REMEDIAL INVESTIGATION / BASELINE RISK ASSESSEMENT
FORT McCLELLAN, ALABAMA

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APPENDIX A
GEOPHYSICAL DATA

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OVERVIEW OF THE GEOPHYSICAL METHODS

Geophysical techniques are commonly employed in the investigation of hazardous waste sites to non-intrusively locate and identify subsurface site features. Techniques commonly used include frequency and time domain electromagnetic surveys and single point, total field magnetometry and gradiometry. Recent innovative magnetometry techniques include GPS-referenced, arrayed magnetometer applications which were used to survey swaths of areas at several of the RI sites at Fort McClellan.

The Frequency Domain Electromagnetic method (FDEM) is a non-destructive geophysical technique for obtaining subsurface information. In the FDEM method, a time-varying magnetic field is generated by driving an alternating current through either a loop of wire or a straight wire that is grounded at both ends. Induced electrical (eddy) currents flow within the conductive solid or fluid material that is present between the transmitter-receiver current loop. The eddy currents generate secondary magnetic fields such that, at any point in space, the total magnetic field is the superposition of the primary (normal) field due to the source current and the secondary (anomalous) fields due to the eddy currents (Figure A-1). By discriminating between primary and secondary field, qualitative interpretations are made regarding regions of anomalous conductivity. When measurements are obtained using different intercoil (transmitter-receiver) separations over an anomalous point, the data can be used to estimate the depth of a detected target. However, the depth estimates are non-unique in that several configurations of depth and conductivity of the source material can produce the same anomalous response.

FDEM methods measure apparent ground conductivity. Apparent ground conductivity reflects true conductivity when the subsurface is homogeneous and isotropic. When heterogeneous conditions exist, the apparent ground conductivity is represented by the "integrated" conductivity of the various subsurface layers affecting the instrument response. However, the apparent ground conductivity is not an average conductivity and may be lower or higher than the lowest or highest true conductivity, respectively. A lateral variation in apparent ground conductivity often indicates a lateral change in subsurface physical properties. The relative conductivity of the subsurface is particularly sensitive to fluid content and to dissolved salts or ions. Accordingly, wet sand, clay, and materials with high ion content typically have high conductivity; dry sand and crystalline rocks typically have low conductivity. Standard FDEM instruments measure both the quadrature-phase and in-phase components of the induced magnetic field. The quadrature-phase component is a measure of apparent ground conductivity while the in-phase component is more sensitive to the presence of metallic objects.

The Time Domain Electromagnetic method (TDEM) is similar to the FDEM method in that both methods are non-destructive geophysical techniques used for obtaining subsurface information. In the TDEM method, a time-varying magnetic field is generated by driving an alternating current through a loop of wire. As with the FDEM method, induced or "eddy" currents flow within conductive solid or fluid material that is present between the transmitter and receiver coils to the depth of investigation. The eddy currents generate their own magnetic fields which can be measured at the surface using a receiver coil. The main difference between the TDEM and FDEM methods is that the TDEM method measures only the secondary magnetic fields that are generated by the primary electromagnetic fields. This is accomplished by having the instrument obtain measurments only when the primary field is terminated at the instrument. In this manner, only the response for the earth is measured, instead of a superposition of both the primary and secondary fields.

Several different TDEM methods are generally used. One system employs the use of "time gates" wherein data are measured at specified times during the decay of the secondary fields. Modeling routines are then used to determine different earth configurations that would cause the observed decay. In contrast, another system measures the secondary field at a single time gate. In this approach, the time gate has been engineered so that only the response of buried metallic materials is measured and not of the surrounding earth materials. Figure A-2 shows the configuration of this system as designed by Geonics Limited (the EM 61 instrument). As seen in the figure, the instrument has two square coils, the bottom one containing the transmitter and one receiver coil, and the top containing a second receiver coil. Two channels of data are recorded including channel 1 from the receiver coil higher above the earth, and channel 2 from the receiver coil close to the earth. Channel 1 has a built in gain to equalize the two channels in cases of near surface metal. In this manner, the effect of surficial, cultural materials can be filtered. The difference between the two channel responses also is calculated and reported. Typically, with only natural earth materials in the subsurface, the response from both channels will be low (close to 0). When a buried metallic object is encountered the response from channel 2 will pick up the deeper object, since this coil is closer to the earth, while the response from channel 1 will be less because of the greater receiver-target separation. The channel 2 response and the calculateddifferential are typically used for interpretation of buried materials.

The magnetic method is based on the measurement of the geomagnetic field. The source of this field is believed to be related to the movement of an electrically-conductive core within the earth. The geomagnetic field resembles that of a large bar magnetic located near the earth's center. The intensity of the field is twice as large in polar regions as compared to equatorial regions; approximately 60,000 and 30,000 gammas, respectively. The angle of inclination of the field with respect to the earth's surface varies, ranging between 60 and 75 degrees in the United States. In addition, the magnetic declination (the angle between the geographic north and magnetic north) of the field varies across the earth's surface.

