LINCOLNSHIRE FENLAND LIDAR
(LFLE12)

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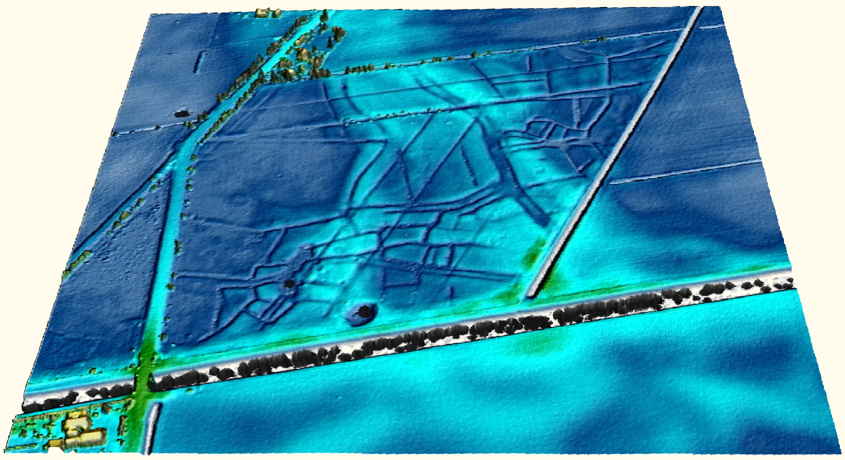

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Lincolnshire Fenland Lidar

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1 Summary

The Environment Agency has undertaken extensive Lidar survey within the Lincolnshire Fenland. Previous work by APS has demonstrated the potential of this data for understanding the palaeo-environment and archaeology of the Lincolnshire Fenland when processed to enhance the very small topographic variations within these low-lying landscapes.

A previous APS project funded by English Heritage, brought together various earlier studies and expanded the areas thus treated to encompass all of the then available data for the Lincolnshire fenland. Additional flying by EA has since filled a large gap in the dataset. The current project has now added this additional data covering some 245km^2. The final processed dataset encompasses the entire area surveyed to date by the Environment Agency within the Lincolnshire Fenland, covering some 2250km^2 and comprising in excess of 750 million data points.

The project has been successful in its principal aim of producing a processed dataset which will be more readily accessible through the HER and provide a tool for planning archaeologists both at county and district level.

The processed data-set will contribute widely to the study of the archaeology of the Fenland, but in many ways the greatest advance here is in illuminating the landscape context of sites and monuments where no other source of information can provide such detail over such a large area.

2 Introduction

2.1 Description of the Project

2.1.1 Lidar survey has significant potential for landscape study in the Lincolnshire Fenland. The Environment Agency Lidar dataset for the area represents an enormous potential resource not easily available to researchers without specialist knowledge of processing. The majority of the Lincolnshire Fenland has already been processed in earlier projects (Malone 2009). The aim of this project is to fill a large gap subsequently surveyed in the southern Lincolnshire Fenland (broadly a triangle from Great Postland, up to Weston and southeast to Tydd St Mary) brought up to the same standard using the same methodology. The processed data has been output as georeferenced imagery which will allow wider and easier access to the data and its understanding and interpretation. The chief archaeological aim of the Project is to enable accurate predictive modelling for the locations of sites partially or wholly buried under flood silts of post Roman date and to record an environmental and landscape context for all sites in the Fenland.

2.2 Background

2.2.1 Detailed descriptions of Airborne Laser Altimetry, more often referred to as Lidar (for Light Detection and Ranging) and its applications in archaeology are available in existing studies (Bewley *et al*. 2005; Crutchley and Crow 2009). Lidar uses the properties of coherent laser light, coupled with precise spatial positioning (through the use of a Differential GPS) to produce horizontally and vertically accurate elevation measurements. This data has considerable potential for archaeological research in terms of mapping archaeological sites where features survive as upstanding earthworks, for identifying depressions where organic sediments may be preserved and more generally for providing landscape context in areas of very low relief where existing topographic mapping lacks detail. Within the marginal landscapes of the Lincolnshire fenland this topographic context is crucial to the understanding of past human use of the landscape and Lidar survey provides unprecedented detail of this subtle topography.

1.2.2 The Environment Agency (EA) has undertaken extensive areas of Lidar survey in coastal zones and river valleys for the purposes of flood risk management. Heritage Trust of Lincolnshire has established expertise in working with EA data which has demonstrated the potential for the use of this data in mapping the landscape of the Fens (Malone 2009). The gradual expansion of data availability and its incorporation into the fenland mapping is illustrated in Figure 1.

2.3 Business Case

2.3.1 Lincolnshire and the Fenland region have a remarkable and much-studied archaeological and environmental background. To the data assembled by early researchers such as Phillips (1970) much was added as part of the English Heritage funded Fenland Project in the 1980s and 1990s (Hall and Coles 1994). The Fenland Project demonstrated the scope for and advantage of combining environmental and archaeological data by placing the evidence for the numerous sites, particularly of the Roman period onwards, onto maps of the reconstructed contemporary environment. The environmental maps showed the contemporary and extinct creeks which were plotted during fieldwalking and hand drawn in the volumes. These creeks, also known as roddons, were key to understanding the development of the Fenland as they represent slightly elevated locations which attracted all the early and subsequent settlement. It is these minor, but hugely significant, changes in elevation which Lidar can pick out with unprecedented detail and accuracy.

2.3.2 Understanding of the early settlement and industry (particularly saltmaking) of the Fenland region was one of the achievements of the Fenland Survey but this could only be undertaken with confidence in the west of the Fenland area. To the east, the creeks/roddons broadened and flattened out and the general landscape was covered by subsequent shallow silting as a result of sea flooding. This broadening and flattening prevented the plotting of the roddons in that area by ground survey. However, manipulation of the Lidar data by Dr Steve Malone for the Witham Valley and the Northern part of the Lincolnshire Fens (Malone 2007; 2008) has demonstrated conclusively that the Lidar picks out the route of the large roddons much further seaward than could be undertaken by ground survey. Knowing from the previously studied western part of the Fenland that the sites are concentrated on the roddons this Lidar work on the northern fens has shown that this pattern continues to be visible within the silted eastern part of the Fenland. This previously unknown fact now enables predictive modelling of the locations of the early sites further seaward than considered possible previously.

2.3.3 Survey products from previous project stages have been provided to the Lincolnshire HER. This project sets out to add to this existing data that for the remaining, southern, part of the Lincolnshire Fenland enabling curatorial access to the data for the entire Fenland region to the benefit of all curators, contractors, consultants and all HER users.

2.4 Research Aims and Objectives

2.4.1 While Lidar data is now more readily available, this is not easily useable to researchers without specialist GIS skills. The Principal Aim of this project (the Primary Driver, see Appendix 1: Project Design) was to produce a processed dataset which can be more readily accessed through the HER and as a tool for planning archaeologists both at county and district level.

2.4.2 Studies of the Fenland landscape benefit particularly from a wide area perspective. The existing format of the Lidar data, based on 1km or 2km squares, limits the possibility of taking this wider perspective, thereby impeding understanding. In addition to a mosaic of 5km squares, the project has also produced larger scale seamless georeferenced imagery allowing easy comparison across the Lincolnshire fenland as a whole.

2.4.5 The principal target was to elucidate the pattern of roddons, extinct watercourses, rather than small scale topographic features, the interpretation of which would require greater input. This pattern is largely self-evident (the colour-scales have been selected expressly to demonstrate this) especially when viewed on the larger scale. However, neither images nor continuous raster grid surfaces have the same GIS utility as polygons and ultimately digitising of features or definition of landscape zones would clearly be appropriate.

3 Methods

3.1 Environment Agency Lidar data is provided in ESRI ASCII grid format. Each .asc file covers an area 2km by 2km and each tile between one million and four million data points (at 2m and 1m resolution respectively). Three different data sets are available for each tile:

i) the unfiltered elevation data;
ii) filtered data, with vegetation and tall buildings removed and ground levels at these points interpolated
iii) points altered during the filtering process.

However, the filtering processes are unsuited to the sort of fine archaeological or topographical detail of relevance here (Challis 2004, 25) and all processing has been undertaken on the unfiltered Digital Surface Model dataset. The vertical accuracy of the data is quoted as +/-6cm to +/-15cm. Relative (point to point) accuracy, more relevant for detailed archaeological mapping, is generally 5-7cm or better (Jones *et al*. 2007, 1576)

3.2 EA Lidar data tiles were read directly into MapInfo 10.0 to create a continuous raster grid surface model. This is the preferred technique for preserving data integrity, and is relatively fast. For presentational purposes an alternative technique involving Inverse Distance Weighting has been found effective. This introduces some smoothing, reducing noise and visible survey-swathe boundaries in the data, but is more time-consuming and is best suited to smaller-area, detailed plans or 3D-perspective views. The large scale plan of the Shell Bridge Romano-British settlement (below 4.1.3 and Fig. 12) was produced using this method, interpolating a 0.5m grid from the 1m-centre data.

3.3 Parameters for processing and presentation were trialled with EA survey data as part of previous projects. The colour ramp was designed to produce the best definition of the roddons and extinct creeks within the Witham Valley and Fenland basin between 0m and 3m above Ordnance Datum. Because of the way the colour shades merge and the way the intervening shades appear to the eye, the steps in the chosen colour sequence are not even (0.00m-1.50m-2.50m-3.00m-5.00m) but the overall effect is close to a more even interval. Figure 3, showing the colour scale overlain with 1m contours, demonstrates the effect. The most marked change in the white-dark blue transition occurs at 1.00m OD; cyan and green shades come in slightly before the 2.00m and 3.00m contours; yellow is most noticeable from about 4.00m with a stronger line at 5.00m. A merging colour scale was selected as being most expressive in depicting landforms and earthwork features, but this does lend some subjectivity to the perception of contour intervals. The ‘upland’ was not part of the specific focus of this project and is represented with a single brown shade, most intense at 10.00m fading to a white above. Negative values are not separately represented but form part of the white scale (this is of significance within the current survey area only on the margins of Tydd St Giles Fen on the Lincolnshire/Cambridgeshire border where large areas fall below 0m O.D.). With Mean High Water along the Wash coast falling at *c*. 3m O.D., the chosen colour ramp also provides a good representation of the coastline and salt marshes. In the context of rising sea-levels and coastal change, it is worth noting that all of the areas coloured blue in the accompanying plots are below the *current* Mean High Water level.

3.4 Working with this pre-defined colour scale each ESRI ASCII file was opened and thematic mapping properties for the raster grid merged with the colour scale gradually building up a mosaic out of the 2km by 2km squares. The size of the mosaic thus produced is limited practically by the availability of computer memory and processing power. Even as processed imagery this is an issue for end users. However, the full resolution dataset will be most useful on a site by site basis and best explored over a range of a few kilometres. Consequently, processing proceeded on the basis of 10km grid squares with georeferenced imagery output as 5km x 5km blocks.

3.5 Artifical 'sunlight' has been used to emphasise subtle earthwork features. As a standard this has been applied as a low light illuminating features from the north-west. While not preserving an exact correspondence of point value to colour shade, such 'hill'-shaded imagery provides the clearest representation of the micro-topography of the survey area. This technique can prove ineffective, however, where features are aligned on or very close to the axis of illumination, some features potentially becoming virtually invisible. As a consequence best practice is to use illumination from more than one direction in order to get the most information out of the plots (Crutchley and Crow 2010, 23-4), or to use alternative analytical techniques such as principal component analysis (Devereaux *et al*. 2008) or sky-view factor visualisation (Kokalj *et al*. 2011) or a combination of these (Bennett *et al*. 2012). Comparison of different suites of techniques in different terrains has concluded that in low relief landscapes the combination of well designed colour scales and hillshading still remains useful but that Solar Insolation Models provide the best overall visibility of archaeological earthworks of any scale and are virtually unaffected by feature orientation (Challis *et al.* 2011, 287). For the mapping of the large scale sinuous roddons within the fenland, which was the principal aim of the project, the combination of colour scale and relief shading has provided excellent results and is continued here. However, it is recognised as a potential limitation on the utility of the processed dataset and a second set of imagery, lit from the northeast, was consequently provided for the 'upland' areas on the western margin of the survey area during the first phase of the project. Alternative visualisation techniques are considered further in Appendix 3. Large scale plots of the Romano-British earthwork site at Shell Bridge (see below 4.1.3 and Fig. 12) have also been produced with varying illumination here to demonstrate this effect within the lower-lying areas of the fenland, but visible differences are minor.

3.6 The mosaic blocks have been output as GeoTIFF files. For consistency with previous survey products, a resolution of 2500 x 2500 pixels has been chosen. For 2m data this preserves the representation of each Lidar survey data point as a single pixel shaded according to the pre-defined colour ramp (but modified by the application of artificial sunlight). For 1m datasets this represents a slight loss of sharpness, but the greater detail can be discerned nonetheless and this does not affect representation of the broader landscape features (Figure 4). These georeferenced image files are platform independent and can be incorporated directly into most standard GIS systems including the Lincolnshire HER's ExeGesis system. A full file listing of the processed imagery from both phases of the project appears as Appendix 2. A key to the layout of the processed survey blocks is provided in Figure 2.

3.7 Further processing of the image data was undertaken within Adobe Photoshop to produce a seamless jpg image of the whole survey area at resolutions suitable for printing to A0 and A1 formats (and smaller where required), in order to provide further options for dissemination or display of the data. ECW compressed format imagery is also provided. Posters in A0 and A1 format have also been designed giving detail of the project, its sponsors and results to aid in such dissemination (Fig. 18).

3.8 EA lidar survey has still not quite filled all of the gaps in this final block of the Lincolnshire fenland. Parts of Crowland parish, and a larger area south of Moulton and Weston are still missing from the completed dataset. In producing overall plans these gaps have been filled using NEXTMap 5m-centred survey data. Detail is insufficient for use at any smaller scale than 1:50000 (see e.g. Fig. 5) but although lacking the detail of the closer-interval lidar survey (and requiring adjustments of between 1-2m in the vertical scales to match with the surrounding lidar) these do allow certain features to be traced which would not otherwise be recorded.

4 Results

4.1 The primary product of the project is the additional processed imagery data-set to be lodged with the Lincolnshire HER (see Appendix 1). This comprises the entire area surveyed to date by the Environment Agency within the Lincolnshire Fenland, utilising some 750 million data points and covering an area of some 2250km^2 (see Fig. 15). The full potential of this data-set will take much further exploration. A number of themes were considered within the earlier report. Some notable aspects of the additional dataset are considered further below.

4.1.1 Crowland

The Lidar survey plot for Crowland parish and environs is shown in Figure 5 alongside the plan of roddons produced during the Fenland Project (Hayes and Lane 1992, 196 fig.118). Two gaps exist in the lidar coverage for this area. NextMap data filled areas are outlined in grey.

Overall the lidar plot is rather less complex and easier to understand, though this may be missing subtler features evident as changes in soil colour, whether on the ground or from the air, but not showing significant differences in height.

However, certain aspects do become much clearer given the ability of the lidar surveys to distinguish between different levels of silting within the water courses. The Fenland Project mapping noted the ‘rare for Lincolnshire’ occurrence of one roddon cutting another near to Green Bank, southeast of Crowland (Hayes and Lane 1992, 197). This is much clearer within the lidar survey. The earlier roddon can be seen (in dark blue) continuing much further eastwards, the earlier and later channels taking much the same course (as initially surmised). Silting within the later channel has attained a greater height and these later silts can be clearly seen (in paler blue) running east and north to join a larger estuarine channel toward the north and east of the parish which appears to have had an input of yet later, and higher, silting (stronger cyan shades).

Comparison of the two surveys again demonstrates the difficulty in identifying broader estuarine channels from ground survey alone, and especially as these move seaward where soil differences are no longer evident at the surface. The large estuarine roddon at the northeastern parish boundary has not been recognised as such. Its western edge has generally been identified but differential deposition within the wider roddon has proved deceptive and hindered understanding of the drainage patterns here. It can now be seen that the higher silts of Little Postland form part of a wide roddon up to 1.25km in width running away northwards from a junction of channels at this corner of the parish. Roman settlement within the parish sits largely upon the high silts of this roddon and its tributaries.

4.1.2 Roman settlement in the Fens

The intimate connection of Roman settlement in the fens with the micro-topography of the roddon systems has been long demonstrated (Hallam 1970). However, mapping of these natural features was not attempted for the maps presented in The Fenland in Roman Times (Phillips 1970). In contrast, the methodology of The Fenland Project specifically sought to map these features and place the distribution of sites in this landscape context (Hall 1987; Hayes and Lane 1992, 7-8). The ground-based survey methodology (supplemented by air-photographic plotting in Cambridgeshire), although time consuming, produced very accurate maps of the roddon systems only now superseded by the Lidar plots (Malone 2009). However, little distinction could be made for differing levels of silting within the roddons, which can show stratigraphic relationships between drainage systems of different dates (see above Crowland: Fig. 5 and further below); nor could the systems be followed on the ground as far seaward where they become broadened and flattened and where later silt overburden masked any surface soil differences.

The Lidar survey plots are georeferenced allowing other datasets to be easily superimposed. A number of plots are appended showing cropmark plots from The Fenland in Roman Times (Phillips 1970: still the best available in this area) and demonstrating again the added value of the topographic context (Figs 6, 8, 17).

FIRT Map 9 (Fig. 6). This shows the wide estuarine silts of Little Postland and silted channels draining westwards to join this. The Roman settlement sites and densest cropmark activity can be clearly seen to match the roddon silts. The modern settlements of Whaplode Drove, Holbeach Drove and Gedney Hill sit on these same roddons, generally on the southern arm which is slightly higher. In the southeast of the area, within Sutton St Edmund parish, a silted linear drain/canal is very evident. Although this cuts across the enclosure pattern of the post-medieval drained landscape here, its initial alignment fits in with the drainage pattern immediately to the east within Leverington and Gorefield, Cambridgeshire (although not aligning precisely on any extant feature and possibly turning southeast at its eastern end: see Fig. 7). If not part of some early modern attempt to extend drainage into this area (which might be subject to documentary confirmation), this may represent something much earlier. The western end is mapped by FIRT although the cropmark pattern is sketchy at this point and it is not clear if or how this fits in.

