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DETECTION OF SHIPWRECKS AND SUBMERGED OBJECTS USING SUB BOTTOM PROFILER AND SIDE SCAN SONAR IN SHATT AL-ARAB RIVER, SOUTHERN IRAQ

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ABSTRACT

A geophysical remote sensing obstruction and debris survey is performed in this work to investigate and describe the shipwrecks and submerged debris at Shatt Al-Arab River in the extreme southern part of Iraq. The study area is extended in a section of Shatt Al-Arab River from Ashar to Siba cities – Basra governorate-Southern Iraq, with approximately 60 Km distance. Side Scan Sonar (SSS) and Sub-Bottom Profiler (SBP) techniques were applied. Seventeen distinct locations were identified that containing numerous objects on the river bottom, however, eleven of them ware correlated with reflections by SBP, included vessels, boats (medium and small sizes), tankers and bridge, as well as some unidentified debris. A total of 25 sonar targets wrer mapped. Two detected targets were found to have indicative signatures of an ancient shipwreck. The most identified objects are the charted shipwreck located near the Maaqal quay northern the study area. Most of the targets are localized in the northern part of the study area particular vicinity of the Basra city center on the river banks in which mostly human activities and old functional port were established. The most number of these wrecks which completely or partially submersible were Pontoon boats or small tanks, that have about 40 meters long and 8 meters wide.

الكشف عن الغوارق الغاطسة باستخدام تقنيات المقاطع العرضية للقيعان والسونار البحري في مجرى شط العرب، جنوب العراق

ولاء مجيد الموسوي

المستخلص

تضمنت الدراسة الحالية استخدام المسوحات الجيوفيزيائية البحرية في الكشف عن الغوارق والحطام البحري الغاطس (المغمور) في مجرى شط العرب للمقطع الممتد من جزيرة السندباد الى منطقة السيبة بحدود 60 كم. تضمنت هذه المسوحات استخدام تقنيات المقاطع العرضية للقيعان والسونار البحري. تم تحديد 17 موقع يحتوي على أهداف متعددة غاطسة باستخدام تقنية السونار البحري، تمثلت بزوارق كبيرة وصغيرة وانقاض العوامات، 11 موقع من هذه المواقع حددت ايضاً بتقنية المقاطع العرضية للقيعان للحصول على تفاصيل دقيقة. بلغ المجموع الكلي للاهداف (الغوارق) المكتشفة 25 هدف وقسم من هذه الغوارق مدفون جزئياً تحت القاع. ويوجد غارقين يمكن ان يشيرا الى انهما غوارق أثرية، العدد الأكبر من الأهداف الغارقة المكتشفة يقع في المقطع الممتد مابين المعقل والعشار شمال منطقة البحث والذي يعزى وجودها الى النشاط البشري وبالخصوص المناطق القريبة من الضفاف في مركز المدينة حيث يوجد ميناء المعقل، الميناء الأقدم في مدينة البصرة. القسم الأكبر من هذه الغوارق هو من نوع العوامات التي يبلغ طول كل منها 40 م وبعرض 8 م. اثبتت الدراسة الحالية كفاءة التقنيات المستخدمة في الكشف الدقيق للغوارق والاهداف الغاطسة وبالخصوص في المياه الضحلة.

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INTRODUCTION

Shatt Al-Arab River is one of the most important Iraqi waterways, with length of about 200 Km, formed by the confluence of the Euphrates and the Tigris rivers in the town of Al-Qurnah in the Basra Governorate, southern Iraq. Shatt Al-Arab River converges with the Karun River near Basra City then flows into the Arabian Gulf. About 130 Km of its course is located within the Iraqi territories, and the rest (about 70 Km) is shared with Iran, representing the Iraqi – Iranian border line (Fig.1). Shatt Al-Arab River has suffered from different types of natural and man-made modifications, especially during the past 40 years, such as, dramatic declination of water discharges due to modern hydraulic constructions at the upper part of the drainage basin. These changes have caused a salinity increase, due to increase of tidal effect from the Arabian Gulf, and increase of sediments deposition in the river course, which subsequently formed new geomorphologic units, such as islands and point bars, (Fig.2). The second crucial man-made alterations are caused by the struggles and war actions that happened in the area of Shatt Al-Arab course, including the First Gulf War (1980 – 1988), the second in 1991 and the third in 2003, which led to the sinking of many ships.

