6.0 GEOPHYSICAL SURVEY

A targeted magnetometer pilot study was undertaken in November 2003 in order to assess the effectiveness of magnetometry on the site. Although the results were not wholly conclusive, a magnetometer area survey of 12 hectares was carried out in Zones A, B, C, and D, during December 2003. Given the relatively disappointing results of the magnetometer area survey, a targeted soil resistance pilot study was undertaken in January 2004. A soil resistance area survey covering 2 hectares was then employed to investigate Zone D during February 2004 (Figure 23).

6.1 SURVEY PROCEDURE

The external edges of the survey areas were set out using a total station theodolite, with intermediate points being positioned using tapes. This procedure ensured an internal grid point accuracy of ±0.05m for the survey.

6.1.1 Magnetometer survey

Magnetometry measures subtle magnetic variation against a consistent magnetic background. Metalwork creates significant magnetic variation, while archaeological features and deposits which contain debris from burning or organic decay will create more subtle variations, both of which can be mapped.

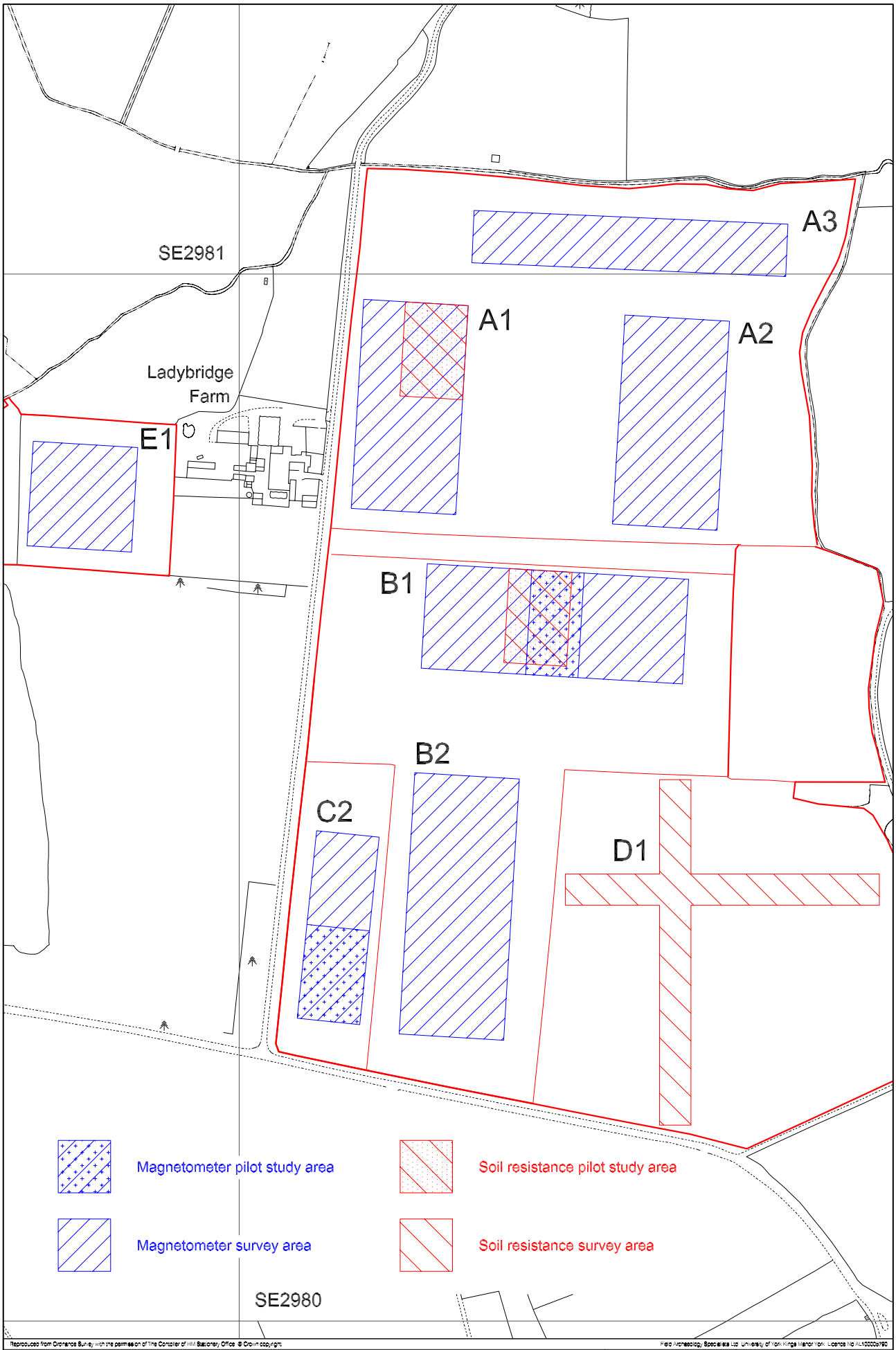
This survey was carried out using a fluxgate gradiometer with digital storage and data transfer facilities (FM36 with ST1 sample trigger - manufactured by Geoscan Research). Each survey grid was undertaken using the parallel traverse method (unidirectionally) to ensure the capture of good quality raw data. Instrument readings were logged at 0.25m intervals along 1.0m traverses. On the completion of four survey grids the data was transferred from the FM36 to a portable computer where it was checked for survey defects.

