CHAPTER 4

Geophysical Detection Equipment

4-1. Introduction. This chapter presents an overview of available geophysical detection systems, their capabilities and limitations. There are many techniques beyond those mentioned in this chapter that have application to the detection of surface MEC and subsurface anomalies. No single detection system can effectively detect all types of military munitions at all locations and depths.

4-2. Factors to Consider.

a. When selecting a geophysical survey instrument for the detection of subsurface anomalies, it is necessary to consider the maximum possible depth of MEC. If MEC is intentionally buried, the factors affecting burial depth may include the type of soil, mechanical versus hand excavation, depth of the water table, etc. If the military munition was fired or dropped, then the depth of penetration can be estimated by considering the soil type, military munition type and weight, and impact velocity. There are many cases where UXO can penetrate deeper than geophysical instruments can currently reliably detect. On such sites, it is possible that undetected UXO remains deeper than it can be detected from the existing ground surface.

b. Geophysical detection equipment used to locate subsurface MEC for avoidance or removal is seldom 100 percent effective. In many cases, military munitions may simply be located too deep, may be too small to be detected, or may be constructed of a material difficult to detect. Since the total number of subsurface MEC at a site is almost never known, complete detection cannot be documented. In addition, most commonly used geophysical survey systems will not detect subsurface bulk explosives. These factors must be considered when designing and implementing MEC support. If subsurface bulk explosives are anticipated based on archival data, then special avoidance techniques must be developed and increased safety precautions employed. Contact the MM CX for additional information. The limitations of detection capabilities must be conveyed to all on-site personnel so that there is a common understanding of expectations.

c. Data collection capability typically depends on the complexity and type of the geophysical instrument used. For instance, most handheld magnetometers cannot record the data produced. However, more complex systems are capable of collecting the data for downloading and processing. Requiring an instrument with the capacity to collect data is

activity-dependent. Anomaly avoidance procedures generally do not require data collection. However, removal operations in support of construction activities generally require the area to be mapped and, therefore, require instruments that are capable of downloading information.

4-3. Types of Instrumentation. The most successful geophysical detection systems for MEC rely on one of two technologies, magnetometry or electromagnetics. Magnetometers are limited to detecting ferrous items. Electromagnetic detectors can detect any conductive metal.

a. Magnetometry.

(1) Magnetometers were one of the first tools used for locating buried military munitions and remain one of the best. Most bombs and gun shells contain iron that causes a disturbance in the earth's geomagnetic field. A magnetic survey measures differences from the earth's normal magnetic field that can be attributed to the presence of ferrous objects. Some magnetometers, which are called gradiometers, use two magnetic sensors configured to measure the difference over a fixed distance of the magnetic field (gradient), rather than the absolute magnetic field. Magnetometers are extremely sensitive and capable of identifying small anomalies. They respond only to ferro-magnetic metals. In addition, magnetometers are sensitive to iron-bearing minerals contained in soils and rock.

(2) Magnetometry will not detect subsurface bulk explosives. If subsurface bulk explosives are anticipated based on the site's history, increased safety precautions and special techniques will be employed. Contact the MM CX for additional information.

(3) Two types of magnetometers and gradiometers are most often used to detect buried military munitions, fluxgate magnetometers and optically pumped magnetometers.

(a) Fluxgate Magnetometers. Fluxgate magnetometers measure the magnetic field component along the axis of the core of the fluxgate. They are inexpensive, reliable, rugged, and have low energy consumption. Fluxgate magnetometers have long been a standard tool of EOD teams, used for a quick, inexpensive field reconnaissance of a site containing ferrous military munitions. However, most fluxgate magnetometers provide analog rather than digital output, which makes it difficult to apply computer enhancement techniques. Fluxgate magnetometers are the instruments typically used for downhole geophysics for anomaly avoidance.

(b) Optically Pumped Magnetometers. Optically pumped magnetometers (traditionally cesium-vapor or potassium-vapor magnetometers) measure the local absolute total magnetic field. They utilize digital technology and are more expensive to purchase than fluxgate

instruments. However, their high sensitivity, speed of operation, and high quality digital signal output make them a good choice for situations where data or digital post-processing is required.

b. Electromagnetic Detectors.

