Helicopter Electromagnetic Data from Everglades National Park and Surrounding Areas, Florida: Collected 9-14 December 1994

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ABSTRACT

This report describes helicopter electromagnetic (HEM) data that were collected over portion of Everglades National Park and surrounding areas in south Florida. The survey was flown 9-14 December 1994. The original data set processed by the contractor, Dighem, are provided as an ASCII, xyz flight-line file. Apparent resistivity grids of the generated from the original data set and JPEG images of these grids are also provided. The data have been corrected by the U.S. Geological Survey to remove the effects of calibration errors and bird-height uncertainty. The corrected data set is included in this report as flight-line data only.

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1. INTRODUCTION

The U.S. Geological Survey contracted with Dighem, then a division of CGG Canada, Ltd. of Mississauga, Ontario, Canada, to fly a helicopter electromagnetic survey over parts of Everglades National Park and surrounding areas in south Florida. Survey covered 398 square miles (1031 sq. km) with total flight-lines totaling 1718 miles (2765 km). The data were collected towards the end of the wet season from 9 December through 14 December 1994. This report contains the contractor's original report and flight-line data set. In addition, a version of the data set that was corrected by the U.S. Geological Survey to remove errors associated with calibration and operational procedures is also included. A brief description of the procedures used to correct the data set is given.

2. ADDITIONAL CORRECTIONS APPLIED TO ORIGINAL DATA SET

In the course of interpretation of the data set provided by Dighem, we became aware of errors in the data which caused difficulty in obtaining reliable layered-earth inversion models (Deszcz-Pan et al., 1998). These errors were traced to problems with calibration and problems with the bird tow-cable length.

Calibration errors were corrected using a procedure described in Deszcz-Pan et al. (1998), outlined in Figure 1. Calibrations are performed on the ground at a site that is assumed to have negligible conductivity. Calibration consists of three parts: 1) adjustment of the system gain, 2) phasing of the receiver coil, and 3) adjustment of the zero level. The first two steps are typically completed on the ground, while step 3 is done with the bird at altitude so that the influence of the ground is removed.

The gain is calibrated by placing a Q coil of known dimensions and electrical properties at a specified distance from the bird receiver coil (R). Currents induced in the calibration coil produce an offset on the chart recorder (Figure 1a). The gain of the electronics is adjusted to make the recorded deflection agree with the theoretically calculated value. The calculated value is usually computed assuming that the conductivity of the half-space below the measurement site is negligible. When the resistivity at the measurement site falls below 100 ohm-m errors of greater than 5 percent are introduced into the calibration especially at frequencies above 50 kHz (Fitterman, 1997, 1998). Errors are also introduced by imprecise positioning of the calibration coil. Positioning errors can be eliminated through the use of jigs which rigidly hold the calibration coil at the proper location with respect to the bird. The gain was adjusted once at the beginning of the survey.

The phasing adjusts the receiver time-base so that the inphase signal is synchronous with the transmitter wave form. This is done by placing a ferrite bar next to the receiver coil (R) and rotating so that it is maximally coupled to the primary field of the transmitter. This configuration should only produce an inphase signal. The phase ϕ is adjusted so that the quadrature signal is zero. For this survey, phasing was adjusted daily.

Sixty-four time-domain electromagnetic (TEM) sounding were collected along or near selected helicopter flight lines and inverted (Fitterman et al., 1999) to obtain the resistivity-depth structure at the sounding location (Figure 1c). Using the radar altimeter data from the HEM survey to estimate the bird height and the resistivity-depth function from 44 TEM inversion and 11 induction logs from nearby wells, the computed HEM response (C_i) is determined.

The tow cable length is adjusted for lift effects which are a function of the airspeed of the bird. This was based upon an average survey flying speed and an airspeed-lift relationship provided by Dighem. The correction for lift effectively shortened the tow cable by 2.9 m. This correction, as well as a second one to compensate for the use of a shorter tow cable, resulted in an overall decrease in tow cable lenght of 5.3 m. The altitude of the bird is then determined by subtracting the tow cable length from the radar altimeter reading. The radar altimeter is mounted on the helicopter so that there is a small error due to bird swing. To avoid errors due to radar reflections from trees, the TEM soundings were made in clear areas—usually freshwater marshes.

