

A Project on the Applications of Ground Penetrating Radar Geophysical Method

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Introduction

The Ground penetrating radar (GPR) is a high-resolution technique for imaging shallow soil and ground structures using electromagnetic (EM) waves in the frequency band of 10-1000 MHz this geophysical method has become increasingly applicable and popular among geoscientists over the last 20-30 years [1], its application has been carried out in a geophysical field work in the southeast outskirts of Enschede, The Netherlands. The area is a flat land covered by grass and sparse deciduous trees, used for mainly agricultural practices since the area is dominantly inhabited by farmers. The soil composition is mostly of clay and sand or a mixture of both, which initiates the aim of this preliminary fieldwork (Figures 1 and 2).

Objective

The purpose of this project is to carry out an analysis using data acquired from fieldwork to delineate sand and clay interface for geologic and geomorphologic structure, and to assess the variation in groundwater table and the impact of moisture variation on the recorded signals, also to make a clear distinction between groundwater and geology/geomorphology.

Method

Ground penetrating radar (GPR) offers a new way of viewing shallow soil and rock complexities. The necessity to have a better understanding of activities such as geochemical sampling, geotechnical investigations and placer exploration as well as factors guiding the flow of groundwater has resulted in an increasing demand for techniques which can image the subsurface with higher resolution than was previously possible [2]. GPR has a lot of applications which include rock mechanics, mineral and ground water exploration, geotechnical and archaeological investigations, mapping bedrock depth, rock type variation, and fractures in bedrock, soil strata and the water table in coarse-grained soils. GPR possesses a very high resolution as a result of its relatively high frequency, and this in effect reduces its depth range, but basically the penetration depth is controlled by the conductivity of the material, a highly conductive material does not allow much penetration but a material with a low electrical conductivity allows deeper penetration. A study carried out in northern Wisconsin by Lowry [3], where the low electrical conductivity of water saturated peat permitted high resolution image to a depth of 16 m. GPR functions with transmitting and receiving antennae, sending pulses to the subsurface and recording the reflections respectively. The velocity of radar through the subsurface is dependent on the dielectric constant (ϵ_r) of the materials, which is the ratio of the amount of stored electrical energy when a potential is applied, relative to permittivity of a vacuum [3]. It is defined thus

$$\epsilon_r = \frac{\epsilon_s}{\epsilon_0}$$

Where;

ϵ_r = dielectric constant

ϵ_s = the static permittivity of the material

ϵ_0 = the electric constant.

The higher the dielectric constant the less velocity as shown in the table below (Table 1).

Data processing and Results

With these parameters in mind the GPR was calibrated and measurements were made by pushing it along the line section for a distance of 420 m, and after that, processing of the data was carried out using RadExplorer1.4 which was also used for the time – depth conversion by estimating the velocity, and the following results were obtained (Figure 3).

The radar gram above shows the result for the first 100 m distance, the first 0.5 m (red arrows) is not taken into account because it is as a result of the space between the sensor and the ground's surface, on the

