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Soil Salinity Profile of Marine Shrimp Aquaculture Farm : A Case Study at Banglen, Nakornpathom, Thailand

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Abstract : In this paper, the Direct Current method is used to investigate the soil salinity profile of marine shrimp aquaculture farm. Inversion process is conducted and finite difference method is used with the iterative technique to minimize the potential difference of the calculated and the measured potential to give an optimal solution rapidly. The iterative procedure is found to be robust with respect to starting models for both the synthesis and real data. The results show the conductivities for marine shrimp aquaculture farm which are vary between 0.15 S/m and 0.33 S/m. These number of conductivities indicate that the salt from marine shrimp aquaculture farm do not have much of an impact on the plant since the conductivity of the ground used for planting should be less than 0.40 S/m. Therefore, from our results imply that the land used for marine aquaculture farm and the surrounding area can be used for orchard and paddy.

Keywords : Salinity, Finite difference.
2002 Mathematics Subject Classification : 76U05, 76V05.

1 Introduction

Detection of the electrical anisotropy of geologic formation is a problem that has attracted the attention of geophysicists for many years. The motivation has varied greatly, ranging from groundwater investigation to hydrocarbon exploration [1], [6]. There are many methods were conducted to attack the problems such as Direct Current method, Electromagnetic method, Seismic method, Magnetometric method, and Magnetotelluric method. All of these methods can also be used to solve some of the related problems, for instance, the atmospheric and oceanic problems. In our study, we intend to examine the community problem at Aumphor Banglen, Nakornpathom Province, Thailand concerning agriculture (see Figure 1).

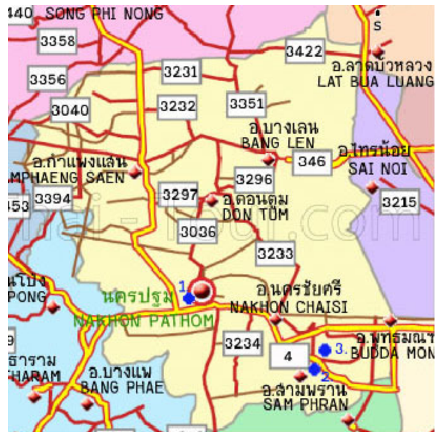

Figure 1: Map of Aumphor Banglen, Nakornpathom Province, Thailand

We conduct the algorithm by using the Direct Current method to solve the disputed problem. We have developed a numerical algorithm that computes the conductivity of the ground of marine shrimp aquaculture farm. The conductivity of the ground will be used to indicate the amount of salt and conductive mineral deposit in the ground [4]. The motivation of this study is to solve the disputed problems of the community between two groups of farmers. The first group grows rice, but the other group works on a marine shrimp aquaculture farm. The salt from marine shrimp aquaculture farm effects the environment as well as to the rice growing. In our study, the Direct Current method with the Finite difference technique is used to investigate the cross section of the ground of marine shrimp aquaculture farm. The conductivity profile of the ground will be computed to show the profile of the salt under the ground. The iterative technique is conducted for constructing the conductivity model whose calculated responses are close to the observed values. A conductivity profile satisfying the data is constructed iteratively via successive perturbation of a starting model. Two examples are performed to investigate the ground structure. The first example is set to test our algorithm and perform the stability of our work. We denote a set of synthesis potential data from the known ground structure location by using the forward problem. For the second example, we used the potential data measured from the marine shrimp aquaculture farm. In the second example, we use SYSCAL KID instrument to measure the potential data on the sites to compute the conductivity of the ground. The computation results may be used to indicate that the government should allow the people to raise marine aquatic animals inland or support only at seashore.

2 Formulation of the Problem

In this paper the method of Direct Current is used and we can represent the vector electric field $\vec{E}$ as the gradient of a scalar potential ϕ as

$$\vec{E} = -\nabla\phi,$$

where ∇ is the vector operator denoted by $\hat{i}\frac{\partial}{\partial x} + \hat{j}\frac{\partial}{\partial y} + \hat{k}\frac{\partial}{\partial z}$.

