipole length is approximately 50 meters (m). Dipole lengths for this investigation were varied from 25 to 50 m because of field conditions. The magnetic field (H field) sensors are orientated in the same X and Y directions. To prevent interaction between the two magnetic sensors, they are separated by at least 2 m. Data are collected and processed using a software program called IMAGEM developed by Geometrics.

AMT surveys are most successful when they are conducted in areas away from sources of electromagnetic interference. Interference sources that are problematic can be categorized by their distance from the AMT receiver. For large active electromagnetic sources such as powerlines or grounded conductors; e.g., pipelines or metal fences, a distance of 1 kilometer (km) should be maintained. For poorly grounded passive conductors or vehicular traffic, a distance of 100 m should be maintained. For small conductive objects, a 50 m separation should be maintained. Interference effects can be partially offset by the stacking of data and in data processing. Soundings conducted for this study were closer that 1 km to overhead powerlines and adjacent to homes.

It is often possible to collect interpretable data in areas near powerlines; however, a portion of the data is often highly polarized. When the data are polarized the calculated impedance values, thereby the resistivities, are different between the X and Y measurement directions. In such instances, only one set of impedances can be used. As a result, the absolute values of the calculated resistivities are not representative of actual site conditions. However, the relative magnitudes in the changes in resistance values are often correct (Geometrics, personal communication)

3.1.2 Data Processing

Data are first analyzed by a review of the time-series data and the associated Fourier transform for each particular frequency. Bad time-series data points, which have been obviously effected by interference sources, are removed. A poor coherency between E and H fields for a particular direction and/or a poor phase relationship between the E and H fields for the two different directions indicate such interference. An example of a good phase and coherancy relationship in which the X and Y direction values are very similar is shown on Figure 4 between the approximate frequency range of 200 to 30,000 Hz. An example of a poor phase and coherancy relationship is shown on Figure 5 in which there is a wide divergence in X and Y values below a frequency of approximately 1000 Hz.

Results from the time-series data is then used to calculate the scalar or tensor apparent resistivity, impedance, phase and coherency as a function of frequency. Scalar resistivity is calculated from the impedance value determined in either the X or Y direction. The tensor resistivity is calculated from both the X and Y direction. The tensor-derived resistivity is the more accurate resistivity measurement. Resistivity values are only calculated to a depth at which pre-selected coherency cutoff criteria are met.

An example of such output is provided in Figure 4. The impedance results are reviewed and calculated resistivity values for particular frequencies are re-evaluated for possible removal from the dataset. As a general rule, individual resistivity values developed from a particular frequency are removed if they differ greatly from the resistivity trend for the remainder of the data set. Resistivity values that have a poor coherency relationship between the X and Y directions are generally considered suspect. Any change in resistivity values that occur on a trend line with a slope greater than 45 degrees are generally considered invalid. Data sets that are in part or completely scattered or show no hydrogeologically-reasonable trends between resistivity values and depth are considered to be severely effected by interference and are considered non-interpretable. In cases where the data sets are polarized there is often a significant difference in the resistivity values for a particular depth between the X and Y directions. In such cases, the X or Y direction data set which provides the most hydrogeologically reasonable trend is used. For example, in Figure 4 the true resistivity values computed for the Y direction show a more hydrogeologically reasonable trend than the data set for the X direction and therefore would be used.

An example of a poor quality, but interpretable, data set is provided as Figure 5. Due to the data values in the X and Y direction being polarized, the data set could only be interpreted as scaler rather than the tensor resistivity values. Referencing Figure 5, scaler resistivity values determined for frequencies less that approximately 1,000 Hertz are highly scattered and considered unusable. The associated phase and coherancy relationships between the X and Y directions for these frequencies are also poor. The poor relationship is indicated by the divergence of both the values in the X and Y directions. The calculated true resistivity values are considered interpretable to an approximate depth of 100 m. Values below 100 m are highly scattered and cannot be interpreted by any reasonable hydrogeologic model. Several points at a depth of approximately 10 to 20 m are also highly scattered likely due to a source of high-frequency interference.

Calculated true resistivities from a depth of approximately 10 to 50-60 m show a generalized trend with a near-surface resistance ranging from approximately 60 to 100 Ohm-m. A decrease in true resistivity appears to occur at an approximate depth of 50 to 60 m. The observed decrease in resistivity beginning at a depth of approximately 50 m is better defined in the Y direction than in the X direction. This is indicative of the data set being polarized. Accordingly, relative changes in the magnitude of the resistivity values with depth are likely correct, however, the absolute value of the resistivity values are not reliable. A hydrogeological interpretation of such a change, would be that the ground water at this depth is becoming less resistive (brackish).

3.2 Field Procedures

The geophysical investigation was conducted over a three-day period from December 1-3, 1998. Mr. Michael J. Wightman, P.G. (Senior Geophysicist) and an SDII field technician conducted the investigation. Technical field assistance was provided by Mr. Jeff Johnston (Geometrics).

A total of nine soundings were performed at Bent Oaks Golf Course (Figure 2). The soundings were spaced on an average 150 m apart and trended in a general east/west direction. The soundings were positioned as to provide a profile of the fresh/salt water interface eastward from the brackish surface water body west of Sounding 1. The soundings were positioned as far away as possible from sources of observable interference. Sources of interference included;

homes, overhead powerlines, electrical wires for the golf course irrigation system and aeration pumps (for the golf course ponds). A conventional utility locator was used to locate buried electrical lines.

Two soundings were performed in an open area north of Astronaut High School. The soundings were positioned as far as possible from observable sources of interference, which consisted of buildings, overhead powerlines and underground pipelines.

Two soundings were performed at the Lundy Drive site. The soundings were located in a field that was south of the residences along the drive. Soundings were positioned to be as far away from the sources of interference (homes and overhead powerlines) as possible.

One sounding was performed at the Garden Street water treatment plant site. The sounding was performed in an open field north of the plant. Sources of interference included overhead powerlines and a municipal water well. The municipal water was not operating at the time of the sounding.

4.0 RESULTS

4.1 Bent Oak Golf Course

A cross-sectional representation of the results from the Bent Oak Golf Course is presented as Figure 6. The sounding results from soundings 1, 4, 3, 5, 6 and 7 were used for the cross-section. The impedance results from the soundings used in the cross-section are presented as Appendices 1-6. Each of the data sets appeared to be impacted from the effect of a highly-polarized source of cultural interference. It is suspected that this highly-polarized source was the multiple sets of overhead powerlines in the site area. Because of the polarization, there was a significant divergence in the calculated resistance between the X and Y directions over a range of the frequencies. The X or Y data set that appeared to be least impacted by cultural interference was used in the development of the cross-sections. The data from soundings 2, 8 and 9 were too severely impacted by the effect of cultural interference to be interpretable.

For each of the interpreted soundings, resistivity decreases with depth. For soundings 1, 4, 3, 5 the maximum resistance was in the range of 20 to 30 Ohm-m. Minimum resistances were in the range of 5 to 10 Ohm-m. The maximum resistance values were within the upper 5 to 10 m and for graphical presentation purposes are not shown on the Figure 6 cross section. For soundings 6 and 7 maximum resistances were in the range of 40 to 80 Ohm-m. Resistances decreased with depth to a minimum level of 2-5 Ohm-m.

Based on the results from the cross section, it appears that resistivity at depth increases significantly between sounding stations 5 and 6. Accordingly, it is expected that water quality would improve in the areas east of this point. Maximum thickness of fresh-water saturated sediments is estimated at 75 m. Based on a depth of 30 m to the top of the Upper Floridan aquifer, the estimated thickness for a fresh-water saturated Upper-Floridan aquifer is 45 m.

The calculated resistivity from the AMT survey for the suspected fresh-water saturated limestones of the Floridan Aquifer ranged from 30 to 80 Ohm-m. These values correlate somewhat to the electrical log results from BR-1572 (approximately 10.5 km south of the site) where the resistances ranged from 25 to 125 Ohm-m. The values also correlate reasonably well to the results from the Blackhawk (1991) TDEM sounding at Astronaut High School (approximately 3.5 km south of the site) where the layer above the saltwater-saturated Floridan Aquifer was 30-Ohm-m.

The AMT survey results for the upper 34 m do not correlate well with the electrical log results from the test well associated with BR1661 east of the site. However, because the AMT-calculated resistivities were developed from the impedances in only one direction, the absolute value of the resistivities are not reliable.

4.2 Astronaut High School

The AMT sounding data (Soundings 10 and 11) at the Astronaut High School Site were non-interpretable due to cultural interference.

4.3 Lundy Drive

The impedance results of AMT Sounding 13 are presented as Appendix 7. An apparent drop in resistivity from 60 to 100 Ohm-meter occurs at a depth range of 50 to 60 m (164 to 197 ft) bls. It is expected that a decline in water quality (increase in chlorides) occurs within this depth range. Based on the survey results, the estimated thickness of fresh water in the Upper Floridan aquifer in this area is 15 to 25 m. The resistance of the suspected freshwater-saturated layer was in the range of 60 to 80 Ohm-m. For the same reasons discussed in Section 3.1, the absolute values of the resistivities are not reliable. The Sounding 12 data was non-interpretable due to cultural interference.

4.4 Garden Street Water Treatment Plant

The AMT sounding data (Sounding 14) at the Garden Street Water Treatment Plant Site were non-interpretable due to cultural interference.

5.0 CONCLUSIONS

An AMT survey was performed at 14 sites in the Titusville area in December, 1998. The principle findings of the survey can be summarized as follows:

AMT is a geophysical method which can be used to estimate the vertical variation or resistivity of subsurface hydrostratigraphic units. Translating the geophysical measurement of electrical resistivity into a model of hydrostratigraphy depends upon a comparison to other available subsurface information and an application of qualitative and quantitative relationships to infer water quality information.

