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Using Shallow Geophysics for Enhanced Remediation Practices and Increased Collaboration Efforts

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Summary

Geophysical investigations can be a powerful tool to explore and delineate physical properties of the subsurface. In the planning stage of remediation and reclamation, geophysics provides valuable guidance for borehole location, soil sampling, and impacted soil delineation. Electromagnetic (EM) surveys are the most widely used preliminary geophysical methods to explore terrain conductivity at a site of interest, but other methods, such as pseudo-3D imaging can provide high-value horizontal and vertical delineation at much greater depths, without many of the drawbacks and limitations of EM surveys.

This study focuses on a collaboration project between DMT Geosciences Ltd. and two other consulting firms focused on historical oil and gas sites located in southern Alberta, where geophysics and previous soil sampling information was combined to inform a Supplementary Phase II Environmental Site Assessment. Two sites are highlighted: one site with complex topography that relied heavily on geophysics for preliminary delineation of salt impact and a second site that illustrates how pseudo-3D resistivity imaging greatly enhances salt impact that extended to depth, beyond where EM surveys were able to provide any vertical delineation.

This project demonstrates strong collaboration between multiple consulting firms. Phase II borehole sampling from the environmental firm is compared with the most recent geophysical results to identify contours of resistivity / conductivity that suggest environmental significance for remediation planning. Both geophysical and borehole data acquired by other firms were incorporated into this study to best inform the most recent sampling strategy and ensure the best possible assessment and remediation strategy is performed.

Theory / Method / Workflow

Electrical Resistivity Imaging (ERI) and the Rapid Conductivity Volume (RCV)

ERI employs some basic physical principles to measure the subsurface. Generally, ERI surveys use an array of 4 electrodes per measurement, and measures hundreds to thousands of points in the subsurface depending on the length of the total array. Two electrodes are used to inject current into the subsurface (via the “C” electrodes), while the other two are used to measure the electrical potential difference, or voltage (the “P” electrodes) at some distance/specified spacing away from the current electrodes (Fig. 1).

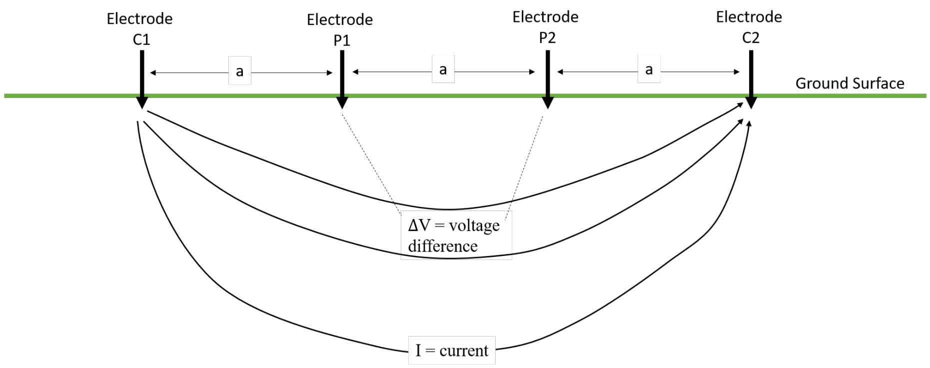

Fig. 1 Standard 4-electrode Wenner array deployed on the surface.

The foundation of this method incorporates Ohm's Law, where the resistance of a material can be measured experimentally when controlling a known amount of current, and measuring the voltage in the subsurface due to that current. In the context of electrodes, this must be related to the specific geometry of an electrode array and to the subsurface, which results in the general formulation:

$$\rho_{app} = \frac{V}{I} K$$

Where ρ_{app} is *apparent* resistivity, and K is a geometric factor that is dependent on the specific electrode array and the spacing between electrodes.

Once an array of electrodes is planted on the surface, a computer controls the measurements and builds a cross section of data points with which we invert using the RES2DINV software by Geometrics. Using a rapid ERI method (RCV), we can acquire multiple lines of resistivity to effectively cover our region of interest (Fig. 2). These lines can then be combined and interpolate between them to obtain a pseudo-3D electrical model of the subsurface, which ultimately provides a much better understanding of the site.

