EM31 electro-magnetic ground conductivity mapping

Electro-magnetic (EM) ground conductivity mapping has been in use since the early 1960s and is one of the most frequently used geophysical methods in environmental and engineering applications today. The Geomics EM31 and its rivals of similar specification are the instruments most commonly employed for this purpose. For further discussion of this method see Reynolds (2011).

Principle of operation

An electro-magnetic field is transmitted in air using a coil of wire separated from a receiver coil by a fixed distance of 3.66 m, the two coils being housed in a fibreglass boom of 4 m length. The boom is carried horizontally; as there is no requirement to couple the coils with the ground it is usual for the operator to carry the boom a set distance above the ground. The transmitted energy propagates into the sub-surface where a secondary electro-magnetic field is generated due to the effect of soil moisture, conductive earth materials and buried objects. Both fields are detected at the receiver coil, but the instrument compensates for the primary field, enabling measurement of the secondary. The ratio of the field strengths is controlled by the apparent conductivity of the ground through which the EM radiation has passed.

Figure 1: Acquisition of EM31 data on two former industrial sites to map foundations, underground storage tanks, voids, pipes, culverts and possible contamination plumes.

Modes of deployment

The EM31 is manufactured by Geonics Ltd, Canada. The EM31 has two modes of deployment: horizontal magnetic dipole (0-3 m effective sensing depth) and vertical magnetic dipole (2-5 m effective sensing depth), shortened to HMD and VMD respectively. The instrument comprises a boom and an electronics box; older models require a separate data logger but more recent instruments contain an integrated logging device. The logging unit can be directly connected to a GPS unit carried by the operator in order to obtain precise reading locations without measuring out a dense grid of survey lines to follow.

The two operating modes are defined by the orientation of the coils relative to the ground surface. When the plane of the coils lies parallel to the ground surface, the Magnetic Dipole orientation is said to be vertical, hence the term Vertical Magnetic Dipole. Conversely, coils are at right-angles to the ground surface represent the Horizontal Magnetic Dipole orientation.

The EM31 measures two components of the field for each dipole orientation, termed the *in-phase* and *quadrature* components. The quadrature component indicates the bulk *apparent conductivity* of the volume of ground sampled, in milli-Siemens per metre (mS/m). Conductivity is the inverse of resistivity; the value measured is an apparent conductivity because it represents an average of the true conductivity values of all materials within the sampled volume.

Interpretation of EM31 data

The true conductivity value is a physically diagnostic property and can be used to differentiate between ground materials. To identify possible buried objects and contaminant plumes the interpreter will look for anomalous values in the data. The two components of the signal (in-phase and quadrature) are usually plotted as separate 2D areal plans (Figure 2), although individual profiles can be extracted for detailed interpretation, so a knowledge of characteristic anomalies is important.

The position of the maximum amplitude anomaly is a function of the width of the causative body and instrument orientation. For example, a narrow conductive body such as a pipe might generate an 'M' shaped anomaly, comprising two high values with a peak-to-peak separation equal to the coil separation ('S') such as that in Figure 2.

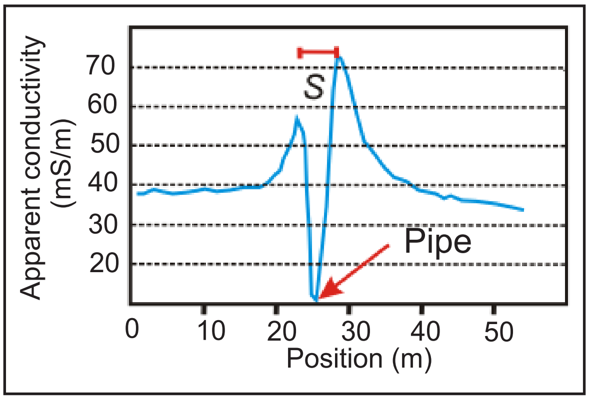

Figure 2: Ground conductivity data acquired across a steel pipe.

Ground conductivity data (quadrature component) are interpreted to indicate locations where the ground conductivity varies and may indicate a change in ground materials or a buried object or void. Linear items such as pipes, wall bases and building foundations are particularly good targets as they produce correspondingly-shaped anomalies in the data set. The in-phase component is expressed in parts per thousand (ppt). Phase changes between the primary and secondary field are used to indicate the presence of metallic objects. In-phase component data provide information on the likely presence of buried metal objects. Combined interpretation of in-phase and quadrature component data may inform the interpreter as to whether an anomaly is caused by a metallic item rather than increased moisture content or a change in the groundwater properties such as those caused by certain contaminants.

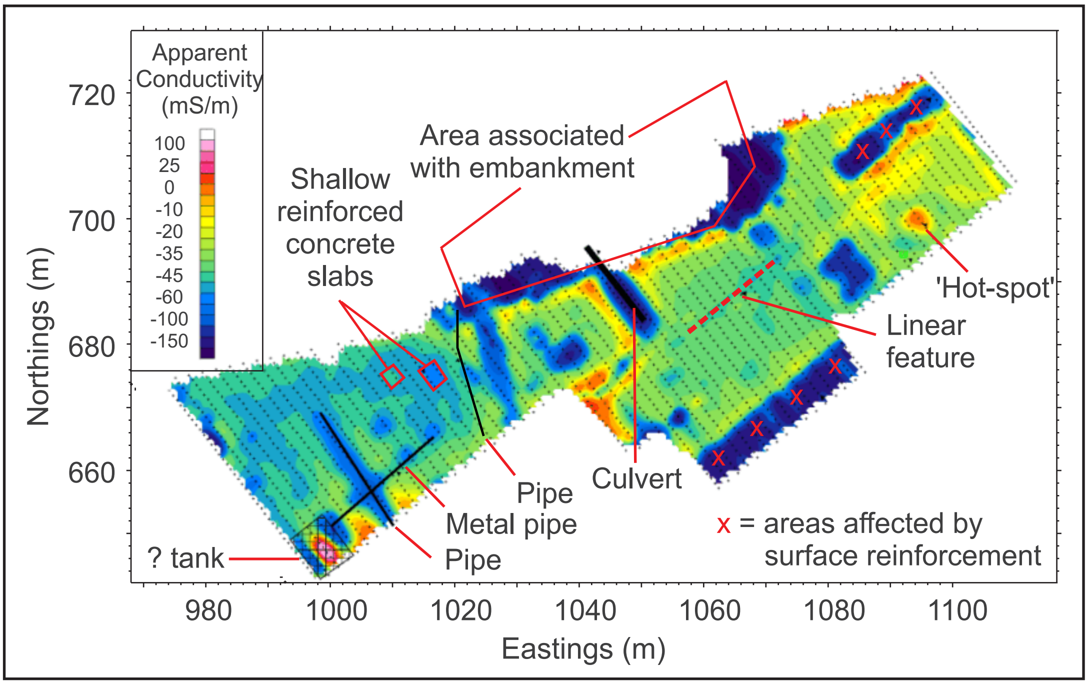

Figure 3: 2D plan of EM31 VMD ground conductivity data acquired over a contaminated site.

Reference

Reynolds, J.M. 2011. *An Introduction to Applied and Environmental Geophysics*. John Wiley & Sons Ltd, Chichester, 712 pp.