SAND RESOURCES AND UXO SURVEY – FUNAFUTI LAGOON, TUVALU

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Screen capture of a LCM (Landing Craft Mechanised) mapped in the lagoon in 12 m of water, which is thought to be previously unknown and of WWII vintage. This is one of 3 units found using a Geometrics GS881 magnetometer.

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Ocean and Islands Programme Staff (Geoscience Division of SPC) with Government of Tuvalu Fisheries Officials completed this survey on a contract to SPIIRE New Zealand

DISCLAIMER

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SUMMARY

This report documents the results of a jetprobe seafloor sampling exercise, and magnetometer survey for possible unexploded ordnance (UXO) and other metal contamination in borrow areas in Funafuti Lagoon. A total of 100 jetprobe holes were drilled to assess both resource thickness and sediment type. At each location underwater video footage was recorded to document the process as well as provide a visual assessment of the seafloor and its immediate surroundings with respect to the jetprobe locations. A magnetic survey was then conducted in each of the borrow areas, with detected anomalies inspected by diving and video recording. Live 0.5 calibre machine gun rounds were found at one location. Most anomalies turned out to be wrecks, anchors, mooring chains and 44-gallon drums. Five of the wrecks are of Second World War (WWII) vintage. Water visibility was very good, except for one out of the nine days of surveying in the lagoon; when an increase in turbidity that appeared to precede a day and a half of strong westerly winds where no work was possible in the lagoon.

Three diamond core drill holes were also completed within the area for the proposed new fisheries complex. While drilling was difficult, there was reasonable core recovery. The deepest hole drilled was 3.2 m. Drill core hole logs were produced.

Collected datasets included 99 lagoon seafloor jetprobe samples, 3 on-land diamond core drill holes, magnetometer profile data and underwater video footage. A large number of wrecks were also identified to be present on the seafloor. These were found on the fringe of borrow areas 1, 4 and 9-10. Positioning was by RTK GPS using a Trimble SPS852, with license to access the Fugro MarineSTAR Service. HYPACK and AutoCAD software were used for survey and data processing, respectively.

Data were collected by the Ocean and Islands Programme of the Geoscience Division of the Secretariat of the Pacific Community (SPC), formerly SOPAC, during the period 10th to the 26th of July 2014 for SPIIRE New Zealand, a Calibre Group company.

The work completed was as follows:

- Acquisition of lagoon sediment samples and underwater video footage at 100 locations in five borrow resource areas.
- Acquisition of magnetic field data to delineate possible ferrous targets within the borrow areas and geophysical interpretation of data and visual underwater footage assessment of targets delineated.
- Diamond core holes for assessment of foundation condition at the site of the proposed fisheries complex.
- Provision of a survey report.

Deliverables to include both digital data and maps; and hard copy report and maps showing sediment sampling locations and magnetic anomalies in borrow areas. Additional products include the drilling of 3 boreholes for geotechnical considerations at the location of the proposed new fisheries building. Mapping coordinates in metres based on the UTM North Zone 60 (174E-180). Datum reference is WGS 84.

Conclusions and recommendations drawn from this work follow:

Conclusions

Prior to undertaking this survey, little was known about wrecks and the explosive remnants of war (ERW) potential in Funafuti Lagoon. Nevertheless, some documentation from the book *Strategic Atolls* provided an excellent profile of possible ERW contamination that would be expected from WWII activities.

Undocumented underwater video footage collected by a local fisheries officer does indicate indiscriminate dumping of anti-aircraft ammunition in the lagoon. Footage was captured near a reef patch of unknown location. None were seen in the areas of this survey.

Detection of buried UXO requires application of geophysical methods that exploit contrasts in magnetic susceptibility and/or electrical conductivity of the UXO relative to surrounding soil and rock. With a lower geologic background magnetic noise the contrast between a possible target and host medium results in clearer target anomaly definition.

For this area, based on the Total Magnetic Field data collected, results delineated good contrasts for target anomalies; concluding that the detection capability is relatively independent of geologic background magnetic noise. Results even indicate increased sensitivity to small anomalies in the order of 0.5 mgal, at a range of approximately 5 m.

Mapping of five potential dredge areas was completed with a number of anomalies seen in all areas. Not all were clearly identifiable, as many appear to be buried. For example, in Borrow Area 1, a number of flagged targets not visible on the seafloor are present .These targets cluster around the small boat channel and harbour that was constructed out of the fringing reef in the north of the borrow area, as defined in this report. Due to the high sedimentation rates associated with the channel and resulting beach loss, these targets are buried. As the location lies within the approach lane to the small harbour entrance, it is thought that many of the anomalies are likely to be discarded iron debris from the LCM Base that was operational here during WWII. Borrow area 9-10 appears to have the highest density of contamination with respect to area size.

Three wrecks were identified on the western boundary of Borrow Area 1. These lie in water depths from 12 m to 14 m; and are actually outside the resource area. Flagged as DMA-1 at this location, there appears to be more than one destroyed vessel. Of the three wrecks, DMA-1 appears to have been bombed or blown up with a considerable field of iron debris present on the seafloor. It would seem that sedimentation rates in this area are low, due to the fact that many of the items remain exposed on the seafloor even after a lapse of seventy years.

Borrow Area 2 in the northeast of the lagoon is much cleaner in terms of magnetic anomalies. Twenty-five anomalies in total were recognised in all the profiles. Of those investigated, four source items were identified as steel wire, an oven, a 44-gallon drum and sheet iron. Borrow Area 2 occupies a narrow lagoon shelf with good quality foraminifera-rich sand with an average thickness of 2.7 m in the 5 to 8 m depth range. Numerous, but scattered, small coral patches can be found in this area. A total of thirteen holes were drilled in this resource zone. Sieve analysis showed the bulk of the sand to be medium to coarse sand.

In Borrow Area 4, the resource area occupies a narrow shelf with an average width of 15 m bordered on the lagoon side by a steep slope, lagoon wards. Depth along the shelf ranges from 7 m to 9 m. Closer to the toe of the fringing reef, coral patches are more frequent. Fourteen holes were drilled in this area to an average depth of 3.9 m. Sieve analysis showed the sand to be medium to coarse in grain size. Twenty anomalies were detected in the profile data – some showing large peak-to-peak values. Visual diver inspection showed these to be mooring related items from WWII. As potential hazards to dredging and mooring operations, these have all been identified and mapped for reference in this resource area. The anomalies identified include a large mooring chain, mooring buoy, pipeline and a large anchor approximately half a tonne in size.

Borrow areas 6-7-8 lie approximately 440 m south of the new wharf. The shelf here is somewhat wider, varying between 60 m and 80 m. Depth over the shelf is between 4 m and 10 m. A small number of coral patches are present on the shelf in what is otherwise a sandy substrate. Significant quantities of sand are available on this shelf. Of the fourteen holes drilled, the average depth was 4.8 m. Sieve analysis showed the sand to have a greater range in size, from fine sand through to fine gravel in some jetprobe holes. Only a small number of anomalies were detected in this resource area and most appear to cluster around the entrance to the small channel dug into the fringing reef for shoreline access. Most, if not all, targets are buried; as no surface expressions were found.

Borrow Area 9-10 lies west of the Catalina ramp, being part of an extensive shallow shelf extending some 500 m from the shoreline. Average depth over the resource area is about 7.5 m, which otherwise is a sandy substrate with occasional coral heads. Only six holes were drilled in this area to an average depth of 1.85 m. The interpretation from the drilling is that only a veneer of sand covers the reef substrate some one to two meters thick with a gravel layer immediately above the substrate. Sedimentation in this area is low as evidenced by the fact that some source anomalies found diving remain exposed after seventy years. In general drilling here was the most difficult with limited penetration. A large sunken barge dominates with a large magnetic anomaly mapped. Some live rounds found near one reef patch not covered by sediment are considered an indicator of low sedimentation in this area. Although large in area, the thin veneer of sand averaging about 1.85 m in thickness suggests that sand resources would be limited.

Overall the good visibility in Funafuti Lagoon is certainly beneficial for UXO detection.

All data and maps are presented in a GIS compatible formats.

Recommendations

Of all the potential borrow areas mapped, Borrow Area 9-10 appears to be the most contaminated with numerous but low-intensity anomalies detected. Anomaly sizes suggest small targets, mostly buried by a surficial layer of sediment. As this area was the designated seaplane base during the war, many of these anomalies may be items dropped or dumped during routine servicing; and loading/unloading operations. The limited documentation found on wartime activities in this area indicate some seaplanes were bombed and destroyed; but it is not clear if this was at the mooring base or on land. As moored seaplanes would have been priority targets in a bombing raid, it is considered that this area has a higher risk factor for buried UXO.

Furthermore, based on the limited thickness of unconsolidated sands < 2 m in Borrow Area 9-10, this area should not be considered as a resource area.

Alternatively, should Borrow Area 9-10 be required as a source for borrow pits 9 and 10, then more detailed mapping for sediment thickness and anomaly delineation should precede any dredging.

INTRODUCTION AND OBJECTIVES

Introduction

The nation of Tuvalu is located between latitudes 12 and 6 degrees south and longitudes 175 degrees east to 179 degrees west. Tuvalu consists of 10 atolls and two islands. Funafuti Atoll lies in the centre of the group.

Fongafale islet in the Funafuti Atoll is the main port of entry by sea and air; the location of central government; the centre of commerce, trade and industry; and home to a significant portion of the population. The islet is 5 km long and up to 500 m wide with a total land area of only 1.45 km^2.

Low-lying areas and borrow pits account for 35% of the area of Fongafale islet. In their present condition, these areas cannot be utilised for developmental purposes such as housing, agriculture, industry or recreation (Figure 1). The borrow pits had been the source of material for constructing the airstrip used during WWII. In-filling of these pits would provide a significant increase in land area for building, agricultural and/or recreational purposes.

A New Zealand-driven project, of which this survey is part, may lead to the rehabilitation of these pits to increase land availability.

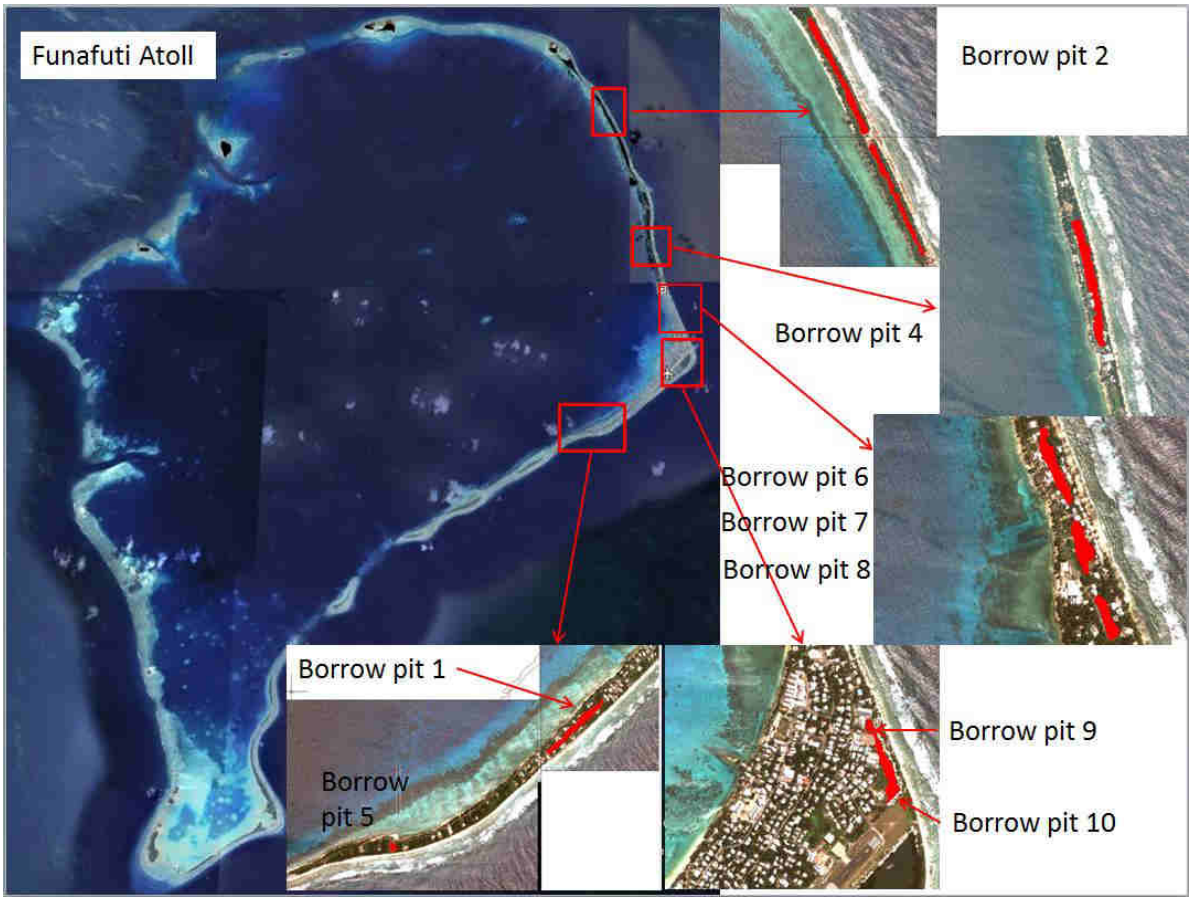

Figure 1 – Location sketch showing the locations of Funafuti borrow pits. Image of Funafuti from Google Earth.

Previous studies have identified foraminiferal sands to be sourced from Funafuti Lagoon (Kaly et al. 2014) as the most suitable material to fill the borrow pits because it matches the natural material making up the island form. Given the significant role of the Funafuti Lagoon in the WWII campaigns of the Pacific, the presence of explosive remnants of war (ERW) or unexploded ordnance (UXO) within it, is assumed; and are considered to be potential hazards to any dredging of sediments to be sourced from the lagoon. The requirement for a UXO survey and possible follow-up 'ordnance clearance programme' is based on this historical fact.

As a major WWII staging post, Funafuti was a strategic area close to and supporting the invasion of Betio Islet (in neighbouring Kiribati), which formed a fundamental part of the Battle of Tarawa; when American Armed Forces undertook a major beach assault in 1942 to wrest control of Betio from the Japanese. As a consequence, Funafuti was reportedly bombed 9 times by the Japanese (McQuarrie 1994).

A difficulty this author has found with post-war UXO clearance work is to source readily-accessible documentation of any work already undertaken by military establishments to clear ERW after WWII; and particularly information on the most likely pieces of ordnance that might be contaminating the area under study. Considerable effort was expended to find information that is invariably buried in military archives. Fortunately for this work in Funafuti Atoll, the research and narrative by Peter McQuarrie (1994) has provided a good starting point.

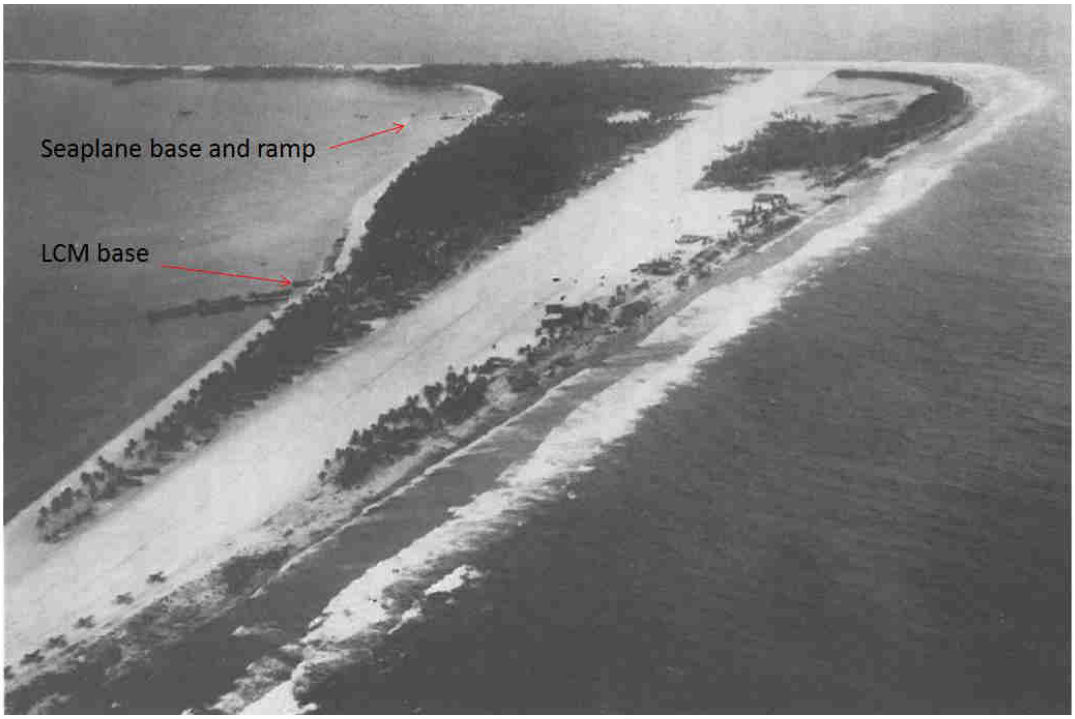

Figure 2 – An aerial view of the airstrip on Funafuti taken on the 22nd of October 1943. This image was sourced from* Strategic Atolls *by Peter McQuarrie (1994). The original is a Marine Corps Photo, National Archives, Washington, 80-G-200358.

In Figure 2, a number of interpretations can be made. In the foreground left of center is the landing craft basin where an access channel was carved out of the fringing reef to provide all tide access to the shoreline. In the middle top was the seaplane mooring area with the seaplane ramp clearly visible at the toe of the bend on the lagoon-side shoreline.

Objectives

The survey works at the location included:

1) jetprobing of the lagoon seafloor for sediment thickness and composition;

2) recording underwater video at each of the locations;

3) conducting magnetometer and metal detection surveys within the resources areas;

4) assessing identified magnetic anomalies and carrying out, where possible, visual inspection with underwater video recording; and

5) carrying out diamond core hole drilling for geotechnical data at the site of a proposed fisheries complex.

This report provides an account of the activities and the results of a field survey undertaken during the period from 10th to 26th of July 2014.

EQUIPMENT AND METHODS

Navigation Control

Navigation control was accomplished with a SPS852 Trimble GPS navigation system using the MarineSTAR Fugro Service for corrected RTK data in real time. Map coordinates are based on UTM North Zone 60 (174E-180). Datum reference is WGS 84.

Image Backdrops

Initially the project started out using 2008 QuickBird multi-spectral satellite image data as a backdrop to the mapping. After the survey, higher resolution imagery covering the proposed borrow areas that provided the best detail for the bathymetry were found and downloaded from Google Earth Pro. This data was then georeferenced against the 2008 QuickBird imagery. The respective imagery data used are shown in Figure 3.

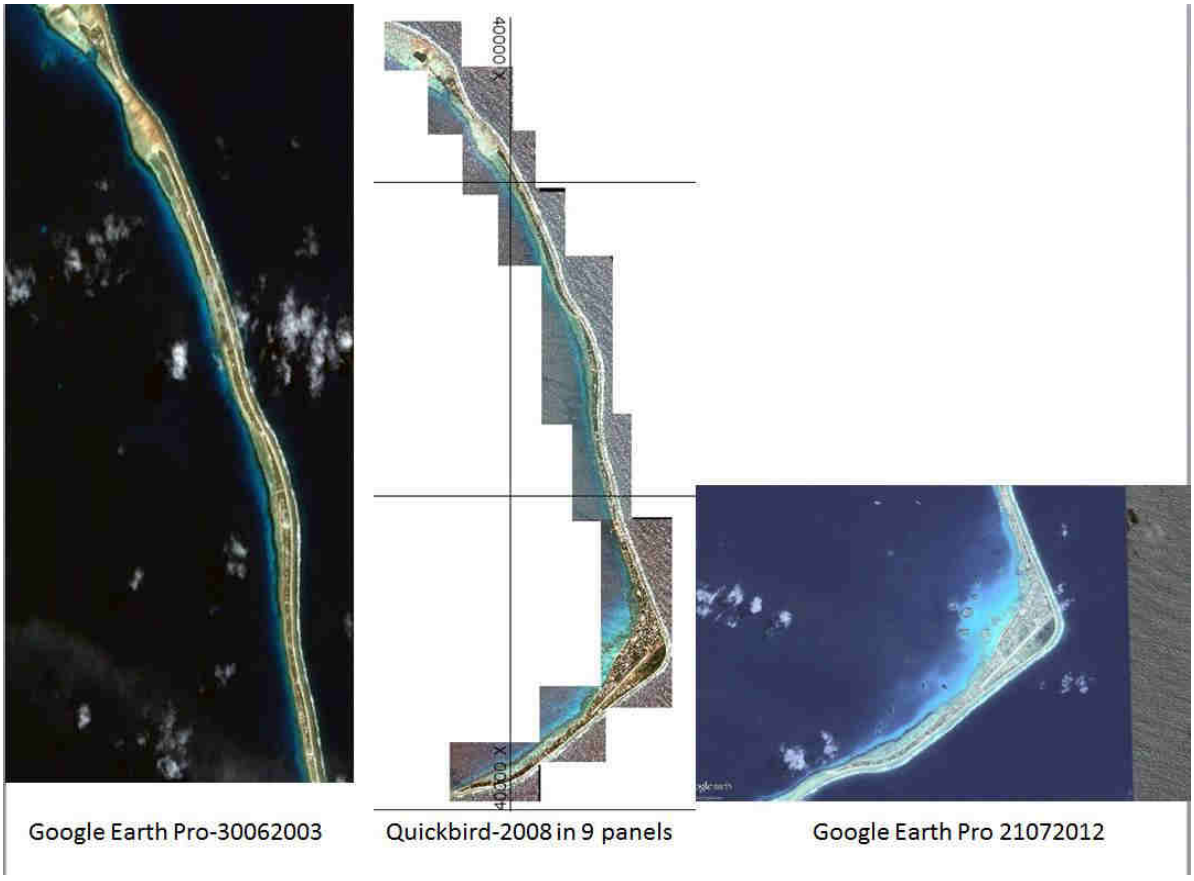

Figure 3 – Imagery data used as backdrops to the mapping in this report.

Of the image backdrop data, the 21072012 image data provides, by far, the greatest clarity of the lagoon seafloor for Borrow Areas 1, 6-7-8, 9-10 and the southern end of Borrow Area 4.

Jetprobing

Jetprobing was seen as a critical component of the survey for quantifying the thickness or vertical extent of sediments in the proposed borrow areas; along with the collection of samples for grain size and composition analyses.

The jetprobe is made up of three basic components: a water pump (in this case a 3-inch Yamaha diesel pump); a delivery hose connected to a 3-m length of 2" galvanised pipe; with a half-inch outlet producing a jet flow of water. The length of delivery hose is dependent on water depth expected to be worked in. In this case we used 25 m of self-supporting 2-inch plastic flexible hose.

The jetprobe has many similarities to on-land rotary drilling, but without rotation. The drilling fluid or mud that is pumped down through the drill pipe emerges through the drill bit and then flows upwards between the pipe and the wall of the hole carrying sediment with it to deposit at the surface around the top of the hole. Drilling a hole into the seafloor with the jetprobe, sample return was dependent on the nature of the substrate being drilled. In loose to semi-consolidated sands, there is reasonable sample return that is deposited with the return flow of water at the top of the hole. In semi-consolidated gravels with high porosity and permeability, as would be expected in a coral detritus and rubble deposit, the sample return is small. The operation of the jetprobe requires two support divers (Plate 1).

Plate 1 – Jetprobing seafloor at location JP-7.

Sediment Assessment of Borrow Areas

Assessment of sediments in the proposed borrow areas is based on jetprobing to determine sediment thickness, ripability and the physical characteristics of the sediments through dry sieve analysis. Samples were oven dried over a 24-hour period and dry sieved using a stack of ten sieves. The sieve range is given Table 1.

Table 1 – Sieve numbers and sizes.

Sieve No.	Sieve size (mm)
5/8”	16
5/16”	8
#5	4
#10	2
#14	1.4
#18	1
#25	0.71
#35	0.5
#45	0.35
#60	0.25
#80	0.18
#120	0.125
#170	0.09
#230	0.063

The grading analysis was based on the British Soil Classification System, as preferred by the client. For the British Soil Classification System, soils are classified into basic soil type groups according to size, with the groups further divided into coarse, medium and fine sub-groups.

Table 2 lists the basic Soil Type groups divided according to size, with these groups further subdivided into fine, medium and coarse sub groups.

Table 2 – British Standard Classification for soil type.

Very coarse soils	BOULDERS		> 200 mm
	COBBLES		60 - 200 mm
Coarse soils	**G** GRAVEL	coarse	20 - 60 mm
		medium	6 - 20 mm
		fine	2 - 6 mm
	S SAND	coarse	0.6 - 2.0 mm
		medium	0.2 - 0.6 mm
		fine	0.06 - 0.2 mm
Fine soils	**M** SILT	coarse	0.02 - 0.06 mm
		medium	0.006 - 0.02 mm
		fine	0.002 - 0.006 mm
	C CLAY		< 0.002 mm

Sieve results were entered into a database and plotted using WinSieve software. Here the data was plotted against the British Soil Classification System 5939-1990.

From the grading data a number of grading characteristic parameters can be determined. These include the following:

d_{10} = the maximum size of the smallest 10% of the sample

d_{30} = the maximum size of the smallest 30% of the sample

d_{60} = the maximum size of the smallest 60% of the sample

From these the grading characteristics are calculated:

Effective size d_{10}

Uniformity coefficient $C_u = d_{60} / d_{10}$

Coefficient of gradation $C_k = d_{30}^2 / d_{60}\, d_{10}$

Both C_u and C_k will be 1 for a single-sized soil

$C_u > 5$ indicates a well-graded soil

$C_u < 3$ indicates a uniform soil

C_k between 0.5 and 2.0 indicates a well-graded soil

$C_k < 0.1$ indicates a possible gap-graded soil or Cc is the term used as in Winsieve data

These results are tabulated and profiled for the jetprobe holes in each of the proposed borrow areas and are reproduced in Appendix 1.

Geophysical Methods and Considerations for UXO Surveys

To detect UXO or ERW, it is important to be familiar with a multitude of properties and/or variables, which complicate detection. These are described below.

UXO characteristics

Classification and type

UXO main characteristics that are of interest in this study include: type of hardware, shape, length, diameter and material type. Most types of ordnance have a ferrous metallic housing or a composite body comprised in part of a ferrous metal, and they are generally spheroidal in shape. They may range in size from munitions (less than 2 cm long), to a 2,000-lb (907-kg) bomb a few meters in length. A compiled source for ordnance munitions is reportedly provided on the ORDATA II Version 1 CD-ROM distributed by the Naval EOD Technology Division (Simms et al. 2004).

No single report compiles the type, volume or variety of UXO ordnance expected to be found in Funafuti Lagoon. There do exist a number of sources that provide some information regarding volume and variety of ordnance that was introduced during the WWII conflict and invasion. A publication titled *Strategic Atolls* by Peter Macquarie (1994) provides a good narrative of the activities in Funafuti during the war. The publication even has a separate chapter on bombings; and it is stated here that Funafuti was bombed nine times by the Japanese. The bombs are reported to be 63 kg and 100 kg types. Some of the 100-kg bombs were known as 'daisy cutters', which were a type of anti-personnel bomb that inflicted damage over a large area. Other types of ordnance that could be expected may be of American origin, but information on what was used is very limited. The American Forces did place Mark XIII and wire-contact type Mark VI mines in some lagoon passages, but these are located on the western and northwest margin of the atolls (McQuarrie 1994).

A study on the state of WWII UXO in four Pacific countries, Francis et al. (2011), did not cover Tuvalu. This suggested to us that data on UXO in Tuvalu is not extensive.

Depth of probable penetration

The depth to which an ordnance item can penetrate the earth and its recovery depth are dependent on ordnance characteristics, firing parameters, and environmental conditions. A projectile when it impacts the ground surface typically follows a J-Shaped path. Figure 4 is a compilation of projectile paths for different paths taken from (Simms et al., 2004).

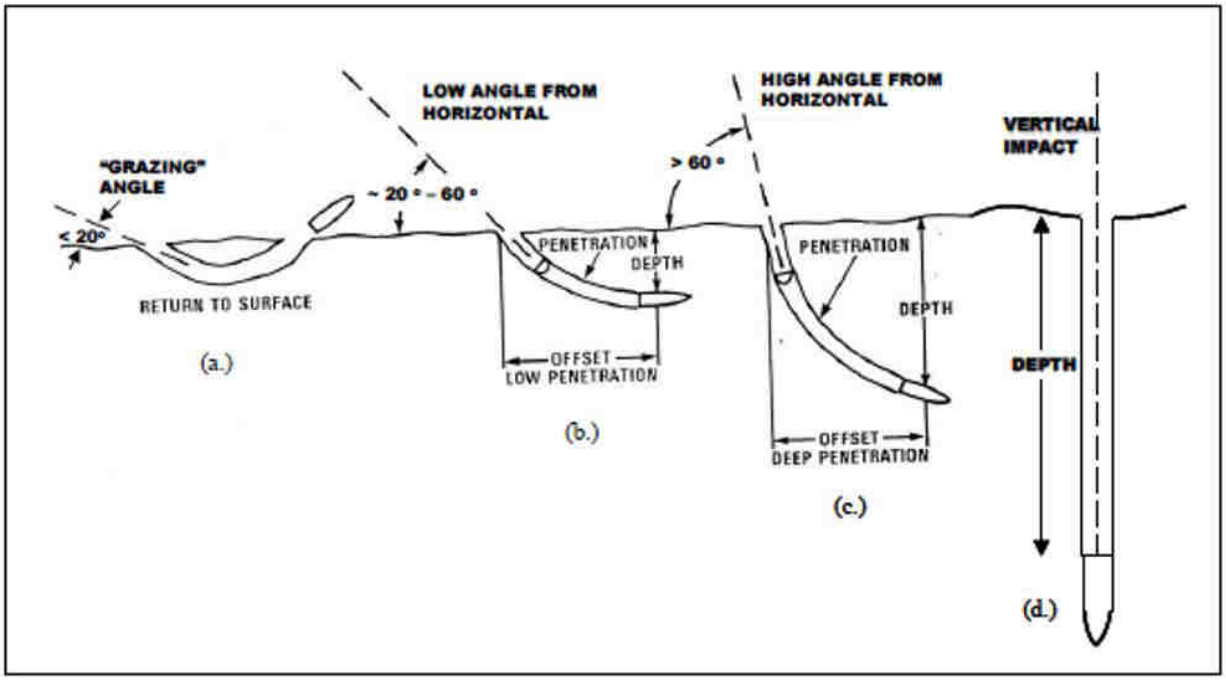

Figure 4 – Projectile paths for different impact angles (after Simms et al., August 2004).

The same publication reports that the recovery depths of over 18,000 UXO items, which include mortars, bombs, rockets/missiles, grenades, rifle grenades were between 0 and 1.25 m (Figure 5).

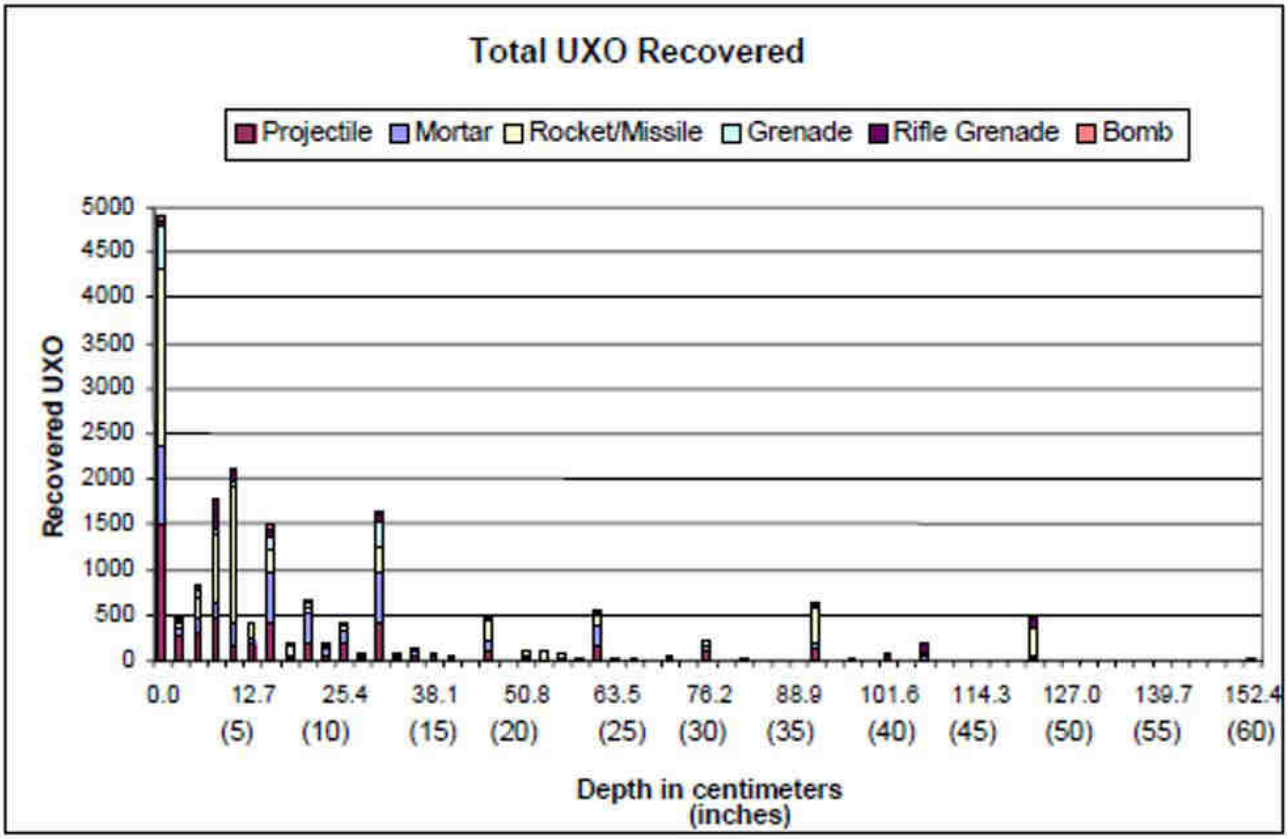

Figure 5 – Recovery depth histogram for over 18,000 UXO items. (NDCEE2003) taken from Simms et al 2004.

Geophysical Sensors for detecting UXOs

There are currently two types of geophysical sensors commonly used at most munitions response sites: magnetometers and electromagnetic induction (EMI) devices. These sensors are well characterised and broadly accepted by the industry. The most frequently used methods for UXO location surveys are total field magnetometers (TMF) and ‘‘simple’’ time domain electromagnetic induction (TDEM) instruments. ‘‘Simple’’ TDEM systems loosely refer to systems that measure one or two time windows (gates) from the induced transient decay signal. Application of these systems by experienced geophysical practitioners during demonstrations at controlled UXO test sites achieved probabilities of detection in excess of 90% (e.g. Pederson and Stalcup, 1997). Generally, for surveys at large sites, only one of these systems would be deployed. Other geophysical methods proposed, demonstrated, and/or utilised for UXO surveys include ground penetrating radar (GPR), frequency domain electromagnetic induction (FDEM) systems, to name a couple.

Magnetometers

Magnetometry is the science of measurement and interpretation of magnetic fields. Magnetometers locate buried munitions by detecting irregularities in the earth's magnetic field caused by the ferromagnetic materials in munitions. Magnetometers are passive devices and respond to ferrous materials, such as iron and steel, the material most commonly used to make munitions. Magnetometers do not respond to metals that are not ferromagnetic, such as copper, tin and aluminium. There are two types of magnetometers, fluxgate and cesium vapour. Given the resource study area is in the lagoon seafloor environment; a marine Geometrics G881 tow-fish cesium vapour magnetometer was used. A disadvantage of this type of magnetometer is that it is insensitive to the magnetic field in certain directions, depending on the latitude of the location and magnetic field inclination. The inclination of the magnetic field at Funafuti posed no restriction to survey direction. This was enabled through use of the Cesium Sensor Active Zone Solution (CSAZ) – a stand-alone Windows™ software designed to inform Cesium magnetometer users about proper sensor orientation in all parts of the world and in all survey directions. CSAZ also provides information about the Earth's magnetic field parameters including field strength (total field), inclination (angle of the Earth's field relative to the surface of the Earth) and declination (angle between magnetic north and true or geographical north). Using the International Geo-Magnetic Reference Field (IGRF) model, CSAZ presents a quick and easy way to determine these values anywhere in the world. Output from the software is shown in Figure 6.

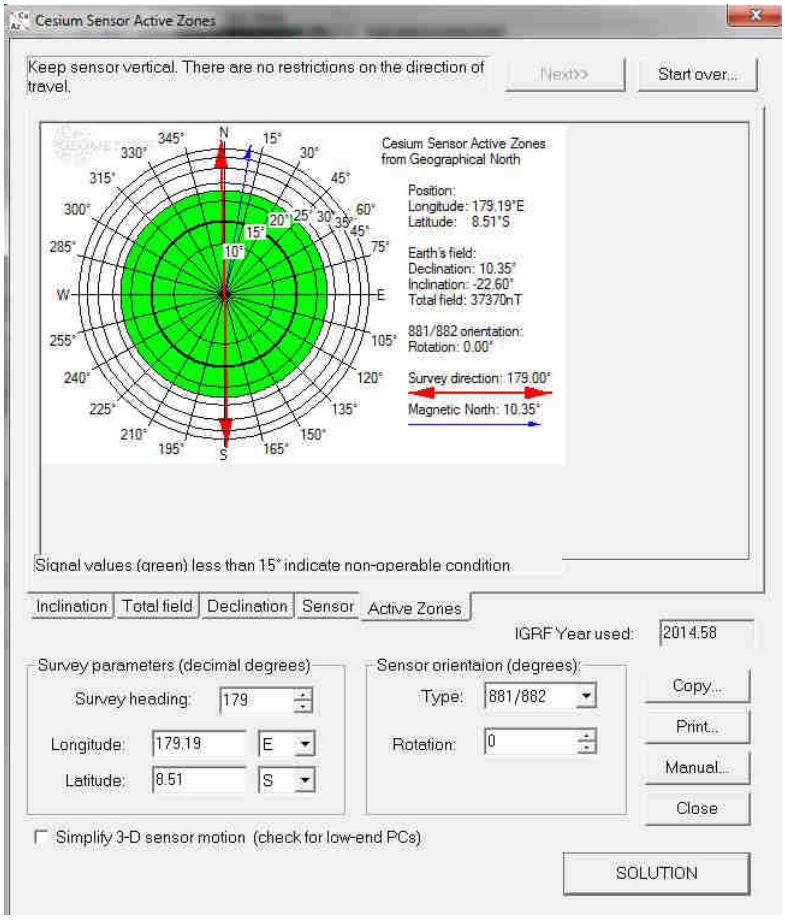

Figure 6 – Determination of survey parameters for the Cesium active zone in Funafuti.

A secondary, but important consideration was interpreting the position of the tow fish correctly to calculate the spatial location of a detected magnetic anomaly or dipole. The tow fish position was determined by the cable layback driver in HYPACK [tm]. The general setup for calculating this layback in HYPACK is shown in Figure 7.

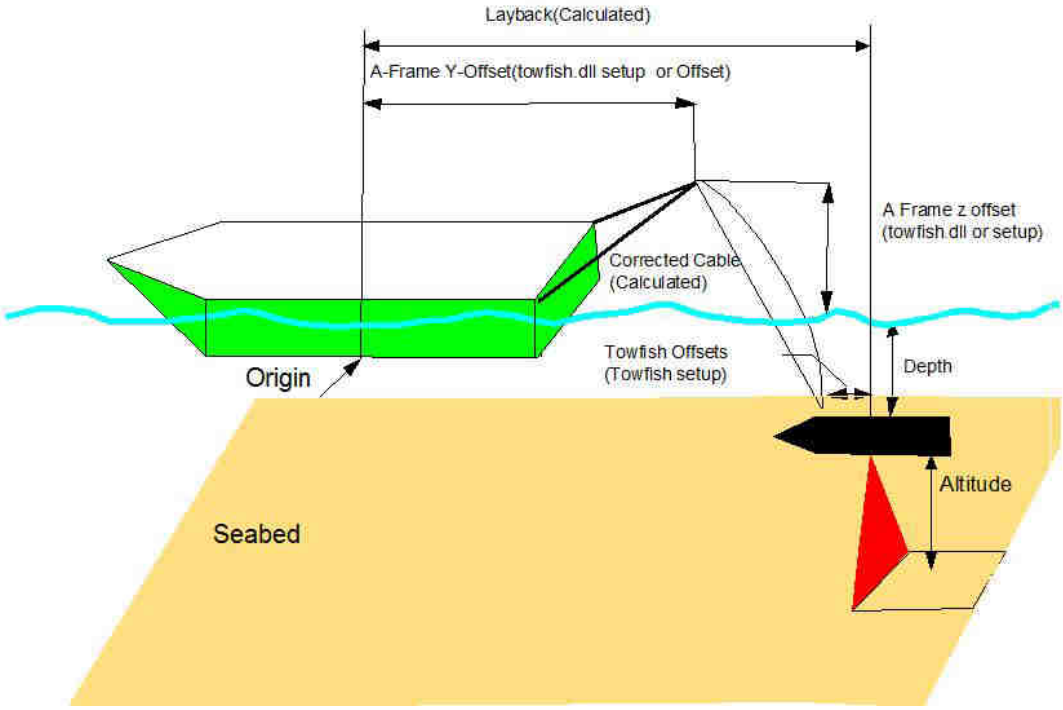

Figure 7 – Parameters used to determine cable layback and position of tow fish (source HYPACK).

Magnetometer data was interfaced to HYPACK using the "magnet.dll driver". Processing of the data raw was also done with HYPACK.

Electromagnetic Induction

Electronic magnetic induction is geophysical technology used to transmit an electromagnetic field beneath the earth's surface, which in turn induces a secondary magnetic field around objects (ferrous and non-ferrous metallic materials) that have conductive properties. When secondary magnetic fields of military munitions and other conductive items exceed background responses, they can be identified as potential anomalies requiring further investigation. The working principle of the detector is based on the physical properties of metals to radiate its own electromagnetic field when exposed to strong external electromagnetic pulse. A metal detector generates and emits a series of pulses, followed by a listening mode, i.e. "scans the space for emerging electromagnetic fields. The signals are amplified and displayed on the indicator unit of the detector and are converted into audio signals and transmitted over headphones."

The unit used in this study is a JW Fisher pulse 8x. For higher resolution metal detection, a Pulse 8x hand-held metal detector for both terrestrial and marine use was used. The unit is manufactured by J.W. Fisher and can be used both on land and in the marine environment. The JW Fisher is shown in Plate 2 being used by the diver, with the 10“ coil.

Plate 2 – Metal detection for targets found with the magnetometer. In this case a 44-gallon drum found in Borrow Area 2.

Different sized coils will have different detection size areas. Two other coil sizes were trialled in this study, a 16-inch coil and a 48-inch coil, which is mounted on a sledge. The detection envelope for the 48-inch coil extends 1.2 m to either side of the coil (3.6 m total width) and 2.4 m below the coil. The 16-inch coil detection envelope extends approximately 1 m either side of the coil and has a maximum detection depth of 2.1 m. The 10-inch coil has a detection envelope of approximately 0.9 m either side of the coil and a detection depth of 1.8 m below the coil. (Source http://www.jwfishers.com/p8xp6xoptions.htm)

Influence of target variables on sensor response

Burial depth and environment of a given target influence the metal detector’s sensor response. Generally, the further away from the target the detector is, the lesser the response. For example, for a magnetic dipole the fall-off rate is $1/r^3$, r being the distance from the target. Likewise, target size influence is generally that the bigger the target the larger the response. In the case of multiple targets in the same location, the larger target will have the bigger response if the sensor passes

directly over it. If in the case of multiple targets, the lateral separation is sufficient, the anomaly signature generated may reveal multiple targets.

Target condition

The condition of the UXO also is a factor that influences the ability of a sensor to detect it. Since most ordnance items are comprised of ferrous metal, they deteriorate and rust over time; hence the measured signal response of a corroded UXO is smaller than one in pristine condition. For Funafuti, any UXO that may be present in the resource area is expected to have been present in the lagoon for a period close to 72 years; given that the American Forces arrived there on 2nd October 1942 (McQuarrie 1994).

Target orientation

The orientation of a target within the subsurface can also influence the shape and magnitude of the received signature. The angle at which the earth's magnetic field or the field from an EMI transmitter impinges upon the target determines the degree of interaction between the field and the target.

Geological Influence

An important consideration in geophysical surveys for locating buried UXO is that the electrical conductivity, di-electric permittivity, and magnetic susceptibility (permeability) of the UXO may be much larger than the host medium so that the physical property contrasts of the anomalies are large. In this case of large contrasts, location (detection) capability is virtually independent of the physical properties of the host medium. That said, there are notable exceptions where geophysical surveys for UXO can indeed be complicated or severely inhibited by the physical properties of the host medium.

For example, in volcanic islands where the host bedrock may have high magnetite content and as a consequence is resistant to erosion; its high concentration in the soils of the host medium can produce a material of high magnetic susceptibility. Magnetic surveys for UXO detection in mediums of high susceptibility can be highly problematic, because it is virtually impossible to delineate the magnetic signature of the target from that of the surrounding medium (Butler 2003). High susceptibility in the host medium can also result in noisy data; hence very difficult to interpret due to the magnetic signal from the background being similar to the signal expected from the UXO. This is best illustrated in Figure 8 (after Butler 2003).

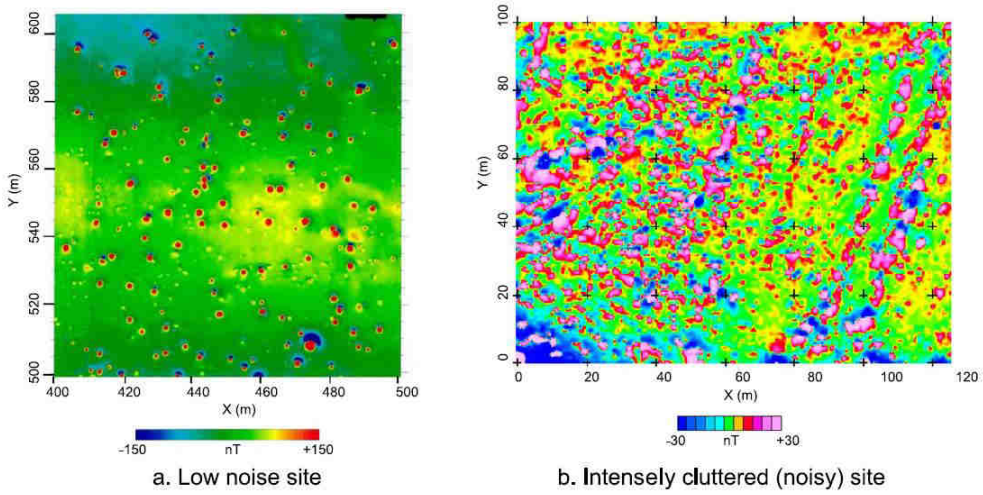

Figure 8 – Total magnetic field maps for sites with two distinct magnetic background conditions (after Butler 2003).

In the image on the left, the total field map readily shows anomalies against a low noise background. The image in Figure 8b (on the right) has a background that is magnetically noisy thus complicating anomaly interpretation.

Marine Magnetometer Survey

Nominal line spacing was 10 m with the tow fish cable set out at 10 m. Line spacing was based on expected target sizes in the order of 63- and 100-kg bombs. In areas where anomalies of low amplitude appeared to occur, lines at 5 m spacing were completed. Weather conditions for the survey were favourable with trade winds from the southeast, which placed the survey area in the lee of the islands for the survey duration except for one day when wind came from the northwest making lagoon conditions too rough to survey. The tow fish altitude was kept at a constant depth of about 1.5 – 2 m below the surface to avoid possible snagging of small coral patches that were observed to be present in the survey areas.

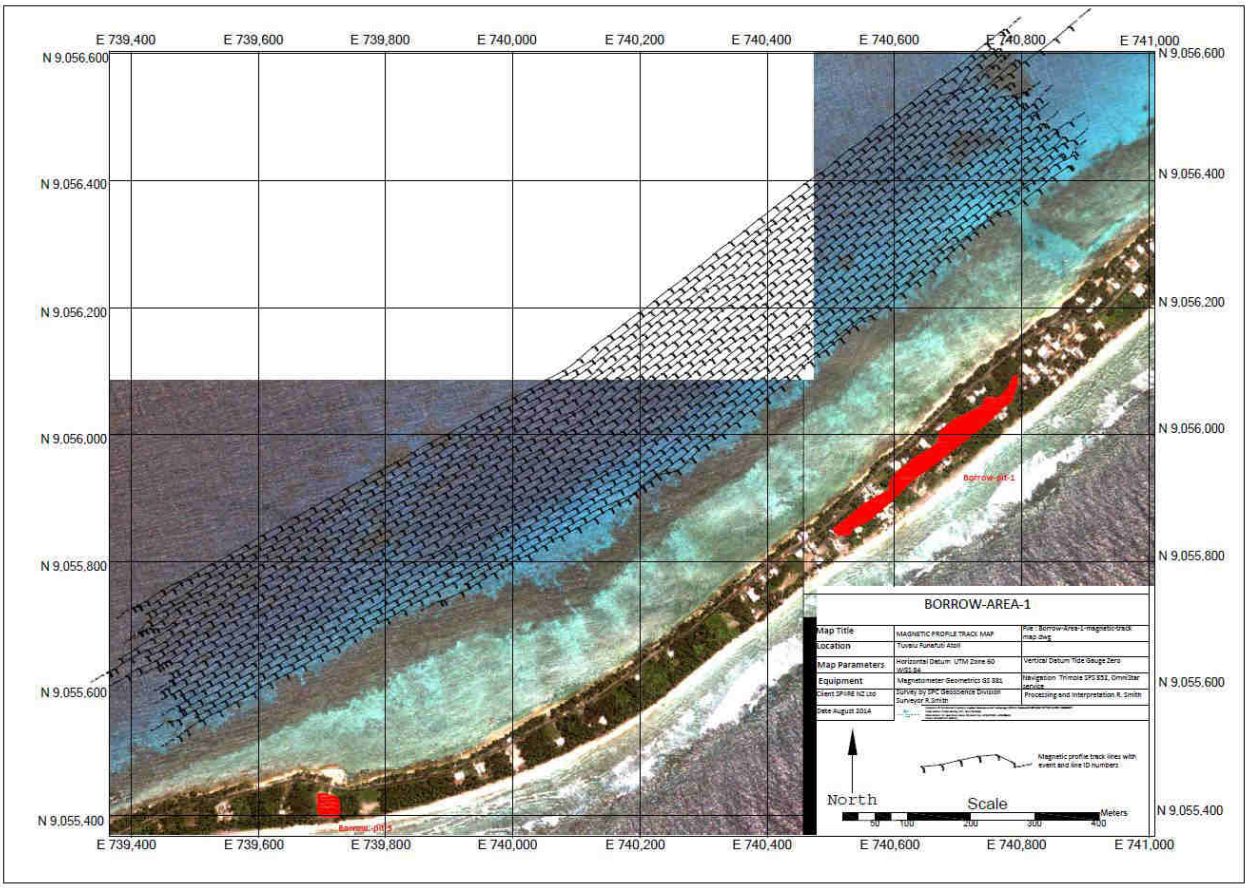

Figure 9 – Sketch map illustrating magnetic survey profile lines in Borrow Area 1.

An average vessel of between 4 to 5 knots, with an along-line sampling rate of 0.1 seconds, approximates a sample interval of between 20 and 25 cm. Sample track plots for magnetic line profiles in Borrow Area 1 are displayed in Figure 9.

As discussed in the section on the classification of UXO; and as documented in a number of writings the principal target sizes considered here are bombs in the 63 kg to 100 kg range. Artillery projectile rounds from anti-aircraft guns are also potential targets to consider but these are smaller targets. Other potential targets may be discarded iron debris, chains, anchors, old moorings; which would be expected remnants from activities during the American military occupation of Funafuti Atoll during WWII. Table 3 is a compilation of the magnetic properties of common objects, to put into context the sizes of the anomalies which could be detected under the current survey parameters and existing host material conditions.

Table 3 – Magnetic properties of common objects (Breiner, n.d.).

Magnetic Properties of Common Objects					
Object	**Near Distance**		**Far Distance**		
	m	**nT**	**m**	**nT**	
1000 lb – (453.5 kg) bomb			30	4-5	
500 lb (226.79 kg) bomb			16	0.5-5	
Grenade	2	1-2			
20 mm shell	1.8	0.5-2			
100 kg iron			15	2-3	
100 lbs – (45.35 kg) iron			9	2-3	
10 lbs – (4.54 kg) iron			5	3-4	
1 lb – (0.45 kg) iron			2.5	2-3	
Revolver 38 special/45 automatic)	1.5	10 to 20	3	2 to 10	
Automobile (one ton)	9	40	30	5 to 10	
File (25.4 cm)	1.5	50 to 100	3	0.5 to 1.0	
Screwdriver (12.5 cm)	1.5	5 to 10	4	0.5 to 2	
Rifle	1.5	10 to 50	3	0.5	
Ball Bearing (2 mm)	0.1	4	0.1	1 to 2	
Fence line	3	15	7	2	
Pipeline	7	50 to 200	15	12 to 50	
Cow magnet (L 1.3 cm; w 7.6 cm)	3	20	6	2	
Well casing & well head	15	200 to 500	150	2 to 5	
Note : Anomalies are only representative and will vary by a factor of 5 or even 10 depending on object orientation, remanent magnetism, sensor orientation, metallurgy, etc. (after Breiner 1973).					
For reference 1 gamma (CGS) is equal to 1nT (SI)					

Processing of magnetic data

The magnetic data recorded by HYPACK was normalised against the international magnetic reference field. The International Geomagnetic Reference Field (IGRF) is a mathematical model of the Earth's magnetic field created by the International Association of Geomagnetism and Aeronomy (IAGA). With known survey time and position, the IGRF algorithm can calculate the expected gamma due to the Earth's main magnetic field. The IGRF method of normalization used in HYPACK for processing the magnetic data will not inadvertently remove legitimate spikes due to operator error that the manual method might.

Once the magnetic data is normalised against the IGRF it was displayed as a triangulated grid with a nominal grid cell size of 5 m to generate a magnetic anomaly map. This is shown in Figure 15. The data includes both negative and positive anomalies.

An alternative interpretation approach was to use the profile data to estimate the location and depth of a particular object. Here, a suspected anomaly is logged with its position and peak-to-peak value plotted as a target file that can be used for relocating real-time with HYPACK or other

software packages that may be used for real-time navigation and dredging control. Plotting of the peak-to-peak values of anomalies with respect to the survey grid lines was one methodology employed in determining the likely location of the object generating the anomaly. This same target file is presented both in table form and map form, with an annotated profile track plotted. As a rule of thumb, for an anomaly in a profile, the half width for discrete objects will be approximately equal to the depth. In analysing the profile data, the occurrence of an anomaly as seen in adjacent profiles for the same source will appear proportionately broader as the object is either deeper or more distant. In this manner it is possible to zero in on the location of the anomaly source by close examination of adjacent profiles and measuring relevant peak-to-peak values.

DELINEATION OF BORROW AREAS

Based on the location of the borrow pits, surveys were concentrated in lagoon areas adjacent to the borrow pits. As a means of determining scale for survey and for the jetprobing density of holes, a polygon representing the size of the borrow pit was drawn on the lagoon seafloor area of the working map for reference. An example is illustrated in Figure 10.

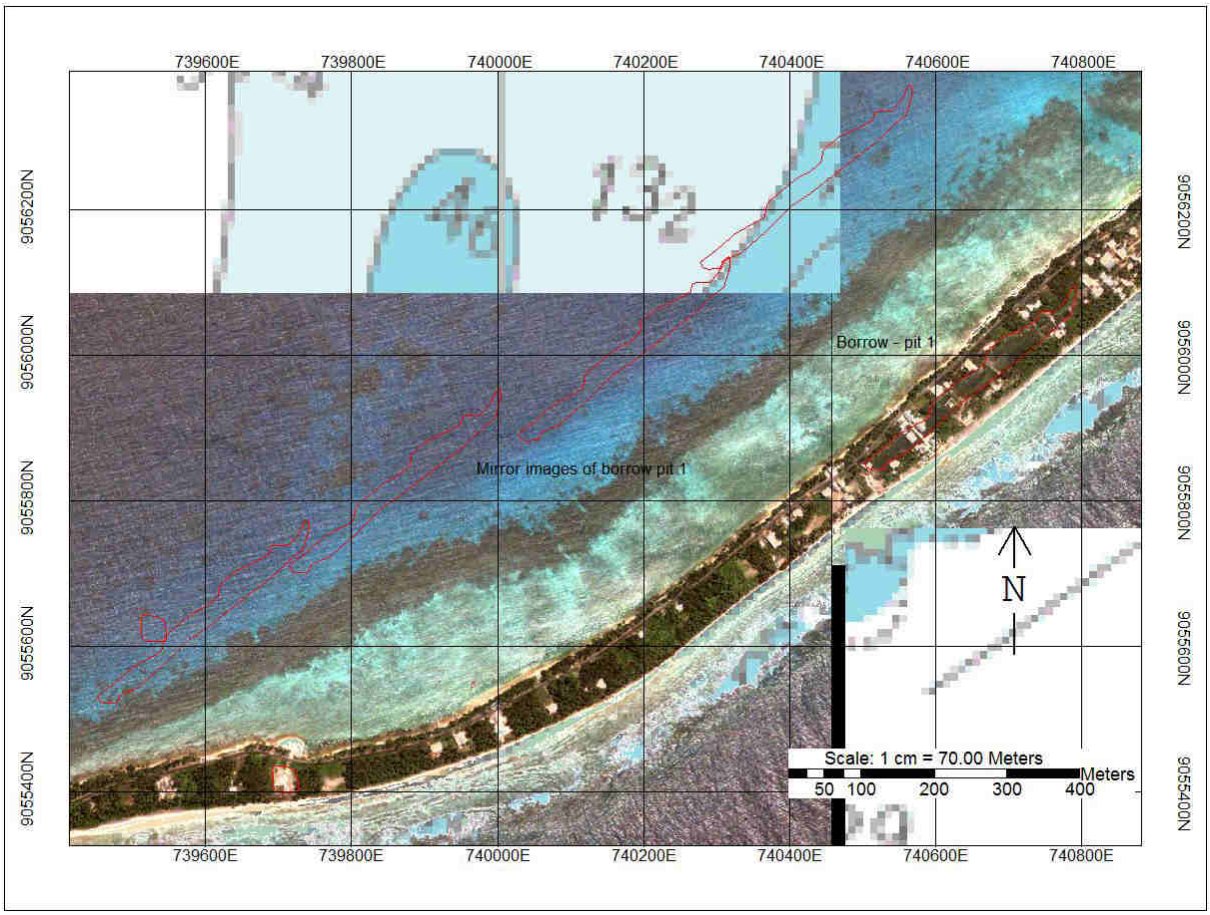

Figure 10 – Scaling borrow pit area to potential lagoon resource area. Pit boundary (red polygons) superimposed onto lagoon side to scale the extent of potential borrow area in the lagoon.

This was done for each borrow pit location as a guide for the jetprobing exercise. Five borrow areas were designated representing the 10 borrow pits. These have been designated as Borrow Area 1 for pits 1 and 5; Borrow Area 2 for pit 2, Borrow Area 4 for pit 4, Borrow Area 6-7-8 for pits 6, 7, 8 and Borrow Area 9-10 for pits 9 and 10, as illustrated in Figure 1.

SURVEY RESULTS

Borrow Area 1

Borrow Area 1 is adjacent to borrow pit 1, located on the southern end of Fongafale, south of the airstrip. At the northern end of the borrow area there is a channel that has been excavated through the fringing reef to the beach. During the occupation, the American military built a small boat basin here for LCMs (Landing Craft Mechanised) that gave them direct access to the shore line. This feature is visible in Figure 11. This feature is significant in that most of the anomalies showing up in the magnetic profiles occur adjacent to this area. On the lagoon slope in water depths of 12-14 m on the boundary of the proposed borrow areas, a number of wrecked (3) LCMs were found.

Bathymetry

Figure 11 is the bathymetry of the area labelled Borrow Area 1. The image backdrop is from Google Earth Pro and is dated 21072012. This image is exceptionally clear with excellent resolution that is better than the 2008 QuickBird image. Bathymetry contours are from a SOPAC 2009 single beam survey (Kumar, 2010) and are reproduced here with a 1-m contour interval. In the back drop image, from about the 13 m isobath, evidence appears to suggest the existence of a karstic topography. The bathymetry data is not at a high enough resolution to define this substrate. This substrate is likely to continue shoreward but at depth. The toe of the fringing reef is best delineated by the 4-m isobath. All depths are based on tide gauge zero with respect to the tide gauge sited at the main wharf. A relatively broad terrace varying between 50 and 80 m between the 4 m and 10 m isobaths represents the borrow resource area. This terrace holds the bulk of the loose unconsolidated sands and gravels which can be the resource for infill material to fill pits 1 and 5.