FIRT Maps 5-7 (Figs 8, 9). This area lies north of Map 6. The cropmark pattern is rather less coherent, especially moving northwards into areas where later marine silts mask features. However, the settlement sites can still be seen to favour locations on the roddons and sinuous droves follow their alignments in many cases. Of particular interest is the Scheduled Romano-British settlement south of Shell Bridge in Holbeach parish (LI168; see further below and Fig. 12) which appears to link to a series of very straight, and apparently artificial, watercourses. This is better seen on Figure 9 without the map overlay which allows the colour distinctions to be seen more clearly. Running northwest for about 500m from the Shell Bridge site a silted watercourse some 30m in width runs very straight to a junction with two others. One runs southwest for at least 800m (continuing more faintly for perhaps a further 700m); the other runs north straight for 600 or 700m, widening to 30 or 40m, before joining a sinuous channel running eastwards and generally northwards apparently falling into the Nene estuary somewhere in the vicinity of Long Sutton. This channel cuts across the earlier drainage pattern here and is filled with higher silts. It appears, tentatively at least, to fit within the pattern of cropmarks seen on Figure 8 (parts of it have in fact been mapped, though more sinuously in places than the surviving landform might suggest) and might represent a contemporary active watercourse. Nothing much clearly cuts across it, at least, except inevitably at its southernmost end where it would be most useful to find a clear connection: here the drove mapped running north from the Shell Bridge site appears to cut across the end of the straight stretch making it difficult to see how the two might have related in practice.

The input of silt filling the Shell Bridge ‘river’ also appear to fill a tributary running south from Gedney Fen but this area is devoid of cropmarks so providing little further confirmation. It is unclear how far the level of the silt within a roddon can be taken as a clue to its age or relationship to other features filled to a similar height. Deposition of marine silts across the fenland was a diachronous process (Waller 1994, 337-8) and although the levels of silting might bear some relationship to changing sea levels over time (if not just entirely to one-off extreme events), it is unclear how much this has been affected by subsequent shrinkage, or how much this might differ across the wider fenland. However, it is possible to infer a sequence where channels cut across one another and, in local areas at least, to propose that connecting channels receiving an input of silt to the same level were probably open/active at the same time.

4.1.3 Earthwork sites

Surviving earthwork sites within the fen are expressed well in the survey plots. A number of such are depicted in Figures 10-13. At Martin's Farm, Crowland earthworks survive in pasture just to the southwest of a Scheduled settlement site (LI224). These can be seen to match well with features plotted on the Fenland in Roman Times mapping (Fig. 10), although apparently only representing field boundaries on the outskirts of the settlement area to the north and west. It is notable again that even on such ploughed out sites the Lidar data can show survival of hollows along the former trackways (e.g. just outside the southeastern boundary of the Scheduled area). This is also the case at The Limes, Gedney Hill (Fig. 11) where a small survival of earthwork boundaries fits in well with the wider mapped pattern. At Shell Bridge, Holbeach, earthwork survival is more extensive and the lidar plot produces very good results at quite large scale (Fig. 12: two different illumination directions are reproduced). Similarly, the surviving earthworks of the settlement near Lambert Drain, Fleet, LI285, are very well expressed (Fig. 13).

4.1.4 Medieval and post-medieval drainage and reclamation

The boundary between Lincolnshire and Cambridgeshire from the Welland to the Nene largely follows the Old South Eau, Lady Nunn's Old Eau and the Shire Drain, except where straightened to follow the 17th century New South Eau. Along most of its course this boundary is not a conspicuous feature. However, in Sutton St James and Tydd St Mary, as it approaches its seaward end, a broader band of silt is evident along the line of the Shire Drain and a curious pattern of regular broad silted channels emerges from its line (Fig. 14). These presumably indicate some episode of marine flooding but the nature of these open channels remains less clear. Across much of the area from Sutton St James to Tydd St Mary the normal sinuous dendritic pattern of drainage seems to have been interrupted, altered or realigned. There is record of enclosure of marsh in Tydd St Mary Parish as early as 1632 (Wheeler 1896, 101) which may account for some early alterations to the drainage patterns here. A pattern of much narrower, but still very rectilinear, field divisions can be seen across much of this area, now amalgamated into larger land parcels. In the southwest corner of Figure 14, just within Sutton St Edmund parish, these take the form of wide ridges 25-30m across, identifiable perhaps as dylings. Such generally take the form of parallel field strips separated by narrow ditches and are often presumed to be medieval in date. Here they conform to the very regular enclosure field layout.

5 Conclusions and Recommendations

The project has been successful in its principal aim of producing a processed dataset which will be more readily accessible through the HER and provide a tool for planning archaeologists both at county and district level. Data has already been transferred to the Lincolnshire HER and to the Heritage Trust of Lincolnshire Planning Team and meetings held with representatives of both bodies in order to demonstrate how the data can be used in conjunction with their GIS systems.

As suggested in the previous report (Malone 2009) the full potential of the data-set will take much further exploration. The themes explored in Section 4 build on those previously highlighted and demonstrate its potential to contribute widely to the study of the archaeology of the Fenland. Each would be worthy of further more systematic study.

The pattern of dendritic channels/roddons is very clear in the processed Lidar data set. Although polygons have greater utility for many GIS applications, in practice the fine detail is almost impossible to digitise. However, there are clear stratigraphic relationships between different drainage regimes and the level of silting within the roddons has potential for elucidating the chronology (accepting that the levels now pertaining may not be the exact levels originally existing). Mapping of the larger roddons, roddon systems and final active channels as GIS polygons tagged with levels (average levels / range of levels) would enhance the data-set.

Undoubtedly, there is much more to be gleaned from detailed study of the Lidar plots, but such study has been made possible by the provision of a uniform processed data-set, now encompassing all of the lidar data currently available for the Lincolnshire fenland. In many ways the greatest advance here is in illuminating the landscape context of sites and monuments in the Fenland where no other source of information can provide such detail over such a large area.

6 Acknowledgements

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8 Abbreviations

APS	Archaeological Project Services
EA	Environment Agency
EH	English Heritage
HER	Historic Environment Record
NMP	National Mapping Program

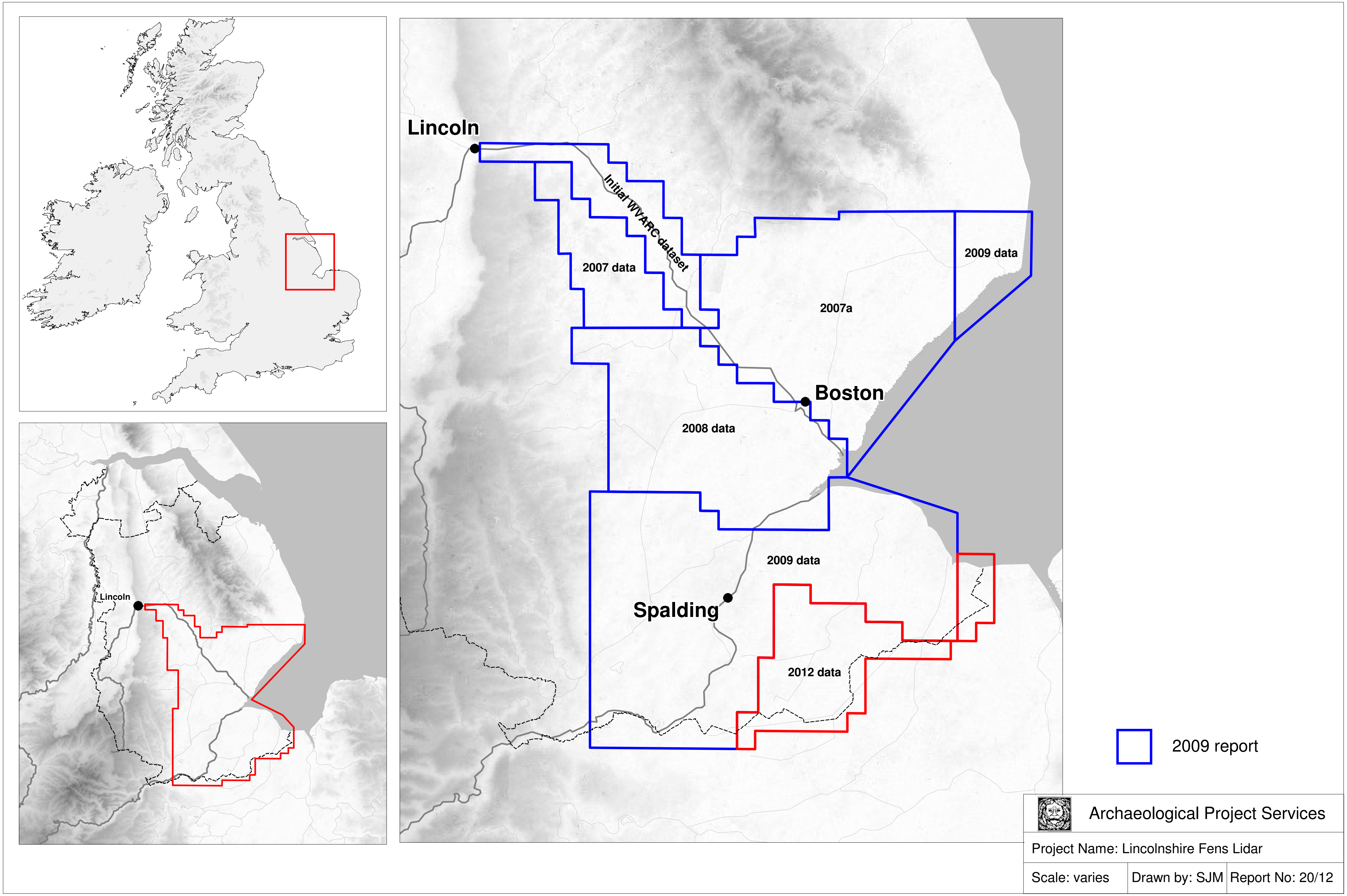


Figure 1 Location of survey area

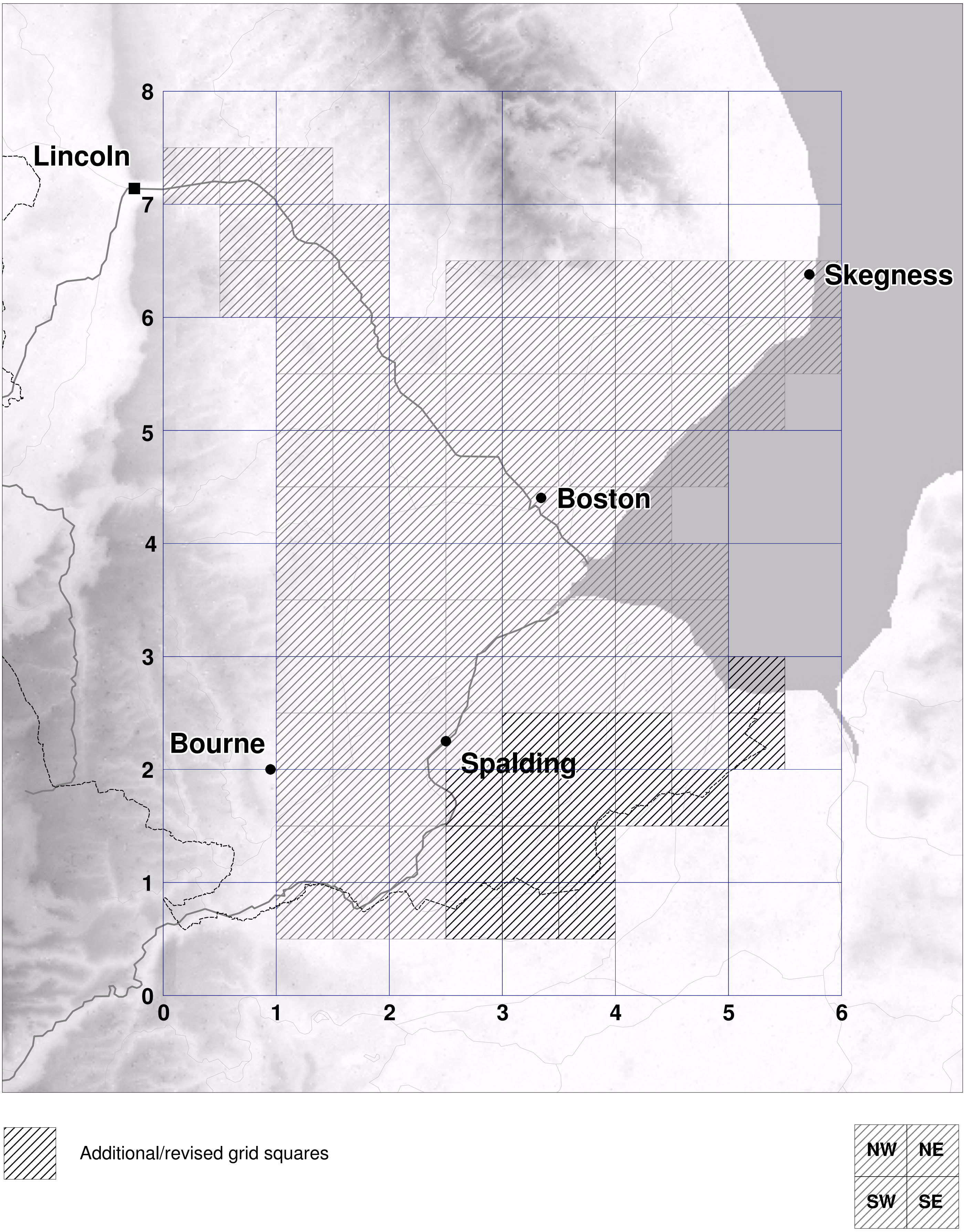


Figure 2 Key to Lidar survey areas and Geotiff imagery

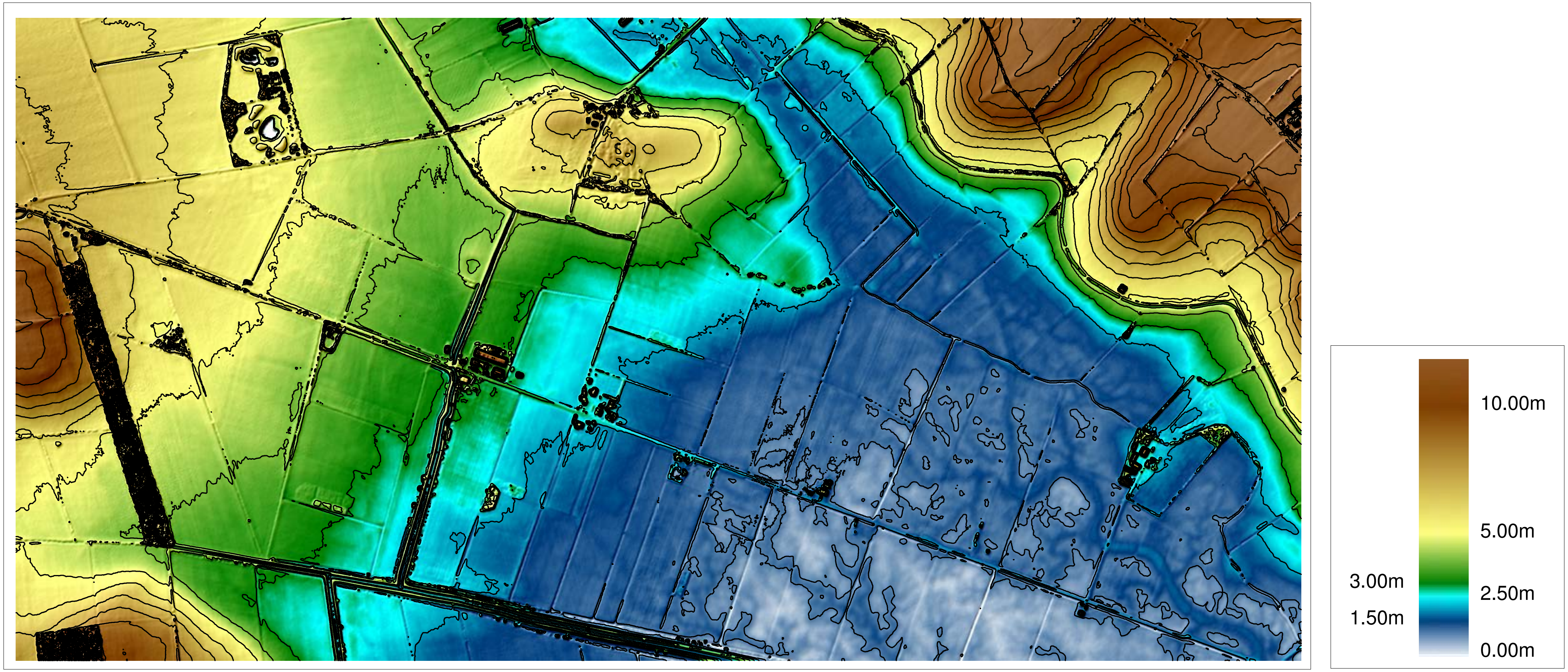
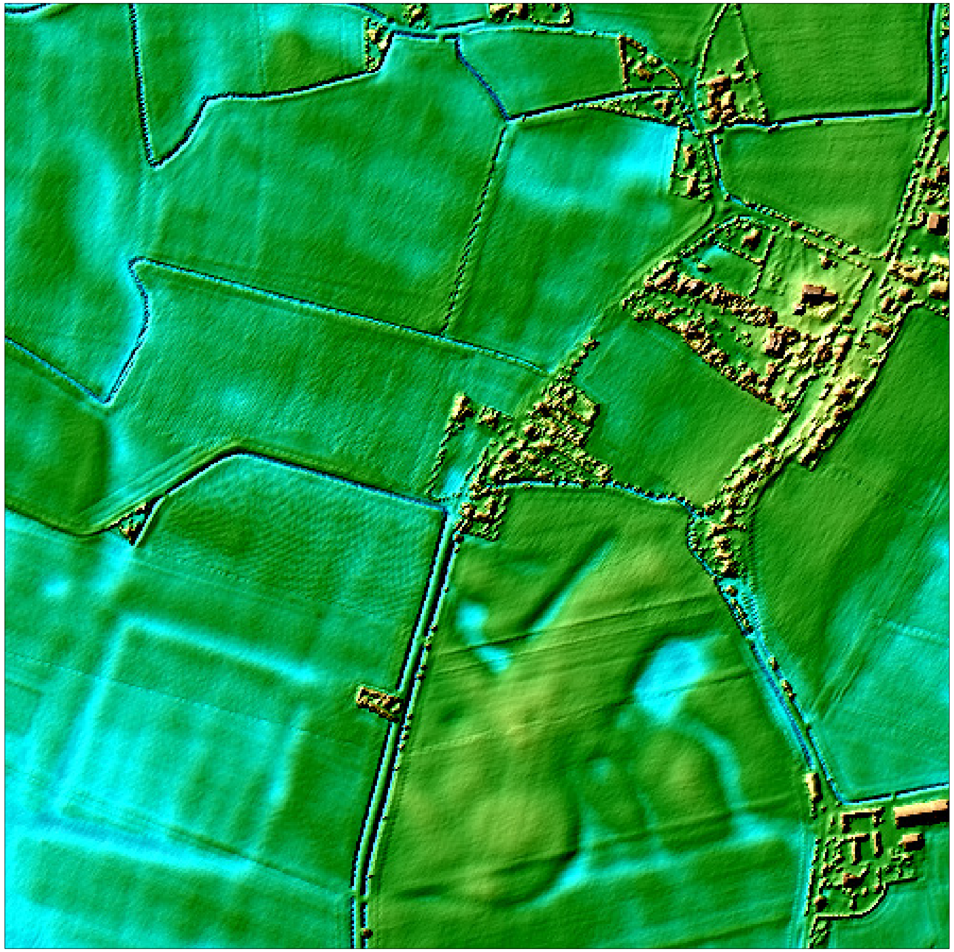
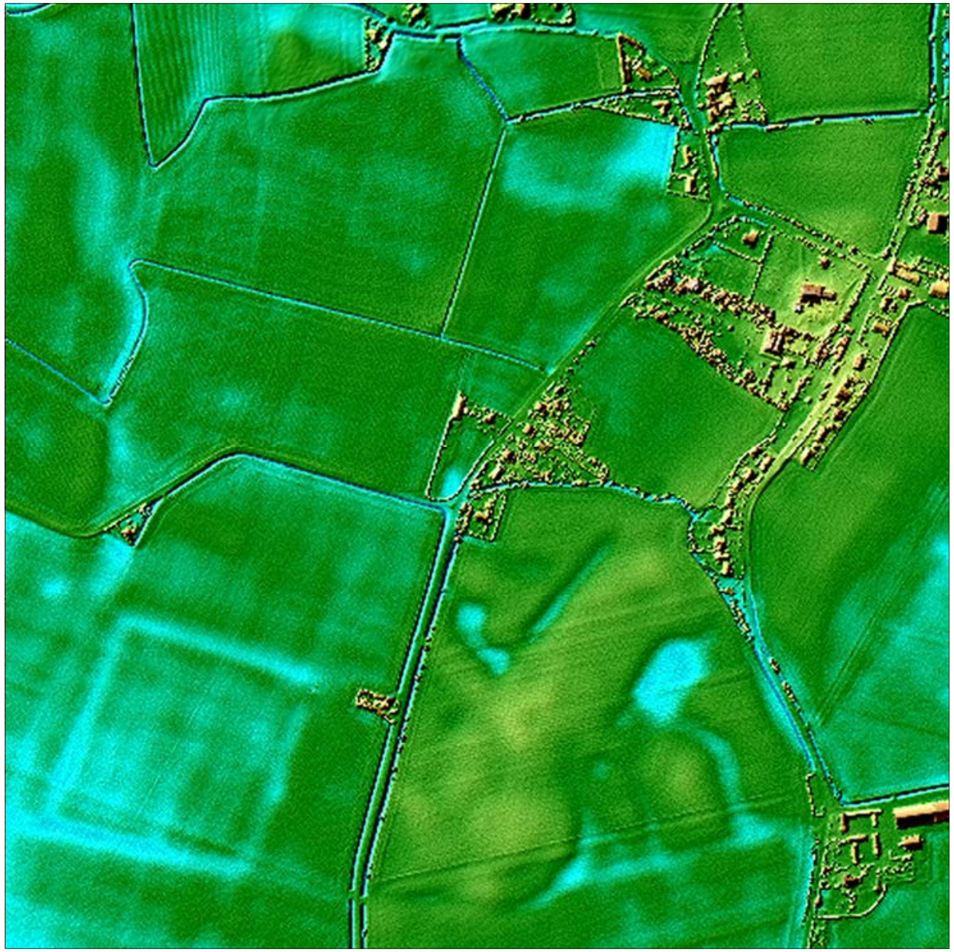


