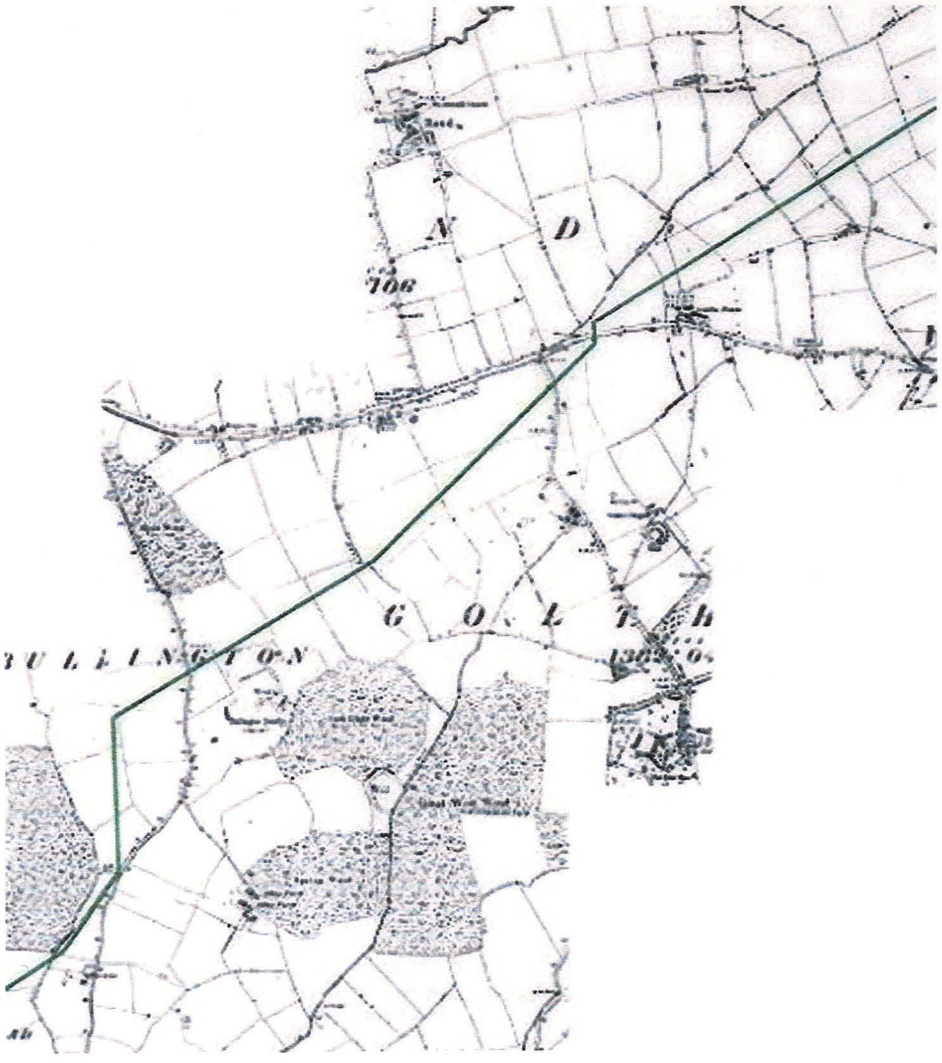
M4/24

FLUXGATE GRADIOMETER SURVEY
HOLTON-CUM- BECKERING TO WELTON
GATHERING CENTRE GAS PIPELINE

NGR: TF0480 7501 TF 1340 7941

VOLUME 1 (OF 2)



