TECHNICAL PAPER #0201

Utilizing a Multiple Metal Detector Array for Locating Anomalies Indicative of Ferrous and Non-ferrous OE/UXO

Prepared by:

Brett E. Pasapane
Senior Geophysicist, Roy F. Weston, Inc.

David R. Sieling
Senior Associate, McLane Environmental, LLC

For Presentation at:

National Defense Industrial Association
28th Environmental & Energy Symposium
Charleston, South Carolina
March 2002

WESTON

02P-0157

Utilizing a Multiple Metal Detector Array for Locating Anomalies Indicative of Ferrous and Non-ferrous OE/UXO

Brett E. Pasapane - Senior Geophysicist, Roy F. Weston, Inc., 1400 Weston Way, West Chester, PA 19380, Phone 610-701-7332, Fax 610-701-7401, Email: Pasapanb@mail.rfweston.com

David R. Sieling – Senior Associate, McLane Environmental, LLC, 707 Alexander Road, Suite 206, Princeton, NJ 08540, Phone 609-919-2702, Fax 609-987-8488, Email: dsieling@McLaneEnv.com

ABSTRACT

An array of three Geonics Limited EM61-MK2 metal detectors was utilized to identify subsurface metallic anomalies at the Mare Island Naval Shipyard in Vallejo, California. The goal of the 120-acre survey was to locate anomalies indicative of ferrous and non-ferrous ordnance and explosives/unexploded ordnance (OE/UXO) in dredge pond berms with particular attention to 20 mm high explosive (HE) rounds. The array spanned a total of 3.5 meters and the centers of the units were 1.25 meters apart. Prior to data acquisition, sensitivity tests were performed to establish the minimum distance between the array and the towing vehicle. Electromagnetic (EM) readings were collected every 0.20 seconds on each instrument equating to a distance of approximately 0.5 to 1 foot between readings along travel lanes. The instruments utilize a synchronization cable that allows the sensors to operate independently without interference. Real-time differential global position system (DGPS) information was collected simultaneously with the EM data for sub-meter location accuracy. Anomaly locations can be reacquired with a DGPS at any time for identification or excavation. Typical production rates using 1.25-meter lane spacing is approximately 6-8 acres in eight hours. A quality control test grid of buried inert ordnance, including 20 mm rounds, was surveyed with the array to help determine an optimal lane spacing and reading frequency. After calibration to the described settings and distances, the instruments imaged 20 mm rounds at depths between 1and 4 feet below land surface in multiple orientations.

INTRODUCTION

Performing ordnance and explosives/unexploded ordnance (OE/UXO) surveys over vast tracts of land poses difficult challenges. Quick mobilization, rapid data acquisition, reliable data, comprehensive coverage and above all, safety are a few of those challenges. A solution to meet these challenges is to mechanize the field survey. The above techniques were applied to approximately 120 acres of active and historical dredge pond berms at the Mare Island Naval Shipyard in Vallejo, California. The goal of the geophysical survey was to locate electromagnetic (EM) anomalies indicative of ferrous and non-ferrous OE/UXO in dredge pond berms with particular attention to 20-millimeter (mm) high explosive (HE) rounds. In order to transfer and begin reusing the dredge pond property, regulatory agencies required the protection of human health and the environment. The results of the survey and subsequent anomaly investigation will ensure that OE/UXO material not pose an accessible hazard to future site workers (Weston, 2001).

Due to past disposal practices and historical dredging activities in the Mare Island Strait, OE/UXO, metallic debris and other scrap material were transported along with dredge spoils through 16-inch diameter dredge pipes into the dredge ponds (Weston, 2001). The majority of the metallic debris gathered and settled near the outfall areas of the discharge pipes. Reworking of the pond interiors and “building-up” of the earthen berm slopes redistributed some of the metallic debris and OE/UXO material.

The dredge pond survey included the berm top and slopes, the pond interior within 25 ft. of the berm toe, and the dredge pipe outfall areas. The berm tops are relatively flat; however, the slopes are 30 to 40 in some areas. Also, the pond interiors were plowed making walking with the EM instruments dangerous for field personnel. Health and safety concerns included fatigue, heat exhaustion and slips, trips and falls. Mechanizing and constructing a towed multiple-unit array of metal detectors minimized potential injuries and met and/or exceeded project objectives including rapid data acquisition, reliable data and complete ground coverage.

EQUIPMENT

The Geonics Limited, EM61-MK2 high-resolution metal detector was utilized to locate ferrous and non-ferrous metallic anomalies. The EM61-MK2 has multiple time gates that enable the geophysicist to sample at three discrete time intervals on the bottom coil and one discrete time on the top coil for a given location. The time gates of 216 microseconds (ìs), 366 µs and 660 ìs provide enhanced signal resolution over the standard EM61, which has a single time gate centered at 660 µs (Bosnar, 2001). The EM61-MK2 and accompanying software has the capability of simultaneously collecting data from five instruments. Our study used two array configurations: a three-instrument and a two-instrument array. A synchronization cable between the instrument electronics allows the sensors (coils) to operate independently without any significant interference.

Position data was collected simultaneously with the EM data utilizing a Trimble Pro XRS differential global positioning system (DGPS). The real-time DGPS data was integrated directly into a PRO4000 data logger for sub-meter location accuracy. A single DGPS antenna was mounted above the top of the middle unit; EM data for the two side units were relative to this antenna position (Figure 1). The coordinates for the side units were calculated based on the arrays precise geometry.

