The Great Grid Upgrade

North Humber to High Marnham

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North Humber to High Marnham

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1. Introduction

1.1 Overview

1.1.1 This appendix to **Application Document 6.10 Chapter 10 Cultural Heritage** presents a geoarchaeological desk-based assessment (DBA) setting out the baseline conditions for the land within the Order Limits and study area. The geoarchaeological background of the Order Limits is described from north to south. Using information from Light Detection and Ranging (LiDAR) survey and available geotechnical data, this geoarchaeological DBA presents a risk map which details the archaeological and palaeoenvironmental potential of the land within the Order Limits. The geoarchaeological DBA concludes with recommendations for further site investigation.

1.1.2 The results of this geoarchaeological DBA have informed the impact assessment and the identification of likely significant effects reported in **Application Document 6.10 Chapter 10 Cultural Heritage**. The recommendations for further site investigation within this geoarchaeological DBA have informed the scope of geoarchaeological mitigation measures which will be carried out to offset any significant effects. Appropriate mitigation measures are secured in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation**.

1.1.3 Figures to support the assessment are provided in Annex A.

1.2 Study Area

1.2.1 The study area for this geoarchaeological DBA comprises a 1 km buffer from the draft Order Limits used at Statutory Consultation. This is considered sufficient to provide relevant information on the geoarchaeological baseline conditions of the land within the Order Limits and has informed the impact assessment and the identification of likely significant effects that are reported in **Application Document 6.10 Chapter 10 Cultural Heritage**. Although the assessment is based on the draft Order Limits used at Statutory Consultation the 1 km buffer applied allows for sufficient understanding of the Geoarchaeological potential of the Projects Order Limits.

1.3 Geology and Topography

1.3.1 An overview of the Project (Figure 2) shows a 1 km buffer from the Order Limits which is considered to be a sufficient study area for this assessment. The Geographic Area Limits (Area Limits; 1-5) which are used as delineations for the study area are shown in relation to the Route Section Areas (A-F) for the Project (Figure 2). The Geographic Area Limits for the study area relate principally to the broad geographic and geological zones that they define, whereas the Route Section Areas are defined for the Project route. There is some overlap with these areas but broadly the study areas are as follows:

- 1: Wolds from Hull to Brantingham – Route Section Area A;
- 2: Foulness Valley – Route Section Area A;

- 3a: Humberhead Levels – Route Section Area B;
- 3b: Isle of Axholme – Route Section Areas B-D;
- 3c: Idle Valley – Route Section Areas D-E;
- 4: Mercian Mudstone 'Uplands' – Route Section Area E; and
- 5: Trent Valley – High Marnham – Route Section Area F.

1.3.2 Moving from the northernmost part of the Order Limits, the Project crosses scarps and lower-lying valleys, reflecting the eastward dipping nature of the underlying sedimentary bedrock and its susceptibility to differential erosion. These geological variations underpin the National Character Areas (NCA) defined by Natural England, with the Project area crossing several, namely:

- NCA 27 (Yorkshire Wolds);
- NCA 39 (Humberhead Levels);
- NCA 40 (Holderness);
- NCA 41 (Humber Estuary); and
- NCA 48 (Trent and Belvoir Vales).

1.3.3 Since the bedrock geology dips and becomes progressively younger from west to east, this means that the youngest strata are recorded at the northernmost end of the Project. The following sections describe these strata from north to south (Figure 3).

1.3.4 To the east of South Cave and Brantingham, the ground rises rapidly to a plateau surface reflecting the cropping out of the Welton Chalk Formation limestone of Cretaceous age. The chalk forms the southern edge of the Yorkshire Wolds NCA and as elsewhere regionally, its west facing scarp slope is characterised by a series of deeply incised dry valleys, often with spring lines at their bases.

1.3.5 Around and immediately west of South Cave and Brantingham, a narrow band of limestones, sandstones, mudstones and siltstones of Jurassic age crop out, marking the edge of the lower-lying vale, which characterises so much of the Foulness Valley, the Lower Trent Valley and the Humberhead regions. These rocks are divided from east to west on the basis of their lithology and fossil content, forming distinct mappable units comprising, the Ancholme Group Mudstone; Kellaways Sand Member Sandstone; Upper Lincolnshire Limestone Member; Whitby Mudstone Formation; and the Charmouth Mudstone Formation.

1.3.6 Around the small settlement of West End, the Jurassic Charmouth Mudstone Formation is replaced by two more relatively thin bands, this time of Triassic age and comprising, the limestones, mudstones and siltstones of the Scunthorpe Mudstone Formation; and the mudstones, sandstones and limestones of the Penarth Group.

1.3.7 For the remainder of the Order Limits, the area is underlain by Triassic mudstones, siltstones and halite-bearing sediments of the Mercia Mudstone Group. Across the northern part of this area, the Mercia Mudstone Group underlies the flat plain of the Humberhead Levels and Lower Trent Valley, but further south, the relief is more undulating with high points within it, notably the Isle of Axholme and Gringley on the Hill.

1.3.8 These bedrock deposits are overlain by superficial deposits including River Terrace deposits, Holocene Alluvium and Peat within the lower lying areas. The slopes and valley sides record various Pleistocene deposits including Till, Head and Glaciofluvial

sediments. These superficial sequences are described in more detail in section 2 of this assessment.

2. Geoarchaeological Background

2.1 Introduction

2.1.1 Whilst the underlying bedrock geology within the Order Limits is at least 100 million years old, the forces that have shaped this part of eastern England are focused on geological processes operating during the alternating warm 'interglacial' and cold 'glacial' stages of the Pleistocene Epoch (2.5 million to 11,000 years before present (BP)). During cold stages, sea levels were low providing land bridges and migration pathways to and from Europe, whilst during warm stages sea levels were high, annexing Britain from the continent.

2.1.2 The natural processes of the Pleistocene provided the template for the landscape of the current postglacial (the Holocene Epoch, 11,000 years until present day), which humans returned to and reoccupied towards the end of the last cold stage during deglaciation.

2.2 Pleistocene Lake Humber

2.2.1 The landscape of eastern England has been glaciated on multiple occasions during Pleistocene cold stages, though terrestrial evidence for icesheets can only be found for three, or possible four discrete events. Along the route of the proposed overhead line, most of the Pleistocene deposits relate to two main phases of the latest part of the Devensian cold stage (Marine Isotope Stage [MIS] 2). The first phase is associated with the glacial, fluvial and lacustrine processes associated with the Last Glacial Maximum (LGM) itself, when ice reached peak coverage across the British Isles between 28-18,000 years BP (Clarke et al, 2022). The second phase is associated with the fluvial and aeolian (wind-blown) processes that operated after the LGM during deglaciation. The climate generally warmed from around 14,500 years BP, albeit with an intense cold snap between 11,000 and 10,000 years BP; collectively this second phase of warm followed by cold temperatures is known as the Late Devensian Late glacial.

2.2.2 In eastern England, the maximum southern limit of the LGM icesheet, formed by the combined forces of Pennine ice flowing down the Vale of York and Scottish/Scandinavian ice flowing down the North Sea basin, is marked by the major moraines at York and Escrick (Bateman M. D., 2015). However, Gaunt (Gaunt G. D., 1976) suggested that this followed a short-lived surge to Wroot on the south side of the Humber estuary, evidenced by Permian pebbles within 'glacial gravels', a hypothesis confirmed from the analysis and dating of glacial deposits at Crowle and Epworth (Bateman M. D., 2015).

2.2.3 The evidence of icesheet dynamics indicates that for the majority of the LGM the route of the proposed overhead line was ice free and therefore LGM sediments laid down directly by ice (Till), are rare within the area. The only large spread of till is recorded on the chalk plateau of the Yorkshire Wolds at the northern end of the Order Limits. To the south of the Humber, the Till forms smaller, isolated fragments, as found at Crowle and Epworth.

2.2.4 The surging of ice south of the Humber scoured the bedrock to create the topographic lowland now known as the Humberhead Levels. North Sea ice flowing further south did however also block the Humber estuary, causing waters draining from the rivers of the

Yorkshire Ouse basin and Trent basin to become ponded, in turn leading to the formation of a large proglacial lake now known as Lake Humber.

2.2.5 Historically, Lake Humber deposits were called the 25-foot Drift simply reflecting the height Ordnance Datum to which the main body of deposits could be mapped (Gaunt G. , 1981) . More recently, the British Geological Survey has renamed these sand, silt and clay deposits as the Hemingborough Glaciolacustrine Formation.

2.2.6 Twenty-five Optically-Stimulated Luminescence (OSL) dates from the Yorkshire and Humberside region provide a secure chronology for ice movement and lake impoundment, demonstrating that Vale of York ice did extend briefly into Lake Humber around 18,700 years ago before retreating to the York-Escrick line (Bateman M. D., 2015). Further OSL dates from around York and Hemingborough demonstrate that Lake Humber was still impounded around 15,000 years ago, though by around 13,700 years, it was gone, as evidenced by OSL dates on blown sands overlying the sediments at Messingham. The expansive nature of Lake Humber across the region's lowlands means that the glaciolacustrine clays and silts are widespread, though they are often buried beneath later aeolian, fluvial/estuarine and anthropogenic (Warp) sediments.

2.2.7 The formation of the glaciolacustrine clays and silts under intensely cold climatic conditions, means that they are devoid of a significant organic component, reflecting the lack of vegetation in the surrounding landscape. Therefore, their palaeoenvironmental potential is generally deemed low.

2.2.8 Along the southwest edge of the Yorkshire Wolds, the British Geological Survey record a mappable unit which is named the Bielby Sand Member. The unit overlies the clays of Lake Humber and is interpreted as fluvial drainage along the edge of the basin. There are no age constraints on the deposit so it could be coeval or marginally later than the main phase of Lake Humber sedimentation. The British Geological Survey 1:50,000 scale mapping also records two small patches of 'interglacial beach deposits' around Brough, though they are not formally named and further information about them is not available.

2.3 Late glacial Deposits Proximal to the Project

2.3.1 Following the drainage of Lake Humber, the Trent established its present course to the Humber Estuary; prior to this it flowed via the Till Valley through the Lincoln Gap to the North Sea (Bridgland, 2014). The transition from the LGM into the postglacial, a period known as the Late Devensian Late glacial spans the timeframe from 13,000 to 10,000 BP, though warming associated with the lower boundary is time transgressive (Lowe and Walker, 1997). In Britain, two distinct climatic regimes are recognised; a distinct warming between 14,500 and 11,000 BP (the Windermere Interstadial), and a distinct cooling between 11,000 and 10,000 BP (the Loch Lomond Stadial).

2.3.2 During the Windermere Interstadial, the spread and subsequent decay of vegetation under a warmer climate led to the development of thin peat units, which have been preserved in favourable localities. Regionally, a number of these peats have been identified, usually beneath wind-blown sand deposits the latter known as 'coversands' (Buckland P. , 1982). However, close to the Project route at Cove Farm, Westwoodside, Bateman et al. (Bateman M. D., 2015) identified an organic-rich pond sequence of Late glacial age, the upper part of which was radiocarbon-dated to 11870 ± 300 BP. These organic-rich Late glacial sediments were overlain by coversands and later peat. Subsequent preliminary palaeoenvironmental analysis of insect remains indicated open sandy heath with cool though not arctic climate (Dinnin & Welsh, 2001) .

2.3.3 Numerous OSL dates demonstrate that the coversands were deposited initially during the intense cold-dry climate of the Loch Lomond Stadial, when vegetation was sparse and fine-grained sediment was abundant, thereby providing copious material for deflation (Bateman M. , 1995) (Bateman M. , 1998). However, such deposits can also be reactivated during periods of climatic stress, such as the 8,200 BP event (Baker, 2012) and/or associated with human impact on the landscape (Radley, 1967) (Matthews, 1970).

