# ELECTRO-SEISMIC SURVEYS APPLIED TO MODDELING OF GROUNDWATER FLOW SYSTEMS

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**Abstract.** Understanding of a ground flow system requires knowledge of the layering information together with the water strike positions. This is accomplished by using an electro-seismic survey before any drilling has taken place. The conceptual model is then used in aquifer management, protection and the strategic placement of boreholes. Typical results are presented for illustration purposes.

**Keywords:** electro-seismic survey, subsurface features, water strikes, conceptual model

## 1 INTRODUCTION

Accurate modelling of a ground flow system requires knowledge of the subsurface features. Through the use of an electro-seismic survey a conceptual model can be constructed of the subsurface features before drilling takes place. The features of interest are layering information and water strike positions. With this information available the boreholes can be placed more strategically for pump test analysis to determine the aquifer parameters used in the model. Results of two case studies are presented to demonstrate the current capability of the system.

## 2 ELECTRO-SEISMIC EFFECT

### 2.1 Background

The electro-seismic effect describes the conversion from seismic to electromagnetic (EM) energy. Several mechanisms are likely to generate couplings between seismic and EM energy in the subsurface (Garambois *et al.* (2002)). The main effects of interest to geophysicists are electrokinetic and piezoelectric phenomena and variations in electrical resistivity.

The macroscopic governing equations were derived from first principals by Pride (1994) which coupled Biot’s theory and Maxwell equations via flux/force transport equations. In this theory the coupling mechanism is explained by electrokinetic effects taking place at pore level.

### 2.2 Wave Behaviour

A seismic wave propagating in a medium can induce an electrical field or cause radiation of an electromagnetic wave. There are two electro-seismic effects that are considered in this paper (Oleg *et al.* (1997)).

The first effect is caused when a seismic wave crosses an interface between two media. When the spherical P-wave crosses the interface, it creates a dipole charge separation due to the imbalance of the streaming currents induced by the seismic wave on opposite sides of the interface. The electrical dipole radiates an EM wave which can be detected by remote antennas as shown in Figure 1.

The second effect is caused when a seismic head wave travels along an interface between two media. It creates a charge separation across the interface, which induces an electrical field. This electric field moves along the interface with the head wave and can be detected by antennas when the head wave passes underneath as shown in Figure 2.

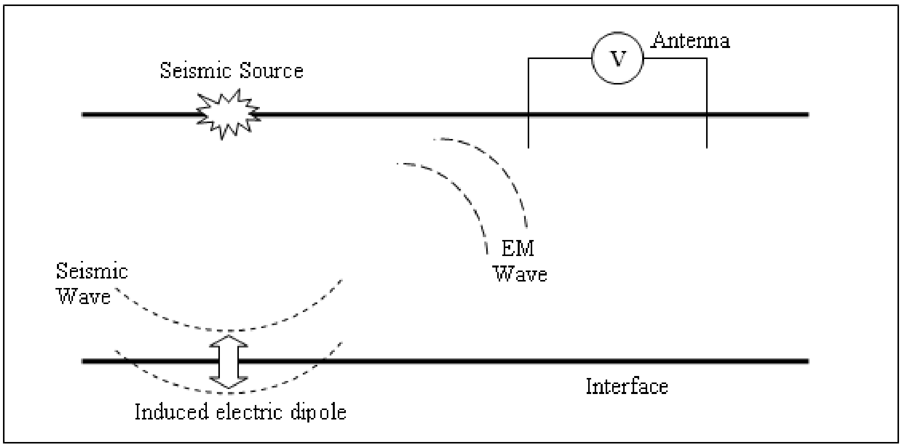


***Figure 1****: Seismic wave crossing an interface generating an electromagnetic wave.*

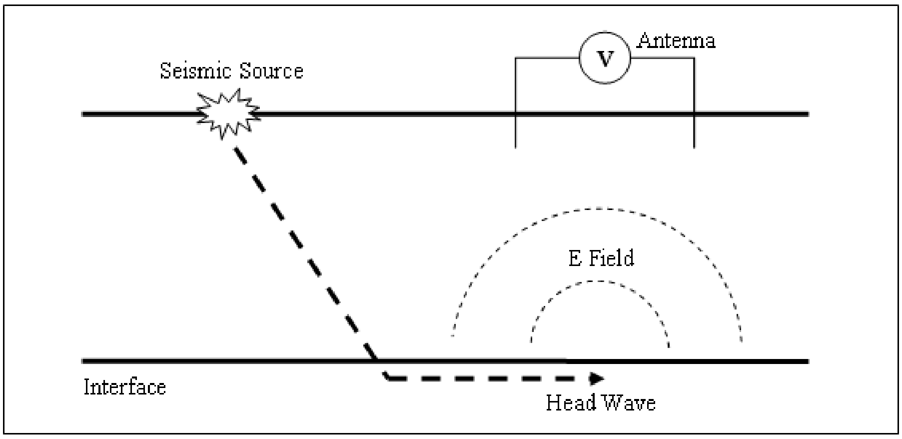


***Figure 2:*** *Head wave travelling along an interface generating an electric field.*

## 3 METHODOLOGY

Two methods are used to analyse recorded data. These methods are discussed in the sections below.

