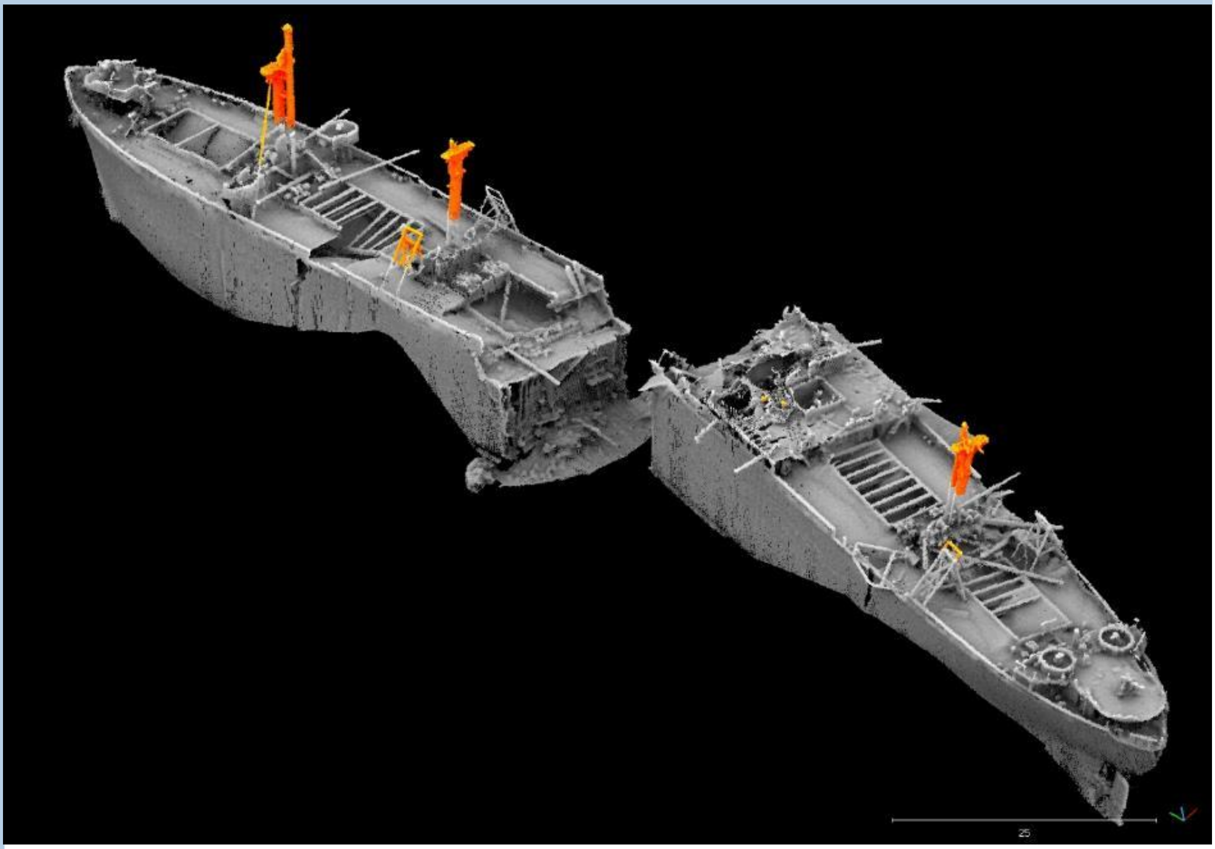
Maritime &
Coastguard
Agency

# SS RICHARD MONTGOMERY
# SURVEY REPORT 2015




MARITIME & COASTGUARD AGENCY
DECEMBER 2016

# 1. Executive Summary

1.1 The SS Richard Montgomery was a US Liberty Ship which went aground in the Thames Estuary in August 1944 whilst carrying a cargo of munitions. Although immediate efforts were made to salvage the cargo, the vessel broke in two, flooded and sank before the salvage operations could be completed. Approximately 1400 tons of explosives remain on board the wreck and, for this reason, the wreck is designated as a dangerous wreck under section 2 of the Protection of Wrecks Act 1973 and regular surveys are undertaken. The wreck lies adjacent to the Medway Approach Channel and is approximately 1.5 miles from the town of Sheerness and 5 miles from Southend.

1.2 For the 2015 survey, the scope of the work included a multibeam sonar survey of the wreck and the seabed surrounding it and laser scanning of those areas of the wreck which are visible above the water. Both of these have been regular features of the SS Richard Montomery survey in recent years. The scope of the 2015 survey also included a requirement to perform a magnetometer survey over the seabed surrounding the wreck in order to provide additional information about the contacts detected within the survey area and possibly identify new items buried and not detected by previous multibeam sonar data. It is the first time that a magnetometer survey of this type has been conducted in the area around the wreck. As a repeat survey, the multibeam and laser data was acquired in a manner that enabled direct comparison with historical datasets and allows for comparisons with data collected in the future.

1.3 The survey was scheduled to be completed during the week commencing 23rd November 2015. However, mechanical problems with the survey vessel, followed by unsuitable weather conditions, meant that the survey took place in phases, with the final part of the survey, the magnetometer survey, being completed on 12th March 2016.

1.4 The results of the 2015 survey work showed that, as in previous years, in general terms, continued deterioration was noted in some areas of the wreck, whilst others showed no evidence of change. The following are some of the main points from the 2015 survey results:

- As in previous years, the 2015 survey covered the entire wreck and surrounding seabed in detail.

- The five main areas where more accelerated levels of deterioration have been noted in previous years again received close scrutiny. Of these five areas, only one showed evidence of deterioration since the last survey (the deck plating at Hold 2).

- The deck plating adjacent to Hold 2 has dropped by 25cm, possibly as a result of increased sediment load, and cross-sections through the data at this area of the wreck suggest that the deck plate is very close to (or possibly in contact with) the contents of Hold 2.

- The clearest evidence of deterioration in the 2015 survey is the advancing collapse of the overhanging bridge section, which sits unsupported at the forward end of the Aft Section of the wreck and, in some areas, has slumped by up to 4m since the last survey.

- One of the life raft davits on the stern section of the wreck demonstrates this deterioration around the remains of the superstructure and, since the last survey, it has increased in depth by 2.9 m and is now partially covered by a sheet of debris.

- The changes on the Forward Section of the wreck are relatively minor, for example the break in the gunnel has increased its tilt by 0.05m towards the east in relation to the collapsing deck plate alongside Hold 2 and one of the holes in the deck plate in the collapsing deck at this location shows a modest increase in size increasing in length from 0.5m to 0.8m.

- The deck plate along the port side of Hold 3 has shown an increase in height from 0.1m to 0.2m. This is unusual as one might expect the wreck to collapse with sections increasing in depth but this rise is consistent over a large area and the difference is observed when comparing data from 2014 and 2010.

- Along the hull on the starboard side of Hold 2 the severe vertical discontinuity appears to protrude further from the wreck by 0.2m when compared to the position in 2014.

- The 2015 seabed survey generated a higher density dataset because the TVG array (which was run alongside the multibeam unit) required a closer line spacing than might have been used for multibeam alone. Comparisons across the survey area with historical surface data showed that the area was mostly stable.

- The density of the multibeam survey and the addition of TVG data led to seven new features being added to the list of seabed targets, only one of which is within the prohibited area.

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# 2. Introduction

2.1 The SS Richard Montgomery (SSRM) was a US Liberty Ship of the EC2-S-C1 class, constructed by the St. John's River Shipbuilding Company in Jacksonville, Florida in 1943. In August 1944, the ship left the US with a cargo of munitions and travelled across the Atlantic in convoy bound for the UK and then on to France. However, on arrival in the Thames Estuary on 20th of August 1944, orders were received to anchor off Great Nore. Unfortunately, this was too shallow for the heavily laden vessel and, as the tide fell, the SSRM dragged its anchor and went aground on Sheerness Middle Sand, a sandbank running east from the Isle of Grain and to the north of the Medway Approach Channel. By that evening, the vessel was already reported to be badly hogged and an explosive like sound was heard. This sound was the steel hull plates splitting forward of the bridge. On 23rd August, stevedores from Gravesend were engaged to discharge the cargo. However, on the afternoon of the following day, the ship's hull cracked further and the bow holds flooded. By the 8th of September, the ship broke its back completely. Divers reported that the crack extended down both sides of the hull, with the vessel clearly open on the starboard side, but the cargo discharge continued. Royal Navy personnel were brought in to finish the cargo removal but they were hampered by deteriorating weather and safety fears as the vessel gradually sank. The salvage operation was abandoned with approximately 1400 tons (NEQ)[1] of munitions remaining within the forward section of the vessel in holds 1, 2 and 3.

2.2 The vessel remains on Sheerness Middle Sand, lying in two sections in its own scour pit and sitting on exposed bedrock which is believed to be London Clay. The SSRM lies across the tide and all three masts are visible above the water at all states of the tide.

2.3 The wreck is designated as a dangerous wreck under section 2 of the Protection of Wrecks Act 1973[2]. There is a prohibited area around the wreck and it is an offence to enter within this area without the written permission of the Secretary of State. The wreck is clearly marked on the relevant Admiralty Charts, the prohibited area is marked with four lit cardinal buoys and twelve red danger buoys and the wreck is under 24hr surveillance by Medway Port Authority (Peel Ports, Port of Sheerness Ltd) under contract to the Maritime and Coastguard Agency.

2.4 Although the wreck is considered to be stable if left undisturbed, the wreck is regularly monitored. Surveys of the wreck are undertaken in order to provide information on its condition, to identify any changes or deterioration and to inform future management strategy. A variety of methods have been used to monitor the wreck. Since 2002, multibeam sonar technology has been the favoured method of survey. Although from time to time diving operations are carried out on the wreck (most recently in 2013), for general surveying multibeam sonar is faster, more cost-effective and provides greater levels of detail, repeatability and reliability than diver surveys. This is in part due to the very poor visibility and high tidal range in the Thames Estuary which makes diving operations very challenging.

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[1] NEQ = Net Explosive Quantity
[2] http://www.legislation.gov.uk/uksi/1973/1690/contents/made

2.5 As in previous years, the 2015 survey required a multibeam sonar survey and laser scanning. The 2015 survey also saw the addition of a magnetometer survey.

2.6 This document is the summarised findings of the 2015 SSRM survey work and contains the results of the comparison between the 2015 dataset with historical datasets from 2010 and 2014. The year on year comparisons of survey data are used to help establish the deteriroration of the wreck and, in this document, the 2015 survey results are also compared with historical datasets from 2010 in order to provide a longer view of the condition of the wreck over this five-year period.

2.7 The data analysis covers the entirety of the wreck and in particular identifies 96 features on the wreck which have been used in successive surveys as markers for measuring levels of change. Of these, there are six areas which have repeatedly demonstrated levels of accelerated deteriroration and are therefore a specific focus of each survey. These six areas are detailed below. This report also includes the results of the surrounding seabed survey and magnetometer survey. The seabed survey aims to identify changes in the local seafloor topography that may have implications for the wreck's stability or for the neighbouring Medway Approach Channel. It is also aims to locate items of debris that may have originated from the wreck, and the magnetometer survey was included in the schedule of work for the 2015 survey in order to compliment the seabed survey and potentially identify new seabed targets which had not previously shown up in multibeam data.

# 3. The Survey

## 3.1 Survey Requirements

3.1.1 For 2015, there were three main requirements of the SSRM survey. These were, a multibeam echo sounder (MBES) survey was to be undertaken of the wreck itself and of the seabed out to 400m distant from the wreck, including the edge of the dredged channel. As in previous years, this was to be fully georeferenced and the results were to be analysed and compared to previous survey data in order to identify any areas of change or deterioration. Any changes or deterioration were to be quantified and particular attention paid to areas that have previously been identified as having higher levels of deterioration than are noted across the rest of the wreck. Secondly, laser scanning was to be undertaken on those areas of the wreck which are visible above the waterline. Again, this data was to be compared to previous datasets in order to identify any changes or deterioration, and was also to be fully integrated into the MBES data in order to provide a picture of the wreck in its entirety both above and below the water. Finally, a magnetometer survey was to be undertaken of the whole of the survey area. This is the first time that a magnetometer survey has been conducted around the wreck. The aim of this magnetometer survey was to provide a greater understanding of the debris and other seabed targets within the survey area aside from the wreck itself, with a particular focus on providing additional information that may inform any future plans to undertake intervention work on the wreck, for example the safe positioning of a working platform or other equipment. Because of the presence of a large metal wreck at the centre of the survey area, magnetometer surveys have not been conducted in the past because it was not clear whether they could provide any useful data. For this reason, the specifics of this part of the survey (equipment, methodology etc.) were not dictated and the contractor was invited to determine the best option for obtaining useful magnetometer results under the circumstances.

This scope of the work can be broken down as:

- Comprehensive MBES survey of the SSRM
- MBES survey of the seabed up to 400 m from the SSRM
- Laser survey of the SSRM above the waterline
- Magnetometer survey of the seabed
- Detailed survey report containing information on any changes noted, using comparisons with a minimum of two previous surveys

3.1.2 The survey was scheduled to be completed during the week commencing 23rd November 2015. However, mechanical problems with the survey vessel, followed by unsuitable weather conditions, meant that the survey took place in phases, with the final part of the survey, the magnetometer survey, being completed on 12th March 2016.

## 3.2 Survey Area

3.2.1 The survey area is located within the Thames Estuary in an area 1.5 miles from the town of Sheerness on the North Kent coast. The survey site covers a section of the Sheerness Middle Sand bar and parts of the Great Nore and Medway Approach Channel (*Figure 1*). The boundary of the survey site is defined as an area extending 400 metres from the centre of the wreck and this has been transformed into a square shaped area that allows for the practical running of survey lines.