Fig.1: Location map of the study area (red line represents the studied part of Shatt Al-Arab River)

Fig.2: Shipwrecks forming a new island in Shatt Al-Arab River (after Al-Wahaely, 2009)

Consequently, these wrecks have given rise to several environmental consequences. For example, there has been a water contamination due to environmental hazardous materials that some of these wrecks were carrying, such as, oil and numerous unexploded ordnance, which brought serious environmental damages and their effects may be prolonged for an extended period of time. Also, the wrecks may work as traps for suspended sediments making a rapid deposition. Subsequently, different islands formed, and some of them may impede ships movement in the navigational channel (Fig.2).

In ancient shipwreck research, the published papers have addressed the detection of relatively recent, wooden- or iron-made wrecked ships, rather complete or relatively well preserved, commonly rising well above the seafloor (Hobbs *et al*. 1994; Søreide and Jasinski, 1998; Barto Arnold III *et al*. 1999), or the geophysical investigation of already known submerged ancient sites (Quinn *et al*. 1997; 1998). Many studies have shown that marine geophysical survey techniques, such as Side Scan Sonar (SSS), Sub Bottom Profiler (SBP) and magnetometer prospecting, are very powerful tools for shipwreck detection. (Ballard *et al*., 2000; Quinn *et al*., 2000; Quinn *et al*., 2002a; Quinn *et al*., 2002b; Chalari *et al*., 2003; Blondel and Pouliquen, 2004; Papatheodorou *et al*., 2001; 2005; Sakellariou *et al*., 2006).

The study area lacks detailed information on shipwrecks, and the marine geophysical studies have not covered this area yet in order to provide accurate and specific information about the position and dimension of shipwrecks. This study aims to use SBP and SSS techniques to investigate and describe the shipwrecks and debris along 60 Km of Shatt Al-Arab River course. These techniques, which are applied for the first time in Iraq, will support dredging operations by giving clear vision about the submerged objects that may obstruct maritime activities in Shatt Al-Arab River.

THE WRECKS IN SHATT AL-ARAB RIVER

Wrecks are distributed along the river course. Some of them are covered partially by the sediments and others are visible above the water surface. There are 60 sites that contain these targets (wrecks) which differ in type, size, and shape. Some sites contain more than one target and many of them are completely submerged and cannot be detected. Our estimation suggests that there are around 36 wrecks in Shatt Al-Arab estuary, beside around the same number in the nearby Khor Abdullah waterway, Umm Qasr and Khor Al-Zubair areas. Some of them sank during the war actions (1980 – 2003) (Fig.3), some fell victims to mined waterways and some sank because of collision accidents in the peace time. In the waterways of the Basra City, several tens of wrecks and debris (ships, vessels and small boats) exist, especially in the tributary channels of Shatt Al-Arab River (Rubat, Khandak, and Dockyard).

Fig.3: Ships sunk in Shatt Al-Arab River during the First Gulf War, http://iraqslogger.powweb.com

METHODOLOGY OF THE SURVEY

Two marine geophysical acoustic techniques are used in this survey: the Sub Bottom Profiler (SBP) and the Side Scan Sonar (SSS). Review and interpretation of the SSS imagery, integrated with the SBP reflections are used to obtain a complete data prospect about the targets. Initially, the SSS survey was conducted to identify location, size and shape of the targets. The SBP interpretation is conducted in an attempt to determine the depth of the targets from the water surface.

SBP is an acoustic investigation technique that maps the sub-bottom by surveying a river cross section through many trips. The general functioning principle of the SBP pinger type system features is the emission of sound waves through the transducer (or array of transducers) toward the bottom with a specific frequency. The waves that impact with water-sediment, sediment-rock interfaces produce a reflected back wave to the transducer. The SBP survey is carried out using the Strata Box™ marine geophysical Instrument (produced by SyQwest, Inc., USA), which operates on 10 kHz frequency. The final output of Strata Box, as a subsurface imagery (cross section), is scaled horizontally in a spatial domain (i.e., feet or meters) and vertically in a temporal domain (in milliseconds) or depth (in feet, or meters), Fig. (4).