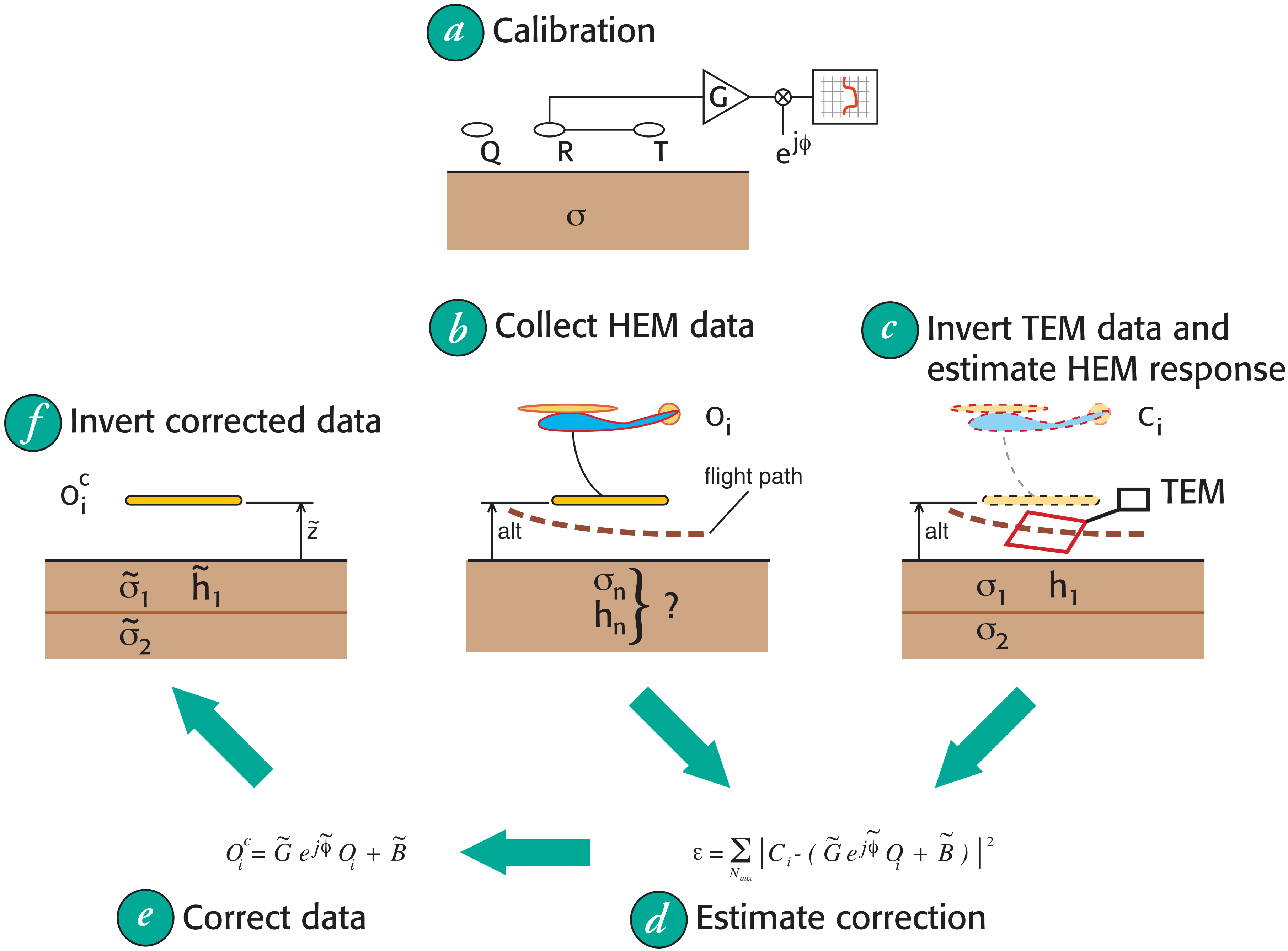

Figure1 Schematic representation of calibration error reduction procedure

A least squares estimation technique is used to determine a correction factor consisting of gain ($\tilde{G}$),phase ($\tilde{\phi}$), and bias terms ($\tilde{B}$) (see Figures 1d and 1e). The corrected data are then obtained through the relationship:

$$O_i^c = \tilde{G} e^{j\tilde{\phi}} O_i + \tilde{B},$$

where O_i is the observed data and O_i^c is the corrected data. Finally, the corrected HEM data are inverted to determine the resistivity-depth function throughout the survey area (Figure 1f). (See Fitterman and Deszcz-Pan (1998) for an example of the results.) Usually the bird height $\tilde{z}$ is solved for in the inversion.

The correction procedure is slightly more complicated than described here as various parameters of the correction factors need to be computed using subsets of the entire HEM and TEM data sets. This is required because the setting of gain, phasing, and zero levels is determined by survey logistics.

Separate gain correction factors ($\tilde{G}$) were computed for each coil-pair. Because the gain of the system was determined only at the beginning of the survey, the same correction factors were used throughout the survey. These factors are summarized in Table 1.

Table 1 Gain correction factors.

Coil Pair Frequency and Geometry	Gain Correction Factor $\tilde{G}$
922 Hz VCX	1.093
844 Hz HCP	1.243
5655 Hz VCX	1.071
7342 Hz HCP	1.295
55780 Hz HCP	1.117

VCX - vertical coaxial
HCP - horizontal coplanar

Phase was adjusted in the field daily, so phase corrections were computed for each day of the survey. The phase corrections are summarized in Table 2. On the fourth day of the survey (12 Dec 1994), the phase corrections have been set to zero because of insufficient time-domain soundings along the flight lines for that day. The largest phase adjustment was 3.1° for the 874-Hz horizontal coplanar channel.