The raw data was processed using Geoplot version 2.02. This involved the adjustment of any differences in the average background reading between individual survey grids as well as inconsistencies caused by instrument drift, which were removed to facilitate clear presentation of the data sets. The processed data was transferred to Surfer version 6.2 in which it was prepared for presentation and the resulting greyscale images were imported into AutoCAD and output on a high definition laser printer. Raw data and trace plots are provided as Appendix C.

6.1.2 Soil resistance survey

This technique involves passing an electrical current through an area of ground and measuring the ground's resistance to the current. Although soil particles and stone are insulators and do not conduct electricity, the presence of water which is a good conductor allows these materials to conduct an electrical current. In effect, a soil resistance survey maps moisture content. Archaeological deposits vary in character and composition and have different moisture retention qualities which can often be mapped by a soil resistance meter.

This survey was carried out using a soil resistance meter with digital storage and data transfer facilities (RM15 Advanced - manufactured by Geoscan Research). The RM15 was used with a MPX15 multiplexer connected



Location of geophysical surveys | Scale 1:5000 | Figure 23

to a PA5 probe array fitted with three probes. The use of a multiplexer and multiple probe array allows a series of different readings to be taken at the same point. In this case, two readings at 0.5m probe separation and one at 1.0m probe separation were logged at each point. This method produces two data-sets: firstly, a higher resolution data set with readings at 0.5m x 1.0m intervals (0.5m probe spacing), and secondly, a lower resolution data set with readings at 1.0m x 1.0m intervals (1.0m probe spacing). The first data-set produces a higher definition image of soil resistance anomalies, while the second, with wider probe spacing, provides a coarser image of soil resistance at greater depth.

The raw data was processed using Geoplot version 2.02. This involved the adjustment of any differences in the average background reading between individual survey grids, as well as inconsistencies caused by changing climatic conditions, which were removed to facilitate clear presentation of the data-sets. The processed data was transferred to Surfer version 6.2, in which it was prepared for presentation, and the resulting greyscale images were imported into AutoCAD and output on a laser printer. Raw data plots are provided as Appendix C.

6.2 MAGNETOMETER SURVEY RESULTS

6.2.1 Magnetometer Pilot Study

Two areas were selected for the magnetometer pilot study, a 50.0m x 100.0m area in the northern part of Zone B (B1) and a 60.0m x 90.0m area within Zone C (C1). B1 was designed to investigate weak circular and curvilinear cropmark features (see Figure 6) and C1 was positioned in an area where fieldwalking had identified a concentration of lithic material. The results of the magnetometer pilot study are presented as Figure 24 and the interpretation of the results as Figure 25.

A total of four anomalies were identified within area B1 and allocated F1 to F4. These have been interpreted as follows:

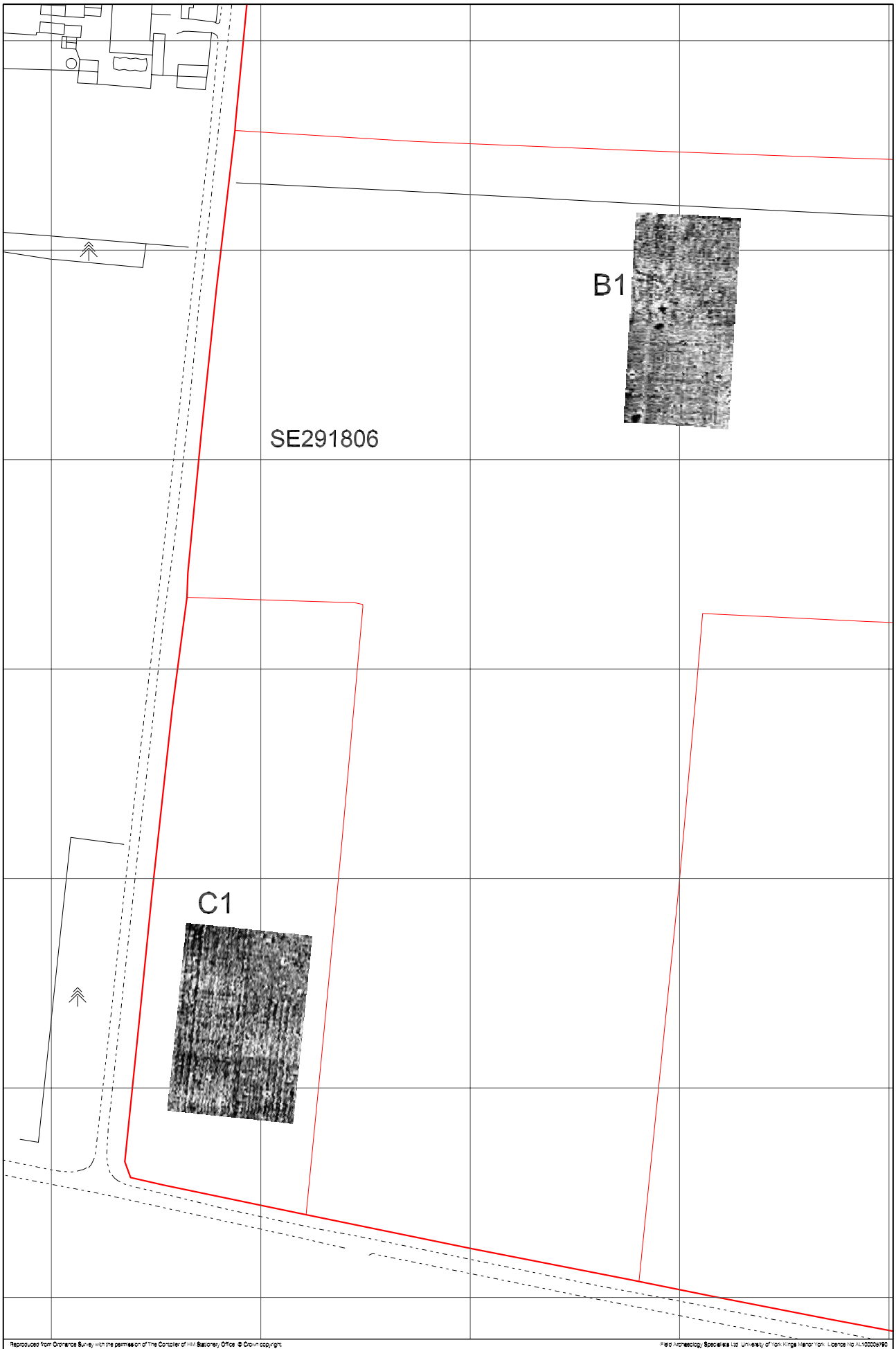
F1 This is a positive curvilinear anomaly forming an irregular ‘u’-shape in plan and measuring approximately 21.00m x 1.00m. The feature roughly corresponds with the plotted position of a weak circular cropmark feature.

