Aquares:

A geophysical method for exploration of marine and fluvial sediments.

The Aquares Resistivity System (ARS) is a high resolution geophysical method modified from the proven principles and methods of land based geoelectrical survey. The ARS includes enhanced acquisition and processing techniques that provide quantitative (i.e. depths and thicknesses) and qualitative (i.e. quality or resistivity) data for sub-bottom strata. It has brought resistivity to the forefront of fluvial and marine sub-bottom investigations. This document explains why the ARS is the superior choice for shallow sub-bottom surveys in most circumstances over conventional acoustic systems.

1. INTRODUCTION

The ARS is a sub-bottom acquisition system that uses resistivity techniques modified from traditional land based systems to provide high resolution quantitative and qualitative data of both consolidated and un-consolidated sub-bottom strata. Quantitative data (commonly acquired from Acoustic reflection systems) is defined as data relating to depth and thicknesses of sub-bottom structures. Qualitative data is defined as data that relates to the quality of the observed structures (e.g. sand, silt or clay in the case of sediments and rock quality, fresh or weathered in the case of rocks). The unique ability of the ARS to provide qualitative data is extremely useful for dredge and trenching operations. Utilising ARS results engineers have a complete picture of the existing sub-bottom environment. This allows (e.g. port) designs to take into account existing sub-bottom structures such as paleo-channels as well as weathered and un-weathered rock outcrops to considerably reduced dredging and construction costs. Deployment methods have also been refined to allow the ARS to be deployed as a standalone system or in concert with other geophysical systems.

2. PRINCIPLES

Both the acquisition and processing methods of the ARS have been modified from traditional land based resistivity, the background of which is detailed here.

2.1. Land Based Applications

In traditional land-based resistivity surveys, an electrical current is injected into the sub-surface by means of two current electrodes or a Current Electrode Pair (CEP). The voltage gradient associated with the electric field of the injected current is measured by a Voltage Electrode Pair (VEP) placed between the CEP (Figure 1). Based then on the values of current and voltage measured between the VEP, the average or Calculated Resistivity (CR –

measured as Ohmmeter (Ohmm)) for the volume of subsurface between the VEP is determined to the limit of penetration. Penetration is largely determined by the distance between the CEP. Therefore, multiple CEPs are placed at increasing distances about the VEP to cover a range of depths. The result is a field curve (Figure 1) that reflects the changing CR from each CEP. In this example, the CR for CEP 1 (Point 1) has returned a relatively low CR that rises quickly (points 2 to 3, etc). This is typical of a thin layer of soft sediments overlying rock. The above described field curves are then the basis for a qualitative assessment of the sub-surface geology.

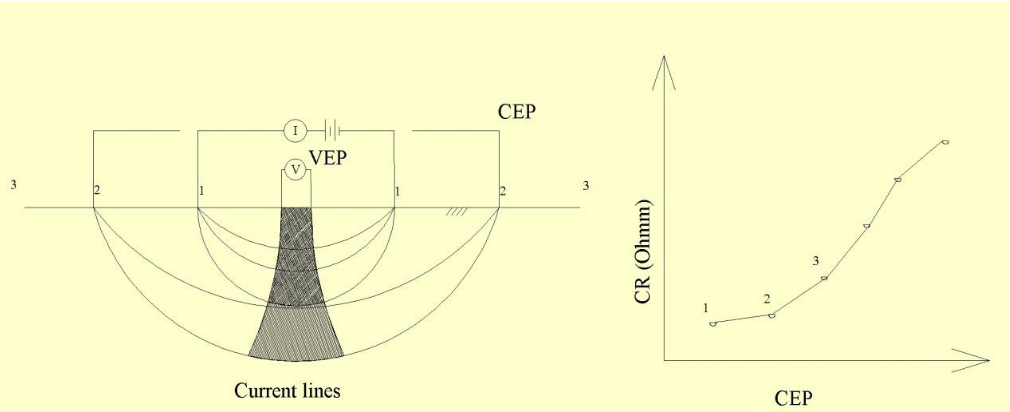

Figure 1 Principles of Vertical Electrical Sounding – On land. Left: a typical land base setup for a resistivity survey. The VEPs are placed between the CEP. Current and voltage measured at the VEP is used to derive the Calculated Resistivity (CR). Right: a typical resistivity curve for a given injection of current as a function of CEP (X axis) and CR (Y axis).