Bias corrections were always set to zero because insufficient TEM data. Furthermore, HEM processing usually requires shifting of line levels to remove effects of offsets in zero levels due to instrument drift. These shifts are usually adjusted to produce smooth apparent resistivity maps, thus the measurements are subject to a somewhat arbitrary bias making estimation of it through our correction procedure superfluous (Huang and Fraser, 1999).

Table 2 Phase corrections.

Date	Flight Number	Frequency [Hz] and Geometry	Phase [deg]
9 Dec 1994	6,7	992 VCX	1.6
		874 HCP	-2.1
		5655 VCX	0.2
		7342 HCP	-1.6
		55780 HCP	-1.3
10 Dec 1994	8,9	992 VCX	-2.8
		874 HCP	-1.5
		5655 VCX	-0.3
		7342 HCP	-1.9
		55780 HCP	-1.3
11 Dec 1994	10,11,12,13,14	992 VCX	-0.9
		874 HCP	1.0
		5655 VCX	-0.2
		7342 HCP	1.1
		55780 HCP	-0.6
12 Dec 1994	15,16,17	992 VCX	0.0
		874 HCP	0.0
		5655 VCX	0.0
		7342 HCP	0.0
		55780 HCP	0.0
13 Dec 1994	18,19,20,21,22	992 VCX	3.0
		874 HCP	3.1
		5655 VCX	-1.8
		7342 HCP	-0.9
		55780 HCP	-0.9
14 Dec 1994	23,24,25	992 VCX	1.6
		874 HCP	2.3
		5655 VCX	2.2
		7342 HCP	2.1
		55780 HCP	0.4

4. DESCRIPTION OF DATA SETS

Two versions of the data set are provided with this report. The original data set is contained in an ASCII file named `616a.xyz`. This data set is described in the original Dighem report. The corrected data set is named `616a_cor.xyz` and are described in Table 3. The channel names for the corrected data set are found in file `616a_cor.title` and are described in Table 4.

The horizontal coplanar channels (HCP) of the original data set are in "Dighem ppm." These values are a factor of 2 smaller than real parts per million (ppm) of the primary signal. All HCP values in the corrected data set have been converted to true ppm.

5. REFERENCES

Deszcz-Pan, M., Fitterman, D.V., and Labson, V.F., 1998, Reduction of inversion errors in helicopter EM data using auxiliary information: Exploration Geophysics, v. 29, p. 142-146.

Fitterman, D.V., 1997, Analysis of errors in HEM calibration data: U.S. Geological Survey 97-742.

Fitterman, D.V., 1998, Sources of calibration errors in helicopter EM data: Exploration Geophysics, v. 29, p. 65-70.

Fitterman, D.V., and Deszcz-Pan, M., 1998, Helicopter EM mapping of saltwater intrusion in Everglades National Park, Florida: Exploration Geophysics, v. 29, p. 240-243.

Fitterman, D.V., Deszcz-Pan, M., and Stoddard, C.E., 1999, Results of time-domain electromagnetic soundings in Everglades National Park, Florida (on CD-ROM): U.S. Geological Survey 99-426.

Huang, H. and Fraser, D. C., 1999, Airborne resistivity data leveling.: Geophysics, v. 64, p. 378-385.

Table 3 Description of data channels in original data set.

Channel	Name	Units	Description
1	record id	-	
2	flight	m	flight number
3	x utm	m	UTM easting[1]
4	y utm	m	UTM northing
5	altr	ft x 10	radar altimeter
6	cxi900	ppm x 10	992 Hz VCX coil-pair inphase[2]
7	cxq900	ppm x 10	992 Hz VCX coil-pair quadrature
8	cpi900	ppm x 10	874 Hz HCP coil-pair inphase[3]
9	cpq900	ppm x 10	874 Hz HCP coil-pair quadrature
10	cxi5000	ppm x 10	5655 Hz VCX coil-pair inphase
11	cxq5000	ppm x 10	5655 Hz VCX coil-pair quadrature
12	cpi7200	ppm x 10	7342 Hz HCP coil-pair inphase
13	cpq7200	ppm x 10	7342 Hz HCP coil-pair quadrature
14	cpi56k	ppm x 10	55780 Hz HCP coil-pair inphase
15	cpq56k	ppm x 10	55780 Hz HCP coil-pair quadrature

[1] UTM coordinates are given in NAD83 and are in zone 17.
[2] All VCX channels are in true ppm.
[3] All HCP channels are in Dighem ppm. To obtain true ppm for the HCP channels, multiply the Dighem value by 2.

Table 3 continued

16	res56k	ohm-m	56-kHz HCP apparent resistivity
17	res7200	ohm-m	7200-Hz HCP apparent resistivity
18	res900	ohm-m	900-Hz HCP apparent resistivity
19	dp56k	m	56-kHz differential resistivity depth
20	dp7200	m	7200-Hz differential resistitivity depth
21	dp900	m	900-Hz differential resistivity depth
22	cen56k	m x 10	56-kHz centroid (Sengpiel) depth
23	cen7200	m x 10	7200-Hz centroid (Sengpiel) depth
24	cen900	m x 10	900 Hz centroid (Sengpiel) depth
25	ddep56k	m	56-kHz differental resistivity depth
26	ddep7200	m	7200-Hz differential resistivity depth
27	ddep900	m	900-Hz differential resistivity depth
28	dres56k	ohm-m	56-kHz differential resistivity
29	dres7200	ohm-m	7200-Hz differential resistivity
30	dres900	ohm-m	900-Hz differential resistivity
31	cxs	ppm	coaxial sferics channel
32	cxpl	pmm	coaxial power line monitor
33	cps	ppm	coplanar sferics channel

Table 4 Description of data channels in corrected data set.

