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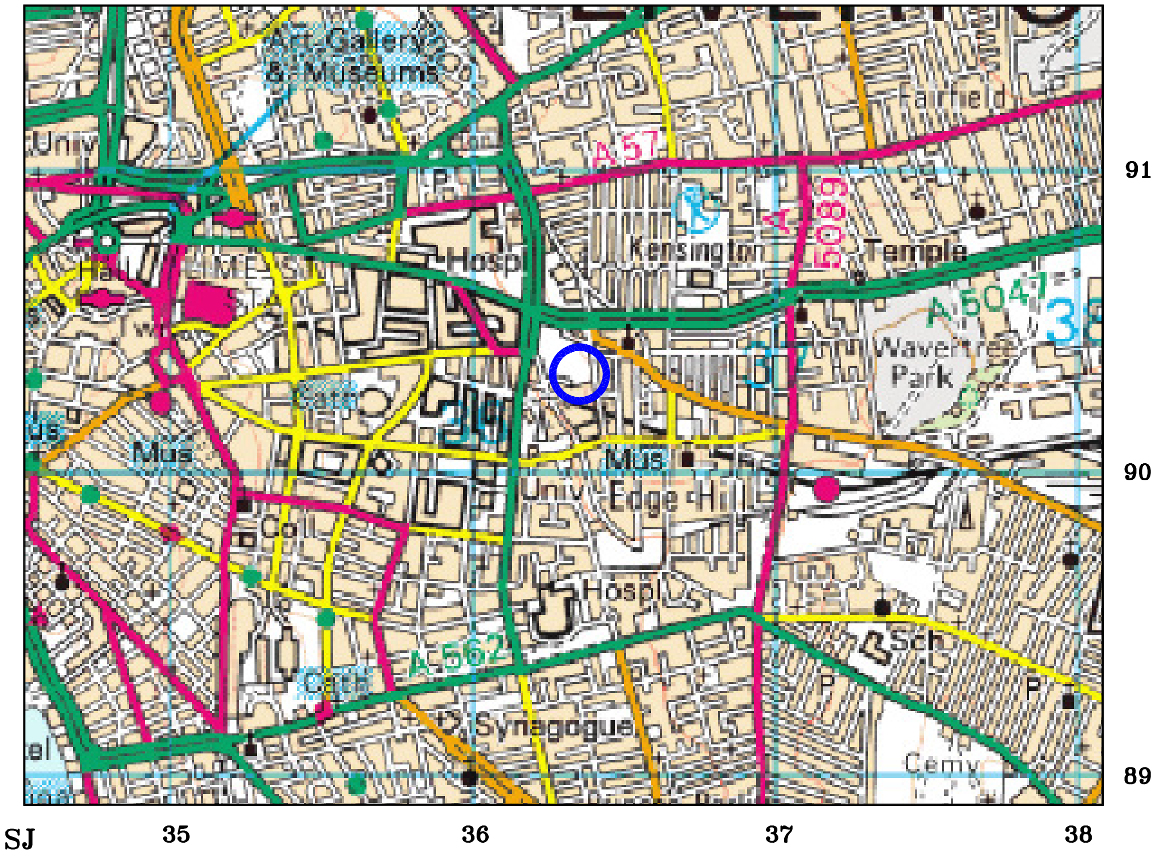

SITE LOCATION

SCALE

0m 500m 1000m

NOTE

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Scale [A4 Sheet]	Drawing	Status
AS SHOWN	HAZ_2072_744_01	FINAL