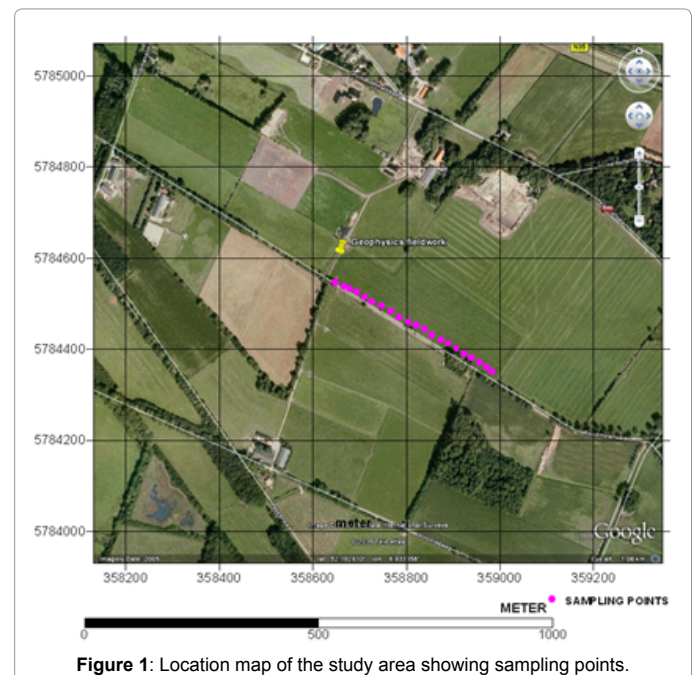


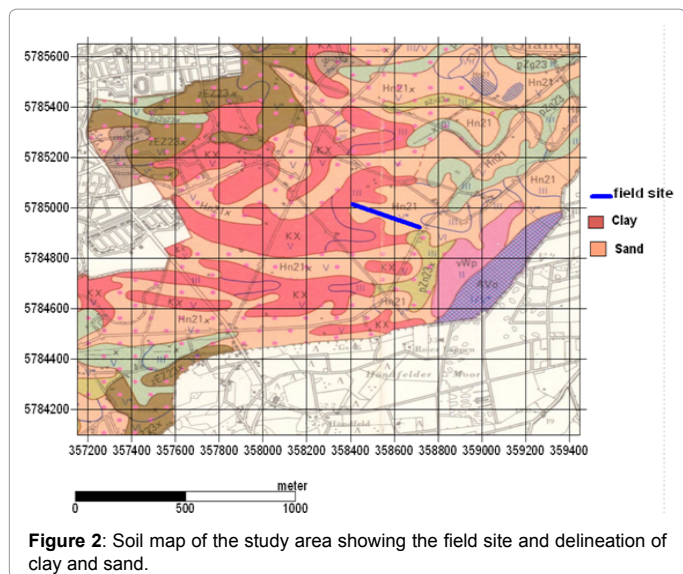
Figure 1: Location map of the study area showing sampling points.

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ground surface down till a few inches is sand because of its texture, further below the yellow green and blue arrows, point out areas of possible clay (wet) content, a discontinuity in layer and area of possible sand (wet) contents respectively. The areas with the yellow arrow are considered clay because clay has a lower dielectric constant than sand; as a result it has a smoother texture on the radagram, while sand with (blue arrows) has a higher dielectric constant thereby having a coarser texture on the radagram due to it agitation of the radar (Figure 4).

From the second 100 m distance the red, yellow and green arrows are also as explained in the first image but at the 187 m distance a sudden upwelling of possible clay or a mix of clay and sand is seen (Figure 5).