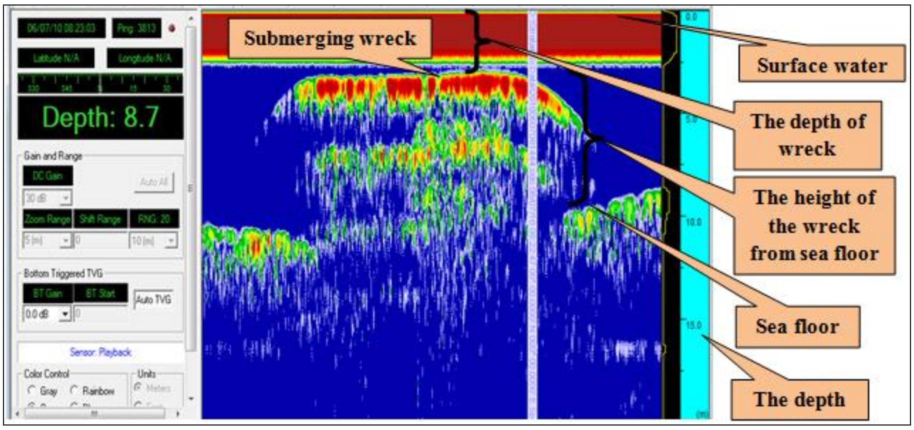


Fig.4: An example of the SBP survey carried out in the sea using Strata Box section, red and blue color refer to high and low amplitude reflection

SSS is an active system consisting of a long acoustic array providing a beam which is wide perpendicular to the array and narrow parallel to the array’s long axis (Urick, 1983; Mazel, 1985). The SSS is a category of sonar systems used to efficiently create an image of large areas of the seafloor. It may be also used to conduct surveys for maritime archaeology, in conjunction with seafloor samples and it is able to provide an understanding of the differences in materials and textures type of the sea/ river bed. The SSS produces acoustic images called sonographs which portray the seafloor texture and seafloor morphology (Fig.5), the interpretation of the "sonographs" is based on the acoustic reflectivity and on specific acoustic criteria, (Blondel, 1999). The energy that penetrates deeper into the sub-bottom will give two types of attenuation. The first is scattering, which occurs due to sound reflects off components in the water column. Some of these reflectors include boundaries (sea surface and bottom), bubbles, biological material and suspended particulate. Once the sound pulse travels from the transducer, it will be reflected off these objects in many different directions. Another attenuation is the bottom reverberation. It occurs whenever a sound pulse strikes the ocean bottom. The SSS survey in the present study is carried out using the Imagenex Model 872

"YellowFin" marine geophysical Instrument (produced by Imagenex Technology Corp., USA).

In the present survey, the YellowFin SSS system was mounted, at the side of the vessel, 1 m below the water surface during the measurements. The acquisition parameters included a low frequency of 260 kHz with swath width of 100 m (50 m on each side of the source). The horizontal beam width of the used transducer is 2.2° and the used vertical beam width is 75°. These parameters are found optimum for the studied area and were held constant throughout the whole survey. The survey was conducted during seven cruises, in the years 2015, 2016 and 2018, using fiberglass vessel appropriate for the marine and river measurement.

