Enhancing the potable water potential of Tsunami-hit areas of NE Sumatra using high resolution airborne and ground geophysics

Eberle, D., Schmidt, H., Klinge, H., Steuer, A., Voß, W.

Co-operation Partners:

DJGSM
Direktorat Jenderal Geologi dan Sumber Daya Mineral
Departemen Energi dan Sumber Daya Mineral

Directorate General of Geology and Mineral Resources (DGGMR)

BADAN PERENCANAAN PEMBANGUNAN NASIONAL
BAPPENAS

National Development Planning Agency

BRR NAD – Nias

Executive Agency for the Rehabilitation and Reconstruction in Nanggroe Aceh Darussalam Province and Nias Islands

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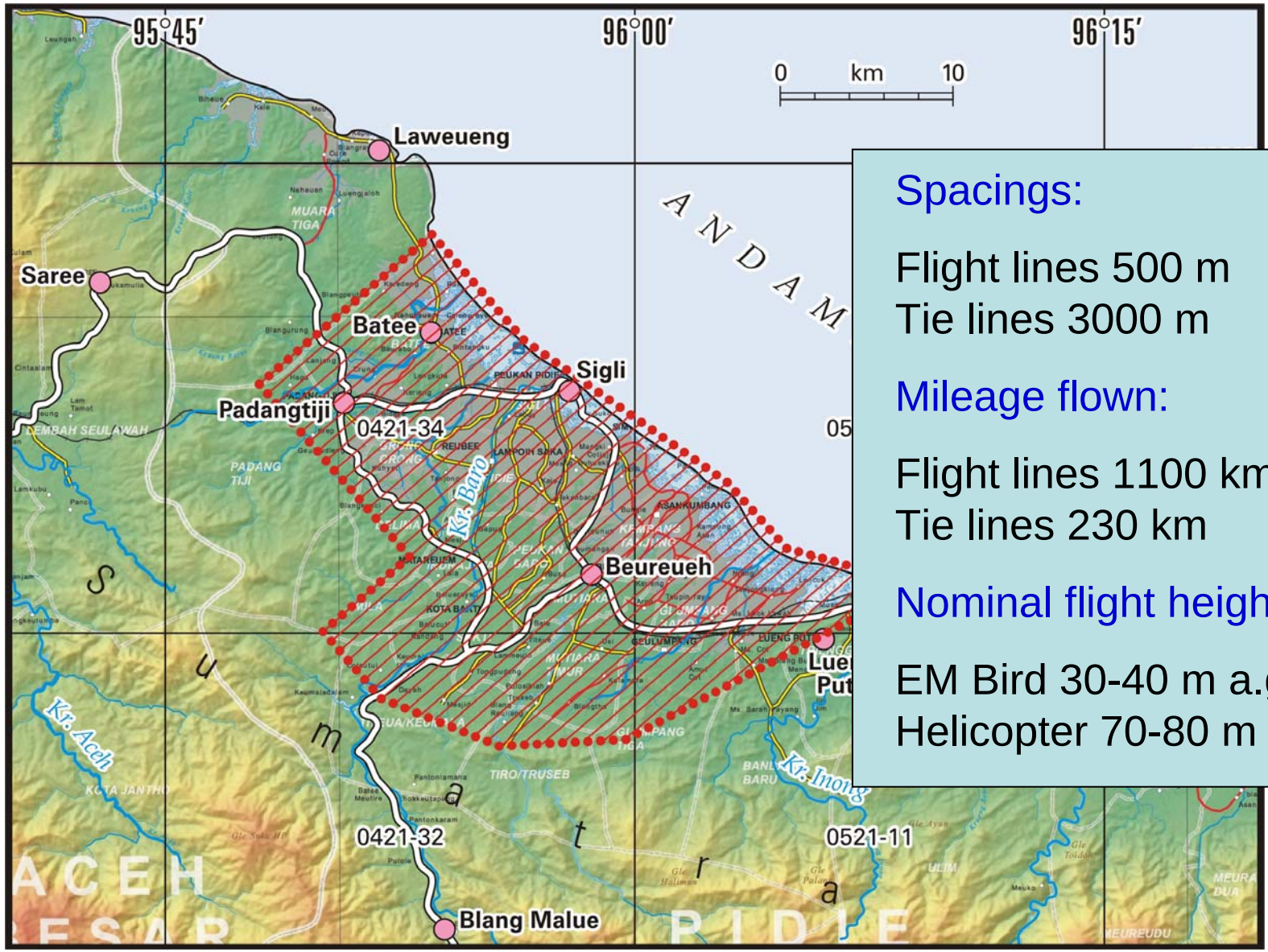
GEOZENTRUM HANNOVER

- Introduction
- Results of the airborne electromagnetic survey
- Results of ground electromagnetic and direct current soundings
- Achievements and recommendations



Spacings:

Flight lines 500 m
Tie lines 3000 m

Mileage flown:

Flight lines 1100 km
Tie lines 230 km

Nominal flight height

EM Bird 30-40 m a.g.
Helicopter 70-80 m a.g.

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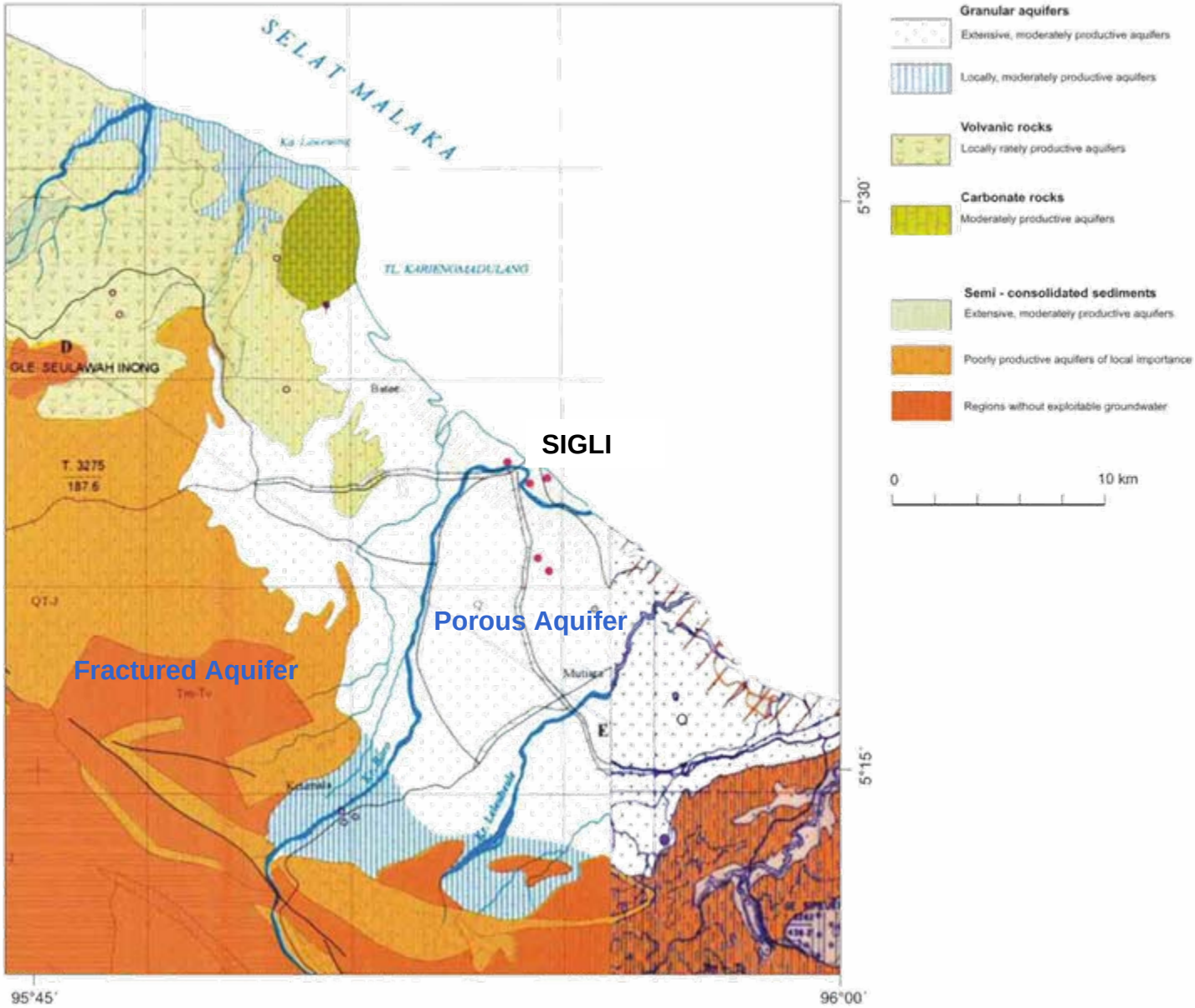

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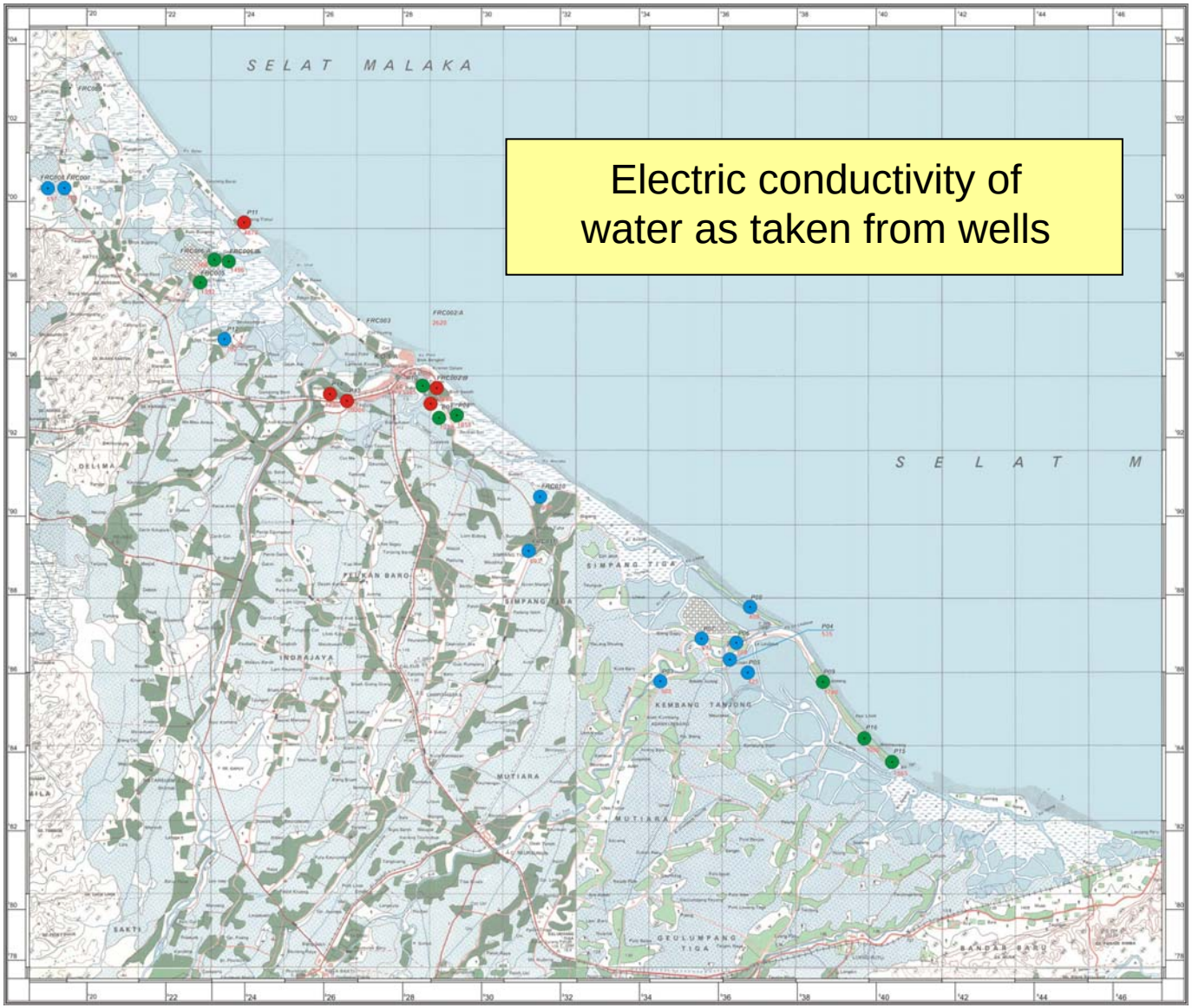

