Quality Control for OE Digital Geophysical Mapping

Amy Walker (Presenter) and Bob Selfridge
U.S. Army Engineering and Support Center, Huntsville
ATTN: CEHNC-ED-CS-G
4820 University Square
Huntsville, AL 35816-1822
Email: amy.n.walker@hnd01.usace.army.mil
Phone: (256) 895-1604
Fax: (256) 895-1602

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Contributors: Mark Howard and Alan Mazurowski, NAEVA Geophysics, Inc.

Abstract: To facilitate the detection of buried munitions, the U.S. Army Engineering and Support Center, Huntsville (USAESCH) has defined standard equipment tests and data quality requirements for its Ordnance and Explosives – Digital Geophysical Mapping (OE-DGM) contractors. USAESCH has found that it is imperative to perform and review QC tests before carrying out production geophysical work. This ensures that the geophysical system is functioning properly and optimized for the target objectives.

The most common instruments in use today for OE detection are magnetometers, and electromagnetic metal detectors. This paper will include explanations of USAESCH required QC tests and acceptance criteria for these types of instruments.

1.0 Introduction

To improve the quality of the Ordnance and Explosives (OE) program, the U.S. Army Engineering and Support Center, Huntsville (USAESCH) has prepared a new manual: Ordnance and Explosives Digital Geophysical Mapping Guidance – Operational Procedures and Quality Control Manual (DGM QC Manual). This manual serves to outline required procedures and methods for OE-DGM surveys, performed by contractors for the U.S. Army Corps of Engineers. The primary purpose of this manual is to address and standardize quality control procedures to be used in DGM surveys. Uniform adoption of these procedures will promote higher quality geophysical surveys resulting in a high quality product for the client.

USAESCH has found that performing and reviewing QC tests before carrying out production geophysical work is essential. This ensures that the geophysical system is functioning properly and optimized for the target objectives. Past experience has shown that too often non-functioning equipment arrives at the site, causing delays in surveying. Worse yet, improperly functioning equipment may result in unreliable data, increased false alarms or missed buried munitions. Beyond this, there are certain errors/biases that may occur based on the way that geophysical instruments operate, such as latency and heading errors. All of these errors must be documented and corrected in order to get the best possible product.

The objective of this paper is to explain these QC tests as defined in the DGM QC Manual and required for OE-DGM projects.

2.0 QC Steps/Tests

The required equipment tests and frequency of testing are summarized in Table 1.

Table 1: QC Test Frequency

Test #	Test Description	Specific detector	Power on	Equipment A…	Beginning of …	Beginning & …	1st … operator	1 Li…	…id or 100 ft. per Linear Mile
1	Equipment Warm-up		X						
2	Record Sensor Positions			X					
3	Personnel Test				X				
4	Vibration Test (Cable Shake)				X				
5	Static Background and Static Spike					X			
6	Azimuthal Test	Magnetometer Only					X		
7	Height Optimization						X		
8	6 Line Test						X		
9	Octant Test - (Heading Error Test)	Magnetometer Only					X		
10	Repeat Lines							X	

2.1 Equipment/Electronics Warm-up

Purpose: Minimize sensor drift due to thermal stabilization. Most instruments need a few minutes to warm up before data collection begins. Follow the manufacturer's instructions or, if none are given, observe the data readings until they stabilize.

Acceptance Criteria: Equipment Specific (typically 5 minutes).

2.2 Record Relative Sensor Positions

Purpose: Document relative navigation and sensor offsets, detector separation, and detector heights above the ground surface. This will ensure that detector offset corrections and gradient calculations can be done correctly and that the surveys are repeatable.

