PRIVATE AND CONFIDENTIAL

THE *NIEUWE HAARLEM* PROJECT

TECHNICAL REPORT ON THE RECONNAISSANCE MAGNETIC SURVEY

FOR AND ON BEHALF OF

AFRICAN INSTITUTE FOR MARINE AND UNDERWATER RESEARCH, EXPLORATION AND EDUCATION

By

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BACKGROUND

During a casual conversation at the 2016 SAGA conference in Cape Town, between B. Steenkamp of BroadBand Geophysical (BBG) and Professor Susan Webb of Wits University, it was decided that BBG would offer its services to Aimure to help search for the wreckage of the ship *Nieuwe Haarlem*. This Dutch ship foundered in 1647 in Table Bay five years before the arrival of Jan van Riebeeck. [1] Reportedly the ship came to her final rest on the beach within the tidal zone and nineteen cast iron cannons and four anchors were left un-salvaged. It is therefore quite likely that the corroded remains of all this metal lie hidden somewhere under about 2-4 metres of sand, just waiting to be detected by a magnetic survey.

During a meeting in early October, 2016 with Dr. Bruno Werz, CEO of Aimure, it was decided that BBG would conduct a magnetic survey to cover the entire beach area that Aimure had prioritized from research, and for which they had obtained an archeological permit from SAHRA (South African Heritage Resources Agency). The magnetic survey was carried out on 26 October, 2 November, 14 November and 15 November.

SURVEY DETAILS

1.1 SURVEY DESIGN AND PROCEDURE

Survey planning was carried out in Google Earth by designing 10m spaced lines that adequately cover the intertidal zone and these lines were transferred to a handheld Garmin GPS to facilitate real-time navigation on the beach. A GSM-19 Proton Precision magnetometer, the sensor of which is omni-directional, was used to collect data points at 1 second intervals along the predefined lines. In order to facilitate post survey positioning of the readings the magnetometers clock was synchronized with the GPS clock to an accuracy of 0.5 seconds. This time synchronization ensured that the data points can be positioned to an accuracy limited only by the accuracy of the GPS. Walking speed was about 3-4 km/hr resulting in average spacing between magnetic measurements along the lines of about 1.2m ensuring that quite small objects could be detected. Due to wave action and other activities and distractions on the beach it was not possible to adhere entirely to the original survey design but care was taken not to create gaps between lines that could hold undetected objects 'larger' than a few kg of ferrous metal.

The magnetometer provides a real-time graph that allows immediate detection of magnetic anomalies. This feature was used to decide when anomalies were significant enough in scale (amplitude and spatial) to justify immediate fill-in lines over the causative objects, thus ensuring sufficient coverage to adequately define important anomalous zones.

1.2 SURVEY ACCURACY

The accuracy of a magnetic survey is a function of positioning accuracy by GPS, density of coverage, instrument accuracy/noise and ambient magnetic noise. The most limiting factor of this survey is the accuracy, or rather inaccuracy of the GPS. At best a positional accuracy of a simple handheld instrument without differential GPS corrections is 3 to 4 metres. It is therefore very important to understand that this survey should be regarded as a reconnaissance survey to detect the approximate whereabouts of objects to about 5 metres. For this reason the plan is to cover the principle targets with a higher density of data that are positioned to an accuracy of about 1 metre. This will allow for more accurate excavations in order to limit environmental disturbance.

The quality of the magnetic data was largely dictated by ambient magnetic noise from the city's power grid. The magnetic noise envelope ranged from about 2 nT to about 5 nT, mostly from point to point (1 Hz). This noise is not considered to be a problem as objects of significant size would cause anomalies in the order of 10's of nT and more, and defined by several points along a line and also along adjacent lines.

1.3 SURVEY DATA PROCESSING

Data processing involved the following steps:

- Download of data from GPS and magnetometer.
- Merging of GPS and magnetometer data using the common time channel.
- Removal of spikes from magnetic data.
- Removal of the diurnal variation in the earth's magnetic field. The diurnal data was kindly donated by the Hermanus Magnetic Observatory (a division of SANSA).
- Gridding of data.

Principle data processing was carried out with Geosoft's Oasis Montaj and Encom's Profile Analyst. Modelling was done with Encom's Modelvision. These three tools were kindly loaned to BBG by Xcalibur Airborne Geophysics (Pty) Ltd. Various other software packages were used for data manipulation.

1.4 SURVEY RESULTS

The research done by Aimure defined a 5 kilometre section of beach as shown by Figure 1. Noteworthy is that a small section of the beach near the Parking Area was previously covered by a magnetic survey. [2] A small section of that survey was repeated this year.

Figure 2 illustrates the typical coverage that was achieved and a magnetic grid of a subsection of the data showing anomalies (red) over a good wreck target. Also noteworthy on this image is how the high tide mark changes along the beach dependant on the levels of sand erosion. This clearly shows that one can expect a wreck to be washed right up to the vegetated dunes depending on the erosion pattern and the intensity of winter storms at the time that the ship foundered.