Channel	Name	Units	Description
1	x utm	m	UTM easting[4]
2	y utm	m	UTM northing
3	fid	-	fiducial number
4	flight	-	flight number
5	bird alt	m	corrected altitude of bird
6	cxi900	ppm	992 Hz VCX coil-pair inphase
7	cxq900	ppm	992 Hz VCX coil-pair quadrature
8	cpi900	ppm	874 Hz HCP coil-pair inphase[5]
9	cpq900	ppm	874 Hz HCP coil-pair quadrature
10	cxi5000	ppm	5655 Hz VCX coil-pair inphase
11	cxq5000	ppm	5655 Hz VCX coil-pair quadrature
12	cpi7200	ppm	7342 Hz HCP coil-pair inphase
13	cpq7200	ppm	7342 Hz HCP coil-pair quadrature
14	cpi56k	ppm	55780 Hz HCP coil-pair inphase
15	cpq56k	ppm	55780 Hz HCP coil-pair quadrature

[4] UTM coordinates are given in NAD83 and are in zone 17.
[5] All inphase and quadrature channels are in true ppm. To obtain Dighem ppm for the HCP channels, divide the corrected value by 2.

APPENDIX: ORGINAL DIGHEM REPORT

The following pages contain scanned pages from the final report provided by Dighem. We have also included in this open-file report the original ASCII xyz files and format description files received from the contractor.

Report #0616

DIGHEM^{V} Conductivity Survey

Everglades National Park

Site Characterization

Dighem, A division of CGG Canada Ltd.
Mississauga, Ontario
February 1, 1995

Douglas L. McConnell, P.Eng.
Geophysicist

A0616FEB.95R

SUMMARY

This report describes the logistics and results of a DIGHEM^V airborne geophysical survey carried out for the U.S. Geological Survey over 398 square miles of the Florida Everglades. Total survey coverage amounted to 1718 miles. The survey was flown from December 9 to December 14, 1994.

The purpose of the survey was to map resistivity variations due to changes in salt water salinity. The results are being used to map the fresh-water/salt-water interface in the Everglades National Park, as well as salinity variations. This is a follow up survey to a an earlier DIGHEM^V survey flown in April 1994. An additional objective is to asses whether the EM system is capable of mapping resistivity variations due to changes in fresh-water runoff. The previous survey was flown during the dry season. It was expected that there should be an increased amount of fresh-water runoff due to higher rainfall late in the year.

A DIGHEM^V multi-coil, multi-frequency electromagnetic system was used. The information from this system was processed to produce maps which display the conductive properties of the survey area. A GPS electronic navigation system, utilizing a UHF link, ensured positioning of the geophysical data with an accuracy of 3 m. Visual flight path recovery techniques were used to confirm the location of the helicopter where visible topographic features could be identified on the ground.

The fresh-water/salt-water interface (FWSWI) is clearly mapped. The three coplanar frequency resistivities and resistivity sections provide qualitative information as to the layering and changes in the FWSWI interface with depth. The maps show sufficient detail to identify near surface influences on fresh-water and salt-water. Additional conclusions follow:

* Highway 9336 (State Highway 27) from Florida City to Flamingo appears to be acting as a barrier to fresh water. This is particularly evident on the 56,000 Hz resistivity.

* An east-west canal, adjacent to a road which connects with Highway 9336, is associated with conductivity which is higher than that of the surrounding, relatively fresh water.

* In the western portion of the survey area, salt water encroachment appears to be associated with drainage. For example, a series of creeks which converge at Tarpon Bay are associated with higher conductivity than the surrounding marsh.

* In the eastern portion of the survey area, Taylor Slough is the main source of fresh water. A similar feature exists parallel and to the east of Taylor Slough.

* Shark Valley Slough, in the western portion of the survey area, does not appear to contain as thick a layer of fresh-water float as Taylor Slough, as Shark Valley Slough is more conductive.

* A similar feature to Taylor Slough may exist near the bend in Highway 9336, centred at 80^0 49' W Lat., 25^0 21' N Long.

A comparison of the results of this survey with the April results shows that near surface conductivities are very similar except for the following main differences:

* The FWSWI appears to have moved to the south by approximately 1/2 mile in the northeast portion of the survey area. This is consistent with an increase in fresh-water runoff.

* The 900 Hz resistivities are generally more conductive by about 20% on this recent survey. As this occurs in both resistive, fresh-water, and conductive, saline-water, portions of the survey area, the difference is probably the result of the lack of an absolute calibration of the EM system. In future surveys, calibration of the system over a half space of sea water may be useful.

