Goodwin Sands

Archaeological Review of Geophysical Data

Prepared for:

Goodwin Sands SOS

September 2017

Peter Holt
BEng CEng CMarEng MIMarEST MCIfA MHydSoc

3H Consulting Ltd

Introduction

Dover Harbour Board (DHB) is proposing to dredge a significant quantity of seabed material from the South Goodwin Sands. In March 2017, 3H Consulting Ltd. was approached by the Goodwin Sands SOS team to evaluate the marine geophysical methodology and results from the first survey acquired between 10th July and 2nd August 2015.

The first survey data set comprised side scan sonar, multibeam echo sounder and sub-bottom profiler (chirp and boomer) data. The data was processed by Wessex Archaeology (WA)[1]. In the report WA noted problems with the side scan sonar data which provides the primary search information used to identify cultural material on the seabed. No magnetometer data was collected and the side scan sonar data was unfit for purpose so no data was available to detect any small-sized cultural objects. The low frequency boomer sub-bottom profiler data was processed but this too would not show small objects as the wrong instrument was used for the task in hand.

Further investigation discovered that inadequate survey methods were also employed on the Plymouth Disposal Site survey in 2013 and the London Gateway survey in 2010, yet all three surveys were signed off by Historic England, the regulatory authority. The results of this investigation by 3H Consulting Ltd. were published in March 2017[2].

At the request of Historic England, a second marine geophysical survey of the proposed dredge area was undertaken in 2017 by Clinton Marine, which included a magnetometer survey specification created by Wessex Archaeology[3]. A review of the survey data detected 315 sites of potential archaeological interest within the exploration area of which 243 (77%) were detected by magnetometer[4].

A revised dredge area was proposed by Dover Harbour Board to avoid many of the targets detected and a second annex report created by WA that considered the location of the anomalies of archaeological potential within the revised dredge area[5]. This report is a reassessment of the targets identified in the revised dredge area and listed in the Wessex annex report (2017b). For brevity, this report does not include the technical details of the survey or any background information and as such it should be read in conjunction with the original WA report (2017a) and the annex report (2017b). For ease of understanding this report uses the same names for targets that were used by WA.

Explanatory Notes

Basic Principles

It is important to state from the outset that the analysis of geophysical data requires interpretation. In essence, the interpretation involves identification of areas of seabed within the search area that are in some way different from the norm.

[1] Wessex Archaeology, 2016, Goodwin Sands: Archaeological Review of Geophysical Data, Report Ref 111510.01

[2] Holt P., 2017, The Suitability of Pre-Disturbance Geophysical Surveys for Underwater Cultural Heritage in England, available at http://www.3hconsulting.com/Downloads/2017_3H_MarineGeoUCHProblems.pdf

[3] Wessex Archaeology, 2016, Goodwin Sands: Magnetometer Survey Specifications, ref 111511.01

[4] Wessex Archaeology, 2017a, Goodwin Sands: Archaeological Review of Geophysical Data (2017). Salisbury, unpubl rep 111511.02

[5] Wessex Archaeology, 2017b, Goodwin Sands Archaeological Review of Geophysical Data (2017) – Annex, unpubl rep.: 111511.03

For archaeology, the requirement is to find the smallest and least detectable objects so the interpretation of geophysics data has to be done with knowledge of the capabilities and limitations of the instruments. Interpretation of geophysical data for archaeology is the most demanding as wooden ships and fragile aircraft often only leave faint traces of their remains on or within the seabed. The tools available to detect the remains are few and they have significant limitations so detection is not guaranteed and is a matter of probabilities.

Wooden shipwrecks on the Goodwin Sands become eroded away unless quickly buried. The buried remains cannot be seen using a side scan sonar or multibeam sonar as they only detect anomalies visible on the seabed. A magnetometer will only detect iron or steel so the wood of the ship will be invisible unless it is held together with a large mass of iron fixings. In theory, a sub-bottom profiler may be able to detect the hull of wooden ship but under the conditions on this site these hulls are all but invisible and it is only their hard ballast or cargo that can be detected.