(1) Electromagnetic induction geophysical instruments are also extensively used to detect buried military munitions. They differ from magnetometers in that they are not limited to detecting ferrous items; they can detect any conductive metal. In addition, electromagnetic detectors are not affected by most of the iron-bearing rocks and soil that adversely affect magnetometers.

(2) There are numerous types of conductivity meters available. However, two types are most commonly used in the search for military munitions- frequency-domain electromagnetics and time-domain electromagnetic conductivity.

(a) Frequency-Domain Electromagnetics. Frequency-domain electromagnetic (FDEM) instruments can be useful to detect large buried caches of military munitions and detecting disturbed earth associated with pits and trenches. In addition, some types of FDEM instruments are the best geophysical tools available for detecting very small, very close objects such as the metal firing pins in plastic land mines buried just beneath the ground surface. However, since the resolution ability decreases dramatically with depth, frequency-domain conductivity meters are not optimum for detecting individual, deeply buried military munitions. Most commercial coin detectors are frequency-domain conductivity meters.

(b) Time-Domain Conductivity Electromagnetics. Time-domain conductivity electromagnetic (TDEM) instruments provide an excellent compromise between detection depth and resolution. These instruments provide a capability to locate all types of metallic military munitions and will see typical intact military munitions to depths of between 1 to 2 meters depending upon site-specific conditions.

4-4. Geophysical Investigation Performance.

a. General. The performance of military munitions detection instruments varies as a result of different site characteristics such as soil type, moisture content, depth to groundwater, vegetation, and type of military munition. Environmental and military munitions factors affecting the performance of detection instruments are so numerous that a prove-out of potential detection instruments for removal operations will be performed on the site to determine which instrument performs the best.

b. Data Quality Objectives/Performance Goals. Geophysical investigation data quality objectives and performance goals will be included in the contractor's SOW. The contractor may propose and document alternative objectives and goals for the Contracting Officer's consideration.

c. Horizontal Accuracy. Horizontally, 95 percent of all reacquired anomaly locations must lie within a 1 meter radius of their original surface location as marked on the dig sheet. Horizontally, 95 percent of all excavated items must lie within a 35-centimeter radius of their mapped surface location as marked in the field after reacquisition.

d. False Positives. If there are more than 15 percent "false positives" (anomalies reacquired by the contractor that result in no detectable metallic material recovered during excavations, calculated as a running average for the sector), a re-evaluation of the data, detection methods being utilized, and overall project QC will be performed at no cost to the government. A written response explaining the reason for the excessive false positive results and a Corrective Action Plan, if appropriate, will be submitted to the Contracting Officer within 10 days of identification of the situation.

4-5. Geophysical Prove-Out (GPO). Before geophysical surveys for buried military munitions can begin on a site, the proposed survey methods and techniques must be tested and evaluated. The purpose of the GPO is to demonstrate and document the site-specific capabilities of the proposed survey platform, sensors, navigation equipment, data analysis, data management and associated equipment and personnel to operate as an integrated system capable of meeting data quality objectives necessary to achieve project performance goals. The results of the GPO will identify realistic capabilities and limitations of applying geophysics at a particular site and aid in determining proper post-processing procedures for the geophysical data. Additionally, a prove-out demonstration offers the client an opportunity to observe the contractor's methods and to evaluate the contractor's ability to meet data quality objectives and compliance with project requirements. A prove-out must be constructed so that it is representative of the project site and the specific buried military munition items known or suspected to exist. The objective of the GPO is mainly to establish and maintain high levels of QC throughout this phase of the project. EM 1110-1-4009 provides a detailed list of general objectives for a GPO. The specific project objectives will be described in the GPO Work Plan. A GPO is needed for removal actions, but is not required for anomaly avoidance. Only a daily geophysical instrument function test is required for anomaly avoidance.

