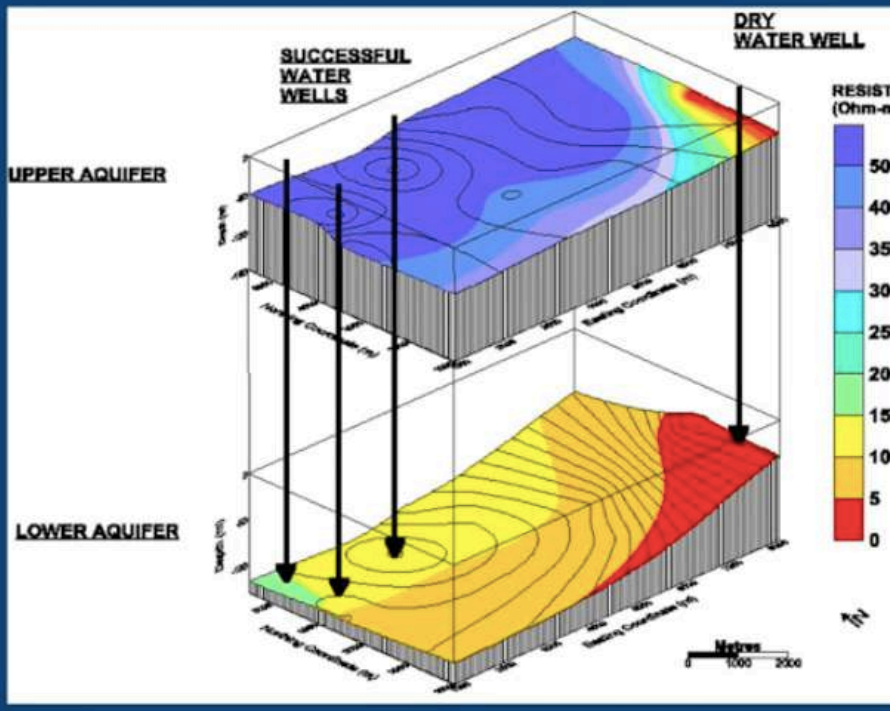
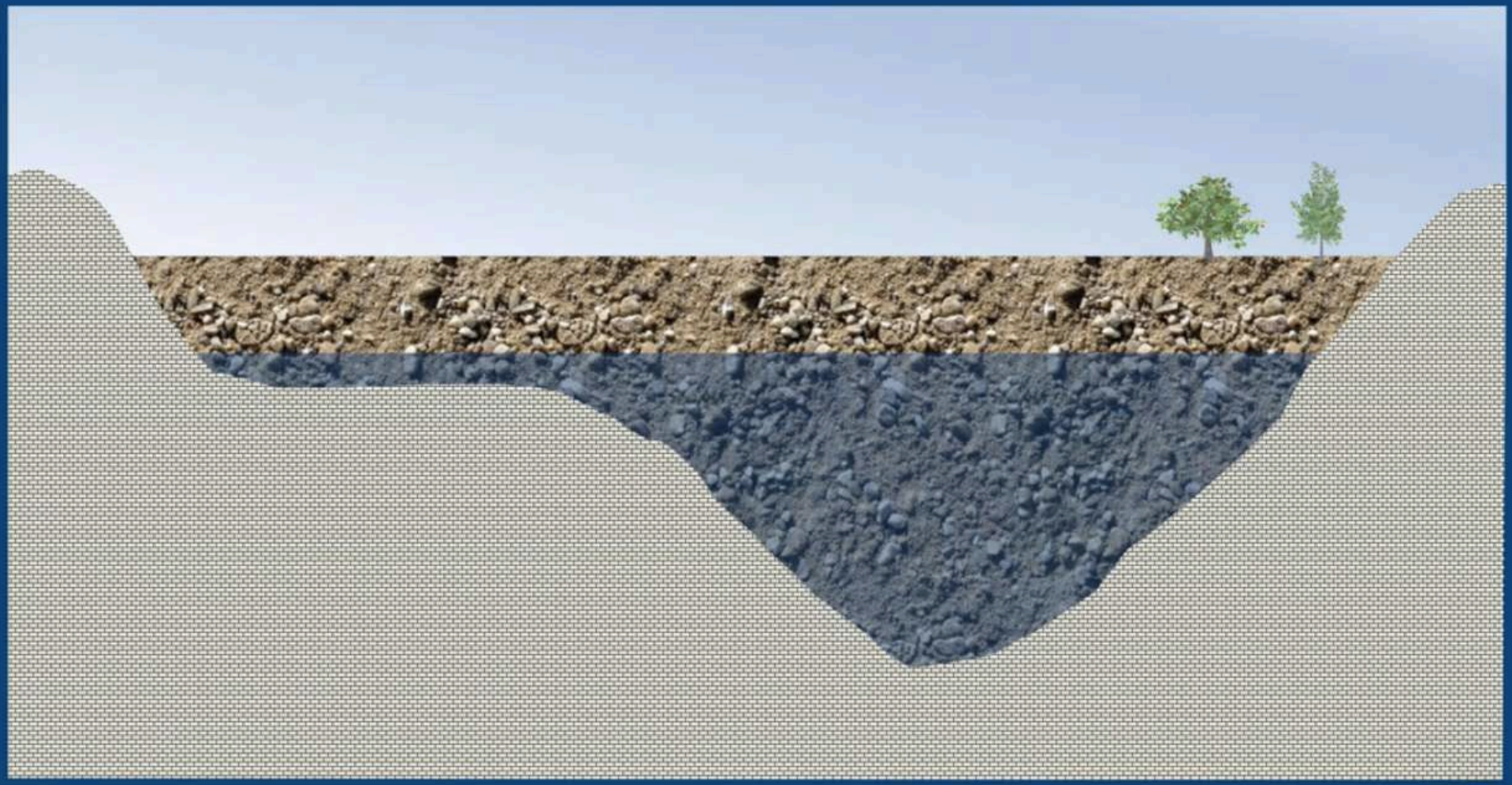
Resistivity Survey

Dr. Raman Kumar Biswas



Introduction to Resistivity Surveys



Drilling is expensive!

There is a cheaper option...

Client : A client
Project : A project
Province : A province
Date : 01/01/2012
Field Operator : ABC
Interpreted by : DEF

Village/Town : A town
Sounding Number : S-52
Coordinates East : 30.3
Coordinates North : 45.5
GPS Datum : WGS84
Azimuth : 180

A town : S-52

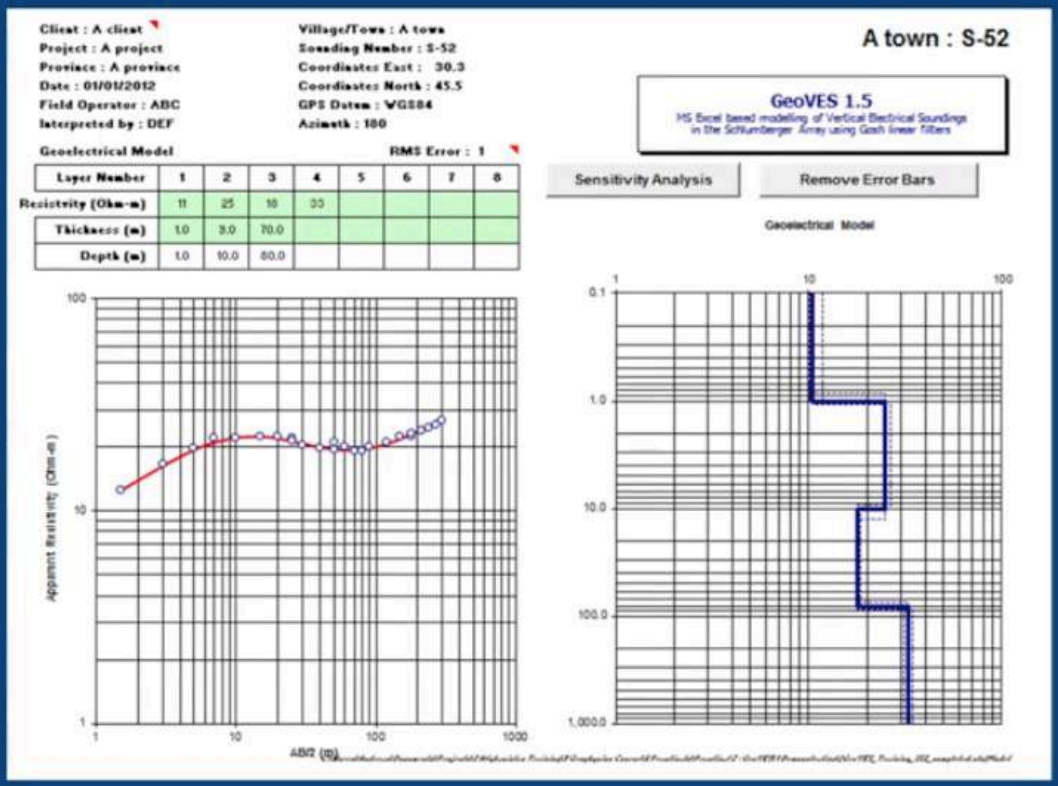
GeoVES 1.5
MS Excel based modelling of Vertical Electrical Soundings in the Schlumberger Array using Ghosh linear filters

Sensitivity Analysis | Remove Error Bars

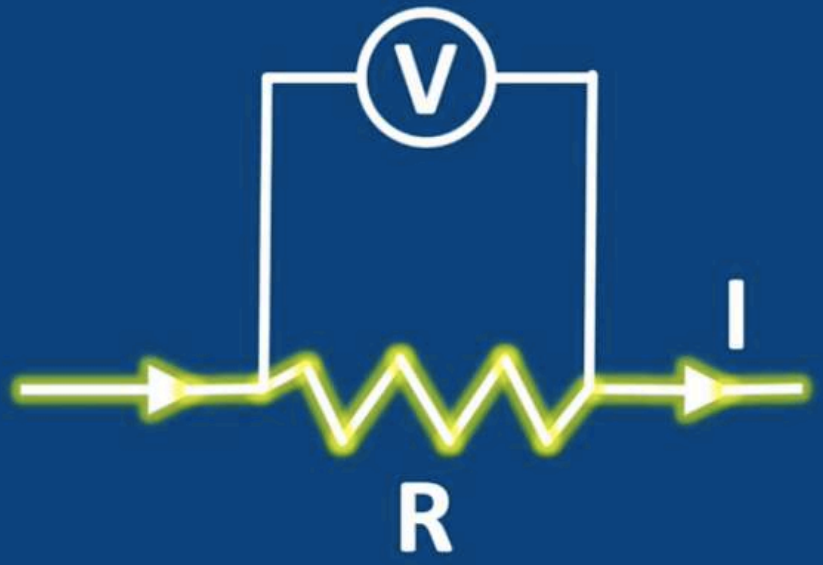
Geoelectrical Model

RMS Error : 1

Layer Number	1	2	3	4	5	6	7	8
Resistivity (Ohm-m)	11	25	18	33				
Thickness (m)	1.0	9.0	70.0					
Depth (m)	1.0	10.0	80.0					



Ohm's Law (1827)



$$R = \frac{V}{I}$$

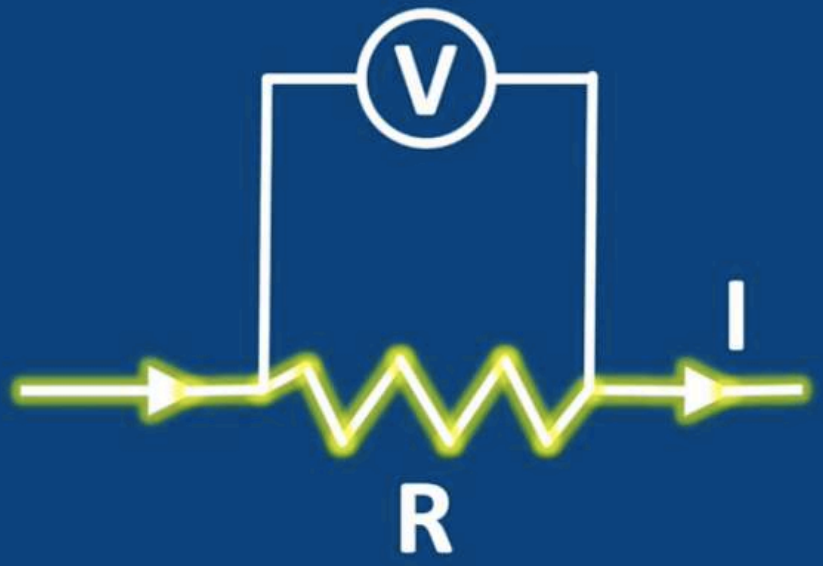
R = Resistance (ohms)

V = voltage (volts)

I = Current (amperes)

What is Resistivity?

Ohm's Law (1827)



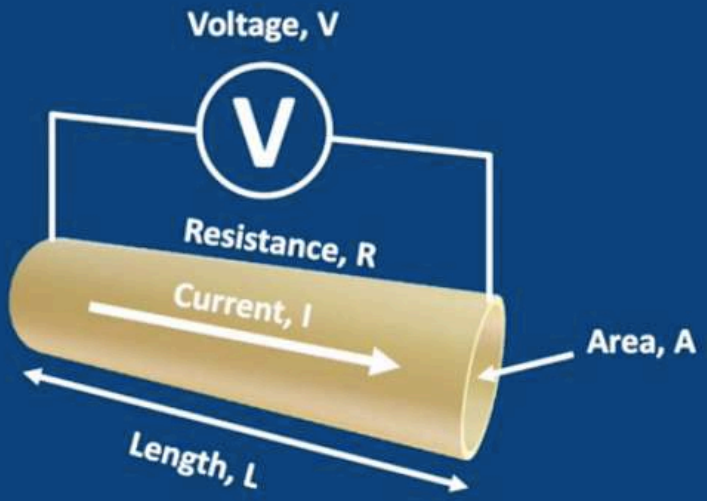
$$R = \frac{V}{I}$$

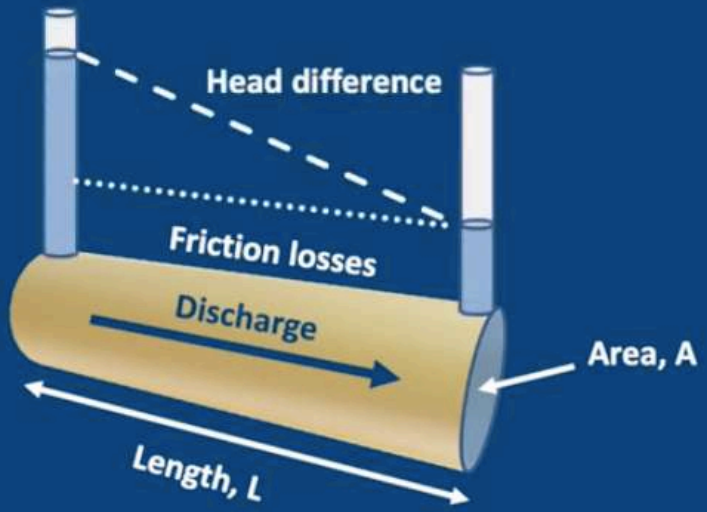
R = Resistance (ohms)

V = voltage (volts)

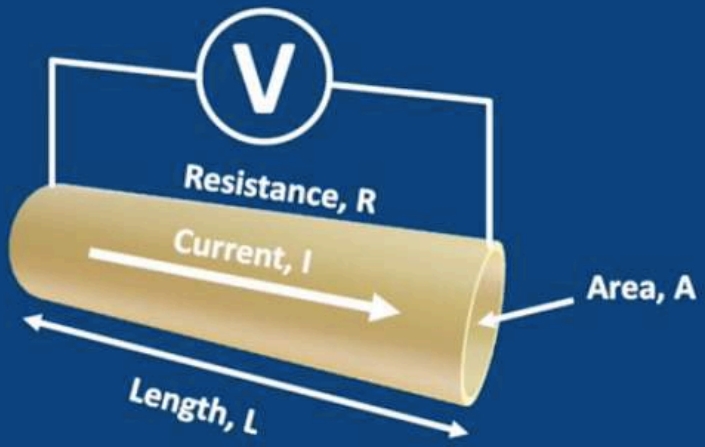
I = Current (amperes)

Analogy with water





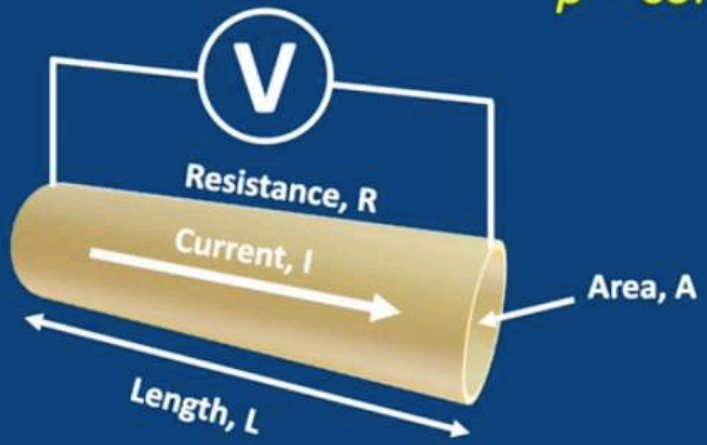
Problems with Resistance (R)



- Changing the length or diameter of the wire changes the resistance.
- Resistance is NOT a fundamental characteristic of the metal in the wire.

