Cottam Solar Project

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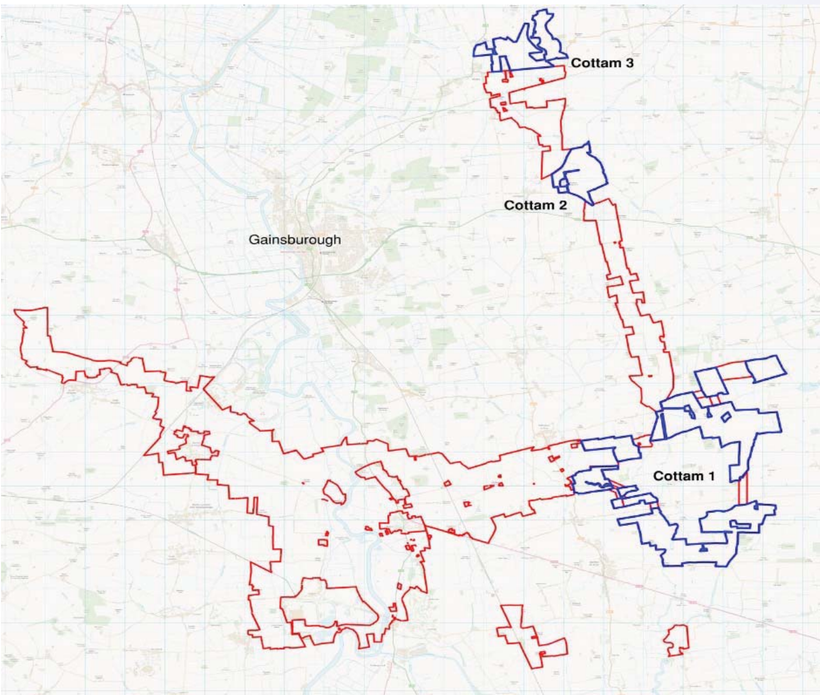
Cottam
SOLAR PROJECT



Cottam Solar Farm, Lincolnshire

Geoarchaeological Assessment Report

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Cottam Solar Farm Geoarchaeological Assessment Report

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Summary

The aim of this desk-based assessment is to investigate and characterise the geoarchaeological potential of the site of the proposed Cottam Solar Project and associated cable routes, to help identify areas of enhanced geoarchaeological interest.

The development lies within the wider Trent Valley, an area known for its rich floodplain archaeology, with evidence of fish traps, log boats, historical mills and bridges, all recovered from postglacial sand and gravel deposits, sealed beneath thick fine-grained alluvium. Low-lying broad river valleys provide access to riverine resources and have previously produced evidence of both ritual and settlement activity.

The geoarchaeological assessment report has shown that there is potential for features such as palaeochannels and gravel islands to exist within the development areas. Previous historic borehole data available across the sites are of little value, as the data lack specific criteria such as altitude records and do not discriminate superficial deposits where identified. Data for generation of a deposit model could, however, be obtained from future engineering interventions especially if consideration is given to positioning interventions in areas likely to yield geoarchaeological information.

Acknowledgements

The project was managed for Oxford Archaeology by Fraser Brown. The report was written by Mairead Rutherford. GIS support was provided by Hannah Leighton and the illustrations were completed by Anne Stewardson.

1 INTRODUCTION

1.1 Scope of work

1.1.1 Oxford Archaeology (OA) was commissioned by Cottam Solar Project Ltd to undertake a desk-based geoarchaeological assessment relating to the Cottam Solar Project, the sites of which are in Lincolnshire and, in part, Nottinghamshire.

1.2 Location

1.2.1 The sites of Cottam 1, 2 and 3 proposed solar farms occupy approximately 1267ha of land that lie to the east of the River Trent, in north-west Lincolnshire (Fig 1). Cottam 1 is north of Sturton by Stow; Cottam 2 is east of Corringham and Cottam 3 is north and east of Blyton.

1.2.2 The sites are to be connected to each other via a narrow cable corridor and to a connection point at Cottam power station. The exact route of the cable corridor is currently undetermined and these areas are therefore considered as search areas (Lanpro 2022, 3.3). The areas of potential cable routes are included in the geoarchaeological assessment.

1.3 Topography and geomorphology

1.3.1 The low-lying landscape of the Cottam sites is characterised by extensive areas covered by historical drainage systems. Extant river channels include those of the River Till, a tributary of the River Witham (which drains into the Wash) but which is connected eastwards via the Fossdyke to the River Trent at Torksey (Cottam 1), Corringham and Yawthorpe Becks (Cottam 2) and Northorpe Beck, tributaries of the River Eau, itself a tributary of the River Trent (Cottam 3).

1.3.2 The River Trent rises in Biddulph Moor, Staffordshire and drains into the Humber Estuary (after it has joined the Rive Ouse) (Howard *et al* 2008). The middle reaches of the River Trent, between Weston and Gainsborough, are characterised by a medium energy, anastomosing and meandering system, within a developed floodplain. In contrast, downstream from Gainsborough, the floodplain is broad and dominated by fine-grained sedimentation, with the river channel showing lateral stability (Baker 2007). Traditionally, the fine silt (warp) load of the Trent in its lower reaches, has been used to improve the soils via warping (allowing water to enter fields through warping drains), for example, Morton Warping drain near Gainsborough. The British Geological Survey (BGS) has mapped “warp” deposits to the west of the Cottam 3 site, extending either side of the River Trent.

1.3.3 The altitude of the development sites is generally very low, below the 20m OD contour. To the east of Cottam sites 1-3, the land rises to form a distinctive sloping ridge, forming a prominent landform. This area of upstanding geology, the ‘Lincoln Cliff’ (also known as the Lincoln Edge or Lincolnshire Edge) comprises a north-south trending ridge of Jurassic rocks, standing approximately 50m above the surrounding flat landscape. Closely following the escarpment is an ancient trackway, an extension of the Jurassic Way (B1398/Middle Street), linking Lincoln with the Humber.

1.3.4 The general distribution of soil types in the proposed sites reflect floodplain areas, indicative of wet meadows prone to flooding. There is also arable/horticultural landuse with some grassland and woodland.

1.4 Geology

1.4.1 The bedrock at the Cottam sites 1-3 is of Triassic and early Jurassic age, comprising largely mudstones of the Scunthorpe Mudstone Fm, Penarth Group and Charmouth Mudstone Fm. The beds dip such that progressively younger strata are present further east (British Geological Survey (BGS) 2022).

1.4.2 The development sites of Cottam 1-3 are bounded to the east by the Jurassic escarpment of Lincolnshire Edge and, further east and south, by the Lincolnshire Wolds escarpment of Cretaceous age, and to the west by older, low hills of Triassic age.

1.5 LiDAR analysis

1.5.1 LiDAR digital images for the development areas are interpreted to show a largely flat, slightly undulating topography, intersected with valley sequences, river channels, palaeochannels and drainage channels.

1.6 Archaeology

1.6.1 The data covering the archaeological aspect of the project are documented in the Environmental Impact Assessment Scoping Report (Lanpro 2022). Of significance is the presence of the excavated Viking site at Torksey (Hadley and Richards 2016). This site is located outside the site boundaries, on a bluff in a bend of the River Trent but may potentially fall within or very close to a cable corridor to connect the solar farms to Cottam Power Station.

2 AIMS AND METHODOLOGY

2.1 Aims

2.1.1 The project aims and objectives are as follows:

i. To review published geoarchaeological and significant palaeoenvironmental data relevant to the sites.
ii. To provide mapped geological and superficial data relevant to the site, to characterise the sediments.
iii. To examine topographical and LiDAR data to identify features such as palaeochannels and gravel islands.
iv. To assess availability of borehole / trial pit interventions that could be used to construct a geoarchaeological model for the site.
v. To consider how the superficial deposits at the sites may hold potential for recovery of archaeological artefacts and ecofacts, highlighting any geoarchaeologically significant zones or deposits.

2.2 Methodology

2.2.1 A review of geoarchaeological and palaeoenvironmental studies relevant to the Cottam Solar Project includes reference to published data and information sourced from academic studies (theses) and grey literature. Although the upper and middle Trent Valley floodplains have been the subject of years of research (e.g. Howard 2004; 2005; Howard *et al* 2008; 2011), the lower reaches of the floodplain have received less attention.

2.2.2 No geotechnical logs, from boreholes or trial pits for the Cottam sites, are available to use to generate a specific deposit model. The database for survey of the superficial and bedrock geology is therefore based on BGS (2022) mapping. Historic borehole data occur across the site; however, much of the data are denoted as confidential. A list of accessible borehole data, within and adjacent to the sites, is tabulated in Appendix A.

2.2.3 Topographical maps and LiDAR images have been scrutinised to identify features that could mask or seal potentially important archaeology. Such features include identification of potential gravel islands (topographic highs) as well as palaeochannels.

3 RESULTS

3.1 Introduction and presentation of results

3.1.1 The results of the desk-based assessment are presented below, including an initial detailed review of geoarchaeological data and background palaeoenvironmental data. A series of maps for the study area accompany the text (Figs 2-7), showing geological, geomorphological topographical (LiDAR) data, presented by site. These data are then used to infer the likely geoarchaeological context for each of the sites.

3.2 Geoarchaeological background

3.2.1 A geoarchaeological study of the middle and lower Trent Valley has shown that OSL dating of glacio-fluvial deposits returned dates from between 212ka and 10.9ka, representing several glacial and inter-glacial phases (Schwenninger *et al* 2007). Deposits within the Bole Ings palaeochannel, in the lower Trent floodplain just south of Gainsborough, record Devensian sands and gravels, including the Holme Pierrepont Sand and Gravel Member (named River Terrace), overlain by a thick sequence of alluvial deposits (Dinnin and Brayshay 1999; Stein 2014). Further south and west, at Farndon Fields, Newark-on-Trent, coversands overlying the Holme Pierrepont Sand and Gravel Member have been dated by OSL to the Windermere Interstadial (Garton *et al* 2020) and were found to seal lithic scatters of late Upper Pleistocene age (Cooke and Mudd 2014; Garton *et al* 2020).

3.2.2 River confluences within the middle and lower Trent Valley, for example, the confluence of the Trent and Derwent (Krawiec 2012; Howard 2005), have also been subject to geoarchaeological research. These studies show the importance of identifying thick layers of alluvium, distributed across the floodplain areas, as these deposits, which may include accumulations of organic sediments, have the potential to preserve both cultural and environmental archaeology. Peat and organic deposits, when found within these deposits, allow for precise dating of specific pre-Holocene and Holocene palaeochannels (Stein 2014). Aston Bank, a palaeochannel of the River Trent, at Shardlow, Derbyshire, is one such example (Krawiec 2012). Palaeochannel mapping of the lower Trent north of Gainsborough has revealed very few surface-visible palaeochannels, as a consequence of thick deposits of alluvium masking the sub-surface topography (Baker 2007). However, the palaeochannel sequence from Bole Ings, was found to contain an important sedimentological and palaeoenvironmental record (Dinnin and Brayshay 1999). Boreholes in this area have indicated a maximum of *c* 9m of Holocene alluvium, including peaty silty-clay deposits.

