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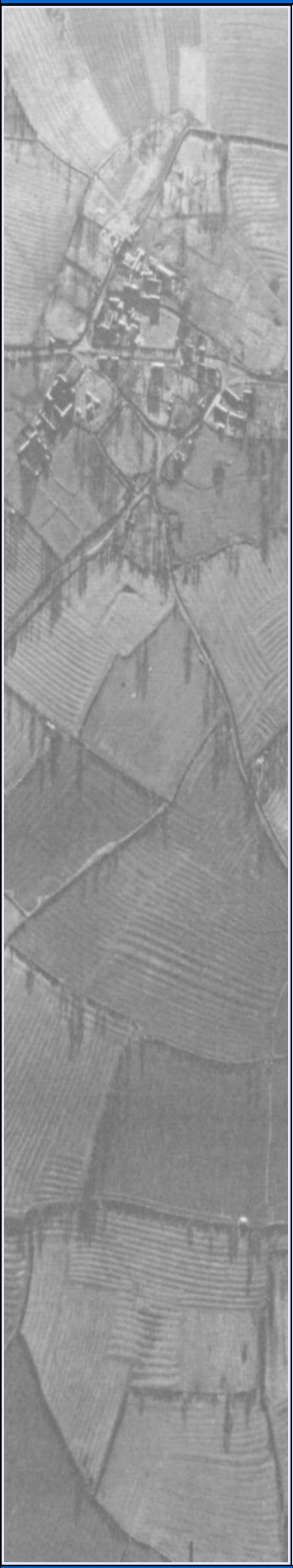

Bromham
Wiltshire

MAGNETOMETER SURVEY REPORT

for

Entec UK Ltd

David Sabin and Kerry Donaldson

Ref. no. 352

ARCHAEOLOGICAL SURVEYS LTD

Bromham, Wiltshire

Magnetometer Survey

for

Entec UK Ltd

Fieldwork by David Sabin and Richard Grove
Report by David Sabin BSc (Hons) MIFA and Kerry Donaldson BSc (Hons)

Survey date - **15th February 2011**
Ordnance Survey Grid Reference – **ST 96540 65360**

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SUMMARY

A magnetometer survey was commissioned by Entec UK Ltd, on behalf of The Crown Estate, to be carried out on an area of land at Bromham in Wiltshire. The survey covered 0.5ha in total and located several positive linear and discrete anomalies that may relate to ditch-like and pit-like features respectively. The archaeological potential of these anomalies cannot be confidently determined from the data.

1 INTRODUCTION

1.1 Survey background

1.1.1 Archaeological Surveys Ltd was commissioned by Entec UK Ltd (Entec) on behalf of The Crown Estate, to undertake a magnetometer survey of an area of land at Bromham in Wiltshire. The survey is intended to inform the decision-making process concerning the archaeological potential of the land as part of the outline planning application for a residential development.

1.1.2 The geophysical survey was carried out in accordance with a Written Scheme of Investigation (WSI) produced by Archaeological Surveys (2011) and approved by David Vaughan, Assistant County Archaeologist for Wiltshire Council, prior to commencing fieldwork.

1.2 Survey objectives and techniques

1.2.1 The objective of the survey was to use magnetometry to locate geophysical anomalies that may be archaeological in origin so that they may be assessed prior to development of the site.

1.2.2 The methodology is considered an efficient and effective approach to archaeological prospection. The survey and report generally follow the recommendations set out by: English Heritage, 2008, *Geophysical survey in archaeological field evaluation;* Institute for Archaeologists, 2002, *The use of Geophysical Techniques in Archaeological Evaluations*.

1.2.3 The geophysical survey can give an indication of the buried features within a site; however, there are many factors that may influence the outcome of the survey and its interpretation. These include the underlying geology, superficial deposits, soil magnetic susceptibility, topography, surface conditions, agriculture and modern land use (see Appendix A).

1.3 Site location, description and survey conditions

1.3.1 The site lies between Horsepool and Breach Close in Bromham, Wiltshire and centred on central Ordnance Survey Grid Reference ST 96540 65360, see

Figures 01 and 02.