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pre-construct geophysics

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Illustrations

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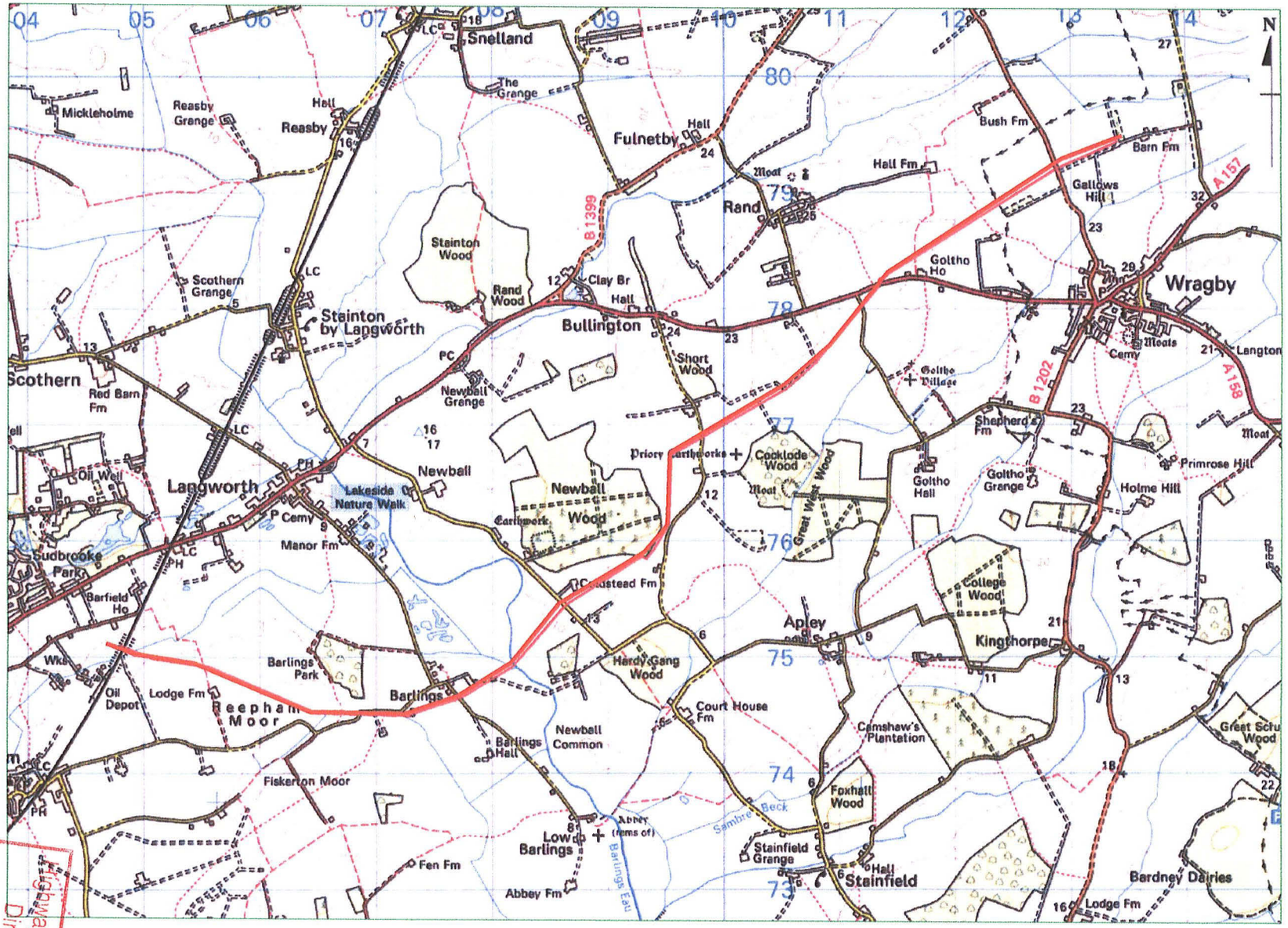

Fig. 1 Location of pipeline route, scale 1:50,000

Summary

- *A fluxgate gradiometer survey was undertaken for Star Energy (East Midlands) Ltd along the proposed route of a gas pipeline from the Welton Gathering Centre (Reepham) to Wragby.*

- *The survey recorded traces of ridge and furrow ploughing in a number of locations. Former field boundaries were also encountered.*

- *Towards the east end of Field 7, traces of a possible enclosure were identified, although the evidence for this is not entirely conclusive.*

- *With reference to the survey results alone, the proposed route does not appear to traverse any major archaeological sites.*

1.0 Introduction

Star Energy (East Midlands) Ltd commissioned Pre-Construct Geophysics to undertake a fluxgate gradiometer survey along the proposed route of a gas pipeline. The survey was undertaken as part of an archaeological evaluation of the proposed route, and it was carried out in accordance with the English Heritage document *Geophysical Survey in Archaeological Field Evaluation* (EH 1995).

