Geophysics For Fun And Profit: How To Manage Your Due Diligence Risk

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PART XI: Site Assessment

Chapter 25

GEOPHYSICS FOR FUN AND PROFIT: HOW TO MANAGE YOUR DUE DILIGENCE RISK

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ABSTRACT

Near-surface geophysics provides an efficient, cost-effective, and non-invasive method for the investigation and assessment of property. When sequenced, implemented, and integrated properly, geophysics can enhance our understanding of site-specific subsurface conditions to optimize further intrusive investigation and corrective action. Geophysical data allow for a more informed decision-making process when evaluating the benefits and potential liabilities associated with property acquisition.

This paper focuses on geophysics as an innovative technical approach to manage risk and optimize site investigations. In addition, the paper draws on case studies where geophysical investigations were used to confirm suspected underground features or identify previously unknown hazards that would have significantly impacted the development cost and timing of these sites had their existence gone undetected.

Keywords: geophysics, site assessment, due diligence

1. INTRODUCTION

Geophysical evaluation is an efficient, straightforward, and inexpensive method to provide non-invasive information on a property. By implementing one or more of the geophysical methodologies discussed in this paper, it is possible to identify and understand potential buried hazards before a shovel of dirt is removed from the site. These non-invasive exploratory methods can greatly reduce the risk of missing critical subsurface problems or encountering a buried hazard by providing a screening tool and strategy for proposed follow-up subsurface investigations.

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2. MANAGING RISK AND UNCERTAINTY

One of the primary reasons for conducting a due diligence assessment on a property that will either be purchased or sold is to understand the potential hazards and liabilities associated with the past and present activities conducted on-site. In summary, the goal is to “manage risk”.

There is an abundance of resources available to aid in understanding the past site usage, such as site permits, building plans or Sanborn mapping. However, these resources do not address the uncertainty related to what was constructed and installed at the site prior to the issuance of permits or approvals, or was simply undocumented. In addition, there is always the possibility that documents are no longer available; having been lost in a fire or flood, or stored away in an unknown repository. Regardless of the reason, a clear understanding of what operations occurred and what the subsurface holds comes into question.

Another obstacle that arises when attempts are made to identify the potential risks and hazards on a property occurs when invasive investigations are not permitted by the current site owner or facility operations. It is also possible that the location of buried utilities or other subsurface hazards may render invasive methods as unsafe or impossible. With these limiting factors, how can a potential buyer or financing institution gather useful information regarding the risks associated with the site? In many instances, a geophysical investigation can be part of the solution to the problem.

3. BENEFITS OF GEOPHYSICAL ASSESSMENTS

Some benefits of utilizing geophysics as a first approach are listed below:

- Non-invasive collection of data
- Cost-effective
- Quick mobilization
- Fast on-site set-up and breakdown
- Identification of hazardous prior to subsurface work
- Permitting generally not required
- Wide and comprehensive area of coverage
- No generation of impacted media

As with all investigatory tools, there are some limitations with geophysical methods, such as heavy use of rebar in concrete or buildings that are not accessible. However, one of the major advantages with geophysics is that multiple options are available to assess different parameters over the same area of concern, thereby allowing for multiple views of the same information.
4. **GEOPHYSICAL METHODOLOGIES**

There are several types of geophysical methods available; all of which can be used independently or in tandem with each other. The five main types utilized for environmental and engineering work are listed below and summarized in Table 1.

4.1 **Ground Penetrating Radar**

This method is useful in a variety of settings to identify underground storage tanks, define aerial and vertical extent of buried debris, aid pipe and cable location, and delineate strong changes in lithology. Depth of usage typically ranges from surface grade to 100 feet.

4.2 **Electromagnetics and Magnetometry**

This method, which has a variable depth range, is excellent for identifying larger subsurface anomalies with magnetic properties (iron, steel, etc.). It can also be used to characterize changes in underlying bedrock horizons. Electromagnetic surveys can also be utilized for groundwater contaminant plume mapping.

4.3 **Gravity Surveying**

This method detects changes in relative gravity of a buried object relative to the local gravity signature of the earth. It is commonly used to delineate broader changes in trends (gravity fields) such as bedrock type or overburden deposits. Depth of usage is typically from the surface to 100 feet.

4.4 **Radio and Audio Frequency Location**

This method can be used to actively or passively induce a signal into the subsurface utilities via a transmitter. Using a handheld receiver, the signal can then be used to trace buried storm sewers, electric lines, piping, etc. This is the method commonly utilized to pre-dig prior to subsurface drilling and excavation activities. Maximum effectiveness locating depth is 20 feet below surface grade if directly connected to the utility.

