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TIME DOMAIN ELECTROMAGNETIC MAPPING OF SALT WATER IN THE UPPER FLORIDAN AQUIFER IN THE NORTHWEST CORNER OF BREVARD AND SOUTHEAST CORNER OF VOLUSIA COUNTIES, FLORIDA

ST. JOHNS RIVER WATER MANAGEMENT DISTRICT

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Prepared for

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EXECUTIVE SUMMARY

A time domain electromagnetic (TDEM) survey was performed at four sites in the St. Johns River Water Management District during the month of November 2000. The TDEM method is a geophysical technique that, through ground surface based measurement, enables description of the vertical distribution (one-dimensional depth layering) of formation electrical resistivity. As such, TDEM 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 comparing TDEM soundings to electric logs, the minimum thickness of an interval that can be resolved by TDEM is several orders of magnitude larger than what can be resolved by electric logs. The confidence in the conclusions from TDEM findings can be enhanced when water quality information from nearby wells is available. The objectives of the TDEM survey were to determine the depths to the 250 mg/l and 5,000 mg/l isochlors and the location in Northwest Brevard County where the fresh water layer in the Upper Floridan aquifer is thickest.

The determination of the depth to the 5,000 mg/l isochlor was made at each of the sites. Depths ranged from 506 to 552 feet (ft) below land surface (bls). The determination of the depth to the 250 mg/l isochlor was also made at each of the sites. Depths ranged from 406 to 452 ft bls. The freshwater layer appears to thin from north to south. The thinning of the freshwater layer is confirmed by both the TDEM results and the water quality results from recently installed wells in the area of the TDEM sites.

At two of the sites the TDEM-derived water quality determination for the Upper Floridan aquifer was brackish (greater than 250 mg/l chlorides). Based on the empirical relationships used for this and previous studies, it would not have been possible to establish the depth to the 250 mg/l isochlor. However, available water quality data for the study area indicated that part of the Upper Floridan aquifer contains fresh water. Accordingly, the TDEM-derived estimate of water quality appears to be in error. This is possibly due to some localized variation in the porosity of the Upper Floridan aquifer at these two sites and because TDEM measures the average water quality for the Upper Floridan aquifer. Using the available water quality information for these two sites, the depth to the 250 mg/l isochlor was determined.

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1.0 INTRODUCTION

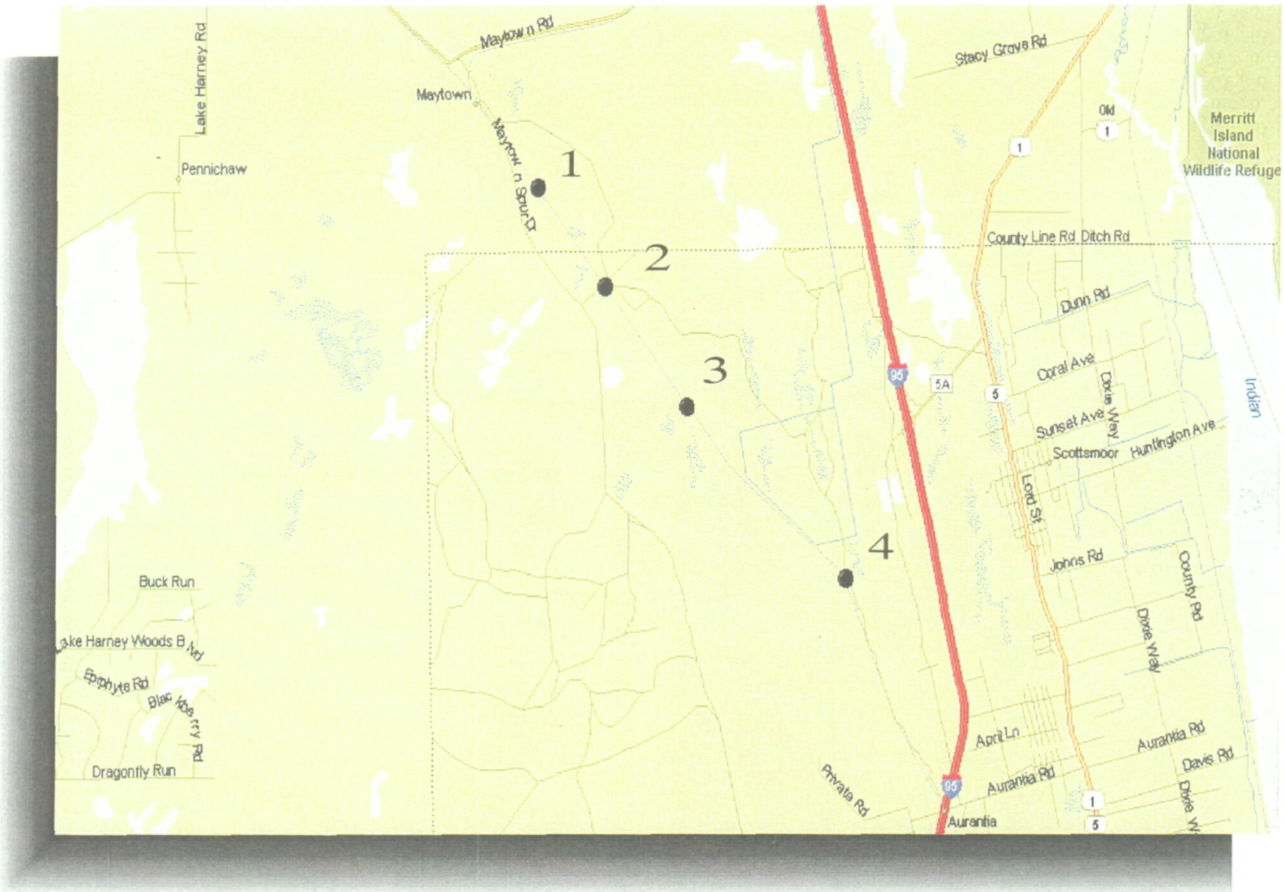
The St. Johns River Water Management District (SJRWMD) has contracted with Subsurface Detection Investigations, Inc. (SDII) to perform a series of Time Domain Electromagnetic (TDEM) survey measurements in northern Brevard and southern Volusia Counties during the month of November 2000. The TDEM method is a geophysical technique, which, through ground surface-based measurement, enables description of the vertical distribution (one-dimensional depth layering) of formation electrical resistivity. As such, TDEM 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 comparing TDEM soundings to electric logs, the minimum thickness of an interval that can be resolved by TDEM is several orders of magnitude larger than what can be resolved by electric logs. As formation resistivity is a direct function of formation lithology, porosity, and pore fluid conductivity, *in situ* determination of formation resistivity offers a means of inferring the water quality within given formations through empirical relationships between assumed porosity, pore-water chloride concentration, and the measured value of resistivity.

Given this background, SJRWMD has set the objectives of this TDEM survey as:

1. Determination of the depth to the saltwater interface (water with chloride concentration greater than 5,000 milligrams per liter [mg/l]);
2. Determination of the depth within the aquifer (above the saltwater interface) at which chloride concentration of pore waters equals 250 mg/l;
3. Determination of the location in Northwest Brevard County where the freshwater layer in the Upper Floridan aquifer is thickest.
4. The chloride concentration of the saltwater layer was also estimated assuming values of 25, 30 and 35 percent for the porosity of that layer.

The principal strength of TDEM is the detection and mapping of depths to the top of a conductive layer within an otherwise resistive medium. As such, the first objective (chlorides greater than 5,000 mg/l) is the easiest to accomplish and is the best resolved. Determination of the second and third objectives and the estimation of the chloride concentrations relies on empirical relationships derived from studies of wells in Seminole County (in east-central Florida) and, therefore, is a less certain and less well-resolved determination.

This report details the field procedures, data quality control and analyses procedures from the four sites as selected by SJRWMD personnel. Figure 1-1 presents the location of the four sites.



EXPLANATION

● 1 TDEM SITE LOCATION (with designation)

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NOT TO SCALE

SJRWMD	SDII GLOBAL	GENERAL SITE LOCATION MAP BREVARD/VOLUSIA COUNTIES STUDY		
		DESIGNED BY: MJW	PROJECT NO.: 1011854	FIGURE
		CHECKED BY: MJW	DRAWING NO.: 1854-1-3	1-3
		DRAWN BY: JMW	DATE: 01/19/01	

2.0 HYDROGEOLOGIC SETTING

Ground water is drawn from three principal aquifer systems within SJRWMD (Figure 2-1); the surficial aquifer system, the intermediate aquifer system and the Floridan aquifer system (Scott et al., 1991). The surficial aquifer system consists primarily of Upper Miocene to Holocene age consolidated to poorly indurated siliclastic sediments (Scott et al., 1991). Permeable interbeds within these sediments are locally significant sources of potable water near coastal areas and within St. Johns, Flagler, southern Brevard, Indian River, Seminole, western Clay, and Alachua counties (Fernald and Patton, 1985).

The Miocene-age Hawthorn Group separates the surficial aquifer system from the Floridan aquifer system and creates confining conditions within the Floridan aquifer. The intermediate aquifer system is comprised of high-transmissivity zones within the Hawthorn Group (Figure 2-1). Typically these high-transmissivity zones occur within sandy phosphatic limestone beds.

The primary source of potable water throughout the majority of the SJRWMD is the Floridan aquifer system. The Floridan aquifer is composed of (from oldest to youngest) the Cedar Keys Formation, Oldsmar Formation, Avon Park Formation, Ocala Limestone (where present), the Suwannee Limestone and the lower formations of the Hawthorn Group (where present; Figure 2-1; Scott et al., 1991). The ages of these formations range from Paleocene to Miocene.

The Floridan aquifer is subdivided into the Upper and Lower Floridan aquifer by a middle semi-confining unit, which is approximately 400 ft thick in the study area. Depth to the top of the semi-confining unit is approximately 450 ft below mean sea level (bmsl) within the study area (Miller, 1986). The middle semi-confining unit is leaky and the hydraulic connection between the Upper and Lower Floridan aquifers is variable (Tibbals, 1990).

Figure 2-1 Lithostratigraphic and Hydrostratigraphic Units SJRWMD

LITHOSTRATIGRAPHIC UNIT	HYDROSTRATIGRAPHIC UNIT
UNDIFFERENTIATED PLEISTOCENE - HOLOCENE SEDIMENTS ANASTASIA FORMATION CYPRESSHEAD FORMATION NASHUA FORMATION	SURFICIAL AQUIFER SYSTEM
HAWTHORN GROUP STATENVILLE FORMATION COOSAWHATCHIE FORMATION MARKSHEAD FORMATION PENNY FARMS FORMATION	INTERMEDIATE AQUIFER SYSTEM OR CONFINING UNIT
SUWANNEE LIMESTONE	FLORIDAN AQUIFER SYSTEM
OCALA LIMESTONE AVON PARK FORMATION OLDSMAR FORMATION	
CEDAR KEY FORMATION	SUB - FLORIDAN
UNDIFFERENTIATED	CONFINING UNIT

From: SCOTT et al 1991

3.0 FIELD ACQUISITION PARAMETERS, EQUIPMENT AND DATA PROCESSING

3.01. Field Acquisition Parameters

Four sites were selected by SJRWMD for TDEM soundings. The TDEM method involves the laying of 12 gauge AWG wire in an approximately square or rectangular loop on the ground surface over a large area (300 ft by 300 ft). This is the transmitter, or Tx loop. A bi-polar electrical current (up to a maximum of 5 amperes) energizes the Tx loop. The response of the ground is sensed by a centrally located (midpoint of the Tx loop) search coil (receiver, or Rx coil). The transient response seen by the receiver is recorded digitally by the data-logging module.

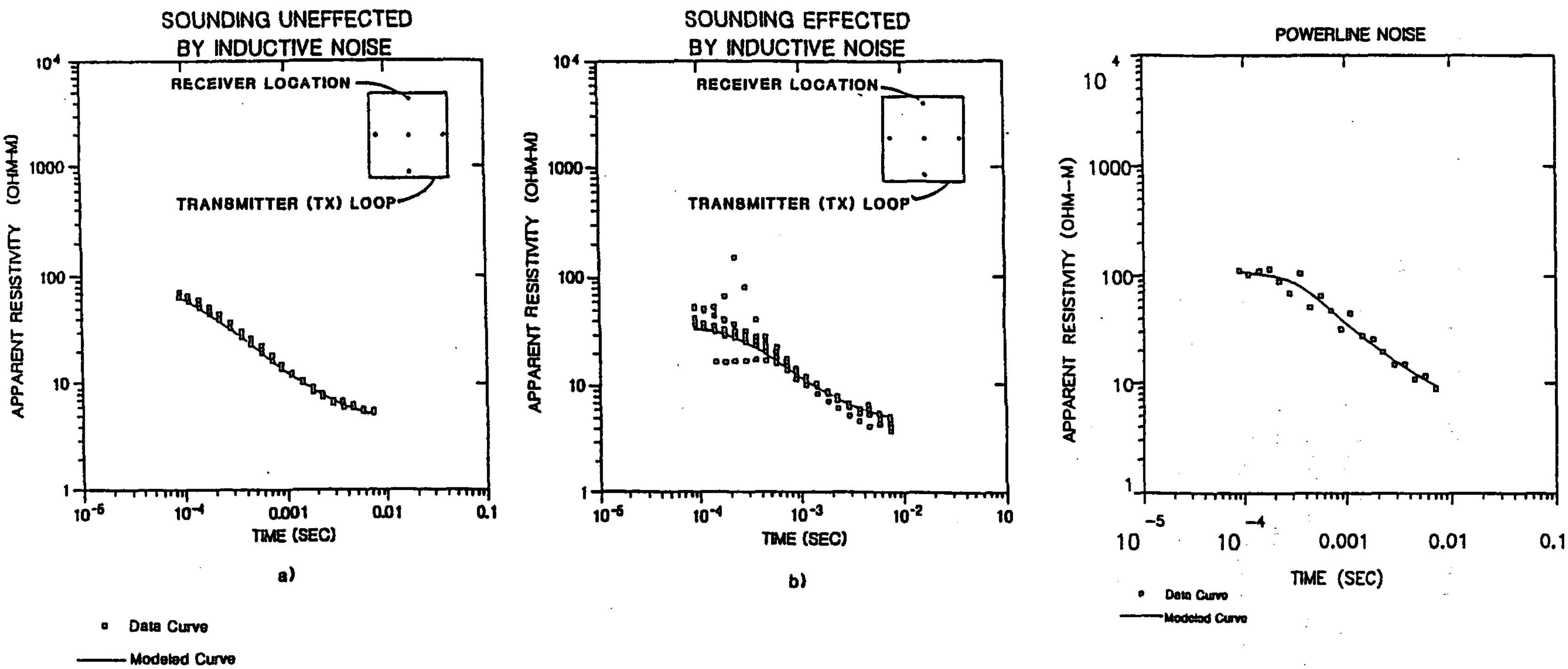
To attain the depth of exploration required to determine the depth to the saltwater interface in the survey area, a Tx loop size of 300 ft by 300 ft was employed. Tx loops were laid out using premarked cables and a compass. Loop dimensions, transmitter currents, and other site-specific information are included in the individual descriptions of the sounding results (Section 5.0).

No sources of potential interference were present within any of the site areas. On Figure 3-1, examples of TDEM data that are; 1) unaffected by induction noise, 2) affected by induction noise (as from buried metal pipelines), and 3) affected by powerlines are provided. None of the TDEM sites surveyed during the SDII investigation appeared to have been affected by noise sources.

The SDII field crew consisted of one project geophysicist, Mr. Michael J. Wightman, Senior Geophysicist, P.G. and a geophysical field technician. Mr. Wightman did all data reductions and analysis. A representative of SJRWMD, Dr. David Toth, P.G., was also present in the field. Table 3-1 summarizes the daily field activities.

