

Static Electrode DC Resistivity Measurement at Surface Water for Pond Subsurface Layer Imaging

Sumintadireja P¹ and Irawan D²

¹Applied Geology Research Group, Faculty of Earth Science and Technology – Institut Teknologi Bandung.

²Graduate Program in Geophysical Engineering, Faculty of Mining and Petroleum Engineering – Institut Teknologi Bandung.

E-mail: prihadi@gc.itb.ac.id

Abstract. Resistivity methods in marine applications show slightly different processing techniques from land based resistivity surveys. Special DC resistivity instruments need to overcome difficulties in arranging the electrode with straight array lines and position. Some geoelectrical instrument manufacturers developed equipment which is able to measure resistivity values and positions in real time. In this paper we demonstrate an application of ordinary geoelectrical instruments for resistivity acquisition in water environment. This study is motivated by the inability to apply conventional DC resistivity instruments in water environment. Land resistivity survey array is arranged on the surface of water using static electrode mode. The method has been tested in various environments, such as ponds/lakes with quiet until rough waves and also measurements at coastal environments. Measurement at the ponds/lakes water environment resulted in data that are almost identic to the measurements obtained using standard land DC resistivity method. On the other hand the measurement in coastal environment does not work properly, possibly due to the lack of power source.

1. Introduction

Geo-electrical measurement uses a multi-electrode system and 2D resistivity inverse modelling can infer the subsurface resistivity structure well. Not only measurement at the ground can be done but also in the water. Electrical resistivity investigations applied in marine environments can be found since the mid-1930s [1] and mid-1980s [2]. Since then, applications for resistivity in marine environmental have spanned a wide array of problems that mostly mimic terrestrial applications, but with a few that are unique to the marine setting [3]. Special DC resistivity instruments need to overcome difficulties in arranging the electrode with straight array lines and position. Several commercial instruments are available for acquiring DC resistivity for marine, which primarily need the ability to automatically log voltage data for a given electrode array which is able to measure resistivity values and positions in real time. Most modern equipment also has the ability to accept GPS data to help georeference each measurement. Supported by these advanced tools some experts have research about geological mapping using marine resistivity data (e.g. [4] and [5]) and also about submarine groundwater discharge ([6] to [9]).

¹ To whom any correspondence should be addressed.



This paper describes the application of conventional geoelectrical measurements, which usually are applied to the land, for resistivity data acquisition in water environment. However the limitation of this method is that it must be ensured that the electrode is in static mode.

2. Method

There are two kinds of methods to arrange the electrodes in the static mode. First, the acquisition of resistivity in aquatic environments can be conducted at the water surface with floating electrodes (e.g. [10] to [12]) but the tip of each electrode needs to be tethered to fixed floating electrodes (Figure 1a). Second, placed submerged at the floor (Figure 1b), as has been done by Toran et al. [13]. Both strategies are typically used in conjunction with 2D subsurface layer imaging using DC resistivity conventional instrument.