4.5 **Seismic Surveying**

This “tried and true” geophysical method uses multiple receivers (geophones) and an induced energy source (strike plate, vibrator, and compression device). This method has a greater depth penetration than most other geophysical devices, but with generally lower resolution. Seismic surveying takes up where the other devices leave off, and is commonly used to characterize bedrock topography and other underground geomorphic structures.
Table 1. Typical Geophysical Methods for Shallow Environmental and Engineering Applications, Benefits and Limitations.

<table>
<thead>
<tr>
<th>Type of Locatable Targets</th>
<th>Ground Penetrating Radar</th>
<th>Electromagnetics and Magnetometry</th>
<th>Microgravity Surveying</th>
<th>Radio and Audio Frequency Location</th>
<th>Seismic Surveying</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Metallic, plastic, geologic targets (e.g. USTs, utilities, voids, interfaces)</td>
<td>Ferrous and non-ferrous metallic targets (USTs, drums, piping, debris, geology) and select groundwater contaminants</td>
<td>Voids and cavities natural or man-made</td>
<td>Utilities (e.g. water, gas, electric)</td>
<td>Geologic targets (e.g. groundwater and rock interfaces)</td>
</tr>
<tr>
<td>Effective Locating Depth</td>
<td>Metal: generally 1-inch diameter target size for each foot depth; Non-metallic targets are site specific; max 100 feet depth</td>
<td>Drum, piping and select targets to 15 foot depth; Saltwater and groundwater plumes over 200 feet depth</td>
<td>10 foot diameter cavities can be detected at 60 feet depth; max depth 100 feet</td>
<td>Up to 20 feet depth when directly coupled to the utility line</td>
<td>For engineering applications max depth of 200 feet</td>
</tr>
<tr>
<td>Depth Estimation</td>
<td>Yes. Dependant on soil heterogeneity</td>
<td>Yes. Accuracy +/- 15% under ideal conditions, but site and target specific</td>
<td>Yes with complementary data sets</td>
<td>Yes. Accuracy +/- 10% under normal conditions</td>
<td>Yes. Depends on soil heterogeneity</td>
</tr>
<tr>
<td>Soil or Backfill Effects</td>
<td>Dry sandy soils best; saturated clay soils or saltwater limit penetration</td>
<td>None unless backfill contains metallic debris</td>
<td>None</td>
<td>Poor tracing in dry or iron rich soils</td>
<td>None</td>
</tr>
<tr>
<td>Limitations</td>
<td>Non-unique</td>
<td>Non-metallic objects</td>
<td>Very sensitive to natural or cultural ground motion; Non-unique</td>
<td>Non-conductive pipes, possible signal bleed onto nearby conductors</td>
<td>Non-unique</td>
</tr>
</tbody>
</table>
5. GEOPHYSICAL APPLICATIONS - CASE STUDIES

In order to illustrate how geophysical investigation can help optimize site investigation, three case studies are presented here:

5.1 Case 1: Underground Storage Tank Location (Small Scale Assessment Area) – Southern Connecticut (Figure 1)

5.1.1 Site Specific Issues

As part of due diligence property transfer, a Phase I investigation was completed during which historic Sanborn maps indicated a former gasoline and automotive service station once existed at the site. Due to incomplete historic records documenting the management of the underground storage tanks (USTs) and associated piping for former service station, a geophysical survey was conducted.

5.1.2 Setting

The area of principle investigation is an irregular shaped 80-foot by 55-foot open lot at the south edge of a manufacturing plant in northeastern United States. This area is bordered to the west by a state road and to the east by a hill, which slopes steeply toward a railroad easement. The ground surface in the survey area is asphalt paved with sparse brush and regional soils are glaciofluvial.

5.1.3 Geophysical Methods

Electromagnetic (EM) and ground-penetrating radar (GPR) techniques were employed for this investigation. A Geonics EM61 electromagnetic conductivity meter was selected for the investigation to provide a rapid, non-invasive scan of the electromagnetic response of the site. The EM61 is a time-domain electromagnetic device that provides subsurface data to approximately 10-feet below surface grade (BSG) and is commonly used to detect ferrous and non-ferrous metal objects in the shallow subsurface. This unit was selected based on historic records which identified that steel USTs once existed at the site. A Geophysical Survey Systems, Inc. (GSSI) SIR-2000 GPR system outfitted with a 200 megahertz (MHz) antenna was used to further investigate areas exhibiting anomalous EM response. Typical radar depth of penetration using this antenna ranges from 8 to 14 feet in developed urbanized setting.

5.1.4 Outcome

Geophysical findings identified two areas of concern which were interpreted to be the location of USTs with associated piping and an area of buried debris. Geophysical data was used
Due Diligence/UST Location

Figure 1. Case Study 1. Ground penetrating radar (GPR) and electromagnetic (EM) survey at manufacturing facility located in southern Connecticut. A contour map of the EM response is shown on the right. GPR was used to investigate the high EM response (red). Excavation revealed two underground storage tanks and associated piping.
to direct test pit activities and subsequently uncovered two steel USTs and associated piping runs and some buried metallic debris (i.e. car parts, bicycle wheel, concrete construction backfill).