2.3.4 Beyond the limits of the main body of Lake Humber, sedimentary evidence for the Late glacial can be identified within river terraces, elevated a few metres above the contemporary valley floor. At Tiln, in the Idle Valley, (Howard A. , 1999) recorded braided river sands and gravels overlain by silty peats, sandy clay showing evidence of soil formation coversands. The silty peat was radiocarbon-dated to around 11,200 BP (c. 11,500 (calibrated)[1] cal. BC; 13,500 cal BP). Palaeoenvironmental analyses of the peaty sediments associated with the Windermere Interstadial, whether beneath coversands or within valley floor wetlands indicates the prevalence of reeds, sedges and mosses around water bodies, whilst open grassland with few trees characterised the surrounding landscape.

2.3.5 At the northern end of the Project, within the small valleys steeply incised into the southwest escarpment of the Yorkshire Wolds, the British Geological Survey map tracts of periglacial slope deposits (Head), which most likely date to the LGM/Late glacial.

2.3.6 Understanding the time period of the Late glacial it important since it is during the warming of the Windermere Interstadial that modern humans returned to mainland Britain following an exodus during the LGM, though these communities may have migrated further south again during the Loch Lomond Stadial (Barton, 2005).

2.4 Palaeoenvironmental and Faunal Evidence

2.4.1 Palaeoenvironmental sequences from earlier in the Devensian are rare but do survive in terrace gravels as organic lenses. At Finningley quarry, near Bawtry, approximately 10km west of the cable route, Buckland et al. (Buckland P. , 2019) recorded organic silts within river terrace gravels which were radiocarbon dated to 37,057 ± 457 BP (40,314 – 39,552 cal. BP); this constrains the site within the Middle Devensian. Plant macrofossil and insect remains indicated tundra with dwarf-shrub heath and bare ground. The climate was probably low arctic with snow cover during the winter months. Mutual climatic range (MCR), based on Coleoptera (insects), shows the mean monthly winter temperatures of -22º to -2ºC and summer of 8–14ºC.

2.4.2 Organic-rich silts from quarry exposures of terrace gravel at Austerfield, approximately 9 km west of the Order Limits, and a borehole drilled ahead of the construction of the M18 at Langham (close to Austerfield), provide evidence of temperate woodland during the last interglacial (MIS5e, the Ipswichian, c. 125 ka[2] BP; (Gaunt G. D., An interglacial near Austerfield, southern Yorkshire. Institute of Geological Sciences Report, 1972), (Gaunt G. D., 1974)).

2.4.3 North of the Humber in the Foulness Valley, mammalian remains of a pre-Ispwichian interglacial were first discovered at Bielsbeck Farm near North Cliffe during the

[1] The term ‘calibrated’ or ‘cal’ refers to the adjustment made to raw radiocarbon years to account for past carbon fluctuations. Dates are calibrated to improve dating accuracy.

[2] Ka derives from ‘kilo annum’ and means ‘thousands of years’. When used alongside the abbreviation ‘BP’ it means, ‘thousands of years before present’.

excavation of a pit in 1829, indicating the presence of elephant, rhinoceros, deer, ox, horse and lion. Schreve (Schreve, 1999) provides a summary of early works and reinvestigation of the site using a vibrocorer in the same year. At Bielsbeck, the original stratigraphy of the site was recorded as: 0.70 m of upper sand; 0.75 m of white gravel with small pebbles of chalk and angular flint; 1.50 m of blue marl containing 'bones'; 3 m + of blacker marl containing 'bones', land, marsh and freshwater molluscs, insects and plant remains. A VibroCore survey carried out in 1999 by Schreve identified organic clay beneath gravel, which was correlated with the 'blacker marl containing bones'. Over 3 m of this organic clay was cored to 6.76 m Below Ground Level (BGL) without the base being reached.

2.4.4 Review of all of the faunal remains previously recovered from Bielsbeck by Schreve (Schreve, 1999) also identified 96 specimens representing 11 mammal species, comprising: wolf; brown bear; lion; straight-tusked elephant; woolly mammoth; elephant; horse; narrow-nosed rhinoceros; indeterminate rhinoceros; red deer; roe deer; aurochs; bison; and indeterminate large bovid (Bos or Bison). Re-analysis of the molluscs indicated species that occur in cold environments, but also several thermophiles indicative of fully temperate conditions.

2.4.5 Work by Halkon (Halkon, P, 1999) at two sites close by identified further faunal remains: at North Cliffe, the remains of red deer, horse and an indeterminate large bovid were recovered; at Mott's Field, South Cliffe, remains comprised straight-tusked elephant; woolly mammoth; horse; red deer and another indeterminate large bovid. Collectively, the faunal assemblage suggests a mixture of open grassland and woodland habitats in close proximity and is considered fully interglacial by Schreve (Schreve, 1999). Furthermore, the assemblage is very similar to those from the Thames terrace sequence at Aveley and Ilford both of which are attributed to MIS 7 (Schreve, 1999). Both Schreve (Schreve, 1999) and Halkon (Halkon, P, 1999) (Halkon P. , Settlement and economy in a changing prehistoric lowland landscape: an East Yorkshire, 2005) consider that the faunal remains can be correlated and are from a discrete sediment body/landform context, termed the proto-Foulness river by Halkon.

2.5 Evidence for Glaciation

2.5.1 Within the landscape crossed by the Order Limits, the British Geological Survey maps a small number of high-level fragmentary Till deposits and associated glacial sand and gravels south of the Humber estuary; these are simply considered as 'pre-Devensian glaciation'. Until as decade ago, such deposits would have simply been assigned to the Anglian glaciation (MIS 12, c. 450 ka BP) but in recent years, compelling evidence has been presented for significant glaciation in eastern England as far south as the region around Melton Mowbray during MIS 8 (c. 275 ka BP), informally termed the Wragby glaciation (White, 2016) (Rose, 2021).

2.5.2 Other researchers have suggested glaciation of eastern England during MIS 10, informally termed the Oadby glaciation and MIS 6, informally termed the Tottenhill glaciation within a useful review provided by Lee et al. (Lee, 2011). However, given the presence of intact MIS 7 deposits from Bielsbeck Farm (Schreve, 1999) and the wider Trent catchment (Bridgland, 2014) suggest that glaciation of the Project route is unlikely during MIS 6 (i.e. any evidence of MIS 7 sediments would have been destroyed).

2.5.3 At Scrooby, north Nottinghamshire, close to Austerfield, silty peats within pre-Devensian glacial outwash gravels have recorded insect remains suggesting a sparely vegetated, landscape of pools under cold climatic conditions (Gaunt G. G., 1997).

2.6 Previous Studies - Holocene

2.6.1 There have been many large scale palaeoenvironmental and archaeological surveys within the vicinity of the Order Limits which provide useful contextual and baseline data. The wetlands area crossed by the Order Limits (i.e. the Humberhead Levels, Foulness Valley, and Lower Trent Valley) have been extensively investigated as part of the Humber Wetlands Survey, a systematic programme of regional archaeological survey funded by Historic England (Van de Noort, 1997). This project provides a useful record of the preservation potential within the deposits recorded, although absolute dating of some of the deposits is lacking.

2.6.2 The Humber estuary and connected catchments were also investigated as part of the Natural Environment Research Council-funded thematic programme entitled LOIS (Land Ocean Interaction Study), a seven-year project which commenced in 1991 (Shennan, 2000). The aims of this project were to understand the character of natural processes, valley floor evolution, sea level change and human impact since the beginning of the Holocene.

2.6.3 The Foulness Valley has been the focus of a landscape archaeological doctoral study by Halkon (Halkon P. , Archaeology and environment in a changing East Yorkshire landscape. The Foulness Valley, 2008), whilst the Humberhead Levels and Lower Trent have been the focus of several doctoral projects investigating palaeoecological and geoarchaeological records. The lower Trent Valley has been further investigated as part of the English Heritage sponsored Trent Valley Survey (Knight & Howard, 2004).

2.6.4 The Heritage Lottery Fund commissioned a five-year project (2016-2021) entitled ‘Reconstructing the Wildscape’ led by Professor Nicki Whitehouse (University of Glasgow) and the Thorne and Hatfield Moors Conservation Forum. Part of this project aimed to synthesis the environmental archaeological data for these areas though at the time of writing, results are not publicly available (Professor Henry Chapman, University of Birmingham, pers. comm.).

2.7 Holocene Deposits

2.7.1 Glacial scouring during the Pleistocene led to the creation of basins which coalesced to form the low-lying topographic region now known as the Foulness Valley, Humberhead Levels and lower Trent Valley, effectively representing the area previously occupied by Lake Humber.

2.7.2 Except for the higher ground at the southern end of the Project route, marked by Grindley on the Hill and isolated islands of bedrock (e.g. Isle of Axholme) and glacial moraine (e.g. Lindholme), the majority of this area formed a vast expanse of wetland until it was drained for agriculture in the post-medieval period; for example, Lindholme Island could only be reached by boat until the mid-19th century (Whitehouse, The Quaternary of East Yorkshire and North Lincolnshire, 2001).

2.7.3 Climatic amelioration associated with the onset of deglaciation led to postglacial sea level rise as the water previously locked up in global ice sheets drained back into the oceans. Rivers adjusted to new base level conditions and a combination of fluvial and estuarine sediments infilled these basins during the early and mid-Holocene to create extensive, resource-rich wetlands. These wetlands, infilled by a mixture of sands silts and clays together with units of organic-rich sediment, notably peat, provide a significant environmental archaeological archive. Furthermore, as resource-rich areas, they have

been the focus of human occupation and exploitation since the earliest hunter-gatherers returned to mainland Britain following deglaciation.

2.8 Humber Deposits

2.8.1 When considering the onshore depositional sequences from the early Holocene the associated offshore deposits and the record of sea level change is an important factor in understanding the timing of rising base levels particularly in the Humber. The connection of the Humber with the North Sea basin, an area now submerged, creates the impression of a wider resource rich landscape linking mainland Britain to Europe during the last glacial and is often referred to as Doggerland (Coles, 1998).

2.8.2 Work around the Humber Estuary has led to a detailed understanding of this sea level change and the deposition of interdigitating freshwater and estuarine deposits, which occupy the low-lying areas of former Lake Humber. By the mid-8th millennium BC, global sea level rise was beginning to lead to the inundation of Doggerland and by 8,000 cal BP (6,000, cal BC), estuarine conditions prevailed in the outer Humber estuary with sea levels about 17m below present.

2.8.3 Between 8,000-6,000 cal BP (6,000-4,000 cal BC), sea level rose rapidly with marine conditions recorded at many sites in the outer and middle estuary; at this time, sea level was around 7m below present. After 6,000 cal BP (4,000 cal BC), marine transgression progressed into the lower parts of the river valleys of the inner estuary leading to waterlogging and paludification of soils.

2.8.4 By 5000 cal BP, global sea level rise as a consequence of deglaciation had all but ended. However, combined factors such as coastal and estuarine land configuration, sedimentation patterns and variable tidal regimes all resulted in continued ‘relative’ sea level change in the Humber Estuary during the later prehistoric and historic period.

2.8.5 Between 4000 and 1900 cal BP (2000 cal BC - cal AD 50), there was an overall period of positive sea level, however from around 3000 cal BP (1000 cal BC), the development of freshwater peats in the Hull and Ancholme valleys suggest a move towards negative sea levels in this part of the estuary. This period from 4000 cal BP represents the maximum extent of marine transgression, leading to the inundation of many earlier prehistoric sites of human activity in the Humber Estuary. Archaeological research suggests a fall in sea level in the Roman period, which may have continued towards the end of 1st millennium AD.