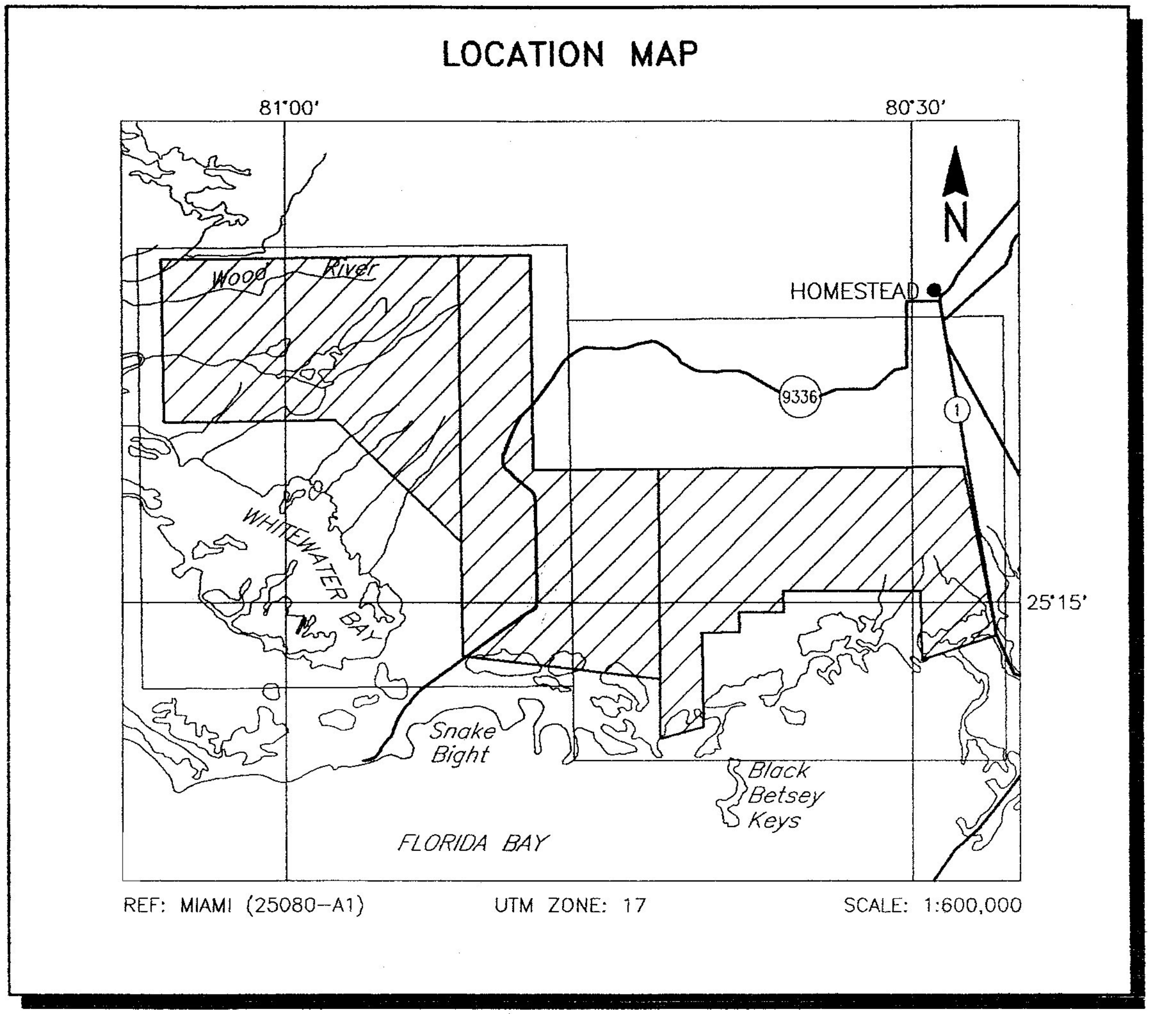

FIGURE 1

EVERGLADES NATIONAL PARK, FLORIDA

SITE CHARACTERIZATION - 616

CONTENTS

INTRODUCTION

A DIGHEM^{V} resistivity survey was flown for The U.S. Geological Survey from December 9 to December 14, 1994 over 398 square miles of the Florida Everglades. The survey area can be located on map sheet Miami 25080-A1 (see Figure 1).

Survey coverage consisted of approximately 1718 line-miles, including tie lines. Flight lines were flown in an azimuthal direction of 0° with a line separation of 1/4 mile (400 metres).

The survey employed the DIGHEM^{V} electromagnetic system. Ancillary equipment consisted of a radar altimeter, video camera, analog and digital recorders and an electronic navigation system. Details on the survey equipment are given in Section 2. Section 2 also provides details on the data channels, their respective sensitivities, and the navigation/flight path recovery procedure.

SURVEY EQUIPMENT

The instrumentation was installed in an Aerospatiale AS350B turbine helicopter (Registration N350LE) which was provided by Bulldog Helicopters Ltd. The helicopter flew at an average airspeed of 100 km/h with an EM bird height of approximately 30 m.

