Surface geophysics

ER Method

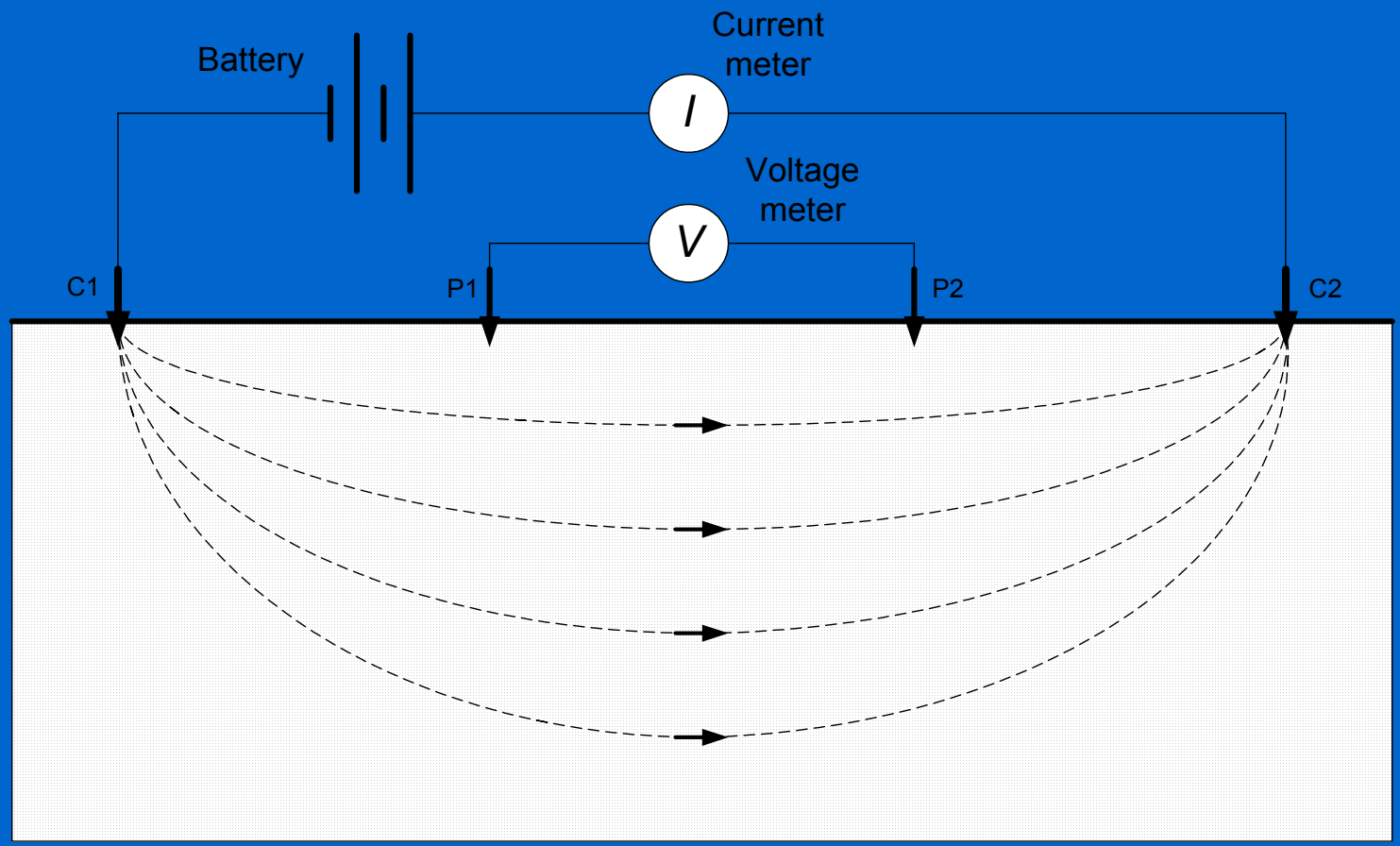
Geophysics

- Theory & application
- Equipment
- Field procedures – good practice and reporting
- Guidelines for Offset Wenner method
- Field sheets
- Need for calibration against other methods
- Trouble shooting
- Case study