FIGURE 1 - SURVEY LOCALITY

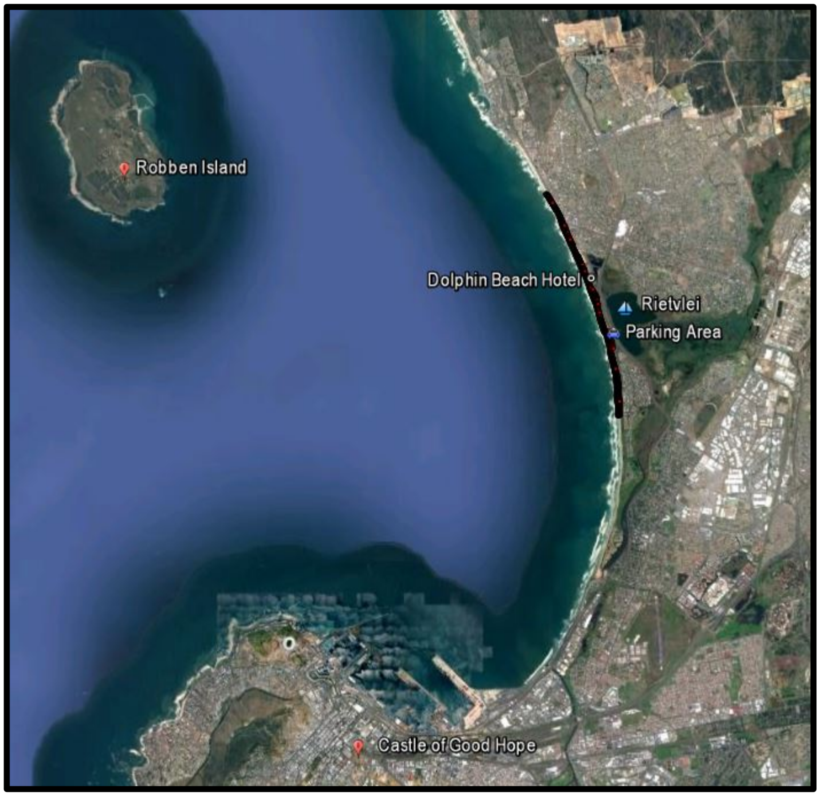
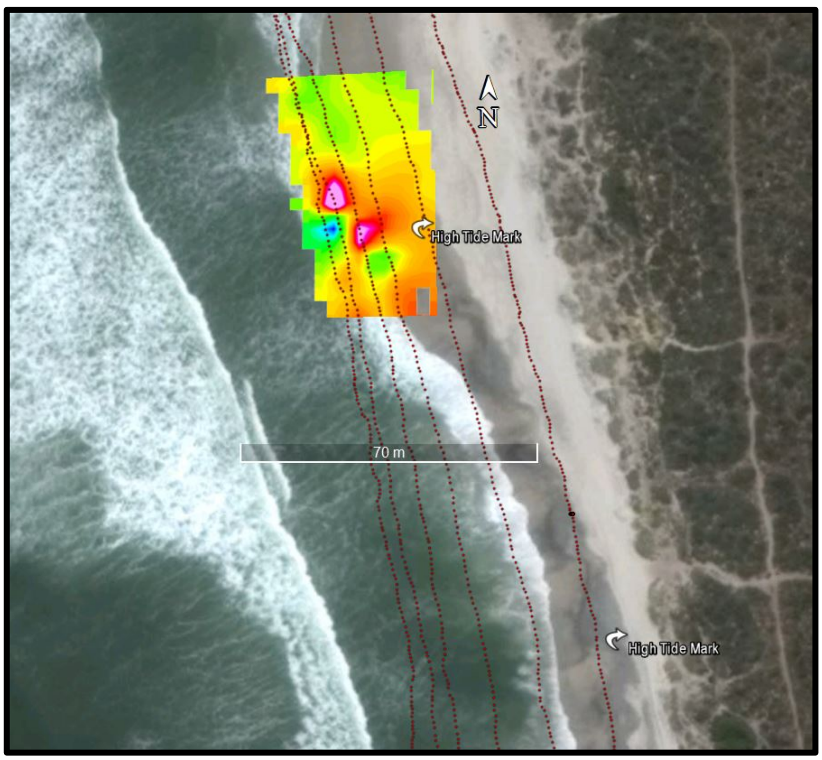


FIGURE 2 - TYPICAL SURVEY COVERAGE

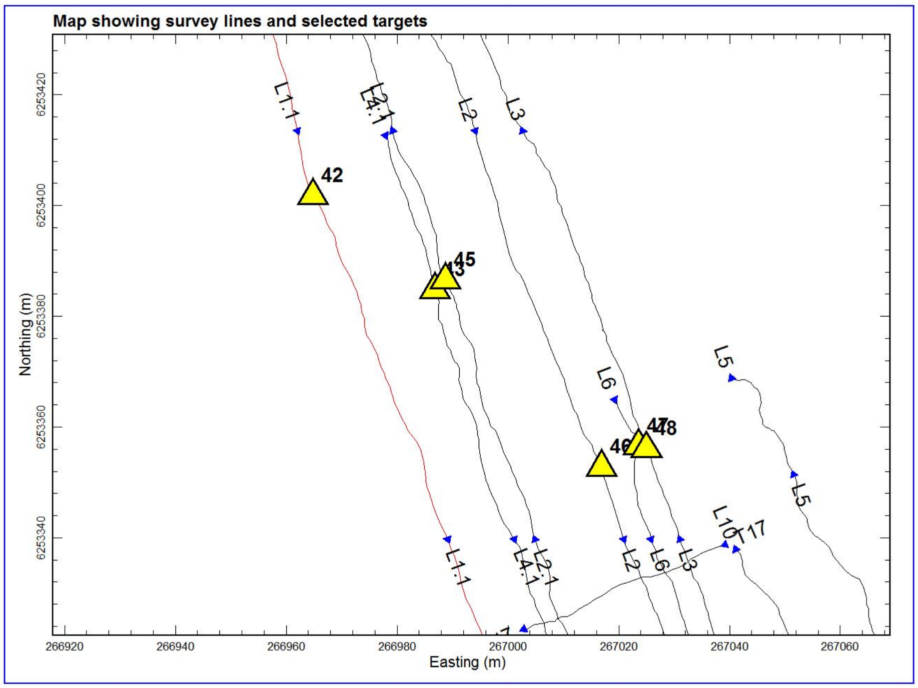


INTERPRETATION

1.5 INITIAL TARGET SELECTION

Target selection was carried out on the magnetic profiles. The targets were written to a database and attributed in terms of anomaly amplitude, priority and a short comment. Figures 2 and 3 illustrate a fairly good target (Priority=2) and a poor target (Priority=3).

