COMPARISON OF A SUBMERGED TRANSIENT ELECTROMAGNETIC DETECTION SYSTEM (SUBTEM) AND THE TELEDYNE SURVEY SYSTEM (TSS) FOR UXO IDENTIFICATION AT PORTSMOUTH INTERNATIONAL PORT.

Paulo Tadeu de Oliveira Júnior[a], Jan Koelbel[a], David Rose[a]

[a]Boskalis Hirdes – Heinrich Hirdes EOD Services GmbH, Am Festungsgraben 10, 21079, Hamburg, Germany

Paulo Tadeu de Oliveira Júnior, Am Festungsgraben 10, 21079, Hamburg, Germany, P:+1520 35 09 486, F: +49 40 76 60 94-40, paulo.de.oliveira@boskalis.com

Abstract: *Given the required improvements in infrastructure to safely accommodate larger vessels at Portsmouth International Port, dredging operations were requested for the main channel along few other enhancements at the port's support facilities. During the site investigation phase, numerous objects were found on the seabed, which could potentially compromise the site excavation and therefore had to be taken out of the investigated locations. The employment of ordinary electromagnetic systems to identification of conductive material has been proved to be successful, however they lack the ability to classify the investigated target as an UXO or regular debris (scrap metal, cannonballs, etc…).*

The use of the SubTEM system turned out to be successful in identifying and classifying targets rather than only pointing out their location. The aforementioned system operates with partially overlapping transmit loops and 84 receiver coils. By combining data from all sensors, the system is capable of also identifying the shape and orientation of the target, which results in a substantial reduction of the number of required digs prior dredging operations take place. As result of its employment, it was calculated that the Master Target List was reduced in over 90% due to SubTEM's better filtering capabilities and a performance of over 70% was computed (conductive material retrieval), which is an enhancement of almost 30% in comparison to the TSS-440.

In this paper, the authors compare the efficiency of both TSS-440 and SubTEM systems at Portsmouth International Port as tools for supporting not only the removal of large debris and other obstruction objects, but also the identification of Unexploded Ordinances (UXOs).

Keywords: *underwater transient electromagnetic system, electromagnetic induction, unexploded ordinance, demining, bomb detection, dredging, underwater acoustic modelling, underwater detection systems*

1. INTRODUCTION

After the requirement for the construction of two Queen Elizabeth Class (QEC) aircraft carriers was endorsed, the Defense Infrastructure Organization requested the enhancement of the base's support facilities, which included the dredging of the approach channel and inner Harbor areas. During the site investigation, numerous objects were found on the seabed, which had to be dredged given their potential to damage the working vessels.

In November 2015, a German sea mine was discovered by one of the vessels when removing large debris and other obstruction objects. The aforementioned type of mine is made of Aluminum and therefore could not be identified by the employed magnetometer, which is capable to only identify ferrous metals. Thus, a special sledge with multiple TSS coils was developed so all kinds of conductive metals could be identified.

At a later stage, the SubTEM system came into play, which features the capability to not only identify conductive material, but also to further classify into a potential UXO or ordinary scrap metal. This asset allows the project to focus on targets that are really important and actually pose a considerable risk to dredging works. Given this greater likelihood of finding an UXO during the investigations, all objects and obstructions to be investigated were treated as UXO until positive identification could be done.

Site Characterization

The dredged areas were divided into 5 main zones with subsections, which were added based on the amount of volume to be dredged. A summary containing a better description of the aforementioned areas is shown in Table 1.

Zone	Targets
Zone A: Outer Approach Channel	
Zone A: Horse Bank	329
Zone A; Spit Bank	151
Zone A: Hamilton Bank	180
Zone A: Centre Channel	1231
Zone B: Harbour Entrance	33
Zone C: Inner Harbour Channel	6
Zone D: Inner Harbour & Turning Circle	
Zone D: Inner Harbour	29
Zone D: Turning Circle	91
Zone E: Berth Pocket	89
Total	**2139**

Table 1: Expected number of targets as of June 2016.

Primarily a Side Scan Sonar scan of the area was performed in which 800 targets were identified. This result was superseded by a later Magnetometer survey that resulted in 1638 targets to be further investigated. As of June of 2016, a TSS survey was performed and a more up to date target list was provided, which showed that 2139 targets were expected to be inspected.

2. DETECTION PRINCIPLE OF ELECTROMAGNETIC INDUCTION SYSTEMS (EMI)

As depicted on Fig. 1, EMI systems work by means of transmitting a pulse and measuring the environment's response to it.