The AMT survey successfully identified the depth to saline water at two of the four surveyed sites. The estimated depth to saline saturated sediments at the Bent Oak Golf Course was approximately 75 m. This correlates to a thickness for a fresh-water saturated Upper Floridan Water of 45 m. Quality appears to improve from the west (where a brackish surface water body is present to the west of the survey area) to the east. The estimated depth to saline water at the Lundy Drive site was 50 to 60 m. This correlates to a thickness for a fresh-water saturated Upper Floridan Water of 15-25 m. The AMT data collected at the Astronaut High School and Garden Street Water Treatment Plant sites was non-interpretable due to the effect of cultural interference.

The AMT method is susceptible to the effects of cultural interference. Depending upon the nature of the interference source, the relative changes in resistivity with depth may be correct but the absolute value of the resistance values may not be reliable. This is suspected to have occurred at two sites (Bent Oak Golf Course and Lundy Drive) where the AMT method successfully determined the depth to the saline water within the Upper Floridan aquifer.

6.0 LIMITATIONS

The geophysical assessment of this site is based on our professional evaluation of the geophysical data gathered and our experience with the properties of audio-magnetotellurics in the geological setting of the site area. The geophysical evaluation rendered in this report meets the standards of care of our profession. No other warranty or representation, either expressed or implied, is included or intended.

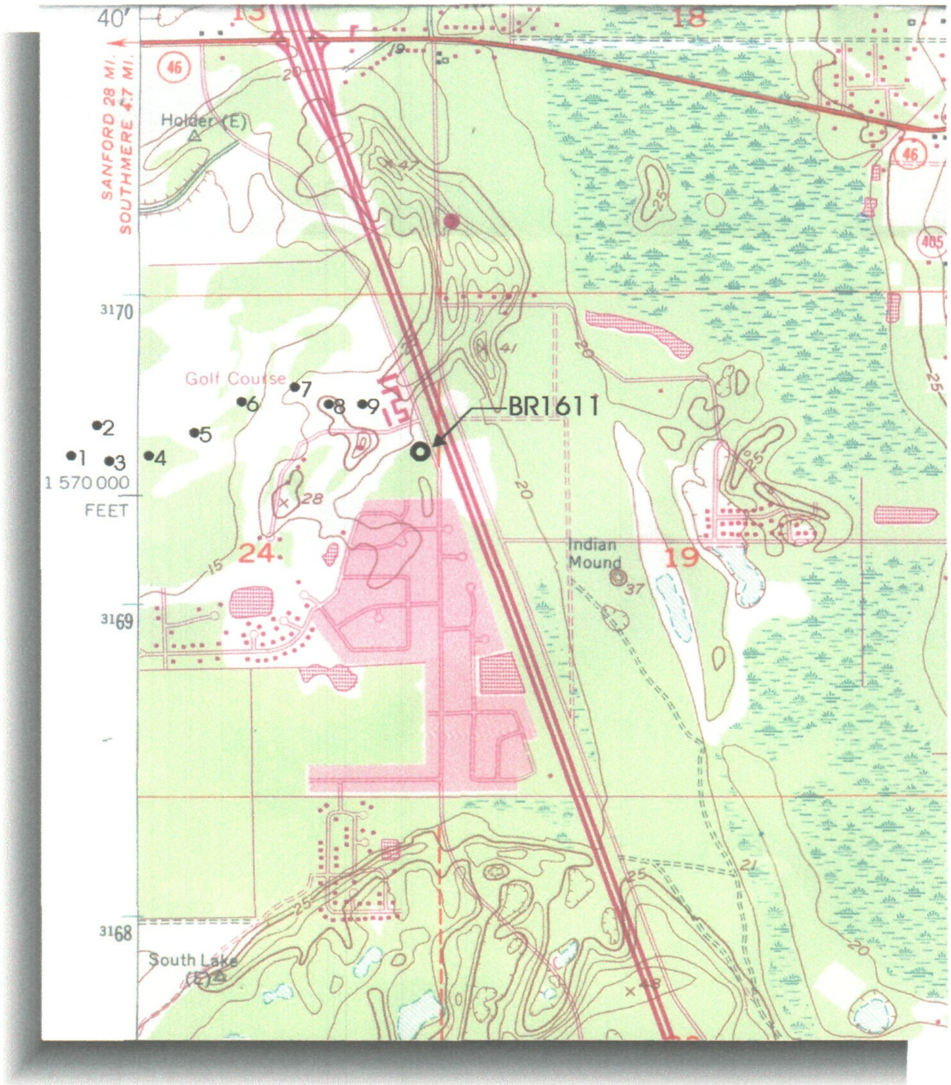
7.0 REFERENCES

Blackhawk Geosciences, Inc., 1991. Time Domain Electromagnetic Measurements East-Central Florida, December 1991: St. Johns River Water Management District Special Publication, SJ92-SP5, Palatka, Florida.

Subsurface Detection Investigations, Inc., 1994. Time Domain Electromagnetic Mapping of Slat Water in the Floridan Aquifer in Northeast & East-Central Florida, St. Johns Water Management District, October, 1994: St. Johns River Water Management District Special Publication SJ94-SP8, Palatka, Florida.

Geometrics, Inc., 1998. Operation Manual of Stratagem Systems Running IMAGEM Version 2.15, January, 1998

FIGURES



APPROXIMATE SCALE
1 INCH = 2000 FEET

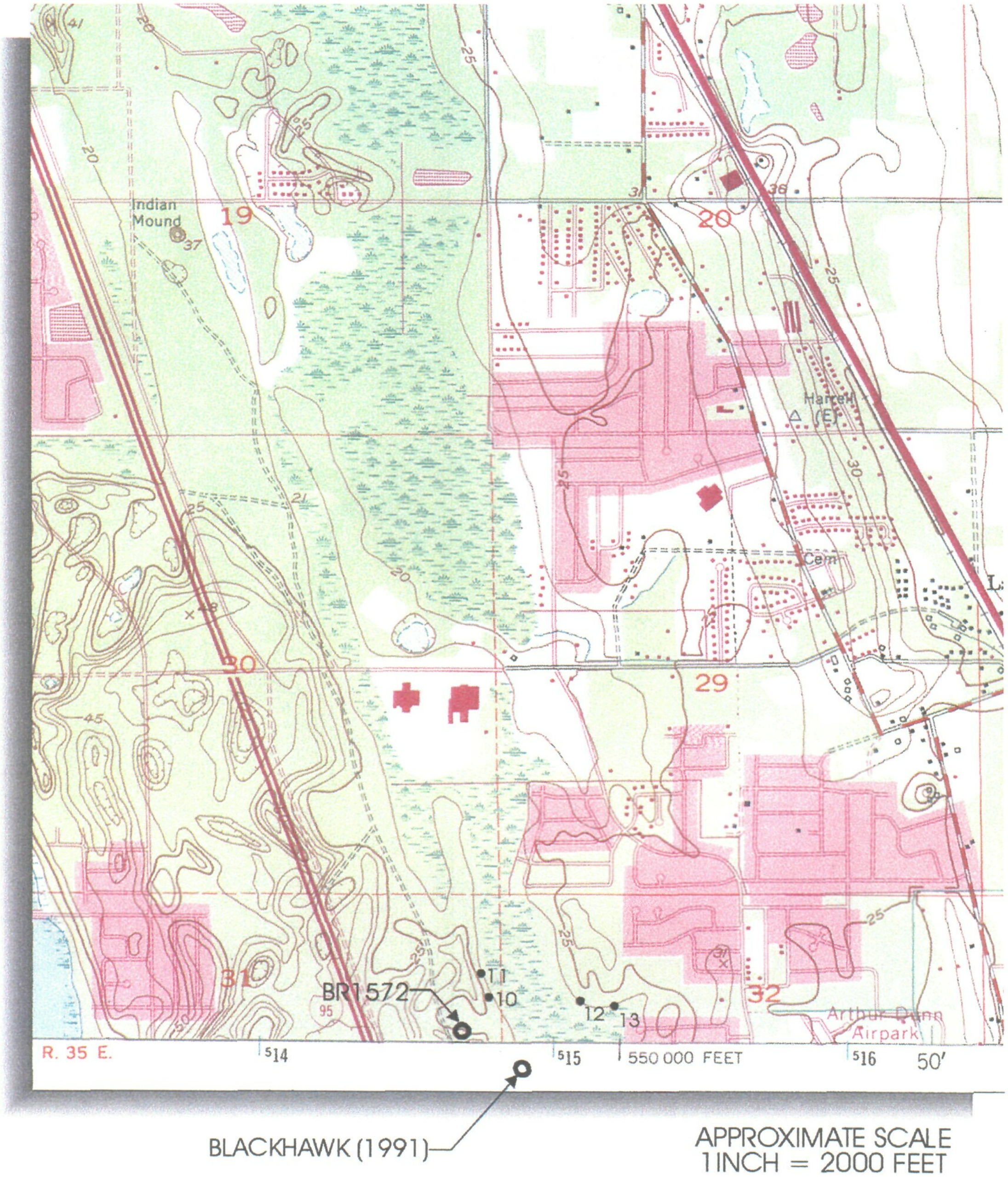
EXPLANATION

● 1 APPROXIMATE LOCATION OF ELECTRICAL RESISTIVITY MEASUREMENT (WITH DESIGNATION)