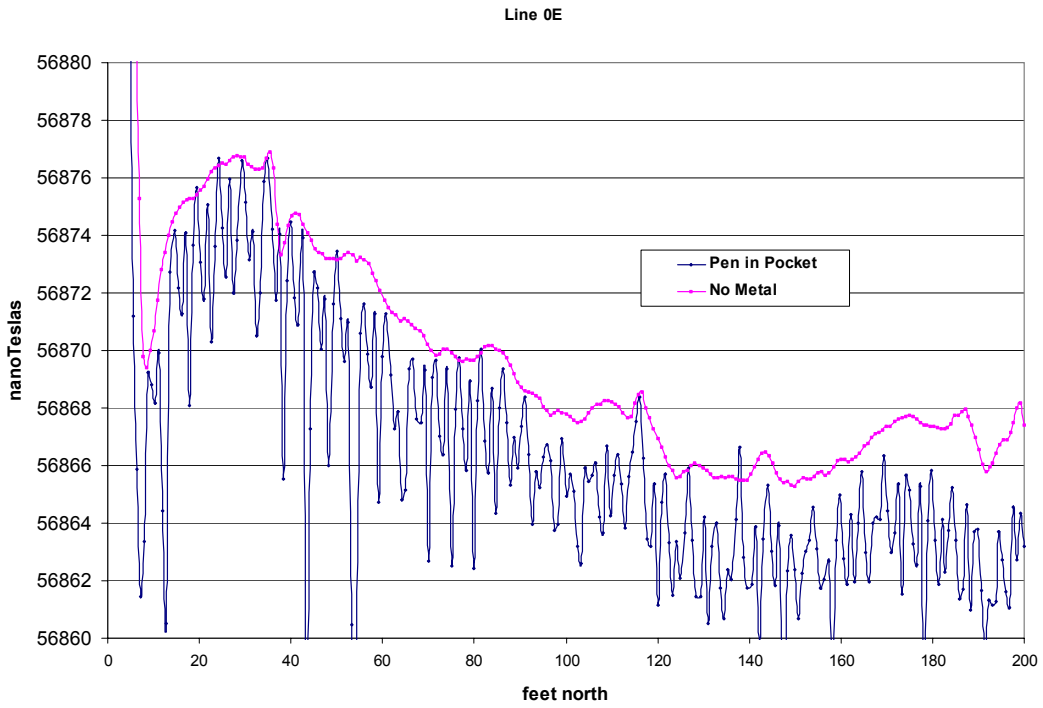
Acceptance Criteria: +/- One inch (2.54 cm)

2.3 Personnel Test

Purpose: Ensure survey personnel have removed all potential interference sources from their "bodies". The example in Figure 1 shows cesium vapor magnetometer data collected with and without a ballpoint pen in the operator's pants pocket. Another common noise source is steel-toed boots, which can produce data anomalies similar to OE targets.

Acceptance Criteria: EM61 +/- 2mV, Mag +/- 3nT

Figure 1

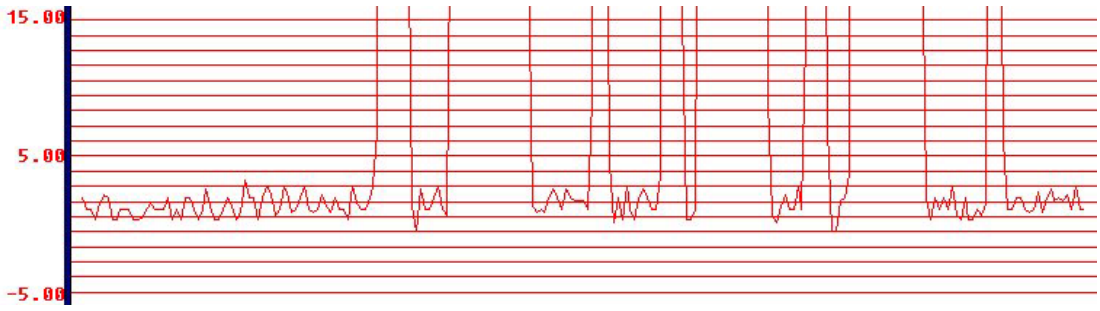


2.4 Vibration Test (Cable Shake)

Purpose: Identify and replace shorting cables and broken pin-outs on connectors. With the instrument held in a static position and collecting data, shake all cables to test for shorts and broken pin-outs. An assistant is helpful to observe any changes in instrument response. If shorts are found, the cable should be immediately repaired or replaced. After repair, cables need to be rigorously tested before use. Figure 2 shows EM61 data spikes caused by cracked pin-outs.