FIGURE 3 - EXAMPLE: TARGET 42 (GOOD TARGET)



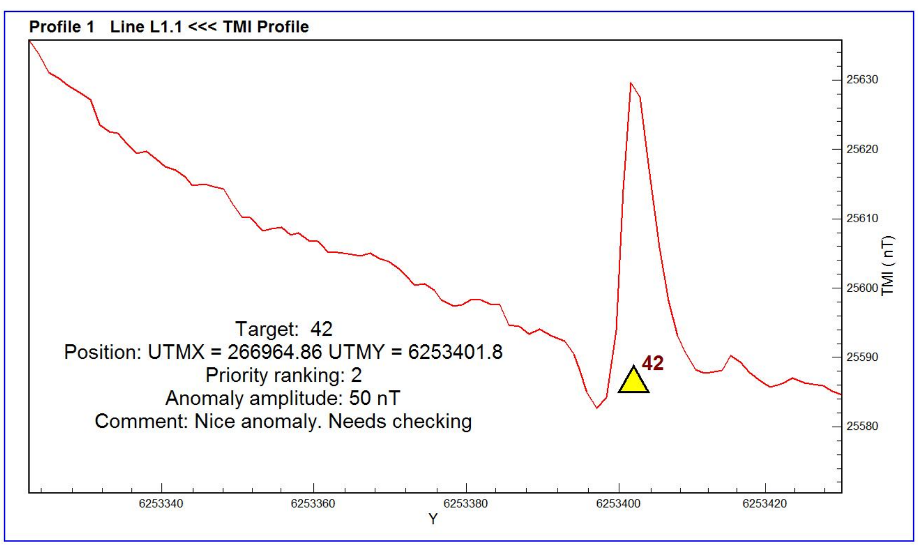
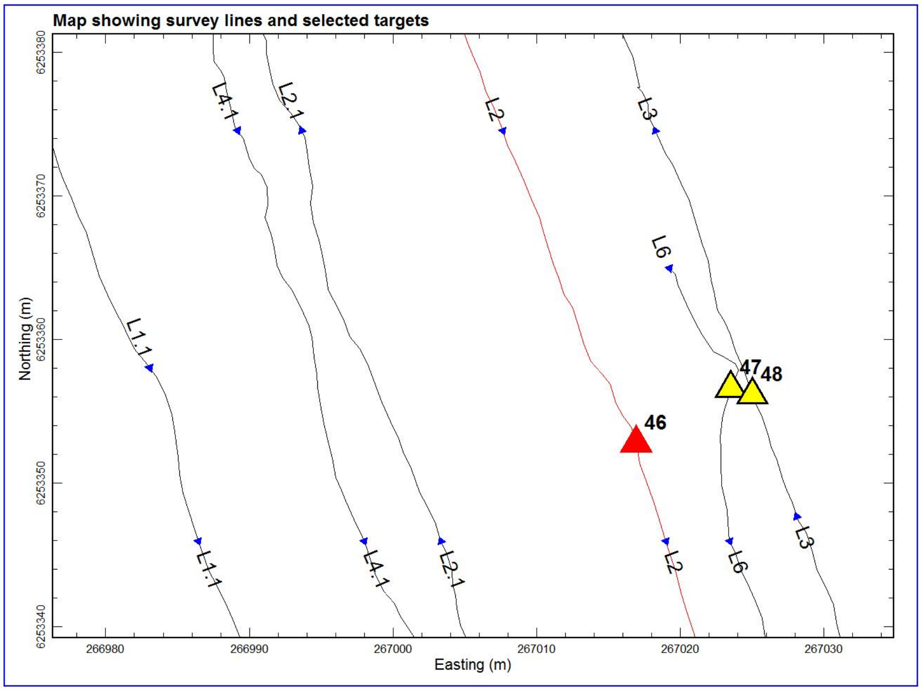
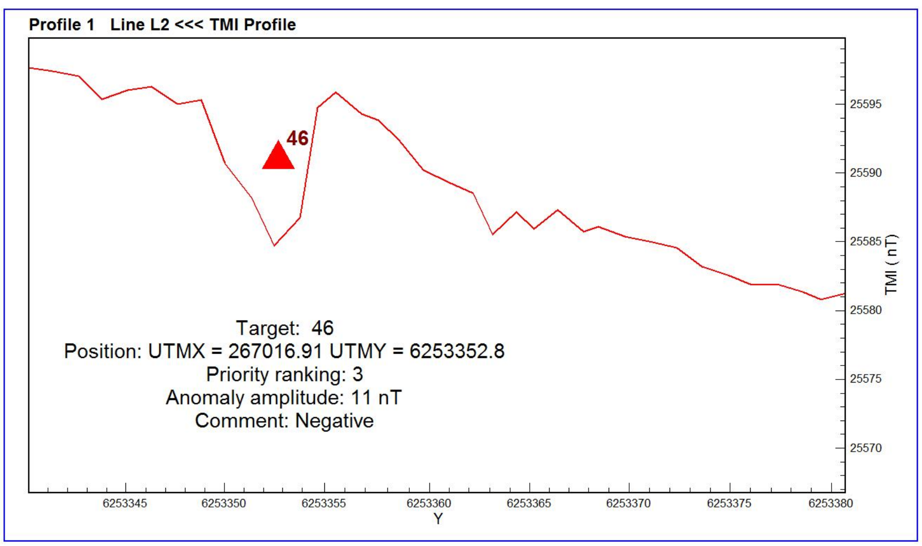


FIGURE 4 - EXAMPLE: TARGET46 (POOR TARGET)





Target 42 could speculatively be caused by an metal object weighing a few kilograms, perhaps something like an old engine part whereas target 42 would probably be a significantly smaller object. Neither anomalies signify the presence of tons of ferrous metal.

In total 76 individual profile-based anomalies were selected but only 5 groups (clusters) were found to be worthy of further investigation.