Resistance (R) & Resistivity (ρ)

ρ = constant of



$$R = \rho \frac{L}{A}$$

Resistance (R) & Resistivity (ρ)

ρ = constant of proportionality = Resistivity

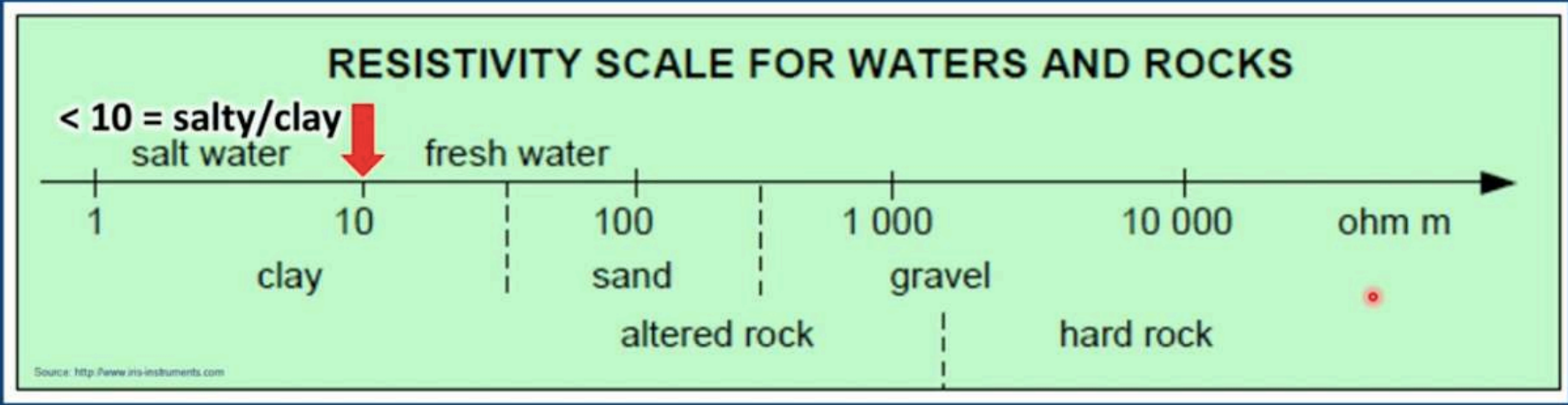
$$R = \rho \frac{L}{A}$$

– Resistivity, ρ is a fundamental physical property of the metal in the wire

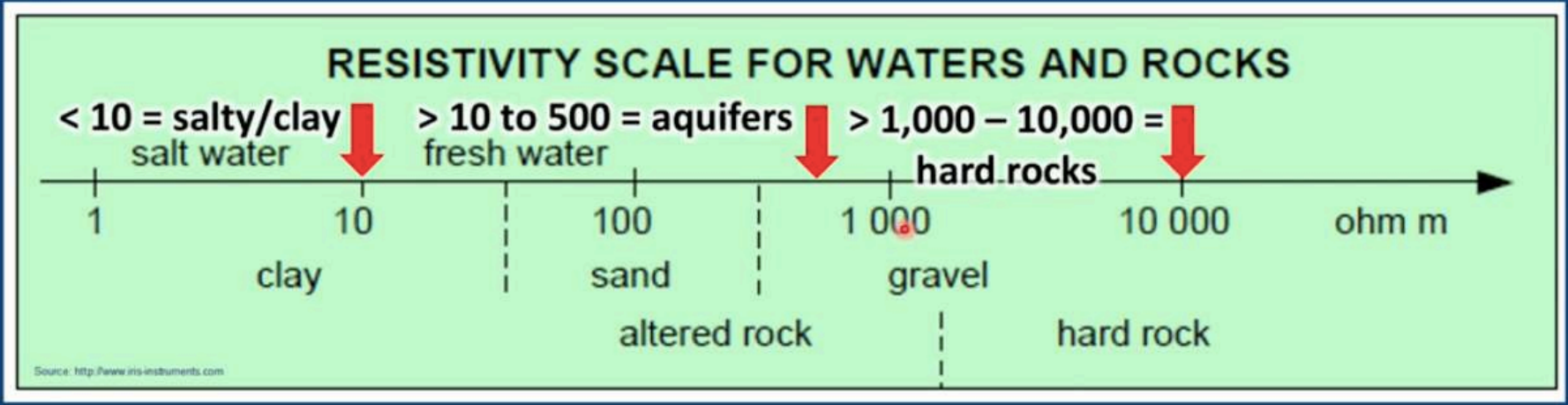
Resistivity, ρ = resistance per unit volume

- Units are ohm-m (ohm-meters)

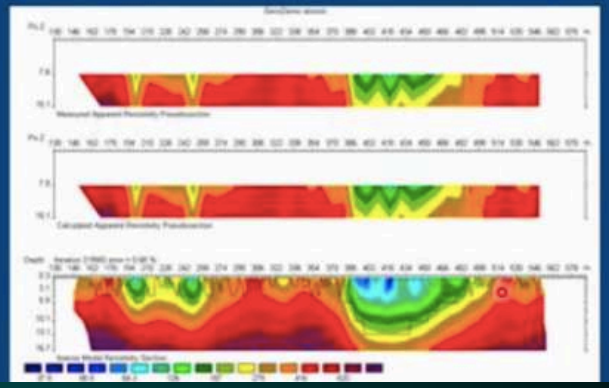
Resistivity of Rock Forming Materials



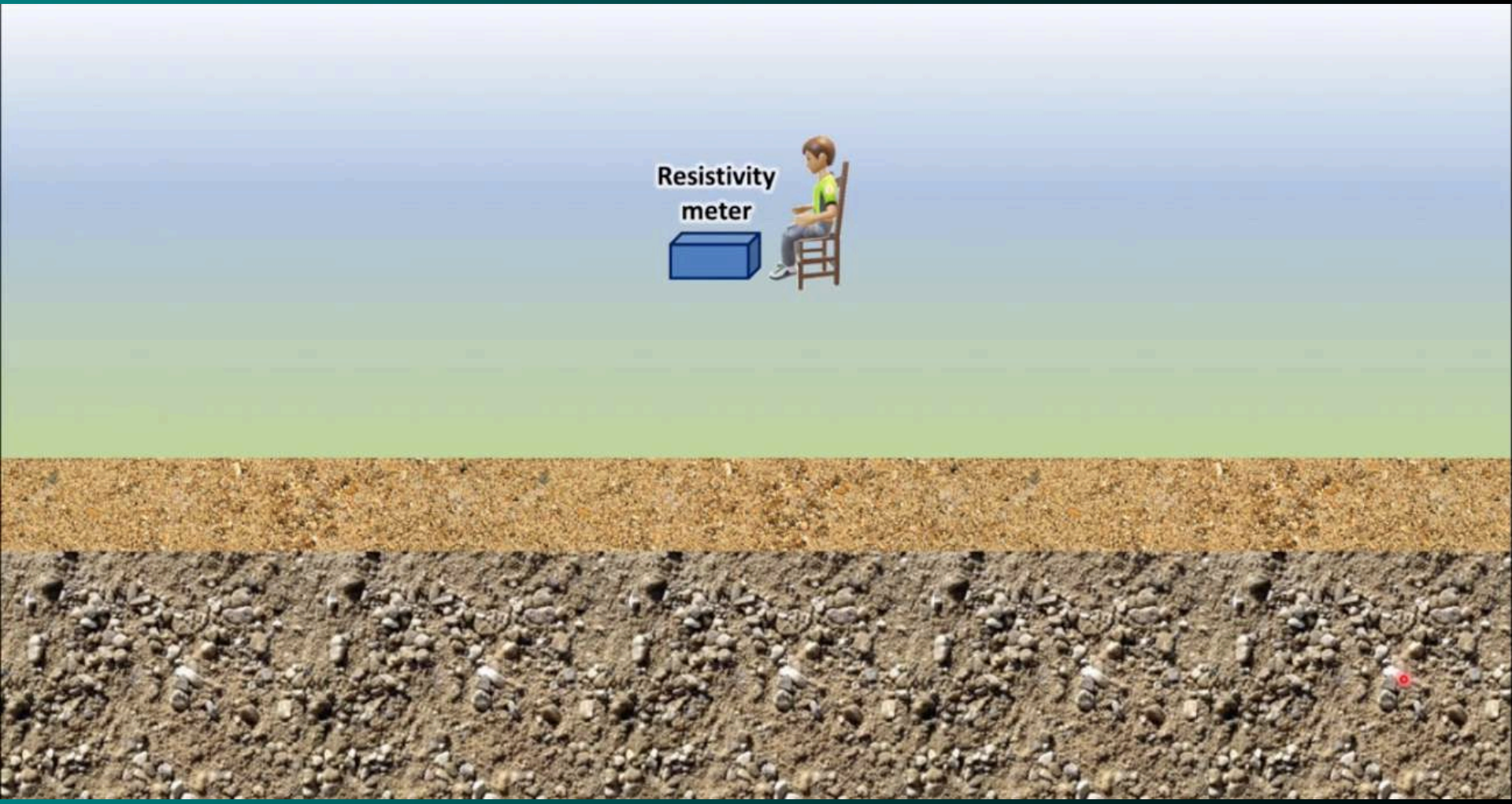
Resistivity of Rock Forming Materials

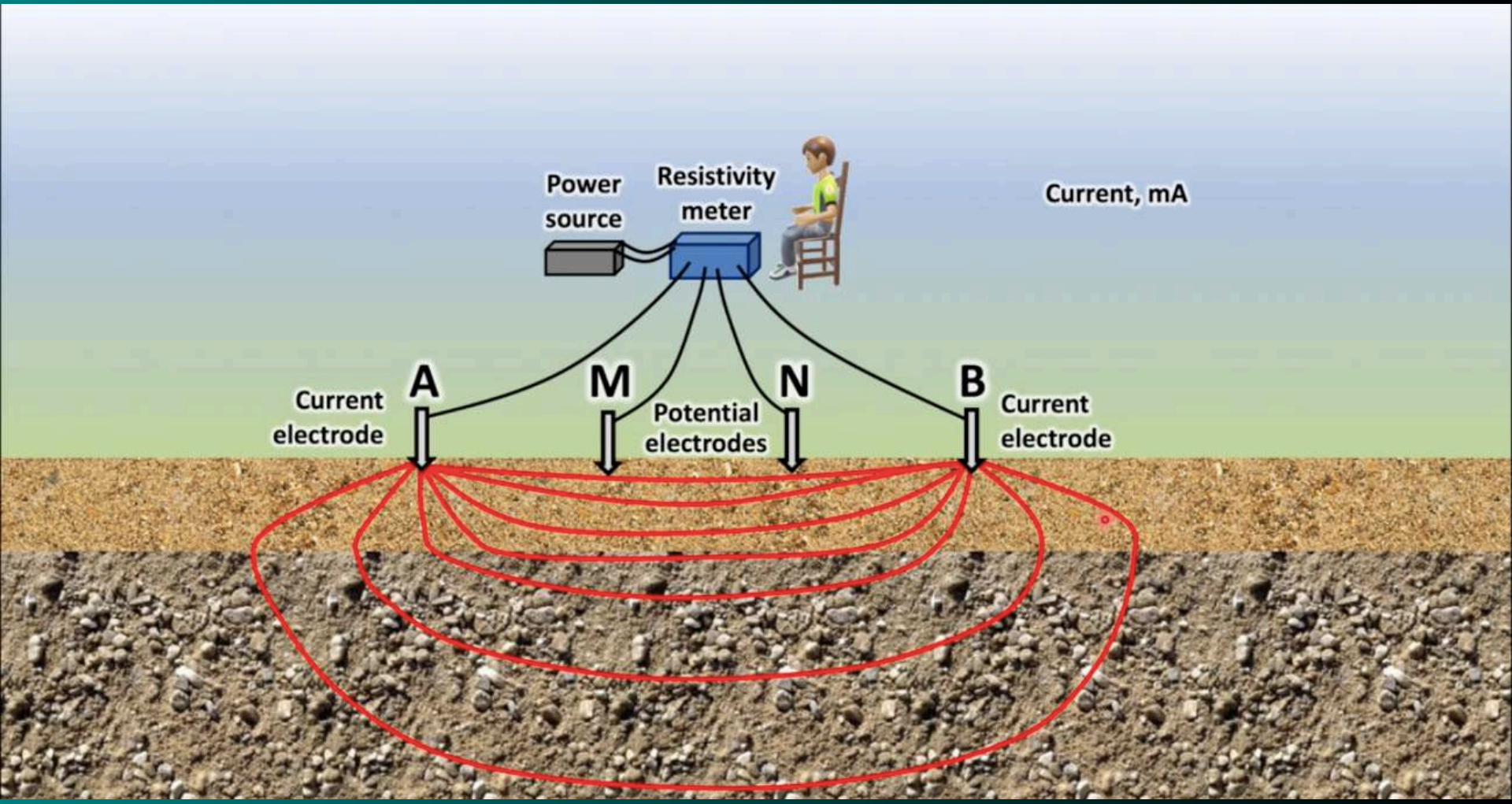


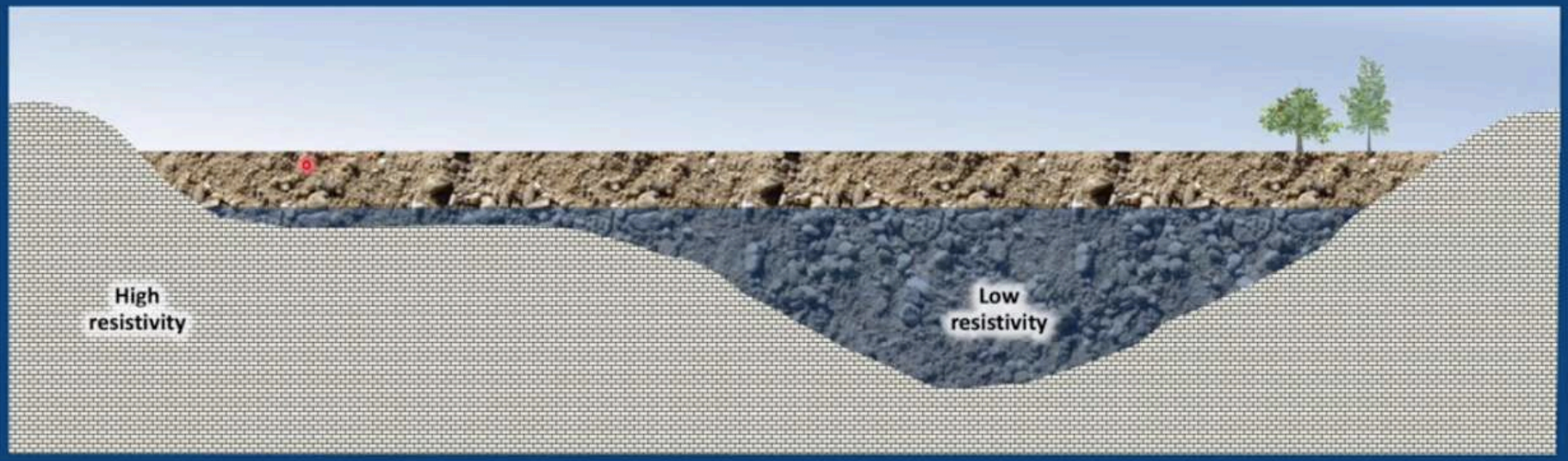
DC Resistivity Equipment – ABEM Terrameter