Acceptance Criteria: Data Profile does not exhibit data spike responses.

Figure 2



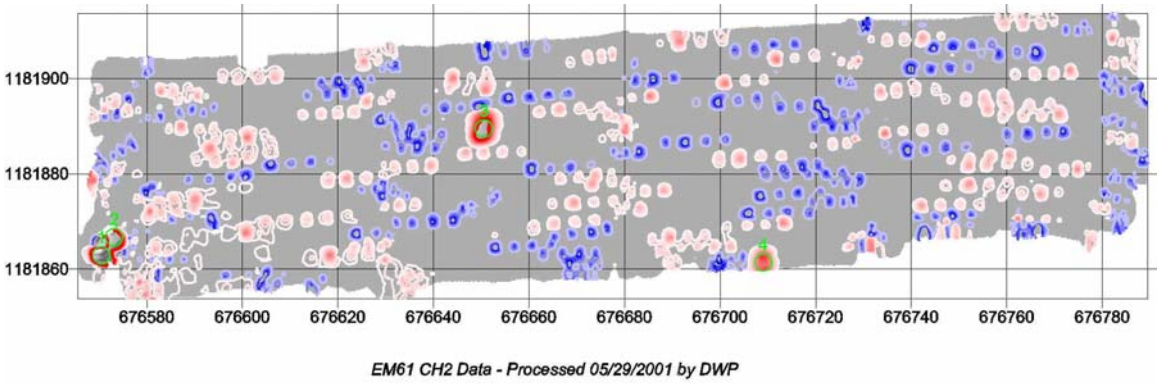
2.5 Static Background and Static Standard Response (Spike) Test

Purpose: Quantify instrument response drift, locate potential interference spikes in the time domain, and determine response and repeatability of the instrument to a standard test

item. A standard 2" diameter steel trailer ball (Uniball- available from U-haul) is the preferred test item, as it is easily acquired and transported.

Improper instrument function, the presence of local sources of ambient noise (such as EM transmissions from high-voltage electric lines), and instability in the earth's magnetic field (as during a magnetic storm) are all potential causes of inconsistent, non-repeatable readings. Figure 3 illustrates interference spikes from a navigation system with a 12 second period.

Figure 3



To perform the static background and spike test, place the instrument at its normal operating height so that it will remain stationary and begin data collection. Collect readings for a minimum of three minutes after instrument warm-up. Place the test item below the sensor and collect data for one minute. Then remove the item and collect for an additional minute. The operator must review the readings to confirm their stability prior to continuing with the geophysical survey.

Acceptance Criteria: Static Background Test: EM61 +/- 2.5 mV, Mag +/- 1nT
Static Spike Test: EM61 and Mag +/- 20% of standard item response, after background correction.

2.6 Azimuthal Test

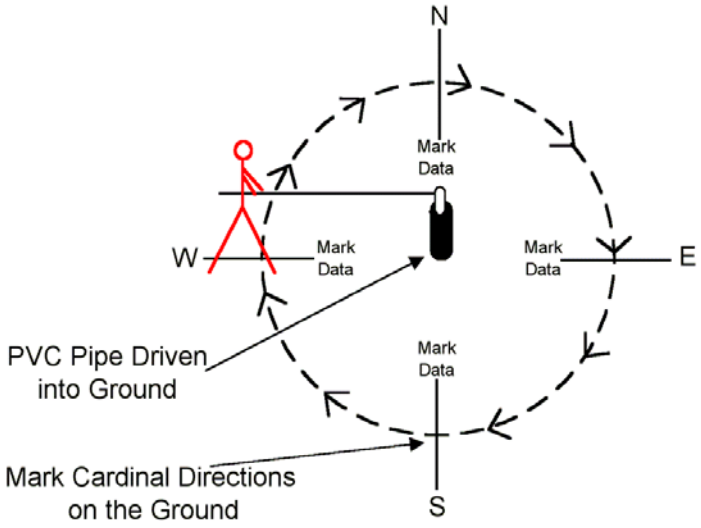
Purpose: Optimize sensor orientation to avoid optically pumped magnetometer sensor "Dead Zones". Applicable to magnetics only, this test is performed to document the differences in readings based on sensor orientation with respect to the earth's local magnetic field. An illustration of the Azimuthal Test is given in Figure 4.