1.6 DISCUSSION AND MODELLING OF THE HIGH PRIORITY TARGETS

The decision whether or not a magnetic anomaly should be regarded as important is subjective and primarily based on the expected total volume of un-salvaged ferrous objects from the wreck. The other unknowns are the type of metal, the level and type of corrosion, the depth of burial, size of individual objects and the distribution pattern of the objects. The following criteria were used in combination to prioritize anomalies specifically for finding the Haarlem:

- Amplitude of anomalies. Given that 19 cast iron cannon and 4 large anchors were lost one would expect anomalies ranging from 10's of nT (nanoTeslas) to 100's of nT.
- Spatial distribution and location of anomalies. The size of the anomaly cluster needs to be represenative of the ship's size. The cluster should be somewhat linear and lie semi-parallel to the beach line, on or below the spring high tide mark assuming of course the present beach erosion levels were more or less the same than in 1647.
- Areal size of anomalies: Some of the individual anomalies of the cluster should be defined by 2 or 3 adjacent lines to indicate significant cumulative volumes of conglomerated objects.
- Depth of burial. On this beach where in most areas the sand seems quite thick one would expect large old objects to be quite deep (3-4 metres).
- Location of cluster. The cluster that fits the researched position of the wreck should be assigned a high priority.

The position, depth and size of the objects can be estimated with numerical geophysical modelling thus somewhat reducing the subjectivity of the prioritization process. Whereas the depth and position can be predicted with reasonable accuracy (~20% error) there are a few of issues that can render the calculation of size/volume inaccurate. The main problem relates to the corrosion process that can significantly reduce the magnetic susceptibility and thus the anomaly amplitude of the ferrous artefacts. Depending on the local environment the artefacts may be: [2]

- totally converted to ferrous sulphide, leaving only a loose slush that may be weakly magnetic.
- completely degraded to a loose granular oxide, perhaps nonmagnetic(?).
- completely mineralized to a massive oxide, magnetite, but retain their original structure and surface detail.

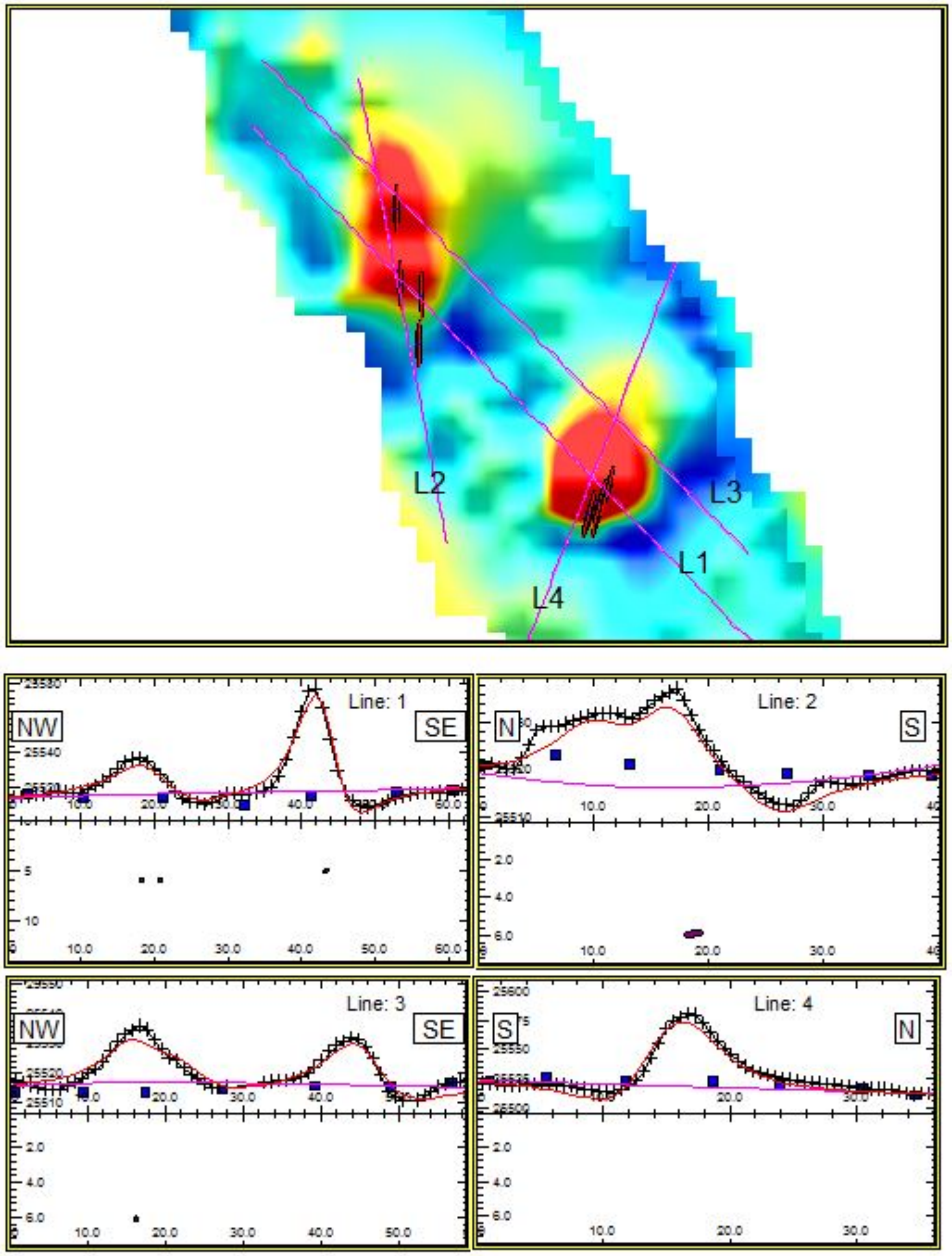
The mineralization of the artefact to form magnetite encrustations is prevalent in the case of buried encrustations. The assumption that this is what happened to the Haarlem's cannon and anchors seems reasonable and allows the choice of a maximum magnetic susceptibility equal to that of pure magnetite (5.7 SI units). The volume of the artefacts thus calculated will then be an estimated minimum because the actual magnetic susceptibility is likely to be lower than 5.7 SI units resulting in a larger calculated volume for the encrustation.

The 5 good targets were prioritized by qualitative consideration of the above criteria resulting in a final target list: Targets A,B,C,D,E (Figure 5).