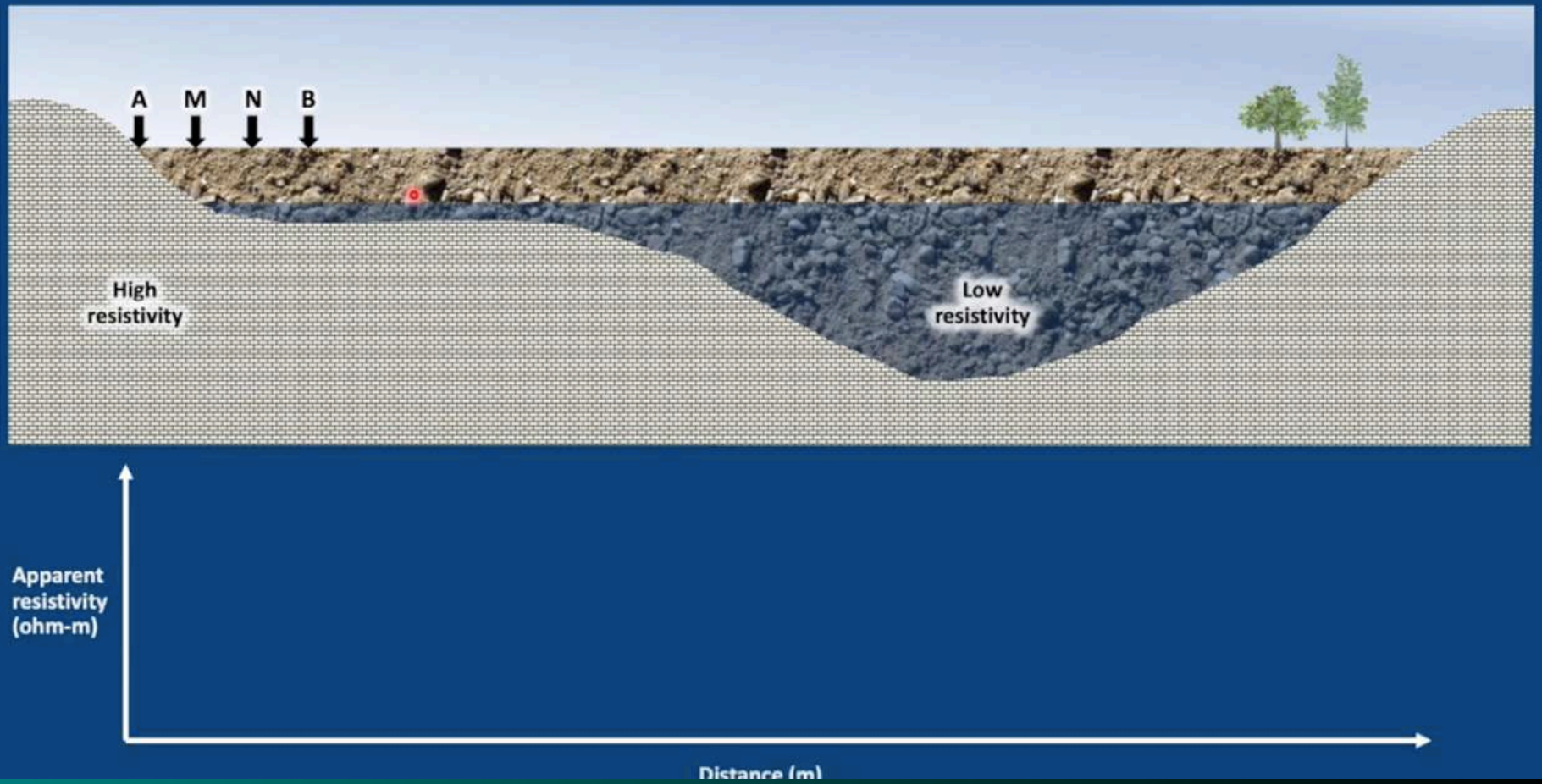


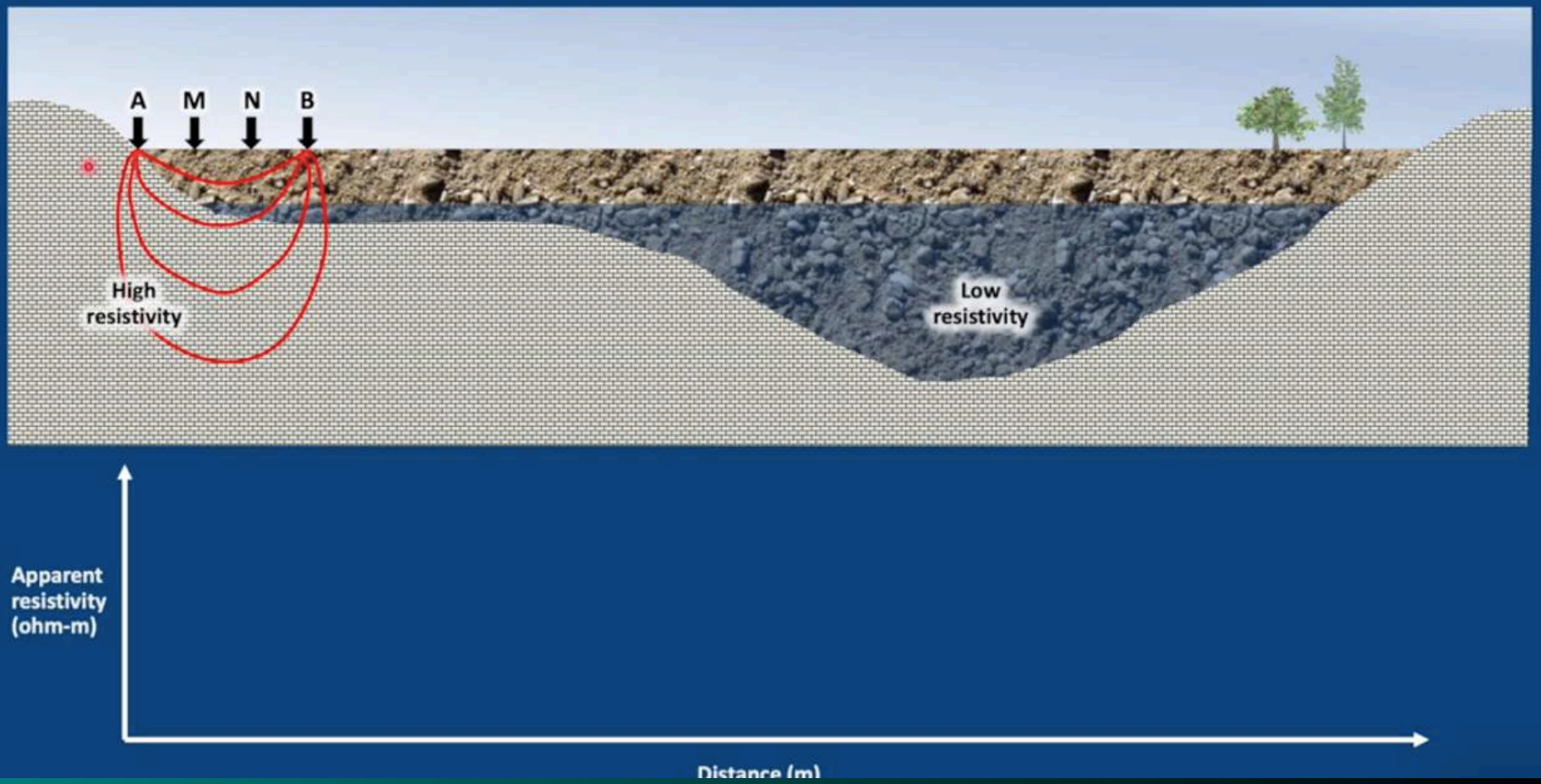
DC Resistivity Equipment – IRIS SYSCAL

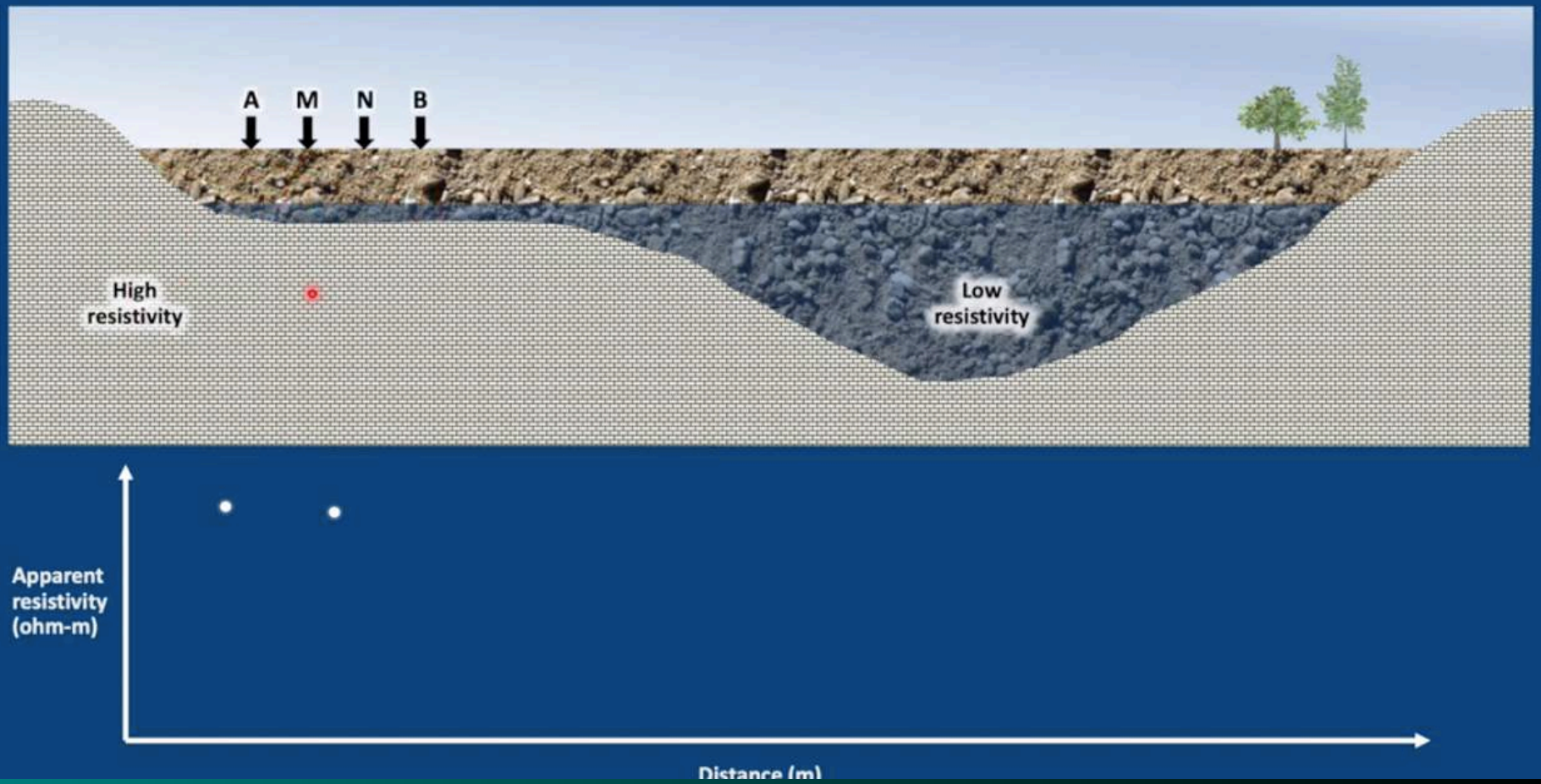

Resistivity
meter

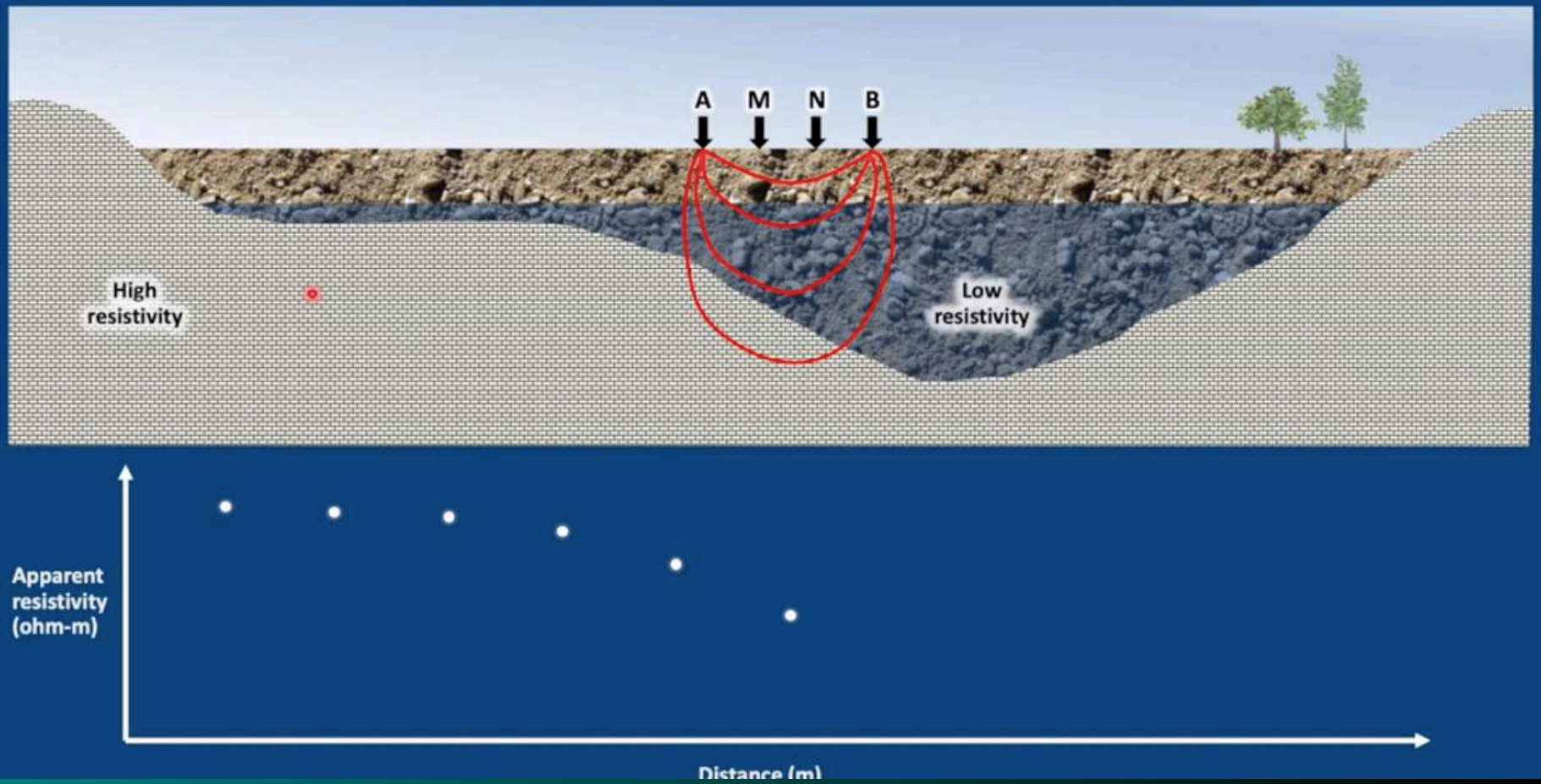

Power source
Resistivity meter
Current, mA
A
M
N
B
Current electrode
Potential electrodes
Current electrode

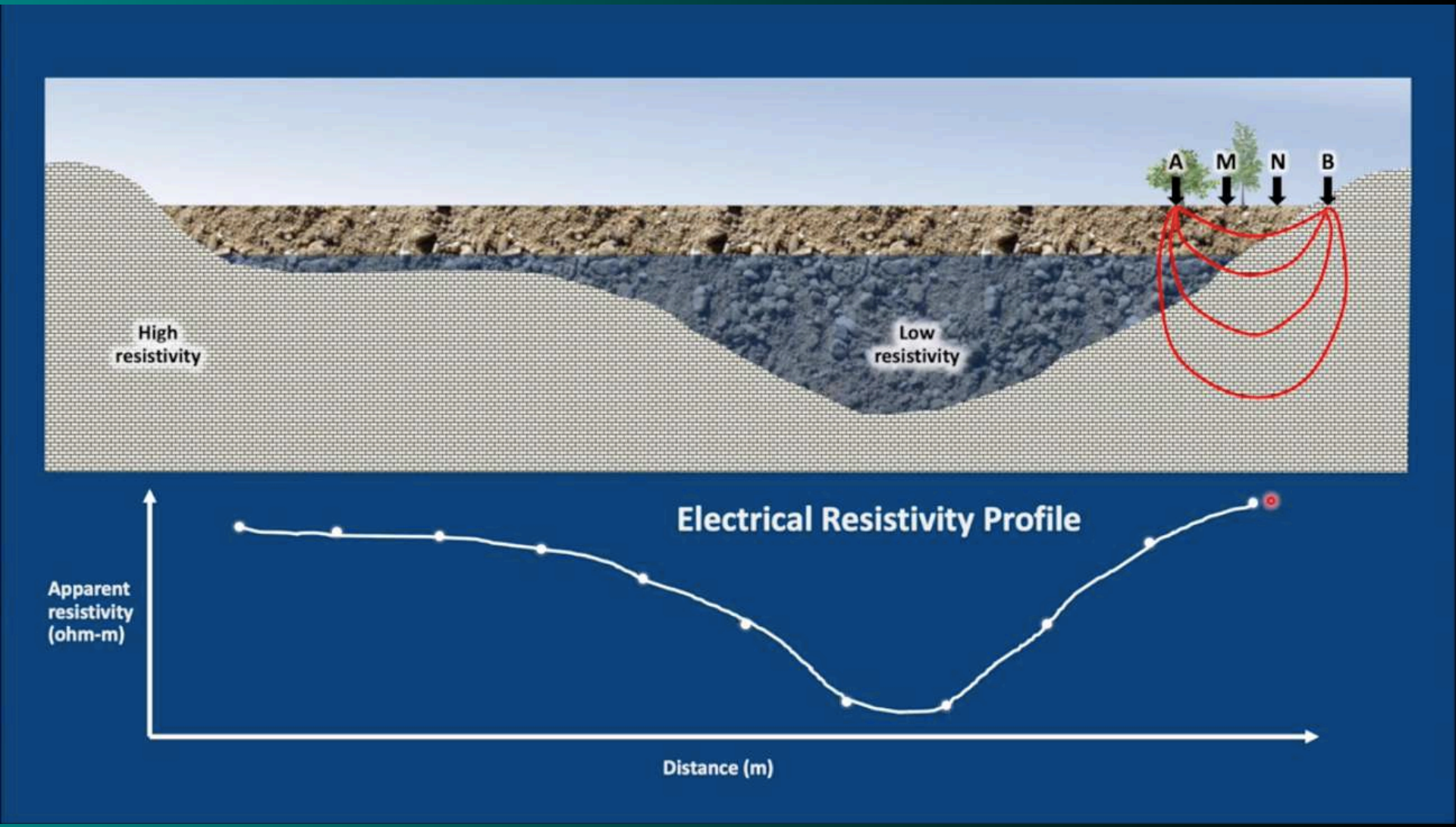

High
resistivity
Low
resistivity


A
M
N
B
High resistivity
Low resistivity
Apparent resistivity (ohm-m)
Distance (m)

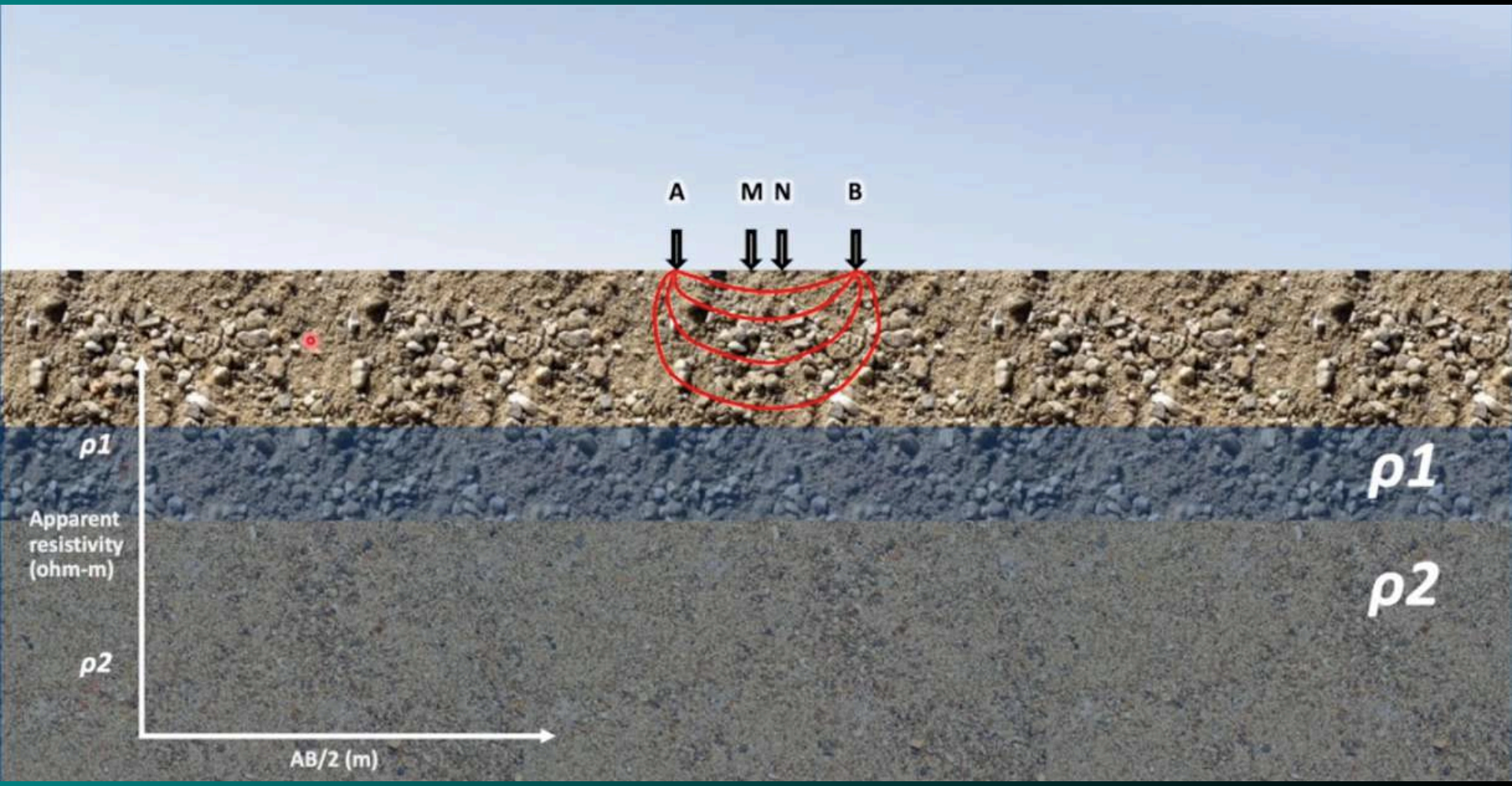

A
M
N
B
High resistivity
Low resistivity
Apparent resistivity (ohm-m)
Distance (m)

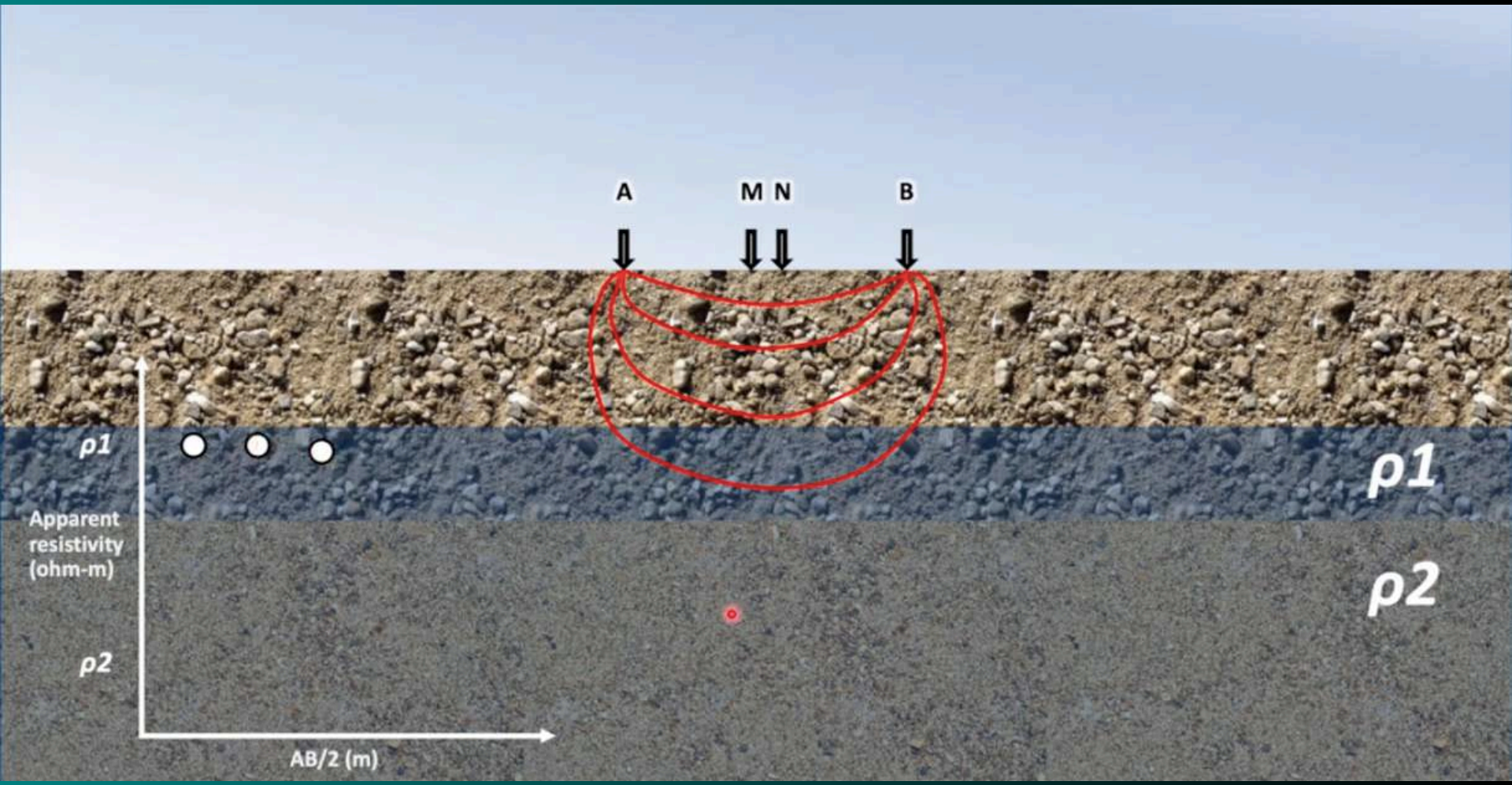

A
M
N
B
High resistivity
Low resistivity
Apparent resistivity (ohm-m)
Distance (m)