The CR of a geological structure depends on its porosity, water saturation and the water resistivity. Gravel usually has a lower porosity than sand and its resistivity thus is higher. Clay with generally very high porosities shows very low resistivities. Conversely, solid rock has a low porosity resulting in very high resistivities. Every geological structure therefore has a unique resistivity.

2.2. Fluvial and Marine Applications

For fluvial and marine based applications the CEP's and VEP's are placed in a multichannel cable trailing behind the survey vessel (Figure 2). According to the circumstances the cable may be floating or towed on the seafloor. A floating cable may be more efficient in shallow water or if obstacles on the seafloor hamper the use of a bottom towed cable however, a bottom towed cable provides far better resolution and is therefore preferred. The electrode geometry is chosen such that good quality data may be obtained even for shallower targets.

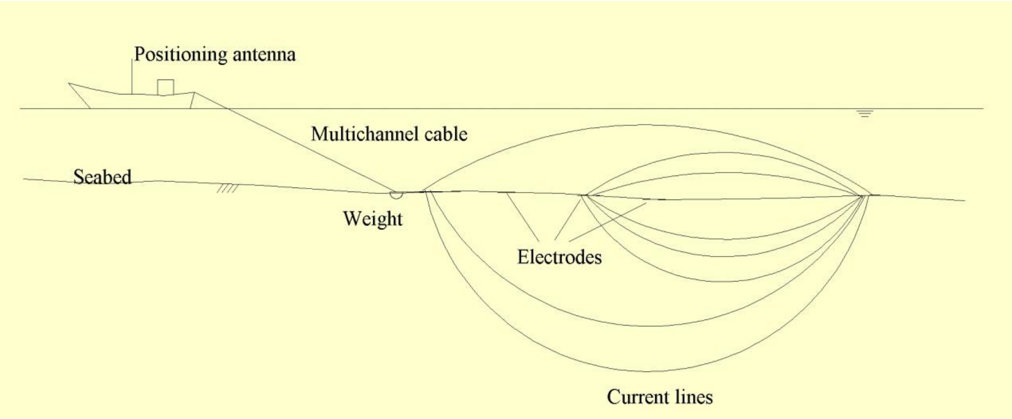

Figure 2 Principles of Vertical Electrical Sounding – On water

While the survey vessel is underway measurements are carried out and stored automatically without any intervention from the operator. As such, an electrical sounding is be obtained every 2.5 seconds. At a boat speed of 2 m/s this corresponds to a horizontal resolution of 1 sounding every 5 meters. In applications concerning the exploration of alluvial diamonds this resolution may be needed to detect smaller diamond bearing “potholes” and buried channels.

A typical marine setup comprises a generator (3 phase, 400V), acquisition and control laptop, power regulator, switch box, signal controller, navigation control laptop, DGPS unit, single beam echo sounder, Conductivity Temperature and Depth (CTD) sensors, an umbilical and a resistivity cable (approximately 60m in length). The system then collects Resistivity, depth (via a single beam echo sounder) position and conductivity data. Resistivity is collected on the acquisition and control laptop while position and depth is displayed and collected on the navigation laptop. GPS time is delivered to both the navigation and acquisition computers and used to synchronise time system wide. Each single resistivity measurement is then tied to GPS time and later merged with navigation, depth, CTD and tidal data.

During the field survey qualitative results are shown on the acquisition computer. The quality of the field data may thus be monitored on line so the operator can intervene to adjust and optimise the survey parameters.