Electromagnetic System

Model: DIGHEM V

Type: Towed bird, symmetric dipole configuration operated at a nominal survey altitude of 30 metres. Coil separation is 8 metres for all coil-pairs except for the 56,000 Hz coil-pair which has a 6.3 metre coil separation.

Coil orientations/frequencies:
coaxial / 900 Hz
coplanar / 900 Hz
coaxial / 5,500 Hz
coplanar / 7,200 Hz
coplanar / 56,000 Hz

Channels recorded: 5 inphase channels
5 quadrature channels
4 monitor channels

Sensitivity:
0.1 ppm at 900 Hz
0.2 ppm at 5,500 Hz
0.2 ppm at 7,200 Hz
0.5 ppm at 56,000 Hz

Sample rate: 10 per second

The electromagnetic system utilizes a multi-coil coaxial/coplanar technique to energize conductors in different directions. The coaxial coils are vertical with their axes in the flight direction. The coplanar coils are horizontal. The secondary fields are sensed simultaneously by means of receiver coils which are maximum coupled to their respective transmitter coils. The system yields an inphase and a quadrature channel from each transmitter-receiver coil-pair.

Radar Altimeter

Manufacturer: Honeywell/Sperry

Type: AA 220

Sensitivity: 1 ft

The radar altimeter measures the vertical distance between the helicopter and the ground. This information is used in the processing algorithm which determines conductor depth.

The altimeter is calibrated by checking the reading when the helicopter lifts-off and reaches the end of the 100 ft EM bird cable.

Analog Recorder

Manufacturer: RMS Instruments

Type: DGR33 dot-matrix graphics recorder

Resolution: 4x4 dots/mm

Speed: 1.5 mm/sec

The analog profiles are recorded on chart paper in the aircraft during the survey. Table 2-1 lists the geophysical data channels and the vertical scale of each profile.

Table 2-1. The Analog Profiles

Channel Name	Parameter		Scale units/mm	Designation on digital profile
1XI	coaxial inphase	(900 Hz)	2.5 ppm	CXI (900 Hz)
1XQ	coaxial quad	(900 Hz)	2.5 ppm	CXQ (900 Hz)
3PI	coplanar inphase	(900 Hz)	2.5 ppm	CPI (900 Hz)
3PQ	coplanar quad	(900 Hz)	2.5 ppm	CPQ (900 Hz)
2PI	coplanar inphase	(7200 Hz)	5 ppm	CPI (7200 Hz)
2PQ	coplanar quad	(7200 Hz)	5 ppm	CPQ (7200 Hz)
4XI	coaxial inphase	(5500 Hz)	5 ppm	CXI (5500 Hz)
4XQ	coaxial quad	(5500 Hz)	5 ppm	CXQ (5500 Hz)
5PI	coplanar inphase	(56000 Hz)	10 ppm	CPI (56 kHz)
5PQ	coplanar quad	(56000 Hz)	10 ppm	CPQ (56 kHz)
ALTR	altimeter		3 m	ALT
CXSP	coaxial sferics monitor			CXS
4XSP	coaxial sferics monitor			
CPSP	coplanar sferics monitor			CPS
3PSP	coplanar sferics monitor			
CXPL	coaxial powerline monitor			CXP
CPPL	coplanar powerline monitor			CPP
3PPL	coplanar powerline monitor			

Digital Data Acquisition System

Manufacturer: Picodas

Type: PDAS 1000

The PDAS 1000 has a built-in hard drive for digital data storage, and two internal magnetometer counters. The data are downloaded from the hard drive to a DC2120 cassette at the end of each flight.

The digital data are used to generate several computed parameters. Both measured and computed parameters are plotted as "multi-channel stacked profiles" during data processing. These parameters are shown in Table 2-2. In Table 2-2, the log resistivity scale of 0.06 decade/mm means that the resistivity changes by an order of magnitude in 16.6 mm. The resistivities at 0, 33 and 67 mm up from the bottom of the digital profile are respectively 1, 100 and 10,000 ohm-m.

Table 2-2. The Digital Profiles

Channel Name (Freq)	Observed parameters	Scale units/mm
ALT	bird height	6 m
CXI (900 Hz)	vertical coaxial coil-pair inphase	8 ppm
CXQ (900 Hz)	vertical coaxial coil-pair quadrature	8 ppm
CPI (900 Hz)	horizontal coplanar coil-pair inphase	8 ppm
CPQ (900 Hz)	horiztonal coplanar coil-pair quadrature	8 ppm
CXI (5500 Hz)	vertical coaxial coil-pair inphase	16 ppm
CXQ (5500 Hz)	vertical coaxial coil-pair quadrature	16 ppm
CPI (7200 Hz)	horizontal coplanar coil-pair inphase	16 ppm
CPQ (7200 Hz)	horiztonal coplanar coil-pair quadrature	16 ppm
CPI (56 kHz)	horizontal coplanar coil-pair inphase	40 ppm
CPQ (56 kHz)	horiztonal coplanar coil-pair quadrature	40 ppm
CXS	coaxial sferics monitor	
CXP	coaxial powerline monitor	

	Computed Parameters	
RES (900 Hz)	log resistivity	.06 decade
RES (7200 Hz)	log resistivity	.06 decade
DP (900 Hz)	apparent depth	6 m
DP (7200 Hz)	apparent depth	6 m
DP (56 kHz)	apparent depth	6m

Tracking Camera

Type: Panasonic Video

Model: AG 2400/WVCD132

Fiducial numbers are recorded continuously and are displayed on the margin of each image. This procedure ensures accurate correlation of analog and digital data with respect to visible features on the ground.