Table 3-1 Daily Log of Field Activities

DATE	SITE	ACTIVITIES
11/29/2000	Site 1	Read EM-57 TDEM sounding
11/29/2000	Site 2	Read EM-57 TDEM sounding
11/29/2000	Site 3	Read EM-57 TDEM sounding
11/30/2000	Site 4	Read EM-57 TDEM sounding



SJRWMD	EXAMPLES OF NOISE EFFECTS ON TDEM DATA BREVARD/VOLUSIA COUNTIES STUDY				
	DESIGNED BY: MJW	PROJECT NO.:	1011854	FIGURE	
	CHECKED BY: MJW	DRAWING NO.:	1854-3-1	3-1	
	DRAWN BY: JMW	DATE:	01/10/01		

3.02. Equipment

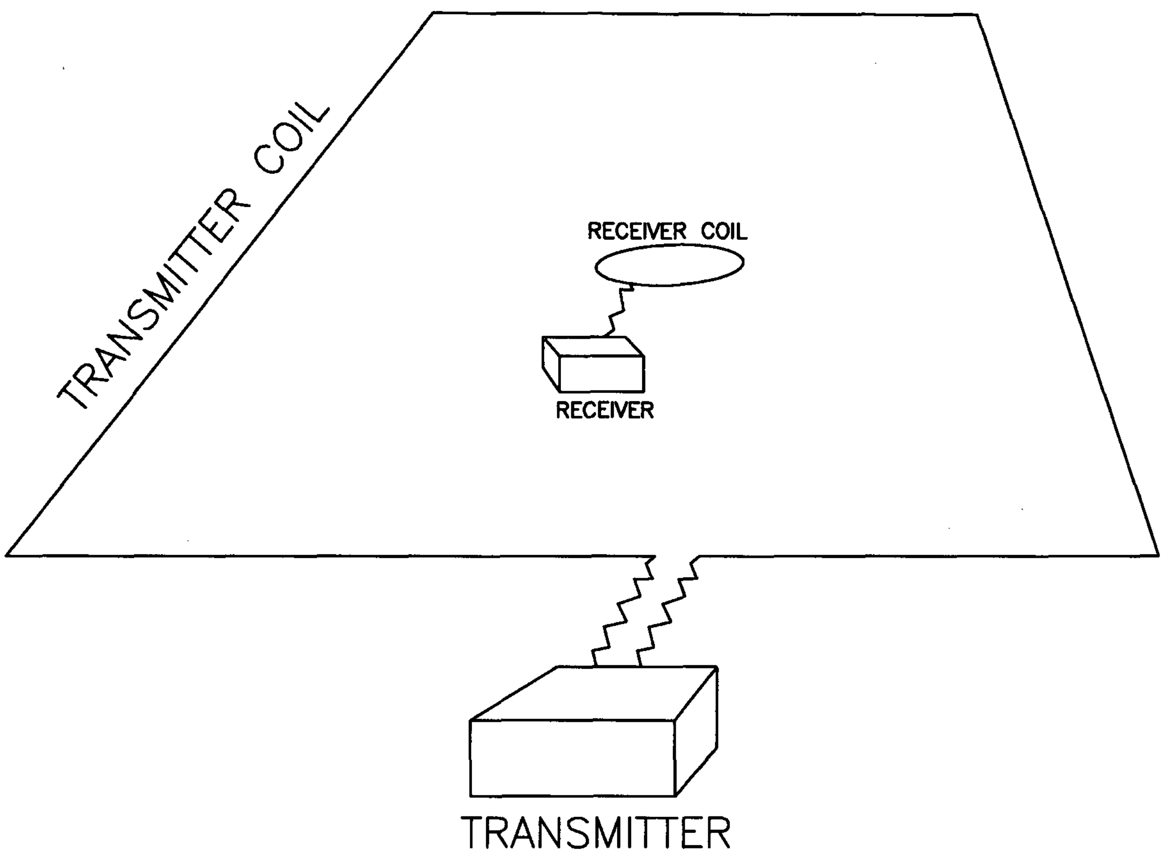
SDII employed the Geonics EM-57 Protem system for the investigation. The principal components of the EM-57 systems are:

- Transmitter (Tx) loop (variable length 12 gauge AWG wire, insulated)
- Gasoline power generator/EM57 transmitter box (maximum 5 ampere, bi-polar square wave)
- Receiver (Rx) coil (100 square meter effective area)
- Protem Receiver Module (system control and parameter selection)

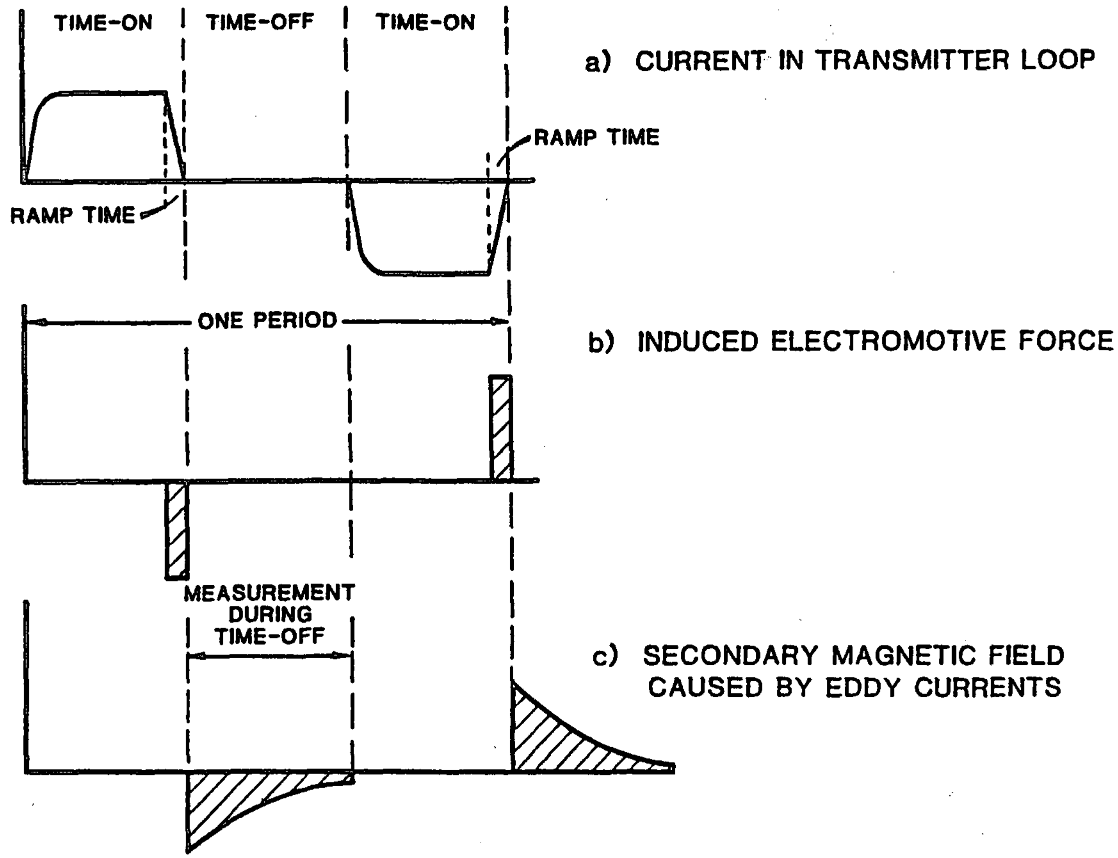
A block diagram of the field setup of the system is given in Figure 3-2. Once setup is completed, a current waveform, as depicted by Figure 3-3, is injected into the Tx loop. The rapid turn-on and turn-off of current in the loop creates a strong EMF that interacts with earth and man-made materials to generate eddy currents within conductive materials. These currents have an associated secondary magnetic field that is detected by the Rx coil as shown on Figure 3-3. Eddy currents close to the Tx coil are induced first and decay below detection limits before deeper currents. Currents in resistive materials also decay faster than currents in conductors. Deeper conductors contribute to responses at later times at the Rx coil than do shallower subsurface features. Thus, by measuring the rate and nature of the decaying magnetic field seen by the Rx coil after Tx shutoff, the distribution of subsurface resistivity can be determined. The survey variables that can be selected by the TDEM operator are the size of the Tx coil, Tx coil current (which controls the penetration depth), analog stacking (number of repetitions of summed tests in order to increase signal-to-noise ratio), gain at the receiver, and repetition rate (frequency) of the current cycles. For this investigation SDII used three different frequencies (3 Hz, 7.5 Hz, and 30 Hz) to acquire detailed and overlapping segments of the decay curve, which enabled resolution of shallow (30 Hz data) and deeper (3, 7.5 Hz data) portions of the subsurface.

3.03. Data Processing

Data acquired by the Protem receiver is downloaded to a portable computer for data editing, processing, and interpretation (inversion). The primary software program used to process the data was TEMIXGL (Interpex, Ltd.). This program accepts raw data from the Protem receiver module and proceeds through the following general processing steps:



SJRWMD	DHI GLOBAL	BLOCK DIAGRAM OF EM-57 TDEM SOUNDING SETUP BREVARD/VOLUSIA COUNTIES STUDY			
		DESIGNED BY: MJW	PROJECT NO.: 1011854	FIGURE 3-2	
		CHECKED BY: MJW	DRAWING NO.: 1854-3-2		
		DRAWN BY: JMW	DATE: 01/10/01		



SJRWMD

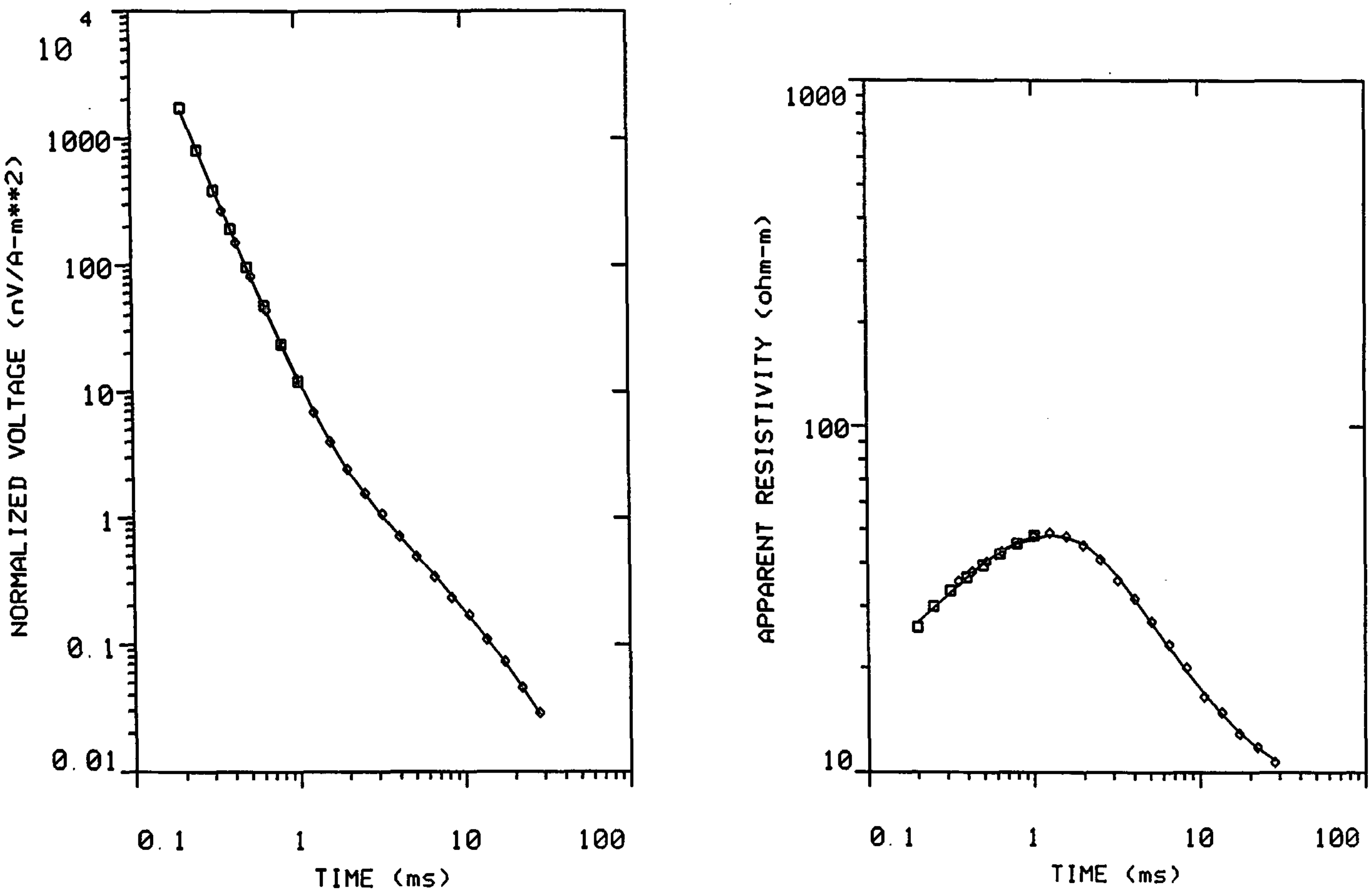
SYSTEM WAVEFORMS
BREVARD/VOLUSIA COUNTIES STUDY

DESIGNED BY:	MJW	PROJECT NO.:	1011854	FIGURE
CHECKED BY:	MJW	DRAWING NO.:	1854-3-3	3-3
DRAWN BY:	JMW	DATE:	01/10/01	

Data Edit - Modification of survey description information, for example, loop size, Tx coil amperage, which may have been entered improperly are performed here. Decay curves for all frequencies and gain values taken at a site are displayed; suspect data points can be deleted and the individual curves for different frequencies and gains are averaged and converted to a single, apparent resistivity versus time (after Tx turn-off) field curve (see Figure 3-4, for an example of voltage data and apparent resistivity versus time curves). The field curve is comprised of 30 data points, where each data point represents an apparent voltage collected at a particular time or time gate. Each frequency has 20 time gates and each frequency overlaps the proceeding or preceding frequency by 10 time gates.

Combining data collected at each frequency produces one sounding curve with 30 time gates, with an overlap between time gates 10 through 20. Data collected at 7.5 Hz provides apparent resistivity values for time gates 5 through 25. An advantage of using 30, 7.5, and 3 Hz frequencies for all the soundings is that different gains can be used for each frequency. Lower gains can be used at a frequency of 30 Hz to avoid saturating early channels, and higher gains can be used at 3 Hz to amplify weaker signals in later channels. The combined data is interpreted as one sounding curve. The modeled sounding curve does not always appear as a continuous single sounding curve (Figure 3-4). This is because during the modeling process, curves are developed for data collected at each frequency. The calculations for the final geoelectric model, however, are based upon a single average curve that is developed from the data collected at each frequency.

Initial Model - Review of the apparent resistivity curve shape allows a trained geophysicist to make an initial guess as to the true resistivity versus depth (layered) model, which would produce the observed data set. After such a model is created, a field curve is calculated from the model and compared with the observed data. The degree of agreement between model and field data is measured statistically and expressed as the fitting error. The geophysicist may then, in an interactive mode, adjust the model to obtain a better fit or can modify the starting model.