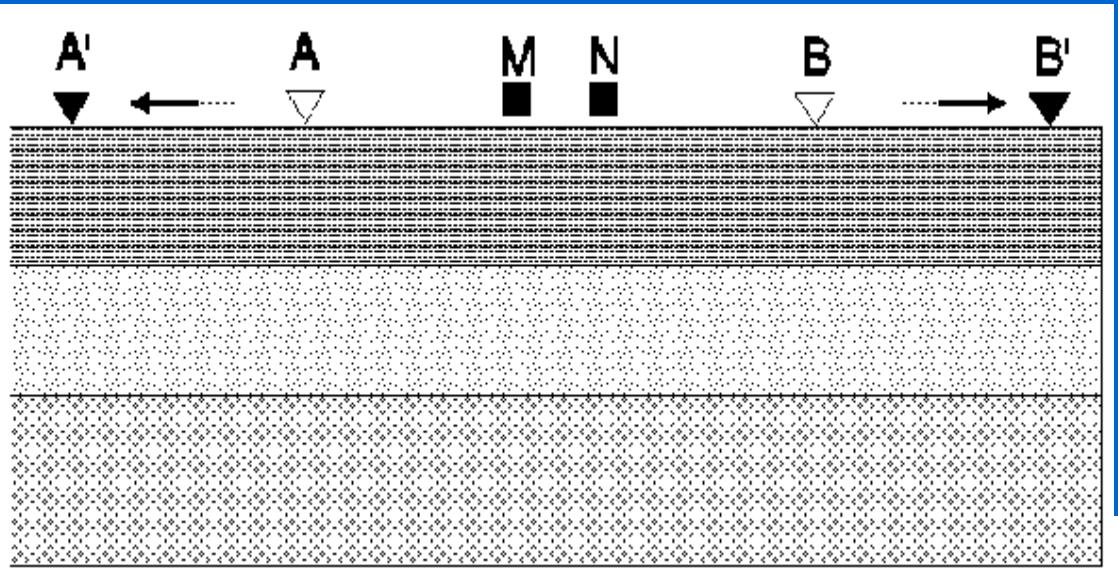
ER Principles

- Apparent resistivity of ground
- Measured using an array of electrodes
  - Two current
  - Two potential
- Effective depth of measurement depends on electrode spacing
  - Soundings (fixed centreline)
  - Profiles (fixed spacing)