Electric conductivity of water as taken from wells

- < 10^3 µS/cm
- 10^3 – $2 \cdot 10^3$ µS/cm
- > $2 \cdot 10^3$ µS/cm

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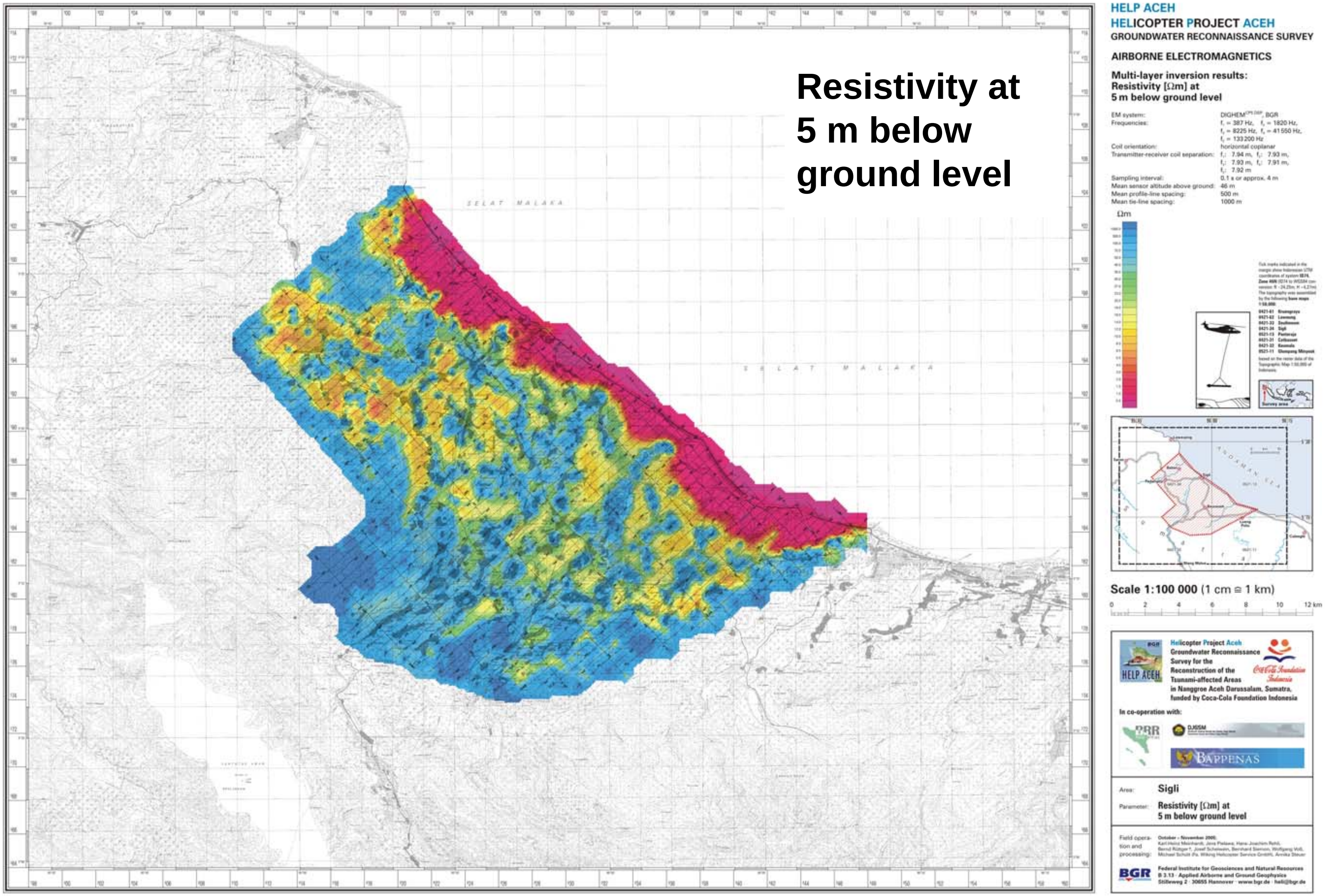
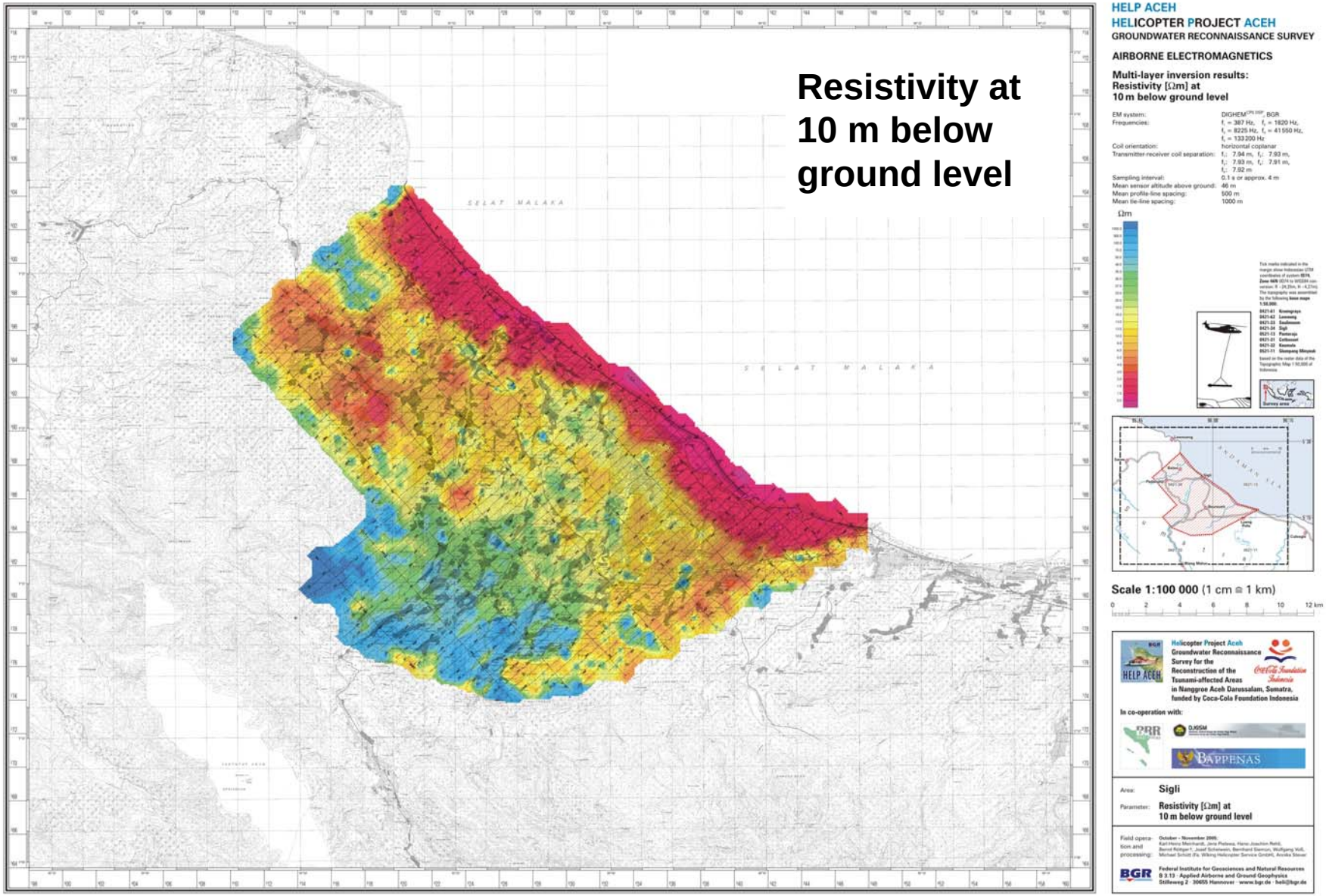
Airborne Geophysics

- Maps depicting resistivity at selected depths below ground (5, 10, 15, 30, 45, 60 m below ground)
- Example vertical resistivity sections along flight path

Resistivity at 5 m below ground level





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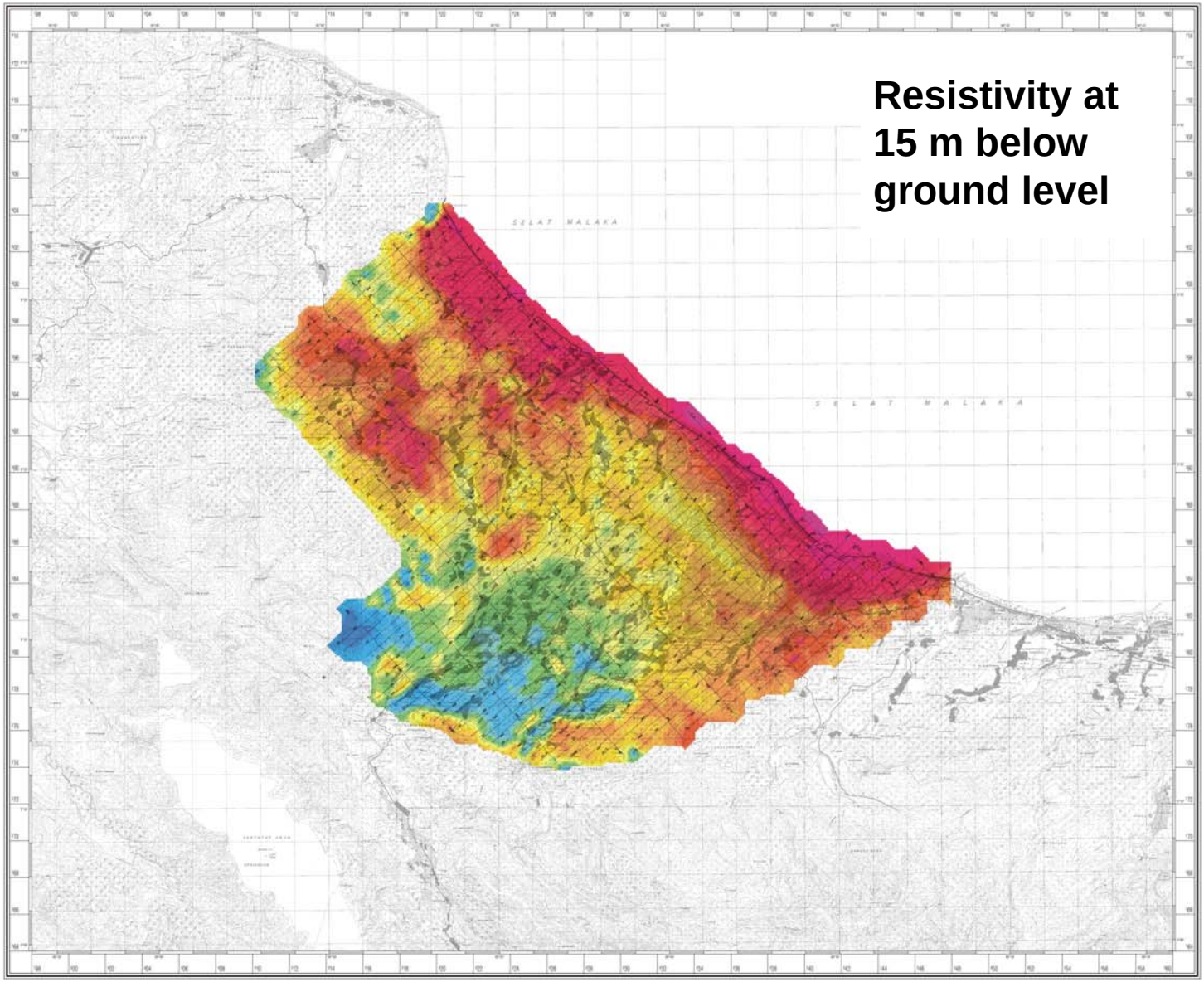

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GROUNDWATER RECONNAISSANCE SURVEY

AIRBORNE ELECTROMAGNETICS

Multi-layer inversion results:
Resistivity [Ωm] at
15 m below ground level

EM system:	DIGHEM$^{(2\%)\,VSP}$, BGR
Frequencies:	f_1 = 387 Hz, f_2 = 1820 Hz, f_3 = 8225 Hz, f_4 = 41550 Hz, f_5 = 133200 Hz
Coil orientation:	horizontal coplanar
Transmitter-receiver coil separation:	f_1: 7.94 m, f_2: 7.93 m, f_3: 7.93 m, f_4: 7.91 m, f_5: 7.92 m
Sampling interval:	0.1 s or approx. 4 m
Mean sensor altitude above ground:	46 m
Mean profile-line spacing:	500 m
Mean tie-line spacing:	1000 m

Ωm

Tick marks indicated in the margin show Indonesian UTM coordinates of system **ED50, Zone 46N** (ED50 to WGS84 conversion: N –24.25m, E –4.27m). The topography was assembled by the following **base maps 1:50,000:**

0421-61 Krueng Raya
0421-62 Lamreng
0421-23 Seulimeum
0421-24 Sigli
0521-13 Pantonlabu
0521-21 Cot Bada
0521-22 Kawula
0521-11 Glumpang Minyeuk

based on the raster data of the Topographic Map 1:50,000 of Indonesia.