SJRWMD	SDII GLOBAL	DEMONSTRATION TDEM SURVEY RESULTS SHOWING NORMALIZED VOLTAGE AND APPARENT RESISTIVITY VERSUS TIME BREVARD/VOLUSIA COUNTIES STUDY		
		DESIGNED BY: MJW	PROJECT NO.: 1011854	FIGURE
		CHECKED BY: MJW	DRAWING NO.: 1854-3-4	3-4
		DRAWN BY: JMW	DATE: 01/10/01	

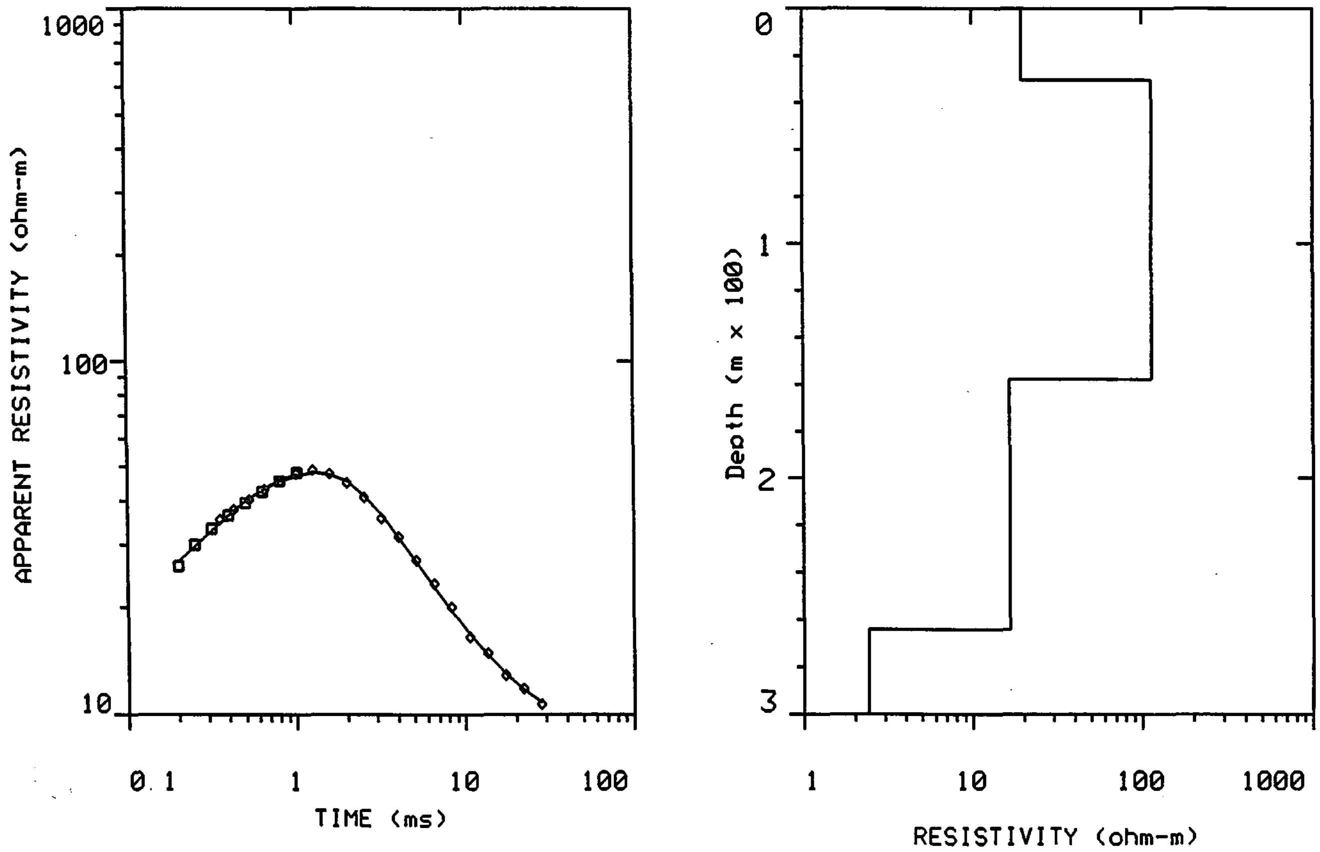
As part of the modeling procedure early and late time data is commonly discarded. Typically, apparent resistivity values collected at early times are discarded because the data collected at these times is often not representative of geological conditions because of the affect of the Tx coil shut off not being truly instantaneous. In the final modeling of this data, in may appear that the model curve passes through several of these early time points, but not all the points. In such a case, all the early time data points are discarded because it is not good modeling practice to delete data points from the middle portion of a curve and utilize data points preceding them. Often, later time data is also not representative of geological conditions because the primary EMF field strength has been too dissipated to provide a representative apparent resistivity value. Suspect late time data is also discarded. Modeled curves quite often demonstrate an upward curvature during early times. This upward curvature is usually due the TDEM response not following theoretical behavior or the affect of the Tx coil shut off not being truly instantaneous. This deviation produces a distortion, however, this distortion has little or no affect on the results from the TDEM survey when the target depth is hundreds of ft bls.

<u>Automatic Inversion</u> - Based upon the initial model, the program will attempt to create a better fit to the observed data using an iterative, Inman Ridge Regression routine to adjust layer thicknesses and resistivities until a minimum error of fit is realized; our goal was to produce models which fit the observed data within a 5% error of fit. This final model is termed the "best fit" model (see Figure 3-5). Only the data points utilized in the determination of the modeled curve are used in calculation of the fitting error.

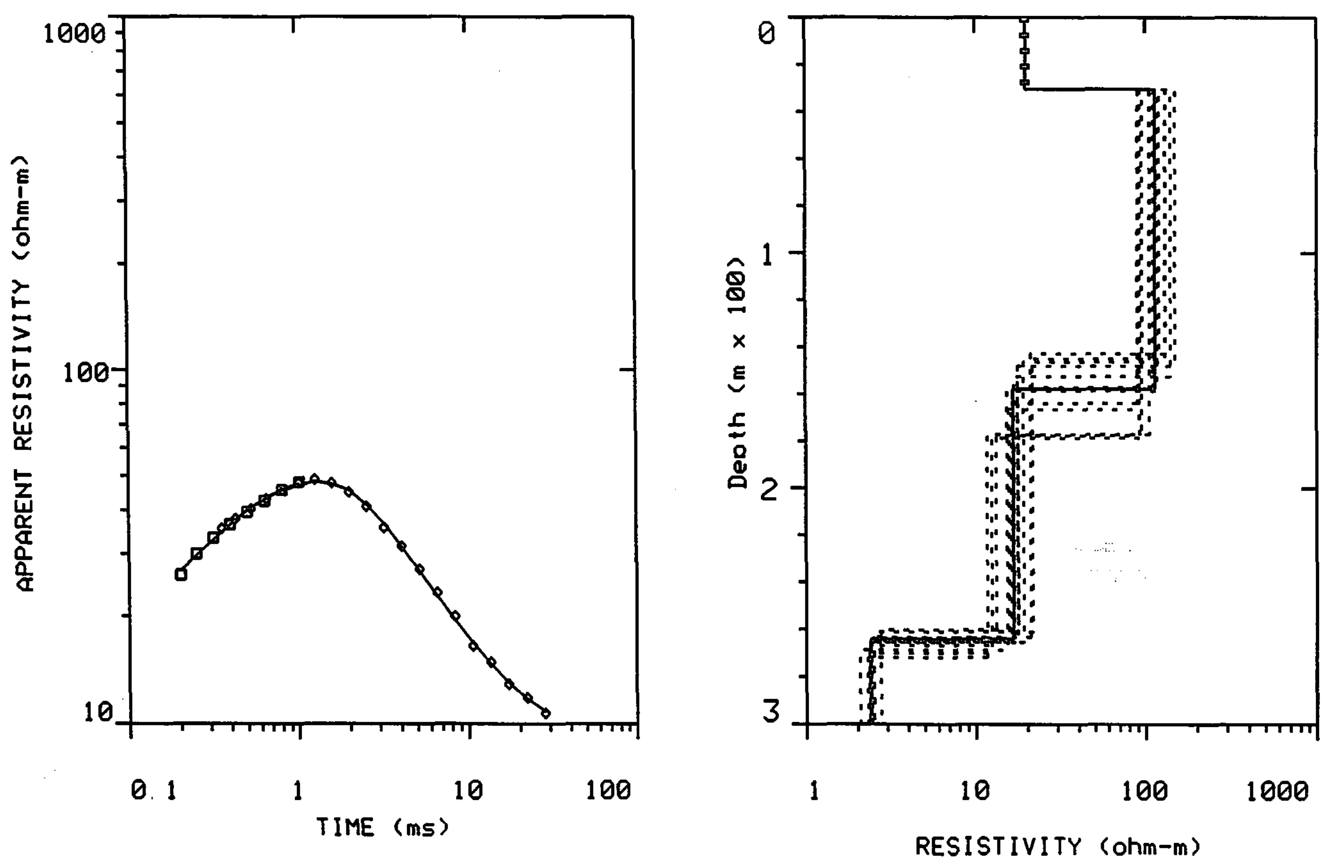
<u>Equivalence Analysis</u> - Electrical resistivity methods are, as with other geophysical methods, plagued by the so-called "non-uniqueness" problem. That is, while best-fit model produces an acceptable fit to field data curves, there are several other models having different thicknesses and resistivities that will also provide a "reasonable" fit to the same data. TEMIXGL will produce a suite of models, using the best-fit model as a start, which would produce a reasonably close fit (see Figure 3-6). If the equivalence model segments (layers and resistivities) are tightly constrained then the layering provided by the best-fit model is very good. Those parts of the equivalence models that scatter quite a bit around the best-fit model show less confidence in the absolute values of layer thickness and resistivity. A poorly constrained equivalence model for a given layer means either there

are too few data points in the raw data to adequately describe that layer or the data is just not very sensitive to that specific layer.

It is important to note that the interpretations resulting from the TDEM data are, specifically, one-dimensional models of layer thickness and layer resistivity. That is, if the earth subsurface is not, effectively, a one-dimensional horizontal layer, then the produced model may have inherent error. Also, the depths to levels of chloride concentration and not resistivity rely on empirical relationships between resistivity and chloride concentration. This latter point will be detailed further in Section 4.0.



SJRWMD		DEMONSTRATION TDEM SURVEY RESULTS SHOWING BEST FIT MODEL BREVARD/VOLUSIA COUNTIES STUDY			
		DESIGNED BY: MJW	PROJECT NO.: 1011854	FIGURE	
		CHECKED BY: MJW	DRAWING NO.: 1854-3-5	3-5	
		DRAWN BY: JMW	DATE: 01/10/01		



SJRWMD		DEMONSTRATION TDEM SURVEY SHOWING RESULTS OF EQUIVALENCE ANALYSIS BREVARD/VOLUSIA COUNTIES STUDY				
		DESIGNED BY:	MJW	PROJECT NO.:	1011854	FIGURE
		CHECKED BY:	MJW	DRAWING NO.:	1854-3-6	3-6
		DRAWN BY:	JMW	DATE:	01/10/01	

4.0 TECHNICAL APPROACH TO SATISFYING SURVEY OBJECTIVES

4.01. General

As stated previously, the final product of the geophysical investigation is a best-fit, one-dimensional model of layer resistivity versus depth. To satisfy the requirements of the survey, these models must be correlated with models of chloride concentration versus depth. Specifically, the resistivity structure must be viewed in terms of determining the depth of occurrence of the 250 mg/l isochlor and the depth to salt water as defined by the 5,000 mg/l isochlor. To ensure that the results from this TDEM survey are directly comparable to and compatible with the results of TDEM surveys performed in previous years (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; and SDII, 1993, 1994, 1995 and 1996), SDII will utilize the identical relationships between resistivity and isochlor depths for the Floridan aquifer. These relationships and assumptions are detailed in the following sections. However, it must be realized that correlation of TDEM-derived layer conductivities with specific chloride values are approximate and based on several simplifying assumptions.

4.02. Correlation of Inverted Geoelectrical (Resistivity) Profiles to Cl^- Concentrations

For the majority of soundings conducted previously, the saltwater interface positions were "inferred to occur within the Floridan aquifer system" (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; and SDII, 1993, 1994 and 1995) and, therefore, the published relationships between resistivity and chloride concentration are applicable. When the saltwater interface occurred within the Floridan aquifer, the following procedure was used in both this and previous studies (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; and SDII, 1993, 1994, 1995 and 1996).

The carbonate rocks of the Floridan aquifer system (as opposed to the highly variable lithologies of overlying formations) are expected to be uniform and, as such, their resistivities are determined principally by porosity and specific conductance of pore fluids. The governing empirical "law" relating formation resistivity (Ro), fluid resistivity (Rw) and porosity (f) in a clay-free lithology is Archie's Law:

$$F = Ro/Rw = af^{-m} \qquad (1)$$

where F = "formation factor" and "a" and "m" are empirically derived constants which are specific to a given formation in a given area. Previous TDEM reports have used the values of m = 1.6 and a = 1 from Kwader (1982) as being most appropriate for the Floridan aquifer. These values are from studies of wells completed in the Upper Floridan aquifer in Seminole County, Florida.

Kwader (1982) has also established the following relationship from his study of Seminole County wells:

$$Cl = (3500/Rw) - 153 \qquad (2)$$

where Cl is the equivalent chloride concentration in mg/l and Rw is fluid resistivity in ohm-meters. Extrapolating these expressions by Kwader outside of Seminole County presumes that the relative ionic chemistry (especially a chloride/sulfate ratio of 5:1) remains the same or reasonably close to conditions in that area. Significant chemical variation would cause Equation 2 to be, quite likely, invalid.

Because formation resistivity, Ro, is what the geophysical analysis of TDEM data has produced, a combination of equations (1) and (2) allows for determining a functional relationship between chloride concentration, inferred formation resistivity, and porosity:

$$Cl = (3500f^{1.6}/Ro) - 153 \qquad (3)$$

or, for an assumed 25% porosity for the Upper Floridan aquifer as per previous TDEM reports:

$$Cl = (32,163/Ro) - 153 \qquad (4)$$

Linking this relationship to the cited survey objectives, we would expect that a Floridan aquifer with 25% porosity, similar water chemistry (5:1 chloride to sulfate ratio) to the Kwader study, and a 250 mg/l chloride concentration would yield a measured formation resistivity of 80 ohm-m. Higher resistivities than this would indicate fresher water. Chloride concentrations of 5,000 mg/l would correspond to formation resistivities of 6.2 ohm-m; higher concentrations would yield lower resistivities. These values, then, are what we should expect to see for the fresh and saltwater sections of the Floridan aquifer.

One final consideration, besides porosity and similar chemical species/ratios, is made by previous reports (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; and SDII, 1993, 1994 and 1995) and, again, will be adhered to in this study. The relationships cited are for a clearly defined, carbonate section within the Floridan aquifer (i.e., beneath Miocene deposits or the Hawthorn Group). If there is a clearly defined thickness of Holocene to Miocene deposits, the Hawthorn Group, or surficial sediments from the electrical sounding results and if that thickness is in agreement with published thicknesses of such deposits for the area of a specific site, then there is presumed to be no affect of the measured formation resistivity for the Floridan aquifer due to interfingering of clay stringers of the Hawthorn Group or Holocene to Miocene deposits. This means that the inversion resistivity results representing the Floridan aquifer layer are valid.

4.03. Determination of Depth to 250 mg/l and 5,000 mg/l Isochlors

The previous discussion of the relationship of formation conductivity to chloride content is particularly applicable to geoelectrical measurements made on a fine, highly resolved scale, such as a borehole electrical log, where an almost continuous measure of resistivity versus depth is available. As known from geophysical logs and water quality studies, the saltwater interface is not a knife-edge interface in the subsurface but is a gradational interface. Within the freshwater section, we would also expect the chloride concentration to follow a gradually increasing-downwards distribution. Therefore, the TDEM sounding, which presents the subsurface as a sequence of a few layers of presumed, uniform resistivity, is not an actual representation of the true subsurface but a low resolution version of it. The saltwater interface (chlorides greater than 5,000 mg/l), which exhibits a much higher gradient of chloride concentration than in the overlying fresher water, comes closest to being a true interface. This is why depth to the saltwater interface from TDEM should be close to the low resistivity layer detected.

Actual reported depth to the 5,000 mg/l isochlor in previous reports (CEES, 1992; SDII, 1993, 1994, 1995 and 1996) is determined by the contrast in resistivity of the layers above and below the geoelectrical interface. If the contrast is large (e.g., greater than 80 ohm-m above and less than 20 ohm-m below), then the depth to the 5,000 mg/l isochlor is assumed to be 50 ft below the interface depth determined from geoelectrical inversion. If the contrast is small (e.g., a 20-80 ohm-m layer above and less than 20 ohm-m layer below), the depth to the 5,000 mg/l isochlor is taken as equal to the depth of the interface determined from the geoelectrical inversion. These adjustments are intended to correct for the existence of the transition zone.

The criterion used to define the depth to the 250 mg/l isochlor in previous TDEM surveys for SJRWMD (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; and SDII, 1993, 1994, 1995 and 1996) is also a data-based criterion. That is, the final reported position of this isochlor, relative to the boundary between the Floridan aquifer freshwater geoelectrical layer and the saltwater geoelectrical layer depends upon the layer resistivities above and below the interface as determined by the inversion. Four data classes have been defined based upon a reference value for resistivity of 80 ohm-m for a portion of the Floridan aquifer. We reproduce the following criteria for positioning the 250 mg/l isochlor (CEES, Table 4-2, 1992).

Summarizing Table 4-2 in CEES (1992), if the Floridan freshwater section is in excess of 80 ohm-m while the underlying layer is less than 20 ohm-m (so-called Class A geoelectrical section), then the 250 mg/l isochlor is placed at a position 50 ft higher than the saltwater interface depth defined from geoelectrical inversion.