Navigation System (RT-DGPS)

Model: Sercel NR106, Real-time differential positioning

Type: SPS (L1 band), 10-channel, C/A code, 1575.42 MHz.

Sensitivity: -132 dBm, 0.5 second update

Accuracy: < 5 metres in differential mode,
± 50 metres in S/A (non differential) mode

The Global Positioning System (GPS) is a line of sight, satellite navigation system which utilizes time-coded signals from at least four of the twenty-four NAVSTAR satellites. In the differential mode, two GPS receivers are used. The base station unit is used as a reference which transmits real-time corrections to the mobile unit in the aircraft, via a UHF radio datalink. The on-board system calculates the flight path of the helicopter while providing real-time guidance. The raw XYZ data are recorded for both receivers, thereby permitting post-survey processing for accuracies of approximately 2 metres.

Although the base station receiver is able to calculate its own latitude and longitude, a higher degree of accuracy can be obtained if the reference unit is established on a known benchmark or triangulation point. The GPS records data relative to the WGS84 ellipsoid, which is the basis of the revised North American Datum (NAD83).

Conversion software is used to transform the WGS84 coordinates to the system displayed on the base maps.

Field Workstation

Manufacturer: Dighem

Model: FWS: V2.41

Type: 80386 based P.C.

A portable PC-based field workstation is used at the survey base to verify data quality and completeness. Flight tapes are dumped to a hard drive to permit the creation of a database. This process allows the field operators to display both the positional (flight path) and geophysical data on a screen or printer.

PRODUCTS AND PROCESSING TECHNIQUES

The following products are available from the survey data. Those which are not part of the survey contract may be acquired later. Refer to Table 3-1 for a summary of the maps which accompany this report, some of which may be sent under separate cover. Most parameters can be displayed as contours, profiles, or in colour.

Base Maps

Base maps of the survey area have been produced from the 1:100,000 scale Cape Sable, Everglades City, Miami and Homestead topographic map sheets. These were joined and photographically reproduced to a scale of 1:48,000. The topographic base maps were hand digitized to produce the skeletal topography for the colour maps.

Resistivity

The apparent resistivity in ohm-m was generated from the inphase and quadrature EM components for the 900 Hz, 7,200 Hz and 56,000 Hz frequencies, using a pseudo-layer halfspace model. A resistivity map portrays all the EM information for that frequency over the entire survey area. The large dynamic range makes the resistivity parameter an excellent mapping tool.

Table 3-1 Survey Products

Final Transparencies @ 1:48,000

900 Hz resistivity contours
7,200 Hz resistivity contours
56,000 Hz resistivity contours

The final prints display the geophysical parameter combined with the flight path on a screened topographic base. Two sets of black and white prints are supplied.

Final Colour maps @ 1:48,000

900 Hz resistivity colours
7,200 Hz resistivity colours
56,000 Hz resistivity colours

The colour maps display superimposed contours, flight path, skeletal topography, Lat/Long's and UTM coordinates. Two sets of colour maps are supplied.

Other Products

Digital XYZ archives with documentation
Digital grid archives
Multi-channel 'stacked' geophysical profiles
Sengpiel and differential resistivity sections for four lines

Note: The XYZ archives are supplied on a DOS compatible CD-ROM in Geopak ASCII format.

Multi-channel Stacked Profiles

Distance-based profiles of the digitally recorded geophysical data are generated and plotted by computer. These profiles also contain the calculated parameters which are used in the interpretation process. These are produced in the final corrected form after interpretation.

Contour and Colour Displays

The geophysical data are interpolated onto a regular grid using a modified Akima spline technique. The resulting grid is suitable for generating contour maps of excellent quality.

Colour maps are produced by interpolating the grid down to the pixel size. The parameter is then incremented with respect to specific amplitude ranges to provide colour "contour" maps.

Conductivity-depth Sections

The apparent resistivities for all frequencies can be displayed simultaneously as coloured conductivity-depth sections. Usually, only the coplanar data are displayed as the quality tends to be higher than that of the coaxial data.

Conductivity-depth sections can be generated in two formats:

(1) Sengpiel resistivity sections, where the apparent resistivity for each frequency is plotted at the depth of the centroid of the inphase current flow[1]; and,

(2) Differential resistivity sections, where the differential resistivity is plotted at the differential depth[2].