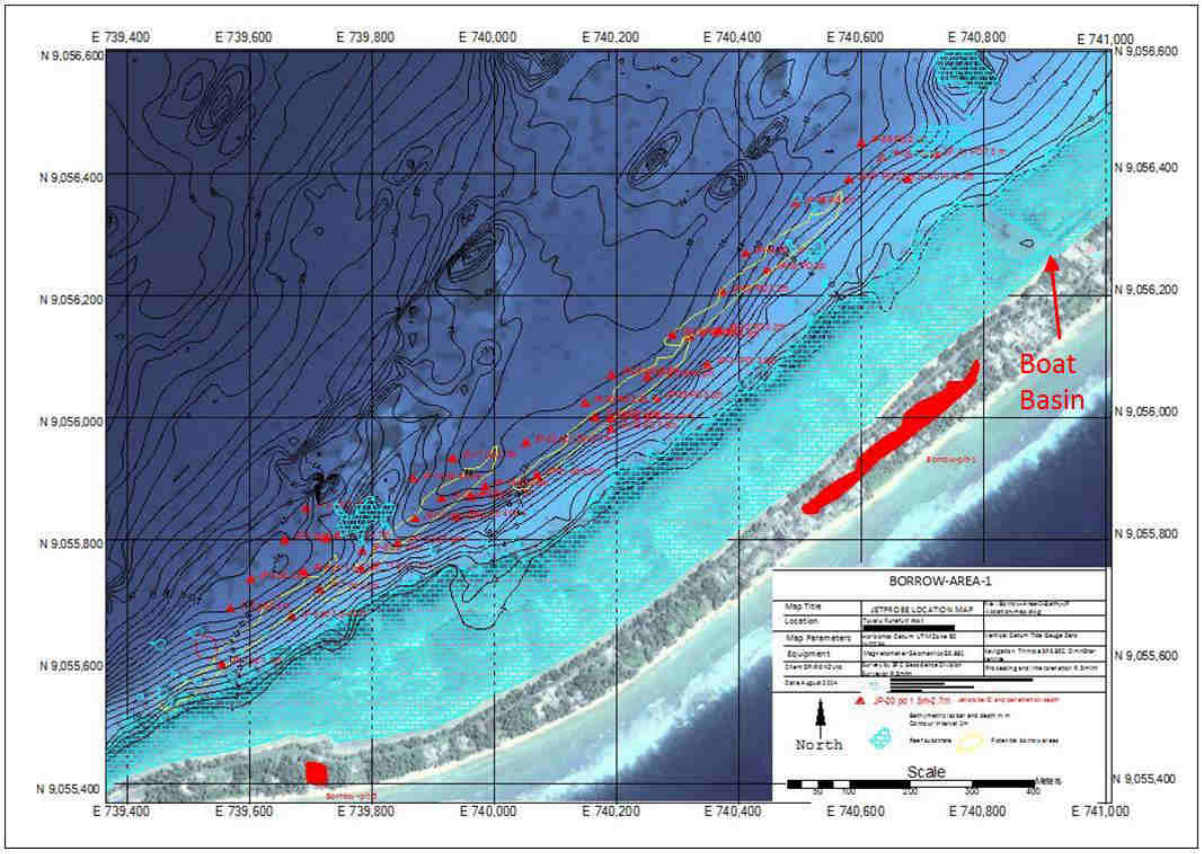

Figure 11 – Map illustrating the bathymetry of Borrow Area 1. Included in the map is the location of the jetprobes holes with depth of penetration labelled. The yellow polygons represent possible borrow areas based on the actual borrow pit area (for scale reference). For a larger scale map, see Appendix 2.

An interesting observation noted between the 2008 imagery and the 2012 imagery is the disappearance of a possible reef patch or seagrass patch. This is illustrated in Figure 12. Given that the missing shoal location is adjacent to the small boat basin channel, the missing patch has been buried by sedimentation, where rates in this locality are higher due to the proximity of the channel. The channel provides a pathway for escaping beach sand.

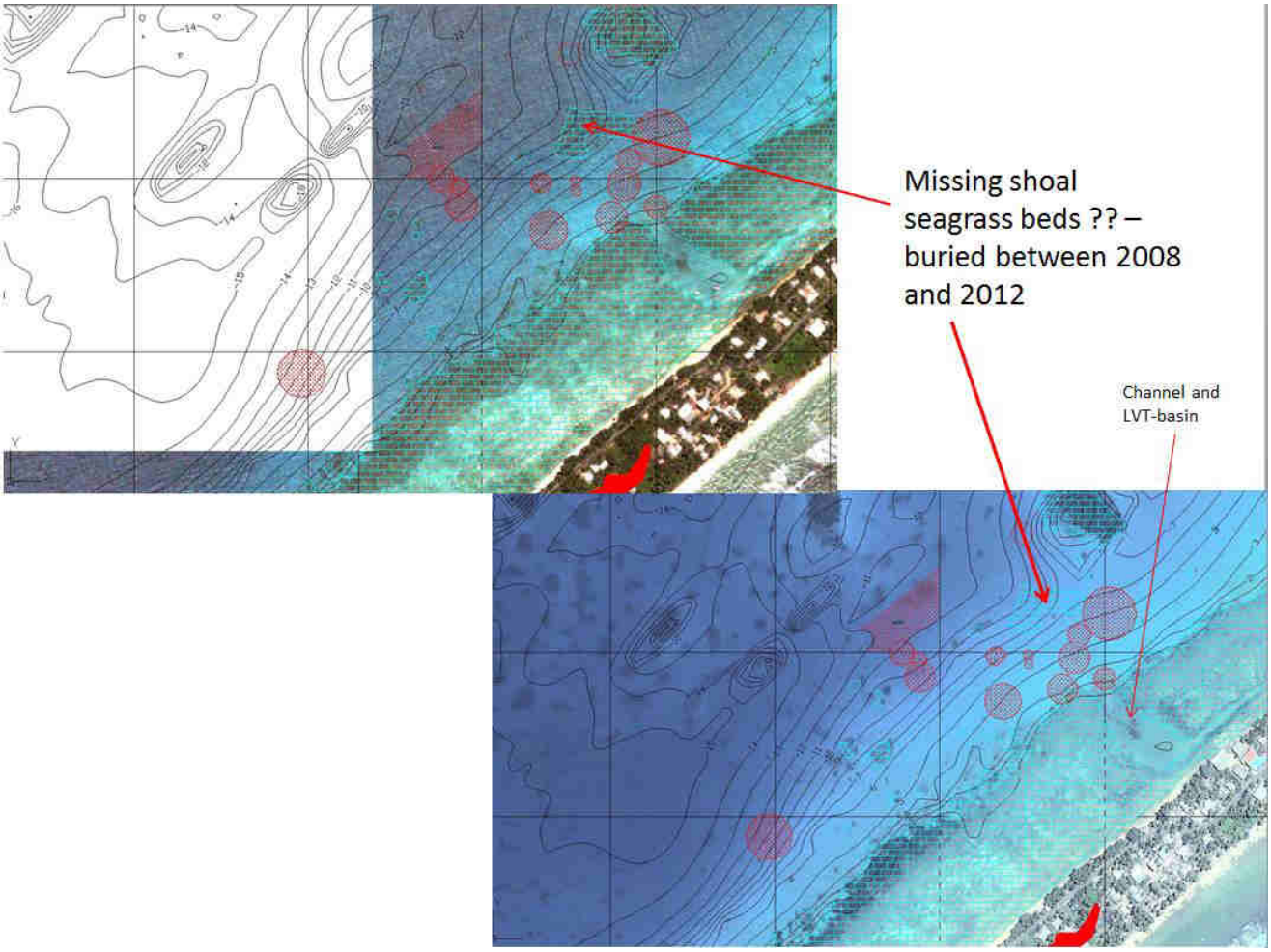

Figure 12 – Evidence for the burial of a shoal or seagrass bed due to sedimentation, seen comparing 2008 QuickBird imagery with a 2012 Google Earth image.

Jetprobe sampling and grading analysis

Forty-one jetprobe holes were drilled in this area numbered JP-1 through to JP-41. Sediment thicknesses drilled ranged from 1.5 m to 7.5 m. The thickest section of unconsolidated sediments appears to occur adjacent to the small boat harbour channel in the northeast of the area shown in Figure 12. The data for the jetprobe holes are tabulated in Table 4.

Table 4 – Borrow Area 1 jetprobe holes data, JP-1 to JP-41.

JP #	Easting m	Northing m	Water depth (m)	Depth of drill (m)	Comments
1	739554.9	9055596	7.5	1.4	sandy bottom-near base of fringing reef gravel at base. No sample collected.
2	739568.7	9055685	7.5	2.5	film-location 4 holes – gravely sand 1.4, 1.2, 1.8, 2.5
3	739669.7	9055672		4	gravelly sand – easy drilling, pipe with delivery hose buried
4	739601.7	9055734	11	3	2 holes drilled 1.5 m, 3.0 m
5	739658.4	9055799	11	4	2 holes drilled first hole 1.5 m
6	739688.9	9055747	7.5	2.5	3 holes drilled gravel at base variable depths, 1.5, 1.9, 2.5 m
7	739715.4	9055718	7	2.4	not far from edge of fringing reef
8	739785.2	9055780	7	4	sandy – easy drilling. Near toe of fringing reef
9	739693.9	9055851	8	2.4	easy drilling – sandy
10	739725.6	9055801	8	3.7	easy drilling -gravel at base of hole 3.7 m
11	739783.7	9055752	5.5	4	sandy – easy drilling
12	739871.6	9055833	11	4	sandy – easy drilling
13	739843.3	9055793	7	5	sandy – easy drilling
14	739868	9055898	11	4	sandy – easy drilling, hole depth 4+
15	739913.7	9055866	10.5	4.5	sandy – easy drilling, could go deeper
16	739939.7	9055835	9	4	easy drilling
17	739932.3	9055932	14	2.7	3 holes drilled 2.7 m max – very sandy all around site.
18	739985	9055887	13	2.7	a/a bottom out in solid rock
19	739960.6	9055869		3	sandy bottom
20	740051.8	9055958	12	2.7	4 holes, 1.5, 1.8, 2.4, 2.7 m bottomed out in rock. Sandy substrate.
21	740070.9	9055905	11	5	very sandy – easy drilling
22	740191.3	9055996	8	5.5	a/a easy drilling
23	740148	9056023	14	2.4	sandy Bottom 3 holes gravel at base of hole
24	740165.9	9055999	13	3	sandy bottom 4 holes drilled
25	740190.6	9055980	10	5	sandy bottom – easy drilling unconsolidated sands
26	740193.2	9056069	14	3.5	sandy bottom
27	740250.9	9056066	12.5	4.5	sandy – easy drilling
28	740266	9056031	10	5.3	easy drilling – gravel at base. Small coral reef patch near location.
29	740291.8	9056134	14	2.6	sandy – hit rock at base of hole
30	740320.5	9056131	13	4.5	sandy – easy drilling
31	740349.6	9056086	9	3.7	Sandy – reef at base of hole
32	740367.6	9056142	10.5	3.2	sandy – gravel at base of hole then rock bottom
33	740372.8	9056204	12	3.2	sand 0-2.2 m – then gravel to 3.2 m then rock at 3.2 m
34	740411	9056268	12.5	2.5	sand 0-1.5 m, gravel to 2.5 m
35	740446.7	9056241	10	3	Sandy to 26 m then gravel to 3.0 m Sediment depth variable here 3 holes 0.6 m, 1.6 m
36	740494.2	9056350	11	3	sandy to 2 m then 1 m gravel then rock at 3 m
37	740580.1	9056389	10	2.8	Drilled 2.8 m intersect bedrock. Sand 0-2.5 m, 2.5-2.8 m gravel, then bedrock at 2.8 m
38	740600.8	9056449	11	2.4	sandy bottom – sand to 1.5 m, gravel 1.5-2.4 m, 4 holes drilled –0.9 and 1.2 m
39	740635	9056425	9	2	sandy bottom – sand 0-1.2 m, 1.2-2 m, gravel difficult to penetrate further
40	740676.8	9056388	6	4.2	4.2 m sandy easy drilling
41	740721.1	9056429	5.5	7.5	Sandy bottom. Easy drilling to 7.5 m

Grading analysis results of sediments recovered from jetprobe samples 12 to 16 is provided in Figure 13. All 40 graded sieve data plots can be found in Appendix 1. In Figure 13, the JP-13 red line has marginally less fine gravel in comparison to jetprobes 12, 14, 15 and 16, which group closer together with very similar grain size content. These results are summarised in Table 5.

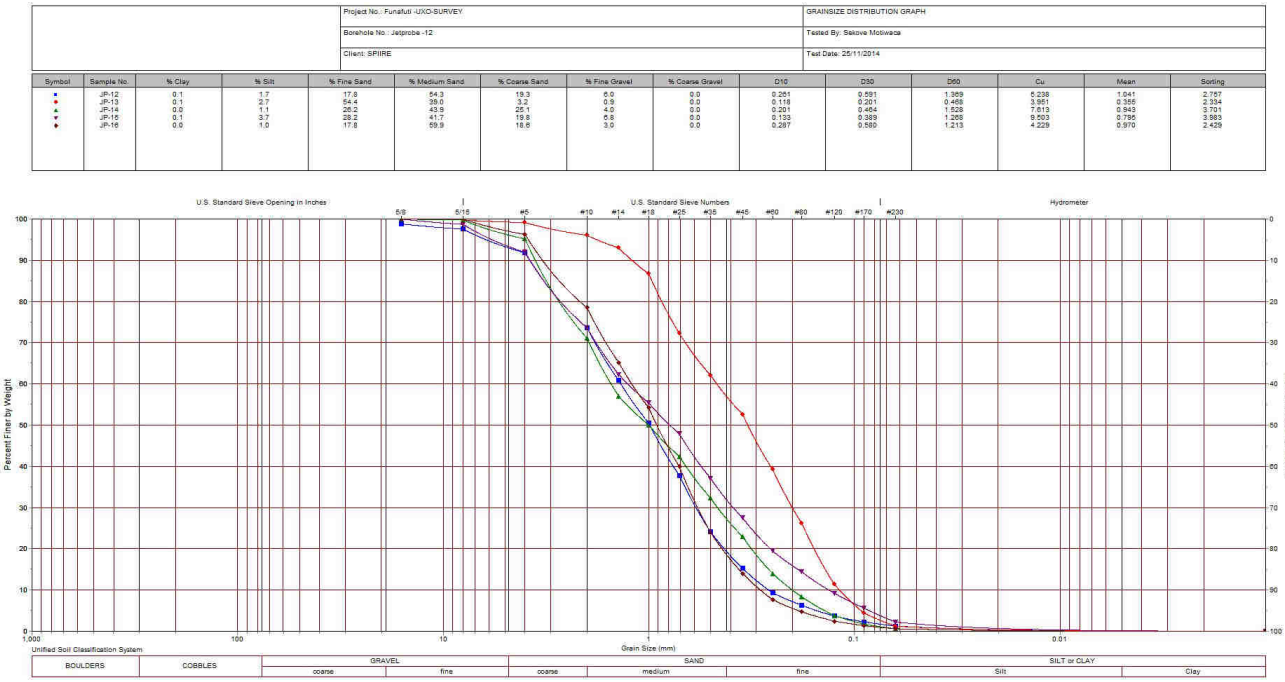

Figure 13 – Grading curves for jetprobe holes 12 to 16.

Table 5 – Borrow Area 1 grading analysis results for jetprobe samples JP-12 to JP-16.

JP#	Easting m	Northing m	% Clay	% Silt (0.02-0.006 mm)	% Fine sand (0.06-0.2 mm)	%Medium Sand (0.2-0.6 mm)	% Coarse sand (0.6-2.0 mm	% Fine Gravel (2-6 mm)	%Coarse Gravel
12	739871.6	9055833	0	1.2	6	3.4	43.1	21	0
13	739843.3	9055793	0	1.2	28.7	37.1	29.2	3.4	0
14	739868	9055898	0	0.7	9.3	27.1	34.1	26.4	0
15	739913.7	9055866	0	2.2	13.7	26.4	31.4	21.8	0
16	739939.7	9055835	0	0.7	5	26.1	47.1	19.7	0

The grading results indicate that the bulk of the material falls in the sand to fine gravel range. All grading results are provided in Appendix 1. Extensive underwater video footage was collected at each jetprobe site and these are made available as mp4 files in the DVD attached to this report (see Appendix 11).

Magnetic mapping and anomaly detection

Twenty-four magnetic line profiles at 10-m spacing representing 39 line kilometres was completed in Borrow Area 1. From this data a TIN model of the data was generated to produce an anomaly map which is shown in Figure 14. Based on analysis of each profile a total of 54 anomalies were detected. Many of these anomalies occur in clusters implying the anomaly seen in adjacent lines represent the same target due to the proximity of them occurring close together with respect to adjacent lines (Figure 15). Therefore, targeting the exact location of the anomaly is based on the highest peak-to-peak value for the anomaly. An example of this is shown in Figure 16, which is a screen capture of the target information, with the line profile against a backdrop of the high-resolution Google Earth Pro image of 2012.

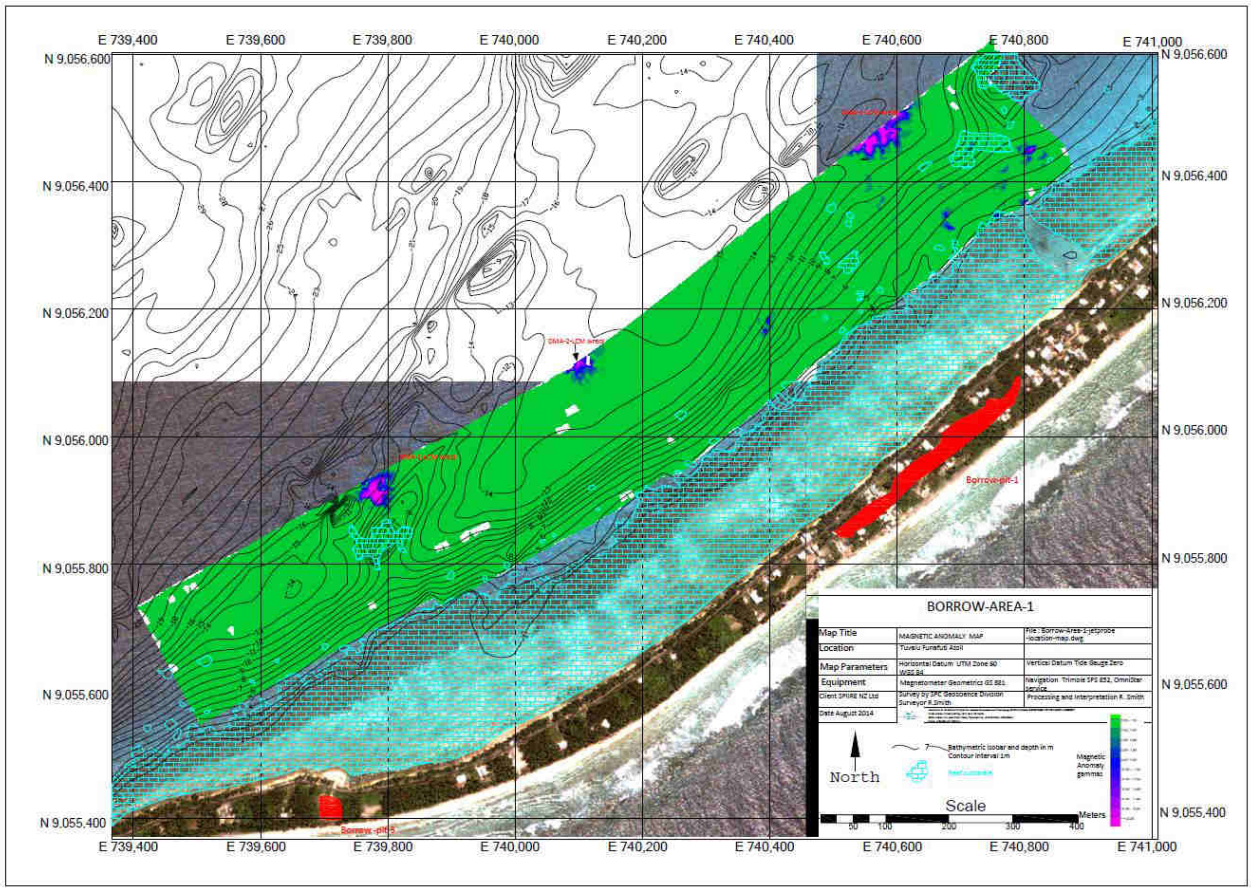

Figure 14 – Total Magnetic Field anomaly map normalised against the IGRF. Potential magnetic anomalies are highlighted by varying of shades of blue through indigo with intense targets shaded indigo. For this map the contoured range was -20 nT through to 20 nT.

The data presented in Figure 14 (above) indicates the background noise level of the host medium. In this case, carbonate sands do have low magnetic susceptibility resulting in a large contrast between host medium and total field magnetic anomaly of potential targets.

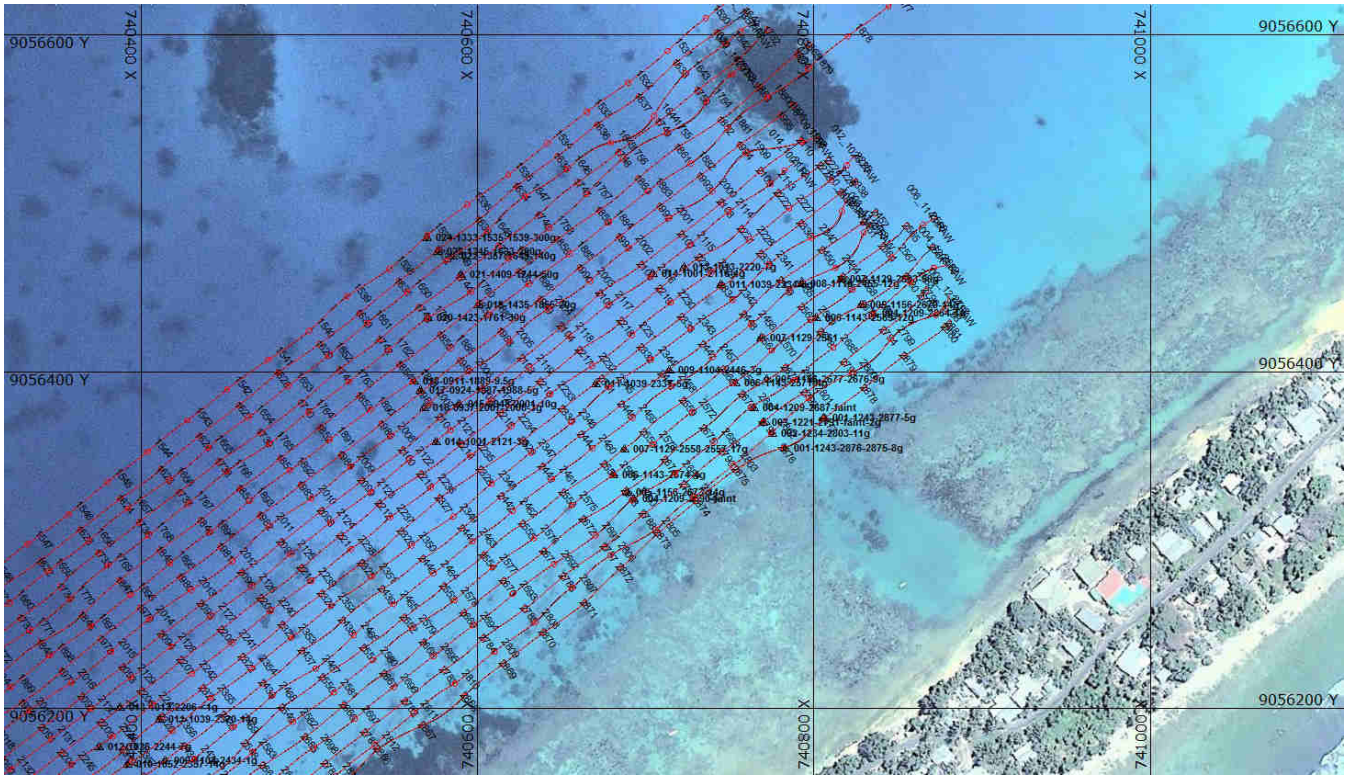

Figure 15 – Cluster of magnetic anomalies as picked and plotted from profile data. Image backdrop is from Google Earth Pro. Many of the anomalies can be attributed to a single target.

In Figures 15 and 16 the magnetic anomalies delineated are shown against a backdrop of a high resolution satellite image from Google Earth Pro dated 21/07/2012. Anomalies indexed as DMA 2 and DMA 3 and DMA 1 are identified as landing craft from WWII. With DMA 3, wreckage appears to be spread over the seafloor implying this may have been blown up either by bombing or scuttled. Other anomalies have no seafloor expression implying that the entity generating the anomalies would appear to be buried. The cluster of anomalies around the entrance to the small boat harbour are considered to most likely be metal detritus discarded or dropped over board during operations. An alternative interpretation based on Figure 2, is that there may be buried mooring blocks near the LCM channel. In Figure 2 one can see 3 LCM moored outside the channel. Table 6 tabulates the individual anomalies, their peak value and possible identity. Each anomaly detected is coded by the following fields: profile line number; location based on event position mark, and a peak-to-peak value of the monopole or dipole anomaly.

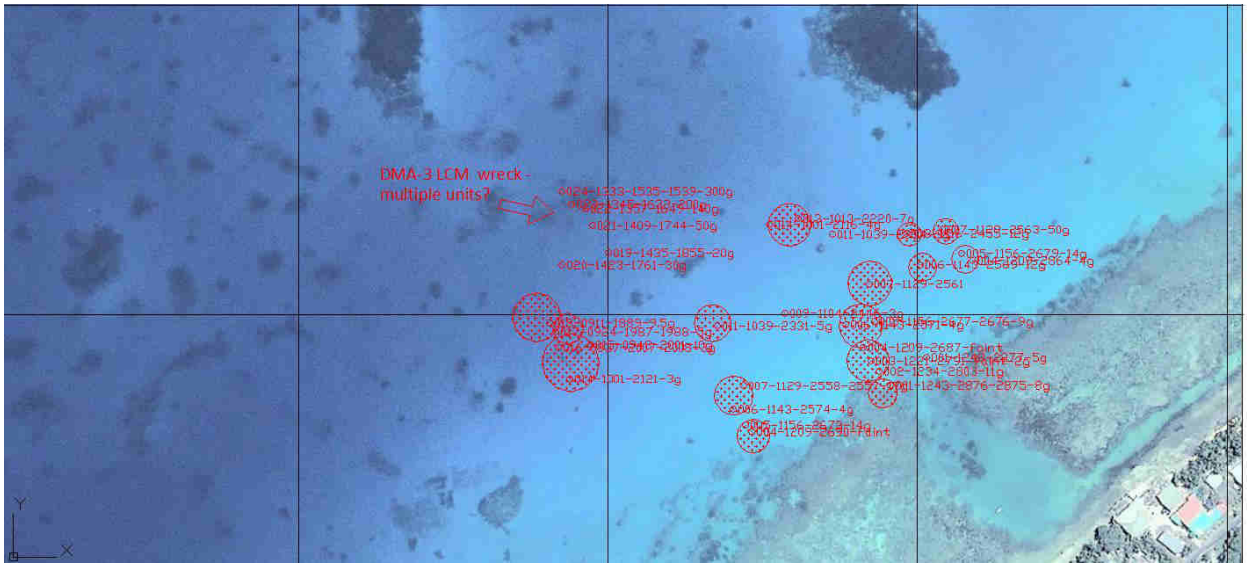

Figure 16 – A portion of the Borrow Area 1 magnetic anomaly map illustrating plots of magnetic anomalies as interpreted from profile line data.

Table 6 – Borrow Area 1 listing of magnetic anomalies identified from profile data.

Profile Anomaly Field is Line # Event Number Peak-2-Peak value	Easting	Northing	Anomaly Shape and Source
024-1333-1535-1539-300g	740570.2	9056480	Compound anomaly LCM wreck DMA 1
024-1333-1557-200g	740097.9	9056115	Single anomaly – distinct – LCM Wreck DMA 2
024-1333-1570-45g	739755.6	9055926	Single anomaly – LCM wreck DMA 1
023-1345-1633-200g	740576.7	9056471	Compound anomaly - LCM wreck DMA 1
023-1345-1612-1613-50g	740118.8	9056113	Single anomaly - LCM wreck DMA 2
023-1345-1600-120g	739786.9	9055931	Single anomaly - LCM wreck DMA 3
022-1357-1649-140g	740585.4	9056468	Compound anomaly
022-1357-1669-40g	740110.5	9056099	Single anomaly
022-1357-1681-1682-225g	739781.9	9055915	Single sharp anomaly - close to source LCM wreck DMA 1
021-1409-1712-175g	739800	9055914	Single - sharp anomaly - close to source
021-1409-1725-20g	740133.3	9056103	broad anomaly - moving away from source
021-1409-1744-50g	740590	9056458	Compound anomaly - moving away from source
020-1423-1761-30g	740570.4	9056432	Compound anomaly flattening out - moving away from source
020-1423-1780-18g	740121.5	9056085	Anomaly flattening out - moving away from source
020-1423-1793-50g	739781.3	9055893	Anomaly - still sharp centred on 1793
019-1435-1855-20g	740600.5	9056440	Anomaly - flattening out - asymmetrical - moving away from source
019-1435-1837-10g	740148.4	9056093	Anomaly - very broad
019-1423-1824-17g	739812	9055900	Anomaly - flattening but very distinct LCM wreck
018-0911-1873-1874-9g	740930.2	9056684	Anomaly - distinct
018-0911-1889-9.5g	740562.2	9056395	Anomaly distinct - occurs on fringe of wreck source so new source
018-0911-1920-14g	739792.2	9055877	Anomaly flattening out most likely associated with wreck
017-0924-1987-1988-5g	740566.2	9056389	Anomaly - flattening - moving away from source
017-0924-1956-6g	739822.5	9055882	Anomaly - very broad - considered wreck source

016-0937-2007-2008-3g	740568.2	9056379	Anomaly flattening - source near adjacent lines
016-0937-2039-?p	739781.5	9055847	Anomaly - faint - considered associated with wreck
015-0948-2001-10g	740588.9	9056381	Anomaly - distinct
014-1001-2116-4g	740704.4	9056458	Anomaly distinct - but small
014-1001-2121-3g	740575.6	9056359	Anomaly - distinct but small
013-1013-2220-7g	740722.7	9056462	Anomaly - distinct - small in profile
013-1013-2206-<1g	740387.6	9056201	Anomaly appears as a faint hint of something < 1 g
012-1026-2244-7g	740374.9	9056177	Anomaly distinct occurs near E2206 on adjacent line
011-1039-2320-14g	740411	9056193	Anomaly distinct - amp increasing closer to source
011-1039-2331-5g	740670.5	9056393	Anomaly small but well formed
011-1039-2334-3g	740744.7	9056452	Anomaly small separate source
010-1052-2357-14g	740392.3	9056167	Anomaly distinct
009-1104-2446-3g	740714.2	9056401	Anomaly small but distinct
009-1104-2434-1g	740414.4	9056169	Anomaly - flat
008-1116-2455-12g	740792.7	9056452	Anomaly distinct
007-1129-2563-50g	740816.1	9056455	Anomaly - distinct - sharp profile-close to source
007-1129-2561	740768.6	9056420	Anomaly distinct - separate source to that at 2563
007-1129-2558-2557-17g	740687.5	9056354	Anomaly - distinct
006-1143-2569-12g	740801.6	9056432	Single anomaly
006-1143-2571-4g	740753.7	9056394	Compound anomaly
006-1143-2574-4g	740681	9056339	Single anomaly
005-1156-2679-14g	740828.3	9056440	Single anomaly well formed
005-1156-2677-2676-9g	740771.9	9056396	Single anomaly flattened
005-1156-2673-14g	740688.8	9056329	Anomaly - well defined
004-1209-2864-4g	740835.5	9056435	Anomaly faint in profile
004-1209-2687-faint	740764.6	9056379	Anomaly faint - implying distant to source
004-1209-2690-faint	740693	9056324	A/a
003-1221-2791-faint-2g	740769.7	9056370	Anomaly small - but distinct
002-1234-2803-11g	740775.1	9056363	Anomaly small but well defined - sharp - indicating close to source
001-1243-2877-5g	740805.8	9056372	Anomaly small but well formed
001-1243-2876-2875-8g	740782.6	9056355	Anomaly broader, well formed

Although the listing of anomalies appears lengthy in Table 5, many of these represent a signal target. The map titled BA-1 *Magnetic Profile Anomaly and Track Plot Map* (Appendix 2) shows all the anomalies delineated by line profile. Single target anomalies that appear as clusters can be readily identified to be due to a single source in Borrow Area 1.

The major source targets identified in Borrow Area 1 were the 3 LCM wrecks and the debris field associated with the DMA 1 wreck.

Large-scale maps are provided in Appendix 2 and individual magnetic profiles are provided in Appendix 7.

Borrow Area 2

Bathymetry

Figure 17 shows the bathymetry of Borrow Area 2, which is located at the northeast end of Tengako island. The image backdrop is from Google Earth Pro and is dated 30062003. This image presents a clearer picture of the seafloor than that of the QuickBird image. The image, however has a darker contrast and as a consequence the contours are a little more difficult to read; however, a larger scale map is provided in Appendix 3.

From the bathymetry, the shelf is where the bulk of the sand lies, between the 5 m and the 8 m isobaths, with respect to tide gauge zero. On average this zone is about 30 m wide. Contours are given at 1 m interval. Inside the 5 m isobath and towards the toe of the fringing reef, many small coral patches increase in abundance, which is best seen in the 2003 image backdrop. Lagoon ward or seaward of the reef, the lagoon floor slopes are much steeper to the 25 m isobath, adding to the narrowness of the shelf.

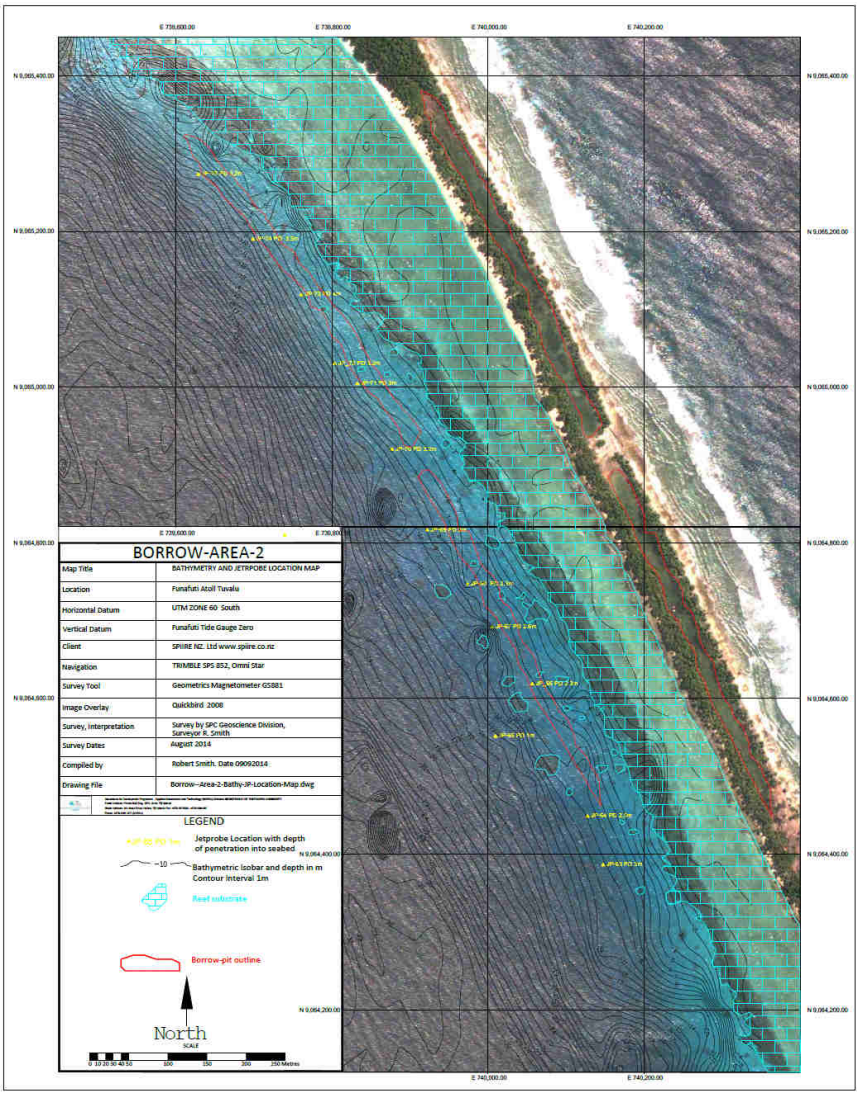

Figure 17 – Bathymetry and jetprobe locations map of Borrow Area 2. For a larger scale map, see Appendix 3.

Jetprobe sampling and grading analysis

Thirteen holes were drilled in Borrow Area 2, numbers JP-63 to JP-75. Sediment thickness drilled ranged from 1 m to 4 m. The shallowest hole that was drilled was in the deepest water at a depth of 14 m. The data for the jetprobe holes are tabulated in Table 7.

Table 7 – Borrow Area 2 jetprobe holes data, JP-63 to JP-75.

JP#	Easting m	Northing m	Water depth (m)	Depth of drill (m)	Comments
63	740147.4	9064386	9	3	Sandy bottom occasional coral heads clear. Drilled 3 m easy - medium sand - Foram, shell, coral rubble.
64	740127.8	740127.8	9	2.5	Sandy occasional bommies - drilled 2.5 m bottom in gravel, sand recovered coarse shelly material
65	740009.4	9064552	14	1	Sandy - coral heads around. Drilled 3 holes all 1 m. Coarse sand - shell coral detritus
66	740056.8	9064619	7	2.3	Sandy with bommies. 3 holes drilled 0.5, 0.7 m. Sandy coarse material.
67	740005.2	9064692	8	2.6	Sandy - coral bommies around. Easy drilling - Sand medium coarse shell Foram coral detritus
68	739973.8	9064747	8	2.3	Sandy - coral bommies around. Easy drilling - Sand medium coarse shell Foram coral detritus, Bottom in gravel
69	739922.2	9064816	9	2	Sandy coral patches scattered. Sand medium coarse - Foram, shell reef detritus. Bottom hole gravel
70	739877.2	9064920	8	3.2	Sandy bottom - coral patches. Sandy very easy drilling. Foram rich sand medium to coarse sand.
71	739832.8	9065004	6	3	Sandy area - coral patches. Easy drilling 3 m, gravel at base. Sand Foram rich.
72	739803.6	9065030	7	3.2	Sandy coral patches: easy drilling - bottom in gravel. Sand coarse - medium Foram rich.
73	739761	9065119	6.5	4	Sandy bottom - coral patches, self-drill 4 m - bottom out in gravel. Foram rich sand
74	739698.7	9065190	8	3.5	Sandy - easy drilling. Gravel to 3.5 m. Sand medium to coarse rich in Foram.
75	739628.9	9065274	8	3.2	Sandy - Foram rich easy drilling to 3.5 m, then gravel intercepted

In general, drilling was easy indicating the sediment to be unconsolidated; and was rich in Forams. The deeper sediment holes were to the north of the area, an indication that this area is closer to the source of the sand, which in part originates from the reef platform.

A sample of the grading results for jetprobe samples from Borrow Area 2 is provided in Figure 18. Here plots of 5 jetprobe stations are shown, three from the southern end of the resource area JP-63, 64 and 65 and two samples from the northern end of the resource area for borrow pit 2. In Figure 19 the outlier is JP-63 which is the most southern hole drilled in Borrow Area 2 and is also the furthest from the sediment source. This is reflected by the increase in fine sand in comparison to the other samples shown in the grading analysis; and as tabulated in Table 8.

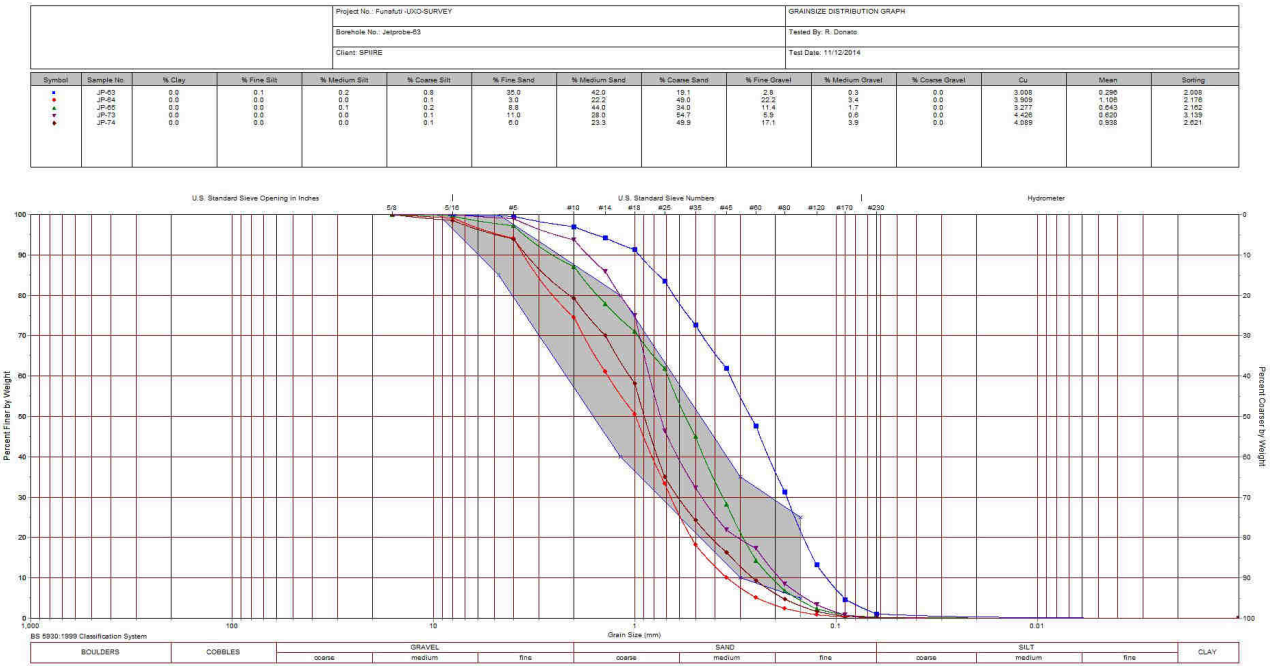

Figure 18 – Sample grading results from Borrow Area 2.

Individual grading curves are provided for each sample station in Appendix 1. In addition to the sampling, underwater footage was recorded at each location and is provided on DVD as MP4 files (Appendix 11).

Table 8 – Grading analysis summary for jetprobe holes in Borrow Area 2, JP-63 to JP-75.

JP#	Easting m	Northing m	% Clay	% Silt (0.002-0.006 mm)	% Fine sand (0.06-0.2 mm)	%Medium Sand (0.2 mm-0.6 mm)	% Coarse sand (0.6-2.0 mm	% Fine Gravel (2-6 mm)	%Coarse Gravel
63	740147.4	9064386.35	0	1.1	35	41.9	19.1	2.8	0
64	740127.8	740127.77	0	0.1	3	22.2	49	22.2	0
65	740009.4	9064551.51	0	0.2	8.8	44	34	11.4	0
66	740056.8	9064618.8	0	0.1	3.2	38.4	50.1	7.8	0
67	740005.2	9064691.76	0	0.3	13.8	48.8	32.6	4.3	0
68	739973.8	9064746.71	0	0.2	6.2	43.7	46.9	3.1	0
69	739922.2	9064816.41	0	0.1	7.7	46.3	42	3.8	0
70	739877.2	9064919.95	0	0.1	3.2	25.2	56.2	13.5	0
71	739832.8	9065004.33	0	0.1	4.5	24.8	50.9	12.7	0
72	739803.6	9065030.29	0	0.1	5.1	26.4	58.4	7.1	0
73	739761	9065118.74	0	0.1	11	28	54.7	5.9	0
74	739698.7	9065189.84	0	0.1	6	23.3	49.9	17.1	0
75	739628.9	9065273.5	0	0.3	10.3	31.8	49.8	7.2	0

Magnetic mapping and anomaly detection

Eleven magnetic line profiles at 10-m spacing representing 13.2 line kilometres was completed in Borrow Area 2. From this data, a TIN model of the data was generated to produce an anomaly map which is shown in Figure 19. Based on the analysis of the eleven profiles, a total of 26 anomalies were detected. As in Borrow Area 1, many of these anomalies occur in clusters implying the anomaly seen in adjacent lines represent the same target due to the proximity of them occurring close together at adjacent lines. As a result targeting the exact location of the anomaly is based on the highest peak–to-peak value for the anomaly.

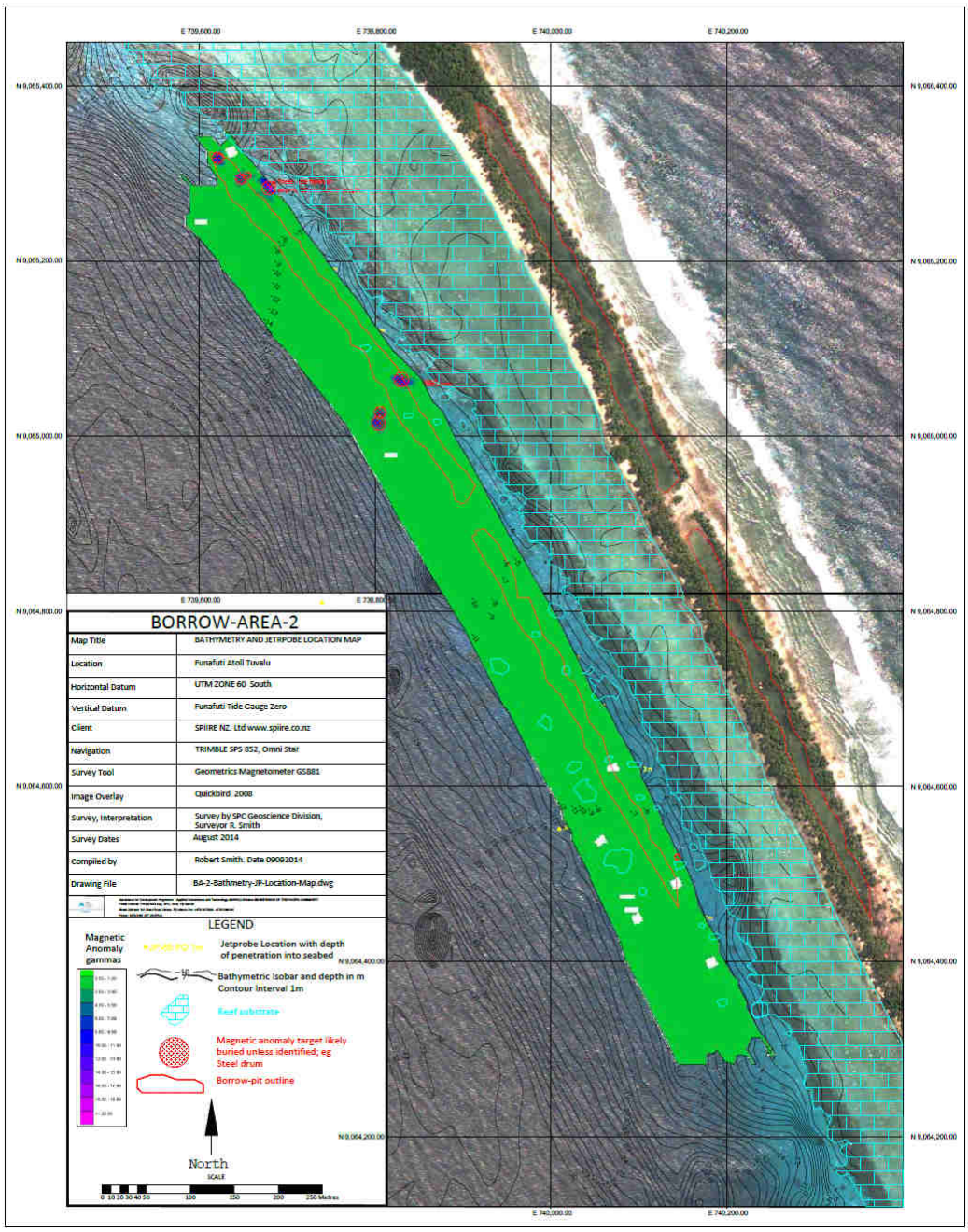

Figure 19 – Total field magnetic anomaly map for Borrow Area 2.

Table 9 – Magnetic anomalies in Borrow Area 2.

Profile Anomaly Field is Line # Event Number Peak-2-Peak value	Easting m	Northing m	Anomaly details
009-1029-860-5g	739780.9	9065026	Anomaly well defined
008-1038-885-15g	739803.6	9065009	Anomaly well defined
007-1048-942-14g	739798.3	9065039	Anomaly well defined
007-1048-951--faint	739631.9	9065246	Possibly anomaly - broad low amplitude
006-1057-964-965-4g	739816.3	9065028	Anomaly appears to be flattening as move away from source
005-1105-1023-2g	739824	9065038	Anomaly appears broad and flat
004-1114-1038-1039-10g	739626.3	9065306	Anomaly well defined - sharp - possible additional sources on flanks
004-1114-1049-2g	739817.8	9065058	Anomaly apparent, somewhat broad
004-1114-1050-1g	739836.7	9065032	Anomaly small but appears separate to that at 1048-1049
004-1114-1074-1g	740171.5	9064392	Anomaly subtle but apparent
003-1123-1086-1085-3g	740169.7	9064413	Anomaly - more pronounced
003-1123-1099-1098-1g	740000.1	9064763	Anomaly subtle
003-1123-1110-23g	739824.8	9065068	Possible compound anomaly indicating more than one source
003-1123-1120-14g	739648.6	9065295	Anomalies appear well defined - multiple targets?
002-1132-1127-11g	739667	9065289	Compound anomaly spread over events 1126-1128
002-1132-1132-2g	739758.4	9065166	Anomaly broad, low amplitude
002-1132-1135-1g	739818.6	9065090	Anomaly faint but apparent
002-1132-1136-7g	739835.3	9065069	Anomaly well defined
002-1132-1148-1149-0.5g	740019.6	9064746	Faint hint of anomaly
002-1132-1161-1162-3g	740190	9064399	Anomaly well formed, but broad
001-1141-1205-25g	739680.9	9065289	Anomaly sharp well defined - close to source
001-1141-1199-3g	739798.6	9065133	Anomaly broad profile
001-1141-1181-1g	740066.9	9064685	Subtle anomaly present, low amplitude
001-1141-1175-5g	740141.7	9064530	Anomaly well defined
001-1141-1171-4g	740193.1	9064412	Anomaly well defined

Of these anomalies presented in Table 9, those investigated in Borrow Area 2 identified target sources that include a 6 m steel wire hawser approximately 19 mm in diameter, an oven, a 44-gallon drum and a sheet of iron. The locations of these finds are shown in Figure 19 by the large red circles. A large-scale plot of this data is provided in Appendix 3. The area in general is much cleaner in terms of magnetic anomalies when compared to Borrow Area 1. Underwater video of the dive site was also collected and is appended in Appendix 11.

Borrow Area 4

Bathymetry

Figure 20 is the bathymetry and jetprobe location map for Borrow Area 4, which is located in an area a kilometre north of the main wharf in Funafuti. The image backdrop is the 2008 QuickBird. This is the better of the images available for this area. Here the shelf is quite narrow with a steep slope to about the 15 m isobath before the angle of repose of the slope begins to flatten out into deeper water greater than 24 m, some 180 m distance from the edge of the fringing reef. From the bathymetry, the shelf is best defined by the 7 m and 9 m isobaths, with respect to tide gauge zero. On average this zone is about 15 m wide. Contours are given at 1 m interval. Inside the 6 m isobath and towards the toe of the fringing reef many small coral patches and reef substrate is present. This is visible in the QuickBird imagery. A number of largish singular coral patches exist within this zone. A large-scale map for Figure 20 is provided in Appendix 4.

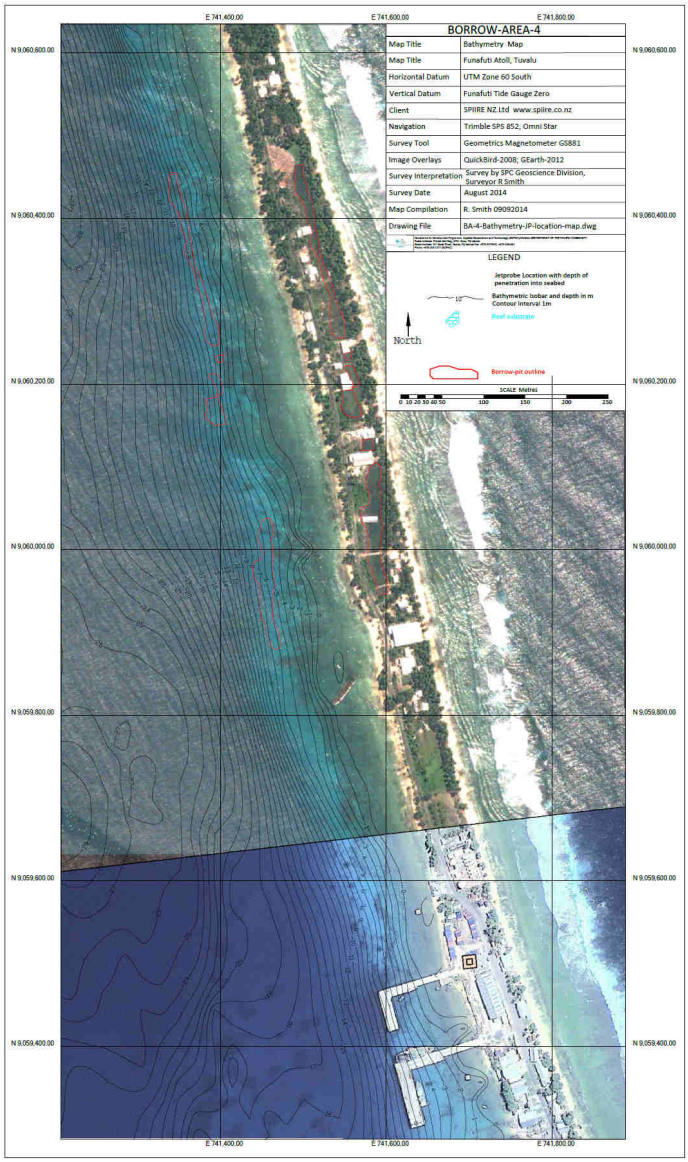

Figure 20 – Bathymetry and jetprobe location map for Borrow Area 4. For a larger scale map, see Appendix 4.

Jetprobe sampling and grading analysis

Fourteen holes were drilled in Borrow Area 4, numbers JP-76 to JP-89. Sediment thickness drilled ranged from 0.3 m to 6.5 m, for an average depth of 3.9 m for the fourteen holes. The shallowest hole that was drilled was on a steep part of the slope near some scattered coral reef patches, in 10 m of water. The deepest hole drilled was 6.5 m in unconsolidated sands in 9 m of water. In this particular hole the drill pipe became stuck and took some effort to recover. This was done by drilling a second hole alongside the stuck pipe. The data for the jetprobe holes are tabulated in Table 10.

Table 10 – Borrow Area 4 jetprobe holes data, JP-76 to JP-89.

JP #	Easting m	Northing m	Water depth m	Hole depth m	Comments
76	741312.4	9060454	13	3	Sandy bottom. 3 holes drilled 0.5 m solid bottom, next hole 1.5 m bottom in gravel, third hole 3.0 m offset about 4 m from first hole bottom in gravel. Sand medium to coarse.
77	741350.2	9060405	8	2.4	Sandy - 5 holes depth between 0.3 and 2.4 m. Holes 0.3, 0.5 and 1 m, bottom in rock. Sand medium coral detritus
78	741348	9060375	10	0.3	Sandy with some scattered patch reefs. 4 holes drilled here all 0.3 m. Steep slope.
79	741350.3	9060309	11	4.2	Sandy bottom - sand 0-1.5 m - resistance than drilled to 4.2 m. Sand medium to course - Foram coral detritus.
80	741389.1	9060071	12	2.1	Sandy with coral patches – 3 holes drilled 0.5, 1.0 m and 2.1 m this hole bottoms in gravel. Sand medium to coarse coral detritus with shell and some Foram.
81	741414.5	9060032	10	3.2	Sandy bottom. Drilled 3 holes down slope first 2 m, 3.2 m 2.8 m bottom in gravel. Sand recovered coarse shell coral detritus more Foram content.
82	741418	9059987	11.5	4	Sandy bottom - more difficult to anchor, one hole easy drilling 4 m. Sand medium white coral detritus.
83	741401.2	9060002	13	4.8	Sandy bottom - easy drilling 4.8 m. Gravel at base of hole. Medium sand shell, Foram coral detritus white with touch of orange colour.
84	741425.9	9059932	11	5	Sandy bottom - difficult anchoring - run long line and advance up on it. Easy drilling 5 m. Sand coarse medium Foram rich shell and coral detritus. White - orange colour which is indicative of Foram presence.
85	741439.3	9059908	10	4.5	Sandy bottom. Soft drilling to 4.5 m. Sand medium coarse. Foram, coral detritus. White orange in colour.
86	741449.4	9059893	9	4	Sandy bottom - closer to fringing reef drilling on starboard side down slope. Easy drilling 4 m sand medium - coarse white-orange - Foram coral detritus.
87	741431.2	9059830	14	5	Sandy bottom. Medium coarse sand orange rich in Foram, easy drilling.
88	741441.7	9059802	13	5.5	Sandy bottom. Medium coarse sand orange to white rich in Foram. Easy drilling.
89	741469.9	9059767	9	6.5	Sandy bottom. Easy drilling to 6.5 m pipe stuck. Use 2nd pipe and hose to free. Sand orange white medium to coarse - Foram rich.

In general drilling was easy indicating the sediment to be unconsolidated and appears rich in Foraminiferal species common in the beach sands of Funafuti. The deeper sediment holes were in the southern portion of the proposed borrow area.

A sample of the grading results for the jetprobe samples from this area is provided in Figure 21. Here plots of 5 jetprobe stations are shown, two from the southern end of the resource area, JP-88 & JP-89; JP-83 from mid-section and JP-76 and JP-79 from the northern end of the resource area. The results of the grading analysis as tabulated in Table 11.

Table 11 – Grading analysis summary of results for jetprobe holes in Borrow Area 4.