3.2.3 During the early Holocene, a relatively open and unstable floodplain environment was also described by Dinnin (1992) from a palaeochannel sequence at Girton (approximately 25km upstream from Bole Ings). The floodplain was characterised by a dynamic, braided channel but by *c* 6000 BC, the Trent had evolved an anastomosing or single channel regime, leading to floodplain stabilisation.

3.2.4 The appearance of the lower Trent floodplain during the Bronze Age and Iron Age has been described by Knight and Howard (2004) as a rich wetland area with channels flowing across the valley floor. Continued clearance of woodland from the floodplain and gravel terraces as well as adjacent upland areas would have resulted in a more open landscape. This landscape would then have been prone to soil erosion and re-deposition of both colluvium and alluvium. The main channel would have remained active but minor streams and abandoned channels fringed by reed swamp would have accumulated under low energy conditions.

3.2.5 There is sedimentological and palaeoenvironmental evidence that major channel shifting took place within the lower Trent Valley during the Iron Age. At Sturton le Steeple, peat deposition that had formed in the Bronze Age, ended during the early Iron Age (Howard 2004). The deposits at Bole Ings show a change from woody peat and organic clays to silty alluvium during the mid-late Iron Age (Dinnin and Brayshay 1999). At Cottam, 4m of alluvium covers Bronze Age peat deposits, which appear to have ended abruptly following a shift in the course of the Trent (Scaife and Allen 1999).

3.2.6 Sediment coring and radiocarbon dating of peat sequences east of the Viking Camp at Torksey, have revealed that a palaeochannel of the Trent existed at the site up until the Bronze Age (Hadley *et al* 2016). Siltation of the river further north resulted in the palaeochannel being cut off from the main channel, permitting peat to accumulate into the late medieval period and the surrounding lowland area east of the camp remained a wetland area. Sediment mapping to the north and south of the site recorded silt but no peat, suggesting that these areas remained open to the Trent, with the area to the north flooding regularly due to the tidal impact of the Trent (Hadley *et al* 2016).

3.2.7 Deforestation and intensified land use activity, which begun during the Iron age and continued during the Roman Period, lead to an increase in sediment load of regional river systems (the Don, Trent, Idle and Ancholme) and consequent deposition of thick deposits of fine-grained alluvium across the floodplain during the later part of the Roman Period (Tweddle 2001).

3.2.8 Deep alluvial deposits began to accumulate across the lower Trent floodplain during the Roman and post-Roman periods, for example, at Littleborough – situated on a gravel island to the west of the present course of the Trent (Stein 2014). Abandonment of land around Sturton le Steeple (which is also located on an island and terrace of sand and gravel, with peat of Late Bronze Age to Iron Age surrounding the gravel island) suggests the Iron Age/Romano-British field systems had become unusable even for grazing, due to flooding and alluvial infilling (Stein 2014). A single wooden stake, radiocarbon dated to 790 to 1030 AD, was recovered from peat deposits infilling Roman features at Sturton le Steeple (Elliott 2004; Stein 2014).

3.2.9 At Torksey golf course, a buried Mesolithic soil (palaeosol) was found to overlie an aeolian drift deposit (Johnson and Palmer-Brown 1997). The palaeosol was covered by a fluvial basal sand, which was itslef overlain by a peat deposit. Radiocarbon dating was interpreted to suggest the peat deposit had started accumulating in the late Bronze Age and may have stopped by Romano-British times but the deposit was truncated (perhaps by post-medieval ploughing). The variation in deposit type between the west and east banks of the river is perhaps due to channel structure and direction (Stein 2014).

3.2.10 Attempts at flood alleviation from around 1485 AD to the present day have resulted in a mosaic of drainage channels all across the lower Trent Valley, resulting in the loss of the natural wetland environment. Channel re-direction and building up of blankets of alluvium (warp) are clearly present at Cottam, North Leverton and Sturton le Steeple, while at West Burton and Bole, the channel was re-directed and straightened, with palaeochannels still clearly visible (Stein 2014).

3.2.11 A recent geoarchaeological study for an area of 280 hectares south of Newark-on-Trent (OA North 2022) for which a deposit model (based on borehole and trial trench interventions) was produced, identified potential terrace edge environments, sandy spurs, floodplain islands, river confluences and palaeochannels, that could have been a focus for human activity. The floodplain islands are separated from extensive deposits of Pleistocene gravel terraces mapped at the valley margins, by a series of alluvium-rich palaeochannels. The islands, gravel terraces and palaeochannel sequences have the potential to preserve archaeological and palaeoenvironmental remains.

3.3 Palaeoenvironmental background

3.3.1 A palaeoenvironmental record is available for an excavation site at Messingham (Carrott *et al* 1997), located approximately 10km north of the most northerly site (Cottam 3). The pollen and plant remains from this site agree with an earlier beetle study from beneath coversands at Messingham (Buckland 1982) that described cold, typically lateglacial sedge-dominated fen conditions.

3.3.2 The most detailed palaeoenvironmental work from the lower Trent is from the Bole Ings palaeochannel, located to the west of the Trent, spanning the early to later Holocene period (Mesolithic to early Iron Age) (Dinnin and Brayshay, 1999). The data have been interpreted to suggest alder-dominated low energy floodplain/backswamp environments with wetland margins along the river bank and gravel islands/ridges on the floodplain, providing habitats for pine woods as well as mixed deciduous woodland. Disturbed habitats during the early Holocene are linked to hydrological changes (for example, waterlogging), possibly in response to rising sea level changes and floodplain aggradation (Dinnin and Brayshay, 1999).

3.3.3 The Elm Decline has been identified at Bole Ings (Dinnin and Brayshay 1999) and broadly correlated with that event at Cottam, with the presence of cereal pollen in post-Elm Decline assemblages recorded at Cottam (Scaife and Allen 1999). Evidence associated with possible tree clearance in the wider landscape, including a Bronze Age decline in lime (dated 2140-1740 cal BC (3579±70 BP; BETA-75271) has been associated with a peak in microcharcoal particles, and together have been interpreted to signify anthropogenic forest disturbance beyond the floodplain, with no evidence of disturbance to the dense alder carr occupying the floodplain (Dinnin and Brayshay 1999). Beetles from borehole sediments from Sturton le Steeple also support development of alder-rich fen carr woodlands on the lower Trent floodplain, with expansion of wetland areas throughout the early Bronze Age and into the Iron Age (Howard 2004).

3.3.4 Land beyond the floodplain was subject to arable and pastoral agricultural activity, dated 1120-540 cal BC (2690±100 BP; BETA-75270) at Bole Ings, and has been interpreted as evidence to support exploitation of areas such as the gravel terraces during the early Iron Age (Dinnin and Brayshay, 1999).

3.3.5 The evidence from peat accumulation at Torksey, suggests the area continued to exist as a wetland throughout the early medieval period, whereas the area north of this site would have been susceptible to the tidal influences of the lower Trent (Hadley *et al* 2016).

3.4 Geological, geomorphological and topographical data

Cottam 1

3.4.1 This solar farm site occupies a large area, of approximately 894ha (Fig 1). Bedrock geology is made up of a series of sequentially younger mudstone formations of early Jurassic – latest Triassic age. These are the Scunthorpe Mudstone Formation (oldest) in the area between Willingham by Stow and Sturton by Stow, and the Charmouth Formation further east (of early Jurassic, Sinemurian-Pliensbachian age; Fig 2). Historic borehole data are limited across the site; available boreholes show bedrock often very close to the surface (Appendix A). Up to 2m of glacial sands and gravels are present in boreholes from near Stow with deposits of alluvium, sand and gravel of approximately 2m thick, present in boreholes from Sturton by Stow (Appendix A).

3.4.2 The superficial sediments comprise Till deposits across much of the site, with alluvial sediments along the river courses; river terrace deposits are also identified (Fig 3). To the east of Willingham by Stow and Sturton by Stow, within the site boundary, the diagonal course of the River Till is associated with deposits of alluvium, as are tributaries further east. To the northwest, undifferentiated river terrace deposits are recorded (Fig 3). The deposits of the site to the north, west of Fillingham, are mapped by the BGS (2022) as largely of mid-Pleistocene Till with some strips of alluvium along stream/river courses. Numerous drains, sourced from the River Till, criss-cross the site. Blank areas exist within the site boundaries, for which no data regarding superficial deposits are available.

3.4.3 LiDAR and contouring images for Cottam 1 show a gentle variation in altitude from approximately 10m in the western part of the site to approximately 20m in the east (Fig 4a). The LiDAR image reveals a tributary of the River Till adjacent to river terrace and alluvium deposits; the river terrace deposits are within the site boundary. Palaeochannel features are present within the site, for example, a palaeochannel of the River Till may be seen towards the west (Fig 4b).

3.4.4 The proposed cable route between Cottam 1 and Cottam 2 appears to run through Till deposits, although the point of contact with Cottam 1 may traverse some alluvial deposits. The cable route boundary for Cottam 1, at its western side closest to the Trent, lies adjacent to the excavated Viking Great Camp north of the village of Torksey (Fig 1). The extended cable route corridor linking to the Cottam power station and substation, on the western side of the Trent, crosses sands and gravels of the Holme Pierrepont terrace deposit as well as alluvium deposits.

Cottam 2

3.4.5 The area of this solar farm covers approximately 132ha and is located near Corringham (Fig 1). Geological bedrock comprises the Scunthorpe Mudstone Formation (mudstones and interbedded limestones, encompassing rocks of late Triassic – early Jurassic age; Fig 5). There are no borehole interventions within the boundary of the site; the nearest BGS borehole (SK89SE118) for which data are available is from outside the site boundary, west of Corringham Beck. These data record 5.7m of glacial sands and gravels overlying bedrock (Appendix 1).

3.4.6 The mapped superficial deposits show that most of the area is underlain by sands, gravels and Till of mid Pleistocene age (BGS 2022; Fig 6). Deposits of alluvium cover the length of Yawthorpe Beck and, at the confluence of Corringham Beck with Yawthorpe Beck (tributaries of the River Eau), a small arc of undifferentiated sands and gravels have been identified as River Terrace Deposits, just outside the site boundary (Fig 6). The LiDAR image (Fig 7) shows a possible palaeochannel, after the confluence.

3.4.7 The cable route between Cottam 1 to Cottam 2 and between Cottam 2 to Cottam 3 traverses glacial Till deposits.

Cottam 3

3.4.8 This solar farm site occupies approximately 241ha. It is centered to the east of Blyton (Fig 1). The geology comprises largely clays of the Scunthorpe Mudstone Formation (mudstones and interbedded limestones, encompassing rocks of late Triassic – early Jurassic age) (Fig 8). Historical borehole data (BGS-SK89 series) record brown and blue clays; however, the ages are unassigned but probably reflect boulder clay/glacial deposits overlying bedrock ('Blue Lias') deposits.

3.4.9 The superficial geology is dominated by mid Pleistocene Till deposits (Fig 9). The cable route corridor between Sites 3 and 2, also traverses mid Pleistocene Till deposits.

3.4.10 The terrain data permit identification of slightly higher ground within the eastern part of the site (Fig 10). There are a few small waterbodies present adjacent to the site, but these appear as probable artificial ponds.