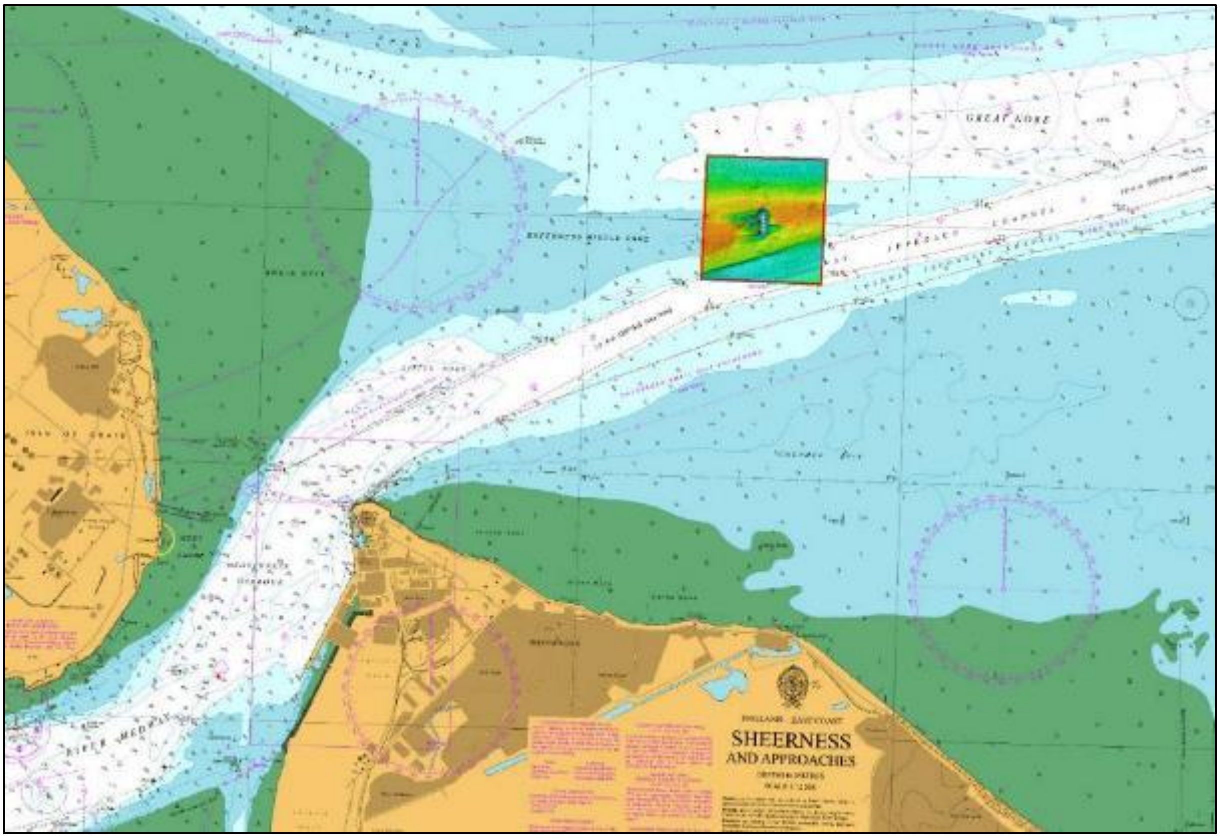


*Figure 1 Overview of the wreck site of the SSRM*

## 3.3 MBES and Laser Survey Methodology and Data Processing

3.3.1 As with other SSRM surveys in recent years, the 2015 survey utilised the Port of London Authority survey vessels Yantlet and Galloper. Both vessels are custom built for survey work. The Galloper is fitted with a Reson 7125 multibeam echo sounder and Applanix POS MV 320 inertial system for positioning. The Yantlet is fitted with a RESON 8125H MBES and Applanix POS MV 320 inertial system for positioning. The Galloper is a small, shallow draught survey vessel and is therefore suited to the running of survey lines directly over the wreck.

3.3.2 Global Navigation Satellite System (GNSS) tide was used to correct the bathymetry data to the defined vertical datum, Chart Datum. The GNSS tide was obtained by post-processing GNSS data collected by an Applanix POS MV 320 system. The tidal reduction methodology encompasses all vertical movement of the vessel, including tidal effect and vessel movement due to waves and currents. The methodology used is robust and provides very good results in complicated mixed wave and swell patterns. The vessel navigation is exported into a post-processed format, Smoothed Best

Estimated Trajectory (SBET) that is then applied to the MBES data. Universal Time Coordinated (UTC) was used on all survey systems on board the vessel.

3.3.3 MMT used a Reson 7125 SV2 during the Galloper operations to survey the wreck and a Reson 8125 Hybrid system was used during the surrounding seabed survey. Both systems have high specifications in terms of along- and across-track beam widths that ensures the beams are properly formed in shallow water and provides the clear digitisation.

3.3.4 On both the Galloper and Yantlet, Applanix POS MV 320 inertial systems were used to output real-time position, attitude and heading data. The sensor outputs heading and attitude to an accuracy of 0.02° and 0.01°, respectively. The POS MV is a tightly-coupled system that uses Inertially-Aided Real-Time Kinematic (IARTK) technology. The POS MV is integrated with each vessel's MBES system to apply time-stamp information to the acquired data. As well as real-time data, the raw inertial and GPS data was recorded as raw sensor files. This meant that the data could be post-processed using POSPac MMS software and imported into the data at a later stage.

3.3.5 An Optech Ilris-3D Laser Scanner and Applanix POS MV 320 inertial system are combined in the Applanix Landmark Marine Laser System. This is a fully integrated marine vessel based mobile mapping solution for producing accurately georeferenced LiDAR point cloud data and complements the data from the MBES to create a complete image of the wreck's structures that extend above the water line. The POS MV provides position, roll, pitch and heading information to correct the range and angle information generated from the laser scanner and allows the user to generate a geo-referenced point cloud.

3.3.6 The acquisition software package QINSy was installed on both the Galloper and Yantlet and used to record all the bathymetry and TVG data. QINSy is an integrated navigation system software package that allows the combination of multiple sensors to produce accurate XYZ data and for real-time quality control of raw data streams.

3.3.7 Survey lines were run using the area of the Medway Approach Channel and the steep channel wall to test the angular offsets of the MBES setup for the Galloper and Yantlet. The deeper area of the dredged channel was used to validate the roll angle and the steep slope used to test the pitch and heading angles. Each component of the system was examined using the calibration tool in CARIS.

3.3.8 The data processing routine in the SSRM survey project is one of the key parts of the repeatability of the survey. An established process has been applied to the SSRM 2015 project and has yielded a dataset that is well aligned with previous surveys. This is an essential factor in being able to perform a comparative analysis of the wreck's structures.

3.3.9 Raw data was exported in the .XTF format from QINSy DBs generated online. These files were then converted into the CARIS HDCS format for post-processing. The raw positional files logged by the POS MV were also post-processed so that any inaccuracies in the online navigation solution could be removed and a positional solution with an accuracy of less than 5cm could be produced.

3.3.10 The raw positional data is combined with imported Ordnance Survey base-station RINEX and GPS ephemeris data.

3.3.11 In the final stage of processing the bathymetry data was merged with a vessel configuration file containing the calibration values obtained during the calibrations of both vessels. A

BASE surface was generated in CARIS. A BASE surface is a gridded DTM that is used to highlight any errors within the dataset. As data was acquired over three different days and using two different vessels this quality control process was used to identify variations in depth where data overlapped.

3.3.12 Once the data had been taken through Caris HIPS it was then loaded into the QPS program DMagic and from that a PFM structure was built. The PFM was opened in Fledermaus, which allowed the data to be viewed in three dimensions so that it could undergo cleaning and editing procedures. Data points that were not needed, or were in fact multibeam artefacts, were then flagged as rejected. Once cleaning had been completed a point cloud could then be exported that would be used in the analysis of the wreck structure. Other products used in the reporting phase are also generated in Fledermaus. Surfaces are created that are used for Surface Difference analysis and contours for comparison with historic datasets are also made.

3.3.13 To improve the visual appearance of the report imagery the software CloudCompare is used to create shaded point clouds. Applying shade to a point cloud conveys a 3D sense that presents the features in far better clarity than other software packages. It is possible to relatively reference point clouds in CloudCompare so that historical datasets can be effectively compared easily, however measurements were taken from CARIS since the data here is reliably geo-referenced.

# 4. Survey Results – The Wreck

4.1 The following sections of this report detail the output of the survey data acquired from the wreck. This combines the results of all of the survey data and uses various tools to analyse the data and identify areas of change. This includes cross-sections through the data and surface difference analysis. Surface difference analysis in particular helps to guide the eye towards new or unexpected areas of change that may need to be prioritised during reporting. In this year's survey, this process brought to attention the large collapse of the overhanging bridge deck on the Aft Section of the wreck and led to its inclusion as a new key feature (see below).

4.2 The survey data demonstrates that the Forward Section of the wreck has generally remained stable since 2014 and where changes have occurred these have been relatively small movements. An exception to this is the sediment that has been deposited on the lower hold hatch of Hold 2 where there has been some redistribution of the sediment with height changes in excess of +0.5m, however, this is not considered to be a deterioration of the wreck.

4.3 Changes to the wreck's structure can be seen in the subsidence of the collapsing deck plate on the port side of Hold 2. Other changes on the deck at the forward end of this section of the wreck appear to result from sediment redistribution on top of the deck's surface. Near the aft end of the Forward Section there is some evidence of a small amount of uplift in the collapsed deck on the port side of Hold 3. This change is typically about 0.15m and it is possible that this is the result of a positional misalignment. Comparisons with the 2014 and 2010 baseline dataset showed that the deck position in 2015 was consistently higher by between 0.1m and 0.2m. It is possible that this measured change is an actual shift in the position of the deck plate and this feature will be monitored in future surveys.

4.4 Examining the results of the data, in particular the surface difference analysis, over the Aft Section of the wreck showed a significant area of collapse. It is apparent that the remains of the bridge deck that overhang the gap between the Forward and Aft Sections of wreck have subsided and viewing cross-sections through this part of the wreck data showed that the bridge deck has subsided by up to 4.0m at the north-western corner of this structure. The changes that are visible elsewhere on the Aft Section of the wreck appear to have been the result of sediment redistribution.

4.5 The marginal conditions in which the survey was conducted has affected the quality of the data. This is most noticeable on the port side of the bridge and boat decks. Removing noise from the dataset has resulted in data gaps that affect the completeness of the surface difference results.

4.6 In previous years, 96 points on the wreck have been identified as markers against which data can be compared year on year. These markers are spread over both the forward and aft sections of the wreck. Added to this, in successive surveys, a number of features of the wreck (Key Areas) have shown a more marked level of deterioration than others and, for this reason, they are a particular focus of the surveys. These features were initially identified for specific attention in the 2009 survey report. At that time, four such key areas were identified. A fifth key area was added in 2013 and, this year, a sixth key area has been added. These features are covered first, followed by details of the survey results over the rest of the wreck.

*Table 1 List of Key Areas of deterioration on the SSRM*

| KEY AREA | ID NUMBER | FEATURE | LOCATION |
|---|---|---|---|
| **1** | ID04 | Crack in Hull | Port Side, Forward Section (near Hold 2) |
| **2** | ID08 | Collapse of Cargo Hold 2 Deck | Port Side, Forward Section |
| **3** | ID96 | Aperture | Aft end, Forward Section |
| **4** | ID22 | Split in Hull | Starboard Side, Aft Section (near Aft Mast House) |
| **5** | ID24<br>ID25 | Split in Deck<br>Split in Hull | Port Side, Aft Section<br>(near Aft Mast House) |
| **6** | ID43<br>ID45<br>ID46 | Boiler Room Casing,<br>Collapsing Bridge Deck<br>Collapsing Boat Deck | Forward end, Aft Section |

### 4.7 Key Area 1 – Crack in the Hull on the Port Side of Hold 2

4.7.1 This feature is a crack in the hull located on the port side of the Forward Section of the wreck, adjacent to Hold 2. This feature has been noted in survey reports going back at least as far as the 1970s. Comparisons of point clouds generated from the 2015 and 2014 survey datasets showed that a change in the size of the crack had occurred. This change is in the form of the addition of a small gap in the hull plate that is located to the right of the two original cracks seen in previous years' data.

However, the large bend in the hull plate that extends from the base of the crack to the seabed does not appear to have become more pronounced in the current dataset.

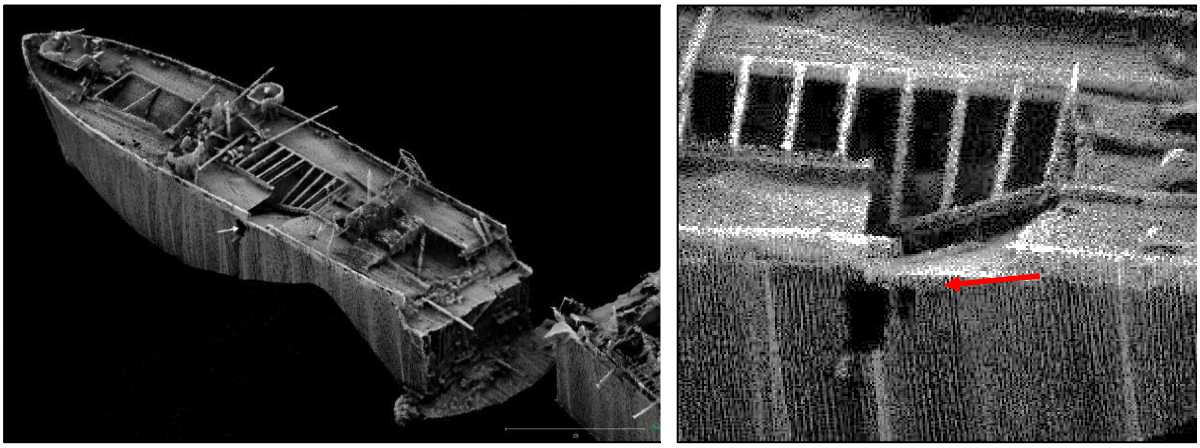

*Fig. 2 & 3 - Crack in hull on the port side of the forward section (arrow marks position).*

4.7.2 Measurements of the hull crack were made in the 2014 and 2015 datasets and the imagery suggests that a third, smaller hole may now be present that had not been identified in previous datasets.

*Table 2 Dimensions of Crack in Hull at Hold 2*

| DIMENSIONS OF CRACK IN HULL (ID04) | | |
|---|---|---|
| **Dataset** | **Height (m)** | **Width (m)** |
| **2013** | 3.3 | 2.2 |
| **2014** | 3.4 | 2.1 |
| **2015** | 3.2 | 2.2 (2.9) |

*Taking the presence of the new gap in the hull to be an extension of the crack, a new width of 2.9m is recorded. This is shown in brackets in the table.*

4.7.3 Examining this feature more thoroughly could not confirm whether the crack had expanded to include the new small hole. It has also been noted from reading diver survey reports that the MBES data may over state the dimensions of this crack. This is due to the effect of shadowing being interpreted as a void in the hull plate. It is possible that the new, small hole is a product of an inward bulge in the hull, however, this area is devoid of soundings in the lines that cover this region of the ship. In order to corroborate the finding of this potential new hole, it may be beneficial to utilise a higher resolution system to investigate this section of the SSRM in the future.