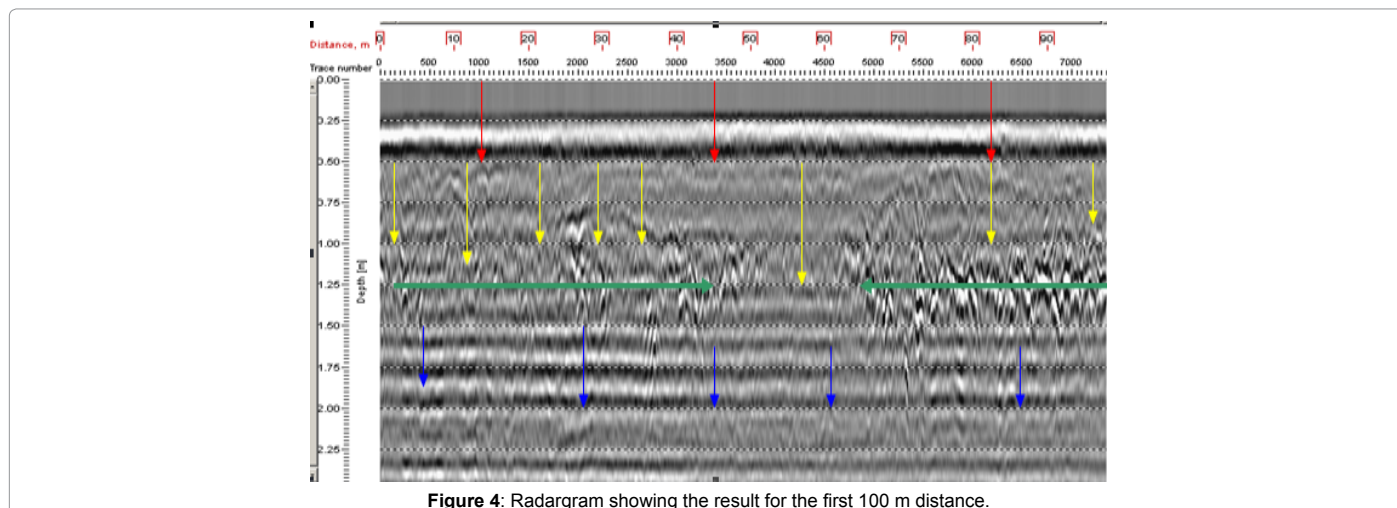
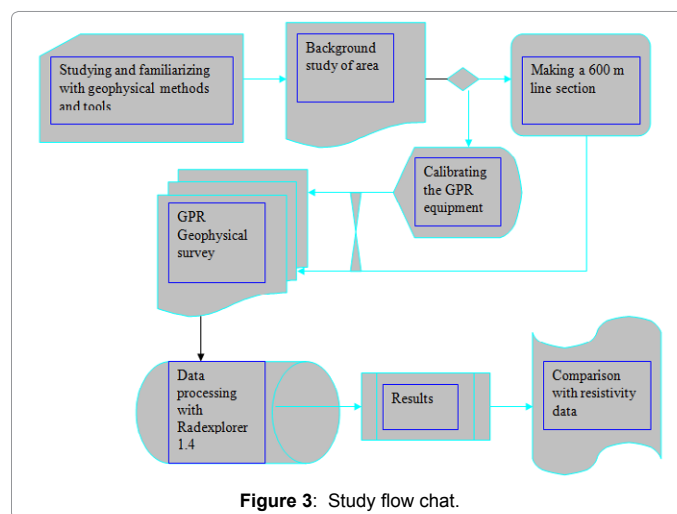
From the third 100 m distance the continuation of the clay or mixed clay and sand layer is seen pointed out by the yellow arrow, and the red oval sign points out a tree root. All other features remain similar in the preceding 120 m. Groundwater was not detected because the profile measured was only about 2 m deep which is too shallow to reach the Groundwater table (Figure 6).

Comparison with resistivity Data

Measurements made using the Resistivity geophysical method produced a similar result with that of GPR, as can be seen below. The results from the GPR data are more or less similar to that of resistivity,

Material	ϵ_r	v
Air	1	0.30
Ice	3-4	0.16
Fresh water	80	0.033
Salt water	80	0.01
Dry sand	3-5	0.15
Wet sand	20-30	0.06
Shale and clay	5-20	0.08
Silts	5-30	0.07
Limestone	4-8	0.12
Granite	4-6	0.13
Dry salt	5-6	0.13

Table 1: Typical values of some radar parameters for some materials [4].