JP#	Easting m	Northing m	% Clay	% Silt (0.002-0.006 mm)	% Fine sand (0.06-0.2 mm)	%Medium Sand (0.2-0.6 mm)	% Coarse sand (0.6-2.0 mm	% Fine Gravel (2-6 mm)	%Coarse Gravel
75	739628.9	9065274	0	0.3	10.3	31.8	49.8	7.2	0
76	741312.4	9060454	0	0.2	5.2	31.3	48.1	13.3	0
77	741350.2	9060405	0	0.3	7.2	33.8	36.1	14.7	0
78	741348	9060375	0	0.5	13.3	33.4	36	10.6	0
79	741350.3	9060309	0	0.4	3.1	19.3	47.7	24.7	0
80	741389.1	9060071	0	0.4	13.8	49.7	30.9	4.3	0
81	741414.5	9060032	0	0.1	3.2	34.2	42.3	15.9	0
82	741418	9059987	0	0.8	47	47.4	4.9	0.2	0
83	741401.2	9060002	0	0.4	18.4	47.5	28.2	5.2	0
84	741425.9	9059932	0	0.1	5.4	37.3	48.7	7.8	0
85	741439.3	9059908	0	0.1	5	45.8	45	3.9	0
86	741449.4	9059893	0	0.1	7.9	50	37.9	3.6	0
87	741431.2	9059830	0	0.1	3.1	32.9	52.4	9.1	0
88	741441.7	9059802	0	0.1	2.9	28	55	12.2	0
89	741469.9	9059767	0	0.1	3.9	34.1	42	11.6	0

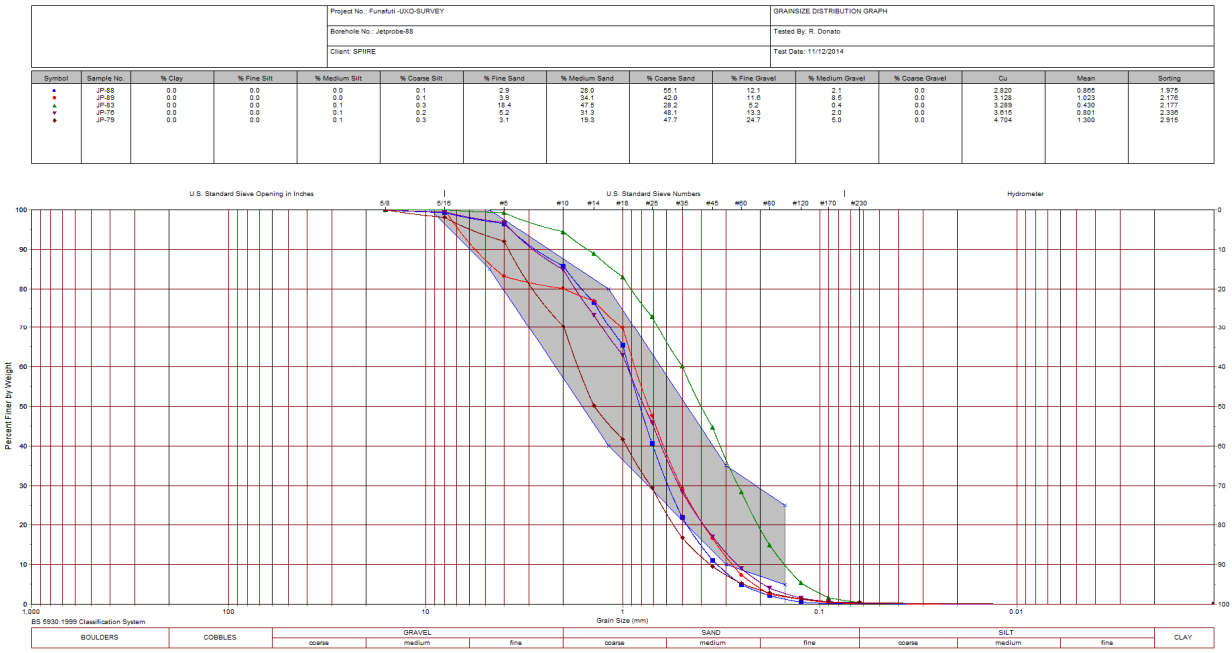

Figure 21 – Sample grading results from Borrow Area 4.

Individual grading curves are provided for each sample station in Appendix 1. In addition to the sampling, underwater video footage was recorded at each location and is provided on DVD as MP4 files (Appendix 11).

Magnetic mapping and anomaly detection

Eleven magnetic line profiles at 10 m spacing representing 10.0 line kilometres was completed in Borrow Area 4. From this data a TIN model of the data was generated to produce an anomaly map which is shown in Figure 22. Based on the analysis of the ten profiles, a total of 20 anomalies were detected. These are detailed in Table 12.

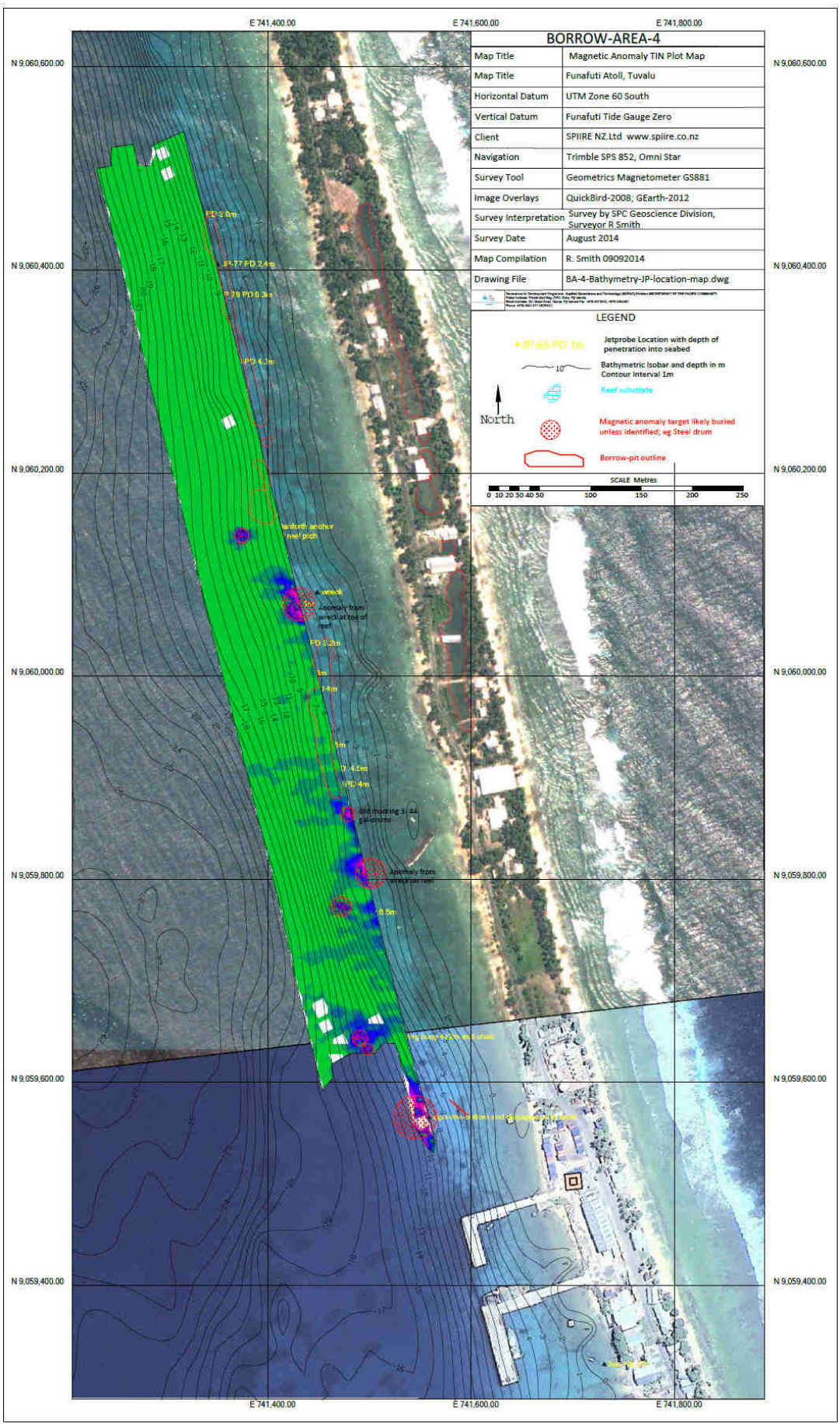

Figure 22 – Total field magnetic anomaly map for Borrow Area 4.

Table 12 – Magnetic anomalies listing for Borrow Area 4.

Profile Anomaly Field is Line # Event Number Peak-2-Peak value	Easting m	Northing m	Anomaly details
005-1402-404-10g	741412.7	9060067	Broad anomaly in line where larger anomaly at 395
005-1402-395-40g	741478.8	9059805	Broad anomaly large distant source wreck on reef
006-1411-429-7g	741308.3	9060443	Broad anomaly 7 g
006-1411-440-11g	741389.7	9060123	Board anomaly associated with Danforth anchor
006-1411-443-5g	741410	9060034	Board anomaly - interpreted as wreck source
006-1411-444-3g	741418	9060007	Broad anomaly - wreck effect??
006-1411-452-30g	741474.6	9059774	Compound anomalies - buried??
007-1420-476-26g	741371.7	9060150	Anomaly well defined associated with anchor Danforth
007-1420-464-11g	741464.6	9059772	Anomaly small but well defined Buried??
007-1420-458->25g	741497.4	9059637	Anomaly partial caught tail end large mooring buoy and chain
008-1429-504-11g	741367.4	9060118	Broad anomaly - Danforth anchor
009-1439-524->10g	741476.2	9059650	Part of anomaly captured at end of line
004-1517-661>100g	741542.3	9059573	Large anomaly at end of line WWII pipeline
004-1517-669->70g	741486.6	9059808	Large broad anomaly - wreck on reef
004-1517-671-672-12g	741469.7	9059879	Definite small anomaly - 3 44-gallon drums
004-1517-678->50g	741424.3	9060070	Well-formed anomaly - from wreck at toe of reef
003-1528-713->150g	741432.1	9060073	Anomaly well formed from wreck at toe of reef
003-1528-722-723-130g	741499.3	9059793	Broad anomaly - wreck on reef
003-1528-730-731->90g	741556.8	9059568	Well defined anomaly adjacent to anomaly generated by wreck on reef
003-1528-733-742->1000g	741607.8	9059313	Wharf generated anomaly

A number of very interesting anomalies showed up in Borrow Area 4. Present also in the area was a large wreck on the reef flat towards the south of the area. This wreck produced a large anomaly. A second wreck was located in the same area but is submerged and occurs at the base of the toe of the fringing reef. This wreck blends into the coral patches around it and is not immediately recognizable. Also located were a large Danforth anchor, a mooring consisting of 3 44-gallon drums, a very large mooring buoy and a large mooring chain and concrete slab. All except the 3 44-gallon drums mooring would appear to be from the military installations from WWII. The mooring chain is particularly large and disappears into the sediment. This would be an issue if an anchoring vessel hooked onto this chain. These targets are shown in Plate 3.

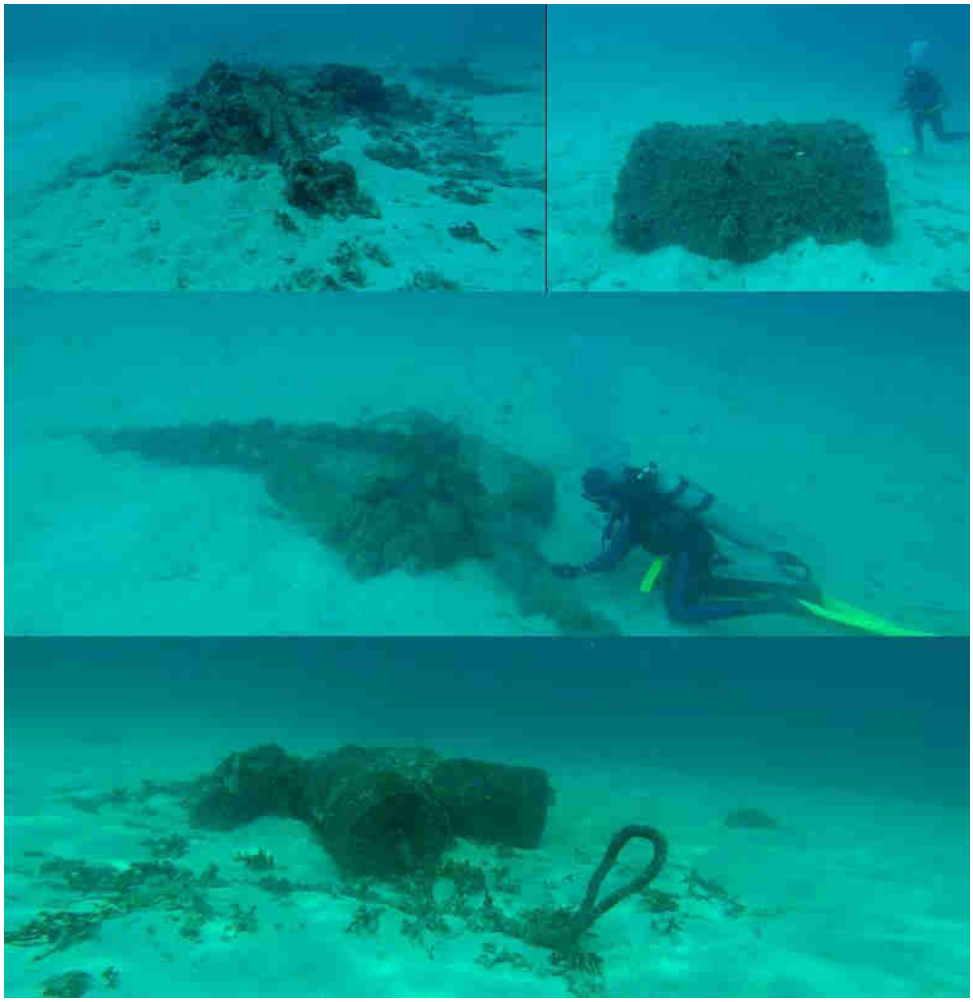

Plate 3 – Underwater pictures of targets which generated anomalies in Borrow Area 4. Top left: a large Danforth anchor on a coral patch. Top right: a large cylindrical mooring drum approximately 4x2 m. Middle: a very large mooring chain and concrete slab. Bottom: Three (3) 44-gallon drums making up a mooring. Diver provides some idea of scale.

Figure 23 is a track plot map of the profiles with the various targets identified and plotted. A large-scale map is provided in Appendix 4.

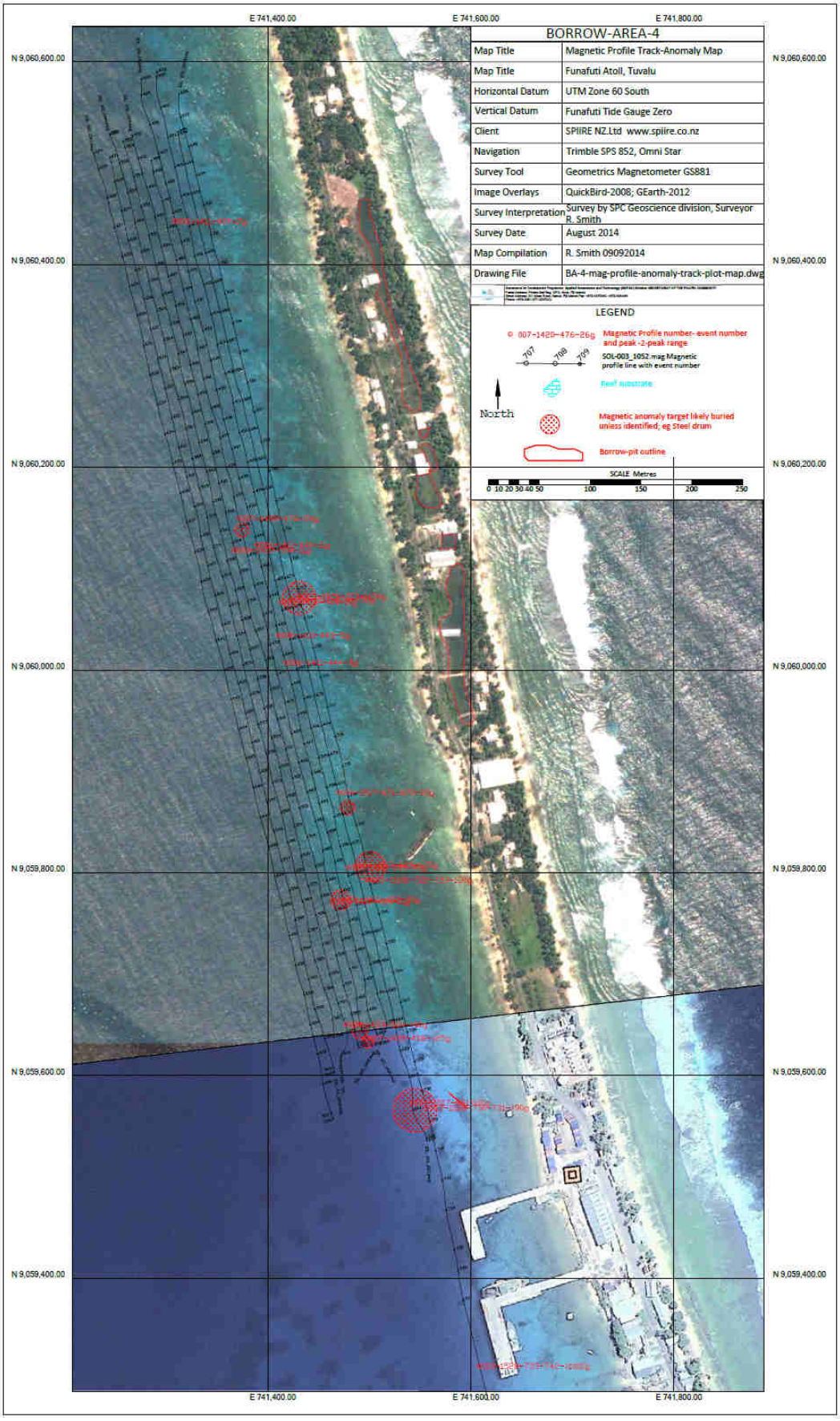

Figure 23 – Magnetic profiles with locations of interpreted anomalies plotted for Borrow Area 4. For a larger scale map, see Appendix 4.

Borrow Area 6-7-8

Bathymetry

Figure 24 is the bathymetry of the area labelled Borrow Area 6-7-8. This borrow area is approximately 440 m south of the new wharf and stretches for about 500 m. At the southern end of the borrow area there are two channels carved into the fringing reef with small associated boat basins. The image backdrop is from Google Earth Pro and is dated 21072012. This image is exceptionally clear with excellent resolution – better than the 2008 QuickBird image.

Bathymetry contours are from the SOPAC 2009 single beam survey, which is reproduced here with a 1 m contour interval. Seen in the backdrop image, around the 13 m isobath, are two large reef patches that mark the western edge of the shelf. The toe of the fringing reef is best delineated by the 4 m isobath. All depths are based on tide gauge zero with respect to the tide gauge sited at the main wharf. A relatively broad terrace varying between 60 m and 80 m wide between the 4 m and 10 m isobaths, represents the borrow resource area. This terrace holds the bulk of the loose unconsolidated sands and gravels which can be resourced for borrow pit in-fill material. A number of small coral reef patches dot the substrate in this area. The southern portion of the area is quite clear of any visible reef patches, with a very sandy substrate. A large-scale plot of this map is provided in Appendix 5.

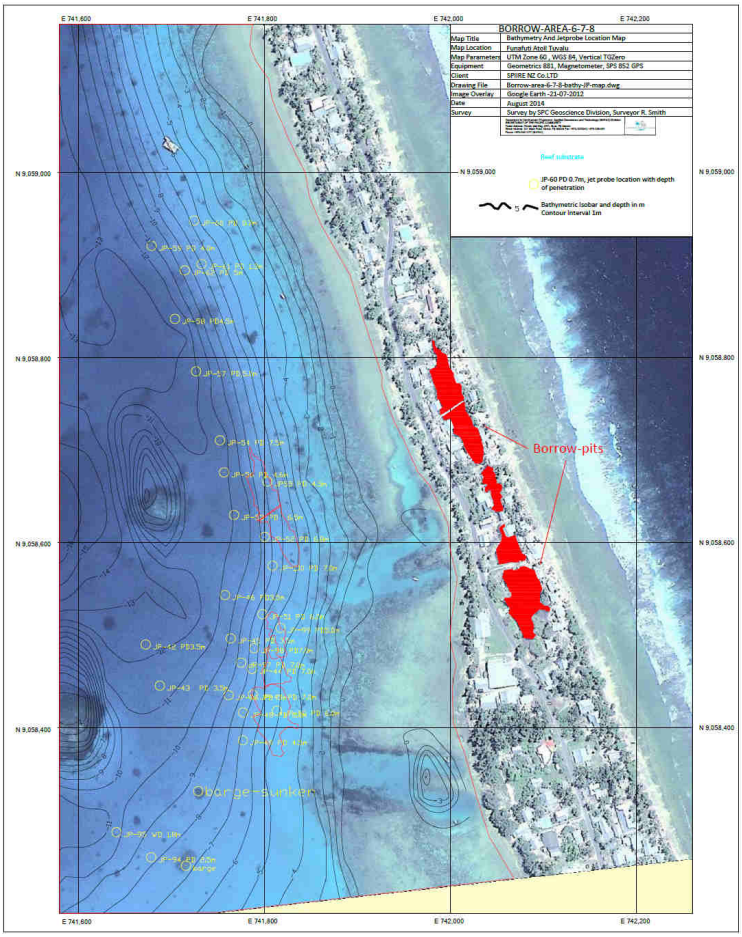

Figure 24 – Bathymetry and jetprobe location map of Borrow Area 6-7-8. For a larger scale map, see Appendix 5.

Jetprobe sampling and grading analysis

Twenty-one jetprobe holes were drilled in this area numbered JP-42 to JP-62. Sediment thickness drilled ranged from 0.7 m to 7.5 m. At the JP-60 location, seven holes were drilled to see if the sediments were thicker after the first hole drilled may have hit a rock; however, even after seven holes were drilled it would appear that the sediment in this area is a thin veneer over reef substrate. The thickest section of unconsolidated sediments appears to occur in the southern half of the proposed borrow area adjacent to the small boat harbour channels as shown in Figure 24. The data for the jetprobe holes are tabulated in Table 13. The average depth for the 21 jetprobe holes was 4.8 m.

Table 13 – Borrow Area 6-7-8 jetprobe holes data, JP-42 to JP-62.

JP#	Easting m	Northing m	Water Depth m	Hole Depth m	Comments
42	741672.6	9058490	12	3.5	Sandy bottom drilled to 3.5 m easy drilling. Hole all sand. Dominantly Halimeda, shell fragments, small bivalves.
43	741687.7	9058446	11.5	3.5	Sandy bottom, 3 holes drilled 2.5, 3, 3.5 m deep. Sand to 3 m, gravel 3.5 m. Very shelly, Halimeda-very coarse sand
44	741786.8	9058464	9.5	7	Drilling easy through sand. Possible gravel intercepted at 7.0 m. Sandy - Forams, shell fragments, some Halimeda medium sand
45	741763.8	9058497	9.5	3.5	3 holes drilled 2.5, 3, 3.5 m sandy - medium sand
46	741757.8	9058543	10.5	3.5	3 holes drilled 2.4 m, 2.7 m and 3.5 m. Sandy. All 3 holes ended in gravel. Noted extra turbidity here. Medium - coarse sand.
47	741787.6	9058436	7	7	Sandy easy drilling to 7.0 m. Sand medium mix of Foram shell fragments.
48	741777.3	9058417	7.5	6	Easy drilling sandy bottom - sand Foram rich.
49	741776.9	9058387	7	4.5	Hit semi consolidated sand at 2.4 m Foram rich sand.
50	741813.5	9058419	5.5	6	Easy drilling to 4 m - drill unaided. Then 4-6 m still easy. Sandy bottom.
51	741798	9058523	7	6	Easy drilling. Sandy bottom. Medium sand Foram rich.
52	741800.3	9058606	8	6.8	Sand all the way. Coarse sand Foram rich shell fragments some Halimeda.
53	741767.4	9058630	10.5	6.5	Sand all the way. Coarse sand Foram-rich shell fragments some Halimeda.
54	741752.4	9058711	11.5	7.5	Easy Drilling. Sand couple of tight spots - compact sand or semi consolidated. Sand coarse Foram, shell fragments.
55	741803.2	9058666	8	4.5	Sandy bottom - edge of fringing reef. Hit gravel at 3 m. Compact coarse sand gravel Foram shell and coral fragments sandy substrate.
56	741756.7	9058676	11.5	4.8	Sandy seafloor. Sand coarse shell and coral fragmented -some Halimeda and Foram. Gravel lens at 3 m. Otherwise easy drilling.
57	741726.6	9058785	12	5	Sandy seafloor, easy drilling. Sand medium to coarse.
58	741703.9	9058842	12	4.8	Sandy bottom. Easy drilling to 4.5 m. Hit gravel layer, sand coarse.
59	741678.8	9058920	11	4	Sandy bottom. Some sea grass mixture of *nama* (Fijian for a sea grape type of edible seaweed) and Halimeda. Easy drilling to 3 m - gravel lens then sandy again. Coarse sand
60	741724.6	9058948	6.5	0.7	Sandy seafloor. PD only 0.7 m rock. 7 holes drilled in area. Sand coarse.
61	741732.5	9058901	8	1.3	Sandy bottom. Number of holes drilled all shallow. Sand coarse.
62	741714.5	9058894	9.5	5	Sandy bottom, some sea grass. Camera battery flat no underwater video footage captured here. Drilled 4 holes 1.3, 1.7, 2.4 and 5 m. Sand medium to coarse.

In general, drilling was easy indicating the sediments to be unconsolidated; and was rich in Forams. The deeper sediment holes were to the south of the area, an indication that this area is closer to the source of the sand, which is beach sand that has been transported from the shore line through the channels cut into the reef to reach the shoreline. Table 14 summarises the grading results for the jetprobe holes drilled in Borrow Area 6-7-8.

Table 14 – Grading analysis summary of results for jetprobe holes in Borrow Area 6-7-8.

JP#	Easting m	Northing m	% Clay	% Silt (0.002-0.006 mm)	% Fine sand (0.06-0.2 mm)	%Medium Sand (0.2-0.6 mm)	% Coarse sand (0.6-2.0 mm)	% Fine Gravel (2-6 mm)	%Coarse Gravel
42	741672.6	9058490	0	0.7	1.4	8.5	45.1	37.7	0
43	741687.7	9058446	0	1.8	2.3	7.1	35.8	42	0
44	741786.8	9058464	0	1.1	11.7	28	42.1	16.1	0
45	741763.8	9058497	0	3	37.8	30.9	22	6.1	0
46	741757.8	9058543	0	1.3	13	22.7	38.1	22.3	0
47	741787.6	9058436	0	0.8	17.8	37	32.1	11.9	0
48	741777.3	9058417	0	0.8	10.3	32.5	37.7	17.7	0
49	741776.9	9058387	0	1.1	47.7	41.4	9	0.9	0
50	741813.5	9058419	0	0.2	16.9	40.7	32.8	9.1	0
51	741798	9058523	0	0.8	23	48.6	23.7	4.1	0
52	741800.3	9058606	0	0.9	11.3	24.6	45	17.1	0
53	741767.4	9058630	0	2	25.1	31.9	28.9	10.9	0
54	741752.4	9058711	0	0.6	8.2	25.2	45.1	19	0
55	741803.2	9058666	0	0.5	3.6	11.9	40.1	33.8	0
56	741756.7	9058676	0	4.1	29.7	19.1	30.2	15	0
57	741726.6	9058785	0	1.7	22	28.7	33.7	13	0
58	741703.9	9058842	0	0.6	4.4	23.2	48.9	21	0
59	741678.8	9058920	0	0.4	2.6	27	54.1	14.9	0
60	741724.6	9058948	0	0.2	3.4	31	44.1	16.9	0
61	741732.5	9058901	0	0.1	0.7	19	54.3	22.2	0
62	741714.5	9058894	0	0.7	7.2	34.2	42.1	14.6	0

A sample plot of the grading results for jetprobe samples from this area is provided in Figure 25. Here plots of 5 jetprobe stations are shown, two from the southern end of the resource area: JP-48 and JP-49; two holes from the middle section of the resource area JP51 and JP-46; and one from the northern end of the resource, JP-59.

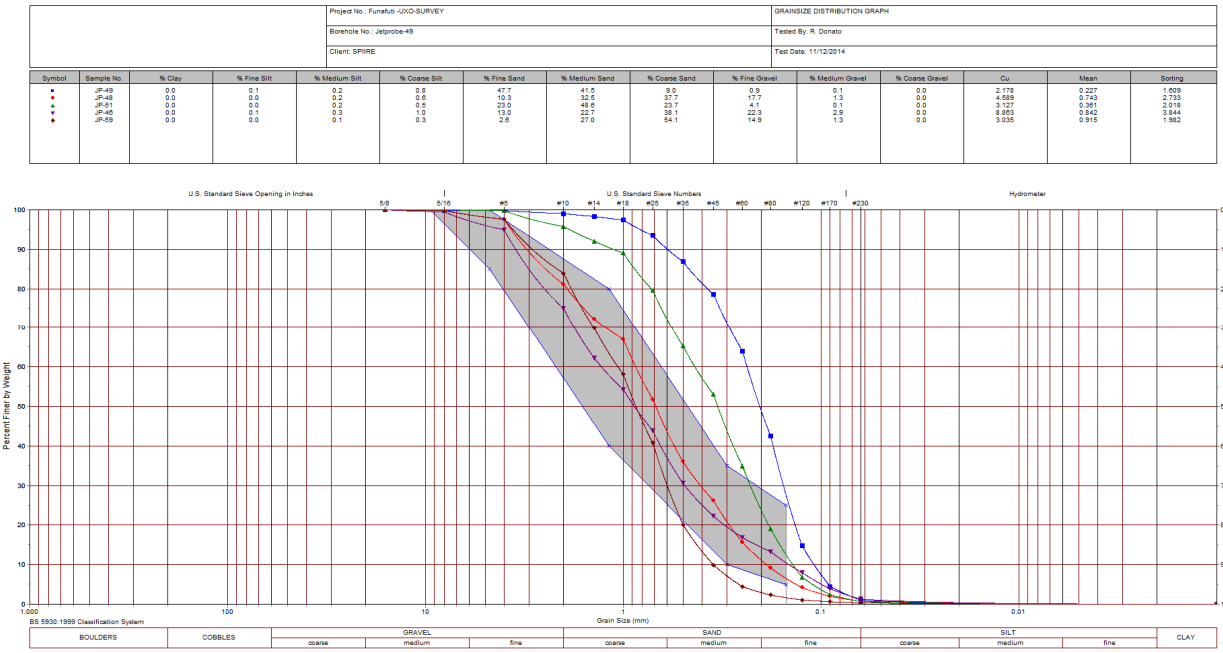

Figure 25 – Borrow Area 6-7-8 summary graph of a batch of grading results.

Individual grading curves are provided for each sample station in Appendix 1. In addition to the sampling, underwater video footage was also recorded at each location and is provided on DVD as MP4 files (Appendix 11).

Magnetic mapping and anomaly detection

Twelve magnetic line profiles at 10 m spacing representing 7.8 line kilometres was completed in Borrow Area 6-7-8. From this data, a TIN model of the data was generated to produce an anomaly map, which is shown in Figure 26. Based on the analysis of the twelve profiles, a total of 12 anomalies were detected. These are detailed in Table 15.

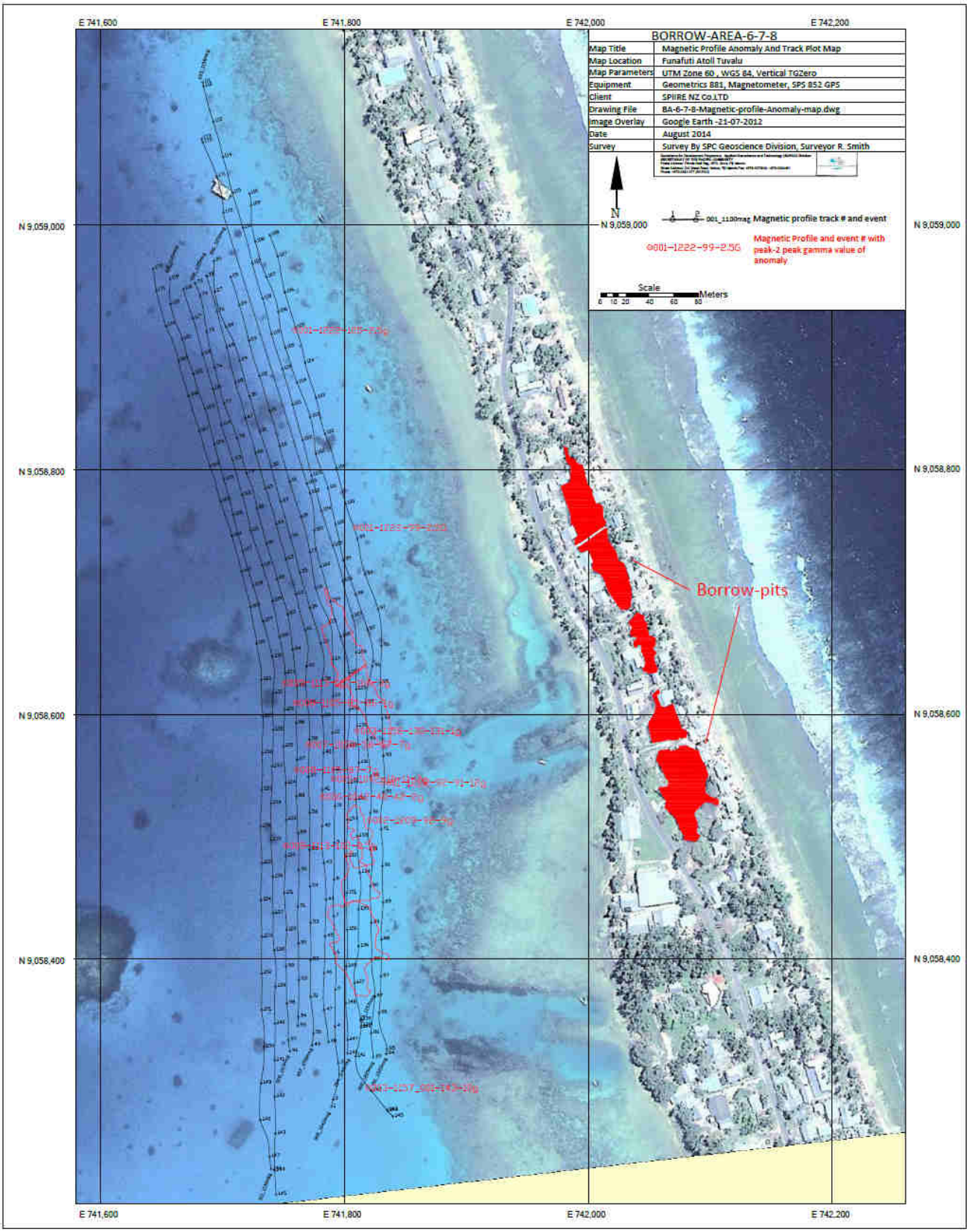

Figure 26 – Borrow Area 6-7-8 magnetic profiles with locations of interpreted anomalies plotted. For a larger scale map, see Appendix 5.

Table 15 – Borrow Area 6-7-8 listing of magnetic profile anomalies.

Profile Anomaly Field is Line # Event Number Peak-2-Peak value	Easting m	Northing m	Anomaly configuration
005-1042-10-11-7g	741790.9	9058547	broad anomaly - monopole
006-1042-40-42-2g	741782.1	9058533	complex anomaly - 2 monopoles
007-1058-58-57-7g	741770.5	9058575	monopole anomaly
008-1105-87-7g	741760.8	9058555	monopole - broad anomaly
003-1157_001-143-10g	741819.5	9058295	anomaly 2 monopoles
002-1209-92-9g	741820.4	9058514	broad Multiple anomaly
001-1222-92-91-12g	741831.8	9058544	complex anomalies
003-1158-130-131-1g	741810.3	9058586	broad monopole anomaly
001-1222-99-2.5G	741809.4	9058753	broad monopole
001-1222-105-2.5g	741759.4	9058914	small but distinct monopole
009-1113-107-106-3g	741751.3	9058626	small monopole
009-1113-102-0.5g	741752	9058493	small monopole
008-1105-85-86-1g	741760.1	9058610	small monopole

Only a small number of anomalies were detected in this resource area and most appear to cluster around the entrance to the small channel dug into the fringing reef for shoreline access. As the channel was built for war time proposes it would appear that the cluster of anomalies around the entrance may be considered, in part, to be operational material dropped or tossed during operations. High sedimentation from beach loss has resulted in the sources of these anomalies being buried.

Borrow Area 9-10

Bathymetry

Figure 27 is the bathymetry of the area labelled Borrow Area 9-10. This borrow area lies west of Vaiaku and the Catalina Ramp, which is located in the hook of Fongafale islet. This area represents a large shallow shelf extending some 500 m west from the lagoon shoreline of Fongafale. The image backdrop is from Google Earth Pro and is dated 21072012. This image is exceptionally clear with excellent resolution that is better than the 2008 QuickBird image. Bathymetry contours are from the SOPAC 2009 single beam survey, which is reproduced here with a 1 m contour interval. Clearly visible in the image is a sunken barge, upright in approximately 7.5 m water depth. There are many very small but scattered reef patches throughout the area in what is otherwise a very sandy substrate. A large-scale plot of this map is provided in Appendix 6.

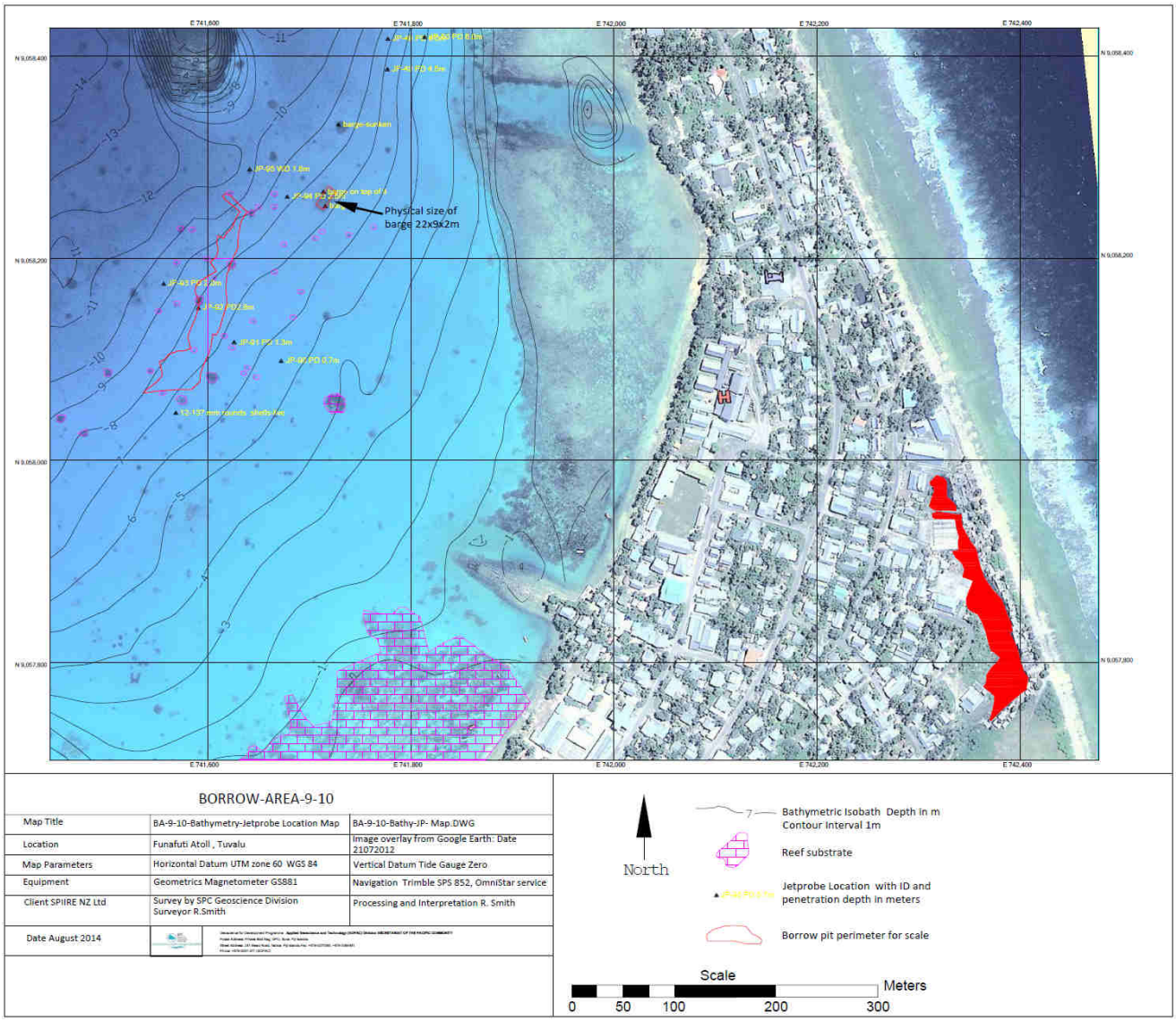

Figure 27 – Borrow Area 9-10 bathymetry and jetprobe location map. For a larger scale map, see Appendix 6.

Jetprobe sampling and grading analysis

Six jetprobe holes were drilled in this area, numbered JP-91 to JP-95. Sediment thickness drilled ranged from 0.7 m to 2.8 m. At all the jetprobe holes in this area, solid reef substrate was intersected. The interpretation here is that only a veneer of sand (some one to two meters thick) covers reef pavement substrate. More than one hole was drilled at a number of locations to test if penetration was limited either by solid substrate, or a solitary rock, or buried small coral reef patch. From the drilling results, it is also interpreted that there is an overlying layer of gravel at the reef substrate level. The data for the jetprobe holes for this area are tabulated in Table 16. For the 6 jetprobe holes, the average depth was 1.85 m.

Table 16 – Borrow Area 9-10 jetprobe data for holes JP-90 to JP-95.

JP#	Easting m	Northing m	Water Depth m	Hole Depth m	Comments
90	741672.4	9058098	5.5	0.7	Sandy bottom - occasional coral head can be seem in area. Gravelly sand white - off white. Solid bottom at base of hole. Number of holes drilled same result.
91	741625.9	9058116	7	1.3	Sandy bottom. Sand 0-0.5 m gravel to 1.3 m. Sand coarse off white.
92	741590.6	9058151	8	2.8	Sandy bottom. 3 holes 1.5 m, 2.0 m 2.8 m gravel intersected at 2 m. Sand recovered - coarse gravelly sand.
93	741556.4	9058175	9.5	2	Sandy bottom. Sand 0-1 m gravel 1-2 m - 3 holes, first hit rock 0.7 m
94	741678.4	9058260	8	2.5	Sandy bottom nothing to anchor to. 3 holes drilled bedrock contact in each - 1.5 m and 2 m, gravel at 1 m. Visibility about 10 m
95	741641	9058288	9	1.8	Sandy bottom. Number of holes all shallow holes bottomed out in reef. Fine to medium off-white sand recovered.

Table 17 – Borrow Area 9-10 grading analysis summary for jetprobe samples.

JP#	Easting m	Northing m	% Clay	% Silt (0.002-0.006 mm)	% Fine sand (0.06-0.2 mm)	%Medium Sand (0.2-0.6 mm)	% Coarse sand (0.6-2.0 mm	% Fine Gravel (2-6 mm)	%Coarse Gravel
90	741672.4	9058098	0	0.3	4.2	13.1	33.9	27	0
91	741625.9	9058116	0	0.1	4.4	34.4	43.7	13	0
92	741590.6	9058151	0	0.3	6.4	30.9	49.1	12.5	0
93	741556.4	9058175	0	0.4	7.1	31.1	33.1	20.9	0
94	741678.4	9058260	0	2	31.7	37.3	23.9	4.7	0
95	741641	9058288	0	1	24.3	40.4	26	6.1	0

In general, drilling was a little more difficult in this area due to the gravel layers intersected and shallow bedrock. Table 17 summarises the grading results for the jetprobe samples from holes drilled in Borrow Area 9-10.

A plot of the grading results for jetprobe samples from this area is provided in Figure 28.

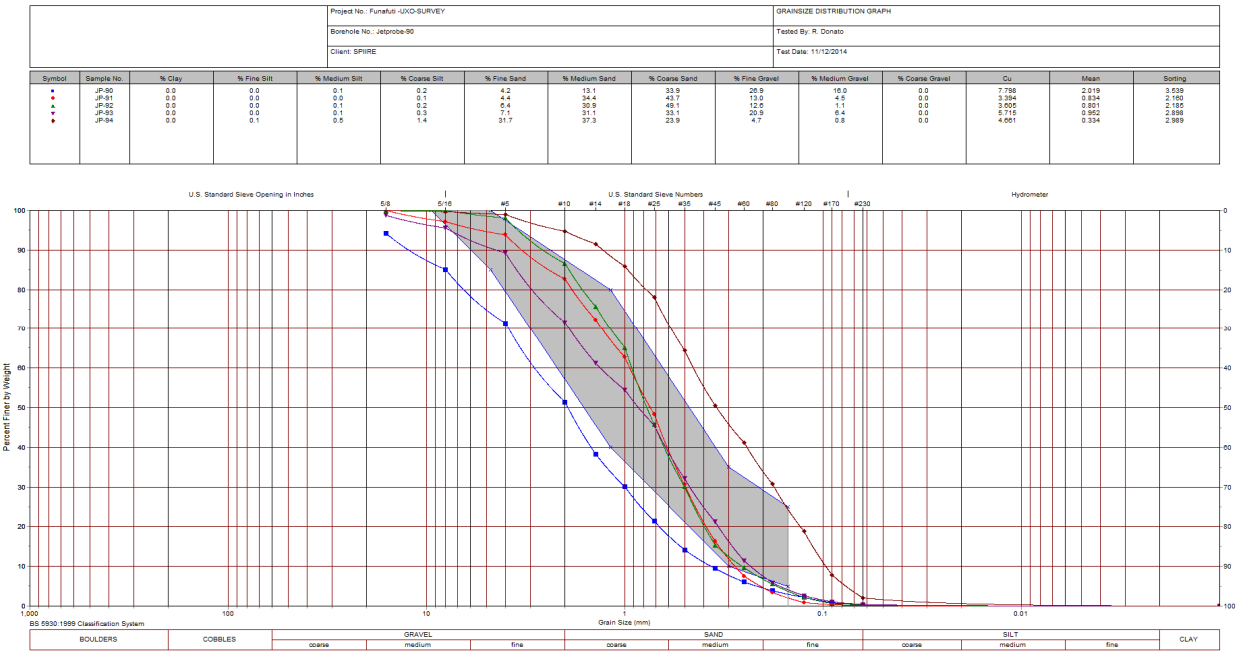

Figure 28 – Borrow Area 9-10 grading results summary.

Magnetic mapping and anomaly detection

Thirteen magnetic line profiles at 10 m spacing representing 5.7 line kilometres was completed in Borrow Area 9-10. From this data, a TIN model of the data was generated to produce an anomaly map, which is shown in Figure 29. Based on the analysis of the thirteen profiles, a total of 46 anomalies were selected. These are detailed in Table 18.

Table 18 – Borrow Area 9-10 listing of magnetic anomalies identified from profile data.

Profile Anomaly Field is Line # Event Number Peak-2-Peak value	Easting	Northing	Anomaly shape and source
001-1239-10-131-55g	741753.2	9058244	Large monopole - associated with barge located on line
001_1239-134-135-14g	741707.1	9058172	Dipole anomaly
001-1239-136-137-10g	741678.9	9058127	Dipole anomaly
001-1239-140-141-4g	741612.9	9058022	Monopole - very distinct
002-1244-153-154-118g	741742.9	9058246	Dipole anomaly - very strong -related to barge on line 005-1300
002-1244-149-4g	741672.1	9058134	Monopole - weak but distinct
002-1244-147-3g	741639.7	9058085	Monopole - weak anomaly
002-1244-145-2g	741609.5	9058027	Monopole weak anomaly
003-1249-167-377g	741728.5	9058244	Dipole - strong anomaly -barge located on line005-1300
004-1254-187->1151g	741729.8	9058260	Dipole - very strong anomaly -barge on line 5 source
004-1254-180-7g	741604	9058063	Monopole - appears weak but on same line as barge so scale of amplitudes
005-1300-200->1200g	741716.1	9058260	Dipole - source at event 200 Amplitude >1000 g
005-1300-208-29g	741582	9058048	Monopole - strong anomaly -distinct new source
006-1306-222->1100g	741711.3	9058273	Dipole - barge source
006-1306-215-7g	741604	9058106	Monopole - small anomaly but distinct
006-1306-214-18g	741588.9	9058080	Monopole - small but distinct
007-1311-234-433g	741694.1	9058266	Dipole - barge anomaly
007-1311-237-2g	741647.3	9058186	Monopole - weak but present
007-1311-238-2g	741630.1	9058161	Monopole - weak but present
007-1311-242-2g	741568.2	9058066	Monopole - weak but easy to identify
008-1316-255-161g	741700.3	9058292	Dipole anomaly - from barge - anomaly weaker as distance from source increases
008-1316-252-251-6g	741643.2	9058200	2 monopole anomalies seen here - 2 sources.
008-1316-249-248-weak	741597.8	9058127	Faint monopole anomaly
008-1316-248-247-weak	741582.7	9058103	Possible monopole - weak signal
008-1316-246-2g	741556.5	9058067	Monopole - weak anomaly
009-1321-266-269-78g	741676.9	9058277	Dipole - anomaly broad effects of barge at distance
010-1326-290-2g	741729.8	9058380	Monopole - anomaly weak but distinct
010-1326-289-5g	741715.4	9058355	Monopole - distinct anomaly new source
010-1326-286-51g	741668.6	9058281	Dipole - broad anomaly form barge @54 m distant
010-1316-281-2g	741588.2	9058151	Broad dipole weak but distinct
010-1316-278-2g	741540	9058076	Monopole anomaly broad - weak but distinct
011-1331-2g	741706.5	9058361	Broad monopole anomaly
011-1331-297-2g	741688.6	9058337	Broad monopole anomaly
011-1331-300-13g	741641.8	9058259	Dipole - possible source barge distant @72 m
011-1331-304-305-1g	741574.4	9058149	Broad monopole - source probable closer to line 10@280-281
011-1331-305-306-weak	741559.3	9058129	Hint of possible monopole between 305-306
012-1336-322-320-6g	741701	9058372	Compound anomalies - monopoles - possible more than one target source
012-1336-318-19g	741651.4	9058290	Dipole - anomaly from barge
012-1336-314-313	741579.2	9058175	Dipole - broad anomaly - low amplitude but distinct
012-1336-310-311-2g	741534.5	9058099	Monopole anomalies - suggesting more than one source
013-1342-328-329	741682.4	9058359	Weak monopole - possible anomaly
013-1342-329-330-weak	741666.6	9058334	Weak monopole possible anomaly
013-1342-332-2g	741629.4	9058273	Broad monopole - barge likely source
013-1342-336-8g	741562.7	9058167	Monopole - distinct - but broad.
013-1342-337-2g	741546.2	9058143	Monopole - broad
013-1342-338-5g	741535.2	9058120	Monopole - broad - distinct

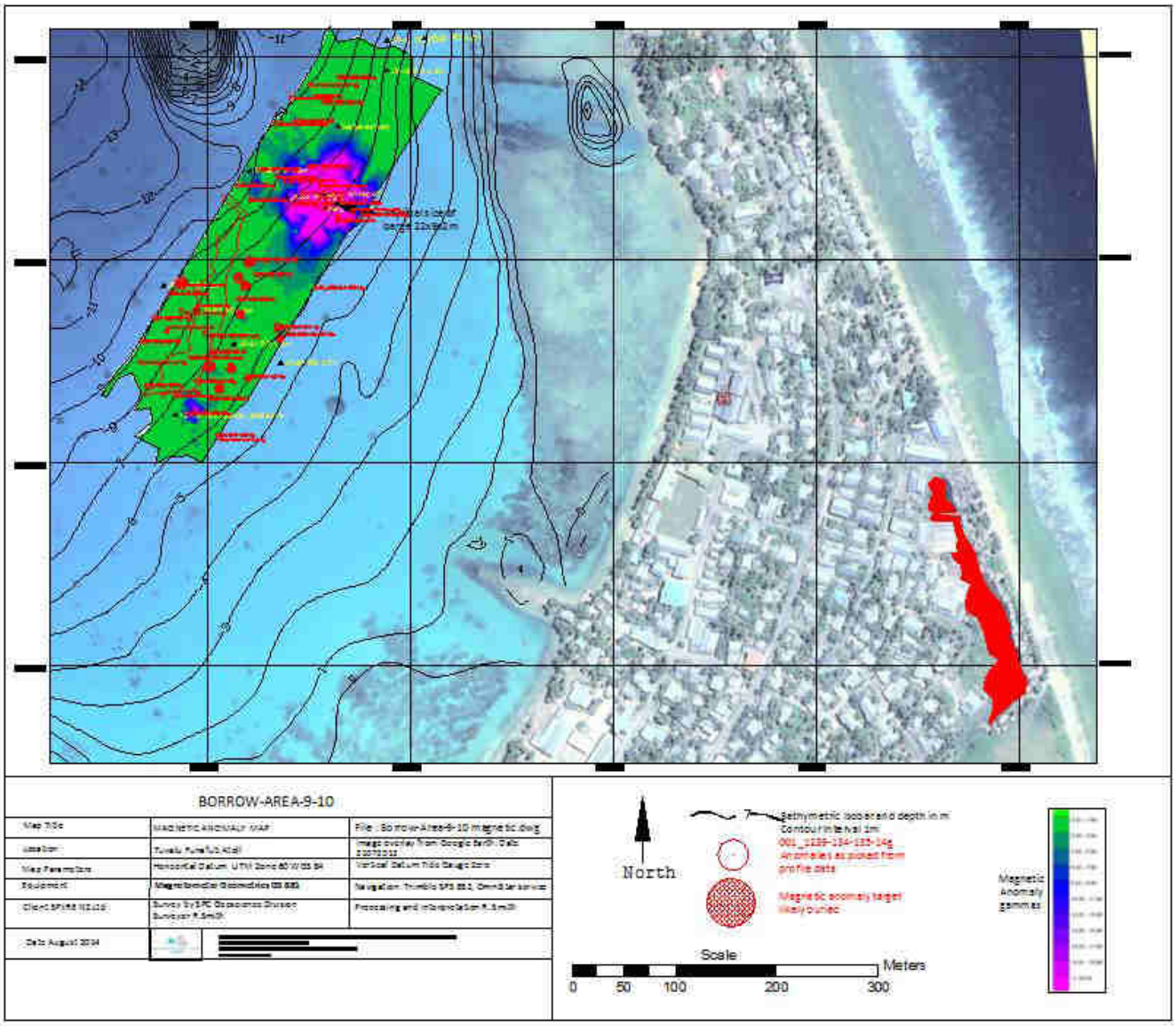

Figure 29 – Total Field Magnetic Anomaly map for Borrow Area 9-10.

In Figure 29, the anomaly produced by the sunken flat-top barge (dimensions are 22x9x2 m) dominate the magnetics in this area. At the front of the sunken barge (northeast end) a large spherical object which is mostly buried is visible. It is thought that this is an old mooring buoy. At a separate location, live rounds of 50-calibre machine gun bullets were found. These are shown in Plate 4. Given that this area was used as a seaplane mooring base during WWII, it is thought that these items were dropped either during loading and unloading operations. It is therefore reasonable to expect many other items of this nature to occur in this locality. This is reflected in the number of anomalies picked out from the individual profiles as shown in Figure 29. This suggests that Borrow Area 9-10 is the most contaminated of the five areas studied.

Plate 4 – Top Frame: Live 50-calibre rounds found at the base of a small coral reef patch. Bottom frame: a mooring buoy next to sunken barge, partially buried in sediments, in Borrow Area 9-10.

DIAMOND DRILL CORE HOLES AT PROPOSED FISHERIES NEW BUILDING COMPLEX

To assist with national civil design works, 3 diamond drill holes were drilled in the courtyard of the Fisheries Department. This drilling was supplementary and not actually part of the original project. Equipment used was a Shaw Back pack drill that is able to produce diamond rock core 37 mm in diameter. Depths greater than 6 m have been achieved with this system.

Figure 30 shows the locations of the three holes drilled. Drilling was difficult, particularly in the top section as the material tended to be broken with a mix of gravel and sand resulting in up-hole collapse, where gravel pieces jammed the drill rod. On all occasions gravel blocked the hole when the drill string was withdrawn to extract the core. The three holes drilled had final depths of Fish-01, 1.07 m; Fish-02, 2.23 m; and Fish-03, 3.2 m.

Figure 30 – Drill hole locations in the courtyard of the Fisheries Department, Fongafale. On the left, drill holes Fish-02 and Fish-03 were drilled. Drill hole Fish-03 was drilled through the concrete which help support the upper part of the hole. Drill hole Fish-01 was drilled adjacent to the room used as a library.

A log of drill hole Fish-03 was compiled based on the interpretation of the rock core recovered. This is shown in Figure 31. Fish-03 was the only hole logged; it being the deepest. It is considered a good representation of the lithology of the other two holes.

SPC- SOPAC
Ocean and Islands Programme
Mead Road, Suva
Fiji Islands

LOG OF BORING No. Fish-03

Station:
Offset:

Date Drilled: 23-07-2014	**Supervisor: Robert Smith**	**Notes:** Hole Location
Casing Length: none	**Ground Elevation: GL -approx 3m above MSL**	Easting 741760.28 m Northing 9059317.70 m
Hammer Type: Gravity ☐ Automatic ☐ Other ☐		
Water Level: MSL	**Drilling Method: Diamond RC**	

Depth (m)	MATERIAL DESCRIPTION	Lithologic Symbol	Sample Type	Drilling data
0	Ground Surface			
	Concrete pad			
	Gravel sand mix. Unconsoildated with sand washing out			
	Coral reef limestone			
	Gravel sand layers -sand washes out.Unconsolidated . Hole keeps jamming pipe. On pipe removal the hole blocks of at about 0.24m			
1	Reef limestone			
	Gravel -sand mix sand washing out			
	Coral framework - white porous easy drilling			
	gravel -sand			
	reef limestone with small cavity infill of cemented foraminiferal sands			
	reef limestone -slower drilling hard producing reasonable core recovery			
2	gravel -unconsolidated		RC	
	Coarse sandstone brown -forams -reef limestone -possible cavity infill cemented			
	Coarse sandstone well cemented-orange - brown -foram rich -beach rock formation			
	Reef limestone - off white hint of orange brown - fine cell structure coral framework			
	medium sandstone -orange appears well cemented and well sorted -compact			
	Reef limestone grey- some cavities showing secondary precipitation of limestone hard			
	Gravel - coral rubble and detritus Color varies from off white to grey			
	coarse sandstone - beachrock most likely cavity in fill well cemented			
3	Limestone - grey -dense			
	Gravel			
				EOH at 3.2m

LEGEND

SAMPLER TYPE		DRILLING METHOD	
SS - Split Spoon	NQ - Rock Core, 1-7/8"	HSA - Hollow Stem Auger	RW - Rotary Wash
ST - Shelby Tube	CU - Cuttings-	CFA - Continuous Flight Augers	RC - Rock Core
AWG - Rock Core, 1-1/8"	CT - Continuous Tube	D C - Driving Casing	

Figure 31 – Drill log of the core recovered from drill hole Fish-03.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Prior to undertaking this survey, little was known about wrecks and the explosive remnants of war (ERW) potential in Funafuti Lagoon. Nevertheless, some documentation from the book *Strategic Atolls* provided an excellent profile of possible ERW contamination that would be expected from WWII activities.

Undocumented underwater video footage collected by a local fisheries officer does indicate indiscriminate dumping of anti-aircraft ammunition in the lagoon. Footage was captured near a reef patch of unknown location. None were seen in the areas of this survey.

Detection of buried UXO requires application of geophysical methods that exploit contrasts in magnetic susceptibility and/or electrical conductivity of the UXO relative to surrounding soil and rock. With a lower geologic background magnetic noise the contrast between a possible target and host medium results in clearer target anomaly definition.

For this area, based on the Total Magnetic Field data collected, results delineated good contrasts for target anomalies; concluding that the detection capability is relatively independent of geologic background magnetic noise. Results even indicate increased sensitivity to small anomalies in the order of 0.5 mgal, at a range of approximately 5 m.

Mapping of five potential dredge areas was completed with a number of anomalies seen in all areas. Not all were clearly identifiable, as many appear to be buried. For example, in Borrow Area 1, a number of flagged targets not visible on the seafloor are present .These targets cluster around the small boat channel and harbour that was constructed out of the fringing reef in the north of the borrow area, as defined in this report. Due to the high sedimentation rates associated with the channel and resulting beach loss, these targets are buried. As the location lies within the approach lane to the small harbour entrance, it is thought that many of the anomalies are likely to be discarded iron debris from the LCM Base that was operational here during WWII. Borrow Area 9-10 appears to have the highest density of contamination with respect to area size.

Three wrecks were identified on the western boundary of Borrow Area 1. These lie in water depths from 12 m to 14 m; and are actually outside the resource area. Flagged as DMA-1 at this location, there appears to be more than one destroyed vessel. Of the three wrecks, DMA-1 appears to have been bombed or blown up with a considerable field of iron debris present on the seafloor. It would seem that sedimentation rates in this area are low, due to the fact that many of the items remain exposed on the seafloor even after a lapse of seventy years.

Borrow Area 2 in the northeast of the lagoon is much cleaner in terms of magnetic anomalies. Twenty-five anomalies in total were recognised in all the profiles. Of those investigated, four source items were identified as steel wire, an oven, a 44-gallon drum and sheet iron. Borrow Area 2 occupies a narrow lagoon shelf with good quality foraminifera-rich sand with an average thickness of 2.7 m in the 5 to 8 m depth range. Numerous, but scattered, small coral patches can be found in this area. A total of thirteen holes were drilled in this resource zone. Sieve analysis showed the bulk of the sand to be medium to coarse sand.

In Borrow Area 4, the resource area occupies a narrow shelf with an average width of 15 m bordered on the lagoon side by a steep slope, lagoon wards. Depth along the shelf ranges from 7 m to 9 m. Closer to the toe of the fringing reef, coral patches are more frequent. Fourteen holes were drilled in this area to an average depth of 3.9 m. Sieve analysis showed the sand to be medium to coarse in grain size. Twenty anomalies were detected in the profile data – some showing large peak-to-peak values. Visual diver inspection showed these to be mooring related items from WWII. As potential hazards to dredging and mooring operations, these have all been identified and mapped for reference in this resource area. The anomalies identified include a large mooring chain, mooring buoy, pipeline and a large anchor approximately half a tonne in size.