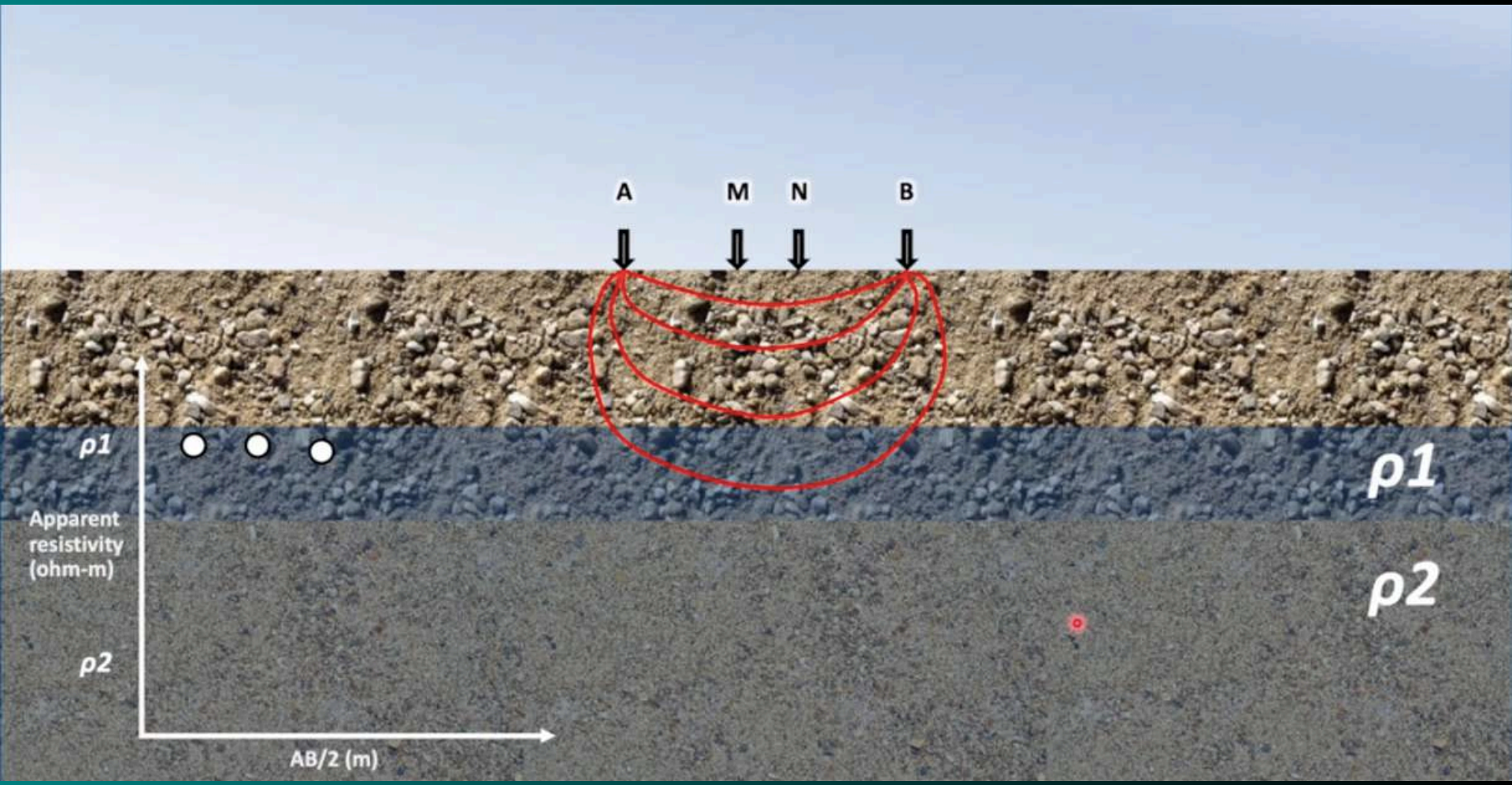

A
M
N
B
High resistivity
Low resistivity
Apparent resistivity (ohm-m)
Distance (m)

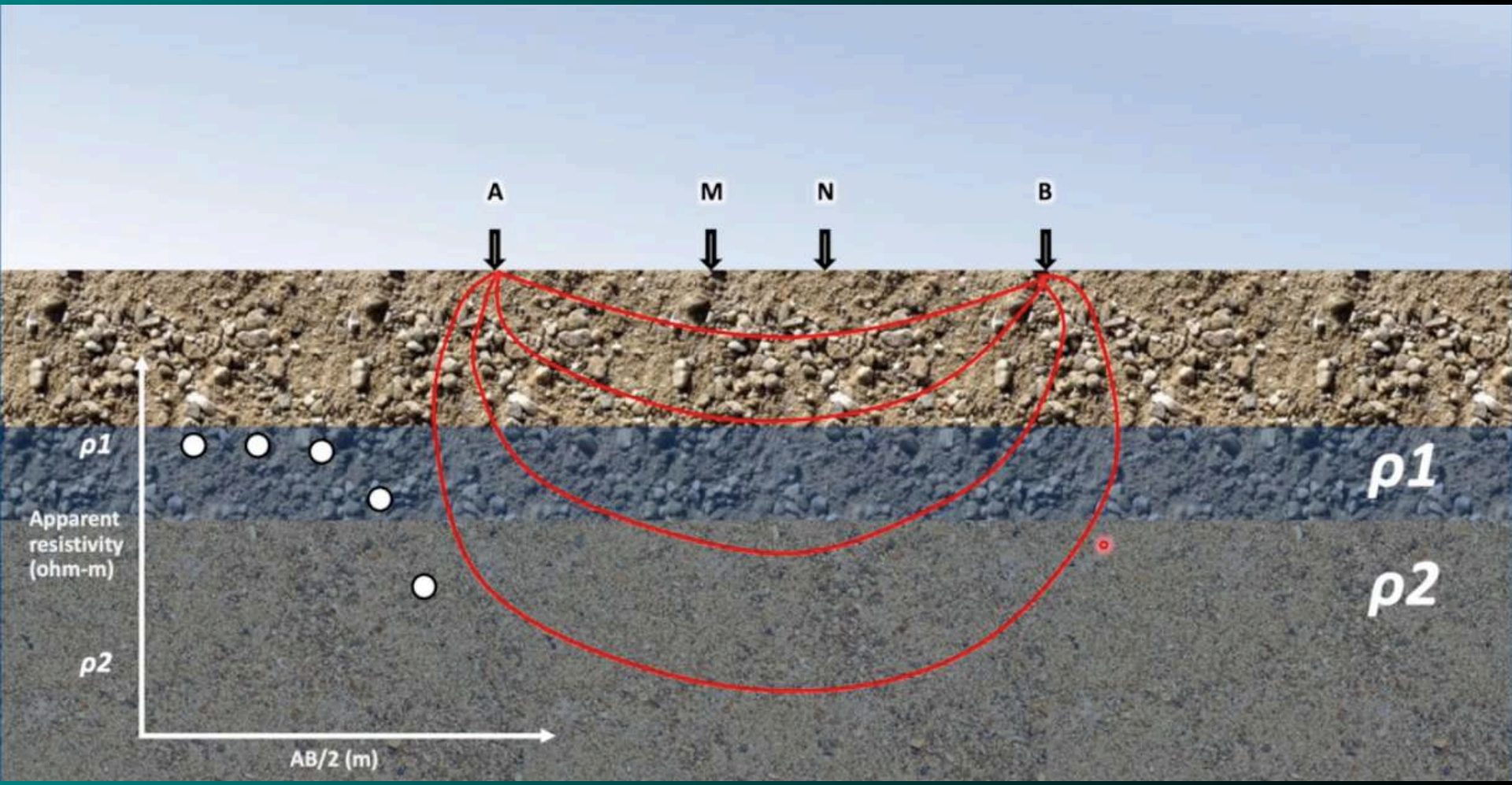

A
M
N
B
High resistivity
Low resistivity
Electrical Resistivity Profile
Apparent resistivity (ohm-m)
Distance (m)

Vertical Electrical Sounding (VES)


A
M N
B
ρ1
ρ1
Apparent resistivity (ohm-m)
ρ2
ρ2
AB/2 (m)

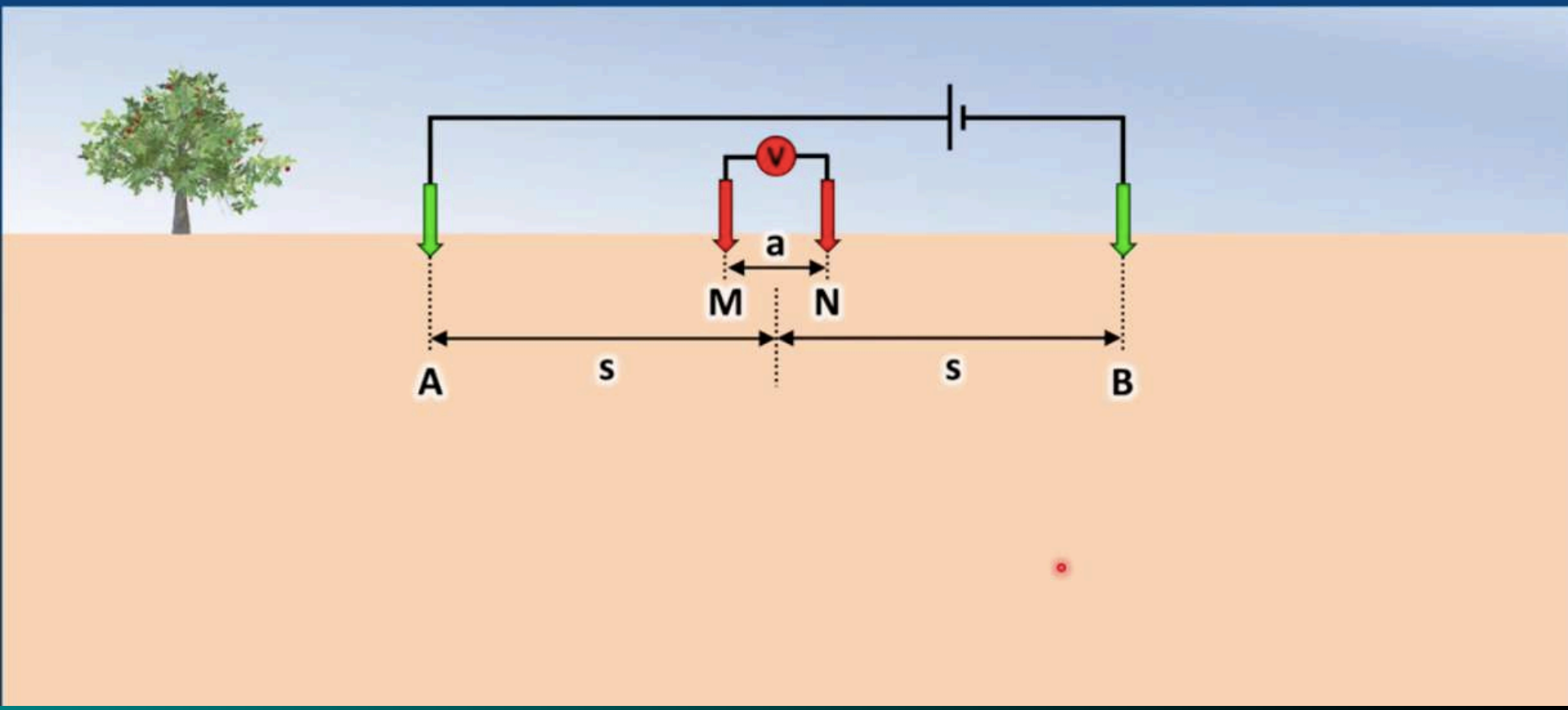

A
M N
B
ρ1
ρ2
Apparent resistivity (ohm-m)
ρ1
ρ2
AB/2 (m)


A
M
N
B
ρ1
ρ2
Apparent resistivity (ohm-m)
AB/2 (m)
ρ1
ρ2

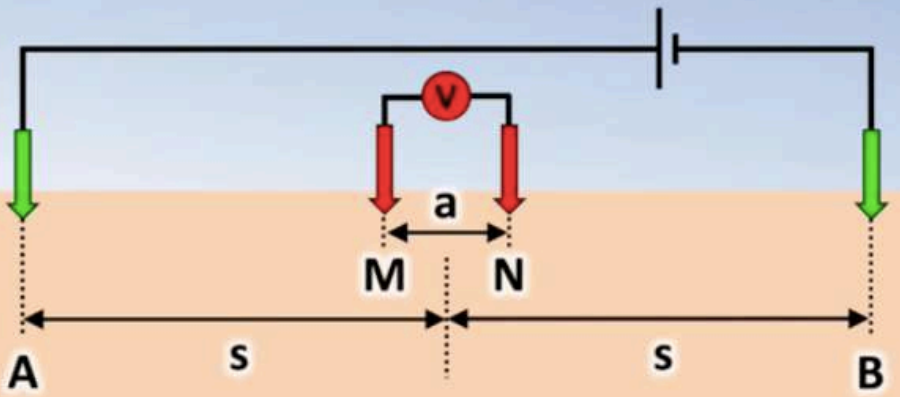

A
M
N
B
ρ1
ρ2
Apparent resistivity (ohm-m)
AB/2 (m)

Main Electrode Arrays

Schlumberger Array

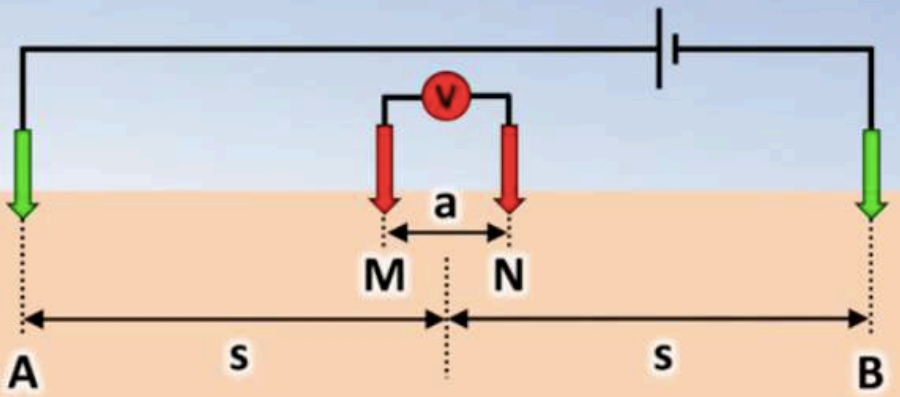


Schlumberger Array



MN <= AB/5

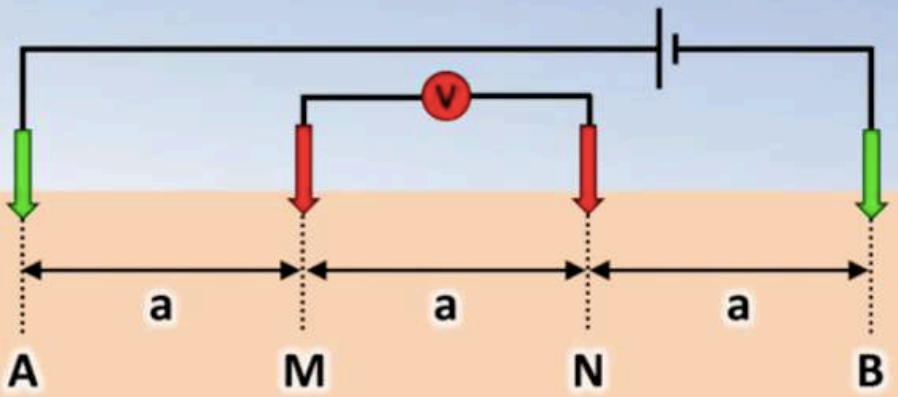
Schlumberger Array



MN <= AB/5

$$\rho_a = k\frac{\Delta V}{I}$$

Wenner Array

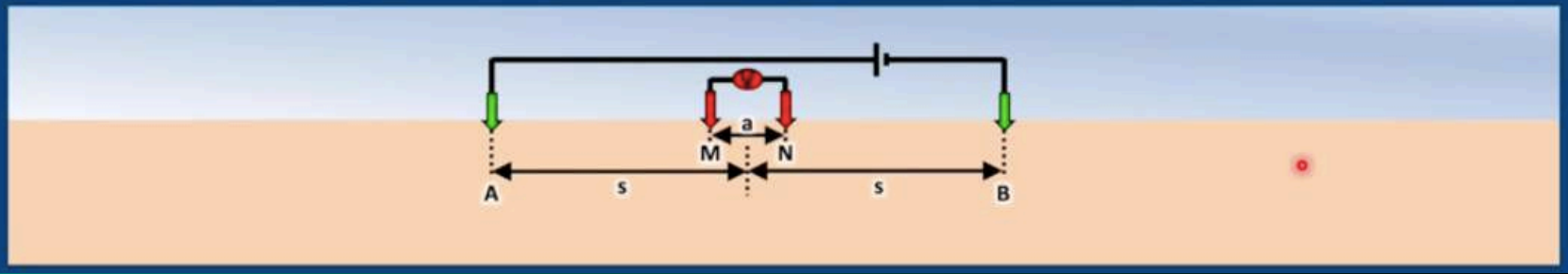


MN = AB/3

$$\rho_a = k\frac{\Delta V}{I}$$

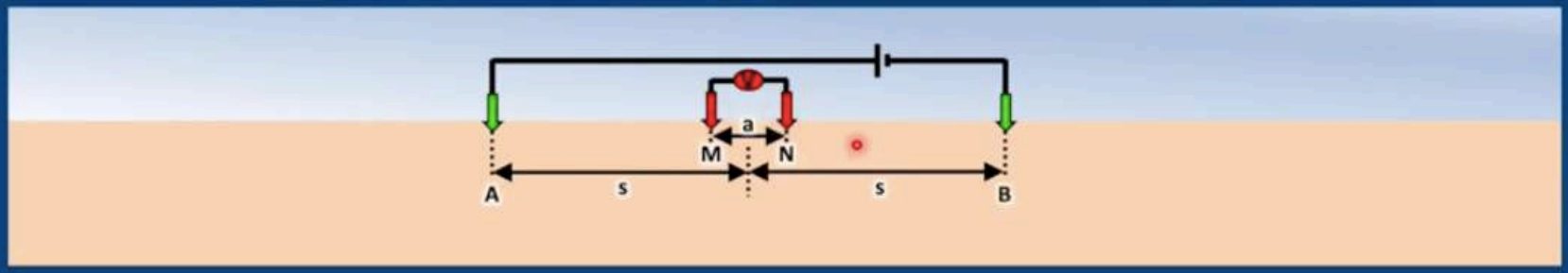
$$k = 2\pi a$$

Use the Schlumberger Array for groundwater exploration



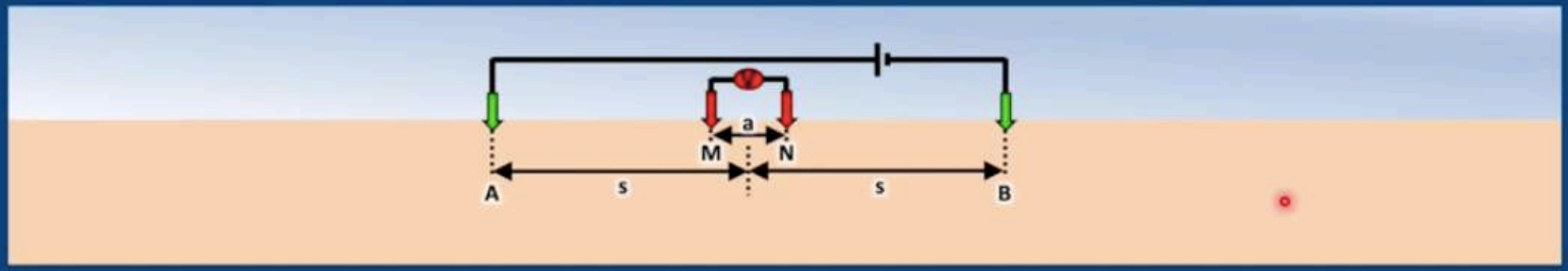
Use the Schlumberger Array for groundwater exploration

- **It is faster:** you only move 2 electrodes for most readings, not 4.
- **It is more accurate:** because MN and AB can be changed independently, lateral variations between the MN electrodes can be detected. These near-surface lateral variations could be misinterpreted in terms of depth variations in resistivity.