1.3.2 The geophysical survey covers approximately 0.5ha of former agricultural land containing areas of dumped and burnt material and overgrown brambles, see Plate 1. A triangular piece of land within the north eastern part of the site, at 29 Horsepool Lane, was not suitable for magnetometer survey due to the presence of garden shrubs and beds and also the close proximity of vehicles and services.

1.3.3 The ground conditions across accessible parts of the site were generally considered to be favourable for the collection of magnetometry data. Weather conditions during the survey were variable with periods of rain and high winds.

Plate 1: Survey area looking south from north western corner

1.4 Site history and archaeological potential

1.4.1 There are no archaeological site or findspots directly within the site, although the Wiltshire SMR indicates that several sherds of Romano-British pottery and Roman coins were found on land immediately to the west of the site. Within the surrounding vicinity are numerous sites and findspots dating from the Prehistoric, Roman and Medieval periods. There is, therefore, some potential for locating geophysical anomalies that may relate to archaeological features.

1.5 Geology and soils

1.5.1 The underlying solid geology across the site is Lower Greensand (BGS, 2011). The overlying soil across the survey area is from the Frilford

association and is an argillic brown sand. It consists of a deep, well drained, sandy and/or coarse loamy soil (Soil Survey of England and Wales, 1983).

2 METHODOLOGY

2.1 Technical synopsis

2.1.1 Magnetometry survey records localised magnetic fields that can be associated with features formed by human activity. Magnetic susceptibility and magnetic thermoremnance are factors associated with the formation of localised fields. Additional details are set out below and within Appendix A.

2.1.2 Iron minerals within the soil may become altered by burning and the break down of biological material; effectively the magnetic susceptibility of the soil is increased, and the iron minerals become magnetic in the presence of the Earth's magnetic field. Accumulations of magnetically enhanced soils within features, such as pits and ditches, may produce magnetic anomalies that can be mapped by magnetic prospection.

2.1.3 Magnetic thermoremnance can occur when ferrous minerals have been heated to high temperatures such as in a kiln, hearth, oven etc. On cooling, a permanent magnetisation may be acquired due to the presence of the Earth's magnetic field. Certain natural processes associated with the formation of some igneous and metamorphic rock may also result in magnetic thermoremnance.

2.1.4 The localised variations in magnetism are measured as sub-units of the Tesla, which is a SI unit of magnetic flux density. These sub-units are nano Teslas (nT), which are equivalent to 10^{-9} Tesla (T).

2.2 Equipment configuration, data collection and survey detail

2.2.1 The detailed magnetic survey was carried out using Bartington Grad601-2 gradiometers. The instruments effectively measure a magnetic gradient between two fluxgate sensors mounted vertically 1m apart. Two sets of sensors are mounted on a single frame 1m apart horizontally.

2.2.2 The instruments are extremely sensitive and are able to measure magnetic variation to 0.01nanoTesla (nT), with an effective resolution of 0.03nT. The data are limited to ±100nT when surveying with the highest sensitivity. All readings are saved to an integral data logger for analysis and presentation.

2.2.3 The instruments are operated according to the manufacturer's instructions with consideration given to the local conditions. An adjustment procedure is required, prior to collection of data, in order to balance the sensors and remove the effects of the Earth's magnetic field; further adjustment is required during the survey due to instrument drift often associated with temperature change.

2.2.4 It can be very difficult to obtain optimum balance for the sensors due to localised magnetic vectors that may be associated with large ferrous objects, geological/pedological features, 'magnetic debris' within the topsoil and natural temperature fluctuations. Imperfect balance results in a heading error often visible as striping within the data; this can be effectively removed by software processing and generally has little effect on the data unless extreme.

2.2.5 The Bartington gradiometers undergo regular servicing and calibration by the manufacturer. A current assessment of the instruments is shown in Table 1 below.

Sensor type and serial numbers	Bartington Grad - 01 – 1000 Nos. 084, 085, 242 and 396
Date of certified calibration/service	Sensors 084 and 085 - 6th August 2010 (due Aug 2012) Sensors 242 and 396 - 3rd December 2009 (due Dec 2011)
Bandwidth	12Hz (100nT range) both sensors
Noise	<100pT peak to peak
Adjustable errors	<2nT

Table 1: Bartington fluxgate gradiometer sensor calibration results

The instruments were considered to be in good working order prior to the survey, with no known faults or defects.