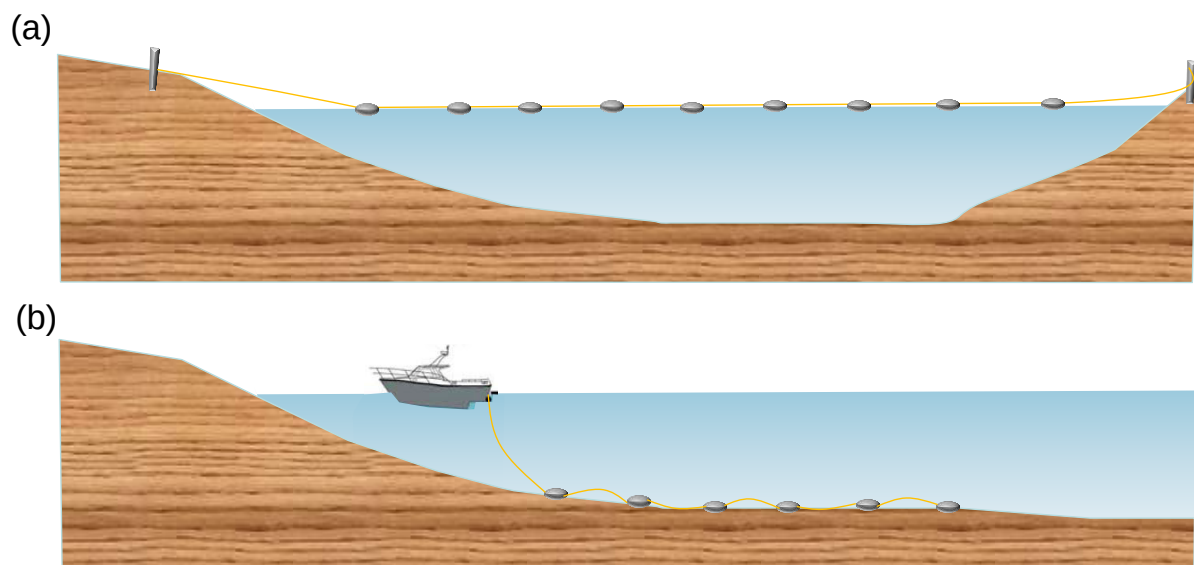


Figure 1. Two techniques to arrange electrodes in static mode

In this study, we use the first method to measure 2D DC resistivity at surface water for pond subsurface layer imaging in the artificial ponds at Eastern Bandung, West Java, Indonesia. The pond is located in the vicinity of housing residents. More than 3000 local households liquid waste empty in this pond.

The survey is planned to follow a line as designed Figure 2. There is overlap between land and water in the measurement to see the response / model between water and soil characters. Fixed floating electrodes shown in Figure 3. 48 electrodes with the smallest electrode spacing of 1.5 meters (total length 70.5 m) were used to perform measurements of 2D resistivity data. Twenty two electrodes placed in the water (floating) and another 26 electrodes at the land. We perform measurements in three configuration arrays (Wenner alfa, Wenner-Schlumberger and dipole-dipole [14]) in the same electrode position to get more convincing data.

The data was processed with two-dimensional inversion by RES2DINV [14] to determine conductive or resistive bodies along the line. At the time of modelling there are no constraints, such as the bathymetry and conductivity of the water, in the inversion process to help resolve issues at the water–rock interface. The parameters used in the inversion are the same as with measurement in the land.

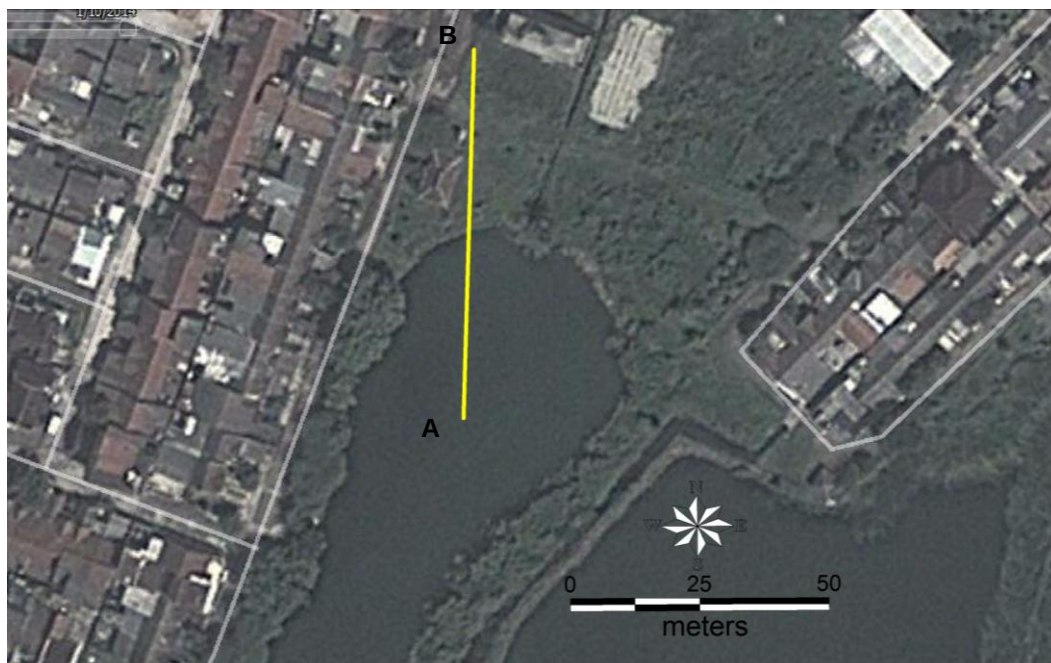


Figure 2. 2D DC resistivity line overlap pond



Figure 3. Photos of fixed floating electrodes.

