Table 3.2-3: Recovery Test Data

| $t'$, min | $t$, min | $t/t'$ | $s'$, m |
|---|---|---|---|
| 1.0 | 241 | 241 | 0.89 |
| 2.0 | 242 | 121 | 0.81 |
| 3.0 | 243 | 81 | 0.76 |
| 5 | 245 | 49 | 0.68 |
| 7 | 247 | 35 | 0.64 |
| 10 | 250 | 25 | 0.56 |
| 15 | 255 | 17 | 0.49 |
| 20 | 260 | 13 | 0.55 |
| 30 | 270 | 9 | 0.38 |
| 40 | 280 | 7 | 0.34 |
| 60 | 300 | 5 | 0.28 |
| 80 | 320 | 4 | 0.24 |
| 100 | 340 | 3.4 | 0.21 |
| 140 | 380 | 2.7 | 0.17 |
| 180 | 420 | 2.3 | 0.14 |

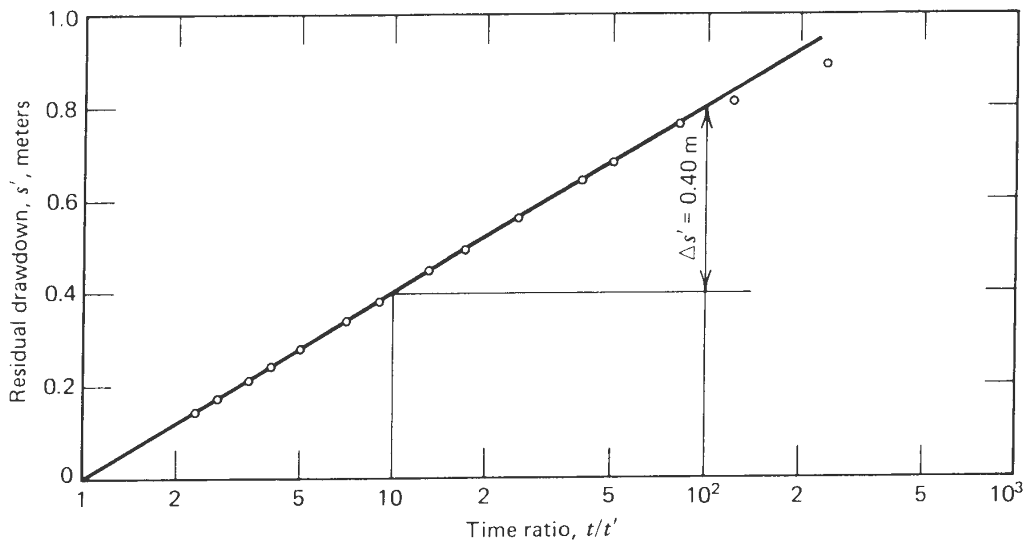


Figure 3.2-4: Recovery Test Method for solution of the Nonequilibrium

## 3.3 Characteristic Well Losses and Specific Capacity

### a. Characteristic Well Losses

The drawdown at a well includes not only that of the logarithmic drawdown curve at the well face, but also a well loss caused by flow through the well screen and flow inside of the well to the pump intake. Because the well loss is associated with turbulent flow, it may be indicated as being proportional to an nth power of discharge, as $Q^n$, where n is a constant greater than one. Jacob suggested that a value n=2 might be reasonably by assumed, but Rorabaugh pointed out that n can deviate significantly from 2. An exact value for n cannot be stated because of difference of individual wells; detailed investigations of flows inside and outside of wells show that considerable variations occur from assumed flow distributions.

Taking accounted of the well loss, the total drawdown $s_w$ at the well may be written for the steady-state confined case

$$s_w = \frac{Q}{2\pi T} In \frac{r_0}{r_w} + CQ^n \qquad \text{(Eq. 3-17)}$$

where $C$ is a constant governed by radius, construction, and condition of the well. For simplicity let

$$B = \frac{In(r_0/r_w)}{2\pi T} \qquad \text{(Eq. 3-18)}$$

so that

$$s_w = BQ + CQ^n \qquad \text{(Eq. 3-19)}$$

Therefore, as shown in Figure 3.3-1, the total drawdown $s_w$ consists of the formation loss BQ and the well loss $CQ^n$.

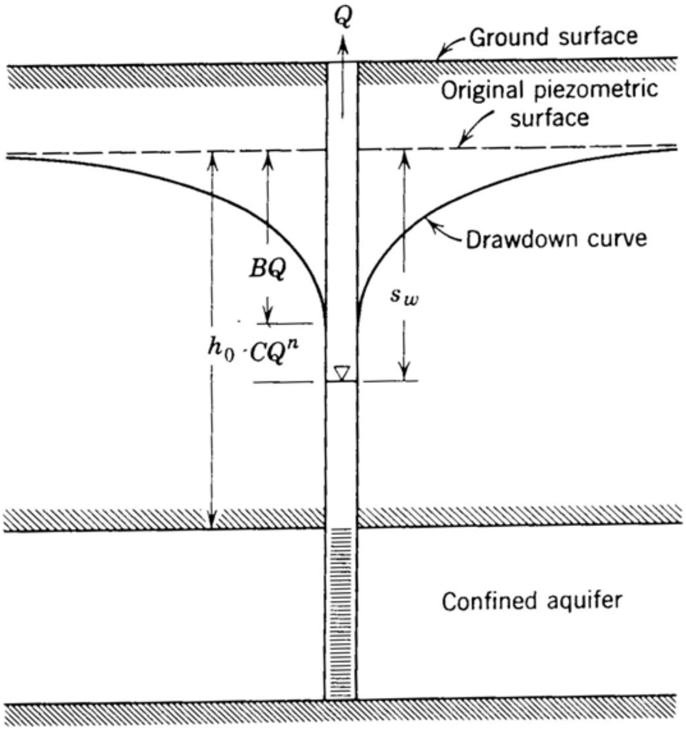


Figure 3.3-1: Relation of Well Loss $CQ^n$ to Drawdown for a Well Penetration a Confined Aquifer

Consideration of Eq. 3-19 provides a useful insight to the relation between well discharge and well radius. It can be seen that Q varies inversely with $\ln(r_0/r_w)$, if all other variables are held constant. This shows that discharge varies only a small amount with well radius. For example, doubling a well radius increases the discharge only 10 percent. When the comparison is extended to include well loss, however, the effect is significant. Doubling the well radius doubles the intake area, reduces entrance velocities to almost half, and (if n=2) cuts the frictional loss to less than a third. For axial flow within the well, the area increases four times, reducing this loss an even greater extent.

It is apparent that the well loss can be a substantial fraction of total drawdown when pumping rates are large, as illustrated by Figure 3.3-2. When proper design and development of new wells, well losses can be minimized. Clogging or deterioration of well screens can increase well losses in old wells. Based on field experience Walton suggested criteria for the well loss coefficient C in Eq. 3-19. These are presented in Table 3.3-1 to aid in evaluating the condition of a well.

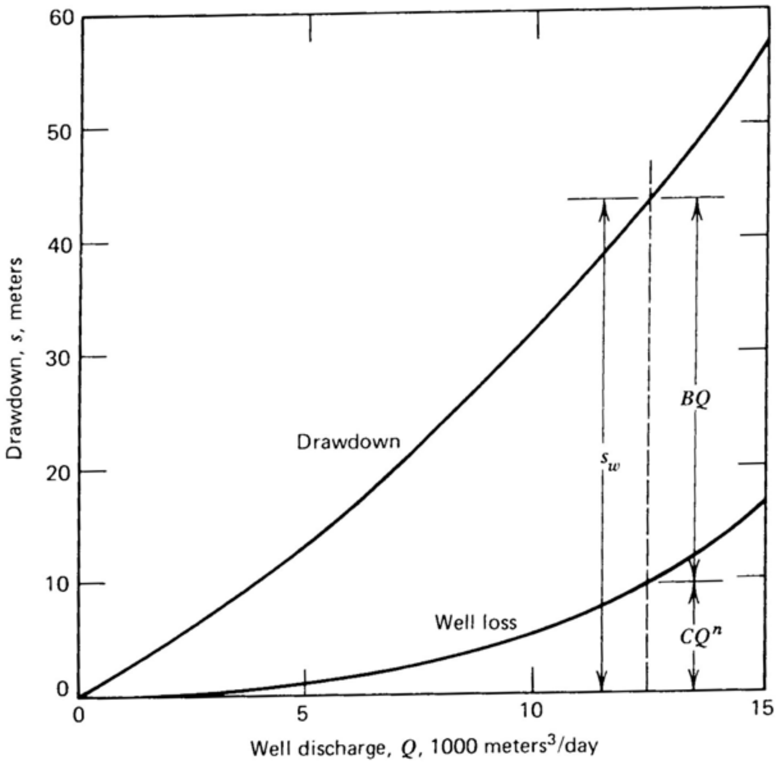


Figure 3.3-2: Variation of Total Drawdown $s_w$, Aquifer Loss BQ, and Well Loss $CQ^n$ with Well Discharge

Table 3.3-1: Relation of Well Loss Coefficient to Well Condition

| Well Loss Coefficient C, $min^2/m^5$ | Well Condition |
|---|---|
| < 0.5 | Properly designed and developed |
| 0.5 to 1.0 | Mild deterioration or clogging |
| 1.0 to 4.0 | Severe deterioration or clogging |
| > 4.0 | Difficult to restore well to original capacity |

### b. Evaluation of Well Loss

To evaluate well loss a step-drawdown pumping test is required. This consists of pumping a well initially at a low rate until the drawdown within the well essentially stabilizes. The discharge is then increased through a successive series of steps as shown by time-drawdown data in Figure 3.3-3(a). Incremental drawdown Δs for each step are determined from approximately equal time intervals. The individual drawdown curves should be extrapolated with a slope proportional to the discharge in order to measure the incremental drawdowns.

From Eq. 3-19and letting n=2,

$$\frac{s_w}{Q} = B + CQ \qquad \text{(Eq. 3-20)}$$

Therefore, by plotting $s_w$/Q curves CQ (see Figure 3.3-3(b)) and fitting a straight line through the points, the well loss coefficient C is given by the slope of the line and the formation loss coefficient B by the intercept Q=0.

Rorabaugh presented a modification of this graphic analysis to determine n in cases where it deviates significantly from 2.

### c. Specific Capacity

If discharge is divided by drawdown in a pumping well, the specific capacity of the well is obtained. This is a measure of the productivity of a well; clearly, the larger the specific capacity, the better the well. Starting from the approximate nonequilibrium equation and including the well loss,

$$s_w = \frac{2.30Q}{4\pi T} \log \frac{2.25Tt}{{r_w}^2 S} + CQ^n \qquad \text{(Eq. 3-21)}$$

so that the specific capacity

$$\frac{Q}{s_w} = \frac{1}{(2.30/4\pi T)\log\left(2.25Tt/{r_w}^2 S\right) + CQ^{n-1}} \qquad \text{(Eq. 3-22)}$$

This indicates that the specific capacity decreases with Q and t; the well data plotted in Figure 3.3-4 demonstrate this effect. For a given discharge a well is often assumed to have a constant specific capacity. Although this is not strictly correct, it can be seen that the change with time is minor.

Any significant decline in the specific capacity of a well can be attributed either to a reduction in transmissivity due to a lowering of the groundwater level in an unconfined aquifer or to an increase in well loss associated with clogging or deterioration of the well screen.

If a pumping well is assumed to be 100 percent efficient ($CQ^n$=0), then the specific capacity from Eq. 3-22 can be presented in the graphic from of Figure 3.3-5. Here specific capacity at the end of one day of pumping is plotted as function of S, T, and a well diameter of 30 cm. This graph provides a convenient means for estimating T from existing pumping wells; any error in S has a small effect on T.