2.0 Location and description (Figs. 1-2)

Sections 2 and 3 contain information extracted from an archaeological desk-based assessment of the proposed route (Tann, 2003).

The proposed pipeline extends for approximately 11km and is intended to link an existing Transco trunk main at Holton-cum-Beckering (north of Wragby) to the Welton Oil Gathering Centre, which lies to north of Reepham (NGR TF0470 7483 – TF 1340 7941). The route traverses agricultural land through the parishes of Reepham, Fiskerton, Barlings, Newball, Bullington, Goltho, Rand and Wragby.

The pipeline route starts at the Welton Gathering Centre, south of the Lincoln-Market Rasen railway line and continues roughly in an east to north-easterly direction across predominately arable farmland. Generally the ground level rises from c.15m OD at the oil depot to c.25m OD at Barn Farm, Wragby. This is interrupted by lower ground (c.5m OD) along the Barlings Eau river valley. The Barlings Eau flows in a south-easterly direction.

The solid geology for the majority of the route is comprised of Wragby Till, with the exception of alluvial and river terrace deposits which occur immediately west of the Barlings Eau (BGS 102, Market Rasen; 103 Louth, 1999).

3.0 Archaeological background

The pipeline route has been designed to avoid woodland and to minimise the impact of the development on known archaeological sites.

The ruins of Barlings Abbey (SMR 53010) lie c. 1.5km to the south of the pipeline corridor in the western half of the route. The abbey was founded in 1154 and later re-established on higher ground in Fiskerton Fen.

Beyond the Barlings Eau, the route skirts around the southeastern edge of Newball Wood, which contains a possible Roman rectangular enclosure (SMR 53054). It then diverts northwards to avoid direct contact with the (earthwork) remains of Bullington Priory, a scheduled ancient monument (SAM 85). Unfortunately, access to a section of the route to the north of the priory was not granted.

It is believed that traces of a Roman field system and associated roads may lie within or close to the route to the north of Bullington Priory.

Bullington, a recorded Domesday settlement, was deserted during the medieval period, and it was excavated in 1970-74 (SMR 51217). The site appears also to have been occupied during the Roman period. The route passes to the north of this settlement, before crossing the A158.

The remaining section of the route is relatively free of known archaeological remains, although it is believed that it crosses the course of a Roman road in Rand or Wragby parish. Also, in 1971, a possible Iron Age ditch was recorded during groundworks for the existing Transco main. However, the precise location of this feature is not known.

A walkover survey carried out in October 2003 by Lindsey Archaeological Services identified occasional Romano-British and medieval artefacts.

4.0 Methodology

Magnetic variation that is detectable within soils can often determine the nature and extent of past human activity. At British latitudes, the earth's magnetic field is approximately 50,000 nanoteslas (The nanotesla is the SI unit of magnetic flux, used in gradiometry to measure magnetic variation in relation to the Earth's magnetic field). Against this background, most archaeological features produce an enhancement of around 5-30 nanoteslas (nT). The strength of this magnetic variation depends largely on the composition of the geology. For example, limestone and chalk exhibits low magnetic susceptibility, and contrasts well against soils: conversely, strongly magnetic igneous rocks can mask subtle anomalies completely.

For the most part, soils tend to be more responsive to magnetic remote sensing than the geologies over which they lie. Ferrous oxides occur naturally in many drift deposits, particularly those derived from, or containing elements of, igneous rocks. Organic decomposition within topsoils can supplement the level of ferrous compounds, a process amplified by agricultural activities.

The fills of ditches and pits tend to increase soil depths, and hence magnetic strengths, relative to surrounding soils. The converse also applies.