Borrow areas 6-7-8 lie approximately 440 m south of the new wharf. The shelf here is somewhat wider, varying between 60 m and 80 m. Depth over the shelf is between 4 m and 10 m. A small number of coral patches are present on the shelf in what is otherwise a sandy substrate. Significant quantities of sand are available on this shelf. Of the fourteen holes drilled, the average depth was 4.8 m. Sieve analysis showed the sand to have a greater range in size, from fine sand through to fine gravel in some jetprobe holes. Only a small number of anomalies were detected in this resource area and most appear to cluster around the entrance to the small channel dug into the fringing reef for shoreline access. Most, if not all, targets are buried; as no surface expressions were found.

Borrow Area 9-10 lies west of the Catalina ramp, being part of an extensive shallow shelf extending some 500 m from the shoreline. Average depth over the resource area is about 7.5 m, which otherwise is a sandy substrate with occasional coral heads. Only six holes were drilled in this area to an average depth of 1.85 m. The interpretation from the drilling is that only a veneer of sand covers the reef substrate some one to two meters thick with a gravel layer immediately above the substrate. Sedimentation in this area is low as evidenced by the fact that some source anomalies found diving remain exposed after seventy years. In general drilling here was the most difficult with limited penetration. A large sunken barge dominates with a large magnetic anomaly mapped. Some live rounds found near one reef patch not covered by sediment are considered an indicator of low sedimentation in this area. Although large in area, the thin veneer of sand averaging about 1.85 m in thickness suggests that sand resources would be limited.

Overall the good visibility in Funafuti Lagoon is certainly beneficial for UXO detection.

All data and maps are presented in a GIS compatible formats.

Recommendations

Of all the potential borrow areas mapped, Borrow Area 9-10 appears to be the most contaminated with numerous but low-intensity anomalies detected. Anomaly sizes suggest small targets, mostly buried by a surficial layer of sediment. As this area was the designated seaplane base during the war, many of these anomalies may be items dropped or dumped during routine servicing; and loading/unloading operations. The limited documentation found on wartime activities in this area indicate some seaplanes were bombed and destroyed; but it is not clear if this was at the mooring base or on land. As moored seaplanes would have been priority targets in a bombing raid, it is considered that this area has a higher risk factor for buried UXO.

Furthermore, based on the limited thickness of unconsolidated sands < 2 m in Borrow Area 9-10, this area should not be considered as a resource area.

Alternatively, should Borrow Area 9-10 be required as a source for borrow pits 9 and 10, then more detailed mapping for sediment thickness and anomaly delineation should precede any dredging.

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LIST OF ACRONYMS USED

CGS	centimeter-gram-second
CSAZ	cesium sensor active zone
DMA	dive magnetic anomaly
EMI	electromagnetic induction
ERW	explosive remnants of war
FDEM	frequency domain electromagnetic induction
GPR	ground penetrating radar
GPS	global positioning system
IAGA	international association of geomagnetism and aeronomy
IGRF	international geomagnetic reference field
LCM	landing craft mechanised
OIP	ocean and islands programme (of geoscience division)
RTK	real time kinetic
SI	international system of units
TDEM	time domain electromagnetic induction
TIN	triangulated irregular network
TMF	total field magnetometer
UXO	unexploded ordnance
WWII	second world war or world war 2

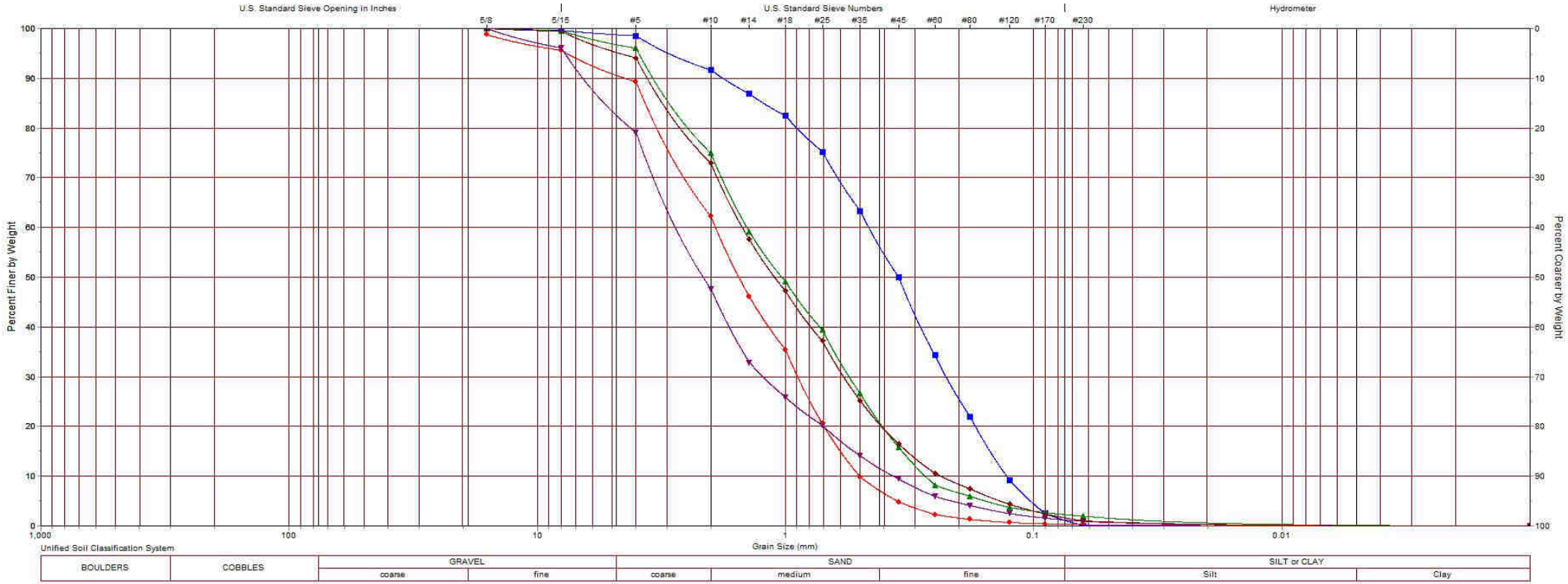
APPENDIX 1

Jetprobe Grading Analysis

BORROW AREA 1
Jetprobe grading profiles 1 through 47

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-2	Tested By: Sekove Motuiwaca
	Client: SPIIRE	Test Date: 24/11/2014

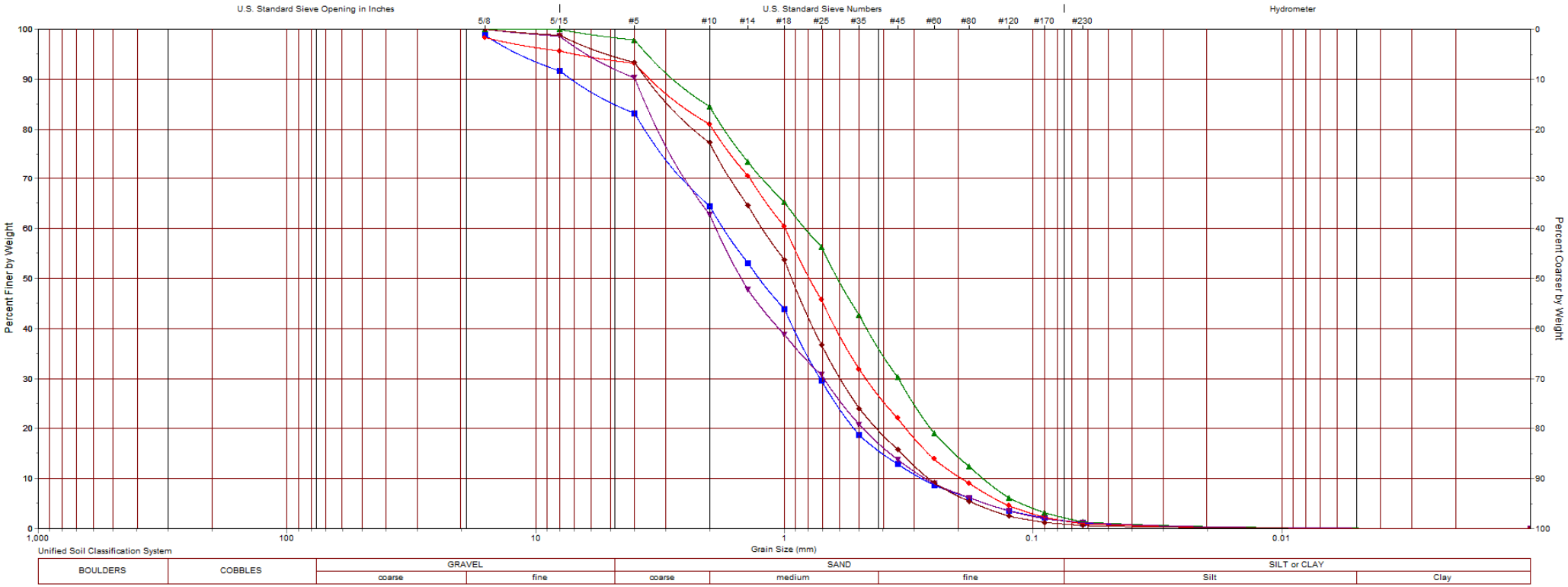
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-2	0.0	1.1	55.1	35.4	7.1	1.3	0.0	0.129	0.226	0.463	3.597	0.395	2.279
●	JP-3	0.0	0.3	6.9	55.1	28.3	8.2	0.0	0.503	0.895	1.916	3.808	1.513	2.500
▲	JP-4	0.1	2.1	18.7	54.0	21.9	3.3	0.0	0.274	0.556	1.432	5.233	1.016	2.962
▼	JP-5	0.1	1.1	10.4	36.0	34.9	17.6	0.0	0.368	1.236	2.785	7.563	1.845	3.868
◆	JP-6	0.1	1.7	19.0	52.3	22.3	4.9	0.0	0.237	0.585	1.495	6.296	1.049	3.277



Borrow Area 1 – Jetprobe holes JP2 through JP-6.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-7	Tested By: Sekove Motiwaca
	Client: SPIIRE	Test Date: 24/11/2014

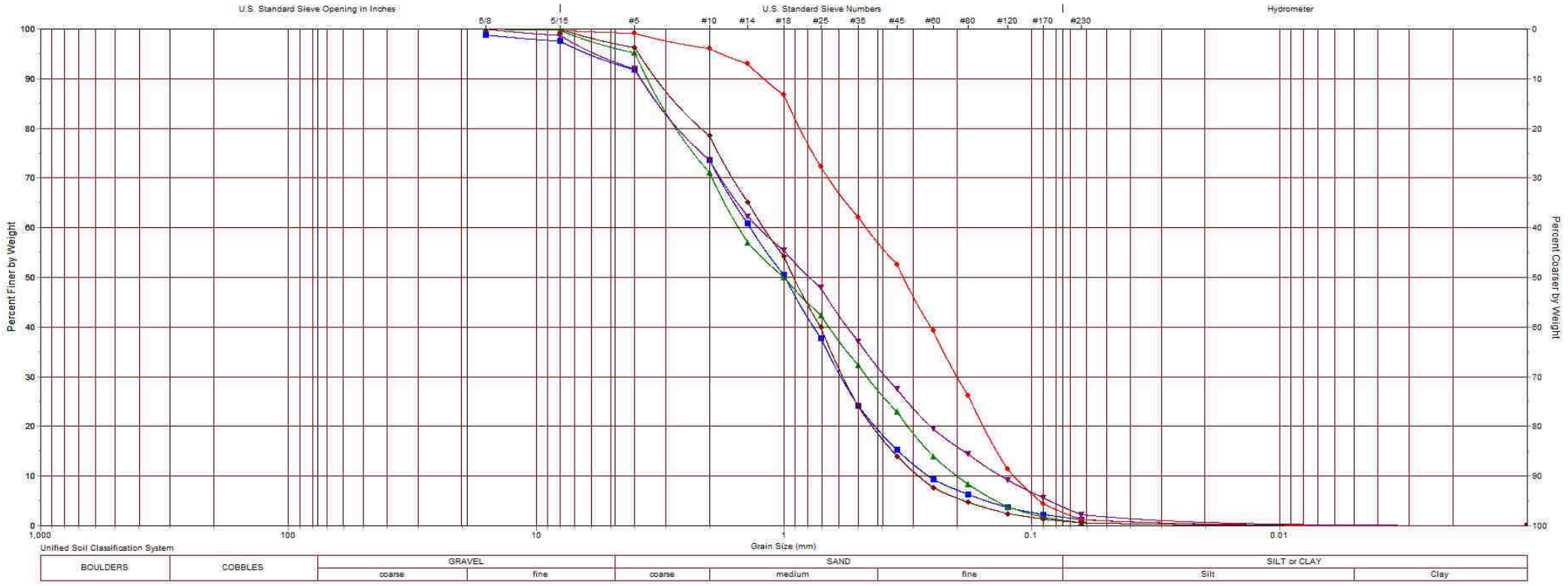
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-7	0.1	1.5	14.0	49.0	20.3	14.1	0.0	0.281	0.719	1.764	6.269	1.341	2.974
●	JP-8	0.1	1.5	25.1	54.4	12.8	4.8	0.0	0.194	0.472	0.991	5.103	0.818	2.907
▲	JP-9	0.1	2.1	34.0	48.6	13.8	1.8	0.0	0.159	0.348	0.828	5.198	0.641	2.839
▼	JP-10	0.1	1.5	15.6	45.8	29.1	8.1	0.0	0.272	0.694	1.888	6.947	1.281	3.798
◆	JP-11	0.0	1.0	18.8	57.7	17.2	5.7	0.0	0.263	0.599	1.231	4.675	0.980	2.676



Borrow Area 1 – Jetprobe holes JP7 through JP-11.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe -12	Tested By: Sekove Motiwaca
	Client: SPIIRE	Test Date: 25/11/2014

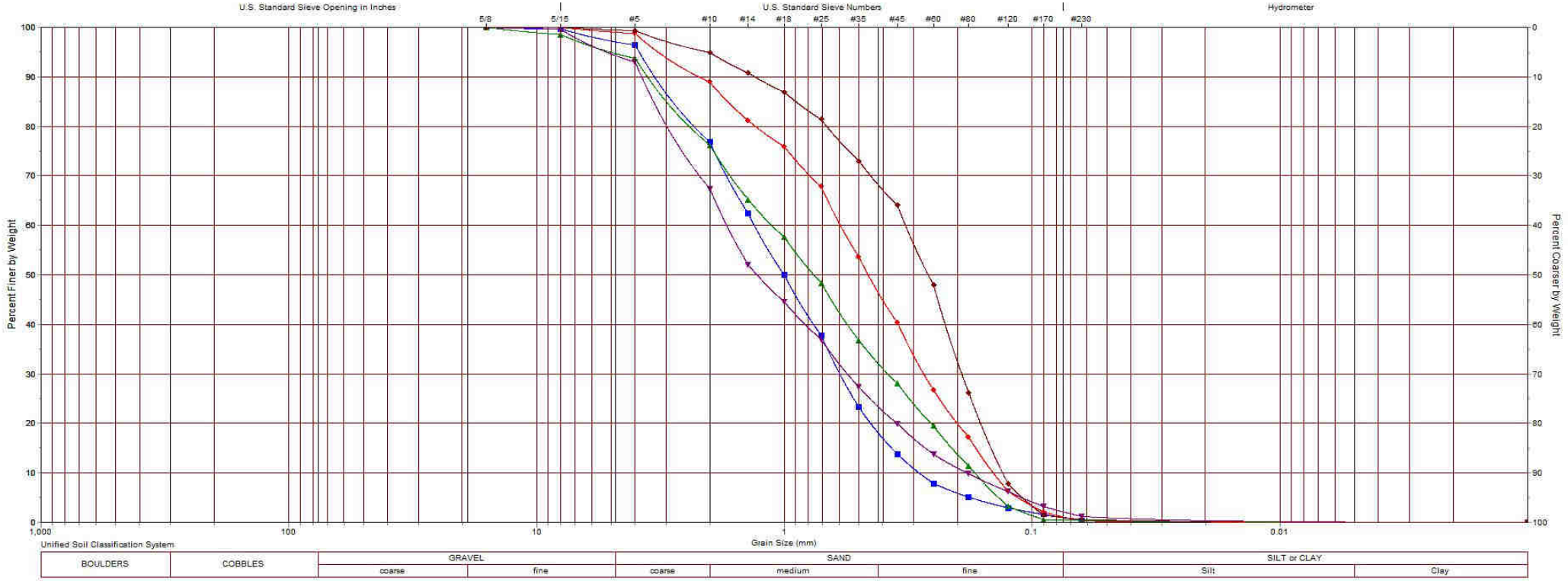
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-12	0.1	1.7	17.8	54.3	19.3	6.0	0.0	0.261	0.591	1.369	5.238	1.041	2.757
●	JP-13	0.1	2.7	54.4	39.0	3.2	0.9	0.0	0.118	0.201	0.468	3.951	0.355	2.334
▲	JP-14	0.0	1.1	26.2	43.9	25.1	4.0	0.0	0.201	0.464	1.528	7.613	0.943	3.701
▼	JP-15	0.1	3.7	28.2	41.7	19.8	6.8	0.0	0.133	0.389	1.268	9.503	0.796	3.983
◆	JP-16	0.0	1.0	17.8	59.9	18.6	3.0	0.0	0.287	0.580	1.213	4.229	0.970	2.429



Borrow Area 1 – Jetprobe holes JP12 through JP-16.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-17	Tested By: Sekove Motiwaca
	Client: SPIIRE	Test Date: 25/11/2014

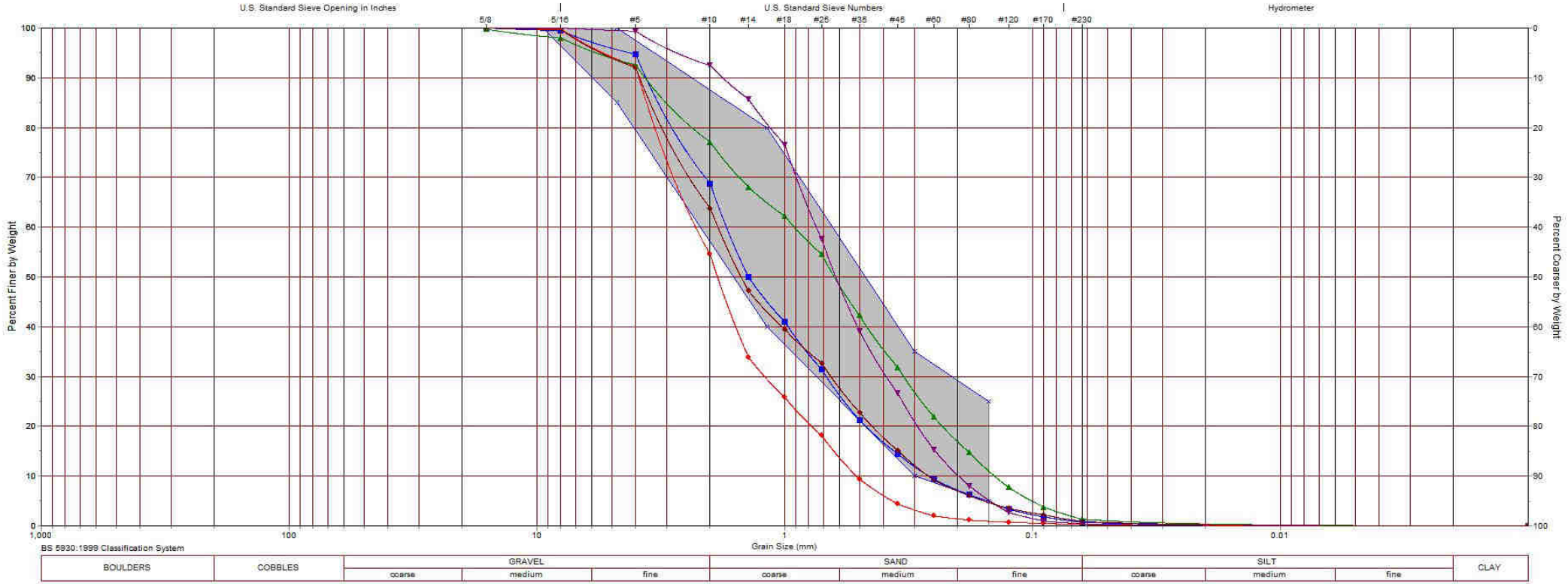
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-17	0.0	1.0	17.2	58.7	20.2	3.1	0.0	0.286	0.598	1.324	4.627	1.018	2.624
●	JP-18	0.0	1.1	45.4	42.4	10.1	1.0	0.0	0.144	0.274	0.595	4.139	0.508	2.655
▲	JP-19	0.0	0.5	31.8	44.1	18.5	5.3	0.0	0.170	0.383	1.126	6.607	0.785	3.494
▼	JP-20	0.1	2.0	21.3	44.1	27.0	5.8	0.0	0.183	0.558	1.711	9.368	1.068	4.570
◆	JP-21	0.0	1.1	67.3	26.7	4.7	0.6	0.0	0.132	0.192	0.325	2.464	0.322	1.766



Borrow Area 1 – Jetprobe holes JP17 through JP-21.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-22	Tested By: Sekove Motiwace
	Client: SPIIRE	Test Date: 25/11/2014

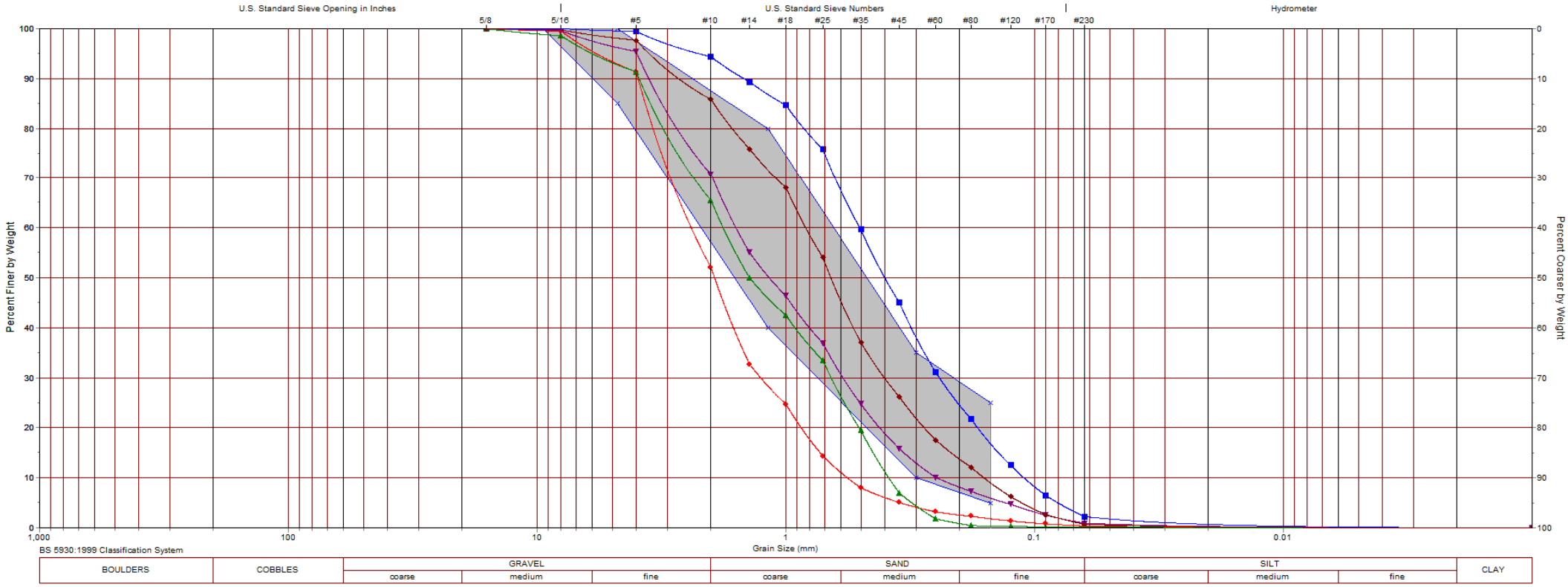
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-22	0.0	0.0	0.2	0.5	6.4	19.1	42.8	28.3	3.0	0.0	6.554	1.196	3.697
●	JP-23	0.0	0.0	0.1	0.2	1.1	12.2	41.0	41.7	4.1	0.0	4.462	1.637	2.862
▲	JP-24	0.0	0.1	0.3	1.0	15.5	31.3	29.1	18.2	4.5	0.0	6.424	0.706	3.324
▼	JP-25	0.0	0.0	0.1	0.3	9.8	37.9	44.5	7.2	0.3	0.0	3.754	0.596	2.447
◆	JP-26	0.0	0.1	0.2	0.7	6.1	20.7	36.2	32.1	4.1	0.0	7.065	1.236	4.138



Borrow Area 1 – Jetprobe holes JP22 through JP-26.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-27	Tested By: Sekove Motiwaca
	Client: SPIIRE	Test Date: 25/11/2014

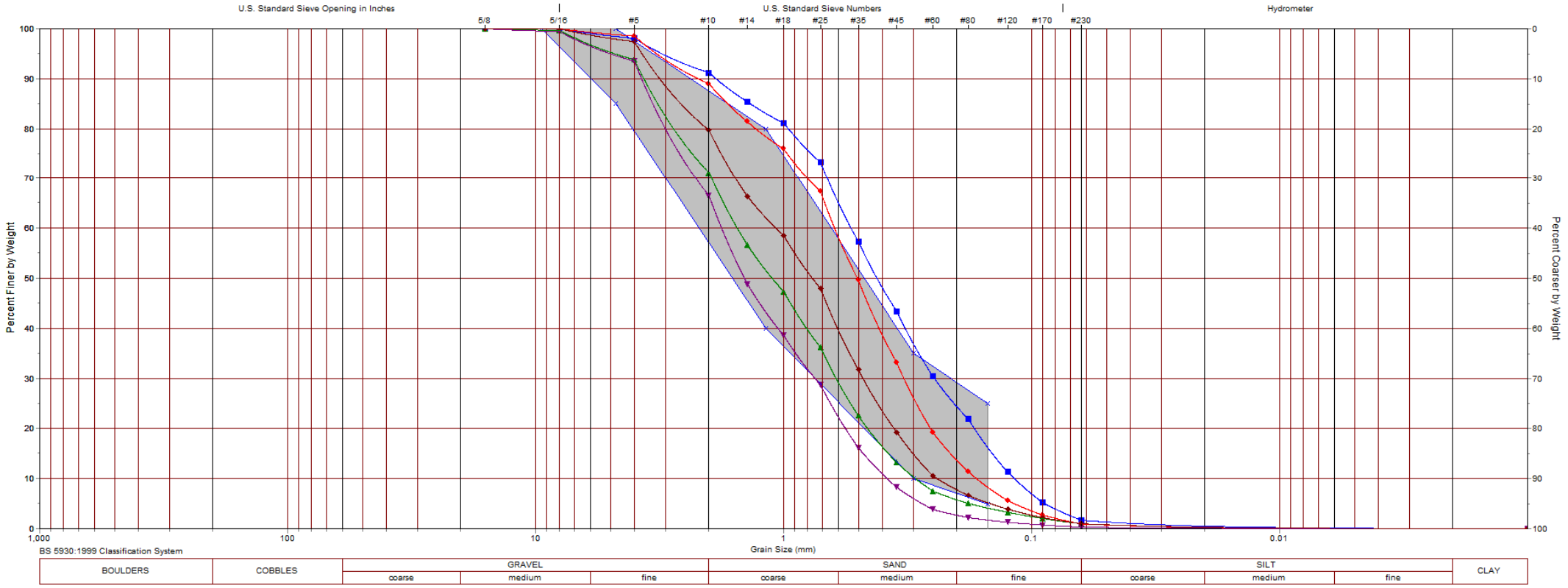
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-27	0.0	0.1	0.6	1.7	22.2	43.0	27.1	5.3	0.3	0.0	4.568	0.385	2.774
●	JP-28	0.0	0.0	0.1	0.3	2.2	8.5	41.0	43.4	4.7	0.0	4.243	1.745	2.579
▲	JP-29	0.0	0.0	0.0	0.1	0.8	25.3	39.3	29.6	5.0	0.0	4.629	1.301	3.073
▼	JP-30	0.0	0.1	0.2	0.7	7.2	22.4	40.2	26.9	2.6	0.0	6.424	1.082	3.348
◆	JP-31	0.0	0.0	0.2	0.6	13.1	31.5	40.7	13.0	1.3	0.0	5.208	0.659	2.911



Borrow Area 1 – Jetprobe holes JP27 through JP-31.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-32	Tested By: Christine Prasad
	Client: SPIIRE	Test Date: 25/11/2014

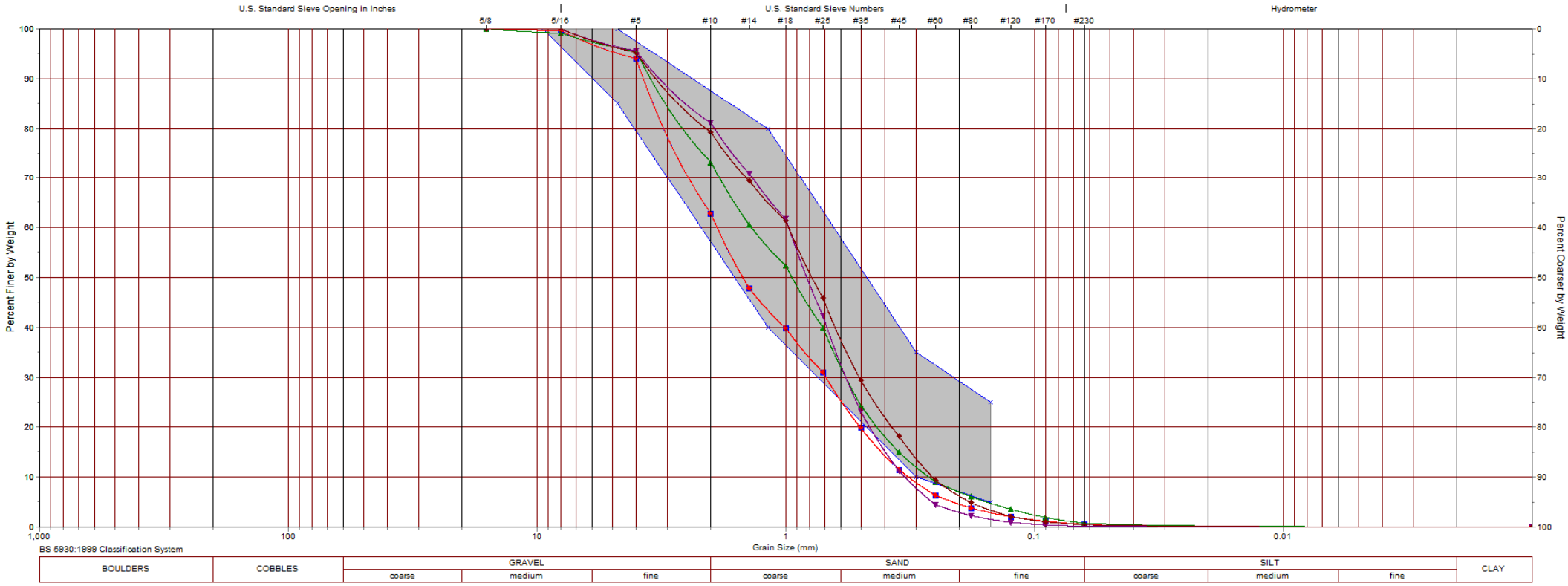
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-32	0.0	0.1	0.4	1.2	22.7	40.7	26.3	7.9	1.1	0.0	4.560	0.431	2.842
●	JP-33	0.0	0.1	0.2	0.8	12.7	44.4	31.1	10.3	0.8	0.0	3.735	0.564	2.300
▲	JP-34	0.0	0.1	0.2	0.8	4.8	23.3	42.1	25.7	3.3	0.0	5.235	1.114	2.845
▼	JP-36	0.0	0.0	0.1	0.2	2.3	19.5	44.3	30.0	3.6	0.0	4.648	1.332	2.927
◆	JP-37	0.0	0.1	0.2	0.8	6.8	31.8	40.2	19.1	1.3	0.0	4.471	0.842	2.472



Borrow Area 1 – Jetprobe holes JP32 through JP-37.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-38	Tested By: S. Motuiwaca
	Client: SPIIRE	Test Date: 12/12/2014

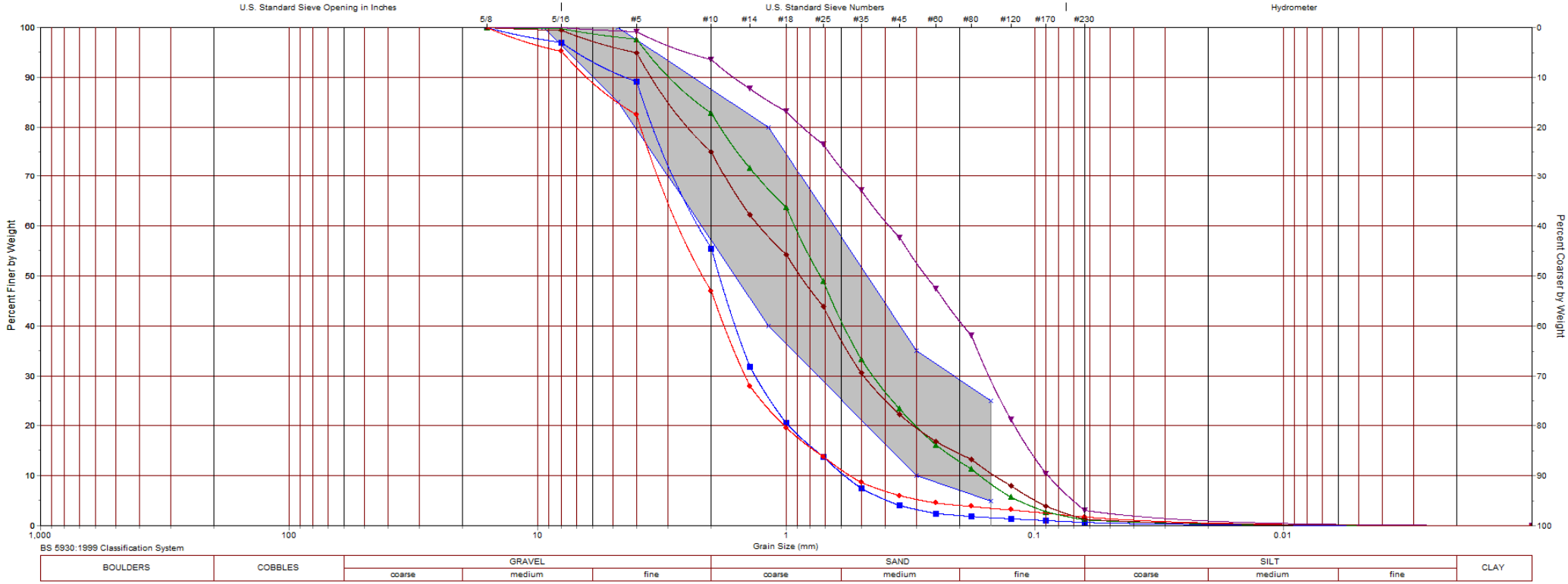
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-38	0.0	0.0	0.1	0.3	4.0	20.7	37.7	34.1	3.2	0.0	5.878	1.293	3.485
●	JP-38	0.0	0.0	0.1	0.3	4.0	20.7	37.7	34.1	3.2	0.0	5.881	1.293	3.488
▲	JP-39	0.0	0.0	0.2	0.6	6.2	25.0	41.4	24.1	2.8	0.0	5.173	1.011	2.598
▼	JP-40	0.0	0.0	0.0	0.1	2.8	29.4	48.9	16.8	2.2	0.0	2.930	0.934	2.023
◆	JP-41	0.0	0.0	0.1	0.3	5.8	31.1	42.1	18.4	2.4	0.0	3.782	0.873	2.434



Borrow Area 1 – Jetprobe holes JP38 through JP-41.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-42	Tested By: S. Motuiwaca
	Client: SPIIRE	Test Date: 11/12/2014

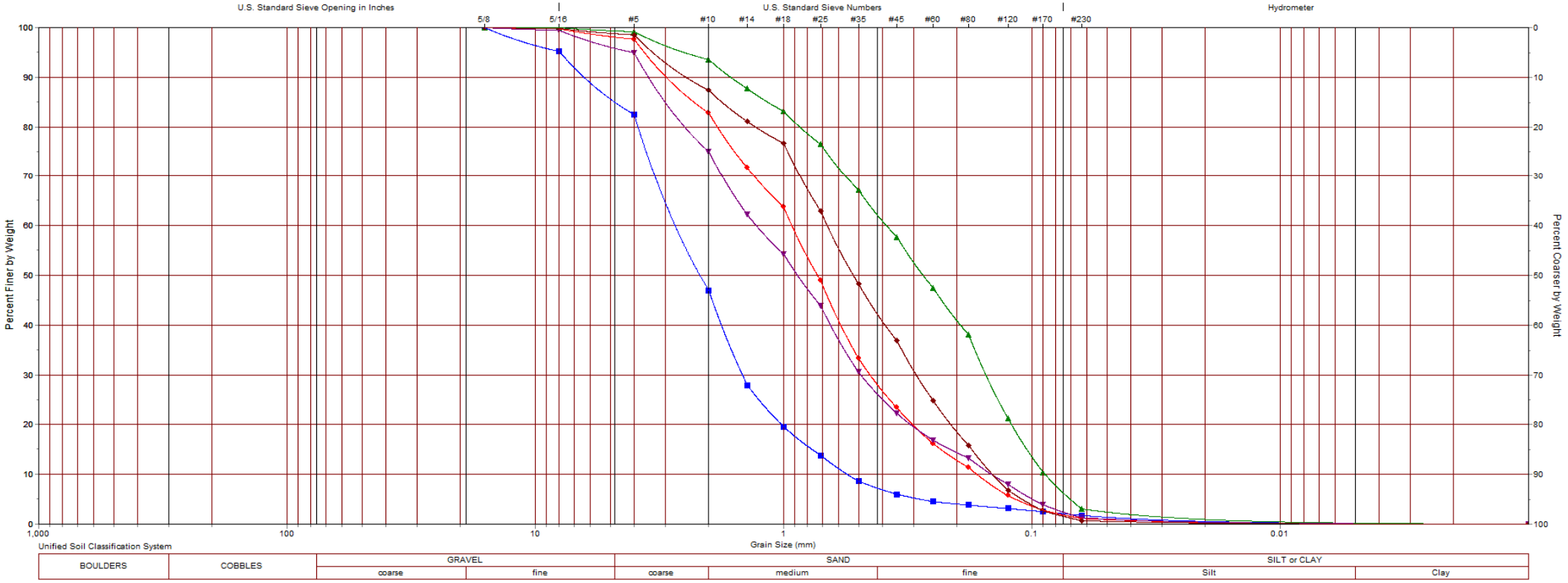
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-42	0.0	0.0	0.1	0.4	1.4	8.5	45.1	37.7	7.1	0.0	3.890	1.771	2.345
●	JP-43	0.0	0.1	0.4	1.2	2.3	7.1	35.8	42.0	11.2	0.0	4.938	2.000	2.692
▲	JP-44	0.0	0.1	0.3	0.9	11.7	28.0	42.1	16.1	1.3	0.0	5.562	0.732	2.994
▼	JP-45	0.0	0.2	0.8	2.1	37.8	30.9	22.0	6.1	0.4	0.0	4.359	0.317	2.558
◆	JP-46	0.0	0.1	0.3	1.0	13.0	22.7	38.1	22.3	2.9	0.0	8.863	0.842	3.844



Borrow Area 1 – Jetprobe holes JP42 through JP-46.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-43	Tested By: Christine Prasad
	Client: SPIIRE	Test Date: 26/11/2014

Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-43	0.1	2.1	5.2	39.7	38.1	15.0	0.0	0.555	1.467	2.743	4.941	2.000	2.695
●	JP-44	0.1	1.9	26.2	54.8	15.3	2.0	0.0	0.167	0.449	0.927	5.562	0.732	2.994
▲	JP-45	0.2	6.1	55.9	31.4	5.9	0.8	0.0	0.089	0.154	0.386	4.359	0.317	2.558
▼	JP-46	0.1	2.3	23.8	48.9	21.0	4.2	0.0	0.146	0.490	1.291	8.863	0.842	3.844
◆	JP-47	0.0	1.6	40.8	45.1	11.4	1.2	0.0	0.144	0.293	0.668	4.626	0.543	2.919

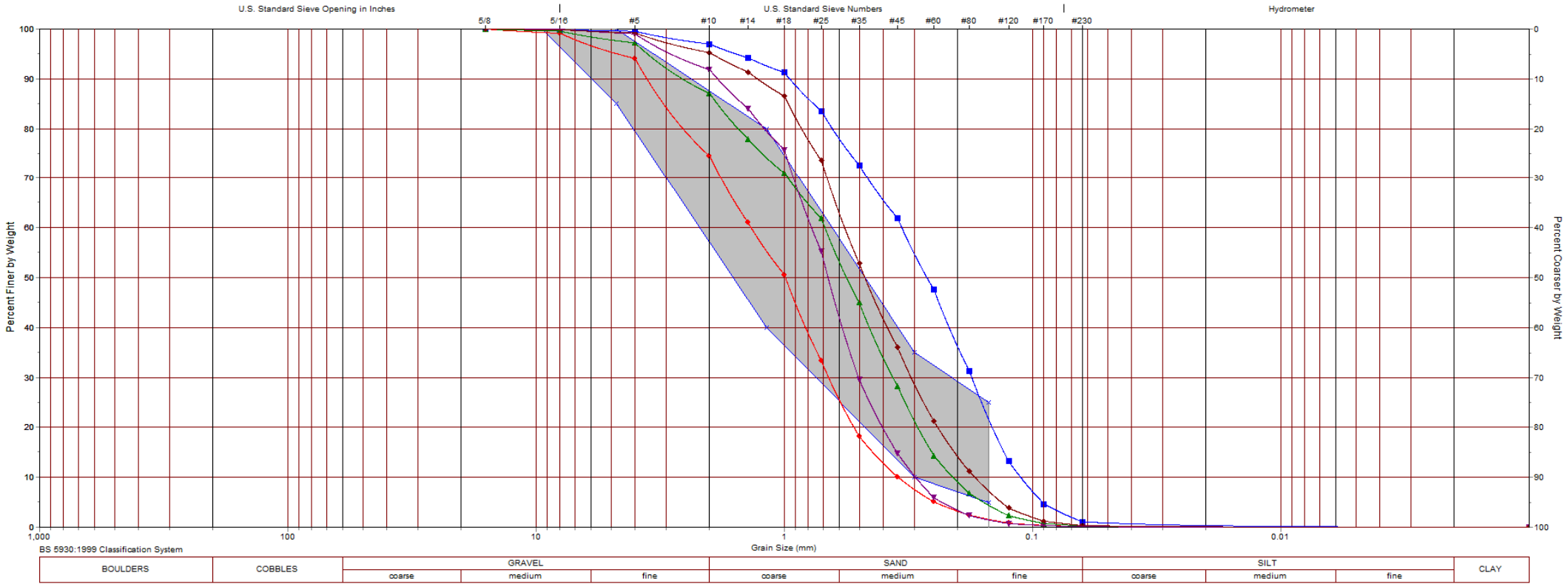


Borrow Area 1 – Jetprobe holes JP43 through JP-47.

BORROW AREA 2
Jetprobe grading profiles 63 through 75

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-63	Tested By: R. Donato
	Client: SPIIRE	Test Date: 11/12/2014

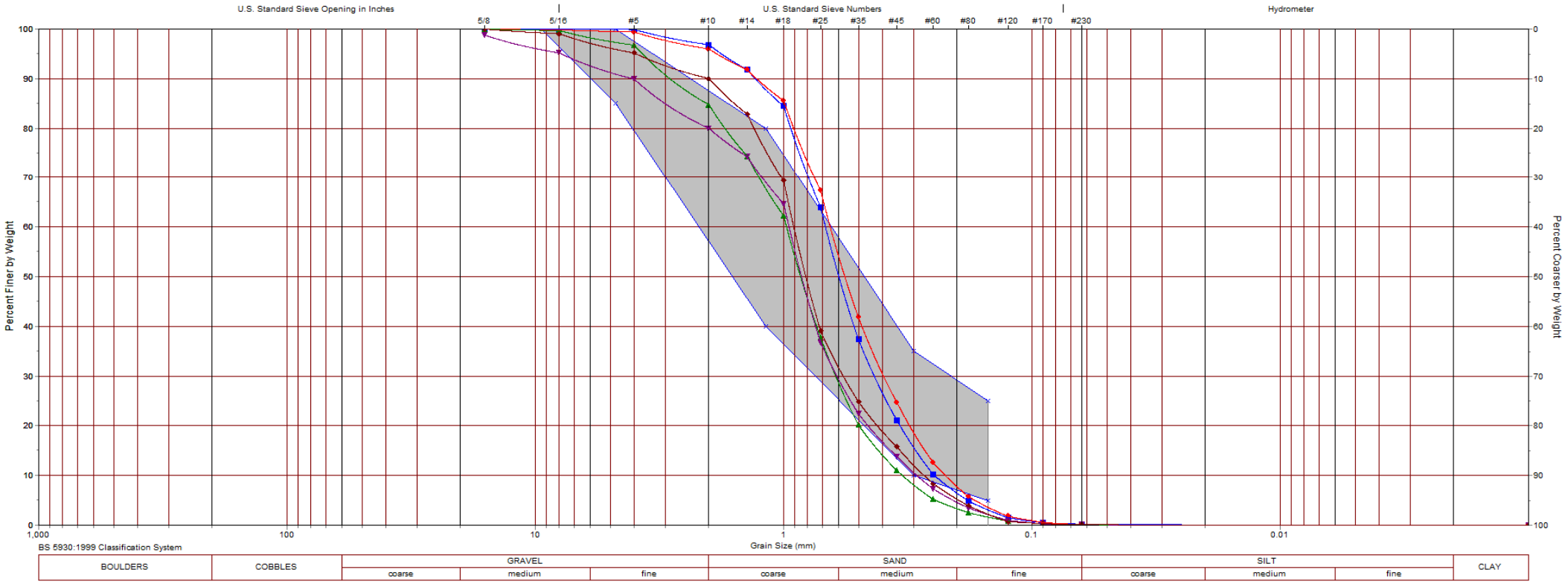
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-63	0.0	0.1	0.2	0.8	35.0	42.0	19.1	2.8	0.3	0.0	3.008	0.296	2.008
●	JP-64	0.0	0.0	0.0	0.1	3.0	22.2	49.0	22.2	3.4	0.0	3.909	1.106	2.176
▲	JP-65	0.0	0.0	0.1	0.2	8.8	44.0	34.0	11.4	1.7	0.0	3.277	0.643	2.162
▼	JP-66	0.0	0.0	0.0	0.1	3.2	38.4	50.1	7.8	0.5	0.0	2.624	0.697	1.852
◆	JP-67	0.0	0.0	0.1	0.2	13.8	48.8	32.6	4.3	0.5	0.0	3.342	0.457	2.236



Borrow Area 2 – Jetprobe holes JP63 through JP-67.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-68	Tested By: S Motuiwaca
	Client: SPIIRE	Test Date: 11/12/2014

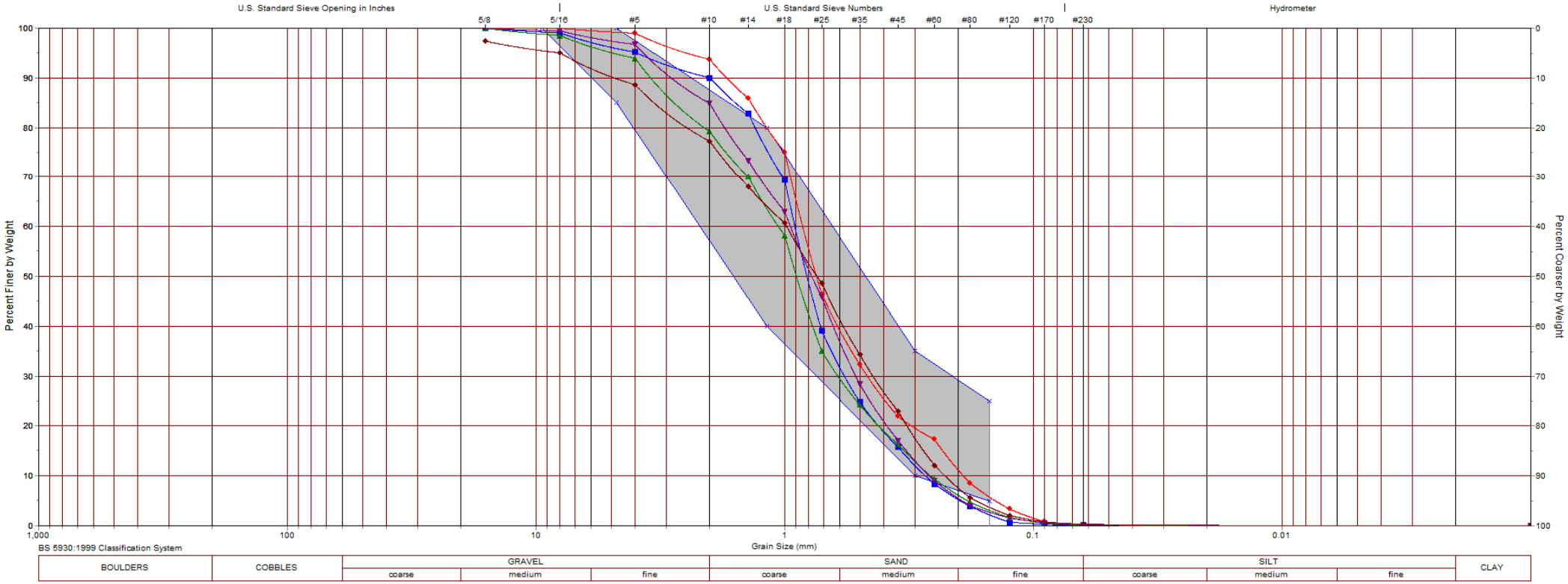
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-68	0.0	0.0	0.1	0.2	6.2	43.7	46.9	3.1	0.0	0.0	2.747	0.566	1.992
●	JP-69	0.0	0.0	0.0	0.1	7.7	46.3	42.0	3.8	0.4	0.0	2.905	0.536	2.052
▲	JP-70	0.0	0.0	0.0	0.1	3.2	25.2	56.2	13.5	1.9	0.0	2.928	0.898	1.998
▼	JP-71	0.0	0.0	0.0	0.1	4.5	24.8	50.9	12.7	6.2	0.0	3.266	0.974	2.208
◆	JP-72	0.0	0.0	0.0	0.1	5.1	26.4	58.4	7.1	3.0	0.0	3.349	0.756	2.325



Borrow Area 2 – Jetprobe holes JP63 through JP-67.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-72	Tested By: R. Donato
	Client: SPIIRE	Test Date: 11/12/2014

Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-72	0.0	0.0	0.0	0.1	5.1	26.4	58.4	7.1	3.0	0.0	3.348	0.757	2.327
●	JP-73	0.0	0.0	0.0	0.1	11.0	28.0	54.7	5.9	0.6	0.0	4.426	0.620	3.139
▲	JP-74	0.0	0.0	0.0	0.1	6.0	23.3	49.9	17.1	3.9	0.0	4.089	0.938	2.621
▼	JP-76	0.0	0.0	0.1	0.2	5.2	31.3	48.1	13.3	2.0	0.0	3.615	0.801	2.336
◆	JP-77	0.0	0.0	0.1	0.2	7.2	33.8	36.1	14.7	5.7	0.0	4.328	0.878	2.615

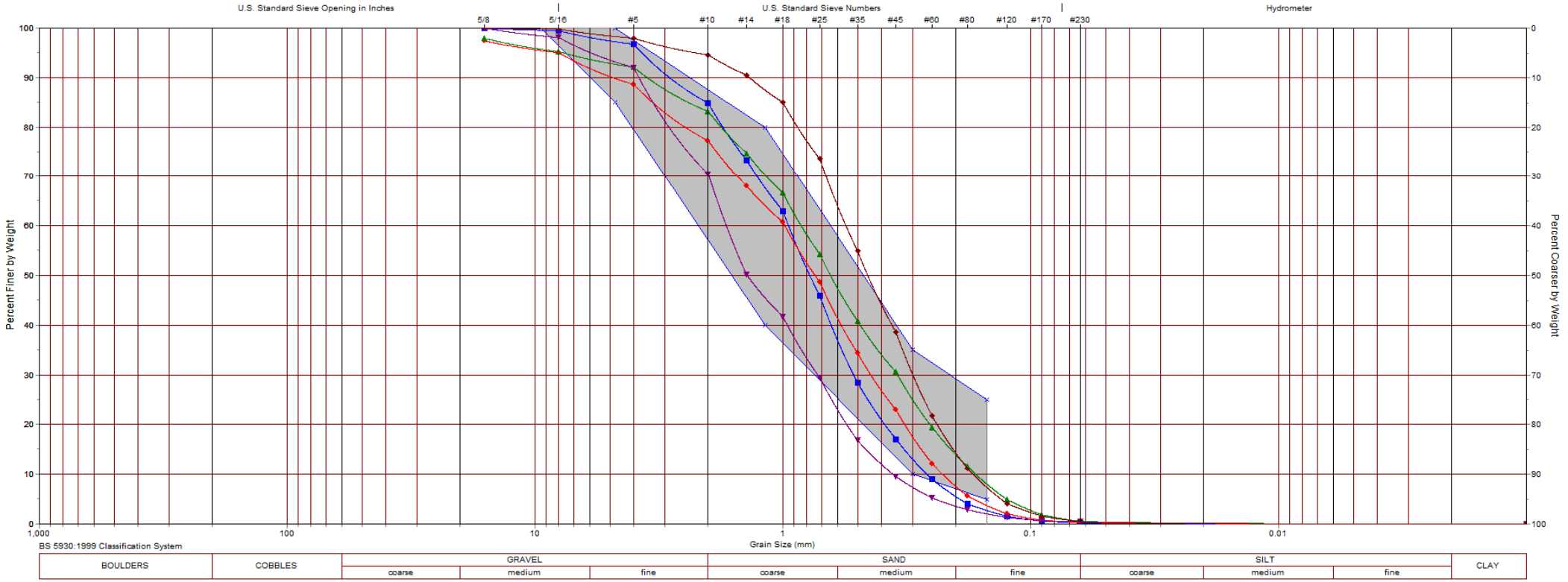


Borrow Area 2 – Jetprobe holes JP72 through JP-75.

BORROW AREA 4
Jetprobe grading profiles 76 through 89

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-76	Tested By: R. donato
	Client: SPIIRE	Test Date: 11/12/2014

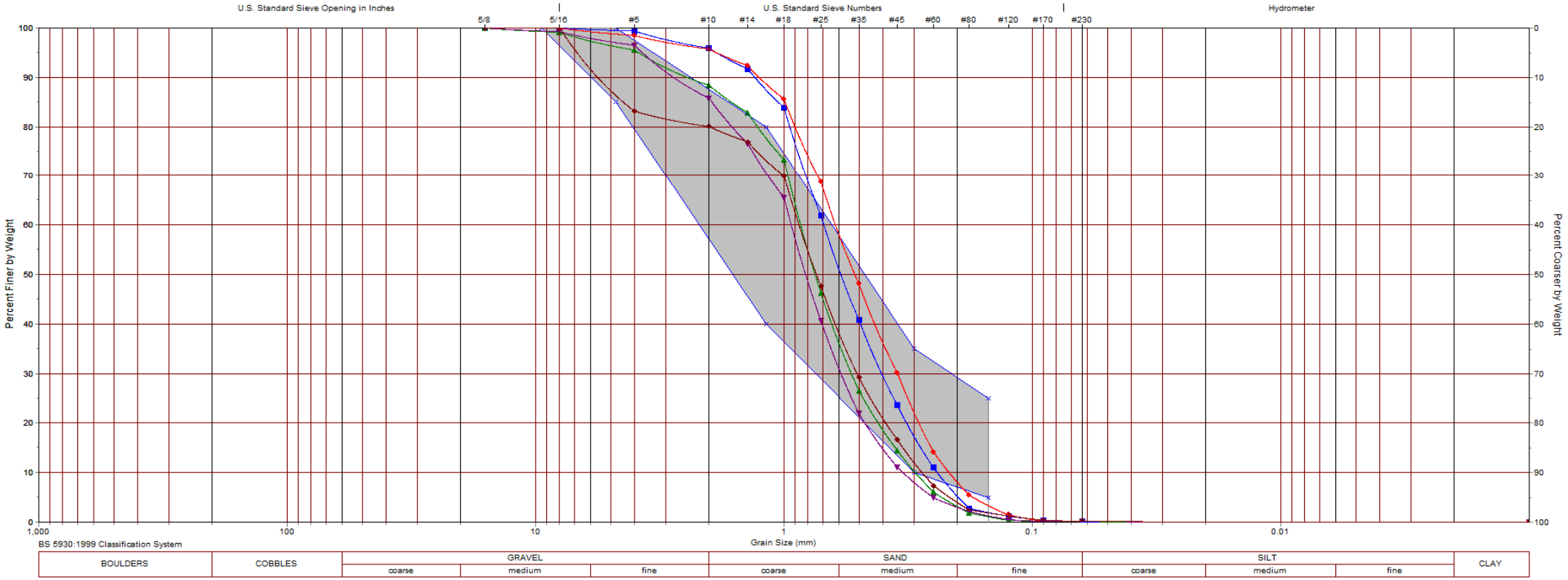
Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-76	0.0	0.0	0.1	0.2	5.2	31.3	48.1	13.3	2.0	0.0	3.617	0.801	2.335
●	JP-77	0.0	0.0	0.1	0.2	7.2	33.8	36.1	14.7	5.7	0.0	4.328	0.878	2.615
▲	JP-78	0.0	0.0	0.1	0.3	13.3	33.4	36.0	10.6	4.3	0.0	5.065	0.676	2.959
▼	JP-79	0.0	0.0	0.1	0.3	3.1	19.3	47.7	24.7	5.0	0.0	4.704	1.300	2.915
◆	JP-80	0.0	0.0	0.1	0.3	13.8	49.7	30.9	4.3	1.1	0.0	3.256	0.455	2.156



Borrow Area 4 – Jetprobe holes JP76 through JP-80.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-85	Tested By: R.Donato
	Client: SPIIRE	Test Date: 11/12/2014

Symbol	Sample No.	% Clay	% Fine Silt	% Medium Silt	% Coarse Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Medium Gravel	% Coarse Gravel	Cu	Mean	Sorting
■	JP-85	0.0	0.0	0.0	0.0	5.0	45.9	45.0	3.9	0.3	0.0	2.859	0.557	2.051
●	JP-86	0.0	0.0	0.0	0.1	7.9	50.0	37.9	3.6	0.9	0.0	2.869	0.510	1.997
▲	JP-87	0.0	0.0	0.0	0.1	3.1	32.9	52.4	9.1	2.8	0.0	2.895	0.750	2.053
▼	JP-88	0.0	0.0	0.0	0.1	2.9	28.0	55.0	12.2	2.1	0.0	2.820	0.864	1.976
◆	JP-89	0.0	0.0	0.0	0.1	3.9	34.1	42.0	11.6	8.5	0.0	3.128	1.023	2.176

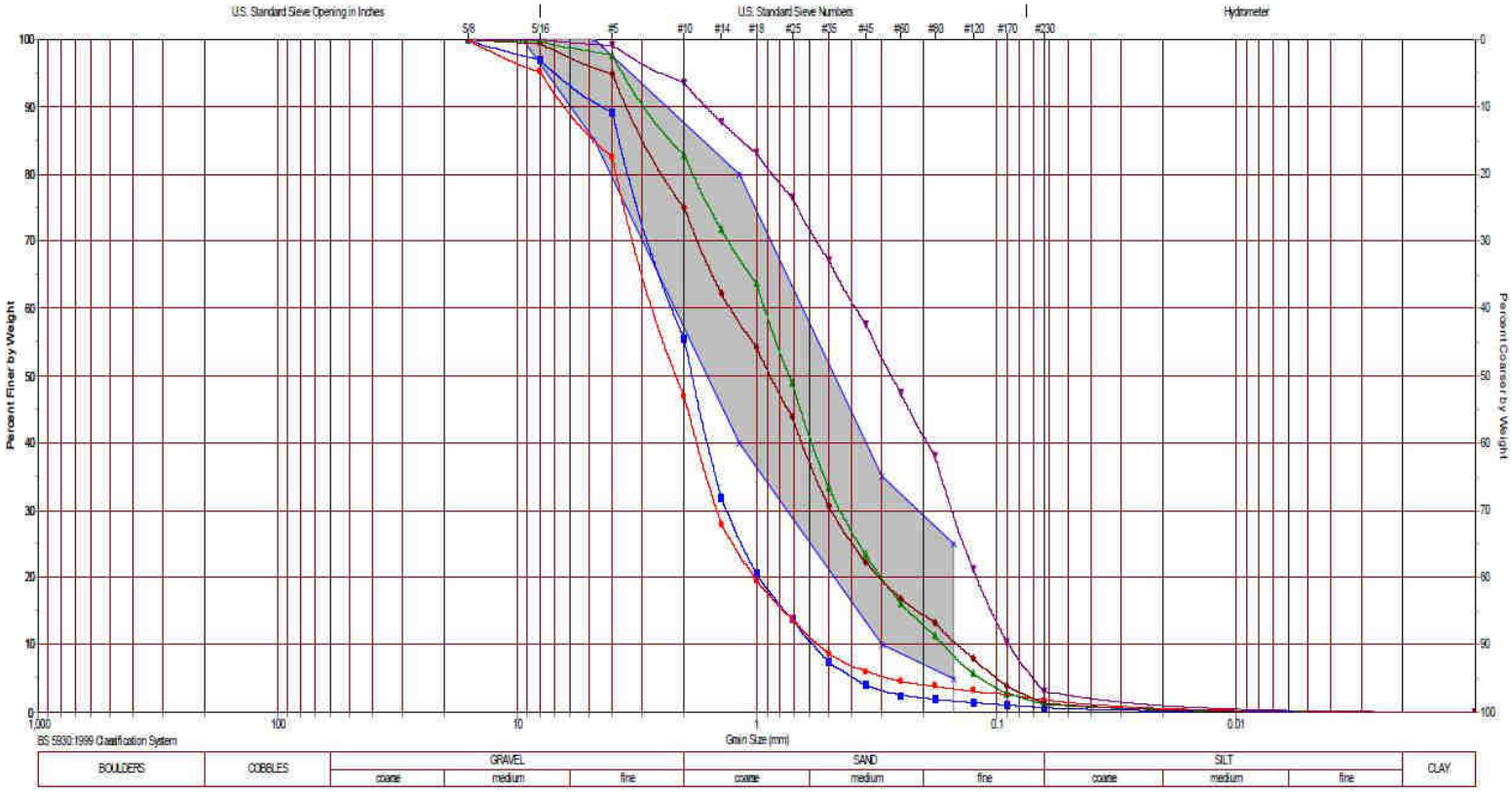


Borrow Area 4 – Jetprobe holes JP81 through JP-89.