The divergence of the current density $\vec{J}$, is zero, $\nabla \cdot \vec{J} = 0$ and we can express this in terms of the electric field $\vec{E}$, using Ohm's law, $\vec{J} = \sigma\vec{E}$, where σ is the conductivity of the medium, as

$$\sigma\nabla \cdot \nabla\phi + (\nabla\phi) \cdot (\nabla\sigma) = 0. \tag{2.1}$$

To investigate the cross section of the ground, we denote $\sigma(x, z)$ as a function of two variables x and z only. Thus, equation (2.1) becomes

$$\sigma\nabla^2\phi + \frac{\partial\phi}{\partial x}\frac{\partial\sigma}{\partial x} + \frac{\partial\phi}{\partial z}\frac{\partial\sigma}{\partial z} = 0. \tag{2.2}$$

Equation (2.2) can be transformed by using finite difference method to get

$$\begin{aligned}\phi_{xz} \approx\ & \frac{(\Delta z)^2\{\phi_x(4\sigma_{xz} + \sigma_x - \sigma_{\bar{x}}) + \phi_{\bar{x}}(4\sigma_{xz} - \sigma_x + \sigma_{\bar{x}})\}}{8\sigma_{xz}\{(\Delta x)^2 + (\Delta z)^2\}} \\ & + \frac{(\Delta x)^2\{\phi_z(4\sigma_{xz} + \sigma_z - \sigma_{\bar{z}}) + \phi_{\bar{z}}(4\sigma_{xz} - \sigma_z + \sigma_{\bar{z}})\}}{8\sigma_{xz}\{(\Delta x)^2 + (\Delta z)^2\}},\end{aligned} \tag{2.3}$$

where $\phi_{xz} = \phi(x, z)$, $\sigma_{xz} = \sigma(x, z)$, $\phi_x = \phi(x + \Delta x, z)$, $\phi_z = \phi(x, z + \Delta z)$, $\phi_{\bar{x}} = \phi(x - \Delta x, z)$, $\phi_{\bar{z}} = \phi(x, z - \Delta z)$, $\sigma_x = \sigma(x + \Delta x, z)$, $\sigma_z = \sigma(x, z + \Delta z)$, $\sigma_{\bar{x}} = \sigma(x - \Delta x, z)$, $\sigma_{\bar{z}} = \sigma(x, z - \Delta z)$, and Δx and Δz are the step of grid in the x and z directions, respectively.

3 Inversion Process and Examples

To find the conductivity profile of the ground, $\sigma(x, z)$, the optimization technique is used to minimize the difference between the electric field from calculation and real data. Equation (2.3) and the boundary conditions for the potential at the edges of domain are applied to construct the matrix and compute the potential by using Pentium IV 1.6 G Hz PC computer. The iterative techniques are performed and given the solution convert rapidly. The robustness of the process is very good compared to some related works such as the work done by Fullagar and Oldenburg [3], Oldenburg [5], Yooyuanyong [7], Yooyuanyong and Siew [9], and Yooyuanyong and Chumchob [8]. The conductivity profile of the starting model for the iterative process can be chosen, without lost of generality, to be the set of non-negative values which gives the process convert to the solution rapidly. In this section, we present two examples of inversion processes. The first example, we simulate the potential data from a two layered earth model with constant conductivity profile as shown in Figure 2. The potential data on the ground surface is generated by the forward problem to simulate the set of real data. The theoretical values are perturbed by superimposing a Gaussian relative error to the three per cent level. The associated errors can be regarded as realizations of normal random variables with zero means and variances s_i^2, $i = 1, 2, 3, \ldots, m$. The boundary conditions for potential at the another three edges of Figure 2 are zeros.

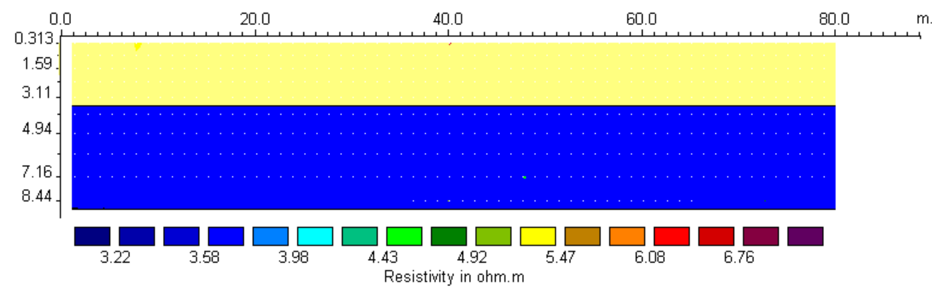

Figure 2: Cross section of a two layered model in XZ plane

Figure 3 shows the result of the conductivity profile from our iterative process. We start the model with the constant conductivity equal to 1 S/m. We see that the result is close to the true model after using 5 iterations only.