### 3.1 Numerical Model

The first approach in analysing the recorded signals was to setup a numerical model that simulated the electro-seismic effect. A ray path model, using the generalized matrix method to solve the governing equations, was setup for this purpose. Problems experienced were the instability of the model for certain inputs and the fact that there was little correlation between the simulated and recorded data.

### 3.2 Quantative Approach

The second approach taken was a quantative one where surveys were done before drilling took place without making any recommendations with respect to the ESS survey results. After drilling all borehole logs and water strikes were recorded. By doing this the authors could gather enough data to develop an analysis technique that provides accurate results.

## 4 CASE STUDIES

Results of two case studies are presented here to illustrate the capability of the electro-seismic survey. These case studies are independent of each other and illustrate two different result sets obtained from an electro-seismic survey.

## 4.1 Sited Borehole

The purpose of this survey was borehole siting. A vertical profile was done across the area of interest and the position that had the best response was chosen. An average seismic velocity typical to the area was used to do the depth scaling. The processed electro-seismic signal is shown on the right hand side of Figure 3. During drilling the borehole log was constructed (left hand side Figure 3) and all water strikes recorded.

For illustration purposes there were no corrections made to the initial seismic velocity used for depth scaling. From Figure 3 it is clear that the first water strike was predicted quite accurately. The second strike prediction was inaccurate with 5m. The reason for this is that a constant seismic velocity was assumed with depth, but it is known that seismic velocities vary according the transmission medium.