3.5 Geoarchaeological deposits

3.5.1 A Without further data it is not possible to construct a geoarchaeological deposit model for the superficial deposits to bedrock, for any of the Cottam sites. However, BGS (2022) mapped superficial and bedrock deposits for the four West Burton sites permits an interpretation of the likely sequence of stratigraphic succession (Table 1).

Stratigraphic Unit	Environment of Deposition	Archaeological Potential
Topsoil	Modern agricultural ploughsoil	Could contain redeposited pottery or lithic material brought to the surface through ploughing and sub-surface disturbance.
Warp	Modern flooding for soil improvement. Mapped by the BGS to the west of the Cottam 3 site, along the River Trent.	Has the potential to seal *in-situ* historic and pre-historic archaeology.
Colluvium	Potential Modern and Ancient soil movement associated with agriculture and vegetation clearance.	Potential to contain re-deposited pottery and lithic material from historic and prehistoric activities on higher ground/slopes and to seal historic and pre-historic archaeology.
Alluvium / Fluvial deposits	Holocene alluviation associated with overbank alluviation and migrating river channels associated with the Rivers Trent, Till, Eau and the becks, Yawthorpe, Corringham and Northorpe.	Has the potential to seal *in-situ* historic and pre-historic archaeology.
Peat / Organic Alluvium	Periods of stabilisation or channel migration that result in encroachment of vegetation. Peat mapped by the BGS to the west of Cottam 3 but could occur within alluvial deposits.	Prehistoric potential.
Pleistocene sands	Aeolian coversands / riverine alluvial deposits overlying the Holme Pierrepont Sands and Gravels (named River Terrace unit), on the floodplain of River Trent.	Palaeolithic potential.
Pleistocene sands and gravels	Undifferentiated Pleistocene terrace deposits – differentiation of which is largely based on altitude and mapping, including the Holme Pierrepont Sands and Gravels (named River Terrace unit).	Palaeolithic potential.
Pleistocene Till	Deposits of sands and gravels deposited by and underneath glaciers.	None.
Bedrock	Geological strata (dominantly mudstones of early Jurassic – late Triassic age.	None.

Table 1: description of site stratigraphy

3.5.2 *Bedrock:* In the development areas, this comprises mudstones of Triassic to early Jurassic age. Reports from boreholes, accessed through the BGS (Geology of Britain Viewer; April 2022), record, for example, bedrock deposits of “Lower Lias” mudstones (early Jurassic-latest Triassic) (e.g. SK89SE118, SK89SE119).

3.5.3 *Pleistocene deposits*: The Devensian (last) glaciation, which ended approximately 12.5ka BP covered east Lincolnshire to the Wolds, but the Trent Valley, south of the Isle of Axholme, was largely ice free during the Devensian. A reconstruction shows the maximum extent of the Devensian glaciation (red line) and the extent of glacial Lake Humber, which inundated the landscape south to Lincoln (Baker *et al* 2013; Fig 11). In the Late Devensian (*c* 12,000ka BP), the lower Trent Valley was situated close to glacial Lake Humber, which was formed as a result of the North Sea Ice Lobe that caused the blocking up of the Humber Estuary and its tributaries (Howard 2001). The silting up and drainage of this large glacial body of water led to early accumulations of sediments along the Trent Valley (Howard 2001). The draining of Lake Humber and other glacial and post-glacial run-off resulted in a very active alluvial channel, and the formation of the Trent Valley terrace sequence. No named units of the Trent Valley terrace sequence have been identified from BGS mapping for Cottam sites 1-3, but the Holme Pierrepont Sand and Gravel named terrace unit is present along the cable corridor search route, west from Cottam 1.

3.5.4 Throughout the Cottam sites, small quantities of undifferentiated river terrace deposits have been identified. These deposits may be indicative of fast-moving braided channels, resulting in development of possible gravel islands. The gravel islands could have played a key role in the development of human settlements, as these islands may have been a focus for human settlement and activity on the otherwise low-lying river valleys. The river terrace deposits identified at Cottam 1 may represent a possible gravel island, occurring at approximately 10m above the river floodplain of the River Till.

3.5.5 The superficial sediments of much of northern Lincolnshire comprise, in part, cold-climate aeolian sands (coversands). The Lincolnshire coversands extend from the Humber in the north to beyond Gainsborough in the south and although most coversand deposition seems to have occurred between 13-11ka BP, localised re-activation of these sediments has occurred during the Holocene and up to the present day (Bateman and Buckland (2001) (Fig 11). The coversands can occur directly on bedrock or overlying river terrace deposits. Further south and west, at Farndon Fields, Newark-on-Trent, coversands overlying the Holme Pierrepont Sand and Gravel Member (river terrace deposit) have been dated by OSL to the Windermere Interstadial (Garton *et al* 2020) and were found to seal lithic scatters of late Upper Pleistocene age (Cooke and Mudd 2014; Garton *et al* 2020). BGS (2022) mapping shows coversands (Sutton Sand Fm) are present to the north of Cottam 3, but outside the site boundary.

3.5.6 *River terrace deposits*: Undifferentiated sand and gravel deposits associated with river terraces are mapped within the study area, for example, in the area of Cottam 1, to the east of Willingham on Stow. The age of these deposits is uncertain and is assigned a broad Quaternary (includes the Pleistocene and Holocene) age by the BGS. A small arc of river terrace deposits, and associated alluvium, are also recorded within/adjacent to the area of Cottam 2.

3.5.7 *Holocene alluvial and peat deposits*: During the early Holocene, as the sea level began to rise, thick swathes of alluvium were deposited within the floodplain of the Lower Trent Valley (Howard *et al* 1999). The Lower Trent is a wide, meandering valley, with low energy and high sediment load output, and the size of the channel allows for deep accumulation of alluvium across the valley (Stein 2014).

3.5.8 Alluvium and peat are currently actively accumulating throughout the Lower Trent Valley (Stein 2014). Consolidation of drainage and alluvial channels has led to the accumulation of pockets of peat where alluviation has not eroded wetland sedimentation. Mapping by Challis (2002) in association with the Trent Valley Geoarchaeological Group, determined that the Lower Trent was covered in fine-grained alluvium with reworked gravels and sands. Records from boreholes have shown alluvial deposits ranging from 2.5m at Cottam to 5.7m overlying terrace sediments at Littleborough (Havelock *et al* 2002, 48). Extensive areas of alluvial deposition occur along the River Till and smaller tributaries of the River Eau, that flow within or close to the Cottam 1-2 sites.

3.5.9 Although Challis (2002) found little evidence for peat and organic sediments within the Lower Trent Valley, excavations and coring have produced occasional organics, for example, peat was recovered to the west, from Sturton le Steeple, within a Romano-British ditch on the present floodplain (Howard 2004; Knight 2000). The presence of late Holocene deposits such as this demonstrates that there may be other features such as abandoned palaeochannels that may hold palaeoenvironmental and dateable organics. Peat deposits are mapped by the BGS (2022) within the extended cable route link across the Trent between Cottam 1 and the Cottam power station/substation.

3.5.10 *Holocene colluvium deposits*: Colluvium deposits represent Holocene slope deposits associated with de-vegetation and agricultural practices. They have the potential to bury land surfaces and earlier deposits that could be associated with worked lithics.

3.5.11 *Warp*: The main area of warp deposition, mapped by the BGS (2022), occurs to the north of the development sites.

3.6 Summary table of potential

3.6.1 The geoarchaeological/palaeoenvironmental potential of features and deposits discussed above are presented by site below (Table 2). This is further differentiated into zones of high, medium or low potential, based on the extent and nature of the deposits found within the site area. It should be noted that this potential is often specific to discrete regions of these zones (eg palaeochannels, valley systems, mires etc), rather than the zone in its entirety.

3.6.2 Deposits of geoarchaeological potential reflect sediment accumulations that could be targeted for further work, for example, targeted ground investigation work or geoarchaeological survey across key sequences. Deposits of palaeoenvironmental potential are more likely to contain organic sediments that may hold prime data for establishing chronological and vegetational histories. The distinction between high, medium and low potential, is based on the extent and nature of the deposits found within the site area.

3.6.3 All these distinctions also take into consideration the potential for these zones to have acted as foci for past human activity and for the evidence of such activity to be preserved. Humans were often drawn to watercourses, springs and wetland-edge environments, as well as the valley slopes. Deposits can seal buried land surfaces associated with well-preserved archaeological features, structures or *in-situ* artefact assemblages, and areas of higher ground or islands could have been favoured for settlement. Much of the area covered by the sites of the study area, lies outside, and on the edges of, the main drainage pattern. Areas such as this were often used as communication routes between lower-lying and higher ground. Within them deposit sequences and archaeological sites could have been protected from the the effects of fluvial erosion and well-preserved remains do not necessarily have to be buried at great depths to survive.

Table of Potential							
		Geoarchaeology			Palaeoenvironmental		
Site name	**Feature/Deposit**	**High**	**Med**	**Low**	**High**	**Med**	**Low**
Cottam 1	Palaeochannel	x	x		x	x	
Cottam 1	Alluvium	x	x			x	
Cottam 1	River terrace	x	x			x	x
Cottam 1	Till			x			x
Cottam 1-2 cable route	Alluvium	x				x	
Cottam 1 cable route (west)	Alluvium	x				x	
Cottam 1 cable route (west)	River terrace (Holme Pierrepont)	x	x			x	
Cottam 2	Palaeochannel	x	x		x	x	
Cottam 2	River terrace		x			x	x
Cottam 2	Alluvium		x			x	
Cottam 2	Till			x			x
Cottam 2-3 cable route	Till			x			x
Cottam 3	Till			x			x

Table 2: Summary of geoarchaeological/palaeoenvironmental potential

4 Discussion

4.1 Significance of deposits

4.1.1 A large geographical area, stretching south from the Humber estuary to north of Newark, with Gainsborough roughly in the centre, represents the modelled extent of former glacial lake Humber (Bateman *et al* 2018; Baker *et al* 2013). The potential therefore exists for the survival of prehistoric remains at or near possible former water edge / wetland environments within the development areas, but these are likely to be buried underneath thick deposits of alluvium.

4.1.2 Mapping floodplain channels and topography of the Cottam Solar Project and the integration of these data with LiDAR, has demonstrated that features likely to be of archaeological importance can be identified. This follows similar geoarchaeological approaches in other areas of the Trent (Challis *et al* 2011; OA North 2022).

4.1.3 River terrace deposits within the central region of Cottam 1 may represent potential topographic highs or sand islands that may have been attractive to prehistoric people. Further thin deposits identified as river terrace deposits are present close to the northern boundary of Cottam 2. The broader corridor between Cottam 1 and the Cottam power station crosses the Trent, potentially in areas where gravel islands might occur.