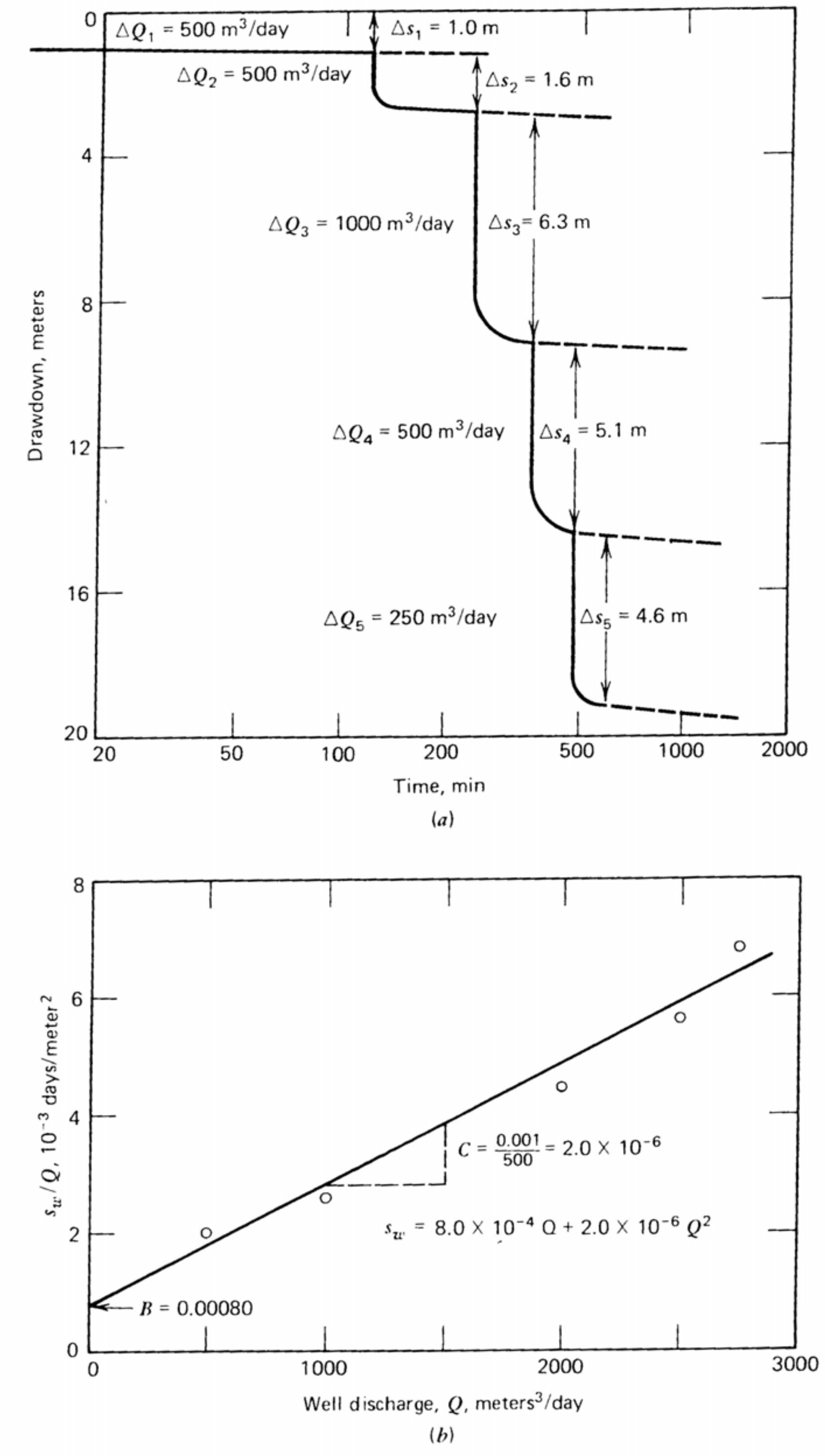


Figure 3.3-3: Step-drawdown Pumping Test Analysis to Evaluate Well Loss. (a) Time-drawdown data from Step-drawdown Test. (b) Determination of B and C from graph of $s_w/Q$ versus Q

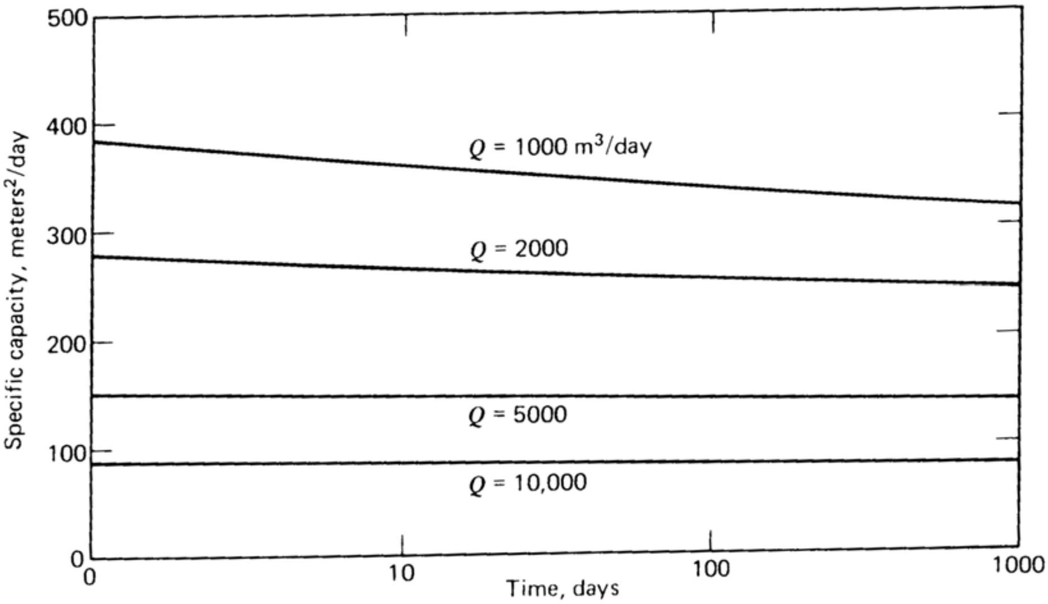


Figure 3.3-4: Variation in Specific Capacity of a Pumping Well with Discharge and Time

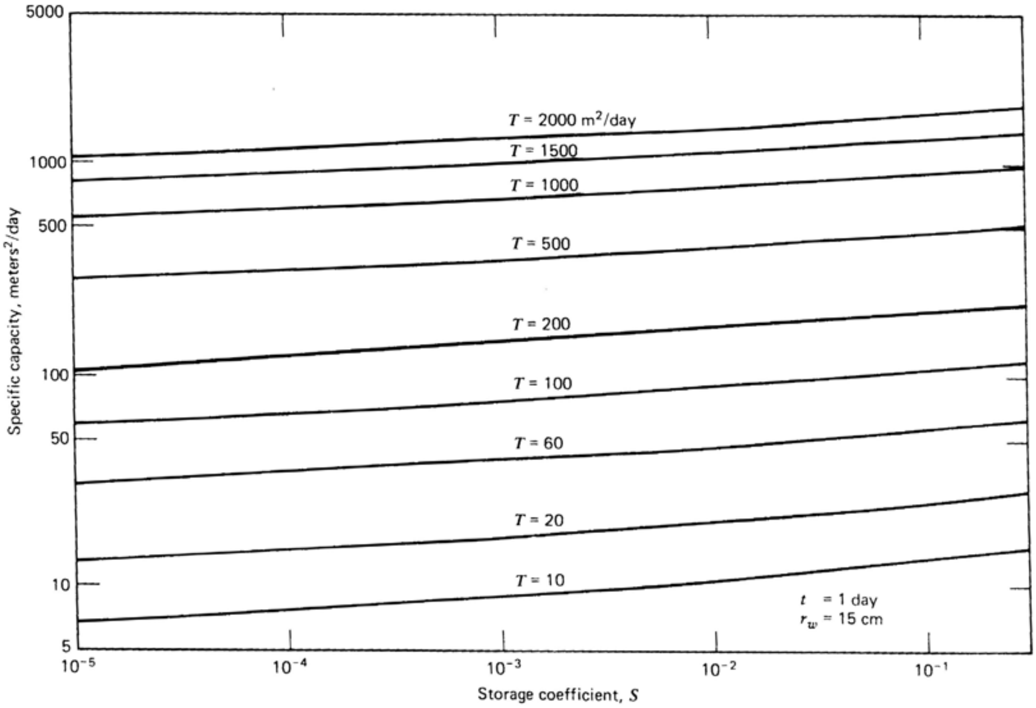


Figure 3.3-5: Graph Relation Specific Capacity to transmissivity and Storage Coefficient from the Nonequilibrium Equation

### d. Well Efficiency

Figure 3.3-5 yields a theoretical specific capacity (Q/BQ) for known values of S and T in an aquifer. This computed specific capacity, when compared with one measured in the field ($Q/s_w$), defines the approximate efficiency of a well. Thus, for a specified duration of pumping, the well efficiency $E_w$ is given as a percentage by

$$E_w = 100 \frac{Q/s_w}{Q/BQ} = 100 \frac{BQ}{s_w} \qquad \text{(Eq. 3-23)}$$

Another method for recognizing an inefficient well is to note its initial recovery rate when pumping is stooped. Where the well loss is large, this drawdown component recovers rapidly by discharge into the well from the surrounding aquifer. A rough rule of thumb for this purpose is; if a pump is shut off after 1 hour of pumping and 90 percent or more of the drawdown is recovered after 5 minutes, it can be concluded that the well is unacceptable inefficient.

# 4 Correlation of Well Drilling Results with Geophysical Survey

## a. T1: Busongo (Ves6 point)

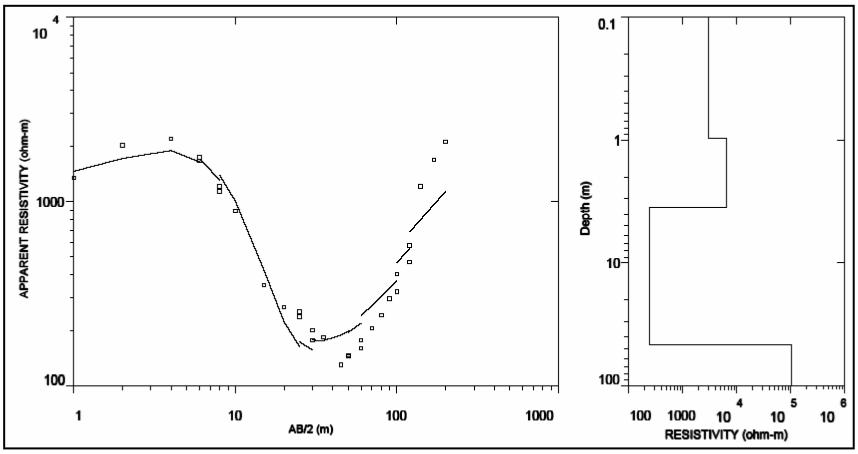


Figure 4-1: Result of Vertical Electric Sounding (T1: Busongo Village, Ves6 point)