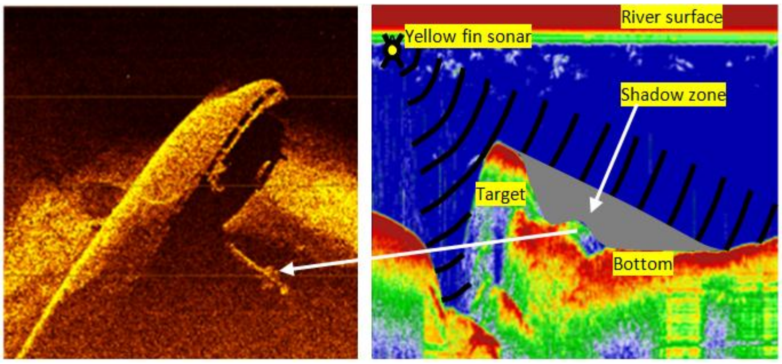


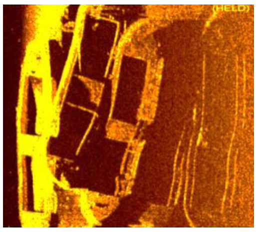
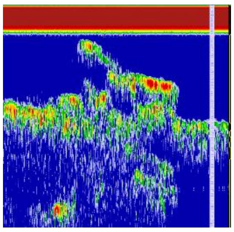
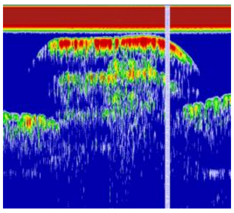
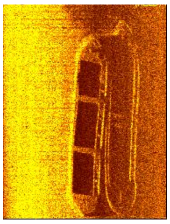
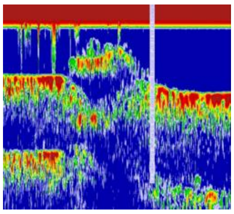
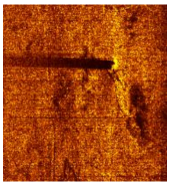
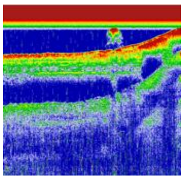
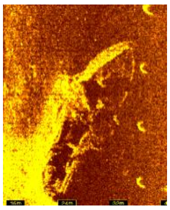
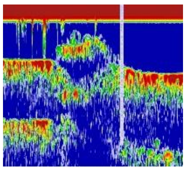
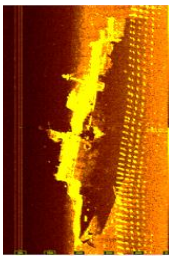
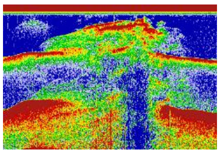
Fig.5: An example of the SSS sonograph (left image) and SBP section (right image) integration to identify a shipwreck, the red and blue colors in the SBP refer to high and low amplitude reflections respectively

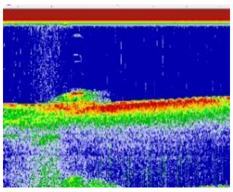
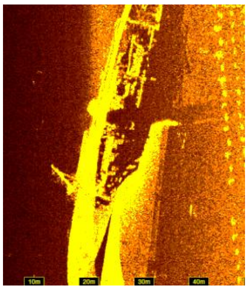
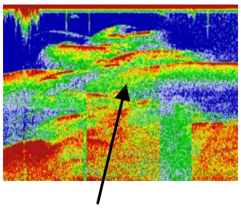
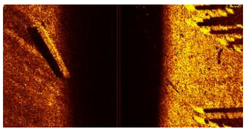
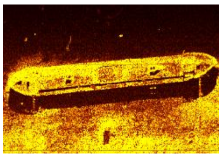
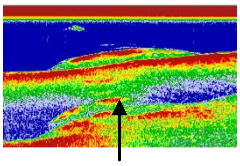
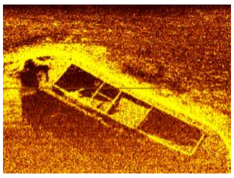
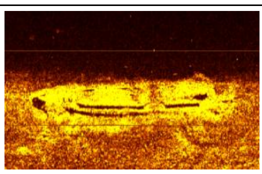
RESULTS AND DISCUSSION

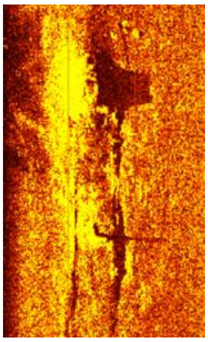
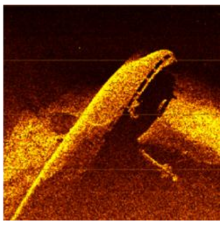
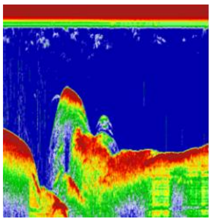
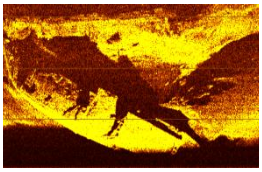
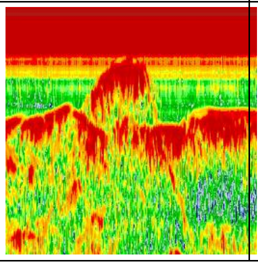
Seventeen distinct locations are identified in this survey containing numerous objects on the river bed. A total of 25 sonar targets are mapped, but only eleven could be correlated with reflections in the SBP. The other six targets were not identifiable by SBP, because the water depth was too shallow and it is difficult to perform the SBP survey in water that has a depth of less than 2 m. The targets identified includ vessels boats (medium and small sizes), tankers and bridge structures, as well as some unknown debris. Images of the SSS signatures, as well as the targets observed on the SBP are shown in Table (1). The targets are identified on the basis of their shapes, sizes, backscatter characteristics and location in the river course. Most of the objects appear to be at least partially buried beneath the surface of the sediment bed. The largest identified object is the charted shipwreck located near the Maaqal quay in the north of the study area (Fig.6).