If the Floridan freshwater section is in excess of 80 ohm-m while the underlying layer is between 20-40 ohm-m (so-called Class B section), then the 250 mg/l isochlor is placed 25 ft above the saltwater interface depth defined from geoelectrical inversion.

If the Floridan freshwater section is in excess of 80 ohm-m and the underlying layer is between 40-80 ohm-m (Class C), then the 250 mg/l isochlor is placed at the interface.

Finally, if there is no contrast (i.e., a uniform layer of > 80 ohm-m; Class D), then we are not seeing an expected saltwater interface within the depth of exploration of the field sounding. Also, there is no detectable/mapable 250 mg/l isochlor.

In the above determinations for the 250 mg/l isochlor, the "depth" to the saltwater interface is the depth to the low resistivity layer taken directly from the TEMIXGL inversion and not the corrected 5,000 mg/l depth as discussed previously.

An underlying assumption of this and Kwader's (1982) work is that the porosity of the limestone, within which estimates of water quality are being made, is constant. By Equation 3 there is an inverse relationship between porosity (f) and formation resistivity (Ro). If porosity should increase, then formation resistivity will decrease for the same given chloride concentration. For example, through a manipulation of Equation 3, it can be shown that for a given chloride concentration of 250 mg/l and formation resistivity of 120 ohm-m that the resultant porosity would be 19.2 percent. Given the same water quality, if the porosity should increase to 33.5 percent, a resultant formation resistivity of 50 ohm-m would be obtained. This becomes particularly important in determining the placement of the 250 mg/l isochlor, which is based upon the resistance of the lowermost saltwater-saturated layer. If the resistance of the lowermost saltwater-saturated layer is increased by a change in porosity rather than by a decrease in chloride concentration, then the designation of the geoelectric section as a Class B or Class C section would be in error. The placement of the 250 mg/l isochlor would likewise be in error.

5.0 RESULTS AND DISCUSSION

5.01. Summary of Results

A summary of the TDEM investigation is presented in this section. The summary includes the resulting geoelectrical inversions, 250 mg/l isochlor depth and the 5000 mg/l isochlor depth. More detailed presentation of the individual site results are contained in the following sections 5.02 through 5.05. Each individual site section will present a site description, apparent resistivity versus time (data) curves, the best-fit geoelectrical section with equivalence analysis, inferred depths to the 5,000 mg/l (salt water) and 250 mg/l isochlors. The location of each of the sounding areas is provided on Figure 1-1.

Table 5.1-1 lists the four sites with summary information describing site number, residing county, latitude, longitude and loop size. Table 5.1-2 summarizes the results of the TEMIXGL geoelectrical inversion section (number of layers, layer thicknesses and resistivities, and range of equivalence models for each layer parameter). Table 5.1-3 summarizes the estimated chloride content of the saltwater layer assuming porosities of 25, 30, and 35% for the Floridan Aquifer System.

Table 5.1-4 summarizes the interpreted depths to the 250 mg/l and the 5,000 mg/l isochlors at each site based upon the criteria outlined in Section 4.3 and as utilized in TDEM surveys performed for SJRWMD in previous years (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; and SDII, 1993, 1994, 1995 and 1996). As in previous years, these calculations are made assuming a 25% porosity for the Floridan Aquifer System and a 5:1 chloride-to-sulfate ratio for the ground water chemistry. The estimated chloride-to-sulfate ratios at each of the sites is also provided in Table 5.1-4.

The effect of a chloride to sulfate (Cl/SO_4) ratio less than 5:1 would be for waters with equivalent conductivity to have different Cl values. SO_4 is less conductive than Cl for an equivalent mass volume. If for example the ratio is less than 5:1, it will take a higher conductivity (lower resistivity) to get a 250 mg/l chloride value. However, based on information provided by SJRWMD, a chloride to sulfate ratio of 5:1 is applicable to the survey sites. Accordingly, the assumptions of Equation 4 are valid.

Table 5.1-1 Summary of TDEM Site Survey Information				
SITE NUMBER	**RESIDING COUNTY**	**LATITUDE[1/]**	**LONGITUDE[1/]**	**LOOP SIZE (in feet)**
1	Volusia	28°47'46.3"N	80°56'59.4"W	300x300
2	Brevard	28°47'10.2"N	80°56'25.2"W	300x300
3	Brevard	28°46'23.0"N	80°55'40.2"W	300x300
4	Brevard	28°45'06.6"N	80°54'59.4"W	300x300

1/ As determined by SJRWMD

Table 5.1-2 Summary of Geoelectric Sections with Range of Equivalence

SITE NAME	NUMBER OF MODELED LAYERS IN GEOELECTRICAL SECTION	LAYER 1						LAYER 2						LAYER 3						TOTAL DEPTH TO DEEPEST CONDUCTOR INTERPRETED AS SALT WATER (Meters)*		
		RESISTIVITY ρ_1 (ohm-m)			THICKNESS h_1 (meters)*			RESISTIVITY ρ_2 (ohm-m)			THICKNESS h_2 (meters)*			RESISTIVITY ρ_3 (ohm-m)			THICKNESS h_3 (meters)*					
		Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max	Min	Best	Max
Site 1	3	13	14	15	30.5	30.5	30.5	36	43	53	116	120	124	2.2	2.4	2.6	----	----	---	146	150	154
Site 2	4	16	17	18	24.4	24.4	24.4	86	104	129	114	129	149	13	18	24	93	109	123	139	153	173
Site 3	3	19	20	21	30.5	30.5	30.5	134	215	403	109	111	113	2.7	3.0	3.2	----	----	----	139	141	143
Site 4	4	28	33	39	30.5	30.5	30.5	33	39	45	105	109	113	0.6	1.0	1.7	----	----	----	135	139	144

*1 meter equals 3.281 feet

Table 5.1-3 Estimated Depth to Salt Water and Estimated Chloride Concentrations at Three Porosities					
SITE	**FORMATION RESISTIVITY (ohm-m)**	**INTERPRETED DEPTH OF SALT WATER [1] (ft)**	**CHLORIDE CONCENTRAT-ION (mg/l) =25%**	**CHLORIDE CONCENTRAT-ION (mg/l) =30%**	**CHLORIDE CONCENTRAT-ION (mg/l) =35%**
Site 1	2.4	492	13,248	9,858	7,670
Site 2	18.3	502	1,605	1,160	873
Site 3	2.9	463	10,938	8,132	6,321
Site 4	1.0	456	32,011	23,873	18,621

[1/] Depth Below Land Surface

Table 5.1-4 Depth to 5,000 mg/l and 250 mg/l Isochlor as Determined by Time Domain Electromagnetics			
SITE	**ESTIMATED CHLORIDE TO SULFATE RATIO** [1]	**INTERPRETED DEPTH 5,000 mg/l ISOCHLOR (ft bls)**	**INTERPRETED DEPTH 250 mg/l ISOCHLOR (ft bls)**
Site 1	5:1	542	442
Site 2	5:1	552	452
Site 3	5:1	513	413
Site 4	5:1	506	406

[1/] Based on Personal Information Provided by SJRWMD, 2001

5.02. TDEM Site 1

5.02.1. Location Description and Geoelectrical Section

The site is located in southern Volusia County, Florida. The site is located along an abandoned railroad right of way. No possible sources of interference were observed within the vicinity of the site.

The Floridan aquifer occurs at an approximate depth of 75 ft below mean sea level (bmsl) or 100 ft below land surface [(bls) SJRWMD, personal communication] and is overlain by Holocene to Miocene deposits. Based on information from Miller (1984), depth to the bottom of the Upper Floridan aquifer is approximately –450 ft bmsl (475 ft bls) and the depth to the top of the Lower Floridan aquifer is –850 ft bmsl (875 ft bls). The water quality in the Upper Floridan aquifer in this area is fresh (Rutledge, 1984).

The resistivity sounding data and best-fit model inversion are presented on Figure 5.2-1. The interpreted geoelectrical section consists of a three-layer subsurface.

5.02.2. Geological Interpretation of Geoelectrical Model

The three-layered geoelectrical section consists of a low resistivity (14 ohm-m) upper layer which is considered to be Holocene to Miocene deposits above the Floridan aquifer. The thickness of Layer 1 was fixed at 30.5 m (100 ft). The second layer has a resistivity of 43 ohm-m, which, because it is less than 80 ohm-m, suggests the Upper Floridan aquifer at this site contains brackish water. However, based on available water quality information (Rutledge, 1984), part of the Upper Floridan aquifer in this area is fresh. Based on the TDEM results the average chloride concentration from the Upper Floridan aquifer (Layer 2) is above 250 mg/l (brackish). The thickness of the brackish water section is 120 m (394 ft). The depth to the low-resistivity (salt-water layer is 150 m (492 ft). The resistivity of the saltwater saturated layer is 2.4 ohm-m. Layer 1 is considered to be the Holocene to Miocene deposits above the Floridan aquifer, Layer 2 to be the Upper Floridan aquifer (brackish), and Layer 3 to be saltwater within the middle semi-confining unit.

5.02.3. Depth to Occurrence of Salt Water

The bottom (third) layer of the geoelectrical model, with a resistivity of 2.4 ohm-m, is interpreted to represent salt water. It occurs at a depth of 492 ft (-467 ft msl). Because the TDEM-derived average chloride concentration for the Upper Floridan aquifer is brackish (43 ohm-m), the interpreted depth to the 5,000 mg/l isochlor is equal to the depth of the geoelectrical interface, or at 492 ft depth (-467 ft msl). The resistivity of Layer 3 (2.4 ohm-m) corresponds to a chloride concentration of 13,248 mg/l assuming a porosity of 25% and the validity and applicability of equation (4) of Section 4.02. It is presumed that because of the expected high chlorinity gradients, this value is sufficiently close to the 5,000 mg/l isochlor that they represent the same effective depth.

5.02.4. Depth of Occurrence of the 250 mg/l Isochlor

The resistivity of Layer 2, 43 ohm-m, corresponds to a chloride concentration above 250 mg/l, assuming a 25% porosity and the validity and applicability of equation (4) of Section 4.02. This conclusion does not agree with available water quality information that indicates that a portion of the water within the Upper Floridan aquifer in this area is fresh. Assuming that the available water quality data is correct, then the lower resistivity value for Layer 2 may be due to a localized increase in the effective porosity for the Upper Floridan aquifer in this area.

Using Equation 3 from Kwader, it is possible to determine the necessary porosity for the ground water to be fresh (less than 250 mg/l chloride concentration) with the TDEM derived formation resistivity of 43 Ohm-m. Such a calculation indicates that a porosity of 37 percent rather than the assumed 25 percent would be required. Assuming that the Upper Floridan aquifer in this area is fresh and that the lower resistivity value for Layer 2 is due to a localized increase in porosity, the 250 mg/l isochlor is interpreted to be 50 feet above the Layer 3 interface or at a depth of 442 ft (-417 ft msl).

5.02.5. Accuracy of Measurement and Interpretation

Figure 5.2-2 is the equivalence analysis at this site and Table 5.2-1 lists the upper and lower bounds of the inverted parameters of the geoelectrical model. The range of equivalence in determining the depth to the low resistivity layer is about ±4 m (13 ft), which is 2.7% of the total depth. The resistivity of this layer has a range from 2.2 to 2.6 ohm-m. This corresponds to a range in interpreted chloride concentration from 14,467 to 12,218 mg/l, again subject to the same assumptions of porosity and validity of equation (4).

The equivalence range of the resistivity of Layer 2 is from 33 to 45 ohm-m that corresponds to a chloride concentration above 250 mg/l. The results are not in agreement with available water quality data for the Upper Floridan aquifer in the area of the project site. It is suspected that the lower resistivity for Layer 2 is due to a localized increase (from 25 to 37 percent) in the effective porosity for the Upper Floridan aquifer in this area. The chloride-to-sulfate ratio at the site is 5:1 (Table 5.1-4). Accordingly, equation (4) is valid.

5.02.6. Summary of TDEM Sounding at Site 1

- The depth to occurrence of salt water (5,000 mg/l isochlor) is interpreted to be 492 ft (-467 ft msl) and occurs within the middle semi-confining unit.
- The ground water within the Floridan aquifer at this site is interpreted to contain an average chloride concentration above 250 mg/l. The TDEM-derived water quality results are not in agreement with available water quality data for the Upper Floridan aquifer in the area of the project site. This may be due a localized increase in the effective porosity of the Upper Floridan aquifer in this area.
- Assuming that the available water quality is correct and that the effective porosity in this area is 37 percent rather than the assumed 25 percent, the 250 mg/l isochlor is interpreted to be present in the Upper Floridan aquifer at a depth of 442 ft (-417 ft msl).