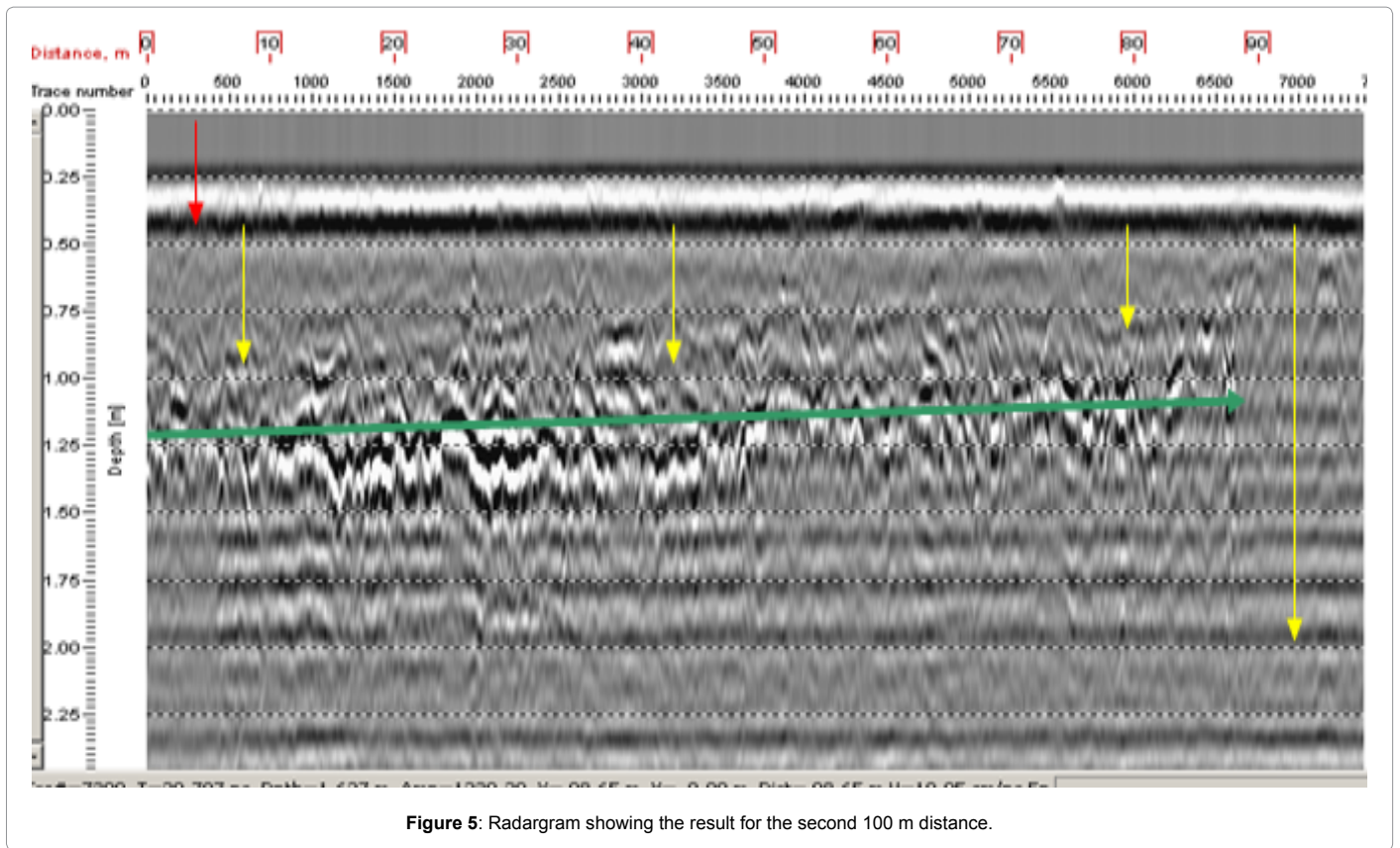


Figure 5: Radargram showing the result for the second 100 m distance.