Most of the targets are localized in the northern part of the study area, in a particular vicinity of the river banks (Fig.6). This site represents the center of the Basra city where the core of human activity. Removing the submerged wrecks began after the end of the last military action in 2003 and was concentrated in the southern part of the river, extending from Abu-Floos port to the river estuary in the gulf, with a distance of 95 Km (Fig.6). These operations aimed to rehabilitate the waterway of the river channel. The salvation operations were focused on the northern part of the study area, near the sites of the new bridges. The river transports very large amounts of sediments with high suspended load which resulted in the interruptions of the dredging operations. This issue led to the burial of large parts of the wrecks, such that they could not be easily salvaged. The majority of the wrecks, both completely and partially submerged, are either Pontoon boats or small tanks; about 40 meter long and 8 meters wide.

Table 1: Images of the SSS signatures compared with SBP, the DSW is the depth of sunken wreck from the water surface (m), the HRB is the height of sunken wreck from the river bottom (m), the red and blue color in the SBP refer to high and low amplitude reflection, respectively

No.	SSS image	SBP section	Description
1			Five Pontoon boats in the vicinity of the Tanumah bridge, on the left side of the river, length 40 m, and width 8 m for each, DSW: 3 m
2			Two submerged wrecks in the right side of the river opposite the naval base quay in the Maaqal port. 1- Sunken boat on one side, unknown, length 40 m, DSW: 3 m; HRB: 6.4 m 2- sunken Pontoon boat, length, 22 m, width 4 m, DSW: 7.5 m; HRB: 1.5 m
3			Two submerged small tanks or Pontoon boats, length: 40 m, width: 4 m, DSW: 5 m; HRB: 2 m
4			Submerged debris, left side of the river, DSW: 3 m; HRB: 2 m
5			Damaged sunken fishing boat, quay Maaqal port, length: 34 m, width: 8 m, DSW: 3.8 m; HRB: 4.7 m
6			Ibn Majid shipwrecks, a military training ship. Length: 95 m, width: 8 m, quay Maaqal port, stable on its left side, the sinking date: 2003, DSW: 7.8 m; HRB: 5 m

7			Sunken fishing boat, length 30 m, width 6 m, quay Maaqal port, DSW: 8 m; HRB: 3 m
8		 Multiple reflection	Two sunken vessels, near the naval force command, Maaqal port, the first, length: 60 m ,width: 9 m, stable on its base, DSW: 5.3 m; HRB: 6.6 m the second, length 82 m, width 9 m, stable on one side, DSW:7.5 m; HRB: 6 m
9		Cannot be imaged by SBP	Bridge debris
10		 Multiple reflection	Submerged small tank or Pontoon boat, length: 40 m, width: 8 m, DSW:7 m; HRB: 2 m
11		Cannot be imaged by SBP	Submerged small tank or Pontoon boat, length: 40 m, width: 8 m, HRB: 2 m
12		Cannot be imaged by SBP	Sunken damaged boat, unknown
13		Cannot be imaged by SBP	Sunken damaged bridge
14		Cannot be imaged by SBP	Submerged small tank or Pontoon boat, length: 40 m, width: 8 m, HRB: 2 m, partially buried under the river bed.

15		Cannot be imaged by SBP	Sunken shipwreck, unknown, length: 80 m, width: 8 m, most of their parts buried under the river bed
16			Sunkenshipwreck, unknown, partially buried under the river bed , in the vicinity of Umm Al-Resas Island, DSW: 8 m; HRB: 4.5 m
17			Sunken military boat, length: 40 m, width: 10 m, DSW: 3 m; HRB: 3 m, in the middle of the channel within the Iraqi territorial borders