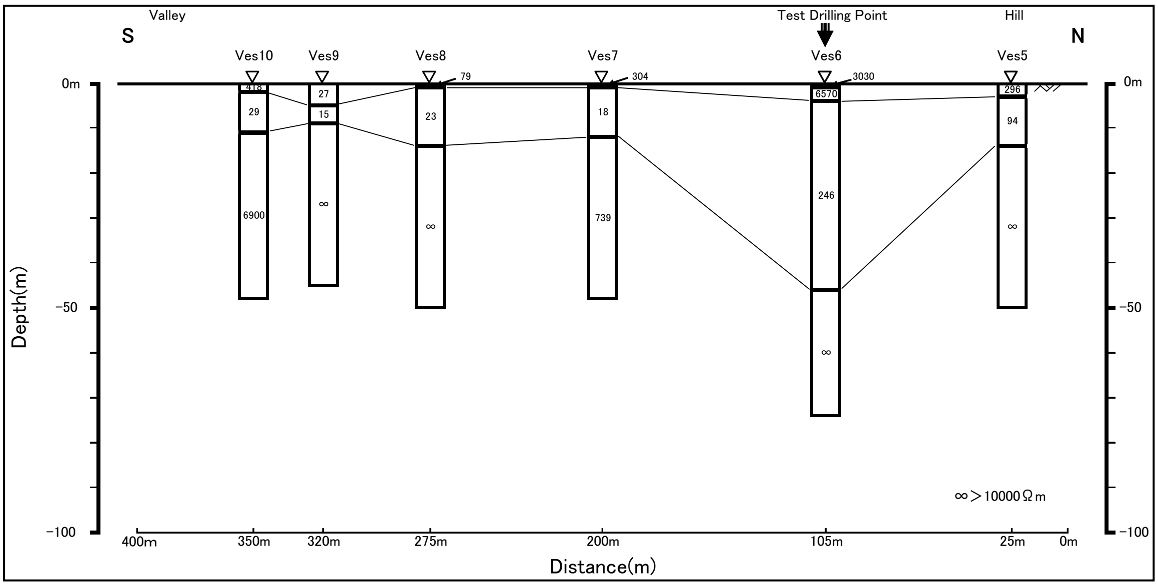
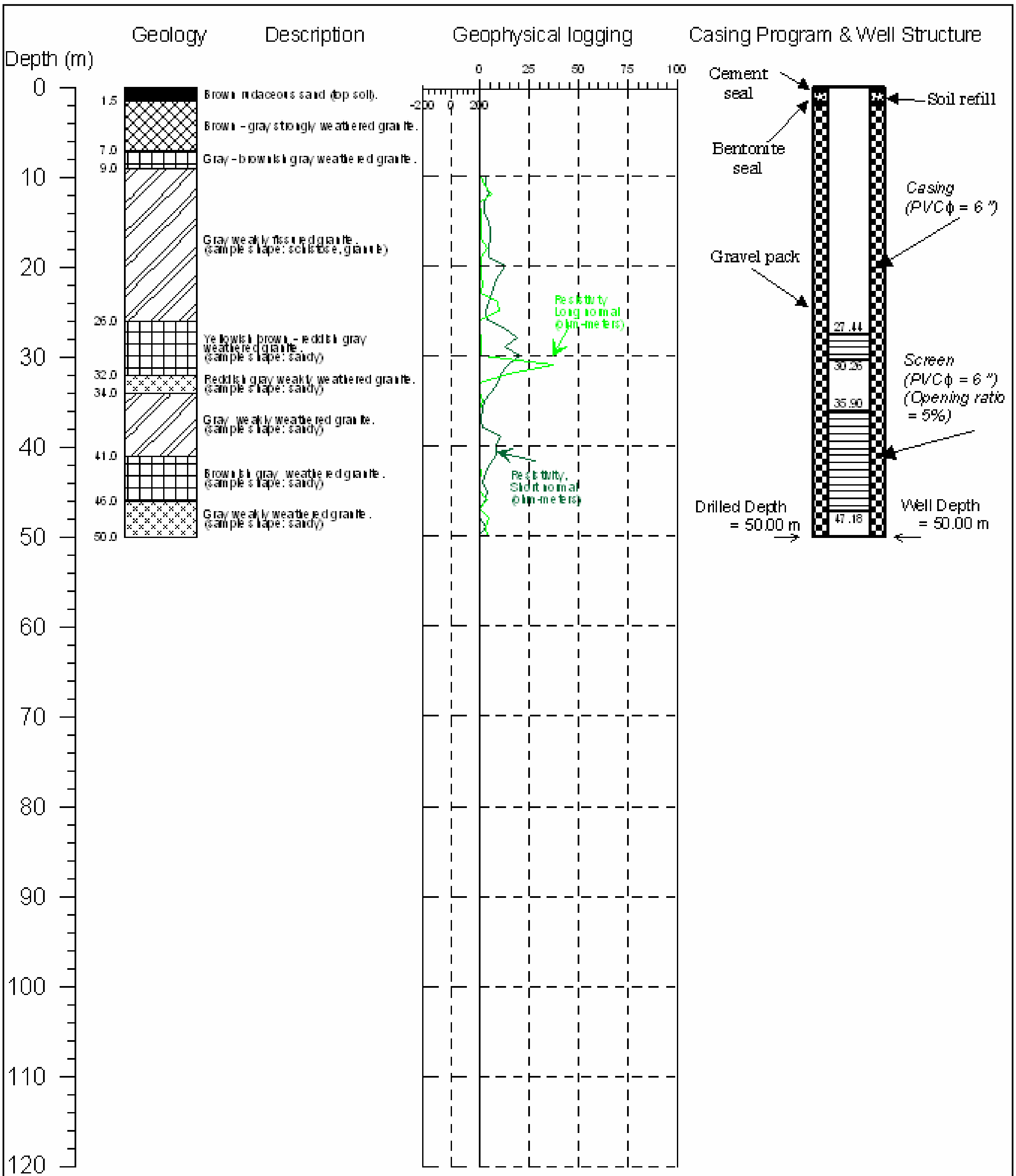


Figure 4-2: Resistivity Section (T1: Busongo Village)



**WELL LOCATION**

Location: Busongo,
Misungwi District, Mwanza Region
Site No.: Misungwi 25
Well No.: T1

**WELL SPECIFICATION**

Well Depth: 50.00 m
Well Diameter: 6"
Screen Depths: 27.44-30.26, 35.90-47.18 m
Screen Length: 14.10 m
SWL: GL-8.07 m
on 29-09-2005

Figure 4-3: Columnar and Section and Well Structure (Busongo)

### b. T2: Busekeseke (Ves4 point)

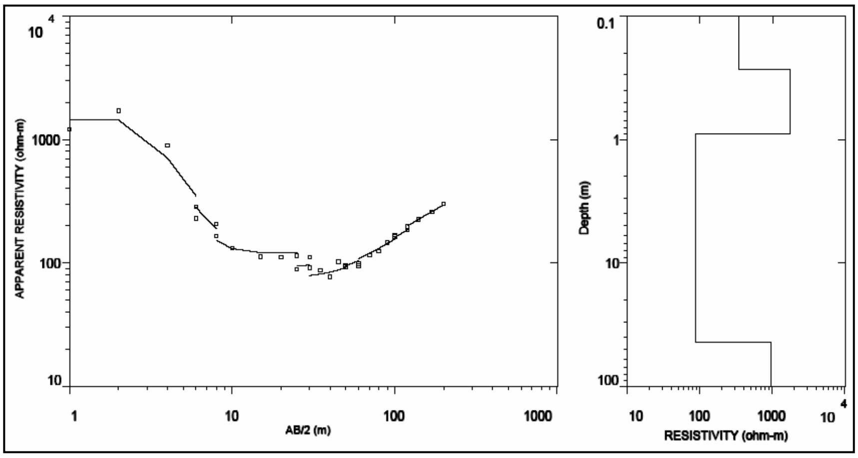


Figure 4-4: Result of Vertical Electric Sounding (T2: Busekeseke Village, Ves4 point)

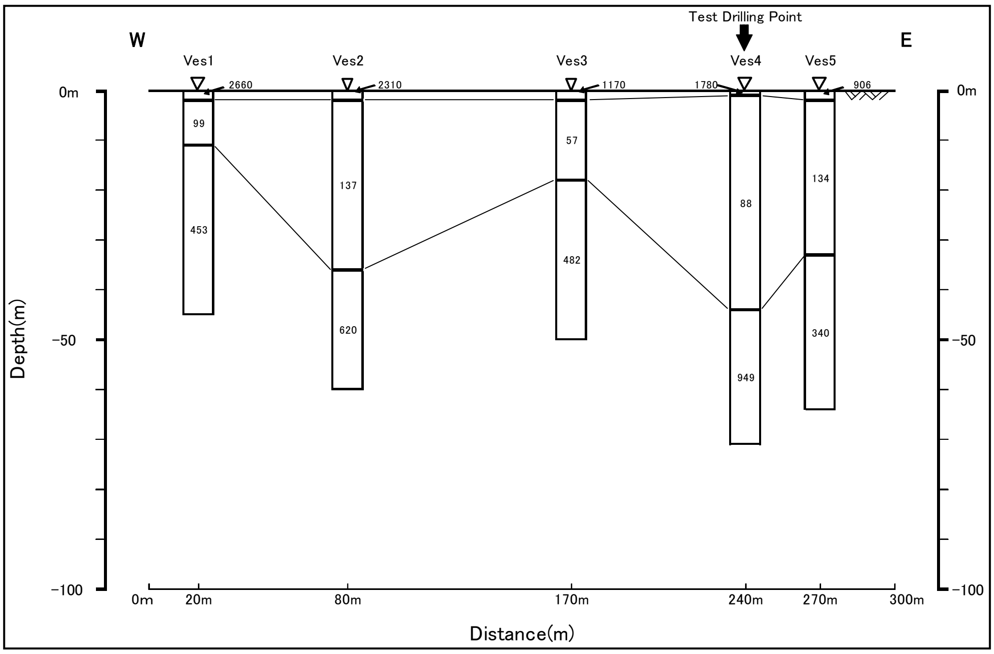
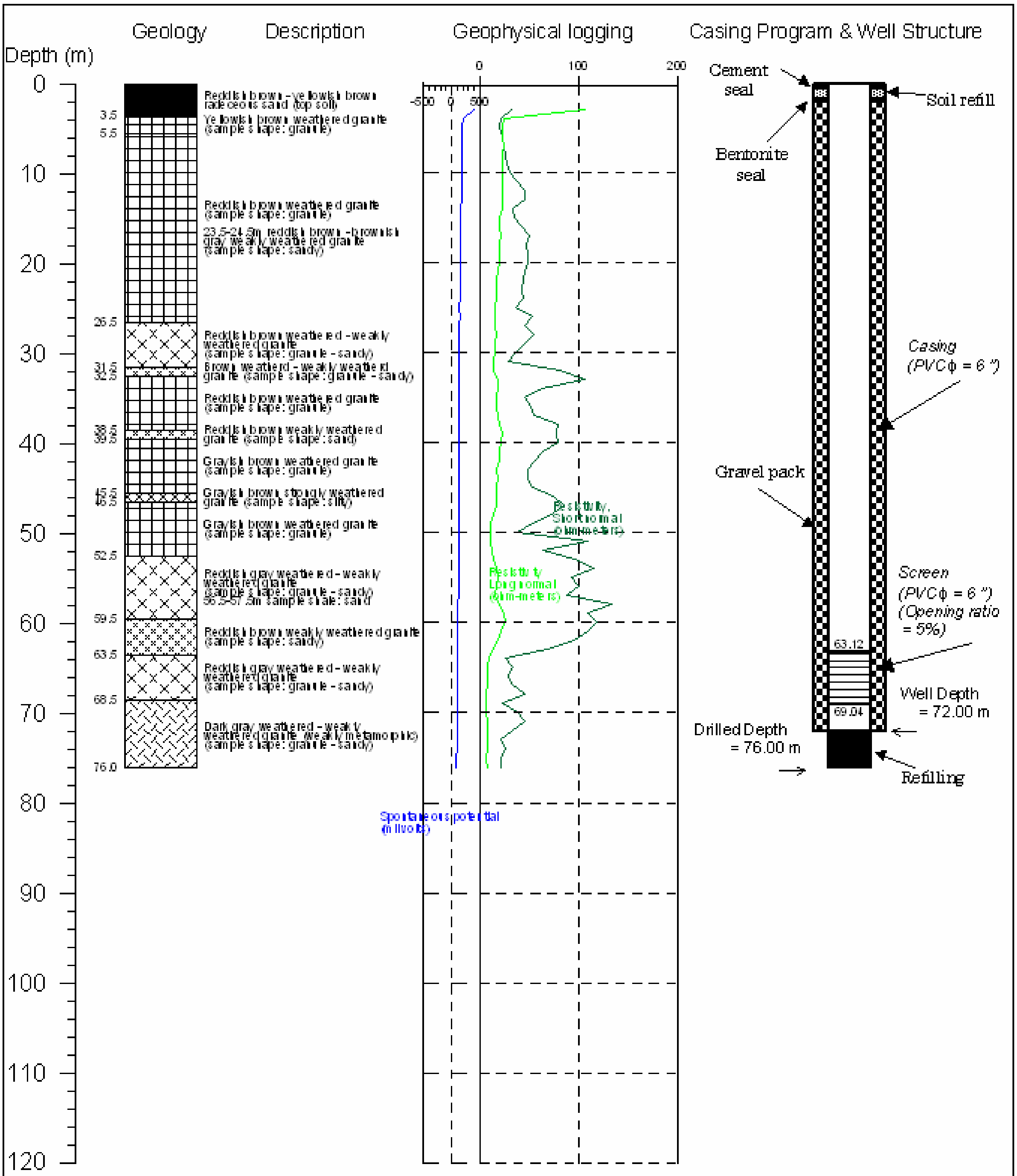


Figure 4-5: Resistivity Section (T2: Busekeseke Village)



**WELL LOCATION**

Location: Busekeseke,
Sengerema, District, Mwanza Region
Site No.: Sengerema 83
Well No.: T2

**WELL SPECIFICATION**

Well Depth: 72.00 m
Well Diameter: 6"
Screen Depths: 63.12-69.04 m
Screen Length: 5.92 m
SWL: GL-1.00 m
on 21-10-2005

Figure 4-6: Columnar and Section and Well Structure (Busekeseke)

### c. T3: Nyamatala (Ves7 point)

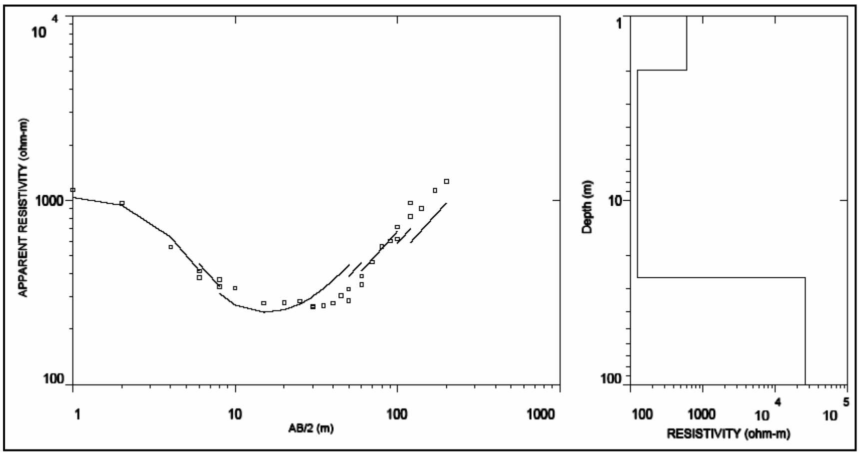


Figure 4-7: Result of Vertical Electric Sounding (T1: Nyamatala Village, Ves7 point)