Survey area

Scale 1:100 000 (1 cm ≙ 1 km)

0 2 4 6 8 10 12 km

Helicopter Project Aceh
Groundwater Reconnaissance Survey for the Reconstruction of the Tsunami-affected Areas in Nanggroe Aceh Darussalam, Sumatra, funded by Coca-Cola Foundation Indonesia

In co-operation with:

BAPPENAS

Area:	Sigli
Parameter:	Resistivity [Ωm] at 15 m below ground level
Field operation and processing:	October – November 2005

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B 3.13 · Applied Airborne and Ground Geophysics
Stilleweg 2 · 30655 Hannover · www.bgr.de · heli@bgr.de

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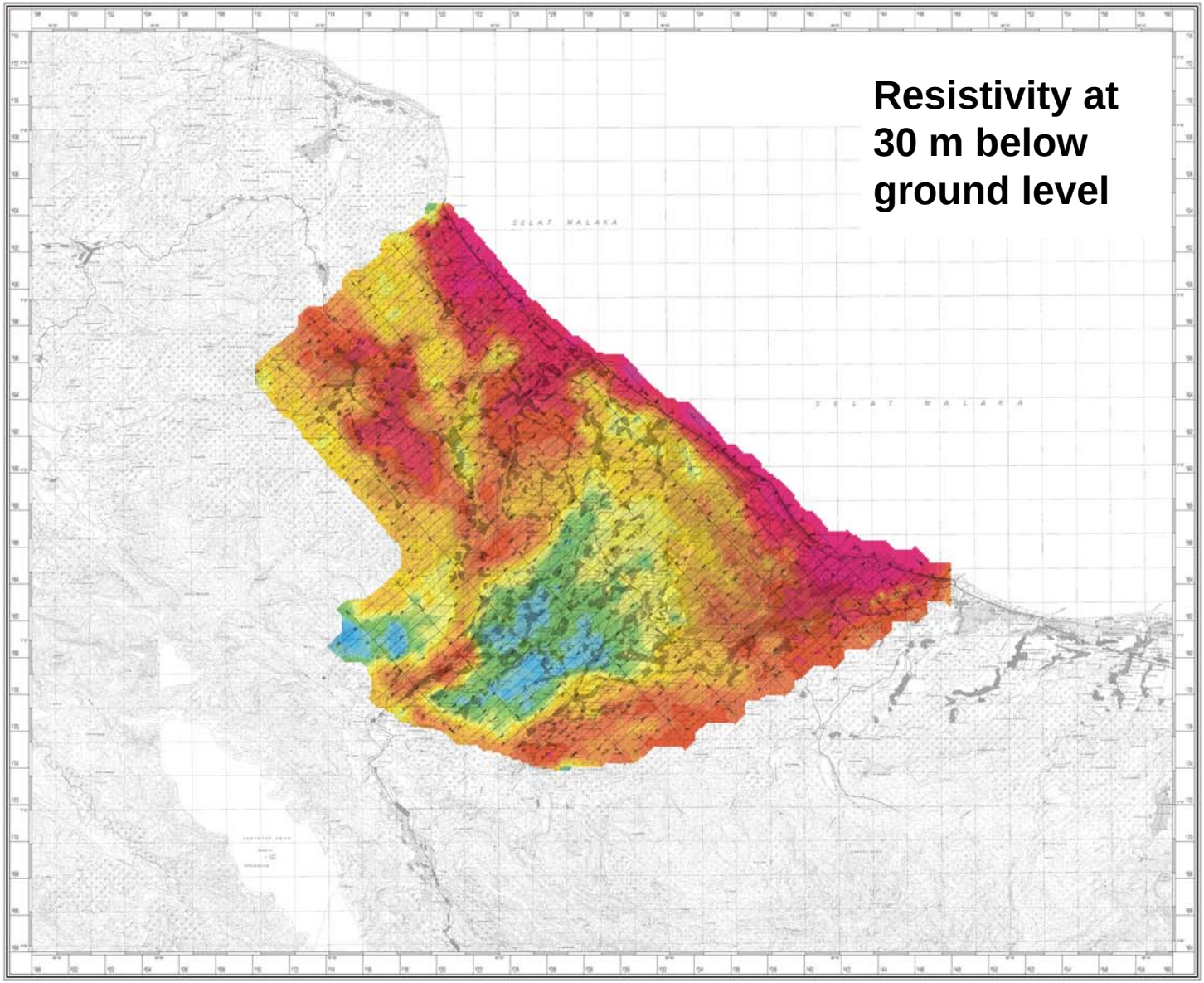
GEOZENTRUM HANNOVER



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GROUNDWATER RECONNAISSANCE SURVEY

AIRBORNE ELECTROMAGNETICS

Multi-layer inversion results:
Resistivity [Ωm] at
30 m below ground level

EM system:	DIGHEM$^{(2V)\,3D}$, BGR
Frequencies:	f_1 = 387 Hz, f_2 = 1820 Hz, f_3 = 8225 Hz, f_4 = 41550 Hz, f_5 = 133200 Hz
Coil orientation:	horizontal coplanar
Transmitter-receiver coil separation:	f_1: 7.94 m, f_2: 7.93 m, f_3: 7.93 m, f_4: 7.91 m, f_5: 7.92 m
Sampling interval:	0.1 s or approx. 4 m
Mean sensor altitude above ground:	46 m
Mean profile-line spacing:	500 m
Mean tie-line spacing:	1000 m

Ωm

Scale 1:100 000 (1 cm ≙ 1 km)

0 2 4 6 8 10 12 km

Helicopter Project Aceh
Groundwater Reconnaissance Survey for the Reconstruction of the Tsunami-affected Areas in Nanggroe Aceh Darussalam, Sumatra, funded by Coca-Cola Foundation Indonesia

In co-operation with:

PRR · DJGSM · BAPPENAS

Area: Sigli

Parameter: Resistivity [Ωm] at 30 m below ground level

Field operation and processing: October – November 2005

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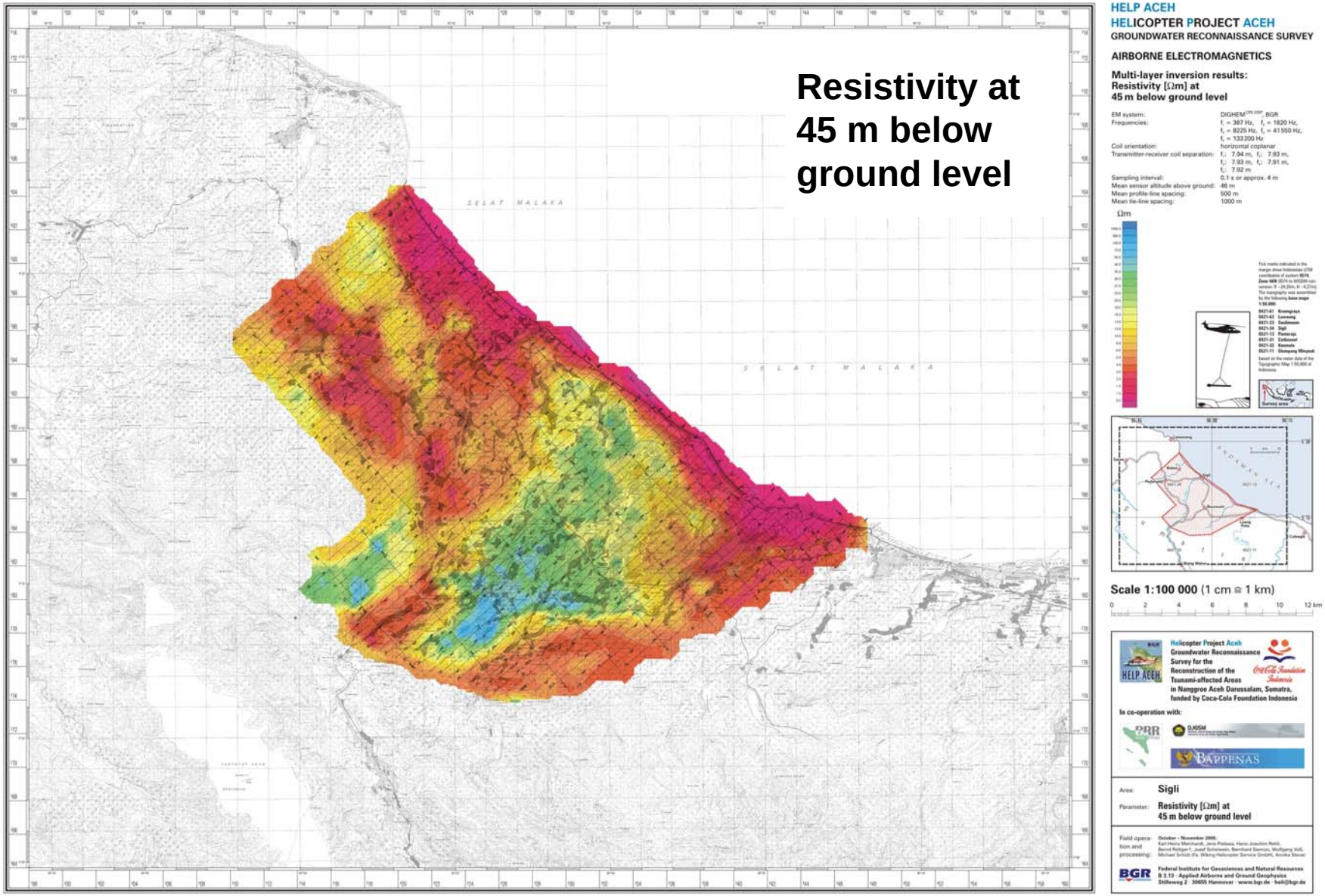

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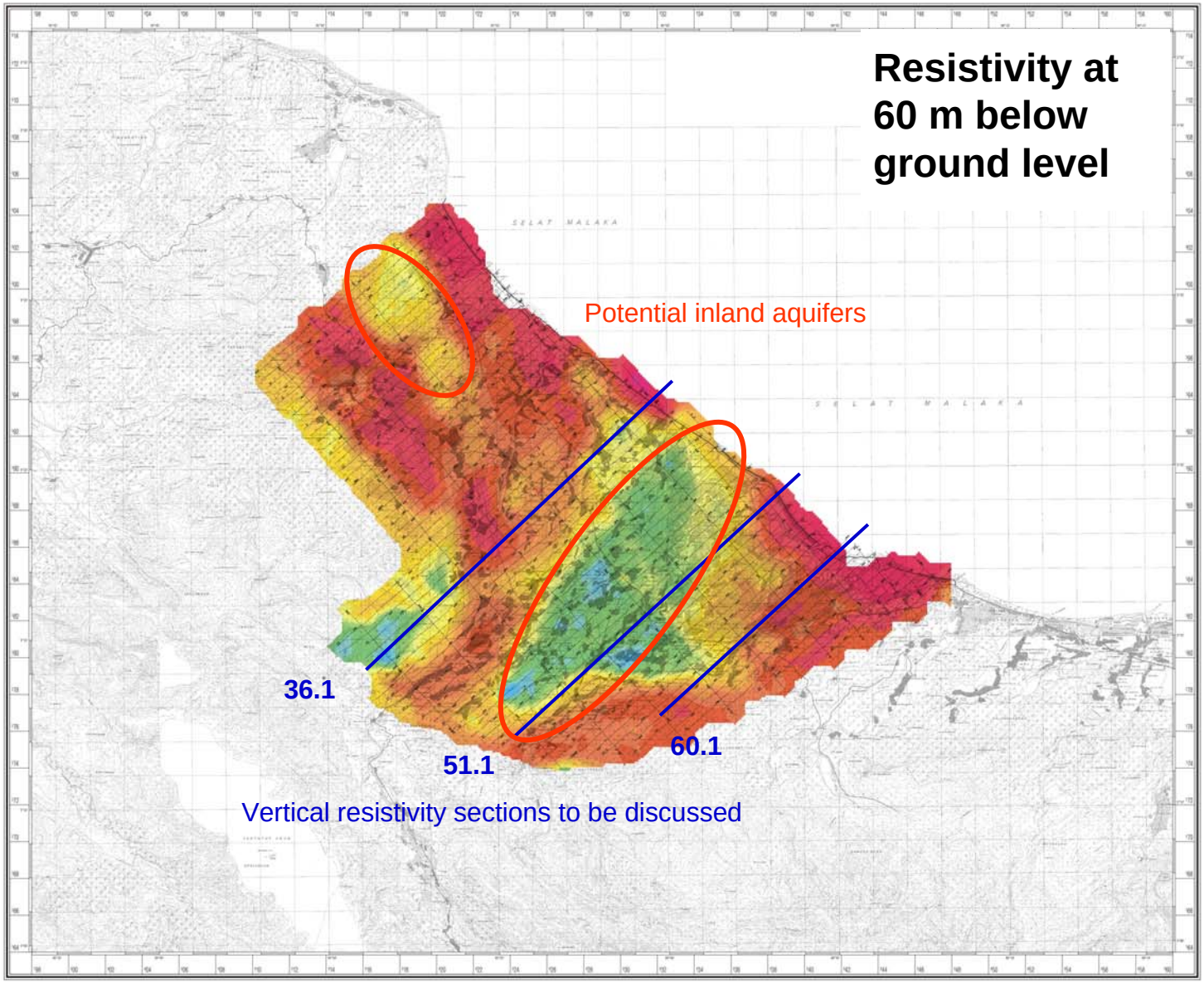
Resistivity at 60 m below ground level



