FORENSIC ANALYSIS OF LANDFILLS USING EM METHODS

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Abstract

Electromagnetic terrain conductivity mapping is an effective method for delineating a landfill's footprint. The degradation of putrescible material increases the conductivity of the integrated water by the generation of soluble ions. Burn pits contain limited to no concentrations of putrescible material; instead, burn pits contain elevated concentrations of refractory waste and metal.

The quadrature phase of the emitted electromagnetic frequency excites ions in landfill leachate. Eddy currents from the excited ions generate an electrical response that is converted, linearly, to apparent terrain conductivity. The in-phase portion of the electromagnetic frequency is very sensitive to ferrous metal. Thus, the footprint of burn pits can be readily distinguished from landfills with placed waste through electromagnetic terrain conductivity mapping methods.

Introduction

The age and constituents of unlined or clay-lined landfills or dumps determine the impact these waste cells have upon groundwater. Prior to the passage of RCRA Subtitle D regulations in 1988, municipal solid waste was buried in pits that were unlined or locally-lined with clay. To expand the capacity of waste pits, operators would often set the waste on fire. This was a common practice prior to 1970, but largely abandoned in the mid-1960s.

Putrescible waste generates leachate, carbon dioxide and methane upon bacterial degradation (Hutchinson, 1993 and 1995). Landfill leachate, a mixture of water, volatile organic and halogenated compounds, and metal ions, can integrate with and contaminate groundwater. Burn pits, conversely, have little to no organic matter and consist mostly of refractory waste and metal. Consequently, the impact to groundwater from burn pits is less than the impact to groundwater from degrading organic matter.

Unfortunately, abandoned waste cells are difficult to age-date without exhumation. In general, burn pits do not generate leachate because the combustion of organic material in burn pits tends to destroy putrescible landfill material leaving behind concentrated amounts of refractory waste and metal. Further, the environment associated with a burn pit is not conducive to the anaerobic methanogenic- and acetogenic-bacterial degradation, characteristic of a non-burn cell. Consequently, burn pits have a low impact on groundwater beneath them.

A landfill footprint can be defined by frequency-domain electromagnetic terrain conductivity mapping methods due to the elevated concentrations of ions in the leachate (Hutchinson and Barta, 2000). Electromagnetic terrain conductivity surveys have been employed for landfill investigations for over 30 years (McNeill, 1990).

Theory

The terrain conductivity meter is used for the measurement of the electrical conductivity of subsurface soil, rock and ground water. The electrical conductivity (or its inverse, resistivity) is a function of the porosity, permeability and the fluids in the pore spaces (McNeill, 1990). In the landfill setting, the pore fluids dominate the measurement and thus electromagnetic terrain conductivity mapping (EM) is an excellent tool for delineating buried waste, trench boundaries, drums and other metallic objects. The absolute values of conductivity obtained in a survey are not necessarily diagnostic but the variations in conductivity can be used to identify anomalies (Benson et al., 1988).

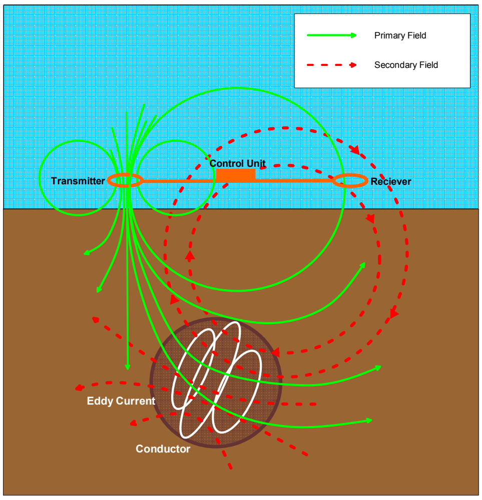

Figure 1: A diagram of the transmitter-receiver orientation of the EM tool. The transmitter creates the primary electromagnetic field that generates eddy currents within the conductor that are measured by the receiver (McNeill, 1990).

The EM tool consists of a transmitter coil that radiates an electromagnetic field (Figure 1). The electromagnetic field induces eddy currents in the earth that generate a secondary electromagnetic field proportional to the magnitude of the current flowing within the coil. Quadrature and in-phase components of the secondary magnetic field are captured by the receiver in the form of an output voltage that is linearly related to subsurface conductivity (McNeill, 1990). The quadrature phase component (terrain conductivity) is measured in milliSiemens/meter (mS/m) and provides a measurement of soil conductivity. The in-phase mode, measured in parts per thousand (ppt), is responsive to highly conductive, buried metallic objects.

The terrain conductivity value is an average conductivity of the effective depth of the survey tool. The effective depth is determined to be about 1.5 times the intercoil spacing (i.e., the distance between the receiving and the transmitting coils). The CMD Explorer (GF Instrument, Brno, CZ) is a multiple dipole tool with 3 different intercoil spacings (4.85, 9.25, 14.7 feet) to allow for an effective penetration depth of 7.2, 13.8, and 22 feet (vertical dipole). The tool measures the bulk conductivity of the entire skin depth specified by the intercoil spacing, thus the tool averages the response determined through the skin depth.

Discussion

Determining the footprint of a former landfill is difficult due to a lack of reliable site construction information. Twenty-two acres of open and wooded land located in Altoona, Pennsylvania, are thought to have at one time served as a local landfill based upon historical aerial photographs and drill core information (Figure 2). This site has no known disposal history, but topography and local resident testimony further support the assertion that the site had been used for waste placement post-WWII.

Figure 2: Site location map, near Altoona, PA. Not drawn to scale.