Client

FAIRHURST
NEWCASTLE UPON TYNE

Site

PPI LIVERPOOL
PADDINGTON PLACE

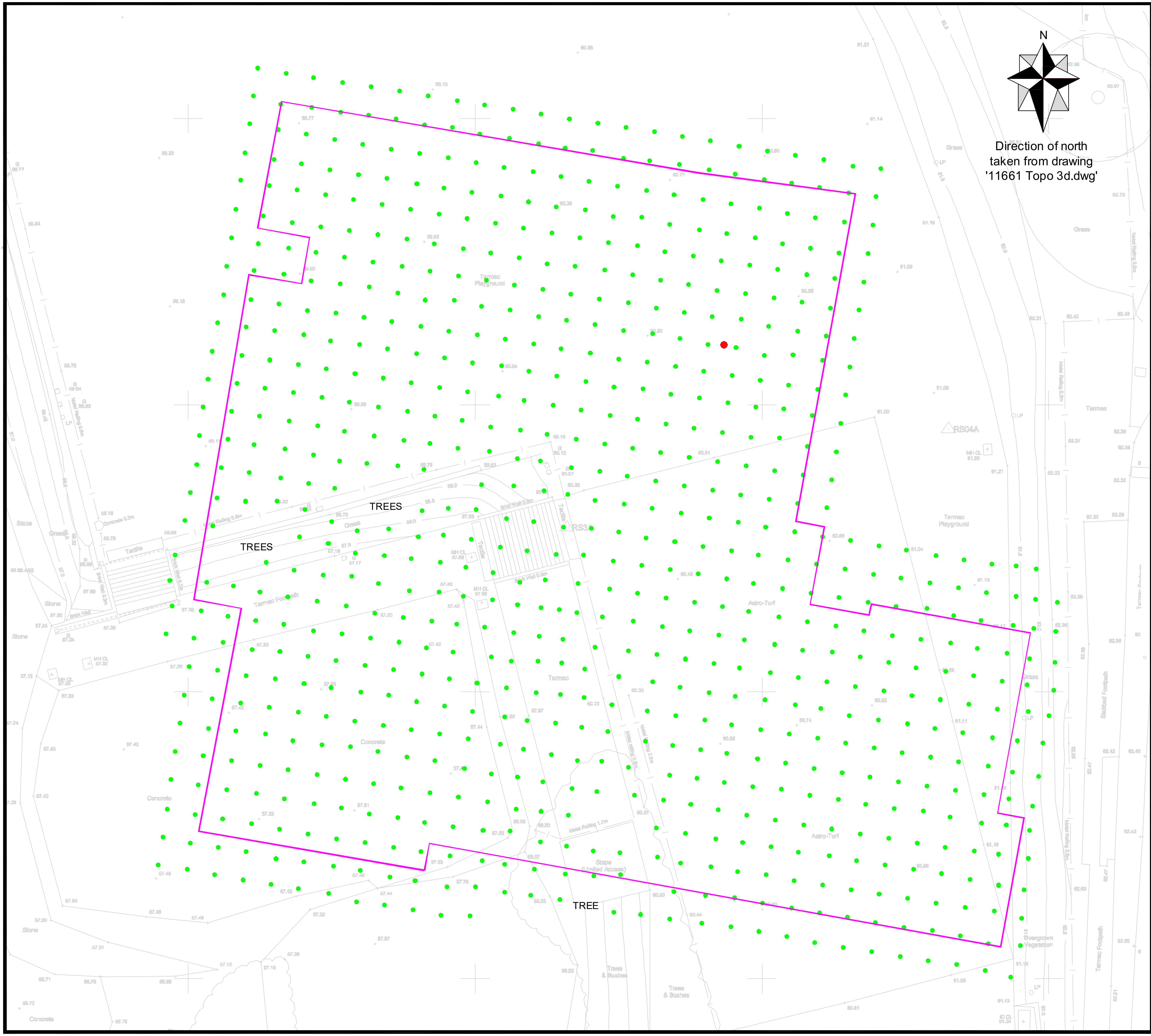
Title

SITE LOCATION MAP

Job No

HAZ_2072_744

		Drawn	CW
Chk.	NF	Date	29/03/2017



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KEY

PROPOSED BUILDING FOOTPRINT

LOCATION OF MICROGRAVITY SURVEY STATION

LOCATION OF MICROGRAVITY BASE STATION

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Scale [A3 Sheet]	Drawing	Status
1:250	HAZ_2072_744_02	PRELIM