2.3. Data Processing and Interpretation

Many current land and marine resistivity systems simply provide a qualitative assessment. However, the ARS has unique and proprietary modelling tools that enable the system to enhance qualitative and derive quantitative results from the field curves. Processing is undertaken through a sequence of operations in a two stage process: Field processing and final processing undertaken in the processing office.

2.3.1. Field Processing

First, the resistivity field data are edited and filtered to improve the signal/noise ratio. The bathymetric and positioning data are edited (cleaned) and if required, tides applied. The resistivity, positioning and bathymetric data are then combined.

Geometrical corrections are then applied to remove instances where the sailed line (including the cable) may show significant curvatures. Additional corrections are made to account for the water depth and changes in salinity throughout the water column.

This then allows Demco and the client to have confidence in the coverage and data prior to demobilization from the field.

2.3.2. Final Processing

After field corrections have taken place post processing and interpolation of the collected data occurs off site. The resistivity data is interpolated onto a regular grid providing vertical and horizontal sections. Interpolation of the resistivity data is undertaken utilizing proprietary Demco software. Results are visualised in colour on cross sections showing the different geological structures as a function of depth and geographical position (Figure 3). At this stage, if available, the results may be calibrated with information from a limited number of boreholes in order to verify and sample each geological structure.

Reasonable qualitative and quantitative estimates of the sub-bottom strata will be achieved in the absence of boreholes. However, when engineering studies are required, particularly for the characterization of rock and sediment types boreholes are considered essential. If a geotechnical survey is to be conducted after an ARS survey, Demco is able to provide advice on the number and location of Boreholes required to compliment the survey.

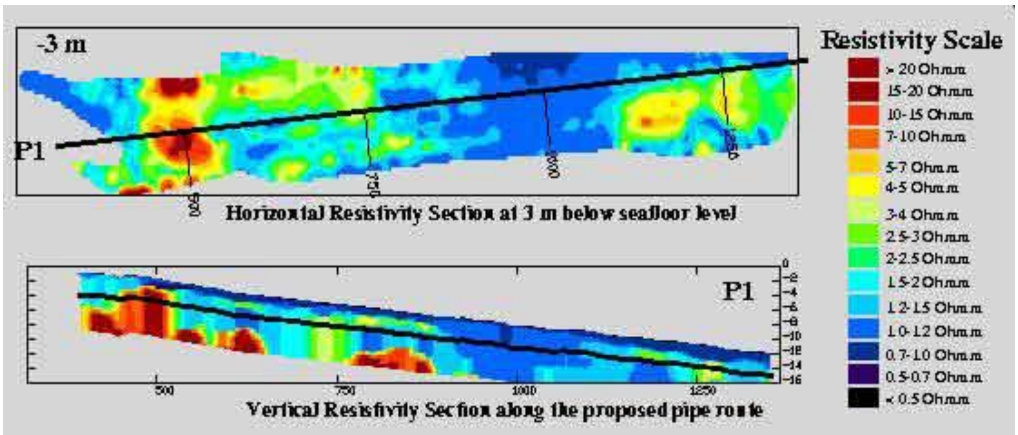

Figure 3 Horizontal and vertical resistivity sections from a pipe route survey in Ireland.

If the survey design provides for sufficient density of data, a 3D representation (model) of the subsurface may be constructed. Vertical cross sections and horizontal slices may then be extracted in all possible directions and levels

(Figure 3). The processing software also includes a module to calculate volumes of each structure found as a result of the Aquares survey.

2.4. Advantages

The ARS is an invaluable part of any marine construction project. It allows the user to minimize the number of boreholes and tailor designs to utilize existing geological structures (Figure 4). The ARS provides superior quantitative and qualitative results to traditional acoustic geophysical systems and is able to operate in geological and environmental conditions that would prevent the operation of acoustic systems.

