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digital geophysical mapping

Enhancing ordnance detection performance

Advanced analysis of combined geophysical data yields a 3-D map of underground anomalies, boosting detection capabilities beyond latest state-of-the-art testing results.

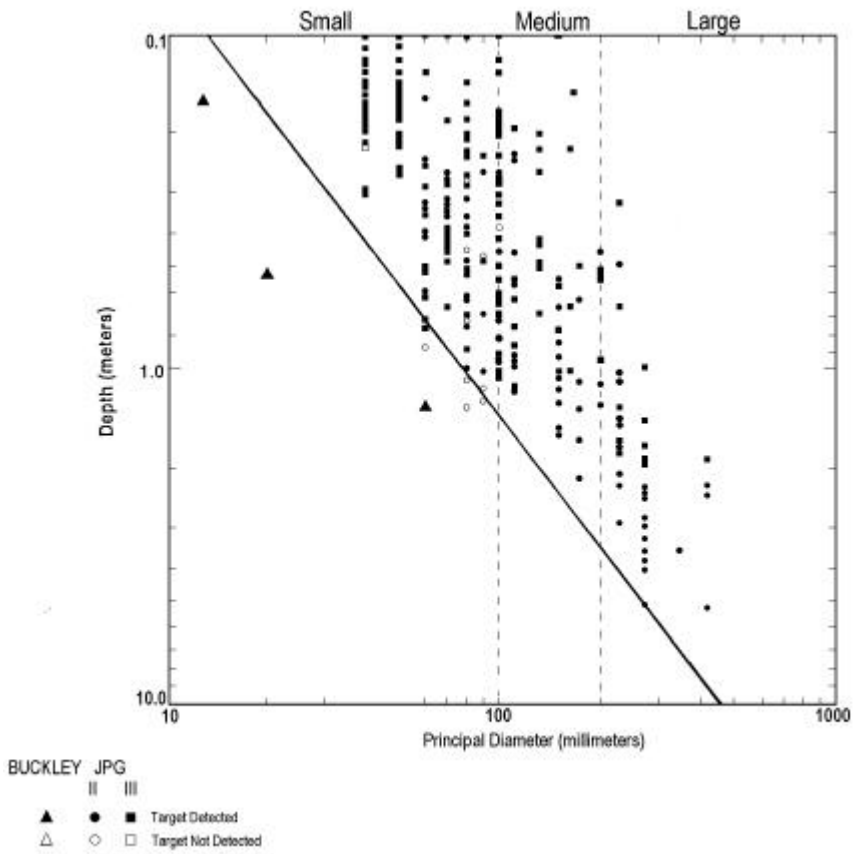
Background Traditionally, the location of buried ordnance has centered around unexploded ordnance (UXO) specialists equipped with hand-held metal detectors (usually magnetometers). The UXO specialists walk across an area under investigation, sweeping a magnetometer from side to side and placing a small flag in the ground wherever the magnetometer suggests an ordnance item may be located. That effectiveness of that process, often referred to as "mag and flag," varies widely, depending on specific site conditions, ordnance size and depth, the instrument used, and the experience and care of the individual UXO specialist. In evaluations at the Jefferson Proving Ground (JPG) Advanced Technology Demonstration (Phase I) and the former Buckley Field geophysical prove out, the effectiveness of mag and flag, in terms of the percentage of items detected, was on the order of 30% to 40% of the UXO present.

New Technology Many new techniques have been proposed and tested in an effort to improve detection performance. One basic element common to all of the most successful is digital geophysical mapping, where the digital data from the geophysical sensor is combined with positional survey or navigation information to develop a three-dimensional map of the characteristic that the sensor is measuring. Ordnance items (along with other debris and natural irregularities) show up as high and low points, or anomalies, on such site maps.

The geophysical mapping process capitalizes on the use of sensors with higher sensitivity, application of noise reduction techniques (real time and post processing), and advanced data-analysis techniques. With a data logging system, the user is no longer constrained to real-time decisions and selections (to place a flag or not to place a flag). Rather, the data stream can be enhanced and analyzed during post processing, and the experience of others can be brought to bear (for example, through expert systems). Furthermore, a permanent record is produced. In evaluations at JPG Phases II and III and at the Buckley geophysical prove out, detection efficiencies were around 70% to 90% for single instrument systems. Systems with two or more instruments, however, have detected over 95% of the targets in test plots at JPG.

Buckley Field Project Design Based on those successes, we chose digital geophysical mapping for the sampling needed to support the engineering evaluation/cost analysis for former Buckley Field. The sensor system was competitively selected using a geophysical prove out plot where various ordnance items (or simulated items) of the types and at the depths expected for the real site were buried in known locations in an area similar to the site. Then, systems representing the most successful of the participants from JPG were used to map the plot. The sensor system with the best combination of detection, false alarm, and production rates was chosen for production work. In addition, several data enhancement techniques were used. Data were screened to identify equipment malfunctions and data sets characterized by excessive noise. Then, each data set was processed to adjust for instrument bias, to remove background level, and to enhance anomaly signatures.

Results by size and depth The figure shows a plot of ordnance size versus burial depth. The solid circles and squares show the items detected by all participants in JPG Phases II and III, respectively. The open circles and squares represent items not detected by any system. Ordnance items ranging from 40-millimeter grenades and submunitions to large bombs are represented in those data sets. Based on the pattern made by the circles and squares, a clear demarcation between detectable and undetectable items can be seen, as shown by the diagonal line. Above that line falls the area of state-of-the-art detection of ordnance for various sizes and depths, according to JPG results.



The solid triangles show the size and depth of the ordnance items actually identified and recovered at Buckley using geophysical mapping techniques. The three triangles represent a 0.50-caliber projectile, a 20-millimeter projectile, and a 3-pound MK23 practice bomb. Although other items were found, those triangles represent the deepest of each size. As the figure shows, digital geophysical mapping at Buckley has led to detection of ordnance items at depths beyond the limits demonstrated by the combined best efforts of JPG Advanced Technology Demonstration participants.