Ferromagnetic substances such as iron induce a very high response to magnetic surveys, and are thus easier to identify. Perhaps of more significance to the archaeological prospector are the weaker ferrous oxides; the randomly orientated magnetic fields of these materials produce minimal magnetic variation in their natural state. Geology and soil type can determine this variance (see above). Specifically, clay soils are ferrous oxide rich, hence their characteristic red colouration. Clay has literally been a fundamental building block in human social development: firing increases its versatility, but also enhances the magnetic properties of its ferrous content. For kilns, this may be in the order of 1000-5000 nT. Similar processes occur during the formation of igneous rocks.

Invariably, most surveys detect discrete anomalies, either in groups, or randomly scattered across a site. In the absence of intrusive investigation, the nature and origin of these anomalies is often difficult to establish. Strongly magnetic dipolar anomalies usually reflect ferrous objects, such as ploughshares and horseshoes. Weaker examples may indicate ceramic materials such as brick and tile, often introduced onto the site during manure spreading. The strength of the magnetic variation derives from permutations of the size and depth of the feature/object and the magnetic susceptibility of the surrounding soil. Pit-like anomalies, usually positive, can be identical to naturally occurring depressions, and the potential of these can only be estimated when they are examined in context with other factors, such as the proximity of definite, or suspected archaeological remains.

The use of magnetic surveys to locate sub-surface ceramic materials and areas of burning, as well as magnetically weaker features, is well established, particularly on large green field sites. The detection of magnetic anomalies requires the use of highly sensitive instruments, in this instance the Bartington 601 Dual Fluxgate Gradiometer. This must be accurately calibrated to the mean magnetic value of each survey area. Two sensors, mounted vertically and separated by 1m, measure slight localised distortions of the earth's magnetic field. Cumulative readings can be stored, processed and displayed as graphic images.

The gradiometer survey was undertaken on accessible land along an 11km x 30m wide corridor. that encompassed all accessible and suitable land that lay along the route between Welton Gathering Station (TF 0470 7483). Each field along the route has been allocated a unique identification number, which ranged from Field 1 (Reepham) to Field 34 (Wragby). The survey was undertaken from west to east, although fields were not investigated sequentially owing to delays and access restrictions.

The survey data has been processed using zero mean functions to correct the unevenness of the plots in order to give a smoother graphical appearance. The data was also processed using algorithm to remove magnetic spikes, thereby reducing extreme readings sometimes caused by stray iron fragments and spurious effects due to the inherent magnetism of soils.

The locations of the surveys have been plotted onto maps at a scale of 1:2500 (Figs 2-

14). The results are also plotted as greyscale and trace images at a scale of 1:1250 (Figs 15-27).

For ease of reporting, left to right along each survey plot (Figs 15-27) has been designated as west to east, regardless of the actual orientation of each survey area. Blocks of fields have been categorised and discussed with reference to figures 15-27 (e.g. Fields 1-4: Fig 15, Fields 6-8: Fig.17).

Instrument	Bartington 601 Dual Fluxgate Gradiometer
Grid size Sample interval	30m x 30m 0.25m
Traverse interval	1.0m
Traverse method	Zigzag
Sensitivity	0.1nT
Processing software	Geoplot (*v. 3.0*)
Area surveyed	9.1km x 30m
Date of survey	April-August 2004
Survey personnel	David Bunn, Peter Heykoop, Peter Masters

Table 1: Summary of survey parameters

5.0 Analysis and Interpretation of results

References in the following text regarding known archaeological sites and the location of former field boundaries are based upon information provided by Lindsey Archaeological Services and First Edition Ordnance Survey maps.

Fields 1-4 (Figs. 2, 3, 15)

Strong magnetic variation along the western edge of Field 1 reflects the close proximity of a wire fence (pink line) forming the eastern boundary of the Lincoln-Market Rasen railway line.