To perform an azimuthal test, identify an area free of sources of geophysical noise. When the test is performed near a magnetic gradient, small shifts in the sensor head position will produce large variations in the total field values. The sensor must be rotated 360° around a fixed point. Placing the sensor head into the top of a vertical section of PVC pipe will help to stabilize it. Mark the four cardinal directions on the ground using pin flags or marking paint. Recording fiducial marks at the moment the operator is facing cardinal directions will aid in determining the heading error for particular survey line directions.

A variety of sensor orientations should be evaluated, to minimize the observed deviation in amplitude, and reduce chances of encountering magnetic “dead zones” for cesium vapor magnetometers.

Acceptance Criteria: Sensor Orientation that minimizes the observed deviation in amplitude and is devoid of drop-outs.

Figure 4

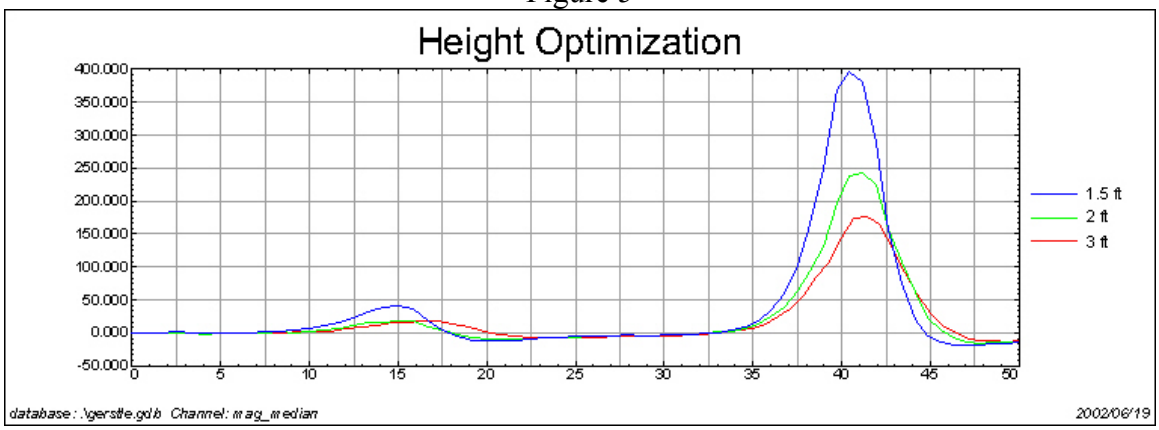


2.7 Height Optimization

Purpose: Determine the sensor height that optimizes the target signal-to-noise ratio and maintains adequate sensitivity. This test is most often applied to magnetics, and for the GEM-3 instrument. It could also be used for an EM-61 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, and the height that best meets the objectives is selected.

Acceptance Criteria: Maximum signal-to-noise ratio that reliably detects smallest target objective.