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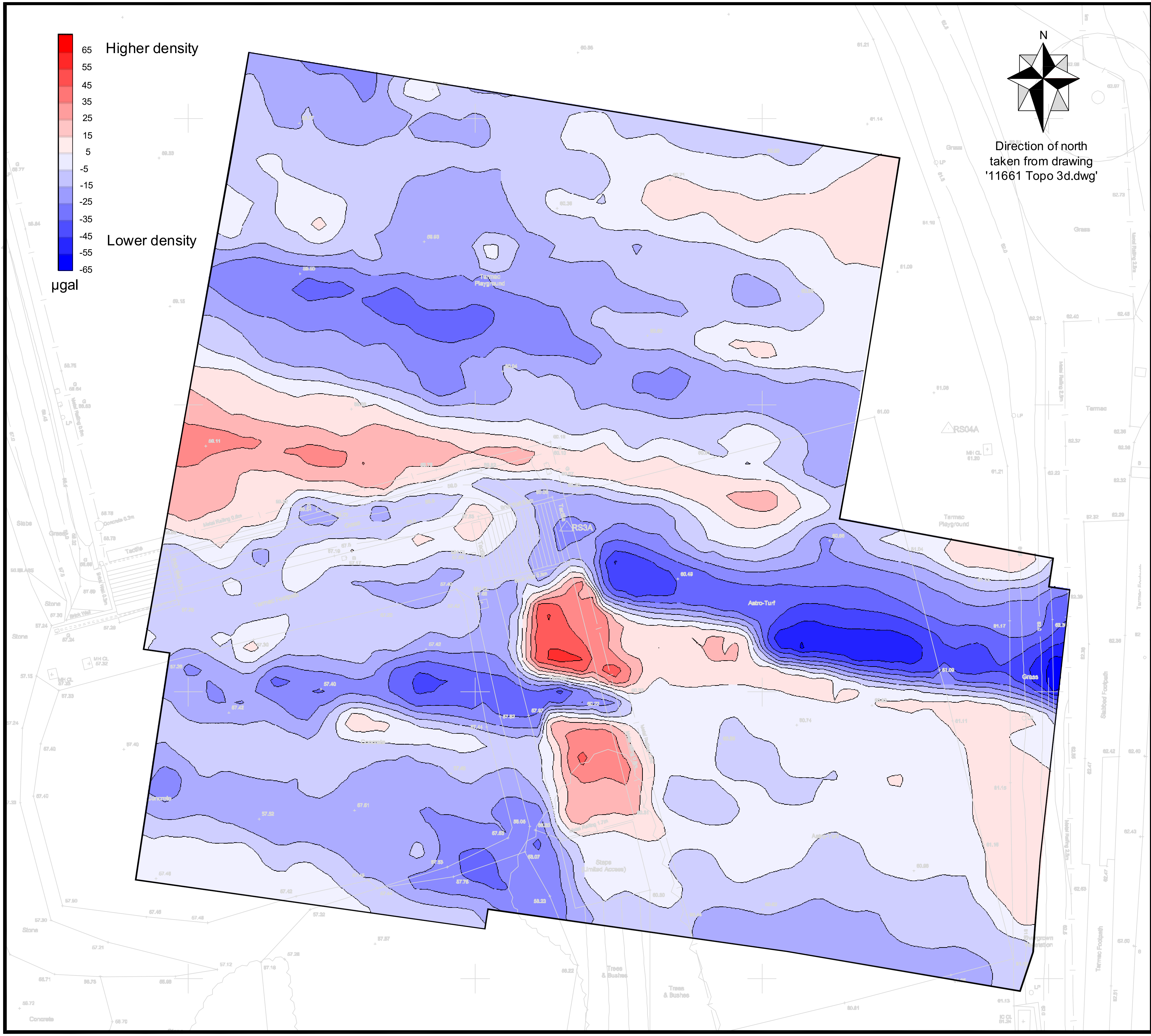
Site
PPI LIVERPOOL
PADDINGTON PLACE