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HELICOPTER PROJECT ACEH
GROUNDWATER RECONNAISSANCE SURVEY

AIRBORNE ELECTROMAGNETICS

Multi-layer inversion results:
Resistivity [Ωm] at
60 m below ground level

EM system: DIGHEM (CPI 200), BGR
Frequencies: f_1 = 387 Hz, f_2 = 1820 Hz, f_3 = 8225 Hz, f_4 = 41 950 Hz, f_5 = 133 200 Hz
Coil orientation: horizontal coplanar
Transmitter-receiver coil separation: t_1: 7.94 m, t_2: 7.93 m, t_3: 7.93 m, t_4: 7.91 m, t_5: 7.92 m
Sampling interval: 0.1 s or approx. 4 m
Mean sensor altitude above ground: 46 m
Mean profile-line spacing: 500 m
Mean tie-line spacing: 1000 m

Ωm

Scale 1:100 000 (1 cm ≙ 1 km)

0 2 4 6 8 10 12 km

Helicopter Project Aceh
Groundwater Reconnaissance Survey for the Reconstruction of the Tsunami-affected Areas in Nanggroe Aceh Darussalam, Sumatra, funded by Coca-Cola Foundation Indonesia

In co-operation with:

Area: Sigli
Parameter: Resistivity [Ωm] at 60 m below ground level

Field operation and processing: October – November 2005:

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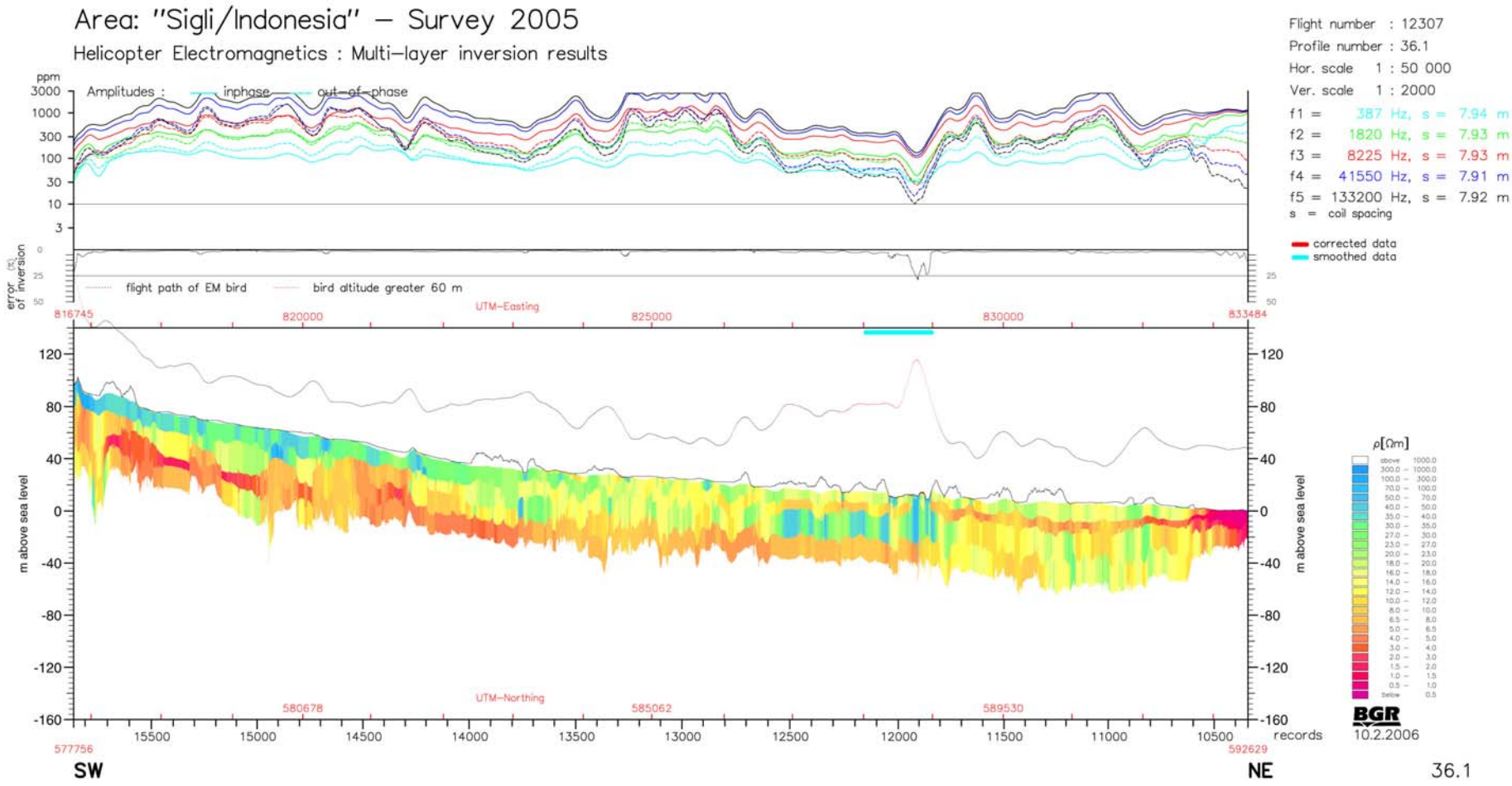

VRS (along flight line 36.1) with minimum salinisation at shore due to fresh water flow from inland

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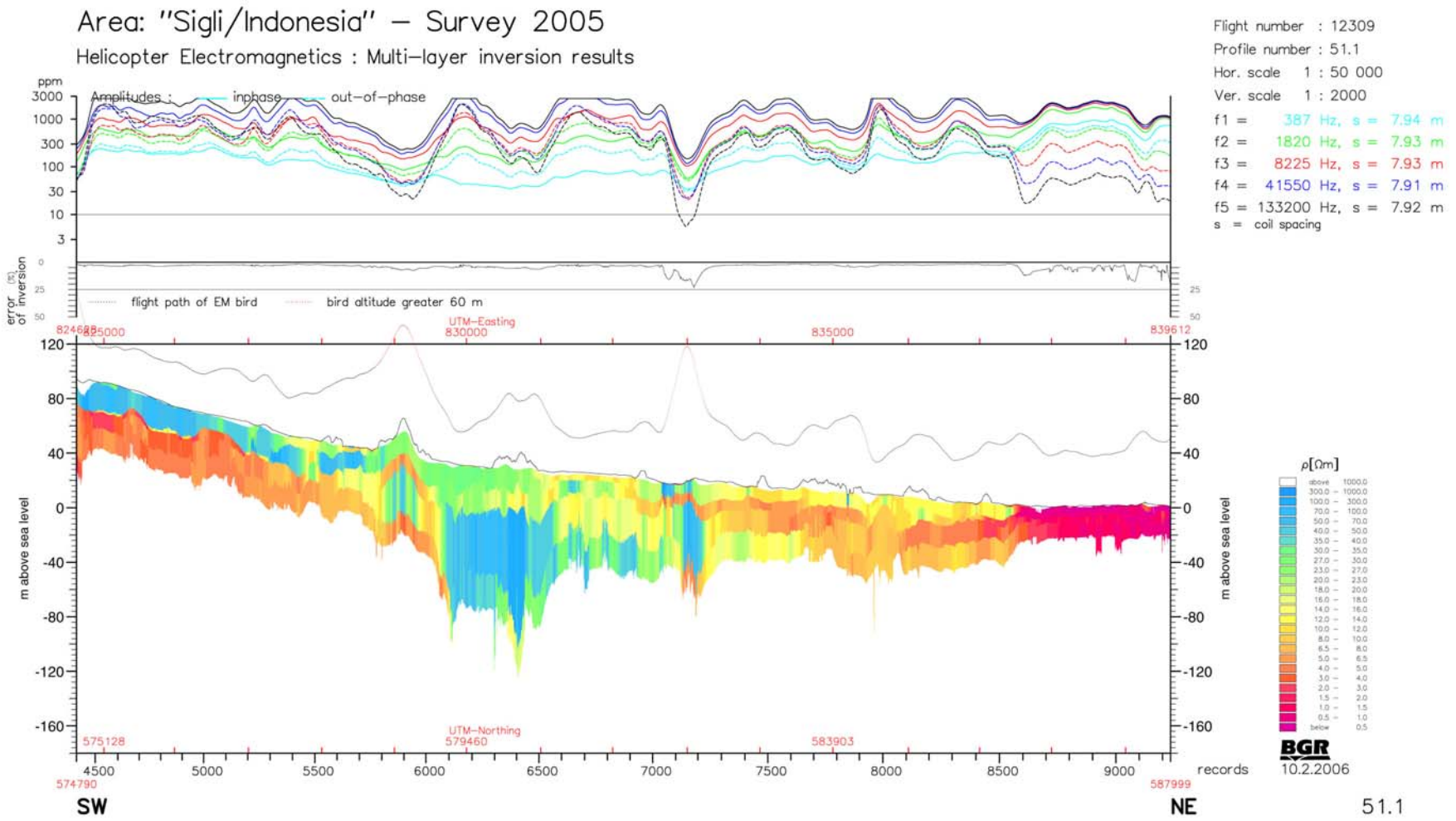

VRS (along flight line 51.1) with major salinisation at shore and SW dipping layers

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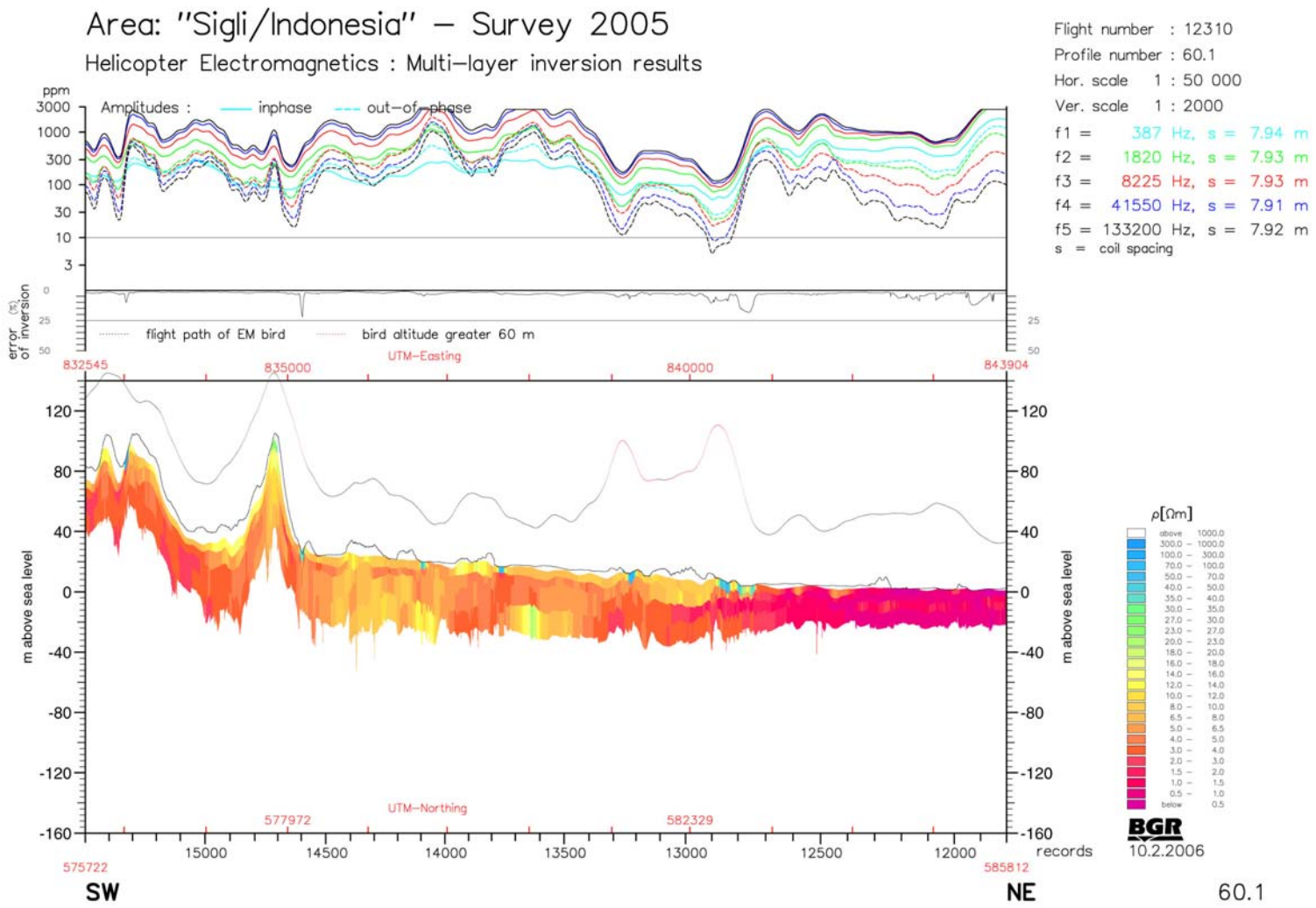
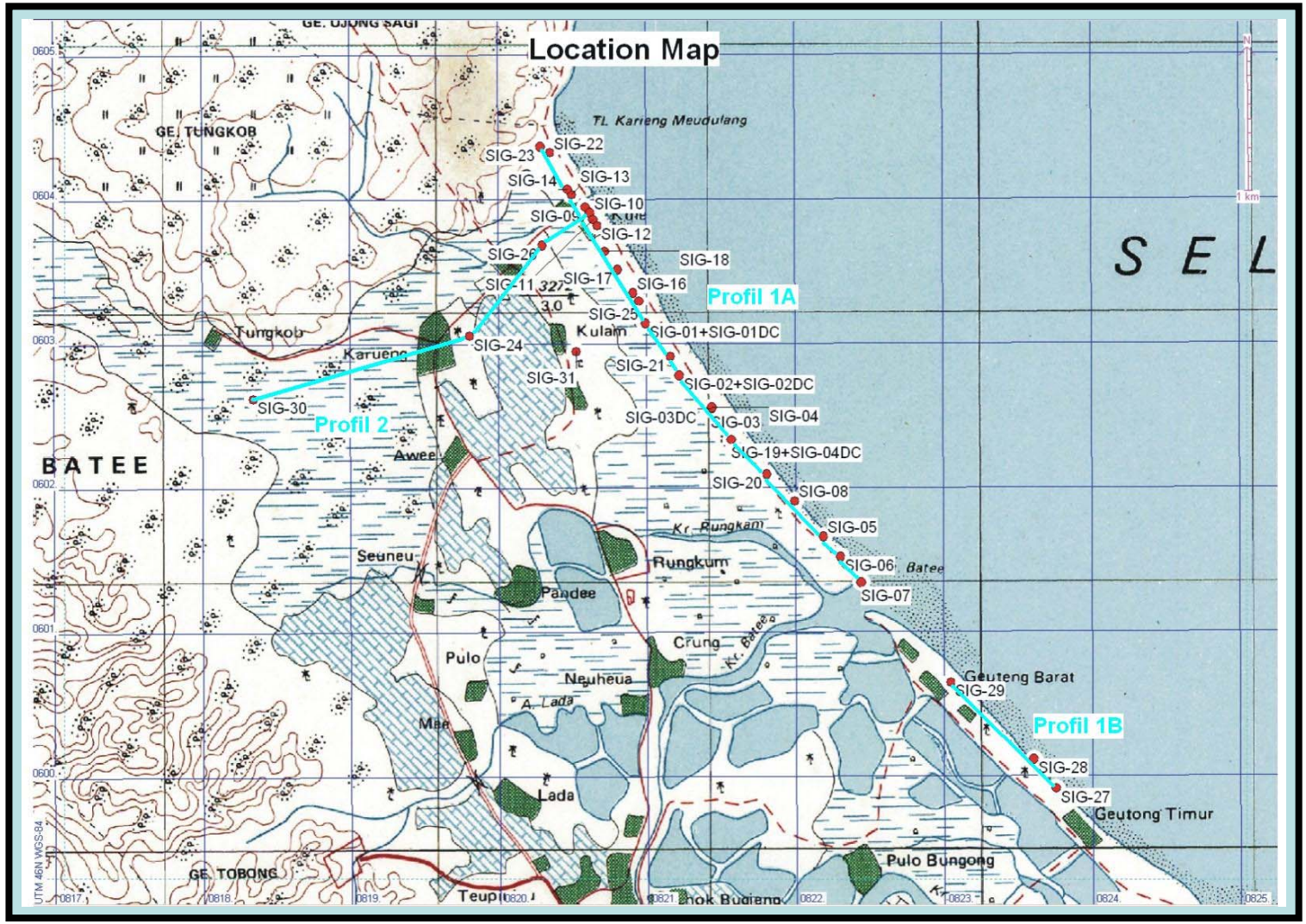
GEOZENTRUM HANNOVER