4.1.4 The scrutiny of topographic maps and LiDAR has permitted identification of potential palaeochannels, for example, near Cottam 1 (palaeochannel of the River Till) and at Cottam 2, adjacent to the confluence of Corringham/Yawthorpe becks and the River Eau. Palaeochannels have the potential to contain buried archaeology, as well as to retain important palaeoenvironmental data that could be used for environmental reconstruction. As previously described, such data was obtained from locations adjacent to the Cottam sites/cable corridors. For example, at Torksey (Stein 2014), and further south on the Trent, at Girton (Baker *et al* 2013), as well as palaeochannel sequences occurring further north, for example, at Bole Ings (Dinnin and Brayshay, 1999).

4.1.5 Mapping of superficial deposits by the BGS (2022) has recorded accumulations of alluvial sediments across sections of the Cottam sites, including across the cable corridor between Cottam 1 and the Cottam power station, representing (in part) low-energy environments depositing organic silts and clays, and sometimes peat, suggesting potential wetland margin locations with vegetated palaeoenvironments. Alluvial deposits may represent channels or streams visited by people drawn to these sites for hunting, fishing, transport or other reasons.

4.1.6 BGS borehole data across all the sites are largely historic and of limited use in construction of a deposit model. The records often lack altitudinal data and have been sited to focus on bedrock geology rather than superficial deposits.

5 RECOMMENDATIONS

5.1 Further work

5.1.1 In order to groundtruth the findings of the geoarchaeological assessment, several survey methods could be employed:

- Identification of unmapped superficial deposits at the sites, to characterise the sediments and provide a more complete dataset for geoarchaeological modelling.

- Targeted borehole surveys through possible sediment sequences (including alluvial/peaty; colluvial and aeolian deposits) would potentially provide stratigraphic data and material for dating, provide chronological control and aid construction of a deposit model. The siting of any interventions for engineering works could also have a dual target of obtaining geoarchaeological data and it would probably be cost efficient to integrate geoarchaeological survey, of targeted higher-potential areas of deeper sediment packages, with engineering ground investigation surveys. Work there should be monitored by a geoarchaeologist, for deposit modelling purposes.

- Archaeological field evaluation is recommended to assess the archaeological potential of the different geomorphological zones within floodplain areas. This could be achieved using a combination of hand-dug test pits and mechanically excavated test pits/trenches and could be undertaken in parallel with other ground investigations and/or archaeological investigations.

- Integration of all datasets (new borehole data, superficial mapping and archaeological survey results) would result in production of deposit models to characterise areas of archaeological potential in greater detail.

6 BIBLIOGRAPHY

Baker, C, Bateman, M, Bateman, P, and Jones, H, 2013 The aeolian sand record in the Trent Valley, *Mercian Geologist*, 18(2), 108-118

Baker, S, 2007 *The palaeochannel record in the Trent Valley UK: contributions towards cultural heritage management* [Online] Available at: [redacted] (accessed April 2022)

Bateman, M D, Evans, D J A, Roberts, D, H, Medialdea, A, Ely, J and Clark, C D 2018 The timing and consequences of the blockage of the Humber Gap by the last British-Irish Ice Sheet, *Boreas*, 47, 41-61

Bateman, M D, Buckland, P C, Frederick, C D, and Whitehouse, N J, (eds) 2001 *The Quaternary of East Yorkshire and North Lincolnshire Field Guide,* Quaternary Research Association, London

Bateman, M D, and Buckland, P C, 2001 Late Quaternary Record from Beyond the Icesheets, in M D Bateman *et al* (eds) *The Quaternary of East Yorkshire and North Lincolnshire Field Guide,* Quaternary Research Association, London, 13-20

British Geological Survey (BGS), 2022 Geology of Britain viewer (classic) [Online] Available at: h[redacted] (accessed April 2022)

Bridgland, D R and Westaway, R 2008 Climatically controlled river terrace staircases: a worldwide Quaternary phenomenon, *Geomorphology*, 98, 285-315

Buckland, P C, 1982 The coversands of North Lincolnshire and the Vale of York, in (eds) B H Adlam, C R Fenn and L Morris, *Papers in Earth Studies*, Geobooks, Norwich, 143-178

Carrott, J, Hughes, P, Kenward, H and Large, F, 1997 *An evaluation of biological remains from excavation at Messingham, North Lincolnshire*, Reports from the Environmental Archaeology Unit, York, 97/48, 5

Challis, K, 2002 *Component 3: Alluvium Depth and Character Modelling*, Trent Valley Geoarchaeology, York

Challis, K, Chris, C, Kincey, M, and Howard, A J, 2011 Assessing the preservation potential of temperate, lowland alluvial sediments using airborne LiDAR intensity, *Journal of Archaeological Science*, 38, 301-311

Cooke, N, and Mudd, A, 2014 *A46 Nottinghamshire: The Archaeology of the Newark to Widmerpool Improvement Scheme 2009*, Cotswold Wessex Archaeology

Cooper, T, 2008 *Laying the Foundations: A history and archaeology of the Trent Valley sand and gravel industry*, CBA Research Report 159, Council for British Archaeology, York

Dinnin, M H, 1992 Islands within islands: the development of the British entomofauna during the Holocene and the implications for conservation, Univ of Sheffield, Unpubl PhD thesis

Dinnin, M H, and Brayshay, B, 1999 The contribution of a multiproxy approach in reconstructing floodplain development, in S B Marriott and J Alexander (eds), *Floodplains: Interdisciplinary Approaches*, Geological Society of London Special Publication, 163, Bath, 179-95

Elliott, L, 2004 *Archaeological evaluation at Sturton le Steeple, Nottinghamshire*, Nottingham: Trent and Peak Archaeological Unit, unpubl rep

Garton, D, Barton, N and Bateman, M D, 2020 Farndon Fields, Newark, Nottinghamshire: Windermere Interstadial deposits with potential for Late Upper Palaeolithic human activity, *Mercian Geologist*, 20, 5-14

Hadley, D M, and Richards, J D, 2016 The Winter Camp of the Viking Great Army, AD 872-3, Torksey, Lincolnshire, *The Antiquaries Journal*, 96, 23-67

Havelock, G, Carrott, J, Gearey, B, Howard, A, Hall, A, Kenward, H, and Marshall, P, 2002 *Component 11a: Extending and Protecting Palaeoenvironmental Data: Deposit Sampling* Advancing the Agenda in Archaeology and Alluvium, Trent Valley Geoarchaeology, York

Howard, A J, 2004 Geoarchaeological analysis, in Elliott 2004, Archaeological evaluation at Sturton le Steeple, Nottinghamshire, Nottingham, Trent and Peak Archaeological Unit, unpubl rep

Howard, A J, 2005 The contribution of Geoarchaeology to understanding the environmental history of the Trent Valley, UK, *Geoarchaeology*, 20, 93-107

Howard, A J, Bateman, M D, Garton, D, Green, F M L, Wagner, P and Priest, V, 1999 Evidence of Late Devensian and early Flandrian processes and environments in the Idle Valley at Tiln, Nottinghamshire, *Proceedings of the Yorkshire Geological Society*, 52, 383-393

Howard, A J, Brown, A G, Carey, C, Challis, K, Cooper, L P, Kincey, M, and Toms, P, 2008 Archaeological resource modelling in temperate rivers: a case study from the Trent Valley, UK, *Antiquity*, 82, 1040-1054

Howard, A J, Carney, J, Greenwood, M, Keen, D, Mighall, T, O'Brien, C and Tetlow, E, 2011 The Holme Pierrepont sand and gravel and the timing of Middle and Late Devensian aggradation in the English Midlands*, Proceedings of the Geologists' Asso*ciation, 122, 419-431

Johnson, S and Palmer-Brown, C, 1997 Archaeological Watching Brief Report: Lincoln Golf Club, Torksey, Lincolnshire, Lincoln: Pre-Construct Archaeology, unpubl rep

Knight, D, 2000 *An Iron Age and Romano-British Settlement at Moor Pool Close, Rampton, Nottinghamshire*, Nottingham: Trent and Peak Archaeological Unit, unpubl rep

Knight, D and Howard, A J, 2004 *Trent Valley Landscapes*, Heritage: Kings Lynn

Krawiec, K, 2012 The Mesolithic to Bronze Age landscape development of the rent-Derwent Confluence Zone at Shardlow Quarry: A multi-disciplinary contribution to the environmental reconstruction in an aggregate-rich landscape, MPhil, University of Birmingham e-theses

Lanpro 2022 Cottam Solar Project, Environmental Impact Assessment Scoping Report, unpubl rep

Oxford Archaeology North, 2022 Newark Phases 2-3, Geoarchaeological Watching Brief Report, unpubl rep

Scaife, R and Allen, M J, 2000 A prehistoric vegetational history from the Trent Valley, near West Burton, Nottinghamshire, *Transactions of the Thornton Society of Nottinghamshire*, 100

Schwenninger, J L, Bridgland, D R, Howard, A J, and White, T S, 2007 Optically stimulated luminescence dating of Trent Valley sediments: problems and preliminary results, in T S White *et al* (eds), *The Quaternary of the Trent Valley and Adjoining Regions: Field Guide*, Quaternary Research Association, London

Stein, S, 2014 Understanding Torksey, Lincolnshire: A geoarchaeological and Landscape Approach to a Viking Overwintering Camp, PhD Thesis, Univ of Sheffield, e-theses

Tweddle, J C, 2001 Regional Vegetation History, in M D Bateman *et al* (eds) *The Quaternary of East Yorkshire and North Lincolnshire Field Guide,* Quaternary Research Association, London, 35-46

APPENDIX A BOREHOLE DATA

Cottam 1

Borehole Reference Number	Deposit
SK88SE5 - Retford	Blue Clay = Lias (early Jurassic) bedrock
SK88SE11 – Lowfield Farm	Lias (early Jurassic) bedrock (on the site)
SK88SE27 – Willingham by Stow	1.6m sand/gravel (Trial Pit)
SK88SE28 – Willingham by Stow	1.6m sand/gravel (Trial Pit)
SK88SE6 – School Lane, Stow	>2m glacial sand and gravel overlying Lias bedrock
SK88SE21-series-Sturton by Stow	>2m alluvium and sands/gravels overlying bedrock
SK98SW53- Thorpe in the Fallows	Alluvium overlying bedrock (on the site)

Summary list of historic borehole data available within and near the area of Cottam 1 site

Cottam 2

Borehole Reference Number	Deposit
SK89SE118 - Corringham	*c* 6m glacial sands and gravels overlying Lias bedrock

Summary list of historic borehole data available for the area of Cottam 2 site.