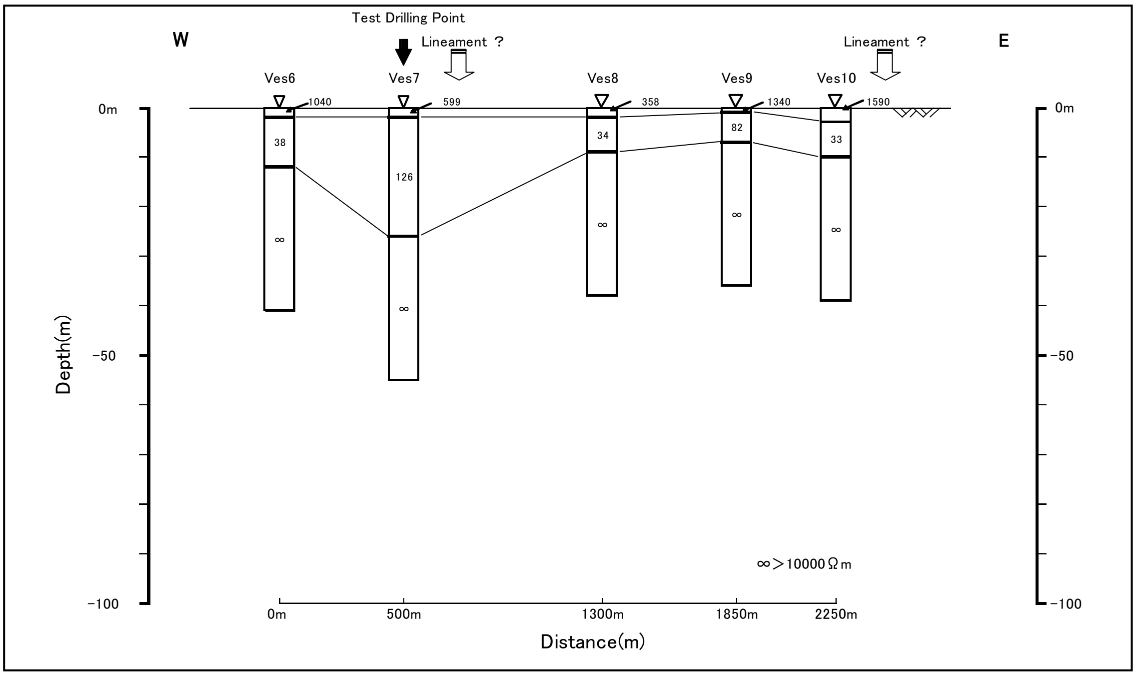
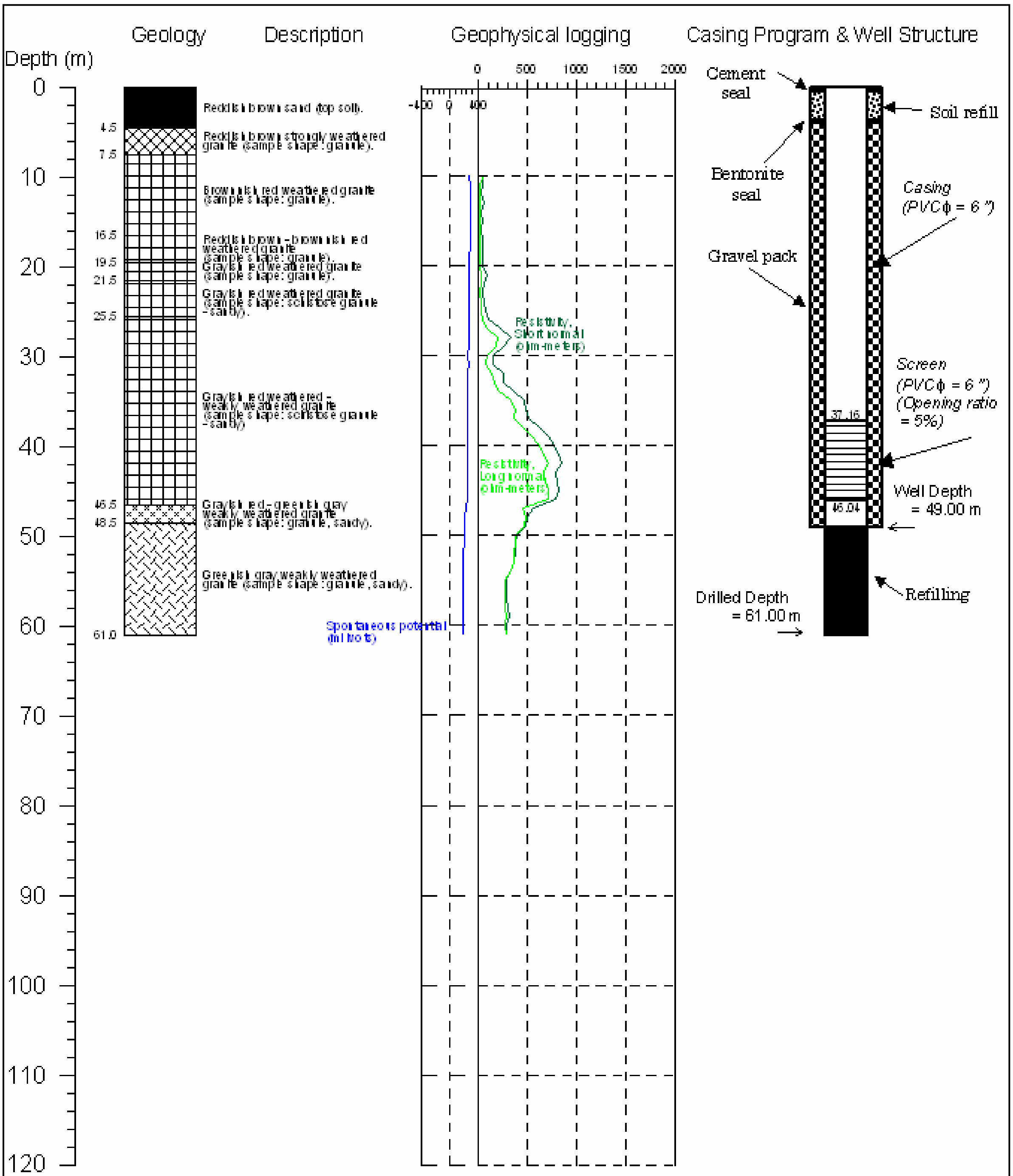


Figure 4-8: Resistivity Section (T3: Nyamatala Village)



**WELL LOCATION**

Location: Nyamatala,
Kwimba, District, Mwanza Region
Site No.: Kwimba 69
Well No.: T3

**WELL SPECIFICATION**

| | |
|---|---|
| Well Depth: | 49.00 m |
| Well Diameter: | 6" |
| Screen Depths: | 37.16-46.04 m |
| Screen Length: | 8.88 m |
| SWL: | GL-8.84 m<br>on 07-10-2005 |

Figure 4-9: Columnar and Section and Well Structure (Nyamatala)

### d. T4: Igekemaja (Ves1 point)

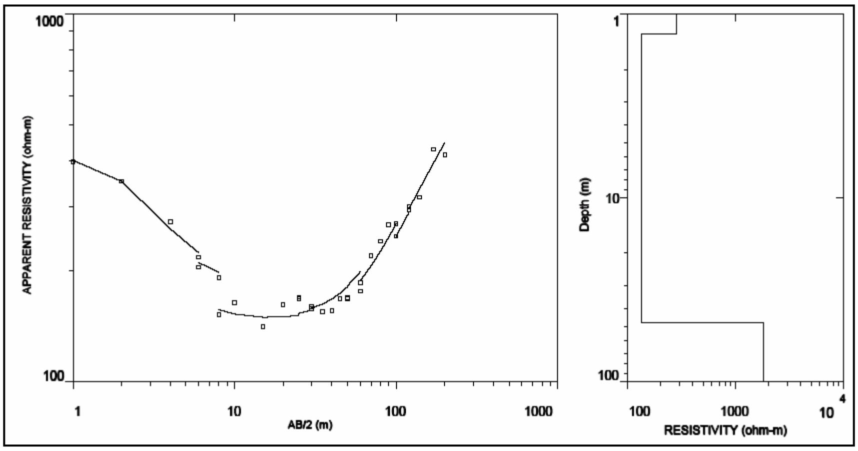


Figure 4-10: Result of Vertical Electric Sounding (T4: Igekemaja Village, Ves1 point)

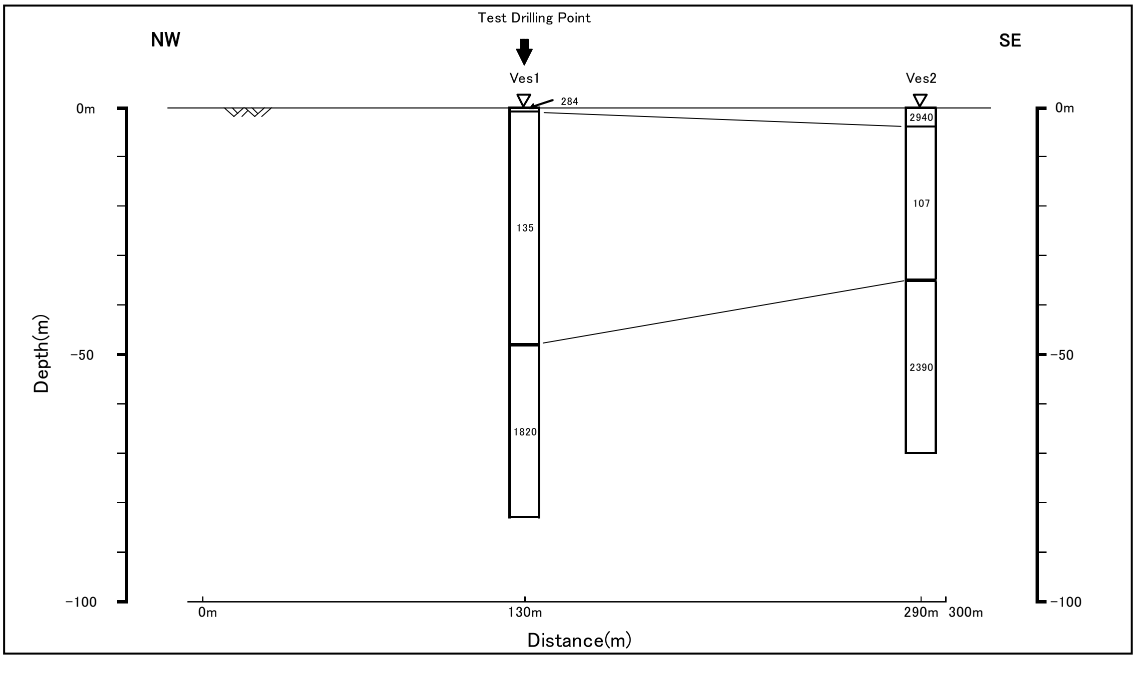
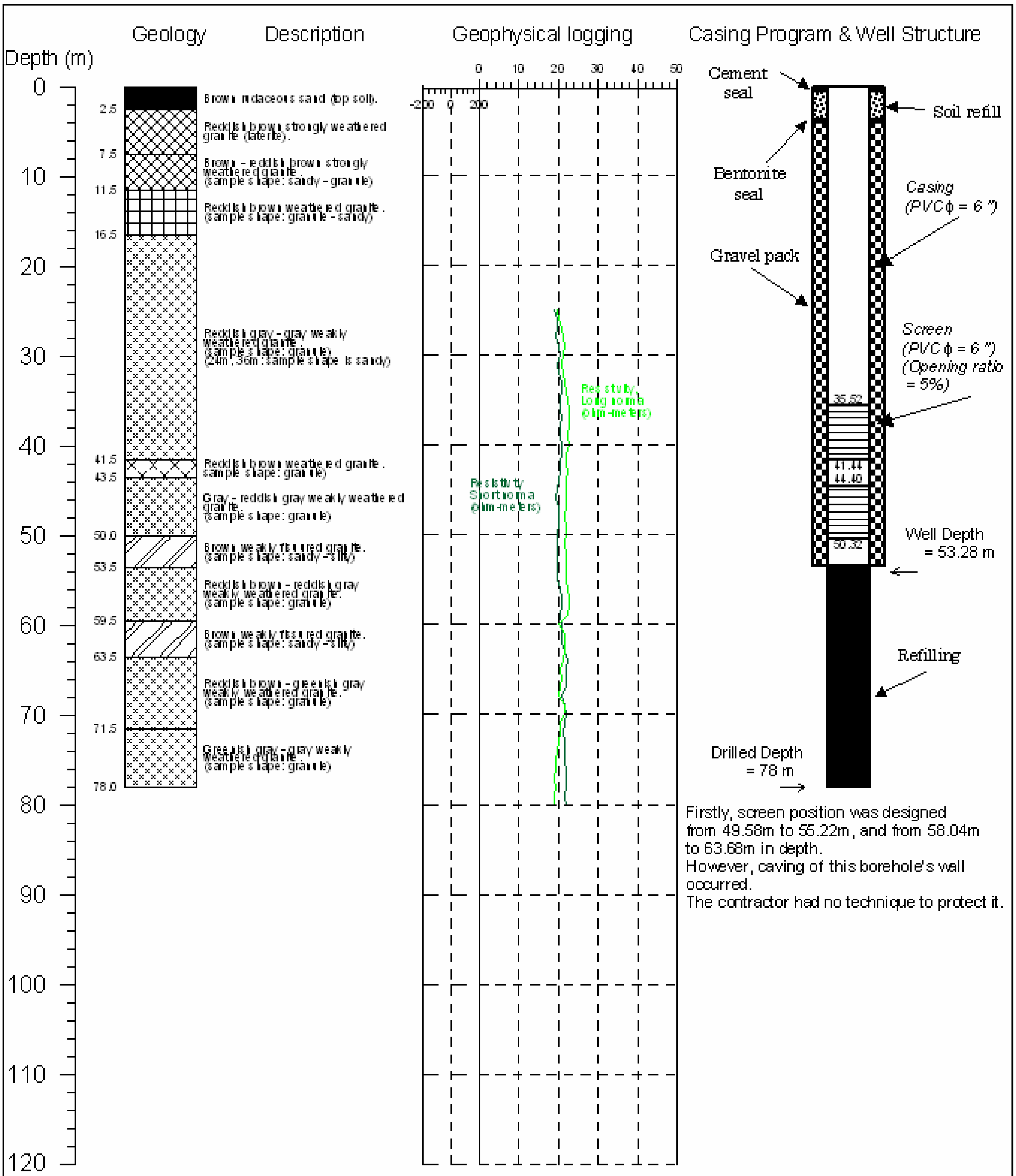