F2 This is a positive anomaly measuring 2.60m in diameter. The anomaly may represent a pit or sink hole.

F3 This is a positive anomaly measuring 3.00m in diameter located 6.00m to the south of F2. The anomaly may represent a pit or sink hole.

F4 This is a relatively large positive anomaly measuring 4.00m in diameter located in the southwestern corner of area B1. The anomaly may represent a pit or sink hole.

Within C1, the magnetometer pilot results consist of a series of linear positive and negative north-south anomalies, which are likely to be the result of modern ploughing. There are also some possible positive and negative anomalies, but these are too weak and obscure to interpret confidently.



Results of magnetometer pilot study | Scale 1:2500 | Figure 24

Interpretation map of magnetometer pilot study | Scale 1:2500 | Figure 25

The magnetometer pilot study demonstrated that magnetometry was capable of defining sub-surface features which may represent archaeological remains. The identification of the four positive anomalies, one of which had also been identified as a cropmark from aerial photography, resulted in a magnetometer area survey of approximately 25% of the site being undertaken.

6.2.2 Magnetometer Area Survey

The results of the magnetometer pilot study indicated that magnetometry would potentially identify archaeological features, and resulted in an initial 25% sample of the area of investigation being the subject of a magnetometer area survey. The sample was distributed across the site as follows (see Figure 23): three areas were positioned within Zone A (A1, A2 and A3). A1 and A2 both measured 100.0m x 200.0m and were orientated north-south and A3 measured 300.0m x 50.0m and was orientated east-west. These areas were selected in order to ensure a reasonable coverage of Zone A, but also to target curvilinear and linear cropmarks previously located in the zone. Two areas were defined for Zone B, B1 and B2, both of which measured 100.0m x 250.0m; B1 was orientated east-west and subsumed the area of the pilot study, and B2 was orientated north-south. B1 was designed to explore further the cropmark features within the zone and to investigate a larger area around the pilot area due to the presence of circular anomalies. B2, along with C1, were designed to further explore the lithic concentration identified by the fieldwalking. C1 measured 60.0m x 180.0m and subsumed the area of the pilot study. Zone D was not available for survey due to the presence of a beet crop. A single area was designed for best coverage within Zone E, E1, which measured 100.0m x 100.0m. The results of the magnetometer survey are presented in Figure 26; the interpretation of the results is presented in Figure 27.

Area A

A total of seventeen anomalies were identified within Zone A, ten in A1 and seven in A2; no anomalies were identified within A3.

The ten anomalies within A1 were allocated F5 to F14 inclusive. Modern east-west ploughing, with some indication of north-south ploughing, was visible within the area.

F5 This is a weak magnetic anomaly consisting of two curvilinear elements. The westernmost element appears as a tight curvilinear anomaly measuring approximately 5.0m long x 3.30m across and 0.70m in width. Approximately 4.70m to the east a broader curvilinear anomaly has been identified 14.80m long x 0.70m wide. This anomaly may represent small enclosures.