VRS (along flight line 60.1) with major salinisation at shore and SW dipping layers

Ground Geophysics

- Time Domain Electromagnetic (TDEM) and
- Direct Current (DC) Resistivity Soundings



Sites of TEM and DC Soundings conducted in Batee Area, Sigli - Pidie

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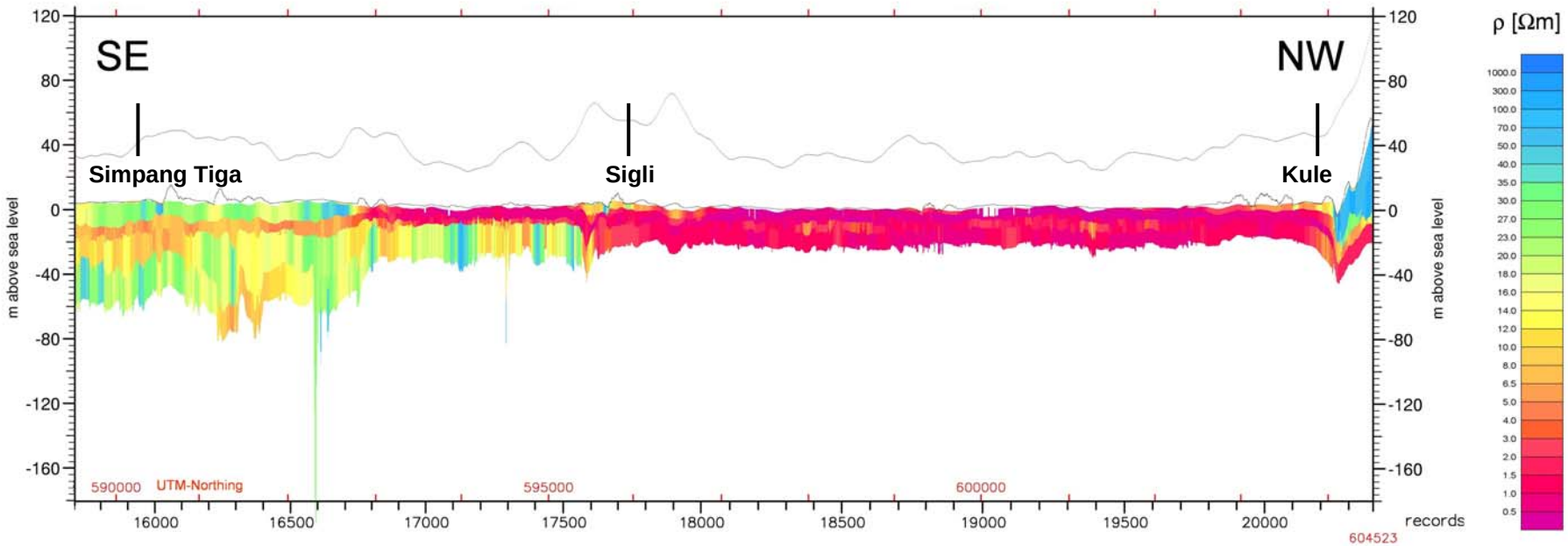
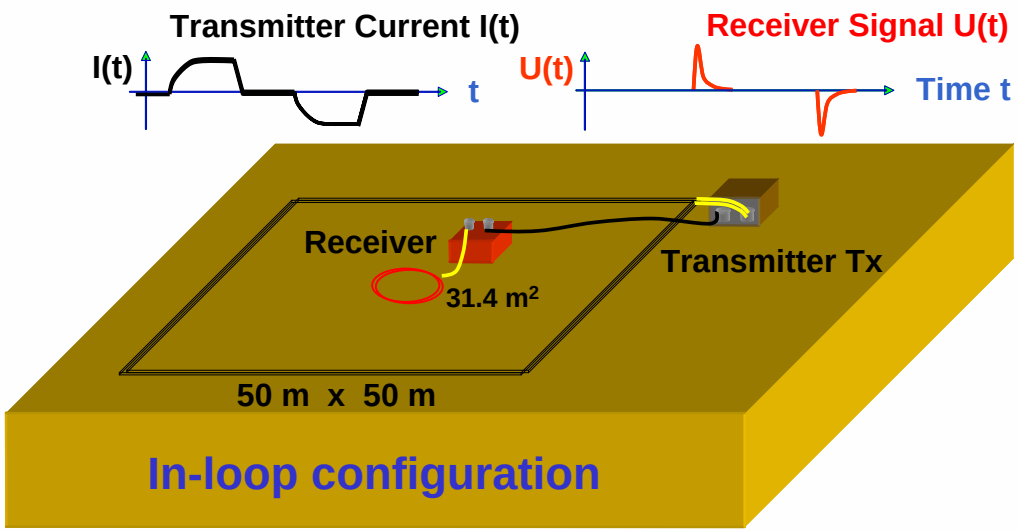
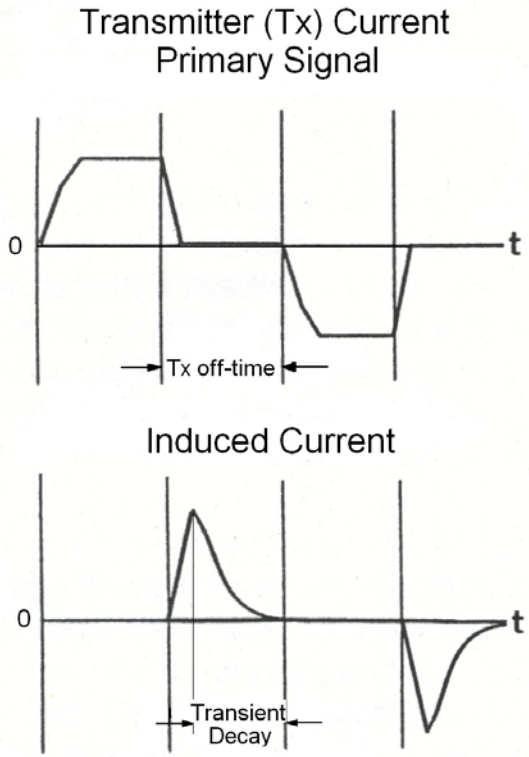


Extent of ground TEM survey lines Kule 1A and Geuteng 1B

VRS running parallel to shore line (flight line 8.9)