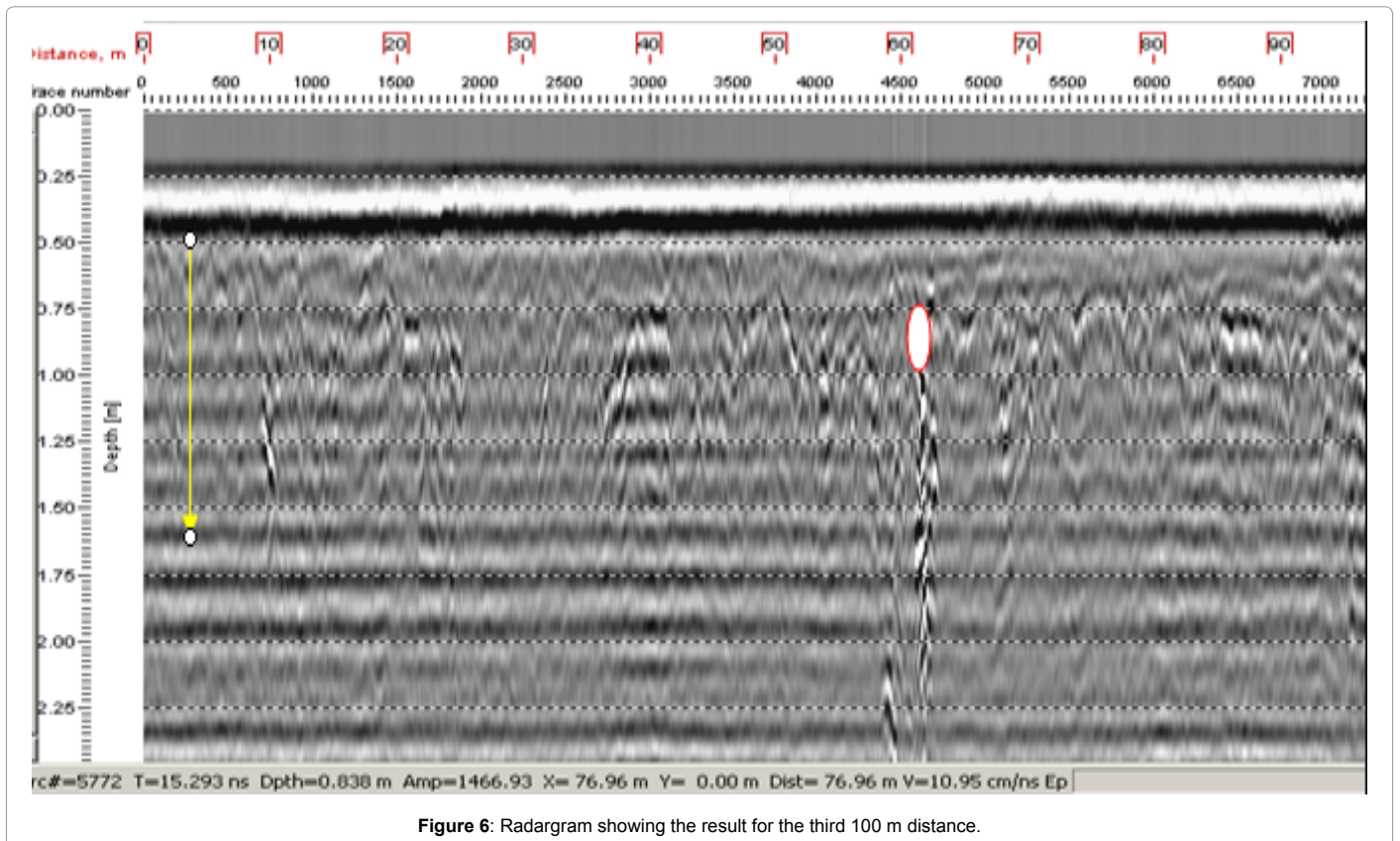
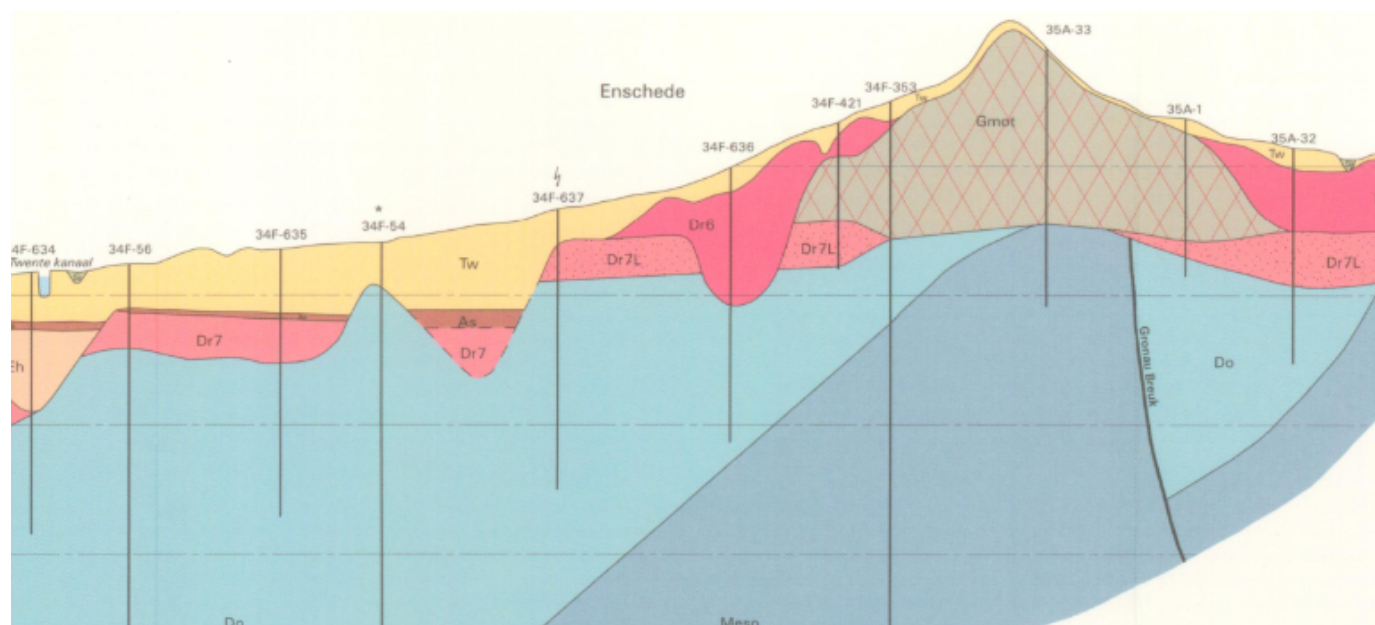