BORROW AREA 6-7-8
Jetprobe grading profiles 42 through 62

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-42	Tested By: S. Moluwaca
	Client: SPIRE	Test Date: 11/12/2014

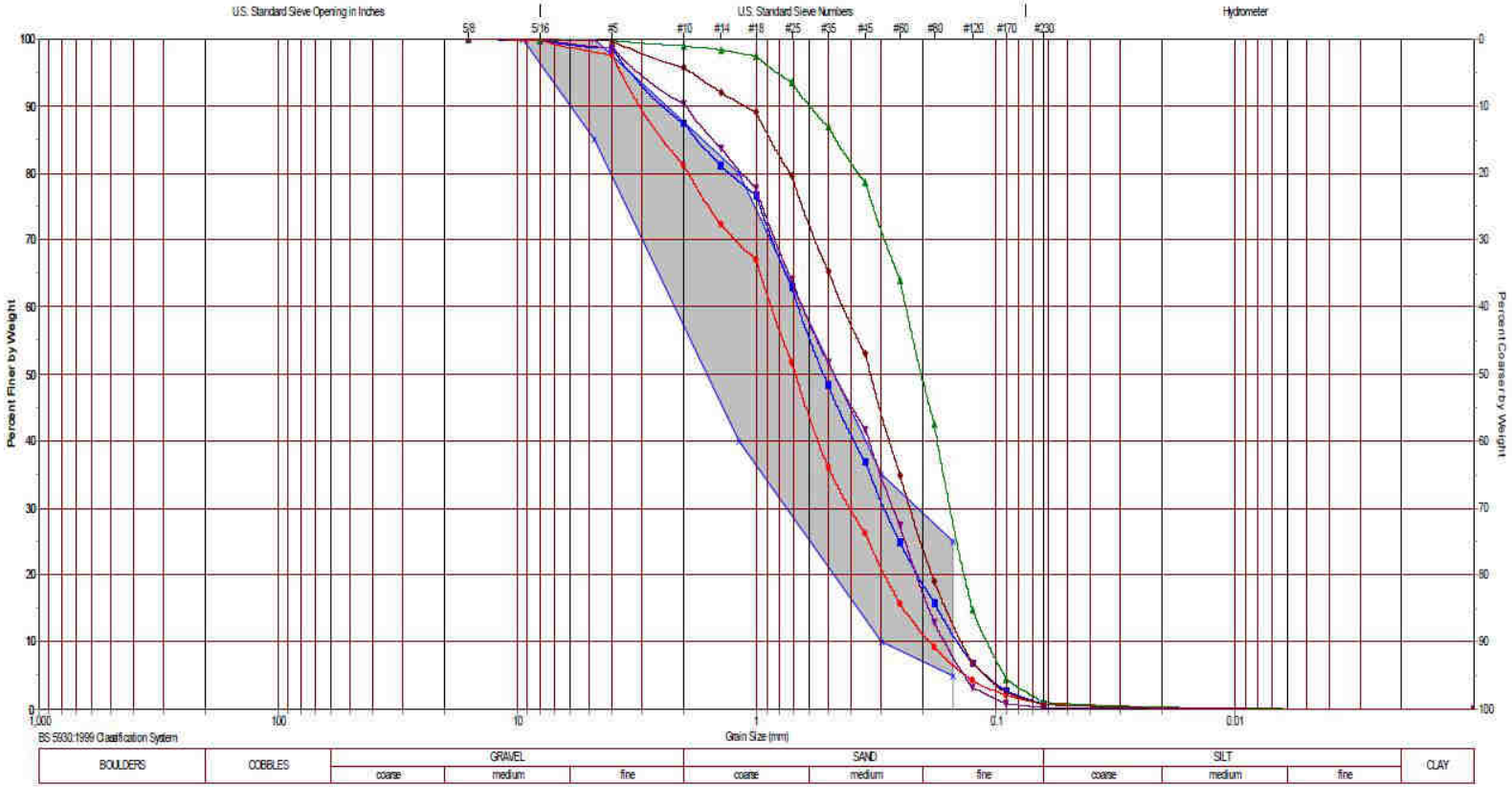
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-42	0.0	0.7	1.4	8.5	45.1	37.7	0.0	0.584	1.337	2.271	3.890	1.771	2.345
■	JP-43	0.0	1.6	2.3	7.1	35.8	42.0	0.0	0.555	1.466	2.741	4.938	2.000	2.692
▲	JP-44	0.0	1.1	11.7	28.0	42.1	16.1	0.0	0.167	0.449	0.927	5.562	0.732	2.994
▼	JP-45	0.0	3.0	37.8	30.9	22.0	6.1	0.0	0.089	0.154	0.386	4.359	0.317	2.558
♦	JP-46	0.0	1.3	13.0	22.7	36.1	22.3	0.0	0.146	0.490	1.291	8.863	0.842	3.844



Borrow Area 6-7-8 – Jetprobe holes JP42 through JP-46.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-47	Tested By: Christine Prasad
	Client: SPIRE	Test Date: 26/11/2014

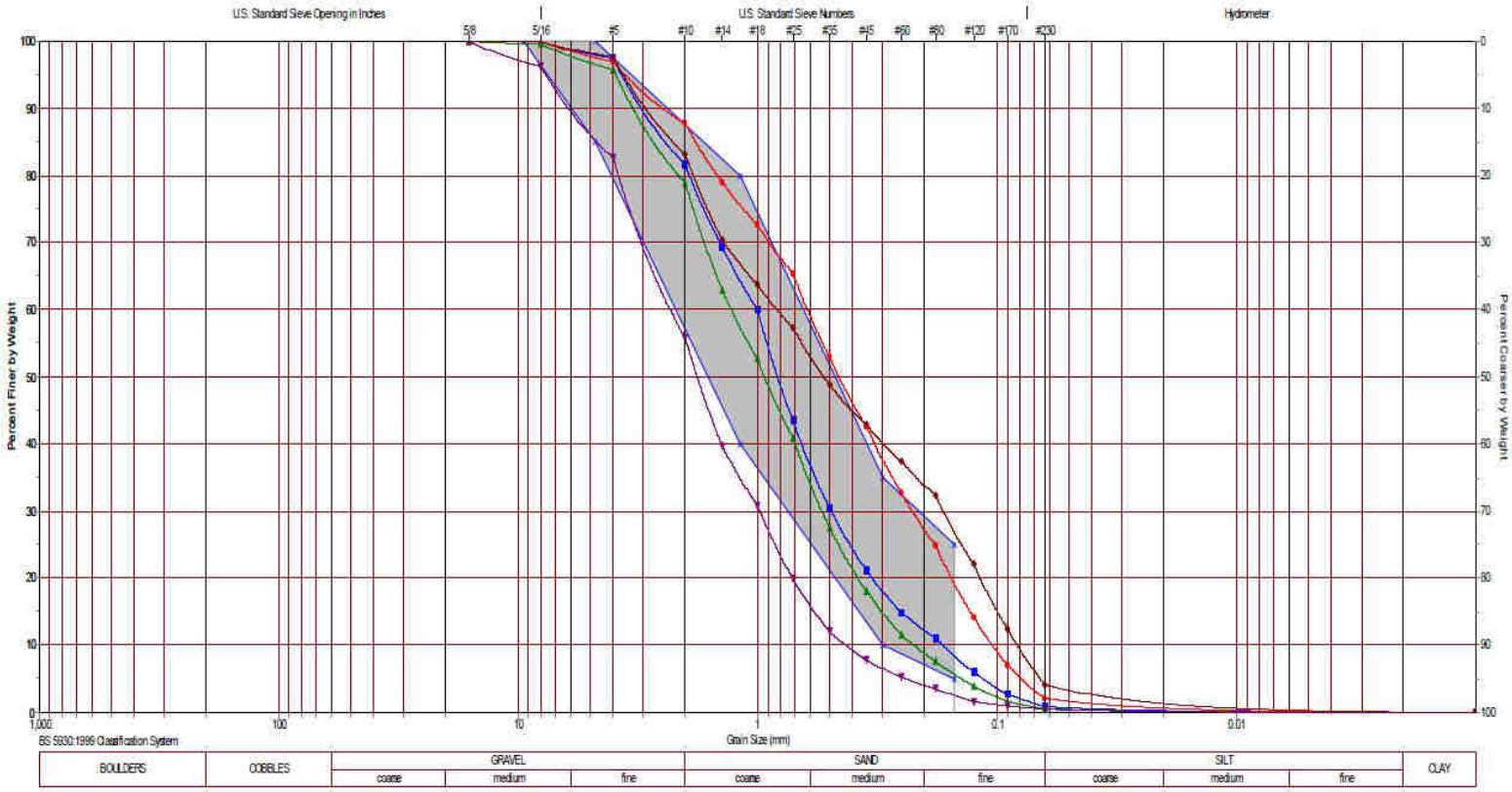
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-47	0.0	0.8	17.8	37.0	32.1	11.9	0.0	0.144	0.293	0.669	4.638	0.542	2.917
■	JP-48	0.0	0.8	10.3	32.5	37.7	17.7	0.0	0.189	0.408	0.866	4.589	0.743	2.733
▲	JP-49	0.0	1.1	47.7	41.4	9.0	0.9	0.0	0.109	0.155	0.237	2.178	0.227	1.612
▼	JP-50	0.0	0.2	16.9	40.7	32.8	9.1	0.0	0.164	0.269	0.641	3.920	0.510	2.446
♦	JP-51	0.0	0.8	23.0	48.8	23.7	4.1	0.0	0.139	0.229	0.436	3.127	0.361	2.018



Borrow Area 6-7-8 – Jetprobe holes JP47 through JP-51.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-52	Tested By: Donato
	Client: SPIRE	Test Date: 10/12/2014

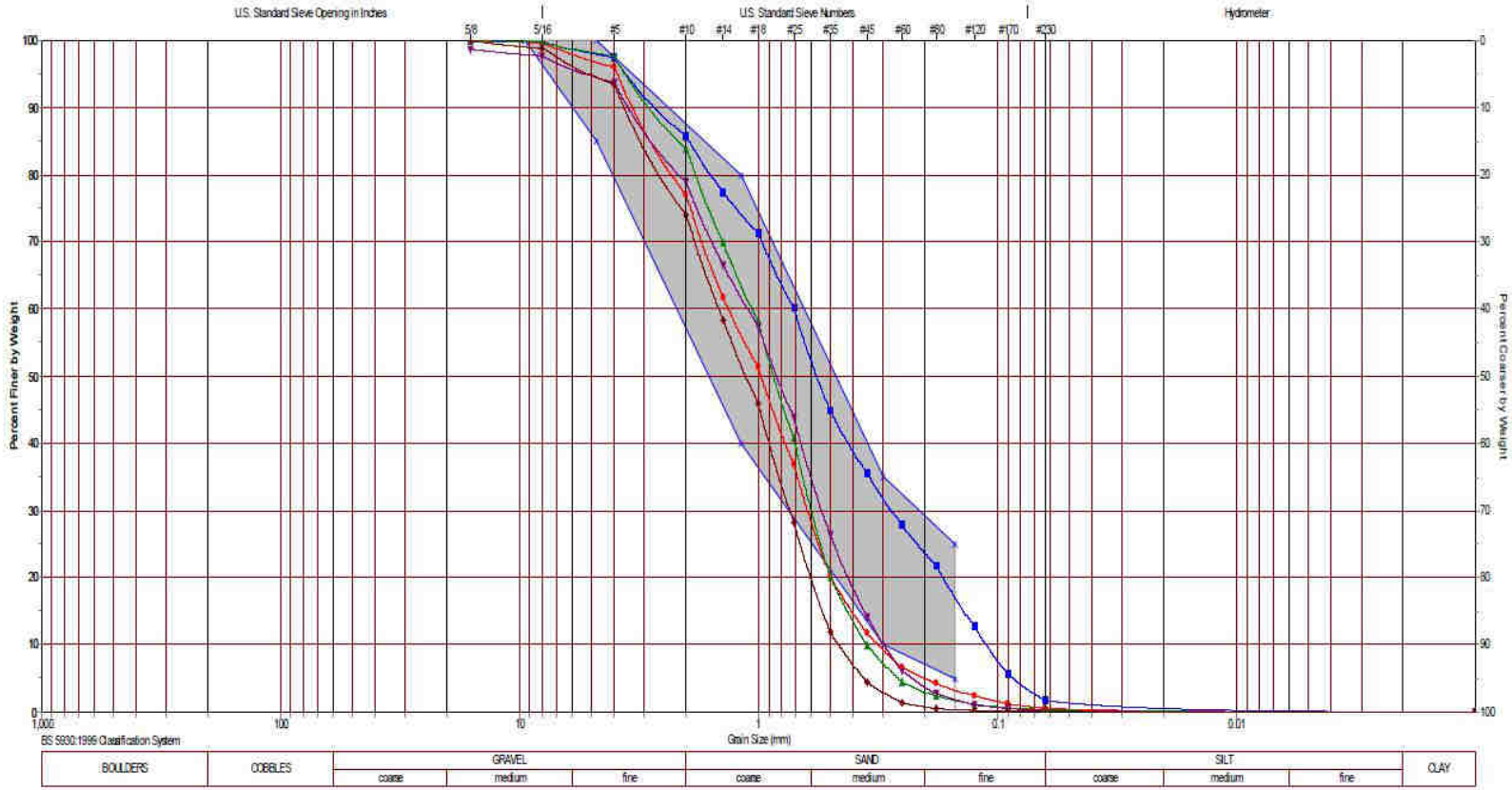
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-52	0.0	0.9	11.3	24.6	45.0	17.1	0.0	0.169	0.493	1.000	5.927	0.800	3.116
●	JP-53	0.0	2.0	25.1	31.9	28.9	10.9	0.0	0.105	0.226	0.619	5.914	0.475	3.435
▲	JP-54	0.0	0.6	8.2	25.2	46.1	19.0	0.0	0.233	0.539	1.287	5.770	0.920	2.968
▼	JP-55	0.0	0.5	3.6	11.9	40.1	33.8	0.0	0.428	0.978	2.315	5.404	1.683	2.974
◆	JP-56	0.1	4.1	29.7	19.1	30.2	15.8	0.0	0.082	0.168	0.831	10.095	0.488	5.171



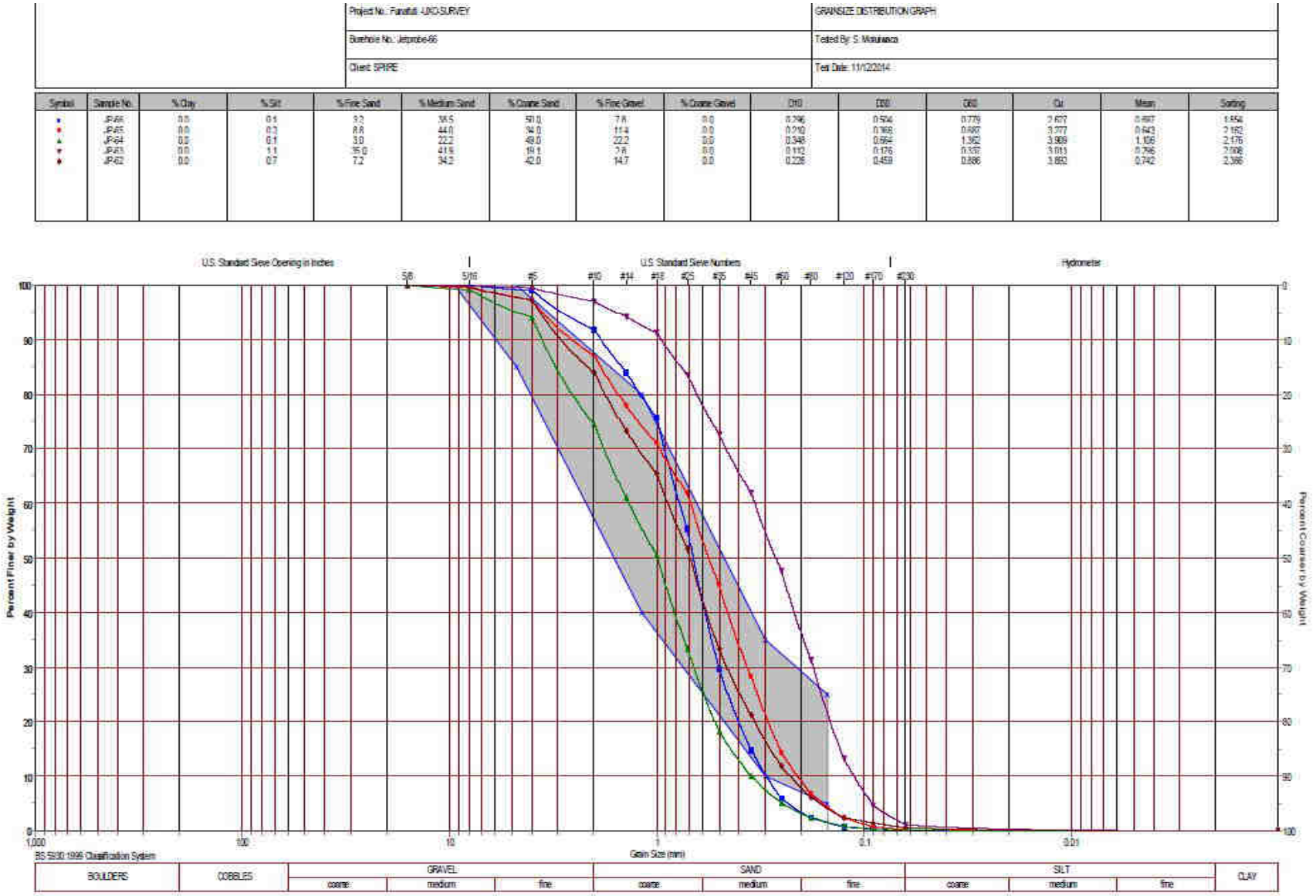
Borrow Area 6-7-8 – Jetprobe holes JP52 through JP-56.

Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
Borehole No.: Jetprobe-57	Tested By: R. Donato
Client: SPIIRE	Test Date: 11/12/2014

Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-57	0.0	1.7	22.0	28.7	33.7	13.0	0.0	0.111	0.278	0.706	6.359	0.537	3.990
●	JP-58	0.0	0.6	4.4	23.2	48.9	21.0	0.0	0.318	0.623	1.335	4.222	1.043	2.307
▲	JP-59	0.0	0.4	2.6	27.0	54.1	14.9	0.0	0.351	0.601	1.065	3.035	0.915	1.982
▼	JP-60	0.0	0.2	3.4	31.0	44.1	16.9	0.0	0.298	0.544	1.109	3.714	0.946	2.271
◆	JP-61	0.0	0.1	0.7	19.0	54.3	22.2	0.0	0.462	0.739	1.463	3.163	1.236	2.054



Borrow Area 6-7-8 – Jetprobe holes JP57 through JP-61.

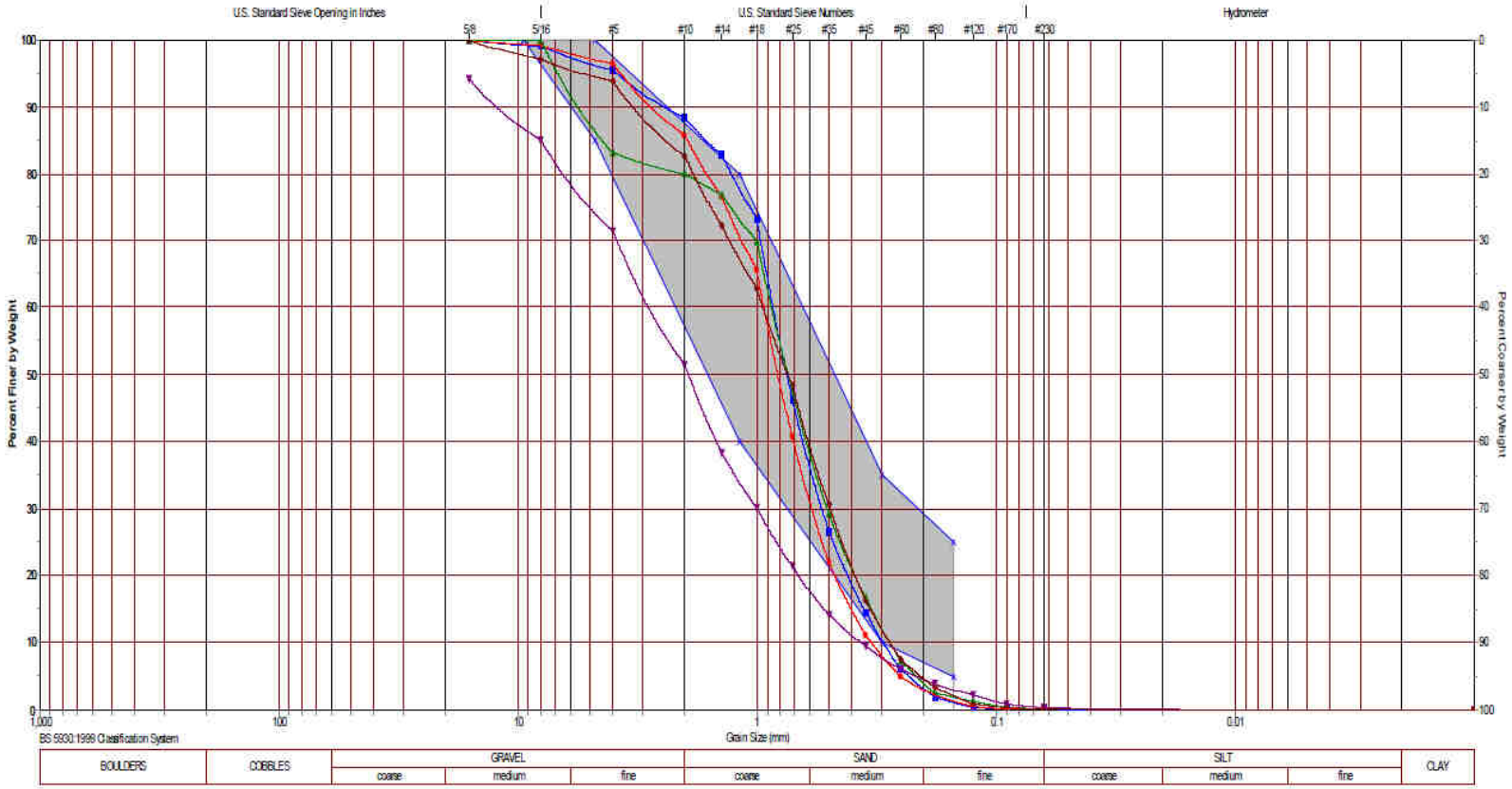


Borrow Area 6-7-8 – Jetprobe holes JP62 through JP-66.

BORROW AREA 9-10
Jetprobe grading profiles 87 through 96

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-87	Tested By: R. Donato
	Client: SPIIRE	Test Date: 11/12/2014

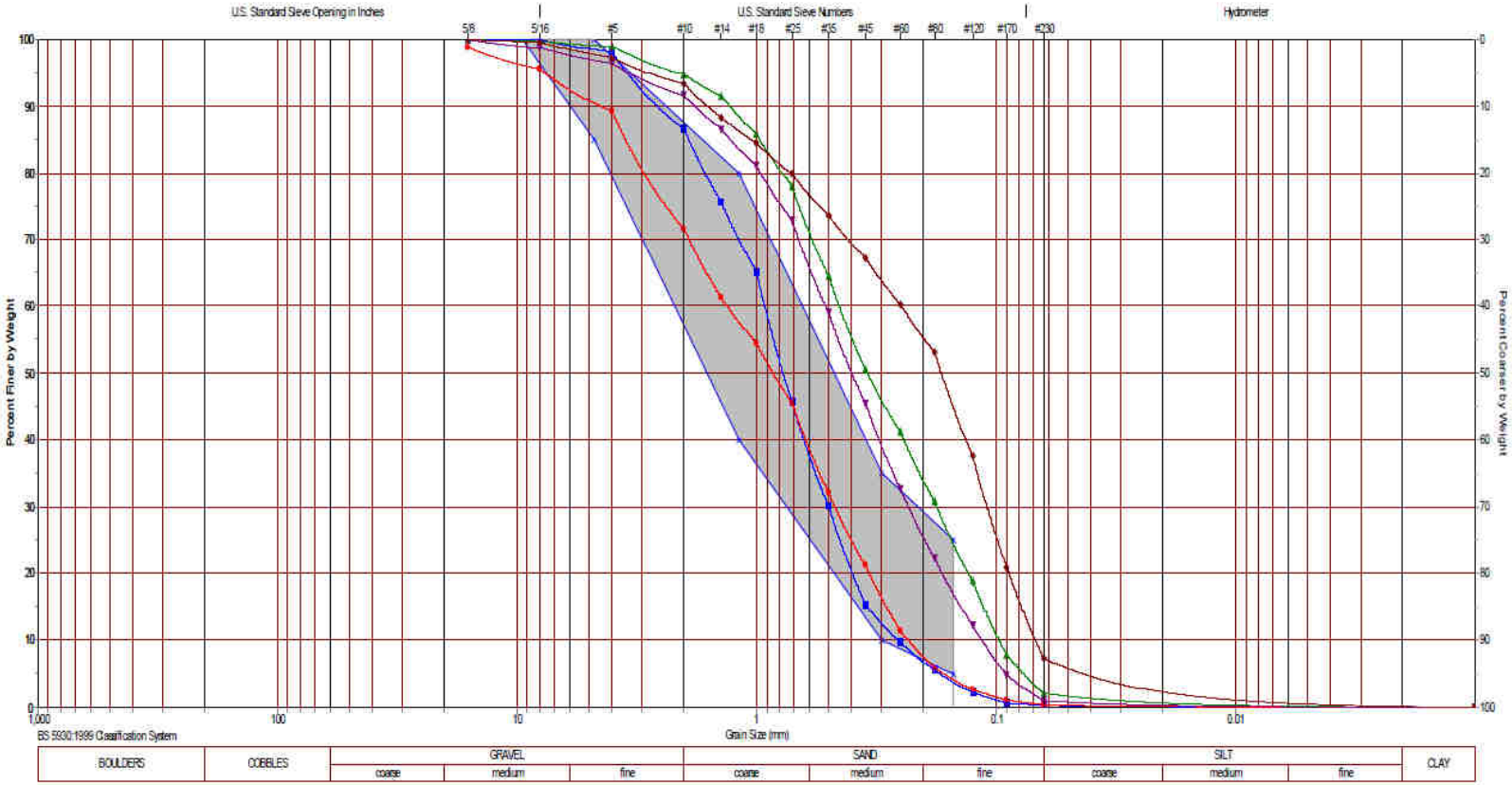
Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-87	0.0	0.1	3.1	32.9	52.4	9.1	0.0	0.297	0.537	0.858	2.893	0.751	2.053
■	JP-88	0.0	0.1	2.9	28.0	55.0	12.2	0.0	0.332	0.591	0.936	2.820	0.864	1.978
▲	JP-89	0.0	0.1	3.9	34.1	42.0	11.6	0.0	0.278	0.509	0.871	3.128	1.023	2.176
▼	JP-90	0.0	0.3	4.2	13.1	33.9	27.0	0.0	0.367	0.997	2.858	7.787	2.016	3.543
◆	JP-91	0.0	0.1	4.4	34.4	43.7	13.0	0.0	0.278	0.464	0.945	3.394	0.834	2.160



Borrow Area 9-10 – Jetprobe holes JP87 through JP-91.

	Project No.: Funafuti -UXO-SURVEY	GRAINSIZE DISTRIBUTION GRAPH
	Borehole No.: Jetprobe-92	Tested By: R. Donato
	Client: SPIRE	Test Date: 11/12/2014

Symbol	Sample No.	% Clay	% Silt	% Fine Sand	% Medium Sand	% Coarse Sand	% Fine Gravel	% Coarse Gravel	D10	D30	D60	Cu	Mean	Sorting
■	JP-92	0.0	0.3	6.4	30.9	49.1	12.5	0.0	0.256	0.496	0.923	3.609	0.801	2.185
●	JP-93	0.0	0.4	7.1	31.1	33.1	28.9	0.0	0.232	0.471	1.328	5.715	0.952	2.698
▲	JP-94	0.0	2.0	31.7	37.3	23.9	4.7	0.0	0.097	0.177	0.452	4.661	0.334	2.999
▼	JP-95	0.0	1.0	24.3	40.4	26.0	6.1	0.0	0.114	0.232	0.515	4.498	0.413	2.772
♦	JP-96	0.1	7.2	47.9	21.6	16.8	5.1	0.0	0.069	0.109	0.248	3.621	0.236	2.120



Borrow Area 9-10 – Jetprobe holes JP92 through JP-97.

APPENDIX 2

Map Sheets Borrow Area 1

Borrow Area 1 – Bathymetry and Jetprobe Locations Map
Borrow Area 1 – Magnetic Profile Anomalies and Track Plot Map

E 739,400 E 739,600 E 739,800 E 740,000 E 740,200 E 740,400 E 740,600 E 740,800 E 741,000

N 9,056,600 N 9,056,400 N 9,056,200 N 9,056,000 N 9,055,800 N 9,055,600 N 9,055,400

JP-38 PD 2.4m
JP-39 PD 2m
JP_41 PD 7.5 m
JP-37 PD 2.8m
JP-40 PD 4.2m
JP-36 PD 3m
JP-34 PD 2.5m
JP-35 PD 3m
JP-33 PD 3.2m
JP-32 PD 3.2m
JP-31 PD 3.5m
JP-30 PD 4.5m
JP-29 PD 4.5m
JP-28 PD 5.3m
JP-27 PD 5.5m
JP-26 PD 5.5m
JP-24 PD 4.0m+
JP-25 PD 5.0m
JP-20 pd 1.5m-2.7m
JP-17 pd 2.7m
JP-14 pd 4.0m+
JP-18 pd 2.6m
JP-21 pd 5.0m
JP-19 pd 4.0m+
JP-12 pd 4.0m+
JP-16 pd 4.0m+
JP-9 pd 2.4m
JP-10 pd 3.7m
JP-13 pd 5.0m+
JP-8 pd 4+m
JP-6 pd 1.5-2.6m
JP-11 pd 4.0m+
JP-4 pd 3.6m
JP-7 pd 2.5m
JP-2 pd 2.5m
JP-3 pd 3.5-4.0m+
JP-1 pd 1.4m

Borrow-pit-1

Borrow -pit-5

BORROW-AREA-1

MAP TITLE	BATHYMETRY AND JETPROBE LOCATION MAP	File: Borrow-Area-1-Bathy-JP-location-map.dwg
LOCATION	Tuvalu Funafuti Atoll Image backdrop Google Earth image 21072012	
MAP PARAMETERS	Horizontal Datum UTM Zone 60 WGS 84	Vertical Datum Tide Gauge Zero
EQUIPMENT	Magnetometer Geometrics GS 881	Navigation Trimble SPS 852, OmniStar service
CLIENT SPIIRE NZ Ltd	Survey by SPC Geoscience Division, Surveyor R.Smith	Processing and Interpretation R. Smith
Date August 2014	Geoscience for Development Programme **Applied Geoscience and Technology (SOPAC) Division SECRETARIAT OF THE PACIFIC COMMUNITY** Postal Address: Private Mail Bag, GPO, Suva, Fiji Islands Street Address: 241 Mead Road, Nabua, Fiji Islands Fax: +679-3370540, +679-3384461 Phone: +679-3381-377 (SOPAC)	

JP-20 pd 1.5m-2.7m Jetprobe ID and penetration depth

-5 Bathymetric Isobar and depth in m
Contour Interval 1m

Reef substrate

Potential borrow areas

North

Scale

0 50 100 200 300 400 Meters

E 739,400 E 739,600 E 739,800 E 740,000 E 740,200 E 740,400 E 740,600 E 740,800 E 741,000

N 9,056,600 N 9,056,400 N 9,056,200 N 9,056,000 N 9,055,800 N 9,055,600 N 9,055,400

DMA-3 LCM wreck - multiple units?

DMA-1 LCM wreck

Borrow-pit-1

Borrow -pit-5

BORROW-AREA-1

MAP TITLE	Magnetic Profile Anomaly and Track Plot Map	File : BA-1-Magneticprofile-trackplot.dwg
LOCATION	Tuvalu Funafuti Atoll	
MAP PARAMETERS	Horizontal Datum UTM Zone 60 WGS 84	Vertical Datum Tide Gauge Zero
EQUIPMENT	Magnetometer Geometrics GS 881	Navigation Trimble SPS 852, OmniStar service
CLIENT SPIIRE NZ Ltd	Survey by SPC Geoscience Division, Surveyor R.Smith	Processing and Interpretation R. Smith
Date August 2014	Geoscience for Development Programme: **Applied Geoscience and Technology (SOPAC) Division SECRETARIAT OF THE PACIFIC COMMUNITY** Postal Address: Private Mail Bag, GPO, Suva, Fiji Islands Street Address: 241 Mead Road, Nabua, Fiji Islands Fax: +679-3370040, +679-3384461 Phone: +679-3381 377 (SOPAC)	

Magnetic profile track lines with event and line ID numbers

011-1039-2320-14g

Magnetic profile anomaly with profile line number event number range with monopole/dipole peak to peak anomaly value

Magnetic anomaly target likely buried

North

Scale

0 50 100 200 300 400 Meters

APPENDIX 3

Map Sheets Borrow Area 2

Borrow Area 2 – Bathymetry and Jetprobe Locations Map
Borrow Area 2 – Magnetic Profile Anomalies and Track Plot Map

E 739,600.00 E 739,800.00 E 740,000.00 E 740,200.00

N 9,065,400.00 N 9,065,200.00 N 9,065,000.00 N 9,064,800.00 N 9,064,600.00 N 9,064,400.00 N 9,064,200.00

BORROW-AREA-2

Map Title	BATHYMETRY AND JETRPOBE LOCATION MAP
Location	Funafuti Atoll Tuvalu
Horizontal Datum	UTM ZONE 60 South
Vertical Datum	Funafuti Tide Gauge Zero
Client	SPIIRE NZ. Ltd www.spiire.co.nz
Navigation	TRIMBLE SPS 852, Omni Star
Survey Tool	Geometrics Magnetometer GS881
Image Overlay	Quickbird 2008
Survey, Interpretation	Survey by SPC Geoscience Division, Surveyor R. Smith
Survey Dates	August 2014
Compiled by	Robert Smith. Date 09092014
Drawing File	Borrow--Area-2-Bathy-JP-Location-Map.dwg

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Phone: +679-3381-377 (SOPAC)

LEGEND

JP-65 PD 1m — Jetprobe Location with depth of penetration into seabed

−10 — Bathymetric Isobar and depth in m Contour Interval 1m

Reef substrate

Borrow-pit outline

North

SCALE

0 10 20 30 40 50 100 150 200 250 Metres

E 739,600.00 E 739,800.00 E 740,000.00 E 740,200.00

N 9,065,400.00 N 9,065,200.00 N 9,065,000.00 N 9,064,800.00 N 9,064,600.00 N 9,064,400.00 N 9,064,200.00

BORROW-AREA-2

Map Title	Magnetic Profile Anomaly And Track Plot Map
Location	Funafuti Atoll Tuvalu
Horizontal Datum	UTM ZONE 60 South
Vertical Datum	Funafuti Tide Gauge Zero
Client	SPIIRE NZ. Ltd www.spiire.co.nz
Navigation	TRIMBLE SPS 852, Omni Star
Survey Tool	Geometrics Magnetometer GS881
Image Overlay	Quickbird 2008
Survey, Interpretation	Survey by SPC Geoscience Division , Surveyor R. Smith
Survey Dates	August 2014
Compiled by	Robert Smith. Date 09092014
Drawing File	BA-2-Magnetic-profile-anomaly-track-plot-map.dwg

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LEGEND

7 — Bathymetric Isobar and depth in m Contour Interval 1m

1167 1166 SOL 001_1141MAG — Magnetic Profile Track plot with event fix

001-1141-1175-5g — Magnetic Profile Anomalies Picked with Line # Event and Peak-2-Peak value

Borrow-pit outline

North

SCALE

0 10 20 30 40 50 100 150 200 250 Metres

APPENDIX 4

Map Sheets Borrow Area 4

Borrow Area 4 – Bathymetry and Jetprobe Locations Map
Borrow Area 4 – Magnetic Profile Anomalies and Track Plot Map

BORROW-AREA-4

Map Title	Bathymetry and Jetprobe Location Map
Map Title	Funafuti Atoll, Tuvalu
Horizontal Datum	UTM Zone 60 South
Vertical Datum	Funafuti Tide Gauge Zero
Client	SPIIRE NZ.Ltd www.spiire.co.nz
Navigation	Trimble SPS 852, Omni Star
Survey Tool	Geometrics Magnetometer GS881
Image Overlays	QuickBird-2008; GEarth-2012
Survey Interpretation	Survey by SPC Geoscience Division, Surveyor R Smith
Survey Date	August 2014
Map Compilation	R. Smith 09092014
Drawing File	BA-4-Bathymetry-JP-location-map.dwg

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Street Address: 241 Mead Road, Nabua, Fiji Islands Fax: +679-3370040, +679-3384461
Phone: +679-3381-377 (SOPAC)

LEGEND

- JP-65 PD 1m — Jetprobe Location with depth of penetration into seabed
- 10 — Bathymetric Isobar and depth in m Contour Interval 1m
- Reef substrate
- North
- Magnetic anomaly target likely buried unless identified; eg Steel drum
- Borrow-pit outline

SCALE Metres
0 10 20 30 40 50 100 150 200 250

JP-76 PD 3.0m
JP-77 PD 2.4m
JP-78 PD 0.3m
JP-79 PD 4.2m
Large Danforth anchor on small reef pich
wreck
JP-80 PD 2.1m
Anomaly from wreck at toe of reef
JP-81 PD 3.2m
JP-83 PD 4.8m
JP-82 PD 4m
JP-84 PD 5m
JP-85 PD 4.5m
JP-86 PD 4m
Old mooring 3- 44 gal-drums
JP-87 PD 5m
JP-88 PD 5.5m
Anomaly from wreck on reef
JP-89 PD 6.5m
Large mooring buoy 4x2m and chain
pipe-line-bottom end disappears in sand
base at slip

E 741,400.00 E 741,600.00 E 741,800.00
N 9,060,600.00 N 9,060,400.00 N 9,060,200.00 N 9,060,000.00 N 9,059,800.00 N 9,059,600.00 N 9,059,400.00

E 741,400.00 E 741,600.00 E 741,800.00

N 9,060,600.00 N 9,060,400.00 N 9,060,200.00 N 9,060,000.00 N 9,059,800.00 N 9,059,600.00 N 9,059,400.00

BORROW-AREA-4

Map Title	Magnetic Profile Track-Anomaly Map
Map Title	Funafuti Atoll, Tuvalu
Horizontal Datum	UTM Zone 60 South
Vertical Datum	Funafuti Tide Gauge Zero
Client	SPIIRE NZ.Ltd www.spiire.co.nz
Navigation	Trimble SPS 852, Omni Star
Survey Tool	Geometrics Magnetometer GS881
Image Overlays	QuickBird-2008; GEarth-2012
Survey Interpretation	Survey by SPC Geoscience division, Surveyor R. Smith
Survey Date	August 2014
Map Compilation	R. Smith 09092014
Drawing File	BA-4-mag-profile-anomaly-track-plot-map.dwg

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LEGEND

007-1420-476-26g — Magnetic Profile number- event number and peak -2-peak range

707 708 709 — SOL-003_1052.mag Magnetic profile line with event number

Reef substrate

North

Magnetic anomaly target likely buried unless identified; eg Steel drum

Borrow-pit outline

SCALE Metres

0 10 20 30 40 50 100 150 200 250

SDL 006_1411.mag SDL 003_1528.mag SDL 010_1449.mag SDL 008_1429.mag SDL 012_1507.mag SDL 009_1439.mag SDL 005_1402.mag SDL 007_1420.mag SDL 011_1458.mag SDL 004_1517.mag

006-1411-429-7g
007-1420-476-26g
006-1411-440-11g
008-1429-504-11g
003-1528-713-150g
006-1411-443-5g
006-1411-444-3g
004-1517-671-672-12g
003-1528-722-723-130g
009-1439-524->18g
007-1420-458->25g
004-1517-661->100g
003-1528-730-731->90g
003-1528-733-742->1000g

APPENDIX 5

Map Sheets Borrow Area 6-7-8

Borrow Area 6-7-8 – Bathymetry and Jetprobe Locations Map
Borrow Area 6-7-8 – Magnetic Profile Anomalies and Track Plot Map

BORROW-AREA-6-7-8

Map Title	Bathymetry And Jetprobe Location Map
Map Location	Funafuti Atoll Tuvalu
Map Parameters	UTM Zone 60 , WGS 84, Vertical TGZero
Equipment	Geometrics 881, Magnetometer, SPS 852 GPS
Client	SPIIRE NZ Co.LTD
Drawing File	Borrow-area-6-7-8-bathy-JP-map.dwg
Image Overlay	Google Earth -21-07-2012
Date	August 2014
Survey	Survey by SPC Geoscience Division, Surveyor R. Smith

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Reef substrate

JP-60 PD 0.7m, jet probe location with depth of penetration

5 Bathymetric Isobar and depth in m
Contour Interval 1m

Borrow-pits

Obarge-sunker

E 741,600 E 741,800 E 742,000 E 742,200

N 9,059,000 N 9,058,800 N 9,058,600 N 9,058,400

E 741,600 E 741,800 E 742,000 E 742,200

N 9,059,000 N 9,058,800 N 9,058,600 N 9,058,400

BORROW-AREA-6-7-8

Map Title	Magnetic Profile Anomaly And Track Plot Map
Map Location	Funafuti Atoll Tuvalu
Map Parameters	UTM Zone 60 , WGS 84, Vertical TGZero
Equipment	Geometrics 881, Magnetometer, SPS 852 GPS
Client	SPIIRE NZ Co.LTD
Drawing File	BA-6-7-8-Magnetic-profile-Anomaly-map.dwg
Image Overlay	Google Earth -21-07-2012
Date	August 2014
Survey	Survey By SPC Geoscience Division, Surveyor R. Smith

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N

1 2 001_1100mag Magnetic profile track # and event

001-1222-99-2.5G Magnetic Profile and event # with peak-2 peak gamma value of anomaly

Scale
0 10 20 40 60 80 Meters

001-1222-105-2.5g

001-1222-99-2.5G

008-1113-107-106-8g

008-1105-85-86-1g

003-1158-130-131-1g

007-1058-58-57-7g

008-1105-87-7g

005-1042-10-11-7g

001-1222-92-91-12g

006-1042-40-42-2g

002-1209-92-9g

009-1113-102-0.5g

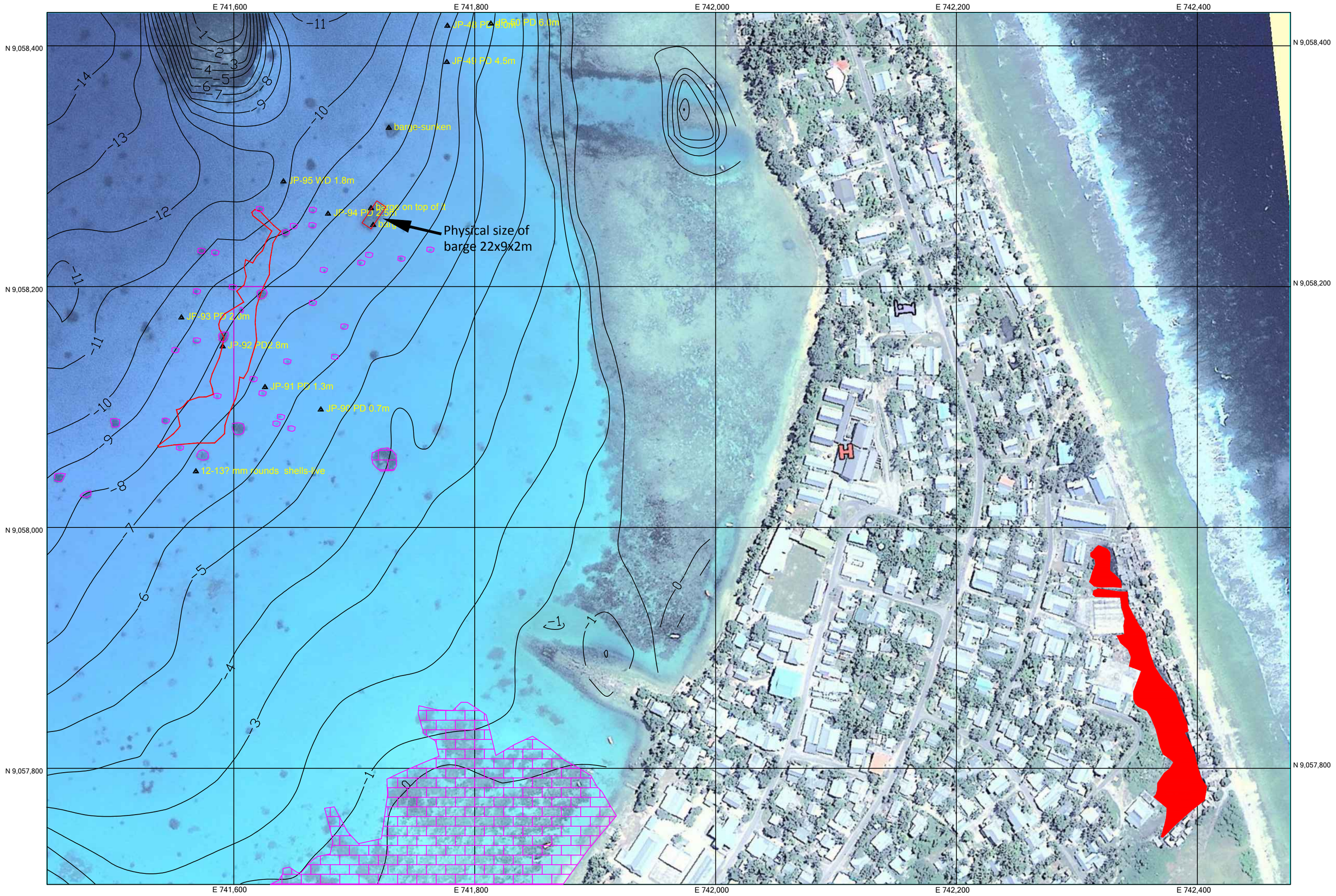
003-1157_001-143-10g

Borrow-pits

APPENDIX 6

Map Sheets Borrow Area 9-10

Borrow Area 9-10 – Bathymetry and Jetprobe Locations Map
Borrow Area 9-10 – Magnetic Profile Anomalies and Track Plot Map



BORROW-AREA-9-10

Map Title	BA-9-10-Bathymetry-Jetprobe Location Map	BA-9-10-Bathy-JP- Map.DWG
Location	Funafuti Atoll , Tuvalu	Image overlay from Google Earth: Date 21072012
Map Parameters	Horizontal Datum UTM zone 60 WGS 84	Vertical Datum Tide Gauge Zero
Equipment	Geometrics Magnetometer GS881	Navigation Trimble SPS 852, OmniStar service
Client SPIIRE NZ Ltd	Survey by SPC Geoscience Division Surveyor R.Smith	Processing and Interpretation R. Smith
Date August 2014		

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North

7 Bathymetric Isobath Depth in m
Contour Interval 1m

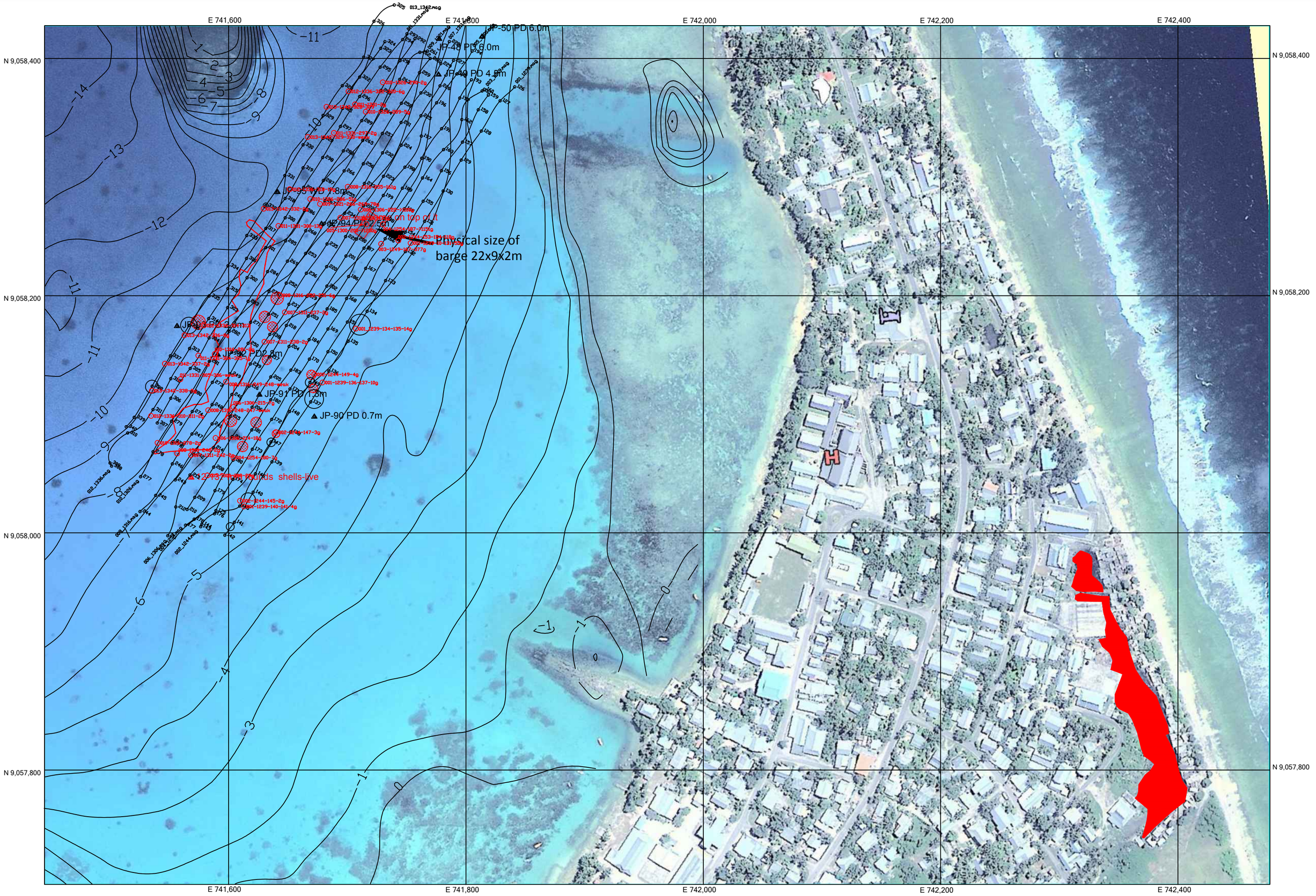
Reef substrate

JP-90 PD 0.7m Jetprobe Location with ID and penetration depth in meters

Borrow pit perimeter for scale

Scale

0 50 100 200 300 Meters



BORROW-AREA-9-10

Map Title	Magnetic Profile Track Plot	File : BA-9-10 magnetic-trackplot.dwg
Location	Funafuti Atoll , Tuvalu	Image overlay from Google Earth: Date 21072012
Map Parameters	Horizontal Datum UTM zone 60 WGS 84	Vertical Datum Tide Gauge Zero
Equipment	Geometrics Magnetometer GS881	Navigation Trimble SPS 852, OmniStar service
Client SPIIRE NZ Ltd	Survey by SPC Geoscience Division Surveyor R.Smith	Processing and Interpretation R. Smith
Date August 2014		

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North

Magnetic Track Profile and Event Label

Bathymetric Isobath Depth in m
Contour Interval 1m

002-1244-145-2g Magnetic profile and event # with magnetic anomaly peak -2- peak value in gammas

Borrow Pit Area

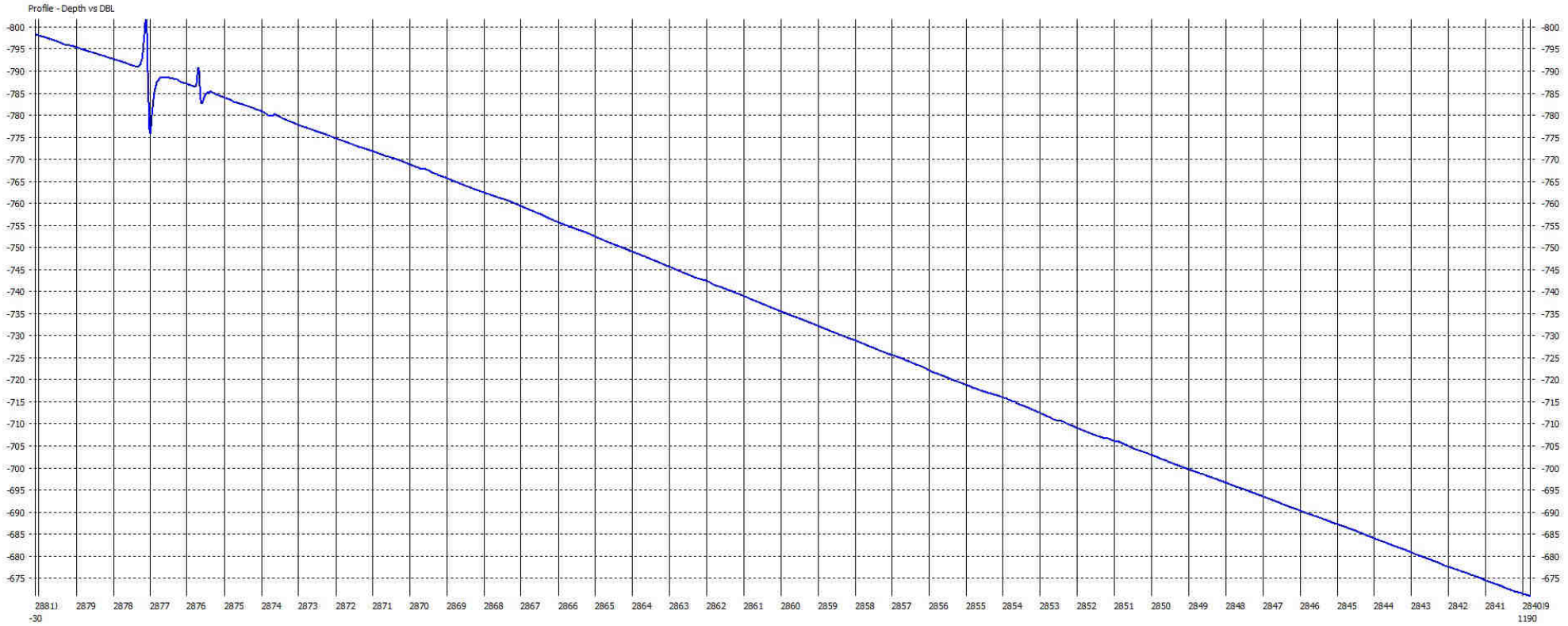
Scale
0 50 100 200 300 Meters

APPENDIX 7

Magnetic Profiles
(Digital files on DVD at Appendix 11)