### 4.8 Key Area 2 – Collapse of Deck Plating at Hold 2

4.8.1 Surface difference analysis comparing the 2015 and 2014 datasets indicated that further subsidence of the collapsing deck plate along the port side of Hold 2 had occurred. The shift in the surface difference is between 0.1m and 0.2m and cross-sections through the data confirmed the conclusion of the surface difference results. The collapsing deck plate appears to be nearly in contact with the material present within Hold 2. This may start to reduce the rate of subsidence unless the material is not sufficiently stable to support the weight of the deck. This area will continue to be a key section for the focus of future surveys.

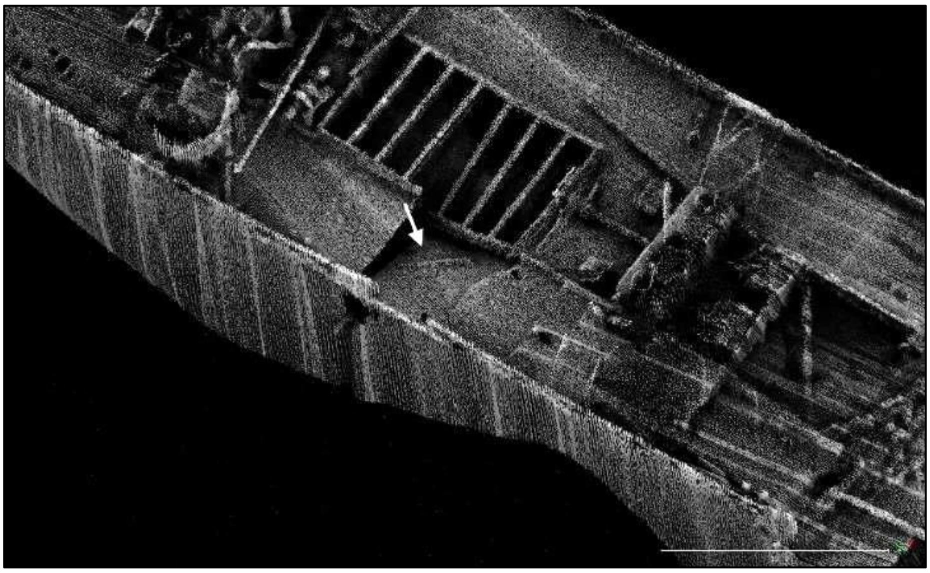

*Fig. 4 Collapsed section of deck plate (arrowed) alongside Hold 2*

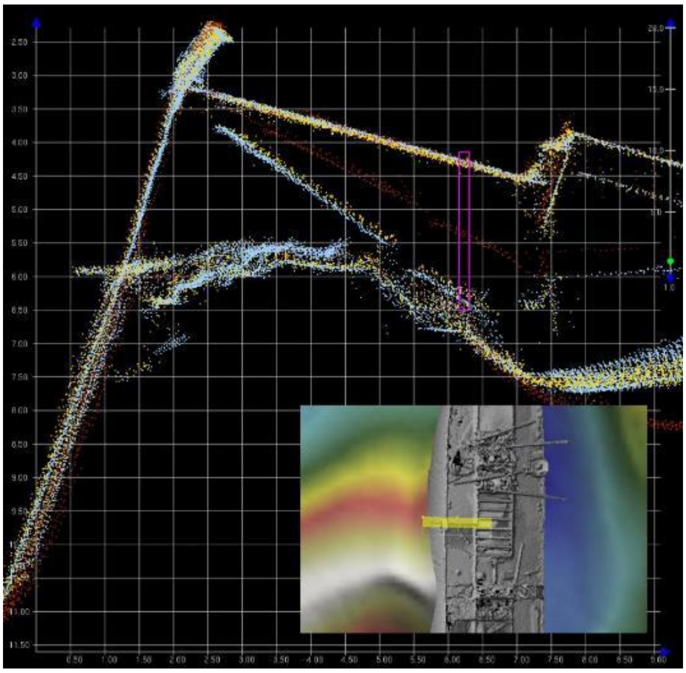

*Fig. 5 Cross-section showing the subsidence of the deck plate at hold 2 showing 2010 data (red), 2014 (yellow) and 2015 (blue), the pink rectangle shows the positions from which the measurements were taken.*

## 4.9 Key Area 3 – Aperture in the Aft end of the Forward Section

4.9.1 The large aperture on the aft end of the Forward Section was well defined in the 2015 dataset. Cross-sections through the data at this area of the wreck showed a good alignment between the datasets and that there was no visible change to the dimensions of the aperture. Measurements taken indicated that the size of the aperture had not increased since the previous survey.

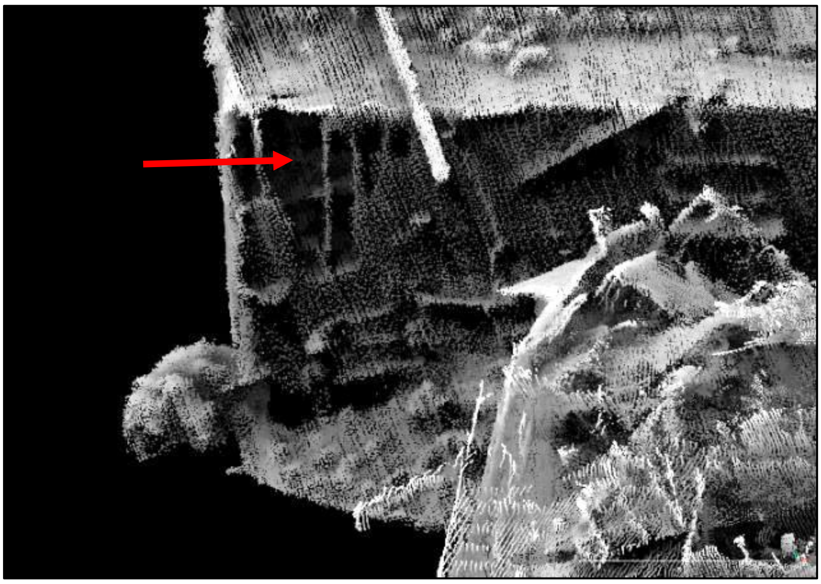

*Fig. 6 Location of Aperture at the aft end of the forward section*

## 4.10 Key Area 4 – Split in the Starboard Side of the Aft Section

4.10.1 This split in the hull is located on the starboard side of the aft mast on the aft section of the wreck. The feature could easily be identified in the 2015 dataset.

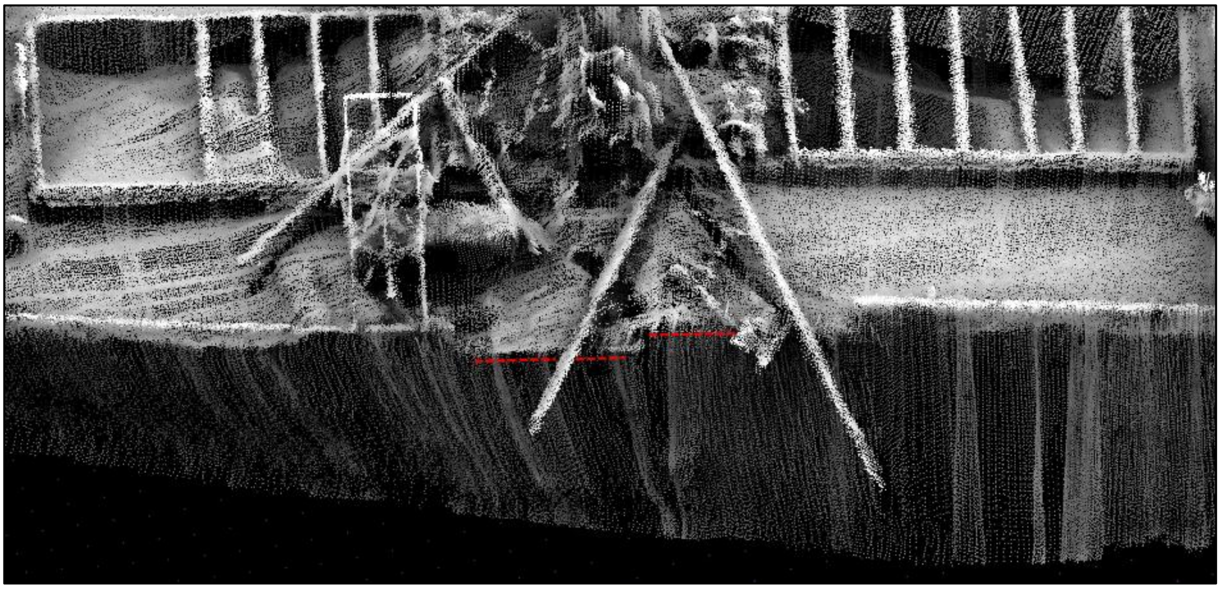

*Fig. 7 The split in the hull (ID22) visible in the 2015 dataset*
*The red dashed line highlights the distortion of the line of the hull in this area*.

4.10.2 Cross-sectional comparison with the previous survey suggested that the size of the split had not increased over the last 12 months as the two datasets were closely aligned. Further examination of this area was performed by conducting a surface difference analysis over the deck in this area of the wreck as a more pronounced split in the hull would result in a shift in the deck above. The analysis showed that the deck near the gunnel had remained stable with minor variations arising from differences in cleaning the data around the intricate structures in this area of the wreck. Towards the centre of the wreck however, there is some evidence of change, an increase in depth of up to 0.3m. However, viewing cross-sections through this part of the deck showed that the 2015 data aligned with that from the 2010 survey and that the perceived change in depth was most likely a reflection of sediment having been removed from the area over the course of the last year.

## 4.11 Key Area 5 – Split in the Deck and Hull on the Port Side near the Aft Mast House

4.11.1 The split in the deck and hull on the port side of the Aft Section was well defined in the 2015 dataset. These features of the wreck are the port side counterparts of the split in the hull and deck on the starboard side of the vessel.

4.11.2 Surface difference results showed that there had been little change in the 12 months between the 2014 and 2015 surveys and any differences with the previous survey appear to be movement of sediment depoits on the deck and in the hold. However, this area will continue to be under close scrutiny in future surveys in order to confirm whether these small changes definitely relate to sediment removal or are a feature of continued collapse.

4.11.3 The findings of the surface difference analysis were supported by viewing cross-sections through the data at this area of the hull and these show a close alignment between the datasets indicating that there has been no further deterioration of the hull or deck since the 2014 survey was performed.

*Fig. 8 Split in Hull and Deck (ID24 & ID25) shown in 2015 data.*

## 4.12 Key Area 6 – Collapsing Bridge Deck Area

4.12.1 Area 6 was added to the list of key areas as a result of changes detected in this survey. This section of the wreck has experienced the greatest amount of degradation in the period since the 2014 survey was completed. The subsiding area is expansive and covers the boiler room casing, the collapsed bridge deck and the collapsed boat deck.

4.12.2 Examination of the surface difference results and cross-sections through the combined datasets showed that the collapsing section encompasses the full width of the wreck and extends back up to 8.0 m from the forward edge. This is roughly in line with the mid-point of the boiler room casing. Along the forward edge of the boiler room casing this subsidence is approximately 0.75m and the degree of displacement increases forward, towards the edge of the wreck. The maximum displacement of 4.0m has occurred along the most forward edge of the bridge deck area on the starboard side.

4.12.3 On the port side of this area is the area of the collapsed boat deck. This location is part of the widespread subsidence but there are movements within the complex debris that manifest as an increase in height. The port side exhibits less subsidence, between 0.5m and 1.0m, than the midships area and starboard side.

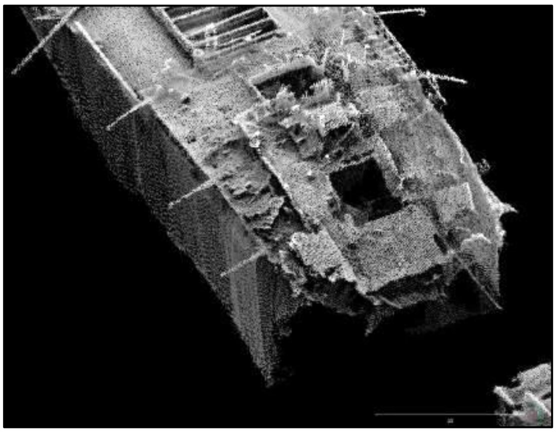

*Fig. 9 Bridge deck, 2014*

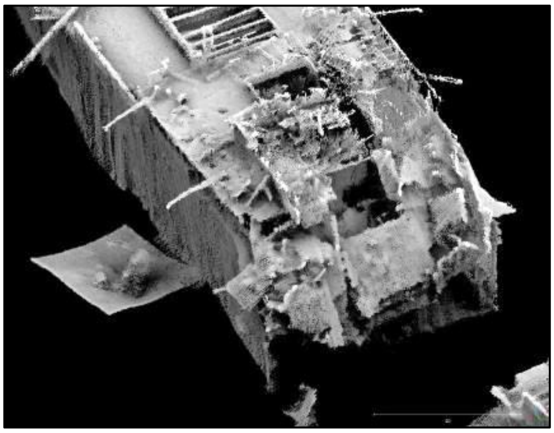

*Fig. 10 Bridge deck, 2015*

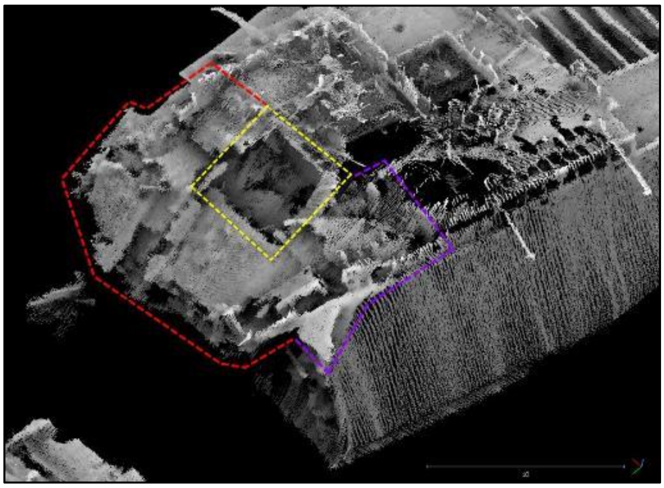

*Fig. 11 Collapse of the structures on the forward end of the Aft Section. Rough outline of the boiler room casing shown in yellow, the collapsed boat deck shown in purple and the red line represents the collapsing bridge deck*

## 4.13 Other Areas of the Wreck Showing Change in the 2015 Survey

4.13.1 Aside from those changes already detailed above, the following table is a summary of other changes in the wreck which are evident in the 2015 survey data when compared with the 2014 data.