Figure 6: Radargram showing the result for the third 100 m distance.



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Formatie van Twente
Twente Formation

Tw Zand, zeer fijn en matig fijn, soms matig grof, plaatselijk met leem of veen
Sand, very fine and moderately fine, sometimes moderately coarse, locally with loam or peat

Formatie van Asten
Asten Formation

As Klei, leem, veen, met dunne matig fijn- en matig grof zandlagen
Clay, loam, peat, with thin layers of fine and moderately coarse sand

Formatie van Eindhoven
Eindhoven Formation

Eh Matig fijn- en grof zand, plaatselijk met leem of veen
Moderately fine and coarse-grained sand, locally with loam or peat

Formatie van Drente
Drente Formation

Dr6 Grondmorene (grindhoudend lemig zand en zandige leem [keileem], soms grof, grindhoudend zand. Met stenen en blokken)
Till (gravelly, loamy sand and sandy loam [boulder clay], sometimes coarse, gravelly sand. Cobbles and boulders)

Dr7 Fluvioglaciale afzettingen (grindhoudend matig grof tot uiterst grof zand, met klei- of leemlagen)
Glaciofluvial deposits (gravelly, moderately coarse to very coarse sand, with clay or loam layers)

Dr7L Fluvioglaciale afzettingen, grindig (grind en sterk grindig zand)
Glaciofluvial deposits, gravelly (gravel and very gravelly sand)

Dr7L Fluvioglaciale afzettingen, Zanden van Lonneker (grindhoudend grof zand)
Glaciofluvial deposits, Lonneker Sands (gravelly, coarse sand)

Dr8 Lacustroglaciale afzettingen (matig fijn- tot matig grof zand, met kleilagen)
Glaciolacustrine deposits (moderately fine to moderately coarse sand, with clay layers)

Dr7L Fluvioglaciale afzettingen, Zanden van Lonneker (grindhoudend grof zand)
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Glaciolacustrine deposits (moderately fine to moderately coarse sand, with clay layers)

Ur2 Formatie van Urk2, (grof, grindrijk zand, met grindlagen)
Urk2 Formation (coarse, gravelly sand, with gravel layers)

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Urk2 Formation (coarse, gravelly sand, with gravel layers)

Figure 7: The Geological map of the study area.