Figure 4-11: Resistivity Section (T4: Igekemaja Village)



Firstly, screen position was designed from 49.58m to 55.22m, and from 58.04m to 63.68m in depth.
However, caving of this borehole's wall occurred.
The contractor had no technique to protect it.

**WELL LOCATION**

Location: Igekemaja,
Magu, District, Mwanza Region
Site No.: Magu 37
Well No.: T4

**WELL SPECIFICATION**

| | |
|---|---|
| Well Depth: | 53.28 m |
| Well Diameter: | 6" |
| Screen Depths: | 35.52-41.44, 44.40-50.32 m |
| Screen Length: | 11.84 m |
| SWL: | GL-5.49 m<br>on 03-10-2005 |

Figure 4-12: Columnar and Section and Well Structure (Igekemaja)

### e. T5: Ikina (Ves5 point)

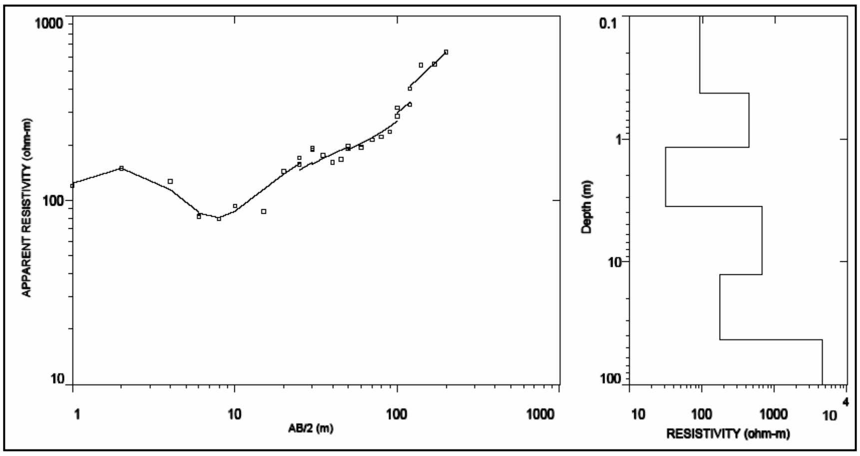


Figure 4-13: Result of Vertical Electric Sounding (T5: Ikina Village, Ves5 point)

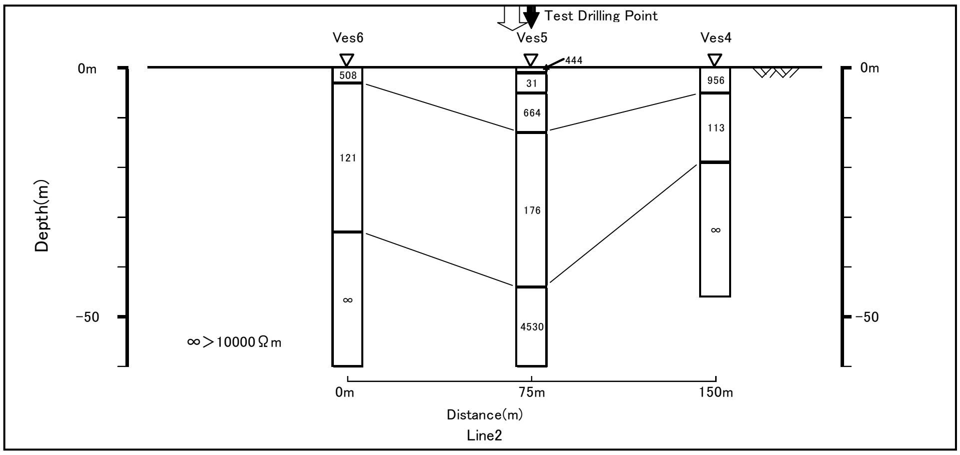
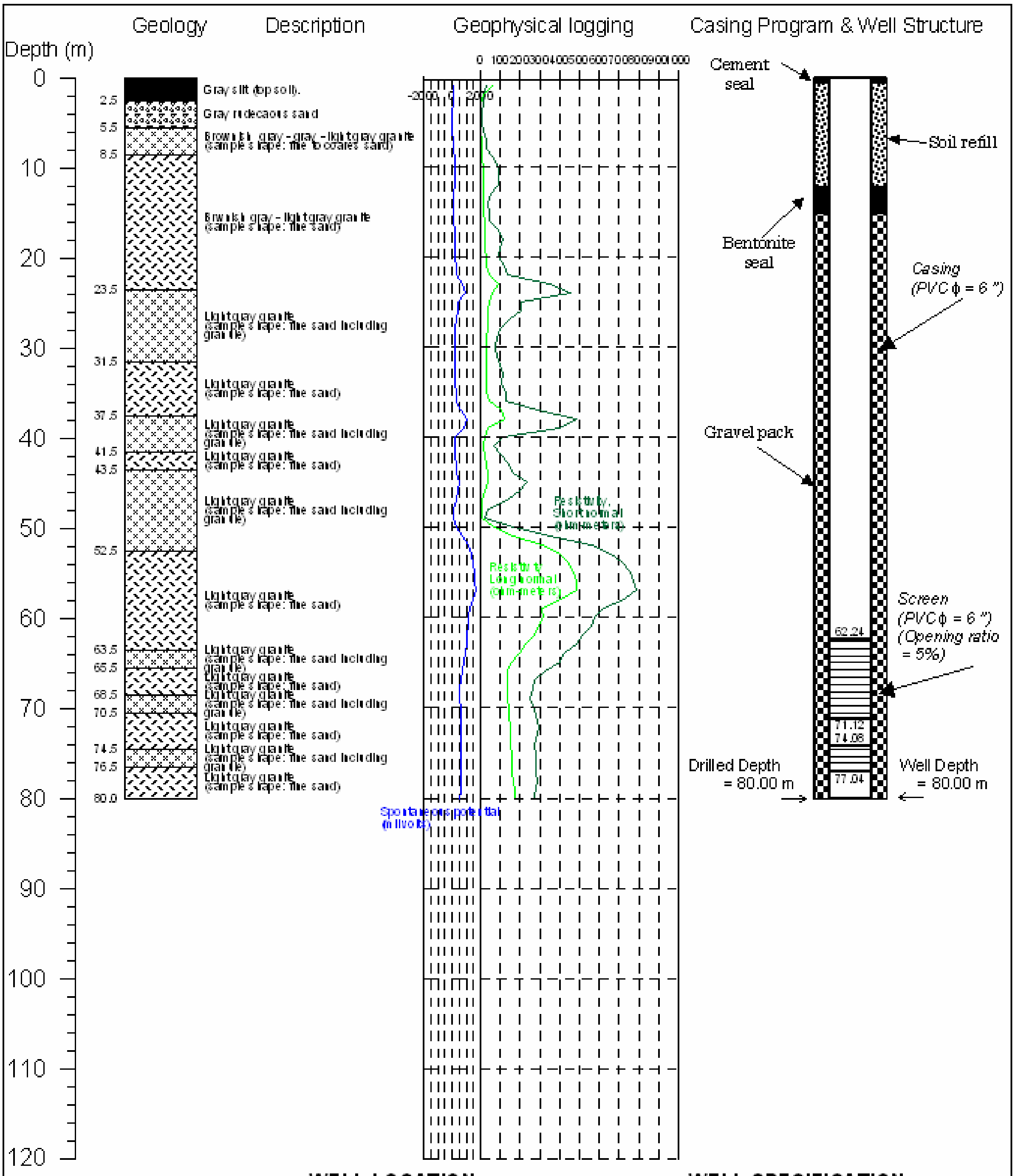


Figure 4-14: Resistivity Section (T5: Ikina Village)



**WELL LOCATION**

Location: Ikina,
Geita, District, Mwanza Region
Site No.: Geita 27
Well No.: T5

**WELL SPECIFICATION**

| | |
|---|---|
| Well Depth: | 80.00 m |
| Well Diameter: | 6" |
| Screen Depths: | 62.24-71.12, 74.08-77.04 m |
| Screen Length: | 11.84 m |
| SWL: | GL-1.30 m<br>on 15-10-2005 |

Figure 4-15: Columnar and Section and Well Structure (Ikina)

### f. T6: Buhima (Ves7 point)

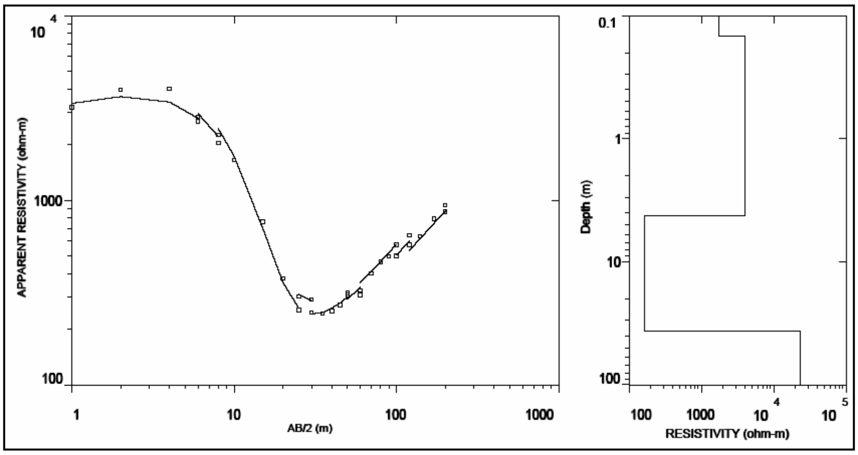


Figure 4-16: Result of Vertical Electric Sounding (T6: Buhima Village, Ves7 point)