*Table 3 List of features exhibiting change or degradation*

| Feature ID | Feature | Location |
|---|---|---|
| ID07 | Break in Gunnel | Port Side, Hold 2 |
| ID13 | Holes in Deck Plating | Port Side, Hold 2 |
| ID15 | Collapse of Deck and Hatch Coaming | Port Side, Hold 3 |
| ID17<br>ID18<br>ID20 | Hole in Hull Plating<br>Severe Discontinuity of Hull<br>Large Hole in Hull | Starboard Side, Hold 2 |
| ID23 | Split in Deck Plating | Starboard Side, Aft Mast |
| ID28 | Collapsed Boat Deck | Port Side, Aft Section (forward end) |
| ID29 | Boat Deck Missing Above Walkway | Starboard Side, Aft Section (forward end) |
| ID30<br>ID31 | Hole in Lower Hold Cover<br>Collapse of Lower Hold Cover | Hold 2 |
| ID32 | Collapse of Lower Hold Cover | Hold 3 |
| ID33 | Collapse of Lower Hold Cover | Hold 4 |
| ID34 | Indications of Tween Deck Cargo | Starboard Side, Hold 1 |
| ID79 | Lifeboat Davit | Starboard Side, Aft Section (forward end) |

## 4.14 Break in Gunnel, Port Side, Hold 2

4.14.1 The break in the gunnel located on the port side of Hold 2 on the Forward Section of the wreck showed that a small amount of movement may have occurred since the 2014 survey. The maximum shift between the datasets is observed at the southern end of the tilted gunnel section and shows movement of approximately 0.05m. This small shift is possibly a product of the misalignment of the datasets as it is approximate to the accuracy of the post-processed position. But, as stated in the 2014 report, the gunnel is moving in tandem with the collapsing deck plate, which does show an identifiable shift in the 2015 dataset.

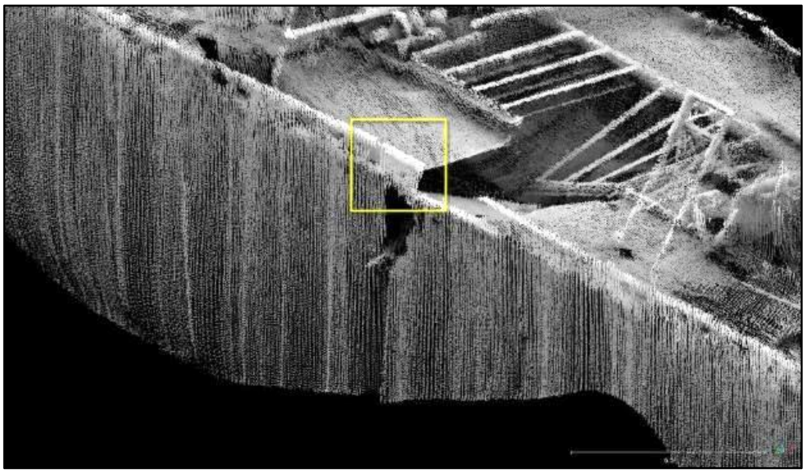

*Fig. 12 The break in gunnel shown in the 2015 dataset*

## 4.15 Holes in Deck Plating, Port Side, Hold 2

4.15.1 The holes in the area of the collapsing deck plate on the port side of Hold 2 were well represented in the 2015 dataset. These were not visible in survey results in 2010 but are clear by the 2014 and 2015 surveys. Measurements were made of the length and width of the holes and these were compared to those taken from the 2014 dataset. Evidence of deterioration was seen in the hole marked as number 2 on the image below, which has increased in length by 0.3m between the 2014 and 2015 surveys. Measurements made across the remaining holes indicated that no identifiable deterioration had occurred.


*Fig. 13 Holes in Deck Plate shown in the 2015 point cloud*

## 4.16 Holes in Hull Plating and vertical discontinuity of hull plating, Starboard Side, Hold 2

4.16.1 These features are located in close proximity on the starboard side of Hold 2. The holes in the hull plate appear either side of a severe vertical discontinuity of the hull plate and the analysis of each can be shown in the same report section since these features are closely related. A hole in the hull located above tween deck level is difficult to fully ensonify due to the presence of the outwardly protruding hull plate, which can cause acoustic shadow to appear as a hole. However, during the 2015 survey, data was returned from within the hull in this area so the presence of a hole is confirmed. The shape of this is hard to determine and measurements taken from this feature cannot therefore be relied upon but the dimensions were recorded as a height of 1.0m and a width of 0.7m. The other hole located at this area of the wreck does not appear to have increased in size.

4.16.2 The severe vertical discontinuity at this point of the hull manifests as distorted hull plating that extends between 0.8m and 2.0m from the original line of the hull. In comparing the 2015 survey data with data from the previous year, the hull appeared very similar with improved coverage in 2015. Profiles were generated for comparison and some differences were seen, the greatest of which was a maximum protrusion of the distorted plate increased by 0.2m. It is likely that distortion of the hull could cause the deck to move accordingly but this does not appear to be the case.

### 4.17 Collapsing Deck Plate and Hatch Coaming, Port Side, Hold 3

4.17.1 To identify movement in the inclined deck plate at this point on the wreck, surface difference analysis was performed. This showed that there had been a slight elevation of the deck since 2014, between 0.1m and 0.2m. Cross-sections through the data confirmed that this had occurred. This direction of movement is unexpected, although it is not considered to be a result of a positional misalignment as the 2015 data forward and aft of the collapsed area shows a consistent alignment with the historical data.

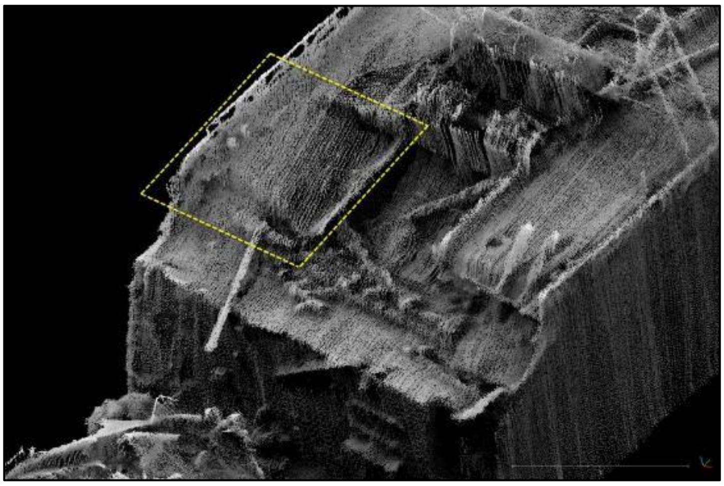

*Fig. 14 Collapsed deck plate and hatch coaming in 2015 dataset*

### 4.18 Split in Deck Plating, Starboard Side of Aft Mast House

4.18.1 This feature is closely related to the split in the hull plate at this point in the hull and both are located on the starboard side of the aft mast house. The deck in this area is quite complex with collapsed booms, holes in the deck and an unidentified frame-like structure all present on the deck. These structures can obscure the access of the MBES to the deck structure below. Despite the debris the 2015 data shows a good density of soundings on the deck in this region and this has shown an increase in depth of up to 0.3m. This is likely to be the result of sediment deposits being removed over the course of the year.

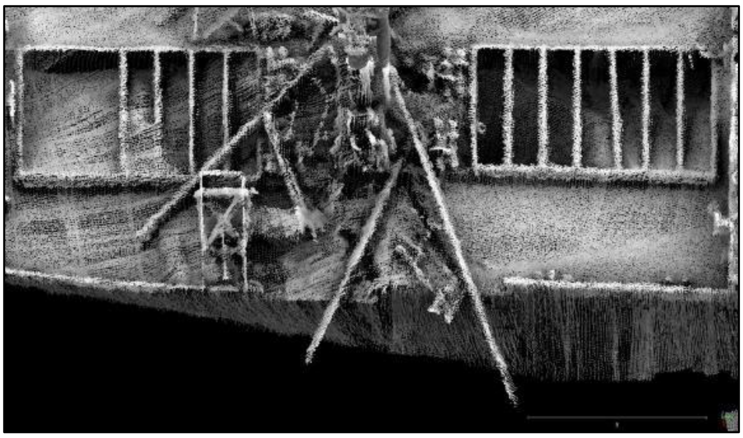

*Fig. 15 Split in deck plate along the starboard side of the Aft Mast House*

## 4.19 Collapsing Boat Deck, Port Side, Aft Section

4.19.1 The collapsing section of the boat deck is located on port side of the Aft Section in close proximity to the overhanging bridge deck. This section of the SSRM was only partially covered by the MBES but it is possible to establish what effect the large scale subsidence is having on this feature. This subsidence is detailed above in the new Key Area 6.

4.19.2 Surface difference analysis comparing the 2014 and 2015 datasets shows that the subsidence of the bridge deck has caused the boat deck to move quite significantly. This effect is mostly over the forward parts of the boat deck that forms a part of the large collapsing area of Key Area 6. Near the port side some evidence of uplift is present. Cross-sections through the data suggest that this is likely to have resulted from a horizontal shift in a section of the complex debris that has manifested as an apparent increase in height when compared with the previous survey.

## 4.20 Boat Deck Missing above Walkway, Aft Section, Starboard Side

4.20.1 Located on the starboard side of the remains of the central superstructure is the boat deck, which was established as being present in the 2012 report, it is a site that has undergone a significant amount of subsidence since the 2014 survey. The forward end of the boat deck on this side forms part of the overhanging section that has subsided by up to 4.0m in the past year (the new Key Area 6). This is clearly evident in the surface difference analysis and in cross-sections through the data.

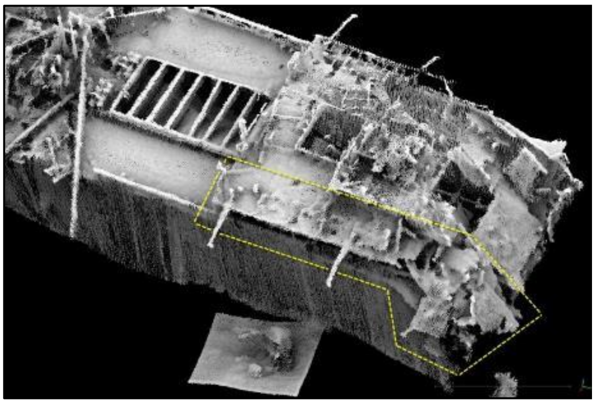

*Fig 16. Boat Deck 2015*

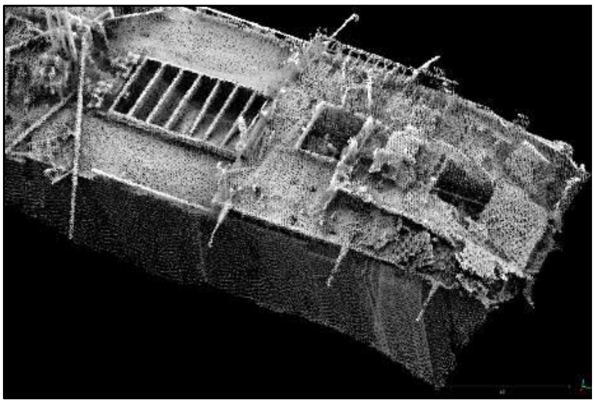

*Fig. 17 Boat Deck 2014*

## 4.21 Hold 2 – Hole in and Collapse of Lower Hold Cover

4.21.1 Over the last three surveys, it has been established that the lower hold cover in Hold 2 is not observable in the MBES data. This is due to the opening to the Hold becoming a sediment trap and the hold cover being completely obscured by mobile deposits. This mobility results in year on year changes in the position of the surface within the hold opening. Surface difference analysis with the 2014 survey showed the variability of the surface with areas becoming deeper (maximum of 0.4m) and shallower (maximum of 0.7m).

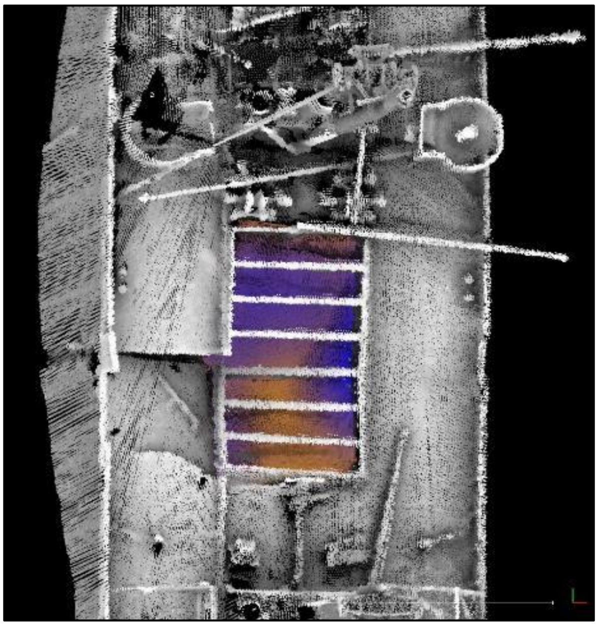

*Fig. 18 Plan view of the area of Hold 2 (ID30 & 31)*
*A smooth undulating surface is present (coloured by depth in brown and blue)*

### 4.22 Hold 3 – Collapse of Lower Hold Cover

4.22.1 The Lower Hold Cover in the region of the aft end of Hold 3 has a smooth undulating form that has shifted from year to year suggesting that it has a covering of mobile sediments. Surface difference analysis comparing the 2015 and 2014 datasets showed that the surface of the sediment deposited on the Lower Hold Cover had again shifted. Across the surface there were areas where sediment movement had caused the surface to increase in height (up to 0.4m) and also to increase in depth (again by up to 0.4m).