Figure 3 Catley Priory and Digby Fen showing relationship of colour ramp to 1m-interval contours



2m dataset



1m dataset

Figure 4 Comparison of GeoTIFF imagery derived from 2m- and 1m-centre data (Fleet 1:8000)

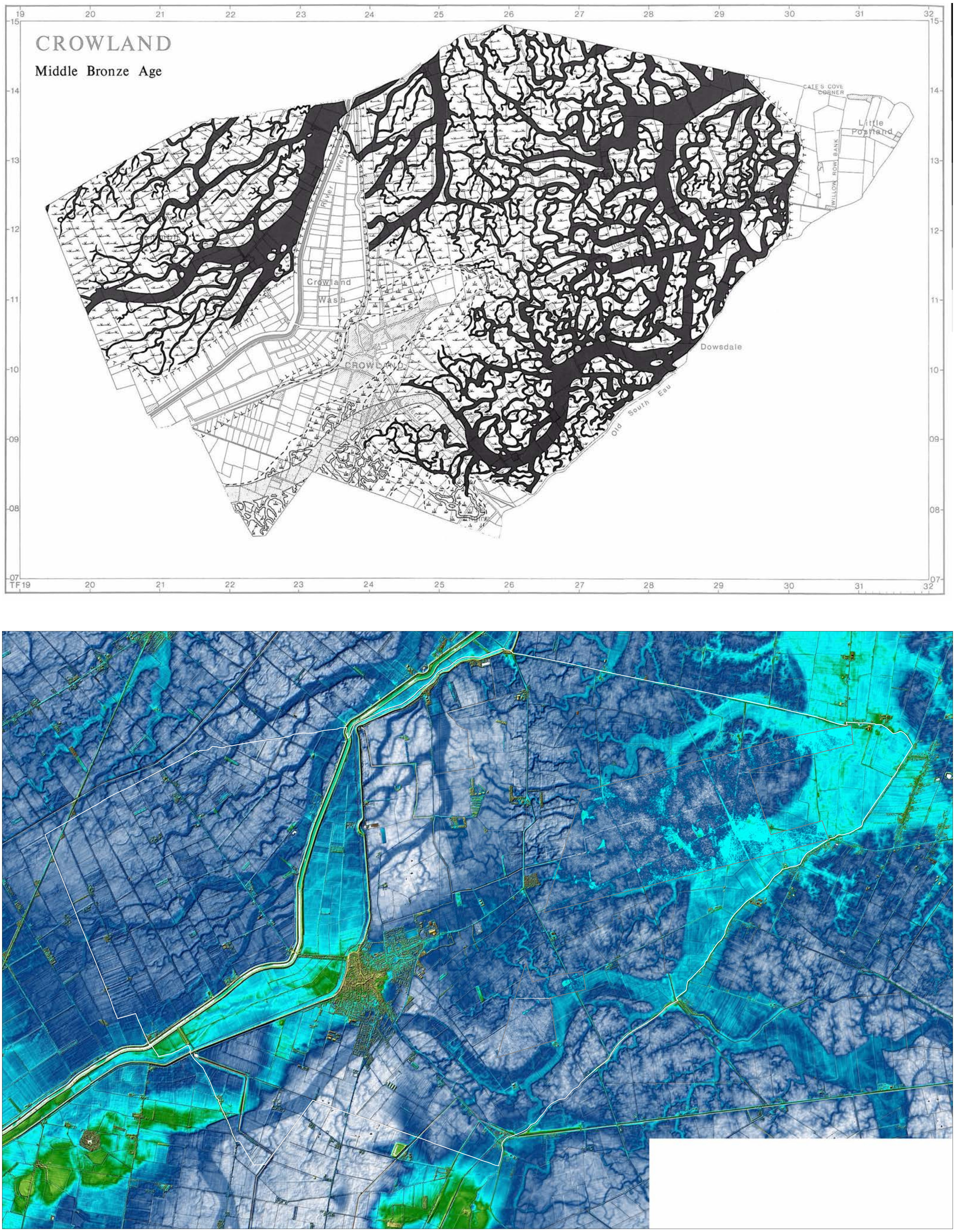


Figure 5 Comparison between Fenland Survey mapping of roddons and Lidar plot (Crowland 1:50000)

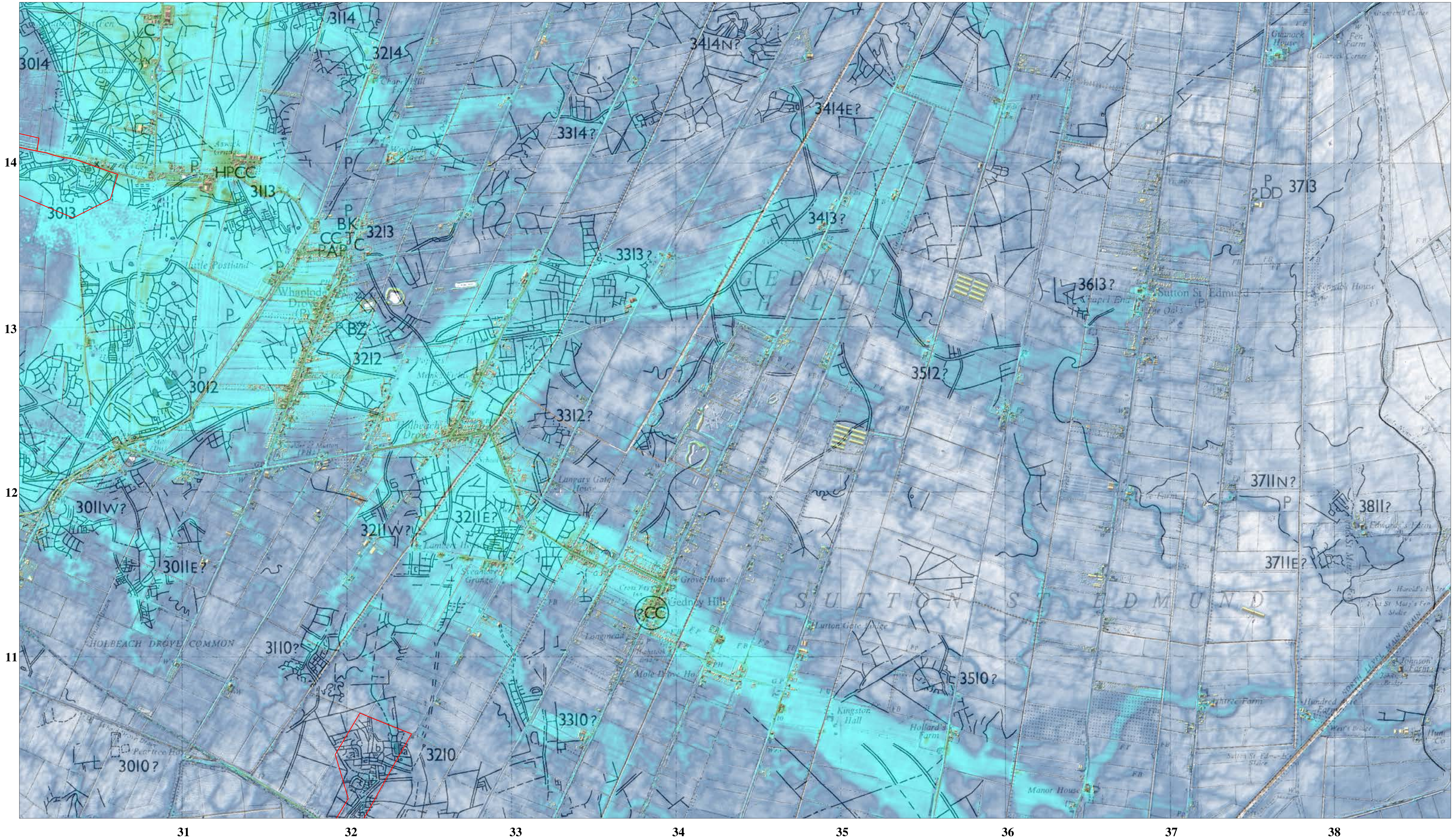


Figure 6 Fenland in Roman Times Map 9 overlaid on lidar survey (Scheduled Monuments outlined in red)

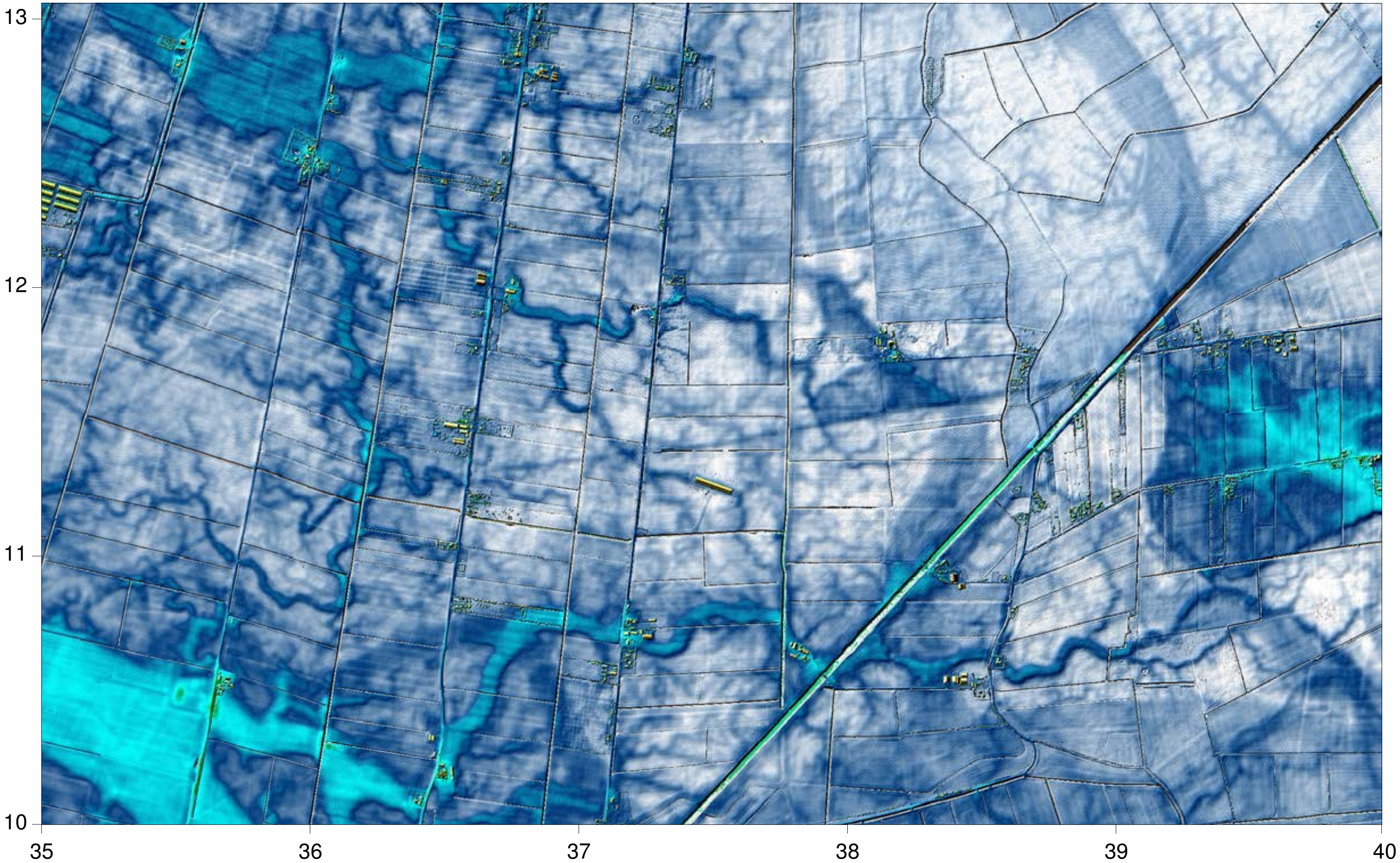


Figure 7 Sutton St Edmund linear drainage/canal feature 1:25000

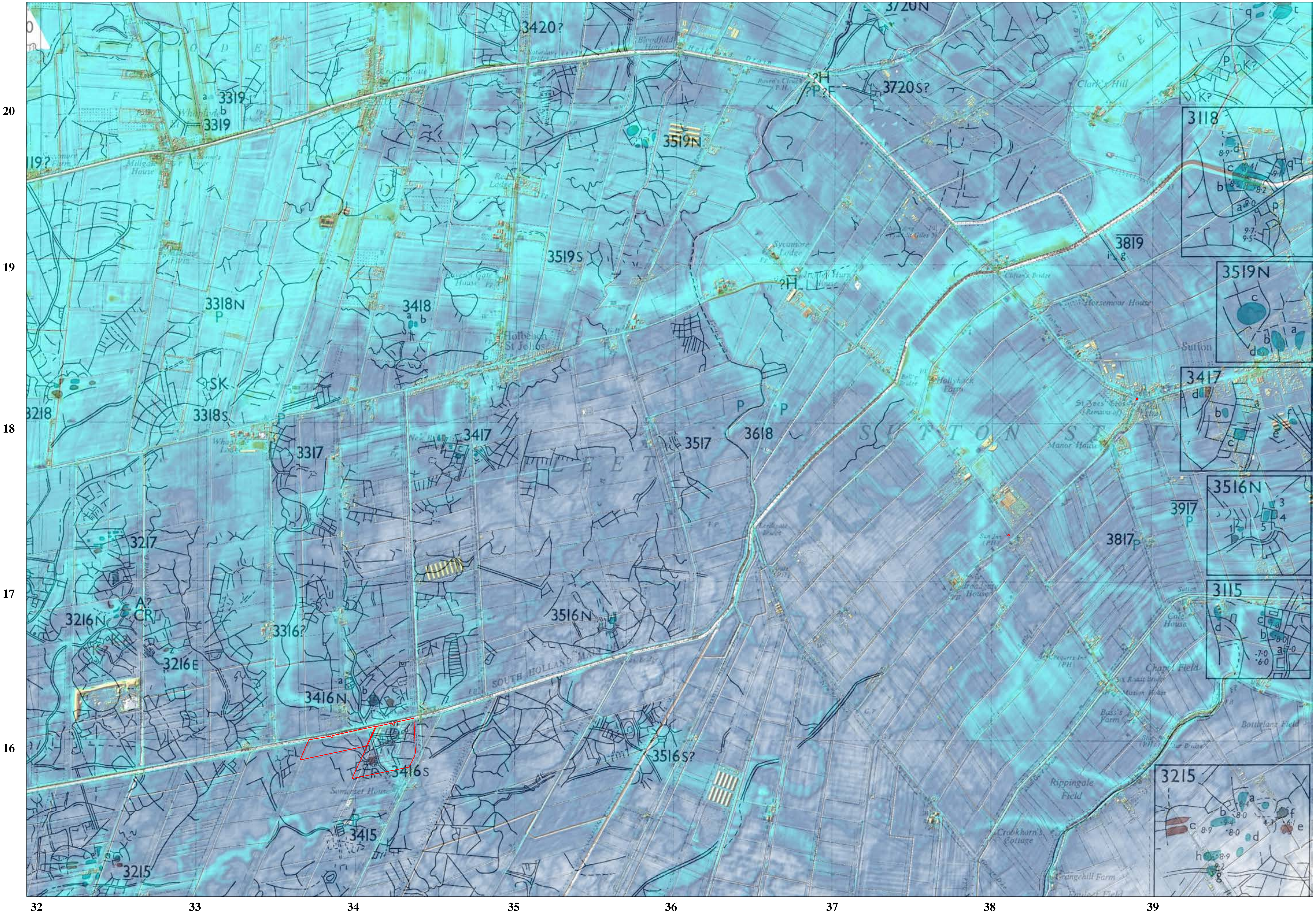


Figure 8 Fenland in Roman Times Maps 5-7 overlain on lidar survey (Scheduled Monuments outlined in red)