F6 This is a sub-circular weak magnetic anomaly measuring approximately 5.35m in diameter. The anomaly may represent a pit or sink hole.

F7 This is a series of six sub-circular strong magnetic anomalies which are arranged in an approximate right angle with an outlier to the west. They measure between 2.60 and 3.90m in diameter. The anomalies may represent a series of pits or sink holes or could indicate linear features.

F8 This is a weak magnetic anomaly consisting of two curvilinear elements. The northernmost element

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A1

A2

A3

B1

B2

C1

E1

0m 100m 200m

Results of magnetometer area survey

Figure 26

SE2981

Ladybridge Farm

A1

A2

A3

B1

B2

C1

E1

F1 F2 F3 F4 F5 F6 F7 F8 F9 F10 F11 F12 F13 F14 F15 F16 F17 F18 F19 F20 F21 F22 F23 F24 F25 F26 F27 F28 F29 F30 F31

Key

Cropmarks

Weak magnetic anomaly

Strong magnetic anomaly

Geological anomaly

Location of survey areas

0m 100m 200m

Results of magnetometer survey

Figure 27

appears as a tight curvilinear anomaly measuring approximately 9.70m long x 6.20m across and 0.80m in width. Approximately 3.95m to the south a curvilinear anomaly orientated approximately east-west and turning 90 degrees at the east has been identified and measures 20.80m long x 0.80m wide. This anomaly may represent small enclosures.

F9 This is a strong magnetic linear anomaly visible for a length of 98.00m and measuring approximately 1.00m wide. The anomaly is orientated NNE-SSW and may represent a field drain or enclosure.

F10 This is a weak sub-circular anomaly measuring approximately 6.00m in diameter. This anomaly may represent a pit or sink hole.

F11 This is a weak magnetic anomaly consisting of a curvilinear and a possibly rectilinear element. The westernmost element appears as an almost crescentic anomaly measuring approximately 14.00m long x 0.60m wide. Immediately to the east a possibly rectilinear anomaly orientated approximately north-south and turning 90 degrees at the south has been identified and measures 19.50m long before disappearing beyond the eastern limit of A1; the anomaly measures x 0.60m wide. This anomaly may represent small enclosures.

F12 This is a strong linear, possibly rectilinear magnetic anomaly measuring approximately 18.50 long x 1.00m wide. The anomaly is orientated north-south and turns 90 degrees at the north where it disappears beyond the western limit of A1. The anomaly may represent a field enclosure or field drain.

F13 This is a weak magnetic anomaly consisting of a curvilinear and a short linear element. The westernmost element appears as an almost slightly irregular curvilinear anomaly measuring approximately 15.20m long x 0.50m wide. Immediately to the east a possibly short linear anomaly orientated approximately NW-SE has been identified and measures 7.60m long x 0.50m wide. This anomaly may represent small enclosures.

F14 This is a weak sub-circular anomaly measuring approximately 4.80m in diameter. This anomaly may represent a pit or sink hole.

The seven anomalies identified within A2 were allocated F15 to F21. Modern east-west ploughing, with some indication of north-south ploughing, was also clearly defined within the area.

F15 This anomaly is a series of three curvilinear elements. To the north, a curvilinear element has been identified and covers an area measuring 16.80m x 12.0m. To the south, two smaller ‘u’-shaped curvilinear elements have been identified and measure 8.90m x 5.90m and 9.10m x 5.5m respectively. The anomaly may represent small enclosures.

F16 This is a strong amorphous anomaly measuring approximately 9.50m x 5.60m. This anomaly may represent a pit or sink hole.

F17 This is a small strong circular magnetic anomaly measuring approximately 3.60m in diameter. This

anomaly may represent a pit or sink hole.

F18 This anomaly consists of two strong magnetic anomalies orientated east-west parallel to one another. The northern anomaly measures 33.20m x 1.10m; the southern is slightly more irregular but measures 29.80m x 1.00m. The anomaly may represent modern ploughing, field enclosure or field drains.

F19 This anomaly consists of two linear strong magnetic anomalies. The northern anomaly is orientated north-south and measures 13.15m x 1.00m; the southern anomaly is orientated east-west and measures 18.20m x 1.00m. The anomaly may represent modern ploughing and could be part of the same anomaly allocated F18.

F20 This is a strong magnetic circular anomaly measuring approximately 5.20m in diameter. This anomaly may represent a pit or sink hole.

F21 This is a weak sub-circular anomaly measuring approximately 4.30m in diameter. This anomaly may represent a pit or sink hole.

With the exception of modern east-west ploughing, no convincing anomalies were identified within A3.

Area B

Only a single additional anomaly was identified within B1 and was allocated F22. The large, weak positive and negative amorphous areas located in the eastern part of B1 were interpreted as geological variations. Modern east-west ploughing was also clearly visible within the area.

F22 This is a strong magnetic circular anomaly measuring approximately 2.60m in diameter. This anomaly may represent a pit or sink hole.

A total of five anomalies have been identified within B2 and allocated F23 to F27. Modern north-south ploughing was also well defined within the area.

F23 This is a strong magnetic sub-oval anomaly measuring approximately 6.30m x 3.60m. This anomaly may represent a pit or sink hole.