Principle of the Transient Electromagnetic Technique

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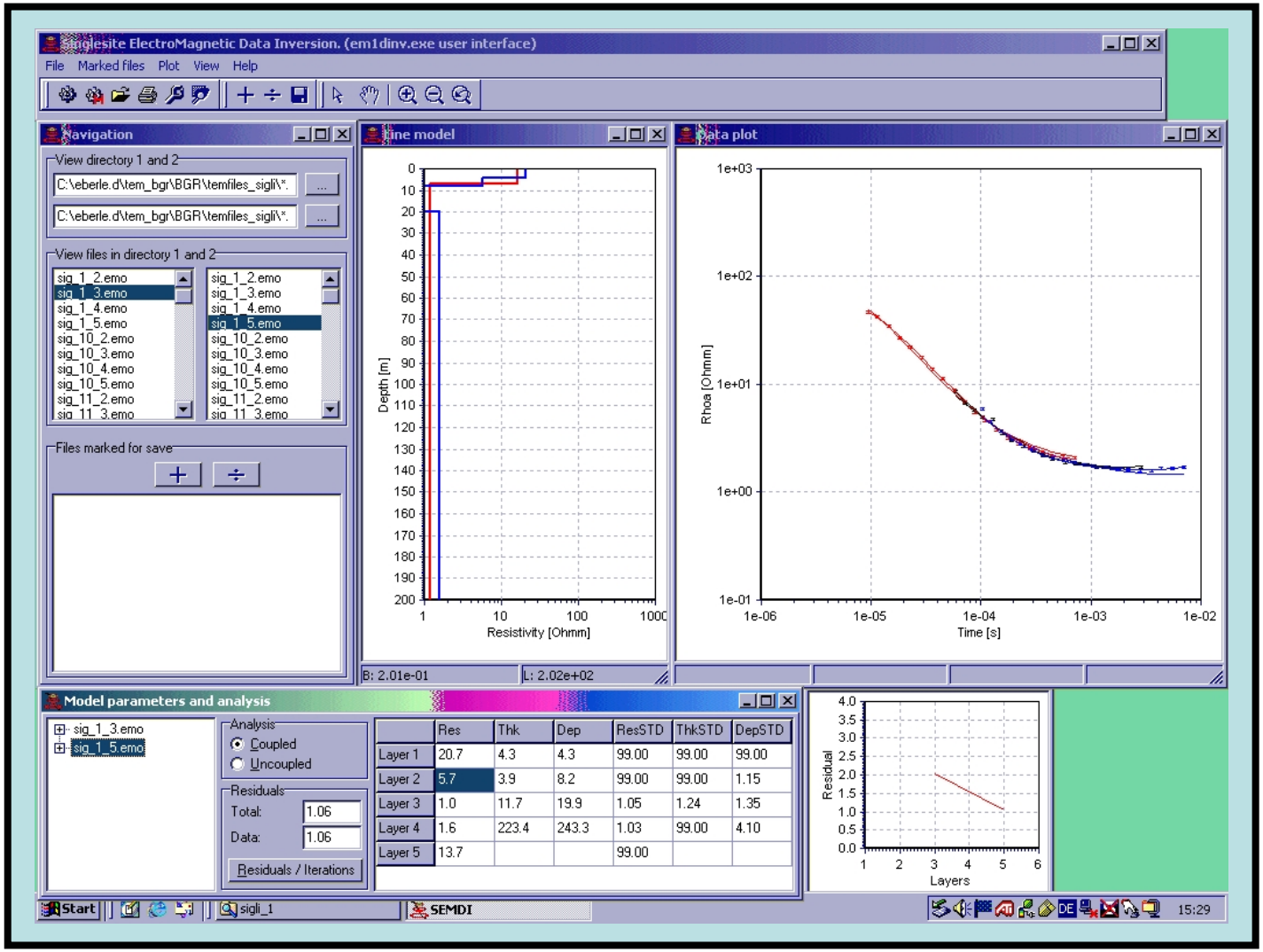
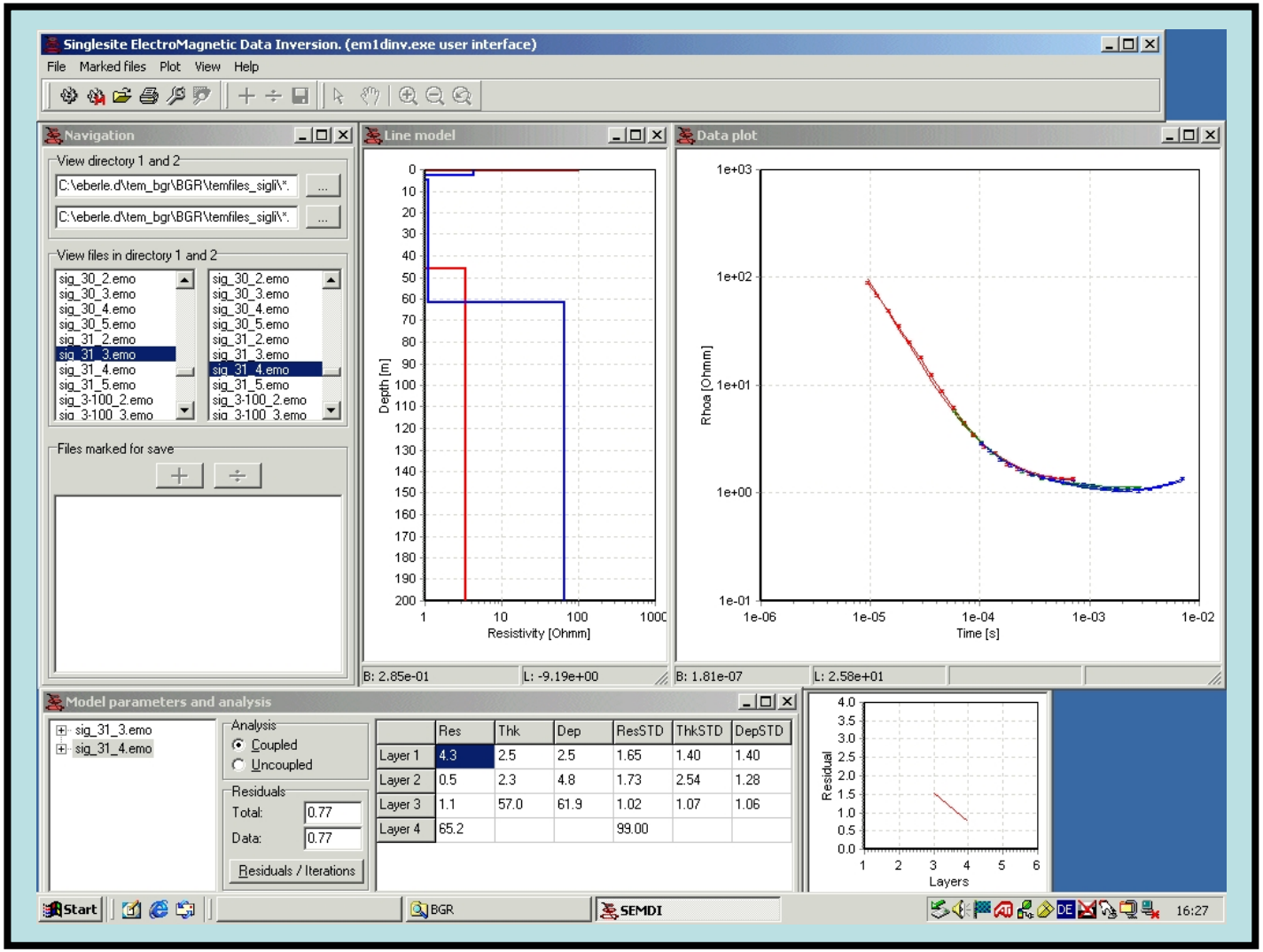
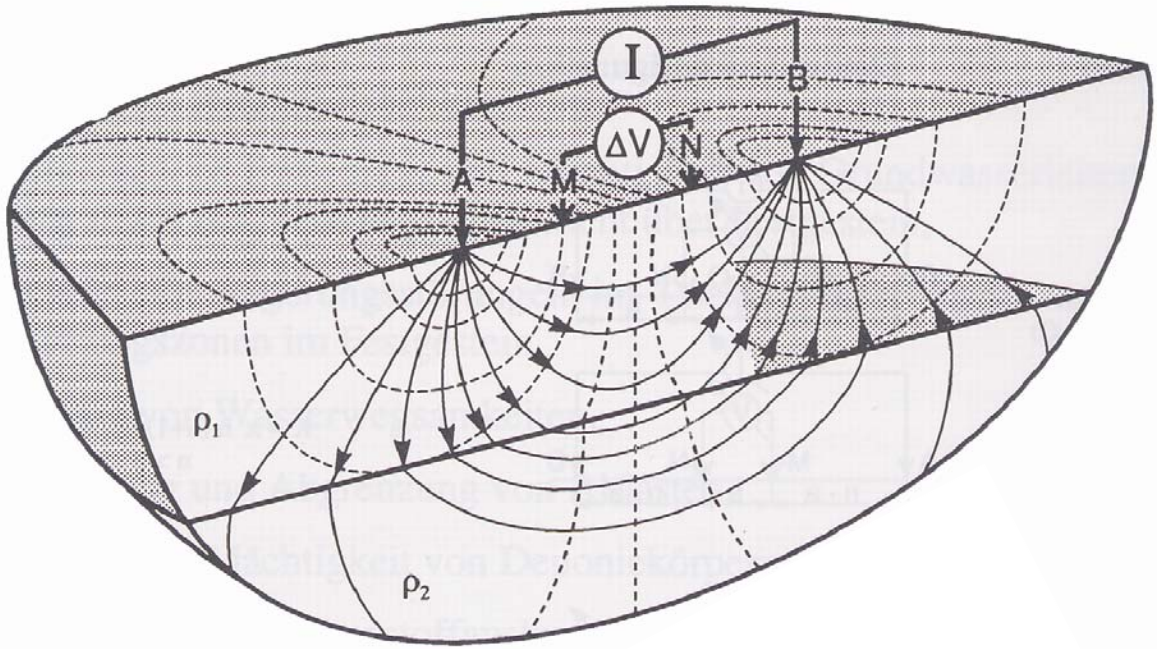


Sample TEM sounding close to shore



TEM sounding about 500 m inland

Principle of the Direct Current (DC) Four-Point Schlumberger Depth Sounding



——— Current Density

- - - - - Equipotential Lines

ϱ_1, ϱ_2 Electric resistiviy of layers 1 and 2 ($\varrho_1 > \varrho_2$)

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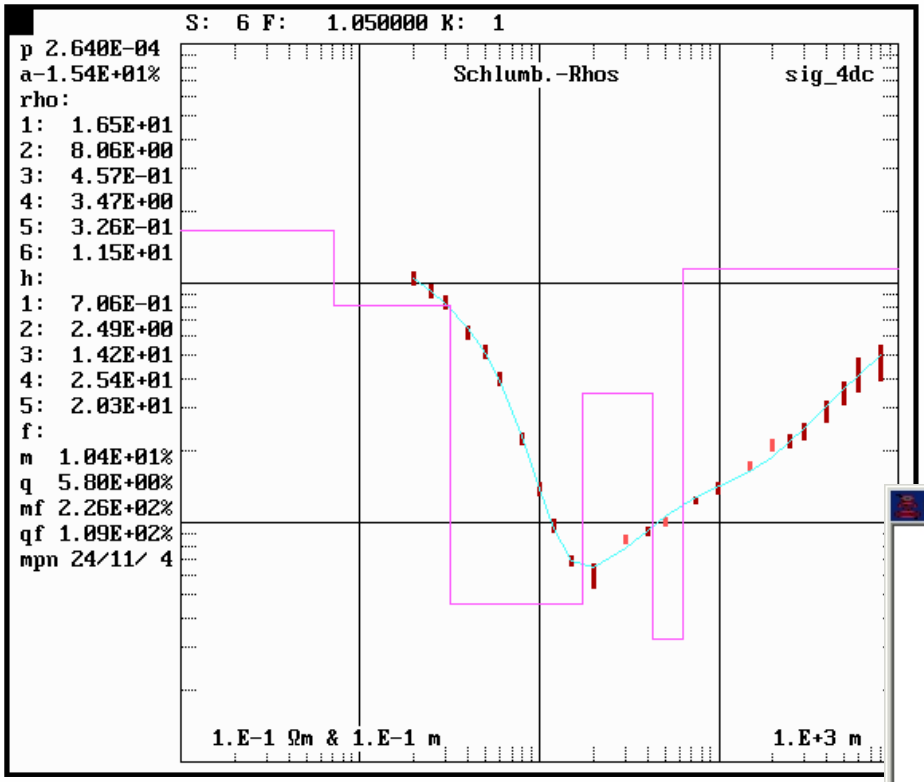
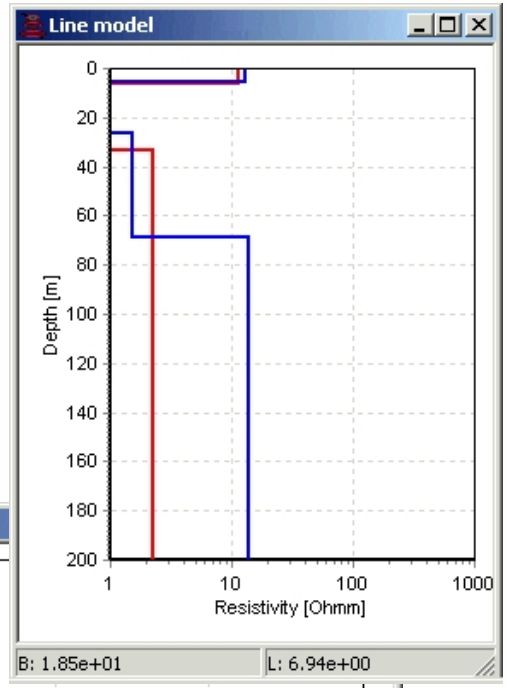
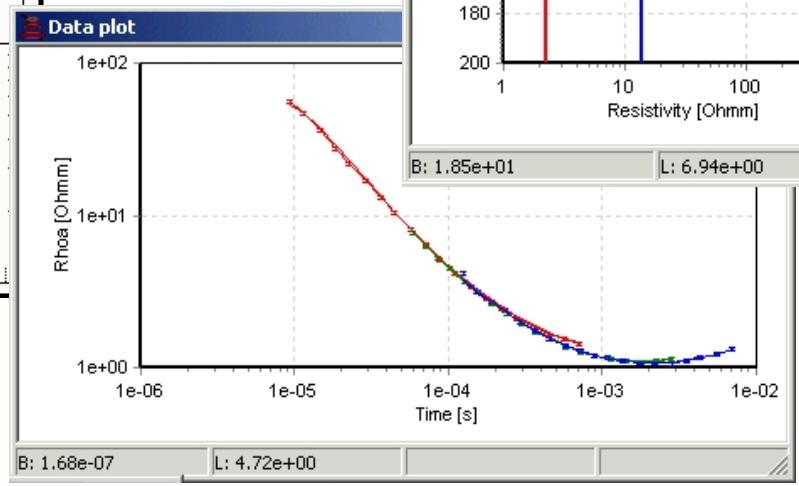
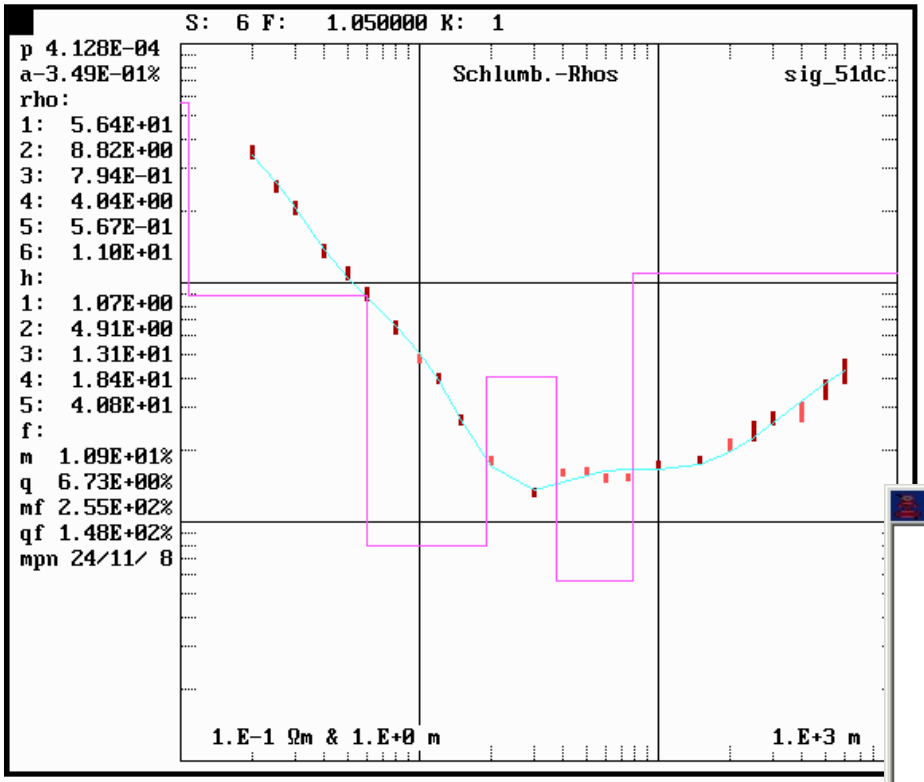
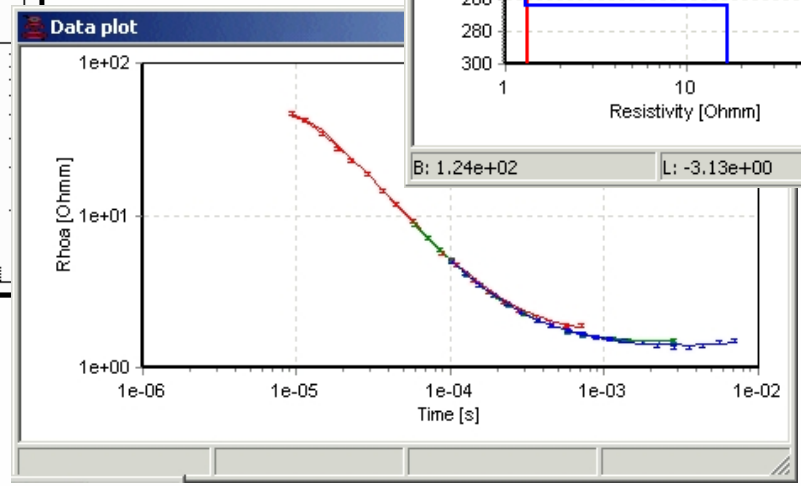