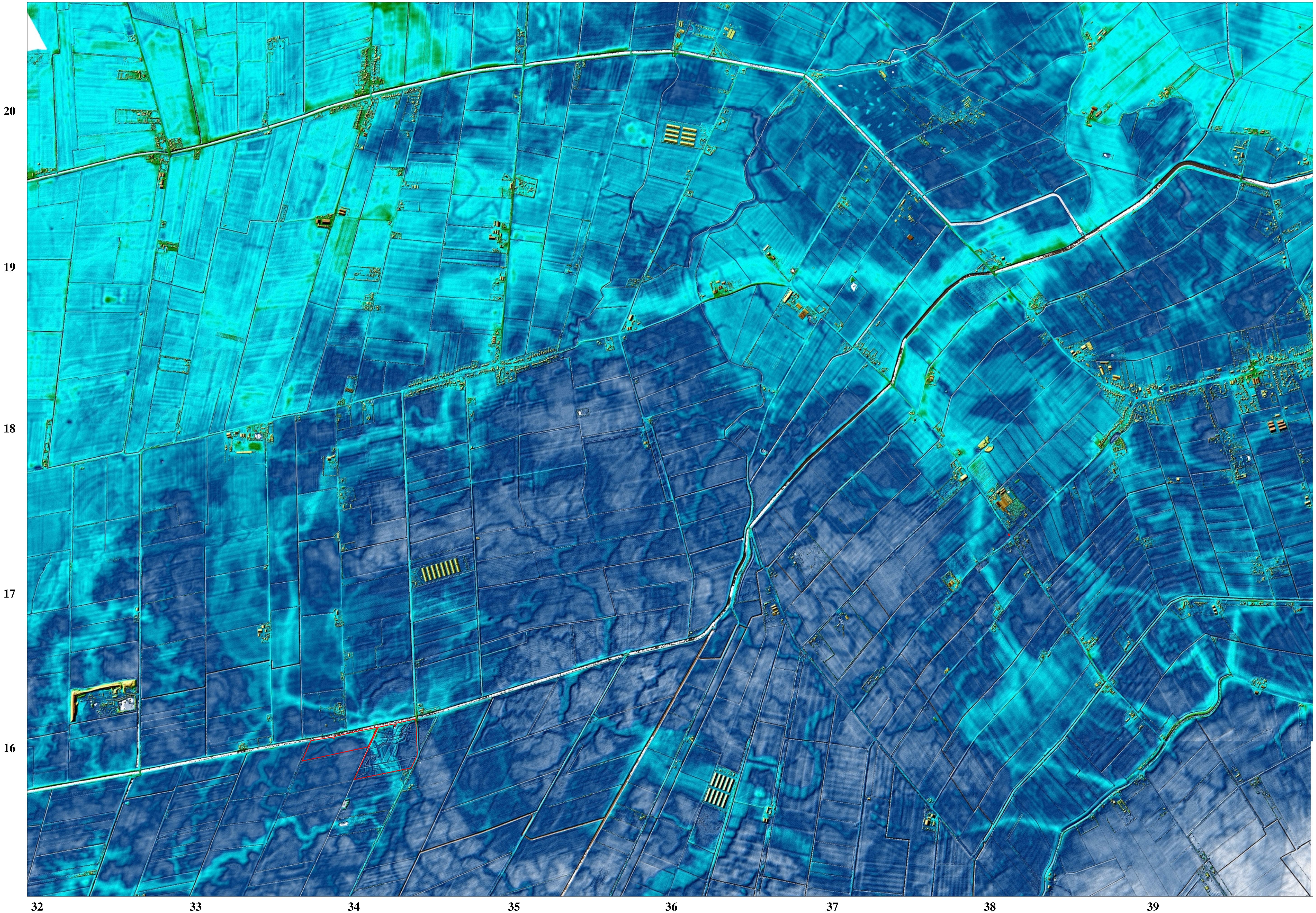


Figure 9 Lidar survey plot for the area of FIRT Maps 5-7 (Scheduled Monuments outlined in red)

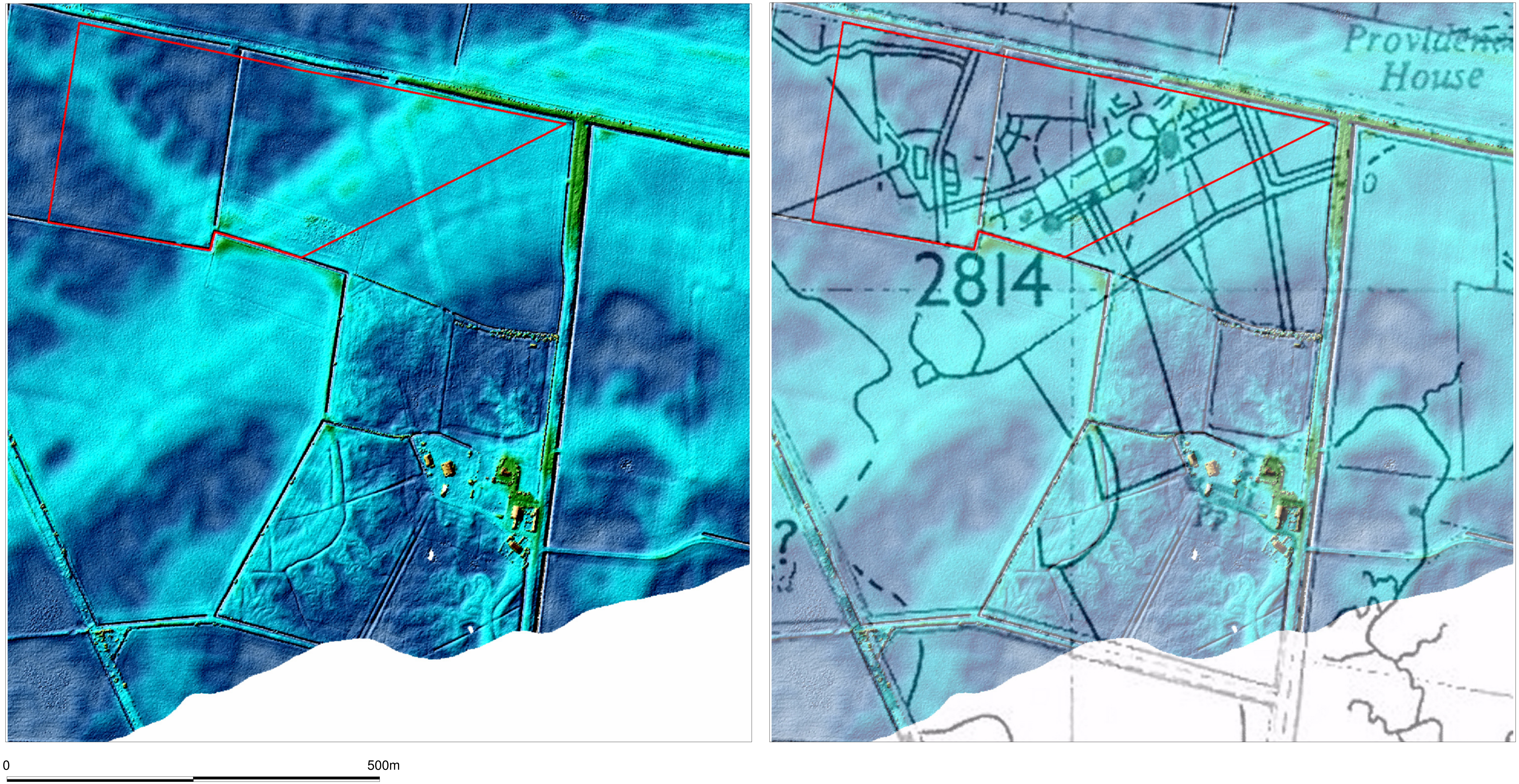


Figure 10 Earthworks at Martins Farm, southeast of LI224, TF 292138, FIRT cropmark plot overlain to right (1:5000)

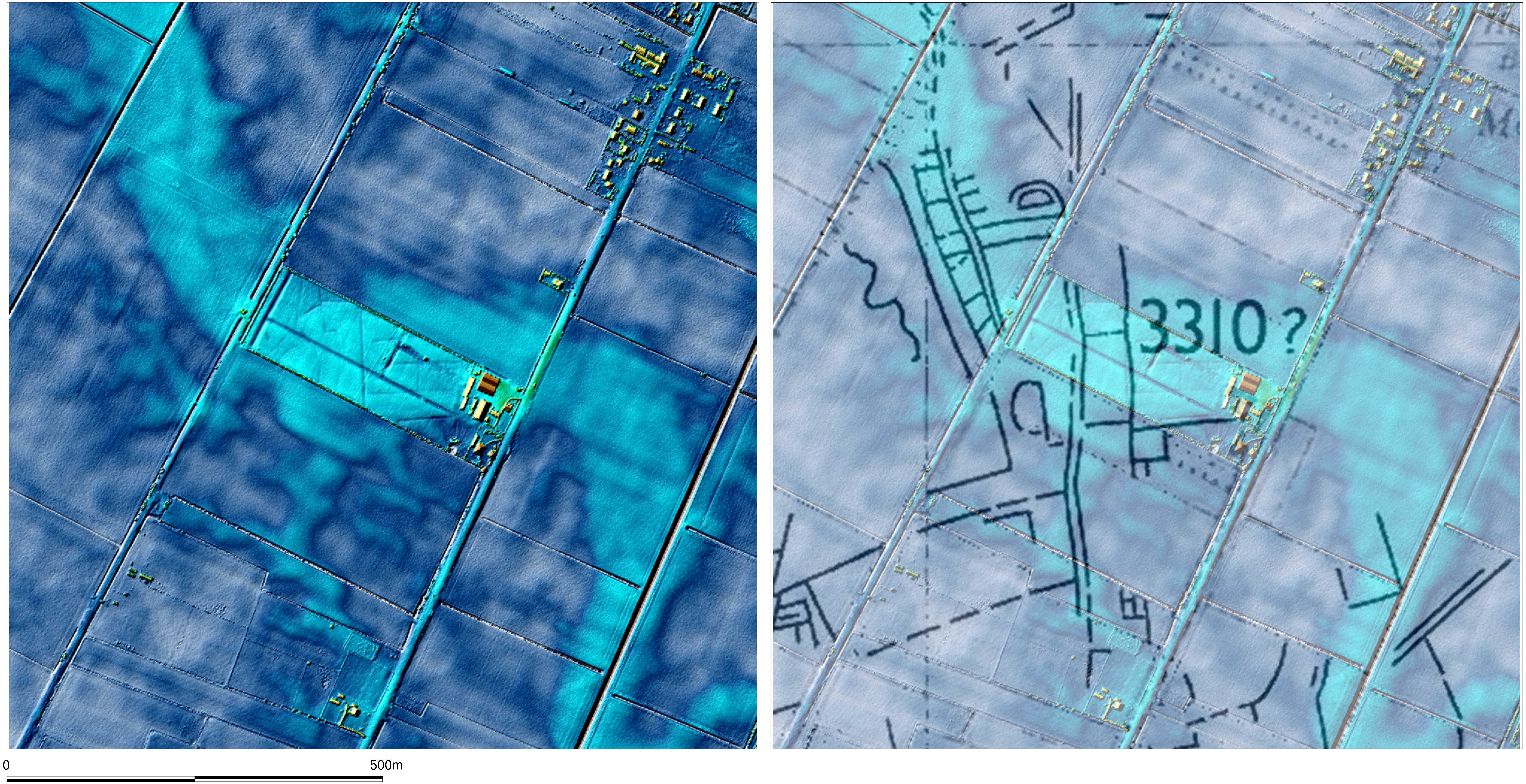


Figure 11 Earthworks at The Limes, Gedney Hill, TF 134105, FIRT cropmark plot overlain to right (1:5000)

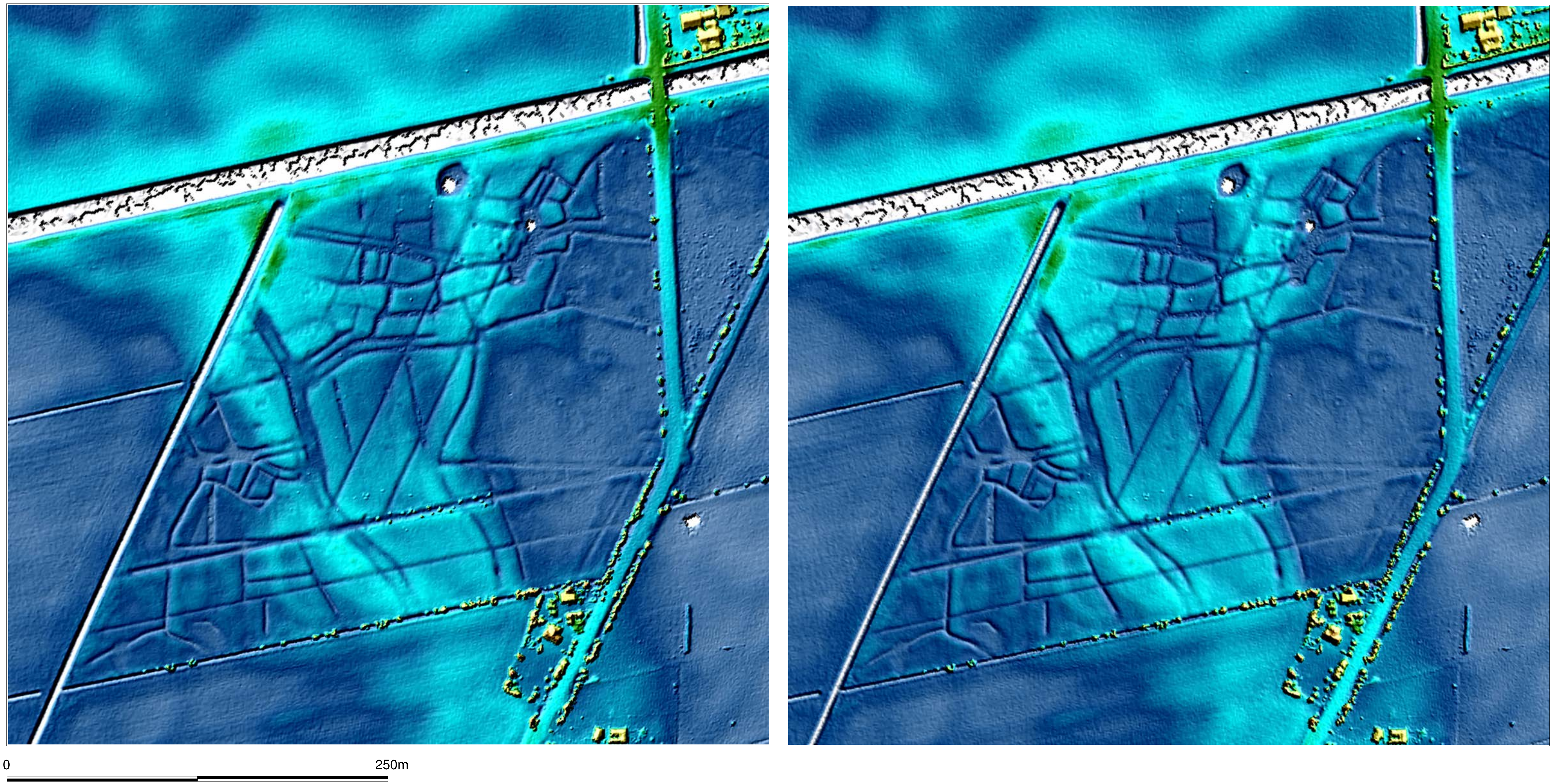


Figure 12 Holbeach: Romano-British settlement south of Shell Bridge, LI168, TF342160, 'sunlight' from northwest (left) and northeast (right) (1:2500)