2.2.6 Data were collected at 0.25m centres along traverses 1m apart. The survey area was separated into 30m by 30m grids (900m²) giving 3600 recorded measurements per grid. This sampling interval is very effective at locating archaeological features and is the recommended methodology for archaeological prospection (English Heritage, 2008).

2.2.7 The survey grids were set out to the Ordnance Survey OSGB36 datum using a Penmap RTK GPS. The GPS is used in conjunction with Topcon's TopNet service, where positional corrections are sent via a mobile telephone link. Positional accuracy of around 10 – 20mm is possible using the system. The instrument is regularly checked against the ETRS89 reference framework using Ordnance Survey ground marker C1ST7784 (Horton).

2.2.8 The fixed orientation of survey grids based on the OSGB36 datum was considered appropriate given that the orientation of land boundaries was variable and consequently partial survey grids were unavoidable. In addition, there is an optimum north – south traverse direction for magnetic survey (English Heritage, 2008). Survey in this direction can produce anomalies with a higher contrast when compared to other orientations; this is a function of their presence within the Earth's magnetic field. A fixed grid across the site also simplifies its relocation should that be required.

2.3 Data processing and presentation

2.3.1 Magnetometry data downloaded from the Grad 601-2 data logger are analysed and processed in specialist software known as ArcheoSurveyor. The software allows greyscale and trace plots to be produced for presentation and display. Survey grids are assembled to form an overall composite of data (composite file) creating a dataset of the complete survey area. Appendix C contains specific information concerning the survey and data attributes and is derived directly from ArcheoSurveyor; this should be used in conjunction with information provided by Figure 02.

2.3.2 Only minimal processing is carried out in order to enhance the results of the survey for display. Raw data are always analysed, as processing can modify anomalies. The following schedule sets out the data and image processing used in this survey:

- clipping of the raw data at ±30nT to improve greyscale resolution,
- clipping of processed data at ±15nT to enhance low magnitude anomalies,
- zero median/mean traverse is applied in order to balance readings along each traverse.

Reference should be made to Appendix B for further information on the specific processes carried out on the data. Appendix C metadata includes details on the processing sequence used for the survey.

2.3.3 An abstraction and interpretation is offered for all geophysical anomalies located by the survey. A brief summary of each anomaly, with an appropriate reference number, is set out in list form within the results (Section 3) to allow a rapid and objective assessment of features.

2.3.4 The main form of data display prepared for this report is the greyscale plot. Both 'raw' and 'processed' data have been shown followed by an abstraction and interpretation plot. Anomalies are abstracted using colour coded points, lines and polygons. All plots are scaled to landscape A3 for paper printing.

2.3.5 Graphic raster images in bitmap format (.BMP) are initially prepared in ArcheoSurveyor. Regardless of survey orientation, data captured along each traverse are displayed and processed by ArcheoSurveyor from left to right; this corresponds to a direction of south to north in the field. Prior to displaying against base mapping, raster graphics require a rotation of 90° anticlockwise to restore north to the top of the image. Greyscale images are rotated by AutoCAD.

2.3.6 The raster images are combined with base mapping using ProgeCAD Professional 2009 and AutoCAD LT 2007, creating DWG file formats. All images are externally referenced to the CAD drawing in order to maintain good graphical quality. Quality can be compromised by rotation of graphics in order to allow the data to be orientated with respect to grid north; this is considered acceptable as the survey results are effectively georeferenced

allowing relocation of features using GPS, resection method etc.. A digital archive, including raster images, is produced with this report allowing separate analysis if necessary, see Appendix D below.

3 RESULTS

3.1 General overview

3.1.1 The detailed magnetic survey was carried out over 0.5ha. Geophysical anomalies located can be generally classified as positive linear and discrete positive responses of an uncertain origin, linear anomalies of an agricultural origin, areas of disturbance and strong discrete dipolar anomalies relating to ferrous objects. Anomalies located within the survey area have been numbered and are described below.