### 4.23 Hold 4 – Collapse of Lower Hold Cover

4.23.1 The Hold 4 hatch opening was well insonified in the 2015 dataset as, once again, the survey vessel was able to pass directly over this part of the wreck. Below the hatch cover supports (the spars that cross the hatch opening) the surface showed the smooth undulating shape observed in previous surveys. Surface difference analysis comparing the 2015 and 2014 datasets showed that the surface was generally deeper in 2015 than the previous year with a maximum depth increase of 0.5m near the aft end of the hatch opening. Cross-sections through the data showed the position of the sediment surface during the 2010, 2014 and 2015 surveys and the form and variability of the surface was consistent with a mobile sediment reservoir that is shifting year on year.

### 4.24 Hold 1 – Indications of Tween Deck Cargo

4.24.1 The holes in the deck plate located on the port side of Hold 1 enabled the MBES to obtain data from within the hull. This was not achieved in the 2014 survey, hence this feature has been listed as one that has changed. The data returned from the hull penetration is sparse and incomplete but may represent an undulating surface, possibly similar to that seen in the Tween Deck Cargo on the port side of Hold 2.

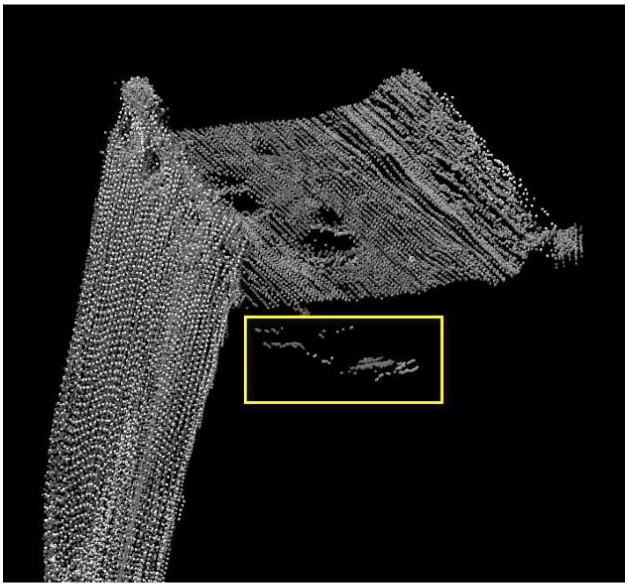

*Fig. 19 Point cloud data showing the data received from the wreck interior indicating the presence of material between decks,*

### 4.25 Lifeboat Davit, Forward of the Boat Deck, Starboard Side

4.25.1 The section of the vessel on which the davit is mounted has been subjected to a large degree of subsidence that has occurred over the last year. The davit is partially obscured by a piece of sheet metal that is supported by the davit's presence. A cross-section through this part of the wreck from 2010, 2014 and 2015 datasets shows that the depth of the tip of the davit has increased from 7.5m in 2010 to 10.4m in the 2015 dataset. The horizontal position of the davit has also changed. The tip now lies 1.8m towards the south-west from its position in 2014. Again, this area of subsidence is part of the new Key Area 6 which is detailed above.

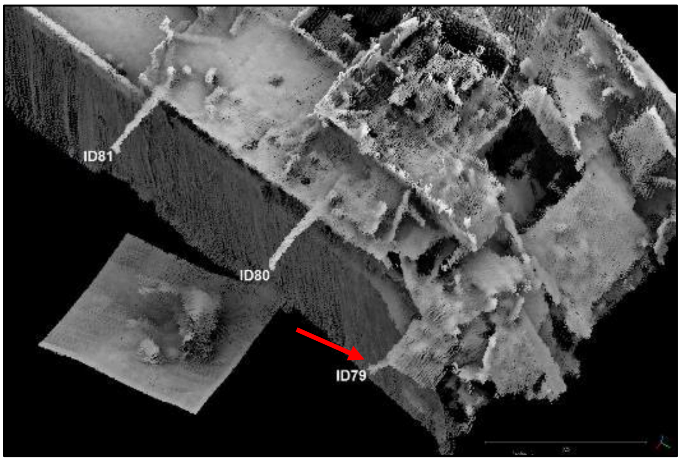


*Fig. 20 Lifeboat Davit, starboard side of aft section*

## 4.26 Areas of the Wreck Showing No Change

4.26.1 The following is a table summarising all of the remaining features of the SSRM that did not show evidence of change or degradation when comparison was made with the 2010 and 2014 datasets.

*Table 4 List of features that did not exhibit change or degradation*

| Feature ID | Feature | Location |
|---|---|---|
| ID01<br>ID02<br>ID03 | Separation of Hull in Two Sections<br>Forward Section<br>Aft Section | Wreck Site |
| ID09<br>ID10 | Severe Buckling of Hull Plating<br>Buckling of Hull Plating | Port Side, Hold 2 |
| ID11 | Hole in Hull Plating | Port Side, Hold 2 |
| ID12 | Buckling of Hull Plating | Port Side, Hold 2 |
| ID14 | Holes in Deck Plating | Port Side, Hold 1 |
| ID16<br>ID19 | Horizontal Crease in Hull Plating<br>Severe Horizontal Buckling of Hull | Starboard Side, Hold 2 |
| ID21 | Bend in Deck Plating | Starboard Side, Hold 2 |
| ID27 | Holes in Boat Deck | Port Side, Aft Section (forward end) |
| ID35<br>ID36 | Indications of Tween Deck Cargo | Port Side, Hold 2 |
| ID37 | Indications of Tween Deck Cargo | Hold 3 |
| ID38 | Hold 1 Hatch Cover Supports | Hold 1 |
| ID39 | Hold 2 Hatch Cover Supports | Hold 2 |
| ID40 | Hold 3 Hatch Cover Supports | Hold 3 |
| ID41 | Hold 4 Hatch Cover Supports | Hold 4 |
| ID42 | Hold 5 Hatch Cover Supports | Hold 5 |
| ID47<br>ID48 | Engine Room Skylight & Casing | Central Superstructure, Aft Section |
| ID49 | Gunnery Officers Cabin | Central Superstructure, Aft Section |
| ID50 | Forward Gun & Gun Tub | Bow |
| ID51 | Stern Gun & Gun Tub | Stern Superstructure |
| ID52<br>ID53 | 20mm Gun Tubs – Fore Mast | Adjacent to Fore Mast |
| ID54<br>ID55 | 20mm Gun Tubs – Stern Superstructure | Stern Superstructure |
| ID56 | 20mm Gun Tub – Lying on Seabed | Starboard Side, Aft Section (forward end) |
| ID57 | 20mm Gun Tubs – Upturned on Boat Deck | Central Superstructure, Aft Section |
| ID59 | Port Anchor | Port Side, Bow |
| ID60 | Fore Mast & Mast House | Forward Section |
| ID61<br>ID62<br>ID63 | Fore Mast Cargo Handling Booms | Forward Section |
| ID64 | Main Mast & Mast House | Forward Section |
| ID65<br>ID66 | Main Mast Cargo Handling Booms | Forward Section |
| ID67 | Mizzen Mast & Mast House | Aft Section |
| ID68<br>ID69<br>ID70 | Mizzen Mast Cargo Handling Booms | Aft Section |
| ID71 | Bilge Keel | Port Side, Forward and Aft Sections |
| ID72<br>ID73 | Life Raft Racks | Adjacent to Main Mast |
| ID74<br>ID75 | Life Raft Racks | Adjacent to Hold 5 |
| ID76 | Anti-Torpedo Net Cage | Port Side, Mizzen Mast |
| ID77 | Propeller and Rudder | Stern |

| | | |
|---|---|---|
| ID78<br>ID95 | Forefoot<br>Bow Section | Bow |
| ID80<br>ID81 | Lifeboat Davits | Starboard Side, Aft Section (forward end) |
| ID82<br>ID83 | Lifeboat Davits | Port Side, Aft Section (forward end) |
| ID85<br>ID86 | Debris on Seabed<br>Seabed Target 1 – Vertical Boiler | Gap between Forward and Aft Sections |
| ID92<br>ID93 | Port & Starboard Lighting Towers | Central Superstructure, Aft Section. |
| | | |

4.26.2 The wreck remains in two distinct sections and the angle of list in both sections of the wreck remained constant over the vast majority of the wreck. The only difference being the forward end of the Aft Section, which is part of the new Key Area 6 that is detailed above. The profiles here show the collapsing Bridge Deck area in the 2015 data, however, this has not affected the whole of the aft section so is not taken to be a change in the angle of list.

4.26.3 The buckling of the hull plating on the forward section of the wreck adjacent to the forward mast house showed no change between 2015 and 2014. Profiles showed some small fluctuations, but these were within the accuracy tolerance of the positional system and did not indicate a continued deterioration. Similarly, buckling in the hull on the port side of the hull at Hold 2 showed no deterioration since 2014, with no movement evident outside of the positional accuracy in the data. Buckling of the hull on the starboard side of Hold 2 showed no change in the angle of bend and the relative angles of the hull appear to have remained constant since at least 2010, suggesting that it has been stable for the last five years.

4.26.4 Other holes in the hull and deck plating which have been observed in previous surveys were again located and assessed for any changes. For example, the hole in the hull plating on the port side of the forward section aft of Hold 2 and holes in the deck plating on the port side of Hold 1 which showed no indication of change

## 4.27 Indications of Tween Deck Cargo

4.27.1 At a number of points in the wreck it has been possible in previous surveys to visualise material inside the holds. In some cases this may represent cargo and in others it may represent sediment build-up. For the 2015 survey, the large crack in the hull at Hold 2 showed some data from within the hold. The Data is sparse but indicates no change from 2014. Examination of the tween deck cargo at Hold 3 showed some subtle differences which are more likely to result from small positional misalignments than movement of debris. The aperture at the aft end of Hold 3 allows the MBES to access the interior of Hold 3. The data acquired during the 2015 survey shows some contents of the hold. Comparisons with the historical datasets showed that the area covered in 2015 matched the 2014 survey, which suggested that none of the items within the hold had been displaced. Greater density of soundings obtained in the 2015 survey showed that some of the exposed items had circular profiles and that they were stacked into 3 or 4 rows.

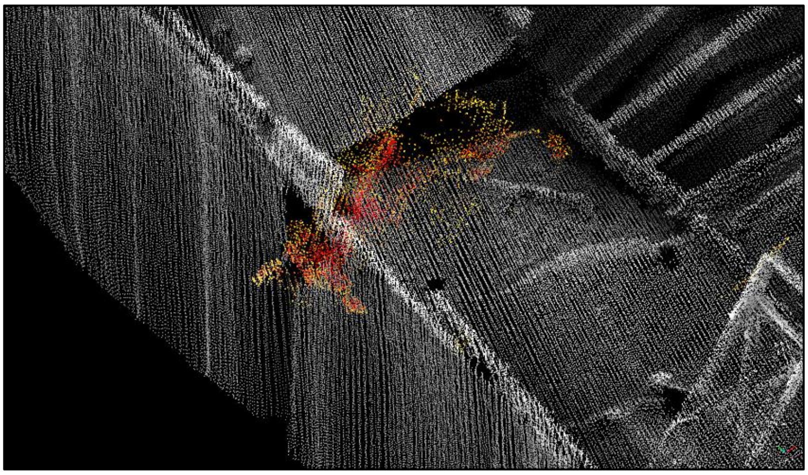

*Fig. 21  Tween deck cargo data (ID35 and 36) on the port side of Hold 2 visible in the 2015 dataset*

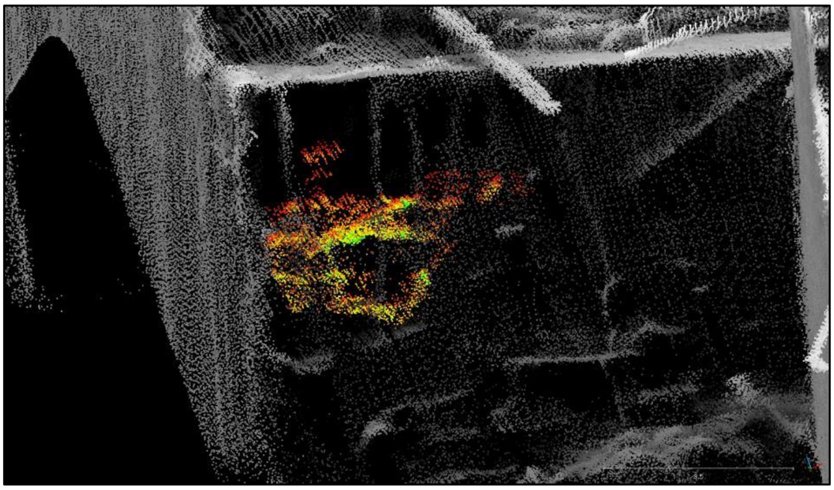

*Fig. 22  2 Contents of Hold 3 (ID94) coloured orange and yellow to distinguish from data from the vessel exterior (SSRM2015)*

*Fig. 23  Debris on the aft end of Hold 3*

## 4.28 Gun Tubs

4.28.1 The Forward Gun and Gun Tub (ID50) are located on the Gun Platform that is placed directly over the bow. This feature was well defined in 2015 dataset with imagery improved over 2014 due to increased density from the use of the 512 beam setting. Comparison of the point cloud imagery shows that there has been no deterioration of the gun, which is still in the same position as in previous datasets. Similarly, the stern gun tub showed no change. Across the other gun tubs on the wreck, no changes were noted, although some sediment movement was evident in some areas.

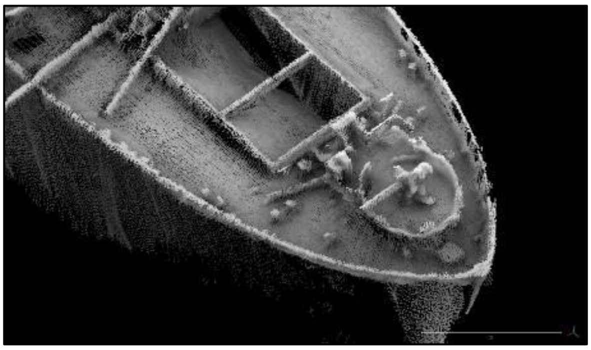

*Fig. 24 Bow gun, 2015*

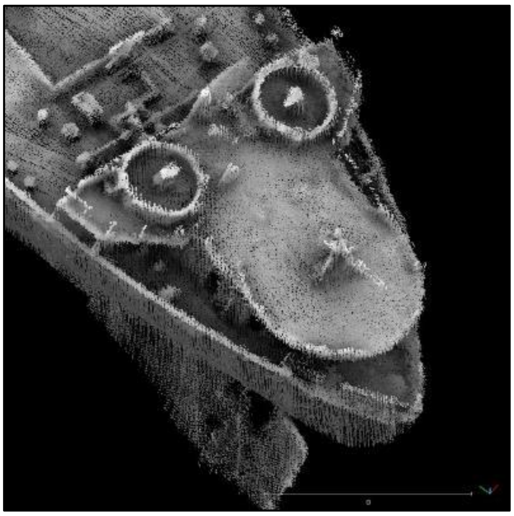

*Fig. 25 Stern gun, 2015*

## 4.29 Masts and Booms

4.29.1 All three of the SSRM's masts remain in situ and all three are visible above the waterline at all states of the tide.