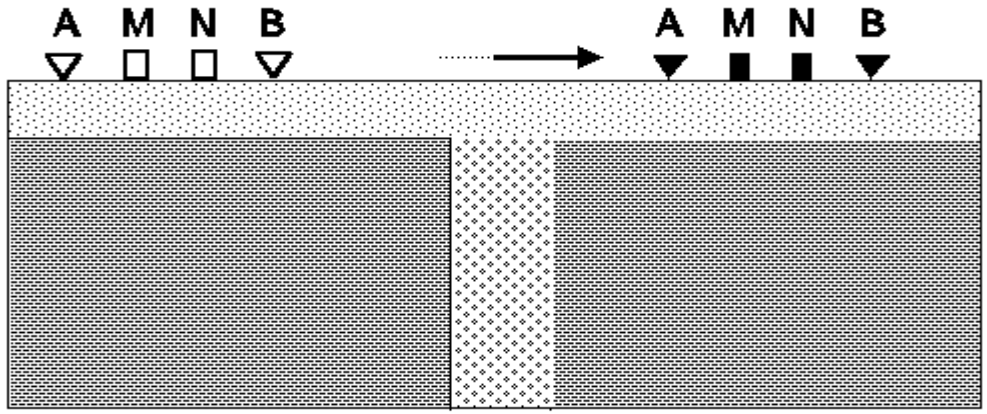
Schematic diagram of ER set up



Sounding & Profiling



Sounding aims to detect vertical changes

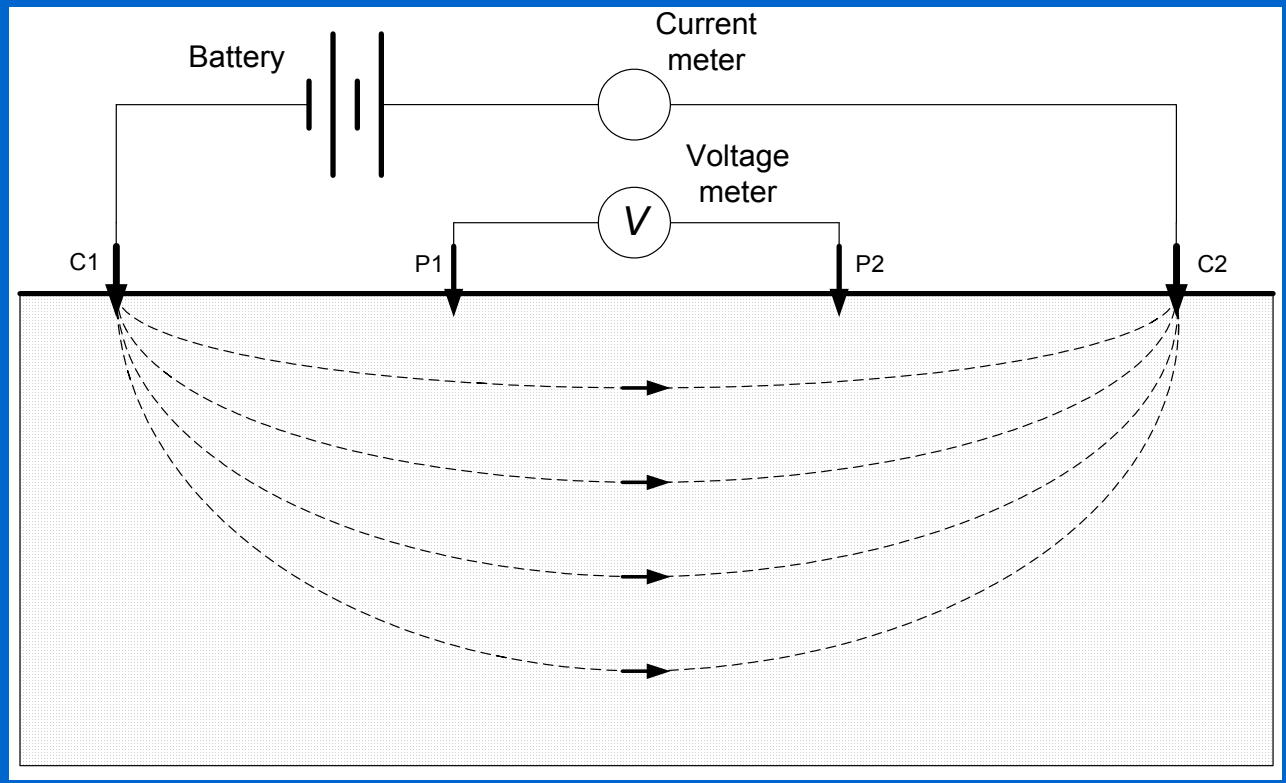


Profiling aims to detect lateral changes

Resistance

- Resistance = Voltage/Current

$R = V/I$



Resistivity

- Measured resistance depends on
  - Array set up
  - Electrical resistivity (intrinsic property)
- Resistivity = Geometric factor for array * R
  - E.g. for the Wenner array