Two different EM61-MK2 array geometries were constructed to accommodate the type of terrain surveyed. Data collected at the Mare Island Dredge Ponds utilized three EM61-MK2 units in areas of relatively flat terrain (Figure 1) and two units along the berm slopes (Figure 2). The three-unit array had the sensors oriented side-by-side and was towed by an all terrain vehicle (ATV). This design was utilized over the majority of the survey area that consisted primarily of flat terrain on the Dredge Pond berm tops and pond interiors. The EM61-MK2 unit arrays were developed and constructed utilizing non-metallic components and materials.

Figure 1: Multi-unit array (three sensors) of EM61-MK2 metal detectors pulled with an ATV.

The top and bottom coils of the EM61-MK2 measure 1.0 meter by 0.5 meter (m) with the instruments oriented with the long axis perpendicular to the direction of travel and mounted as closely as possible (Figure 1). The total width of the array was 3.5 m. Given these dimensions, the coil center points (data point locations) were 1.25 m apart. The coil electronics and power for each sensor were mounted on the back of the ATV. The data loggers for the EM and DGPS were mounted on the front of the ATV allowing for easy acquisition, start/stop and data monitoring.

Figure 2: Dual unit array (two sensors) of EM61-MK2 metal detectors pulled with an articulating mower along berm slope.

The berm slopes posed a unique challenge for data acquisition as well as for personnel safety. The berm slopes typically had an incline of approximately 30 or less, but were too steep to safely operate the ATV. An articulating mower was used to tow a modified version of the multi-unit EM61-MK2 array (Figure 2). The mower allowed the operator to maintain an upright vertical position, while the array followed the sloped terrain. The array was modified to include two EM61-MK2 sensors, making the array lighter and more maneuverable. The sensor separation and orientation of the dual-unit array spanned 2.3 m, while maintaining a 1.25 m data point separation. The DGPS antenna was mounted to maintain a vertical position above the actual data collection location and was adjusted for each slope encountered (Figure 2).

SAMPLE PARAMETERS

Sensitivity/proximity tests were conducted with both arrays and their respective towing vehicles. These tests determined the optimal distance between the EM61-MK2 sensors, ATV, the articulating mower and DGPS antennas. The towing vehicles were kept approximately 2 meters from the sensors to minimize noise in the EM signal. The mower was kept at an optimal RPM threshold to minimize EM noise.

Prior to testing the arrays on a test grid of known inert ordnance, sampling interval was estimated based on data logger battery power, memory and vehicle towing speed. EM readings were collected every 0.2 seconds (s) (five readings per second) on each sensor equating to a distance between readings of approximately 0.5 to 1.0 ft along travel lanes. This range between readings was a function of the vehicle towing speed ranging between 1.7 and 3.4 miles per hour (mph). The typical production rate on the flat areas with the multi-unit array was approximately six to eight acres per eight-hour field day. These sample parameters and production rates were sufficient to image 20 mm projectiles in multiple orientations at depths of two feet below ground surface (bgs). Production rates include the quality control measures discussed below.

QUALITY CONTROL

Quality control measures were taken each survey day to ensure reliable data. Dedicated "null" locations were used to zero the instruments. EM readings were taken at the null locations at the beginning and end of each survey day to monitor for proper instrument null and potential instrument drift. A quality control line of finite length was set up at each null location to document reproducibility of EM readings and proper DGPS positioning each survey day. Data were downloaded to a field computer at the end of each day or when the loggers were full, reviewed for completeness and differentially corrected positions, and archived daily.

TEST GRID

A test grid measuring 100 ft. by 100 ft. was constructed and seeded with inert ordnance typical of expected targets to "calibrate" the geophysical equipment. Surveying the test grid with the multi-unit array and dual-unit array helped establish optimal lane and sample interval spacing for data acquisition. The inert ordnance items included 20 mm HE projectiles, 5 inch (in.), 6 in., 8 in. and 155 mm projectiles in various orientations and depths. Analysis of the EM data was accomplished using Geosoft OASIS montaj™ data processing and analysis system along with the optional UX-Detect™ module. The 20 mm items within two feet of the ground surface had relatively strong amplitudes compared to the 20 mm items buried at 3 and 4 ft. bgs. Utilizing the multiple time gates of the EM data and analyzing the signal, the deeper items were also located. However, the signature of these items was within the background EM range. The larger items (5 to 8 in. items), some planted in clusters up to 10 ft. bgs, were also located within the test grid.

CONCLUSIONS

The EM61-MK2 units were designed by the manufacturer (Geonics Limited) to be used individually or as in this case integrated together to form a larger "swath". Multi-unit metal detector arrays allowed a safe, rapid means of collecting reliable and comprehensive data to locate EM anomalies indicative of ferrous and non-ferrous materials. Using a mechanized approach reduced manpower costs and potential injury. The arrays also effectively located small items; including 20 mm HE rounds with the relatively large towed swath.

Since the data are digital and permanently archived, interpreted EM anomalies can be easily reacquired in the field with a DGPS unit for subsequent intrusive activities. After witnessing this data acquisition technique, the regulatory agencies involved with the dredge ponds approved the multi-array approach to facilitate transfer to commercial reuse.

REFERENCES

Bosnar, M., 2001. Geonics Limited, Technical Note TN-33, "Why did Geonics Limited Build the EM61-MK2? Comparison Between EM61-MK2 and EM61".

Weston, 2001. "Unexploded Ordnance Intrusive Investigation, Dredge Spoils Ponds, Mare Island", Revised Draft Summary Report, Roy F. Weston, Inc., August 31, 2001.