Title
GEOPHYSICAL SURVEY EXTENTS

Job No
HAZ_2072_744

Surveyed	MW, AD	Drawn	NF
Chk.	MW	Date	15/03/2017



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KEY

EXTENT OF PROCESSED MICROGRAVITY DATA

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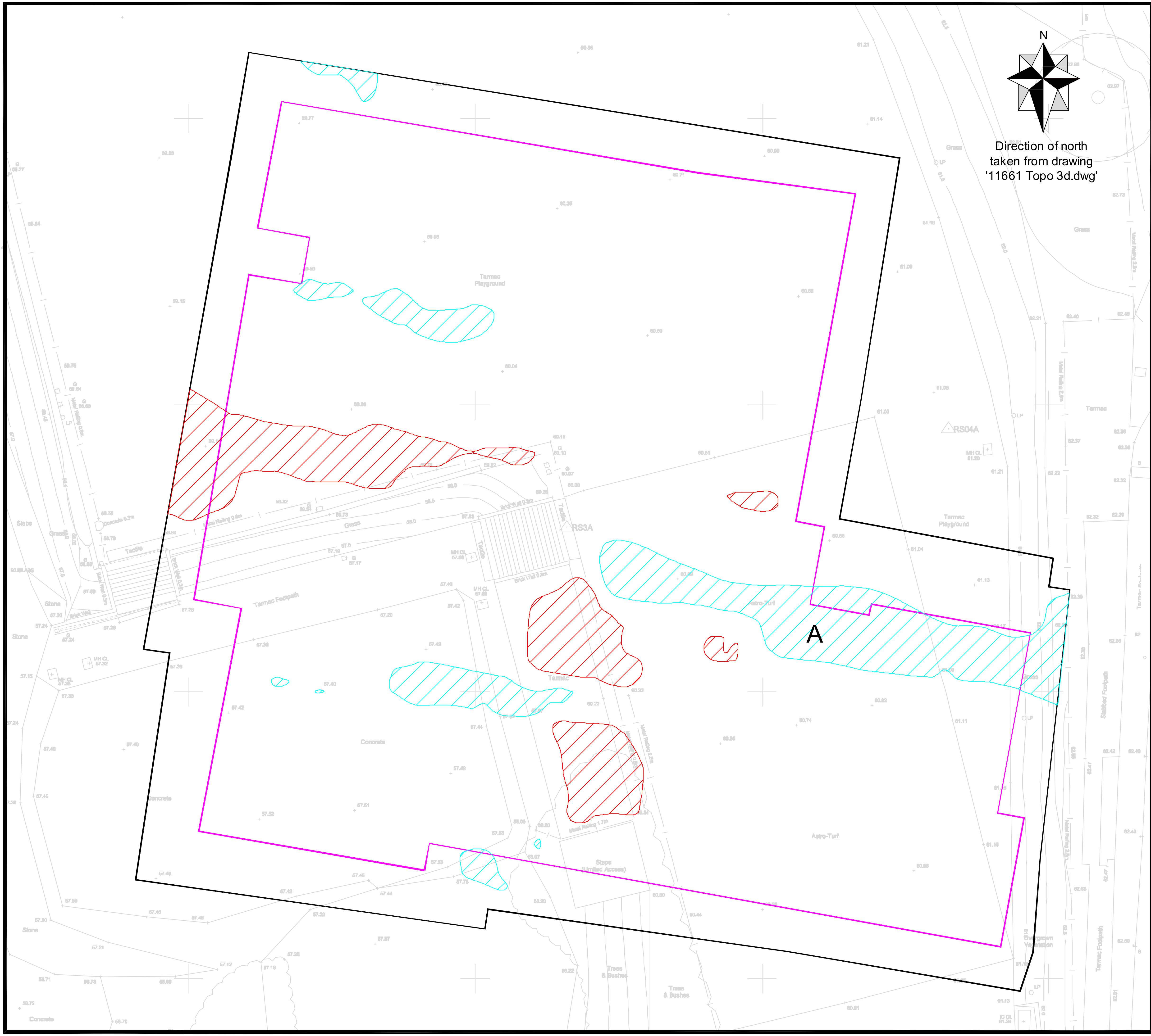
FAIRHURST
NEWCASTLE UPON TYNE