2.9 Wider Wetlands

2.9.1 Proximal to the Project to the west are the remains of large-scale wetlands. Thorne and Hatfield Moors are the remnants of former raised mires which were once divided by the original course of the River Don and which rest on Lake Humber and coversand deposits respectively (Whitehouse, The Humberhead Peatlands: Thorne and Hatfield Moors, 2001).

2.9.2 Peat initiation across both Moors was broadly coeval, beginning around 4500 BP (c. 3350-3100 cal BC) with paludification across a dryland surface in response to rising sea levels and associated base level changes within the local valley floors (Whitehouse et al., 2001b). The Moors have been the focus of pollen insect and dendrochronological studies and there is little in the way of evidence for human disturbance to the vegetation

which would have contributed to the increasing wetness of the area (Whitehouse, The ontology of Thorne and Hatfield Moors, 2001).

2.9.3 Insect remains demonstrate the presence of an Urwald fauna indicating ancient woodland. In the 1990s, commercial peat extraction of Thorne moors exposed thousands of well preserved, pine, oak and birch charred stumps over an area of around 5km though no signs of human interference were discovered. Dendrochronology indicated that the oaks dated to 3777-3017 BC whilst the pines dated to 2916-1489 BC, suggesting woodland succession overtime, before the onset of peat formation (Boswijk, 2001).Charred pines were also recorded at Hatfield with insects demonstrating sandy heathland habitats (Whitehouse, The ontology of Thorne and Hatfield Moors, 2001).

2.9.4 In 1971, a Bronze Age trackway was discovered on Thorne Moor during commercial peat extraction and radiocarbon-dated to 1390-1060 cal BC Boswijk (Boswijk, 2001). The subsequent discovery of a Neolithic trackway and platform on Hatfield Moors in 2004 provided an opportunity to reassess the landscape and environmental setting of both areas using modern geoarchaeological techniques supported by robust geochronologies (Chapman, 2013) . Whilst this work provided little in the way of new findings in terms of the palaeoenvironmental record, it provides detailed contextual frameworks for the archaeological remains across both areas. The potential of such deposits to preserve wooden archaeological remains is high but prospection for such remains is a challenge.

2.10 River Valley Sequences - Trent, Idle and Foulness

2.10.1 Away from the raised mires, the river valleys within the Project have several significant datasets. Palaeoenvironmental investigations have been undertaken both within channel and associated floodplain sequences of the river valleys proper. South of the Humber at Bole Ings, a 2km southwest of Gainsborough on the west bank of the Trent, palaeoenvironmental analysis of a large palaeomeander of the Trent recorded a sequence spanning much of postglacial prehistory (Dinnin M. , 1997) (Brayshay, 1999). Pollen and insect analysis demonstrated that during the Mesolithic (8000-4000BC), the Trent would have formed a multi-channel, anastomosing system with extensive wetlands on the wooded floodplain. Towards the end of the Mesolithic the floodplain started to change, becoming dominated by alder carr, most likely a response to the increasing groundwater levels.

2.10.2 Within drier, higher parts of the floodplain, closed canopy forest with isolated clearings, possibly used by grazing animals were present. This reflects the general picture of the onset of the Neolithic in the Trent valley with sporadic areas of clearing for cereal cultivation and the grazing of livestock. The alder carr environment appears to peak during the Middle Bronze Age and represents an apparent period of landscape stability at Bole Ings. By the end of the Bronze Age, this period of floodplain stability had ceased and there is evidence for small scale clearance continuing leading to the expansion of grasslands and reedswamp. This increasingly open landscape would have led to further waterlogging of the floodplain, with the lack of trees leading to an increase in surface runoff and river bank instability. The alder carr declined and was replaced by open sedge fen. Increased soil erosion led to increased overbank minerogenic alluviation.

2.10.3 Extensive aerial photographic analysis of the Late Pleistocene terrace of the lower Trent immediately above the postglacial floodplain has demonstrated extensive settlement and human activity across its surface since later prehistory (Whimster, 1989).

Numerous archaeological evaluations, full excavations and watching briefs associated with a range of activities from quarrying to power station expansion has demonstrated significant preservation of features ranging from the Neolithic through to the medieval period, with notable evidence for significant Roman activity (Knight & Howard, 2004).

2.10.4 The tributary valleys of the Trent also provide a record of early landscape change. Approximately 1km south of Cove Farm on the eastern edge of the Idle floodplain, (Dinnin & Welsh, 2001) recorded a woody peat-filled depression in the coversand surface with preliminary pollen assessment suggesting an arboreal taxa dominated by pine, oak, alder and elm attributable to the mid Holocene.

2.10.5 North of the Humber estuary across the lowlands of the Foulness valley, the environmental history of the postglacial up to the Iron Age has been summarised by Halkon and Innes (Halkon & Innes, Settlement and economy in a changing prehistoric lowland landscape. East Yorkshire , 2005). By the early Mesolithic, the landscape was dominated by woodland with fen wetlands, pools and numerous river channels providing a resource-rich environment for early hunter gatherers. During the later Mesolithic, bogs and carr environments started to develop in response to groundwater changes, whilst full deciduous forest developed on the higher drier areas. Nearing the end of this period and into the early Neolithic, the lower Foulness valley became an estuarine inlet (Walling Fen). Pollen evidence suggests the beginnings of farming around the Mesolithic-Neolithic transition.

2.10.6 Falling sea levels during the early Bronze Age accelerated clearance of valley side woodlands and there is evidence for animal grazing close to the river and pools. By the Middle Iron Age, sea level rise again led to severe waterlogging and more extensive flooding of places like the Foulness valley. Within this wetland environment, the importance of the river for transport and trade is demonstrated by the discovery of log boats in a former estuarine inlet beneath Hasholme (M, McGrail, Creighton, & Gregson, 1997) and South Carr Farm (Halkon P. , A log boat from South Carr Farm near Newport, 1997), both attributed to the Iron Age.

2.10.7 Whilst no similar craft have been identified south of the Humber in the vicinity of the cable route, examples of Bronze to Iron Age date vessels have been found more regionally at Brigg in the Ancholme valley, demonstrating the potential of these low-lying, estuarine landscapes (McGrail, 1981). In addition, further south the palaeochannels of the Trent have demonstrated good preservation of watercraft from the Bronze Age to the Roman period, although these are recorded much further south in the Middle Trent Valley.

2.10.8 Greater exploitation over time of the wetlands of the Humberhead and adjoining wetlands required the manipulation and control of water. Gaunt (Gaunt G. D., 1976) identified that the River Don once flowed eastward from Thorne, through Crowle to join the Trent at Adlingfleet, suggesting a medieval date for this diversion. However, (Jones, 1995) suggested the diversion was of Roman date, also indicating a similar age for the diversion of the Idle to West Stockwith via the Bycarrs Dyke. Again the Trent also records extensive wooden structural remains relating to passive fishing methods, in the form of fish traps, and revetment structures which are often preserved within both organic palaeochannel and reworked sand and gravels.

2.11 Post-medieval Landscape Development

2.11.1 What is more certain is the timing of large-scale drainage and river engineering of the Humberhead Levels and adjacent regions, including the Lower Trent, by the Dutch

engineer Cornelius Vermuyden, which commenced in the early 17th century on behalf of the King (Buckland P. , 2001). Once drained, agricultural soils were improved further from the mid-17th century by the practice of warping, where fertile alluvium was introduced to fields, either locally via carts or across wider areas by way of complex drain and sluice systems operating on the ingoing and outgoing tide.

2.11.2 Archaeological, geoarchaeological and environmental investigations funded by commercial partners have been relatively limited across the Project route, but areas to the east within the Trent Valley have undergone extensive monitoring programmes during aggregate extraction. Outside of the valleys, extensive tracts of peatland across Thorne and Hatfield Moors were the focus of commercial peat extraction until the early 2000s, the licenses to extract predated archaeological planning constraints, hence the focus on academic studies.

2.11.3 Building on a desk-based assessment of Hislop and Krawiec (2004), geoarchaeological investigations of Beckingham Marshes on the opposite side of the Trent to Gainsborough comprised a watching brief on shallow floodplain scrapes created to improve local biodiversity (Krawiec, 2010). The investigations revealed two east to west orientated ditches infilled with peat, in turn buried by alluvium. No finds were recorded in the features and they did not appear on historic mapping, demonstrating the potential for the burial of archaeological remains by alluvium. Two-pointed wooden stakes of unknown date were also recovered. The pollen record examined from Beckingham (Hopla and Gearey 2009) recorded a heavily wooded landscape most probably dating to the early Neolithic (4000-2000 BC), which correlates well with the results from Bole Ings. In contrast, similar works for biodiversity within the Idle Valley revealed little of archaeological value (Espley, 2021).

2.11.4 At Sturton Le Steeple, building on a desk-based assessment by Challis (Challis, 1999), borehole drilling identified significant well-preserved peat deposits, lying thickest within a depression interpreted as a former channel of the River Trent. The peat was found to contain rich organic deposits including wood, sedge and beetle remains. Analysis of the environmental samples pointed to an alder carr wetland with areas of pool and fen. Elsewhere there was evidence for dryland woodland with a partially open canopy, dung beetles indicated pasture and charcoal pointed to fire. Radiocarbon dating showed that the organic sediments were laid down from the Late Neolithic through the Bronze Age and probably into the Iron Age (Howard A. J., 2004).

2.11.5 In terms of investigations into more marginal and minerogenic sequences, at Langholme Lake, Haxey, York Archaeology excavated two test pits in order to understand the depositional sequence through a series of windblown sands. The pits recorded sandy topsoil developed on Warp deposits, in turn sealing organic silts and clays but no archaeological remains were encountered. With this area the sands are extremely thick, up to 14 m and have the potential to mask archaeological deposits.

2.11.6 The most detailed and significant commercially funded investigations undertaken regionally are those associated with the development of new electricity generating facilities at Keadby on the west bank of the Trent opposite Scunthorpe (Keadby 2 Power Station; Keadby 3 Power Station; and Keadby Wind Farm). Geoarchaeological test pitting associated with these Projects identified basal aeolian Sutton Sand Formation deposits which were OSL dated to around 7270-5490 BC and therefore demonstrably reworked, most probably by a mixture of fluvial and aeolian activity.

2.11.7 The fluvio-aeolian sands were overlain by organic-rich silts, clays and interdigitating peat units, occurring at several levels and each up to around 0.50m thick. Radiocarbon dating demonstrated the earliest peats were formed in the Late glacial/early Holocene

(11,423–11,196 cal BC) whilst the latest preserved were attributable to the Iron Age (350–54 cal BC). The peats showed varying levels of humification but palaeoenvironmental assessment indicated that although pollen preservation was variable, there was a high abundance of well-preserved pollen indicative of alder carr woodland within the Neolithic to Early Bronze Age periods (between 4000-2000 BC).

2.11.8 Overlying organic-rich, silts, clays and peats was a variable thickness (c. 0.10-0.50m) of fine-grained oxidised silts and clays, interpreted as the product of both natural overbank alluviation and deliberate flood-warping. The latter is distinguished from the former more homogenous, structureless alluvium by the presence of fine laminations, indicative of successive discrete warping 'events'. These 'events' consist of the controlled flooding of land by way of a series of ditches and sluice gates allowing the settling out of suspension fine particles. Documentary research suggests that warping has its origins from the mid-late 17th century in both the Trent Valley (Lillie, 1998) and Humberhead Levels (Lille, 1997).

2.11.9 An overview summary of the deposits within the Project is provided in **Error! Reference source not found.**.

Table 2-1 - Summary of deposits within the Project.