Aircraft airframes are usually made of wood or aluminium which quickly corrodes and erodes away unless they become buried. The hard parts of the aircraft may survive such as the engine, propeller and wheel struts along with a scatter of smaller metal parts. A side scan sonar may see the remains of a crashed aircraft if it is lying on the seabed but not if wholly or partly buried. The engine may be detectable with a magnetometer so long as the sensor passes close enough to detect the minimal amount of steel used in the cylinder linings and crank shafts; unfortunately, most aero engines are made from non-magnetic aluminium alloy. A sub-bottom profiler is no use in this case as they can only detect objects larger than an aircraft engine under the conditions found on this survey.

Data Collection Methodology

The data collection methodology and selection of instruments and positioning equipment used for the Goodwins survey by Clinton Marine was appropriate and sufficient. This survey method was a huge improvement over the previous surveys undertaken on the Goodwins site and the Plymouth Disposal Site, the improvement being clearly highlighted by the number and nature of the targets detected. This second survey also showed that these survey requirements can be achieved even in the difficult environment found on the Goodwin Sands.

The side scan sonar data was limited in its ability to resolve smaller objects as the data was affected by wave noise, large and upstanding objects were visible, however smaller objects were difficult to identify' (WA 2017a, 2.3.2). This was due to the conditions on site and must be seen as an acceptable limitation.

It was not expected that the sub-bottom profiler (SBP) would detect many targets because sand is not a good medium for detection of small buried objects using a parametric sub-bottom profiler.

The magnetometer data was collected under optimal conditions with close survey lines and the magnetometer sensor run just a few metres above the seabed. The background noise level was in the order of 3-4nT and under these conditions the magnetic objects can be detected as small as 20kg. Multiple survey lines were run over the same area which meant that the same target was detected on multiple lines; this gives us confidence that the target is real and not just random noise recorded by the instrument.

One improvement can be suggested. Under these conditions one could expect that the multibeam data be gridded to a higher resolution than the 0.5m grid provided, as a 0.3m or 0.25m grid would allow smaller surface objects to be identified.

Note: The specification for the second Goodwins survey should be used from the outset by the regulator as the minimum requirement for all future geophysical surveys of this kind.

Data Processing

This report concentrates on reprocessing the magnetometer data collected during the Clinton survey. The multibeam data requires little interpretation and is unlikely to show any features that were not previously known. The side scan data was not of sufficient quality to show seabed textures that identify buried remains so further reprocessing was not worthwhile. The sub-bottom profiler is unlikely to detect small features and large features are easy to see, so again further reprocessing would be unnecessary. For this survey, the magnetometer is the one instrument that could detect small remains and one where careful processing can tease out more information.

Wessex processed the magnetometer data in a way that is usually done for this kind of work but also in a way that can hide significant details about each magnetic target. Gridding the magnetometer data highlights the large variations in the Earth's magnetic field caused by iron and steel objects, but these are obvious anyway and do not need accentuating. Unfortunately gridding hides the low-level variations in the magnetic field caused by small objects and debris which are hard to see and are often more interesting to archaeologists than the bigger objects. More information about the limitations of gridding magnetometer data and optimal processing methods can be found in the book Marine Magnetometer Processing[6].

Some other aspects of the WA interpretation bear further scrutiny. Many of the objects are described as 'buried'. As noted above the side scan data was not of high enough quality to identify small objects and it would be this tool that would show if an object was visible on the seabed. An equally likely alternative is that the object is lying on the seabed but not detectable with the side scan sonar under the conditions found during the survey.

WA interpretation suggests that some targets may be natural features, yet geological magnetic features are never small and distinct like the objects listed below. Geological magnetic features are hundreds or thousands of metres in size and usually have very characteristic magnetic signatures. The normalisation process that was part of the WA workflow would remove most of the large-scale variation caused by background geology as well as the effects of diurnal variation. Consequently, the anomalies listed below are very unlikely to be natural.