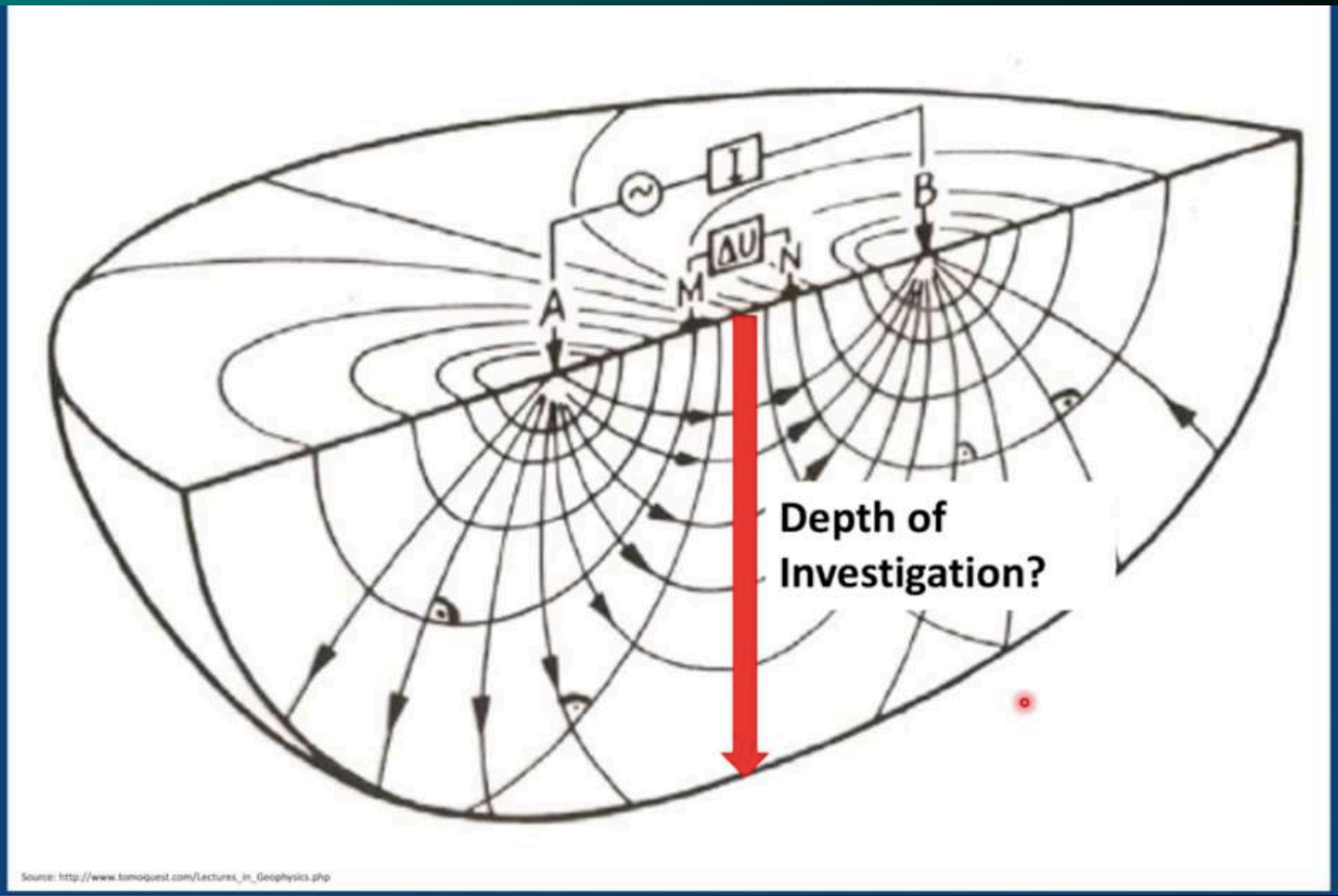


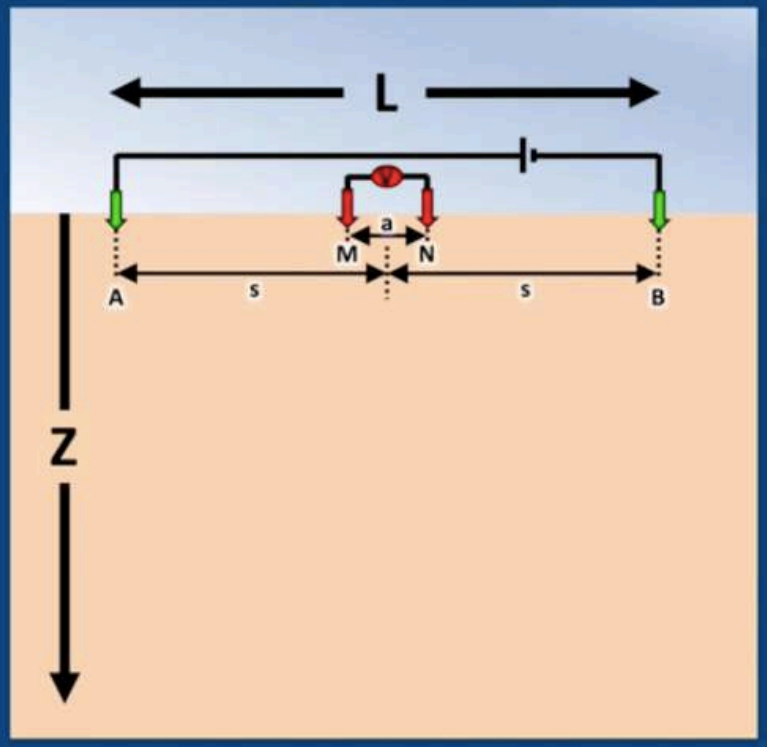
Use the Schlumberger Array for groundwater exploration

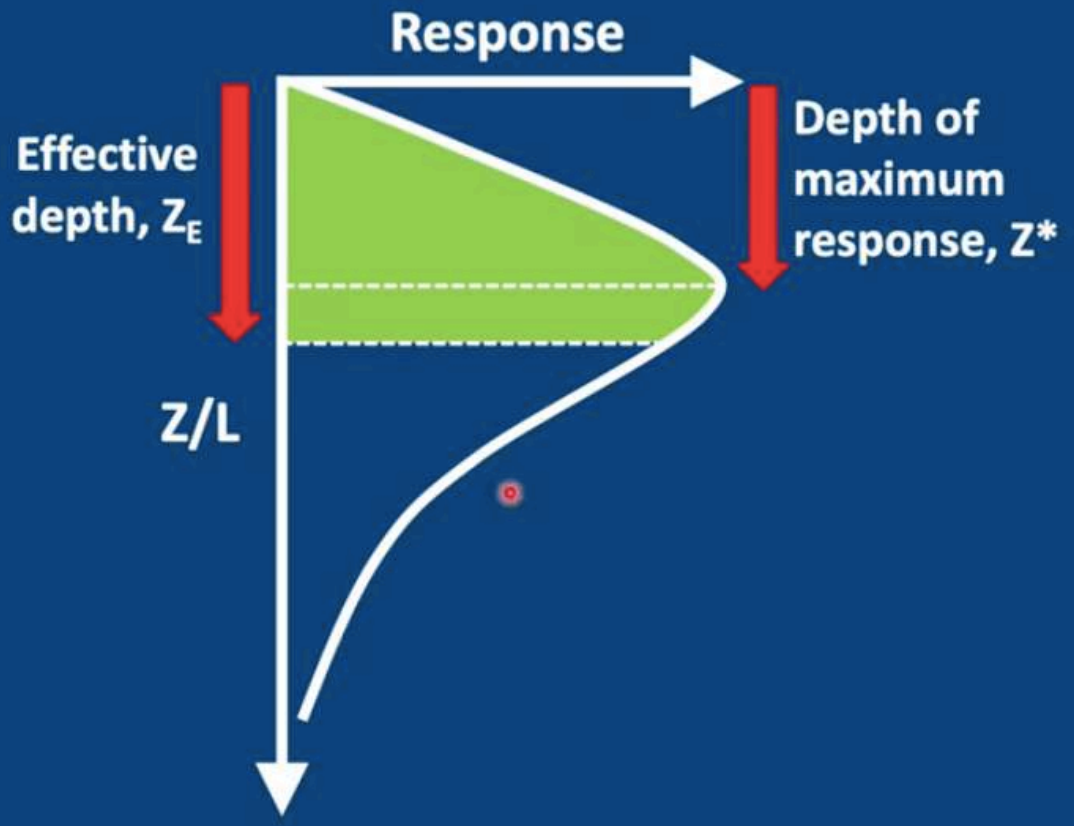
- **It is faster:** you only move 2 electrodes for most readings, not 4.
- **It is more accurate:** because MN and AB can be changed independently, lateral variations between the MN electrodes can be detected. These near-surface lateral variations could be misinterpreted in terms of depth variations in resistivity.
- **Deeper data:** it has a slightly greater depth of investigation.



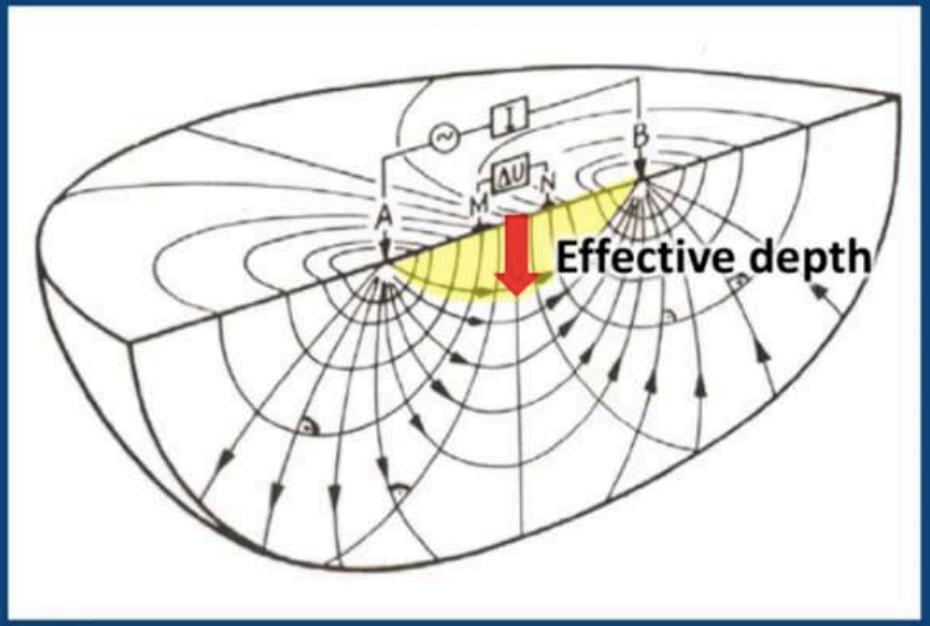
Depth of Investigation

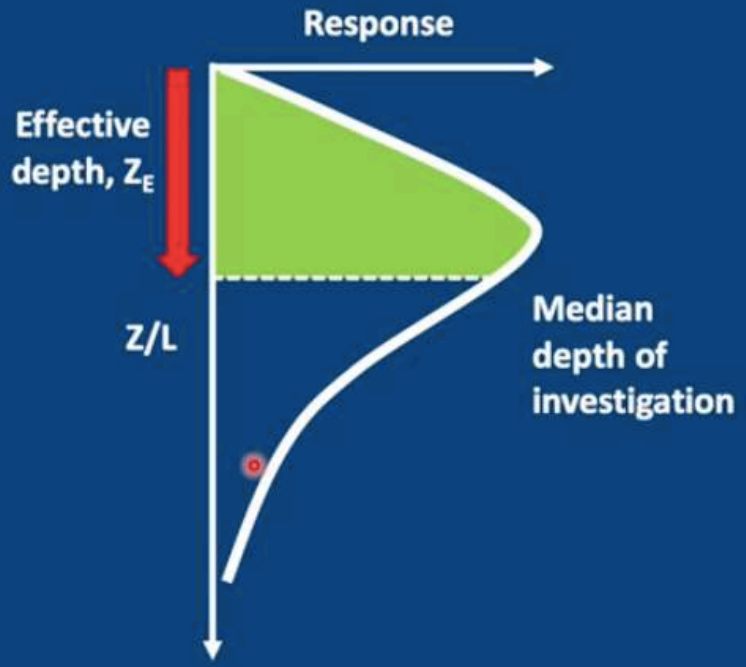

I
B
ΔU
M
N
A
Depth of
Investigation?
Source: http://www.tomoquest.com/Lectures_in_Geophysics.php





Adapted from: Szalai,Sándor et al., 2009; *Depth of Investigation and Vertical Resolution of Surface Geoelectric Arrays* Journal of Environmental and Engineering Geophysics(2009),14(1):15; http://dx.doi.org/10.2113/JEEG14.1.15

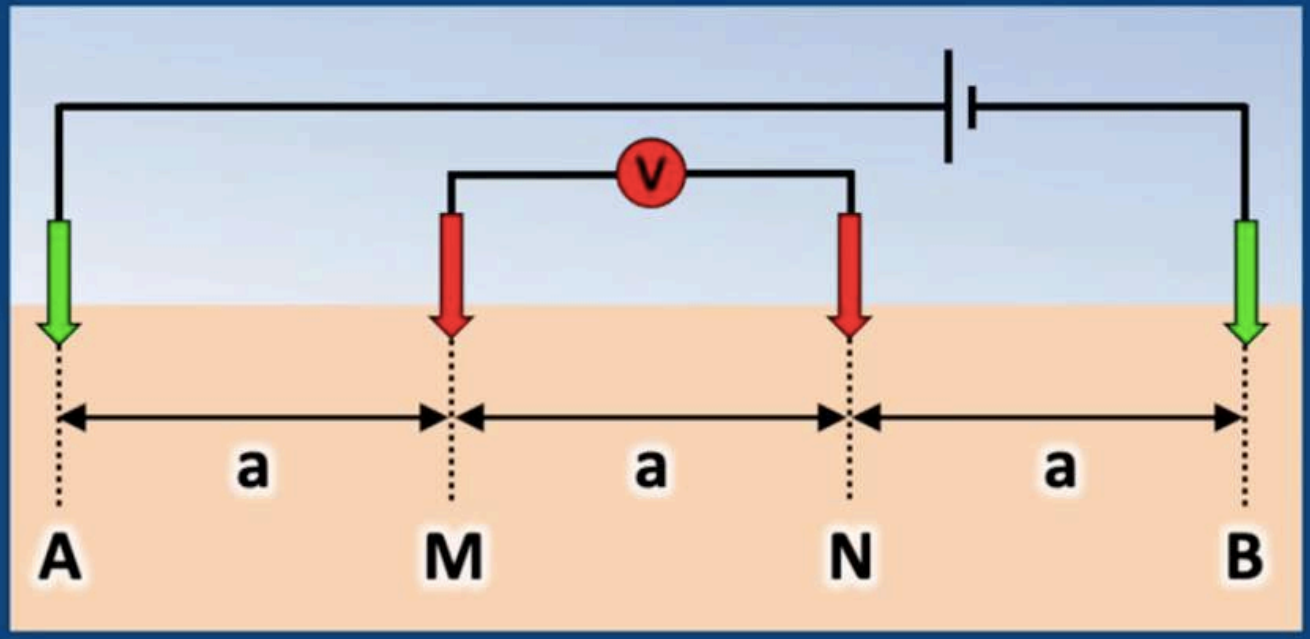




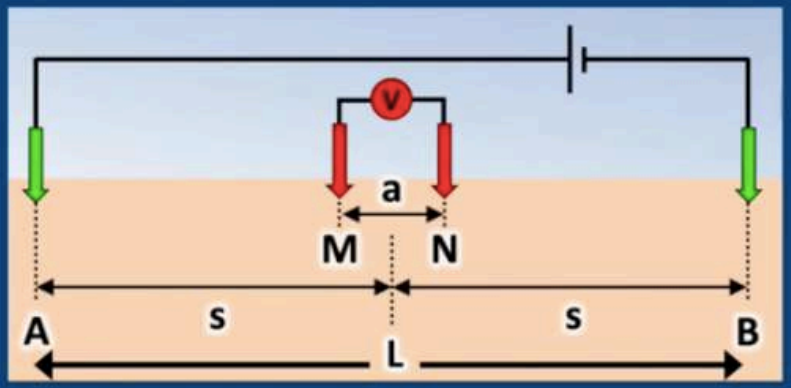
EFFECTIVE DEPTH (Z_E) = the interval within the subsurface of a homogeneous earth that contributes 50% of the measurement. Edwards (1977)