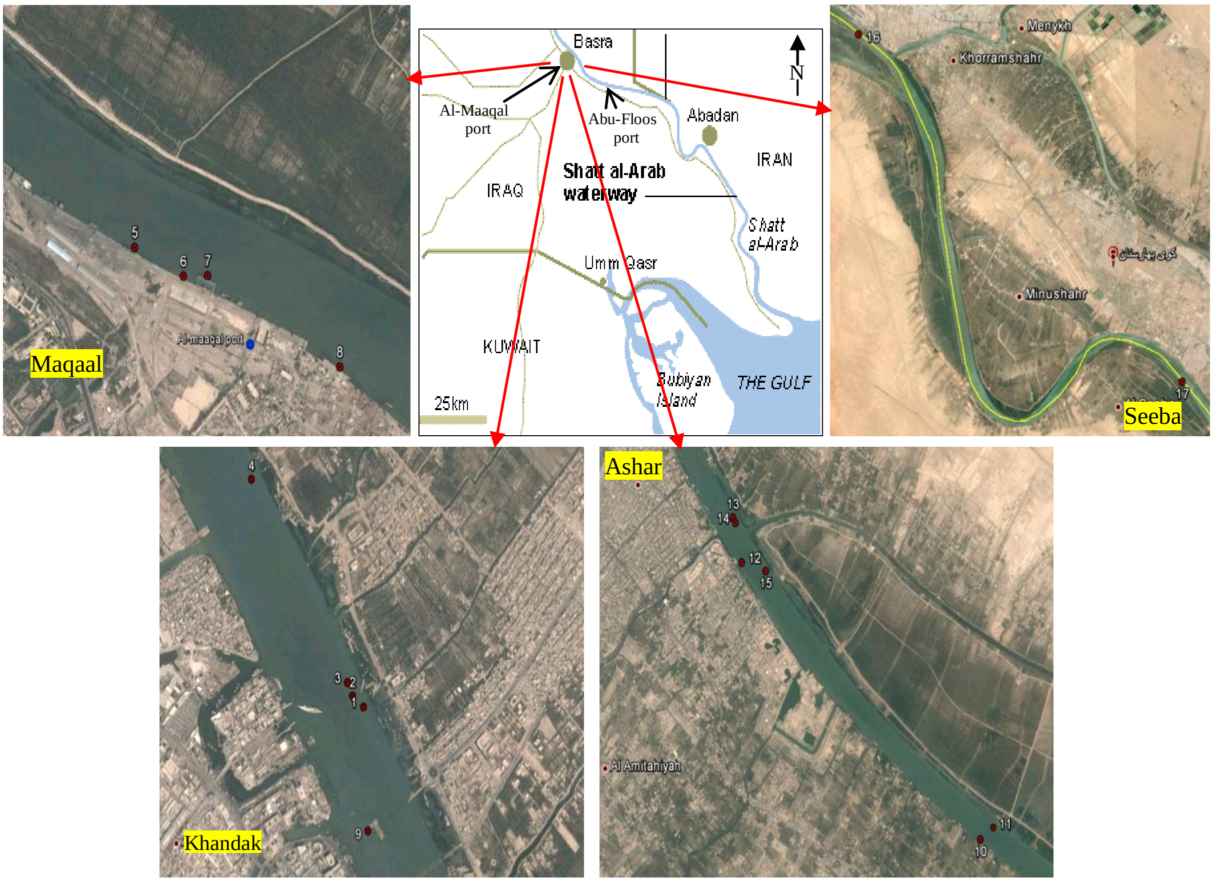


Fig.6: Locations of the identified targets in Shatt Al-Arab River

Attempts of diving operations were not successful for the wreck investigation due to the underwater poor vision, which becomes impaired deeper than 1 meter due to the large amounts of the suspended loads. In these circumstances, the interpretation of the sonar images only (no ground records) revealed two targets (No.15 and 16), which are found to have indicative signatures of ancient shipwreck (Fig.7). Because of the lack of ground authentication, the targets remain unidentified and it is difficult to link a specific backscatter and shape pattern of the submerged object to the target origin. Some of the materials generating the targets are buried below the surface of the river bed sediment, so they could not be identified by using remote sensing techniques, while the boundaries of these shipwrecks appear clearly and the mast of the two targets (No.15 and No.16) can be seen in the images shown in Table (1).

Considering these observations, these sites could represent old (ancient) shipwrecks, where the larger part of the sunkens was buried under the bottom sediments. Therefore, to identify these objects more precisely more information is required and further investigation is necessary to determine their nature, type, age and burial depths in order to verify the anomalies generated. Detailed future investigations could be accomplished using jet probing, ground truthing and/ or diving facilities. Whereas, magnetometer prospecting can be used to differentiate metal- from wood-made sunkens.