3.1.2 Data are considered representative of the magnetic anomalies within the site. Zones of magnetic disturbance occur close to the southern end of the survey area, and it is possible that these may obscure very low magnitude anomalies. Minor positional errors, due to uneven and overgrown ground in the northern part of the site, were corrected for. Some small zones could not be surveyed due to brambles and and saplings. Parts of the site had been subject to a small amount of dumping of soil and rubbish although this does not appear to have greatly affected the data.

3.1.3 The list of sub-headings below attempts to define a number of separate categories that reflect the range and type of features located during the survey. A basic explanation of the characteristics of the magnetic anomalies is set out for each category in order to justify interpretation, a basic key is indicated to allow cross referencing to the abstraction and interpretation plot. CAD layer names are included to aid reference to associated digital files (.dwg/.dxf). Sub-headings are then used to group anomalies with similar characteristics for each survey area.

Report sub-heading **CAD layer names and plot colour**	**Description and origin of anomalies**
Anomalies with an uncertain origin AS-ABST MAG POS LINEAR UNCERTAIN AS-ABST MAG POS DISCRETE UNCERTAIN	The category applies to a range of anomalies where there is not enough evidence to confidently suggest an origin. Anomalies in this category may well be related to archaeologically significant features, but equally relatively modern features, geological/pedological features and agricultural features should be considered. Positive anomalies are indicative of magnetically enhanced soils that may form the fill of 'cut' features or may be produced by accumulation within layers or 'earthwork' features; soils subject to burning may also produce positive anomalies. Negative anomalies are produced by material of comparatively low magnetic susceptibility such as stone and subsoil.
Anomalies with an agricultural origin AS-ABST MAG AGRICULTURAL	The anomalies are often linear and form a series of parallel responses or are parallel to extant land boundaries. Where the response is broad, former ridge and furrow is likely; narrow response is often related to modern ploughing.

Anomalies associated with magnetic debris AS-ABST MAG STRONG DIPOLAR ●	Strong discrete dipolar anomalies are responses to ferrous objects within the topsoil.
Anomalies with a modern origin AS-ABST MAG DISTURBANCE ▨	The magnetic response is often strong and dipolar indicative of ferrous material and may be associated with extant above surface features such as wire fencing, cables, pylons etc.. Often a significant area around such features has a strong magnetic flux which may create magnetic disturbance; such disturbance can effectively obscure low magnitude anomalies if they are present. Fluxgate sensors may respond erratically and with hysteresis adjacent to strong magnetic sources. Buried services may produce characteristic multiple dipolar anomalies dependant upon their construction.

Table 2: List and description of interpretation categories

3.2 List of anomalies

Anomalies with an uncertain origin

(1) – A positive linear anomaly, extending almost east-west across the northern part of the survey area. This may indicate a cut ditch-like feature.

(2) – Discrete positive anomalies may indicate pit-like features that are located close to anomaly (1).

(3) – A series of discrete positive anomalies are located in the central part of the survey area. It is possible that they relate to a removed boundary, or form of agricultural activity.

(4) – Discrete positive anomalies in the southern part of the survey area may relate to pit-like features.

(5) – The site contains several short, positive linear anomalies of an uncertain origin.

Anomalies with an agricultural origin

(6) – A series of linear anomalies located in the southern part of the survey area are oriented northeast to southwest and are likely to relate to former agricultural activity. They do not appear to have a similar orientation to the current ploughing trend.

(7) – A series of linear anomalies, oriented north-north-east to south-south-west, represent the most recent agricultural activity on the site.

Anomalies associated with magnetic debris

(8) – The site contains several strong discrete dipolar anomalies which are responses to ferrous objects within the topsoil.

Anomalies with a modern origin

(9) – Magnetic disturbance from ferrous material within and surrounding the survey area.

4 CONCLUSION

4.1.1 The geophysical survey located a number of positive linear and discrete anomalies that may relate to ditch-like and pit-like features. A positive linear ditch-like feature crosses the northern part of the survey area, orientated almost east-west with several pit-like anomalies located close by. In the central part of the survey area pit-like anomalies have also been located although their origin is uncertain.

5 REFERENCES

Archaeological Surveys, 2011. *Bromham, Wiltshire, Geophysical Survey, Written Scheme of Investigation.*

British Geological Survey, 2010. *Geology of Britain viewer, 1:50 000 scale [online]* available from http://maps.bgs.ac.uk/geologyviewer/ [accessed 14/2/2011].

