

Resistivity Surveys

1. Starting with the general equation for resistivity as a function of electrode node spacing:

$$\rho = \frac{2\pi\Delta V}{I} \frac{1}{\left(\frac{1}{r_A} - \frac{1}{r_B}\right) - \left(\frac{1}{R_A} - \frac{1}{R_B}\right)} \quad (1)$$

show that the equation for the apparent resistivity profile for a Wenner array is [10 pts]:

$$\rho_a = 2\pi a \frac{\Delta V}{I} \quad (2)$$

- (a) Its useful to start by re-arranging this equation to get a common denominator.

$$\frac{1}{\left(\frac{1}{r_A} - \frac{1}{r_B}\right) - \left(\frac{1}{R_A} - \frac{1}{R_B}\right)} \quad (3)$$

First, deal with the sets of fractions in the denominator:

$$\frac{1}{\left(\frac{r_B - r_A}{r_A r_B}\right) - \left(\frac{R_B - R_A}{R_A R_B}\right)} \quad (4)$$

Second, combine the two terms in the denominator into one term:

$$\frac{1}{\left(\frac{R_A R_B (r_B - r_A) - r_A r_B (R_B - R_A)}{r_A r_B R_A R_B}\right)} \quad (5)$$

Third, simplify:

$$\frac{r_A r_B R_A R_B}{R_A R_B (r_B - r_A) - r_A r_B (R_B - R_A)} \quad (6)$$

- (b) For the Wenner array, all electrode spacings are equal to a . Therefore,

$$\begin{array}{ll} r_A = a & R_A = 2a \\ r_B = 2a & R_B = a \end{array}$$

Substituting into Equation 6 given above:

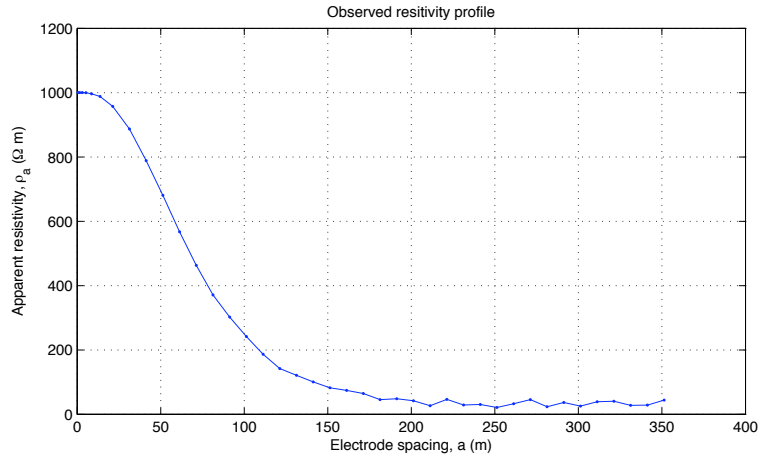
$$\frac{4a^4}{2a^2(a) - 2a^2(-a)} = \frac{4a^4}{2a^3 + 2a^3} = \frac{4a^4}{4a^3} = a \quad (7)$$

Therefore,

$$\rho_a = \left(\frac{2\pi\Delta V}{I}\right) a = 2\pi a \frac{\Delta V}{I} \quad (8)$$

2. A VES survey using a Wenner array is conducted to determine the aquifer depth in a remote shale-filled basin. The file *hw6input.dat* has the electrode spacing, a , in column one (meters) and the measured potential drop, ΔV , in column 2 (Volts). The measurements were all made with an input current of 1.5 Amps.

- (a) Calculate and plot the observed apparent resistivity, ρ_a , versus the electrode spacing, a . [4 pts]



- (b) Based on the observed profile, determine the resistivity of the two layers? [4 pts]

$$\rho_1 = 1000 \Omega\text{-m}$$

$$\rho_2 = 10 \Omega\text{-m}$$

- (c) Based on the values for ρ_1 and ρ_2 , is it likely that the survey has penetrated the aquifer? Explain your answer? [2 pts]

The resistivity of the top layer is similar to that expected for shale, while the very low resistivity value of the second layer is less than what you'd expect for shale, so this could indicate that the survey does penetrate the aquifer.

- (d) Based on the electrode spacing used in the survey, estimate the maximum thickness of the top layer and explain how you arrive at this estimate. [2 pts]

Maximum spacing is 350 m. If 90% of the current needs to go through the layer, then the maximum thickness is something like 40–50 km.

- (e) The theoretical apparent resistivity profile for a two layer structure measured with a Wenner array is calculated using the following equations:

$$F = \sum_{n=1}^{\infty} k^n \left(\frac{1}{\sqrt{1 + 4n^2 z^2/a^2}} - \frac{1}{\sqrt{4 + 4n^2 z^2/a^2}} \right) \quad (9)$$

$$\rho_a = \rho_1(1 + 4F) \quad (10)$$

where $k = (\rho_2 - \rho_1)/(\rho_2 + \rho_1)$ is calculated based on the values of ρ_1 and ρ_2 determined above, a is the electrode spacing and z , is the unknown depth. The series summation converges after a small number of terms, $n \geq 4$, because $k < 1$.

Use these two equations to determine the thickness of the top layer, by trial-and-error comparison to the observed profile, and compare your best-fitting value to the value estimated above. Include a plot showing your best-fitting theoretical curve plotted on top of the observed profile. [8 pts]

Start the trial-and-error testing with a value of $z = 40$ m based on the maximum depth estimate above. The best-fitting curve is found for $z = 50$ m.