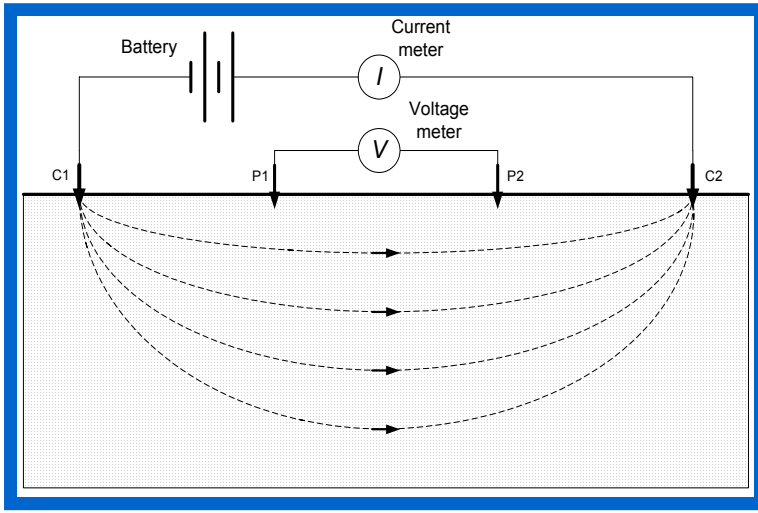
$$\rho_a = 2\pi aR$$

where a = electrode spacing

Array configurations

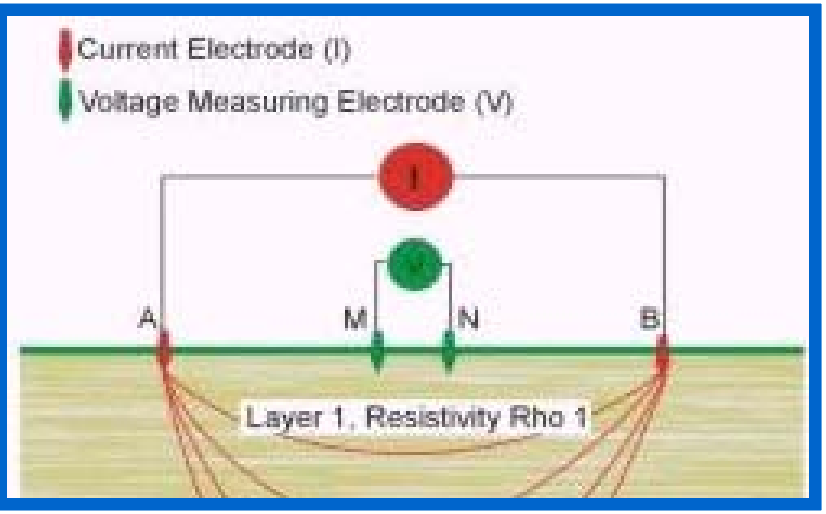
- Standard arrays
  - Wenner (equal spacing between all electrodes)
  - Schlumberger (voltage measurement over a smalling spacing)
- Non-standard
  - Offset Wenner (5 electrodes/spacing)
  - Multi-electrode systems

Wenner vs Schlumberger

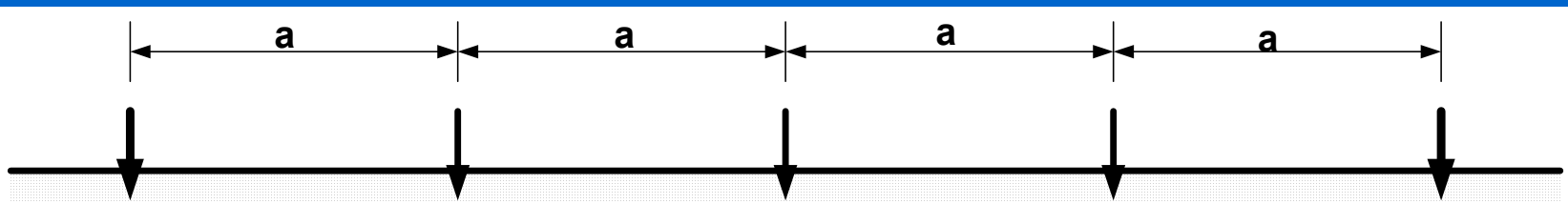


- Requires less instrument sensitivity
- Reduction of data marginally easier
- Favoured in the US

- Faster because only outer electrodes need to be moved
- More sensitive in distinguishing lateral from vertical variations
- Favoured in Europe