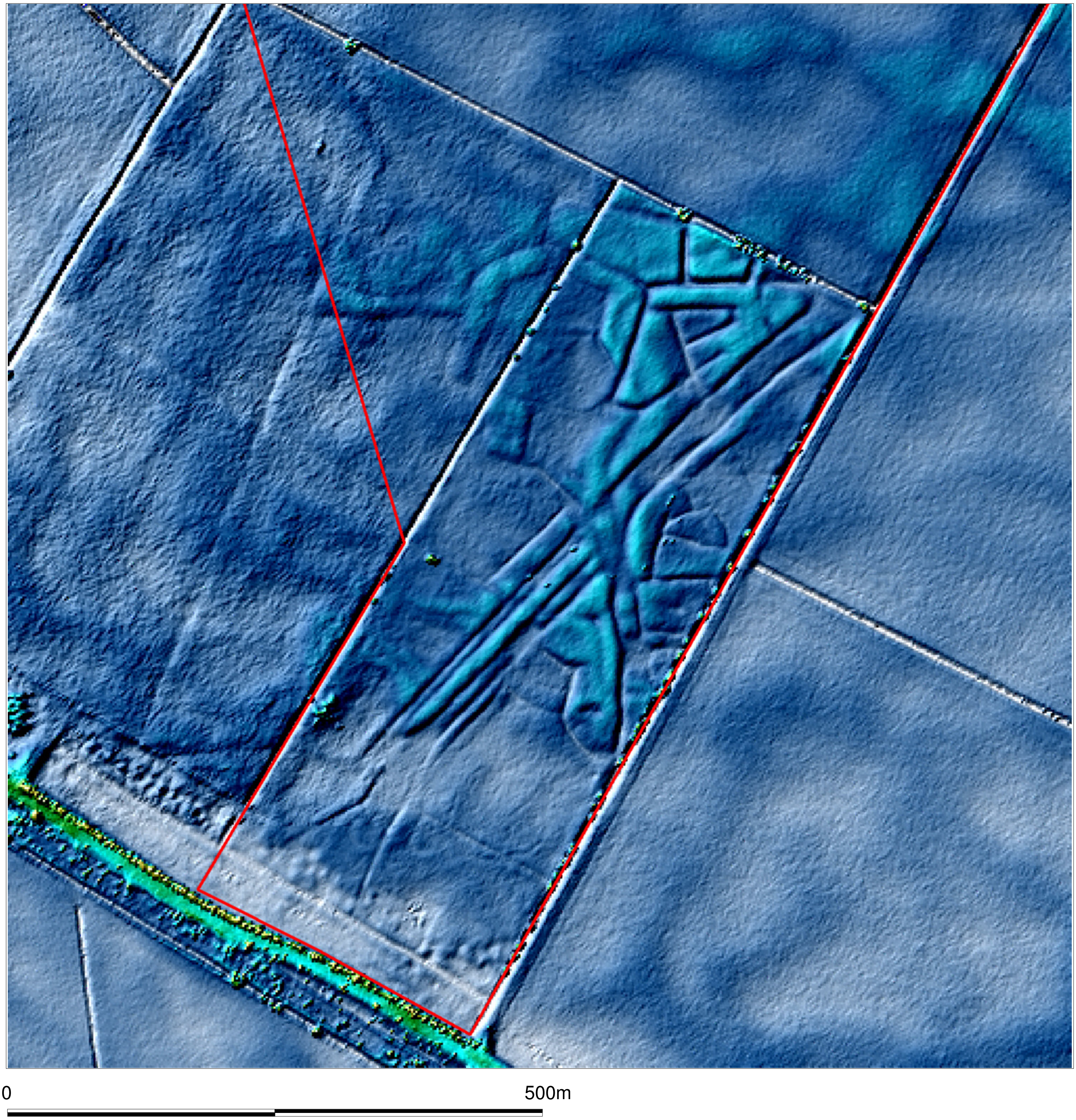
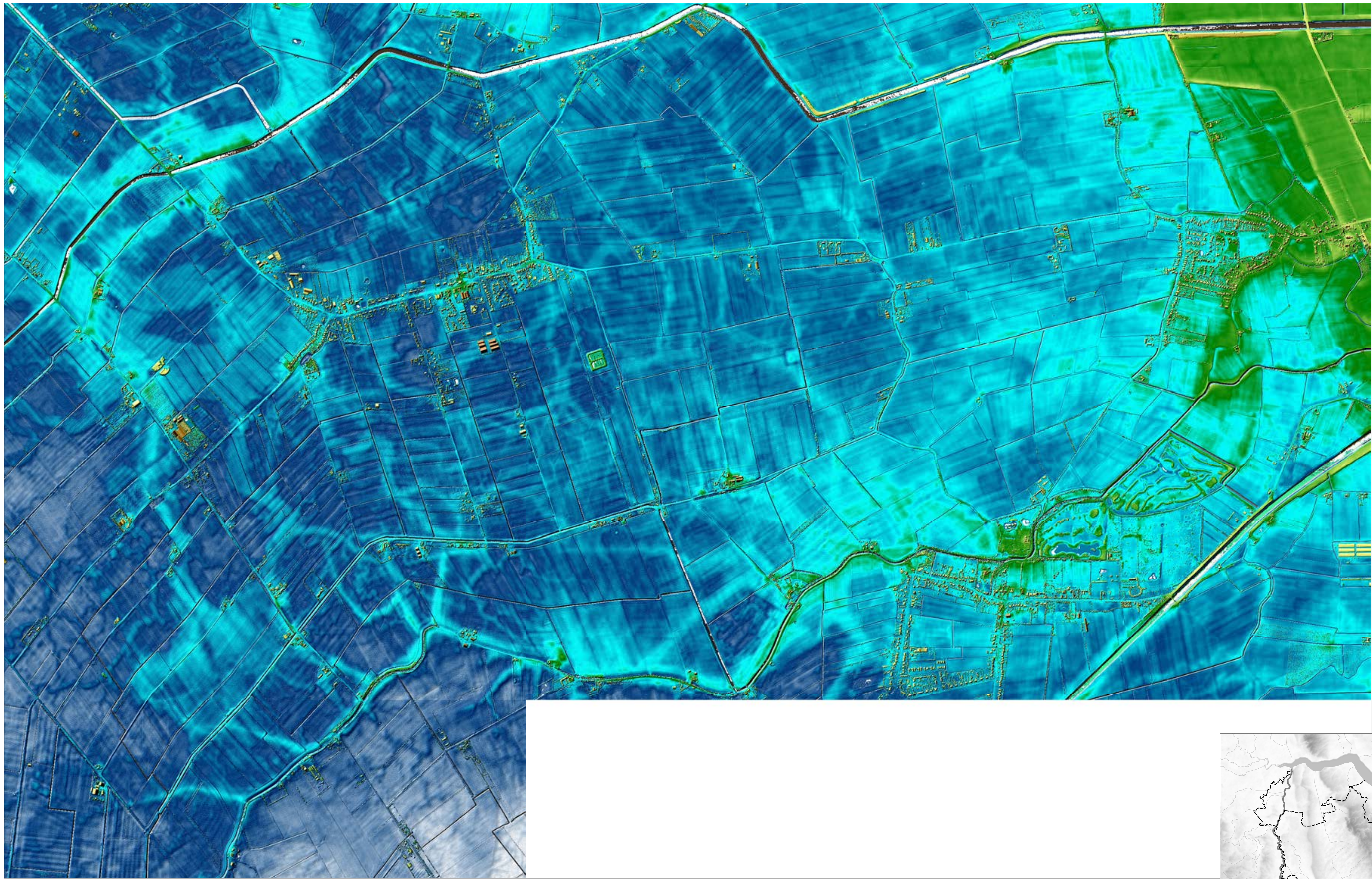


Figure 13 Fleet: settlement near Lambert Drain, LI285, TF321102 (1:5000)



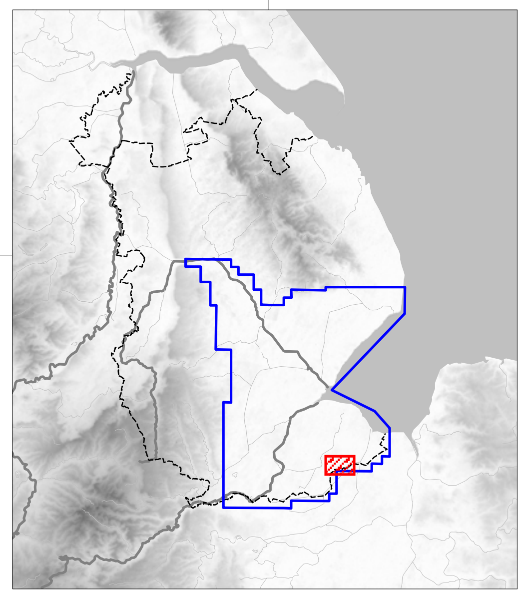


Figure 14 Sutton St James and Tydd St Mary: The Shire Drain (Lady Nunn's Old Eau) (1:25000)

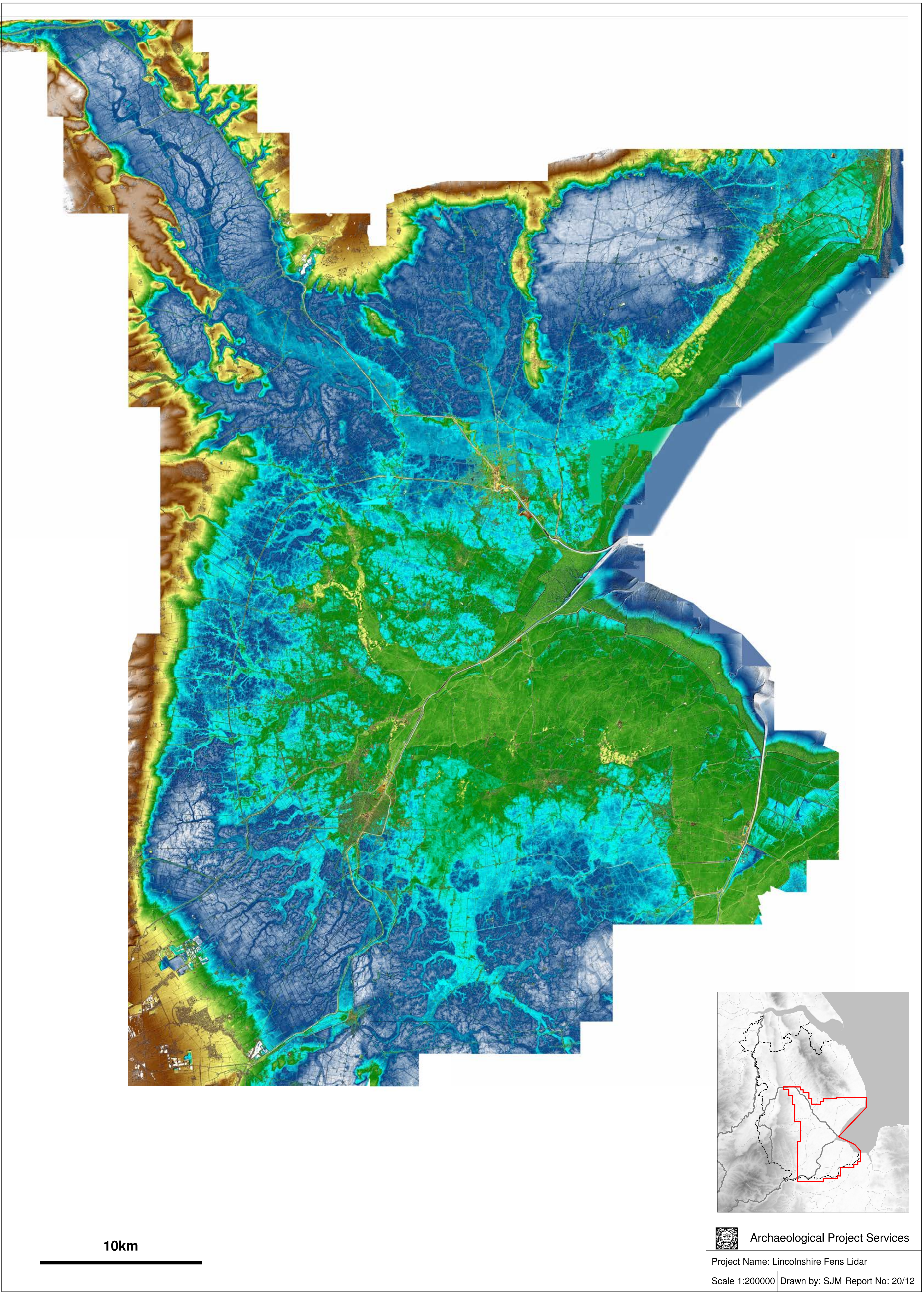


Figure 15 Lincolnshire Fenland Lidar: plot of entire survey area

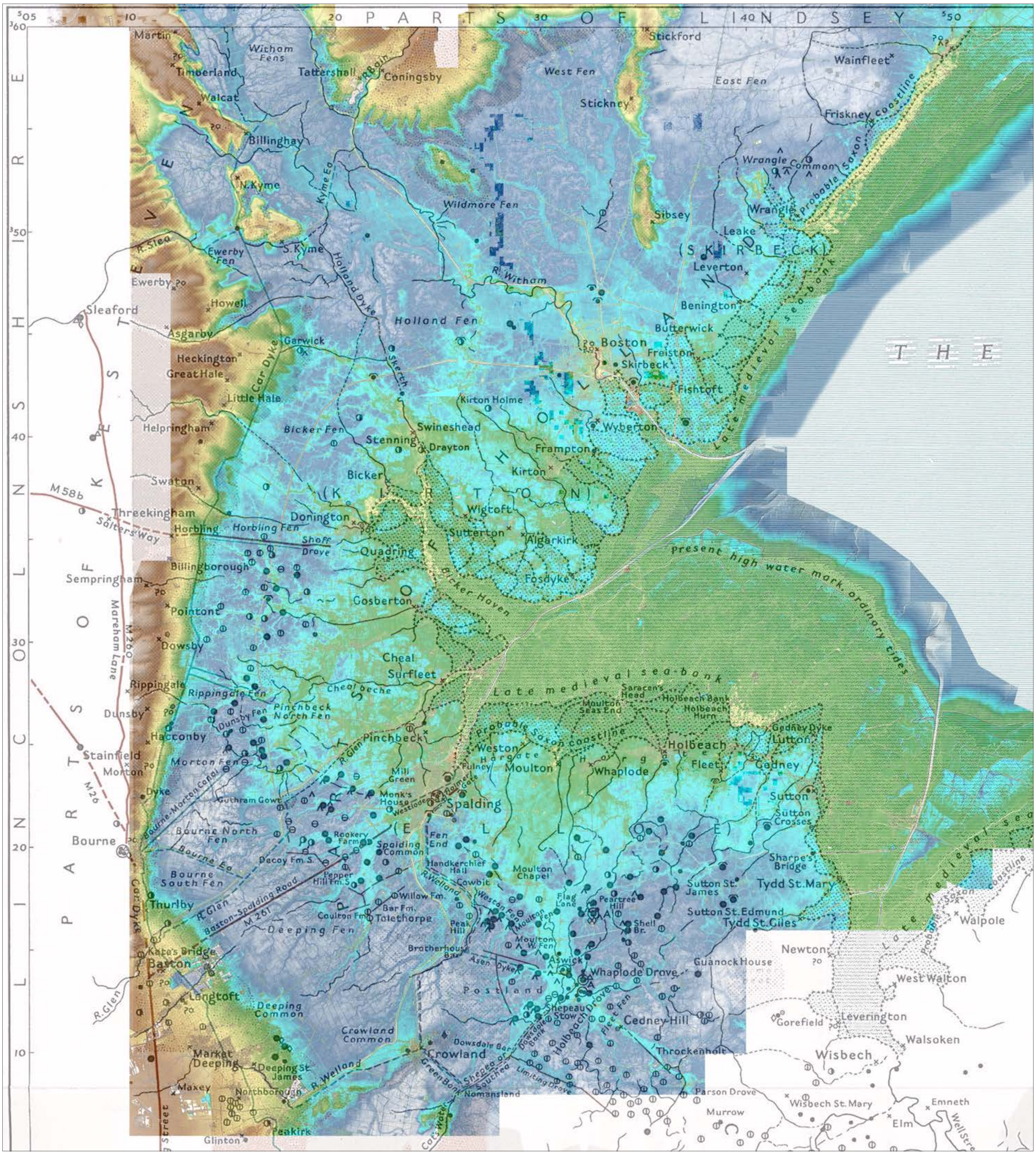


Figure 16 Fenland in Roman Times Sheet K: general distribution map overlaid on lidar plot

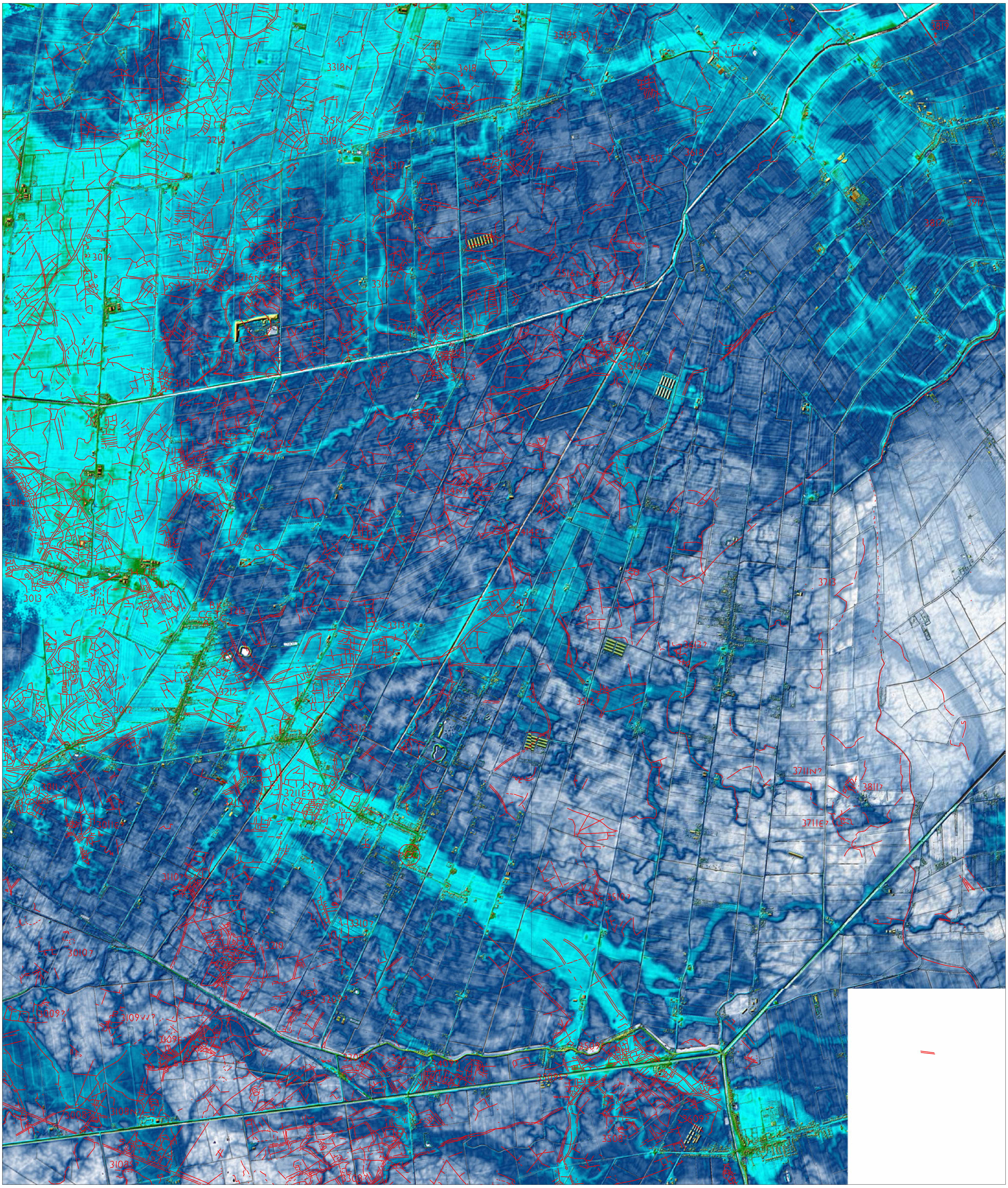


Figure 17 Southern Lincolnshire fenland: FIRT cropmark plotting overlain on lidar