FIGURE 5 - LOCATIONS OF THE FIVE BEST TARGETS

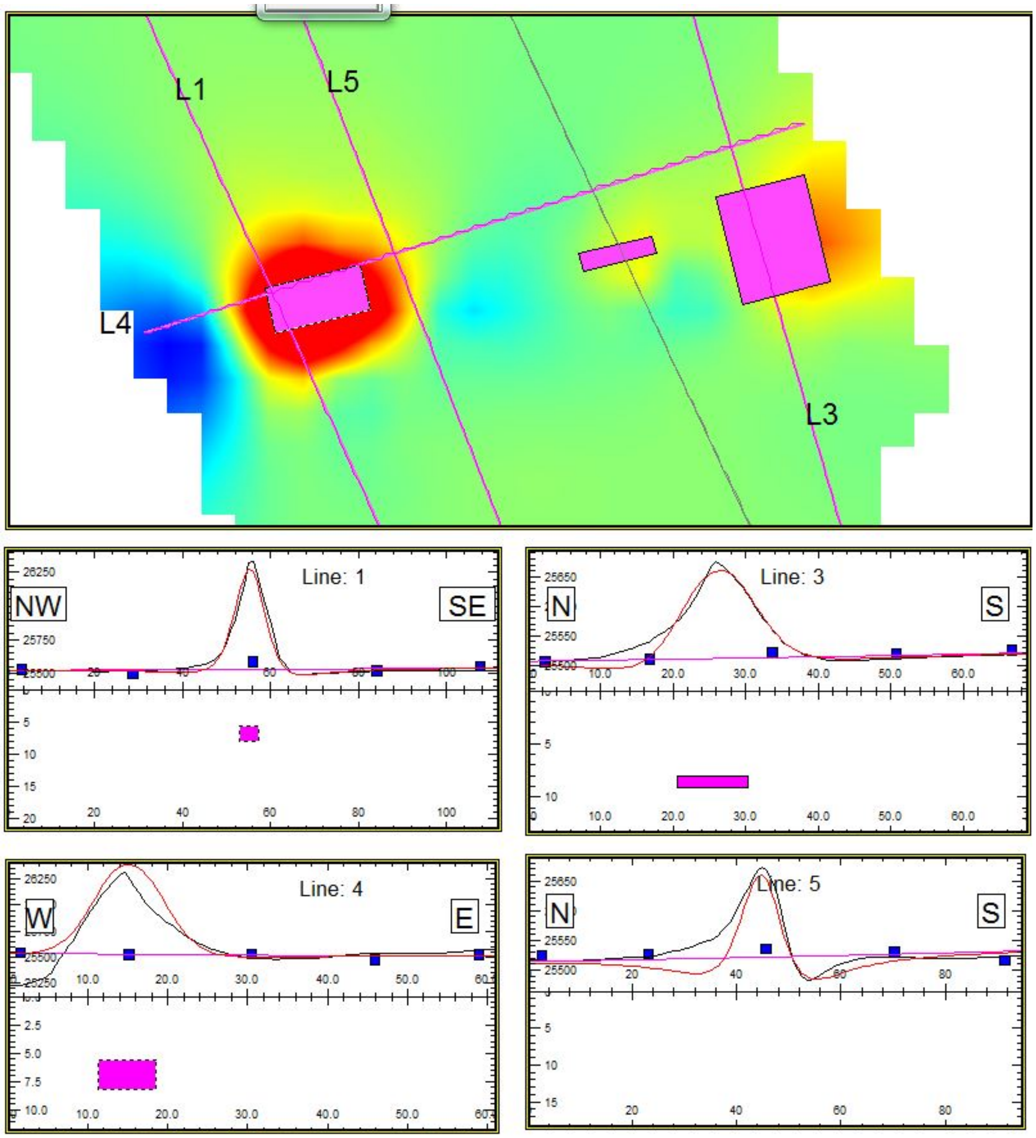
Target A receives the highest priority as it lies closest to where the historical maps place the wreck, which is just north or just south of the Dolphin Beach Hotel. The target consists of a cluster of two main anomalies that lie about 35 metres apart roughly parallel to the beach line. The model (Figure 6) that fits the observed magnetic field comprises of eight 2000 cm long, 30 cm diameter objects (approximating cannon) that lie 3m-4m below the surface. Fresh cast iron with this total volume would weigh in the order of 20 tons. The assumed magnetic susceptibility is 5.7 Si units (that of pure magnetite) and the effect of demagnetization was considered in the calculation. The estimated volume/mass is a minimum and it is therefore possible that originally the volume/mass might have been considerably larger. This is therefore considered a most feasible target for the Haarlem.

FIGURE 6 - TARGET A: 3D MODEL



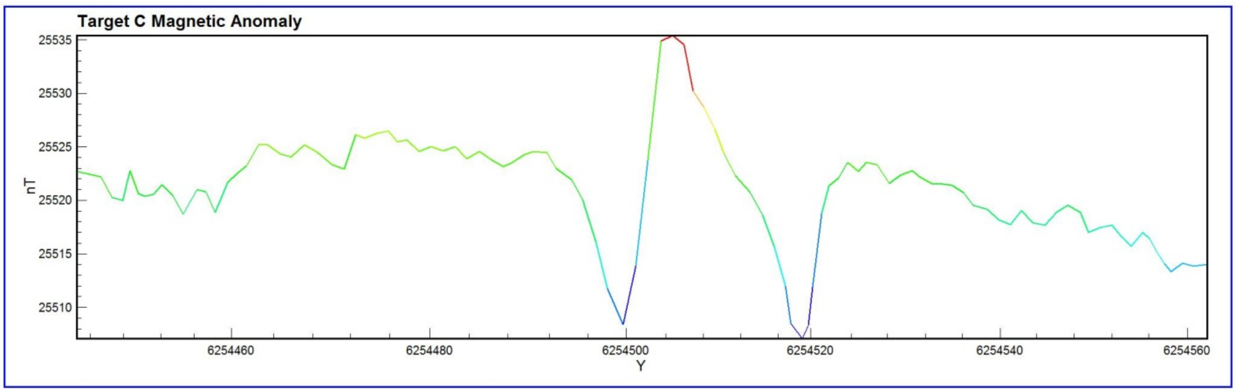
Target B lies to the north and consists of 3 anomalies. The anomaly closest to the ocean is large (~1000 nT) and the modelling (Figure 7) indicates large volumes of ferromagnetic objects, possibly as much as 100's of tons. The remanent vector is strong and appears to be in a significantly different direction than that of the present day field. This might suggest that the objects have not yet been corroded to form magnetite and in the process adopting the average direction of the field. The orientation of this cluster of anomalies is linear and perpendicular to the beach line suggesting it could be an old pipeline.