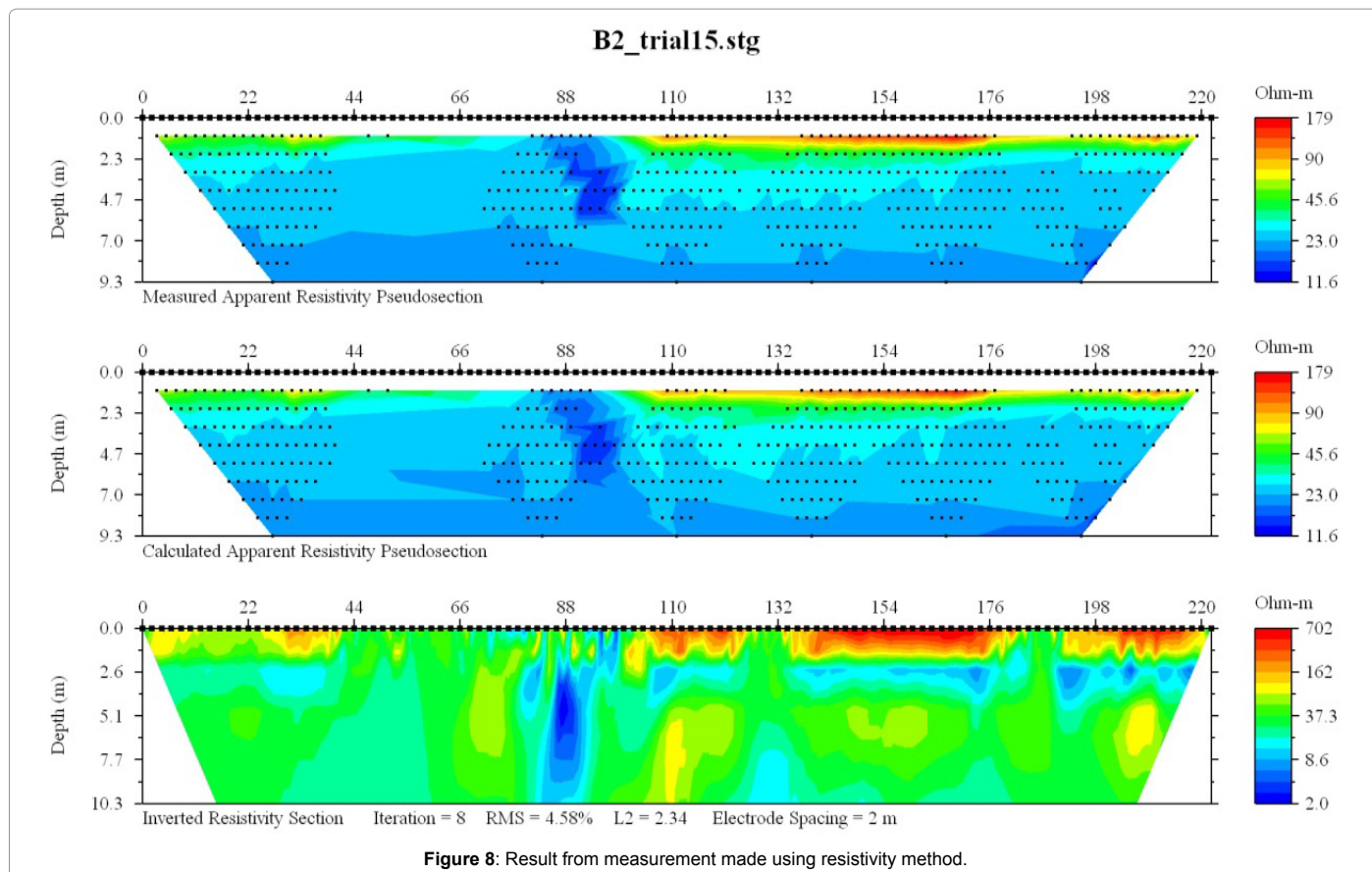


Figure 8: Result from measurement made using resistivity method.

looking at the inverted resistivity section the top 1 m depth has a higher resistivity value showing possible sand, and shows a lower resistivity at the 2.6 m depth denoting possible clay and it can be see that there is a significant change in the resistivity values at about 187 m distance showing possible clay or a mixture with sand, all these reflect the same trend in the GPR data as illustrated and explained in section 4 (Figures 7 and 8).

Conclusions

Because of the shallow depth of penetration which was about 2 m the groundwater table was not accounted for in this project, but generally from the study and similarity in the results from the different

methods it is evident that GPR and other geophysical methods are efficient and accurate for geophysical exploration.

References

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