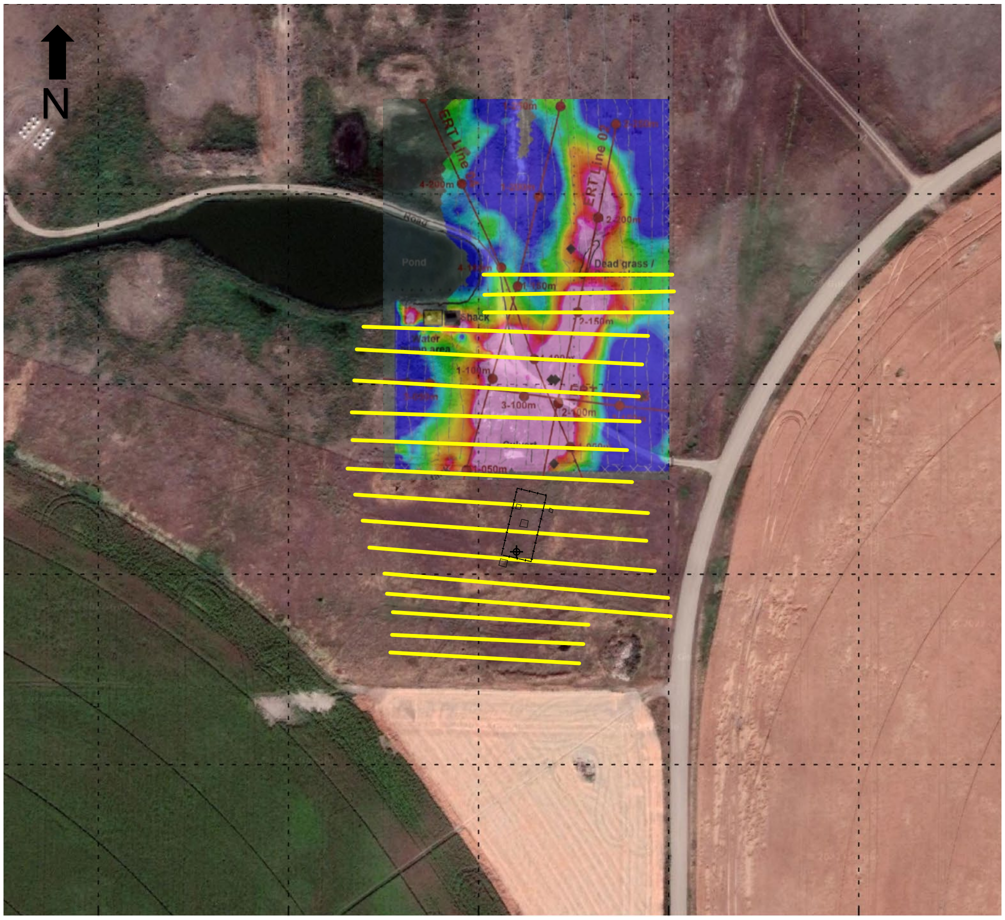

Fig. 2 Yellow lines indicate ERI lines used to build the pseudo-3D volume. A previous EM31 survey is overlain to illustrate the shape of the preliminary conductive anomaly (pink = high conductivity, blue = low conductivity). Black lines show the historical location of facilities.

Results, Observations, Conclusions

Site #1

The results of the RCV survey on ‘Site #1’ are shown in Fig. 3. Resistivity values were converted to conductivity (mS/m) to better compare with preliminary EM surveys, and map out terrain conductivity throughout the subsurface. A very good correlation was found between the EM31 survey and the 2021 RCV results presented here. The RCV survey results were used to guide the borehole sampling strategy performed by Envirosearch Ltd, which are the boreholes shown in Fig. 3. Boreholes are coloured according to chloride concentration in mg/kg, where values greater than 100 mg/kg were considered above background levels.