FIGURE 7- TARGET B MODEL



Target C lies immediately south of Target B and the anomaly occurs only on the line closest to the ocean just above the low tide mark. The amplitude of the anomaly is about 50 nT (Figure 8). With only one line crossing the object it is difficult to estimate magnetization and geometrical properties but the resultant magnetization appears to be different than the current field direction and the burial depth is estimated to be 3 metres. It is quite likely that this is wreckage from a ship.

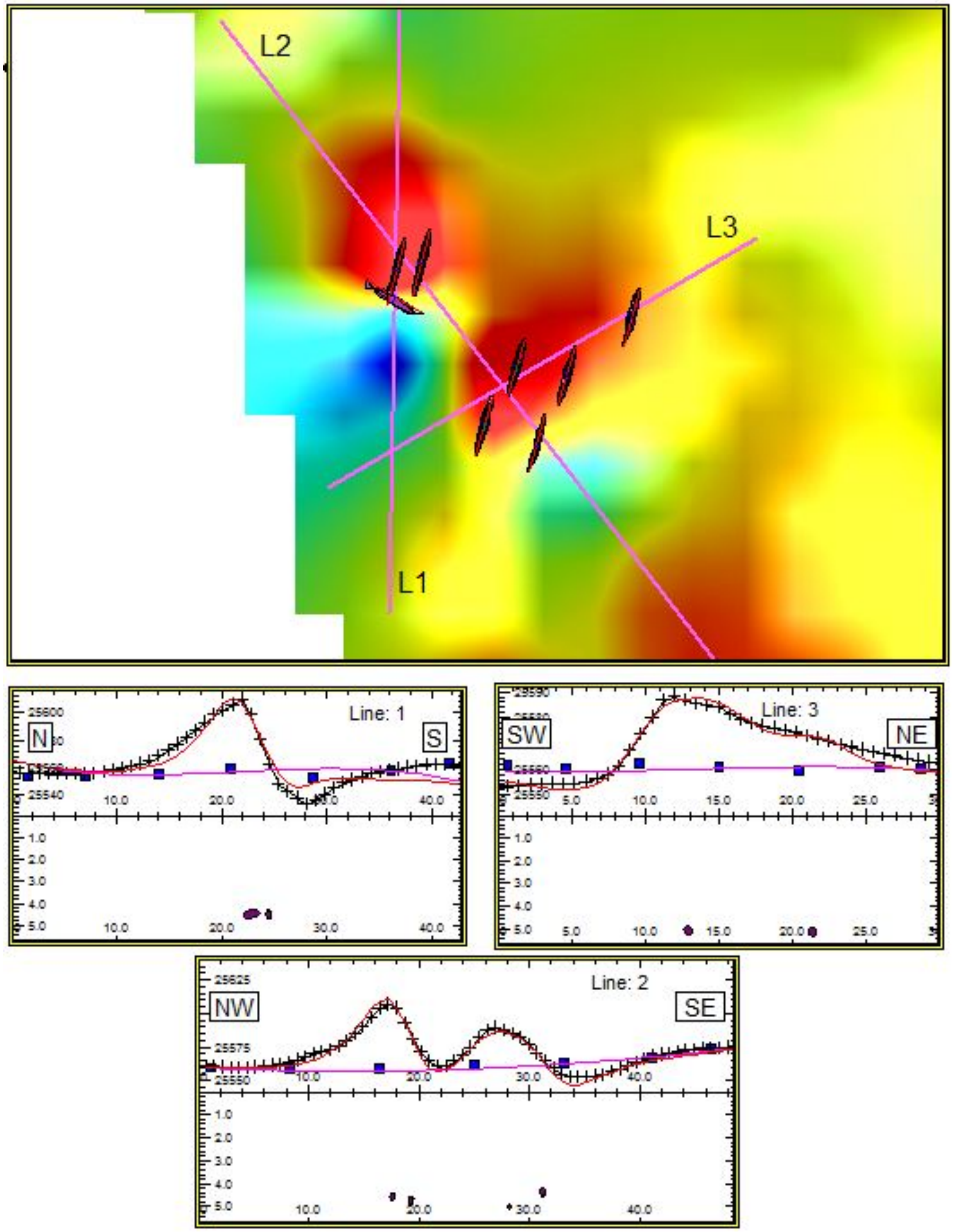
FIGURE 8 - MAGNETIC PROFILE OVER TARGET C



Target D is similar in character to Target A in terms of its orientation with respect to the beach line, magnetization character, total estimated volume of objects and estimated depth of burial (Figure 9). The position of this target is however is closer to the low tide mark and the footprint is only about 15m which is considerably smaller than the footprint of Target A. This target is almost certainly wreckage from a ship and should receive a high priority.

Target E was discovered during the first magnetic survey in 2015 and is thought to be caused by an old pipeline that was used to pump sand to Cape Town for the reclamation of land and building of the harbour. In fact several metal objects can be seen on surface. The magnetic data here was not modelled. The possibility that wreckage from the *Haarlem* lies beneath cannot be ignored.

FIGURE 9 - TARGET D MODEL



INFORMATION MONTAGES AND GEOGRAPHICAL LOCATIONS OF TARGETS

The details of each high priority target is summarized by information montages and Google Earth maps (Figures 10, 11, 12). The recommended excavation sites are indicated on the figures and listed in the following table.