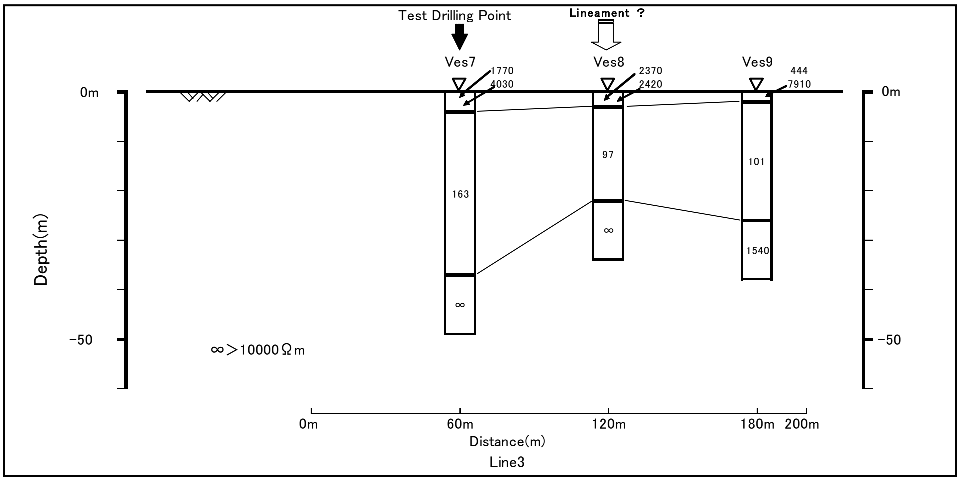
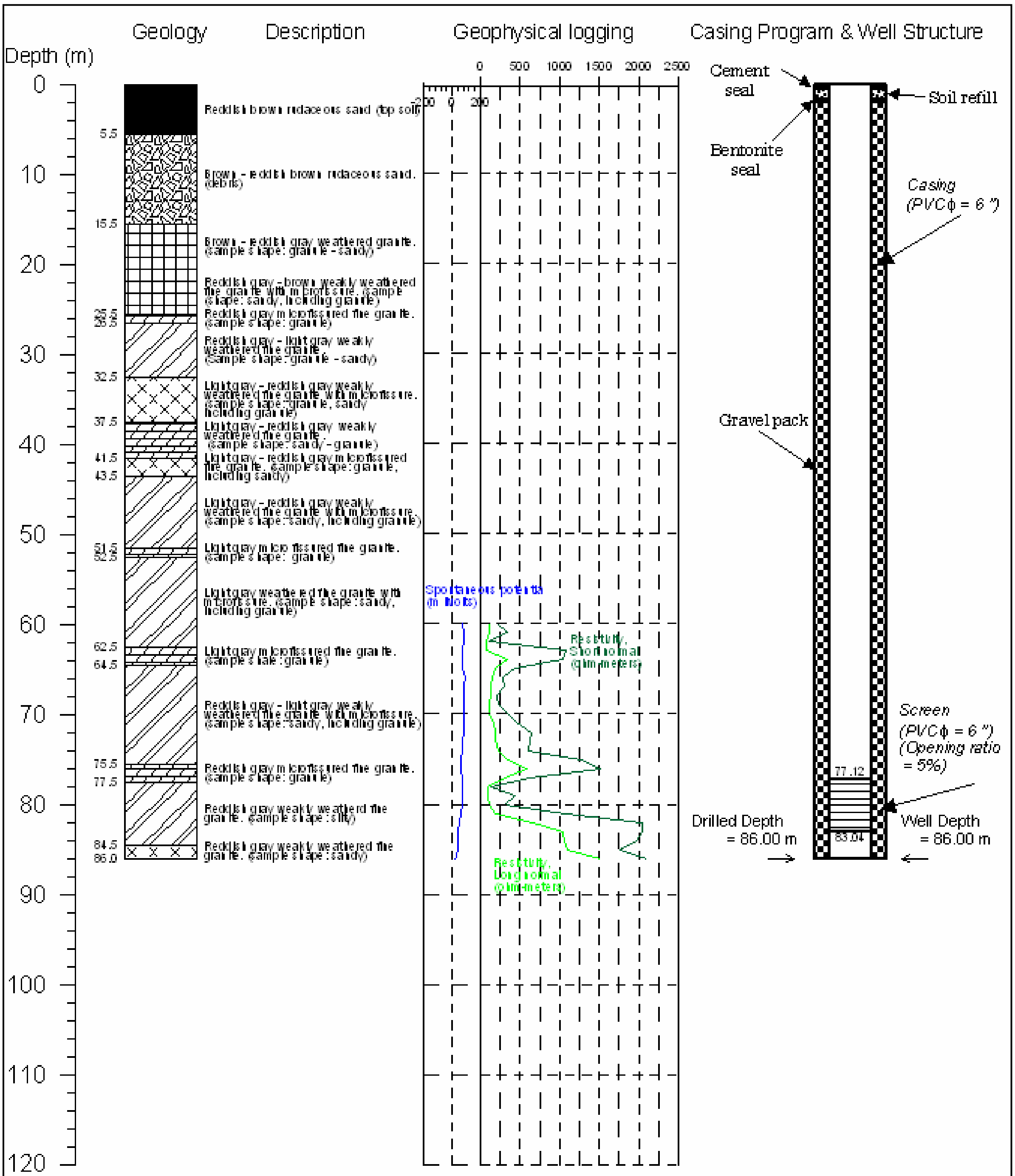


Figure 4-17: Resistivity Section (T6: Buhima Village)



**WELL LOCATION**

Location: Buhima,
Ukerewe District, Mwanza Region
Site No.: Ukerewe 73
Well No.: T6

**WELL SPECIFICATION**

Well Depth: 86.00 m
Well Diameter: 6"
Screen Depths: 77.12-83.04 m
Screen Length: 5.92 m
SWL: GL-59.70 m
on 01-11-2005

Figure 4-18: Columnar and Section and Well Structure (Buhima)

]

### g. T7: Mcharo (Ves5 point)

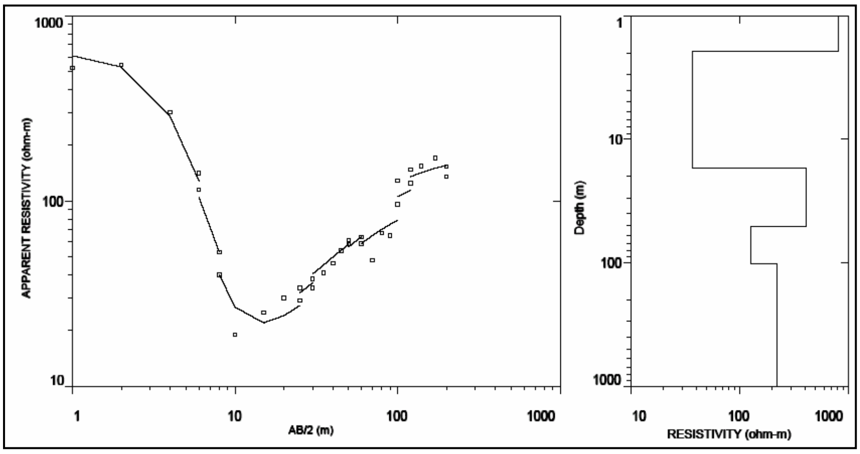


Figure 4-19: Result of Vertical Electric Sounding (T7: Mcharo Village, Ves5 point)

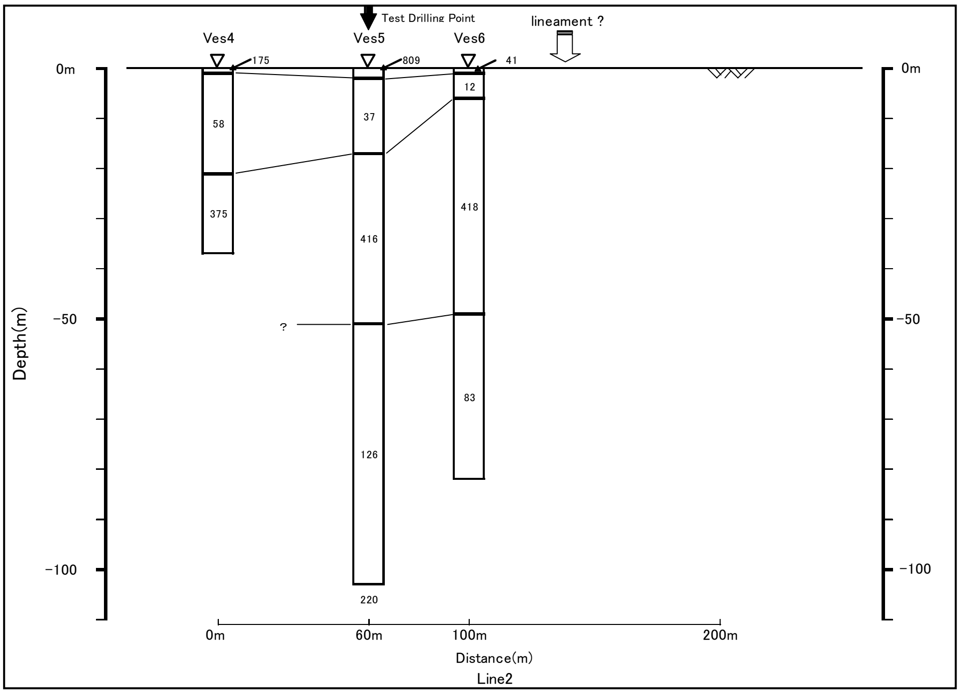
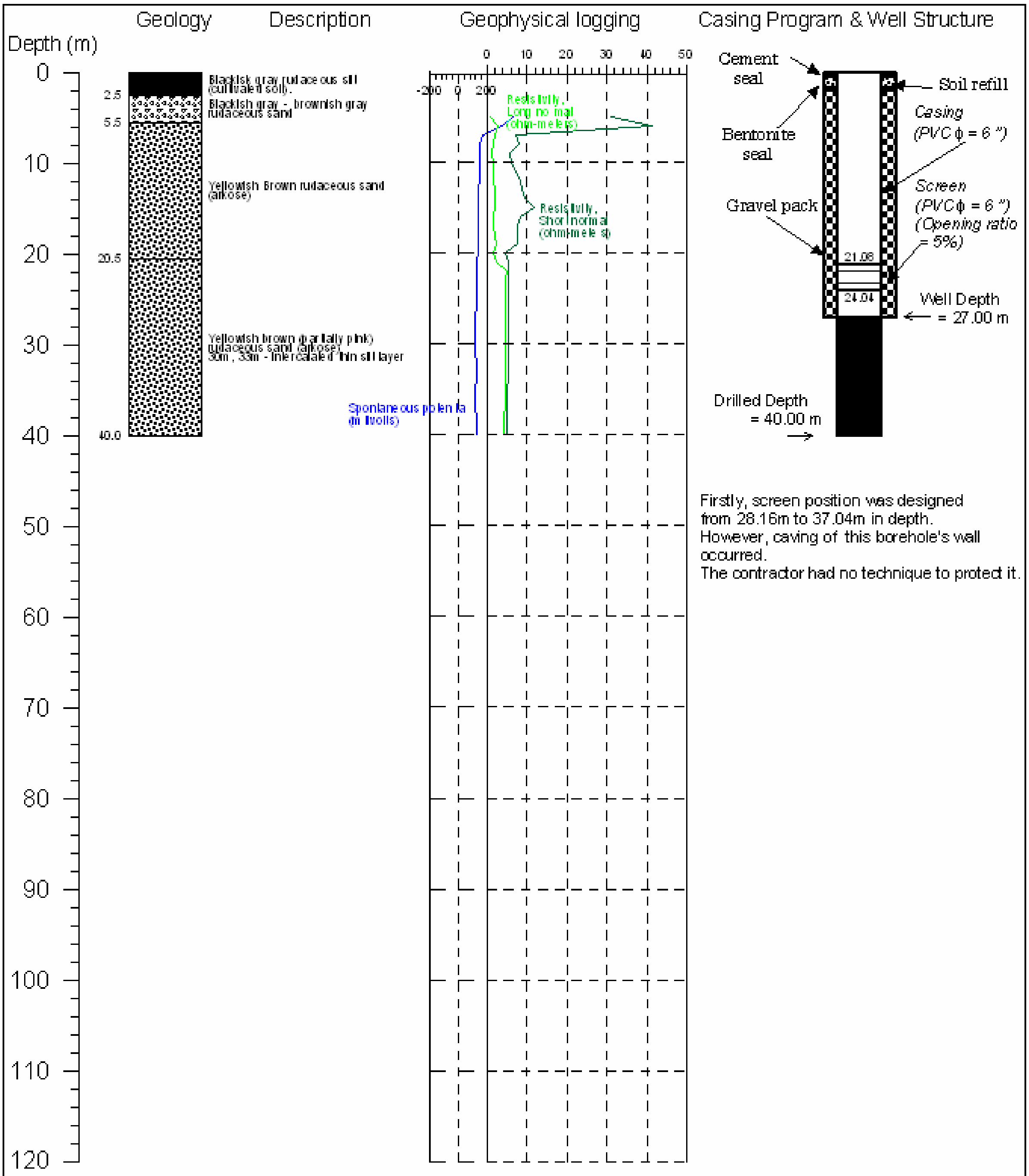


Figure 4-20: Resistivity Section (T7: Mcharo Village)



Firstly, screen position was designed from 28.16m to 37.04m in depth.
However, caving of this borehole's wall occurred.
The contractor had no technique to protect it.