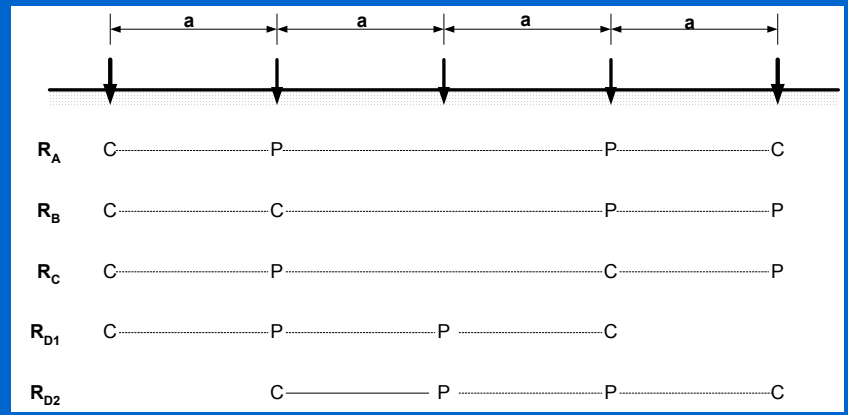
Offset Wenner array



R_A	C	P	P	C
R_B	C	C	P	P
R_C	C	P	C	P
R_{D1}	C	P	P	C
R_{D2}		C	P	P	C

Offset Wenner measurements

- 5 electrode positions to measure
  - Two (offset) Wenner resistances (R_A and R_B)
    - reduce effects of lateral underground resistivity variations
  - 3 additional resistances (R_C, R_{D1} and R_{D2})
    - Allow calculation of observation error
    - $R_A = R_B + R_C$



Equipment

- ABEM SAS 300 Terrameter
- BGS 256 multi-electrode system
  - 2 Multi-core cables
  - 21 electrodes
  - Switch box
- Total cable spread 512 m
- NB: Solomon Islands, Vanuatu, Fiji (MRD), SOPAC have this equipment

Guidelines for method

- Best used in horizontal layered situation
- To detect coastal saline water, soundings should ideally be parallel to the coast
- Desirable to use full cable spread where possible
- Resistance measurements should begin with smallest electrode spacing
- Observations and observation errors should be recorded at each setting
- Apparent resistivities should be calculated and plotted in the field

Field procedures

- Preparation
- Location
- Setting up
- Taking measurements
- Field Calculations

Preparation – equipment list

- 1 SAS300 Terrameter (ABEM)
- 1 Switch Box
- 2 Reels with cables + 3 short cables
- 21 Electrodes with Clips
- 1 Compass
- 1 Calculator
- 1 ABEM Instruction Manual
- Standard Data Sheets
- 2 Pens/Pencils

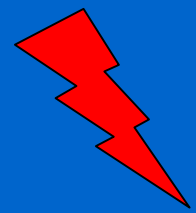
Battery voltage must be
➢11.5 volts,
& should be
➢ 12.5 volts

Location - consider

- Location of proposed borehole/s.
- Line requires a reasonably straight site.
- Line should avoid large obstacles or metallic objects.
- If less than 500 metres from the shoreline make the line run approximately parallel to the shore.
- Avoid cables running onto slopes and over hills.

Location - continued

- Avoid running the cable along formed roads
- If cable lines cross roadways, either stop traffic or raise the cable to allow traffic to pass.
- Take weather conditions into consideration:
  - Do not make measurements in the rain
  - Avoid thunderstorms and lightning



Setting up

- Centre point close to proposed borehole
- Run cables out in a straight line
- Connect electrodes to cable breakouts
- Connect cable to switch box
  - Note bearing of cable connected to D1
  - P1 & P2 on SAS300 to P1 & P2 on switch box
  - C1 & C2 on SAS300 to C1 & C2
  - Central electrode connected to switch box

Taking measurements

1. Fill out site details on standard data sheet.
2. Check the battery to ensure it is still charged,
   - > 11.5 volts (use battery check on the SAS300)
3. Set PC switch towards the BGS label.
   - Start with a current setting of 20mA. Always use maximum current obtainable and decrease as required.
4. Set the resistivity range either to 1 ohm or 100 ohms

Taking measurements (cont.)

5. Take measurements for A, C, D1, D2 and B at settings 1 to 9.
   - If an error code is displayed refer to the error code sheet. (e.g. error message "1" indicates that a current electrode is disconnected)
6. Record the measured resistance
   - make sure consistent readings are obtained
   - Note the units recorder e.g. mohms, ohms or kohms
   - Use the standard data sheet
   - Measure the direction of the cable line using a compass and record on the data sheet.