Haarlem Project - Coordinates of Recommended Excavation Sites Projection: UTM zone 34 South Datum: WGS84 (for more details refer to figures 10, 11, 12 in survey report)			
X	**Y**	**Site name**	**Description**
266832	6253796	A1	Best location - Near Dolphin Beach Hotel
266816	6253812	A2	Best location - Near Dolphin Beach Hotel
266421	6254585	B1	Possibly a pipe-line - Bloubergstrand
266453	6254503	C1	Small anomaly - Boubergstrand
267577	6251555	D1	Good wreck target - Sunset Beach
267583	6251547	D2	Good wreck target - Sunset Beach

FIGURE 10 - TARGET A

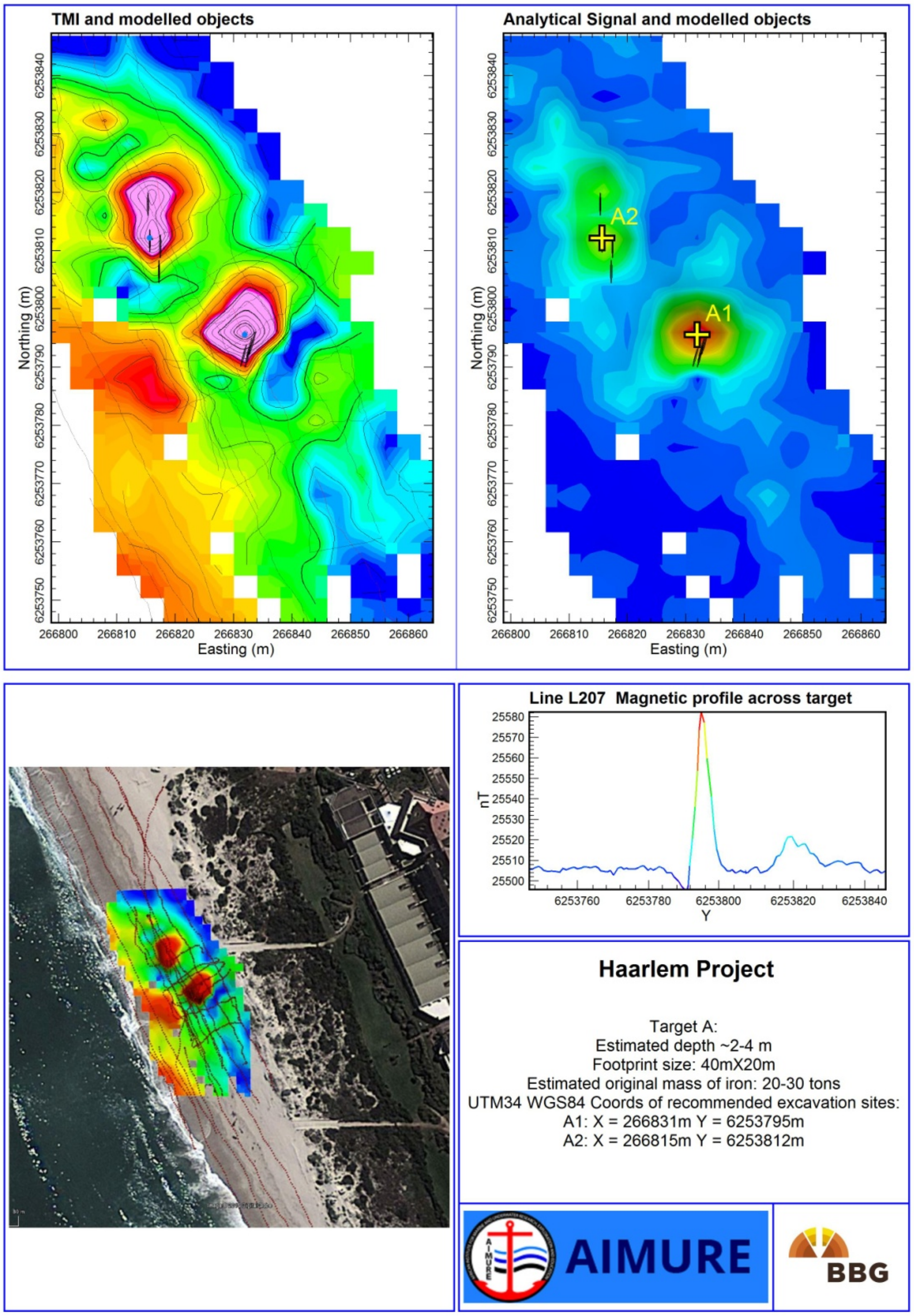


FIGURE 11 - TARGETS B AND C

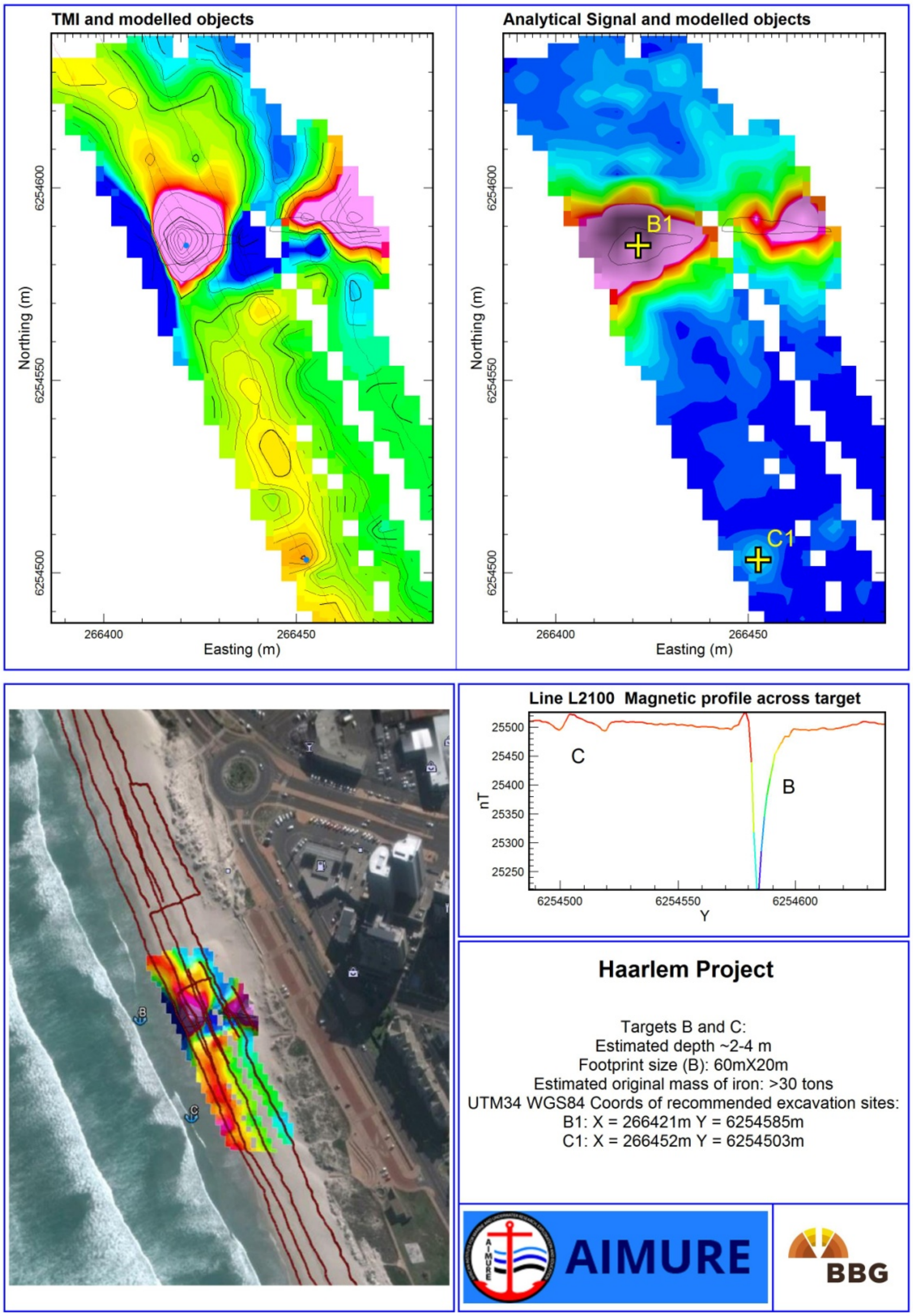