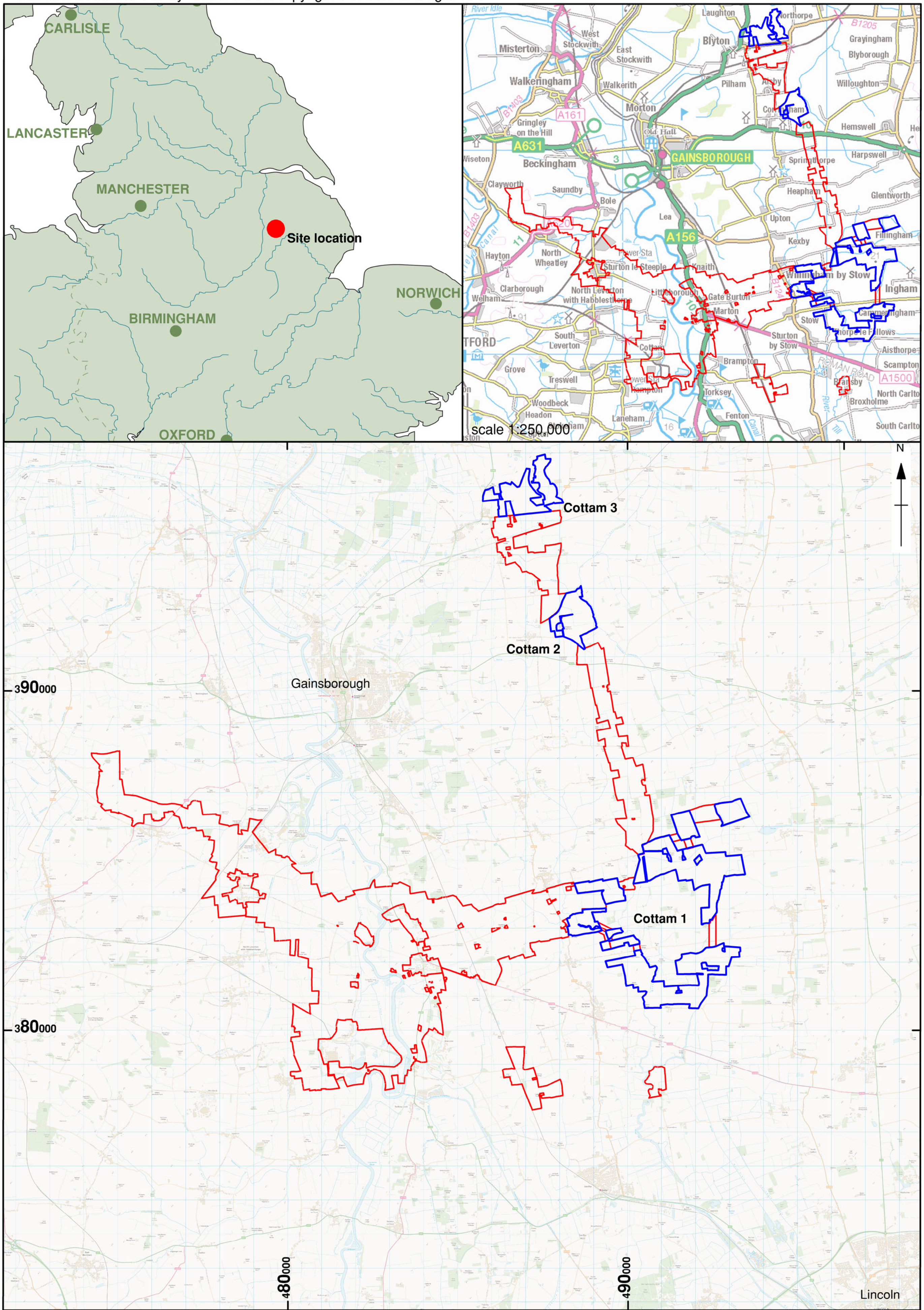
Cottam 3

Borehole Reference Number	Deposit
SK89NE53- Scunthorpe series	Clays/Bedrock
SK89NE89 – around Brigg	Clays/Bedrock

Summary list of historic borehole data available for the area of Cottam 3 site.

APPENDIX B SITE SUMMARY DETAILS

Site name:	Cottam Solar Farm, Lincolnshire
Grid Reference	487461 384552
Type:	Desk-based Geoarchaeology Assessment
Area of Site	1267 hectares
Location of archive:	The archive is currently held at OA, Mill 3, Moor Lane Mills, Moor Lane, Lancaster, LA1 1QD.
Summary of Results:	The aim of this desk-based assessment is to investigate and characterise the geoarchaeological potential of the site of the proposed Cottam Solar Project and associated cable routes, to help identify areas of enhanced geoarchaeological interest. The development lies within the wider Trent Valley, an area known for its rich floodplain archaeology, with evidence of fish traps, log boats, historical mills and bridges, all recovered from postglacial sand and gravel deposits, sealed beneath thick fine-grained alluvium. Low-lying broad river valleys provide access to riverine resources and have previously produced evidence of both ritual and settlement activity. The geoarchaeological assessment report has shown that there is potential for features such as palaeochannels and gravel islands to exist within the development areas. Previous historic borehole data available across the sites are of little value, as the data lack specific criteria such as altitude records and do not discriminate superficial deposits where identified. Data for generation of a deposit model could, however, be obtained from future engineering interventions especially if consideration is given to positioning interventions in areas likely to yield geoarchaeological information.



Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Solar Project

0 25 km

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Figure 1: Site location map

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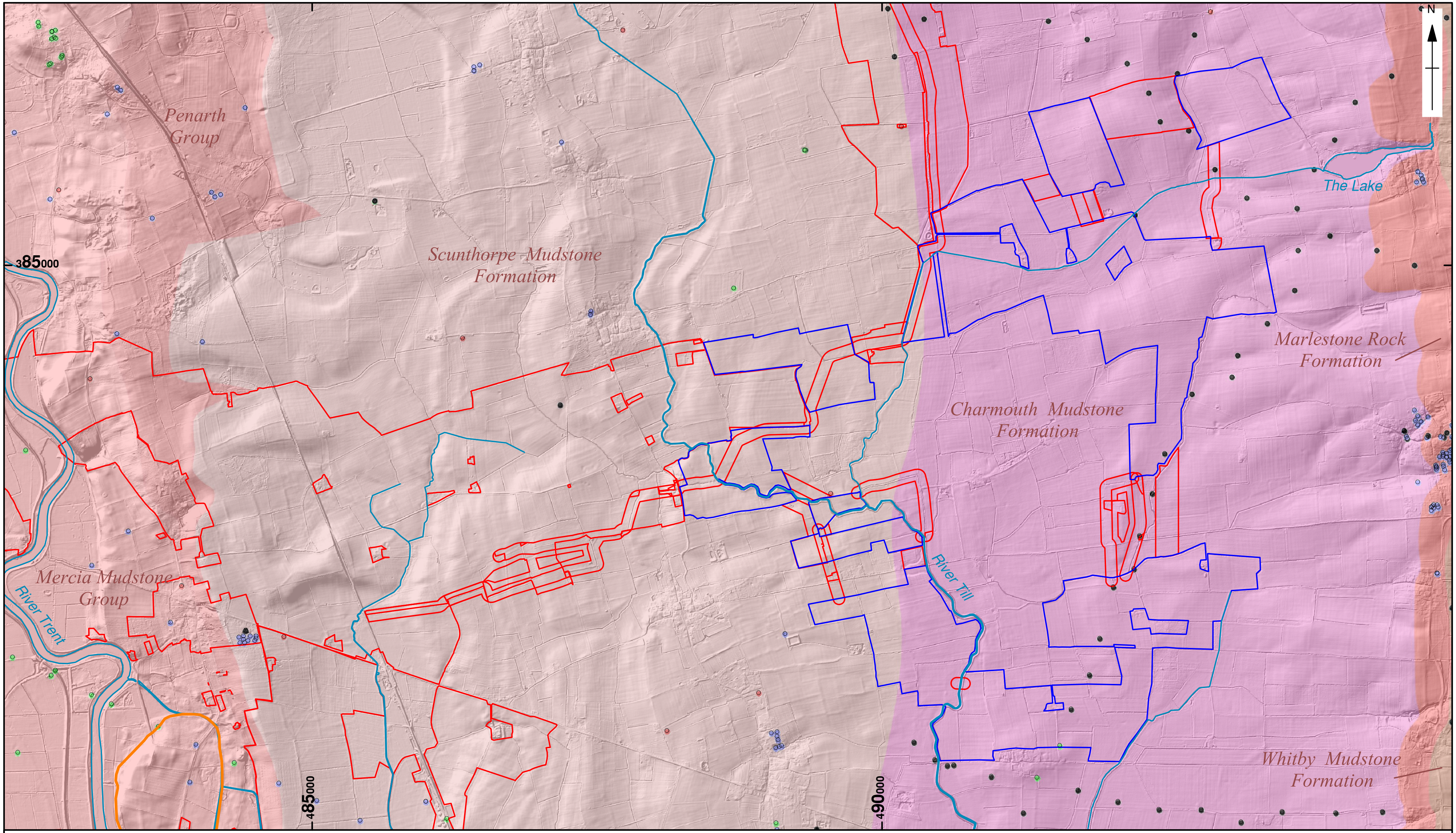


Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 1 boundary

Viking winter camp

BGS Borehole location

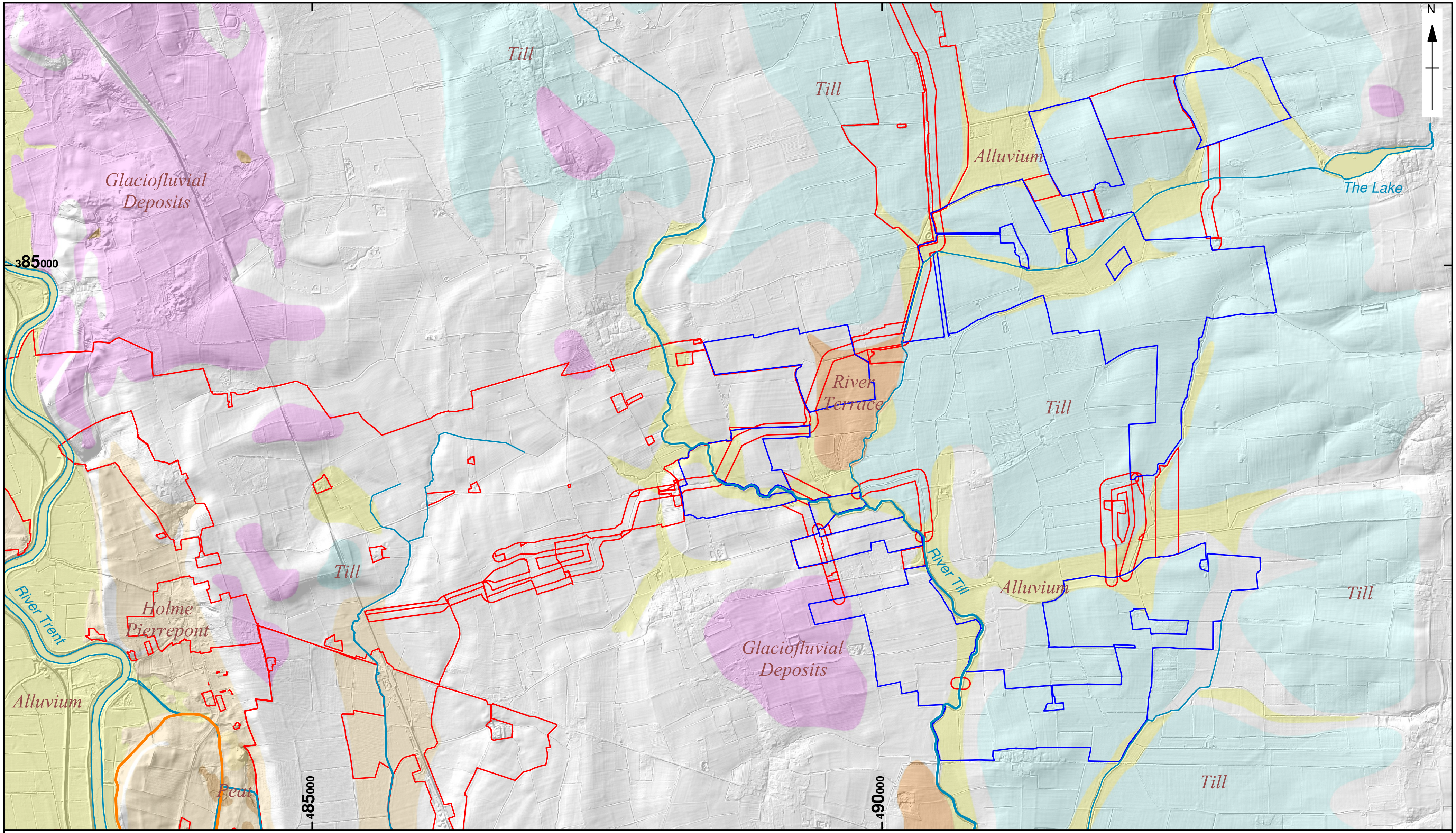
0 1 km

1:5,000 @ A4

oxfordarchaeology north

Figure 2: Baseline geology map and BGS boreholes - Cottam 1

FB*L11427*AMS*12052022



Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 1 boundary

Viking winter camp

0 1 km

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Figure 3: Baseline superficial deposits map - Cottam 1