Field calculations

- Field calculation of the Wenner Resistivity should be carried out using the field sheet.
- Calculations involve
  - finding the average of measurements R_{D1} and R_{D2}
  - multiplying by $2\pi a$ (a = spacing)
- Plot values on log-log graph paper.
- Draw a curve to fit the plotted points.

Field sheet

Site:	Rarotonga International Airport	Ref No:	**RARO2**	Weather:	Hot, overcast
Observers:	David, Giovanni, Ben, Adrian	Bearing:	D2 towards east	Topography:	Flat
Date:	16/01/98	Soil:		Geology:	Aroa sands

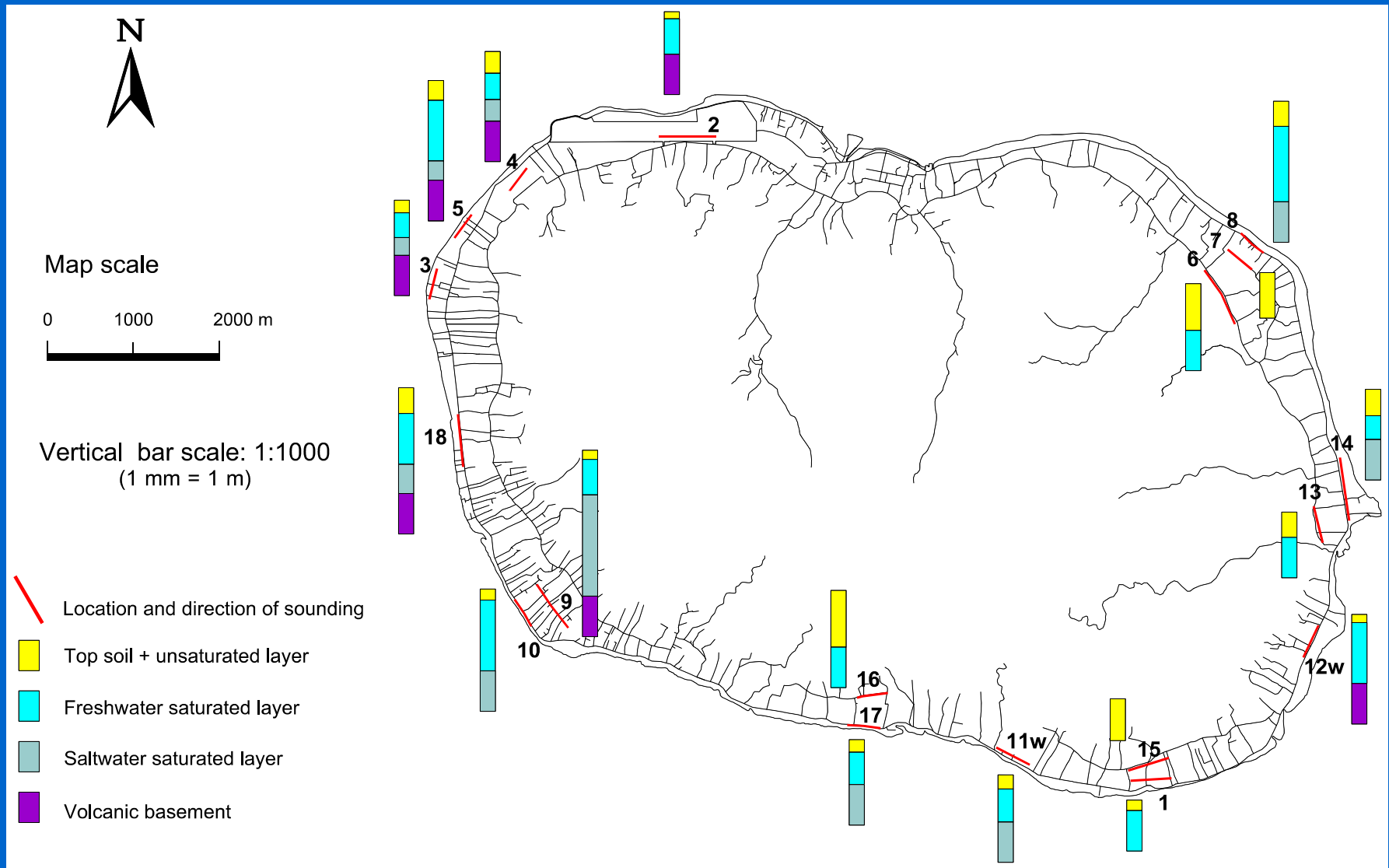
SETTING (n)	OBSERVED MEASUREMENTS RA	RC	RD1	RD2	RB	ERRORS OBS	OFFSET	LATERAL	SPACING (metres)	WENNER RESISTIVITY
1	551	507	495	443	43.9	0.02	11.09		0.5	1473.41
2	222	212	170.2	183	9	0.45	-7.25	56.91	1.0	1109.61
									1.5	647.40
3	26.4	25.4	29.5	31.6	1.0185	-0.07	-6.87	-134.88	2.0	383.90
									3.0	150.68
4	1.286	1.267	1.397	1.486	0.0497	-2.36	-6.17	815.77	4.0	36.23
									6.0	-4.51
5	0.485	0.461	0.391	0.1234	0.0228	0.25	104.04	247.31	8.0	12.93
									12.0	14.98
6	0.374	0.35	0.278	0.1073	0.0527	-7.40	88.61	-112.17	16.0	19.37
									24.0	42.86
7	0.537	0.588	0.481	0.1589	0.00575	-10.06	100.67	9.73	32.0	64.33
									48.0	160.96
8	2.2	1.983	1.229	0.447	0.0881	6.04	93.32	43.07	64.0	336.98
									96.0	1006.37
9	4.74	4.45	3.17	1.4865	-0.01483	6.65	72.31	-3.50	128.0	1872.49
					RMS Error:	5.19	69.13	291.09	192.0	3836.01
									256.0	6825.64