Marine Isotope Stage (MIS)	Deposit Type	Location	Archaeological Potential
The Holocene postglacial (MIS 1)	Warp (artificially deposited silts and clays	Across the lowlands under tidal influence	Potential for burial of earlier surfaces, cultural and palaeoenvironmental remains). Discovery of structures associated with Warp engineering (e.g. sluices)
	Interdigitating fluvial and estuarine sands, silts, clays and peats	Across the lowlands previously occupied by Lake Humber.	Potential for postglacial cultural, including structural and palaeoenvironmental remains to be interleaved and buried at several depths within the sequence and across former gravel islands
Late Devensian (MIS 2)	Wind-blown sand (Coversand).	Spreads on eastern edge of Foulness Valley and across the Humberhead Levels and Trent Valley.	Potential for Late Upper Palaeolithic and later material to be located on surface (notably lithics) and palaeoenvironmental remains (peats) both internally and as surface pockets.
	Head (poorly sorted slope material moved under periglacial conditions).	Infilling small, incised valleys of Yorkshire Wolds escarpment.	Potential to contain reworked Palaeolithic material or bury earlier in situ remains. May include palaeoenvironmental remains (probably molluscs).

Marine Isotope Stage (MIS)	Deposit Type	Location	Archaeological Potential
	Bielby Sand Member (fluvial sand, reworked in part by aeolian processes).	Southwest edge of Yorkshire Wolds escarpment.	Potential for Late Upper Palaeolithic and later material to be located on surface and earlier Palaeolithic and palaeoenvironmental remains internally (organic-rich sediments, faunal remains).
	Hemingborough Glaciolacustrine Formation (Lake Humber Deposits).	Across the lowlands of the Foulness Valley, Humberhead Levels and Lower Trent Valley.	Humans absent from Britain during time of formation so devoid of archaeology and low palaeoenvironmental potential
	Till (poorly sorted gravelly clays) deposited directly by LGM icesheet.	Most widespread on Yorkshire Wolds plateau but occasional isolated remnants south of the Humber (e.g. Lindholme Island).	Humans absent from Britain during time of formation, but Late Upper Palaeolithic and later archaeology may be found across the surface. There is also a small chance that earlier Lower and Middle Palaeolithic material (lithics) might be incorporated into these sediments through the reworking of earlier deposits.
Middle Devensian (MIS 3)	Fluvial sands and gravels	Western side of the Humberhead Levels.	Potential for Lower, Middle and Upper Palaeolithic (lithics) and later material to be located on surface and within, and palaeoenvironmental remains within (organic-rich sediments, faunal remains).
Ipswichian Interglacial (MIS 5e)	Organic-rich fluvial and estuarine deposits.	Recorded from western edge of the Humberhead Levels. Possible interglacial beds on the eastern edge of the Foulness Valley.	Humans thought to be absent from Britain during the last interglacial but deposits a source of important palaeoenvironmental information. There is also increasing evidence that whilst humans may not have been present at the height of the interglacial, they may have returned very soon afterwards on the falling limb of the glacial-interglacial cycle.

Marine Isotope Stage (MIS)	Deposit Type	Location	Archaeological Potential
Aveley Interglacial (MIS 7)	Fluvial sands and gravels with organic-rich silts and clays.	Buried palaeovalley centred on Bielsbeck Farm following the broad alignment of the Foulness.	Contemporary Middle Palaeolithic lithic and palaeoenvironmental remains, including large vertebrate material recovered from buried palaeovalley/channel around Bielsbeck Farm. Small chance of earlier Palaeolithic material being incorporated through reworking of earlier sediments.
Wragby Glaciation (MIS 8)	Till (poorly sorted gravelly clays) deposited directly by icesheet, attributed to MIS 8 though possibly earlier. As well as tills glaciofluvial deposits will be associated with any such tills.	Occasional eroded remnants south of the Humber, usually on higher ground.	Middle Palaeolithic and later archaeology has the potential to be spread across the surface and buried internally. Small chance of coeval palaeoenvironmental sediments internally. Small chance of earlier Palaeolithic material being incorporated through reworking of earlier sediments.

3. Geoarchaeological DBA's Aims and Objectives

3.1.1 The aims of this geoarchaeological DBA are as follows:

- To understand the age, extent and depositional processes within the Order Limits and 1 km study area;
- To assess how the deposits may be impacted by the Project and inform the assessment of impact and identification of likely significant effects reported in **Application Document 6.10 Chapter 10 Cultural Heritage**; and
- To identify potential mitigation measures that will offset likely significant effects, which are secured in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation**.

3.1.2 The objectives to meet the aims are as follows:

- to undertake a review of the lithological record of deposits from existing British Geological Survey (BGS) data;
- to interrogate Lidar data and identify potential features;
- to create a risk map for the Project; and
- to provide recommendations for potential further work.

3.1.3 A provision for potential further geoarchaeological work is included in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation** and may be influenced by detailed design changes carried out at post-consent. As such, **Application Document 7.9 Outline Archaeological Written Scheme of Investigation** includes a requirement for Site-Specific Written Schemes of Investigation (SSWSI) to be produced and agreed with the Archaeological Advisor to the relevant local planning authority.

3.1.4 As detailed in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation** the scope of any future SSWSI should consider the following East Midlands Research Agenda topics (East Midlands Research Framework, 2026) summarised in Table 3-1.

Table 3-1 - Potential research themes

Period	Research Themes
Pleistocene	1G Elucidate from terrestrial sources the changing Pleistocene environment of the East Midlands. 1.5.1 Can we shed further light upon the development of the pre-Anglian river systems that may have served as corridors of movement for the earliest hominins (especially the Bytham and precursors of the Trent)?
Mesolithic	2A Enhance understanding of the environmental background to Mesolithic activity.

Period	Research Themes
	2.6.2 How can we maximise the potential of palaeochannels and other organic-rich deposits as sources of data on Early Holocene landscapes and changes in subsistence strategies and diet?
Neolithic and Early to Middle Bronze Age	3I Investigate the development and intensification of agriculture. To clarify further the development of farming communities, additional targeted sampling of palaeochannels, peat bogs and other locations likely to preserve environmental remains of these periods is recommended. It is suggested that this be combined with studies of soil micromorphology and geochemistry, which may provide valuable information on the extension of cultivation and agricultural intensification. Special emphasis should be placed on the recovery of large assemblages of animal bone from excavations.
Late Bronze Age to Early Iron Age	4C Characterise the Late Bronze Age and Early Iron Age settlement resource and investigate intra-regional variability. Further research is recommended to investigate the morphology and functions of settlements dating from this crucial transition period and to investigate the environmental evidence for seasonal or permanent settlement.
Romano-British	5H Investigate the landscape context of rural settlements. Appropriate environmental sampling strategies need to be encouraged to accumulate botanical and faunal data that will provide a secure foundation for studies of changing landscape context and site location strategies.
Early Medieval	6.3 Roads and rivers: transport routes and cultural boundaries. 6.3.1 What roles may rivers have played as corridors for the movement of goods and people, and how might these have varied over time?
Medieval	7C Investigate the provisioning of the medieval town. 7.7.4 What can the environmental remains teach us about diet and living conditions in urban communities? 7.6.3 Can we identify, investigate and date sites associated with the region's key extractive industries (especially iron, coal, lead and alabaster), the production and distribution of cloth and leather-work, and freshwater or marine fishing?

4. Geoarchaeological Methodology

4.1 Overview

4.1.1 A review of the main landform assemblages and other evidence for landscape evolution was undertaken using the specialist knowledge of the authors and all available published documentary resources. As well as geoarchaeological literature published in a range of journals (e.g. Mercian Geologist, Proceedings of the Geologists Association, Quaternary Science Reviews, Journal of Quaternary Science, fields guides of the Quaternary Research Association).

4.2 Lidar

4.2.1 The use of Airborne Laser Altimetry, more often referred to as Lidar (Light Detection and Ranging), for archaeological survey has become increasingly established. 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 over large areas.

4.2.2 In England the Environment Agency (EA) has undertaken extensive areas of Lidar survey building up a library of data which is now freely available for processing and analysis under Open Government Licence 3.0.

4.2.3 EA provide processed datasets as 5 km-square raster grid tiles on the Ordnance Survey National Grid with two different datasets available for each tile:

- DSM = Digital Surface Model, i.e. the unfiltered elevation data; and
- DTM = Digital Terrain Model; filtered data, with vegetation and buildings removed and ground levels at these points interpolated.

4.2.4 The DTM has the advantage of screening out vegetation producing a bare earth model with significant potential for the study or archaeological earthworks in wooded environments (where the woodland has often preserved features from agricultural degradation) and is the principal dataset used here. The vertical accuracy of the dataset is quoted as +/-5 cm to +/-15 cm. Relative (point to point) accuracy, more relevant for detailed archaeological mapping, is generally +/-5 cm or better; absolute spatial error is +/-40 cm horizontally, relative accuracy rather smaller, but at 0.50 m or larger resolution the error is effectively absorbed in the pixels of the raster image in any case.

4.2.5 The Lidar DTM comprises a close-interval raster grid of spot-height data but require the application of further processing and visualisation techniques in order to emphasise features of potential archaeological interest. Relief modelling through the use of artificial light sources (hill-shading) often provides the most readily understandable representation. However, this can suffer from directional sensitivity with features aligned with the lighting direction potentially much less visible or potentially lost in shadow or saturated lighting in areas of high relief. A growing suite of techniques exists to overcome this, ranging from multi-directional hill-shading and principal component analysis to non-directional techniques such as local relief modelling and sky-view factor. Comparison of different techniques indicates that no one single technique will work in all circumstances and their use in combination is generally recommended. Standard

processing utilised here combines multi-directional hill-shading with negative openness using the Relief Visualisation Toolbox developed by the Scientific Research Centre of the Slovenian Academy of Sciences and Arts with the processed outputs loaded into QGIS 3.10 and inspected for potential archaeological features.

4.3 Targeted Deposit Modelling

4.3.1 A series of targeted deposit models of key localities were constructed using the existing British Geological Survey records (Transect locations Figures 04-10). a large quantity were deep boreholes, for understanding the bedrock geology primarily related to mining and had little to no information about the superficial deposits. Only 55 locations were within the Project Order Limits, with 16 being confidential. The majority of the usable records utilised for the transects derive from mineral prospection surveys, so had more detailed descriptions / interpretations of the superficial deposits. A total of 487 of the boreholes in the 1km buffer targeted superficial deposits - 114 of these being confidential. Prior to modelling, the data was cleaned and sorted for relevance and only those records that were readily available and considered robust were used. A spreadsheet detailing the justification for exclusion/inclusion of data was compiled.

4.3.2 The models were constructed with reference to the areas of highest potential (risk) and informed by the results of the Lidar assessment. These sections have also been related to the HER data and using the author's knowledge of the area.

4.3.3 The modelling followed procedures set out within the Historic England Guidance for Deposit Modelling and Archaeology (Historic England, 2020). The data was entered into a Rockworks database in order to generate cross-sections and strip logs.

4.3.4 The data is archived in an excel spreadsheet and will be submitted to the Archaeology data Service.

4.4 Risk Mapping

The shapefiles for the risk mapping are divided chronologically into Pleistocene and Holocene with the accompanying database providing additional information regarding the deposits, their age and associated archaeological and geoarchaeological remains. The rational is detailed in Table 4-1.

Table 4-1 - Risk mapping table.

Deposit Unit	Approx age of archaeology	Archaeological potential (coeval and later human)	Potential evaluation approaches
Glacial tills	Mid Pleistocene (MIS 12)	Coeval human activity during warmer parts of the cold stage related to hunter-gathers so remains likely to be restricted to stray finds of lithics. The land surfaces are of considerable antiquity and hence have the potential to include multi-period postglacial remains at or near the contemporary ground surface	Trial trenching across areas of postglacial archaeological potential identified using other techniques (e.g. geophysical and Lidar survey). Coring and/or trial trenching to allow recording and sampling of any temperate organic remains.