The survey recorded a number of positive magnetic anomalies in Field 1 and the western end of Field 2 (boxed in green). A broad, deep drain separates these fields, and it is possible that elements of this variation reflect materials that have been dredged from the drain, during its construction and/or during maintenance. However, the route in this area extends across low-lying land and is close to a large stream to the immediate northwest of the railway. It is more likely therefore that these anomalies reflect naturally deposited materials, such as pockets of ferrous rich minerals, and/or the remnants of peat deposits.

Moderately strong readings in the northeast corner of the Field 1 (circled in pink) probably indicate modern ferrous materials. Similar anomalies were recorded at the eastern edge of Field 2 and elsewhere along the route. Typically, this type of variation indicates ceramic material (e.g. brick and tile) or miscellaneous iron objects, such as

horseshoes and ploughshares. However, it should be noted that weaker anomalies (dipole and monopole) could also represent naturally occurring glacial erratics within till.

Regularly spaced parallel linear anomalies were recorded in Fields 2-4. Indeed, similar anomalies were encountered along many sections of the route (see below). Some, particularly the magnetically weaker and closely spaced examples, probably indicate traces of cultivation, such as ridge and furrow ploughing. Possible examples of the latter have been highlighted as orange lines and other cultivation marks as olive green. Some resolve as magnetically stronger linear anomalies at wider intervals. These are more characteristic of land drains (examples shown as brown lines). However, in certain instances (including Fields 1-4), the results do not clearly define linear anomalies as traces of cultivation or clay drains.

The survey detected ditch-like linear anomalies in the eastern half of Field 3 (red lines). The archaeological significance of these is unclear, but the largest could signify a former land division (not depicted on the 1st Edition OS map, dated 1891). The northeastern boundary of the field dog-legs slightly to the east; this may indicate that it was diverted around an obstacle, possibly a farmstead (Tann, 2003), and the linear features may relate to this putative settlement, possibly as part of a small enclosure.

The eastern part of field 4 was not suitable for survey (tall, impenetrable oilseed rape). A probable service was recorded in the mid point of the field (blue line).

Field 5 (Figs. 2, 4, 16)

The survey recorded magnetic traces of an existing farm track that extends along the western edge of the field (circled in pink).

For the most part, magnetic variation resolves as linear anomalies. These have been categorised according to their likely origins. Regularly spaced northwest to southeast linears could reflect ridge and furrow (examples shown as orange). Perpendicular to these, other linear anomalies may indicate traces of modern cultivation, such as plough scores or tramlines (olive green). The survey may also have detected land drains (examples shown as brown).

A magnetically strong linear anomaly appears to indicate a former land boundary (yellow).

Fields 6-8 (Figs. 2, 5, 6, 17)

Probable traces of ridge and furrow and drains were recorded in Field 6.

The survey detected an ill-defined linear anomaly at the western end of Field 6. It is possible that this represents an earlier alignment of the drain that extends along the northern edge of the field (Fig. 5).

Land drains and a service account for the majority of magnetic variation in field 7, although a curvilinear anomaly at the eastern end possibly indicates a ditch forming the southern extent of an enclosed feature. This interpretation is offered tentatively,

given the limited extent of the anomaly and the magnetic interference of land drains. A number of potentially significant pit-like anomalies were also recorded (circled in red).

Drains were detected in Field 8.

Fields 9-12 (Figs. 2, 6, 7, 18)

In Field 9, a magnetically strong linear anomaly appears to correspond to a former field boundary (shown yellow; also depicted on the 1st edition OS map). The positions and alignments of probable land drains suggest that this former boundary contains a drain (shown as brown). Linear anomalies close to the eastern end of the field respect the boundary and may be traces of a headland (ridge and furrow) and modern cultivation (shown as olive green line).

Land drains were recorded in Field 10.

Broad linear anomalies were recorded in Fields 11 and 12 (zones boxed in green). These occur along an approximately north to south-aligned band of River Terrace Deposits, comprising loam, sand and gravel (B.G.S., 1999). These were deposited by a precursor of the Barlings Eau, which lies within 1km to the east. It seems likely that the anomalies relate to alluvial deposition, possibly as silt filled palaeochannels.