○ APPROXIMATE LOCATION OF OTHER FEATURE

FROM USGS MIMS QUADRANGLE, PHOTOREVISED 1976

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SITE PLAN SHOWING LOCATION OF AMT SOUNDINGS BENT OAK GOLF COURSE SITE TITUSVILLE AREA, FLORIDA			
	DESIGNED BY: MJW	PROJECT NO.: 1010997	FIGURE	
	CHECKED BY: MJW	DRAWING NO.: 0997-1	1	
	DRAWN BY: SAB	DATE: 05/11/99		



APPROXIMATE SCALE
1INCH = 2000 FEET

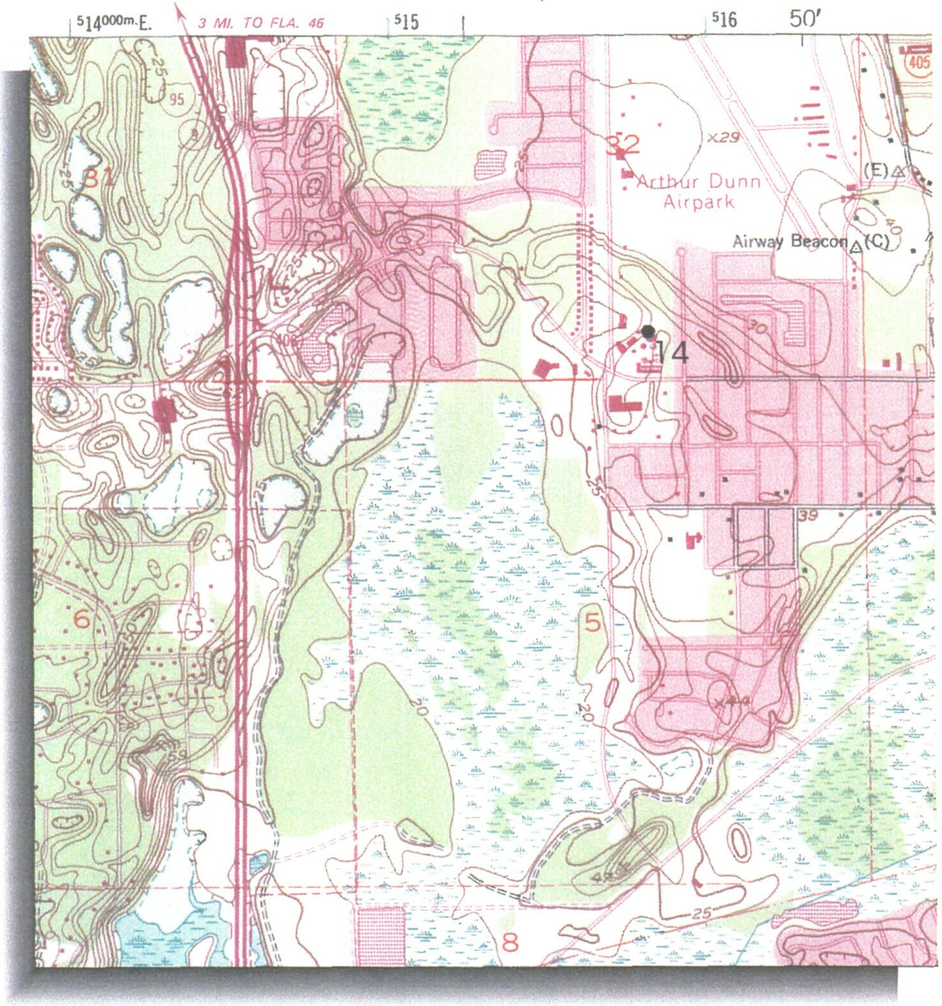
EXPLANATION

●11 APPROXIMATE LOCATION OF ELECTRICAL RESISTIVITY MEASUREMENT (WITH DESIGNATION)

O APPROXIMATE LOCATION OF OTHER FEATURE

FROM USGS MIMS QUADRANGLE, PHOTOREVISED 1976

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII GLOBAL	SITE PLAN SHOWING LOCATION OF AMT SOUNDINGS ASTRONAUT HIGH SCHOOL & LUNDY DRIVE SITES TITUSVILLE AREA, FLORIDA			
		DESIGNED BY: MJW	PROJECT NO.: 1010997	FIGURE	
		CHECKED BY: MJW	DRAWING NO.: 0997-1	2	
		DRAWN BY: SAB	DATE: 05/11/99		



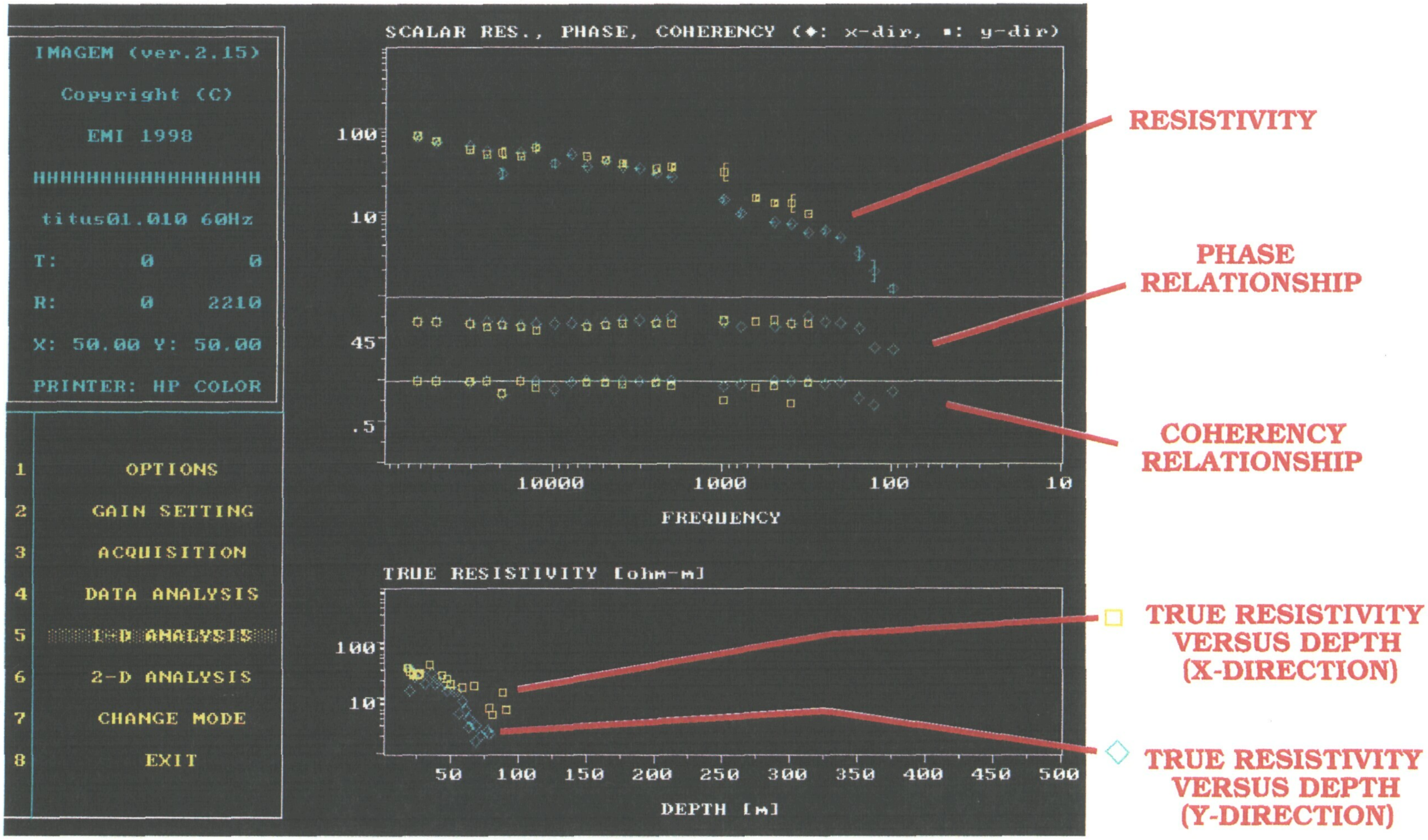
APPROXIMATE SCALE
1 INCH = 2000 FEET

EXPLANATION

• 14 APPROXIMATE LOCATION OF ELECTRICAL RESISTIVITY MEASUREMENT (WITH DESIGNATION)