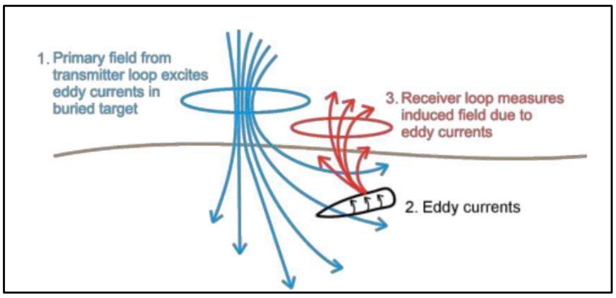

Fig. 1: Basic principle of EMI systems. (Beran, Zetl, & Lutes, 2016)

a) A transmitter coil (blue) is energized. Due to the flowing current in the coil, a magnetic field is generated (blue).
b) Any conductive object within this (suddenly switched on) magnetic field, tries to resist to it by generating eddy currents (induction) which generate an opposite magnetic field (red). Due to the electrical resistance in the objects, the eddy currents die out over time and with it the generated field. The primary field is then switched off, again resulting in a change in the magnetic field which the conductive object tries to resist by generating its own field. Also, this field dies out over time. This on-off loop of the primary field is constantly repeated. (Beran, Zetl, & Lutes, 2016)
c) The receivers (red loop) measure the decaying field from the objects the when primary field is switched off.

3. PERFORMANCE OF THE TELEDYNE SURVEY SYSTEM (TSS)

Using electromagnetic induction (EMI) system to investigate anomalies on the seabed of a given site has proven to be an efficient way to identify large debris and other obstructions. EMIs, like the employed TSS-440, are well known for their capabilities of detecting all kind of conductive materials, including non-magnetic metal-made obstructions like the found German sea mine (LMB).

The TSS-440 consists of three coils, each measuring 1m x 1m and they were mounted crossline with 0.5m gap in adjacent positions. Each coil covers an area of 1.5m, thus a total survey swath of 4.50m is achieved for each line.

A drawback of this kind of system is the fact that the device is only able to scan up to approximately 2 meters below the seabed. Thus, for a required dredging depth to be fully scanned and labeled as "clear of anomalies" the site scanning had to occur multiple times and always followed by the excavation of the respective layer.

At Portsmouth International Harbour this system was responsible for the investigation of 614 targets from which 211 conductive objects were retrieved, what represents 34.4% of the total amount of anomalies inspected. The other 65.6% is composed of either not conductive materials or spots where nothing was found, with 0 anomalies identified as a UXO-like-target. The employed TSS was able to scan the seabed at a rate of approx. 16,500 $\mathrm{m}^2/_{hour}$

4. PERFORMANCE OF THE SUBMERGED TRANSIENT ELECTROMAGNETIC DETECTION SYSTEM (SUBTEM)

The SubTEM assembly, as depicted in Fig. 2, is composed of a completely non-metallic sledge constructed from HDPE that weights around 10 ton and is combined with a time- domain-electromagnetic-survey system, which is able to detect not only ferromagnetic materials, but also non-ferrous conductive materials. With this system, it is possible to identify either conventional UXOs and non-magnetic UXOs, such as the German LMB (GC) mine.

The assembly is dragged along the seabed to ensure the maximum survey penetration depth is successfully achieved. Its exact positioning is guaranteed due to the positioning systems present on both the sledge and on the vessel, which are combined to guarantee maximum accuracy. The SubTEM system collects data at a nominal survey speed of 2.0 knots (1.03m/s) and covers a swath of 5m. At this survey speed and swath, the system is capable of covering over 18,000m^2 per hour, with a recording rate of 4,700 m^2/hour depending on the environmental conditions.

Fig. 2: SubTEM sledge attached to a dedicated towing vessel.

Keeping in mind that one of the biggest problems issues regarding conductive material detection is the background response from the seawater, the employed algorithm is responsible for removing this "noise" from the readings so a clearer signal can be obtained. At a later step, these signals are then compared to an extensive library, depicted in Fig. 3, which also contains standard responses from commonly retrieved unexploded ordinances and scrap metal, and if an agreement is reached the anomaly is labeled accordingly.

Fig. 3: Library used to validate the readings from SubTEM.

Given the SubTEM high reliability, all anomalies detected by the system were considered to be potential UXOs. However, if a positive identification of the obstruction could be attempted, i.e. if the operator was 100% sure the object was not an UXO, the item wasn't further inspected, otherwise the target would be put on the dig list. The amplitude, relative size of the three polarization tensor components and the fall-off with time of the polarization tensor parameters are related to the size, shape and material properties (metal type, metal thickness) of the buried item. Fig. 4 shows an example of the SubTEM results over an item that was subsequently found to be a 250kg German bomb left over from a World War II bombing raid.