Both the Sengpiel and differential methods are derived from the pseudo-layer halfspace model. Both yield a coloured conductivity-depth section which attempts to portray a smoothed approximation of the true resistivity distribution with depth. The Sengpiel method is most useful in conductive layered situations, but may be unreliable in areas of

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[1] Approximate Inversion of Airborne EM Data from Multilayered Ground: Sengpiel, K.P., Geophysical Prospecting 36, 446-459, 1988.

[2] The Differential Resistivity Method for Multi-frequency Airborne EM Sounding: Huang, H. and Fraser, D.C., presented at Intern. Airb. EM Workshop, Tucson, Ariz., 1993.

moderate to high resistivity where signal amplitudes are weak. In areas where inphase responses have been suppressed by the effects of magnetite, the computed resistivities shown on the sections may be unreliable. The differential technique was developed by Dighem to overcome problems in the Sengpiel technique. The differential resistivity section is more sensitive than the Sengpiel section to changes in the earth's resistivity and it reaches deeper.

SURVEY RESULTS

Resistivity maps, which display the conductive properties of the survey area, were produced from the 900 Hz, 7,200 Hz and 56,000 Hz coplanar data. The conductivity units, in mS/m, are calculated from the resistivity units in ohm-m as: mS/m = 1000/ohm-m.

The maximum resistivity value, which is calculated for each frequency, is approximately 1.15 times the numerical value of the frequency. This cutoff eliminates the meaningless higher resistivities which would result from very small EM amplitudes. The minimum resistivity value is .0000054 times the frequency. This cutoff eliminates errors due to the lack of an absolute phase control for the EM data. This cutoff only affected the 56,000 Hz data.

Several points of interest, which appear on the coplanar resistivity maps, in addition to those identified in the report of the April 1994 survey results, are as follows:

* A red-orange to green-blue resistivity contrast is obvious on all three resistivity colour maps. It undoubtedly reflects a major salinity contrast, and indicates relatively saline water dominates the western and southern portions of the survey area. This contrast, which is characterized by resistivities below 10 ohm-m (100 mS/m) to the south and west and resistivities over 10 ohm-m to the north and east, is

almost identical in its location on the 7,200 and 900 Hz maps, but differs in location on the 56,000 Hz maps, east of 80^0 33' W, in that for the most part the 10 ohm-m contour does not go north of 25^0 18' N. This contrast on the 56,000 Hz maps, which is less obvious on the other frequencies, may reflect a secondary salinity interface due to some controlling source that is not indicated on the topographic maps.

* A comparison of the results from the April survey with this recent survey shows that the main interface mentioned above has moved about 1/2 mile to the south, north of 25^0 20' and east of 80^0 31'. This may reflect an influx of fresh-water.

* The 900 Hz is consistently more conductive in this recent survey than in the April survey. This occurs in both fresh-water, high resistivity areas, and salt-water low resistivity areas. The difference between the resistivity values in any one location for the two surveys is about 20%. This is probably due to the lack of an absolute calibration of the EM system. A calibration test over a salt-water half space would allow post-survey phase rotation to ensure that all EM parameters were giving the same value for salt-water. Assuming that the resistivity of the salt-water did not change over time, this calibration would allow season to season comparisons.

* Highway 9336 (State Highway 27) from Florida City to Flamingo appears to be acting as a barrier to fresh water. This is particularly evident on the 56,000 Hz resistivity.

* A relatively resistive feature, which is similar to Taylor Slough, may exist near the bend in Highway 9336, centred at 80^0 49' W Lat., 25^0 21' N Long. The shape of this resistive area may be affected by the road.

* An east-west canal, adjacent to a road which connects with Highway 9336, is associated with conductivity which is higher than that of the surrounding, relatively fresh water.

* In the western portion of the survey area, the area hosting a series of creeks that converge at Tarpon Bay is associated with higher conductivity than the surrounding marsh. This indicates that saline water encroaches more where there is existing drainage channels.

* Shark Valley Slough, in the western portion of the survey area, does not appear to contain as thick a layer of fresh-water float as Taylor Slough, as Shark Valley Slough is more conductive.

Respectfully submitted,

DIGHEM

D. McConnell

Douglas L. McConnell, P.Eng.
Geophysicist

APPENDIX A

LIST OF PERSONNEL

The following personnel were involved in the acquisition, processing, interpretation and presentation of data, relating to a DIGHEM^{V} airborne geophysical survey carried out for the U.S. Geological Survey of a selected area of the Florida Everglades.

Don Ellis	Senior Geophysical Operator
Jordan Cronkwright	Second Geophysical Operator
Steve Alexander	Pilot (Bulldog Helicopters Ltd.)
Gordon Smith	Data Processing Supervisor
Dak Darbha	Computer Processor
Doug McConnell	Interpretation Geophysicist
Lyn Vanderstarren	Drafting Supervisor
Mike Armstrong	Draftsperson (CAD)
Susan Pothiah	Word Processing Operator
Albina Tonello	Secretary/Expeditor

All personnel are employees of Dighem, A Division of CGG Canada Ltd., except for the pilot who is an employee of Bulldog Helicopters Ltd.

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