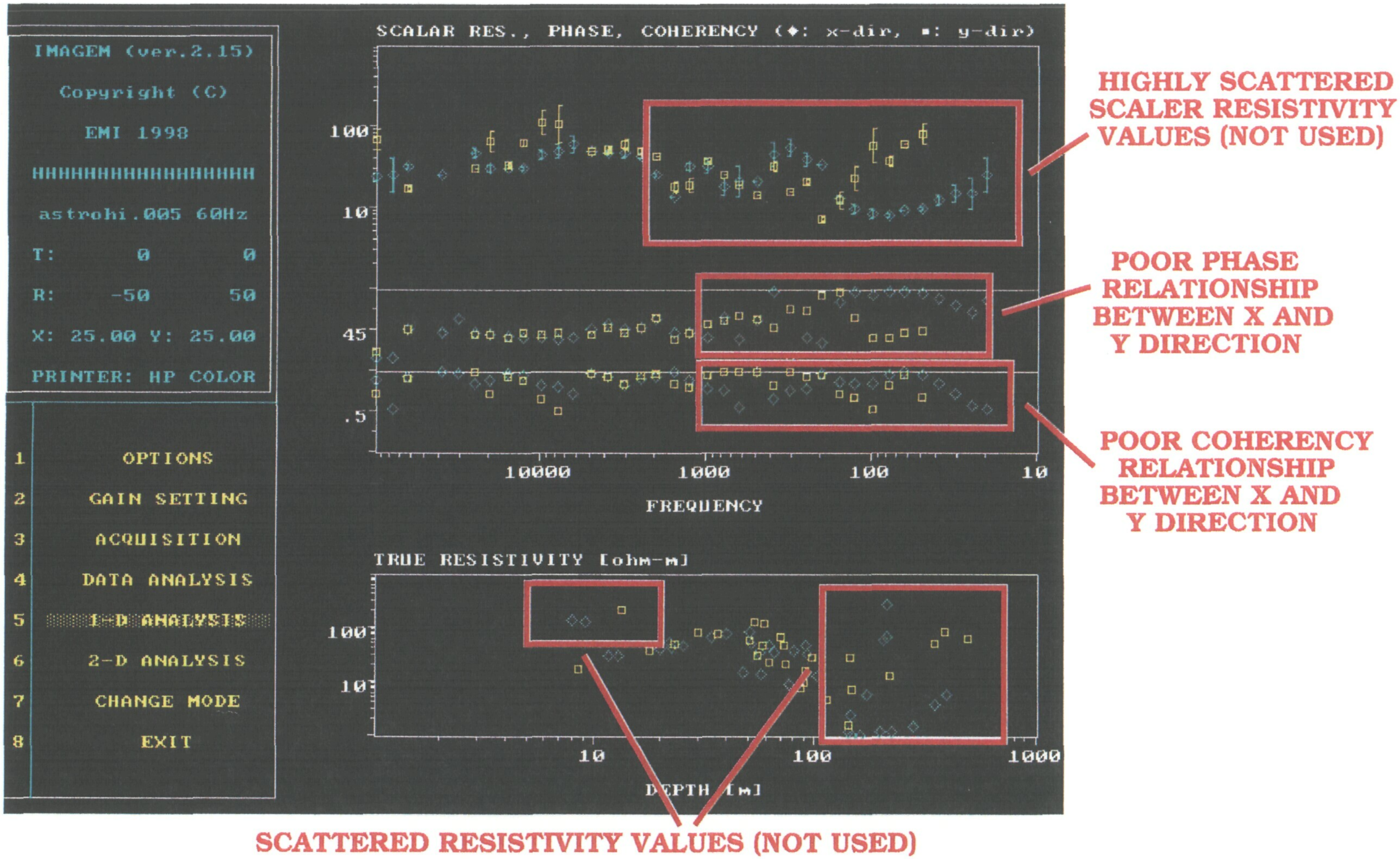
FROM USGS TITUSVILLE QUADRANGLE, PHOTOREVISED 1988

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII GLOBAL	SITE PLAN SHOWING LOCATION OF AMT SOUNDING GORDON STREET WATER TREATMENT PLANT SITE TITUSVILLE, FLORIDA				
		DESIGNED BY:	MJW	PROJECT NO.:	1010997	FIGURE
		CHECKED BY:	MJW	DRAWING NO.:	0997-3	3
		DRAWN BY:	SAB	DATE:	05/11/99	

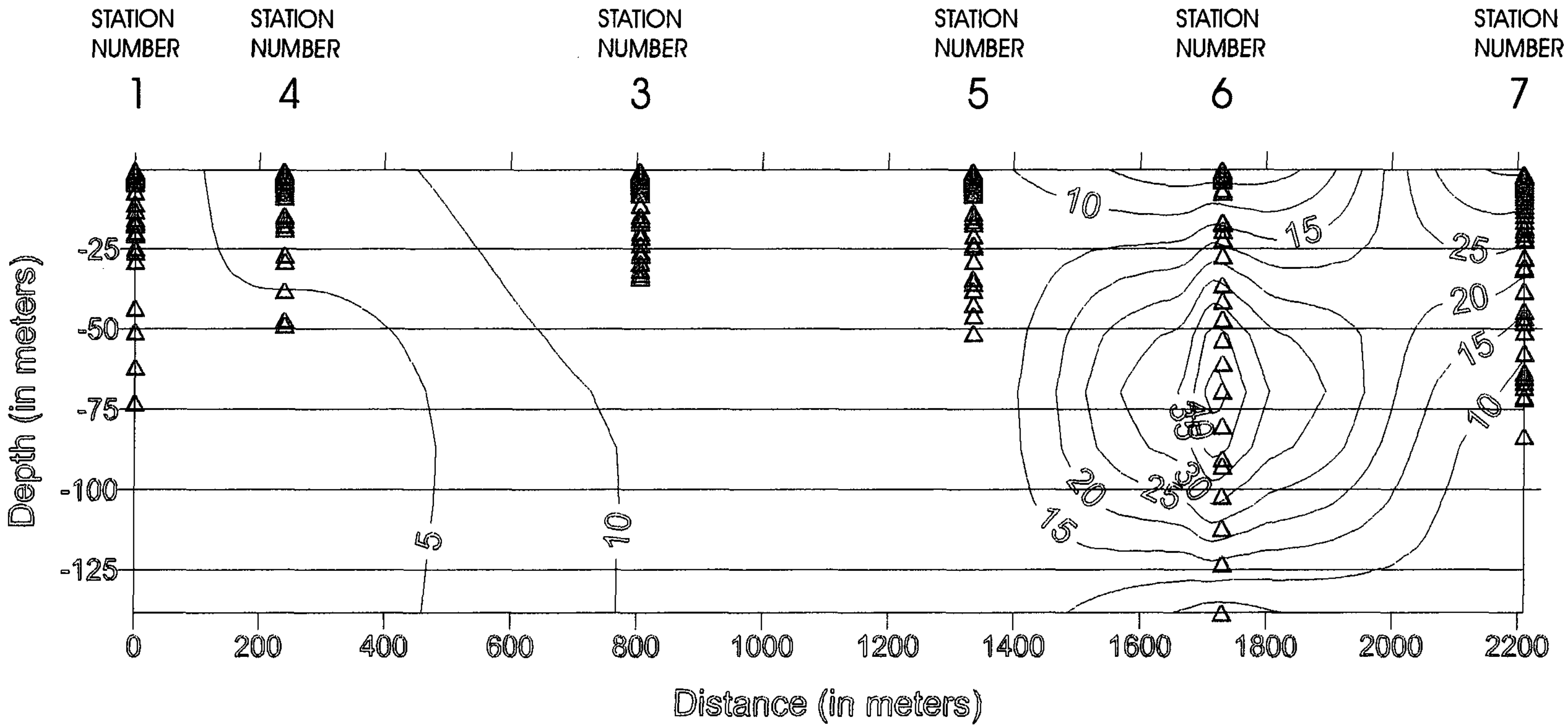


ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	GLOBAL	SAMPLE AMT DATA SHOWING IMPEDENCE RESULTS TITUSVILLE AREA, FLORIDA

DESIGNED BY:	MJW	PROJECT NO.:	1010997	FIGURE
CHECKED BY:	MJW	DRAWING NO.:	0997-4	4
DRAWN BY:	SAB	DATE:	05/12/99	



ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII GLOBAL	SAMPLE AMT DATA SHOWING IMPACT OF INTERFERENCE TITUSVILLE AREA, FLORIDA			
		DESIGNED BY: MJW	PROJECT NO.: 1010997	FIGURE	
		CHECKED BY: MJW	DRAWING NO.: 0997-5	5	
		DRAWN BY: SAB	DATE: 05/12/99		



EXPLANATION

RESISTIVITY CONTOUR (IN OHM-M)

POINT OF CALCULATED RESISTIVITY

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII GLOBAL	GEO-ELECTRICAL CROSS-SECTION BENT OAKS GOLF COURSE SITE TITUSVILLE AREA, FLORIDA