Effective Depth (Z_E) – Wenner Array

$$\frac{Z_E}{a} = 0.519$$

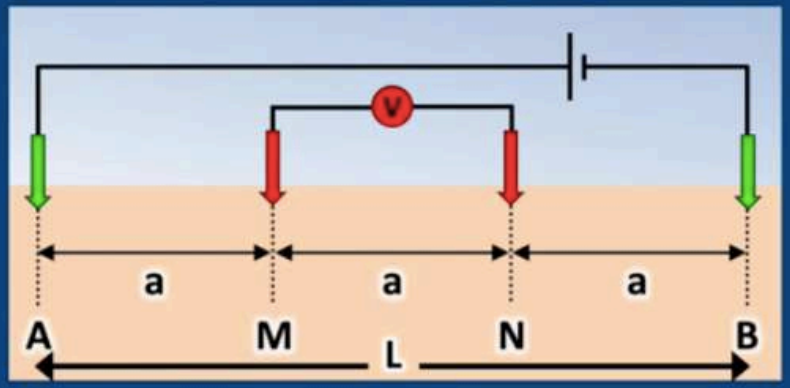


Schlumberger Array



$$\frac{Z_E}{L} = 0.190$$

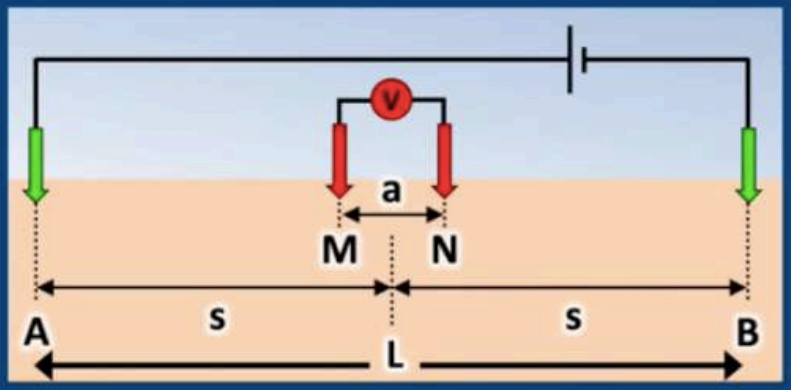
Wenner Array



$$\frac{Z_E}{a} = 0.519$$

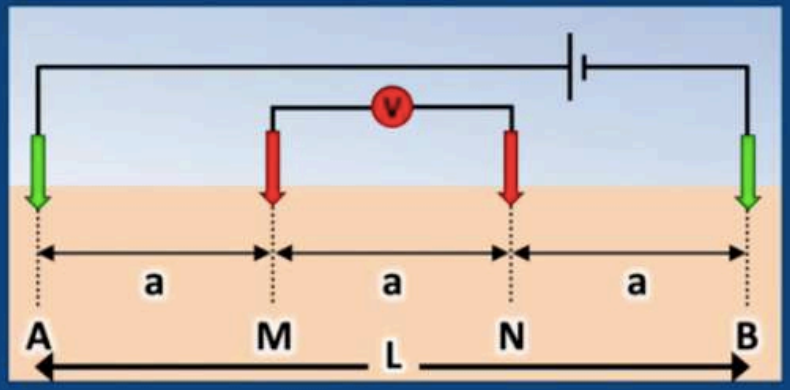
$$\frac{Z_E}{L} = \frac{Z_E}{a * 3} = \frac{0.519}{3} = 0.173$$

Schlumberger Array



$$\frac{Z_E}{L} = 0.190$$

Wenner Array



$$\frac{Z_E}{a} = 0.519$$

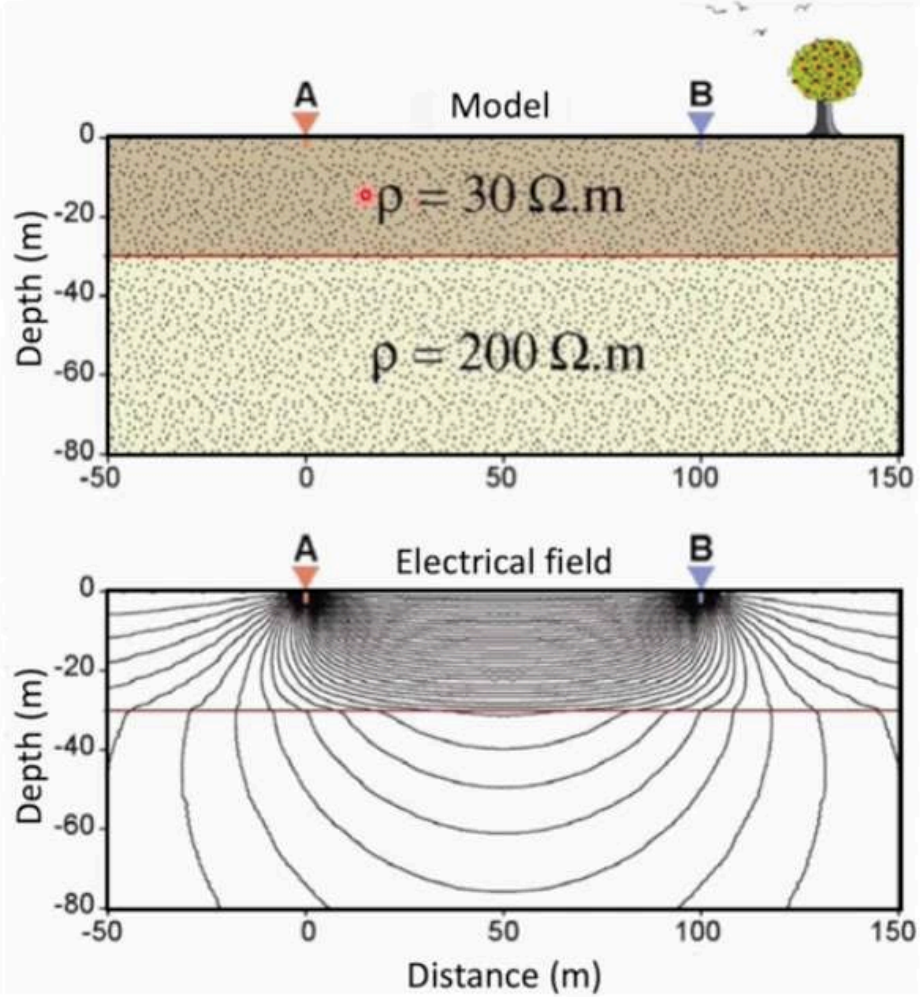
$$\frac{Z_E}{L} = \frac{Z_E}{a * 3} = \frac{0.519}{3} = 0.173$$

e.g. AB = 300 m,

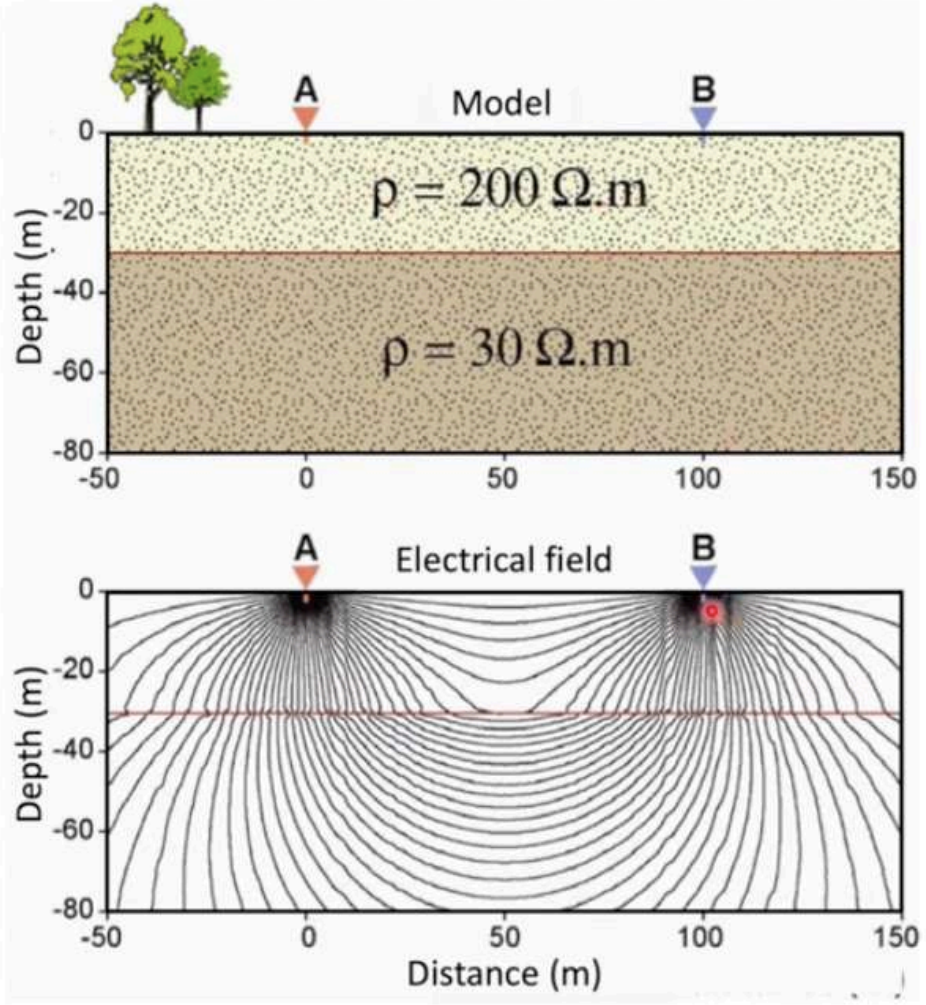
Z_E Schlumberger = 300 * 0.190 = 57 m

Z_E Wenner = 300 * 0.173 = 52 m

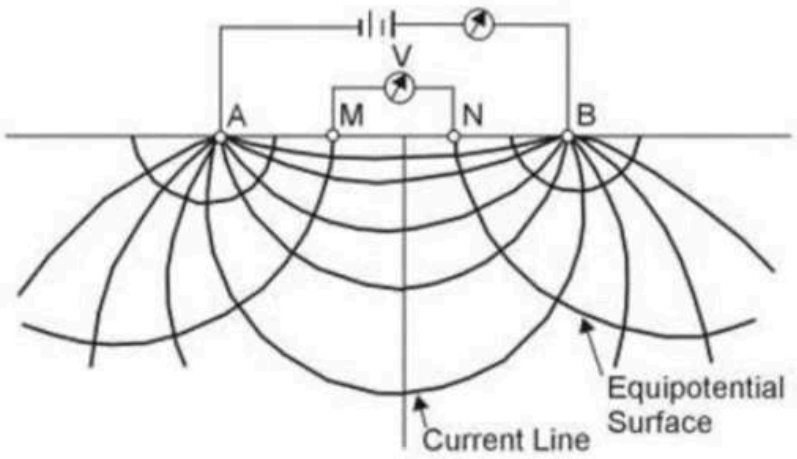
Current Flow Lines



Current Flow Lines



Rule of Thumb:
Depth of investigation = 1/3 of AB Spacing



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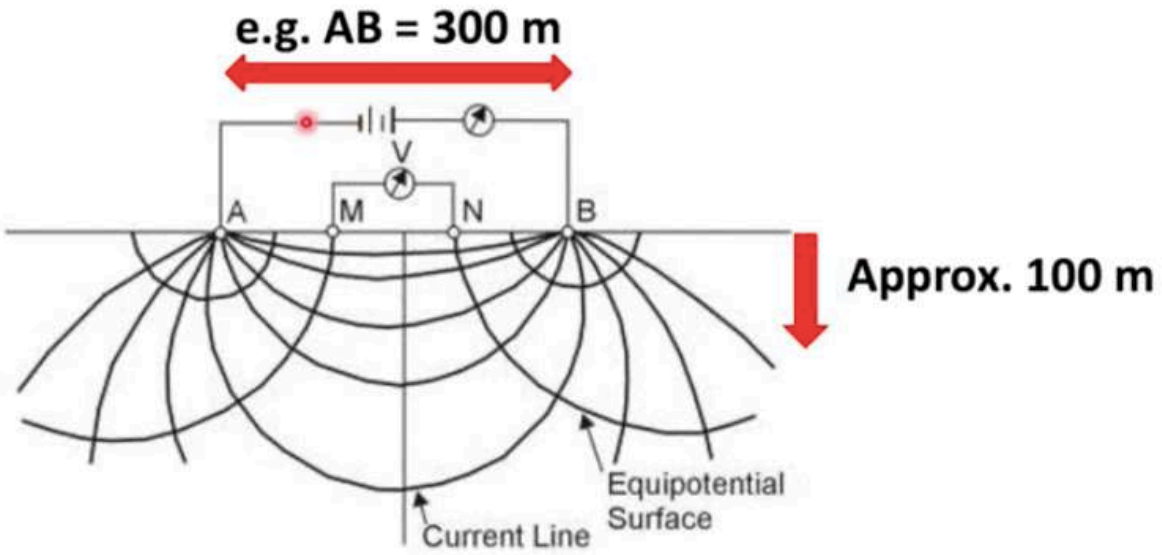
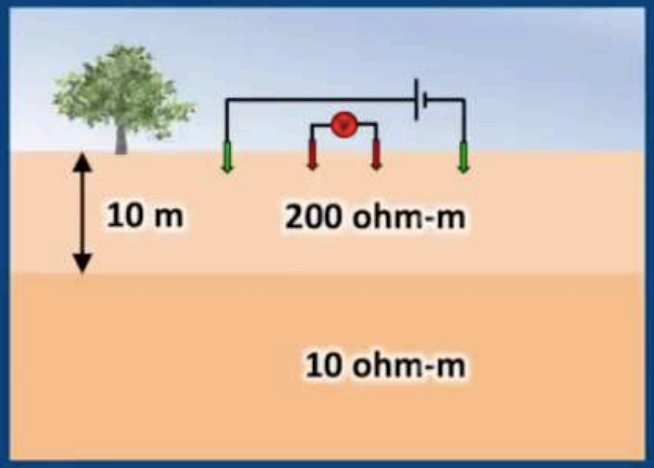


2-Layer Apparent Resistivity Curves: Case 1



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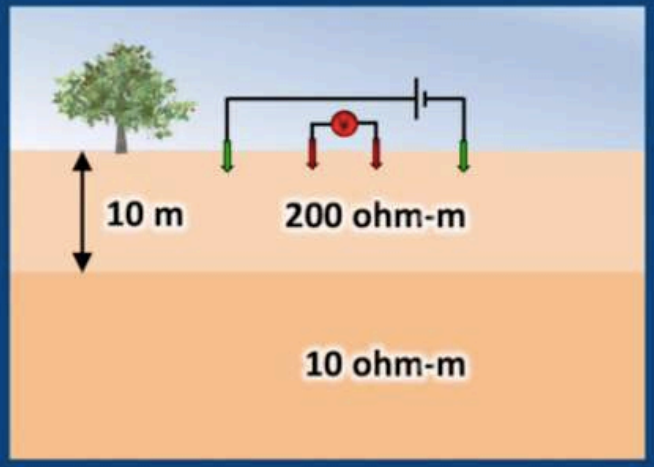
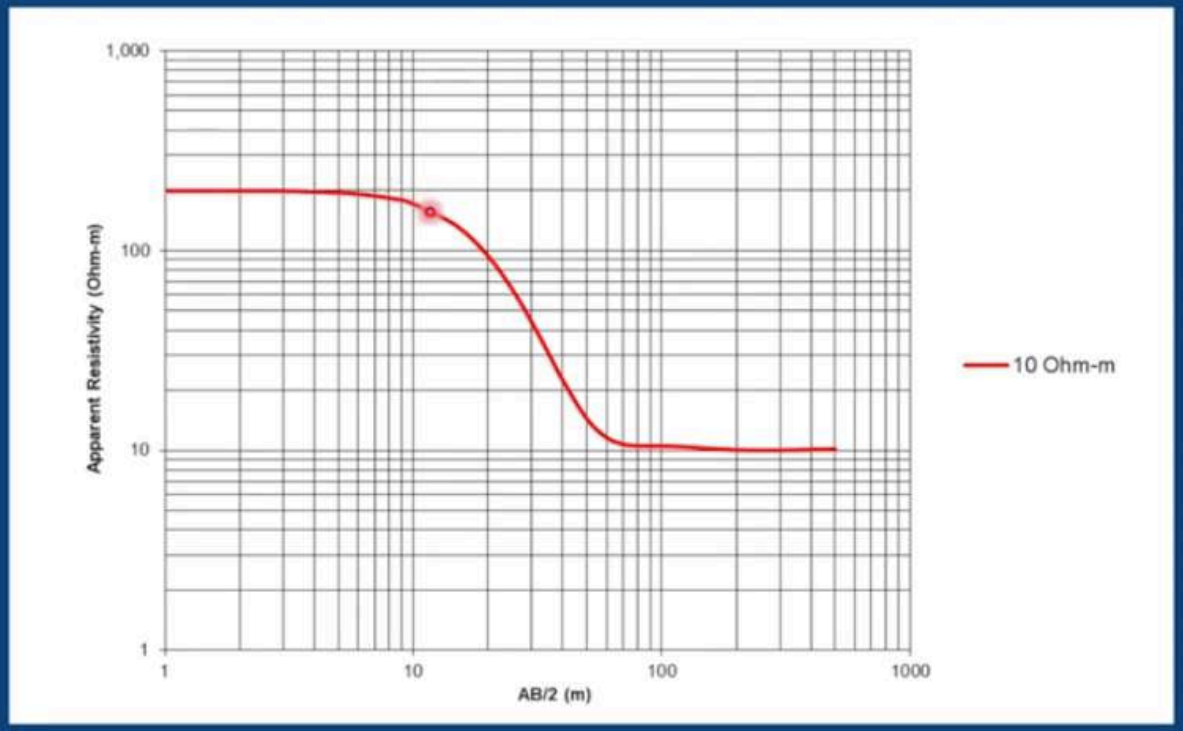
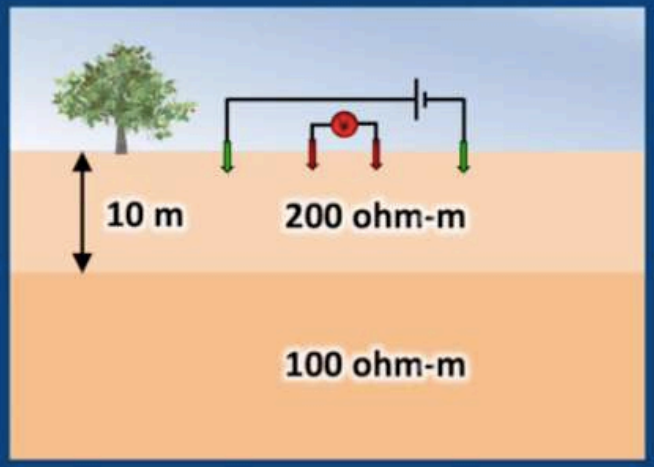
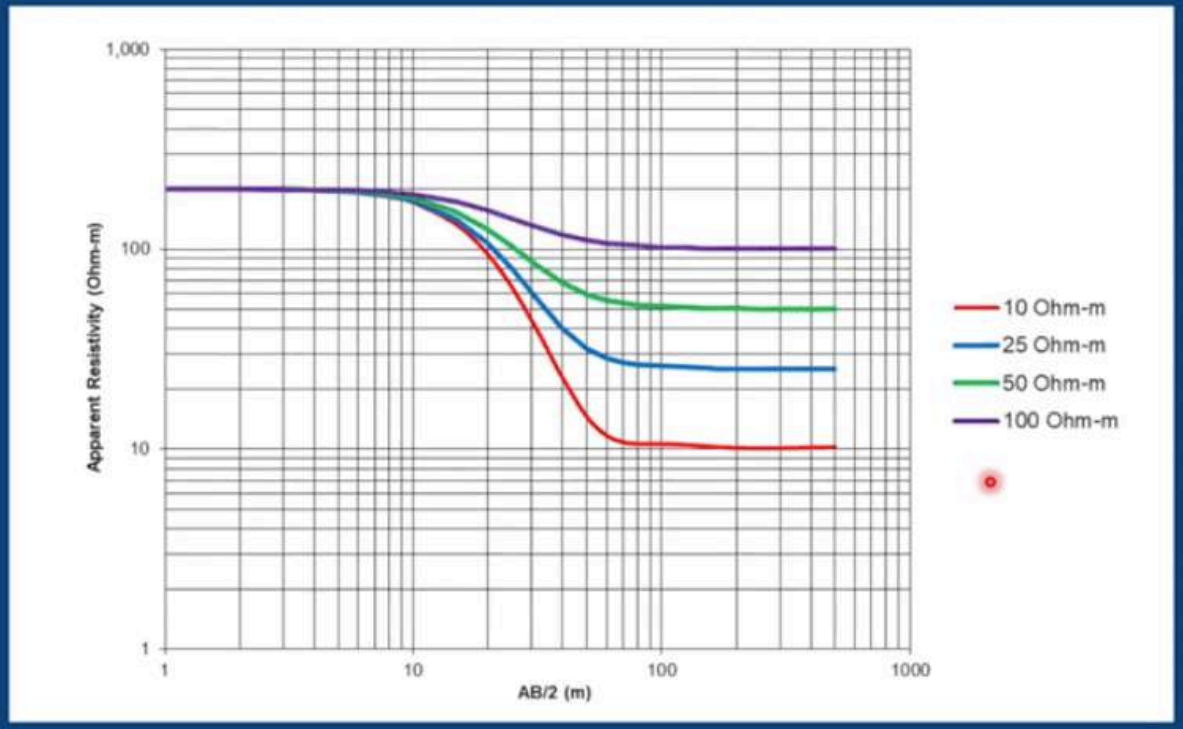