F24 This is a strong magnetic sub-oval anomaly measuring approximately 6.30m x 3.60m. This anomaly may represent a pit or sink hole.

F25 This anomaly consists of three weak magnetic elements, two curvilinear elements and a short linear element. The linear element is orientated approximately north-south and measures 4.20m long x 0.70m wide. To its west a small possibly curvilinear element has been identified and is orientated approximately north-south and curves in a westward direction at the southern end. The anomaly measures 6.90m long x 0.60m wide. To the south of both a broader curvilinear element has been identified and measures approximately 18.00m x 0.60m. The anomaly may represent small enclosures.

F26 The anomaly consists of a group of four weak magnetic anomalies, a cluster of three anomalies to the south and a single irregular but broadly linear anomaly to the north. The clustered curvilinear anomalies consist of two opposing anomalies measuring approximately 11.10m x 0.70m and 9.00m x 0.70m respectively. Within these anomalies, a small curvilinear anomaly is situated and is orientated approximately NNW-SSE and measures 4.00m in length x 0.50m in width. The northernmost anomaly of F26 consists of an irregular but linear anomaly measuring 10.0m x 0.50m wide, orientated approximately NE-SW, and turns 90 degrees at the northeastern end. At the southwestern end the feature disappears beyond the western limit of B2. The anomaly may represent small enclosures.

F27 This is a strong magnetic large sub-circular anomaly measuring approximately 8.90m in diameter. This anomaly may represent a pit or sink hole.

Area C

A total of three features have been identified within C1 and allocated F28 to F30, along with clearly defined north-south modern ploughing.

F28 This is a strong magnetic sub-oval anomaly measuring approximately 6.20m x 4.30m. This anomaly may represent a pit or sink hole.

F29 This is a strong magnetic large sub-circular anomaly measuring approximately 9.50m in diameter. This anomaly may represent a large pit or sink hole.

F30 This is a strong magnetic slightly irregular sub-circular anomaly measuring approximately 5.30m x 3.70m. This anomaly may represent a pit or sink hole.

Area E

A single very weak positive anomaly (F31) was defined within Area E1, along with east-west, and possibly north-south, modern ploughing. F31 may represent an archaeological feature, although regular curvilinear swirls within the data suggests that F31 may simply be the result of local ground conditions or variation in the local geology.

Although the magnetometer area survey clearly defined the results of modern ploughing and several possible sink holes, the results were considered to be fairly disappointing. Many of the possible archaeological features defined by the survey were very weak magnetic anomalies which are often found to result from geological variation, or magnetic variations in the topsoil. Based upon experience gained at Nosterfield Quarry, many archaeological features in the area, particularly boundary features, often contain fairly sterile fills which are unlikely to exhibit any significant magnetic variation in comparison to the surrounding subsoil. With this limitation in mind, it was decided to test the effectiveness of soil resistance on the site, rather than extending the inconclusive magnetometer area survey.

6.3 SOIL RESISTANCE SURVEY RESULTS

6.3.1 Soil Resistance Pilot Study

Due to the relatively inconclusive results of the magnetometer area survey, a pilot soil resistance survey was undertaken. Two areas were targeted, a 60.0m x 90.0m area in Zone A (A1) and a 60.0m x 90.0m area in Zone B (B1). Both of these areas were targeted due to the presence of cropmark features; within Zone A these appeared as linear features and within Zone B the curvilinear features noted prior to the magnetometry were targeted again. The results of the pilot soil resistance survey are presented in Figures 28 and 29 and the interpretation of the results in Figure 30.

A total of seven anomalies were identified within A1, six low resistance and one high resistance. In addition, an area of high resistance and an area of low resistance were identified and interpreted as variation in the underlying subsoil.

F32 This is a circular low resistance anomaly measuring approximately 4.30m in diameter. The anomaly may represent a pit or sink hole.

F33 This is a circular low resistance anomaly measuring approximately 3.20m in diameter situated 9.80m to the south of F32. The anomaly may represent a pit or sink hole.

F34 This is a linear low resistance anomaly orientated NNW-SSE with a western spur orientated approximately east-west. The anomalies are visible for a length of 94.50m and 12.20m respectively. The weaker response on the 1.0m probe spacing results suggests that this anomaly may be fairly shallow. These anomalies may represent field enclosure or field drains.

F35 This is a circular low resistance anomaly measuring 3.50m in diameter. The anomaly may represent a pit or sink hole.

F36 This is a circular low resistance anomaly measuring 2.35m in diameter situated 4.80m to the southwest of F35. The anomaly may represent a pit or sink hole.