The data was not completely processed by WA as the equivalent mass of each target was not calculated and the measurements were left in magnetic nanoTesla units which are hard to interpret. In the analysis below the equivalent mass of iron (or steel) has been calculated but it has been given a range of values. The smallest estimated mass of iron assumes that the object is as close as possible to the magnetometer, which would be lying on the seabed and directly under the sensor. But the iron object may be offset to one side and at least partly buried, thus further away from the sensor, and it would require a larger mass of iron to achieve the same magnetic anomaly. **The effect of distance on the magnetic field is considerable, for example a small anchor of 100kg just 6m from a magnetometer gives a similar reading as a cannon weighing 2000kg which is 16m away.**

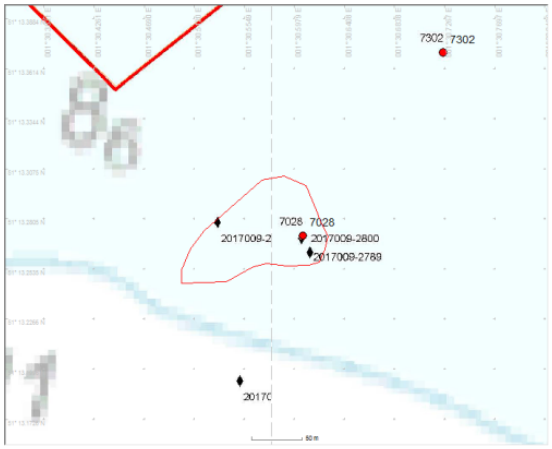
Note: For the purposes of this document the terms Anomaly, Contact and Target are used interchangeably to refer to some feature of interest detected by the survey.

[6] Holt, 2014, Marine Magnetometer Processing, 3H Consulting Ltd.

Target Interpretation

This section lists the targets identified by WA in the revised dredge area along with their interpretations.

WA ID 7028



WA Interpretation:
Magnetic anomaly observed over several lines. No SSS or MBES contact and interpreted as possible buried ferrous material or a natural feature.

3H Interpretation:
This is in fact a debris field covering an area 150m x 90m with discrete object 80-800kg at 7028 position, repeatable on multiple lines.
Also includes Clinton anomalies 2017009-2, 2017009-2789

This target should be re-rated as A1 - Anthropogenic origin of archaeological interest

WA ID 7029

WA Interpretation:
Magnetic anomaly observed on one line in an area of increased magnetic response. No SSS or MBES contact and interpreted as possibly buried ferrous material or a natural feature.

3H Interpretation:
This is a discrete (separate) target 15-150kg with a magnetic disturbance that extends 20m to the south east, possibly an anchor chain. This is not a natural feature.

WA ID 7031

WA Interpretation:
Magnetic anomaly observed over several lines. No SSS or MBES contact and interpreted as possible buried ferrous material or a natural feature.

3H Interpretation:
A discrete and repeatable magnetic target with estimated mass of 45-450kg. Not a natural feature

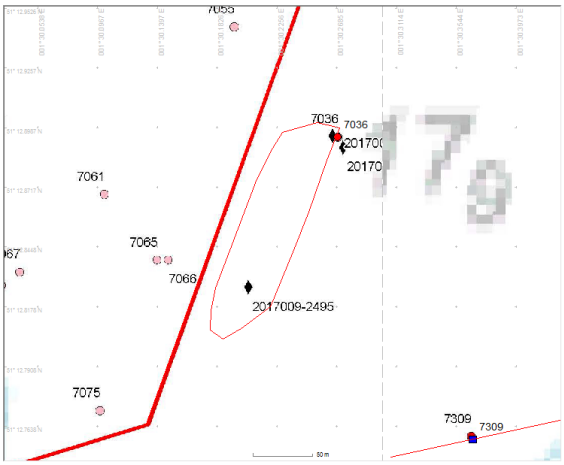
WA ID 7033

WA Interpretation:
Magnetic anomaly observed over several lines. No SSS or MBES contact and interpreted as possible buried ferrous material.

3H Interpretation:
A discrete and repeatable magnetic target with mass estimated at 200-2000kg

WA ID 7036

WA Interpretation:
Magnetic anomaly observed over several lines. No SSS or MBES contact and interpreted as possible buried ferrous material.