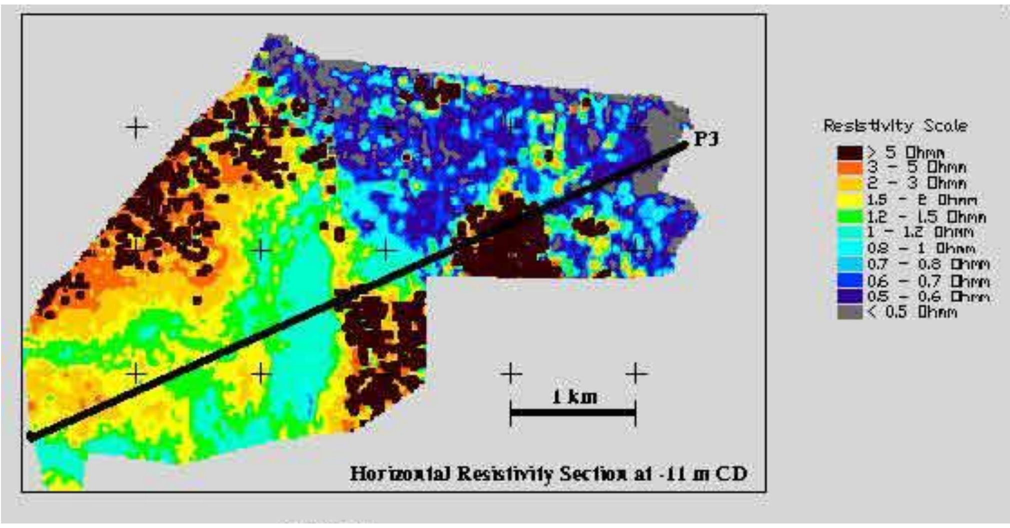

Figure 4 The results of the JNPT port pre-construction survey allowed engineers to visualise the sub-bottom structures and take advantage of the paleo-channel (light blue) and paleo-delta areas (dark blue) to locate channels and vessel turning areas resulting in substantially reduces dredging costs.

2.4.1. Geotechnical Surveys

The high information density obtained with the ARS allows for quicker and more accurate mapping of the study area when compared to geotechnical surveys. Compared to drilling, the ARS method has the advantage that a much larger volume is being sampled by a single sounding. The subsurface volume sampled by a borehole corresponds exactly with the borehole diameter (a few centimeters), while the volume sampled by each electrical sounding may in some cases exceed 5 or 10 m in diameter. As such, the resistivity technique are more suitable for determining horizontal variations of sub-bottom structures as well as various degrees of fracturing and weathering in rock. As discussed, an ARS survey does benefit from a limited number of boreholes to provide ground truthing, particularly in the case of engineering studies.

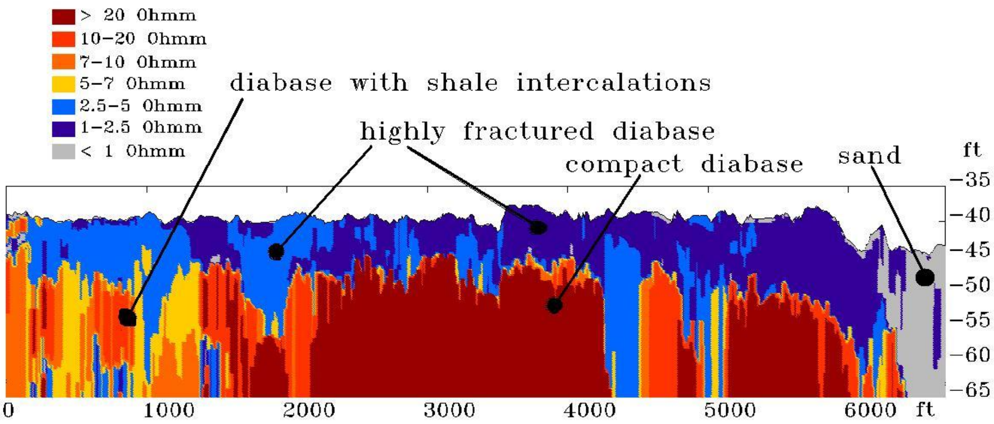

Figure 5: Highly fractured rock overlying less fractured rocks as a result of previous blast dredging.