Figure 5



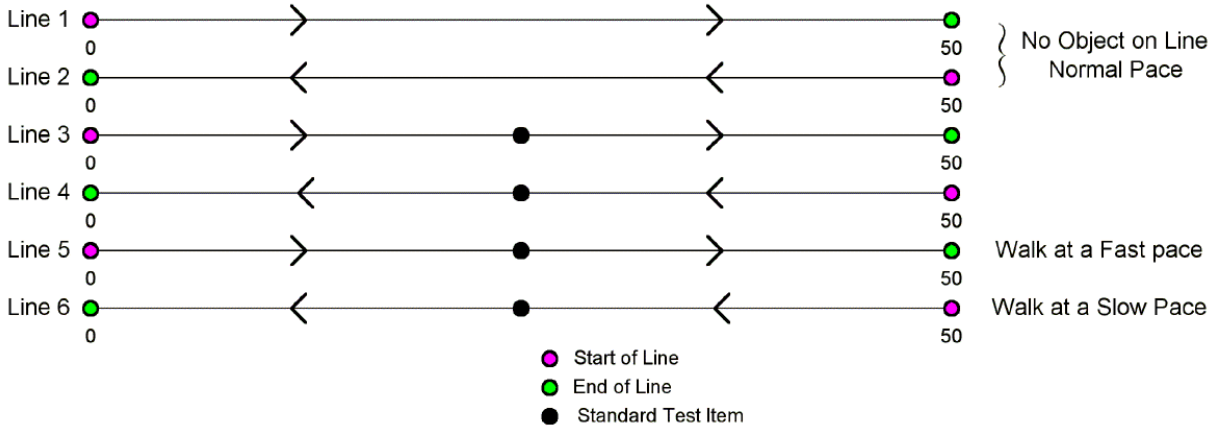
2.8 **Six Line Test**

Purpose: Document latency, heading effects, repeatability of response amplitude, and positional accuracy.

This test should be performed in an area relatively clear of anomalous response. 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.

Acceptance Criteria: Repeatability of response amplitude +/-20%, Positional Accuracy +/- 35cm

Figure 6



2.9 Octant Test (Heading Error Test)

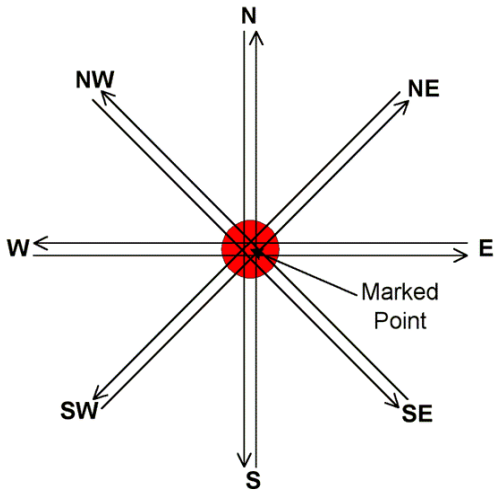
Purpose: Determine Heading effects (systematic shift based on direction of travel along the survey line). This test is for magnetics only. A magnetometer's response to

ferromagnetic objects varies slightly according to the orientation of the sensor in relation to the console electronics and the operator. It is recommended that test be performed for all equipment and operator combinations.

A total of eight lines of magnetic data are collected, passing over the same central point. The arrangement of lines for the test is illustrated in Figure 7. The difference in the response over the central point documents heading effects.

Acceptance Criteria: Document heading error for post-processing correction.

Figure 7



2.10 Repeat Data

Purpose: Determine positional and geophysical data repeatability. One line per grid, or 100 feet per mile for transect or meandering path surveys, will be repeated before and after the survey. This repeat line should have the test standard placed at approximately the halfway point in an area lacking anomalous responses. The repeat line will be located at least 10 feet outside of the grid and parallel to the direction of travel.

When viewed in profile and compared to original data, repeat data provides a means of evaluating the ability of the instrument to respond consistently, and evaluates the positional accuracy of the data. Errors in positional repeatability indicate a problem in the method of navigation or in the ability of the operator to perform an adequate survey.

Acceptance Criteria: Repeatability of response amplitude +/-20%, Positional Accuracy +/- 35cm

3.0 Conclusion

This paper has explained the QC tests required for U.S. Army Corps of Engineers OE-DGM projects as defined in the DGM QC Manual. Uniform adoption of these procedures will promote consistently higher quality geophysical surveys resulting in improved public safety.