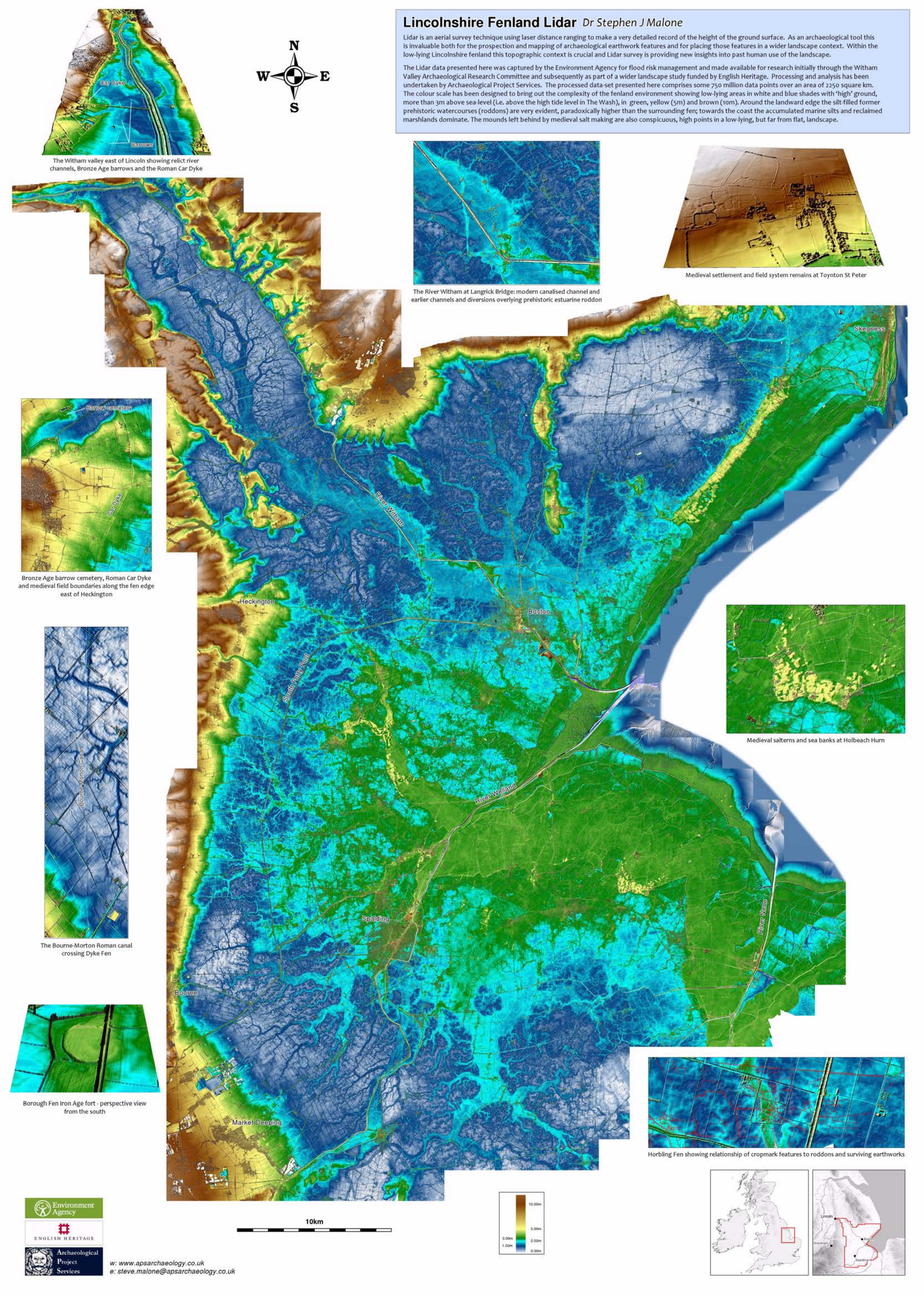


Figure 18 Revised poster presenting results of project

Appendix 1

PROJECT PROPOSAL

Submitted to:	English Heritage
Submitted by:	Archaeological Project Services (Part of the Heritage Trust of Lincolnshire)
Project Name:	Lincolnshire Fenland Lidar Processing (addition of the Spalding-Crowland – Long Sutton landscape block)
Stakeholders:	1) **Archaeological Project Services/ Heritage Trust of Lincolnshire** (processing expertise) 2) **Environment Agency** (suppliers of lidar data [free of charge]) 3) **Lincolnshire County Council Historic Environment Record** (provider of the HER data and recipients of the final dataset) 4) **County and District archaeological curators**
Project Summary:	L*idar data for the Fenland of Lincolnshire, supplied by the Environment Agency free of charge for research purposes, was processed in an earlier project. The outcome of this previous project was customised maps of the Lincolnshire Fenland with HER data overlain. This constituted a valuable and vital asset to understanding the archaeology and landscape of that area. However, not all of the Lincolnshire Fenland data was available at the time of the previous project.* *As the data is now available this project proposal seeks complete the map and the data for the remainder of the Lincolnshire Fenland (the triangular area broadly between Spalding in the north, Crowland in the southwest and Long Sutton in the southeast).*

Project Proposal
Lincolnshire Fenland Lidar Processing
(Addition of the Spalding-Crowland-Long Sutton landscape block)

Background
Lidar (Light Detecting and Ranging) has proved to be a remarkable tool for identifying and understanding archaeology.

While the gathering of lidar data is prohibitively expensive for archaeological purposes the Environment Agency (EA) has undertaken extensive areas of lidar survey in coastal and other lowland zones, such as Fenland and river valleys for the purposes of flood risk management. Archaeological Project Services/ Heritage Lincolnshire has established expertise in working with EA data which has demonstrated the potential for the use of this data in mapping ancient landscapes of the Fens.

The previous project, resulting in maps and an explanatory document, has gone a long way towards enabling a greater understanding of the the nuances of landscape change in the area and highlighted in remarkable detail areas of ancient settlement and industry.

Lidar

Detailed descriptions of Airborne Laser Altimetry, more often referred to as Lidar (for Light Detection and Ranging) are available in existing studies (Challis 2004; Bewley *et al*. 2005). Lidar uses the properties of coherent laser light, coupled with precise spatial positioning (through the use of a Differential GPS) to produce horizontally and vertically accurate elevation measurements. This data has considerable potential for archaeological research in terms of mapping archaeological sites where features survive as upstanding earthworks, for identifying depressions where organic sediments may be preserved and more generally for providing landscape context in areas of very low relief where existing topographic mapping lacks detail.

Proposal
It is proposed that the data for the remainder of the Fenland are acquired and processed to the customised colour scale highlighted below. This will complete the data available fopr the Lincolnshire Fens. HER data will be added to provide an up-to-date statement of the relationship of known sites to landscape features such as roddons (elevated extinct creeks on which all early settlement took place e.g. Fenland Survey Hayes and Lane 1992; Lane 1993). Moreover, where the Roman and prehistoric landsurfaces shelve beneath the post Roman silts, the roddons can still be identified by means of lidar whereas the changes in land level and increasing width (up to 5km) make them too muted to be plotted from ground survey. Although buried by later (post-Roman) silts these roddons were the locations of the earlier settlements and salterns. Processed lidar data will enable predictive modelling of the locations of these early sites (such as the recently excavated Roman saltern and settlement found during construction beneath up to 1m of overlying post Roman silt near Spalding). The plotted information may also lead to the discovery of previously unknown landscape features, such as the ‘Monks Canals’ reported in the press in late August 2008

Research Aims and Objectives
The primary aim is to plot the remaining lidar data for the Lincolnshire Fens between Spalding, Crowland and Long Sutton and overlay the HER information in order to enhance the record, relate archaeology and landscape and enable predictive modelling of site locations under later silting.

Objectives will be to

- obtain the lidar data
- process the data in the manner described below
- add the Lincolnshire HER data
- present it to the Lincolnshire HER in the form described below

F.A.Q.
Q -Who will benefit from this work?
A – Many organisations and researchers into the Fenland, but primarily the curatorial archaeologists in charge of those areas

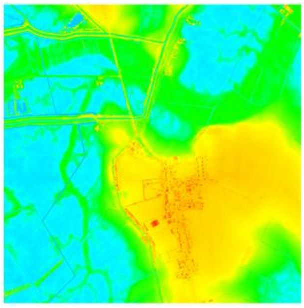
Q- Who else?
A- All archaeological researchers in the area, both professional and part time, various groups, such as the Wash Study Group.

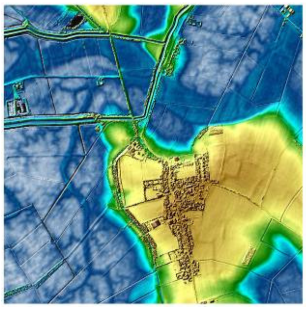
Q – How will curators benefit?
A – By finally having access to the remaining lidar data, by being able to understand the landscape context of each site before they provide advice to planning authorities and by being able to predict where sites are going to be affected by development, even in areas where those sites are buried by later silting

Q- Have you got any external support for the Project?
A – Yes, the Environment Agency supports it enough to provide the raw data free of charge. The curators at county and district level support it as it will be a critical tool for them in understanding the locations of sites

Processing
Environment Agency lidar data is provided in the form of ESRI SHP files, in ASCII grid format. These can be read directly into ArcInfo or MapInfo (the latter is the platform utilised at APS) to create a continuous raster grid surface model. This is the preferred technique for preserving data integrity, and is relatively fast. For presentational purposes an alternative technique involving Inverse Distance Weighting has been found effective. This introduces some smoothing, reducing noise and visible survey-swathe boundaries in the data, but is more time-consuming and is best suited to smaller-area, detailed plans or 3D-perspective views. Parameters for processing and presentation have already been trialled with EA survey data as part of Witham Valley project. Default greyscale or colour images can be quite simply produced, but are less expressive than customised colour scales combined with artificial sunlight / relief shading designed to emphasise subtle height differences in these landscapes of very low relief.


Default greyscale


Default colour scale


Customised colour scale

Method Statement
Processed survey data will be output as georeferenced image files which can be incorporated into the Lincolnshire SMR's ExeGesis system. Selective mapping of individual topographic features will be undertaken in vector format suitable for incorporation within a GIS.

Stages, Products Tasks
The proposed project is straightforward with four main tasks
- obtain and install copy of MapInfo 9
- obtain and process lidar data
- add newly processed data to existing data to make complete plan of the Lincolnshire Fenland area
- deliver to HER

Proposed Project Team
Tom Lane (Senior Archaeologist) – role – Project Management
Dr Steve Malone (Project Manager) – role – Data management

Estimated overall budget

Estimated overall Timescale

References

Bewley, RH., Crutchley, SP and Shell, CA., 2005, 'New light on an ancient landscape: lidar survey in the Stonehenge World Heritage Site', *Antiquity* 79, 636 – 647.

Challis, K., 2006, 'Airborne laser altimetry in alluviated landscapes', *Archaeological Prospection* 13, 103-127.

Hayes, P.P. and Lane, T.W., 1992, *The Fenland Project Number 5: Lincolnshire Survey, the South-West Fens*, East Anglian Archaeology 55

Lane, T., 1993, *The Fenland Project Number 8: Lincolnshire Survey, The Northern Fen-Edge*, East Anglian Archaeology 66

Appendix 2

Survey Products (provided on accompanying DVD)

GeoTiff imagery (additional/revised)

TF06NE.tif
TF06SE.tif
TF07SE.tif
TF07SW.tif
TF10NE-2.tif
TF10NE.tif
TF10NW-2.tif
TF10NW.tif
TF11NE.tif
TF11NW-2.tif
TF11NW.tif
TF11SE.tif
TF11SW-2.tif
TF11SW.tif
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TF12SE-2.tif
TF12SE.tif
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TF14SW.tif
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TF15NW.tif
TF15SE.tif
TF15SW.tif
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TF16NW.tif
TF16SE.tif
TF16SW.tif
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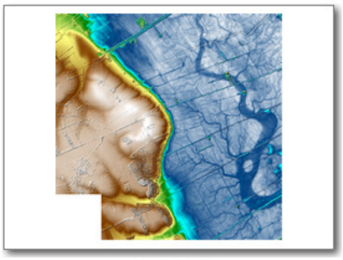
TF44NW.tif
TF44SW.tif
TF45NE.tif
TF45NW.tif
TF45SE.tif
TF45SW.tif
TF46SE.tif
TF46SW.tif
TF52NW.tif
TF52SW.tif
TF55NE.tif
TF55NW.tif
TF55SW.tif
TF56SE.tif
TF56SW.tif