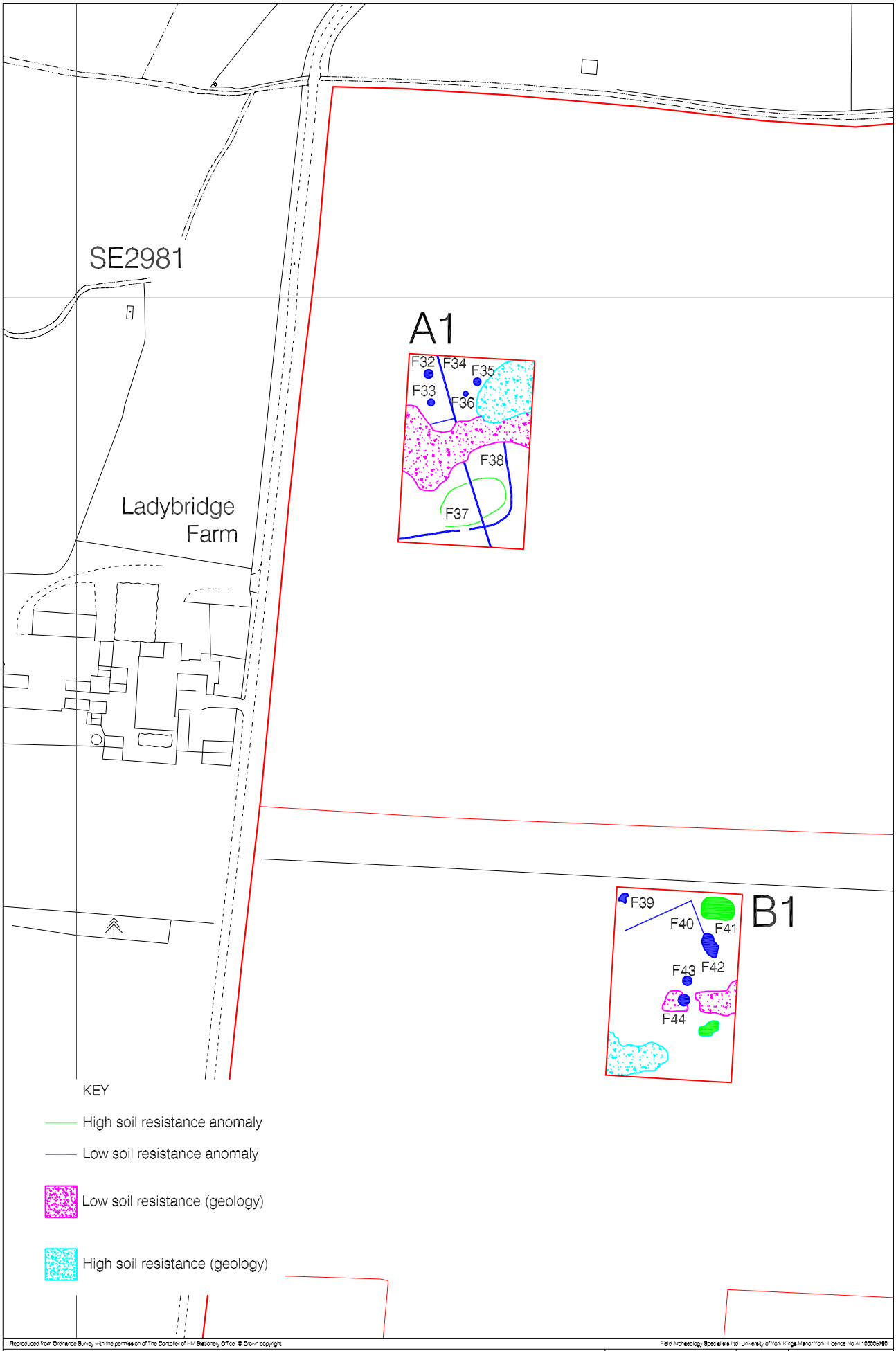
F37 This is a high resistance curvilinear possibly sub-oval anomaly situated in the southern part of A1. The anomaly is orientated approximately east-west and measures *c*.33.0m across x 18.50m in width. The anomaly may represent a small enclosure or geological variation.

F38 This is a high resistance curvilinear anomaly consisting of a north-south length extending for a distance of 34.40m before turning approximately 90 degrees to the west and continuing for a length of 22.0m. The second element consists of an east-west length measuring 30.70m before it disappears beyond the western limit of A1.

A total of six anomalies have been identified within B1 and allocated F39 to F44. In addition, a high resistance anomaly located in the southeastern corner has been interpreted as geological variation. Two areas of low soil

Results of soil resistance survey pilot study (0.5m probe separation) | Scale 1:2500 | Figure 28

Results of soil resistance pilot study (1.0m probe separation) | Scale 1:2500 | Figure 29



Results of soil resistance pilot study | Scale 1:2500 | Figure 30

resistance and one of high resistance were identified and interpreted as variation in the natural subsoil.

F39 This is an amorphous low resistance anomaly measuring approximately 5.20m x 4.0m. The anomaly may represent a pit or sink hole.

F40 This is a possible rectilinear low resistance anomaly orientated NNE-SSW and NNW-SSE measuring 34.80m and 16.50m respectively. The anomaly may represent a field enclosure or field drain.

F41 This is a sub-oval high resistance anomaly measuring approximately 34.80m x 16.5m in diameter. The anomaly may represent local variation in the underlying natural subsoil.