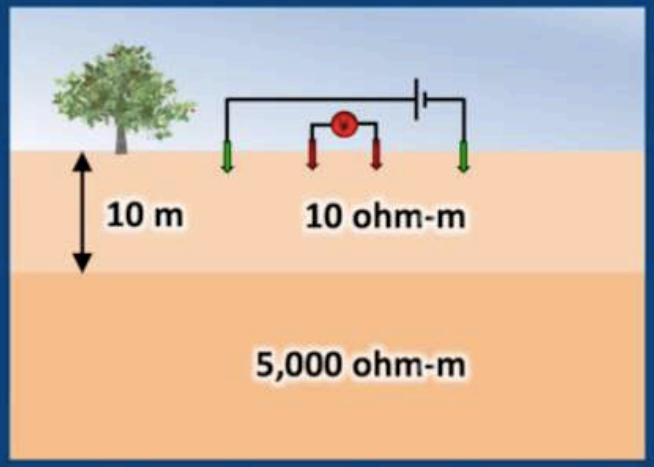


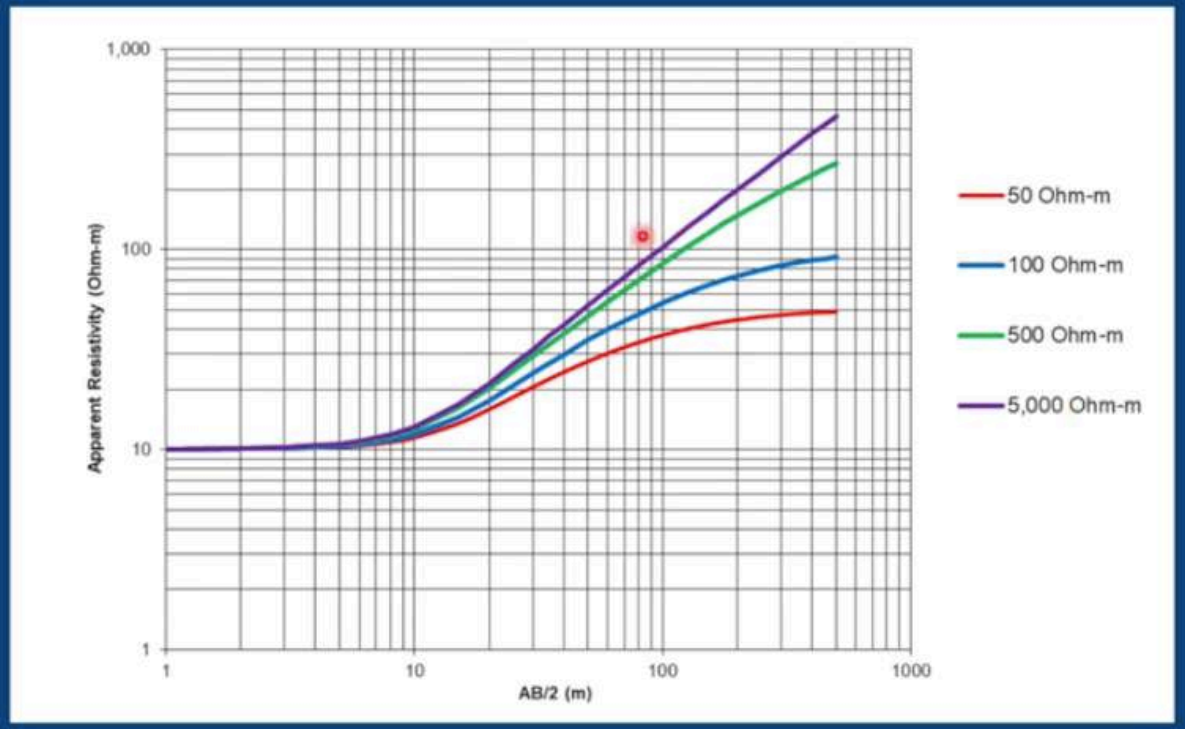
2-Layer Apparent Resistivity Curves: Case 1



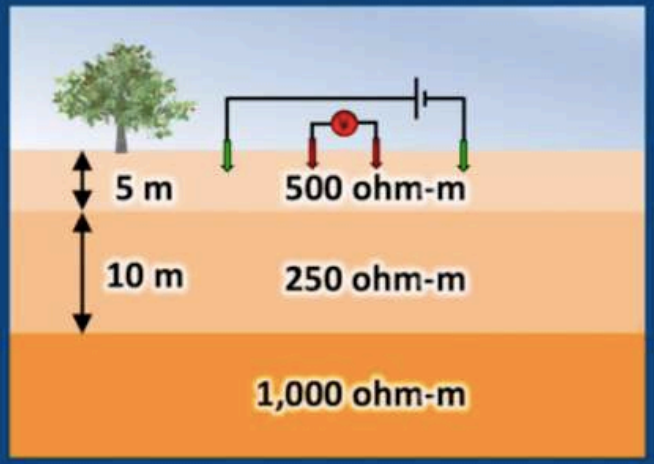


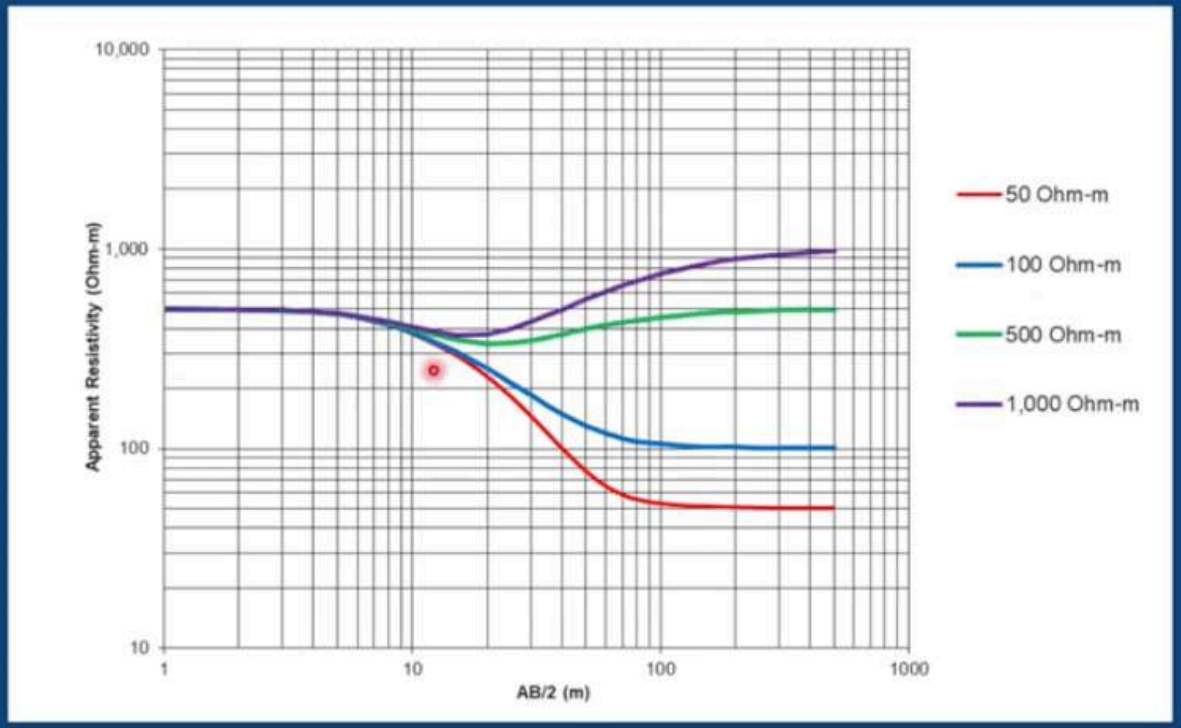
2-Layer Apparent Resistivity Curves: Case 2



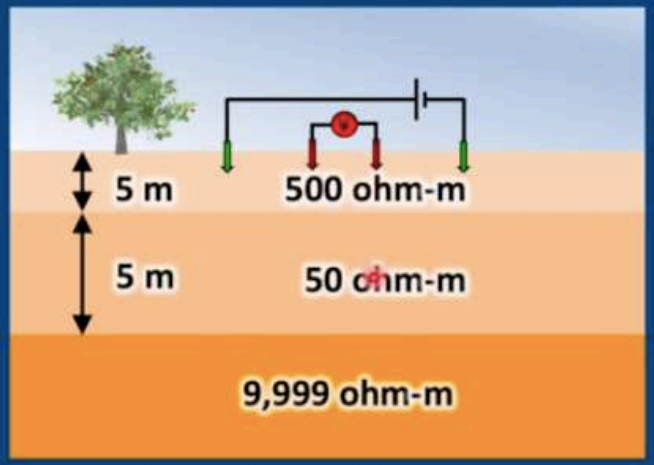


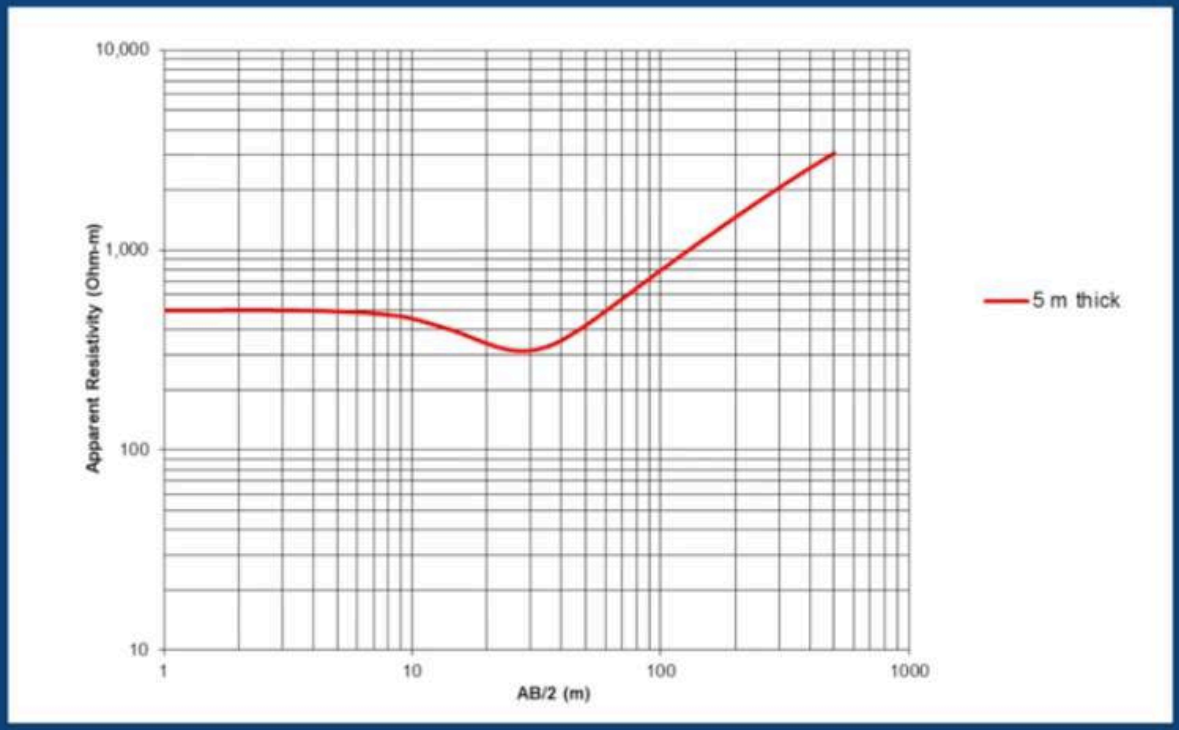
3-Layer Apparent Resistivity Curves: Case 3



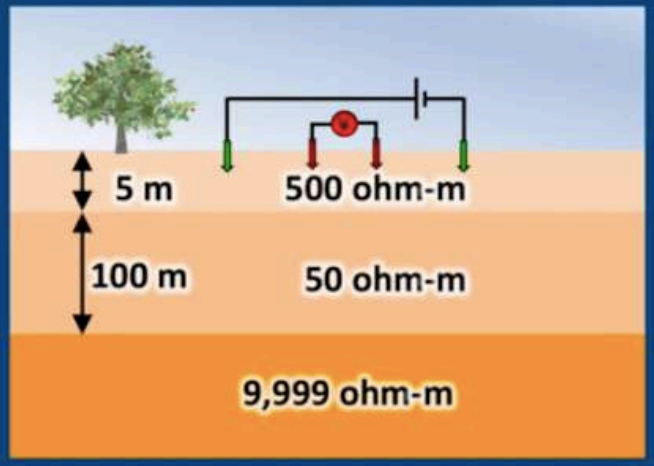


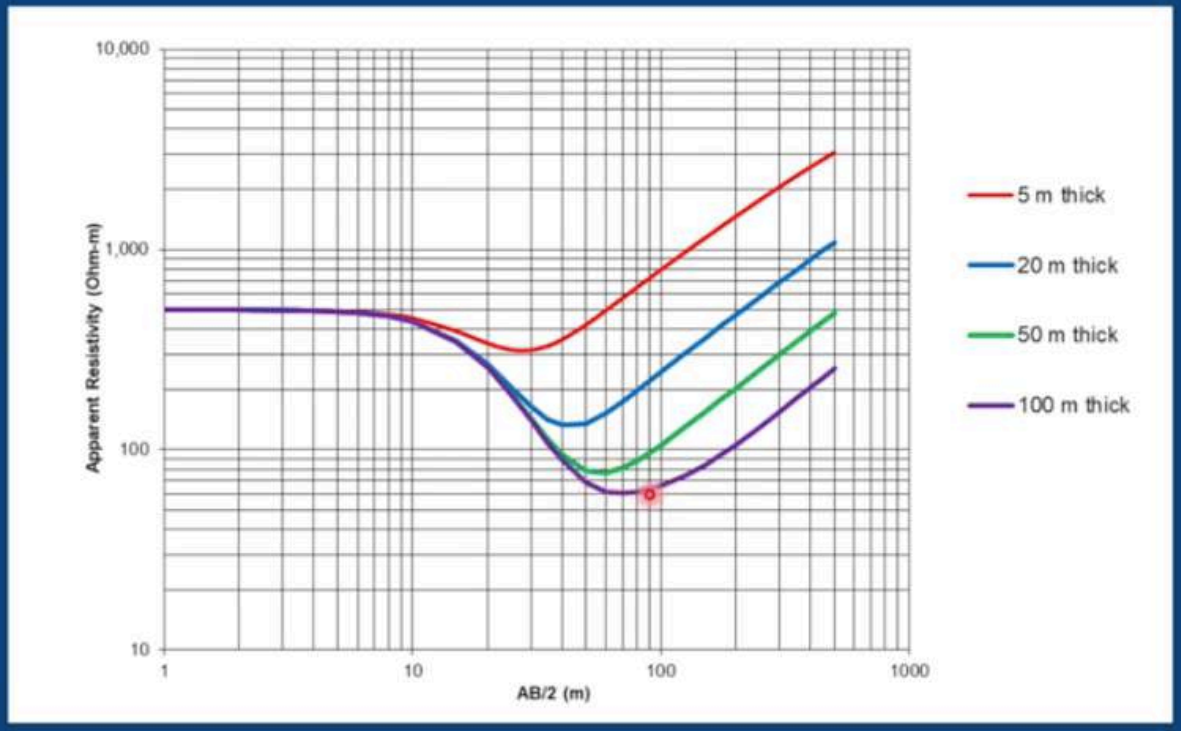
3-Layer Apparent Resistivity Curves: Case 4