DESIGNED BY:	MJW	PROJECT NO.:	1010997	FIGURE
CHECKED BY:	MJW	DRAWING NO.:	0997-6	6
DRAWN BY:	SAB	DATE:	05/12/99	

APPENDICES

APPENDIX 1

Geophysical Logs for Test Hole at BR1661 and BR1572

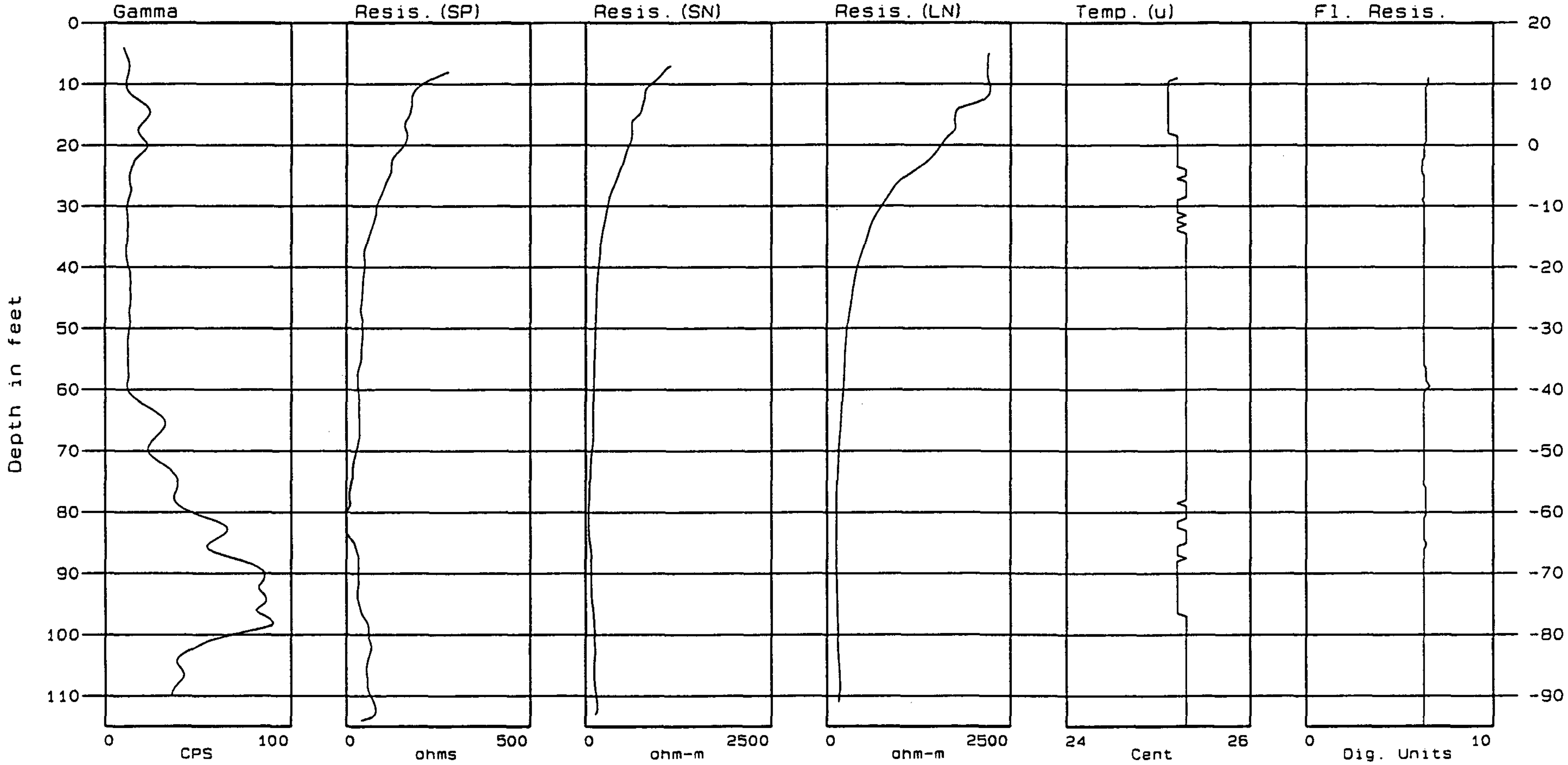
GEOPHYSICAL LOGS FOR WELL BR1661

Log Source: St. Johns River Water Management District

Station Name:	County: BREVARD	Date Logged:
Well ID: BR1661	Latitude: 28D 39M 15S	Depth Logged: 115 ft.
FGS ID:	Longitude: 80D 51M 58S	Cased Depth:
Other ID:	Elevation: 20 ft.	Water Level: ft.
Owner:	Topo Quad: MIMS	Date Measured:

Logs Available: GAM, RES, RSN, RLN, TMP, FLR

BR1661 03/08/99 (in mudded hole)



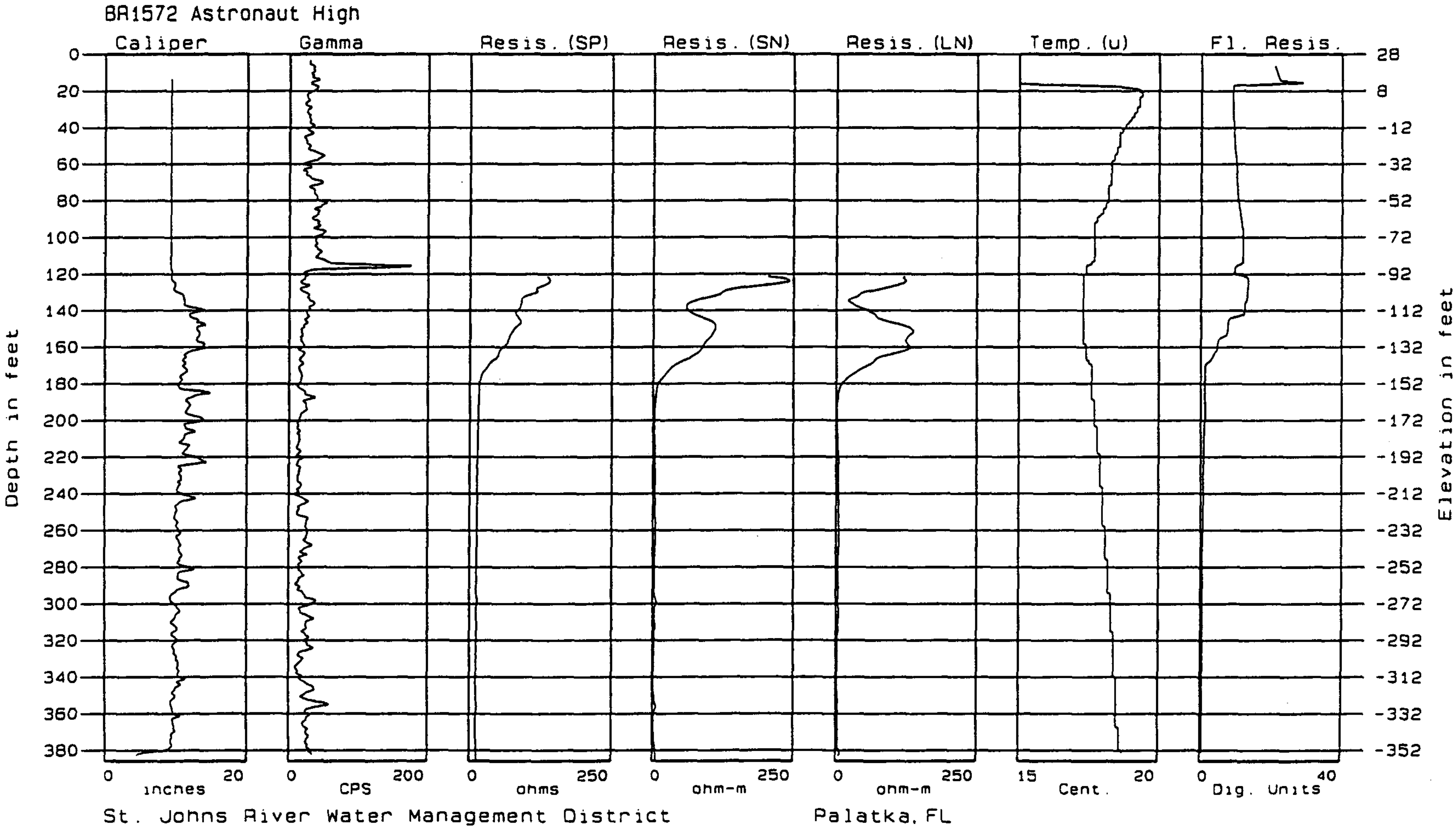
St. Johns River Water Management District Palatka, FL

GEOPHYSICAL LOGS FOR WELL BR1572

Log Source: St. Johns River Water Management District

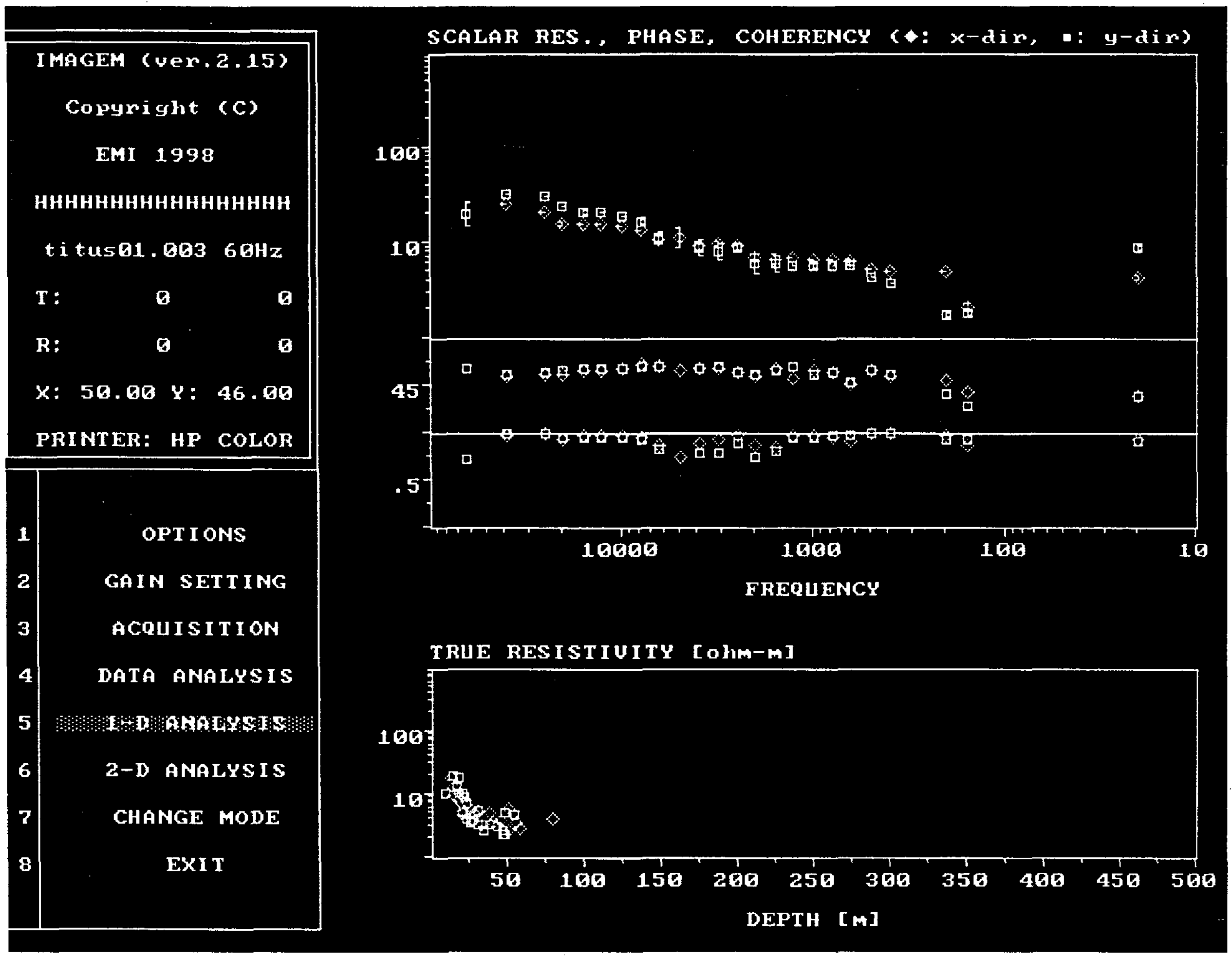
Station Name:	County: BREVARD	Date Logged:
Well ID: BR1572	Latitude: 28D 37M 32S	Depth Logged: 386 ft.
FGS ID:	Longitude: 80D 51M 01S	Cased Depth:
Other ID:	Elevation: 28 ft.	Water Level: ft.
Owner:	Topo Quad: MIMS	Date Measured:

Logs Available: CAL, GAM, RES, RSN, RLN, TMP, FLR



APPENDICES 2-8

IMPEDANCE RESULTS



SUMMARY

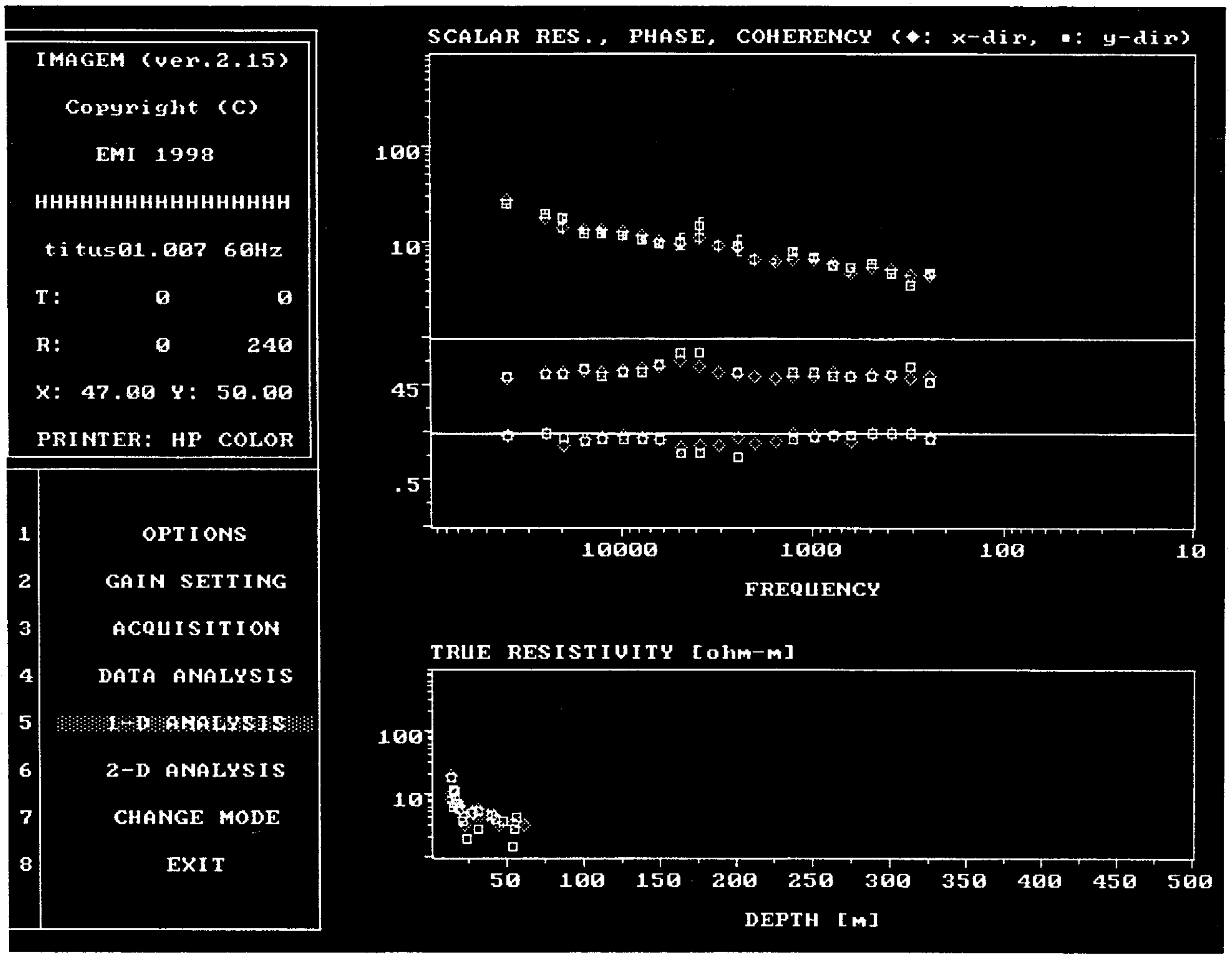
RESISITVITY DECREASES FROM 10 - 20 OHM-M AT APPROXIMATELY 25 METERS. THE FLORIDAN AQUIFER CONTAINS NO FRESH WATER IN THIS AREA.

ST. JOHNS RIVER
WATER MANAGEMENT
DISTRICT
PALATKA, FLORIDA

SDII GLOBAL

IMPEDANCE RESULTS - AMT SOUNDING #1
BENT OAKS GOLF COURSE SITE
TITUSVILLE AREA, FLORIDA

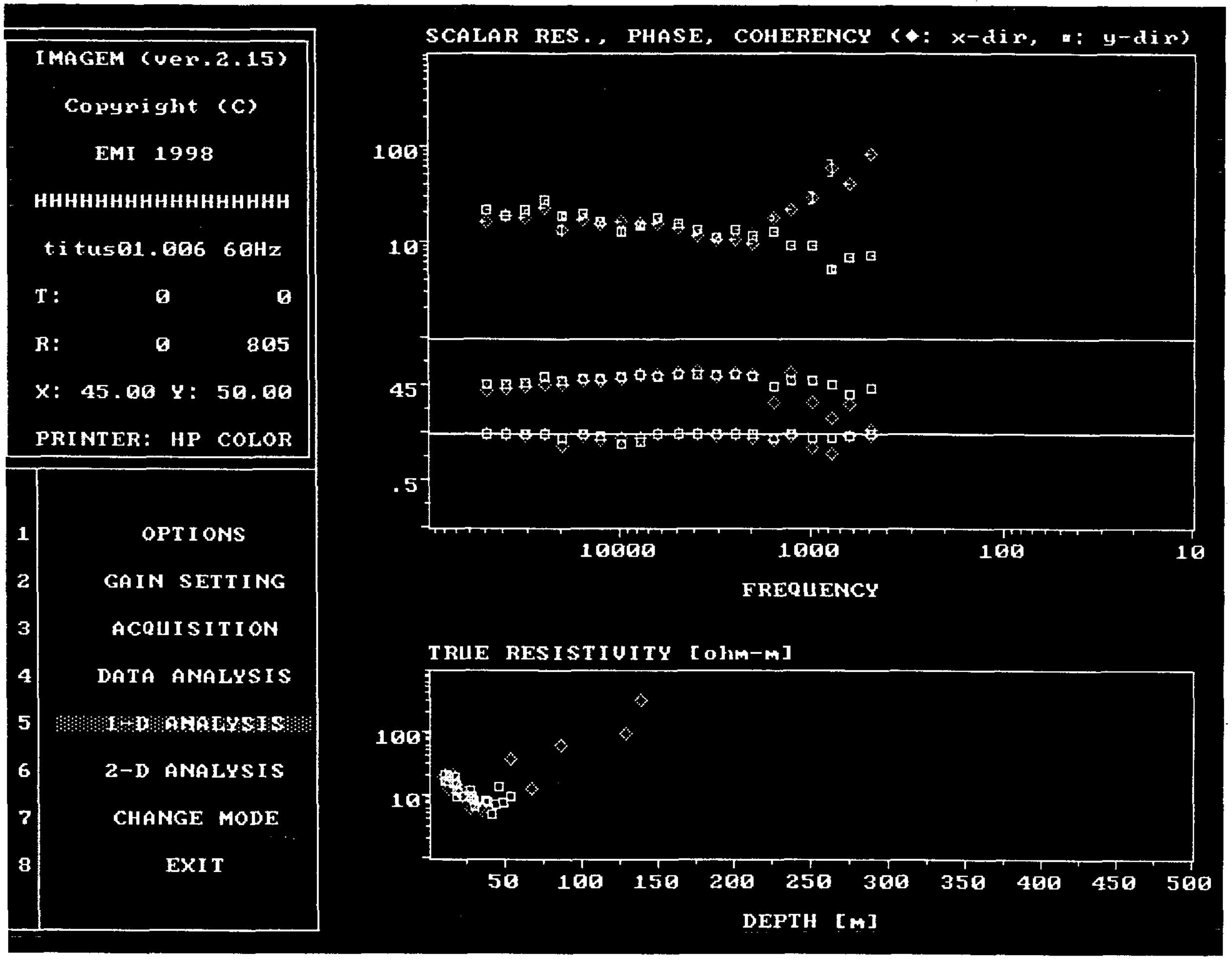
DESIGNED BY:	MJW	PROJECT NO.:	1010997	APPENDIX
CHECKED BY:	MJW	DRAWING NO.:	0997-A2	2
DRAWN BY:	SAB	DATE:	05/12/99	



SUMMARY

RESISITIVITY DECREASES FROM 10 - 20 OHM-M AT APPROXIMATELY 25 METERS. THE FLORIDAN AQUIFER CONTAINS NO FRESH WATER IN THIS AREA.