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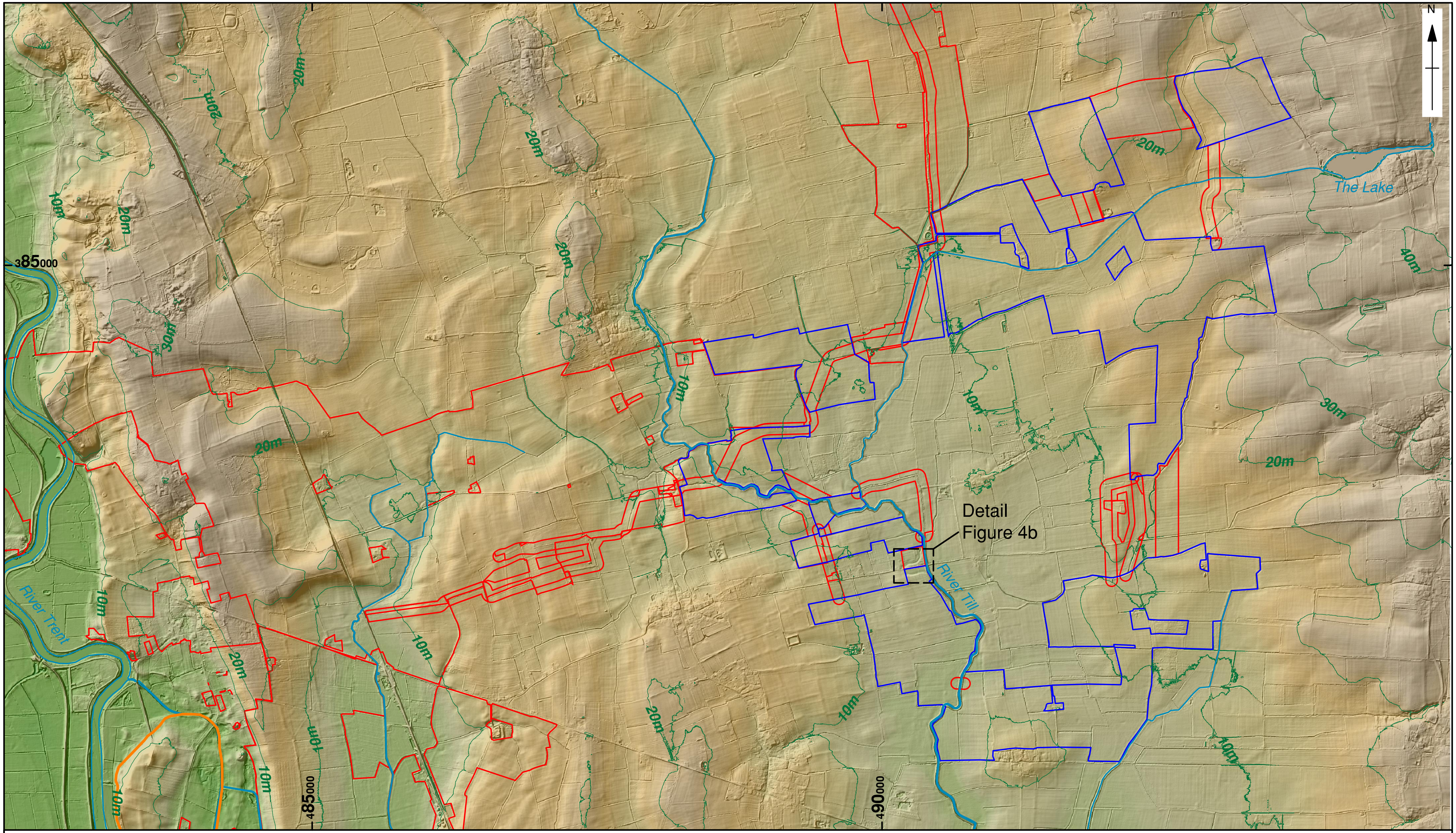

Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 1 boundary

Viking winter camp

0 1 km

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oxfordarchaeology north

Figure 4a: LiDAR image and contour topography - Cottam 1

FB*L11427*AMS*12052022

Cable route assessment area (West Burton and Cottam Projects combined)

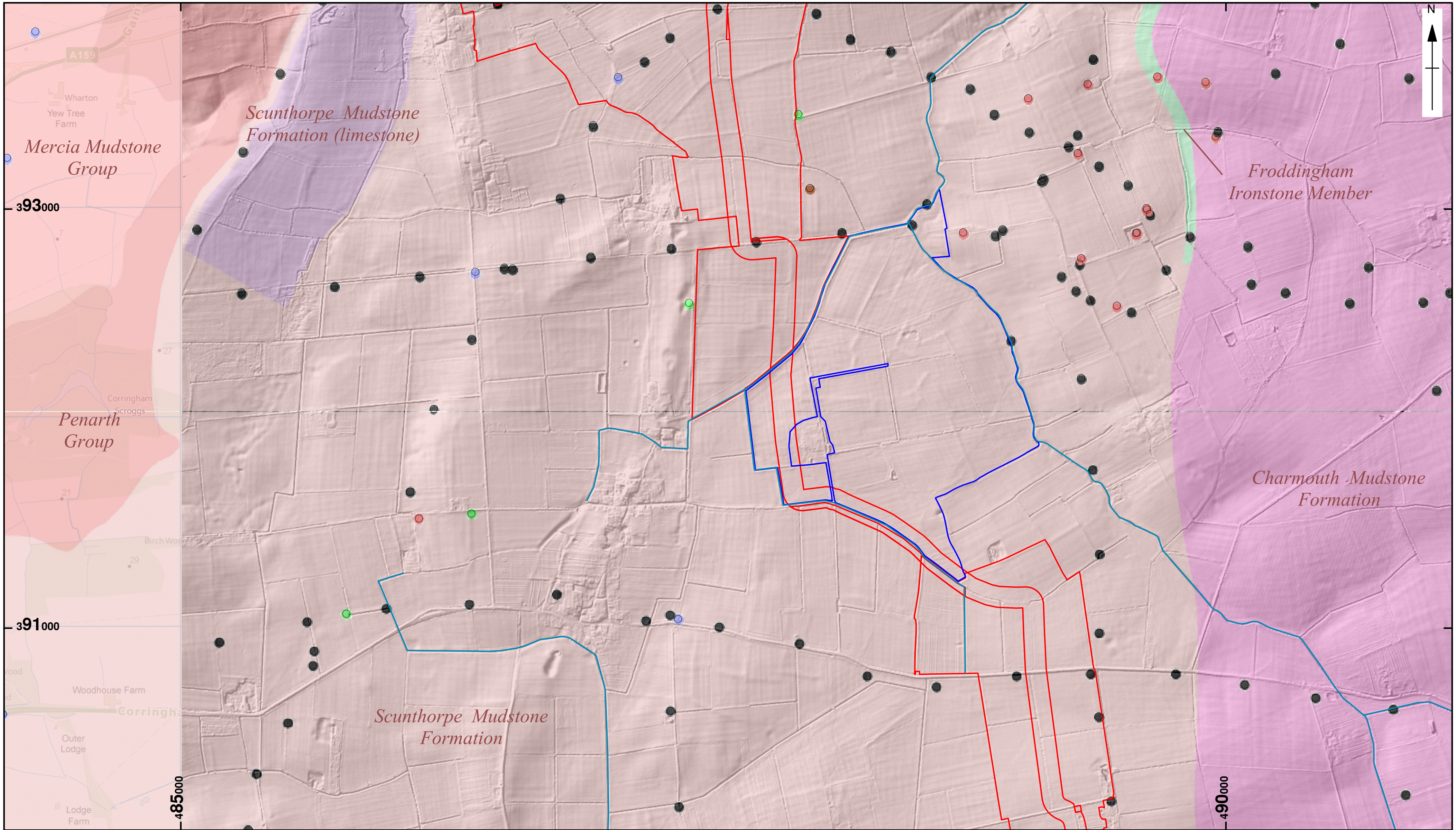
Cottam Site 1 boundary

Paleochannel

0 50 m

1:2500 @ A4

Figure 4b: LiDAR palaeochannel detail - Cottam 1



Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 2 boundary

BGS Borehole location

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Figure 5: Baseline geology map and BGS boreholes - Cottam 2