BORROW AREA 1

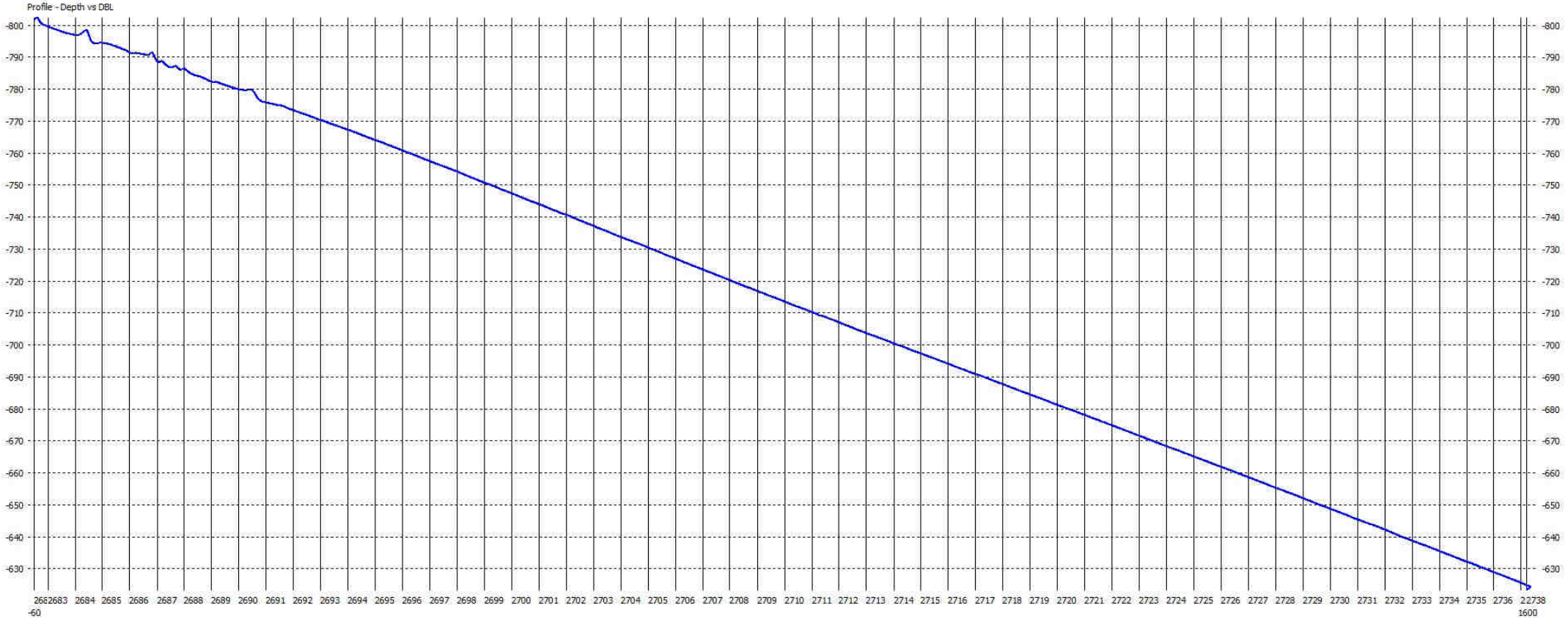
Magnetic Profile 001_1243.jpg



Magnetic Profile 002_1234.jpg

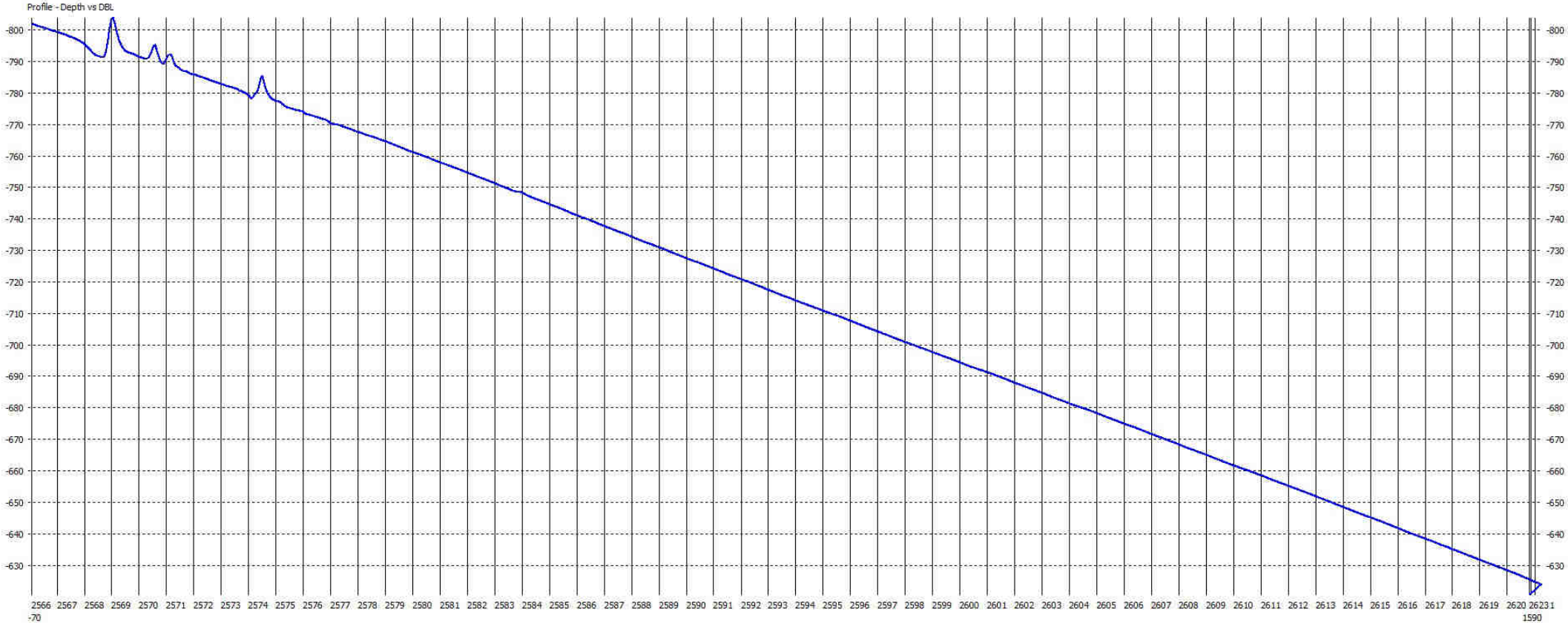
Magnetic Profile 003_1221.jpg

Magnetic Profile 004_1209.jpg

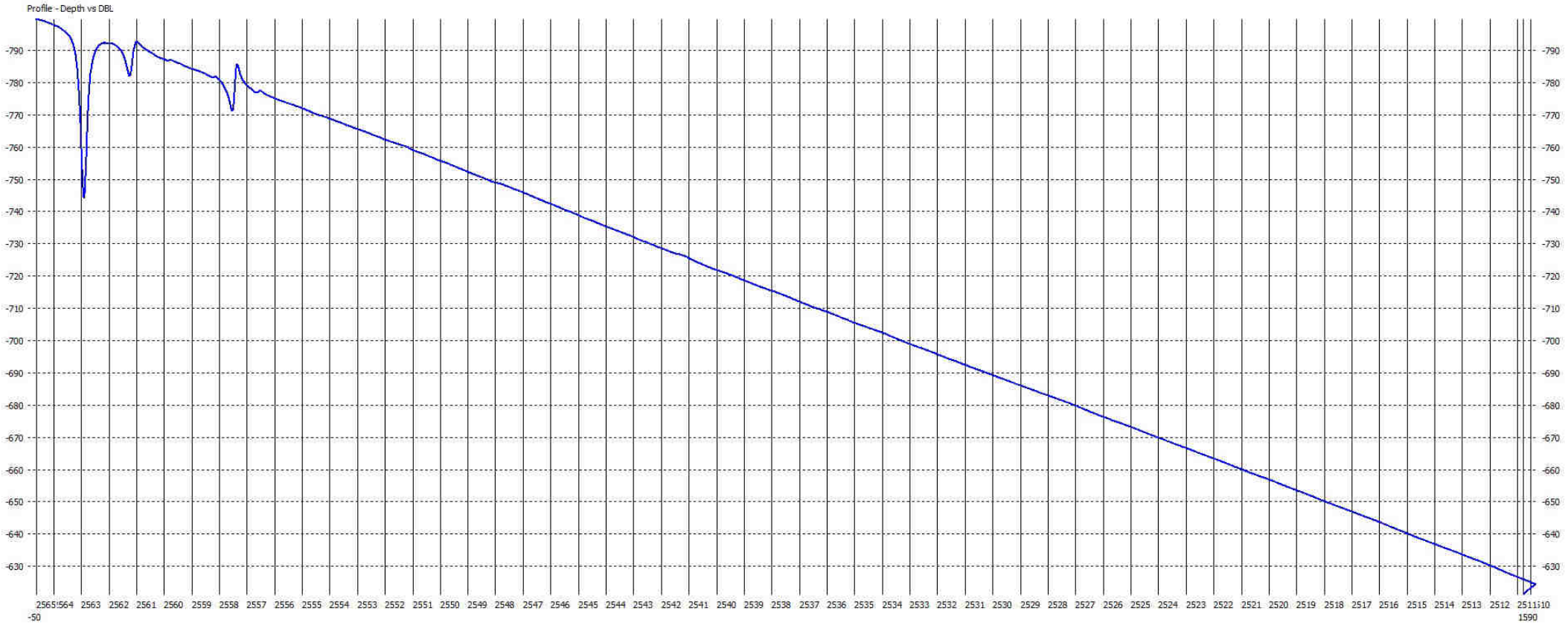


Magnetic Profile 005_1156.jpg

Magnetic Profile 006_1143.jpg



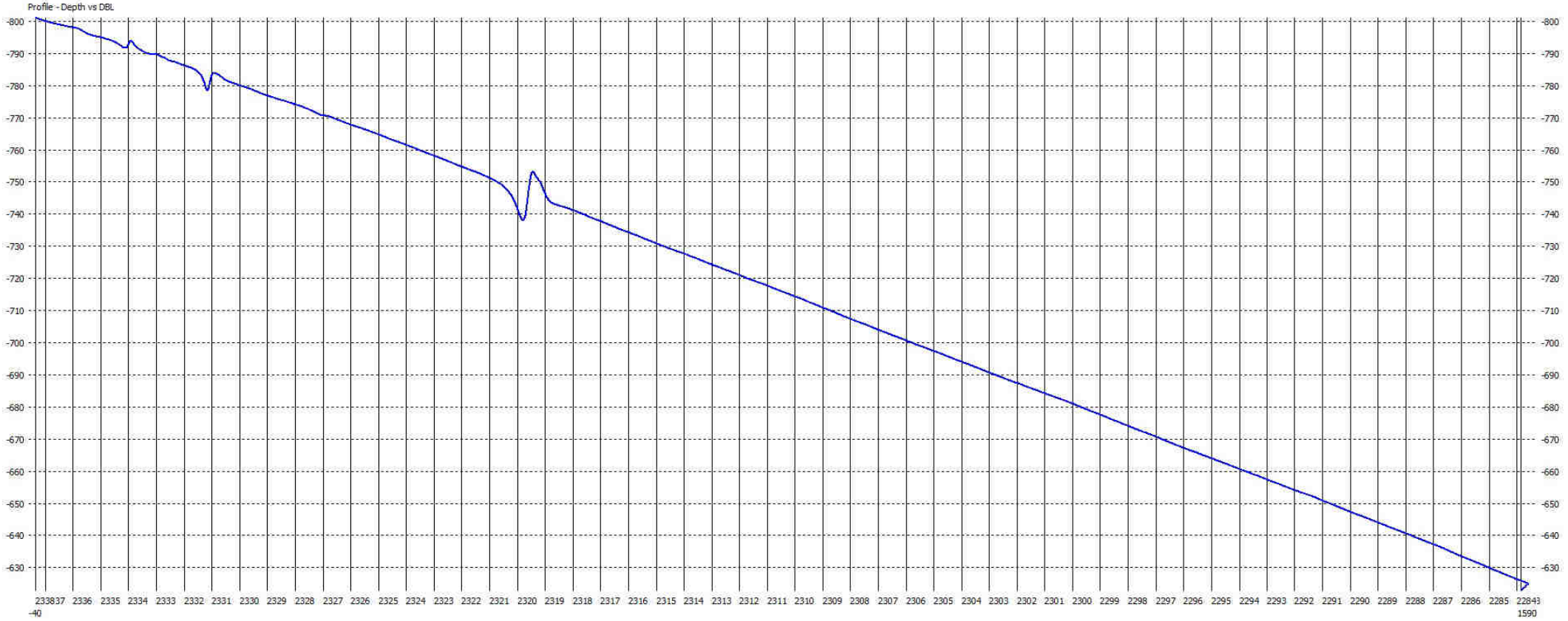
Magnetic Profile 007_1129.jpg



Magnetic Profile 009_1104.jpg

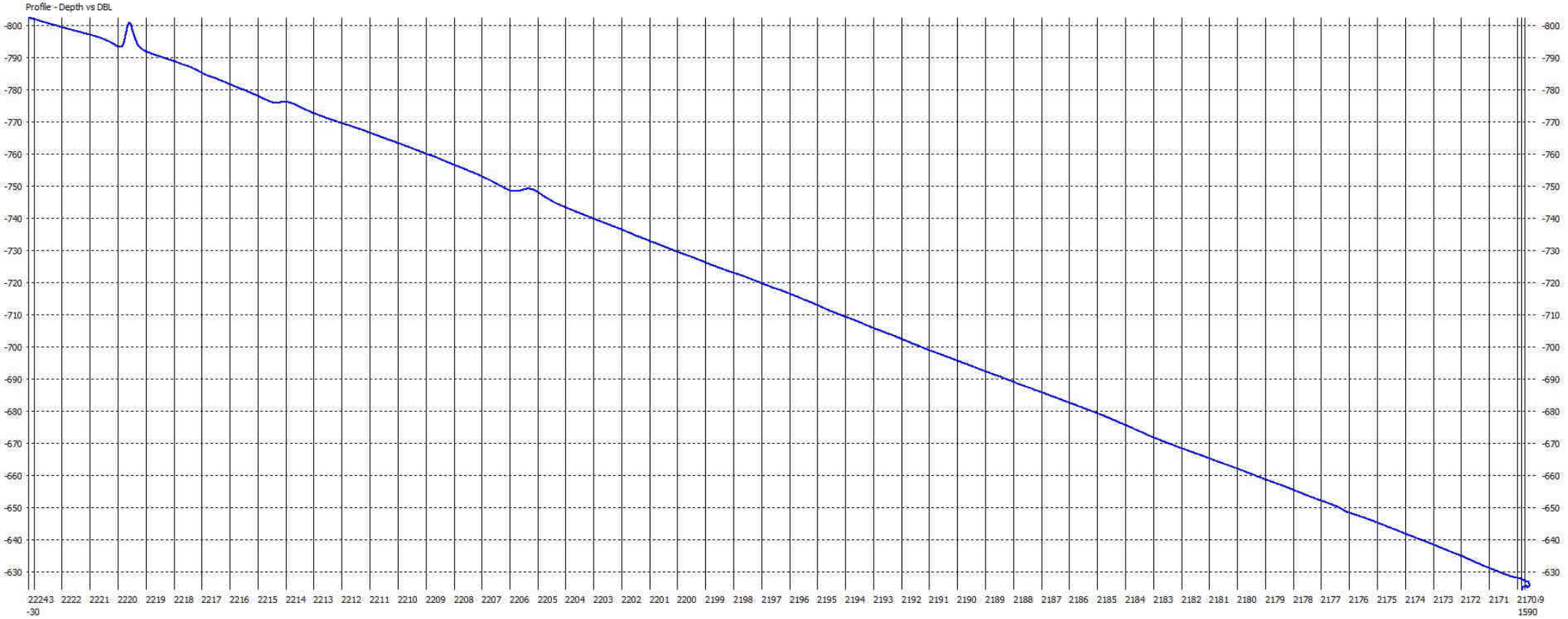
Magnetic Profile 010_1052.jpg

Magnetic Profile 011_1039.jpg

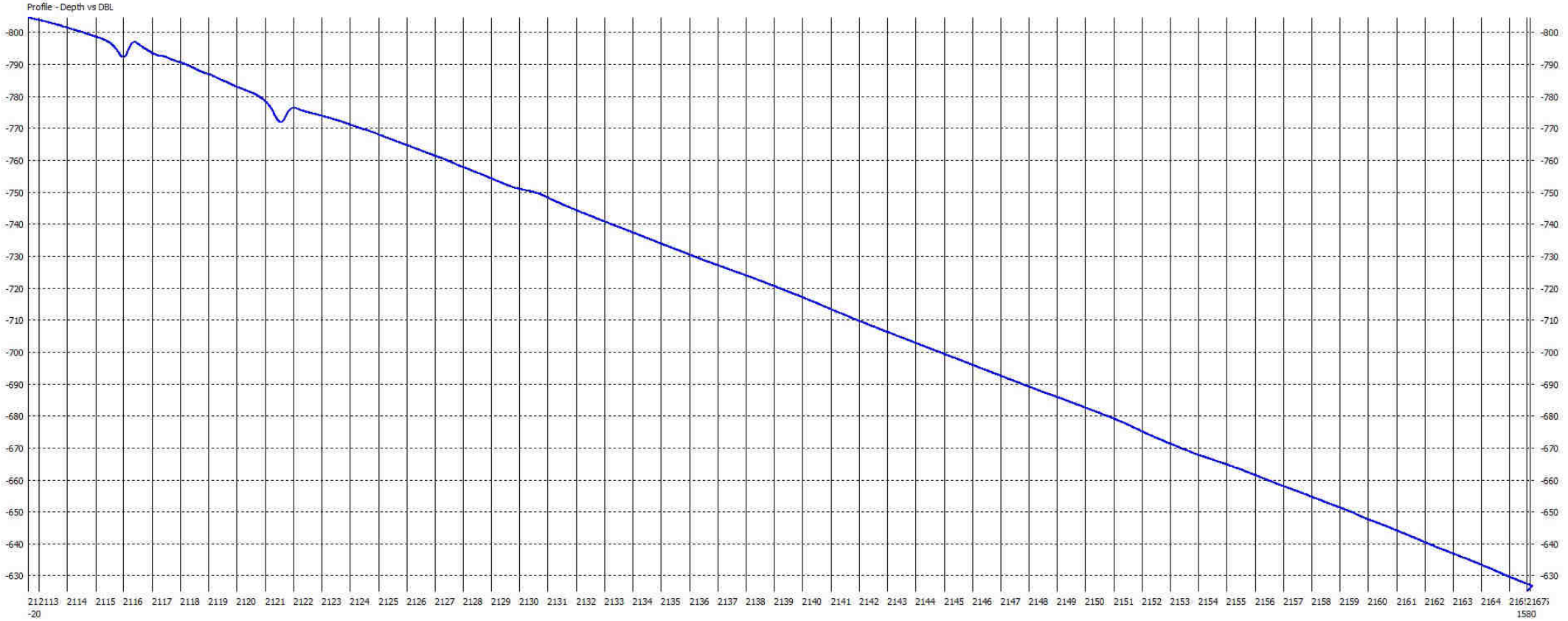


Magnetic Profile 012_1026.jpg

Magnetic Profile 013_1013.jpg

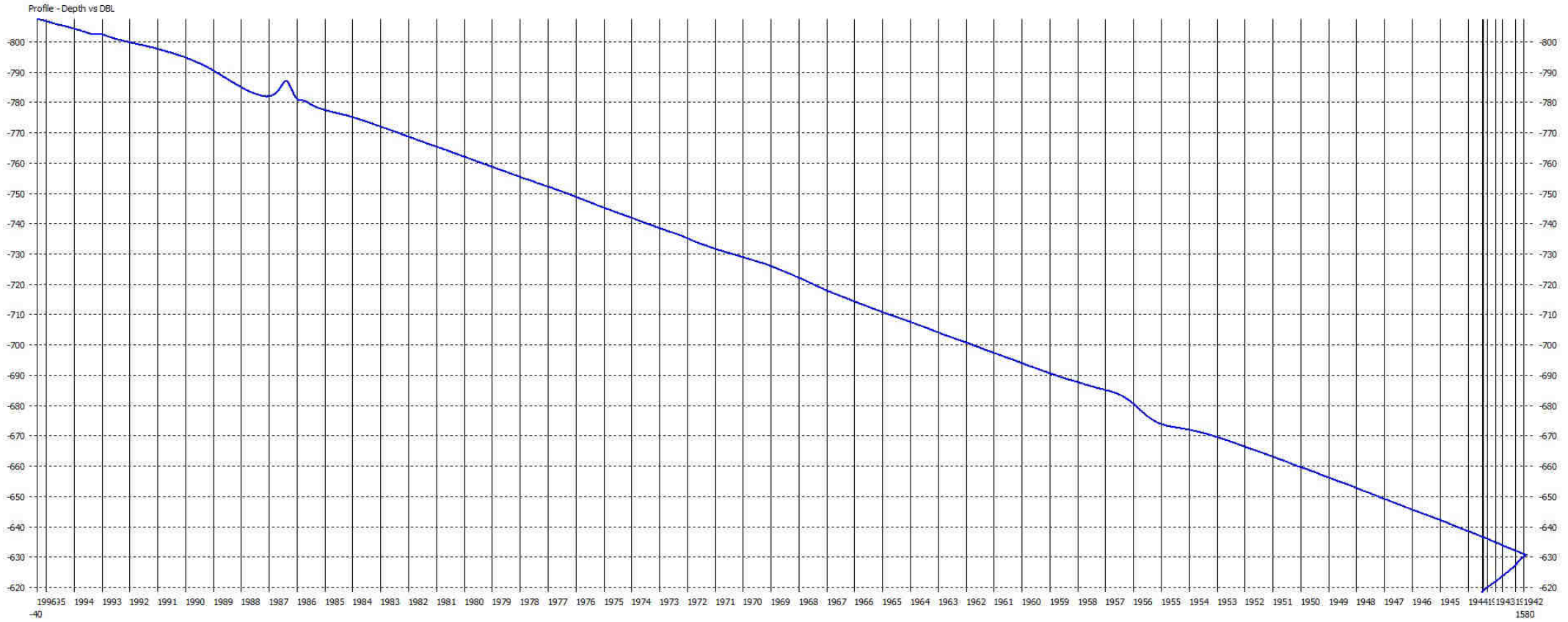


Magnetic Profile 014_1001.jpg

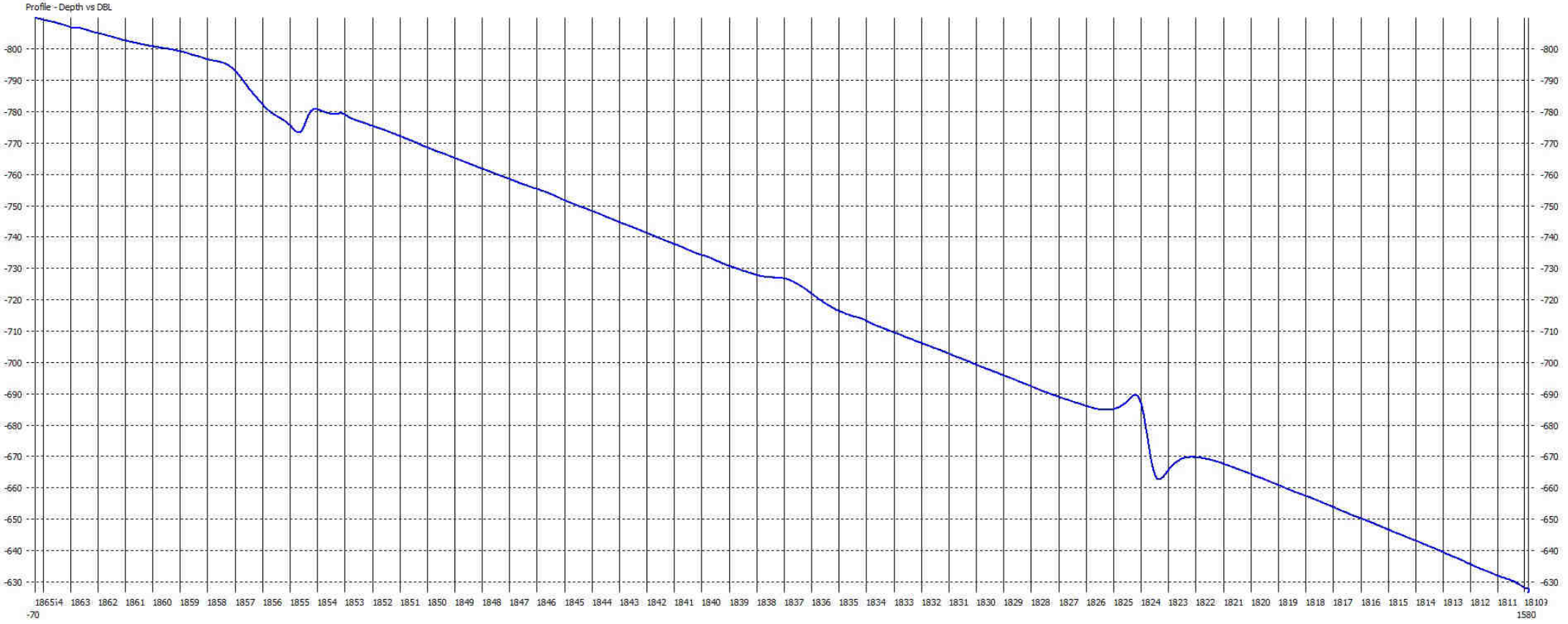


Magnetic Profile 015_0948.jpg

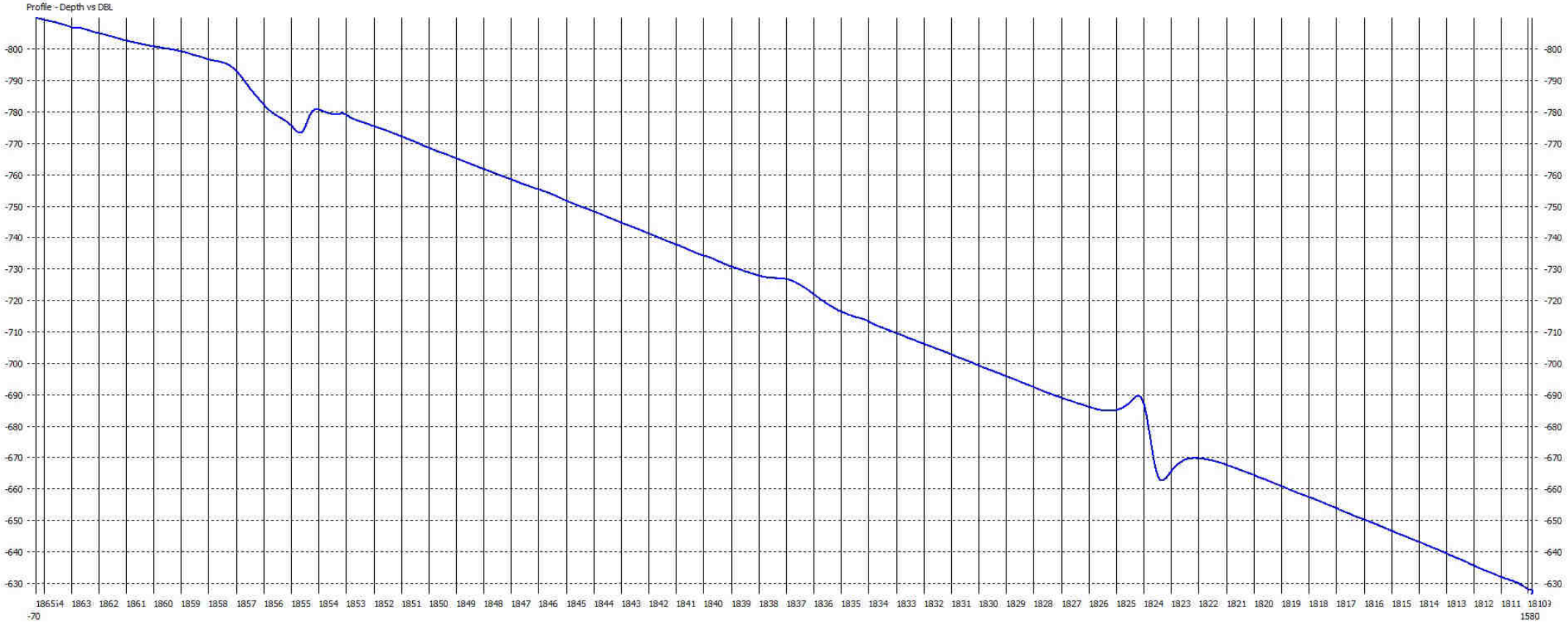
Magnetic Profile 017_0294.jpg



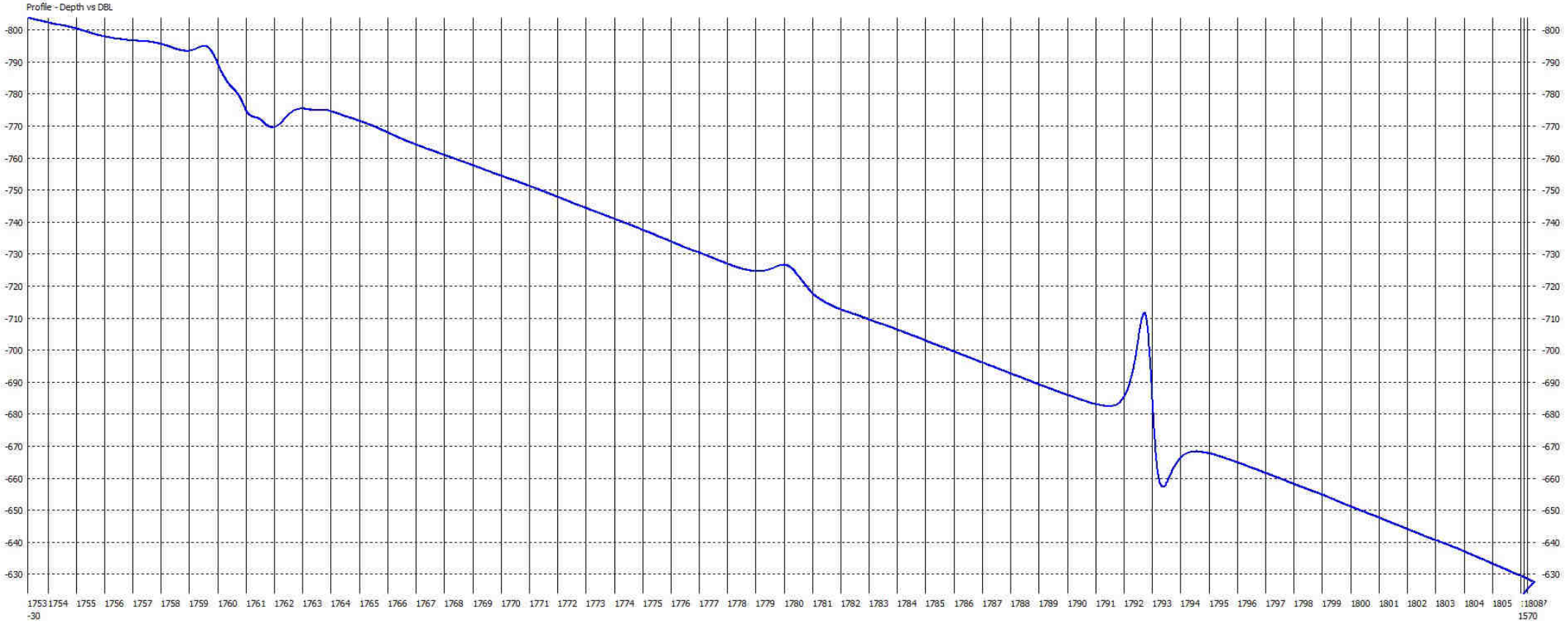
Magnetic Profile 018_0911.jpg



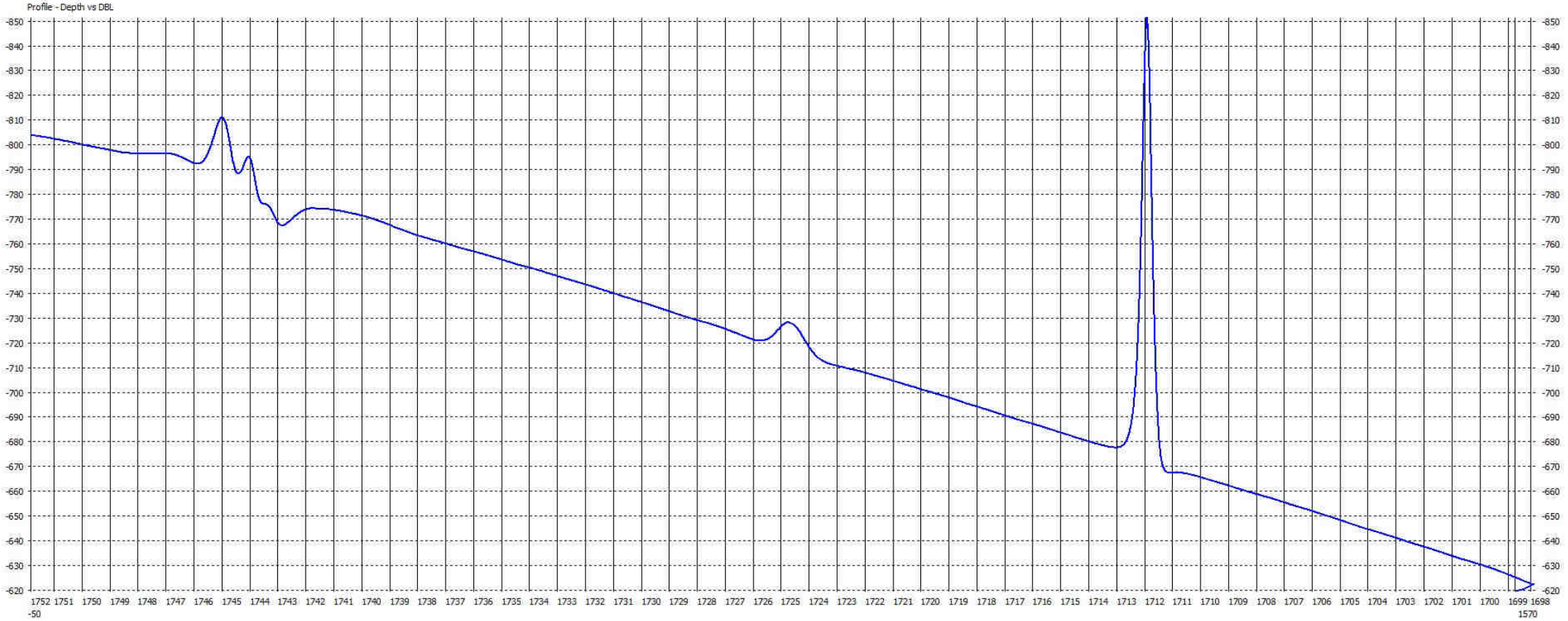
Magnetic Profile 019_1435.jpg



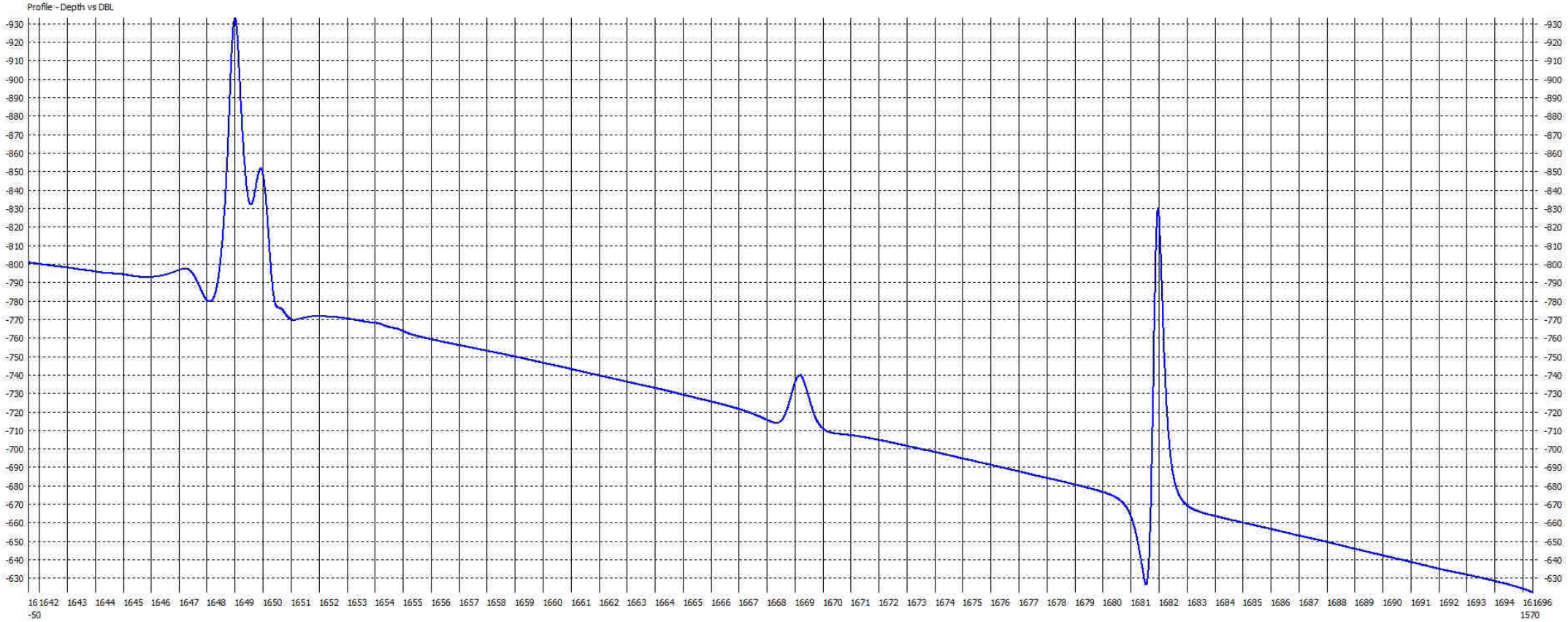
Magnetic Profile 020_1423.jpg



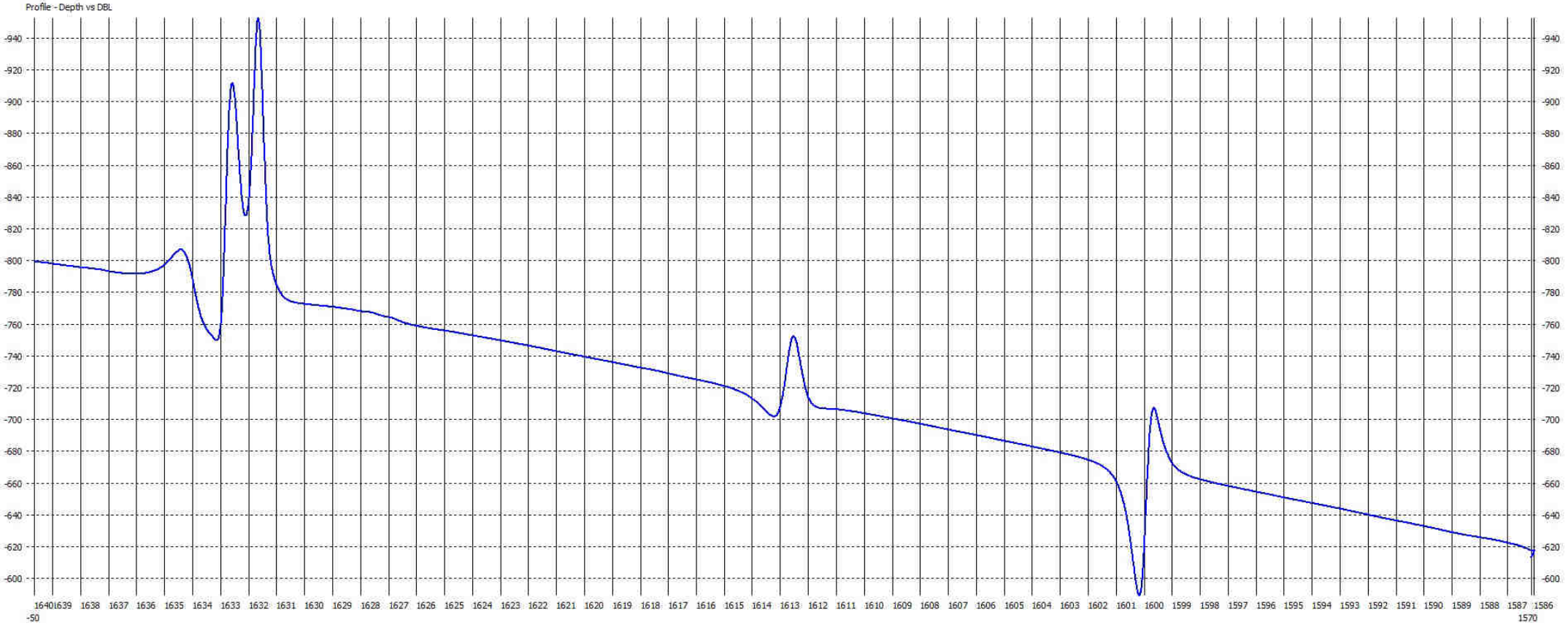
Magnetic Profile 021_1409.jpg



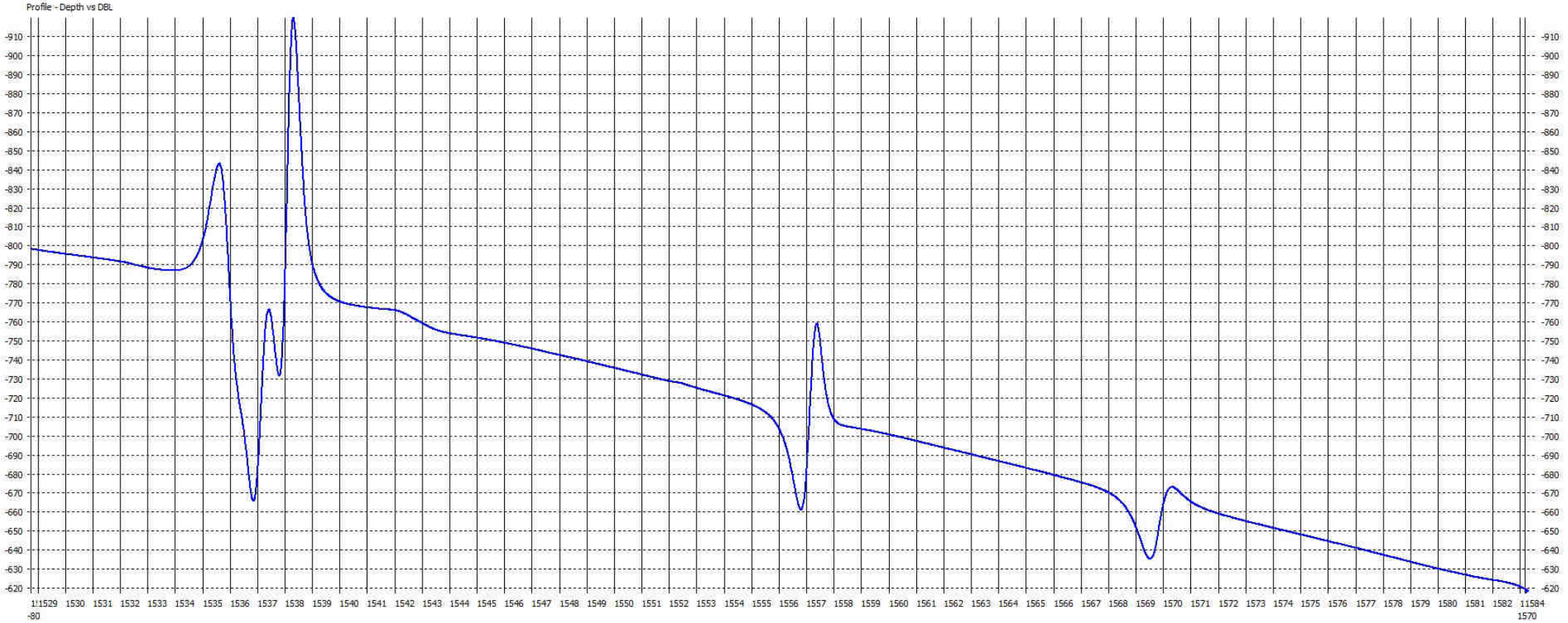
Magnetic Profile 022_1357.jpg



Magnetic Profile 023_1345.jpg

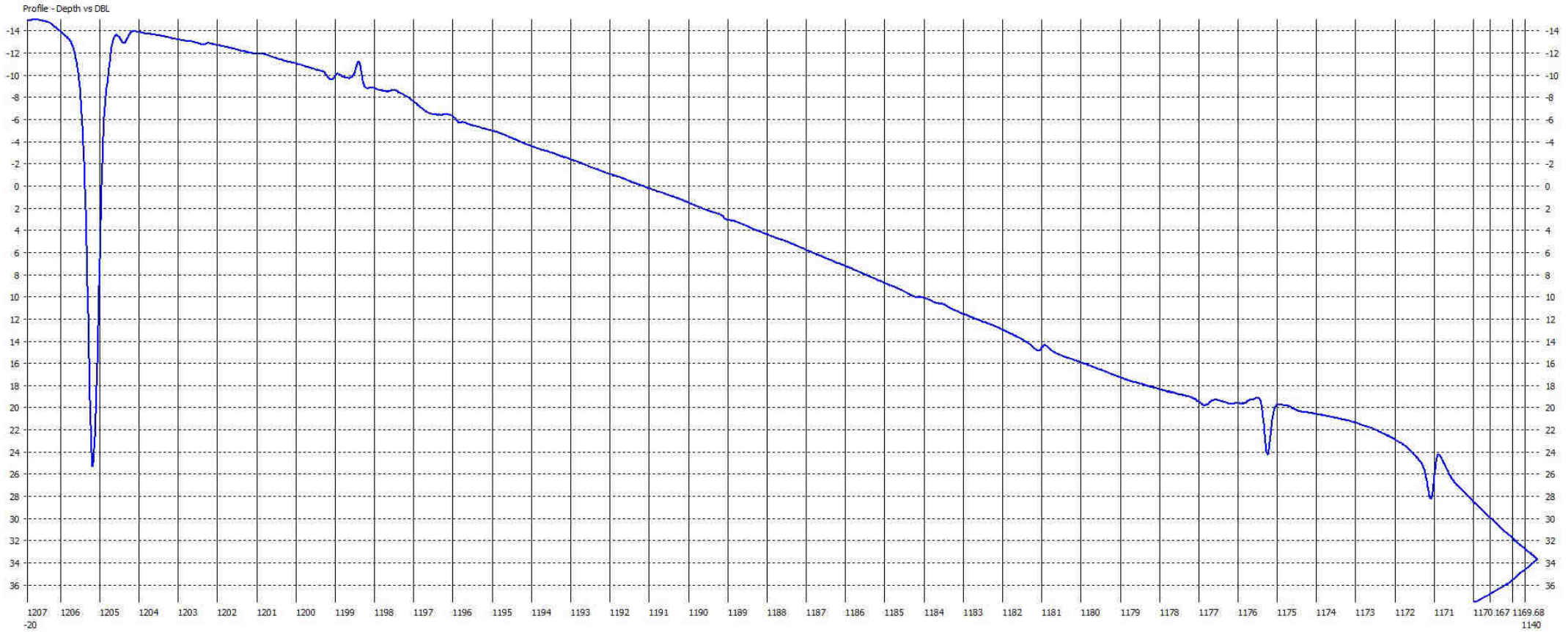


Magnetic Profile 024_1333.jpg

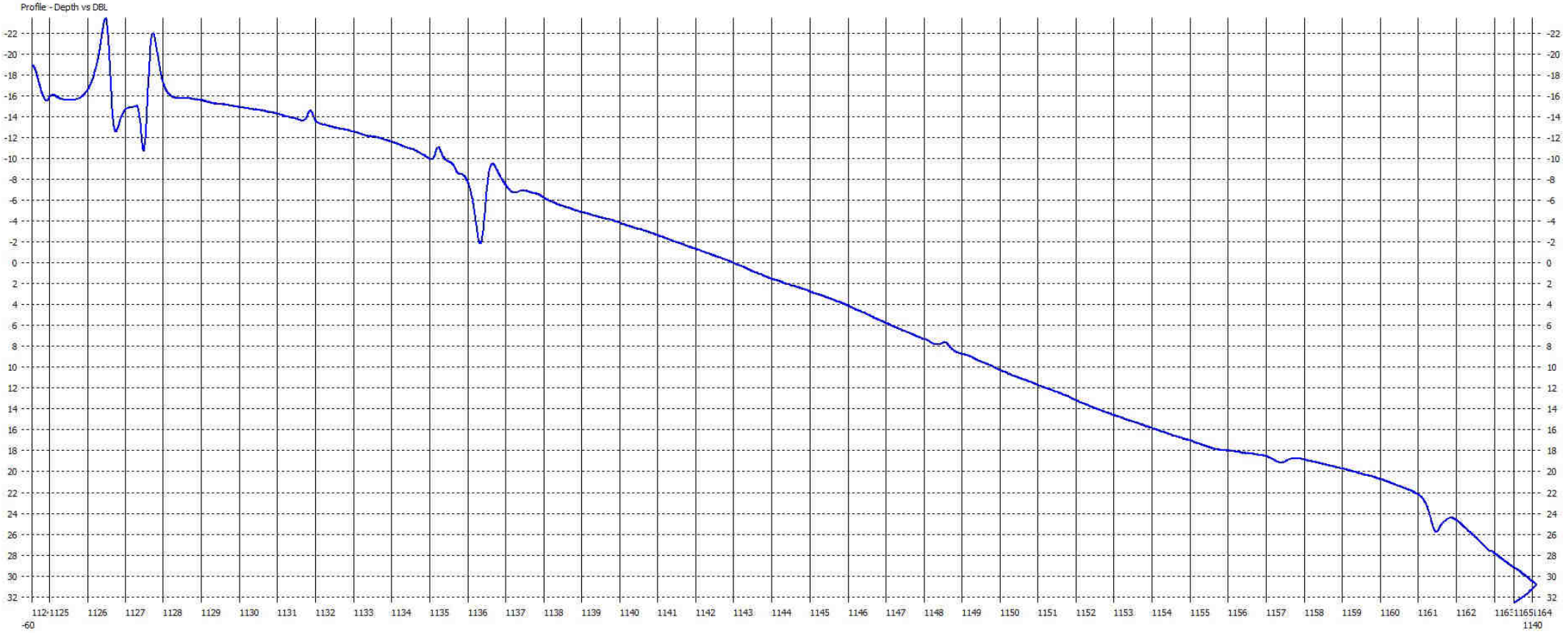


BORROW AREA 2 MAGNETIC PROFILES

Magnetic Profile 001_1141.jpg

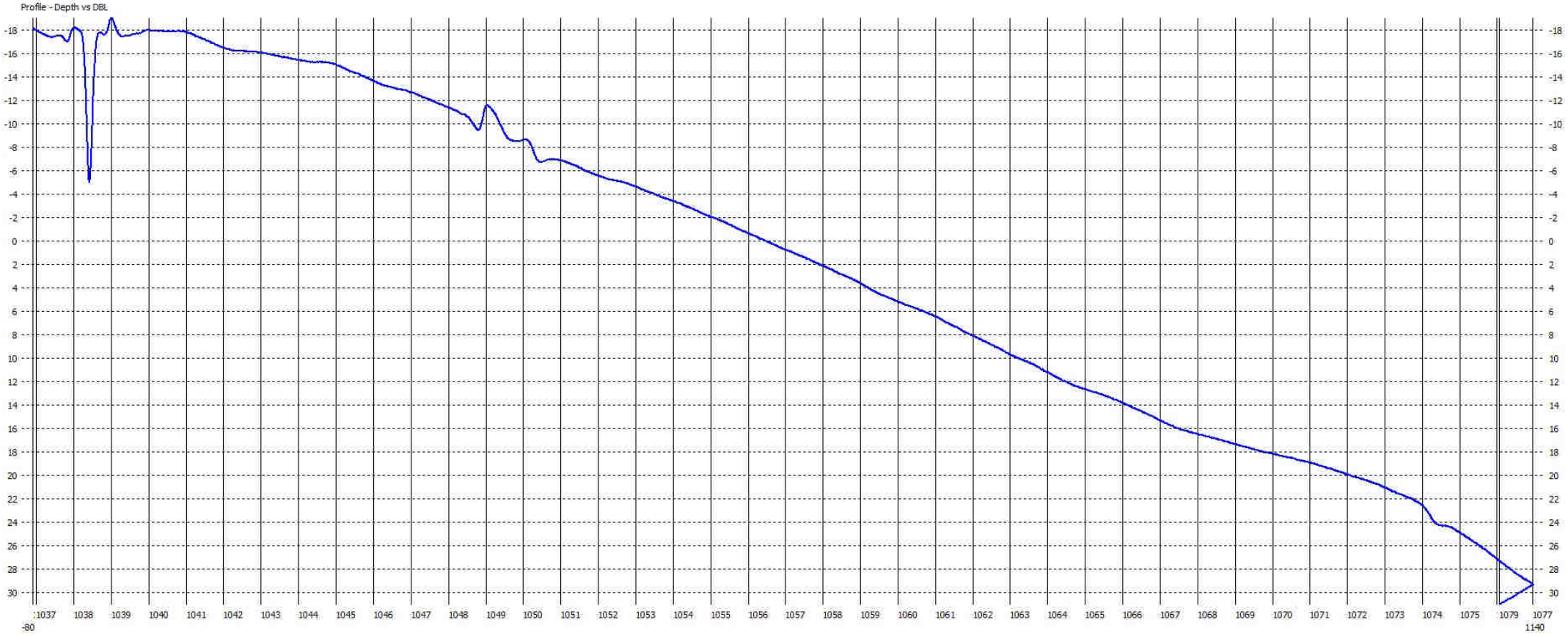


Magnetic Profile 002_1132.jpg

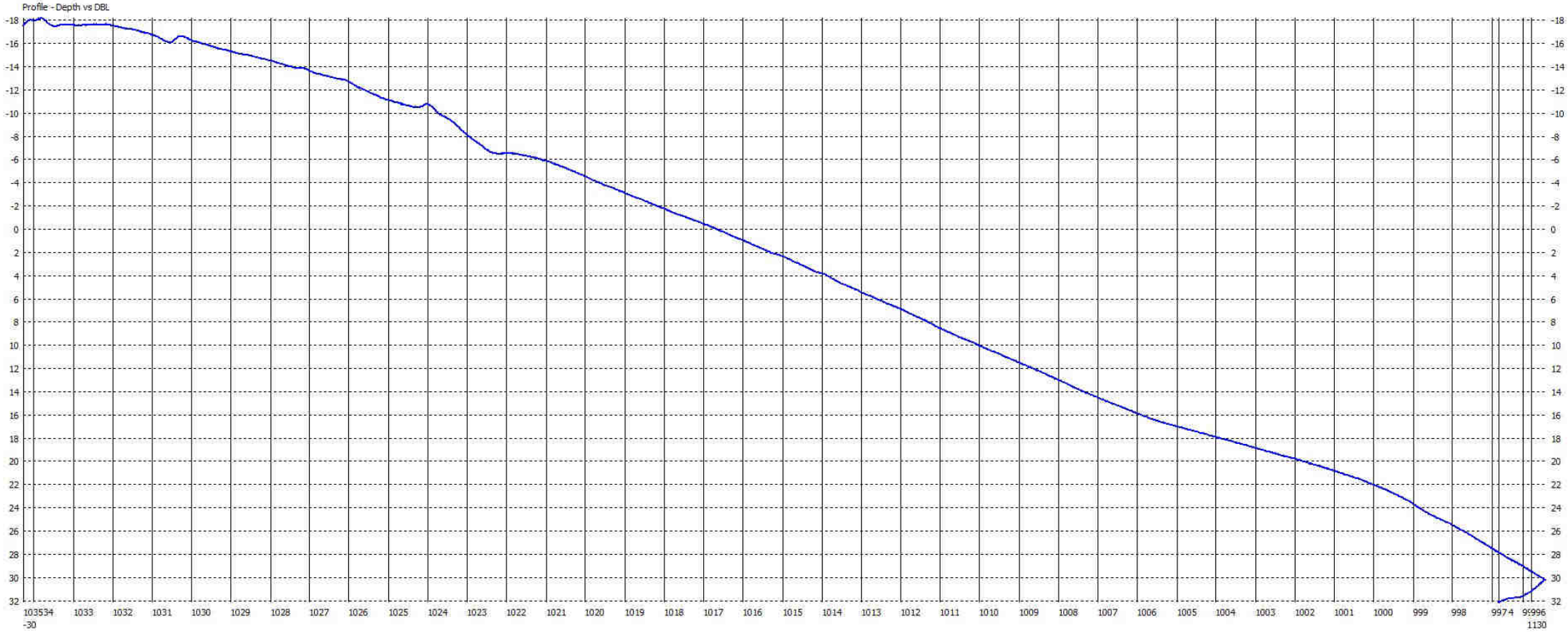


Magnetic Profile 003_1123.jpg

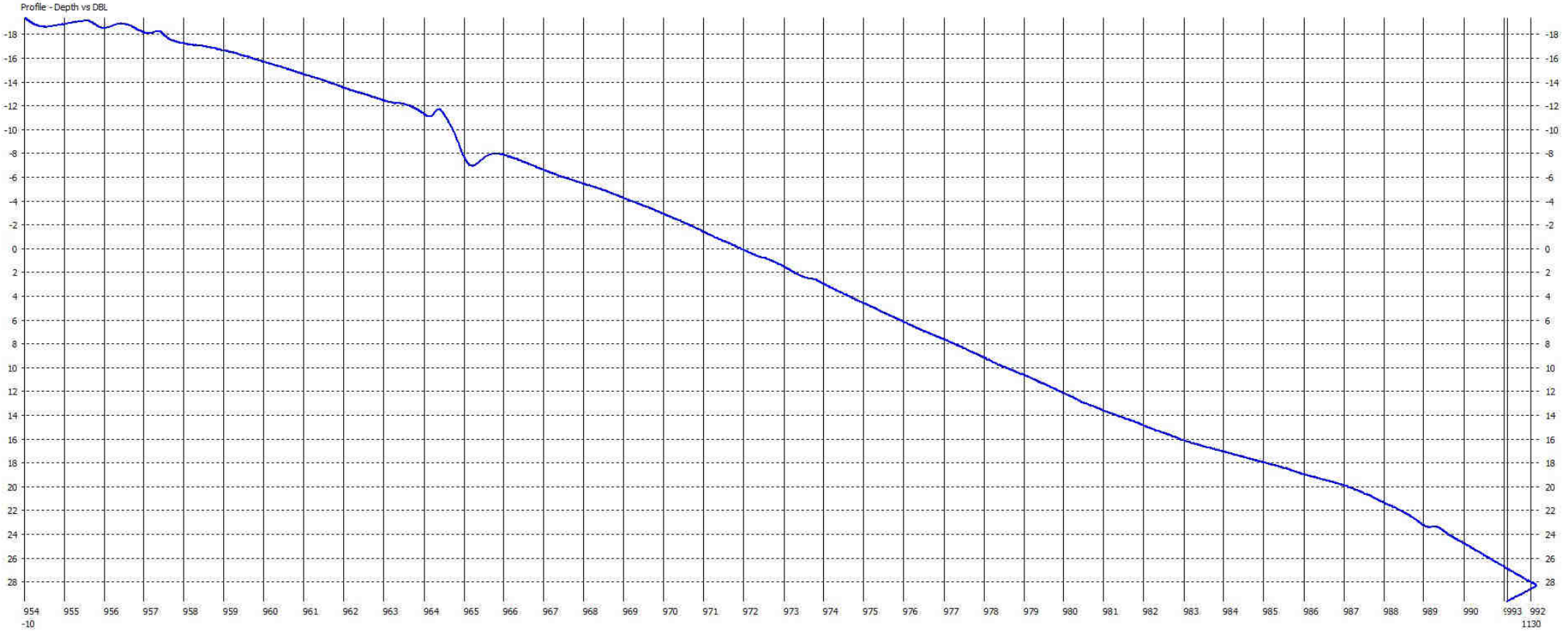
Magnetic Profile 004_1114.jpg



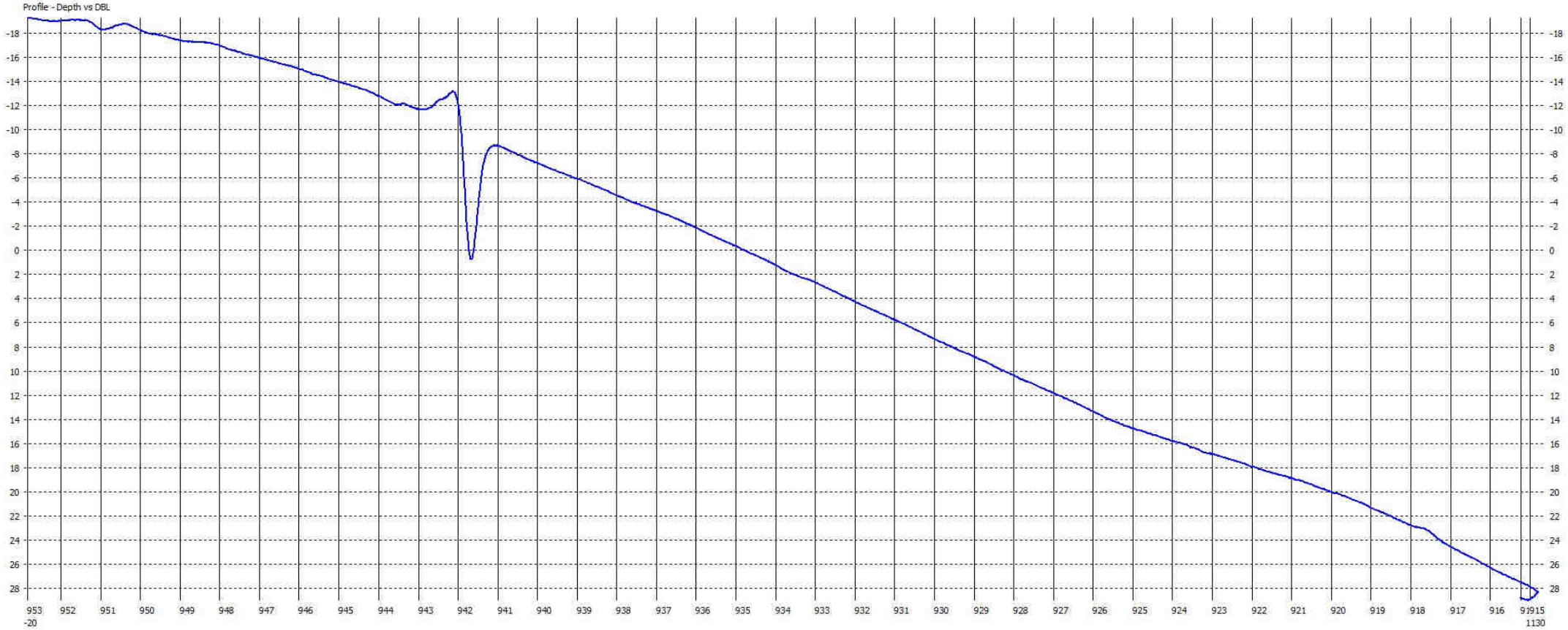
Magnetic Profile 005_1105.jpg