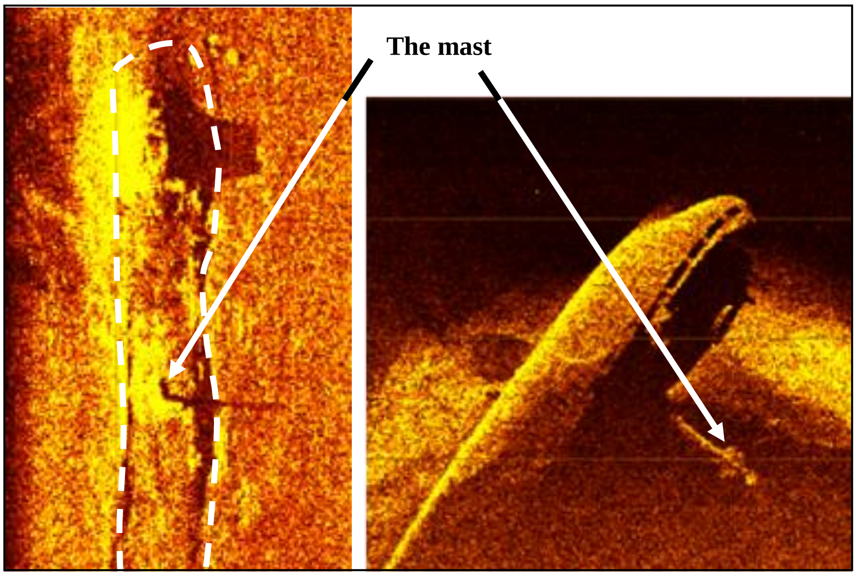


Fig.7: Two located targets (No.15 and No.16) found to have signatures indicative of ancient shipwrecks

In site No.16, the results show that the river bed was exposed to scouring processes which appeared clearly in the SBP section. At this location, the water flow is strong due to the small width of the river channel. River-bed erosion processin one site is always accompanied with sedimentation at another site and thus will cause some changes in the morphology of the river course.

It might be difficult to give a complete view and depth estimation of the sunken parts buried below the river bed using SBP technique due to the limitation in acoustic energy. In deep water, this limitation normally does not cause a serious problem, whereas in the shallow water, reverberation can happen multiple times, causing high background signal levels, i.e.

the sound travels from the surface to the bottom and back again many times, as seen in No.8 and No.10 targets (Table 1).

The depth of some sunken ships are effective and bring risks to navigation (No.2, 5, 6, 8, 16 and 17 in Table 1), the others are ineffective for navigation but may have effects on environmental and morphological features of the river (Table 1). Because the water carries huge amounts of silt and clay, so the river needs to be dredged frequently to keep depth suitable enough for ships to move along the river course. Many parts of these targets are buried below the surface of the river bed sediment and these targets are of concern for the future dredging operations. It is possible to remove the sunken ships and other large objects, which may cause future navigation problems and geomorphological modifications in Shatt Al-Arab River, by using geophysical remote sensing techniques for locating these submerged objects and characterizing their type, depth and other criteria to facilitate easier salvation operations.

CONCLUSIONS

- The SSS imaging and SBP techniques proved to be highly efficient geophysical tools in this survey for investigating shallow-water targets, such as shipwrecks and ancient submerged objects. They are found useful where direct underwater vision is poor and when ground truthing is not available.
- The submerged objects identified in this survey includ medium and small size vessels, boats, tankers and bridge structures, as well as some unknown debris. Most of the targets are found in the north of the study area, and two of them have indicative signatures of an ancient shipwrecks. Most objects detected appear to be at least partially buried beneath a sediment layer. Pontoon boats or small tank wrecks are found either completely or partially submerged.
- Shatt Al-Arab River carries huge amounts of suspended sediments and sunken objects, which have several effects on the river course; impeding dredging and sweeping operations of these sediments. Some parts of the investigated objects on the river bed were covered and buried by the sediments, and it would be difficult to extract. Subsequently, sediments trapped by the wrecks are also influencing the river course and making changes to the waterway of ships corridor. Deposited sediments work with the submerged objects to form obstacles for the passage of ships and boats, as well as forming new islands. Additionally, due to erosional and depositional processes, related to the river meander, the Iraqi bank of Shatt Al-Arab is retreating, while the Iranian bank is growing.
- Because of the limitation of acoustic energy to penetrate deeper into sub-bottom sediments, the use of SBP technique, to estimate depth of the buried targets, was not accurate enough, specifically in areas with high percentage of fine-grained sediments (silt and clay).

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