The intensity of the geomagnetic field is affected by ionospheric conditions which can cause large and rapid variations. Also, local distortions (anomalies) are caused by changes or contrasts in magnetization due to the presence of near-surface features, both natural and artificial, which magnetically interact with the field (Figure A-3). Anomalies may be caused by the natural distribution of iron oxides or by the presence of ferrous metals such as iron and steel. Note that, in general, anomalies arising from near-surface features can be discerned from the natural field. In turn, an interpretation may be made concerning its cause (i.e., natural or artificial) based on the size and shape of the anomalous signature. Total field and gradient measurements differ in that the former measures the absolute value of the ambient geomagnetic field using one sensor; the latter measures the gradient of the ambient field by using two sensors separated by a known distance.

Arrayed magnetometer technology expands the application of single point magnetometry by utilizing a linear array of magnetometers arranged to obtain continuous measurements while being towed over a survey area at speeds up to 4 miles per hour. The magnetometer array utilized at Fort McClellan consisted of nine magnetometers linearly arranged with a one foot seperation between instruments. The array is traversed across the survey area and is aligned perpendicular to the direction of the survey. Continuous, kinematic global positioning system (GPS) data are commonly acquired from the survey vehicle as it traverses the site. The site is surveyed in ten foot swaths until continuous coverage of the area is achieved. Using this technique, detected magnetic anomalies are accurately mapped and can be quantitatively modeled to estimate target depth, orientation, and size. Satellite accessibility is an important component for the success of arrayed magnetometer surveying.

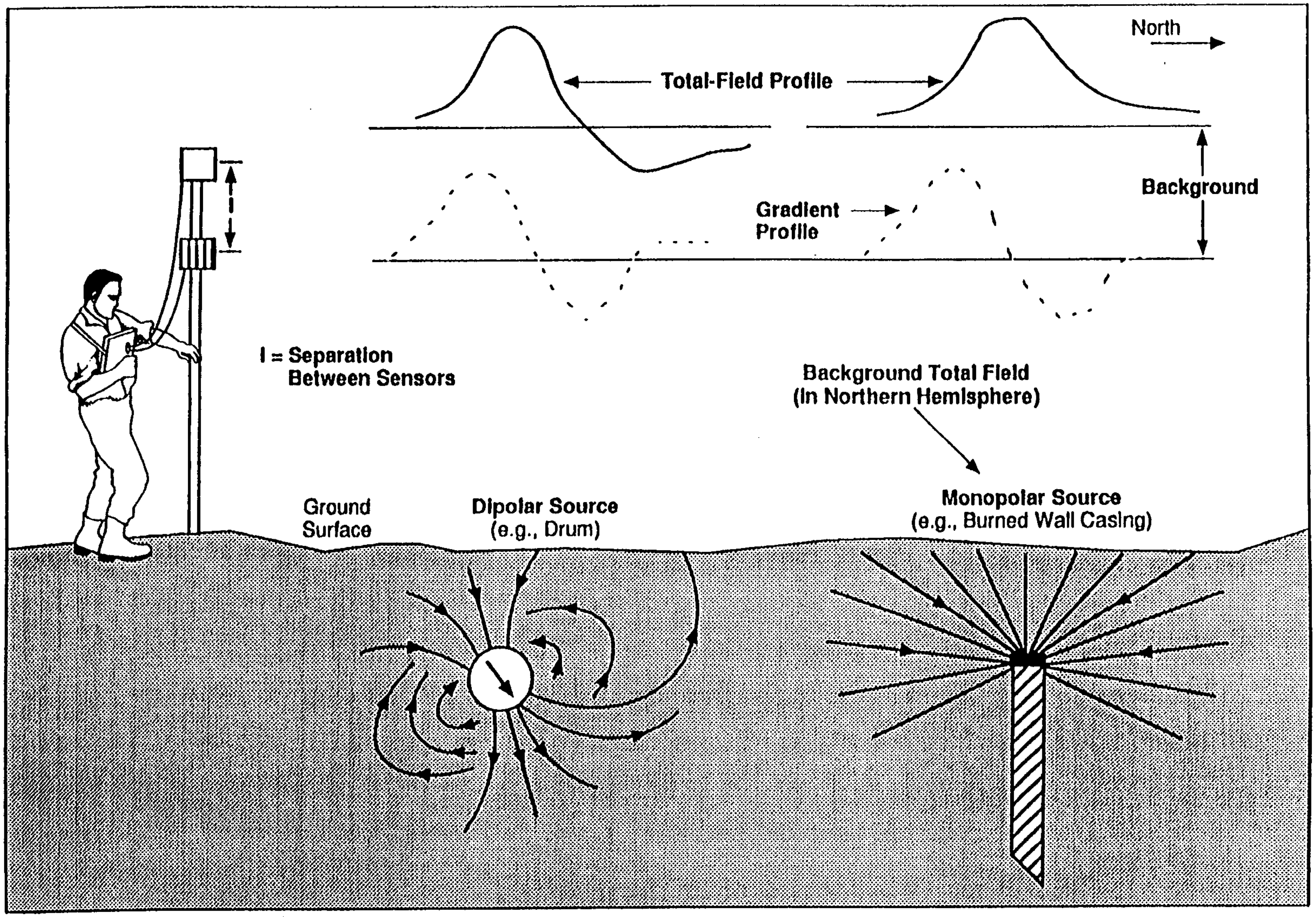

Figure A-3. Schematic Diagram Depicting Principles of the Magnetic Method and Typical Magnetic Anomaly sources and Responses as Total Field Profiles and Vertical Gradient Profiles.