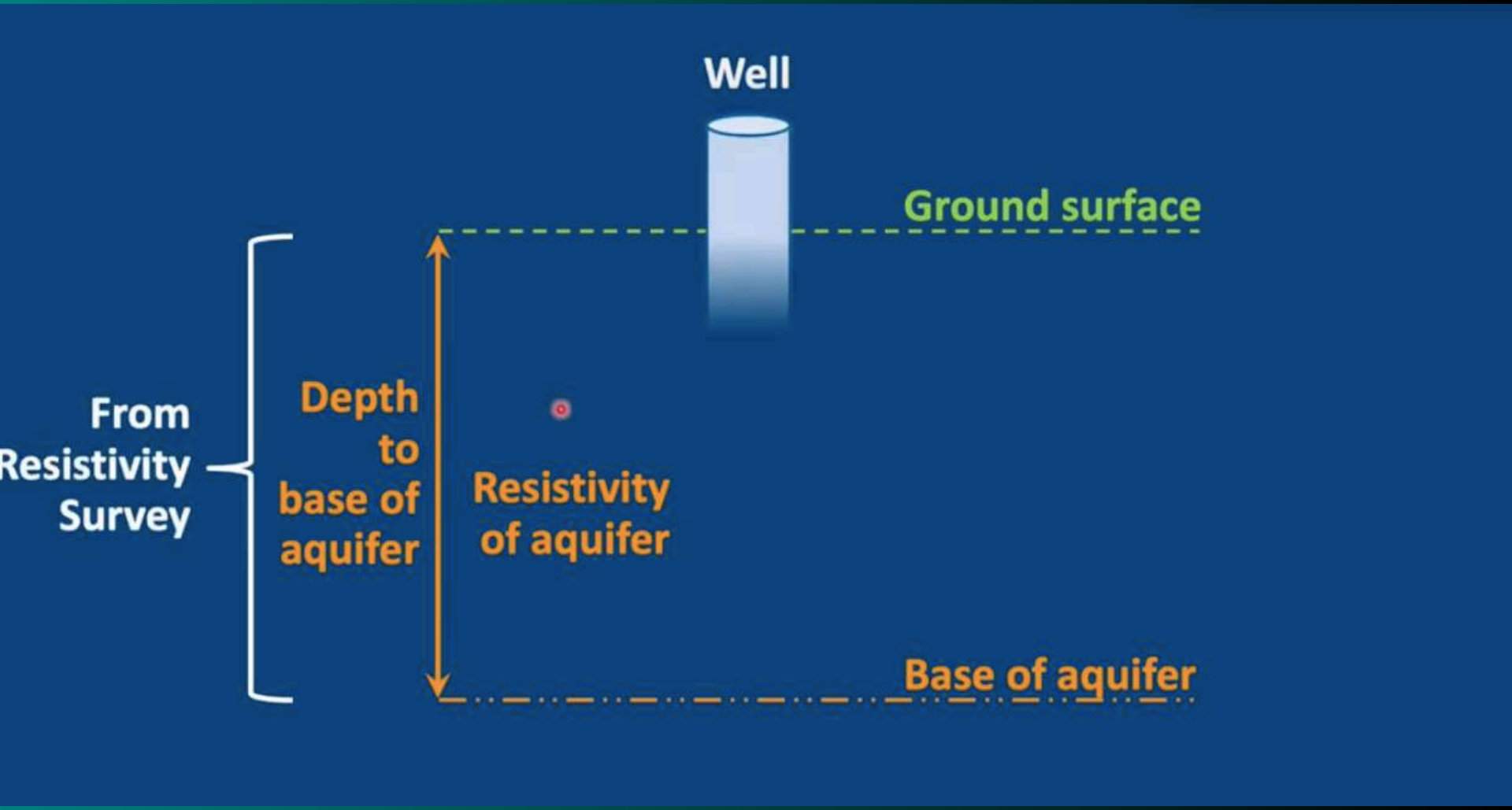


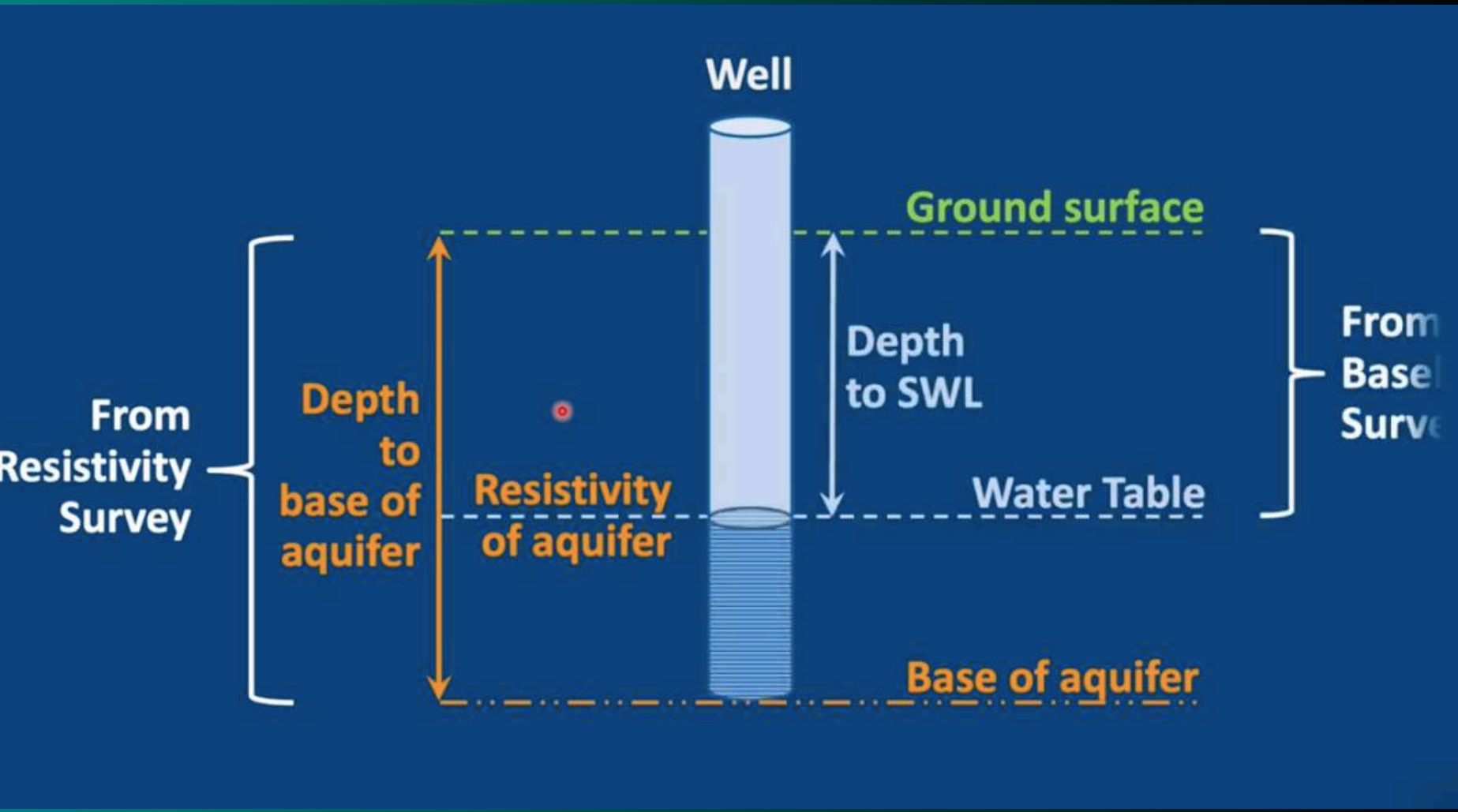


3-Layer Apparent Resistivity Curves: Case 4



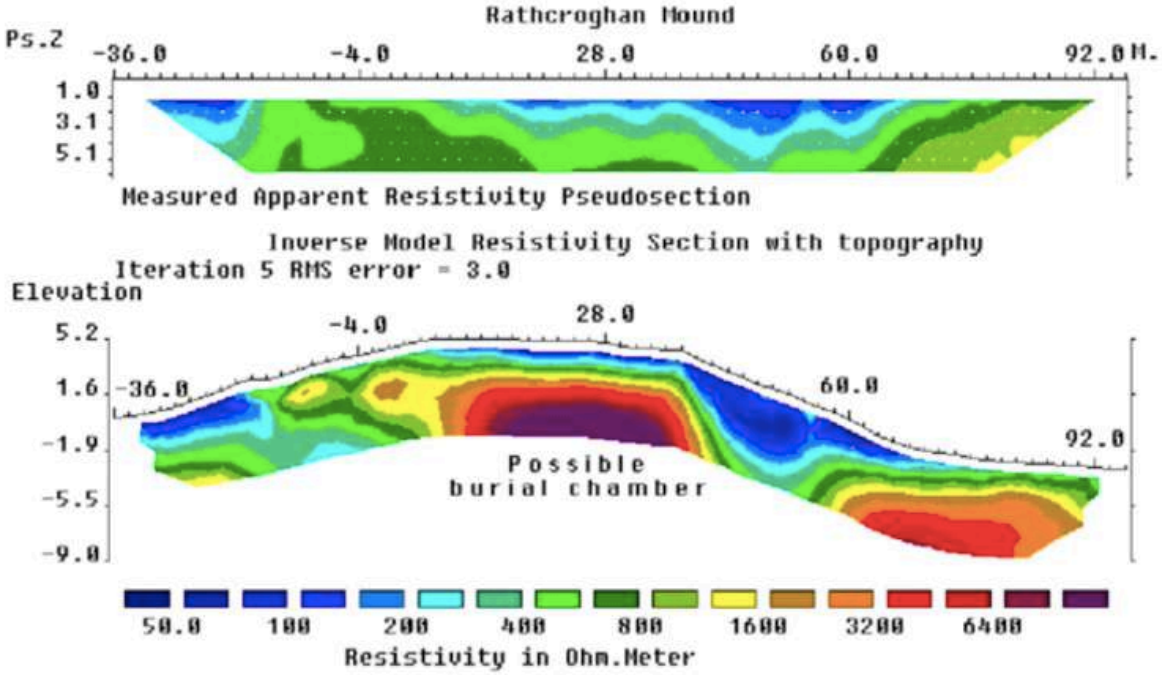



Well
Ground surface
From Resistivity Survey
Depth to base of aquifer
Resistivity of aquifer
Base of aquifer


Well
Ground surface
Depth to SWL
Water Table
From Base Surve
From Resistivity Survey
Depth to base of aquifer
Resistivity of aquifer
Base of aquifer

Interpretation Software

2D Inversion: Res2DInv GeoTomo Software



Survey is expensive, slow, complicated...
only for special projects like new Salang tunnel, Afghanistan

Client : A client
Project : A project
Province : A province
Date : 01/01/2012
Field Operator : ABC
Interpreted by : DEF

Village/Town : A town
Sounding Number : S-24
Coordinates East :
Coordinates North :
GPS Datum : WGS84
Azimuth : 180

A town : S-24

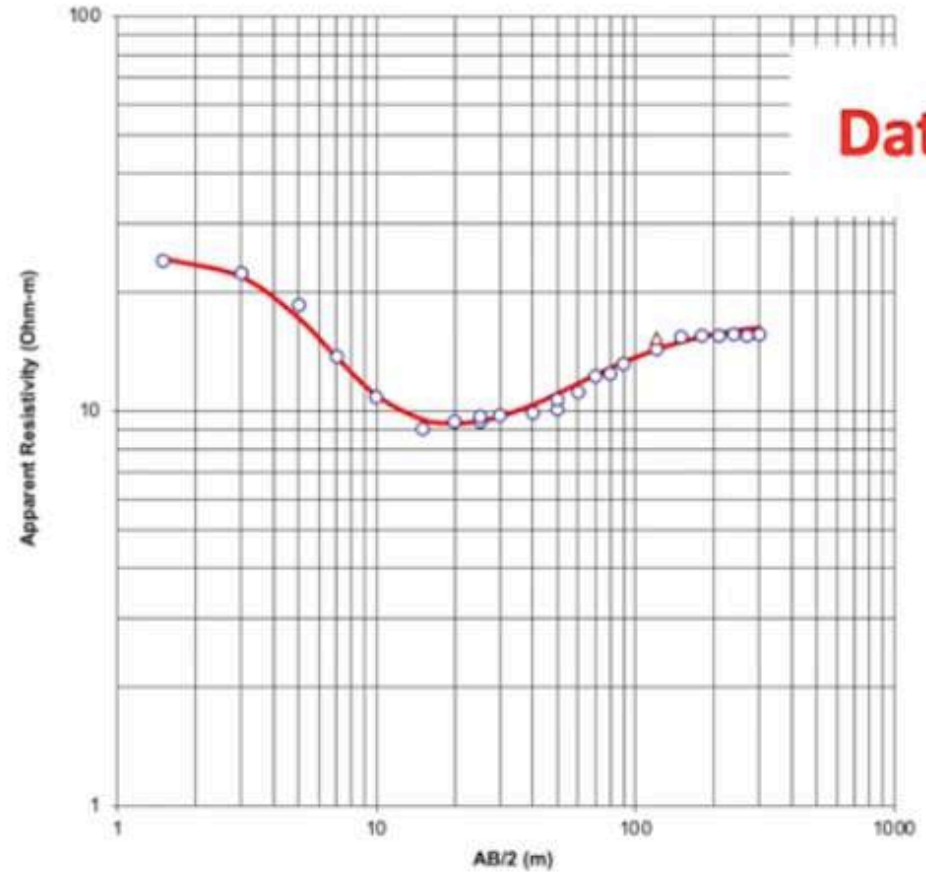
GeoVES 1.5
MS Excel based modelling of Vertical Electrical Soundings in the Schlumberger Array using Gosh linear filters

Sensitivity Analysis | Remove Error Bars

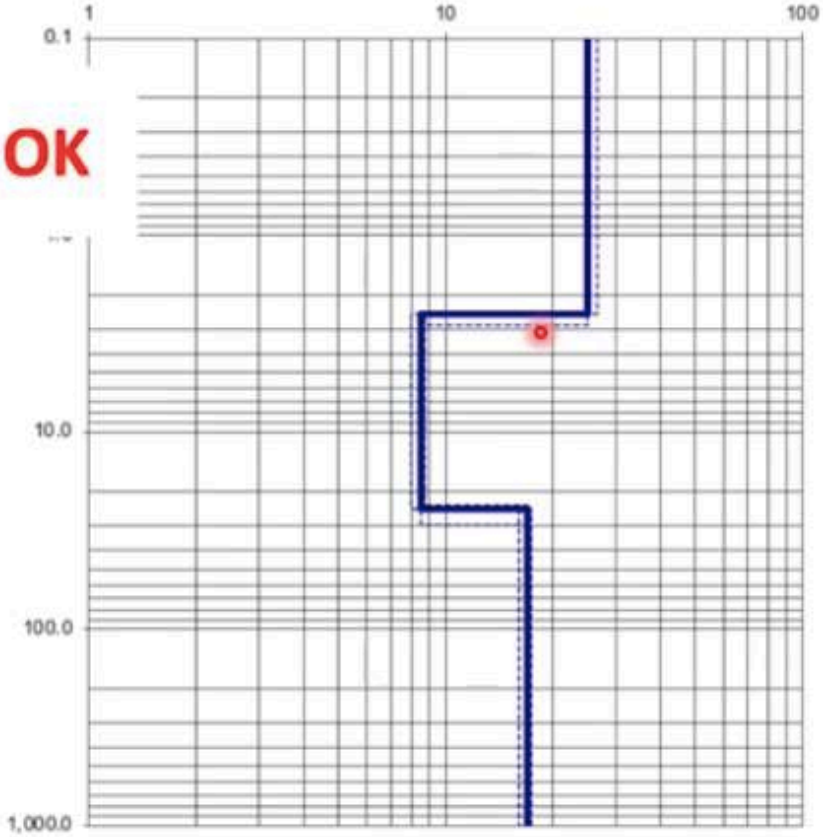
Geoelectrical Model

RMS Error : 0

Layer Number	1	2	3	4	5	6	7	8
Resistvity (Ohm-m)	25	9	17					
Thickness (m)	2.5	22.0						
Depth (m)	2.5	24.5						



Data OK



Client :
Project :
Province :
Date : 23/05/2019
Field Operator :
Interpreted by :

Village/Town : High School
Sounding Number : VES-2
Coordinates East :
Coordinates North :
GPS Datum : ?
Azimuth : ?

VES-2

GeoVES 1.5
MS Excel based modelling of Vertical Electrical Soundings
in the Schlumberger Array using Gosh linear filters

Geoelectrical Model

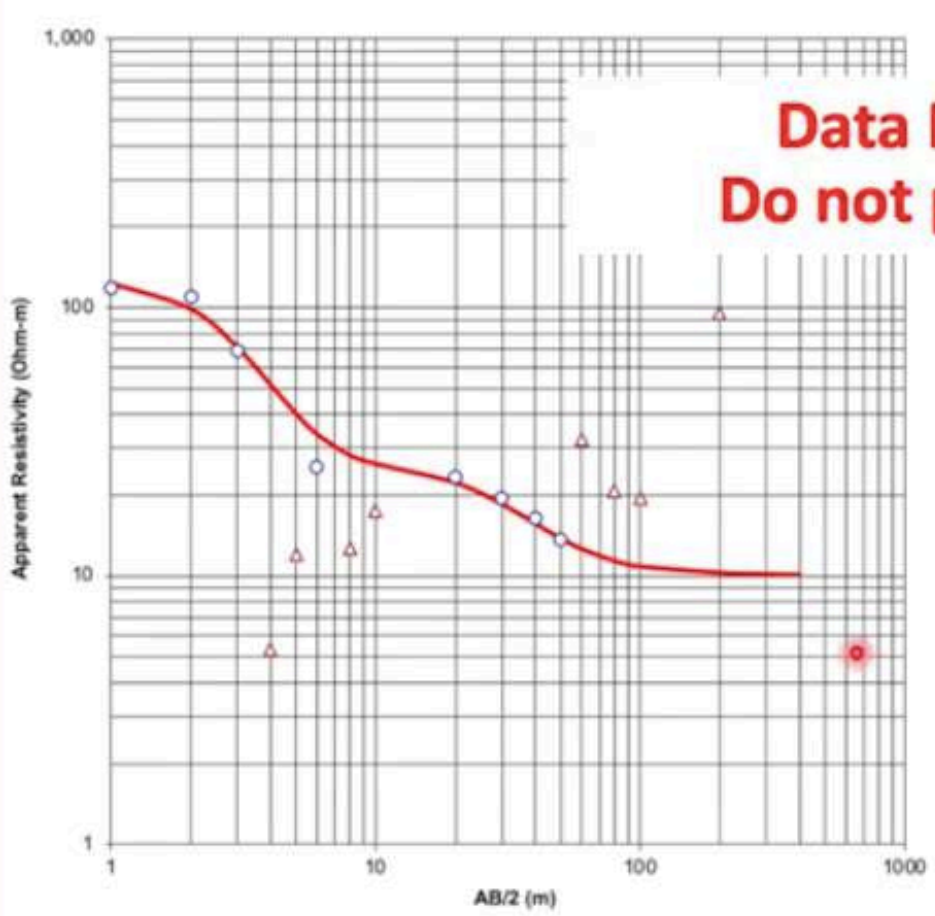
RMS Error : 4

Layer Number	1	2	3	4	5	6	7	8
Resistvity (Ohm-m)	130	25	10					
Thickness (m)	1.4	15.0						
Depth (m)	1.4	16.4						

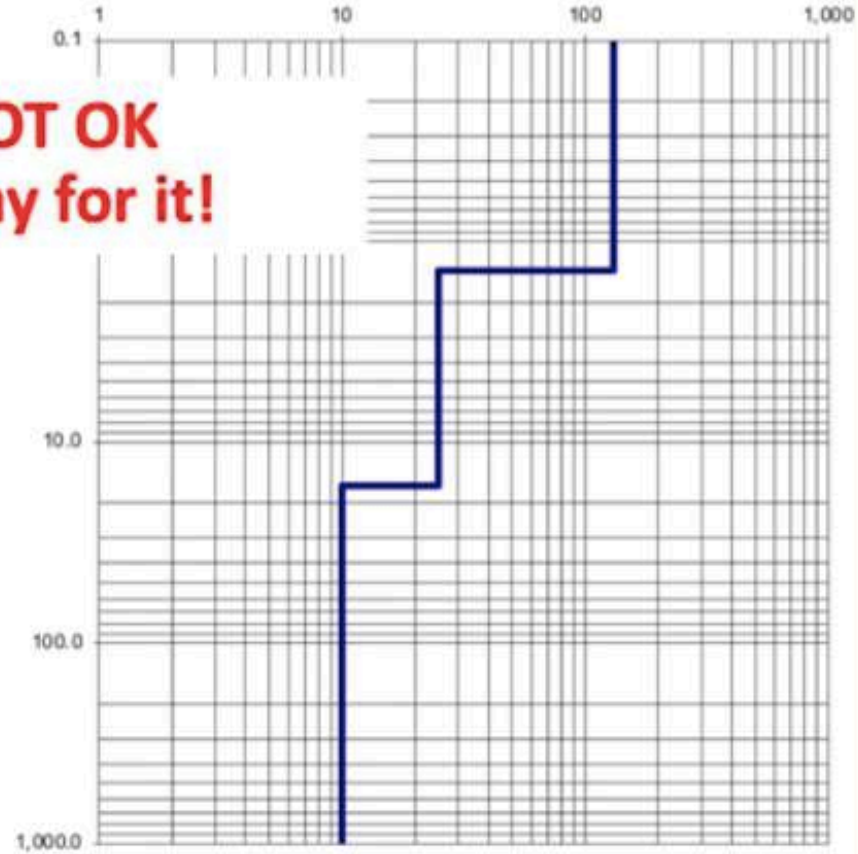
Sensitivity Analysis

Remove Error Bars

Geoelectrical Model



Data NOT OK
Do not pay for it!



Thank You