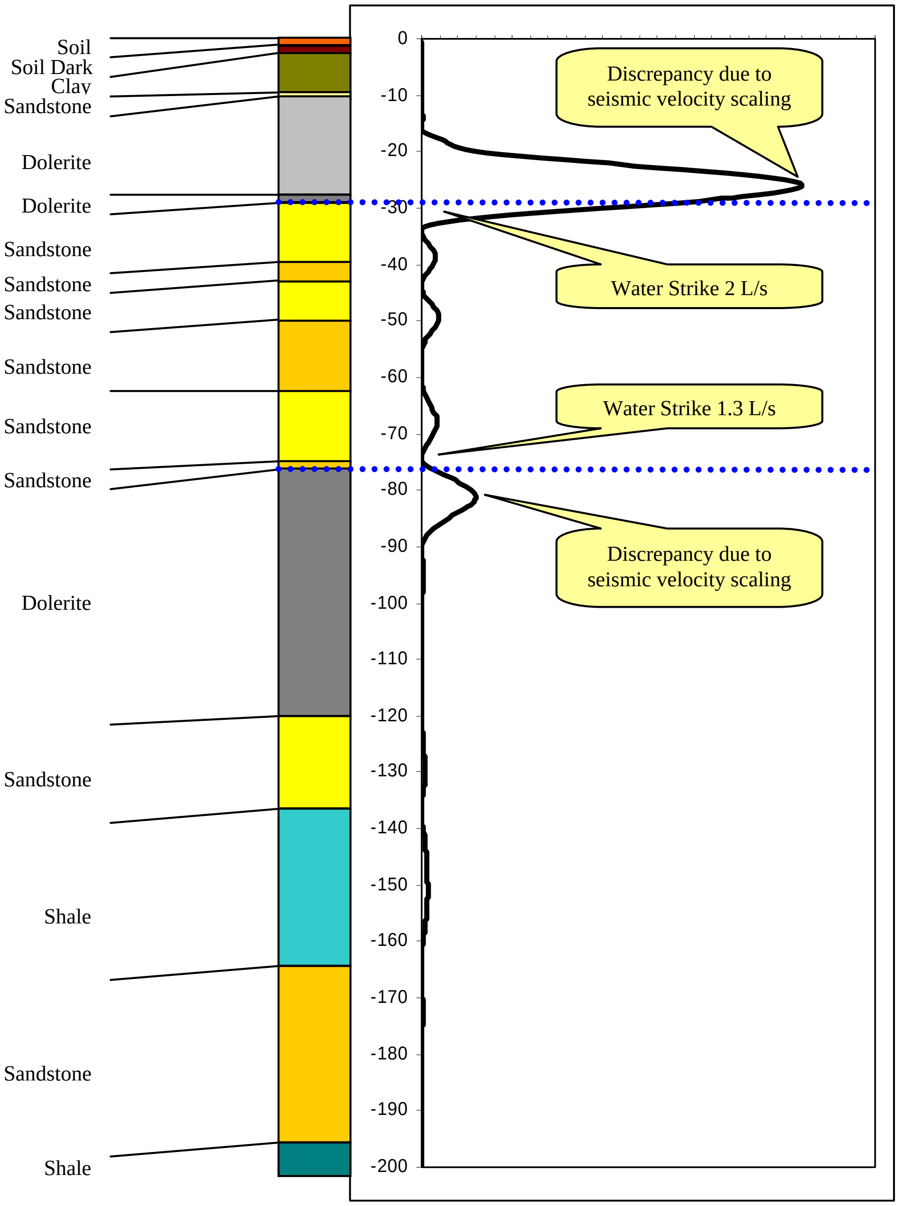


***Figure 3:*** *Processed electro-seismic signal and borehole log comparison.*

In this particular survey the largest anomaly on the processed signal represented the main water strike. It is important to note that various surveys have shown that the largest anomaly does not necessarily represent the main water strike. Some of the reasons for this are that the type of interface effects the signal response, the seismic wave attenuates with depth and seismic energy dissipates due to the seismic to electromagnetic conversion.

### 4.2 Salt Pan

The purpose of this survey was to determine the thickness of the clay layer in a salt pan. A vertical profile starting 60m away from the edge of the pan and moving closer to the edge of the pan was conducted. Visual inspection of the area confirms that the top layer is a clay layer. From the layer plot shown in Figure 4 it is clear that the clay layer is about 1.5m thick if a seismic velocity of 4000 m/s is assumed. Accurate velocity scaling can only be done once a borehole log becomes available. The layer plot shown in Figure 4 provides valuable information to the hydrogeologist in setting up a conceptual model before any drilling has taken place.

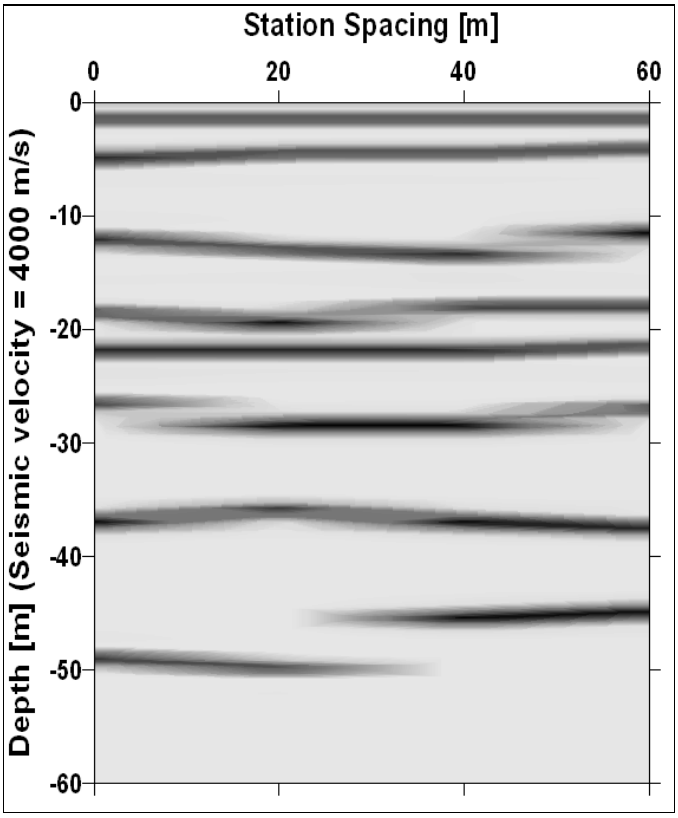


***Figure 4:*** *Salt pan layer features.*

## 5 CONCLUSIONS

From the results it is clear that the electro-seismic survey does provide accurate results if the correct seismic velocity is used for depth scaling. The electro-seismic survey provides valuable information regarding possible water strike positions and physical layering of the media, but no successful yield estimation can be done to date. This information can be used to construct a conceptual model of the subsurface for aquifer management, protection and to strategically place boreholes.

## 6 REFERENECS

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