MapInfo Tab files
Seamless combined imagery: LFLE12 wholesurvey50pcj.jpg; LFLE12 wholesurvey50pc.ecw; LFLE12FensN.ecw; LFLE12 FensS.ecw
Posters: LFLE12 A0 poster.pdf; LFLE12 A1 poster.pdf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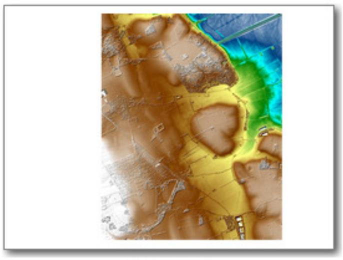
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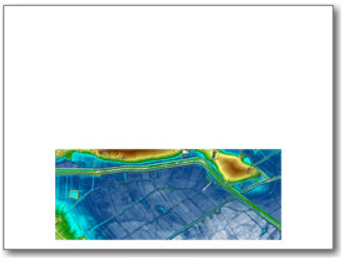
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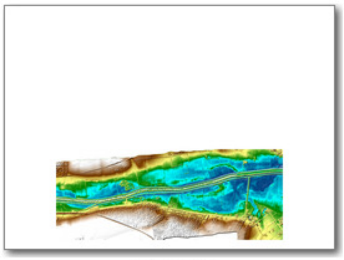
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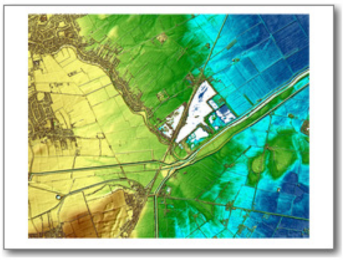
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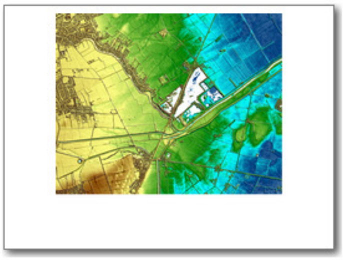
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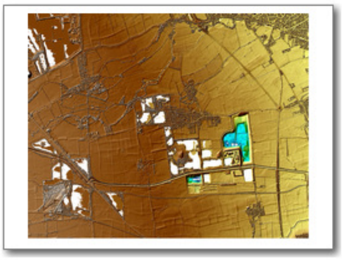
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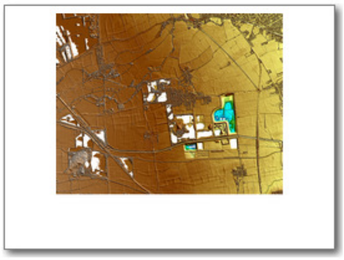
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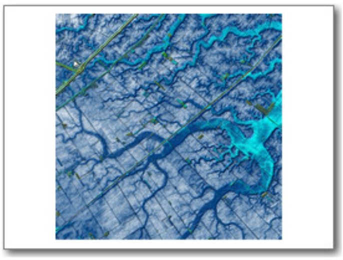
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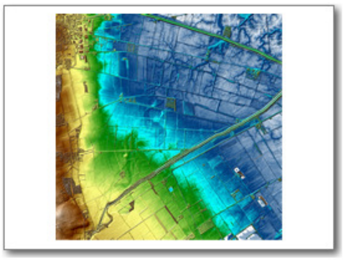
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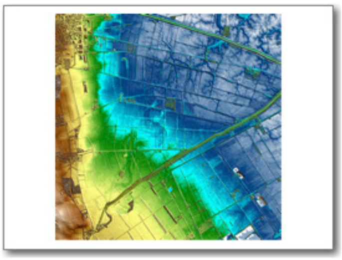
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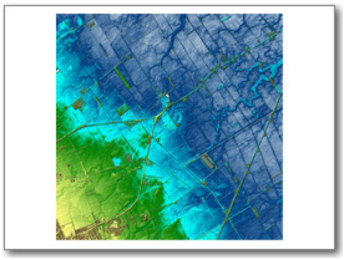
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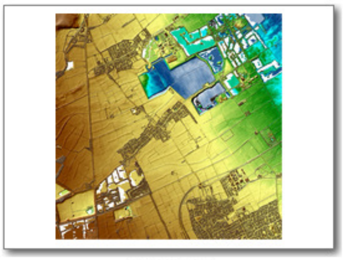
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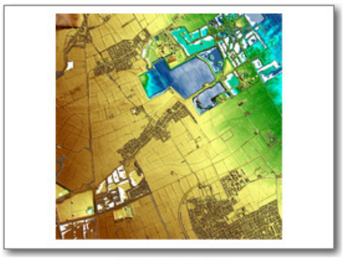
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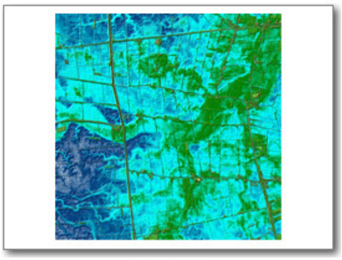
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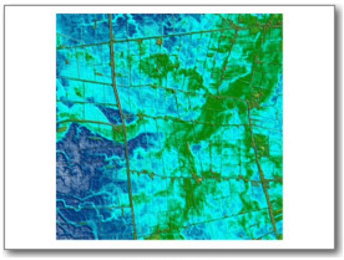
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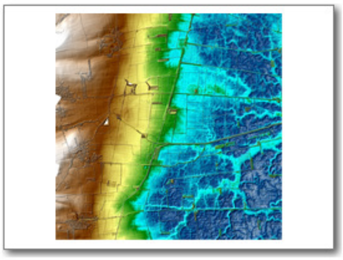
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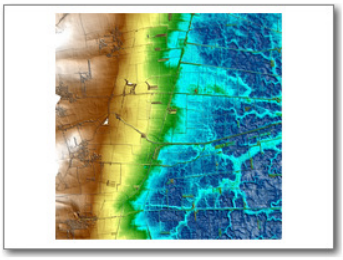
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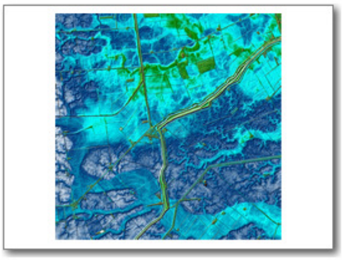
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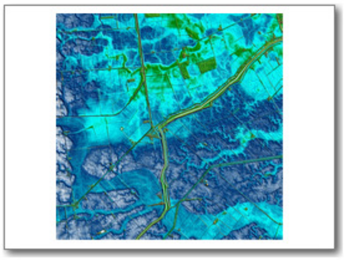
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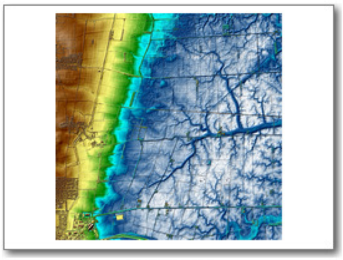
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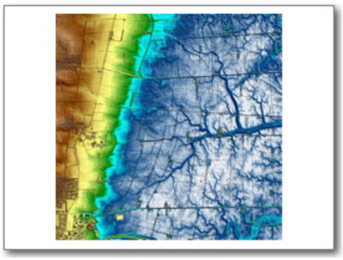
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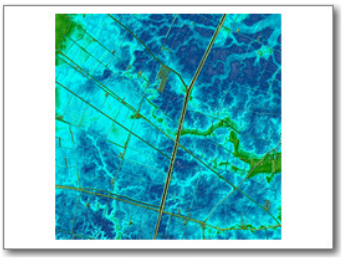
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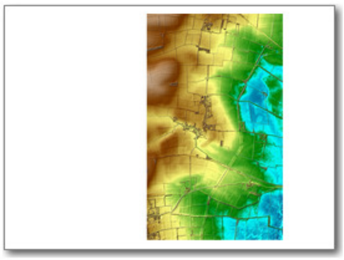
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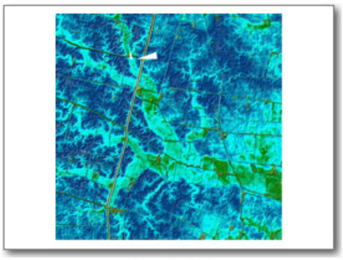
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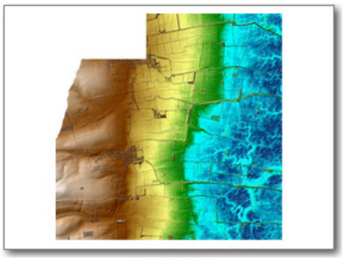
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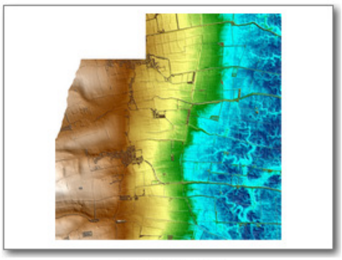
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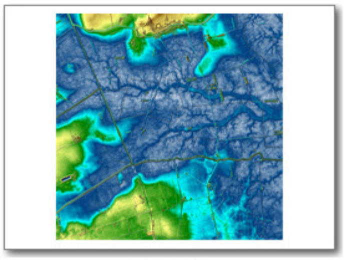
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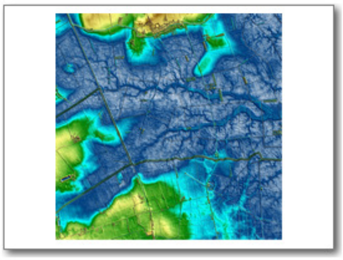
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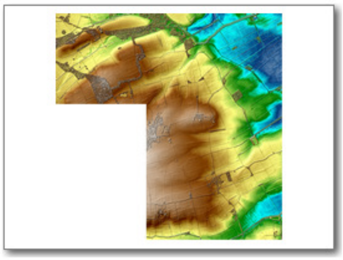
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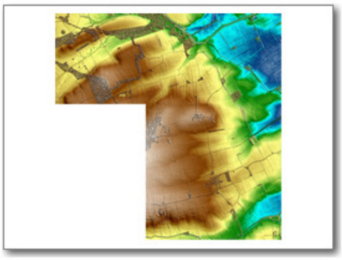
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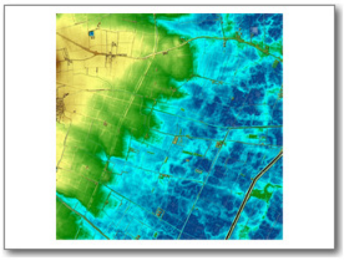
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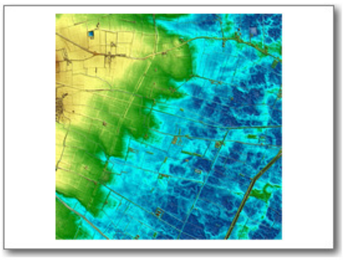
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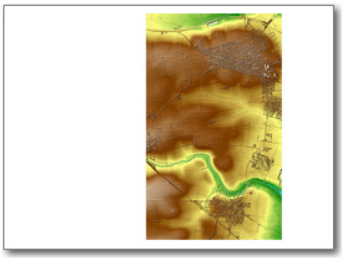
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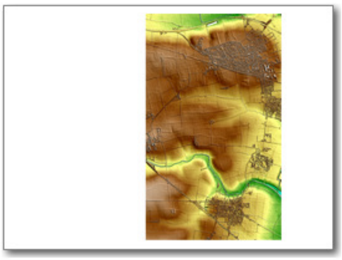
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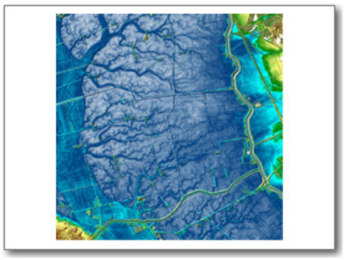
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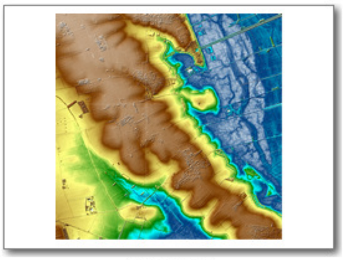
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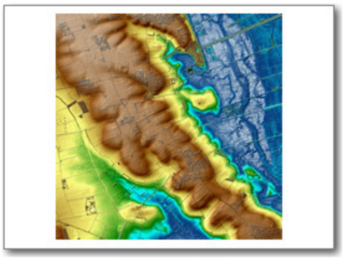
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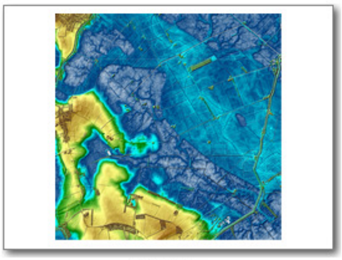
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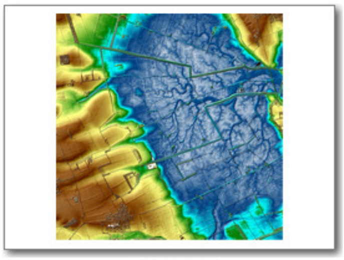
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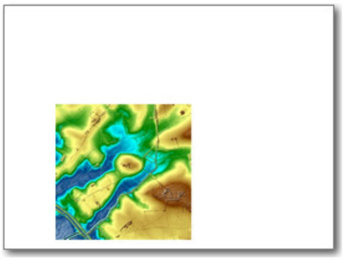
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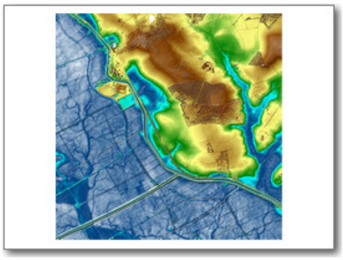
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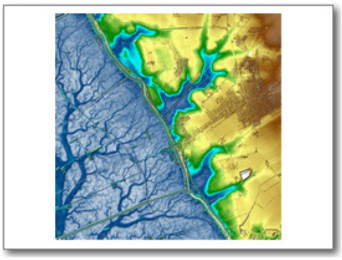
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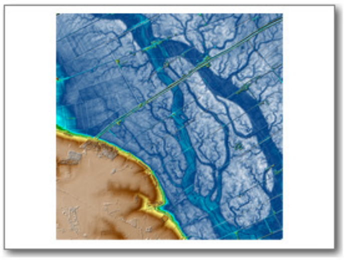
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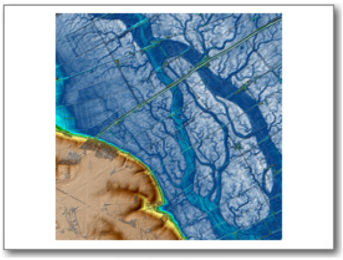
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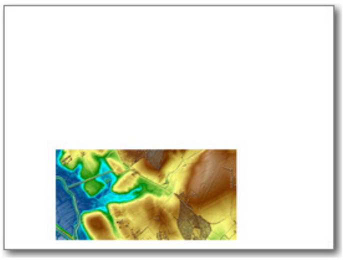
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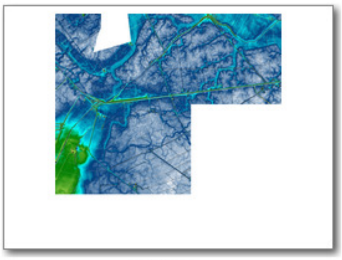
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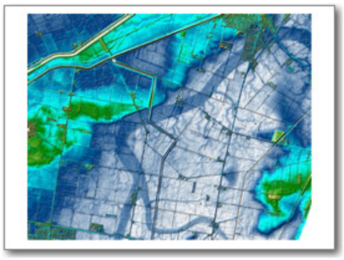
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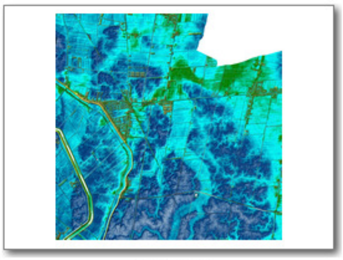
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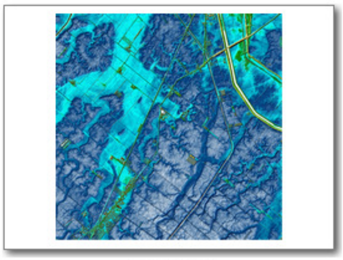
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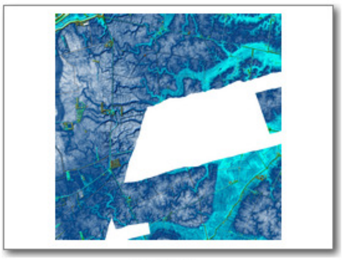
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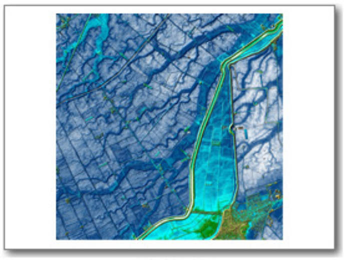
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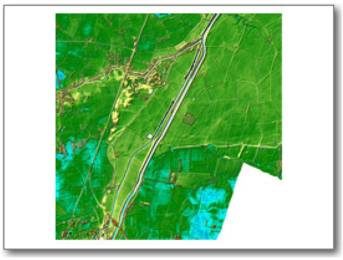
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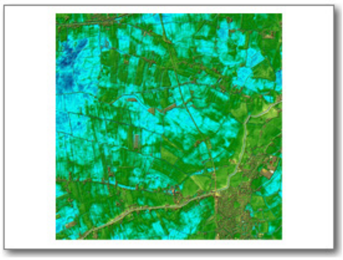
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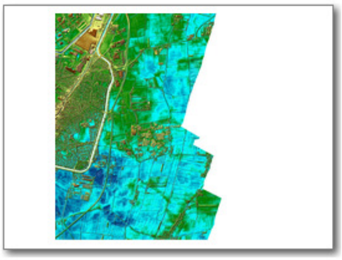
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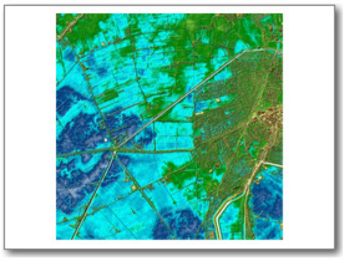
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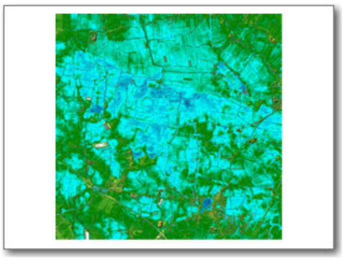
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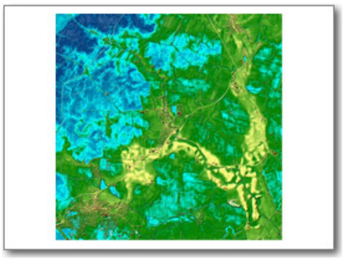
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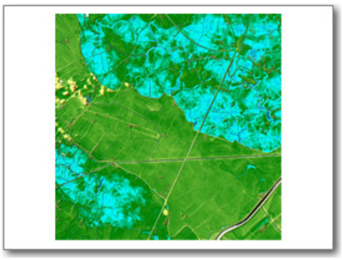
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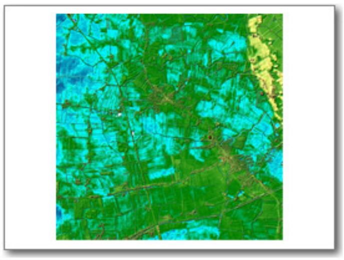
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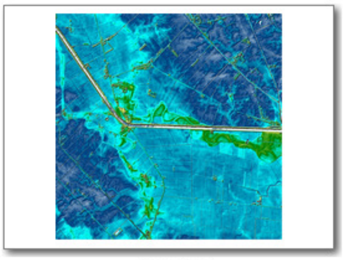
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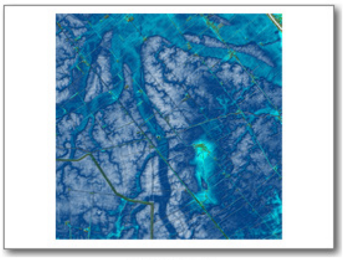
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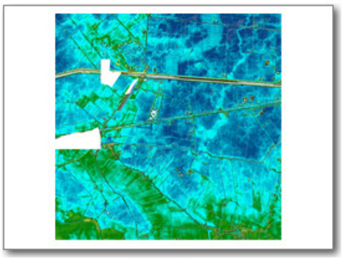
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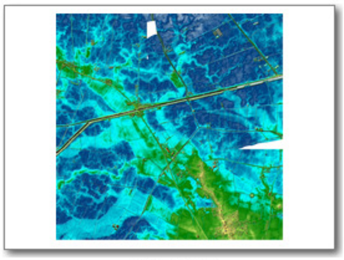
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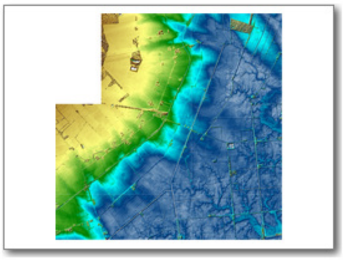
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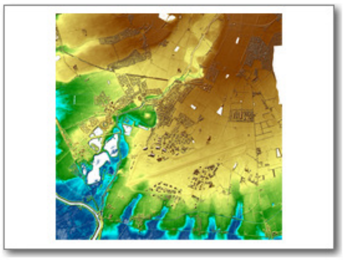
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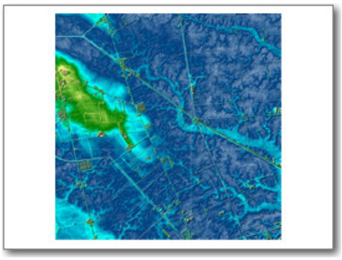
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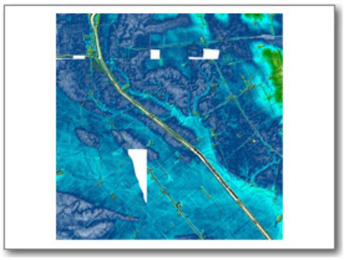
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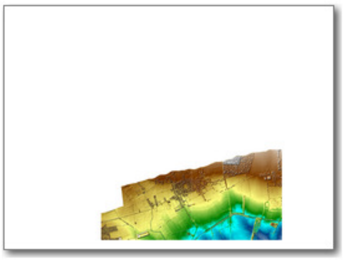
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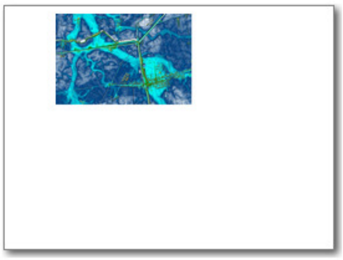
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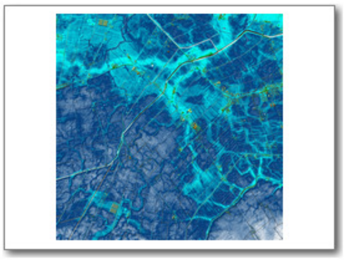
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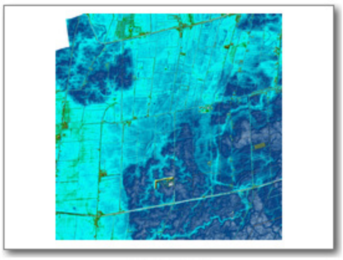
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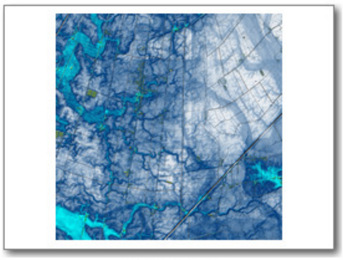
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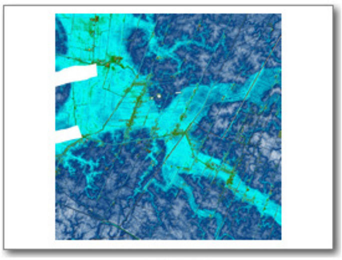
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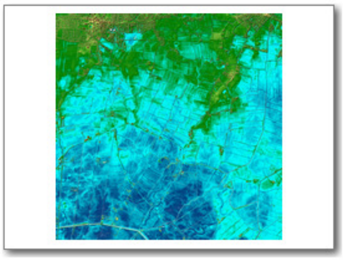
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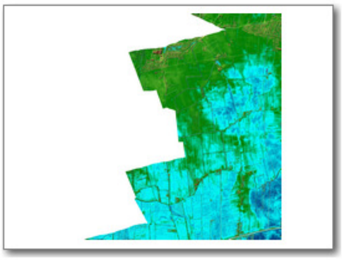
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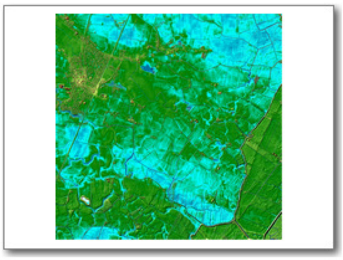
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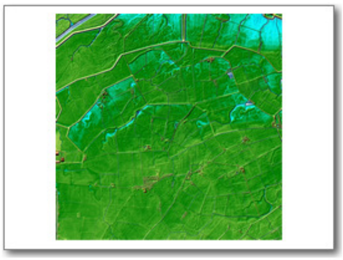
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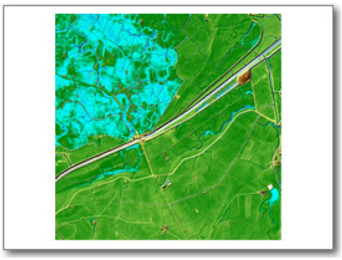
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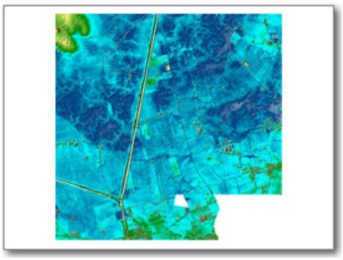
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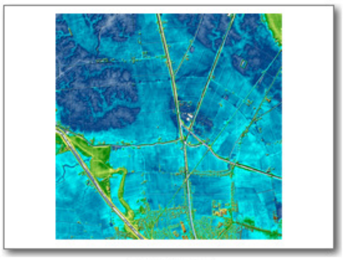
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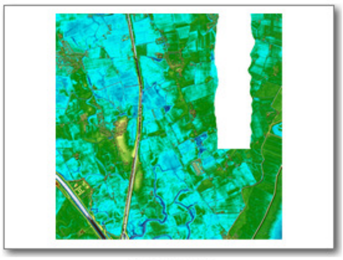
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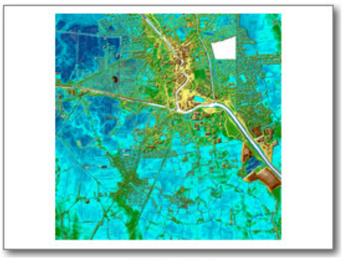
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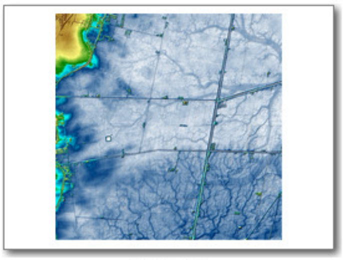
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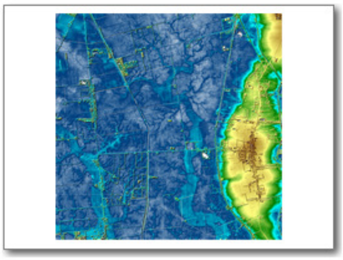
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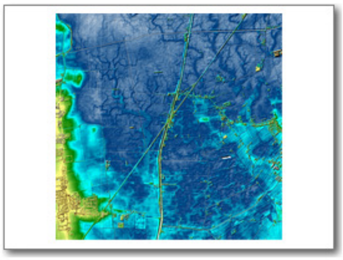
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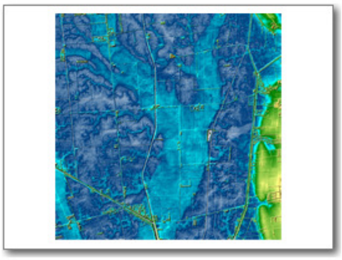
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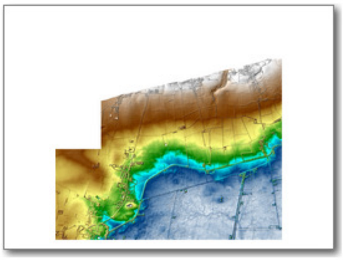
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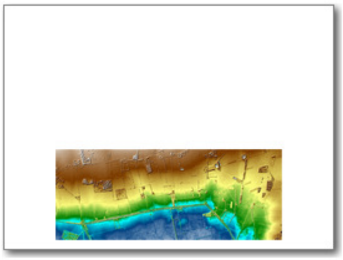
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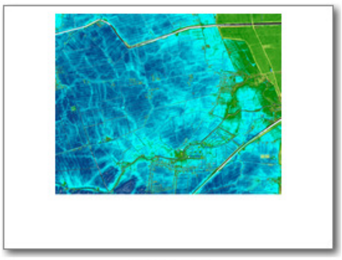
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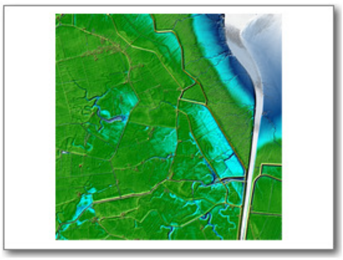
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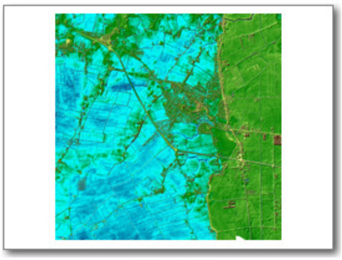
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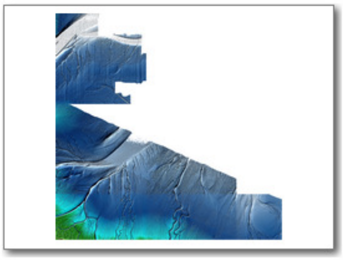
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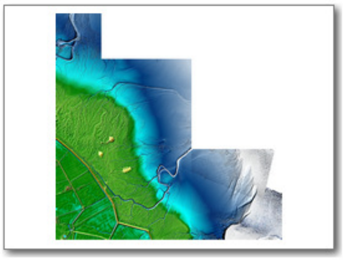
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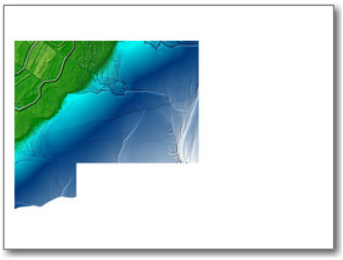
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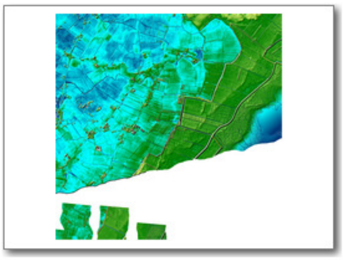
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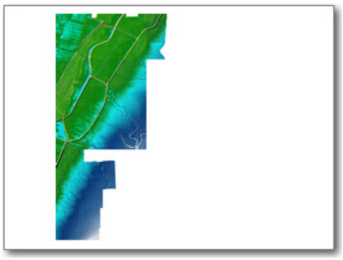
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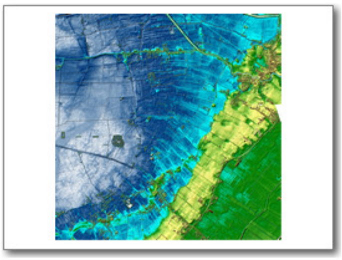
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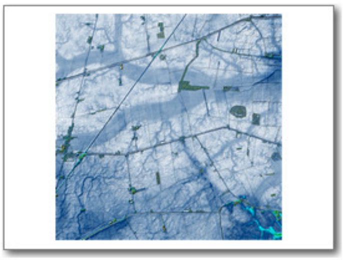
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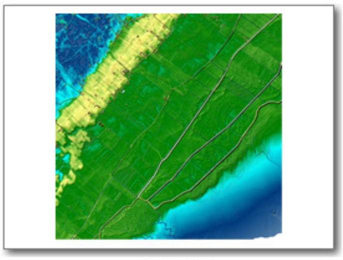
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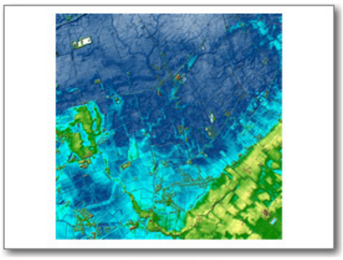
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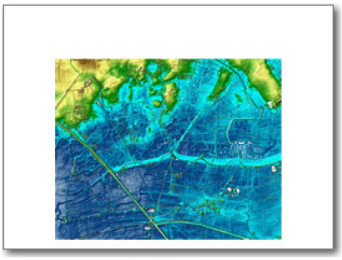
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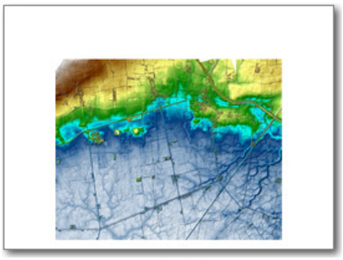
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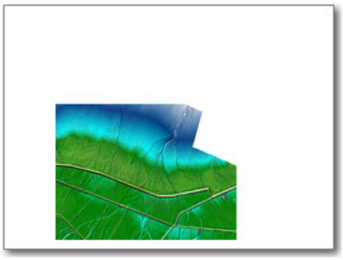
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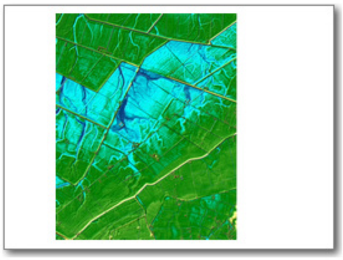
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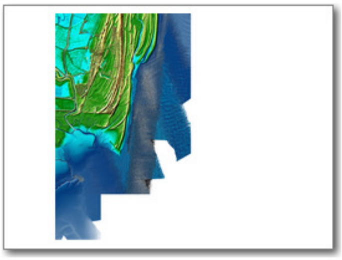
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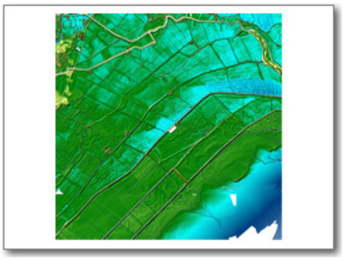
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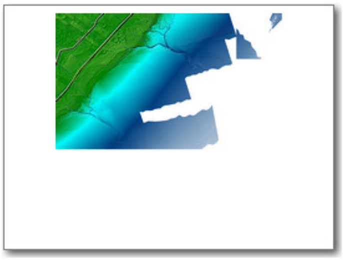
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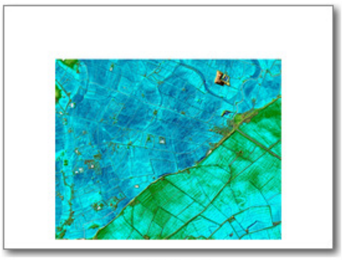
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Appendix 3