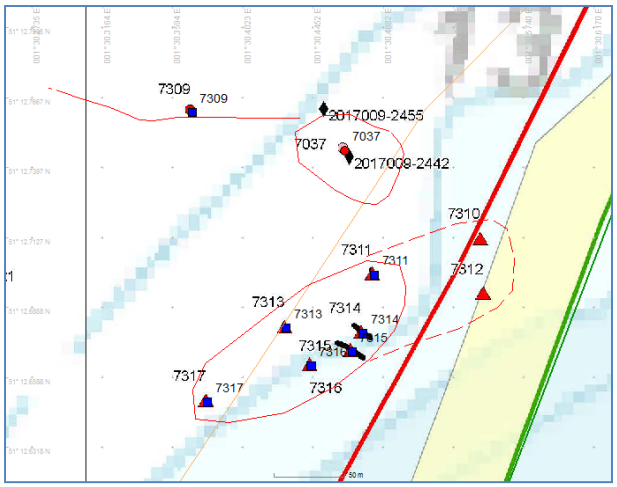
3H Interpretation:
Area of magnetic disturbance covering an area 200m x 50m, aligned north-south which extends down to 51 12.777N 001 30.196E, repeatable on L1028 and L1437, includes Clinton anomaly 2017009-2495

The debris field includes a discrete magnetic object at the north east end, estimated mass 90-900kg

This target should be re-rated as A1 - Anthropogenic origin of archaeological interest

WA ID 7037

WA Interpretation:
Broad magnetic anomaly observed over several lines. Possibly natural but very compact. No SSS or MBES contact and interpreted as possible buried ferrous material.



3H Interpretation:
Target 7037 is surrounded by an area of magnetic disturbance covering an area 75m x 50m. This target and associated debris field may be associated with target 7309 and the 7311 group of SBP targets. Not a natural feature

This target should be re-rated as A1 - Anthropogenic origin of archaeological interest

WA ID 7038, 7039

WA Interpretation:
Magnetic positive monopole observed on two lines, associated but separate from 7039. No SSS or MBES contact and interpreted as possible buried ferrous material.

3H Interpretation:
The two discrete targets 7038 and 7039 lie within an area of magnetic disturbance at least 20m x 20m in area, with masses in the order of 300-400kg

WA ID 7040

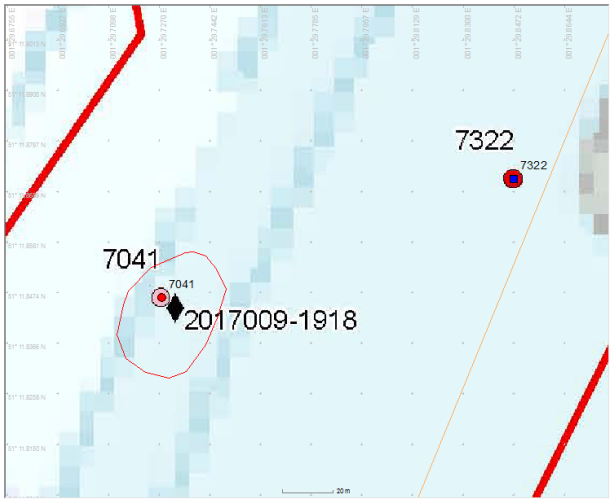
WA Interpretation:
Sharp magnetic anomaly spread over several lines. No SSS or MBES contact and interpreted as possible buried ferrous material.

3H Interpretation:
Small distinct 20kg with similar small target 10m to the east

WA ID 7041

WA Interpretation:
Broad dipole observed on multiple lines. Could be natural but very compact rounded halo. No SSS or MBES contact and interpreted as possible buried ferrous material.

3H Interpretation:
Multiple small targets forming a debris field 30m x 50m surrounding a discrete 100-1000kg object. This area includes the Clinton anomaly 2017009-1918
Not natural.



WA ID 7042

WA Interpretation:
Broad magnetic anomaly observed over several lines. Possibly natural but compact anomaly. No SSS or MBES contact and interpreted as possible buried ferrous material.