Magnetic Profile 006_1057.jpg



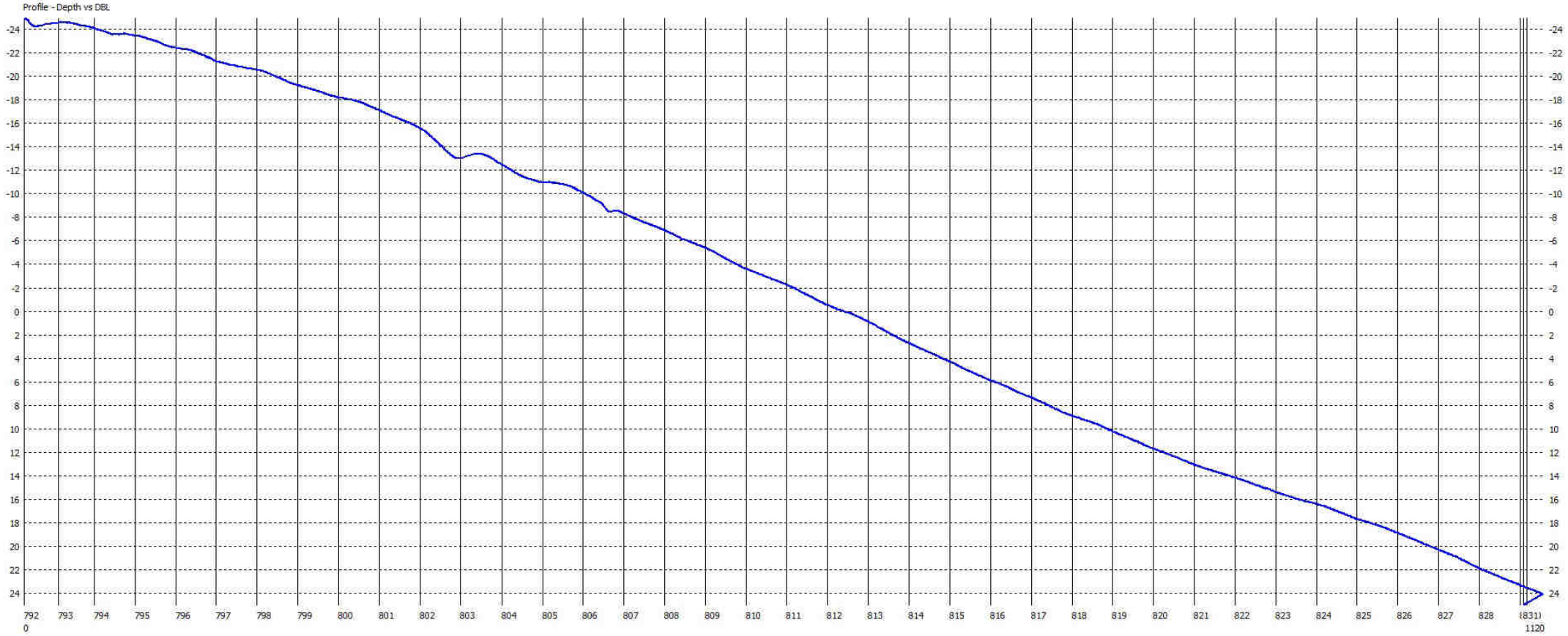
Magnetic Profile 007_1048.jpg



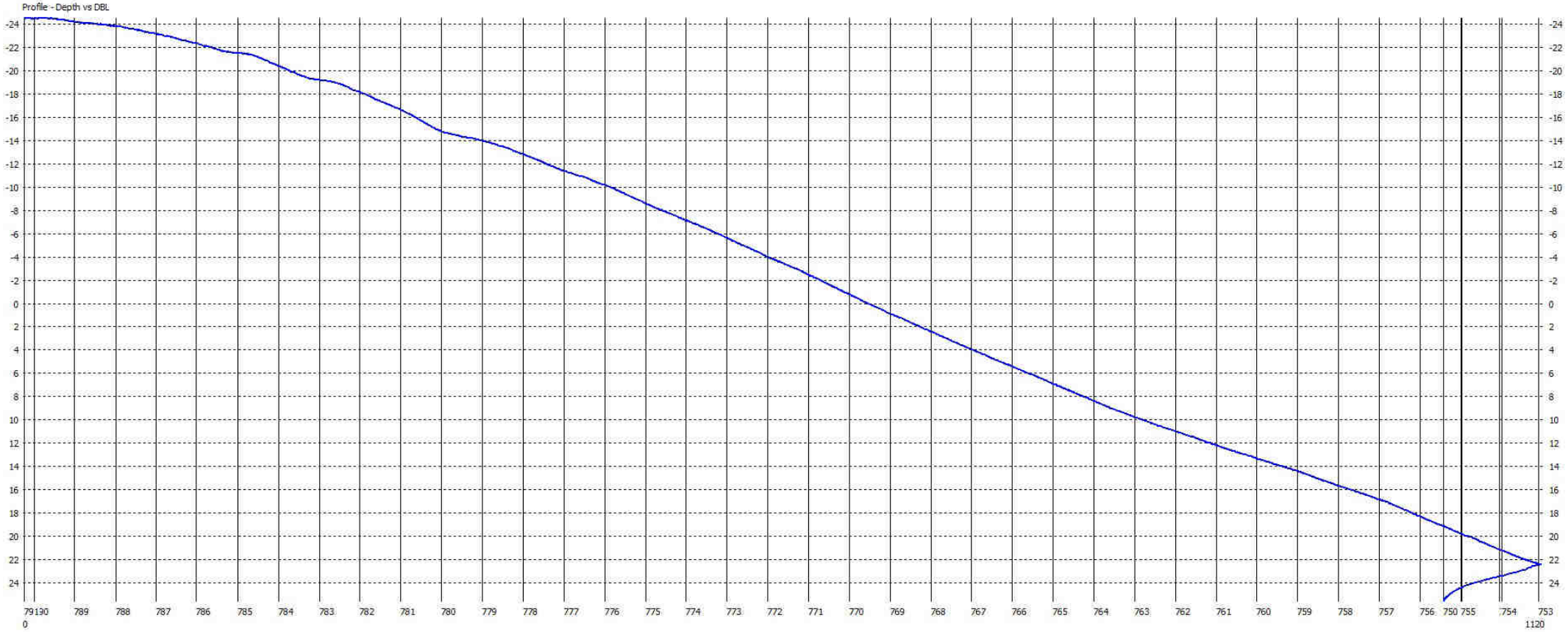
Magnetic Profile 008_1038.jpg

Magnetic Profile 009_1029.jpg

Magnetic Profile 010_1020.jpg

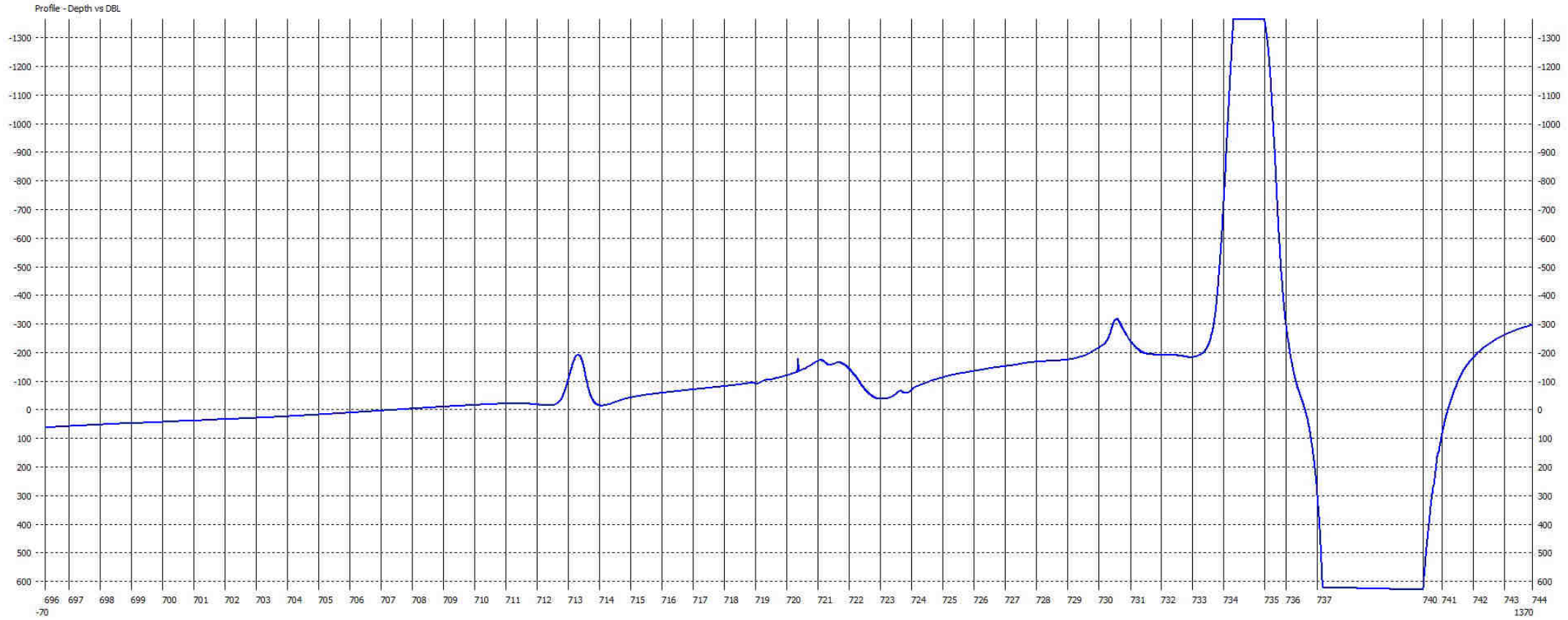


Magnetic Profile 011_1008.jpg

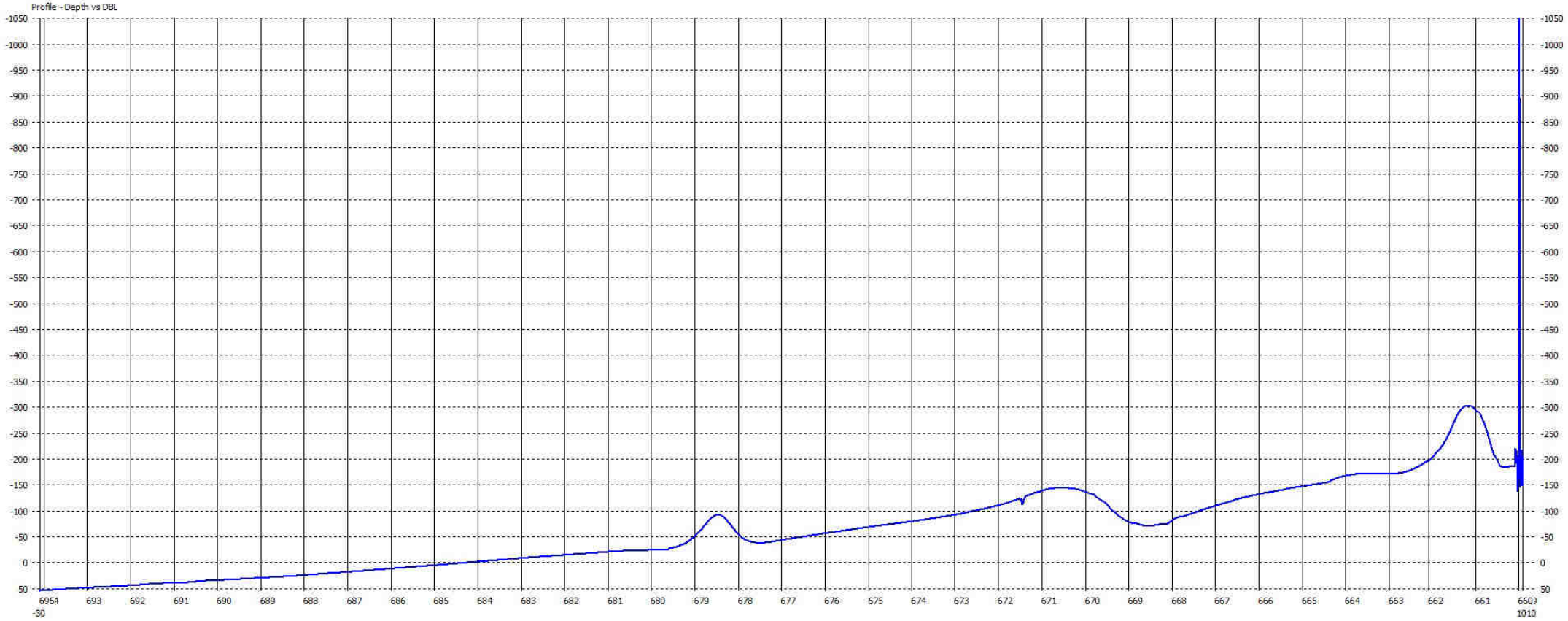


BORROW AREA 4 MAGNETIC PROFILES

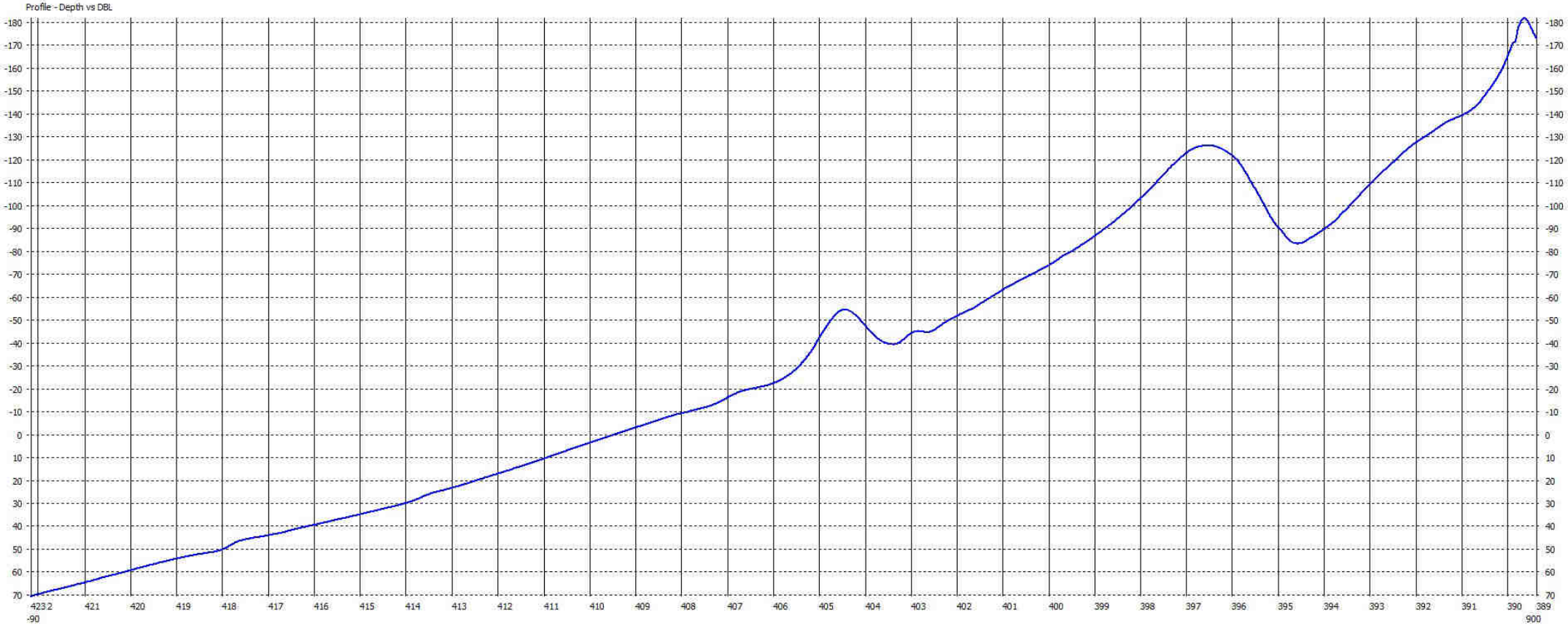
Magnetic Profile 003_1528.jpg



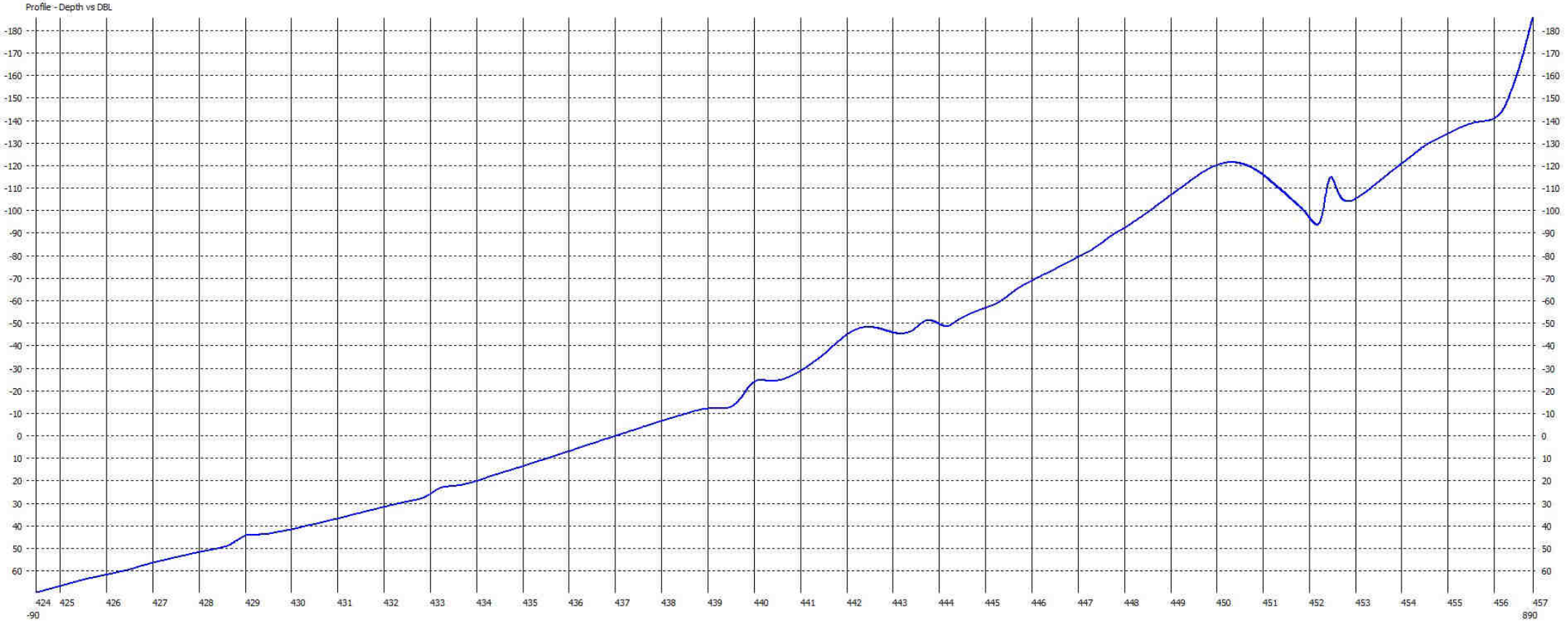
Magnetic Profile 004_1517.jpg



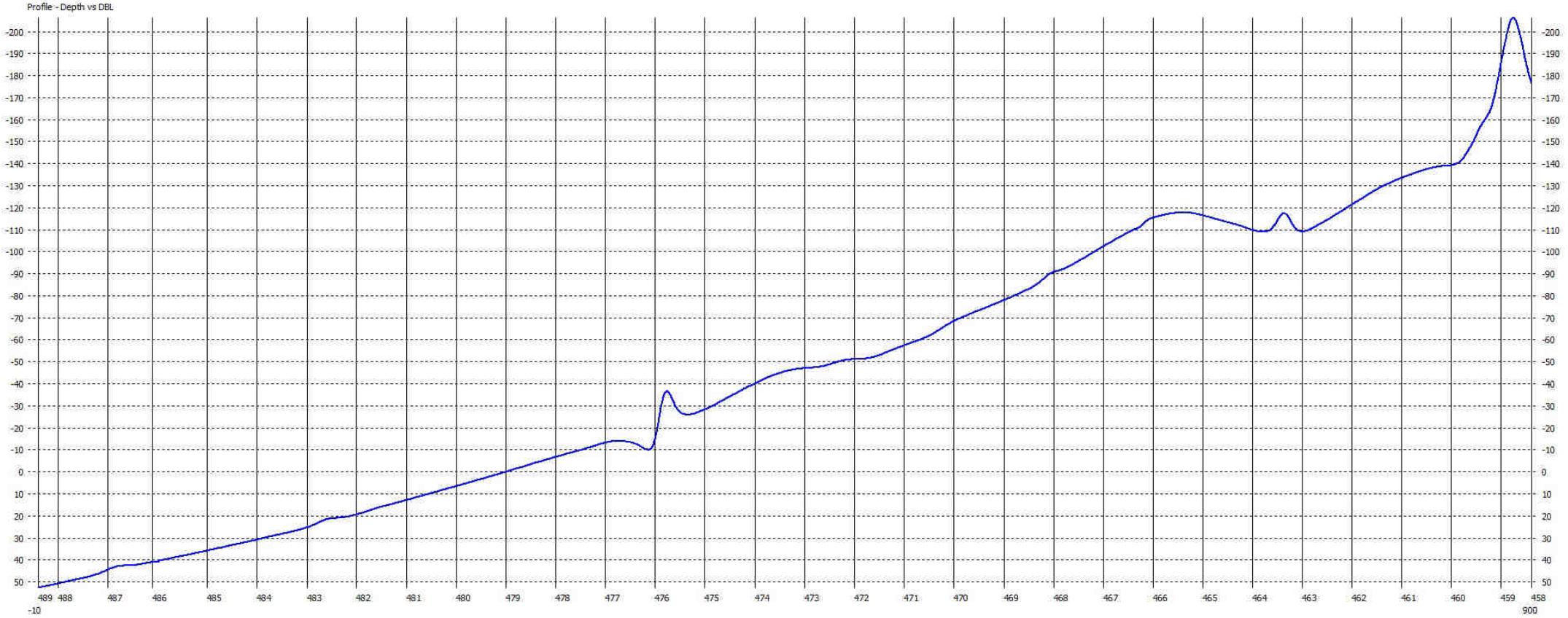
Magnetic Profile 005_1402.jpg



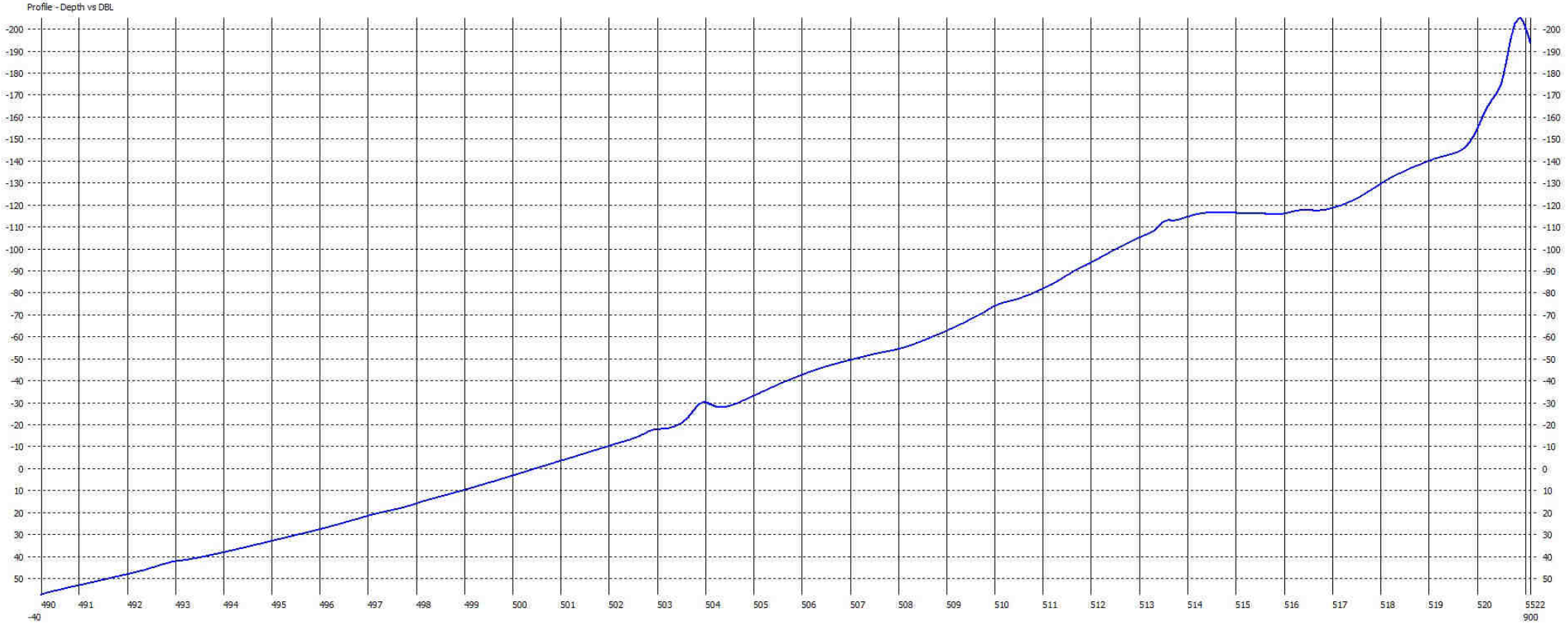
Magnetic Profile 006_1411.jpg



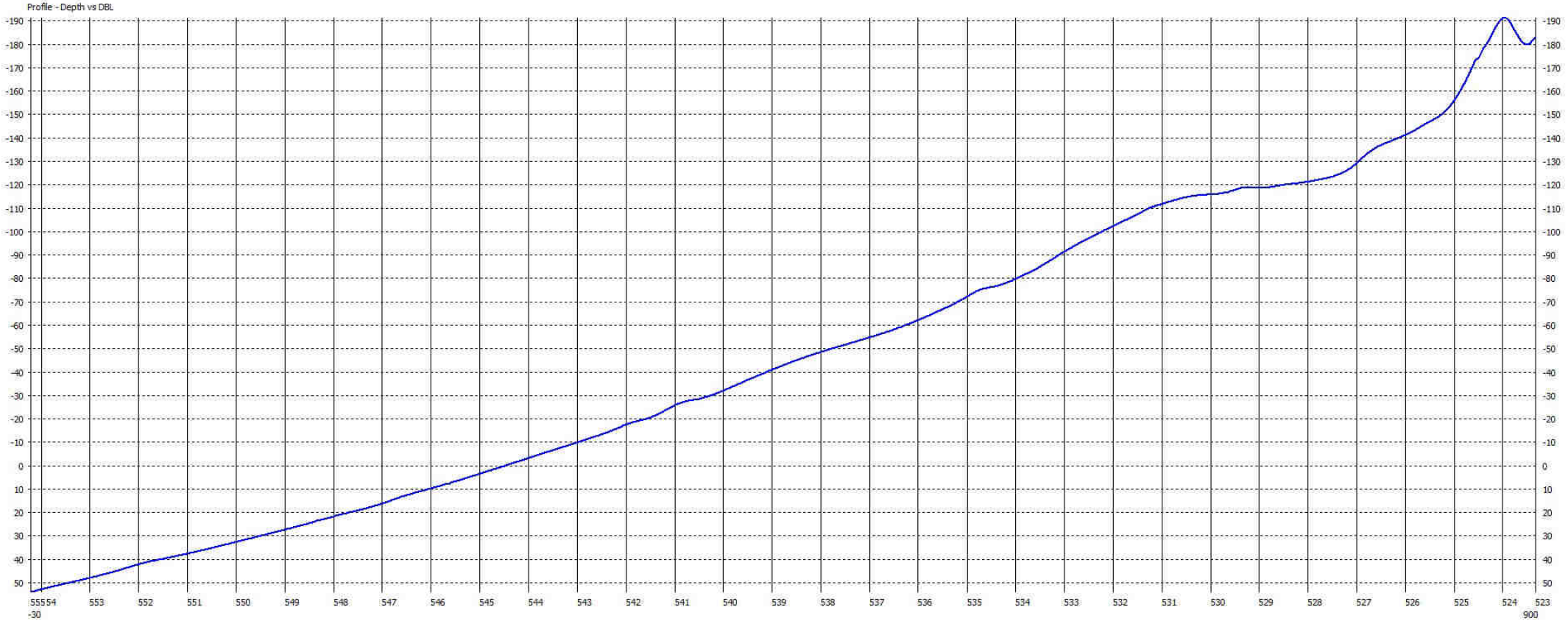
Magnetic Profile 007_1420.jpg



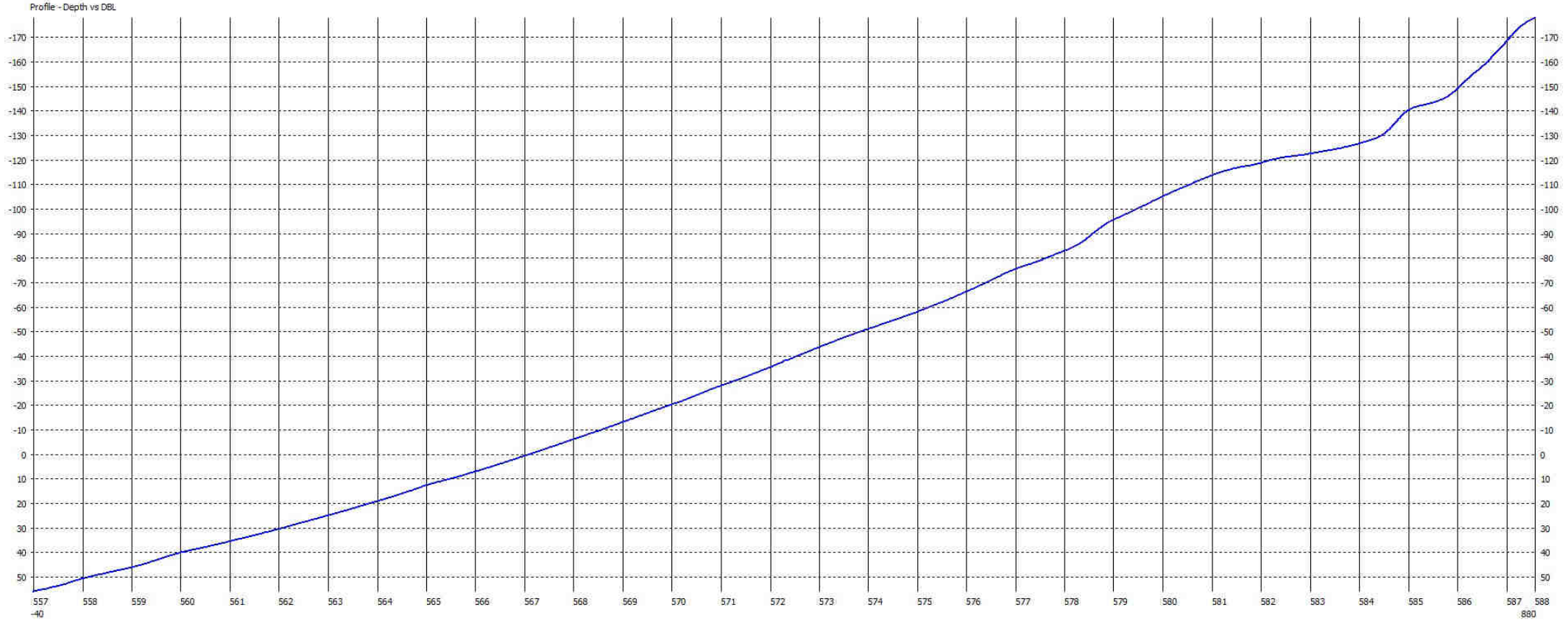
Magnetic Profile 008_1429.jpg



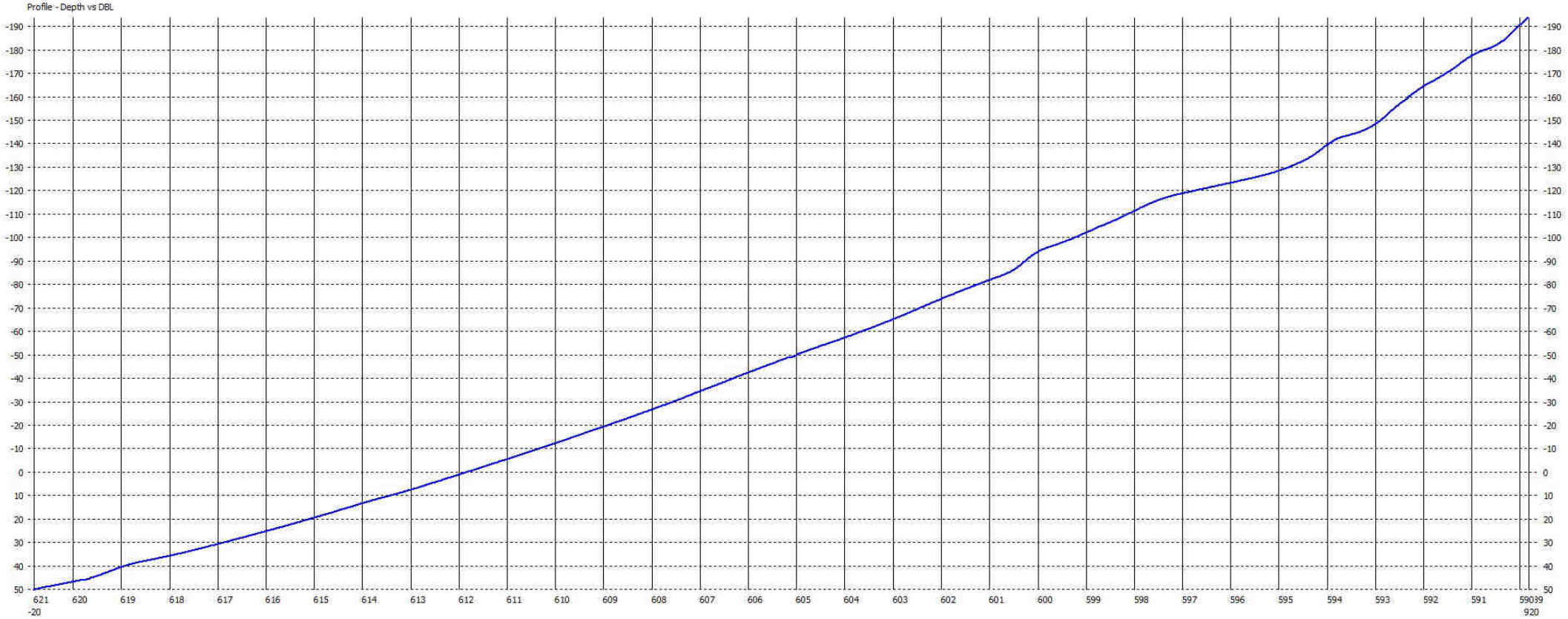
Magnetic Profile 009_1439.jpg



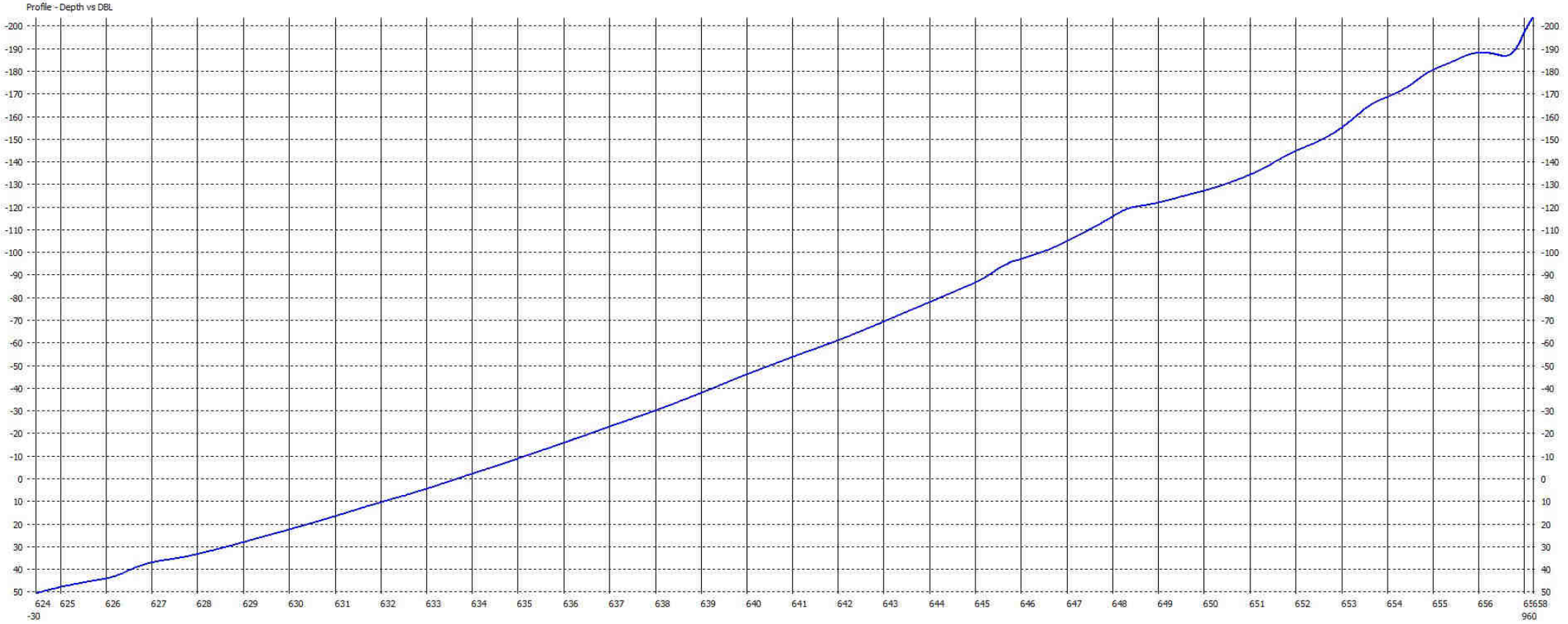
Magnetic Profile 010_1449.jpg



Magnetic Profile 011_1458.jpg



Magnetic Profile 012_1507.jpg



BORROW AREA 6-7-8 MAGNETIC PROFILES

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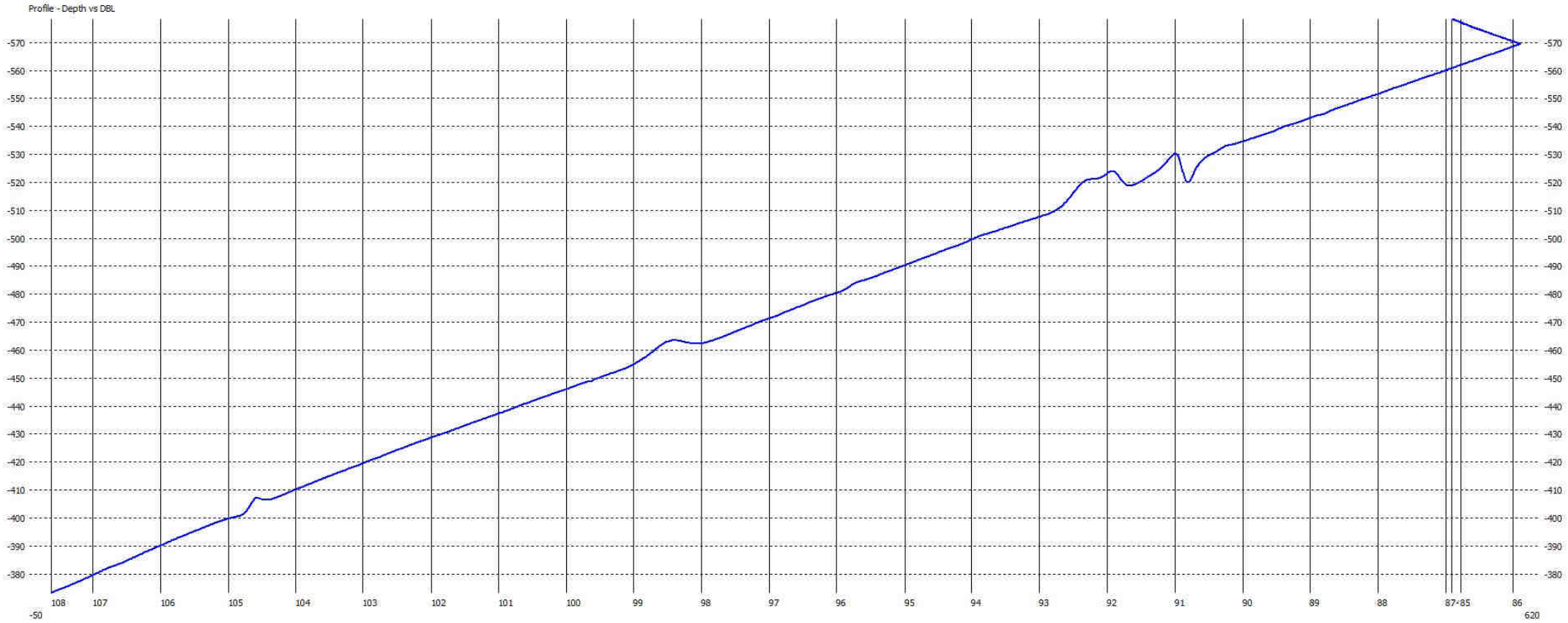

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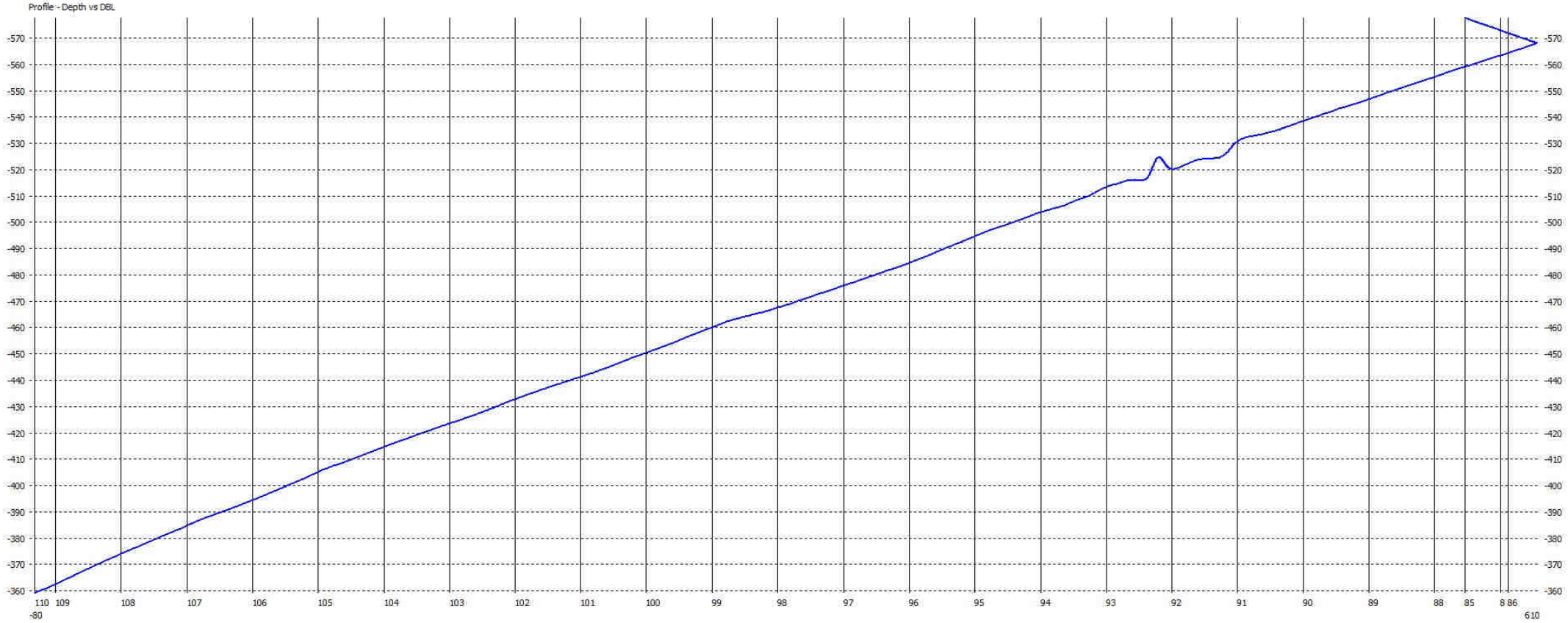

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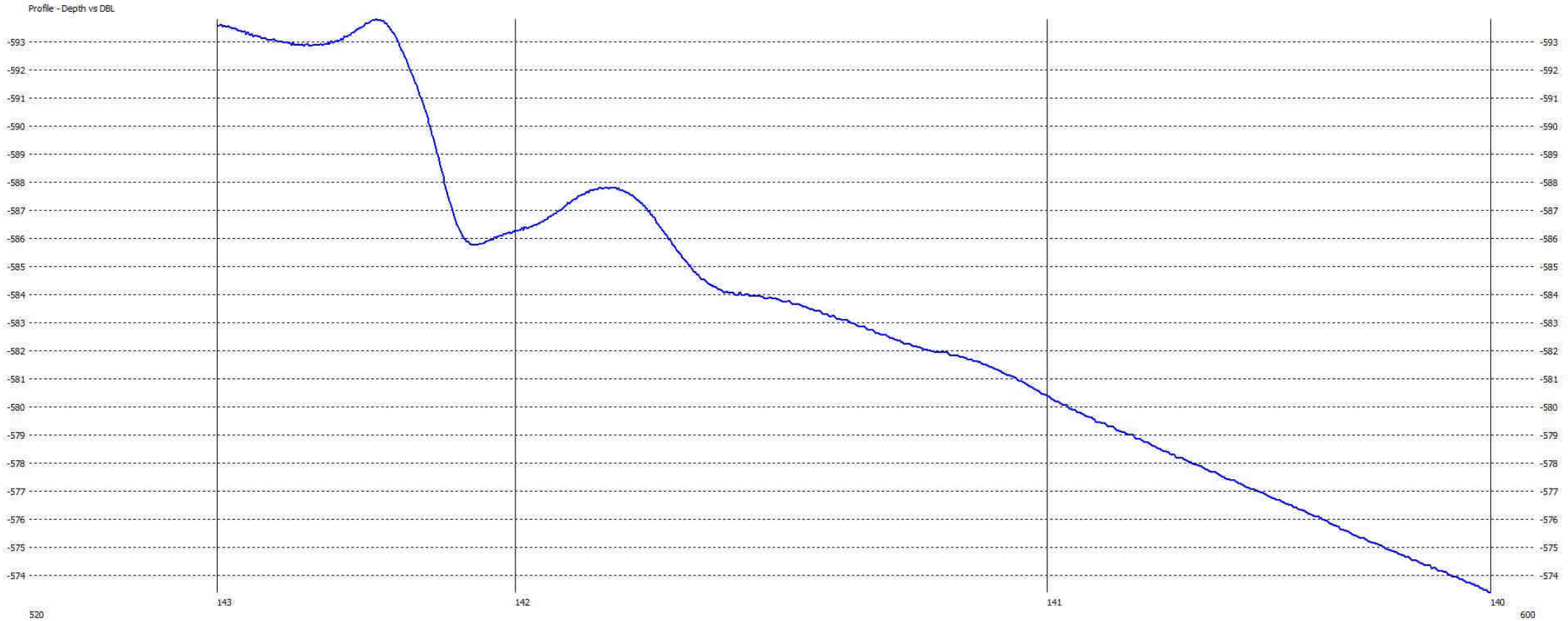

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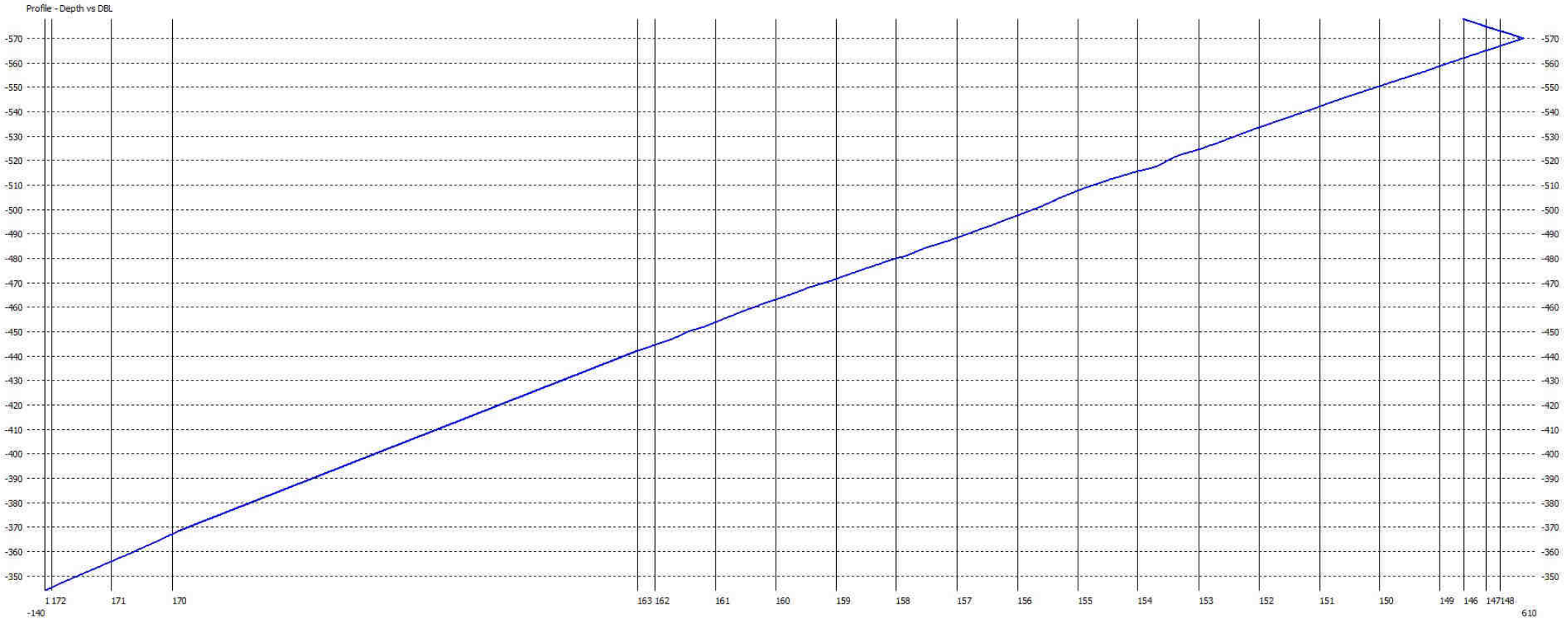

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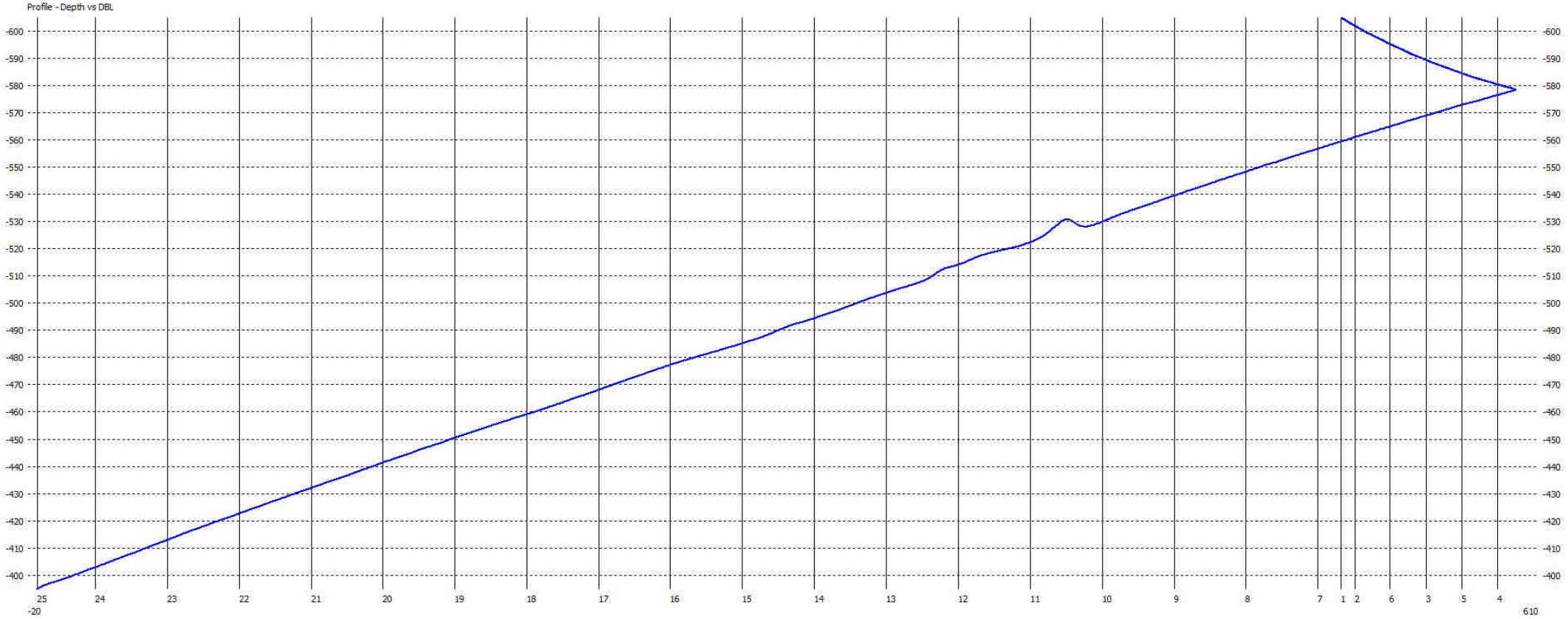

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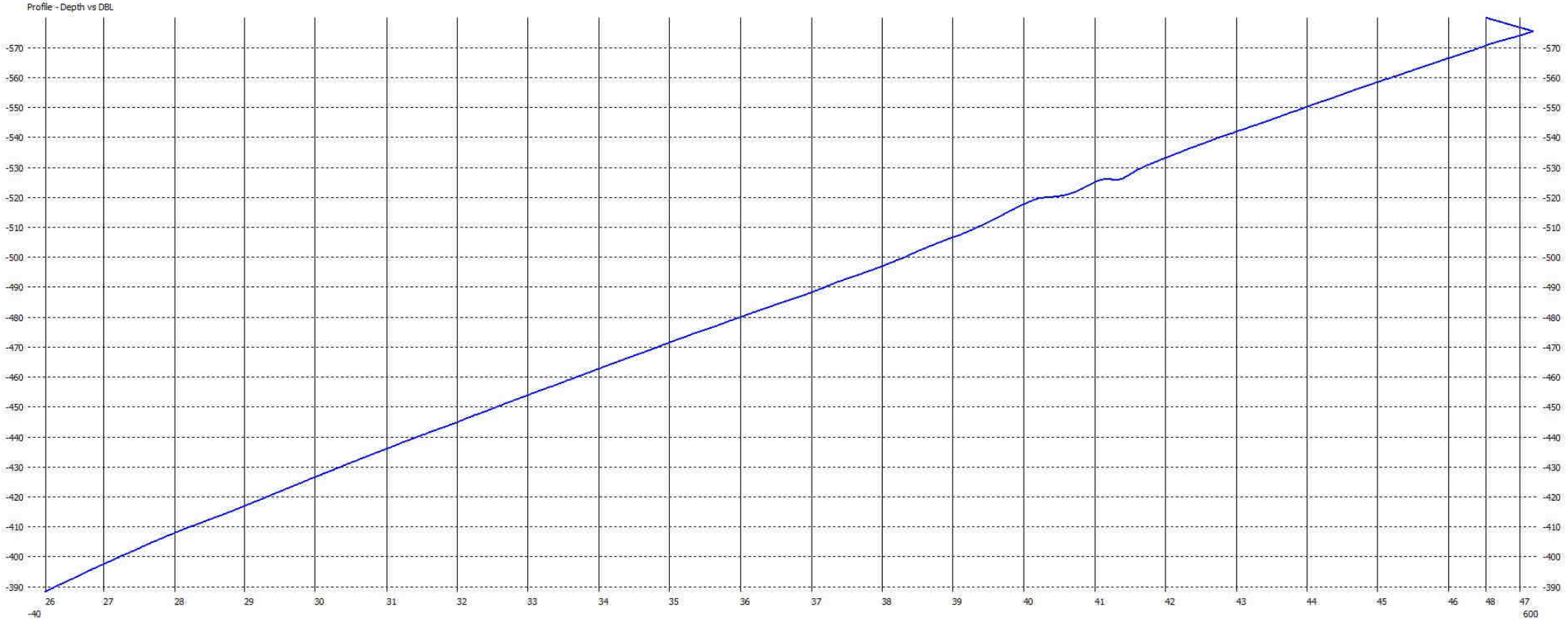
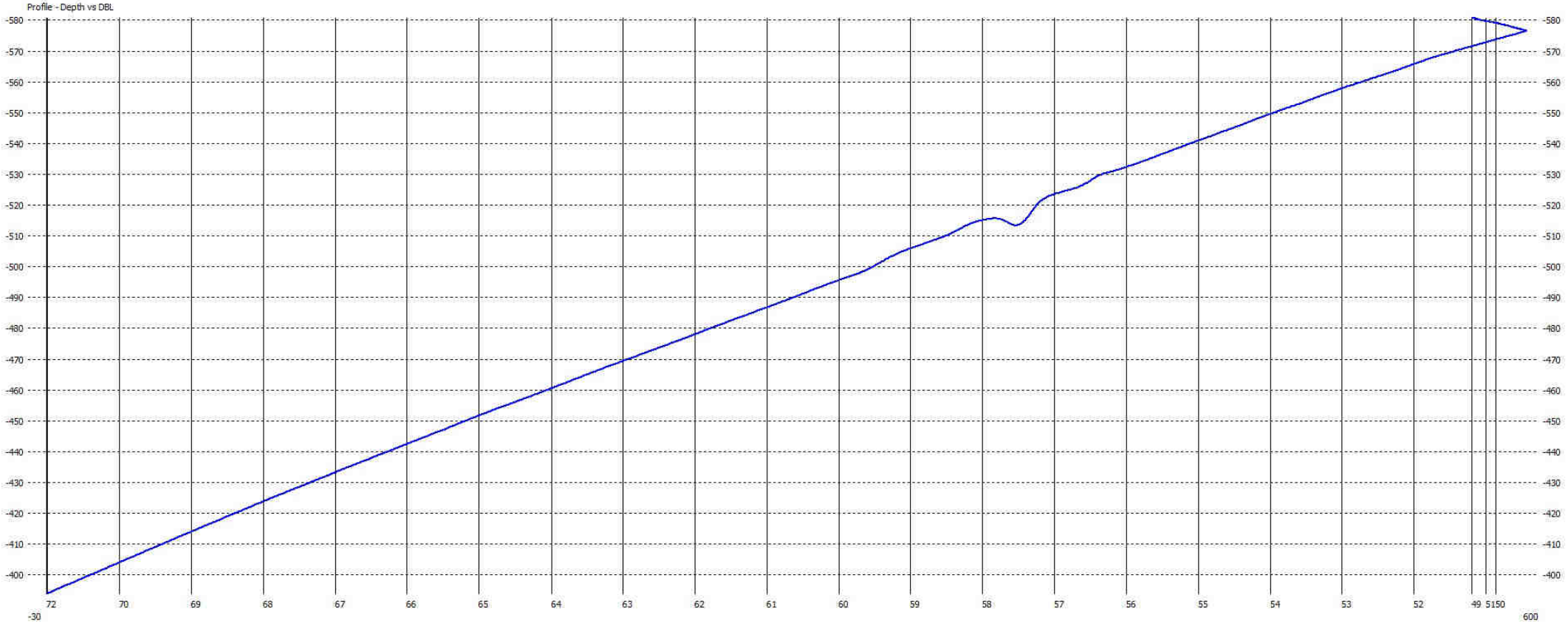
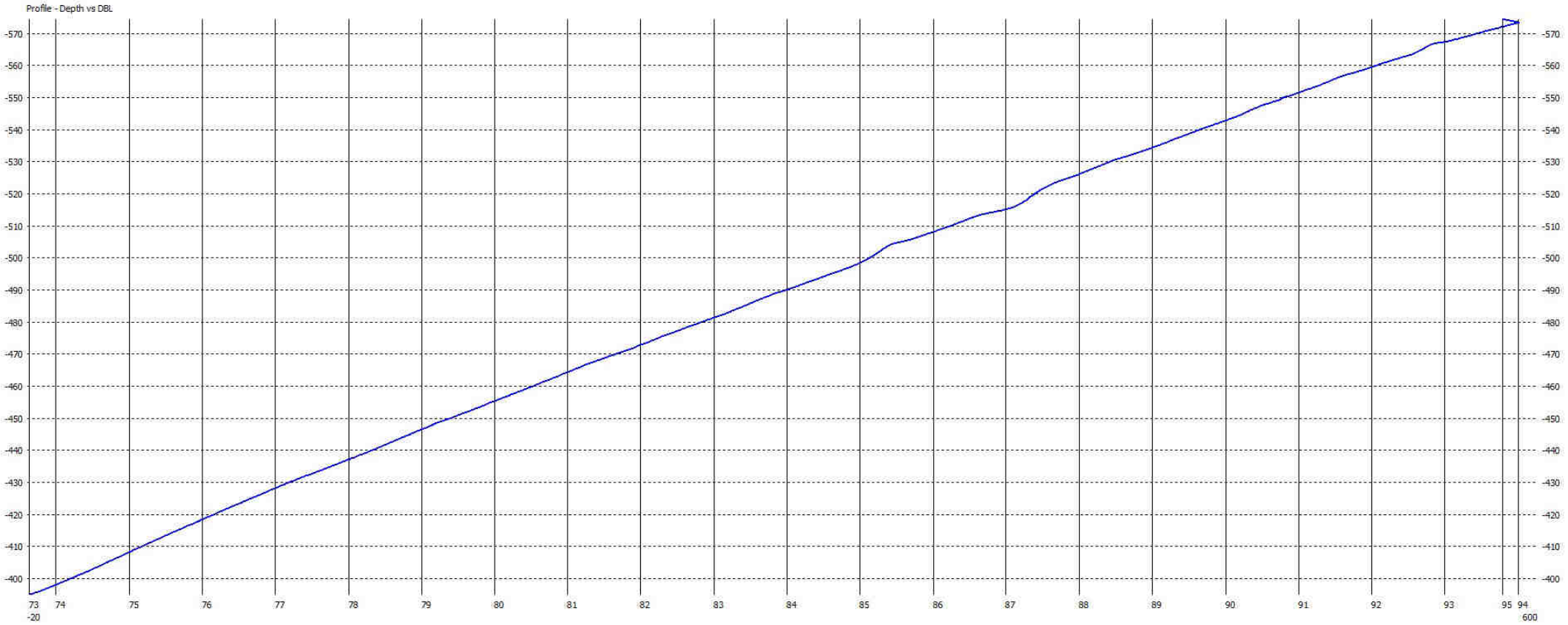