Deposit Unit	Approx age of archaeology	Archaeological potential (coeval and later human)	Potential evaluation approaches
		Sediments deposited under cold climate conditions with minimal vegetation cover so environmental potential of these glacial sediments is low. Since they have been impacted by later glacial and periglacial processes, there is low potential for finding Middle Pleistocene organic-rich sediments near the surface in landforms such as kettle holes	
Glacial tills and glaciofluvial deposits	Mid Pleistocene (MIS 8)	Coeval human activity related to hunter-gathers (Neanderthals) so remains likely to be restricted to occasional stray finds of lithics. The land surfaces are of considerable antiquity and hence have the potential to include multi-period remains at or near the contemporary ground surface Sediments deposited under cold climate conditions with minimal vegetation cover so environmental potential is low.	Trial trenching across areas of postglacial archaeological potential identified using other techniques (e.g. geophysical and Lidar survey).
River terraces	Mid to Late Pleistocene – (MIS 8/2)	Coeval human activity related to hunter-gather activity (Neanderthals and modern humans) so remains likely to be restricted to either stray finds of lithics or clusters of material associated with temporary encampments. The land surfaces are of considerable antiquity and hence have the potential to include postglacial multi-period remains at or near the contemporary ground surface. Sediments deposited under a mixture of warm (interglacial, interstadial) and cold (stadial) climate conditions so sediments may include major or minor channels infilled with organic material (major channels most likely to occur basally).	Trial trenching and/or test pitting across any lithic scatters. Trial trenching across areas of postglacial archaeological potential identified using other techniques (e.g. geophysical and Lidar survey). Trial trenching, power/hand augering to establish the 3-dimensional character of the subsurface sedimentary sequence and provide information on timing of alluviation of any postglacial fluvial deposits. Post-glacial, organic rich sediments sampled from open trial pit sections, and or through hand/power

Deposit Unit	Approx age of archaeology	Archaeological potential (coeval and later human)	Potential evaluation approaches
		Warming of climate and expansion of vegetation during the early postglacial may result in substantial organic sequences preserved within palaeochannels and / or across wider backswamp surfaces.	augering depending upon ground conditions.
Estuarine and Marine Deposits	Mid to Late Pleistocene – (MIS 9/5e) and Holocene	Sediments deposited under Pleistocene estuarine / marine conditions so primary cultural material is highly unlikely to be found close to the contemporary ground surface, but may be found at depth within the sequence, possibly associated with higher islands. There is a higher probability of reworked material. Coeval environmental remains may provide evidence about the character of the wetland/dryland landscape both locally, but which may also inform other debates (e.g. nature of sea level change during the Ipswichian interglacial). Sediments may form islands within the wetland and being of considerable antiquity, they have the potential to preserve multi-period postglacial remains upon their surfaces. Postglacial environmental records may be preserved in channels and / or archaeological features close to the contemporary surface.	Trial trenching across areas of postglacial archaeological potential identified using other techniques (e.g. geophysical and Lidar survey). Postglacial, organic rich sediments sampled from open trial pit sections, and or through hand/power augering depending upon ground conditions.
Alluvium and Peat	Holocene (MIS 1)	Multi-period human activity ranging from Mesolithic hunter-gather activities to sedentary lifestyles. The land surfaces may be of considerable antiquity or relatively young. There is the potential to include multi-period remains at or near the contemporary ground surface, including on buried gravel	Trial trenching across areas of postglacial archaeological potential identified using other techniques (e.g. geophysical and Lidar survey). Trial trenching, power/hand augering to establish the 3-dimensional character of the subsurface sedimentary sequence and provide

Deposit Unit	Approx age of archaeology	Archaeological potential (coeval and later human)	Potential evaluation approaches
		islands, within and beneath later alluvium.	information on timing of alluviation.
		Sediments deposited under postglacial climatic conditions and hence potential for substantial organic sequences preserved within palaeochannels and/or across wider backswamp surfaces.	Organic rich sediments sampled from open trial pit sections, and or through hand/power augering depending upon ground conditions.

4.4.1 The risk map in Annex A is colour coded from High to Low and in the first instance using the geological mapping as a framework for the shapefiles. Where channels are clearly identifiable within an alluvial unit, these have been assigned separate shapefiles to provide nuance to the map.

5. LIDAR

5.1 Summary

5.1.1 The Phase 1 National Lidar Programme (NLP), undertaken by the Environment Agency (EA) between 2017 and 2023, provides full coverage of England at 1m resolution. This dataset is freely available for processing and analysis under Open Government Licence and has been utilised in analysis here.

5.1.2 EA provide processed datasets as 5km-square raster grid tiles on the Ordnance Survey (OS) National Grid with two different datasets available for each tile:

- DSM = Digital Surface Model, i.e., the unfiltered elevation data.
- DTM = Digital Terrain Model; filtered data, with vegetation and buildings removed and ground levels at these points interpolated.

5.1.3 The Lidar DTM/DSM comprise close-interval raster grids of spot-height data but require the application of further processing and visualisation techniques to emphasise features of potential archaeological or geomorphological interest. Relief modelling using artificial light sources (hill-shading) often provides the most readily understandable representation. However, this can suffer from directional sensitivity with features aligned with the lighting direction potentially much less visible or lost in shadow or saturated lighting in areas of high relief. A variety of non-directional techniques exists and can be used in combination to help overcome this. Multi-directional hill shading has been used in the production of figures here, combined with positive openness where this is more informative.

5.1.4 In low-lying landscapes such as the Humberhead levels, very slight elevation changes can be significant and are not necessarily well expressed in a standard relief model. Here a customised colour ramp has been used. This is designed to make a sharp distinction at the edge of higher ground (above the 3 m O.D. contour, effectively the Mean High-Water mark in the Humber estuary). Land above this shades from green (3 m) to yellow (5 m) to brown (10 m). The white-blue-cyan scale represents everything below 3 m, with the lowest values white (as low as -1 m). The use of a continuous rather than discrete colour scale makes for a less objective plot but is much more expressive of the landscape with fine distinctions in surface levels apparent.

5.2 Foulness Valley (Figure 11)

5.2.1 As the route leaves the higher ground of the Wolds, it enters low-lying ground, below 3 m O.D., in the Foulness valley at the margins of the Humber. A sinuous downcutting palaeochannel [A] is evident here running through Walling Fen to the Crabley Beck and Sands Drain. This channel is 25 m-30 m across and 0.5-0.6 m in depth along most of its course, but a much shallower 0.2 m at its southeastern end. More complexity is evident at the western end with a number of possible branching channels. This clearly belongs to a drainage regime earlier than the 18th and 19th century improvements, possibly a route of the River Foulness itself before it became captured by the Market Weighton Canal. It is notable that it does not run in what is now the lowest part of the landscape, suggesting that this had been infilled with peat when the channel was active. At its

southeastern end it is cut across by the higher sands at the northern edge of the estuary. A smaller tributary [B] crosses Cave Ings. In both cases higher elevation and roddon-like form suggest a spread of silts likely from periodic overbank flooding (Blaeu 1665; Moll 1724 maps: all of this drains into the estuary at or west of Broomfleet).

5.3 Blacktoft (Figure 12)

5.3.1 This is likewise seen along the Broomfleet Beck [C]. Here the silting largely appears to follow the canalised form of the Beck, but would appear to belong to an earlier tidal phase with more direct connection to the estuary. Westwards of here the causes of elevation changes are less clear cut, although much appears to conform to 19th century and later field boundaries and warping, the deliberate introduction of flood silts, has clearly been practised (the 'Warping Bridge' on the Hull railway line). Sinuous channel forms [D. E] are nonetheless evident west of Oxmardike Marr perhaps taking drainage from the higher ground above Gilberdyke. A series of slight, straight negative features [F] west and southwest of Staddlethorpe appear likely to represent the remains of warping drains.

5.4 Ousefleet (Figure 13)

5.4.1 On the south bank of the Humber, south of Ousefleet, the marshland is crossed by a large branching roddon [G] running generally west to east and formerly falling into the estuary at Blacktoft Sands just to the west of the Trent Falls. The roddon varies from 140-200 m in width but little more than 0.5 m in height at its most pronounced. A downcutting channel form up to 25 m in width but no more than 0.2 m in depth is evident at points along its course. The drainage regime appears anomalous in a historic context. It appears too large a feature for the area it would seem to drain and with the silts only rising to c. 2 m it perhaps suggests a lower sea level when it was an inlet open to the sea.

5.4.2 The line of the former Swinefleet Warping Drain [H] is evident as a surface feature west of, and apparently just extending into, the route corridor, although its 19th century mapped extent stops short. Superficial Warp deposits are mapped here by BGS.

5.4.3 Just west of Garthorpe the route crosses the line of the Old River Don [I], also encompassing part of its course at Haldenby Ness just south of Luddington. The river course is marked by a wide levee c. 700 m in width rising to above 3 m O.D. The sinuous river channel is still marked by field boundaries and drainage ditches in places, and as a sinuous linear hollow, some 40 m wide 0.3 m deep, in others.

5.5 Luddington-Beltoft (Figures 14-15)

5.5.1 East and southeast of Luddington a block of higher silts [J] with sharply defined edges (along some sides) appears to relate to warping south of the Mere Dyke. The BGS maps warping deposits over the majority of this block to the south and west skirting the higher ground at Crowle to edge of the Isle of Axholme. Sinuous channel forms [K], some up to 0.6 m deep, are evident nonetheless, suggestive of some natural surface drainage, but perhaps only seasonally active or intermittently reactivated.

5.5.2 Just at the northern edge of the higher ground of Axholme a linear bank [L] is apparent running through the former site of Temple Belwood to Beltoft Grange and ultimately to the Trent at Derrythorpe Grange. Modern field boundaries and drainage ditches still

follow parts of this course, and the furthest eastern end serves as a causeway for the road to the banks of the Trent, but stretches were apparently out of use by the 19th century. Whilst this feature is of unknown origin/function, possible interpretations might include a causeway, warping drain or a catchwater.

5.6 Isle of Axholme (Figure 16)

5.6.1 From Beltoft to East Lound, the route corridor crosses the eastern edge of the Isle of Axholme, part of the route dropping below 3 m O.D. with superficial deposits of alluvium, sands and peat mapped in this lower-lying area. Few clear landforms are evident; Cowsitt Hill represents an eastern outlier of higher ground, while some natural drainage features [M, N] are apparent at the eastern margin.

5.7 East Lound-Misterton (Figure 17)

5.7.1 Between the Isle of Axholme and the edge of higher ground at Misterton there is another zone of lower-lying ground with superficial deposits of alluvium, warp, sands and peat. The canalised River Idle and Warping Drain/Ferry Drain take advantage of this gap to reach the Trent, draining the carrs to the west. Aside from this wider topographic context, the Lidar shows little in the way of interpretable landforms.

5.8 Trent Floodplain at High Marnham (Figure 18)

5.8.1 A small area of the Trent floodplain at High Marnham falls within the study area. A number of palaeochannel features relating to older courses of the Trent are evident here, including a cut-off meander at Fledborough [O] and the northern end of a channel [P] named ‘Old Trent’ at High Marnham. Shallow channel forms [Q] on the higher Holme Pierpont terrace might potentially represent remnants of much older river courses, but are hard to separate from more recent drainage of the higher ground to the west or seasonally active flood channels.

6. Deposit Modelling

6.1 Summary

6.1.1 The deposit modelling has been restricted to transects due to the low number of useable datapoints within the Project area.

6.2 Transect 1 - Foulness Valley (Figures 05 and 19)

6.2.1 Transect 1 described the suite of deposits within the Foulness Valley on a northwest to southeast orientation. To the northwestern end of the transect the mudstone is overlain directly by peat deposits up to 6m thick. These logs are from 1888 and there is likely to have been significant changes to the condition and thickness of the peat in the intervening time period. More recent logs seem to record an absence of peat but these are derived from CPT readings rather than direct sediment observations. There are likely to still be substantial accumulations/pockets of peat within this area.