Fields 13-17 (Figs. 2, 6, 7, 19)

Probable paleochannels were recorded in Fields 13, 14 and 17 (boxed in green). At this point the ground level gradually falls as the route approaches the Barlings Eau (flanked by fields 15 and 16), and rises beyond the river in Field 17. The upper geology around the Barlings Eau comprises river terrace deposits (see above), evidence of which was apparent in Fields 13 and 14, where the topsoil included sands, gravels and flint.

During the survey, a scatter of probable Roman pottery sherds was noted in the mid and eastern parts of Field 14. This may be evidence of occupation, although the survey results do not confirm this. A zone of random and weak magnetic variation was recorded in the western half of Field 14 (boxed in red and tentatively flagged as potentially significant), but this does not resolve as diagnostic traces of human activity. A lack of potentially significant anomalies may reflect the inherently poor response of sands and gravels to magnetic prospection.

The potential of a series of diffuse and evenly spaced linear anomalies in the mid parts of Field 13 is enhanced by the close proximity of artefacts. However, it is more likely that they indicate more recent features, such as cultivation marks or drains. Linear anomalies at the eastern end of the field align with, and probably relate to, the current southern field boundary, possibly as cultivation marks (olive green).

Anomalies recorded in Field 15 probably reflect recently improved flood defences (circled in pink) or alluvial deposits (boxed in green).

Possible rubble spreads were detected in Field 16 (circled in pink). This interpretation

is enhanced by the presence of what may be a rubble-filled pit or well that was noted on land to the immediate north of the survey. The desktop assessment of the route suggests that quarrying may have taken place in this area (Tann, 2003). The 1891 O.S. also shows a pond-like feature to the immediate north of the route. This study also reports that probable northwest to southeast aligned ridge and furrow has been identified as cropmarks in field 17. The survey did not detect clear traces of this activity. At least one extremely diffuse linear anomaly was recorded, although this aligns from northeast to southwest. This may indicate a drain or a cultivation mark.

Fields 18-20 (Figs. 2, 8, 9, 20)

Northwest to southeast aligned ridge and furrow appears as cropmarks in Field 18. Again, the survey has not substantiated this evidence. The results do indicate relatively strong northwest to southeast aligned features, but these almost certainly resolve as land drains, spaced at c.40m intervals (example shown as brown). More closely spaced drains were recorded in field 19.

A series of weakly magnetic northeast to southwest-aligned anomalies were detected in Field 18. These appear to reflect traces of cultivation, possibly plough scores (olive green).

No clearly defined significant anomalies were detected in Field 20.

Fields 21-22 (Figs. 2, 9, 21)

The survey detected a probable former field boundary in the mid part of field 21 (yellow line). A group of stronger anomalies in this area probably indicate traces of this boundary (circled in pink). Distinct linear anomalies in the eastern half of the field resolve as probable land drains (examples shown as brown). Faint linear anomalies are discernable between the land drains. These align with the former boundary (east to west), and probably indicate cultivation (example shown as olive green). Strong magnetic variation at the eastern end of the field reflects the close proximity of a boundary drain.

No clearly defined significant anomalies were detected in Field 22. Most of the variation probably indicates miscellaneous ceramic and iron objects within the ploughsoil and field boundaries or naturally occurring materials within glacial till.

Field 23 (Figs. 2, 10, 22)

Three groups of linear anomalies were recorded. The clearest, possibly land drains were detected in the western half of the field. Others may indicate cultivation, including possible ridge and furrow. Alternatively, it is also possible that at least two deep sub-soiling passes (up to a depth of 60-70cm) may account for the criss-cross alignment of the weaker linear anomalies.

The ground surface was clear of dense vegetation at the time of survey and nothing of archaeological interest was noted.

Field 29 (Figs. 2, 11, 23)

Fields 24-28 were not available for survey. These fields lie close to Bullington Priory, a Scheduled Ancient Monument (SMR 54188).