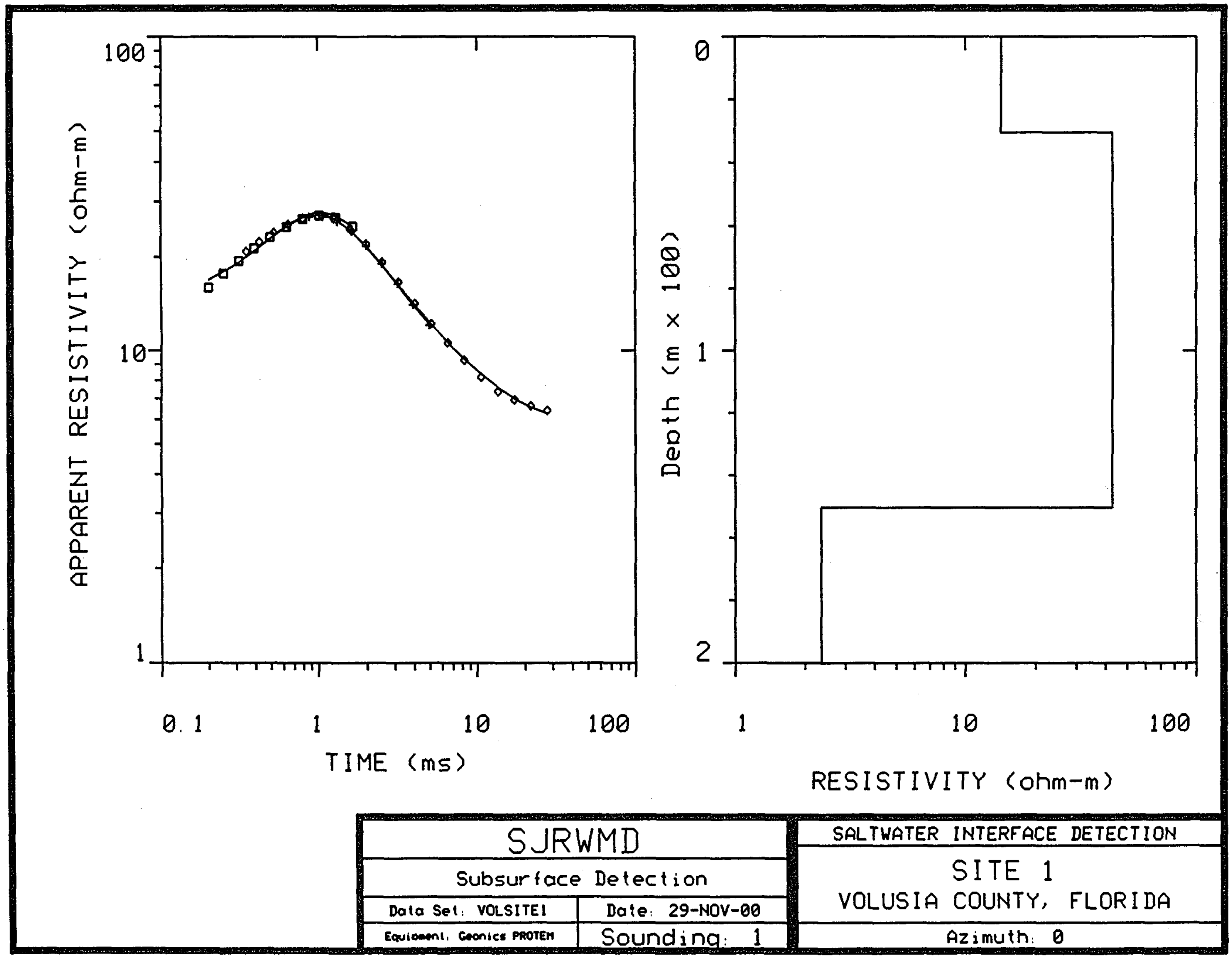


Figure 5.2-1 Measured TDEM Apparent Resistivity and 1-D Inversion - Site 1

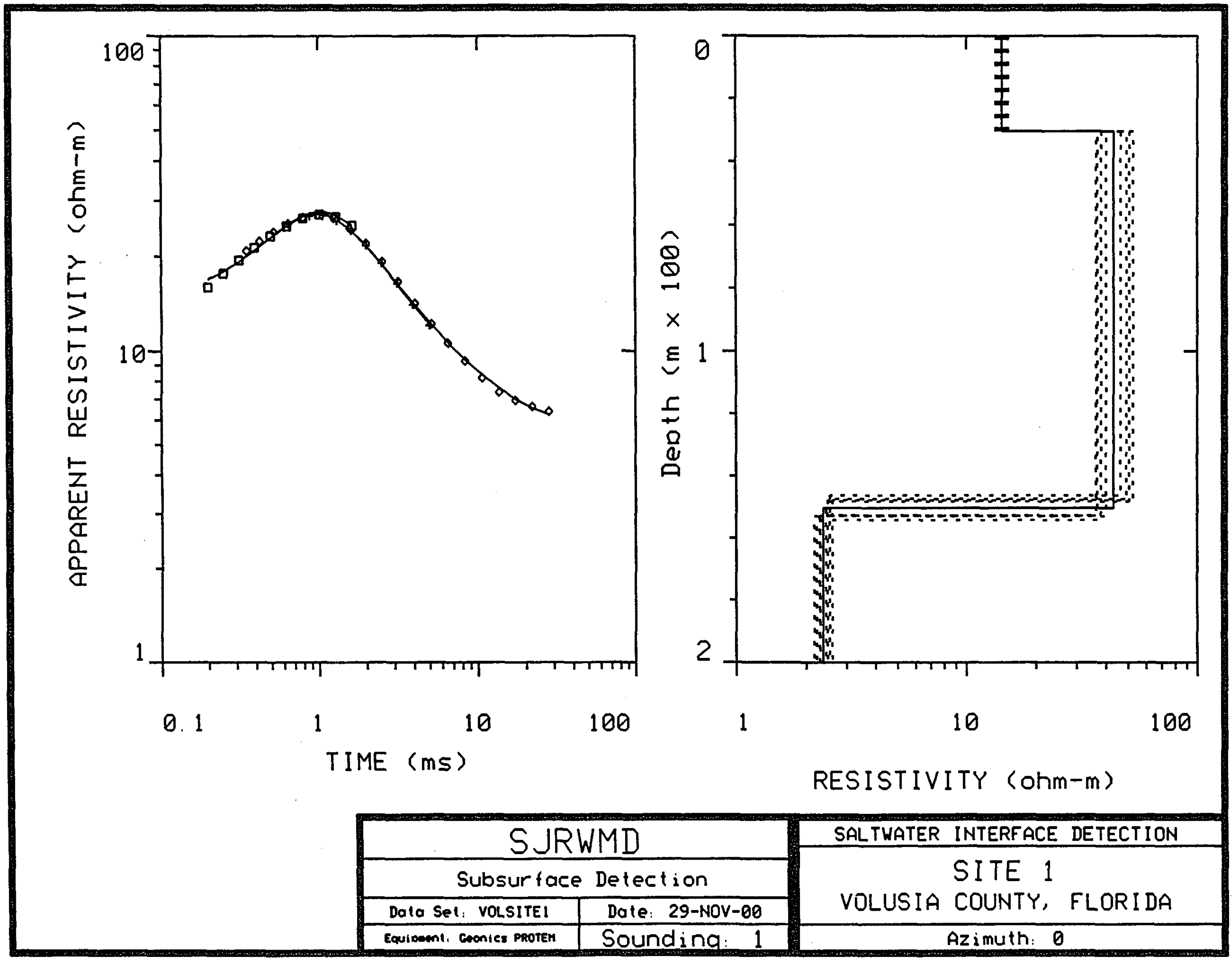


Figure 5.2-2 Measured TDEM Apparent Resistivity and Equivalence for 1-D Inversion - Site 1

Table 5.2-1 TDEM Sounding Data Table - Site 1

DATA SET: VOLSITE1

```
   CLIENT: SJRWMD                                        DATE: 29-NOV-00
 LOCATION: SITE 1                                    SOUNDING: 1
   COUNTY: VOLUSIA COUNTY, FLORIDA                  ELEVATION:     8.00 m
  PROJECT: SALTWATER INTERFACE DETECTION            EQUIPMENT: Geonics PROTEM
LOOP SIZE:     91.000 m by       91.000 m             AZIMUTH: 0
 COIL LOC:      0.000 m (X),      0.000 m (Y) TIME CONSTANT: NONE
SOUNDING COORDINATES:  E:        1.0000 N:          1.0000 SLOPE: NONE
```

Central Loop Configuration
Geonics PROTEM System

```
              FITTING ERROR:       2.891 PERCENT
  SMOOTH MODEL FITTING ERROR:       2.097 PERCENT
```

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)		ELEVATION (meters)	CONDUCTANCE (Siemens)
				8.00	
1	14.23	30.50	*	-22.50	2.14
2	43.09	119.8		-142.3	2.78
3	2.36				

"*" INDICATES FIXED PARAMETER

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	13.389	14.238	15.164
	2	36.219	43.098	52.520
	3	2.170	2.369	2.587
THICK	1	30.500	30.500	30.500
	2	115.808	119.867	123.793
DEPTH	1	30.500	30.500	30.500
	2	146.308	150.367	154.293

```
  CURRENT:   13.40 AMPS   EM-58    COIL AREA:    100.00 sq m.
FREQUENCY:   30.00 Hz   GAIN: 2    RAMP TIME:    3.00 muSEC
```

SYNTHETIC FROM LAYERED MODEL:

No.	TIME	emf (nV/m sqrd)	DIFFERENCE

	(ms)	DATA	SYNTHETIC	(percent)
1	0.200	48752.4	44605.5	8.50
2	0.250	24001.1	23423.3	2.40
3	0.314	11746.6	11950.8	-1.73
4	0.395	5759.3	5917.5	-2.74
5	0.499	2835.5	2883.7	-1.69
6	0.631	1414.1	1398.2	1.12
7	0.799	720.0	698.4	2.99
8	1.01	382.1	368.0	3.67
9	1.28	215.7	211.0	2.19
10	1.63	130.2	130.0	0.202

CURRENT: 13.40 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 7.50 Hz GAIN: 4 RAMP TIME: 3.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
11	0.352	7964.2	8447.5	-6.06
12	0.427	4424.4	4668.6	-5.51
13	0.525	2390.3	2479.1	-3.71
14	0.647	1289.1	1303.9	-1.14
15	0.802	706.1	699.9	0.876
16	1.00	394.3	387.2	1.79
17	1.25	232.1	230.0	0.901
18	1.58	145.8	146.3	-0.378
19	1.99	95.63	97.99	-2.46
20	2.52	65.37	67.44	-3.15
21	3.19	45.00	46.70	-3.78
22	4.05	31.70	32.21	-1.59
23	5.14	21.80	21.97	-0.749
24	6.54	14.79	14.74	0.368
25	8.32	9.89	9.73	1.69
26	10.59	6.52	6.29	3.57
27	13.49	4.17	3.97	4.77
28	17.19	2.48	2.45	1.30
29	21.90	1.45	1.47	-1.70
30	27.92	0.837	0.864	-3.23

CURRENT: 13.40 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 6 RAMP TIME: 3.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
31	0.881	551.9	542.5	1.70
32	1.06	340.5	332.0	2.49
33	1.31	214.6	211.2	1.60
34	1.61	141.0	141.1	-0.0481
35	2.00	97.12	98.02	-0.926
36	2.50	67.89	68.89	-1.47
37	3.14	47.92	48.57	-1.34
38	3.95	34.16	34.09	0.196
39	4.99	23.94	23.63	1.29

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.98				
P 2	0.06	0.82			
P 3	0.01	-0.04	0.95		
F 1	0.00	0.00	0.00	0.00	
T 2	-0.01	0.02	0.01	0.00	0.99
	P 1	P 2	P 3	F 1	T 2

5.03. TDEM Site 2

5.03.1. Location Description and Geoelectrical Section

The site is located in northern Brevard County, Florida. The site is located along an abandoned railroad right of way. No possible sources of interference were observed within the vicinity of the site.

After completion of the TDEM sounding, the City of Titusville installed two wells (UF-1S and UF-1 D) near the site. UF-1S was installed to a depth of 215 feet bls and UF-1D was installed to a depth of 500 feet bls. Results from the wells indicate that the Floridan aquifer occurs at an approximate depth of 55 ft below mean sea level (bmsl) or 80 ft below land surface and is overlain by Holocene to Miocene deposits. Based on information from Miller (1984), depth to the bottom of the Upper Floridan aquifer is approximately –450 ft bmsl (475 ft bls) and the depth to the top of the Lower Floridan aquifer is –850 ft bmsl (875 ft bls). The water quality information indicates that the 250 mg/l isochlor is present between a depth of 200 and 331 feet bls and that the 1,000 mg/L isochlor is present between a depth of 400 and 442 feet bls.

The resistivity sounding data and best-fit model inversion are presented on Figure 5.3-1. The interpreted geoelectrical section consists of a four-layer subsurface.

5.03.2. Geological Interpretation of Geoelectrical Model

The four-layered geoelectrical section consists of a low resistivity (17 ohm-m) upper layer which is considered to be Holocene to Miocene deposits above the Floridan aquifer. The thickness of Layer 1 was fixed at 24.4 m (80 ft, based on the results from well UF-1S). The second layer has a resistivity of 104 ohm-m, which, because it is greater than 80 ohm-m, indicates the Upper Floridan aquifer at this site contains fresh water. The thickness of the fresh section is 129 m (423 ft), placing the depth to the low resistivity (saltwater) layer at 153 m (502 ft) below ground surface. The resistivity of the saltwater saturated layer is 18.3 ohm-m. The fourth layer has a resistivity of 2.4 ohm-m and is considered to represent a porosity change in the middle semi-confining unit. Using Equation 3 from Kwader, given the calculated chloride concentration for Layer 3, a change in porosity from 25 percent (Layer 3) to 89 percent (Layer 4) would be necessary to explain the difference in the TDEM-determined formation resistivity for the two layers. This is assuming that the chloride concentration in the two layers is the same.

Layer 1 is considered to be the Holocene to Miocene deposits above the Floridan aquifer, Layer 2 to be the Upper Floridan aquifer (fresh), and Layers 3 and 4 to be the saltwater within the middle semi-confining unit.

5.03.3. Depth to Occurrence of Salt Water

The bottom (third) layer of the geoelectrical model, with a resistivity of 18.3 ohm-m, is interpreted to represent salt water. It occurs at a depth of 502 ft (-478 ft msl). Because the resistivity of Layer 2 (104 ohm-m) is interpreted to represent fresh water within the Upper Floridan aquifer, the interpreted depth to the 5,000 mg/l isochlor is 50 ft greater than the depth of the geoelectrical interface, or at 552 ft depth (-527 ft msl). The resistivity of Layer 3 (18.3 ohm-m) corresponds to a chloride concentration of 1,605 mg/l assuming a porosity of 25% and the validity and applicability of equation (4) of Section 4.02. It is presumed that because of the expected high chlorinity gradients, this value is sufficiently close to the 5,000 mg/l isochlor that they represent the same effective depth.

5.03.4. Depth of Occurrence of the 250 mg/l Isochlor

The resistivity of Layer 2 (104 ohm-m) corresponds to a chloride concentration of less than 250 mg/l, assuming a 25% porosity and the validity and applicability of equation (4) of Section 4.02. The 250 mg/l isochlor is placed in the Floridan aquifer at a depth 50 ft above the Layer 3 interface or at 452 ft (-427 ft msl). This is not in agreement with available water quality information which indicates that the 250 mg/l isochlor occurs between a depth of 250 and 331 ft bls.

5.03.5. Accuracy of Measurement and Interpretation

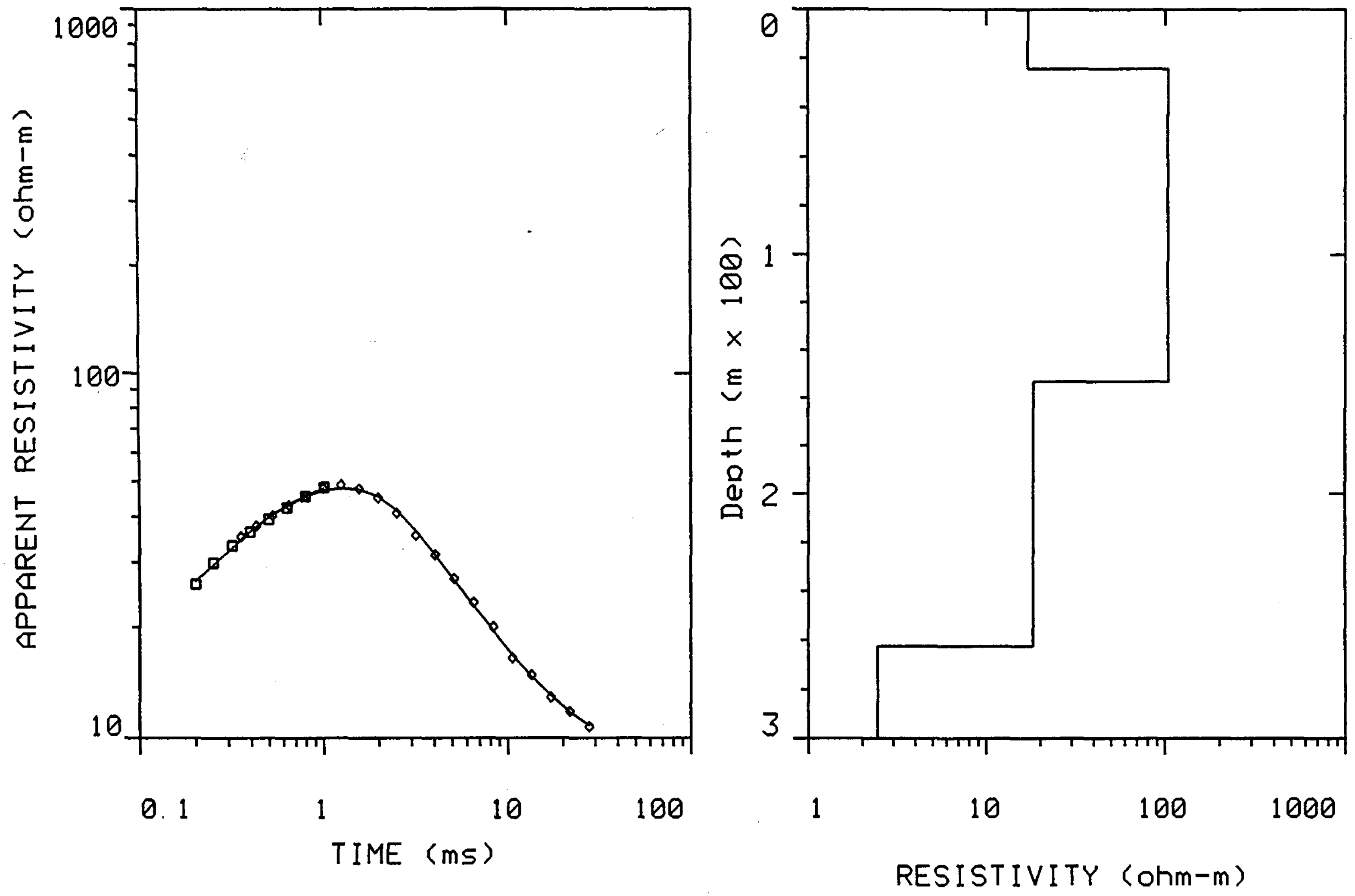
Figure 5.3-2 is the equivalence analysis at this site and Table 5.3-1 lists the upper and lower bounds of the inverted parameters of the geoelectrical model. The range of equivalence in determining the depth to the low resistivity layer is about ±18 m (59 ft), which is 11.4% of the total depth. The resistivity of this layer has a range from 11.6 to 21.5 ohm-m. This corresponds to a range in interpreted chloride concentration from 2,620 to 1,343 mg/l, again subject to the same assumptions of porosity and validity of equation (4).