6.2.2 To the southeast, the peat appears be absent and the mudstone bedrock is directly overlain by glaciolacustrine deposits, the Hemingbrough Formation. The logs here are derived from CPT readings so there is a lack of detail in the logs regarding the lithology.

6.2.3 Within the centre of the transect up to 3.7 m of gravelly made ground material is recorded although this appears to be absent in the far northwestern end of the Transect. The character of this made ground is unknown and the alluvium is likely to be highly oxidised.

6.3 Transect 2 - Foulness Valley (Figures 05 and 19)

6.3.1 Transect two is located on a broadly north to south alignment towards the area of warp mapped by the BGS. The underling bedrock has not been encountered in the logs modelled here and the deepest deposit is represented by the Hemingbrough Glaciolacustrine Formation, defined as a stiff aminated clay. This is directly overlain by warp across the centre of the transect line.

6.3.2 The warp, recorded as up to 3 m thick, is likely to be unevenly distributed across the area despite the BGS mapping suggesting it is widespread. Such deposits are vulnerable to erosion from later land use and this deposit is likely to vary in depth across the area.

6.3.3 At the southern end of the transect the Hemingborough Glaciolacustrine Formation is overlain by Holocene alluvium characterised by soft sandy clays. To the far south organic deposits are recorded at the base of the alluvium up to 1.10 m thick.

6.4 Transect 3 - Humberhead Levels (Figures 06 and 20)

6.4.1 Transect 3 crosses the extensive area of Holocene alluvium at the head of the Humber proximal to the confluence with the Trent. Multiple palaeochannels are recorded here and are mapped by the Palaeochannels of the Trent (PTC) project. These likely represent tidal creek systems and as such reflect the latest iteration of channel

development in the area, with older and larger channels obscured beneath alluvial cover.

6.4.2 The underlying mudstone bedrock is overlain by Pleistocene sands and gravels which vary in thickness across the transect, ranging from 4 m to the west and 2 m to the east. These are overlain by the Hemingborough Glaciolacustrine Formation, the thickest part of which (at the eastern end of the transect) correspond to the thinnest gravel deposits.

6.4.3 The Lake Humber deposits are overlain by mainly minerogenic Holocene alluvium characterised as clayey sand up to 2 m thick. There are likely to be discrete organic deposits throughout this area, but none are recorded within the transect location, simply reflecting the low resolution of the data. The transect crosses several minor palaeochannels which cannot be modelled due to the lack of datapoints within these landform footprints.

6.4.4 There are areas of warp mapped by the BGS in this area but again no such deposits were recorded in the boreholes used to construct the transect. The distribution of data in this area is too sparse to provide the level of detail needed to more accurately define the spread of these deposits. In addition, as previously stated, the warp is likely to vary across the area in terms of thickness and distribution.

6.5 Transect 4 - Trent Valley (Figures 06 and 20)

6.5.1 Transect 4 is located 4km south of Transect 3 within the main western part of the Trent's contemporary floodplain. Again, a series of minor palaeochannels are mapped in this area, which also has extensive areas of warp according to the BGS.

6.5.2 The mudstone is again overlain by variable thickness of Pleistocene terrace sands and gravels which are overlain by Lake Humber deposits. These sands and gravels are up to 2.5 m thick although are completely absent at the northeastern end of the transect, which is likely due to later channel migration and erosion by the Trent. Here the lake deposits are directly overlain by Holocene alluvium up to 4m thick.

6.5.3 At the centre of the transect, the lake deposits are overlain by thin Holocene peat deposits which may relate to minor channel incision or channel-edge deposits. These are likely to be present in discrete locations across this suite of deposits. The alluvium is described as sandy silt clay and is soft and organic in places.

6.5.4 To the southwest, the lake deposits are overlain by aeolian (Sutton) sand deposits up to 2.50 m thick. These sediments often have an undulating upper surface within which discontinuous peat deposits are recorded. However, these are often too thin to be mapped as BGS records and the friable nature of the sand makes it prone to Holocene reworking.

6.6 Transect 5 - Trent Valley Edge (Figure 07 and 22)

6.6.1 Transect 5 is a north to south transect parallel with the edge of the Trent valley and this marginal location is reflected in the shallow nature of the deposits. The underlying mudstone bedrock is encountered between 0.50 m below ground level (bgl) at the southern end of the transect and 5.50 m bgl at the southern end.

6.6.2 The mudstone is directly overlain by Holocene alluvium at the northern end of the transect and is replaced by Sutton Sands towards the centre of the transect. This area

records the edges of multiple channel sequences, again mapped by the PTC project and peat deposits, although none were encountered in the transect logs.

6.6.3 Glaciolacustrine deposits are recorded, although intermittently, and these are sealed by a thin veneer of Holocene alluvium to the south. The distribution of BGS datapoints is too sparse to properly refine the subtle or localised changes in depositional regime here. The valley edge location is reflected in the thinly developed alluvial sequence for the majority of the area.

6.7 Transect 6 - Idle Valley Edge (Figures 08 and 21)

6.7.1 Transect 6 is located along the edge of the Idle valley on a northeast to southwest alignment. The mudstone bedrock is located c. 10 m bgl at the southwestern end of the transect and is overlain by varying thicknesses of Pleistocene terrace sands and gravels. Again, where these are thinnest they are overlain by thicker deposits of Glaciolacustrine deposits. These changes in gravel thickness are due to the creation of the lake, which in the wider area is marked by an irregular surface linked to later fluvial incision events.

6.7.2 The mudstone rises significantly to the northeast and is less than 2.50 m bgl. Here the sands and gravels are less than 0.50 m thick and record a thin veneer of peat which underlies the Sutton Sands. These peats are likely to be similar to those recorded in the Lower Trent in the Keadby/Scunthorpe area, being discontinuous and variable in thickness depending on the surface relief of the sands.

6.7.3 Alluvial cover here is unevenly distributed and less than 0.50 m thick. This area is unlikely to contain significant depths of overbank alluvium or in-channel deposits.

6.8 Transect 7 - Idle Valley Edge (Figures 08 and 21)

6.8.1 Transect 7 presents a much longer alignment and demonstrates the complexity of the deposits in this area which vary with each intervention. The mudstone surface clearly undulates, and this corresponds with the varying thicknesses of Pleistocene terrace sand/gravel and glaciolacustrine deposits. This provides a profile through Lake Humber deposits in the centre of the transect.

6.8.2 The transect is also defined by ridges of aeolian (Sutton) sands that characterise this part of the Idle-Trent valley. The sands are unevenly distributed across the area and to the north are overlain by a thin veneer of alluvium. Such sand ridges may have formed high points at the edge of the surrounding wetland and may have been favourable locale for hunter gatherer activity.

6.8.3 The lack of peat deposits in the transect is perhaps not surprising given not only the valley edge location, but the likely erosion of the deposits by subsequent agricultural activity and drainage. This area has demonstrated in recent fieldwork that the peat is rapidly shrinking and there has been wholesale erosion of alluvial cover, as such the BGS mapping does not reflect this.

6.8.4 The lack of warp in this transect is likely due to a combination of too few data points and perhaps a true absence in places as warp is vulnerable to erosion and reworking.

6.9 Transect 8 - High Marnham (Figures 10 and 22)

6.9.1 Transect 8 is located at the very southern extent of the Project route and presents a north to south transect in a valley edge location. To the north and south the mudstone is overlain by Pleistocene terrace sands and gravels, here assigned to the Holme Pierrepont Member; the deposits are up to 3 m thick. The alluvium associated with the Trent is confined to a narrow floodplain to the east of the transect. There are several mapped channels including a large meander loop in close proximity, but no datapoints are available to characterise this feature.

6.9.2 A single borehole log (SK87SW29) records no superficial deposits but entirely made ground. This is likely related to the construction of High Marnham Power Station.

6.10 Summary

6.10.1 The deposit modelling is constrained in many locations by the sparse coverage of the available BGS data. Despite this, a reasonable overview of the depositional sequences is possible.

6.10.2 Pleistocene terrace sands and gravel and Lake Humber deposits are recorded throughout the Project route and where the gravels are thinnest on the whole these locations display the thickest lake deposits and vice versa. Within the main river valleys these deposits are mostly overlain by Holocene alluvium and the Project route records very little in the way of made ground deposits, although this should be accepted with caution given the low number of useable data points.

6.10.3 Other organic deposits are recorded at the base of the Sutton Sands, although these organic lenses can appear throughout the sand sequence. Significant thickness of organics are also recorded in the BGS borehole data for the Foulness Valley although these logs are over 200 years old and require ground truthing. Other substantial organic deposits are likely to the present with the palaeochannels of the Trent and as localised deposits within the general floodplain alluvial sequence.

6.10.4 Within the northern part of the Project there is the potential for estuarine sequences associated with the Humber and tidally-influenced deposits in the Lower Trent. These are mainly laminated silt-sand-clays but again organic deposits are likely to be present as intermittent lenses within the overall sequence.

7. Risk Mapping

7.1 Summary

7.1.1 The risk mapping has been divided to consider separately the archaeological and palaeoenvironmental potential of sediments deposited during the Pleistocene and Holocene (Figure 03c; 03d). The reason for dividing it in this way is that the nature of climate, natural processes and human activity varies significantly between the two, in turn influencing preservation and geoprospection.

7.1.2 In terms of the Pleistocene record, the northern part of the Order Limits in Route Section A, has an overall Medium to Low Risk being composed mainly of glacial till and outwash deposits. These deposits may contain reworked Lower and Middle Palaeolithic artefacts but they are likely to be scattered widely through the deposits. There is a small chance that in situ lithic scatters of Upper Palaeolithic age could be found upon or close to the contemporary ground surface. There are some dry valleys which may contain possible Late Pleistocene (soliflucted) or postglacial (colluvial) sediments, which may incorporate or mask earlier archaeological remains.

7.1.3 Overall within the Project route the areas of Highest Pleistocene Risk are located where variable deposits of fluvial and aeolian sand are recorded (Beilby and Sutton Sands) and deposits relating to the past shoreline of Lake Humber, elevated above the wetlands.

7.1.4 The Holocene risk map is in part a reflection of the Pleistocene map, particularly in areas of fluvial and aeolian sand, and dry valley deposits, which may contain earlier deposits reworked by colluviation and later phases of wind-blown activity. The areas of highest risk are within the Foulness, Humberhead, Trent and Idle valleys, with both well-defined palaeochannels (Foulness, Trent) and more widespread floodplain peats (Idle/ Humberhead) recorded. The Project area may also contain possible localised peat deposits within the Sutton and Bielby Sands, which also have both archaeological and palaeoenvironmental potential.

7.2 Wolds from Hull to Brantingham (Figure 23)

Pleistocene

7.2.1 The key deposits and landforms within this stretch of the Project are associated are the glacial deposits of LGM age that blanket the Wolds, the periglacial dry valleys on their western edge infilled with cold climate slope deposits (solifluction) and later slope materials, and sand and gravel deposits mapped below the dry valleys along the fen edge. The latter terrace gravels, whilst largely fluvial and associated with the evolution of Lake Humber, may include interglacial beach deposits.

7.2.2 The surfaces of the till and terraces are of considerable antiquity so may be the focus of multiperiod settlement activity, commencing in the Late Upper Palaeolithic, although both surfaces may include earlier reworked lithic remains, though this is a low risk.

7.2.3 Internally, the till is unlikely to include significant palaeoenvironmental sediments since the environment at the time of deposition was harsh. In contrast, depending on their age

and mechanism of formation, the terrace sediments may include organic remains, but again the potential is relatively low.

7.2.4 Any soliflucted sediment preserved within the dry valley systems will have a low palaeoenvironmental potential though is the small chance that they contain reworked Palaeolithic material therefore their Pleistocene Risk is considered Medium but the remainder of this area is considered Low Risk.