In Field 29, a series of regularly spaced parallel linear anomalies appear to indicate land drains. These are partially masking weaker linear anomalies that may signify remnants of ridge and furrow ploughing.
A strong magnetic anomaly in the mid part of the field probably represents modern ferrous material (circled in pink). At least two pit-like anomalies were detected in this area (circled in red). These may have archaeological significance. To the east of these, the survey recorded a zone of random magnetic variation (boxed in red). This may indicate recent human activity, such as a storage area for drain backfill material (?clinker). However, given the close proximity of Bullington Priory and a deserted medieval village (SMR 51217, to the south of Fields 29 and 30), a more significant origin should not necessarily be discounted.

Field 30 (Figs. 2, 12, 24)

As in field 30, the archaeological potential of this area is high, with a number of known and suspected settlement remains that date from at least the Romano-British period (Tann, 2003).

A diffuse and fragmented linear anomaly was detected at the northern edge of the survey corridor (red line). Stronger magnetic variation at the eastern end of the field (see below) may be masking traces of its continuation into this area. Its archaeological potential is unclear, but it does appear to relate to existing boundaries and other anomalies that were detected in the field. It may represent traces of a former track or path.

A strong linear anomaly was recorded close to the western boundary (brown line). It could represent a drain, although its apparent isolation diminishes this interpretation. Alternatively, it could signify a buried ditch, possibly related to the current field boundary.

The survey detected a series of linear anomalies and more random variation at the eastern end of the field. The magnetically weaker linear anomalies may be traces of ridge and furrow or more recent cultivation (olive green). They extend parallel to the northern boundary of the field and the A158, which lies to the immediate north. They also share an alignment with probable land drains (brown lines) that appear to abut, in perpendicular fashion, a north to south linear feature (shown as yellow). The latter probably marks the position of a former field boundary, as depicted on the 1891 O.S. map. This may have been a ditch with drains flowing into it. Random variation in this area could indicate material dredged from the drain.

This part of the field also appears to contain a second drainage system, which is predominately aligned northwest to southeast.

Field 31 (Figs. 2, 12, 25)

Stronger linear anomalies probably reflect land drains (examples shown as brown). Weaker examples in the eastern third of the field resolve as probable ridge and furrow (examples shown as orange). Others (yellow) correspond to former boundaries. It is interesting to note that the ridge and furrow is confined to the easternmost former field.

Fields 32-33 (Figs. 2, 13, 14, 26)

Both fields contain traces of ridge and furrow. Unusually, in Field 33, there appears to be two phases of ridge and furrow-like cultivation. Probable land drains were also recorded.

Magnetic variation at the western end of Field 32 probably reflects material dredged from the drain.

Magnetic variation in the mid part of Field 33 (boxed in yellow) corresponds to a former field boundary (O.S., 1891).

Field 34 (Figs. 2, 14, 27)

Strong magnetic variation along the southern edge of the survey was produced by a metalled track that lies to the immediate south of the route. Other discrete anomalies probably signify miscellaneous ferrous materials.

The results include a series of diffuse parallel linear anomalies toward the western and eastern ends of the field (orange). These may be ridge and furrow or modern deep cultivation marks.

At least one ephemeral linear anomaly is discernable in the mid part of the field (shown as red). It does not align with existing boundaries and may be of archaeological significance. A number of probable Roman pottery sherds were noted on the surface in the mid part of the field.

6.0 Conclusions

The survey did not identify any clear traces of direct past human settlement activity. Areas of ridge and furrow ploughing and a number of former boundaries were encountered in many fields, in addition to modern land drains.

With reference to the survey results alone, the archaeological potential of the proposed pipeline corridor is considered to be low and that it is unlikely that any major sites lie within the areas that were available for survey. It is possible that the southernmost elements of an enclosure were recorded in Field 7, although the results are not entirely conclusive.

Roman pottery sherds were noted in Fields 14 and 34, and these may be indicative of former occupation. However, with the possible exception of a ditch-like anomaly in

Field 34, the survey did not record clear diagnostic features in either field.

7.0 Acknowledgements

Pre-Construct Geophysics would like to thank Star Energy (Midlands) Ltd for this commission.

8.0 References

Abbreviations

BGS = British Geological Survey
EH = English Heritage

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