Geophysical Services for

GROUNDWATER EXPLORATION

Geophysical methods can be very effective in the search for groundwater resources. The appropriate geophysical program should be designed to meet the geological objective and the expected stratigraphic section. When combined with other available geologic and borehole information geophysical data can refine the conceptual model of the subsurface geology and provide additional detail to the geologic interpretation.

Several geophysical techniques are commonly applied in the search for ground water. These include ***electromagnetic*** methods, both ***frequency-domain*** and ***time-domain, seismic refraction, seismic reflection,*** and ***DC resistivity.***

ELECTROMAGNETIC METHODS:

Electromagnetic methods induce small electrical currents in the ground. These currents flow more readily in conductive earth materials than in resistive strata. Sand or gravel aquifers tend to be much more resistive than silts and clays. By studying the behavior of the electrical currents in the ground we can deduce the location of resistive strata (aquifers).

Frequency-domain electromagnetic (FDEM) techniques are often used in a profiling mode to search for lateral changes in soil conditions (e.g., mapping the geometry of a gravel paleo-channel). The instruments are carried by one or two persons and can cover a large area relatively quickly. However, FDEM profiles provide only limited depth information.

Time-domain electromagnetic (TDEM) methods in groundwater exploration are useful as sounding techniques, as opposed to profiling techniques. Sounding techniques measure the depth to an interface, or interfaces. They can be used to measure the thickness of a gravel unit, depth and thickness of a clay aquitard, or depth to bedrock.

In the most common groundwater exploration configuration, TDEM soundings are made by laying out a loop of wire 20 to 200 feet on a side and pulsing it with a controlled current. Measurements are made, usually in the center of the loop, with an antenna coil about three feet across. All the equipment is easily portable; six to sixteen soundings can be made in a day, depending on field conditions.

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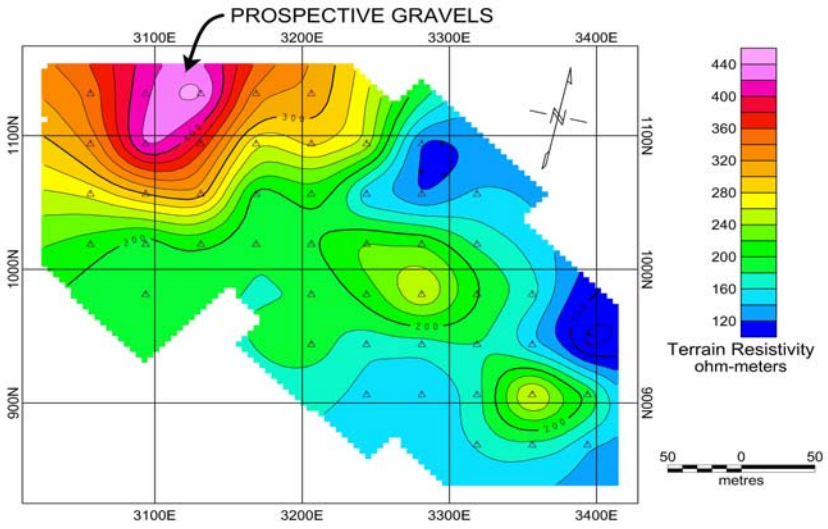

FIGURE 1: TDEM RESISTIVITY CONTOUR MAP
The resistivity contour plot shown above is from a time-domain electromagnetic (TDEM) survey over alluvial deposits in the Willamette Valley. It shows the interpreted resistivity of a sand and gravel unit 20-30 meters in thickness. The higher resistivity gravels are expected to have a lower percentage of silt and clay, and hence a higher hydraulic transmissivity.

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SEISMIC REFRACTION and REFLECTION:

Seismic techniques use a small explosive or mechanical energy source to impart a seismic pulse to the ground. The seismic waves travel through the soils to the bedrock or other competent layers below. There, the seismic waves are both *reflected* back to the surface and *refracted* along the bedrock surface for some distance before they return to the earth's surface.

Seismic Refraction is commonly used for engineering and groundwater applications. The most common objective is to map the bedrock surface (i.e., determine the depth to bedrock, and variations in depth, along the survey line).

Seismic Reflection can provide higher resolution of overburden stratigraphy and the bedrock surface, but at substantially higher cost. The reflection technique involves acquiring more field data, and processing data more intensively than seismic refraction. In some applications higher resolution may justify the higher survey costs, depending on the expected geologic conditions and the objectives of the exploration program.

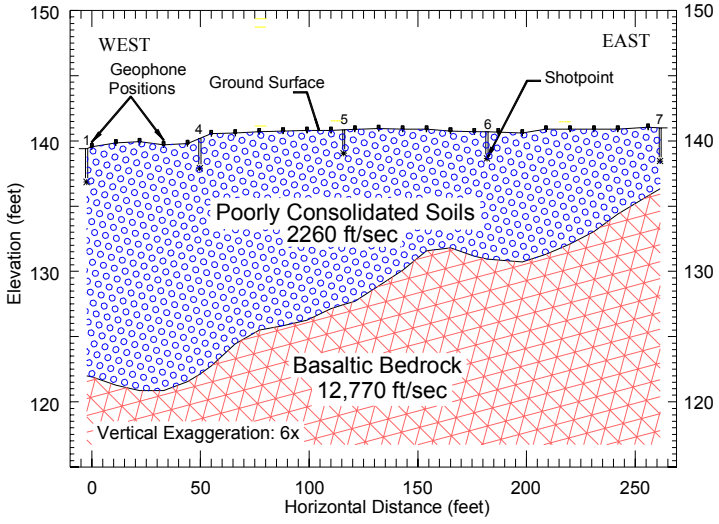

FIGURE 2: SEISMIC REFRACTION PROFILE

ELECTRICAL (DC) RESISTIVITY:

DC resistivity is one of the oldest and most well known geophysical methods used in groundwater exploration. This technique measures the electrical resistivity of the ground, as do the EM techniques. Two-dimensional (2D) geology can be readily modeled with electrical resistivity data. However, DC resistivity generally has lower resolution than the TDEM technique, both vertically and horizontally.

DC resistivity involves deploying long lengths of wire on the ground and injecting a DC current into the earth through a widely spaced pair of electrodes. The distance between current electrodes must be three or more times the intended depth of exploration. DC resistivity can be an effective shallow sounding method. In general, electrical techniques are not well suited to developed areas due to interference from utilities, fences and structures.

OTHER TECHNIQUES:

There are other geophysical techniques which can be used for groundwater exploration. These include ***gravity, magnetics, controlled source audio magneto-telluric (CSAMT), and "VLF"*** techniques. NGA is familiar with these techniques and has employed them on numerous projects. NGA will recommend the most cost effective geophysical methods to meet the geological objective in the search for groundwater resources.

Northwest Geophysical Associates, Inc. (NGA) provides geophysical services for groundwater exploration and development including program design, field services, and interpretation.

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