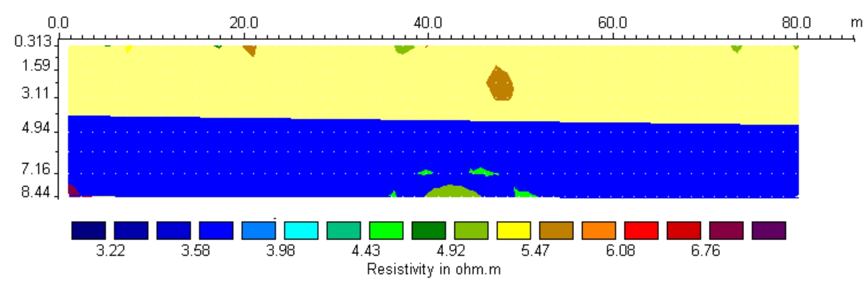

Figure 3: Cross section of the model which is calculated by using the synthesis data in XZ plane

In the second example, we collect the potential data from the ground surface of marine shrimp aquaculture farm by using SYSCAL KID instrument at Tumbol Bangluang Aumphor Banglen, Nakornpathom Province, Thailand as shown in Figure 4. The land used for marine shrimp aquaculture farm is used for more than 6 years. As same as the previous example, the boundary conditions for the potential at very far from source are set to be zero according to the inverse square law of energy and source-receiver spacing.

Figure 4: Collection of potential data using SYSCAL KID at Tumbol Bangluang, Aumphor Banglen, Nakornpathom Province, Thailand

The iterative technique performs quite well and the results are shown in Figure 5. The figure 5 shows the conductivity of the cross section of the ground. At the location of blue color, the conductivity of the ground is about 0.33 S/m but at the location of red color, the conductivity of the ground is around 0.15 S/m. We found that the rice paddy and orchard can grow in this conductive area since the conductivity of the ground used for planting should not more than 0.40 S/m (Department of Mineral Resources, n.d.). However, we note that the saline soil affects to the amount of rice product.

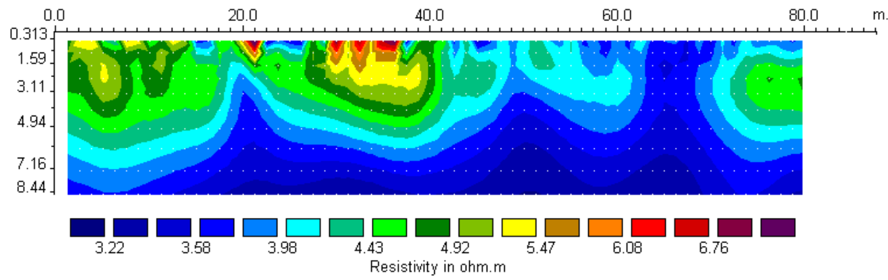

Figure 5: Cross section of marine shrimp aquaculture farm in XZ plane

4 Conclusions

In this paper, we perform the method to investigate the conductivity profile of the saline ground at the marine shrimp aquaculture farm. The Direct Current method is used with the iterative technique to minimize the difference of the calculated and the measured potentials. The optimization technique is used to construct iterative procedure. The method shows the results of conductivity profile of the cross section of marine shrimp aquaculture farm. Figure 5 shows the conductivity profile of the marine shrimp aquaculture farm using difference color. The color of the figure represents the conductivity of the ground and it varies from red, yellow, and blue where the color mainly is blue and the conductivity varies from 0.15 to 0.33 S/m. In this range of conductivity profile of the ground, it can be used for planting. We found that the salt concentration used from marine shrimp aquaculture farm do not effect much for the orchard and paddy. The tree can grow very well but the product of them may decrease.

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