Site
PPI LIVERPOOL
PADDINGTON PLACE

Title
MICROGRAVITY DATA
RESIDUAL BOUGUER ANOMALY

Job No
HAZ_2072_744

Surveyed	MW, AD	Drawn	NF
Chk.	MW	Date	15/03/2017



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KEY

- PROPOSED BUILDING FOOTPRINT
- EXTENT OF PROCESSED MICROGRAVITY DATA
- NEGATIVE BOUGUER ANOMALY. AREA OF LOWER DENSITY MATERIAL - POSSIBLE GEOLOGICAL VARIATION OR LESS COMPACTED MATERIAL
- POSITIVE BOUGUER ANOMALY. AREA OF HIGHER DENSITY MATERIAL - POSSIBLE GEOLOGICAL VARIATION OR MORE COMPACTED GROUND

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Scale [A3 Sheet]	Drawing	Status
1:250	HAZ_2072_744_04	PRELIM

Client
FAIRHURST
NEWCASTLE UPON TYNE

Site
PPI LIVERPOOL
PADDINGTON PLACE

Title
INTERPRETATION OF
MICROGRAVITY DATA

Job No
HAZ_2072_744

Surveyed	MW, AD	Drawn	NF
Chk.	MW	Date	15/03/2017

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APPENDIX 1

1. Microgravity surveys: technical information

1.1 Theoretical background

1.1.1 Gravity surveys measure variations in the earth's gravitational field (specifically changes in the acceleration due to gravity) and have been used to identify large scale geological variations and features since the early part of the twentieth century. Over the last couple of decades improving equipment sensitivity has enabled small localised variations to be detected which allows the technique to be used for engineering and environmental applications. To detect features on this local scale instrumentation that is capable of measuring the Earth's acceleration due to gravity (g) to 1 part in 1 billion is required. These are termed microgravity surveys as the variations are usually measured in micro Gals (µGal).

1.1.2 If the main constituents that make up the Earth's gravity field are broken down it can be seen exactly how accurate the instrumentation and procedure for acquiring gravity needs to be.

1.1.3 The total acceleration due to the Earth's gravity is approximately 983 Gals which is ~983,000,000 µGal. The mass of the Earth accounts for ~974,899,700 µGal. The equatorial radius of the Earth is 21 km greater than the polar radius which contributes ~5,000,000 µGal. The difference in elevation between the highest mountains and the deepest oceans contributes ~3,000,000 µGal. A further ~100,000 µGal is accounted for by regional geology and crustal structure. The remaining several hundred µGal are the values that are measured in a microgravity survey and these are due to changes in the near-surface geology, including variations caused by sub-surface features, coupled with effects from the sun and the moon which can vary rapidly during the course of a day by 100 to 200 µGal.

1.1.4 There are a number of ways that these small variations in the acceleration due to gravity can be measured. The most common method, for microgravity surveys, involves suspending a mass on a spring between two capacitors. The mass is supported by the electrostatic repulsion of the capacitor and is allowed to move upwards or downwards by the spring. When changes in gravity cause the mass to move fractionally, either down or up, this causes a change in capacitance which can be measured. This change in capacitance is directly proportional to the change in gravity. This system requires instrumentation with highly complex and temperature stable electronics.