Visualisation

Shaded relief modelling has been recognised as perhaps the most user-friendly and easy to interpret method of visualising lidar data. However, such models do suffer from problems of feature definition where these are aligned on or close to the direction of illumination and for best results the production and comparison of multiply lit models would be recommended (Crutchley and Crow 2010, 22-23 and see below Fig. A3.2).

A variety of alternative techniques have been proposed to overcome these limitations, e.g. principal component analysis to combine multiple hill-shaded images (Devereaux *et al*. 2008), local relief modelling (Hesse 2010), or sky-view factor visualisation (Kokalj *et al*. 2011). Two recent papers have sought to compare these techniques and provide recommendations for best practice. Challis *et al*. (2011) is the more wide ranging, looking at a variety of different site and terrain types. Bennett *et al*. (2012) is somewhat more systematic, comparing the results of feature mapping using a range of techniques in an already well studied landscape. Both conclude that best results can be obtained using a combination of techniques and both recommend the use of Sky View Factor or Solar Insolation Modelling alongside relief modelling techniques. In addition Challis *et al*. conclude that modelling of slope severity provides good results in high-relief landscapes, or of well defined (high intensity) earthworks in low-relief landscapes.

The technique adopted for the Lincolnshire fenland mapping combines constrained colour shading with relief modelling (both recommended by Challis *et al*. for low relief landscapes). This is something of a compromise in that the colour scale was originally defined in order to produce best definition of the extinct creek systems in the Witham valley. However, extension of the project to cover the entirety of the Lincolnshire fenland has shown this to work extremely well in mapping the roddons and larger scale estuarine channels. Providing landscape context was the primary aim, but the detail available within lidar mapping means that the potential for site prospection must also be explored and there are potential weaknesses to the approach in this regard.

Sky-View Factor calculations assume diffuse illumination and apply shading based on the area of visible sky for each location within the terrain model (Kokalj *et al*. 2011). Thus the tops of earthwork banks see virtually all of the sky and appear in light to white colours; the bottoms of ditches see much less, and are darker. The result is that all features, however aligned, are represented in the same way. Insolation modelling relies on a similar concept but allows calculation of direct, diffuse and global solar radiation received over time. Again, because these summarize received radiation over a period of time (a day, a month, etc.), the shadow effects resulting from the single illumination azimuth used in hill-shade calculations are largely removed.

The benefits of these techniques seem clear from the examples given in the papers quoted and have been trialled here with the fenland data-set looking at three different cases: earthworks within the fenland; earthworks on the ‘upland’ margins; and superposed roddons in the fenland. Sky-View factor plots have been produced using Sky-View Factor Version 1.11, downloaded from the ZRC SAZU site referenced in the original paper. Calculations have been run using 8 search directions, a search radius of 5 or 10 metres and a vertical scale of 5. Insolation models (potential incoming solar radiation) have been produced using SAGA Version 2.0.7.

Example 1: Shell Bridge, Holbeach. (1m centred data) (see also Fig. 12 for colour-shaded plots). The Sky-View image picks out the earthworks of the settlement very clearly with some fainter features more strongly expressed than in the relief models. However, the overall effect is not convincingly better than the relief shaded image. Most unfortunate is the loss of topographic context. We can hardly see the roddon on which the settlement sits at all. This is a major drawback in this region where topographic context is often as important as the earthwork features themselves. Unfortunately, a wide flat area 1m above sea level sees just as much sky as a wide flat area 3m above sea level, but in terms of settlement location, there is an enormous difference. Total insolation performs better, recording the earthworks well and representing the higher parts of the roddon, but in comparison to the colour-shaded relief plots, still fails to demonstrate as clearly the topographic context.

Fig. A3.1 Shell Bridge: left, conventional relief-shaded plot; centre, sky-view factor; right, total insolation

Example 2: Dyke village. (2m centred data) The Roman Car Dyke runs past the eastern side of the village which also has extensive surviving medieval earthworks. The colour plots illustrate the potential pitfalls of relief shading with ridge and furrow on the southeastern edge of the village especially susceptible to illumination direction. The SVF plot picks up all of the ridge and furrow alignments here and also picks out the top of the banks of the Car Dyke well. However, subtler features are not as well represented (e.g. the slight narrow ridging in the fields north of the village) with the colour-shaded relief plots providing much greater clarity. Total insolation here adds little (the western side of the plot is affected by persistent edge effects introducing deep shading for low sun angles).

Fig. A3.2 Dyke village: top, relief-shaded colour plots illuminated from northeast and northwest; bottom left, sky-view factor plot; bottom right, total insolation (sum monthly, June-July)

Example 3: River Witham. Northern edge of wide prehistoric estuarine roddon overlain by marine silting of later watercourse and final downcutting active channels (modern canalised river crosses the southwest corner). The Sky View Factor plot defines the downcut channels well and picks up the edges of better defined roddons but the representation of these can be confused with the channel forms and we still lose the sense of topographic location. Total insolation defines the channel forms very well and performs better in definition of the roddons although representation of the wider band of silts of the prehistoric roddon is somewhat variable.

Fig. A3.3 River Witham: : left, relief-shaded colour scale; centre, sky-view factor; right, total insolation

Discussion. Although potentially representing a significant advance whereby representation of earthwork features is not dependent on the choice of illumination, in practice the results of trials on this dataset provide mixed results. Within the fenland slightly better clarity in representation of earthwork features is outweighed by the failure of the techniques to express the landscape context as clearly. On the upland margins there is undoubtedly something to be gained in the mapping of earthwork features. However, the Sky View Factor plot would not in most cases stand alone as a replacement for the more expressive relief plots and the additional processing time might perhaps be as easily spent working with varied illumination directions. The best results within the original SVF paper (Kokalj *et al*. 2011) related to structural remains, apparently all surveyed at a high

(0.5m) resolution. SVF picked out wall lines where conventional relief shading showed only a low building platform. On an individual site basis SVF certainly represents a useful extra tool in the kit, but on a wider landscape scale not yet a replacement for the more conventional, and more easily readable, relief shading. Experiments with Solar Insolation Modelling (using both SAGA and GRASS GIS software) have not produced plots with anything like the clarity of those presented in Challis *et al*. (2011) where some of the examples presented do present sufficient clarity to stand alone as the primary survey product. This may reflect better familiarity with the effects of variation in input parameters but perhaps also a difference in the way the GIS programs calculate or represent the results of such modelling. The better results may be somewhat platform dependent and not as easily achievable with other software as the authors suggest. However, this technique certainly seems to offer much promise as an interpretative tool and of the techniques trialled is certainly worth pursuing.

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