2.4.2. Acoustic Geophysical Surveys

Classical acoustical methods for shallow sub-bottom surveys are often limited by prevailing geological and environmental conditions, these include:

- The presence of gravel in the subsurface tending to obscure information due to the appearance of diffractions.
- The occurrence of multiple reflections in shallow water that obscure real data.
- The possible occurrence of “gas masking” occurring in sediments rich in organic matter.
- The presence of strong shallow reflectors such as “cap rock” tending to reflect almost all acoustic energy preventing the exploration of lower geological formations.

Due to the nature of geo-electrical methods, the above mentioned effects do not cause problems in an Aquares survey. Furthermore, the results of an Aquares survey not only provide depths and thicknesses, but information about the nature (resistivity) of the geology (sediments and rock) including instances where soft or extremely soft sediments underlie compacted sediments or rock.

Compared to more traditional existing geo-electrical systems, Aquares has a remarkably high sampling rate (down to 2.5 seconds per sounding). This is combined with the use of 3000 fold stacks, high electrical currents, signal enhancing electrode configurations, noise free electrode design and newly developed statistical techniques to provide excellent signal/noise ratios. In addition, proprietary processing algorithms result in a significant increase of the vertical resolution of the shallower geological structures.

3. SURVEY PROCEDURES

Based on geological information supplied by the client a noise evaluation is carried out to define the maximum resolution and penetration depth expected.

If the conditions appear to be suitable for the geoelectrical survey to be successful the survey project is accepted.

A typical Aquares survey involves the following steps.

Phase 1: Preparations.

Based on the information provided by the client concerning water depth, depth of interest, exploration targets, general geology, geography and specific details concerning the local situation, survey parameters are determined and a multichannel cable is designed and constructed. Each project requires a cable to be designed and constructed to meet the requirements imposed by each specific survey site.

Phase 2: Geophysical survey.

A typical survey crew consists of 2 or 3 geophysicists and the ARS comprising Laptops, acquisition software, power supply, accessories, multichannel cable, positioning and sounding gear and spare parts. The positioning system and echosounder may be supplied either by Demco or by the client. The vessel with sailing crew is supplied by the client. The vessel should contain a shelter for the equipment and should offer a minimum of work space. The fieldwork of a typical Aquares survey is usually carried out in close cooperation with the client. Good communication with the client during the survey increases the efficiency by offering the flexibility to adjust survey strategies according to local field conditions.

Phase 3: Data processing and interpretation.

After the field survey data is processed following the procedures explained above (Section 2.3). The data may be calibrated based on additional information (eg bore holes) supplied by the client.

In most cases subsequent drilling operations may be planned. Structural geological knowledge obtained from the Aquares survey allows borehole locations to be planned in a justified and systemic way reducing drilling costs to a minimum.

The data processing results in a final report containing the following items:

- A description of the exploration targets.
- A description of the applied method.
- A discussion of the survey results.
- The data interpretation.
- The volumes of each geological structure.
- A conclusion including a number of recommendations.
- A number of figures and maps (according to the nature of the application).
- Map of the sailed lines.
- Bathymetric map (colour coded and/or 3D-visualization).
- Thickness maps for each geological structure.

- Topographic maps of specific horizons (top bedrock, ...).
- Colour coded and/or 3D-visualization (if applicable). and
- Vertical and horizontal interpreted cross sections.

On the client's request the report may be presented in a separate meeting.

4 Conclusion

The Aquares sub-bottom system provides a unique sub-bottom acquisition system that is usually operated in water depth of up to 150m. The system is tailored to each job and will usually work in weather conditions in which the client provided vessel can operate safely. The Aquares system provides the client with a fast, reliable and high resolution sub-bottom data collection system that is not affected by issues that prevent or degrade data collected by traditional acoustic or electrical systems. The Aquares system will even provide data about (thickness and densities) and below high density structures (cap rock) structures. Further information about the Aqures system or whether the system is right for a particular application, please contact Peteralv Brabers or Jason Errey.

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