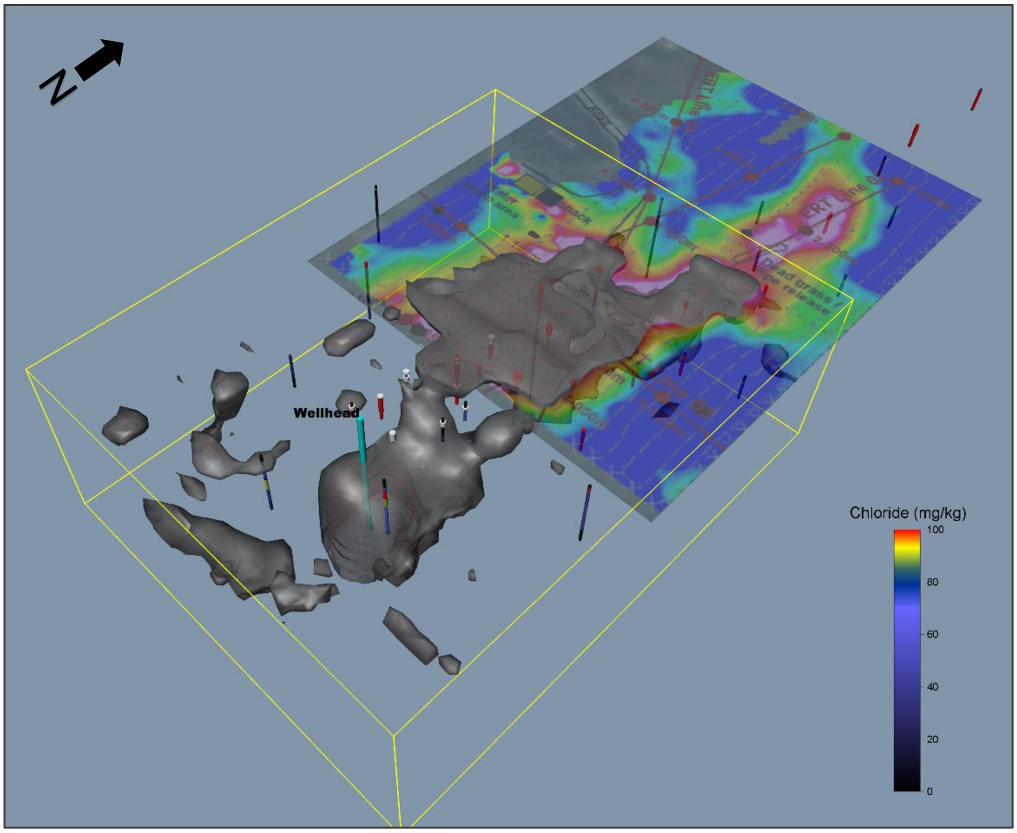

Fig. 3 Looking from the SE corner of the site: A gray isosurface is mapped at 120 mS/m to indicate where terrain conductivity was modeled at 120 mS/m or greater. Note the conductivity effect of the abandoned wellhead, and the good correlation between the EM31 and RCV isosurface.

Fig. 4 illustrates the improved delineation of salt impact at depth, below the EM31 survey. There are also two boreholes that were sampled in this area which effectively show the RCV delineating high chloride concentrations both above and below an unimpacted lens of soil (circled in red). Such information can be used going forward to greatly improve volume estimation during remediation.