4.29.2 The fore mast and fore mast house were covered by the MBES data but the coverage acheived was not quite as complete as in 2014. However, the data was suffiicient to allow for the examination of this area of the wreck. Visual examination of the point cloud data, photographs and laser scanning showed that the Fore Mast had remained stable with no loss of features (i.e. pulley or signage) since the 2014 survey. Complete coverage of the last remaining Mast Stay suggested that the MBES and laser data were well aligned. Soundings from the mast were temporarily removed from the dataset so that surface difference results could be obtained for the features of the wreck that lie beneath the structure of the mast itself. This showed that the upper surface of the Mast House had broadly remained stable.

4.29.3 The Cargo Handling Booms were all clearly visible in the Fore Mast Area. Surface difference results and visual comparison of the point clouds suggested that the booms had remained static since the 2014 survey.

4.29.4 The main mast area of the SSRM was well defined, however, due to the tidal state and the motion experienced during the 2015 survey, the coverage of the mast in MBES data is not as complete as the previous survey. As in the case of the Fore Mast, the additional laser data acquired at the low tide helps to resolve this issue as there is an overlap between the two datasets on the forward side of the mast.

4.29.5 The main mast and mast house has been well defined by the two datasets. On the upper surface of the mast house the bases of the cowled vents are clearly visible. Visual examination of the point clouds and the surface difference analysis indicated that there had been no deterioration of the structures present. There is only one visible cargo handling boom in the Main Mast region. This boom is wedged between the starboard side of the Mast House and the base of the adjacent Life Raft Rack. The point cloud imagery showed that it had remained static since 2010 survey. Unidentified in previous survey reports is a section of uplifted deck plate that has moved upwards by up to 0.75m since 2010. This section lies to the port side of boom and just forward of the Main Mast House.

4.29.6 MBES coverage up the Mizzen Mast was not as extensive as in the 2014 survey. However, the improved Laser coverage means that there is still a continuum of data up the forward side of the mast in particular. The locations of the life raft racks behind the mizzen mast prevented a similar degree of MBES coverage on the aft side compared to the forward side. The timing of the Laser survey, performed during a particularly low tide, has increased the area of mast that was captured in the combined point cloud when compared to the previous survey.

4.29.7 The Mast House was well defined in the 2015 survey. Point cloud imagery and cross-sections viewed in CARIS showed that no identifiable degradation had occurred and the features on top of the mast house, either side of the mast, were present and appeared to be in the same condition.

4.29.8 Examination of the point clouds from the 2015 and 2014 surveys suggested that the mast structure had remained static and no signs of advancing structural deterioration were observed. Surface difference analysis showed that there has been little deterioration here although small changes around the complex debris are present. These changes are likely to relate to subtle differences in cleaning but larger scale shifts indicative of deterioration of the wreck were not observed.

4.29.9 Three cargo handling booms remain in the Mizzen Mast area and are clearly visible in the point cloud imagery. All appeared to have remained stable, which no indication of deterioration.

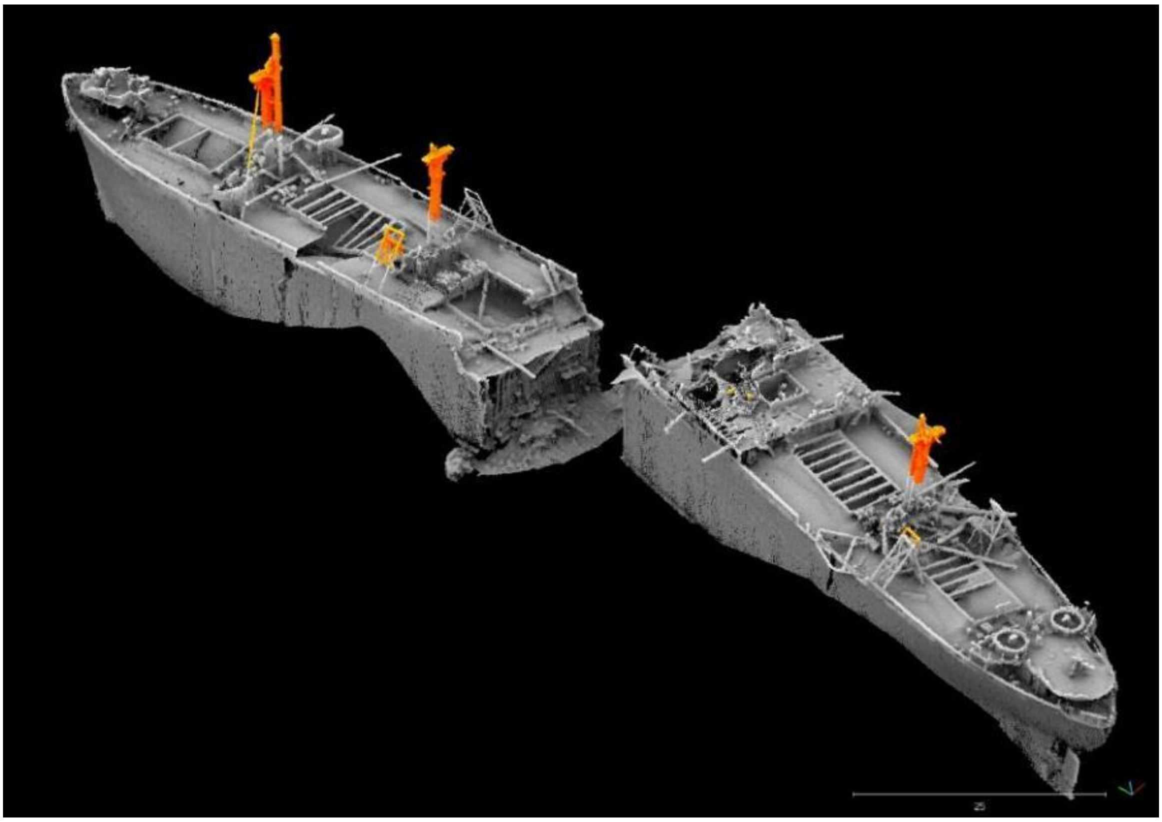

*Fig.  26  Multibeam & laser data (orange), 2015, showing all three masts*

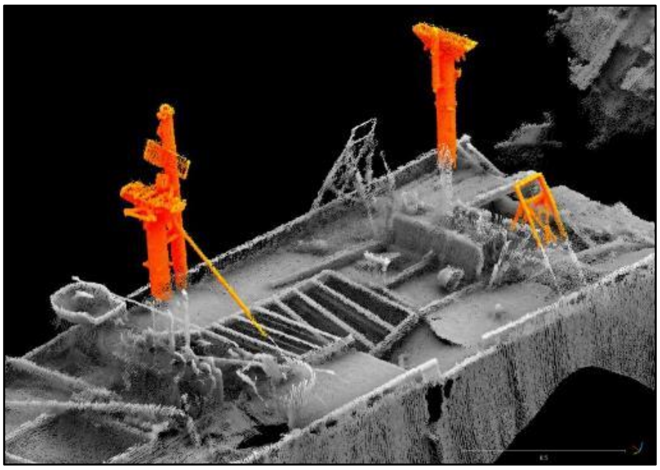

*Fig.  27 The foward section showing multibeam data in grey, laser scanning in orange.*


*Fig.  28 The fore mast, showing warning sign*

# 5. Survey Results – The Seabed

5.1 A key part of the SSRM project is to undertake a high-resolution survey that covers the seabed over an area extending 400 metres from the centre of the wreck. This was performed using the MV Yantlet whilst also acquiring the TVG data. Fig. 29 shows the results of this seabed survey. The data collected is used identify where changes to the seabed topography around the wreck have occurred. This is achieved by performing surface difference analysis against historical datasets and by comparing contours created from these surfaces.

5.2 In addition to providing information about sediment migration, the seabed survey is used to identify changes or new additions to the list of known objects on the seabed within the survey area.

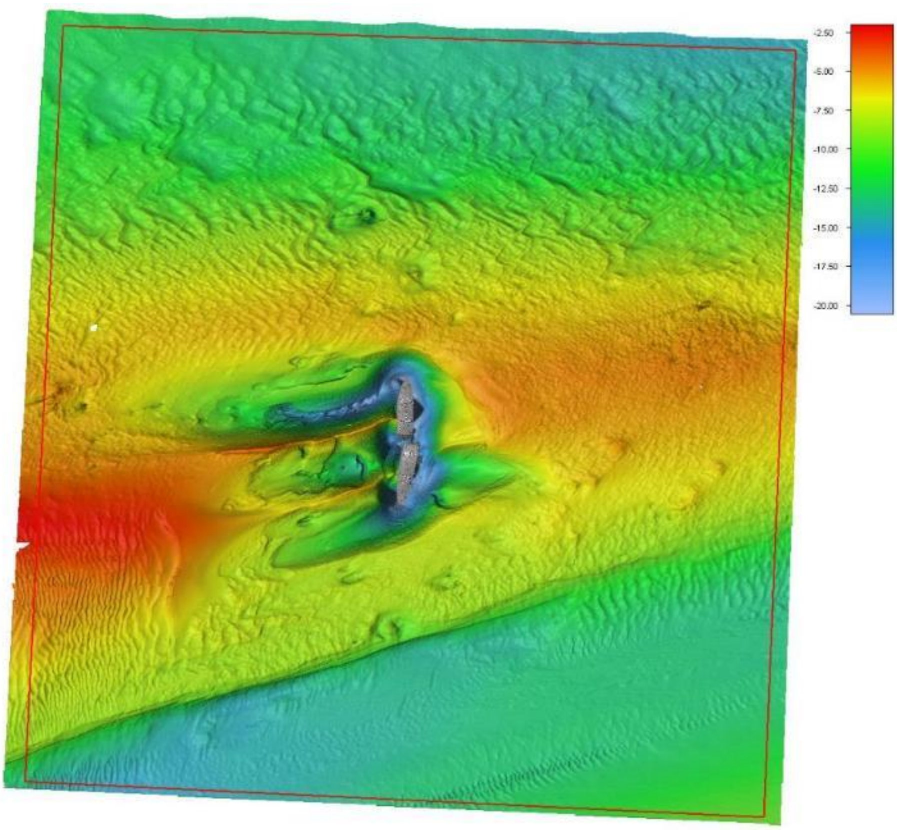


*Fig. 29 Results of the SSRM 2015 seabed survey*

## 5.3 Seabed Comparison

5.3.1 In order to compare differences in the seabed across the surveys, the seabed survey area was divided into three sections. Area A is the dredged channel to south of the wreck, Area B is the scour patterns around the wreck and Area C is the seabed adjacent to the wreck. Surface difference analysis was used to compare the depths across the 2015 seabed data with the 2014 dataset.

Examination of the surface difference showed that between the 2014 and 2015 surveys, the site has generally remained stable with differences in depth mostly within the +/- 0.1 m threshold. Areas that have experienced the greatest changes include the shallow sand bank to the south-west of the wreck and the scoured areas immediately to the west. A prominent area where sediment has been eroded can be seen directly to the north of the wreck. Smaller scale changes are seen in the Medway Approach Channel to the south, the Great Nore near the north-east corner and on the sand bar to the east of the wreck.

## 5.4 Area A – Dredged Channel

5.4.1 Due to the proximity of the wreck to the shipping channel, a close inspection of the seabed was made in order to identify any items of debris that might have derived from the SSRM. This resulted in no items being observed.

The surface difference results showed that, in general, the seabed within the channel had experienced minor changes. Deposition within the channel has occurred in the south-east and south-west corners and this was typically between 0.3m and 0.5m. Near to the northern side of the channel there is an extensive band that has undergone sediment erosion. This is generally between 0.2m and 0.5m.

The steep flanks of the channel have seen the greatest change in this area, with sediment erosion occurring along the entire length of the channel wall. The maximum amount of material lost is 1.2m and this has resulted in a consistent north-westerly shift in the 10m contour, however, this is only a minor change, typically between 1m and 2m.

## 5.5 Area B – Scour Patterns

5.5.1 The central part of the survey area is characterised by the prominent scours that have developed around the wreck. The surface difference results in this zone show that the large scale features have remained stable and with the greatest changes occurring in the western scours.

The single scour to the east of the wreck largely remained stable over the last year. Slight increases in depth (0.2m) have occurred along the northern and eastern flanks but a prominent change has occurred in the south-west. Here there is a marked depression in the flank of the scour in which there is a bulge of sediment. In this region the maximum depth and height increases are 1.0m and 1.1m respectively.

The southern most of the western scours has mostly remained very stable. Areas of change include the southern slope on which there is a broad expanse that has seen between 0.2m and 0.4m of sediment eroded. On the northern flank an increase in depth of up to 1.0m was seen. This region is highly variable as in the period between the Galloper wreck survey and the Yantlet seabed survey there is a 0.5m increase in depth.

The central scour has shown a marked variability since the 2014 survey. The overall shape of the scour is consistent with previous surveys but there are some complex scour patterns within the larger scale feature. The “pear-shaped” scour has been reworked: in the east a pronounced increase in depth has occurred and to the north, sediment has been deposited into the scour. The central section of this scour has seen widespread deposition of sediment, typically 0.4m. The greatest amount of material deposited in this scour is in the north where up to 1.1m of sediment has accumulated.

West of the “pear-shaped” scour are areas that have seen sediments accumulate and erode with depths of accumulation here ranging between 0.2m and 0.75m. The northern flank of this central scour has undergone erosion. This is mostly quite minor levels, but with two sites where more erosion has taken place (up to 2.0m).

The northern most of the western scours has experienced low levels of sediment accumulation over its southern flank, typically 0.3m. On the northern flank, the scour has generally remained stable but with isolated regions that have been eroded. The most pronounced of these is in the east of the scour where up to 1.1m of sediment has been removed. The steep wall at the base of the scour has shifted northwards by 1m to 4m when compared with its position in 2014. Along this feature the maximum change in depth is 1.7m, which is located in the more expansive region of erosion towards the west.