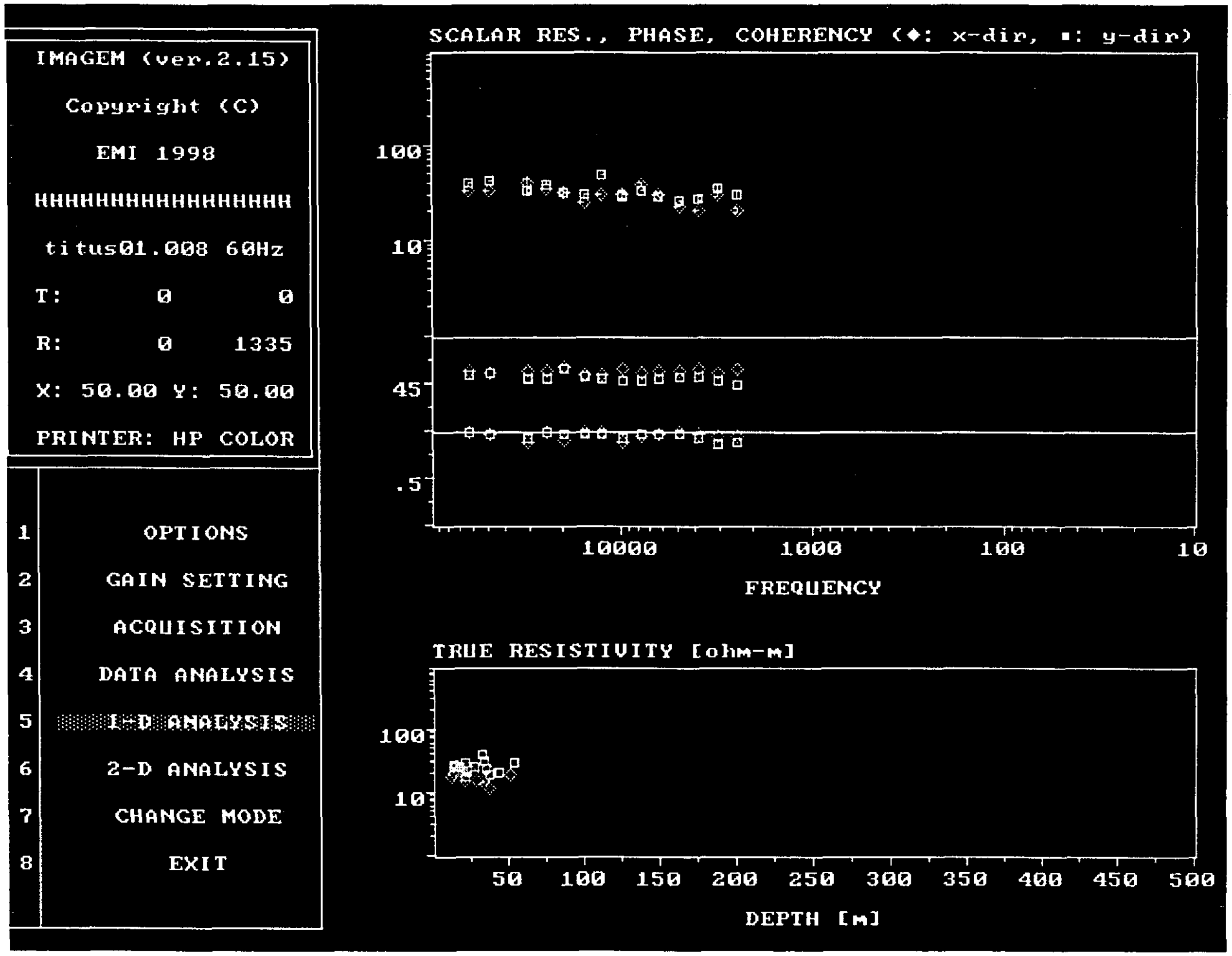
ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII GLOBAL	IMPEDANCE RESULTS - AMT SOUNDING #4 BENT OAKS GOLF COURSE SITE TITUSVILLE AREA, FLORIDA				
		DESIGNED BY:	MJW	PROJECT NO.:	1010997	APPENDIX
		CHECKED BY:	MJW	DRAWING NO.:	0997-A3	3
		DRAWN BY:	SAB	DATE:	05/12/99	



SUMMARY

RESISITVITY DECREASES FROM 10 - 20 OHM-M AT APPROXIMATELY 25 METERS. THE FLORIDAN AQUIFER CONTAINS NO FRESH WATER IN THIS AREA.

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT PALATKA, FLORIDA	SDII GLOBAL	IMPEDANCE RESULTS - AMT SOUNDING #3 BENT OAKS GOLF COURSE SITE TITUSVILLE AREA, FLORIDA	
		DESIGNED BY: MJW CHECKED BY: MJW DRAWN BY: SAB	PROJECT NO.: 1010997 DRAWING NO.: 0997-A4 DATE: 05/12/99
			APPENDIX 4



SUMMARY

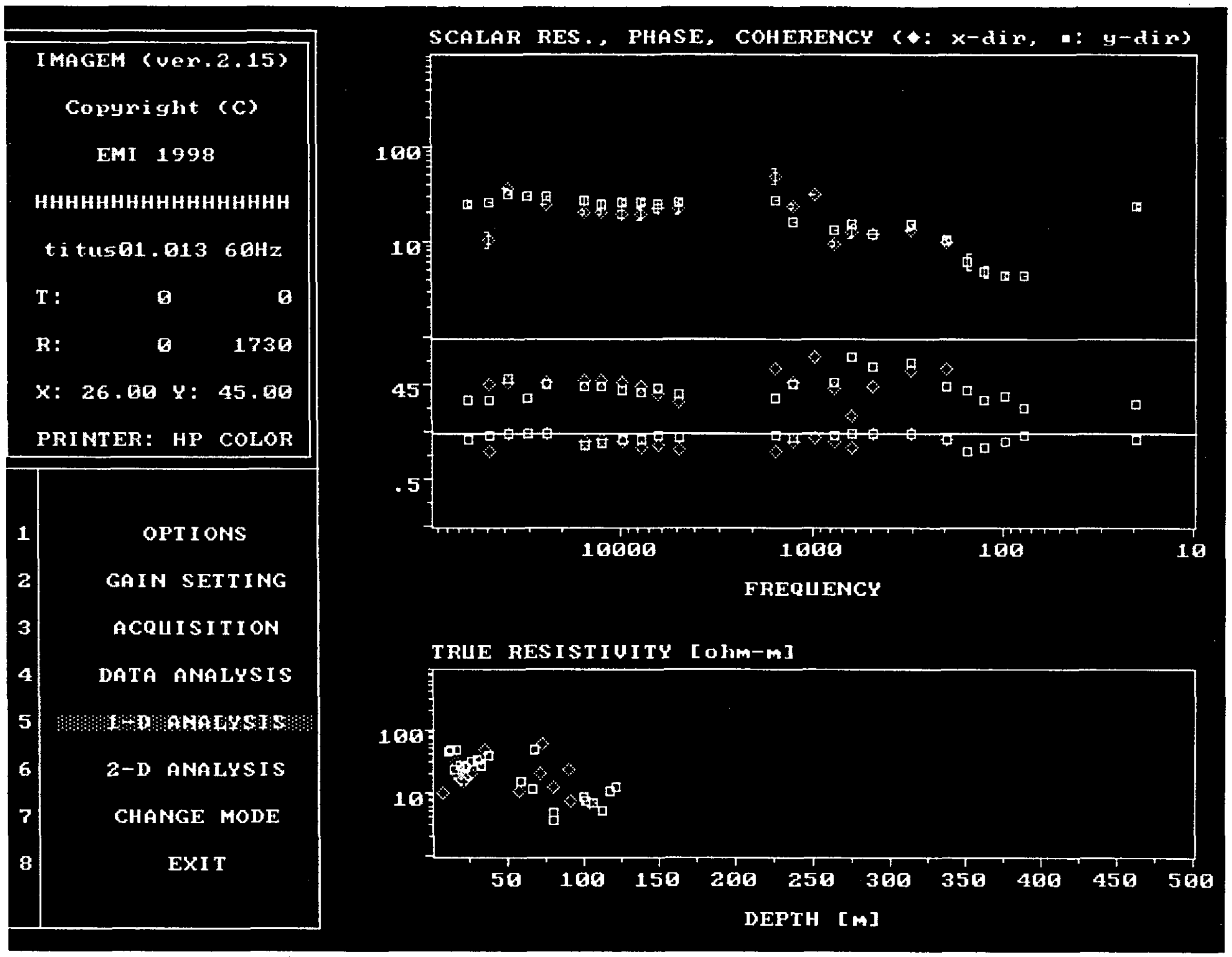
RESISTIVITY FROM NEAR LAND SURFACE TO APPROXIMATELY 50 METERS IS APPROXIMATELY 20 - 40 OHM-M. THE FLORIDAN AQUIFER CONTAINS NO FRESH WATER IN THIS AREA.