3. Result and Discussion

Figure 4 shows the inversion results of three different configuration arrays. Figure 4(a) is a model of the measurement using Wenner-alfa, Figure 4(b) from Wenner-Schlumberger and Figure 4(c) from dipole-dipole configuration. Every model was obtained from 5 iterations with rms error not more than 3%. Generally the three models look relatively similar in that the body anomalies have similar depth and thickness.

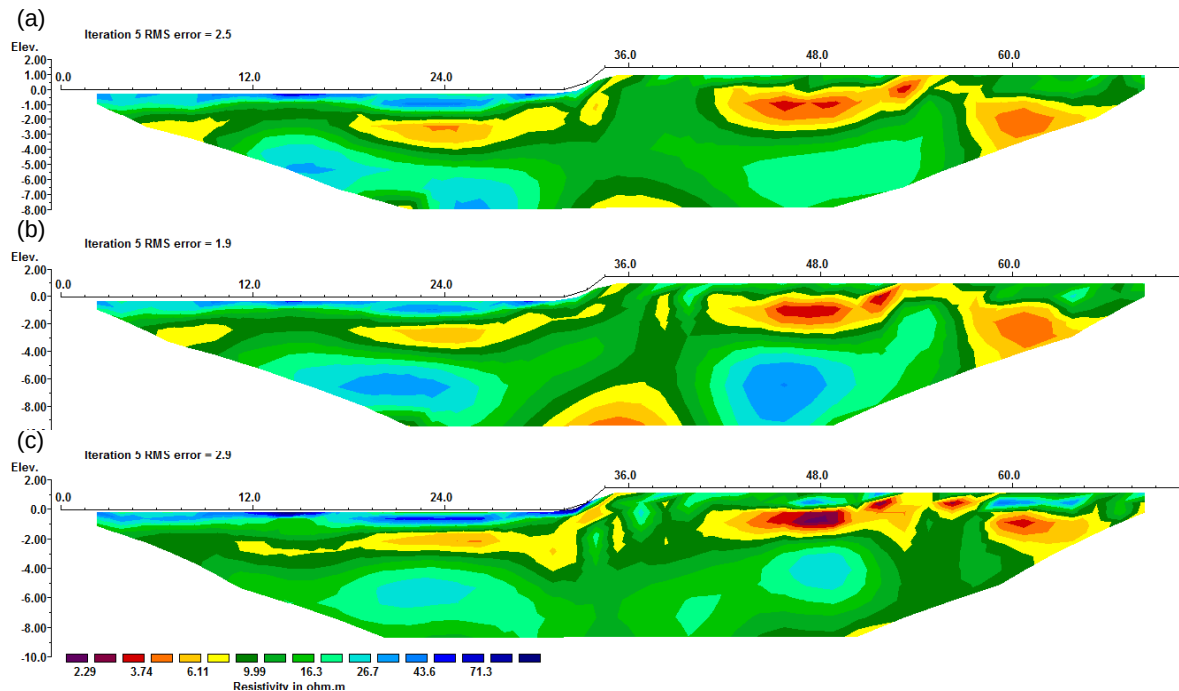


Figure 4. Models resistivity with topography for each electrode array. (a) Wenner Alfa, (b) Wenner-Schlumberger, (c) dipole-dipole configuration

Geological model interpretation was built using history-guided approach. Figure 5a shows that at the time first digging, the pond has been extracted 5 meter deep, more than 14 years ago (excavated in 2001). Next, Figure 5b, more than 15 year since the ponds has been flooded until now. The main problem of this pond is about sedimentation. Not too long after first excavation the pond has been already filled by sedimentation to a thickness of approximately 3 meters. The sedimentation came from downstream irrigation around area (Figure 5c). More than 3000 local houses empty liquid waste to the pond. It makes the water of pond more alkaline with a relatively high pH value. It is one of the reasons why the water is very resistive. On the other hand, in 2013 the local residents dug a well for getting fresh water. The location of well is at a distance of 48 meters from the DC resistivity line. The existence of fresh water made the surrounding conventional well area more conductive. The recent condition of geological model then is shown in Figure 5d. The final geological model shows good correlation with the inversion model result look.