## 5.6 Area C – Wreck Site

5.6.1 The wreck sits in a deep scour with large ridges of sediment forming in the lee sides of the Forward and Aft Sections. The surface difference analysis shows that only minor changes in the depths around the wreck have occurred since the 2014 survey. The upper slopes of the eastern side of the wreck scour have accumulated sediment over a wide area. This is typically 0.2m to 0.4m. Adjacent to the forward end of the Aft Section a local high of 0.6m of sediment has been deposited on the slope.

At the northern end of the wreck site there is a mixture of erosion and accumulation that is typically +/- 0.2m. Immediately under the bow the sediment has remained stable.

To the west of the Forward Section the flanks of the sediment ridge generally show small amounts of deposition of between 0.2m to 0.4m. Along the port and starboard sides of the Aft Section small amounts of erosion have taken place. This does not appear to have affected the stability of this part of the wreck and surface differencing and assessment of profiles do not show a change in the listing angle of the Aft Section. Towards the stern, the portside shows small amounts of deposition (0.2m to 0.5m) and directly beneath the rudder the scour has been slightly reshaped.

## 5.7 Contour Assessment

5.7.1 Contours were generated from the 2015 dataset in Fledermaus and viewed in conjunction with contours from 2014 and 2010. The latter set of contours is provided to identify any long-term trends that might not appear as significant alterations from year to year.

Generally, there is a close alignment between the contours from 2014 and 2015. This suggested that although the site is highly dynamic due to the strong tidal currents, the sediment transport processes are in relative equilibrium.

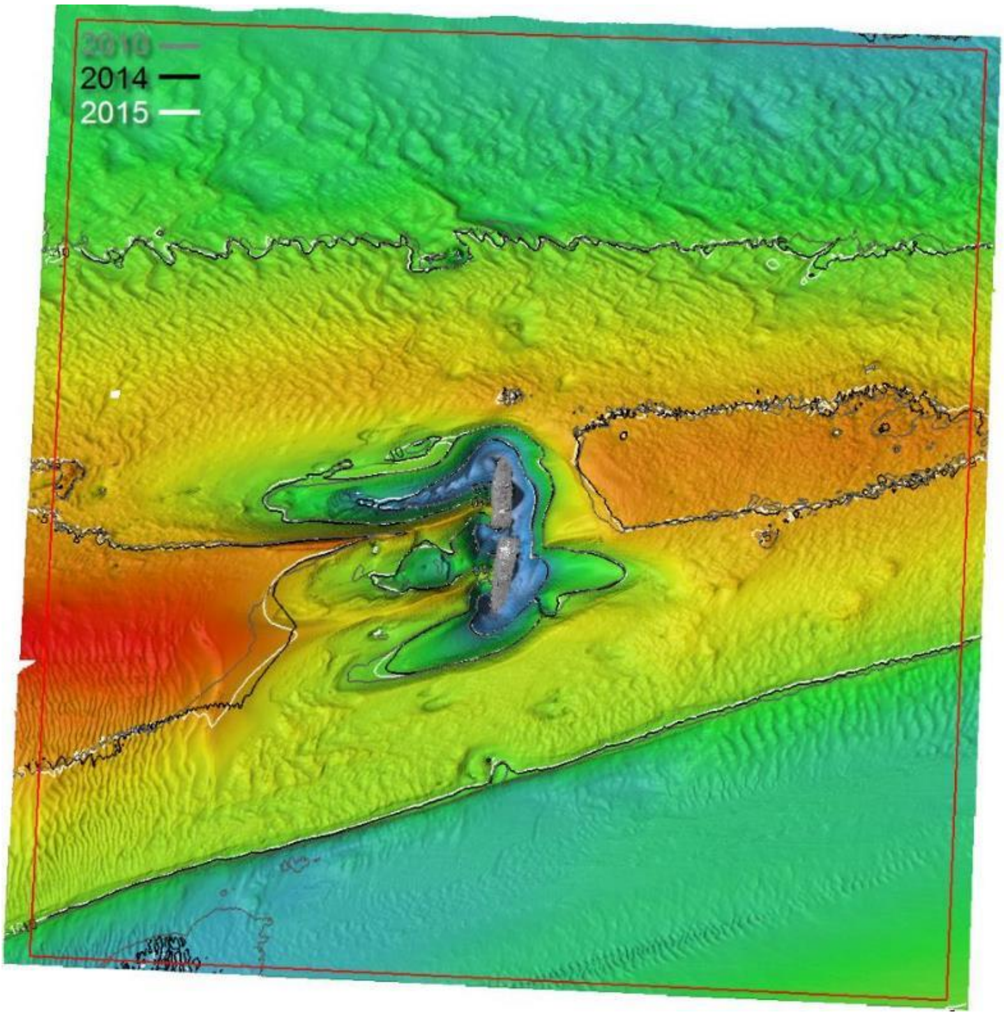


Fig. 30 Charted depth contours across the whole survey site
Contours generated are 5m, 10m, 15m and 20m

## 5.8 Backscatter Data and Seabed Targets

5.8.1 Continuing from the 2014 survey report, the backscatter data acquired by the MBES has been processed to produce information on the seabed texture. Backscatter data is acquired simultaneously with the bathymetry as the MBES records an intensity in addition to the two-way travel time of the sound pulse. The intensity value is determined by the texture of the seafloor and can be used to identify foreign objects on the seabed around the wreck. Backscatter data can also be processed to produce imagery with higher resolutions than the bathymetry. As in the 2014 report, the resolution of the backscatter imagery is 0.1m. This can be combined with the bathymetry to help identify features around the wreck site and, in the 2014 survey data, this combination led to 12 new objects being added to the list of known seabed targets.

5.8.2 There are some factors which impact on the output and interpretation of the backscatter data. For example, the intensity of the returned sound waves varies depending on the type of MBES system used. In the 2015 survey, two different MBES systems were used and data was acquired on different days at different states of the tide and this will impact on the final result.

5.8.3 Through close scrutiny of the backscatter data and bathymetry (and the magnetometer survey which is outlined below), previous seabed targets were relocated and a small number of new ones were detected.

5.8.4 The majority of seabed targets identified in the 2015 survey data related to ones which have been previously recorded. Four new objects were located, only one of which lies within the prohibited area.

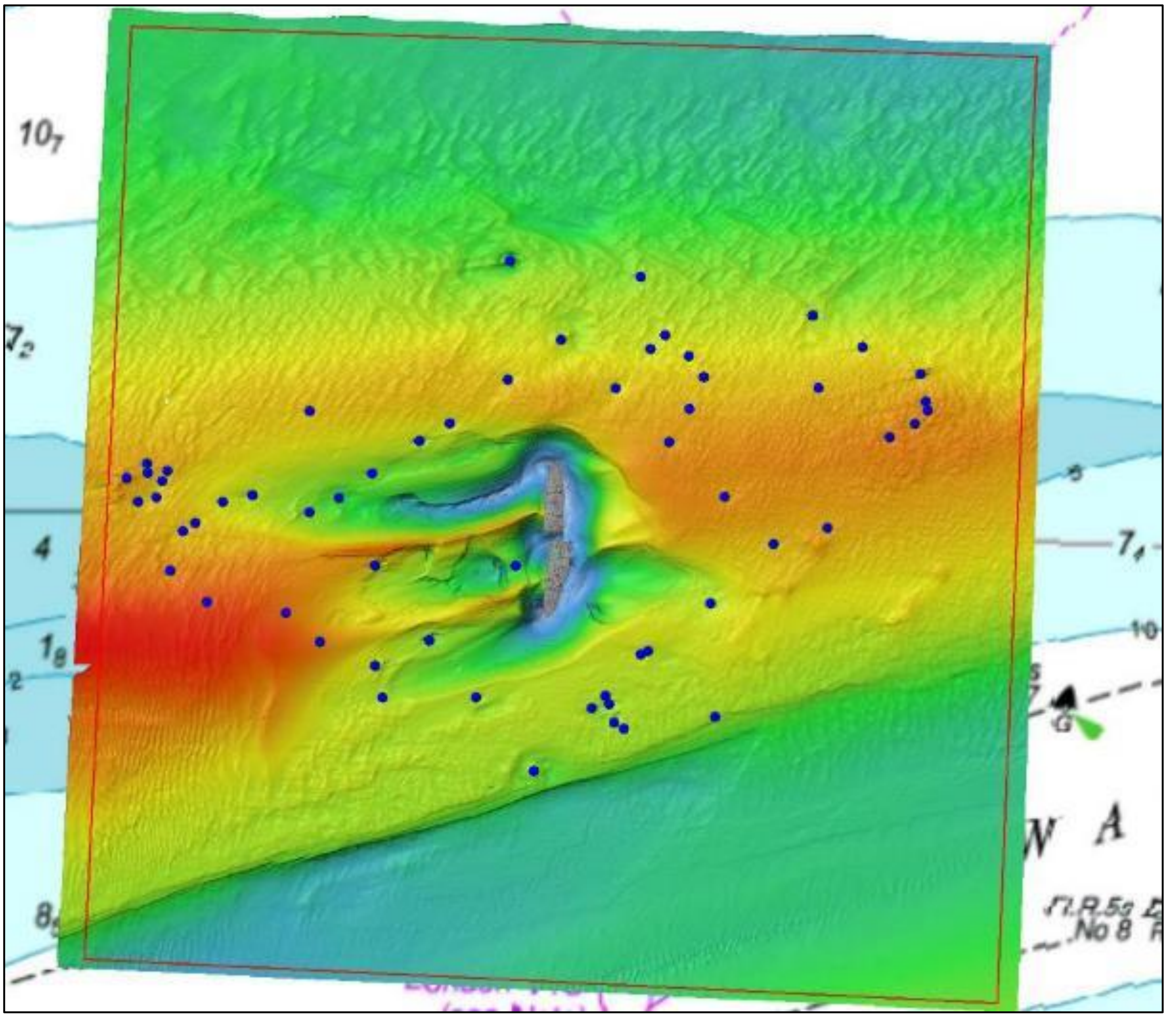

*Fig. 31 Locations of the Seabed Contacts 2015*

# 6. Magnetometer (TVG) Survey

6.1 Added to the scope of work for the 2015 survey was the requirement to perform a magnetometer survey over the seabed surrounding the wreck. The purpose of the survey was to provide additional information about the contacts detected within the survey area and possibly identify new items buried and not detected by the MBES.

6.2 The magnetometer survey was conducted using a Transverse Gradiometer (TVG) that consisted of two Geometrics G-882 caesium-vapour marine magnetometers attached in parallel to a non-magnetic frame that is towed behind the vessel. Using two magnetometers permits the relative difference in magnetic anomaly strength between the two systems to be determined and this information is used to locate the magnetic debris on the seabed. The wreck itself forms a large magnetic anomaly which has a strong effect on the quality of the magnetometer data in the centre of the survey area and also presents a physical hazard to the towed instrument. Survey lines were cut short on the East and West sides of the wreck to permit sufficient space for the vessel to safely turn without the TVG coming into close proximity to the wreck.

6.3 The TVG equipment was mounted in a rigid frame that held them with a 1.5m spacing. In addition to the dual magnetometers, the system contains a motion sensor to record the angle of the system, a depth sensor and an altimeter, which provides information of the vertical position relative to the surface and seabed. Horizontal positioning was provided by a navigation string output from QINSy that applied a 20m or 30m layback from a reference point on the aft end of the survey vessel. The initial position information was supplied by the POS MV system.

6.4 All of the data was recorded by QINSy, which also logged the positon and motion data and bathymetry for the MBES system.

6.5 The environment for conducting a towed TVG survey was a challenging one. The seabed has a highly variable topography, there are strong tides and there are physical obstructions in the form of the wreck and the marker buoys. Generally, it is best to avoid turns whilst towing a system but manoeuvres to avoid the marker buoys and the wreck were necessary. Two large buoys were attached to the TVG frame to provide a visual reference of the position of the equipment and to give some buoyancy to prevent the system from colliding with the seabed during low speed turns.

6.6 The challenges of surveying around the wreck meant that the TVG could not be flown above the seabed at a near constant altitude and the shallow waters of the survey area and the shallow draught of the vessel meant that it would not be appropriate to use an acoustic positioning system on the TVG and noise created by proximity to the surface created some issues for data acquisition and some misalignments between the positioning of the MBES and TVG data.

6.7 A number of anomalies were detected in the TVG results and these are mainly clustered in three areas within the survey area. These are on the West, North and East of the wreck. At these locations the targets are also present in the MBES data. A few smaller anomalies were detected that could not be seen in the bathymetry. These may correspond to smaller items of debris or items that have become buried.

6.8 36 anomalies were selected from the residual data. The positions of the magnetic anomalies were compared to the known seabed targets, although noting that there were some positional misalignments. Where TVG anomalies were identified that had not been previously seen in the MBES data the area was examined closely and, if present, the contact was added to the list of seabed targets. An image of the seabed point cloud was recorded and approximate measurements made. The majority of TVG contacts could be assigned to previously identified features, however, a total of four new contacts were added to the list of seabed targets (along with the three new targets added from the MBES data). As noted above, only one of these new targets is inside of the prohibited area. Anomalies that were not identified in the MBES data were not added but a comment was made to indicate that it was possibly buried.