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII GLOBAL

IMPEDANCE RESULTS - AMT SOUNDING #5
BENT OAKS GOLF COURSE SITE
TITUSVILLE AREA, FLORIDA

DESIGNED BY:	MJW	PROJECT NO.:	1010997	APPENDIX
CHECKED BY:	MJW	DRAWING NO.:	0997-A5	5
DRAWN BY:	SAB	DATE:	05/12/99	



SUMMARY

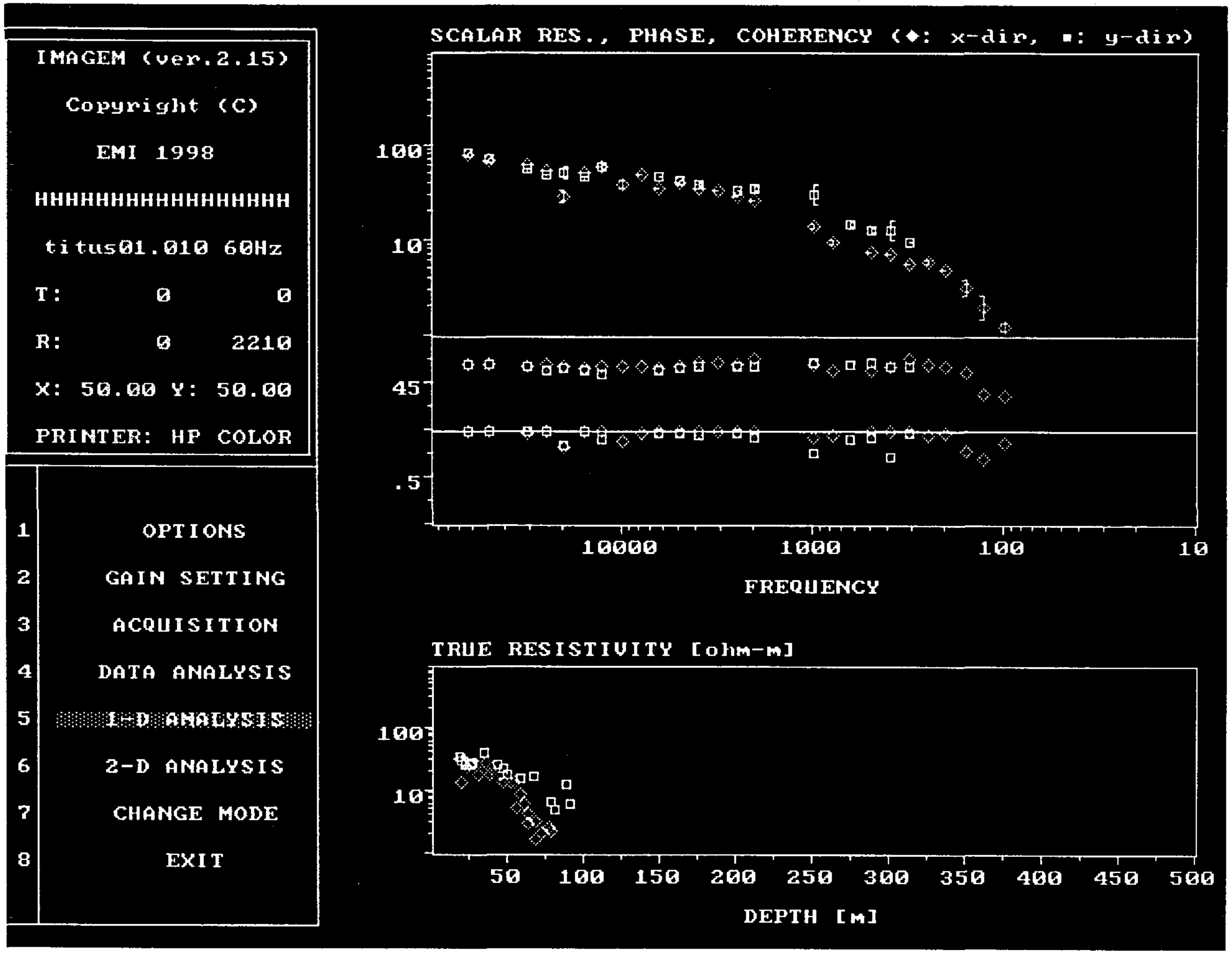
RESISTIVITY DECREASES FROM 40 - 80 OHM-M TO LESS THAN 10 OHM-M. THICKNESS OF FRESH WATER IN THE FLORIDAN AQUIFER ESTIMATED AT 45 METERS.

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII GLOBAL

IMPEDANCE RESULTS - AMT SOUNDING #6
BENT OAKS GOLF COURSE SITE
TITUSVILLE AREA, FLORIDA

DESIGNED BY:	MJW	PROJECT NO.:	1010997	APPENDIX
CHECKED BY:	MJW	DRAWING NO.:	0997-A6	6
DRAWN BY:	SAB	DATE:	05/12/99	



SUMMARY

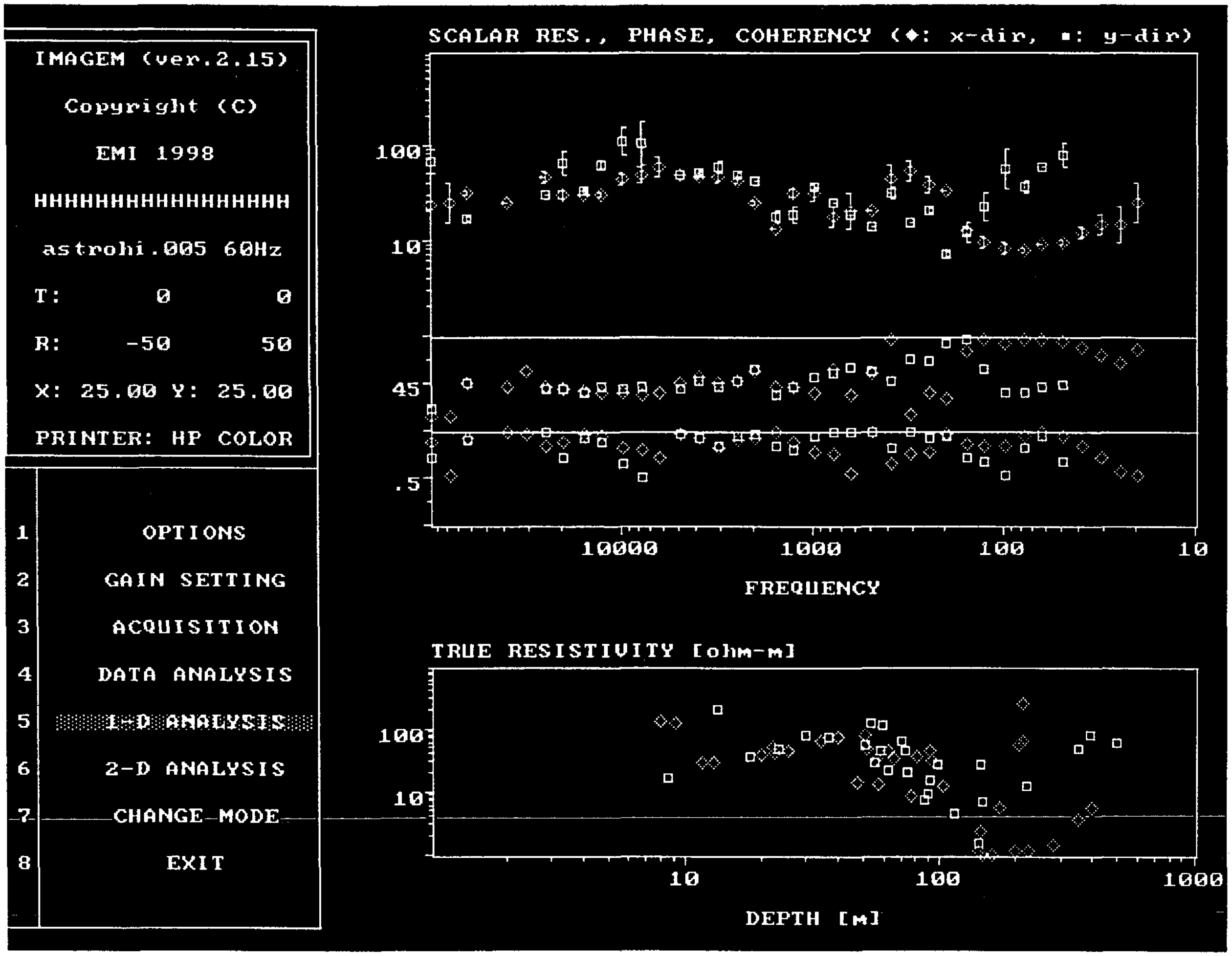
RESISTIVITY DECREASES FROM 20 - 40 OHM-M TO LESS THAN 10 OHM-M AT 50 - 60 METERS BELOW LAND SURFACE. THICKNESS OF FRESH WATER IN THE FLORIDAN AQUIFER ESTIMATED AT 45 METERS.

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT
PALATKA, FLORIDA

SDII GLOBAL

IMPEDANCE RESULTS - AMT SOUNDING #7
BENT OAKS GOLF COURSE SITE
TITUSVILLE AREA, FLORIDA

DESIGNED BY:	MJW	PROJECT NO.:	1010997	APPENDIX
CHECKED BY:	MJW	DRAWING NO.:	0997-A7	7
DRAWN BY:	SAB	DATE:	05/12/99	



SUMMARY

RESISTIVITY DECREASES FROM 40 - 200 OHM-M TO LESS THAN 10 OHM-M AT 50 - 60 METERS. THICKNESS OF FRESH WATER IN THE FLORIDAN AQUIFER ESTIMATED AT 15 - 25 METERS.

ST. JOHNS RIVER
WATER MANAGEMENT
DISTRICT
PALATKA, FLORIDA

SDII GLOBAL

IMPEDANCE RESULTS - AMT SOUNDING #13
LUNDY DRIVE SITE
TITUSVILLE AREA, FLORIDA

DESIGNED BY:	MJW	PROJECT NO.:	1010997	APPENDIX
CHECKED BY:	MJW	DRAWING NO.:	0997-A8	8
DRAWN BY:	SAB	DATE:	05/12/99	