F42 This is an amorphous low resistance anomaly measuring approximately 12.50m x 5.60m. The anomaly may represent a pit, sink hole, or variation in the local geology.

F43 This is a group of three small circular low resistance anomalies orientated NW-SE measuring 1.50m, 2.00m, and 1.75m in diameter. The anomalies may represent pits or sink holes.

F44 This is a group of two large circular low resistance anomalies measuring 4.00m and 5.50m in diameter situated 4.30m to the southwest of F43. The anomalies may represent pits or sink holes.

The soil resistance pilot study detected possible field enclosures, isolated anomalies and other possible features. The results of the pilot study indicated that soil resistance may prove to be a more reliable method of detecting a broader range of sub-surface features. As such, a soil resistance area survey was employed to investigate Zone D, which had become available for study, having not been accessible during the magnetometer area survey.

6.3.2 Soil Resistance Area Survey

A cruciform-shaped sample area was designed to target possible linear features in the zone. The survey area consisted of two linear areas which crossed one another. These measured 30.0m x 330.0m north-south and 30.0m x 300.0m east-west. The results from the 0.5m and the 1.0m probe separation survey results are presented in Figures 31 and 32, and the interpretation of the survey results is presented in Figure 33.

Only two potentially archaeological anomalies were identified within area D1 and were allocated F45 and F46. Several high resistance anomalies have been identified, as well as broader areas of high and low resistance throughout D1; all of these areas are considered to relate to variation in the local geology.

F45 This is a circular low resistance anomaly measuring approximately 7.50m in diameter and disappears beyond the northern limit of D1. The anomaly may represent a pit or sink hole.

F46 This is a possibly linear 'Y'-shaped low resistance anomaly visible for the width of area D1 at this point (30.0m), orientated approximately east-west and measures no more than 4.20m wide. The linear anomaly splays towards the east to form two spurs. The feature may represent a field boundary or field drains, or possibly geological variation. The improved definition of this feature on the 1.0m probe

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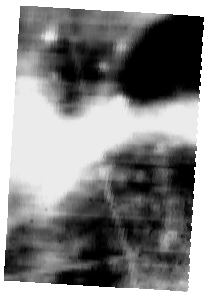
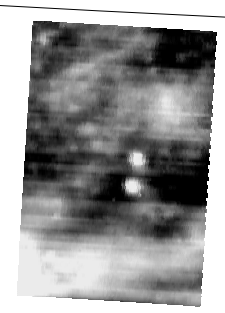
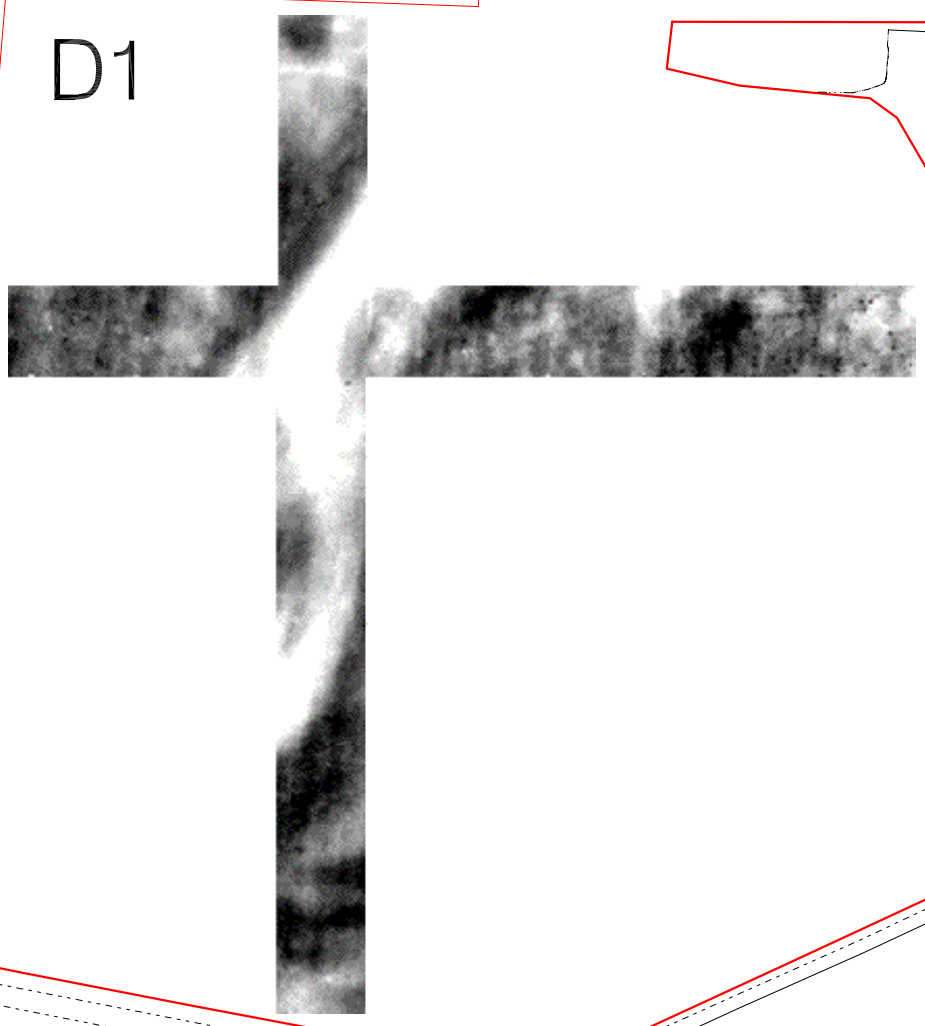
A1