1.1.5 As well as having to accurately measure these very small variations a microgravity survey must also take into account a large number of variables before the measured value can be converted into useable data which can allow the comparison of gravity variations across a site. During the course of a survey the instrument will drift due to the elastic properties of the spring. As mentioned above the movement of the sun and the moon have an effect on *g* and this affect varies during the course of a day. The latitude and altitude of a survey need to be taken into account and if the height of survey stations varies within a survey then these must also be allowed for when determining relative sub-surface gravity values. The density of the material beneath a survey area and the effects of surface features also affect the measured value. Details of how these factors can be corrected for are presented in Section 1.3.

1.1.6 Finally there are a number of factors that contribute to 'noise' which can reduce data quality and must be kept to a minimum. These include vibrations from passing vehicles (or even pedestrians walking in close proximity to the instrument), wind and other industrial activity which can all vibrate the instrument sufficiently to cause variations in the data measurements. The instrument must be kept level when taking a reading and slight tilts during the measurement process can also detrimentally affect the data quality.

1.1.7 It can be seen that when measuring such small values which have a number of variables that must be accounted for that that good data collection is paramount. The quality and reliability of the interpretation of the data is limited by the quality of the raw data.

1.2 General survey methodology

1.2.1 The following general survey methodology was adopted unless otherwise stated in the survey report.

1.2.2 The microgravity survey will be carried out using a Scintrex CG5 microgravity meter. The CG-5 is an automated gravity meter with a resolution of 1µgal.

1.2.3 Gravity measurements are usually acquired on a regular grid with survey stations set up at predetermined points along the grid. The grid spacing determines the resolution of the survey and is dependent on the survey objectives. Increasing the concentration of data points increases the resolution of the survey, as well as the associated survey time and costs. Forward modelling of a-priori data can optimise the survey procedure by establishing the survey grid resolution needed to detect the survey target with the minimum of data points.

1.2.4 Gravity measurements can be acquired along a single profile. However, the interpretation of the data is limited as it is not possible to determine whether the source of an anomaly is located in the same plane as the profile or to the side.

1.2.5 A base station is established in a quiet, stable, sheltered area. Readings are taken at this position at the start and end of the survey and also at regular intervals (between 1 hour and 1.5 hours) during the course of the survey. A minimum of five readings should be taken at each base station visit.

1.2.6 In between the base station readings the survey stations are occupied in sequence. It is important that the instrument is level at each survey station and remains so throughout the measuring process. Environmental effects such as boggy terrain and soft tarmac can cause the instrument to tilt and result in a false value being recorded and so extra care and should be taken in such areas. If tilts do occur then multiple readings may need to be taken at each point to ensure that the measured values are consistent.

1.2.7 Each station should be occupied for between 60 and 90 seconds and an average value for the readings during that time will be recorded.

1.2.8 As a matter of course repeat readings should be taken at a number of stations, regardless of the terrain conditions, to ensure that the values are consistent and repeatable and to check that no unforeseen factors are adversely affecting the data quality. Extraneous activities such as weather or urban noise may reduce the data quality and whilst these may be beyond the control of the survey a check of the data quality needs to be carried out to determine the reliability of the data.

1.2.9 Between 5% and 10% of the survey stations should be reoccupied (more in some terrains) to determine the repeatability of the data. If there is a large difference between the repeat readings then the overall reliability and quality of the data decreases and if this is too high then some types of features may not be identifiable. Repeat readings within 3 µGal to 5 µGal of the original value indicate high quality data.

1.2.10 Each survey station must be accurately recorded in both plan and elevation, relative to the base station, to allow accurate processing of the data. This will be done by tying in each station using a GNSS with an epoch of 10 (the higher epoch was used to increase the level accuracy to within 0.01 m).

1.3 Data processing, presentation and interpretation

1.3.1 As discussed above the measurements recorded by the microgravity meter are subject to several external effects that are not related to the sub-surface geology or features. For a valid geophysical interpretation to be made these effects must first be removed. The process of correcting for these effects is a well-established routine in any gravity survey and is often called the reduction of data. The necessary corrections are (1) free-air correction, (2) Bouguer correction and if the survey area requires it (3) terrain correction. As well as the above corrections, the instrument itself must be corrected for internal drift and Earth tides.