Comments: No direct conductivity measurement carried out in Airport water well. Conductivity was reported to be around 800 µS/cm @ 25 C degrees.

Need for calibration

- Reliability is improved by measuring soundings at points where a depth or material property is known e.g.
  - Water table position
  - Freshwater lens thickness
  - Geology
- Interpreted resistivity values can be considered for similar soundings

Rarotonga case study



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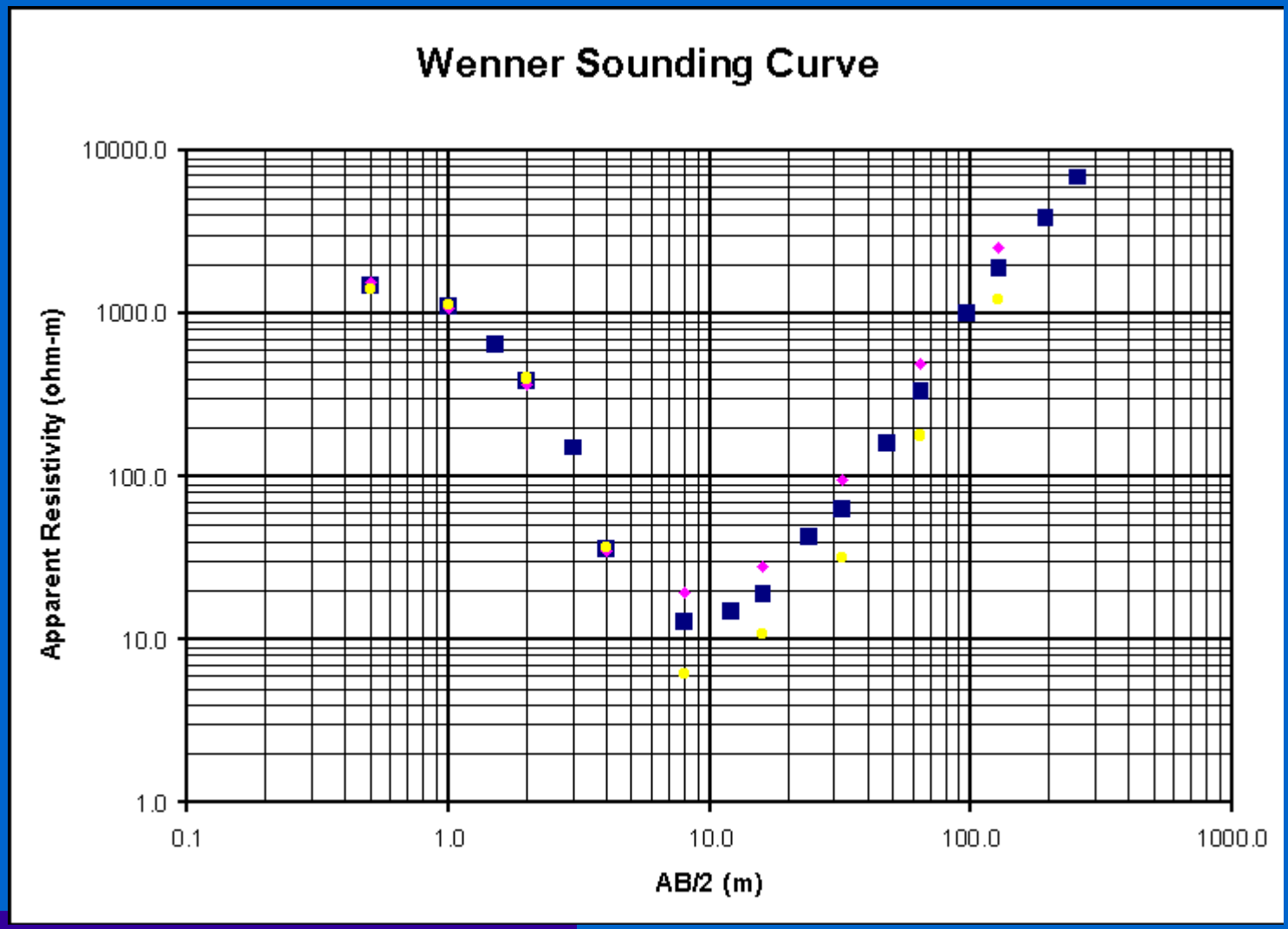
Plotted Wenner resistivity



Sounding interpretations

Sounding RMS Error	Depth (m)	Thickness (m)	Resistivity (ohm-m)	Equivalence	Lithology	Altitude *WT Depth*
RARO1	0	0.45	70	Minor	clayey top soil	4
2.95%	0.45	1.6	27.6	Minor	dry sand + clay	***2.05***
	2.05		20		freshwater sat. sand and clay	
RARO2	0	0.8	1800	Severe	top soil (gravel)	3.6
27.4%	0.8	0.6	400	Severe	dry sand	***1.4***