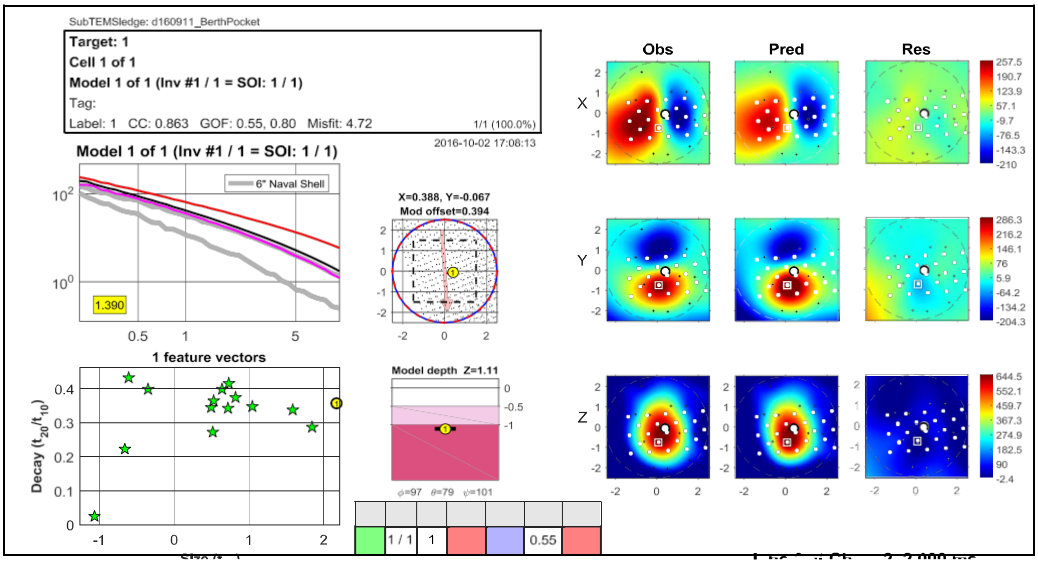

Fig. 4: Example of a SubTem result from the inversion model employed to classify the investigated anomalies.

The colored images show the three vector components observed by the SubTEM (left column), the predicted data from inversion (middle column) and the difference between the two (right column). The main result from the inversion is the polarizability plot on the center left, which shows that this object is very large and approximately axially symmetric (displays the characteristics of an intact bomb).

The SubTEM's technical advantages of identifying and classifying the targets provide cost saving on the overall survey budget, which, ultimately, are the reasons that turn this equipment so competitive in comparison to other standards magnetometers.

At Portsmouth International Port, 95% of the detected metals have been classified as non-hazardous or too small to be a dredging hazard and did not have to be excavated before dredging. The system was able to maintain a scanning production equal to 10.8 m^3/s, which resulted in 980 targets to be further investigated. From the total number of targets, 73% resulted in the excavation of conductive objects.

The overall goal is to continuously work on the improvement of the system, by means of expanding the library's dataset. This would certainly reduce the number of safety digs, which, at the present moment, accounts for roughly 25% of the dig list. It is estimated that with better decision-making capabilities the numbers of safety digs will be minimized with an increasing number of relevant obstructions found on site. Considering the fact that some of these locations were neighbors of other places where some other objects (such as large wire ropes) were excavated, one could say that clearing one site the other one was also cleared.

5. CONCLUSIONS

Given SubTEM's inherent proprietary configuration of transmitters and receivers, the system is capable to better reduce the effect of the large background signaling caused by the conductive sea water environment, which provides the user a more reliable database to work with.

Regarding the fact that the identification and classification of the anomalies are ultimately performed by subjective means, i.e. by visual inspection of the data administrator, the reader may expect an increase in the performance as the data manager gains more confidence on the system, which, as a matter of fact, is directly correlated to the amount of targets placed on the safety dig list. It is important to know that the person responsible for all data uses standard responses from library items to assess each target and the expansion of such database would also increase the system's overall efficiency.

ACKNOWLEDGEMENTS

This paper was sponsored by Boskalis Hirdes EOD Services GmbH. The authors extend their appreciation to all Boskalis Hirdes' team for their invaluable contribution to the development of this project.

REFERENCES

[1] Beran, D., Zetl, D. B., & Lutes, D. D. (2016). *Decision Support Tools for Munitions Response Performance Prediction and Risk Assessment.* Black Tusk Geophysics, Inc., Strategic Environmental Research and Development Program. Vancouver: SERDP, pp. 128, 2016.