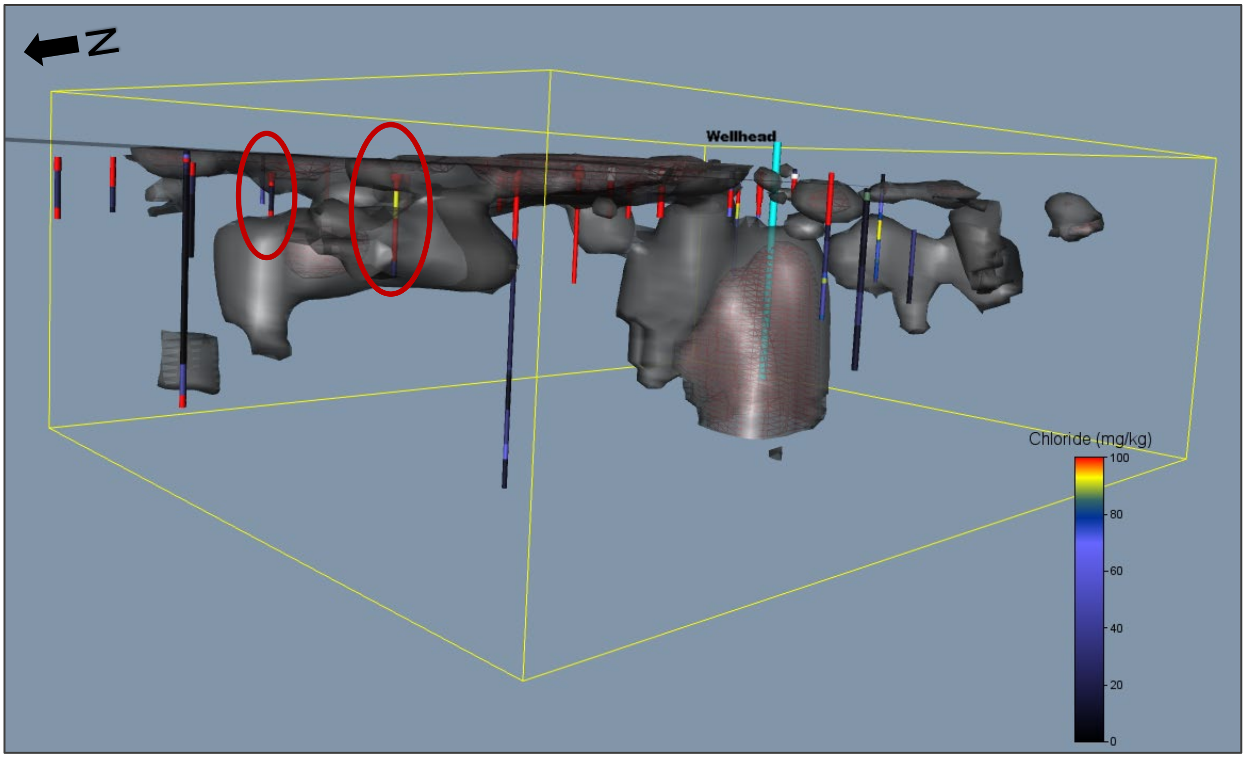

Fig. 4 Looking from the NW corner of the site: Note the isosurface is widespread at the surface, and also steps down to depth below the EM31 surveyed area. Circled in red show two boreholes that effectively capture chloride impact at the surface, and at depth with an unimpacted lens of soil in between.

Well Site #2

The second site is shown in Fig. 5. Yellow lines show the locations of RCV lines, and illustrate the complex/steep environment. The gully terrain made subsurface sampling very challenging, so the results of the geophysical RCV survey were relied on heavily for soil impact delineation. Geophysical results (Fig. 5b) show conductive anomalies on the top of the hill where historical infrastructure was located, and down the ravine to the south of the hill crest where a surface casing vent pipe is known to be leaking fluids down into the coulee. Vertical delineation of this anomaly was achieved down to ~13 metres below ground surface at the bottom of the ravine.

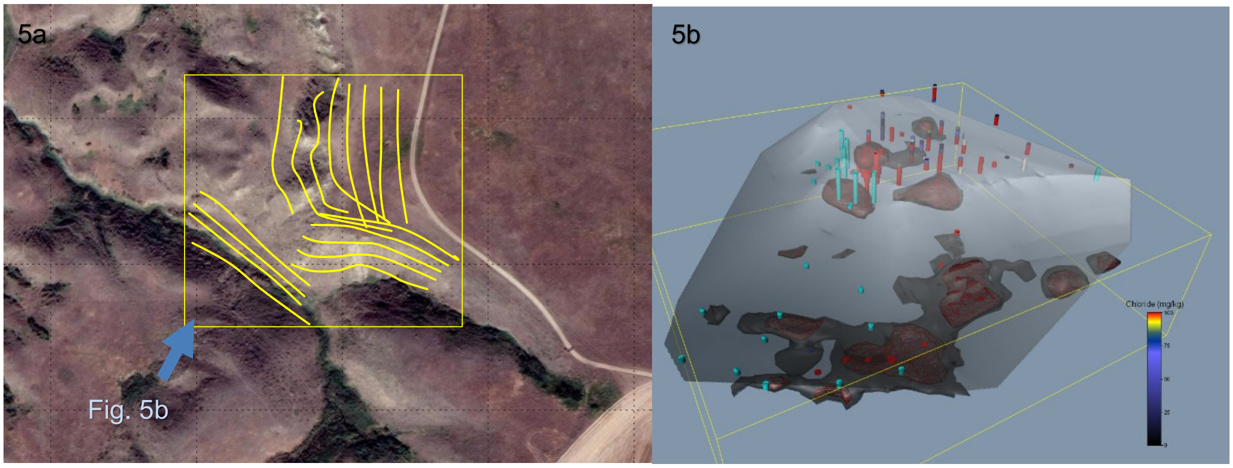

Fig. 5 a) Overview of lease site and lines (yellow) showing rapid ERT lines. b) Pseudo-3D volume showing 120 mS/m isosurface (gray) and 150 mS/m isosurface (red). Previously sampled boreholes are coloured according to chloride concentration (mg/kg). Planned boreholes based on RCV results are shown in cyan.

Fig. 5b shows previously sampled borehole locations coloured according to measured chloride concentrations, and the planned boreholes as a result of the RCV results are shown in cyan.

The success of the results presented here are the direct consequence of a collaboration between DMT Geosciences Ltd, Stantec Consulting Ltd, and Envirosearch Ltd, in the interest of improved site assessment and remediation strategies. This collaboration of sampling and surveying will further the understanding of these sites, and ensure that the desired end land-use is achieved and appropriate actions towards closure are performed.

Acknowledgements

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