3H Interpretation:
A discrete and repeatable target with estimated mass 30-300kg, not natural.

WA ID 7043

WA Interpretation:
Sharp dipole split over two lines. No SSS or MBES contact and interpreted as possible buried ferrous material or a natural feature.

3H Interpretation:
Discrete and repeatable magnetic target, mass estimated to be 50-500kg, not natural.

WA ID 7044

WA Interpretation:
Sharp magnetic anomaly observed on only one line. No SSS or MBES contact and interpreted as possibly buried ferrous material.

3H Interpretation:
Discrete and repeatable magnetic target, mass estimated to be 20-200kg

WA ID 7045

WA Interpretation:
Sharp magnetic anomaly observed over several lines. No SSS or MBES contact and interpreted as possibly buried ferrous material.

3H Interpretation:
A discrete magnetic target with estimated mass 15-150kg

WA ID 7046

WA Interpretation:
Sharp dipole observed over multiple lines with a large halo. No SSS or MBES contact and interpreted as possibly buried ferrous material.

3H Interpretation:
A discrete and repeatable target was detected with estimated mass 125-1250kg

WA ID 7093

WA Interpretation:
Magnetic anomaly observed over multiple lines. No SSS or MBES contact and interpreted as possible buried ferrous material.

3H Interpretation:
A distinct and repeatable target with estimated mass 150-1500kg.

WA ID 7302

WA Interpretation:
Small strong straight reflector observed below the seabed surface. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

3H Interpretation:
Magnetic target with estimated mass of 14-140kg lies 30m to the south-west of target 7302 at 51° 13.359 N 001° 30.709 E

WA ID 7308

WA Interpretation:
Small very strong reflector observed just below the seabed surface. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

3H Interpretation:
Agreed. No magnetic targets were detected on multiple survey lines over this area

WA ID 7309

WA Interpretation:
Small strong reflector observed just below the seabed surface. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

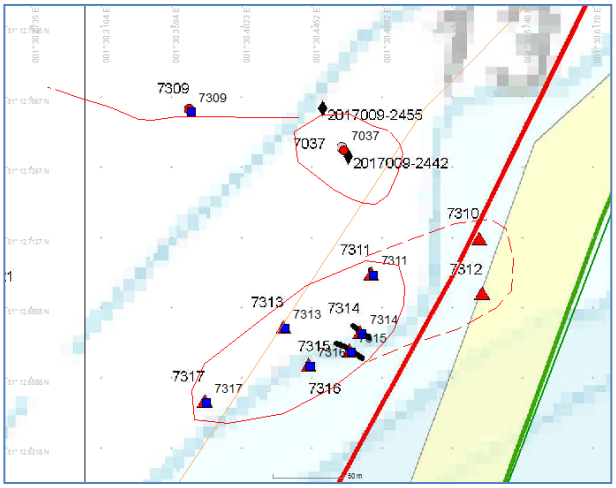
3H Interpretation:
As well as the shallow reflector a curved linear magnetic anomaly runs 180m bearing 77° T between 51° 12.754 N 001° 30.313 E and 51° 12.774 N 001° 30.446 E. The shape of the anomalies on multiple lines suggests that this is an anchor chain. The eastern end may be previously identified as Clinton anomaly 2017009-2455 which lies 20m to the south. This target may also be associated with the 7037 area, the edge of which lies just 30m to the south.

Note that the linear feature was detected by the sub-bottom profiler in just one runline of many run over it. The failure to detect the feature highlights the variability in sub-bottom profilers in detecting small near-surface buried targets.

WA ID 7311- 7317 Group

WA Interpretation:
Strong reflector with hyperbole[7] *observed well below the seabed surface and identified on two separate lines. Possible long feature, one of three with 7314 and 7315. No associated seabed feature. Interpreted as possible buried non-ferrous debris. This feature is located below the 2.5 m limit given to dredging, but kept as is located within the Study Area boundary.*

3H Interpretation:
Targets 7311 to 7317 form a group that includes 7310 and 7312 which lie outside of the newly-defined area. The group lies in an area 235m long x 70m wide bearing 240° T from target 7310 to 7317.