Magnetic Profile 007_1058.jpg



Magnetic Profile 008_1105.jpg



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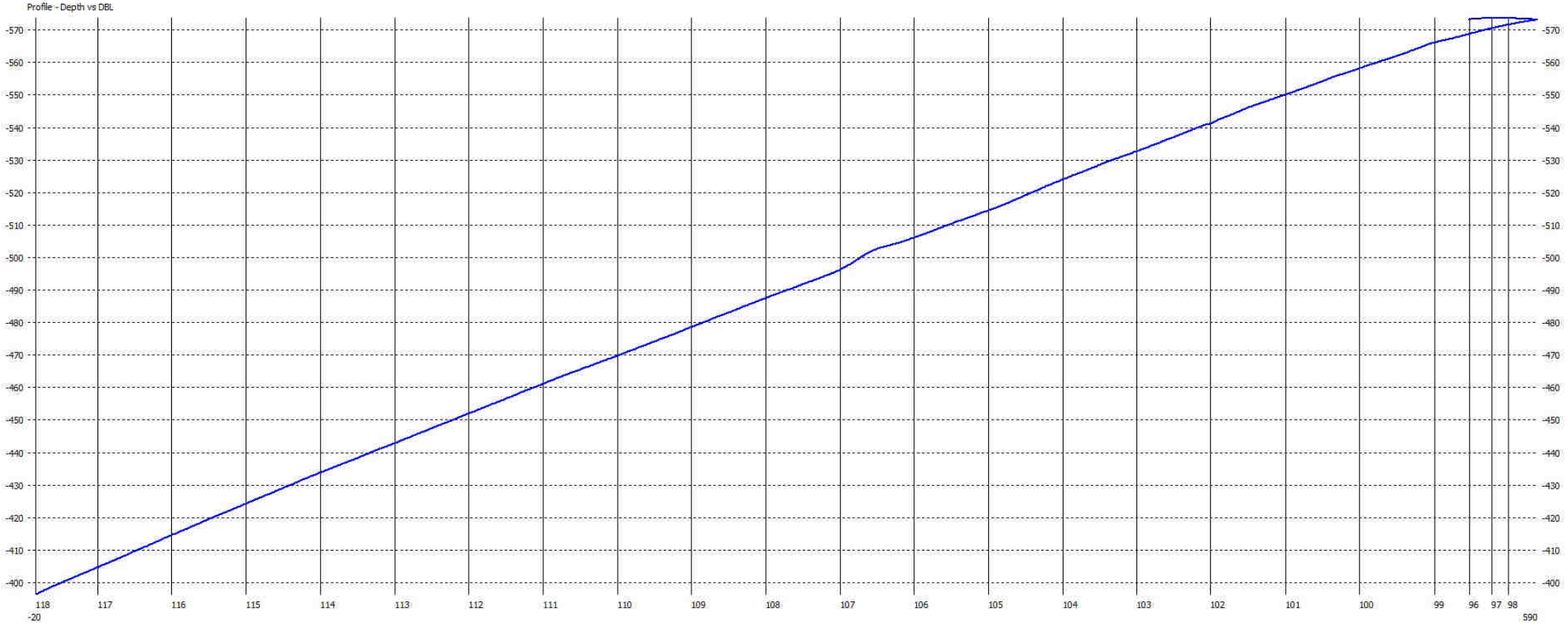

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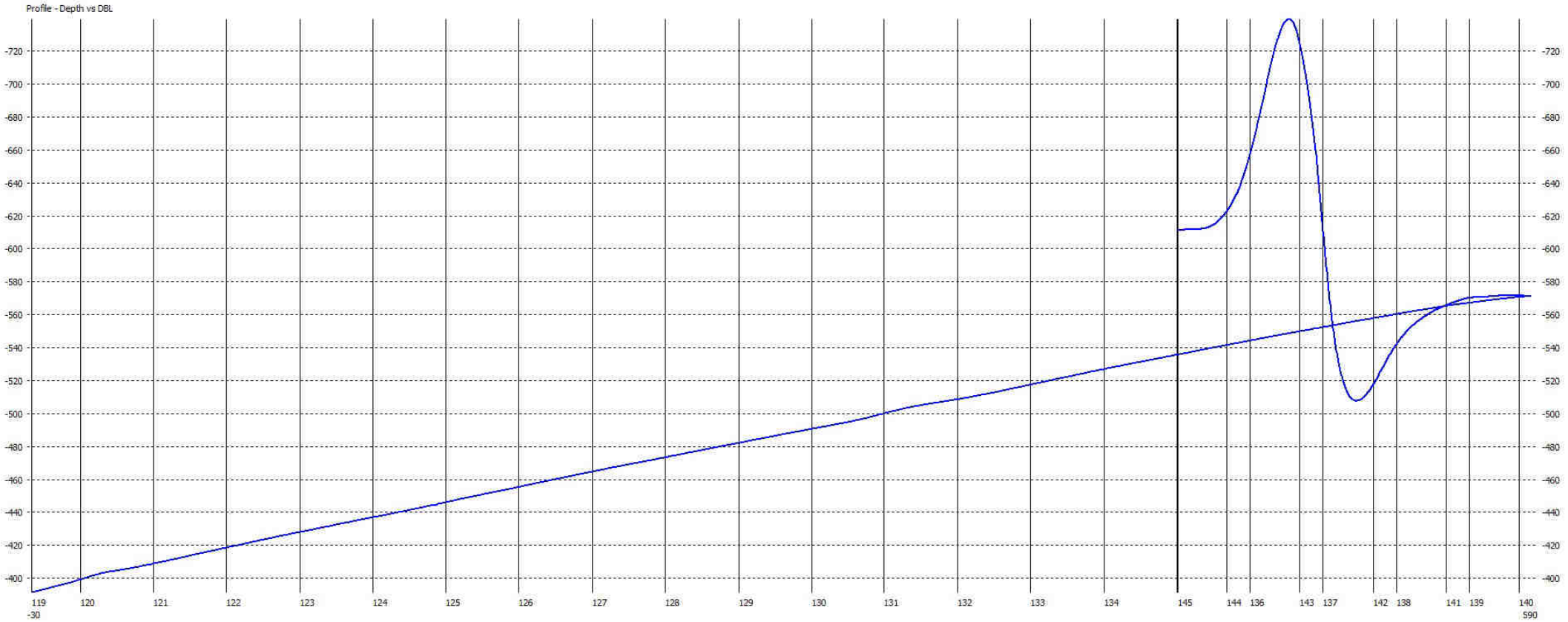
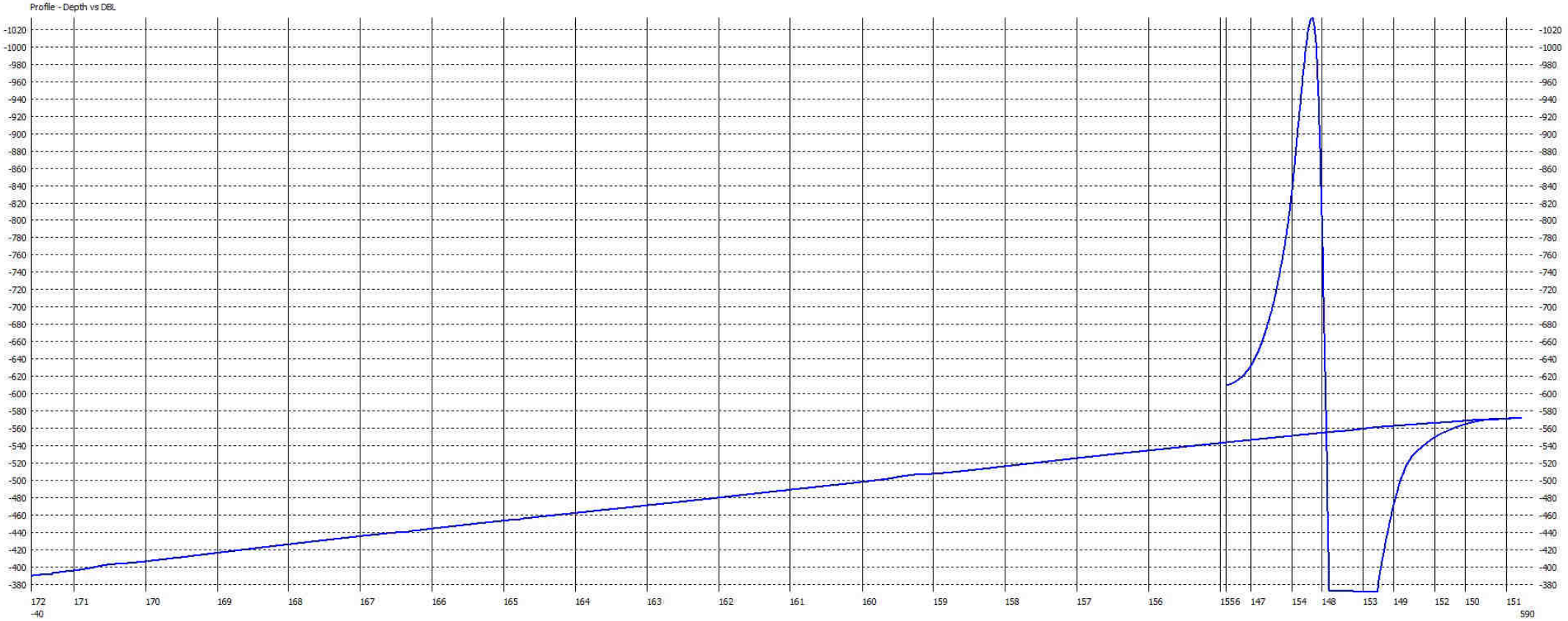
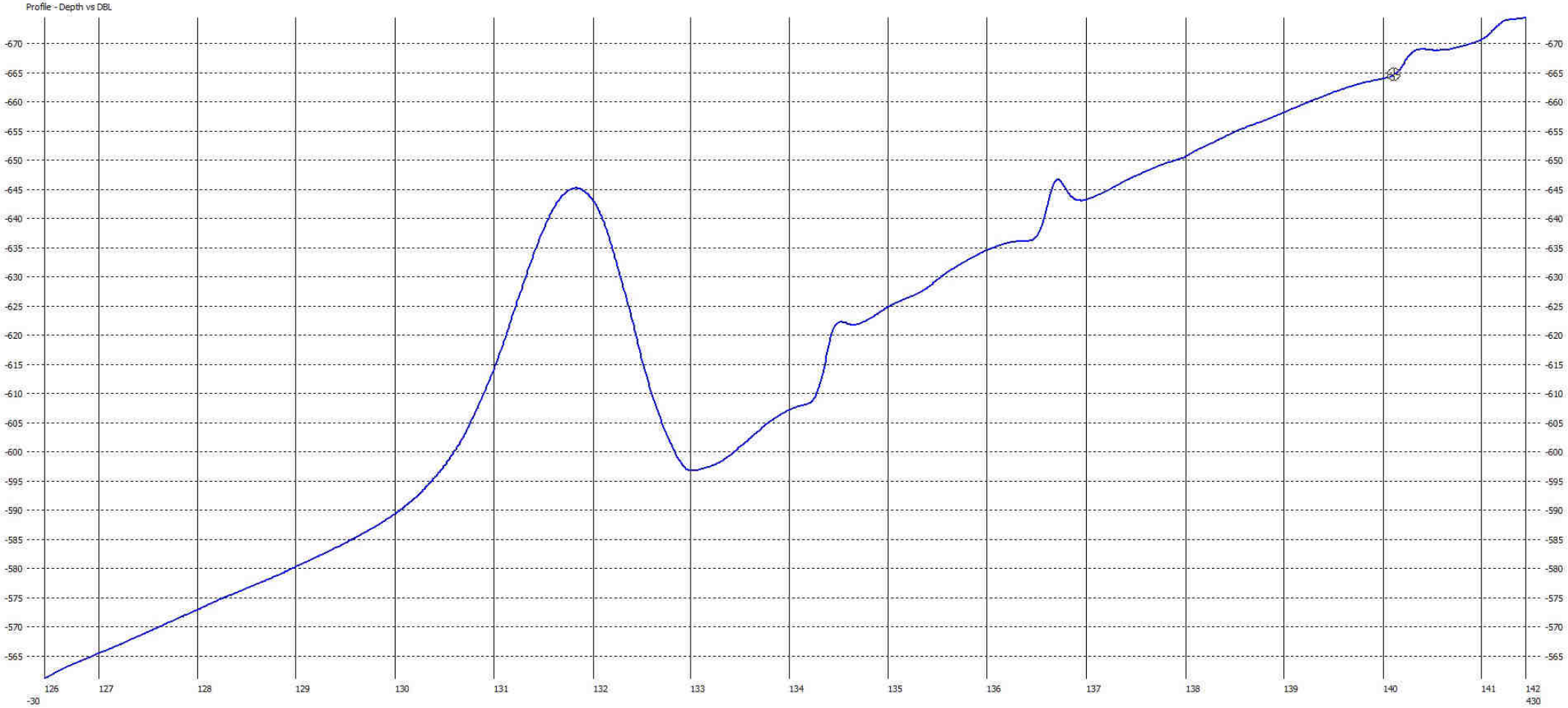


Magnetic Profile 011_1130.jpg



BORROW AREA 9-10 MAGNETIC PROFILES

Magnetic Profile 001_1239.jpg



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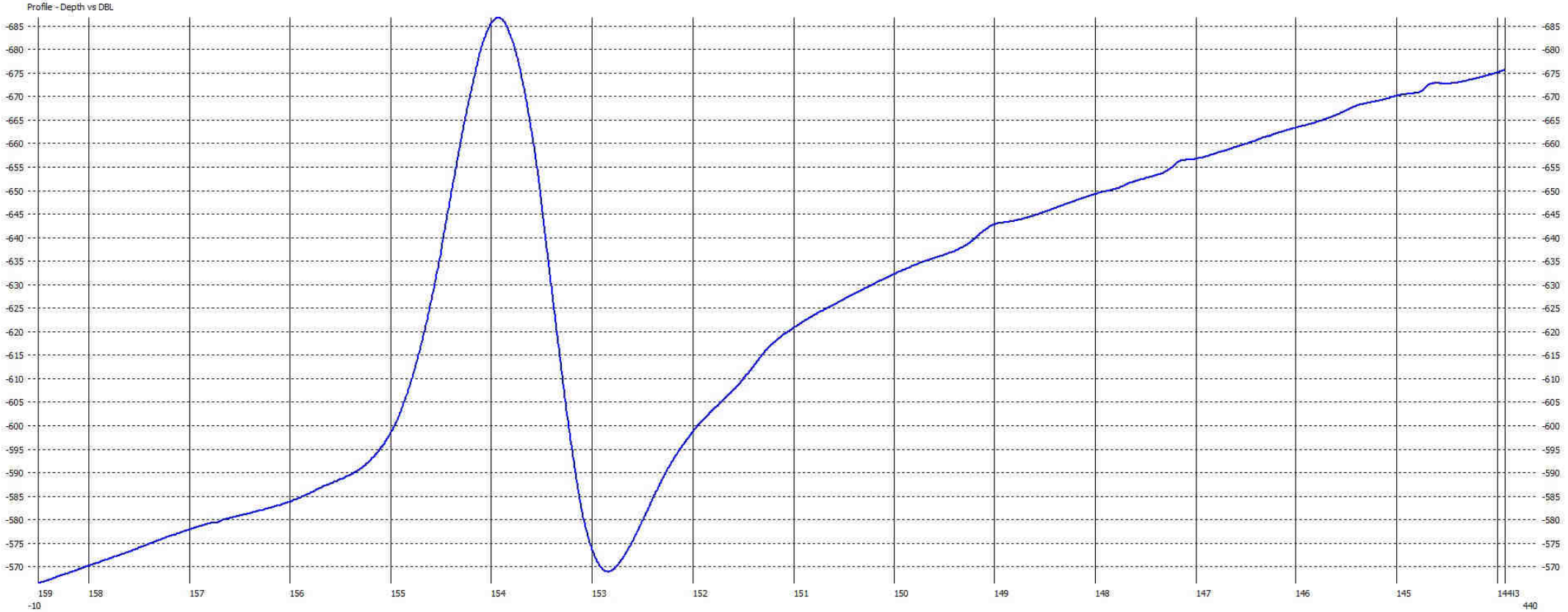

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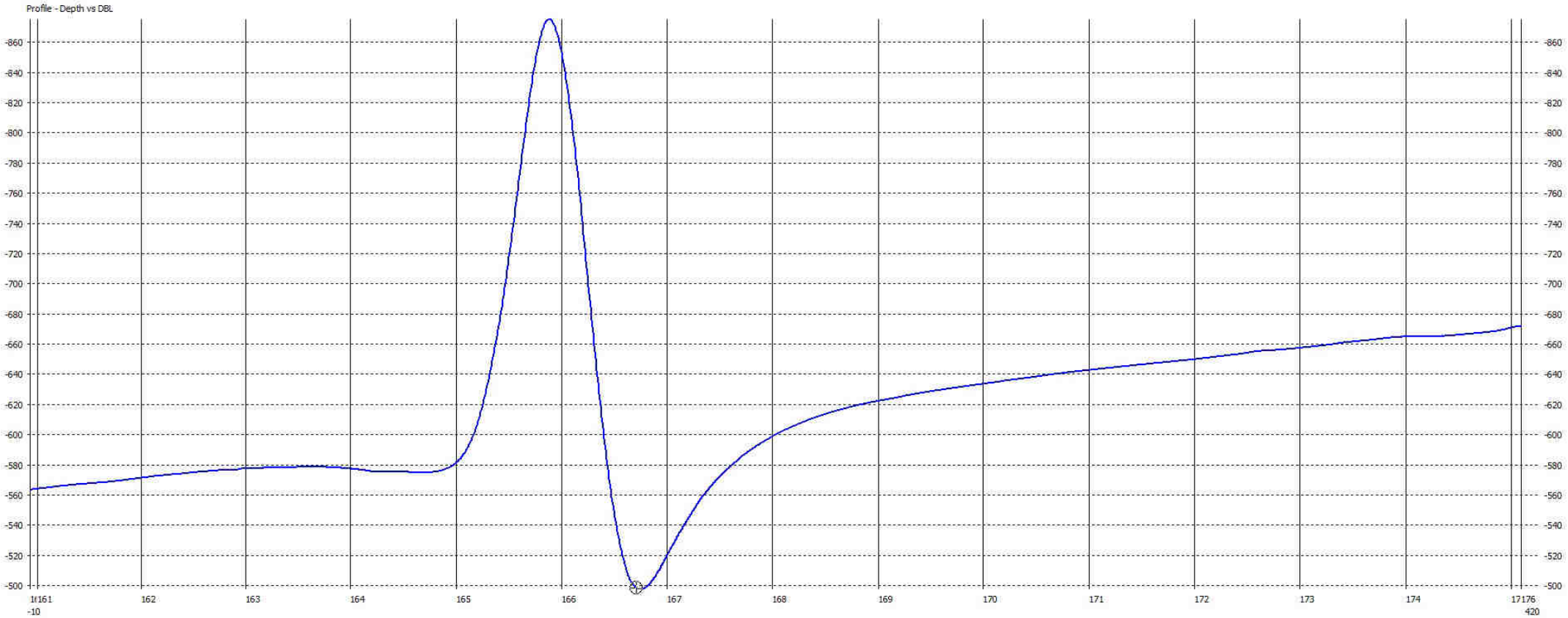
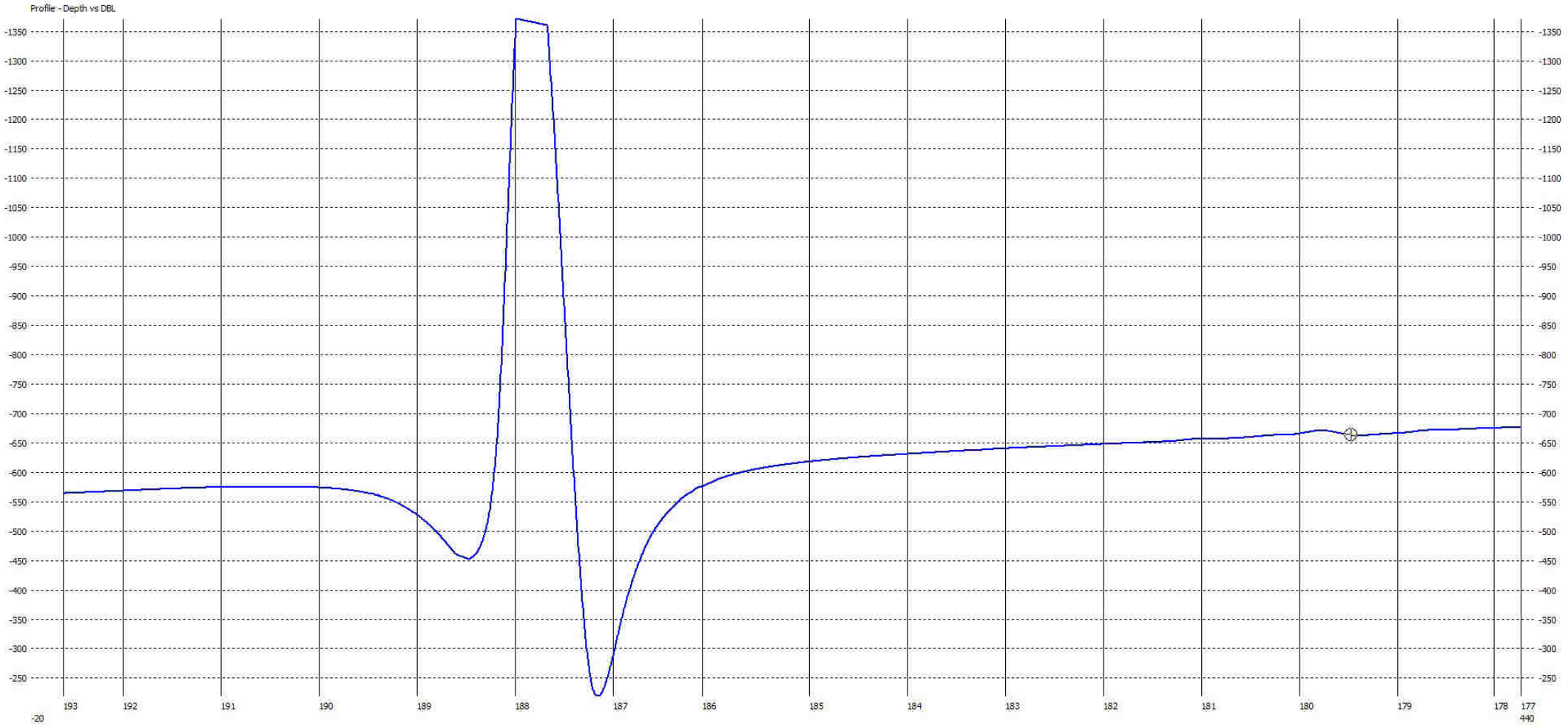


Magnetic Profile 004_1254.jpg



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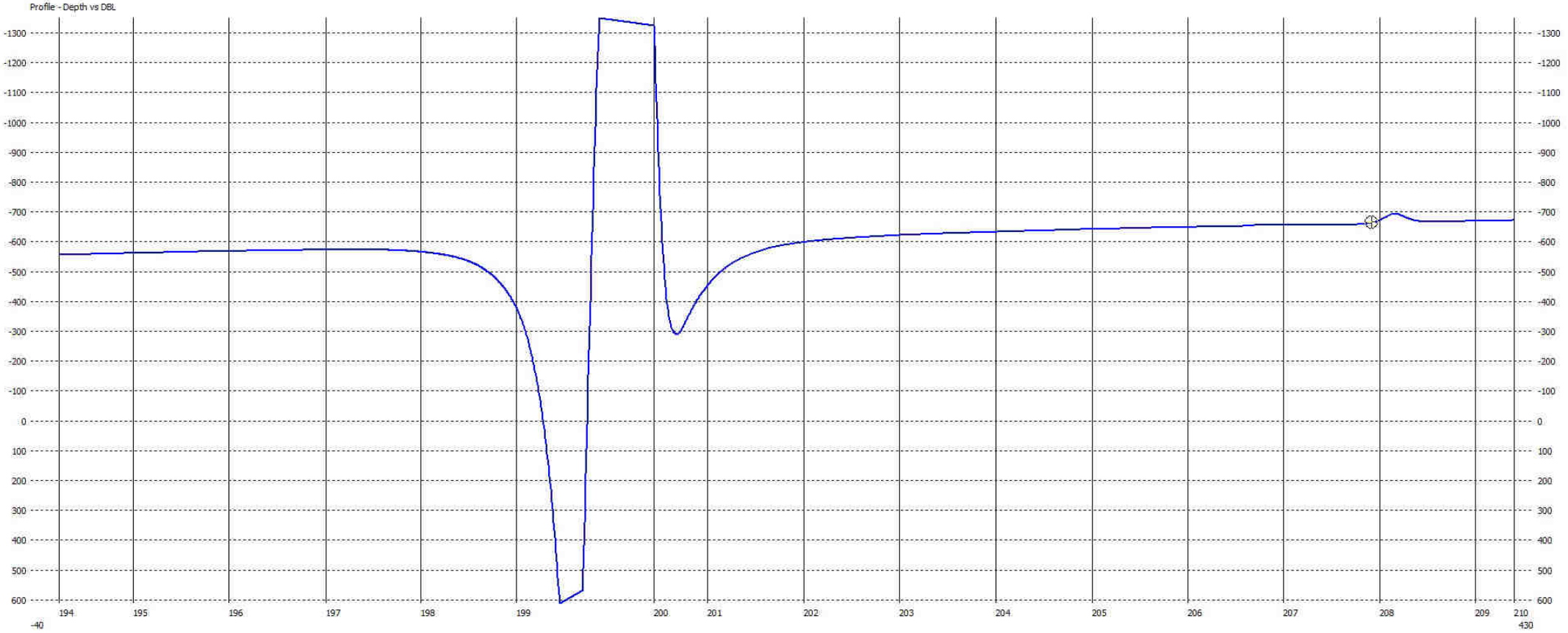
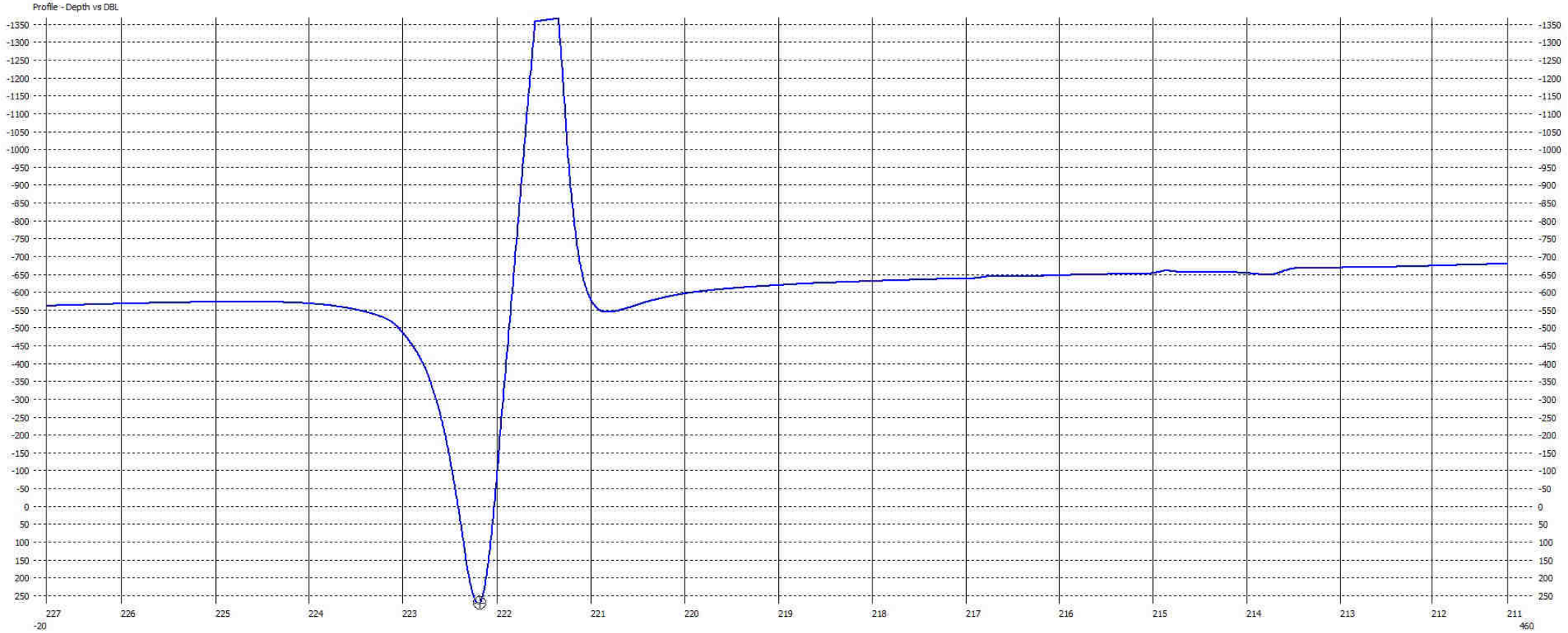
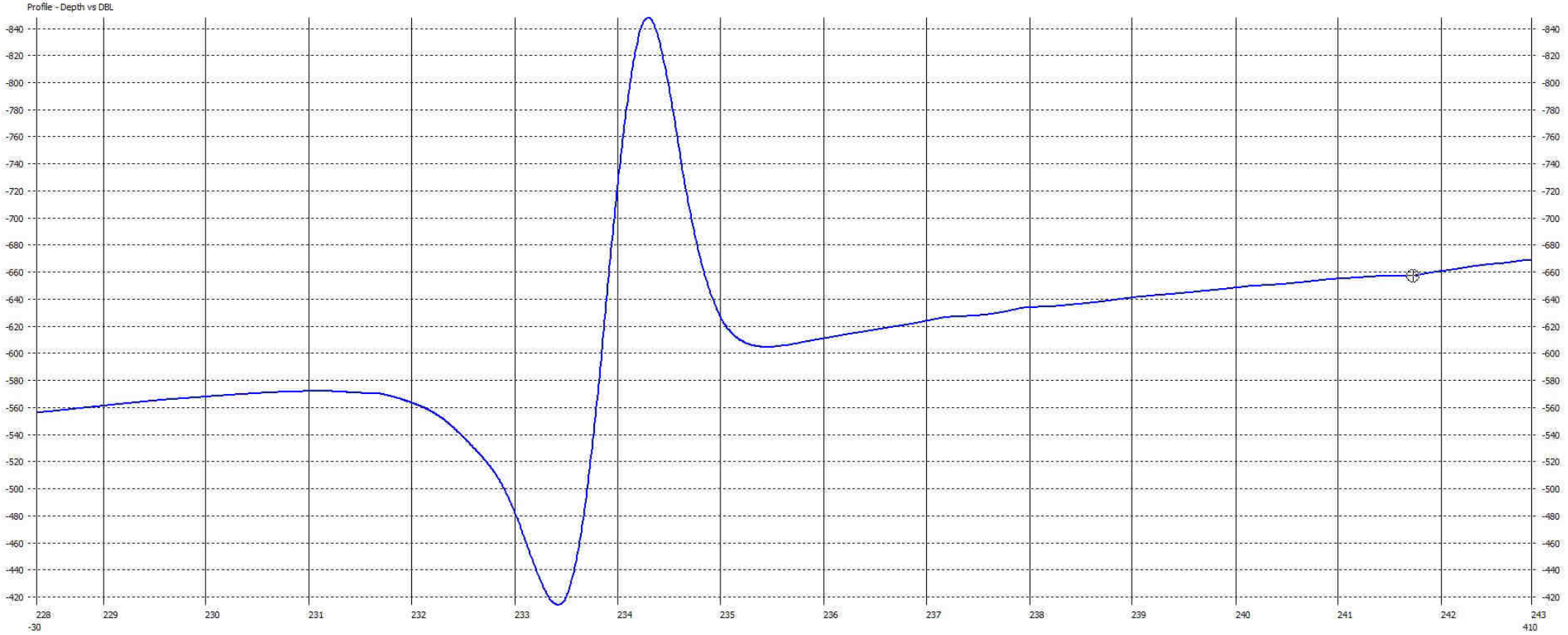


Magnetic Profiles 006_1306.jpg



Magnetic Profile 007_1311.jpg



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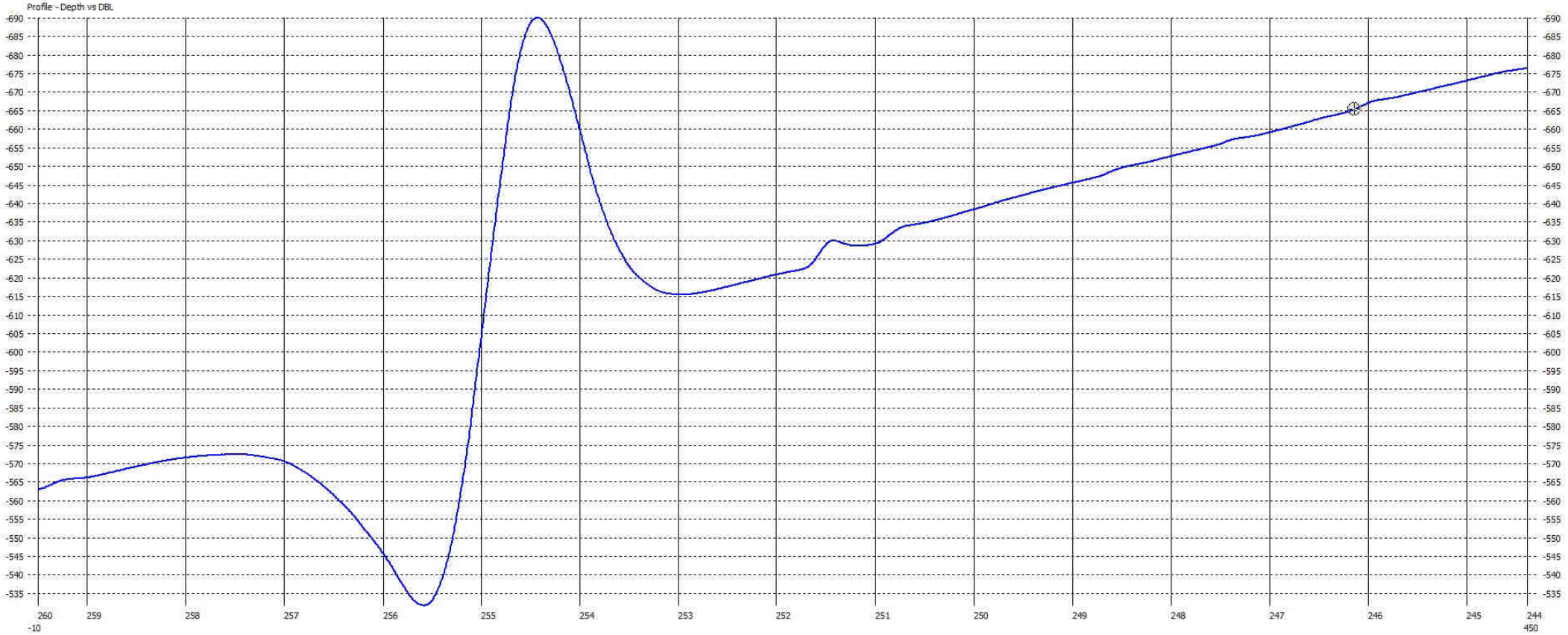
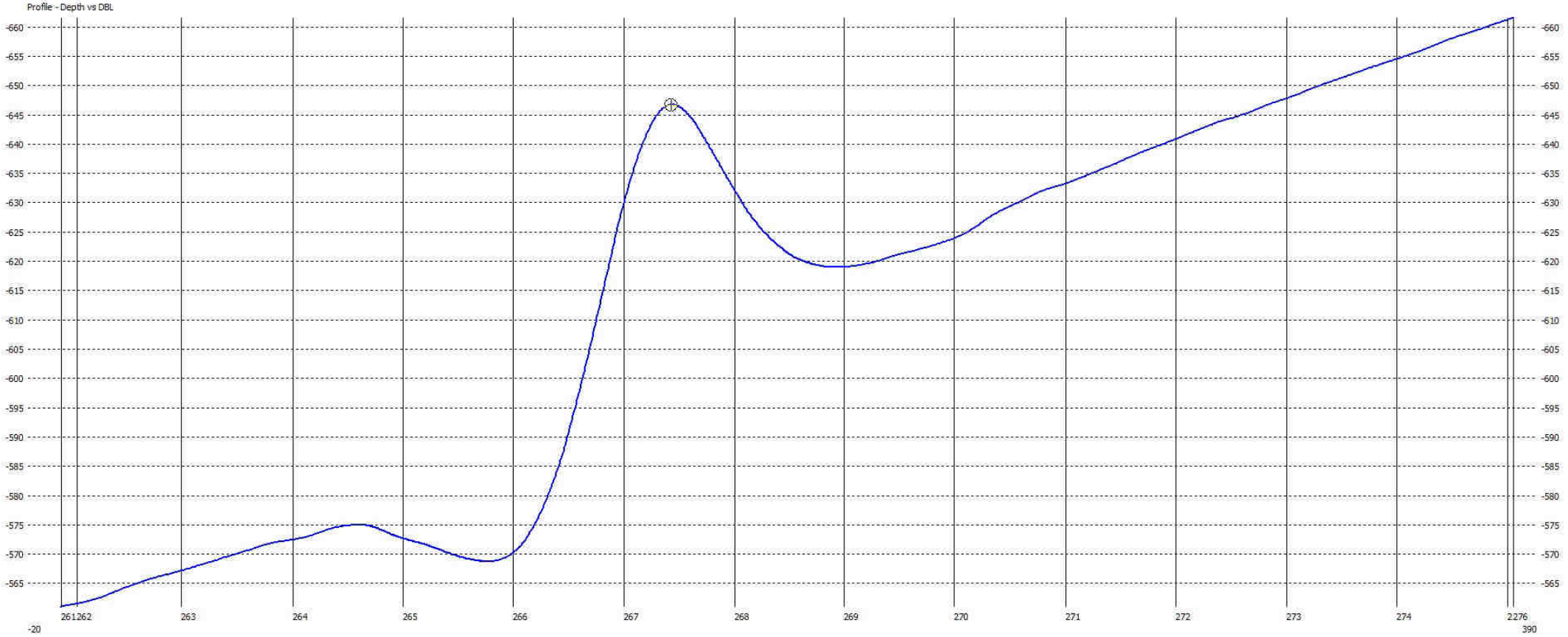
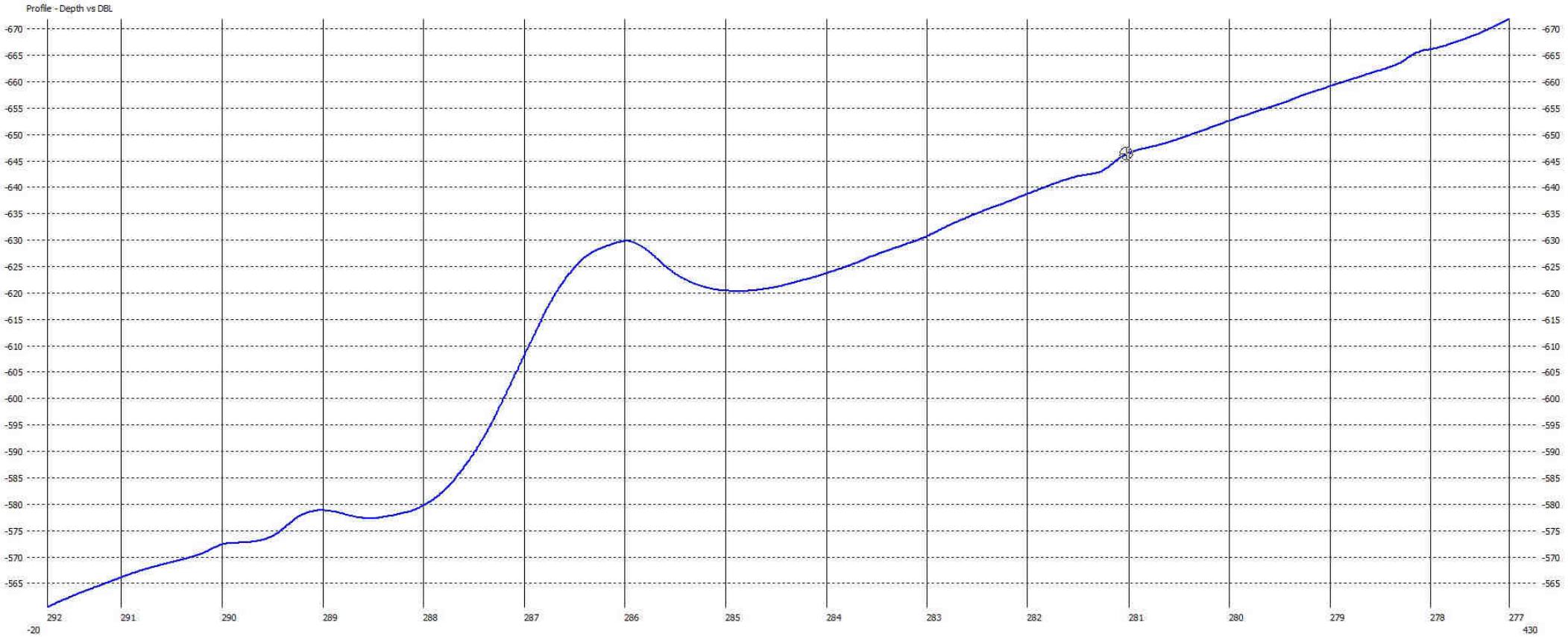


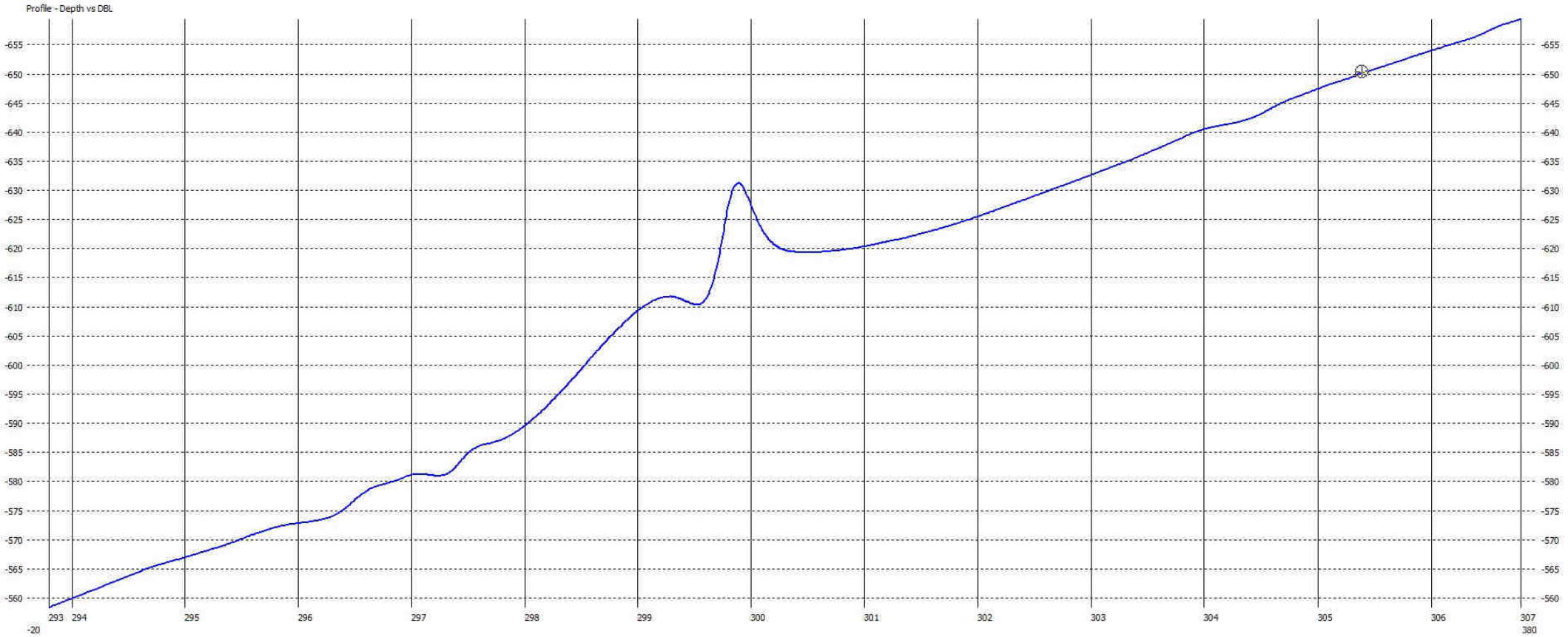
Magnetic Profile 009_1321.jpg



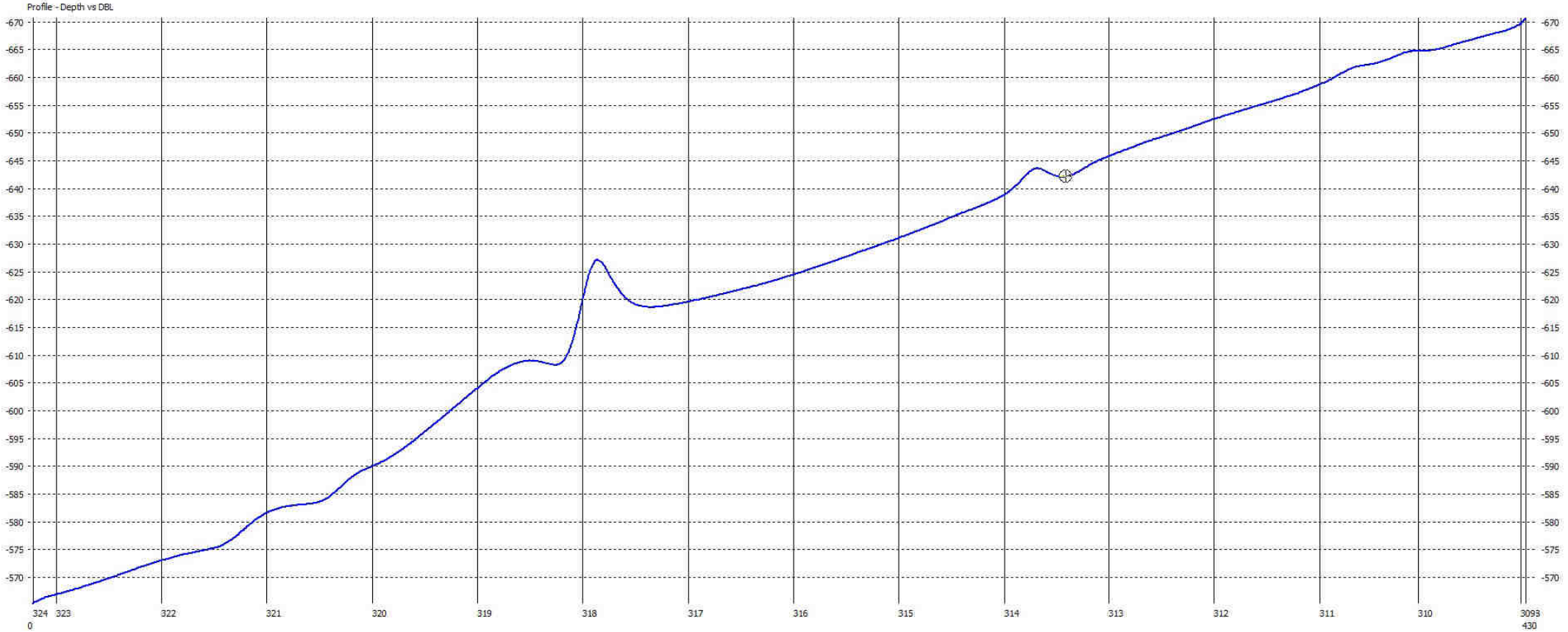
Magnetic Profile 010_1326.jpg



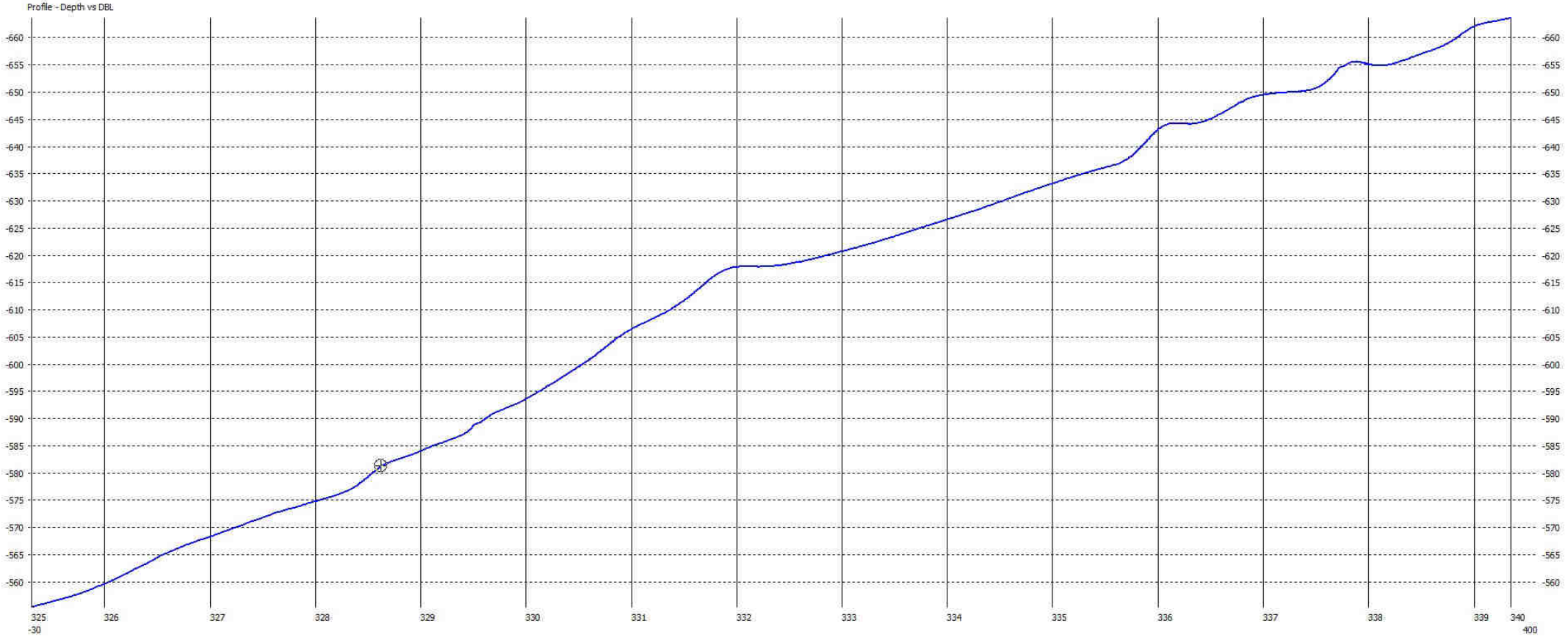
Magnetic Profile 011_1331.jpg



Magnetic Profile 012_1336.jpg



Magnetic Profile 013_1342.jpg



APPENDIX 8

Fugro MarineSTAR Signal Service

General Description

Fugro MarineSTAR provides consistent and highly reliable DGNSS corrections signal for both the American Global Positioning System (GPS) and the Russian Global Navigation Satellite System (GLONASS) for marine survey and positioning. DGNSS corrections are broadcast on dedicated communication satellite channels in all four INMARSAT ocean regions and in addition to high power satellite SPOT beams including Oceania (OC-Sat) and Eastern Pacific (AM-Sat).

Technical benefits:

- The world's first composite GPS/GLONASS orbit and clock solution (G2) to cope with the effect of the forecast increase in solar activity and interference [ref. Appendix B]
- The G2 service increases the number of satellites available by accessing the GLONASS satellite constellation in addition to the GPS constellation. More satellites mean less likelihood of shadowing when operating close to steep shorelines, mangroves and other obstructions ; "more is better"
- Integrated L-band corrections demodulator, GNSS positioning and heading sensor in a single rugged enclosure combined with two antennas for ease of configuration and mobilisation.
- With seamless coverage, approximately 100 reference stations, 14 satellite uplinks and 2 global network control centres, Fugro MarineSTAR provides consistent and highly reliable positioning services worldwide, 24 hours a day, 365 days a year.
- Fugro Satellite Positioning offers three totally independent decimeter level DGPS augmentation services that provide High Accuracy positioning for the marine user:
    - Orbit/Clock Carrier Phase Based GPS Service (XP)
    - Orbit/Clock Carrier Phase Based GPS/GLONASS Service (G2)
    - Wide Area Network Carrier Phase Based Service (HP)

MarineSTAR DGNSS Signal Services

VBS
– Single frequency DGPS Service,
– Accuracy: 1 m, 2dRMS within 1000 km of a reference station

XP
– Dual frequency DGPS Service,
– XP positioning is based on satellite 'orbits and clocks' data based on the JPL reference station network.
– Accuracy: 20 cm, 2dRMS world-wide

HP
– Dual frequency DGPS Service,
– Based on the Fugro 100 + reference station network.
– Accuracy: 10 cm, 2dRMS within 1000 km of a reference station

G2
– Dual frequency DGPS Service,
– Based on precise 'orbits & clocks' technology for both GPS and Glonass using the Fugro~ESA G2 reference station network.
– Accuracy: 15 - 20 cm, 2dRMS world-wide

Modular GPS Receiver
Receiver Name SPS852 Modular GPS Receiver
Configuration Option
Base and Rover interchangeability Yes
Rover position update rate 1 Hz, 2 Hz, 5 Hz, 10 Hz, 20 Hz
Rover maximum range from base radio Unrestricted, typical range 2–5 km (1.2–3 miles) without radio repeater
Rover operation within a VRS™ network Yes
Heading and Moving Base operation Yes7
Factory options See Receiver Upgrades below

General
Keyboard and display Vacuum Fluorescent display 16 characters by 2 rows. Invertable
On/Off key for one-button startup

Escape and Enter keys for menu navigation
4 arrow keys (up, down, left, right) for option scrolls and data entry
Dimensions (L × W × D) 24 cm × 12 cm × 5 cm (9.4 in x 4.7 in x 1.9 in) including connectors
Weight 1.65 kg (3.64 lb) receiver with internal battery and radio
1.55 kg (3.42 lb) receiver with internal battery and no radio

Antenna Options
GA510 L1/L2/L2C GPS, SBAS, and OmniSTAR
GA530 L1/L2/L2C GPS, SBAS, and OmniSTAR
GA810 GPS, Glonass, OmniSTAR, SBAS, Galileo (optimized for OmniSTAR)
L1/Beacon, DSM 232 Not Supported
Zephyr™ Model 2 L1/L2/L2C/L5 GPS, Glonass, OmniSTAR, SBAS, Galileo
Zephyr Geodetic™ Model 2 L1/L2/L2C/L5 GPS, Glonass, OmniSTAR, SBAS, Galileo
Zephyr Model 2 Rugged L1/L2/L2C/L5 GPS, Glonass, OmniSTAR, SBAS, Galileo
Zephyr, Zephyr Geodetic, Z-Plus, Micro-Centered™ Refer to Antenna specification

Temperature
Operating1 -40 °C to +65 °C (-40 °F to +149 °F)
Storage -40 °C to +80 °C (-40 °F to +176 °F)
Humidity MIL-STD 810F, Method 507.4
Waterproof IP67 for submersion to depth of 1 m (3.3 ft), dustproof

Shock and Vibration
Pole drop Designed to survive a 1 m (3.3 ft) pole drop onto a hard surface
Shock – Non-operating To 75 g, 6 ms
Shock – Operating To 40 g, 10 ms, saw-tooth
Vibration Tested to Trimble ATV profile (4.5 g RMS): 10 Hz to 300 Hz: 0.04 g/Hz2
300 Hz to 1,000 Hz; –6 dB/octave

APPENDIX 9

Specification of the G-881 Cesium Marine Magnetometer

MODEL G-881 CESIUM MARINE MAGNETOMETER	Self-oscillating split-beam Cesium Vapor (non-radioactive)
SYSTEM SPECIFICATIONS OPERATING PRINCIPLE:	
OPERATING RANGE:	20,000 to 100,000 nT
OPERATING ZONES:	The earth's field vector should be at an angle greater than 6° from the sensor's equator and greater than 6° away from the sensor's long axis. Automatic hemisphere switching.
CM-221 COUNTER SENSITIVITY:	<0.01 nT/ _Hz rms. Typically 0.5 nT P-P at a 0.1 second sample rate or 0.005 nT at 1 second sample rate. Up to 10 samples per second
HEADING ERROR:	±1 nT (over entire 360° spin and tumble)
ABSOLUTE ACCURACY:	<3 nT throughout range
OUTPUT:	RS-232 at 9600 Baud
MECHANICAL:	
Sensor Fish:	Body 2.75 in. (7 cm) dia., 5.75 ft (1.75 m) long with ring fin (15 in. OD), 27 lbs. (12.3 kg) Includes Sensor and Electronics
Tow Cable:	Kevlar Reinforced multiconductor tow cable. Breaking strength 4,000 lbs, 0.47 in OD, 200 ft maximum. Weighs 17 lbs (7.7 kg) with terminations.
OPERATING TEMPERATURE:	-30°F to +122°F (-35°C to +50°C)
STORAGE TEMPERATURE:	-48°F to +158°F (-45°C to +70°C)
ALTITUDE:	Up to 30,000 ft (9,000 m)
WATER TIGHT:	O-Ring sealed for up to 200 ft (61 m) depth operation
POWER:	24 to 32 VDC, 0.75 amp at turn-on and 0.5 amp thereafter
ACCESSORIES:	
Standard:	CM-201 View Utility Software operation manual and ship case
Optional:	AC Power supply, Surfer for Windows, GPS, Computer
MagLog-Lite or MagLog NT Software:	Logs, displays and prints Mag and GPS data at 10 Hz sample rate.

APPENDIX 10

1. Digital Data File Directories

Borrow-Area-1
- Jetprobe grading analysis files
- Magnetic profile data
- Map files-bathymetry-jetprobe-magnetics
- Underwater videos

Borrow-Area-2
- Jetprobe grading analysis files
- Magnetic profile data
- Map files-bathymetry-jetprobe-magnetics
- Underwater videos

Borrow-Area-4
- Jetprobe grading analysis files
- Magnetic profile data
- Map files-bathymetry-jetprobe-magnetics
- Underwater videos

Borrow-Area-6-7-8
- Jetprobe grading analysis files
- Magnetic profile data
- Map files-bathymetry-jetprobe-magnetics
- Underwater videos

Borrow-Area-9-10
- Jetprobe grading analysis files
- Magnetic profile data
- Map files-bathymetry-jetprobe-magnetics
- Underwater videos

Fisheries Complex drill core samples

APPENDIX 11

DVD containing Underwater Videos of Borrow Areas &

Digital Data as listed in Appendix 10

A PDF file of this survey report