	1.4	7	28	Mild	freshwater sat. sand and clay	
	8.4		10000000		volcanic basement	
RARO3	0	2.5	250	Minor	dry sand	2.5
16.6%	2.5	4.9	140	Severe	freshwater sat. sand	***2.5***
	7.4	3.5	1.8	Severe	saltwater sat. sand	
	10.9		400000		volcanic basement	
RARO4	0	4.3	2240	Minor	dry sand and gravel	5.5
14.9%	4.3	5.2	135	Severe	freshwater sat. sand	***4.3***
	9.5	4.2	6.16	Severe	saltwater sat. sand	
	13.7		400000		volcanic basement	

Interpreted resistivity values

LAYER TYPE	CONDITION	RESISTIVITY (ohm*m)
Top soil	Sandy	100 – 500
	Clayey	30 – 70
	Gravel (base course)	1200 – 2000
Unsaturated	Dry sand	200 – 600
	Dry sand and gravel (beach deposit)	1200 – 2400
	Sand and clay (depending on proportion)	20 – 120
	Clay	0.4 - 6
Saturated	Freshwater sand and gravel	150 – 200
	Freshwater sand	100 – 150
	Freshwater sand and clay	20 – 30
	Saltwater sand and gravel	2 – 10
Volcanic basement		300,000 – 600,000

Sounding #2 - Airfield

Trouble shooting

Interpretation