5.1.5 Client Benefits

USTs were appropriately decommissioned and subsequent environmental investigation was conducted to determine the condition of the area prior to completing property transfer.

5.2 Case 2: Brine Contamination Delineation (Medium Scale Assessment Area) – Southern Florida (Figure 2)

5.2.1 Site Specific Issues

The site was developed for petroleum production in the mid-1960s and the area of concern was used as a saltwater injection well area. Recent desire to redevelop the area prompted an environmental investigation, and chloride concentrations above applicable standards were identified. Furthermore, the chloride plume has had 40+ years to migrate and initial groundwater studies are unable to define the extent of the chloride impacts. Geophysics was employed to better estimate the horizontal and vertical extent of local chloride impacts.

5.2.2 Setting

The 4,800-foot by 4,800-foot survey area located in the southeastern United States is a flat land area surrounded by citrus groves featuring permeable surficial sands underlain by low-permeability marls and clays. Due to use of a portion of the site as construction backfill, several over-excavated areas contain impounded water.

5.2.3 Geophysical Methods

Two EM methods were used at this site to estimate the three-dimensional extent of chlorides in groundwater. A Geonics EM34 frequency-domain EM instrument was used to map the aerial extent of the chloride plume. The EM34 was operated in a horizontal dipole mode with a 20 meter coil spacing and recorded apparent ground conductivity response to an effective depth of 50 feet. A Geonics EM47 time-domain electromagnetic (TDEM) survey technique was used to measure the vertical extent of the chloride plume. An EM47 was used to record TDEM soundings at approximately 350-400 points (estimated 1 TDEM sounding per 250 feet) across the study area. Operated at two frequencies (30 Hertz and 300 Hertz), TDEM soundings recorded conductivity response with an effective depth of 200 feet below surface grade.
Brine Contamination Delineation

Figure 2. Case study 2. Frequency domain [EM34 (top left)] and time domain electromagnetic [EM47 (bottom center)] survey to map a chloride (brine) plume at a former petroleum production area located in southeast Florida. The EM34 contour map (top and bottom right) show the aerial extent of the plume and the EM47 geo-electric cross-section (bottom left) shows the vertical extent of the contaminant plume.
5.2.4 Outcome

The extent of chloride impacts in groundwater was mapped successfully and used to develop a more complete conceptual site model. Data is currently being evaluated to support remedial activities.

5.2.5 Client Benefits

Cost savings were realized due to comprehensive area of data coverage used to optimize the number and location of intrusive soil borings for geochemical delineation of the chloride plume. Off-site impacts were also identified, which resulted in a proactive environmental response.

5.3 Case 3: Oil Field Decommissioning (Large Scale Assessment Area) – Eastern Texas (Figure 3)

5.3.1 Site Specific Issues

Former oil production area in the southern United States which was abandoned in the 1940s. A residential community which flourished during oil production times sits on top of former structures and piping alignments. Several property owners looking to sell their properties prompted an environmental investigation to assess soil and groundwater quality across 10 leased properties. Geophysics was used to identify buried piping alignments and direct intrusive investigations.

5.3.2 Setting

Vegetated and open areas located within a residential community cover the former oil production areas. Soils are generally dry sands underlain by shallow clay.

5.3.3 Geophysical Methods

Two frequency-domain EM methods (Geonics EM-38B and EM-31) were used to detect variations in ground conductivity that may be a result of a ground disturbance such as trenching, pipelines or utilities, or other buried conductive targets. In addition to ground conductivity data collection, these EM instruments collected magnetic susceptibility data which can be used to identify metallic subsurface objects. The Geonics EM-38B has an effective depth of investigation of 5 feet and the Geonics EM-31 can detect conductive responses to approximately 15 feet.
Figure 3. Case Study 3. Electromagnetic (EM) survey of former crude oil production areas located eastern Texas. The aerial photo on the right shows the vegetated and open residential areas covering former structures. The contour map on the left is of EM response interpretations indentifying subsurface piping alignments and areas of suspected debris.
5.3.4 Outcome

Geophysical data were used to direct hydro-excavation to locate suspected piping alignments. Specifically, piping termination points were identified and investigated as locations of suspected contamination.

5.3.5 Client Benefits

Cost savings focused the drilling program by reducing the number of soil borings required to identify potential contamination areas. Identified subsurface obstructions resulted in the increased health and safety awareness for future work.

6. SUMMARY AND CONCLUSIONS

Geophysics is a proven tool in the evaluation of risk and hazards associated with the due diligence and environmental investigations at a broad array of sites and subsurface conditions. It is also a cost-effective, safe and efficient tool when planning future site strategy and reducing both financial and legal liability.

7. REFERENCES