The equivalence range of the resistivity of Layer 2 is from 90 to 148 ohm-m that corresponds to a chloride concentration above 250 mg/l. The calculated depth to the 250 mg/l isochlor from the TDEM study (452 ft depth) is deeper than the depth determined from available water quality information (250-331 ft depth). This may be due to a wider transition zone thickness between fresh and salt water in this area.

The chloride-to-sulfate ratio at the site is 5:1 (Table 5.1-4). Accordingly, equation (4) is valid.

5.03.6. Summary of TDEM Sounding at Site 2

- The depth to occurrence of salt water (5,000 mg/l isochlor) is interpreted to be 552 ft (-527 ft msl) and occur within the middle semi-confining unit.
- The ground water within the Floridan aquifer at this site is interpreted to contain an average chloride concentration of less than 250 mg/l. The 250 mg/l isochlor is interpreted to be present in the Upper Floridan aquifer at a depth of 452 ft (-427 ft msl). This estimated depth is not in agreement with available water quality information that places the 250 mg/l isochlor at a depth between 250 and 331 ft. This may be due to a wider transition thickness between fresh and salt water in this area.
- The resistivities of the two saltwater saturated layers are 18.3 and 2.4 ohm-m. Assuming the change in the TDEM-determined formation resistivity for the two layers is only due to changes in porosity (and not water quality) a change in porosity from 25 percent (Layer 3) to 89 percent (Layer 4) would be required.



SJRWMD		SALTWATER INTERFACE DETECTION
SDII Global		SITE2 BREVARD COUNTY, FLORIDA
Data Set: SITE2A	Date: 29-NOV-00	
Equipment: Geonics PROTEM	Sounding: 2	Azimuth:

Figure 5.3-1 Measured TDEM Apparent Resistivity and 1-D Inversion - Site 2

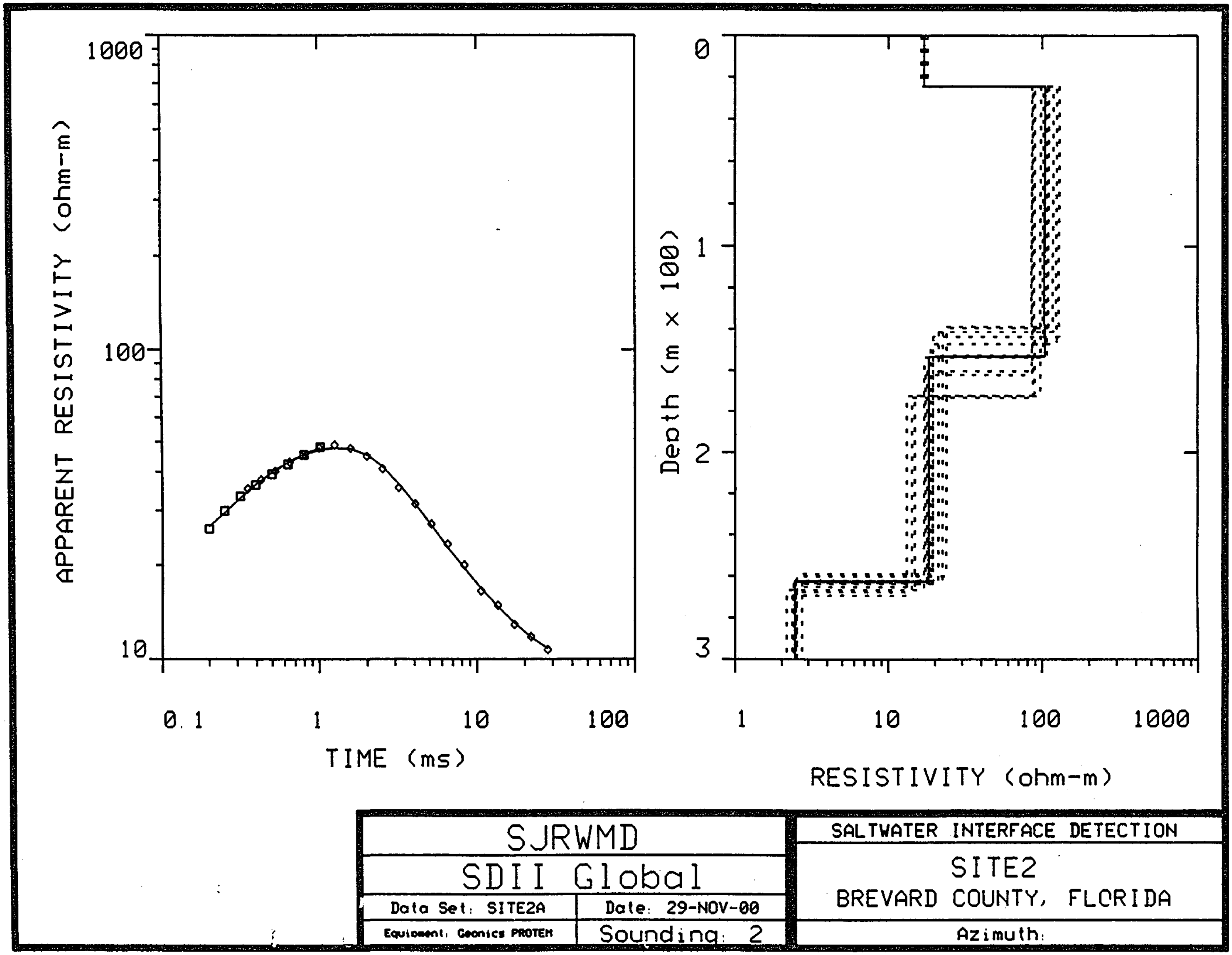


Figure 5.3-2 Measured TDEM Apparent Resistivity and Equivalence for 1-D Inversion - Site 2

Table 5.3.1 TDEM Sounding Data Table - Site 2

DATA SET: SITE2

CLIENT: SJRWMD
DATE: 29-NOV-00
LOCATION: SITE2A
SOUNDING: 2
COUNTY: BREVARD COUNTY, FLORIDA
ELEVATION: 8.00 m
PROJECT: SALTWATER INTERFACE DETECTION
EQUIPMENT: Geonics PROTEM
LOOP SIZE: 91.000 m by 91.000 m
AZIMUTH:
COIL LOC: 0.000 m (X), 0.000 m (Y)
TIME CONSTANT: NONE
SOUNDING COORDINATES: E: 0.0000 N: 0.0000
SLOPE: NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 2.094 PERCENT
SMOOTH MODEL FITTING ERROR: 3.439 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)		ELEVATION (meters)	CONDUCTANCE (Siemens)
				8.00	
1	17.05	24.40	*	-16.40	1.43
2	104.4	128.7		-145.1	1.23
3	18.26	109.4		-254.6	5.98
4	2.44				

"*" INDICATES FIXED PARAMETER

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	16.285	17.055	17.919
	2	85.766	104.468	129.088
	3	13.219	18.266	23.751
	4	2.159	2.449	2.736
THICK	1	24.400	24.400	24.400
	2	114.384	128.792	149.055
	3	92.920	109.408	123.421
DEPTH	1	24.400	24.400	24.400
	2	138.784	153.192	173.455
	3	259.106	262.601	269.508

CURRENT: 13.80 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 30.00 Hz GAIN: 3 RAMP TIME: 5.00 muSEC

* SDII Global *

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.200	23839.9	23131.2	2.97
2	0.250	11154.6	11370.7	-1.93
3	0.314	5385.6	5486.6	-1.87
4	0.395	2657.7	2652.5	0.195
5	0.499	1320.4	1291.2	2.20
6	0.631	656.6	640.6	2.43
7	0.799	327.5	325.1	0.747
8	1.01	166.2	167.5	-0.752

CURRENT: 13.80 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 7.50 Hz GAIN: 5 RAMP TIME: 5.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
9	0.352	3703.4	3806.8	-2.79
10	0.427	2073.6	2089.9	-0.783
11	0.525	1125.7	1111.5	1.26
12	0.647	603.7	598.6	0.850
13	0.802	323.0	324.6	-0.495
14	1.00	172.3	175.5	-1.84
15	1.25	94.62	97.52	-3.07
16	1.58	55.18	55.46	-0.512
17	1.99	33.69	33.21	1.41
18	2.52	21.62	21.10	2.40
19	3.19	14.79	14.22	3.87
20	4.05	9.80	9.82	-0.173
21	5.14	6.77	6.88	-1.74
22	6.54	4.66	4.81	-3.40
23	8.32	3.21	3.33	-3.61
24	10.59	2.35	2.27	3.00
25	13.49	1.50	1.52	-1.56
26	17.19	1.01	0.995	1.59
27	21.90	0.631	0.634	-0.568
28	27.92	0.398	0.391	1.79

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.98						
P 2	0.10	0.56					
P 3	0.01	-0.12	0.39				
P 4	-0.01	0.03	-0.07	0.87			
F 1	0.00	0.00	0.00	0.00	0.00		
T 2	-0.03	0.16	0.26	0.00	0.00	0.85	
T 3	0.03	-0.19	-0.23	0.03	0.00	0.15	0.82
	P 1	P 2	P 3	P 4	F 1	T 2	T 3

5.04. TDEM Site 3

5.04.1. Location Description and Geoelectrical Section

The site is located in northern Brevard County, Florida. The site is located along an abandoned railroad right of way. No possible sources of interference were observed within the vicinity of the site.

After completion of the TDEM sounding, the City of Titusville installed a well (UF-3D) near the site. UF-3D was installed to a depth of 500 feet bls. Water quality results indicate that the 250 mg/l isochlor occurs at a depth ranging from 400 to 445 ft bls. The Floridan aquifer occurs at an approximate depth of 75 ft below mean sea level (bmsl) or 100 ft below land surface [(bls) SJRWMD, personal communication] and is overlain by Holocene to Miocene deposits. Based on information from Miller (1984), depth to the bottom of the Upper Floridan aquifer is approximately –450 ft bmsl (475 ft bls) and the depth to the top of the Lower Floridan aquifer is –850 ft bmsl (875 ft bls).

The resistivity sounding data and best-fit model inversion are presented on Figure 5.4-1. The interpreted geoelectrical section consists of a three-layer subsurface.

5.04.2. Geological Interpretation of Geoelectrical Model

The three-layer geoelectrical section consists of an upper layer with a resistivity of 20 ohm-m, which correlates with the Holocene to Miocene deposits above the Floridan aquifer. The thickness of Layer 1 was fixed at 30.5 m (100 ft, SJRWMD, personal communication). The second layer has high resistivity (215 ohm-m) which means that because it is greater than 80 ohm-m the Floridan aquifer at this site contains fresh water. The thickness of the freshwater section is 111 m (364 ft), placing the depth to the low resistivity (saltwater) layer at 141 m (463 ft) below ground surface. The resistivity of the saltwater layer is 2.95 ohm-m. Layer 1 is considered to be the Holocene to Miocene deposits above the Floridan aquifer, Layer 2 to be the Upper Floridan aquifer containing fresh water, and Layer 3 to be the salt water within the middle semi-confining unit.

5.04.3. Depth to Occurrence of Salt Water

The bottom (third) layer of the geoelectrical model, with a resistivity of 3.0 ohm-m, is interpreted to represent salt water. It occurs at a depth of 463 ft (-438 ft msl). Because the resistivity of Layer 2 (215 ohm-m) is greater than 80 ohm-m, the interpreted depth to the 5,000 mg/l isochlor is taken as 50 ft greater than the depth of the geoelectrical interface, or at a depth of 513 ft (-488 ft bmsl). The resistivity of Layer 3 (3.0 ohm-m) corresponds to a chloride concentration of 10,568 mg/l, assuming a porosity of 25% and the validity and applicability of equation (4) of Section 4.02. It is presumed that because of the expected high chlorinity gradients, this value is sufficiently close to the 5,000 mg/l isochlor that they represent the same effective depth.

5.04.4. Depth of Occurrence of the 250 mg/l Isochlor

The resistivity of Layer 2 (215 ohm-m) corresponds to a chloride concentration of less than 250 mg/l, assuming a 25% porosity and the validity and applicability of equation (4) of Section 4.02. The 250 mg/l isochlor is placed in the Floridan aquifer at a depth 50 ft above the Layer 3 interface or at 413 ft (-388 ft msl). This correlates well to the measured depth range (400 to 445 feet bls) for the 250 mg/l isochlor from Well UF-3D.

5.04.5. Accuracy of Measurement and Interpretation

Figure 5.4-2 is the equivalence analysis at this site and the inversion table (Table 5.4-1) lists the upper and lower bounds of the inverted parameters of the geoelectrical model. The range of equivalence in determining the depth to the low resistivity layer is about ±2 m (6 ft), which is 1.5% of the total depth. The resistivity of this layer has a range of from 2.7 to 3.2 ohm-m. This corresponds to a range in interpreted chloride concentration of from 11,759 to 9,898 mg/l, again subject to the same assumptions of porosity and validity of equation (4).

The equivalence range of the resistivity of Layer 2 is from 134 to 403 ohm-m, which corresponds to a chloride concentration of less than 250 mg/l. The chloride-to-sulfate ratio at the site is 5:1 (Table 5.1-4). Accordingly, Equation (4) is valid.

5.04.6. Summary of TDEM Sounding at Site 3

- The depth to occurrence of salt water (5,000 mg/l isochlor) is interpreted to be 513 ft (-488 ft msl) and occur within the middle semi-confining unit.
- The ground water within the Upper Floridan aquifer at this site is interpreted to contain an average chloride concentration of less than 250 mg/l. The 250 mg/l isochlor is interpreted to be present in the Upper Floridan aquifer at a depth of 413 ft (-388 ft msl). This correlates well to the measured depth range of 400 to 445 feet bls for the 250 mg/l isochlor from Well UF-3D.