The same method has been tested in various environments, such as ponds/lakes with quiet until rough waves and also measurements at coastal environments. The result has produced good imaging of sub-surface under area target. Unfortunately a measurement at the coastal environments does not work properly, possibly due to the lack of power source. In highly conductive seawater, higher powered systems (>1kW) are recommended to overcome the noise. Corwin et al. [2] state that 10 A of current was sufficient to overcome noise in seawater for a submerged Schlumberger array with electrode spacing maximum ($AB/2$) = 316 m.

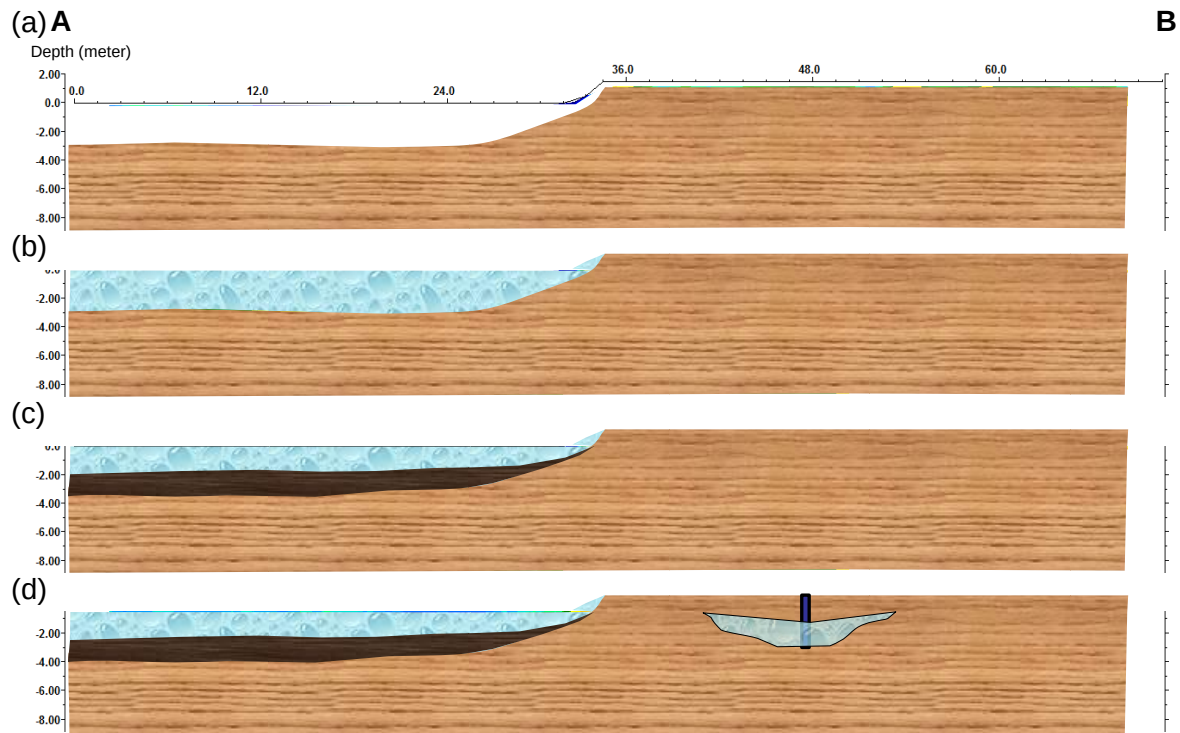


Figure 5. Geological model from history of pond. (a) Pond is extracted with 5 meter depth, (b) flooded for 15 years, (c) sedimentation from downstream irrigation around area, (d) local residents dug well (in 2013)

4. Conclusion

Static electrode DC resistivity measurement at surface water at artificial ponds has produced good imaging relation with geological model using historical approach. Measurement at the ponds/lakes water environment provided data that are almost identical to the measurements obtained using standard land DC resistivity method using low power instruments. For freshwater environments, where the resistivity values of the water column are relatively high, low powered systems (200–400 W) can be used quite effectively.

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