4-6. Equipment Standardization and QC Tests. Geophysical instruments have a number of standardization tests that need to be performed in order to ensure that they are functioning properly. For this discussion we will focus on the EM61 and GEM-3 (trade names of specific geophysical survey instruments) to identify some specific tests to be conducted.

a. Out-of-Box Equipment Tests. Past experience has shown that, too often, non-functioning equipment arrives at the site, causing delays in surveying, producing unreliable data, and increasing false alarms or missing buried military munitions. For this reason, the following out-of-box equipment tests are mandated to ensure that all instruments are operating correctly:

(1) Inventory and inspect all components.

(2) Assemble the instrument and power up.

(3) Test the instrument's cable connectors for shorts using the cable shake test.

(4) Null instrument (Electromagnetic (EM) only). The EM instrument will be nulled prior to conducting the following tests. Standard EM61 backpacks are provided with potentiometers for the top and bottom coils, which can be adjusted to null (zero) the instrument.

(a) Static Test. Establish an area for these tests that offers convenient access, is free of metal (surface and subsurface), and is sufficiently far from roads and power lines, transmitters, etc., to avoid these sources of noise. This same point may be used throughout the duration of the project for the daily static (background) test and response tests and for nulling instruments. Collect readings for a minimum of 3 minutes after instrument warm-up. Data collected during static tests will be retained for documentation.

(b) Instrument Response Test. The Instrument Response Test quantifies the response of the instrument to a standard test item. A steel trailer ball is a preferred test item that is easily acquired and transported. Leaving the instrument in the same position as used in the Static Test, place the test item below the sensor, then collect data for a minimum 3-minute period. The test will document the amplitude of response to the test item and instrument drift. To pass the Instrument Response Test, the value of the response must vary less than 20 percent from test to test.

b. Initial Geophysical Instrument Checks. Initial geophysical instrument checks will be performed on the first day of the survey. These tests include the following:

(1) Six-Line Test. This test is used for all geophysical instruments. Use an area that has little background noise and no sources of anomalous responses. The test line will be well marked to facilitate data collection over the exact same line each time the test is performed. Background response over the test line is established in Lines 1 and 2. A standard test item, such as a steel trailer hitch ball, will be used for Lines 3 through 6. Heading effects, repeatability of response amplitude, positional accuracy, and latency are evaluated in Lines 3 through 6. For anomaly avoidance, a test similar to a six-line test would be used in lieu of a prove-out.

(2) Azimuthal Test and Octant Test. These tests, applicable to magnetic instruments only, are performed to document the differences in readings based on orientation.

(3) Height Optimization Test. This test is applied to magnetic instruments, as well as for the GEM-3 instrument, and the EM61 used in harness or “litter” mode. A line is established with at least one test object along its length. Data is collected with the instrument using a minimum of three different sensor heights. The goal is to optimize the target signal-to-noise ratio and maintain adequate sensitivity.

(4) Pull-Away Test. This test demonstrates the effects of navigational equipment and/or vehicles used to tow sensors or arrays.

c. Daily Instrument Checks. Data collected in these tests must be closely examined each morning, before starting the collection of survey data. These tests will be performed for both removals and anomaly avoidance procedures.

(1) Cable Shake Test.

(2) Null instrument (EM only).

(3) Static Test: This test will be performed twice daily in the same location, prior to data collection, and at the end of the day. Data will be recorded during a minimum 3-minute duration static test to demonstrate stability of readings.

(4) Instrument Response Test: Following the static test, a standard test item will be placed below the sensor, and readings recorded for at least 3 minutes. Instrument response of equal amplitude from test to test demonstrates that the calibration of the instrument has not changed.

(5) Personnel Test: The instrument operator moves around the stationary, operating instrument to scan for any effects of metal remaining on his or her person.

4-7. Maintenance. Preventive maintenance will be performed on a regularly scheduled basis in accordance with the manufacturer's directions. If an equipment problem is encountered, maintenance will be performed as soon as possible and records of the unscheduled maintenance and corrective action will be maintained and will indicate equipment identification, problem description, corrective action, the person performing the maintenance, and associated costs. Equipment Standardization and QC Tests will be performed and the test results reviewed and accepted by the site or project geophysicist prior to the use of all repaired or new equipment received at the site.