**WELL LOCATION**

Location: Mcharo,
Bunda District, Mara Region
Site No.: Bunda 33
Well No.: T7

**WELL SPECIFICATION**

| | |
|---|---|
| Well Depth: | 27.00 m |
| Well Diameter: | 6" |
| Screen Depths: | 21.08-24.04 m |
| Screen Length: | 2.96 m |
| SWL: | GL- 4.07 m<br>on 10-10-2005 |

Figure 4-21: Columnar and Section and Well Structure (Mcharo)

### h. T8: Saragana (Ves6 point)

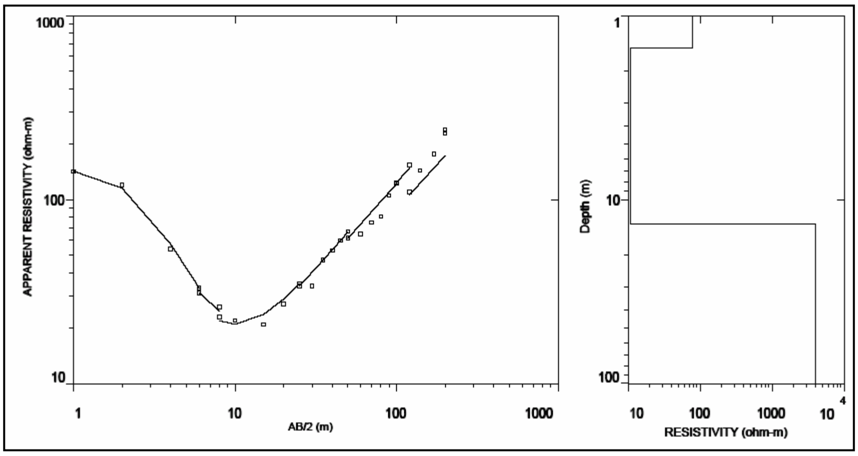


Figure 4-22: Result of Vertical Electric Sounding (T8: Saragana Village, Ves6 point)

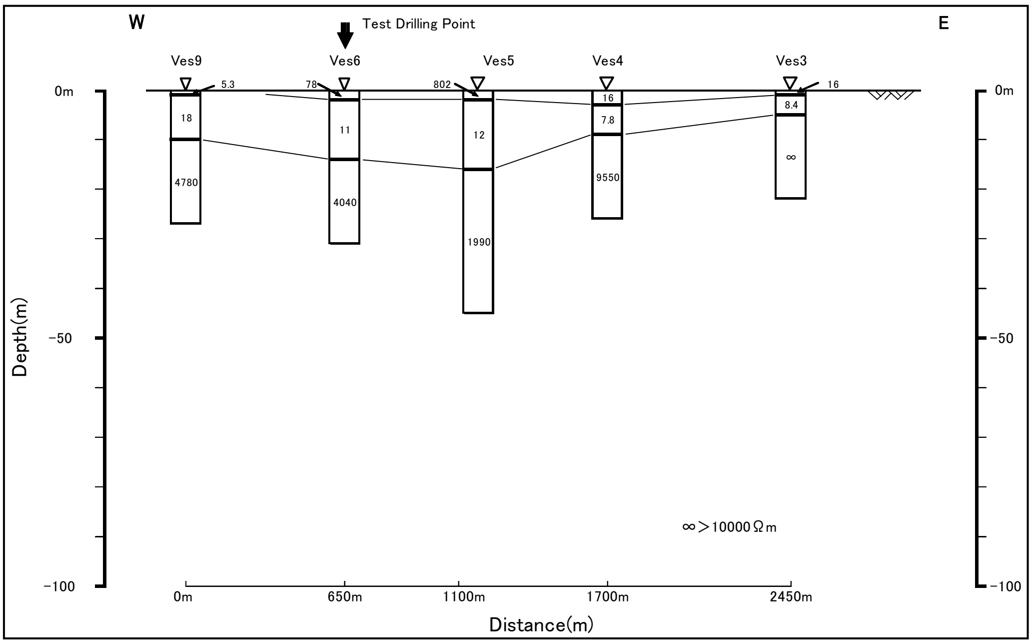
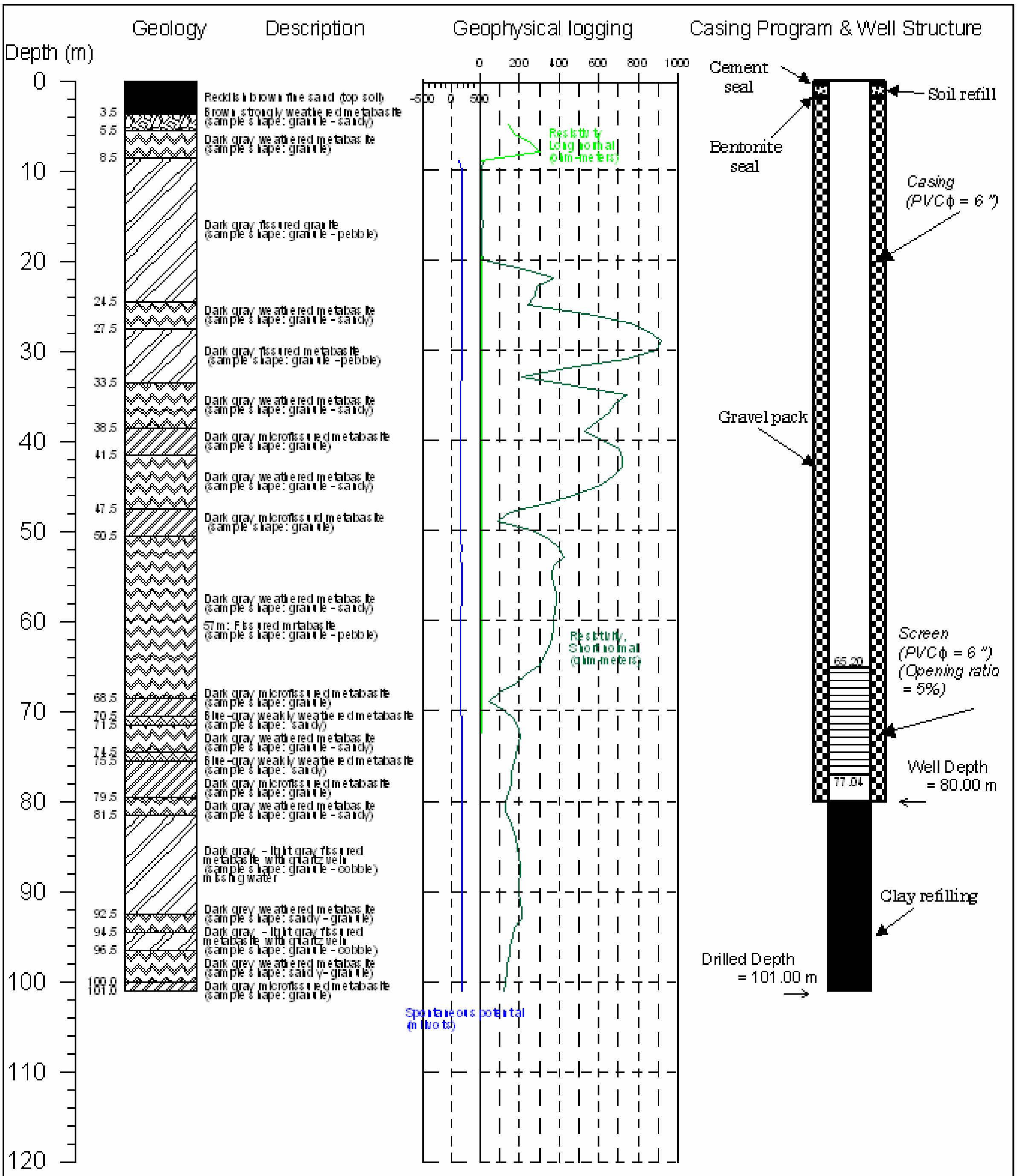


Figure 4-23: Resistivity Section (T8: Saragana Village)



**WELL LOCATION**

Location: Saragana,
Musoma District, Mara Region
Site No.: Musoma 35
Well No.: T8

**WELL SPECIFICATION**

Well Depth: 80.00 m
Well Diameter: 6"
Screen Depths: 65.20-77.04 m
Screen Length: 11.84 m
SWL: GL-9.00 m
on 23-10-2005

Figure 4-24: Columnar and Section and Well Structure (Saragana)

### i. T9: Raranya (Ves12 point)

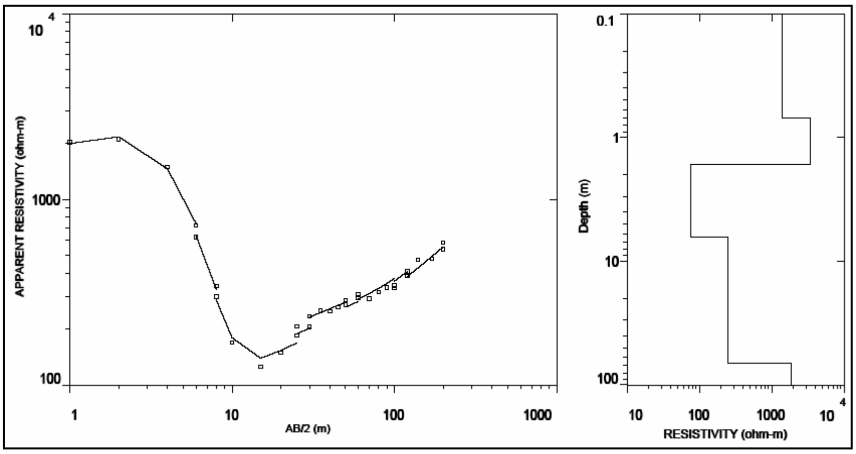


Figure 4-25: Result of Vertical Electric Sounding (T9: Raranya Village, Ves12 point)

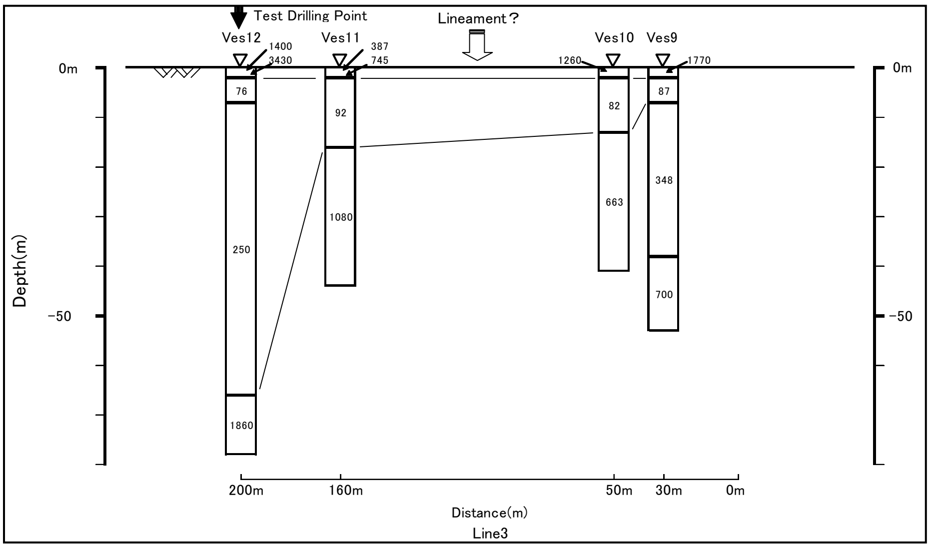


Figure 4-26: Resistivity Section (T9: Raranya Village)

### j. T10: Kebancha (Ves2 point)

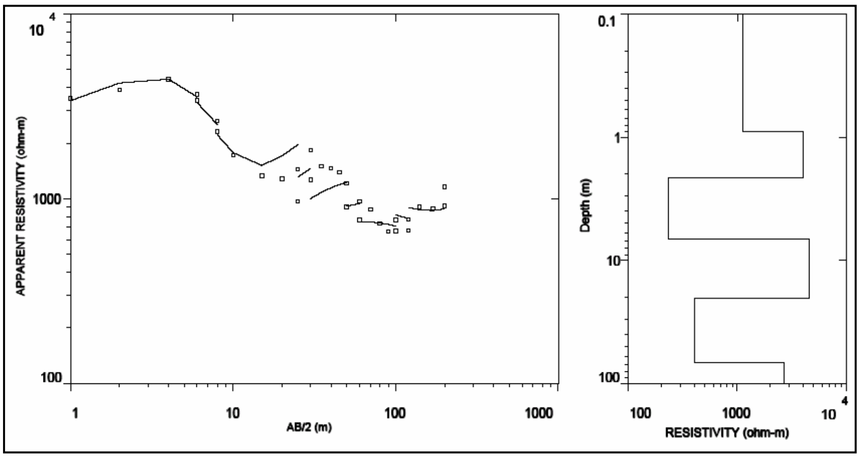


Figure 4-27: Result of Vertical Electric Sounding (T10: Kebancha Village, Ves2 point)