Free air correction (FAC) This correction takes into account the vertical decrease in gravity with increased elevation. The correction is based on the inverse square dependence of the acceleration due to gravity on the distance from a datum plane.

Bouguer correction (BC) The free air correction accounts solely for the variation in height between gravity points. The Bouguer correction accounts for the attraction of material between a reference height and that of the gravity station. This can be approximated by treating the intervening rock material as an infinite horizontal slab, of a thickness equal to the elevation difference, Δh, between the reference base and the gravity station.

Terrain correction The Bouguer correction makes the assumption that the topography around the gravity station is flat. This is rarely the case and for areas with significant relief a further correction, the terrain correction, is needed. A hill rising in the vicinity of a gravity station will tend to have an upward attraction due to the extra mass contained in the hill. This will have the effect of reducing the measured value of gravity. Similarly a valley below the gravity station will also tend to reduce the measured value of gravity. In this case it is the missing mass within the valley that reduces the expected attraction due to gravity. There are several methods used for calculating the terrain correction including the Hammer, Ketelaar Plouff and Parker Methods. The most suitable method is selected depending on the character of the site.

Drift correction The zero length spring used in the gravity instruments experience gradual change in reading with time. This drift is a result of the imperfect elasticity of the springs, which undergo an elastic creep with time and are unrelated to gravity changes. The correction for instrument drift is very simple and is based on repeated readings at a base station at recorded times throughout the day. A sample time between base station readings of one hour is normally used and the drift within this time is assumed to be linear.

Tidal correction As well as the above effects, gravity measured during a survey varies with time because of periodic variation in the gravitational effects of the Sun and Moon associated with their orbits. In a high precision survey these effects must be corrected for. There is a small but measurable gravitational effect of up to 240 µgal, changing with time at a maximum rate of 50 µGal/hr at the Earth's surface due to its spin and the relative motion of the sun and the moon. It is possible to predict the Earth tides using Longman's formula but ideally it is advisable to record gravity continuously for at least a full day in the field location to check the prediction method used.

1.3.2 The results of the microgravity survey will be presented as a 2D contour plot, overlain onto to the digital map base. Anomalies of interest will be highlighted on a separate drawing and discussed in the accompanying report. The interpretation is made based on the type, size, strength and morphology of the anomalies, coupled with the available information on the site conditions. Each type of anomaly is displayed in separate, easily identifiable layers annotated as appropriate. The report and drawings will be provided in both hardcopy and digital formats.

1.4 Limitations of microgravity surveys

1.4.1 The data collection quality must be high. Slight errors in data collection can significantly reduce the effectiveness of a survey.

1.4.2 A microgravity survey requires the operator to accurately balance the instrument in a stable position for the duration of the reading. The presence of an uneven or unstable ground surface can reduce the data quality and dense, high or mature vegetation or surface obstructions may mean that some areas cannot be surveyed.

1.4.3 If data is too 'noisy' due to site and weather conditions then it may not be possible to identify features that produce weak anomalies.

1.4.4 Each type of material or feature beneath a point contributes to the gravity value measured at that point and so unless the probable sub-surface conditions are known then reliable interpretation of microgravity data is very difficult. Any given anomaly can also have a large number of possible causes. A small, shallow feature can produce the same response as a large, deep one and likewise features of different sizes and depths but which have different densities can all produce the same type of response.

1.4.5 Complex geologies and variations in sub-surface material across a site can make interpretation of the data more difficult and may require additional information on the site conditions to enable a reliable interpretation to be made.

1.4.6 To help in interpreting the data a sufficiently large enough area should be surveyed to enable the 'background' density, caused by the natural geology, to be determined which can allow any variations from this to be identified. Unfortunately the size of the area that needs to be covered to determine the background gravity values is dependent on the site specific conditions, particularly how complex the geology is, and so it is often not possible to determine what size area should be covered.