It would not be hyperbole to say that these hyperbolas form the most interesting group of all as no magnetic targets were detected on multiple lines (B22, L3700; B11 L3021, L3022; B21 L3695)
Associated with 7037 and 7309

This is one of the most interesting targets in the survey area. The area of the targets is clearly very different to the rest of the survey area and the targets are in a group which is comparatively small in size, which suggests that this is the remains of a shipwreck or a military aircraft crash site. The targets are also not magnetic so are unique in this dataset and very rare anywhere else. Together this group of targets are clearly man made and of archaeological interest.

The statement below is taken from the WA report (WA 2017a 6.1.2 p11):

*Nine SBP contacts (**7310-7317**, and **7323**) have been discriminated as O2 – Uncertain origin of possible archaeological interest but outside the vertical footprint of the proposed works. As these anomalies have been identified at depths exceeding 2.5m below seabed, and as the maximum dredge depth will not exceed 1.95 m, then no impact will occur.*

[7] This should be 'hyperbola'. Hyperbole is exaggerated statements.

The sub-bottom profiler will only detect objects if they are large enough and dense enough and smaller objects will be missed. Here the sub-bottom profiler has only detected a few larger objects and the idea that they are not associated with many smaller but undetectable buried objects is fanciful at best. **Impact will occur if dredging is allowed over this feature, furthermore this entire feature is significant and should be placed within an exclusion zone.**

This target should be re-rated as A1 - Anthropogenic origin of archaeological interest

WA ID 7318

WA Interpretation:
Small straight strong reflector, which appears to interrupt the natural geology, observed below the seabed surface. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

3H Interpretation:
Agreed. No magnetic targets were detected on multiple survey lines over this area

WA ID 7322

WA Interpretation:
Small strong reflector observed below the seabed surface at the base of sand wave. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

3H Interpretation:
Agreed. No magnetic targets were detected on multiple survey lines over this area

WA ID 7325

WA Interpretation:
Small strong reflector observed below the seabed sediments. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

3H Interpretation:
Agreed. No magnetic targets were detected on multiple survey lines over this area

WA ID 7327

WA Interpretation:
Small strong reflector observed just below the seabed surface. No associated seabed feature. Interpreted as possible buried non-ferrous debris.

3H Interpretation:
Agreed. No magnetic targets were detected on multiple survey lines over this area

Conclusions

The reanalysis of the dataset has identified a number of significant additional features on the site:

- Debris fields have been identified surrounding four targets that were previously identified by WA as discrete targets (7028, 7036, 7037, 7041)
- One sub-bottom profiler target (7309) appears to be a curved linear magnetic target, possibly an anchor chain.
- The targets 7311-17 group have been identified as unique in this dataset, thus significant and of archaeological interest

Equivalent masses of iron or steel have been calculated for each magnetic target. The discrete targets are within the range of masses that include anchors, cannon or parts of an aircraft. The precautionary principle demands that we should assume that each are parts of an aircraft wreck until proved otherwise.

As discrete magnetometer targets can be lost anchors or oil drums we usually rate targets with debris fields as being of more archaeological interest. Here we include four such targets which warrant further investigation.

The data collection methodology and selection of instruments and positioning equipment used for the Goodwins survey by Clinton Marine was appropriate and sufficient. This second geophysical survey showed that these survey requirements can be achieved even in the difficult environment found on the Goodwin Sands.

Note: The second survey detected 315 sites of potential archaeological interest within the exploration area of which 243 (77%) were detected by magnetometer. These statistics clearly justify the use of a marine magnetometer and curtail entirely any debate about the usefulness of this instrument on this type of survey.

Investigation of each target is entirely feasible despite the shallow water and strong tidal currents. This ability was demonstrated in August this year where a team of volunteer divers completed the exact same type of investigation in the same depth of water just a few miles to the north of this site on the wreck of the Dutch East Indiaman *Rooswijk*.