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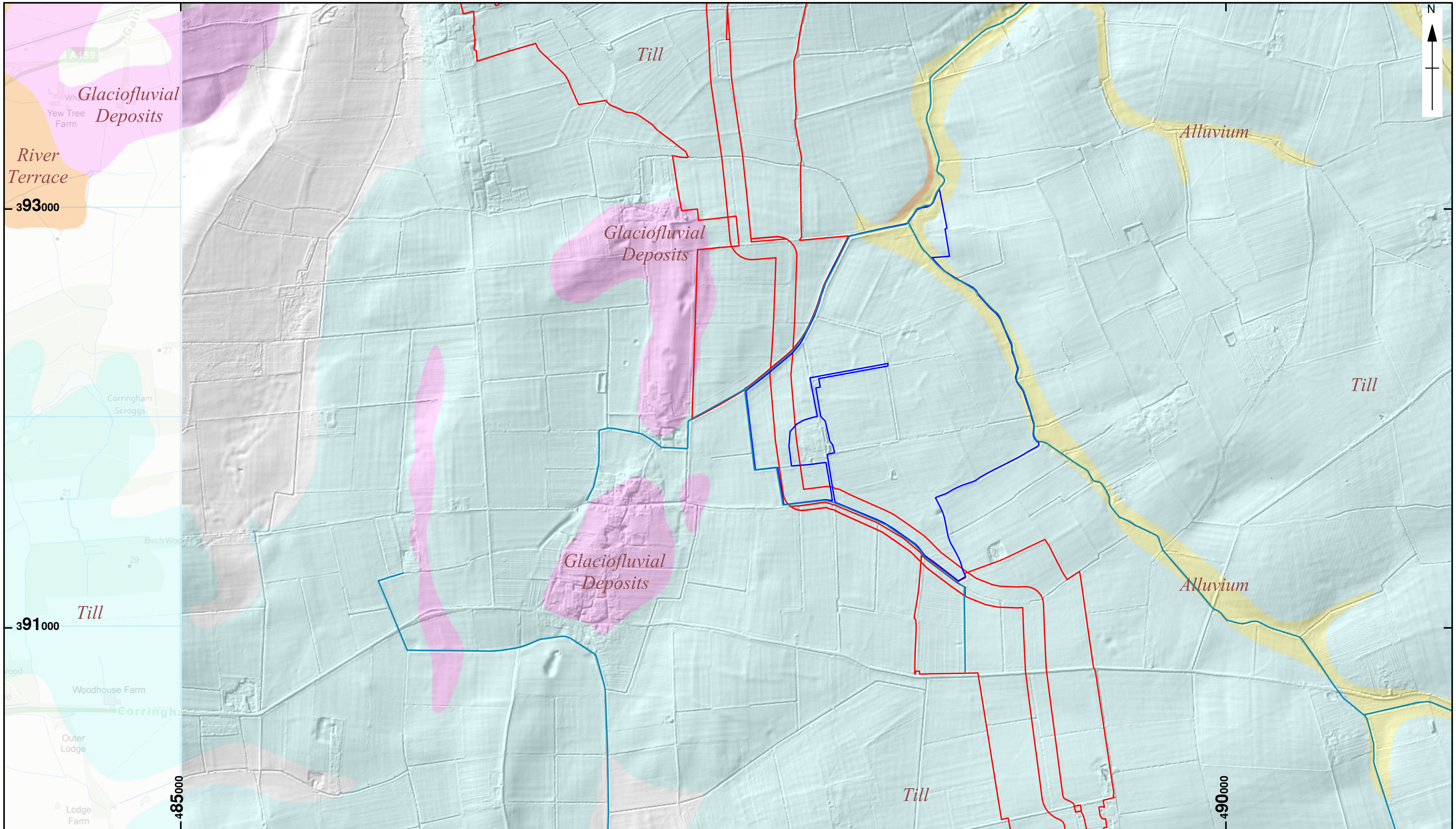

Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 2 boundary

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Figure 6: Baseline superficial deposits map - Cottam 2

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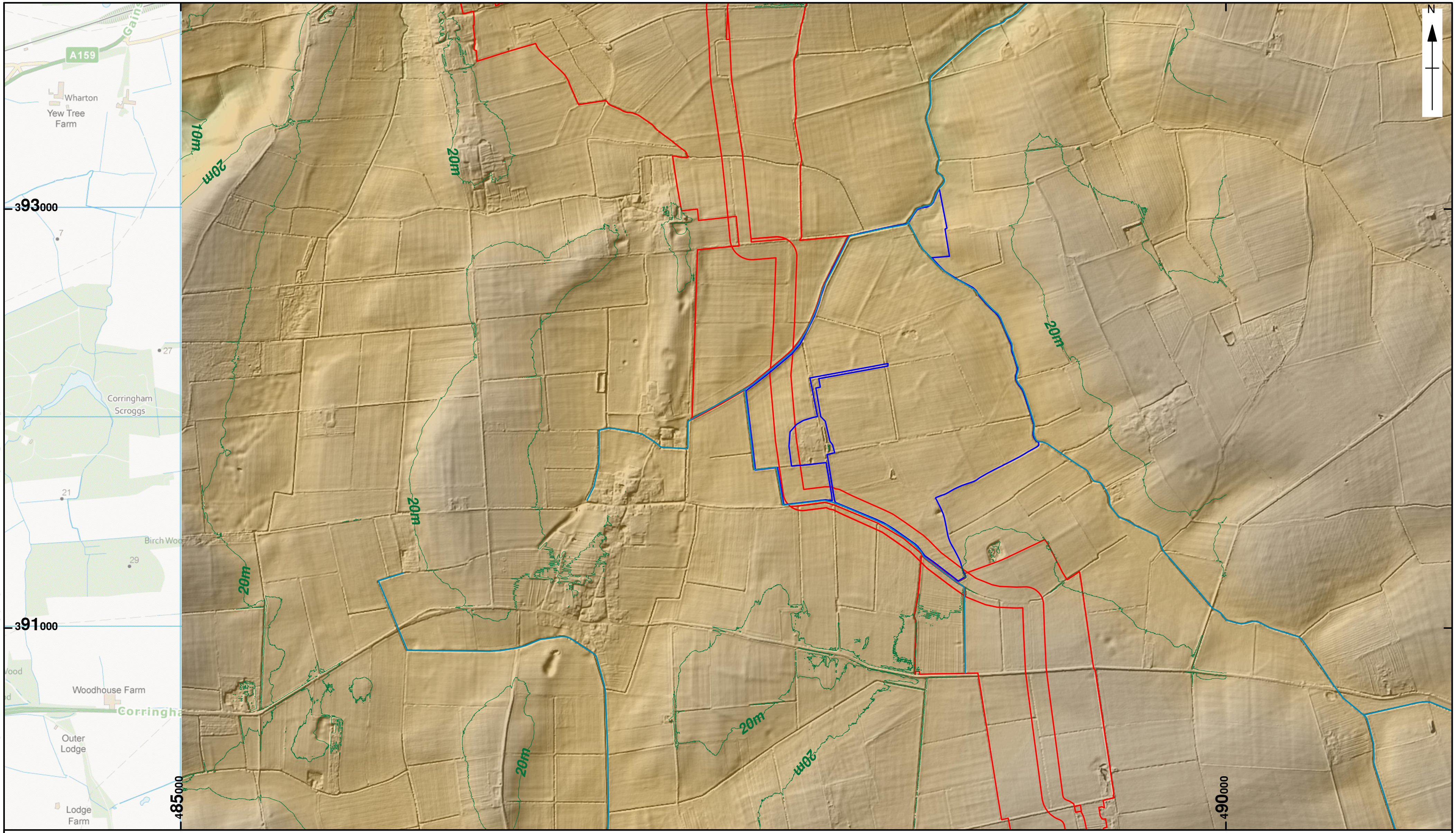

Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 2 boundary

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Figure 7: LiDAR image and contour topography - Cottam 2

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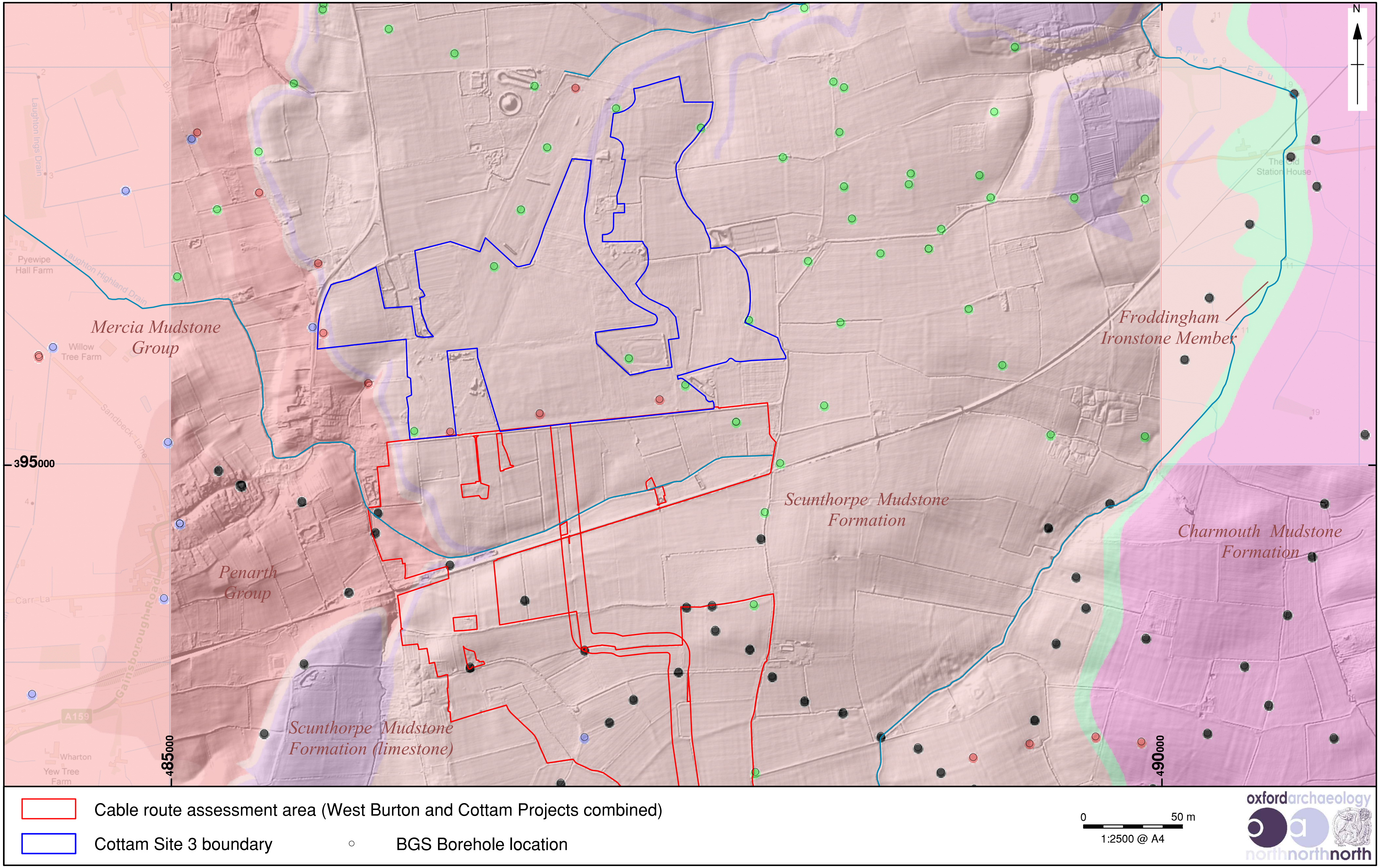