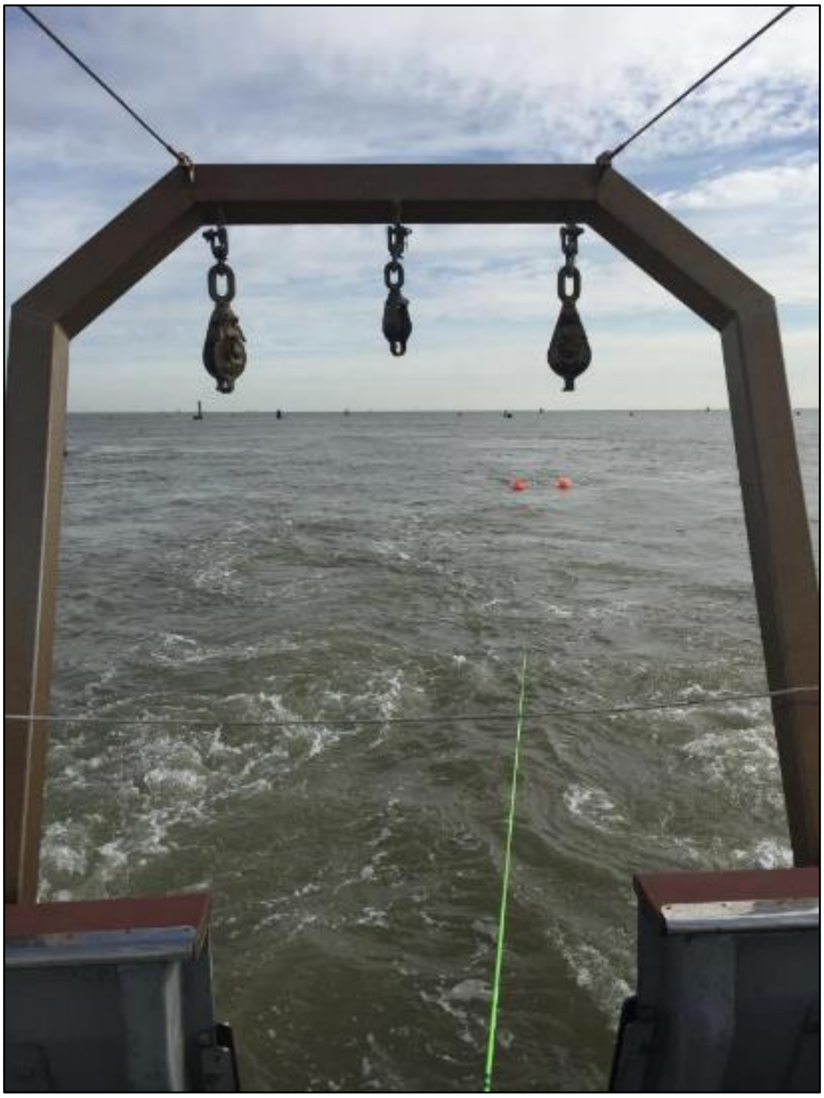

*Fig. 32 The TVG array under tow with the SSRM visible in the background*

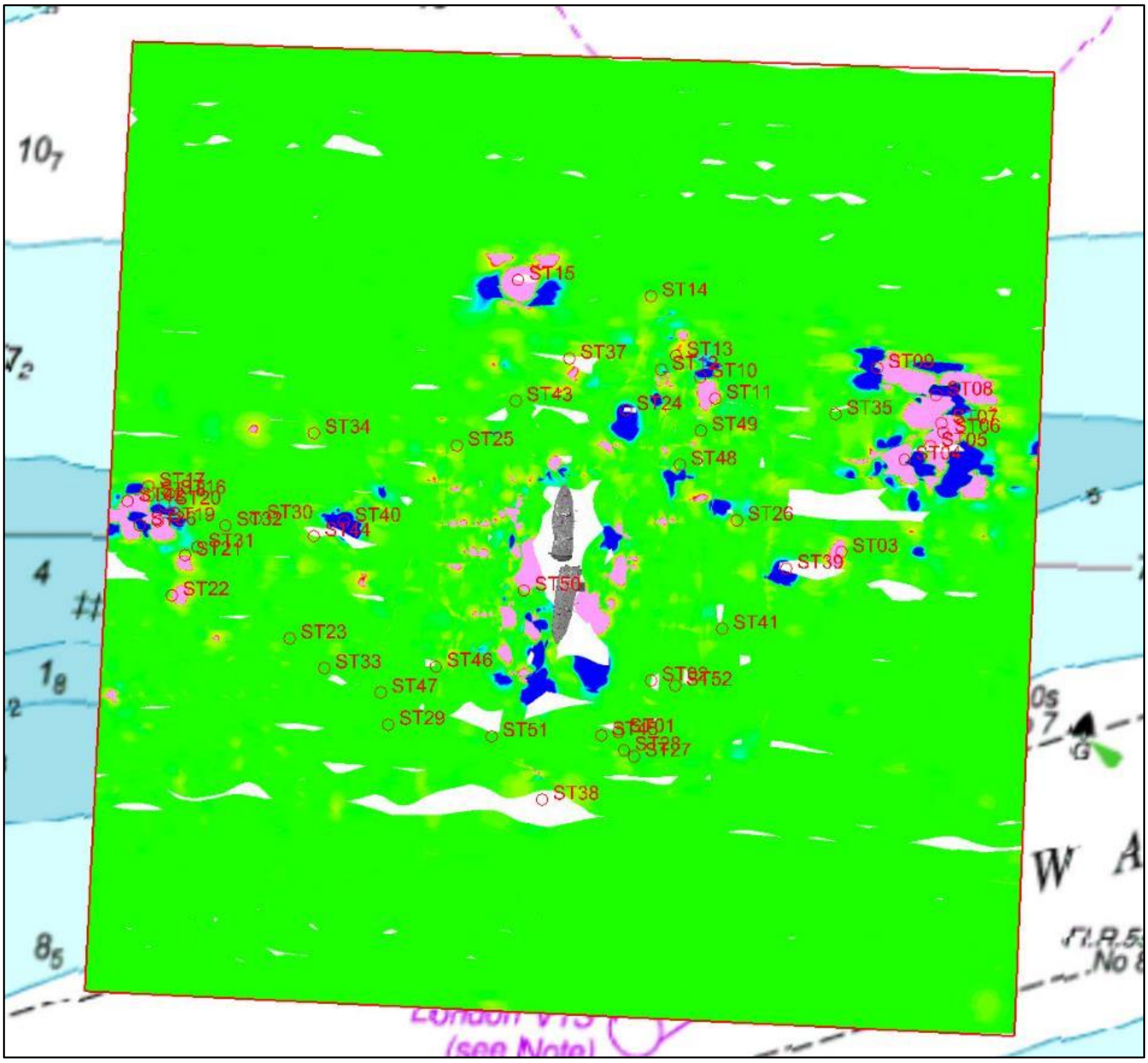

*Fig. 33 TVG results with Seabed Target locations shown*

*Table 5 - Example of TVG Anomalies*

| RICHARD MONTGOMERY TVG ANOMALY LIST 2015 | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **ID** | **Easting UTM31 N (m)** | **Northing UTM31 N (m)** | **LAT (DD MM.mmm)** | **LON (DD MM.mmm)** | **WATER DEPTH (m)** | **ANOMALY Peak to Peak (nT)** | **Type** | **Seabed Target** |
| **G-Y-001** | 345759 | 5704075 | 5128.008 | 0046.764 | 6.9 | 217 | Monopole | **ST19** |
| **G-Y-002** | 345766 | 5704069 | 5128.005 | 0046.770 | 5.8 | 264 | Monopole | **ST19** |
| **G-Y-003** | 345785 | 5704035 | 5127.987 | 0046.788 | 5.5 | 18 | Monopole | **ST21** |
| **G-Y-004** | 345736 | 5704056 | 5127.997 | 0046.745 | 5.2 | 9 | Monopole | **ST36** |
| G-Y-005 | 345781 | 5704004 | 5127.97 | 0046.785 | 4.4 | 33 | Monopole | ST22 |

# 7. Results & Conclusions

7.1 In this report the newly acquired dataset is compared to the 2014 survey results and a benchmark dataset from 2010. Comparing the current dataset with the previous survey enables changes that have occurred during the last year to be identified as well as longer-term changes. Given the positional accuracy of the POS MV system is at best +/-0.05m it is reasonable to discount small changes with this magnitude. Performing the comparison with an older dataset aims to prevent gradual small changes from escaping detection.

7.2 As in previous years, as much information as possible has been extracted from the MBES data in order to observe any changes.

7.3 The complete survey of the wreck of the SSRM in 2015 has required the acquisition of MBES, laser, photographs and magnetometer data.

Comparative analysis was undertaken of the wreck and the dynamic topography in the immediate area of the wreck to determine if and how it has changed.

7.4 The 2015 survey provided high quality results and enabled the features of the wreck to be seen clearly and inspected. The density of the latest data is the highest yet. This was achieved through the use of a different sonar setting than in other surveys since 2010.

7.5 The timing of the laser survey was highly beneficial to the final point cloud. The laser data was acquired over two days with the later attempt taking place during the lowest part of a low spring tide. As a result laser data reaches further down the masts.

7.6 The wreck was assessed for structural deterioration by three key methods. Point clouds were visualised in CloudCompare, surface differencing was performed in Fledermaus and cross sections through a combination of the current and historical datasets were viewed in CARIS.

7.7 The key finding of the wreck data analysis was observing the collapse of the overhanging bridge section that sits unsupported at the forward end of the Aft Section of the wreck. This section of the wreck was not one of the previously identified key features that receive closer inspection at the earliest opportunity. This is in part because the levels of subsidence seen in previous surveys has not been as dramatic. The area of subsidence covers the full width of the wreck at this point and encompasses the the forward edge of the boiler room casing, the collapsed boat deck and the remains of the bridge deck. The severity of the collapse is greatest on the starboard side of the wreck where, at the forward edge, the magnitude of subsidence was 4m from its position in 2014. The collapse appears to be pivoting from a stable region of the wreck that is roughly in line with the middle of the boiler room casing. As a result, the level of subsidence is reduced towards the aft. When the SSRM split into two sections, she did so with this structural part remaining on the Aft Section. This caused the remains of the bridge deck to be unsupported and overhanging and, during the period between the 2014 and 2015 surveys, this section of the wreck has seen a much accelerated level of subsidence. It is possible that the overhanging section may ultimately become detached from the Aft Section and fall onto the seabed. If it does tear free, the current steeply inclined position may result in this section dropping down onto the seafloor immediately in front of the Aft Section. If this occurs it is not likely to have an impact on the Forward Section of the wreck as the distance between the two parts is a minimum of 7.5 m and the area of maximum subsidence is orientated away from the other section due to the relative angles of the Aft Section.

7.8 It is recommended that this section of the vessel is the focus for future surveys (it has been added to the list of Key Features) and would benefit from repeat surveys on a more regular basis to track the progress of the deterioration.

7.9 The remaining Key Areas showed less changes in the period between the surveys. Area 2, is the collapsing deck plate along the port side of Hold 2 and this showed a small progression of the subsidence. This was between 0.1m and 0.2m and appeared to increase with distance from the gunnel. Since the change does not relate to a static shift in position across the whole feature it is not likely to be a positional misalignment. Cross-sections through the data at this area showed that the deck plate is very close (possibly in contact) with the contents of Hold 2.

7.10 The Crack in Hull on the port side of Hold 2 (Key Area 1) appeared to show some evidence of change in the form on a new small hole opening up in the hull on the southern side of the main crack. This region was examined to ascertain whether this was a new feature or a product of acoustic shadowing. This was inconclusive. However, the main crack did not appear to have increased in size since the 2014 survey.

7.11 The Aperture in the port side of Hold 3 and the contents of Hold 3 were ensonified with greater clarity than in previous surveys. Although the degree of coverage within the Hold was not improved upon, the use of a higher density beam mode resulted in a clearer image. This showed a row of round or cylindrical shaped objects with possibly another two rows stacked on top. The dimensions of the aperture remained the same as in 2014.

7.12 The three features covered by Key Areas 4 and 5 did not show evidence of deterioration when compared with previous datasets. These include the splitting of the hull on the starboard side of the Aft Section and the split in deck and split in hull, which are located in close proximity on the port side of Aft Section.

7.13 The collapsing bridge deck region has affected a number of other features located in this part of the wreck. Features that have subsided in association with this include the boat deck on the port side and starboard side and the forward-most life raft davit on the starboard side of the wreck. The life raft davit near to this section of the wreck has shown the largest collapse and this feature has itself increased in depth by 2.9m and is now partially covered by a sheet of debris.

7.14 Away from this dynamic region of the wreck the other changes on the Forward Section are quite minor. For example, the break in gunnel, has increased its tilt by 0.05m towards the east in relation to the collapsing deck plate alongside Hold 2 and one of the holes in the deck plate in the collapsing deck at this location shows a modest increase in size increasing in length from 0.5m to 0.8m. The deck plate along the port side of Hold 3 has shown an increase in height of 0.1m to 0.2m. This is unusual as one might expect the wreck to collapse with sections increasing in depth but this rise is consistent over a large area and the difference is observed when comparing data from 2014 and 2010. Some redistribution of the sediments trapped within the holds has occurred.

7.15 On the Aft Section of the wreck, aside from the collapsing bridge deck, some small changes were noted.

7.16 The 2015 seabed survey generated a high density dataset that resulted from acquiring MBES on every line run with the TVG array. This close line spacing meant that features were well resolved in the point cloud and seabed targets could be seen more clearly. Comparisons across the survey area with historical surface data showed that the area was mostly stable. The greatest changes were observed on the shoal bank in the west of the area and in the complex scour features immediately west of the wreck. The position of the dredged channel bank had consistently moved north-west by between 1.0m and 2.0m since 2014. The sediments immediately beneath the wreck showed only minor levels of changes. Beneath the bow and stern there is evidence of the scour reshaping but both ends of the wreck are well supported. This is confirmed by the surface difference analysis of the wreck, which shows these features to be stable.

7.17 A combination of bathymetry, backscatter and TVG led to several new features being added to the list of seabed targets. Many of the features already identified in the MBES were confirmed by the presence of magnetic anomalies in the TVG data. Despite the difficulties in towing around the wreck and the marker buoys the TVG has generated worthwhile data, however it is interesting to note that there is only one seabed target that has been picked out from all the datasets within the diamond shaped area defined by the marker buoys.

7.18 The 2015 SSRM survey has produced a dataset that is fit for purpose in analysing the structural degradation of the wreck and examining changes in the surrounding seabed. However, there are a number of recommendations that could be made for future surveys.

7.19 Primarily, it would be preferable if the survey could be conducted during the summer. Vessel, survey crew and representatives from the MoD and MCA need to be available during a daytime spring high tide with gentle weather conditions in order for the wreck survey to go ahead. Attempting to perform the survey during the winter increases the likelihood for poor weather.

7.20 The MBES systems used during the 2015 survey are of high quality and enable high density, high resolution surveys to be undertaken. However, a new system with the capacity for improvements in resolution could be used to capture data along the sides of the wreck. This new technology is available on a PLA survey vessel, although the vessel is too large to go over the top of the wreck it could safely ensonify parts of the wreck.

7.21 Towing the TVG amongst the physical hazards of the wreck, marker buoys, tides and the complex seafloor topography was a challenging operation. Despite this, the results obtained during the 2015 survey identified a small number of new targets. Performing such an operation again would be made substantially easier if for the survey period the marker buoys could be removed, enabling the survey vessel to run straight lines.