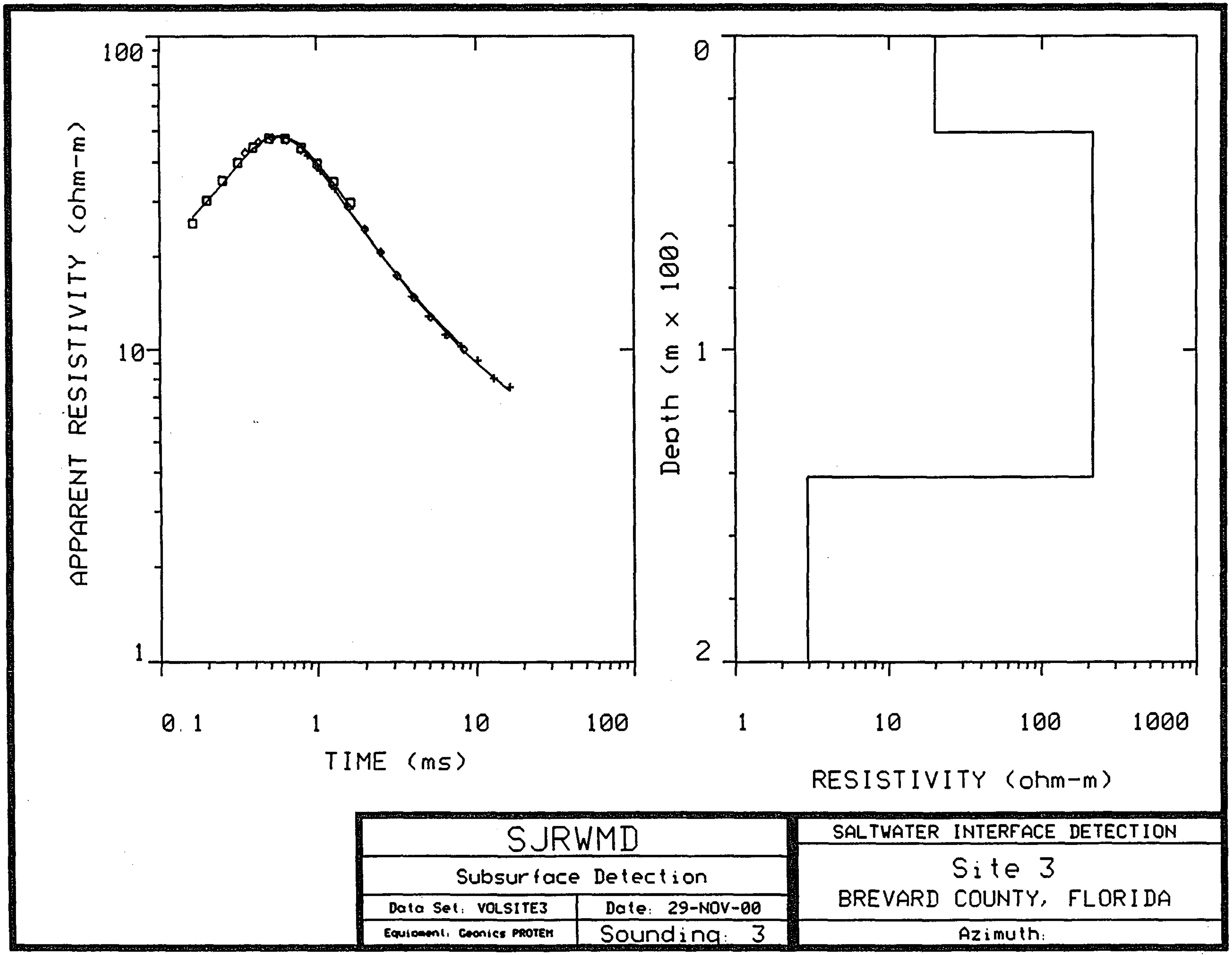
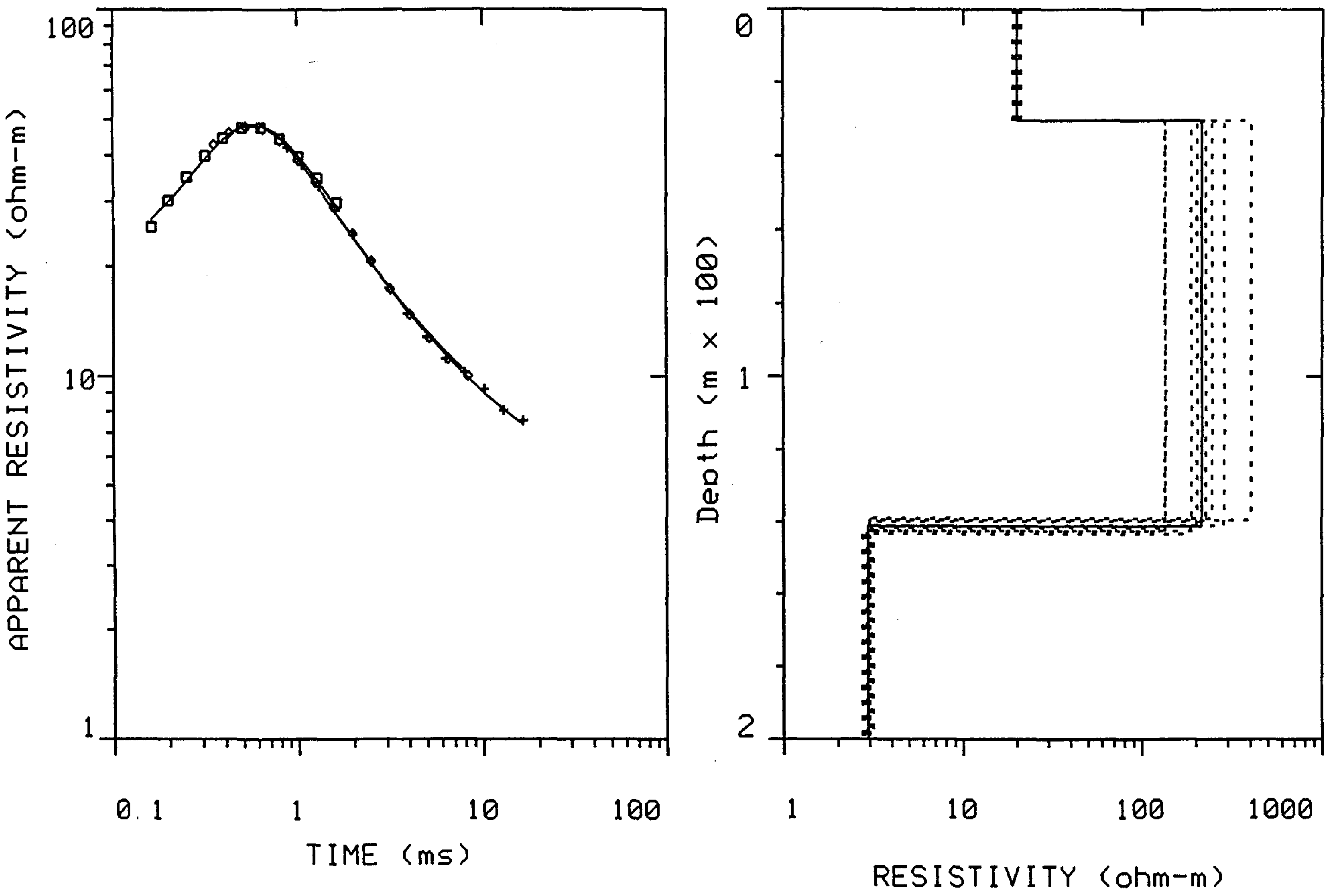


Figure 5.4-1 Measured TDEM Apparent Resistivity and 1-D Inversion - Site 3



SJRWMD		SALTWATER INTERFACE DETECTION
Subsurface Detection		Site 3 BREVARD COUNTY, FLORIDA
Data Set: VOLSITE3	Date: 29-NOV-00	
Equipment: Geonics PROTEM	Sounding: 3	Azimuth:

Figure 5.4-2 Measured TDEM Apparent Resistivity and Equivalence for 1-D Inversion - Site 3

Table 5.4-1 TDEM Sounding Data Table - Site 3

DATA SET: VOLSITE3

```
   CLIENT: SJRWMD                                        DATE: 29-NOV-00
 LOCATION: Site 3                                    SOUNDING: 3
   COUNTY: BREVARD COUNTY, FLORIDA                  ELEVATION:      8.00 m
  PROJECT: SALTWATER INTERFACE DETECTION            EQUIPMENT: Geonics PROTEM
LOOP SIZE:      91.000 m by      91.000 m            AZIMUTH:
 COIL LOC:       0.000 m (X),      0.000 m (Y)  TIME CONSTANT: NONE
SOUNDING COORDINATES:  E:         0.0000 N:          0.0000 SLOPE: NONE
```

Central Loop Configuration
Geonics PROTEM System

```
             FITTING ERROR:      2.724 PERCENT
  SMOOTH MODEL FITTING ERROR:      3.296 PERCENT
```

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)		ELEVATION (meters)	CONDUCTANCE (Siemens)
				8.00	
1	19.83	30.50	*	-22.50	1.53
2	215.3	110.7		-133.2	0.514
3	2.95				

"*" INDICATES FIXED PARAMETER

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	18.935	19.836	21.095
	2	134.046	215.328	403.346
	3	2.748	2.951	3.151
THICK	1	30.500	30.500	30.500
	2	108.626	110.736	112.884
DEPTH	1	30.500	30.500	30.500
	2	139.126	141.236	143.384

```
  CURRENT:   14.00 AMPS   EM-58    COIL AREA:    100.00 sq m.
FREQUENCY:   30.00 Hz    GAIN: 4   RAMP TIME:    5.00 muSEC
```

SYNTHETIC FROM LAYERED MODEL:

No.	TIME	emf (nV/m sqrd)	DIFFERENCE

	(ms)	DATA	SYNTHETIC	(percent)
1	0.161	42694.3	39821.8	6.72
2	0.200	19541.7	19679.2	-0.703
3	0.250	8961.1	9276.8	-3.52
4	0.314	4168.6	4280.7	-2.68
5	0.395	1995.8	2015.4	-0.984
6	0.499	1013.4	989.4	2.36
7	0.631	564.0	548.1	2.82
8	0.799	345.1	333.9	3.22
9	1.01	225.1	223.9	0.555
10	1.28	152.3	154.8	-1.64
11	1.63	105.0	109.2	-3.98

CURRENT: 14.00 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 7.50 Hz GAIN: 5 RAMP TIME: 5.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
12	0.352	2820.8	2938.0	-4.15
13	0.427	1562.2	1583.0	-1.33
14	0.525	885.9	872.9	1.46
15	0.647	536.7	525.3	2.12
16	0.802	349.8	340.0	2.79
17	1.00	237.5	235.9	0.689
18	1.25	166.2	167.8	-1.00
19	1.58	118.4	121.9	-2.96
20	1.99	85.02	87.34	-2.72
21	2.52	61.45	62.52	-1.74
22	3.19	44.27	43.82	1.01
23	4.05	31.13	30.33	2.56
24	5.14	21.35	20.62	3.40
25	6.54	14.26	13.74	3.66
26	8.32	9.21	8.98	2.51

CURRENT: 14.00 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 3.00 Hz GAIN: 6 RAMP TIME: 5.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
27	0.881	293.3	290.6	0.898
28	1.06	213.4	214.4	-0.467
29	1.31	155.8	158.6	-1.75
30	1.61	114.8	118.7	-3.36
31	2.00	85.18	87.42	-2.62
32	2.50	62.93	63.78	-1.34
33	3.14	45.73	45.49	0.523
34	3.95	32.76	32.06	2.13
35	4.99	22.76	22.14	2.69
36	6.31	15.59	15.05	3.46
37	7.99	9.85	10.05	-2.08
38	10.13	6.34	6.59	-3.98
39	12.86	4.28	4.25	0.715
40	16.35	2.58	2.69	-3.91

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.99				
P 2	0.07	0.10			
P 3	0.00	-0.03	0.96		
F 1	0.00	0.00	0.00	0.00	
T 2	0.00	0.02	0.01	0.00	1.00
	P 1	P 2	P 3	F 1	T 2

5.05. TDEM Site 4

5.05.1. Location Description and Geoelectrical Section

The site is located in northern Brevard County, Florida. The site is located within an open field. No possible sources of interference were observed within the vicinity of the site.

After completion of the TDEM sounding, the City of Titusville installed a well (UF-2S) 0.7 miles northeast of the site. The well was installed to a depth of 210 feet bls. The water quality information indicates that the 250 mg/l isochlor is present between a depth of 160 and 186 feet bls. Results from the well indicate that the Floridan aquifer occurs at an approximate depth of 75 ft below mean sea level (bmsl) or 100 ft below land surface and is overlain by Holocene to Miocene deposits. Based on information from Miller (1984), depth to the bottom of the Upper Floridan aquifer is approximately –450 ft bmsl (475 ft bls) and the depth to the top of the Lower Floridan aquifer is –850 ft bmsl (875 ft bls).

The resistivity sounding data and best-fit model inversion are presented on Figure 5.5-1. The interpreted geoelectrical section consists of a four-layer subsurface.

5.05.2. Geological Interpretation of Geoelectrical Model

The four-layered geoelectrical section consists of a low resistivity (33 ohm-m) upper layer which is considered to be Holocene to Miocene deposits above the Floridan aquifer. The thickness of Layer 1 was fixed at 30.5 m (100 ft). The second layer has a resistivity of 39 ohm-m, which, because it is less than 80 ohm-m, suggests the Upper Floridan aquifer at this site contains brackish water. However, based on available water quality information (Well UF-2S), part of the Upper Floridan aquifer in this area is fresh. Based on the TDEM, the average chloride concentration for the Upper Floridan aquifer (Layer 2) is above 250 mg/l (brackish). The thickness of the brackish water section is 109 m (358 ft), placing the depth to the low resistivity (saltwater) layer at 139 m (456 ft) below land surface. Layer 1 is considered to be the Holocene to Miocene deposits above the Floridan aquifer, Layer 2 to be the Upper Floridan aquifer (brackish), and Layers 3 and 4 to be the saltwater within the middle semi-confining unit.

The resistivity of the saltwater saturated layer is 1.0 ohm-m. The fourth layer has a resistivity of 6.5 ohm-m and is considered to represent a porosity change in the salt water saturated middle semi-confining unit. Using Equation 3 from Kwader, given the calculated chloride concentration for Layer 3, a change in porosity from 25 percent (Layer 3) to 8 percent (Layer 4) would be necessary to explain the difference in the TDEM-determined formation resistivity for the two layers.

5.05.3. Depth to Occurrence of Salt Water

The bottom (third) layer of the geoelectrical model, with a resistivity of 1.0 ohm-m, is interpreted to represent salt water. It occurs at a depth of 456 ft (-431 ft msl). Because available water quality information indicates that the Upper Floridan aquifer is fresh, the interpreted depth to the 5,000 mg/l isochlor is 50 feet greater than the depth of the geoelectrical interface, or at 506 ft depth (-481 ft msl). The resistivity of Layer 3 (1.0 ohm-m) corresponds to a chloride concentration of 32,011 mg/l assuming a porosity of 25% and the validity and applicability of equation (4) of Section 4.02. It is presumed that because of the expected high chlorinity gradients, this value is sufficiently close to the 5,000 mg/l isochlor that they represent the same effective depth.

5.05.4. Depth of Occurrence of the 250 mg/l Isochlor

The resistivity of Layer 2, 39 ohm-m, corresponds to a chloride concentration above 250 mg/l, assuming a 25% porosity and the validity and applicability of equation (4) of Section 4.02. This conclusion does not agree with available water quality information that indicates that the water within the Upper Floridan aquifer in this area is fresh. Using available water quality information, the 250 mg/l isochlor is placed in the Floridan aquifer at a depth 50 ft above the Layer 3 interface or at 406 ft (-381 ft msl).

Using Equation 3 from Kwader, it is possible to determine the necessary porosity for ground water to be fresh (less than 250 mg/l chloride concentration) with the TDEM derived formation resistivity of 39 ohm-m. Such a calculation indicates that a porosity of 39 percent would be required rather than the assumed 25 percent.

5.05.5. Accuracy of Measurement and Interpretation

Figure 5.5-2 is the equivalence analysis at this site and the inversion table (Table 5.5-1) lists the upper and lower bounds of the inverted parameters of the geoelectrical model.

The range of equivalence in determining the depth to the low resistivity layer is about ±4 m (12 ft), which is 2.9% of the total depth. The resistivity of this layer has a range of from 0.6 to 1.7 ohm-m. This corresponds to a range in interpreted chloride concentration of from 53,453 to 18,767 mg/l, again subject to the same assumptions of porosity and validity of equation (4).

The equivalence range of the resistivity of Layer 2 is from 33 to 45 ohm-m that corresponds to a chloride concentration above 250 mg/l. The results are not in agreement with available water quality data for the Upper Floridan aquifer in the area of the project site. It is suspected that the lower resistivity for Layer 2 is due to a localized increase in the effective porosity (39 percent vs 25 percent) for the Upper Floridan aquifer in this area. The chloride-to-sulfate ratio at the site is 5:1 (Table 5.1-4). Accordingly, equation (4) is valid.

5.05.6. Summary of TDEM Sounding at Site 4

- The depth to occurrence of salt water (5,000 mg/l isochlor) is interpreted to be 506 ft (-481 ft msl) and occurs within the middle semi-confining unit.
- The ground water within the Floridan aquifer at this site is interpreted to contain an average chloride concentration above 250 mg/l. The TDEM-derived water quality results are not in agreement with available water quality data for the Upper Floridan aquifer in the area of the project site. This may be due to a localized increase in the effective porosity for the Upper Floridan aquifer in this area.
- Assuming that the water quality data is correct and that the effective porosity for the Upper Floridan aquifer in this area is 39 percent rather than the assumed 25 percent, the 250 mg/l isochlor is interpreted to be present in the Upper Floridan aquifer at a depth of 406 ft (-381 ft msl). This is not in agreement with the measured depth to the 250 mg/l isochlor (160 to 186 ft) from well UF-2S that is 0.7 miles northeast of the site.