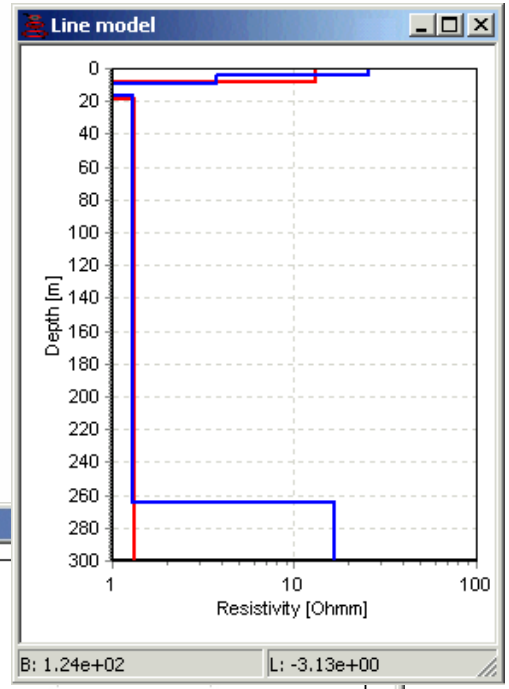




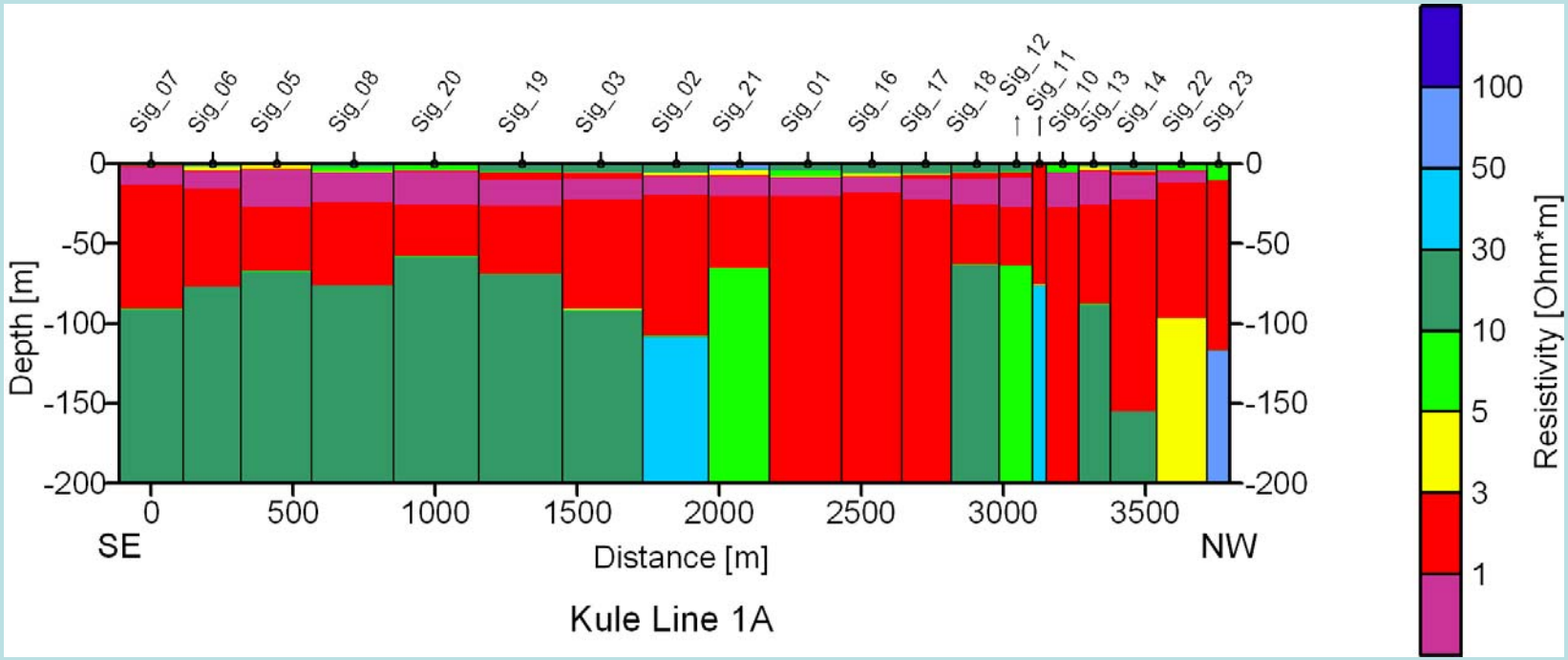
Comparison of DC (left) and TEM (right) soundings at site sig_19

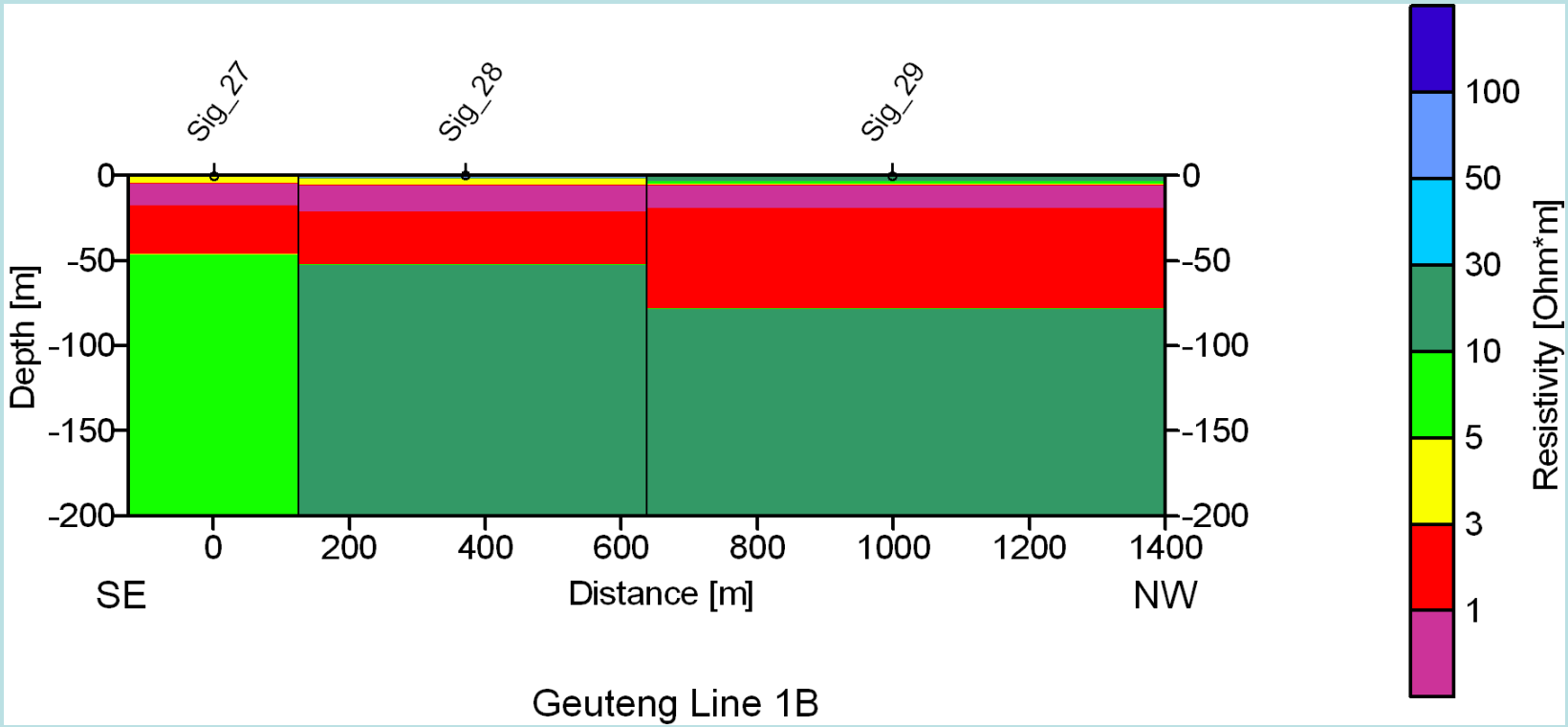






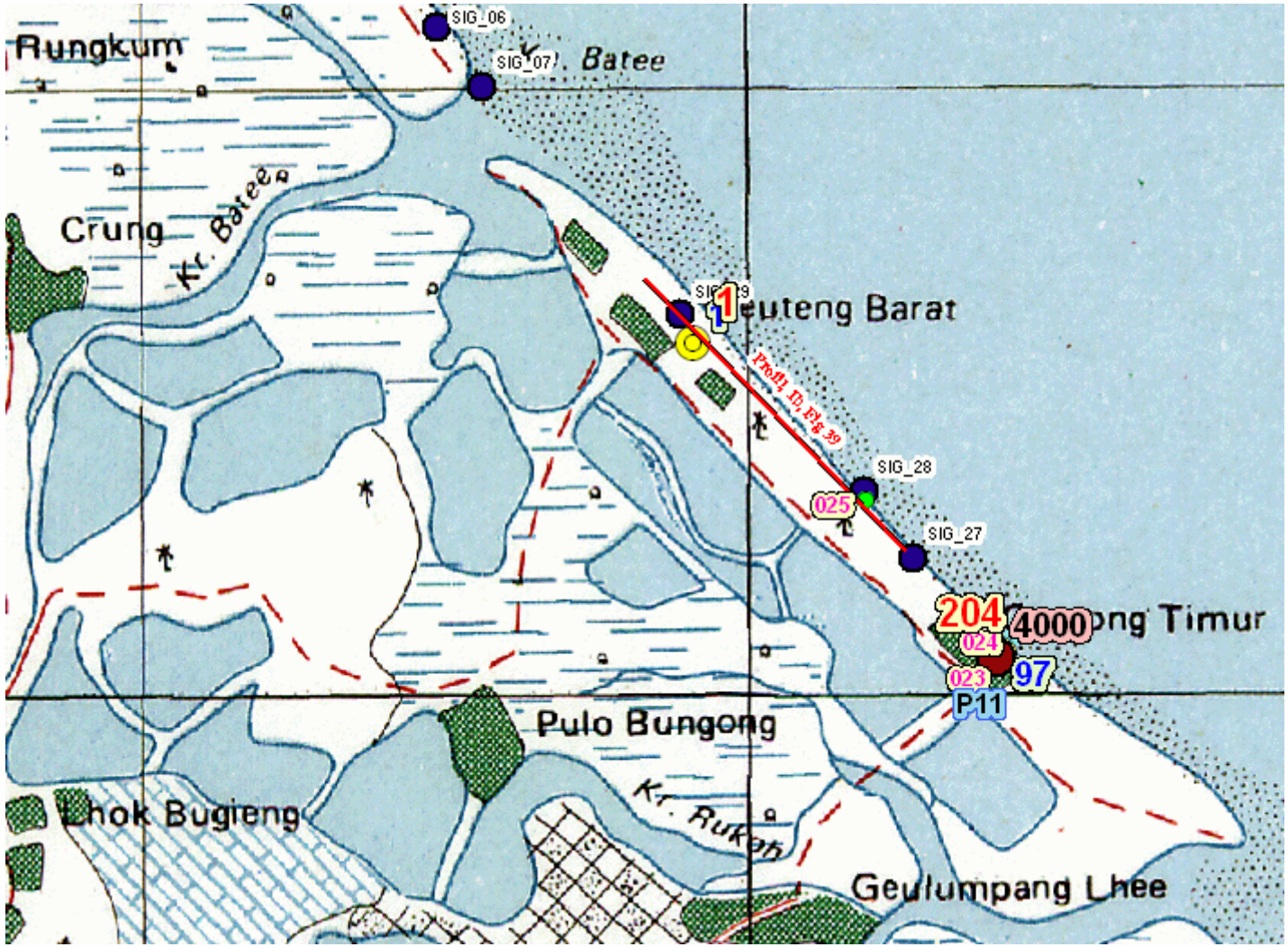
Comparison of DC (left) and TEM (right) soundings at site sig_16