Holocene

7.2.5 The dry valleys have the potential to contain later fills of slope deposits (colluvium) which may include reworked archaeological material or seal earlier horizons. These fills may also include a palaeoenvironmental element (primarily snails).

7.2.6 There is the potential for slope deposits to extends across the later terrace surfaces either bringing with it reworked archaeological material or sealing earlier deposits. The colluvium may also be interleaved with later alluvial material and if so, has the potential to elucidate land-use/sedimentation histories.

7.3 Foulness Valley (Figure 24)

Pleistocene

7.3.1 The Foulness valley is known to contain large mammalian faunal remains, artefacts and other palaeoenvironmentally significant deposits attributable to a Middle Pleistocene interglacial, most likely MIS 7. These deposits are thought to infill a major river valley (the proto-Foulness) which drained towards the North Sea via the line of the present-day Humber estuary. There is therefore the potential to locate such deposits along the Project corridor. The areas of Bielby Sands have a High Pleistocene Risk but the majority of the valley is Low Risk as any deposits of this age are likely to be deeply buried.

Holocene

7.3.2 The main risk is also with the areas of deep alluvial sequences where palaeoenvironmentally significant organic-rich freshwater sediments (peats) are likely to be interleaved with more minerogenic estuarine/marine deposits. Whilst BGS records suggest considerable thicknesses of peat, these records are over 100 years old and the actual sequences now preserved may be considerable thinner; Nevertheless, these sequences will likely have significant palaeoenvironmental potential.

7.3.3 The entire sediment sequence has the potential to preserve significant artefactual and other archaeological remains, including structural evidence. This may be present upon discrete foci, for example buried gravel islands or across the wider expanse of wetland (e.g. trackways, causeways). The potential of this area is amply demonstrated by the discovery of two later prehistoric logboats.

7.3.4 Warp mapped across this area has the potential to mask earlier deposits and archaeological remains. These areas are considered Medium Risk. Areas of Hemingborough Formation are considered Low Risk given the minerogenic content and oxidised nature of the deposits.

7.4 Humberhead Levels, Isle of Axholme and Idle valley (Figures 24, 25 and 26)

Pleistocene

7.4.1 Whilst the majority of this area was covered by Lake Humber during the LGM, the archaeological and palaeoenvironmental potential of the associated sediments is Low since humans were absent from mainland Britian during this timeframe and there was little in the way of vegetation cover. However, the edges of what would have remained wetland features even once drained, and together with the higher areas of glacial sediment, they would have been attractive places for settlement upon the return of humans during the Windermere interstadial.

7.4.2 Aeolian reworked fluvial sands (Sutton Formation) may include organic-rich remains either buried within or upon their surfaces which have palaeoenvironmental potential. Furthermore, these areas of dryland also seem to have been attractive for early human settlement, though remobilisation of these sediments at various times throughout the postglacial has the potential to mask and rework earlier activity/remains. These areas are located at the western edge of the Project and are considered High Risk, the majority are however Low Risk given the deeply buried nature of such deposits. Areas of Medium risk correlate with small areas of Head which may contain reworked archaeological material but are unlikely to preserve extensive palaeoenvironmental significant deposits.

Holocene

7.4.3 The main opportunity is also with the areas of alluvial deposition where palaeoenvironmentally significant organic-rich freshwater sediments (peats) are present. These may be interleaved with more minerogenic estuarine/marine deposits within the Humber Trent confluence zone. These alluvial sequences will likely have significant palaeoenvironmental potential. Investigations across Thorne and Hatfield Moors has also demonstrated the preservation of former forests beneath peats, although these are located to the west of the Project area. The northern part of this zone is considered High Risk given the potential for these sequences to be present.

7.4.4 The entire sediment sequence has the potential to preserve significant artefactual and other archaeological remains, including structural evidence. This maybe present upon discrete foci, for example buried gravel islands or across the wider expanse of wetland (e.g. trackways, causeways). The potential of this area is amply demonstrated by the discovery of the Hatfield trackway.

7.4.5 Warp mapped across this area has the potential to mask earlier deposits and archaeological remains and is considered Medium Risk. Important to note is that this deposit is poorly defined in places and where it has become eroded the underlying alluvial sequence will be closer to the modern ground surface which presents area of Higher Risk.

7.5 Mercia Mudstone 'uplands' (Figure 28)

Pleistocene

7.5.1 Only isolated patches of till and glacial sand and gravel are recorded on the mudstone uplands, but unlike for the rest of the Project route, they predate the LGM. The surface of the till is of considerable antiquity so may be the focus of multiperiod settlement activity dating from the Middle Palaeolithic, though there is a Low Risk of encountering such material.

7.5.2 Internally, the till is unlikely to include palaeoenvironmentally significant sediments since the environment at the time of deposition was harsh. However, any associated outwash gravels has the potential to contain organic remains, as demonstrated from deposits at Scrooby, but again the potential is relatively low.

Holocene

7.5.3 The mudstone uplands are unlikely to yield significant organic-rich deposits suitable for palaeoenvironmental reconstruction. The contemporary land surface has the potential to preserve multiperiod evidence that could be identified using airborne and terrestrial remote sensing techniques (e.g. commissioned geophysics, Lidar survey). The majority of the area is considered Low Risk for Holocene deposits, the exception is the minor Beck system which are considered Medium Risk as these may preserve shallow alluvial sequences. There are areas of High Risk in a mapped area of shell marl to the south of East Drayton but this lies outside the main Project, and the larger Beck system to the west of the Trent Valley at High Marnham. These are likely to have more substantial organic sequences.

7.6 Trent Valley (High Marnham) (Figure 29)

Pleistocene

7.6.1 Numerous archaeological investigations have demonstrated that the terrace surfaces of the sands and gravels have the potential to preserve multi-period remains from the Late Upper Palaeolithic onwards. Internally, the sands and gravels may include organic-rich lenses of material suitable for palaeoenvironmental reconstruction. These are considered Medium Risk due to the overlying Holocene alluvium.

Holocene

7.6.2 Palaeochannels incised through the Pleistocene terrace surfaces have the potential to preserve organic-rich sediment archives as demonstrated by the long sequence from Bole Ings. Overbank alluvium has the potential to bury archaeological remains and invisible to standard geoprospection techniques. This area is considered High Risk for both palaeoenvironmental and waterlogged archaeological remains.

7.6.3 Colluviation off the terraces onto the floodplain has the potential to bury archaeological remains at the floodplain edge as well as incorporating reworked remains.

8. Discussion of Geoarchaeological Potential

8.1 Overview

8.1.1 The north of the Project in the vicinity of the Wolds from Hull to Brantingham is defined by Devensian Till and dry valley deposits. These sediments are minerogenic and of antiquity and therefore they are unlikely to preserve significant Holocene sequences, the exception being colluvial deposits within the dry valleys. These deposits may mask archaeological features. The potential for Pleistocene deposits to preserve Palaeolithic remains is considered to medium to low but will depend on the depths of the proposed impacts on this area. Periglacial Head (solifluction) deposits may contain reworked material that has moved from further upslope.

8.1.2 The Foulness valley contains glaciolacustrine deposits which are likely to be of low geoarchaeological potential The Hemingbrough Formation is highly minerogenic and unlikely to preserve microfossil remains. The Bielby Sand Member does contain thin organic lenses that may preserve microfossil remains and may represent rare survival of high-level phases of Lake Humber. In addition, the deposit has the potential for Late Upper Palaeolithic and later prehistoric material to be preserved on the surface or within later reworked sands. There are also suggestions by the BGS of interglacial beach gravels within this general area. The Holocene alluvium has the potential preserve deep sequences of organic deposits which are complicated by areas to the west being overlain by anthropogenic warp, which may mask buried land surfaces. The Foulness also has the potential for the preservation of Middle Pleistocene faunal and artefactual remains (MIS 7) in a proto-Foulness valley.

8.1.3 The Project skirts the western edge of the Trent Valley which again presents a Holocene sequence of peats, silts and clays overlain by warp. The warp can vary in thickness across an area and can even be absent for large areas; it is poorly mapped by the BGS and work at Keadby and Scunthorpe has shown there to be uneven coverage within the floodplain. In addition, patches of friable Sutton Sands are mapped, aeolian deposits which are vulnerable to reworking and may mask both land surfaces and artefact scatters. There are also several large palaeochannels as mapped by the PTC project which have the potential to preserve palaeoenvironmental sequences as well as archaeological remains. At the very southern end of this section the Project crosses the very edge of the Idle Valley and the peats here are likely to be extremely thin and desiccated. However, this may mean that any former land surfaces are now closer to the modern land surface and so the potential for artefact scatters is high.

8.1.4 The southern end of the Project traverses the Mercia Mudstone and the main suite of deposits here are represented by minor Beck systems draining the uplands. These are likely to be infilled by a combination of Head, colluvium and alluvium and have seen little in the way of targeted investigation. These deposits may preserve discrete sequences which provide rare opportunity to record palaeoenvironmental sequences away from the main river valleys.

8.2 Deposit Survival and Existing Impacts

8.2.1 The lack of detailed lithological and stratigraphic data for the majority of the Project makes specific comment regarding deposit survival problematic. However, based on past experience in the region some general statement can be posited. The warp deposits as mapped by the BGS are often unevenly distributed across large areas and have seen substantial weathering and erosion due to later agricultural practice. As such the presence of warp should not be used to define limits of impacts as the deposit varies in thickness and distribution. In addition, despite being highly oxidised and minerogenic, the warp can preserve features such as warping drains as well as wooden remains such as sluice gates.

8.2.2 The alluvial sequences recorded for the Foulness and Trent Valley are likely to have variable preservation along the Project. Those closest to the floodplain edge are likely to be more vulnerable to oxidation and weathering. The alluvium is mainly minerogenic but can still preserve organic archaeological remains and mask land surfaces. The deepest organic deposits are likely to be located within palaeochannels, not all of which are visible on the Lidar mapping.

8.2.3 More difficult to define with any precision is the Palaeolithic/Pleistocene potential of deposits. Very little in the way of targeted prospection has been carried out, particularly on the Sutton and Bielby Sand Formations. The Head deposits within the Project may contain reworked material. Within the Foulness/Humber area there is the potential for earlier interglacial remains within the more deeply buried parts of the sedimentary sequence.

8.3 Summary of Potential

Wolds from Hull to Brantingham

8.3.1 The Wolds area is of relatively low Holocene risk due the presence of Till and dry valley deposits and the lack of deep organic sequences. Such deposits may contain reworked Palaeolithic remains but are unlikely to preserve significant geoarchaeological archives.

Foulness Valley

8.3.2 The thick Holocene peat deposits within the Foulness are of interest given the potential to preserve long chronologies of palaeoenvironmental data. In addition, the peats associated with the Bielby Sands and organic deposits within the proto-Foulness valley should also be considered given their potential to preserve much earlier indications of landscape and climate change. The Holocene and Pleistocene risk of this area is overall considered high.

8.3.3 The uneven coverage of warp may suggest that the upper surface of the alluvial sequence is vulnerable to erosion and change. The warp itself is often found to be highly oxidised and is of low palaeoenvironmental potential, however the deposit may still preserve wooden remains associated with warp drains such as sluice gates. These types of structures may be present at the junctions of drains which can be seen on the Lidar imagery. The deposit may also mask former land surfaces.

Humberhead Levels, Isle of Axholme and Idle valley

8.3.4 The Project route traverses the edge of the main alluvial sequence within the Humberhead levels/Trent and Idle therefore it is unlikely to encounter large infilled palaeochannels. More likely the deposits encountered will be discrete floodplain and channel edge peats and overlying minerogenic alluvial sequences. There for the Pleistocene risk is Low and Holocene risk is Low-Medium.