Figure 8: Baseline geology map and BGS boreholes - Cottam 3

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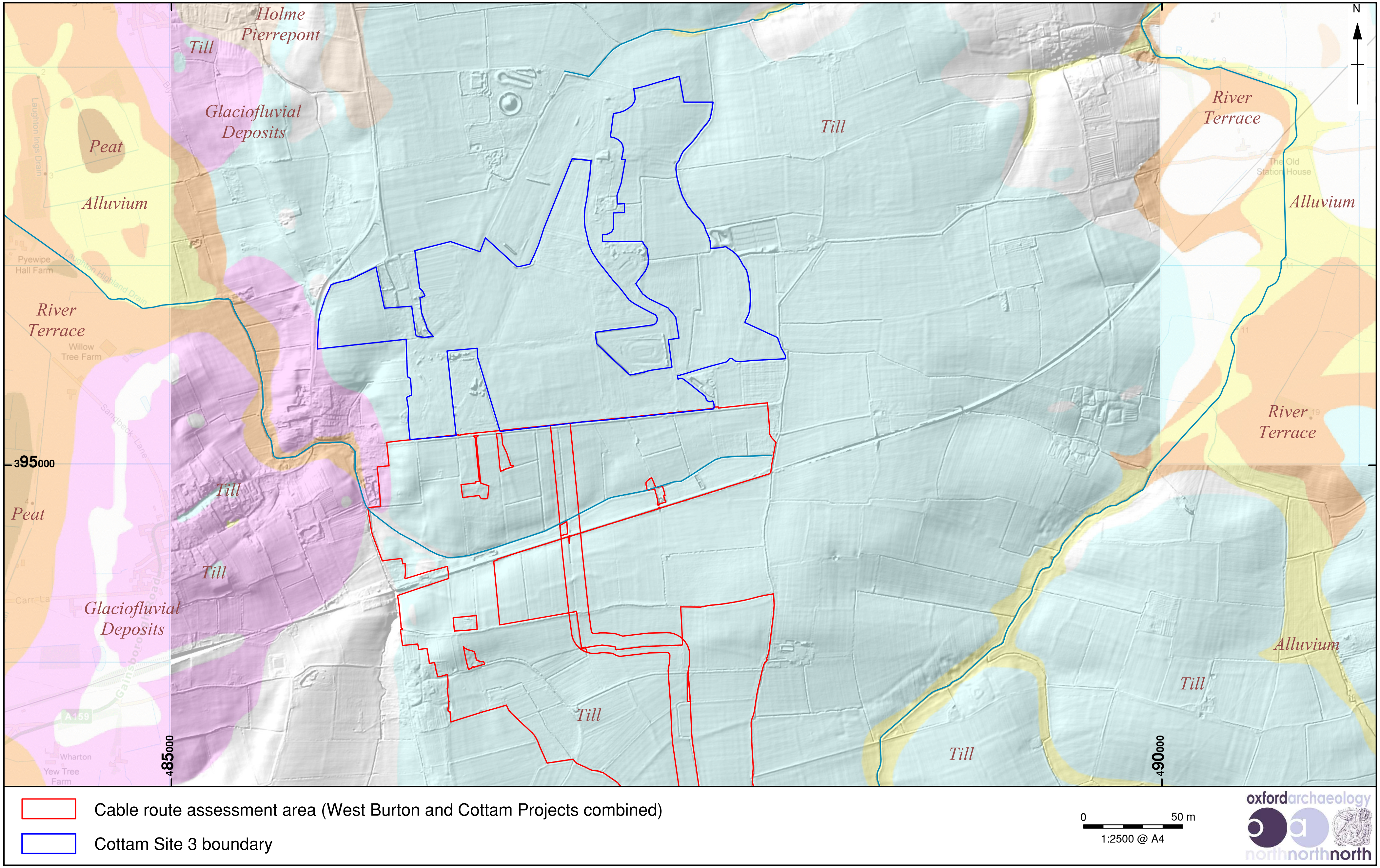

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Figure 9: Baseline superficial deposits map - Cottam 3

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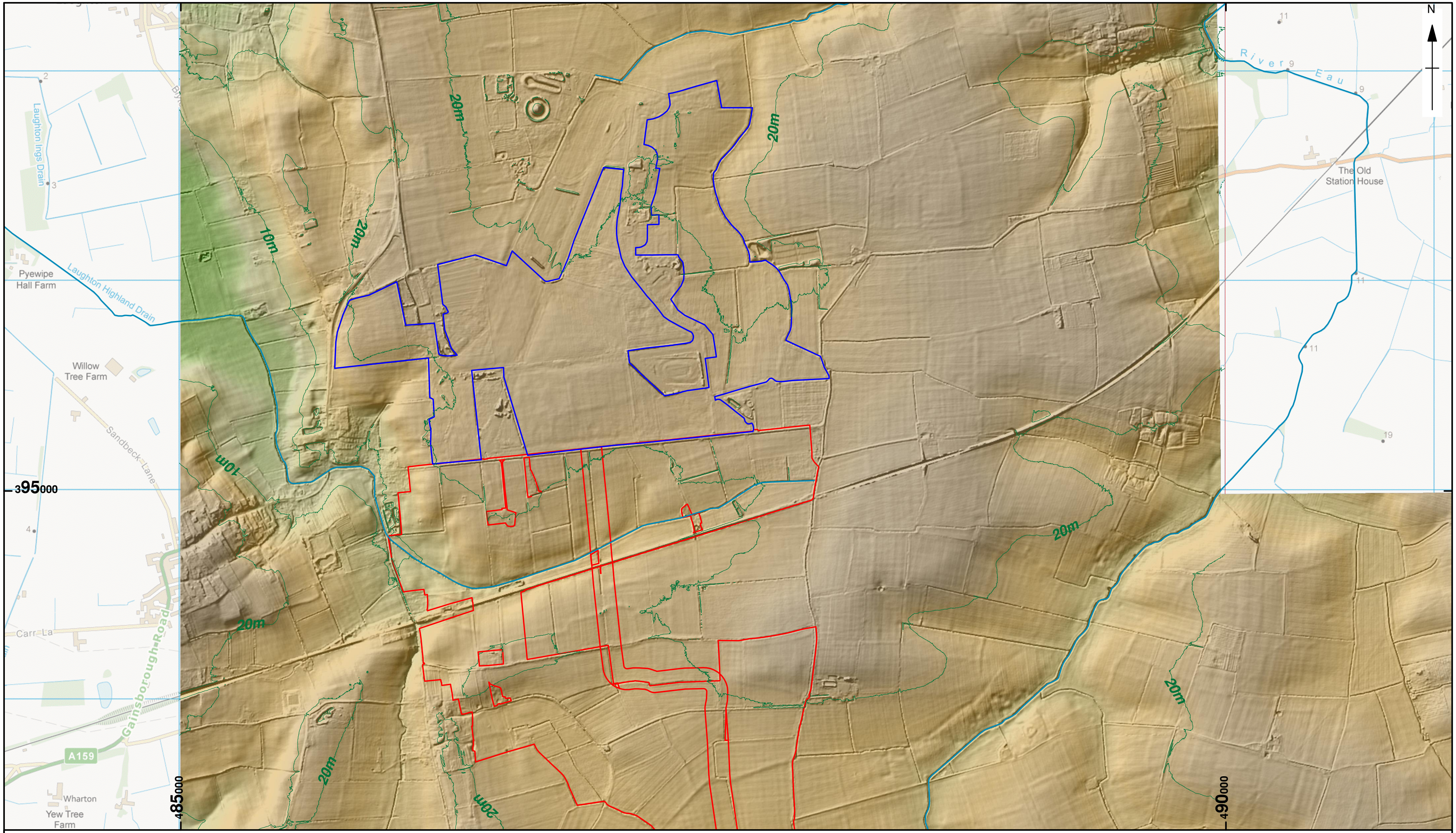

Cable route assessment area (West Burton and Cottam Projects combined)

Cottam Site 3 boundary

0 50 m

1:2500 @ A4

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Figure 10: LiDAR image and contour topography - Cottam 3

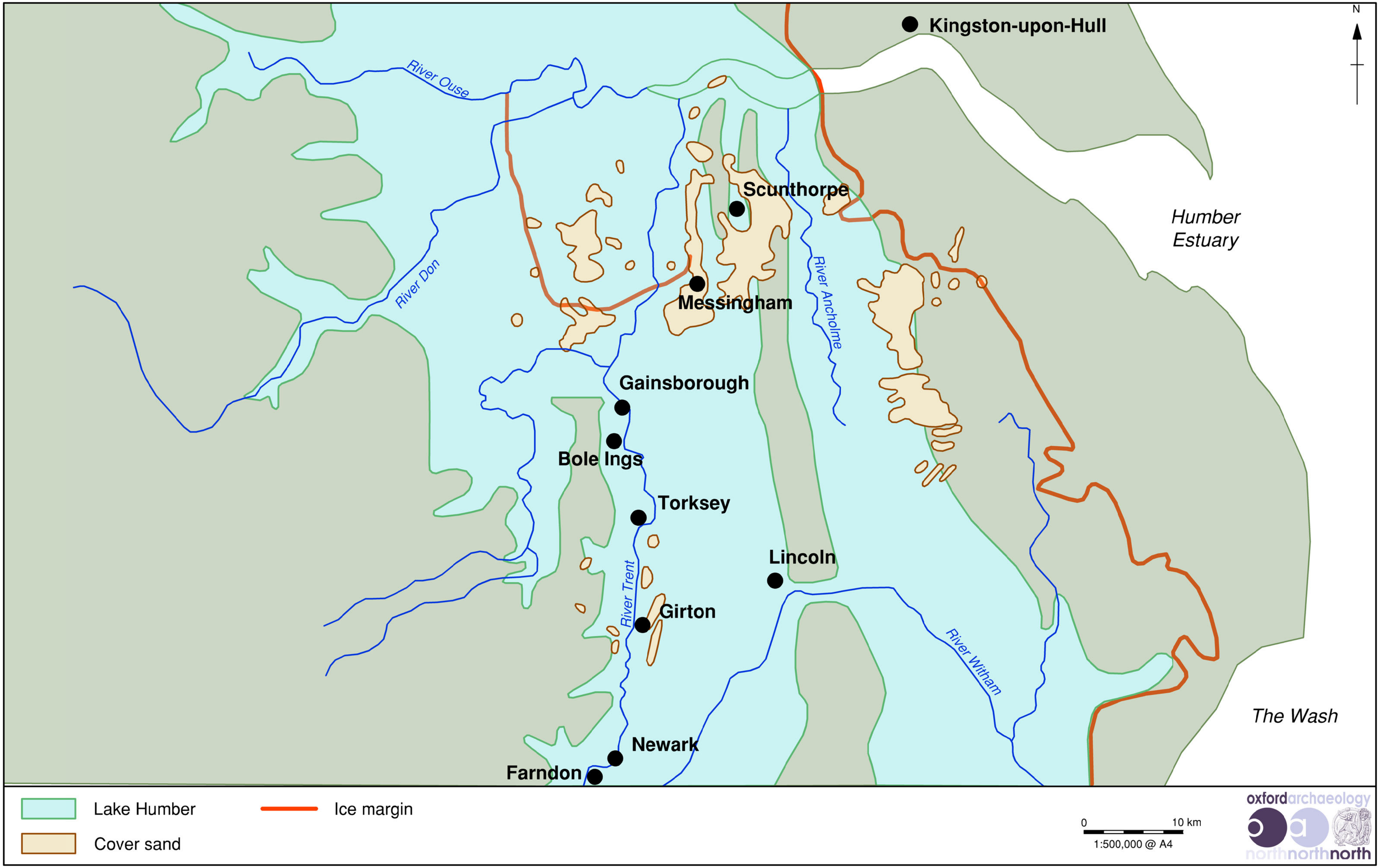

Figure 11: Extent of Lake Humber and Devensian ice margins

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