Geuteng Line 1B

Aid Organisation	Targeting at
German Agro Action (Welthungerhilfe)	Rehabilitation of existing wells, drilling program covering Bireuen – Sigli region
German Development Cooperation (GTZ) Aceh Emergency and Transitional Aid	Running refugee camps and providing these with fresh water
French Red Cross - Sigli	River water treatment and logistics of fresh water for settlements and refugee camps with no nearby fresh water
International Red Cross/Norwegian Red Cross - Sigli	Drilling program for settlements and refugee camps
Oxfam – Sigli (UK)	Drilling program for settlements and refugee camps
International Professionals (US Aid)	Reconstruction of heavily hit settlements



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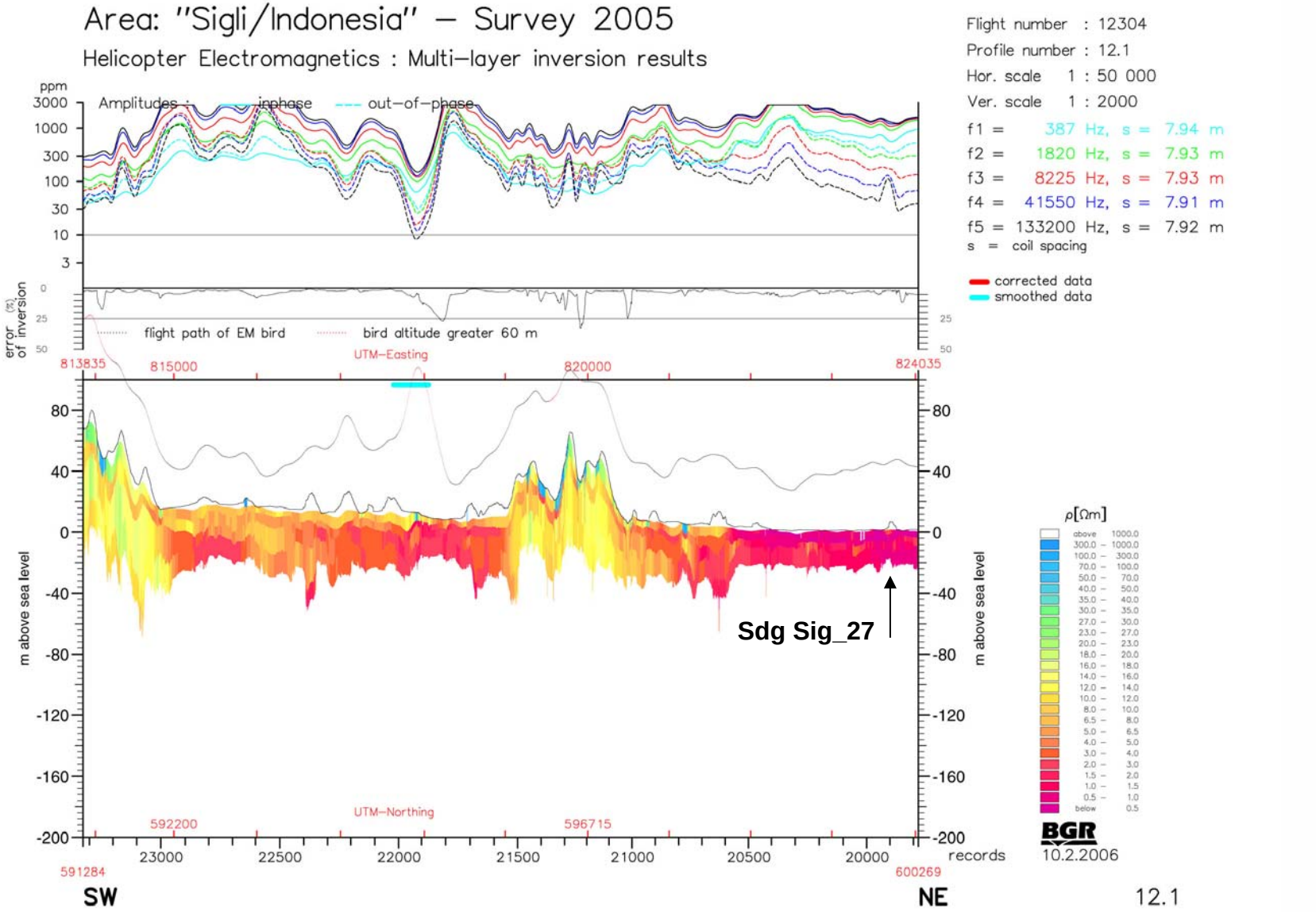

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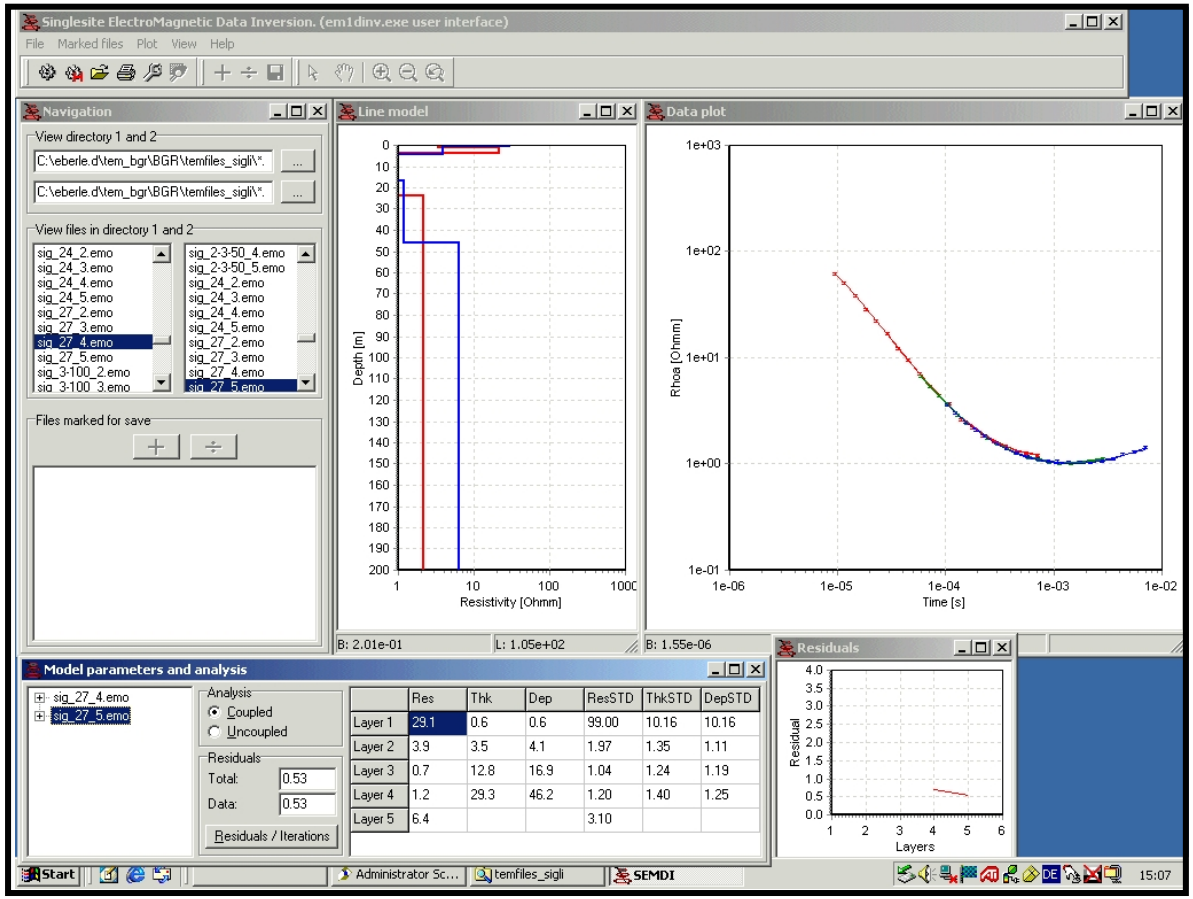

TEM sounding 27 reveals a 6 Ohm*m resistive substrate with top at 45 m below ground

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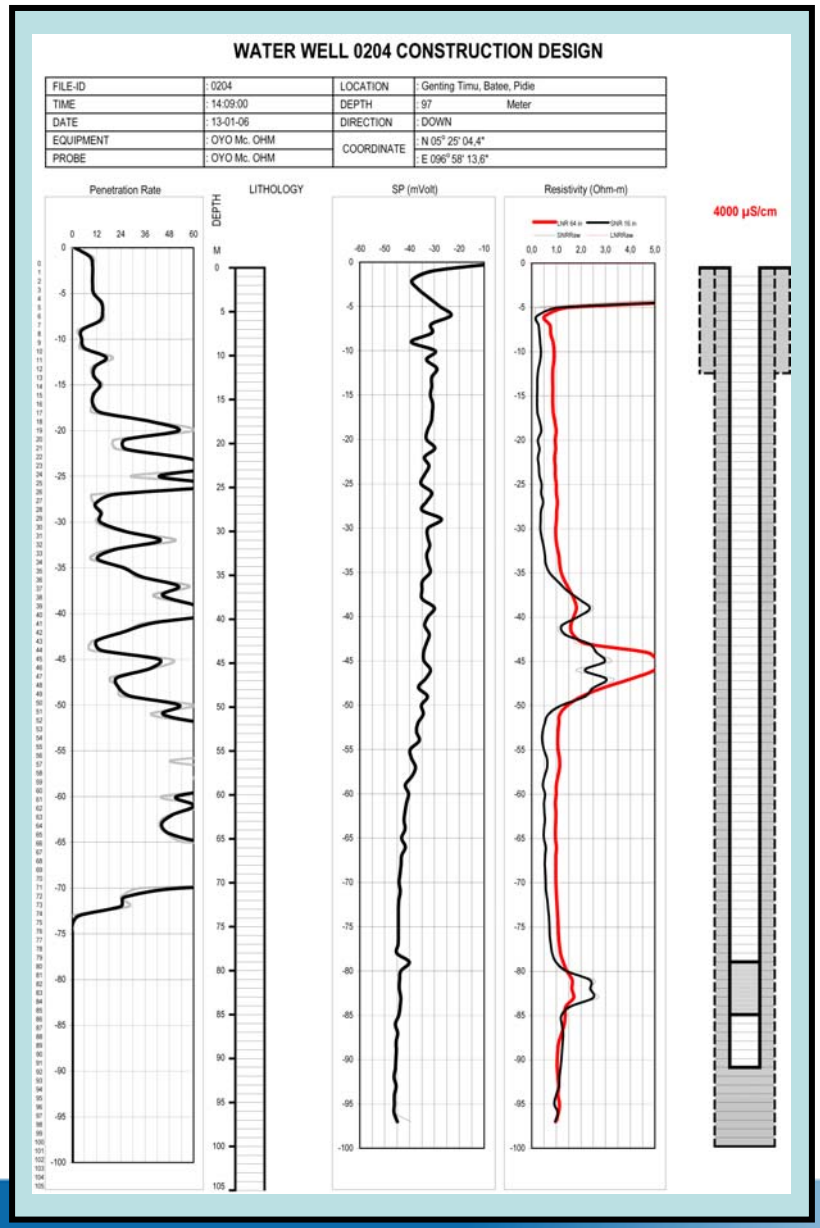
GEOZENTRUM HANNOVER



Electric borehole log (right hand side track) reveals resistive intercalation with 5 Ohm*m at 45 m below ground

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GEOZENTRUM HANNOVER

Achievements and Recommendations

- Potential inland aquifers outlined by airborne electromagnetics
- Salinisation along the Sigli coastal zone is hardly a product of the Tsunami flooding
- Artesian fresh water resources are confirmed in major parts of the Sigli coastal zone
- Ground electromagnetic surveys achieved greater depth of investigation in the coastal zone
- Ground electromagnetic surveys required to guide drilling programs, maximising the chance to hit potable water in the coastal zone
- Drilling would support back-evaluation of geophysical survey data

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