The shallow map, based upon a dipole spacing of 4.85 feet suggests the presence of shallow buried waste; however, much of the response is derived from surface debris, visible during data collection (Figure 3). The in-phase map documents the presence of surface metal, but the elevated area in the center of the map may be shallow buried putrefying municipal waste.

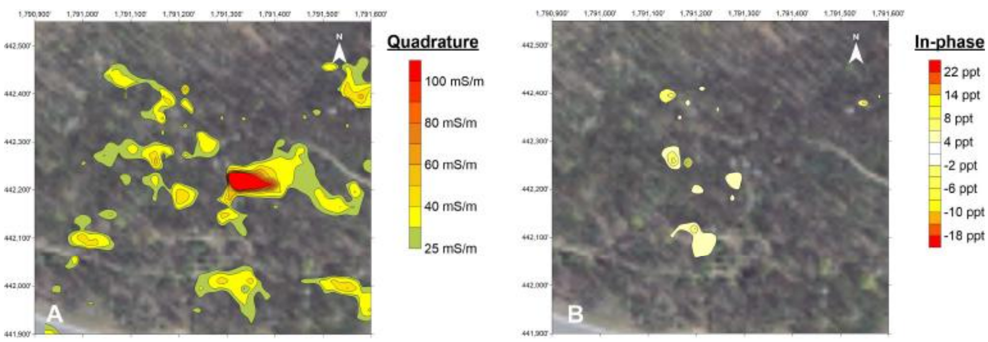

Figure 3: Quadrature component map (A) and the in-phase component map (B) at the depth of 7.2 ft. Map coordinates set to NAD 1983 Pennsylvania South State Plane in feet.

The intermediate dipole spacing of 9.25 feet with an effective depth of 13.8 feet below grade indicates that the surface metal and conductive materials (i.e., putrefying waste) occur on the surface (i.e., metals) or in the subsurface to a depth no deeper than 5-6 feet below grade (Figure 4).

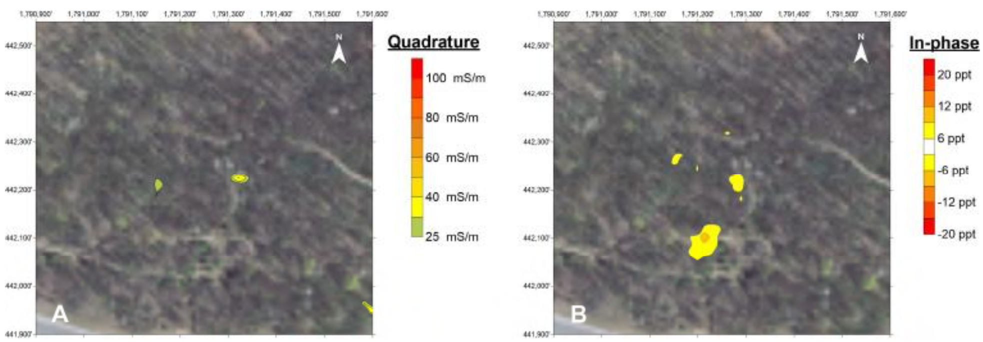

Figure 4: Quadrature component map (A) and the in-phase component map (B) at the depth of 13.8 ft. Map coordinates set to NAD 1983 Pennsylvania South State Plane in feet.

At the effective depth of 22 feet below grade, the quadrature component of the data shows no indication of any buried waste. The in-phase component of the data, however, shows elevated readings which indicate the presence of buried metallic debris at a depth of probably 12 to 18 feet below grade (Figure 5). The interpretation is that the landfill at some point in the past was a burn pit with little to no degrading organic compounds.

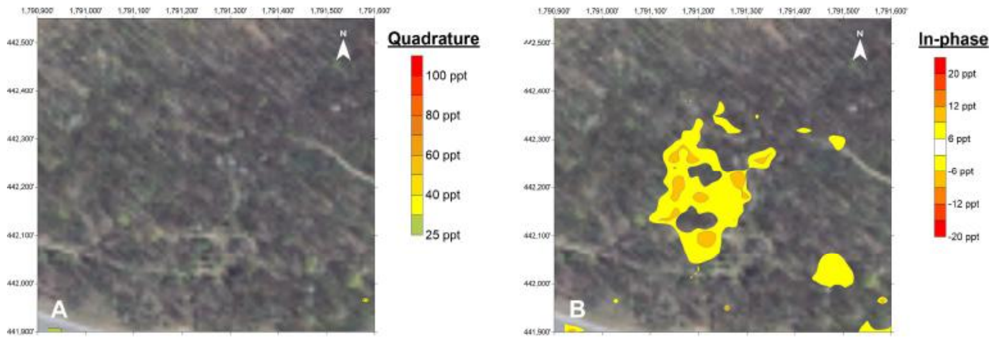

Figure 5: Quadrature component map (A) and the in-phase component map (B) at the depth of 22 ft. Map coordinates set to NAD 1983 Pennsylvania South State Plane in feet.

Conclusion

EM surveys are a useful method for delineating landfill boundaries. Municipal solid waste landfills undergoing anaerobic degradation of organic compounds generates ions that are readily discernible through electromagnetic terrain conductivity mapping methods. Landfills that were burn pits can also be readily identified through the elevated concentration of metal through the in-phase portion of the frequency. Burn pits do not generate leachate due to the lack of putrescible waste; consequently, burn pits tend to be environmentally reticent. Landfills with poor to nonexistent historical information can be forensically identified through EM methods and categorized by their potential for impacting groundwater.

References

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