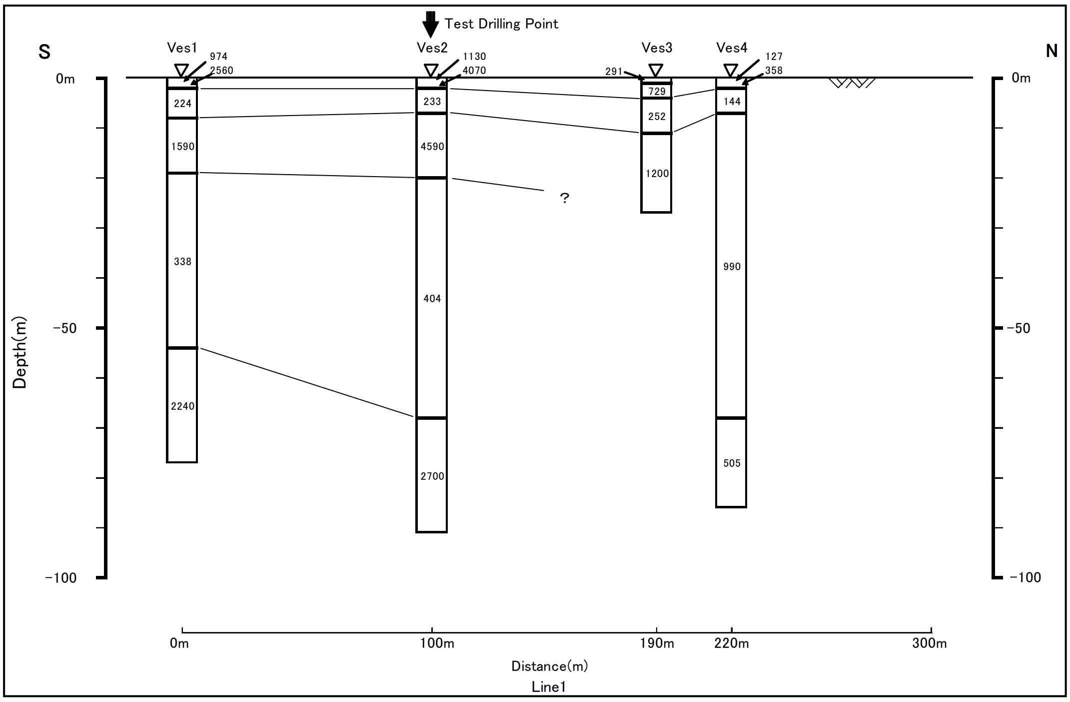


Figure 4-28: Resistivity Section (T10: Kebancha Village)

# 5 Exercise

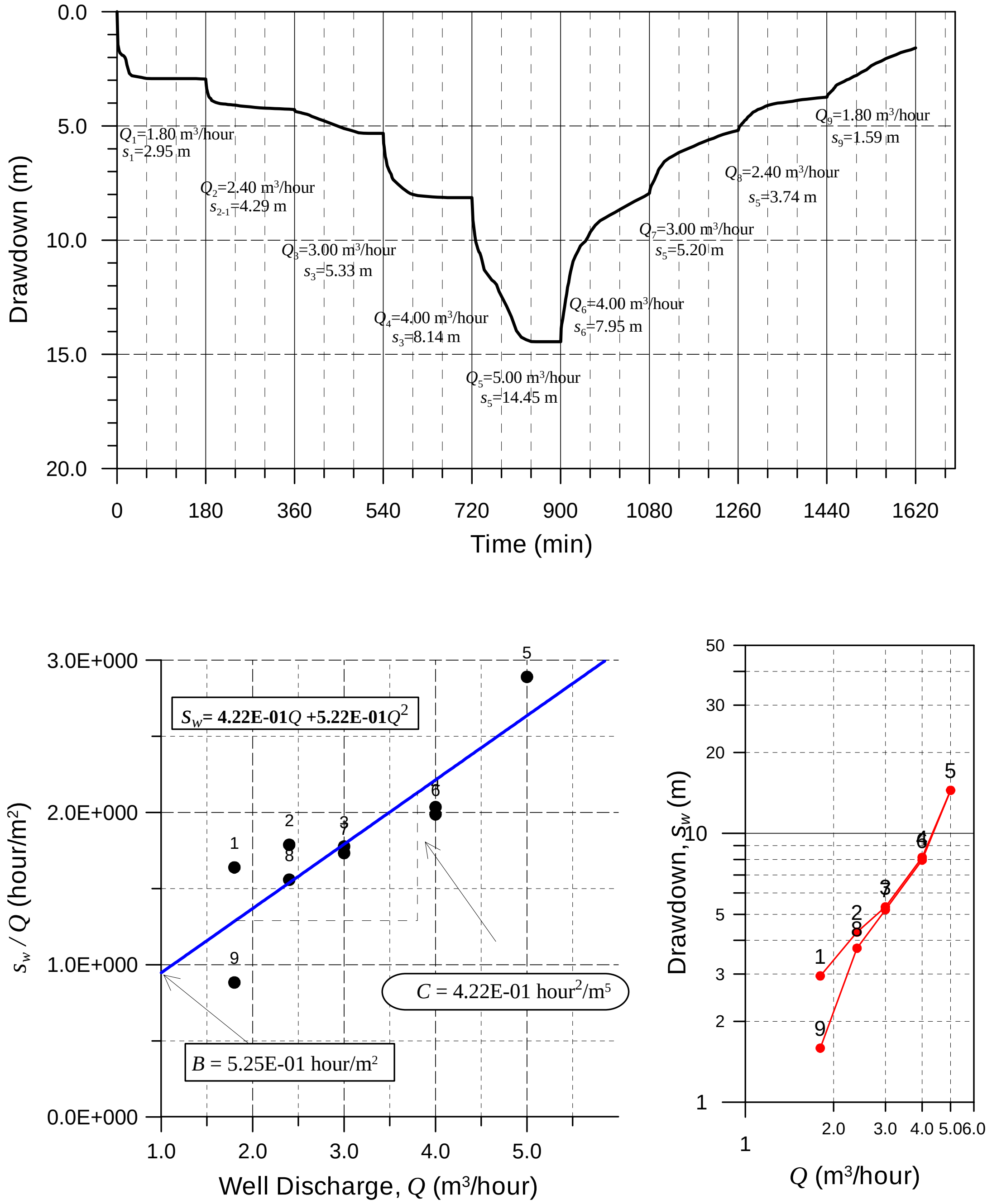
1. Calculate the well loss coefficient and the aquifer loss coefficient by using the data of the step drawdown test of Mcharo village.

2. Calculate the well efficiency of each pumping stage by using the data of the step drawdown test of Mcharo village.

3. Calculate the transmissivity and the storage coefficient from the data of the continuous pumping test of the Mcharo village by Cooper-Jacob method.

4. Calculate the transmissivity from the data of the continuous pumping test of the Mcharo village by recovery method.

## Example of analytical result (Step drawdown test)



| | |
|---|---|
| Location: | Saragana, Musoma District,<br>Mara Region |
| Site No.: | Musoma 35 |
| Well No.: | T8 |
| Well Depth: | 80.00 m |
| Well Diameter: | 6" |
| Screen Depths: | 65.20-77.04,m |
| Screen Length: | 11.84 m |
| SWL: | GL- 9.00 m<br>on 23-10-2005 |

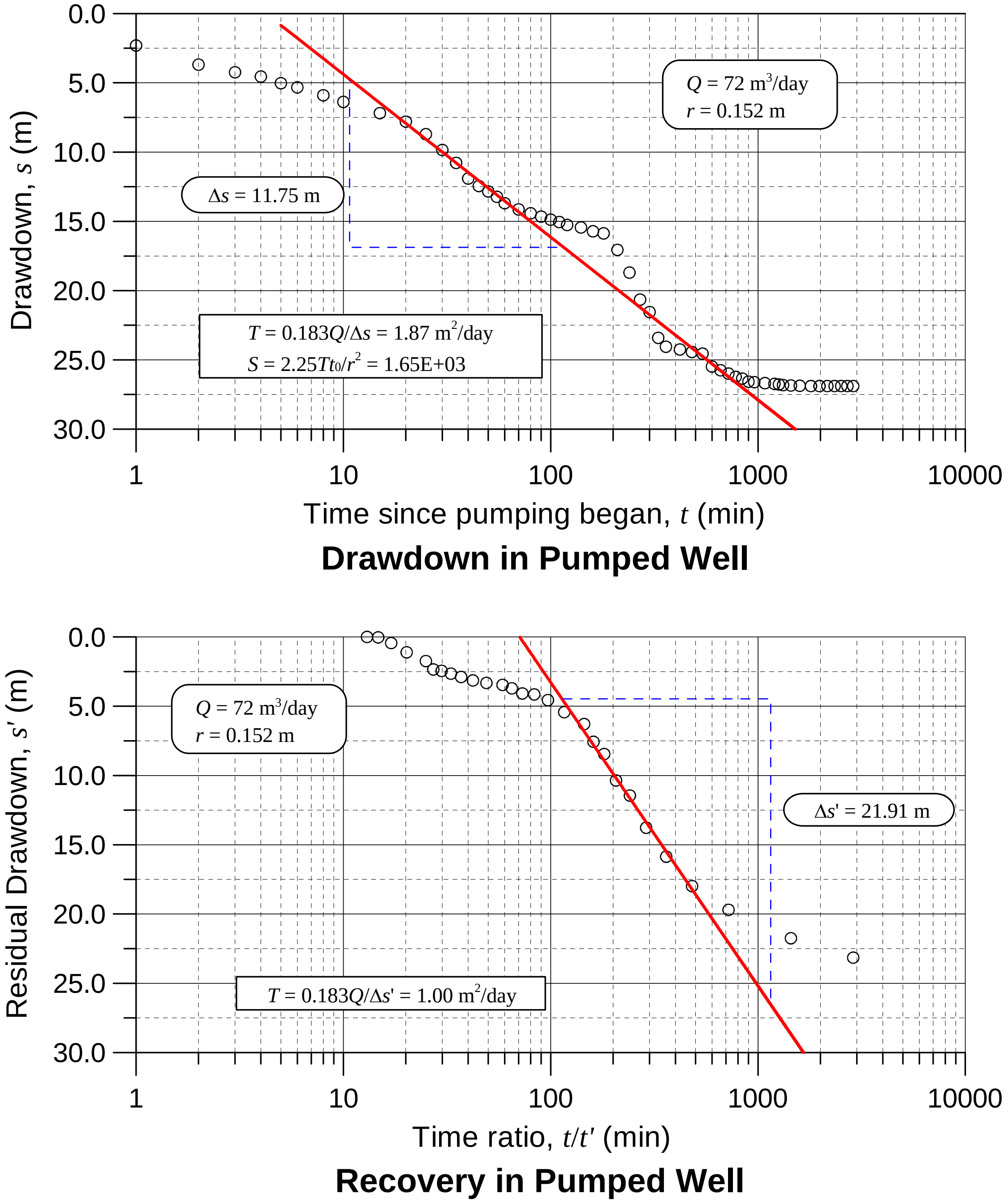
**Figure 2.3-29**

**Results of Step-Drawdown Test
at T8 Test Well (SARAGANA)**

**THE STUDY ON RURAL WATER SUPPLY IN MWANZA AND MARA REGIONS
IN THE UNITED REPUBLIC OF TANZANIA**

JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

## Example of analytical result (Continuous pumping test and recovery test)



| | |
|---|---|
| Location: | Saragana, Musoma District,<br>Mara Region |
| Site No.: | Musoma 35 |
| Well No.: | T8 |
| Well Depth: | 80.00 m |
| Well Diameter: | 6" |
| Screen Depths: | 65.20-77.04,m |
| Screen Length: | 11.84 m |
| SWL: | GL- 9.00 m<br>on 23-10-2005 |

**Figure 2.3-39**

**Results of Continuous Pumping Test
and Recovery Test
at T8 Test Well (SARAGANA)**

**THE SUTUDY ON RURAL WATER SUPPLY IN MWANZA AND MARAREGIONS
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