1.4.7 The depth at which features can be detected will vary depending on their composition, size and the surrounding material.

1.4.8 Surface features such as buildings and rapid changes in topography can have a detrimental effect on data quality.

1.4.9 A microgravity survey does not directly locate sub-surface features - it identifies variations or anomalies in the background readings caused by features. It can be possible to interpret the cause of anomalies based on the size, shape and strength of response but it should be recognised that a microgravity survey produces a plan of reduced gravity variations and not a plan of all sub-surface features. Interpretation of the anomalies is often subjective and it is rarely possible to identify the cause of all of the anomalies.

1.4.10 Anomalies identified by a microgravity survey are located in plan. It is not usually possible to obtain reliable depth information on the features that cause the anomalies unless there is supporting evidence on the anticipated size, density and depth of features.

1.4.11 Not all sub-surface variations will produce a measurable response and the effectiveness of a microgravity survey is also dependant on the site-specific conditions. It is not possible to guarantee that a microgravity survey will identify all sub-surface features.

1.4.12 The best way to substantiate the interpretation of the microgravity data is to include a second method in the process of interpretation. In this way, techniques that use different characteristics of the sub-surface can be used to supplement one another. If lithological knowledge can be provided from drilling logs or seismic data, then the geophysicist can have a high degree of confidence in their interpretation.

1.4.13 The microgravity technique is a guide to the sub-surface density distribution. Its primary aim is to target intrusive investigation by identifying anomalous areas. Once ground truth has been established, interpretations can be extrapolated across the site. Microgravity and geophysics in general, should not be viewed as an alternative to intrusive investigation but as a supplementary tool. Preliminary geophysical investigations have the potential to improve the success of an intrusive investigation as well as dramatically reduce its cost.

APPENDIX 8

Principles of Environmental Risk Assessment

The Environmental Protection Act 1990, Part II A Contaminated Land (Section 57 of the Environment Act 1995) and the Contaminated Land Regulations 2006 (and 2012 amendments) provide a basis on which to determine the risks and liabilities presented by a contaminated site. Contaminated Land is defined within Section 78A(2) of the Environmental Protection Act 1990, Part II A Contaminated Land (by commencement of Section 86 of The Water Act 2003 [Commencement Order No. 11] Order 2012) as:

"Any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land that-

(a) Significant harm is being caused or there is significant possibility of such harm being caused; or

(b) Significant pollution of controlled waters is being caused, or there is a significant possibility of such pollution being caused."

Section 57 of the Environment Act 1995 requires that any site identified as being "contaminated" by the Local Authority will be registered by them and remediation will be required to render the site fit for use.

The presence of contamination is not the sole factor for deciding whether a site is contaminated. Relevant parties should identify site-specific risks and provide objective, cost-effective methods to manage the contamination in a manner which satisfies the proposed end-use.

A risk-based approach, which takes both technical and non-technical aspects into consideration when making decisions on contamination resulting from past, present or future human activities, is advocated. The assessment of environmental risks generally relies on the identification of three principal elements forming a 'pollutant or contaminant linkage':

Source: the contaminant

Pathway: the route through which the contaminant can migrate, and

Receptor: all human, animal, plant, controlled water or property that may be adversely affected (harmed) by the contaminant

In the absence of one of these elements, on a given site, there is no risk. Where all three elements are present, risk assessment is required to determine the significance of the harm or pollution that is being or may be caused. As outlined above, the terms of the Contaminated Land regime specify that remediation need only be implemented where a site is causing, or there is a significant possibility that it will cause, significant harm, or that pollution of controlled waters is being caused or there is a significant possibility of such pollution being caused.

Development of contaminated land is usually addressed through the application of planning and development legislation and guidance (i.e. NPPF). The suitable for use approach is seen as the most appropriate basis to deal with contaminated land, taking account of environmental, social and economic objectives. The assessment is made in the context of the proposed land use.

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