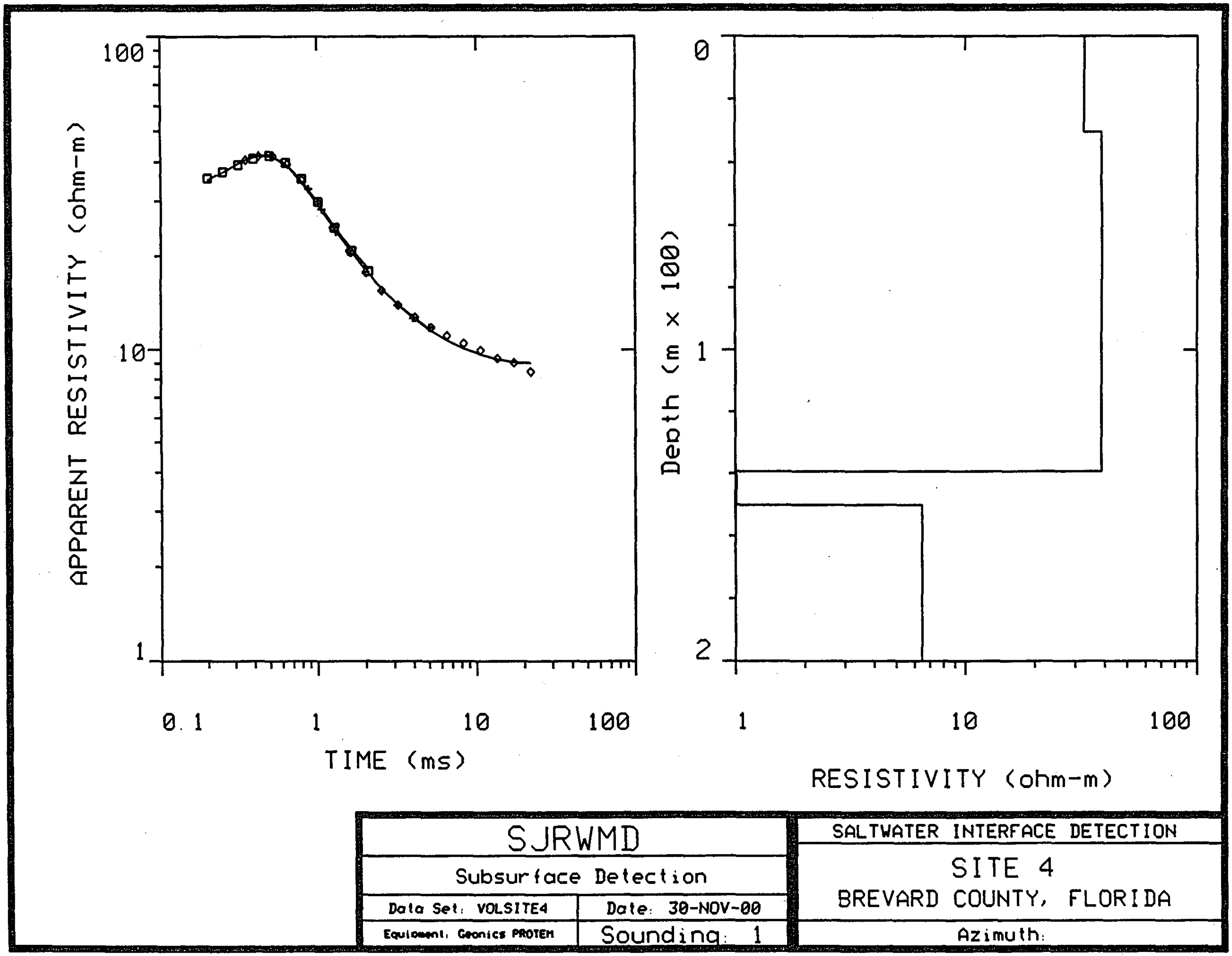


Figure 5.5-1 Measured TDEM Apparent Resistivity and 1-D Inversion - Site 4

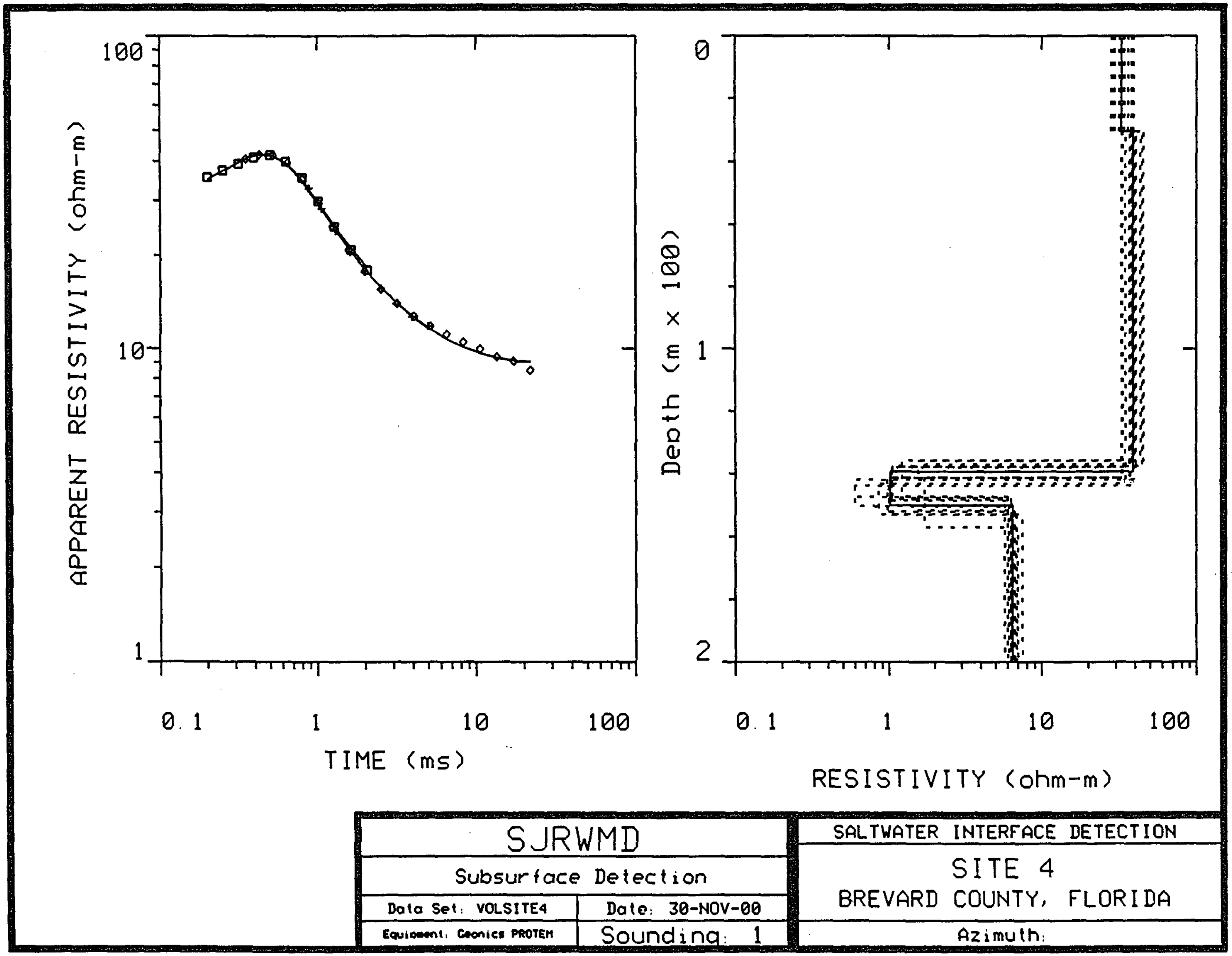


Figure 5.5-2 Measured TDEM Apparent Resistivity and Equivalence for 1-D Inversion - Site 4

Table 5.5-1 TDEM Sounding Data Table - Site 4

DATA SET: VOLSITE4

CLIENT:	SJRWMD	DATE:	30-NOV-00
LOCATION:	SITE 4	SOUNDING:	1
COUNTY:	BREVARD COUNTY, FLORIDA	ELEVATION:	8.00 m
PROJECT:	SALTWATER INTERFACE DETECTION	EQUIPMENT:	Geonics PROTEM
LOOP SIZE:	91.000 m by 91.000 m	AZIMUTH:	
COIL LOC:	0.000 m (X), 0.000 m (Y)	TIME CONSTANT:	NONE
SOUNDING COORDINATES:	E: 1.0000 N: 4.0000	SLOPE:	NONE

Central Loop Configuration
Geonics PROTEM System

FITTING ERROR: 2.781 PERCENT
SMOOTH MODEL FITTING ERROR: 0.939 PERCENT

L #	RESISTIVITY (ohm-m)	THICKNESS (meters)		ELEVATION (meters)	CONDUCTANCE (Siemens)
				8.00	
1	32.57	30.50	*	-22.50	0.936
2	38.74	108.9		-131.4	2.81
3	1.00	10.70		-142.1	10.61
4	6.46				

"*" INDICATES FIXED PARAMETER

PARAMETER BOUNDS FROM EQUIVALENCE ANALYSIS

LAYER		MINIMUM	BEST	MAXIMUM
RHO	1	28.018	32.577	38.848
	2	32.643	38.746	45.290
	3	0.594	1.008	1.699
	4	5.733	6.468	7.480
THICK	1	30.500	30.500	30.500
	2	105.269	108.938	113.453
	3	5.621	10.702	20.206
DEPTH	1	30.500	30.500	30.500
	2	135.769	139.438	143.953
	3	147.483	150.140	157.214

CURRENT:	14.00 AMPS	EM-58	COIL AREA:	100.00 sq m.
FREQUENCY:	30.00 Hz	GAIN: 4	RAMP TIME:	5.00 muSEC

* Subsurface Detection *

Table 5.51 continued

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
1	0.200	15277.1	15533.6	-1.67
2	0.250	8135.0	8173.2	-0.469
3	0.314	4284.8	4211.3	1.71
4	0.395	2248.4	2195.5	2.35
5	0.499	1224.2	1208.8	1.25
6	0.631	729.5	737.7	-1.13
7	0.799	484.3	493.9	-1.98
8	1.01	346.4	349.5	-0.882
9	1.28	252.4	249.9	0.979
10	1.63	180.2	175.7	2.45
11	2.08	123.7	120.1	2.92

CURRENT: 14.00 AMPS EM-58 COIL AREA: 100.00 sq m.
FREQUENCY: 7.50 Hz GAIN: 5 RAMP TIME: 5.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
12	0.352	3049.0	3038.1	0.358
13	0.427	1802.3	1791.5	0.598
14	0.525	1080.3	1086.2	-0.548
15	0.647	694.5	712.2	-2.54
16	0.802	486.0	499.1	-2.69
17	1.00	357.2	362.6	-1.52
18	1.25	266.1	265.5	0.246
19	1.58	195.1	191.5	1.86
20	1.99	137.8	134.6	2.30
21	2.52	93.88	92.00	2.00
22	3.19	61.40	61.02	0.617
23	4.05	38.94	39.36	-1.06
24	5.14	23.92	24.74	-3.46
25	6.54	14.39	15.17	-5.42
26	8.32	8.61	9.09	-5.58
27	10.59	5.07	5.34	-5.22
28	13.49	3.04	3.06	-0.896
29	17.19	1.74	1.72	0.933
30	21.90	1.05	0.952	9.34

CURRENT:	14.00 AMPS	EM-58	COIL AREA:	100.00 sq m.
FREQUENCY:	3.00 Hz	GAIN: 6	RAMP TIME:	5.00 muSEC

SYNTHETIC FROM LAYERED MODEL:

No.	TIME (ms)	emf (nV/m sqrd) DATA	SYNTHETIC	DIFFERENCE (percent)
31	0.881	424.4	435.0	-2.50
32	1.06	328.8	332.7	-1.17
33	1.31	252.6	250.5	0.862
34	1.61	189.2	185.7	1.88
35	2.00	137.9	134.1	2.73
36	2.50	95.80	93.51	2.39
37	3.14	64.08	63.24	1.31
38	3.95	41.56	41.54	0.0398
39	4.99	25.88	26.57	-2.68

PARAMETER RESOLUTION MATRIX:
"F" INDICATES FIXED PARAMETER

P 1	0.77						
P 2	0.22	0.77					
P 3	0.03	-0.04	0.50				
P 4	-0.03	0.04	0.03	0.89			
F 1	0.00	0.00	0.00	0.00	0.00		
T 2	-0.02	0.03	0.04	-0.01	0.00	0.99	
T 3	-0.01	0.01	-0.46	-0.07	0.00	0.02	0.44
	P 1	P 2	P 3	P 4	F 1	T 2	T 3

6.0 SUMMARY AND CONCLUSIONS

A TDEM survey was performed at four sites in the St. Johns River Water Management District during the month of November 2001. The principal findings of this survey can be summarized as follows:

TDEM is a geoelectrical method that can be used to estimate the vertical variation of resistivity of subsurface formations and/or hydrostratigraphic units. Translating the geophysical measurement of electrical resistivity into a model of geology and water quality depends upon comparison to other available subsurface data, consistency of data sets from nearby soundings and application of empirical relationships to produce interpreted water-quality results. As outlined in Section 4, the conversions to water quality values (chloride concentrations) are based upon the relationships established using Kwader's (1982) data for Seminole County, as used for SJRWMD in previous studies (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; SDII, 1993, 1994, 1995 and 1996). The formulae employed use assumptions of a 25% porosity, similar water chemistry (specifically, a 5:1 chloride-to-sulfate ratio) as Kwader's data, and that the saltwater interface occurs within the Floridan Aquifer System. With regards the latter point, chloride concentration values are generally presented only for those portions of the geoelectrical section that corresponds to the Floridan aquifer.

Finally, because the freshwater/saltwater boundary is not an abrupt interface but a transition zone, criteria relating to the relative resistivities above and below the geoelectrical interface were used to establish an empirical definition of depths to the 250 and 5,000 mg/l isochlors. Again, these were the same criteria as used in past years' TDEM surveys (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; SDII, 1993, 1994,1995 and 1996) in order to maintain consistency from year to year.

6.01. Determining the Depth of the Interface Between Fresh Water and Ground Water of High Chloride Concentration (Greater Than 1,450 mg/l)

As stated in previous years' reports (Blackhawk, 1990; Blackhawk, 1991; CEES, 1992; SDII, 1993, 1994, 1995 and 1996), "ground water with a chloride content greater than 1,450 mg/l is characterized in the Floridan aquifer by resistivities less than 20 ohm-m when the aquifer has a porosity of about 25%." In accordance with this statement, a deep layer with a resistivity of less than 20 ohm-m was detected at each of the surveyed sites. All the interpreted depths place the saltwater interface at or very near the base of the Upper Floridan aquifer.

6.02. Water Quality in the Floridan aquifer and Depth of Occurrence of the 250 mg/l Isochlor

Based on the assumptions that: (a) the Floridan aquifer has a porosity of 25%, (b) ground water within the study area have a chemistry similar to those analyzed by Kwader (1982), and (c) equation (4) in Section 4.02 is valid, ground water having chloride concentrations of less than 250 mg/l correspond to geoelectrical layers having resistivities in excess of 80 ohm-m. When a layer with a chloride concentration of less than 250 mg/l is interpreted, the position of the 250 mg/l isochlor is fixed by the relative resistivities of the deep, conductive layer and the fresh (resistive) layer above - generally placing it 50 ft above the geoelectrical interface.

The distribution of resistivities of the Floridan aquifer show, for the most part, high resistivities and, therefore, fresh waters of less than 250 mg/l are present in the Floridan aquifer for the study area. At two of the sites, however, the average resistivity of the Floridan aquifer was less than 80 ohm-m and brackish water is interpreted to be present. Conversely, available water quality data for the Upper Floridan aquifer within the entire study area indicates that the water is fresh. It is suspected that a localized increase in the effective porosity in the Upper Floridan aquifer is responsible for the lower resistance values in these areas. This suspected increase in effective porosity for the two sites in question ranged from 37 to 39 percent.

The TDEM-derived depth to the 250 mg/l isochlor ranged from 452 to 406 ft bls. The thickness of the freshwater layer appears to thin from north to south. This is supported by the water quality results from the wells that were installed after the completion of the TDEM field study. Results from those wells, however, indicate that the thinning of the freshwater layer is more severe from 400 to 445 feet bls (well UF-3D, TDEM Site 3) to 160 to 186 feet bls (well UF-2S, TDEM Site 4). The difference between the water quality results derived from the wells and the TDEM results are likely due to a combination of factors. These factors include: 1) the thickness of the transition zone between the fresh and salt water layers being greater than what is assumed in the TDEM calculations and 2) the TDEM method not being able to resolve the relatively thin layers of freshwater within the upper portions of the Upper Floridan aquifer that is otherwise brackish.

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