B1



D1



Results of soil resistance area survey (0.5m probe separation)

Scale 1:2500

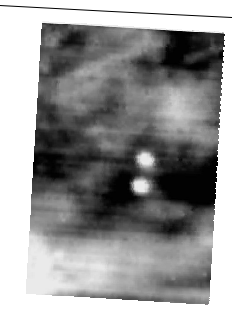
Figure 31

SE2981

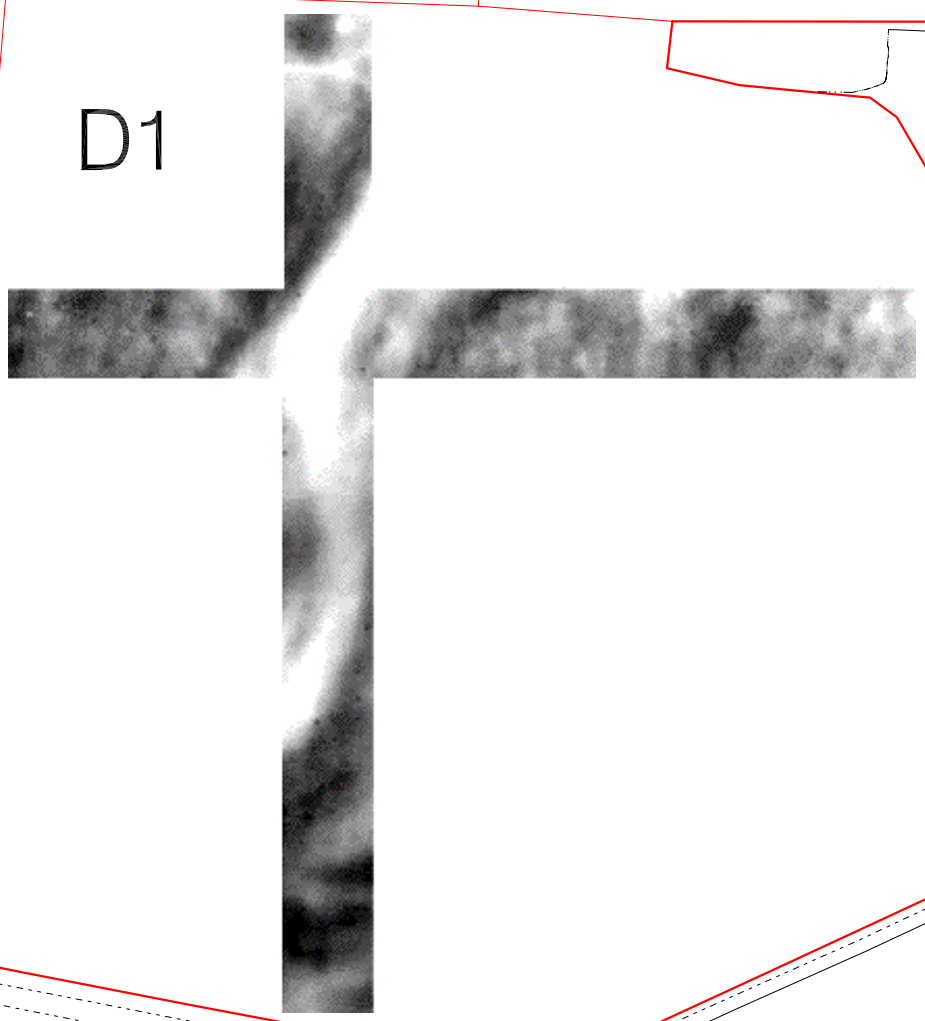
A1

Ladybridge
Farm

B1



D1



Results of soil resistance area survey (1.0m probe separation)

Scale 1:2500

Figure 32

SE2981

Ladybridge Farm

A1

F32 F34 F35 F33 F36 F38 F37

B1

F39 F40 F41 F43 F42 F44

D1

F45 F46

KEY

High soil resistance anomaly

Low soil resistance anomaly

Low soil resistance (geology)

High soil resistance (geology)

Interpretation of soil resistance survey

Scale 1:2500

Figure 33

spacing data set suggests that this anomaly is not superficial.

The soil resistance area survey did not detect any anomalies which could be interpreted as boundary features. The results of the survey were dominated by large low and high soil resistance anomalies considered to represent variation in the underlying sand and gravel subsoil. As was found with the magnetometer area survey, the soil resistance survey identified few potential features of archaeological origin. The relatively poor results of the geophysical surveys either indicated that few archaeological features were present on the site, or that the two techniques applied do not provide a reliable means of remotely mapping and characterising a full range of archaeological feature types on the site.