English Heritage, 2008. *Geophysical survey in archaeological field evaluation. Research and Professional Service Guideline No.1.* 2nd ed. Swindon: English Heritage.

Institute for Archaeologists, 2002. *The use of Geophysical Techniques in Archaeological Evaluations*. IFA Paper No. 6. IFA, University of Reading.

Soil Survey of England and Wales, 1983. *Soils of England and Wales, Sheet 5 South West England.*

Appendix A – basic principles of magnetic survey

Iron minerals are always present to some degree within the topsoil and enhancement associated with human activity is related to increases in the level of magnetic susceptibility and thermoremnant material.

Magnetic susceptibility is an induced magnetism within a material when it is in the presence of a magnetic field. This can be thought of as effectively permanent due to the presence of the Earth's magnetic field.

Thermoremnant magnetism occurs when ferrous material is heated beyond a specific temperature known as the Curie Point. Demagnetisation occurs at this temperature with re-magnetisation by the Earth's magnetic field upon cooling.

Enhancement of magnetic susceptibility can occur in areas subject to burning and complex fermentation processes on biological material; these are frequently associated with human settlement. Thermoremnant features include ovens, hearths, and kilns. In addition thermoremnant material such as tile and brick may also be associated with human activity and settlement.

Silting and deliberate infilling of ditches and pits with magnetically enhanced soil can create an area of enhancement compared with surrounding soils and subsoils into which the feature is cut. Mapping enhanced areas will produce linear and discrete anomalies allowing an assessment and characterisation of hidden subsurface features.

It should be noted that areas of negative enhancement can be produced from material having lower magnetic properties compared to the topsoil. This is common for many sedimentary bedrocks and subsoils which were often used in the construction of banks and walls etc. Mapping these 'negative' anomalies may also reveal archaeological features.

Magnetic survey or magnetometry can be carried out using a fluxgate gradiometer and may be referred to as gradiometry. The gradiometer is a passive instrument consisting of two fluxgate sensors mounted vertically 1m apart. The instrument is carried about 30cm above the ground surface and the upper sensor measures the Earth's magnetic field as does the lower sensor but this is influenced to a greater degree by any localised buried field. The difference between the two sensors will relate to the strength the magnetic field created by the buried feature. If no enhanced feature is present the field measured by both sensors will be similar and the difference close to zero.

There are a number of factors that may affect the magnetic survey and these include soil type, local geology and previous human activity. Situations arise where magnetic disturbance associated with modern services, metal fencing, dumped waste material etc., obscures low magnitude fields associated with archaeological features.

Appendix B – data processing notes

Clipping

Minimum and maximum values are set and replace data outside of the range with those values. Extreme values are removed improving colour or greyscale contrast associated with data values that may be archaeologically significant. It has been found that clipping data to ranges between ±5nT and ±1nT often improves the appearance of features associated with archaeology. Different ranges are applied to data in order to determine the most suitable for anomaly abstraction and display.

Zero Median/Mean Traverse

The median (or mean) of each traverse is calculated ignoring data outside a threshold value, the median (or mean) is then subtracted from the traverse. The process is used to equalise slight differences between the set-up and stability of gradiometer sensors and can remove striping. The process can remove archaeological features that run along a traverse so data analysis is also carried out prior its application.

De-stagger

Compensates for small positional errors within data collection by shifting the position of the readings along each traverse by a specified amount. Data lost at the end of each traverse are extrapolated from adjacent value in the same row.

Deslope

Corrects for striping and distortion caused by metal objects/services etc.. The process calculates a curve based on a polynomial best fit mathematical function for each traverse. This curve is then subtracted from the actual data.

FFT (Fast Fourier Transform) spectral filtering

A mathematical process used to determine the frequency components of a traverse. Repetitive features, such as plough marks, produce characteristic spectral zones that can be suppressed allowing greyscale images to appear clearer.