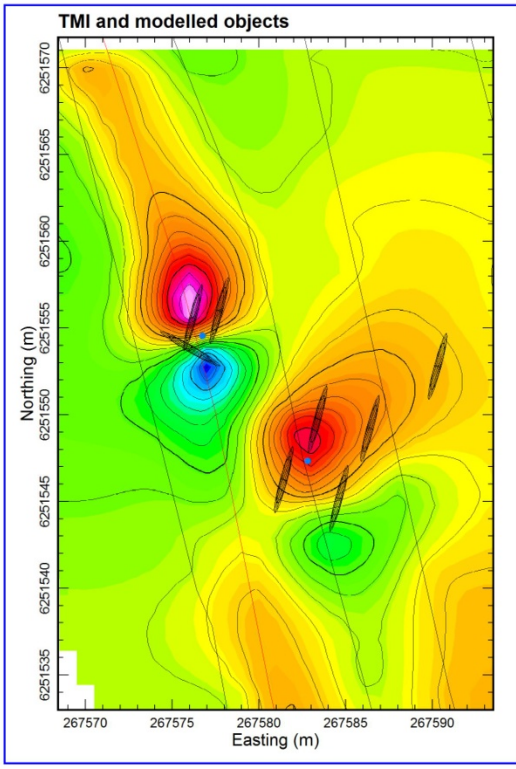
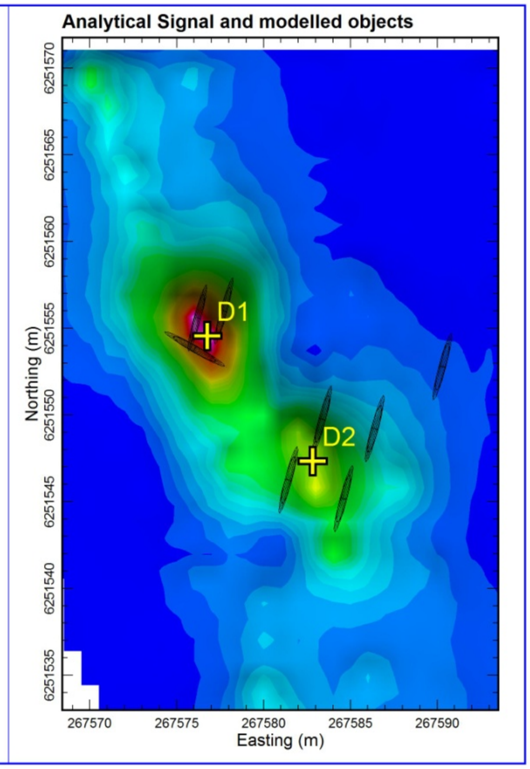
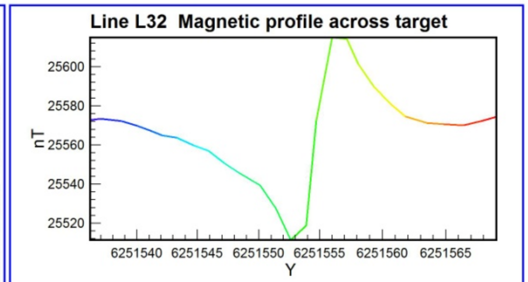


FIGURE 12 - TARGET D







Haarlem Project

Target D:
Estimated depth ~2-4 m
Footprint size: 20mX6m
Estimated original mass of iron: 10-20 tons
UTM34 WGS84 Coords of recommended excavation sites:
D1: X = 267576m Y = 6251554m
D2: X = 267582m Y = 6251547m

AIMURE

BBG

REFERENCES

1. Page 4, para.1. Thom, H.B. (ed.), *Journal of Jan van Riebeeck* I. *1651–1655*. A.A. Balkema, Cape Town/Amsterdam 1952: xxiv-xxvi.

2. Page 5, para.2. Mills, E.G. & Werz, B., *Milnerton Magnetic Survey Report 2015*. Cape Town, March 2016 (unpublished).