Appendix C – survey and data information

Raw data

COMPOSITE
Filename: J352-mag-raw.xcp
Instrument Type: Bartington (Gradiometer)
Units: nT
Surveyed by: on 15/02/2011
Assembled by: on 15/02/2011
Direction of 1st Traverse: 0 deg
Collection Method: ZigZag
Sensors: 2 @ 1.00 m spacing.
Dummy Value: 32702

Dimensions
Composite Size (readings): 960 x 90
Survey Size (meters): 240 m x 90 m
Grid Size: 30 m x 30 m
X Interval: 0.25 m
Y Interval: 1 m

Stats
Max: 30.00
Min: -30.00
Std Dev: 7.81
Mean: -0.70
Median: -1.45
Composite Area: 2.16 ha
Surveyed Area: 0.50835 ha

Processes: 2
1 Base Layer
2 Clip from -30.00 to 30.00 nT
Source Grids: 16
1 Col:0 Row:1 grids\01.xgd
2 Col:1 Row:1 grids\02.xgd
3 Col:2 Row:0 grids\03.xgd
4 Col:2 Row:1 grids\04.xgd
5 Col:3 Row:0 grids\05.xgd
6 Col:3 Row:1 grids\06.xgd
7 Col:4 Row:0 grids\07.xgd
8 Col:4 Row:1 grids\08.xgd
9 Col:5 Row:0 grids\09.xgd
10 Col:5 Row:1 grids\10.xgd
11 Col:6 Row:0 grids\11.xgd
12 Col:6 Row:1 grids\12.xgd
13 Col:6 Row:2 grids\13.xgd
14 Col:7 Row:0 grids\14.xgd
15 Col:7 Row:1 grids\15.xgd
16 Col:7 Row:2 grids\16.xgd

Processed data

Filename: J352-mag-proc.xcp

Stats
Max: 15.00
Min: -15.00
Std Dev: 5.60
Mean: 0.29
Median: 0.00
Composite Area: 2.16 ha
Surveyed Area: 0.508 ha

Processes: 6
1 Base Layer
2 DeStripe Median Traverse: Grids: All
3 Clip from -30.00 to 30.00 nT
4 Clip from -15.00 to 15.00 nT
5 De Stagger: Grids: 12.xgd Mode: Both By: -1 intervals
6 Clip from -15.00 to 15.00 nT (Area: Top 30, Left 720, Bottom 59, Right 839)

Appendix D – digital archive

Archaeological Surveys Ltd hold the primary digital archive at Castle Combe, Wiltshire (see inside cover for address). Data are backed-up onto an on-site data storage drive and at the earliest opportunity data are copied to CD ROM for storage on-site and off-site. Digital data are also supplied to the client on CD ROM, see below.

Surveys are reported on in hardcopy (recycled paper) using A4 for text and A3 for plots (all plots are scaled for A3). The distribution of both hardcopy report and digital data is considered the responsibility of the Client unless explicitly stated in the survey Brief, Written Scheme of Investigation or other contractual agreement.

This report has been prepared using the following software on a Windows XP platform:

- ArcheoSurveyor version 2.5.8.46(geophysical data analysis),
- ProgeCAD Professional 2009 (report graphics),
- AutoCAD LT 2007 (report figures),
- OpenOffice.org 3.0.1 Writer (document text),
- PDF Creator version 0.9 (PDF archive).

Digital data are supplied on CD ROM which includes the following files:

- ArcheoSurveyor grid and composite files for all geophysical data,
- CSV files for raw and processed composites,
- geophysical composite file graphics as Bitmap images,
- AutoCAD DWG files in 2000 and 2007 versions,
- report text as OpenOffice.org ODT file,
- report text as Word 2000 doc file,
- report text as rich text format (RTF),
- report text as PDF,
- PDFs of all figures,
- photographic record in JPEG format.

The CD ROM structure is formed from a tree of directories under the title J352 Bromham – CD. Directory titles include Data, Documentation, CAD, PDFs and Photos. Multiple directories exist under Data and hold Grid, Composite and Graphic files with CSV composite data held in Export.

The CAD file contains externally referenced graphics that are rotated with separate A3 size layouts for each figure. Layouts are fixed using frozen layers and named views allowing straightforward plotting or analysis on screen. (Note – CAD files are prepared using AutoCAD's e Transmit function to produce a directory containing the digital drawing along with any externally referenced graphics which may need reloading).