8.3.5 The Sutton Sands have the potential to preserve both thin discrete organic sequences as well as archaeological features and artefact scatters. The lack of targeted investigation of the sands in general means that no baseline data is available as to the success of standard prospection method such as sieving and test pitting. The vulnerability of these deposits to later reworking means multi-period deposits may be masked and therefore the Holocene risk here is Medium, and the Pleistocene risk Low.

8.3.6 Again the warp in this section is unevenly distributed and poorly defined in terms of extent and is likely to vary in thickness across short distances. The deposit itself is of low palaeoenvironmental potential but it may mask earlier land surfaces and features.

Mercia Mudstone ‘Uplands’

8.3.7 The Mudstone uplands are unlikely to contain significant deposits with palaeoenvironmental or geoarchaeological potential. The Beck drainage system may contain discrete organic deposition and alluvial/colluvial sequences but these are unlikely to be especially deep. That said they do present an opportunity to gather palaeoenvironmental sequences away from the main river valleys and therefore these areas are considered to have a medium risk for the Holocene.

8.3.8 The Pleistocene risk is considered to be Low. The mapped glaciofluvial deposits and intermittent Head may contain reworked material but are unlikely to preserve significant thicknesses of organic deposits.

Trent Valley (High Marnham)

8.3.9 The Project here is located mainly on the first Pleistocene terrace (the Holme Pierrepont Sands and Gravel Member). These may display a level of reworking towards the current postglacial floodplain of the Trent and as such are considered Low Risk for Pleistocene deposits but a medium risk for Holocene deposits. This is due to the reworking of these deposits which has in other areas demonstrated the preservation of wooden archaeological remains from the Prehistoric to post-Medieval period. These remains very often survive in highly minerogenic deposits and can be present throughout the sequence depending on the nature of change change/migration.

8.3.10 This is a constrained part of the Trent Floodplain and few channels are mapped on the western side of the valley. However there is a large meander cut off channel recorded within part of the Project route that is likely to represent a very substantial channel. This is highly likely to contain both palaeoenvironmental and archaeological waterlogged remains.

8.3.11 The surface of the gravels may also preserve the remains of later prehistoric to Medieval dryland activity. Certainly to the south of High Marnham extensive cropmarks of field systems are mapped as well as funerary monuments and occupation sites.

8.4 Considerations for Further Geoarchaeological Work

Overview

8.4.1 This geoarchaeological DBA has detailed the archaeological and palaeoenvironmental potential of the land within the Order Limits. The results of this DBA have informed the assessment of impact and identification of likely significant effects reported in Application Document 6.10 Chapter 10 Cultural Heritage and appropriate mitigation measures to offset any impact are secured in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation**.

8.4.2 Geotechnical investigations (GI) are being carried out for the Project and will inform the detailed design stage. Geoarchaeological monitoring of the GI is also being carried out and this will inform any necessary mitigation that may be required following detailed design changes. As detailed in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation**, the scope of geoarchaeological mitigation will be set out in a Final Archaeological Written Scheme of Investigation and agreed with the Archaeological Advisor to the relevant local planning authority.

8.4.3 **Application Document 7.9 Outline Archaeological Written Scheme of Investigation** requires that the Applicant's Archaeological Clerk of Works (ACoW) will review detailed design changes against the information in this geoarchaeological DBA and the results of the geoarchaeological monitoring of GI, which will be submitted during the Examination phase of this Project.

8.4.4 As further stated in **Application Document 7.9 Outline Archaeological Written Scheme of Investigation**, the design of further geoarchaeological mitigation, detailed in the Final Archaeological Written Scheme of Investigation, will consider the methodological approaches recommended below and will be detailed in a SSWSI agreed with the Archaeological Advisor to the relevant local planning authority.

Discussion of Deposit Types and Potential Methodologies

8.4.5 The Pleistocene potential for the Project lies mainly within the Bielby Sands and any deposits associated with a proto-Foulness valley and earlier Trent Terraces. These have the potential to not only preserve organic deposits indicative of changing climates but also primary, coeval stone tools, as well as reworked lithic artefacts, relating to earlier warm phases. These organic fills could also include faunal remains. There is also the potential for Upper Palaeolithic remains to be preserved upon or close to the contemporary surface.

8.4.6 The nature of prospection for the Palaeolithic within the region has mainly been confined to deep aggregate extraction localities. Therefore, deposits which lie outside the main river valleys, notably the valley sides and interfluves, have received little attention. The East Midlands Research Framework (East Midlands Research Framework, 2026) has highlighted the need to understand depositional sequences within the wider region beyond river valleys in order to understand the likely potential for those areas to preserve evidence of human activity. Therefore, the design of further geoarchaeological assessment should be undertaken where feasible in the areas defined within the mitigation framework of the risk mapping where this coincides with potential impacts from the Project following detailed design changes.

8.4.7 Historic England Guidance for the Curation of the Palaeolithic has set out methodological approaches in order to evaluate the potential of a site for Palaeolithic

remains (Historic England, 2023) and these methods should be considered during the preparation of SSWSIs for geoarchaeological assessment:

- Coring;
- Geophysics;
- Paleoenvironmental sampling;
- Test pits;
- Trenching; and
- Watching brief.

8.4.8 The applicability of these techniques will be influenced by and proportionate to the types of deposits expected and the predicted impacts.

8.4.9 The areas of aeolian sand deposits have the potential to preserve multiple archaeological horizons in addition to fine-grained organic deposits. These deposits may also preserve lithic material that may require targeted sieving in order to understand taphonomic issues. Palaeosols and buried land-surfaces might also be expected and if identified, suitable targeted geoarchaeological recording and sampling is required.

8.4.10 Historic England Guidance for Managing Lithic Scatters and Sites (Historic England, 2024) recommends targeted sample sieving of topsoil or potential lithic-bearing deposits based on fieldwalking or geoarchaeological surveys, within the development area or project area. This could be implemented in tandem with other evaluation techniques, such as a test-pit survey or trial trenching and should be considered during the design of further SSWSIs.

8.4.11 In areas with deep alluvial sequences purposive window sample surveys are recommended in addition to targeted monitoring of any Geotechnical Investigations. The resulting data from any GI surveys should then be used to update the existing model and provide a guide for the purposive sampling.

8.4.12 Provision for targeted palaeoenvironmental assessment and dating should also be made. This is particularly relevant for the less well understood sequences outside the main river valleys, i.e., Beck systems, and within poorly understood sequences, i.e. the Foulness.

8.4.13 In areas of the proto-Foulness, Bielby and Sutton Sand Formations, consideration during any archaeological trenching should be given to test pitting these deposits for the presence of further land horizons, artefact scatters and palaeoenvironmental sequences. Any absolute dating should consider the recovery of samples for both radiocarbon and OSL, and with the latter the extended timescales associated with the return of the results should also be factored into any reporting.

8.4.14 Dry valleys are recorded in several locations and are particularly visible within the Lidar imagery. Many of the sequences mapped within them are interpreted as alluvial deposits by the BGS; however, such interpretations require verification through fieldwork. It is more likely that the dry valleys are infilled with minerogenic Late Pleistocene solifluction and / or postglacial colluvial deposits; at present, the age of any fills are unknown. With the exception of molluscan remains the palaeoenvironmental potential of these deposits is generally likely to be low. However, the sediments have the potential to contain archaeological material reworked from further upslope and may also bury former land surfaces and any preserved associated archaeological remains.

8.4.15 The methodology for investigating these areas should start with test-pitting/machine trenching but should include a level of flexibility. In exposures where it can be demonstrated no archaeological remains are preserved, a basic lithological record of the deposits will suffice, with detailed recording restricted to any palaeosols or buried land-surfaces within the sequence. If archaeological material is present, then measured 5 litre bulk samples should be taken through the entire depositional sequence and assessed for environmental remains (principally molluscs).

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Annex A
Figures

Annex A Figures

The Geoarchaeological Desk Based Report was based on the Project Design at Statutory Consultation and therefore the figures presented below show the draft Order Limits at this time.

FIGURES

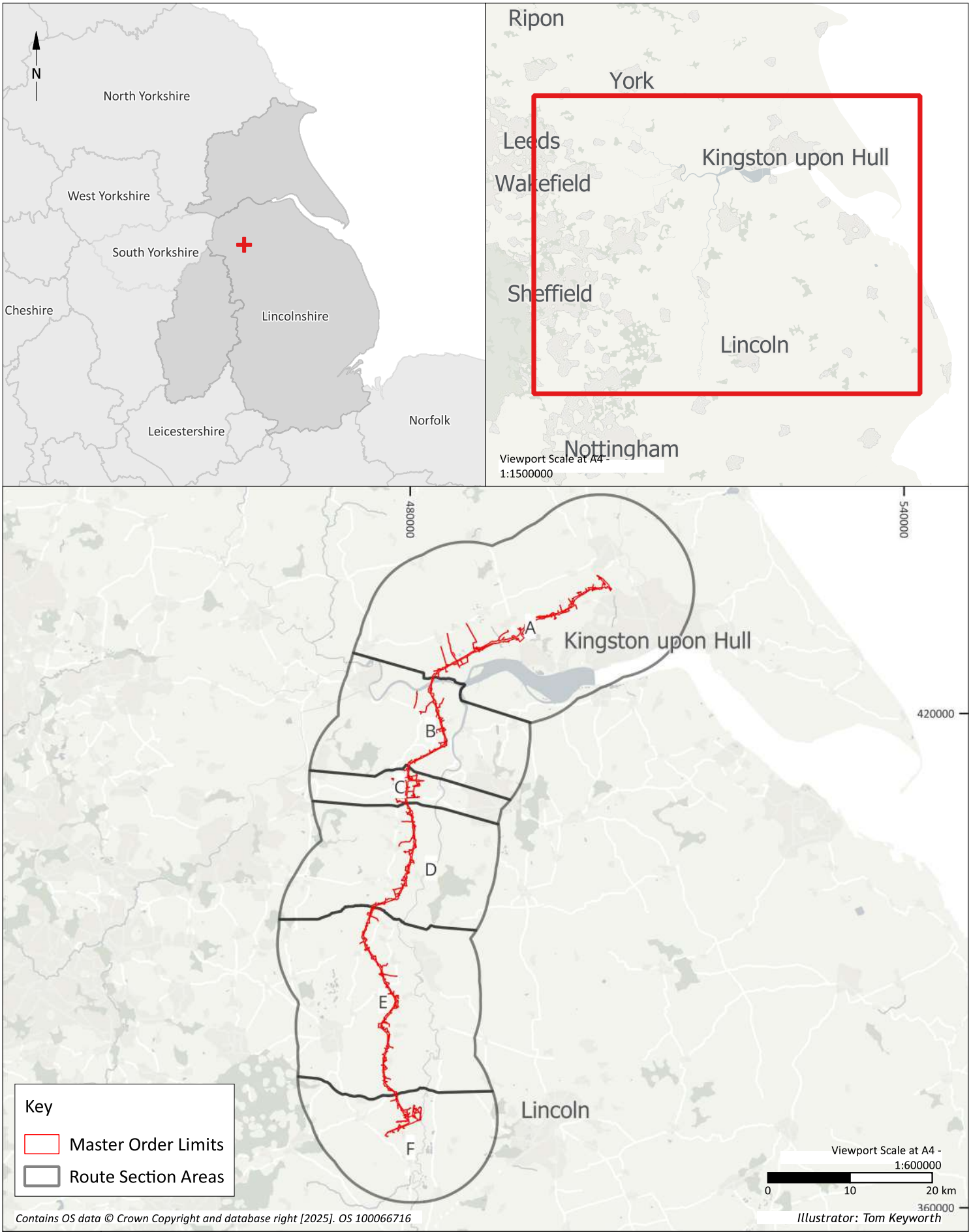


Figure 01 - Location Map
10326 - North Humber to High Marnham

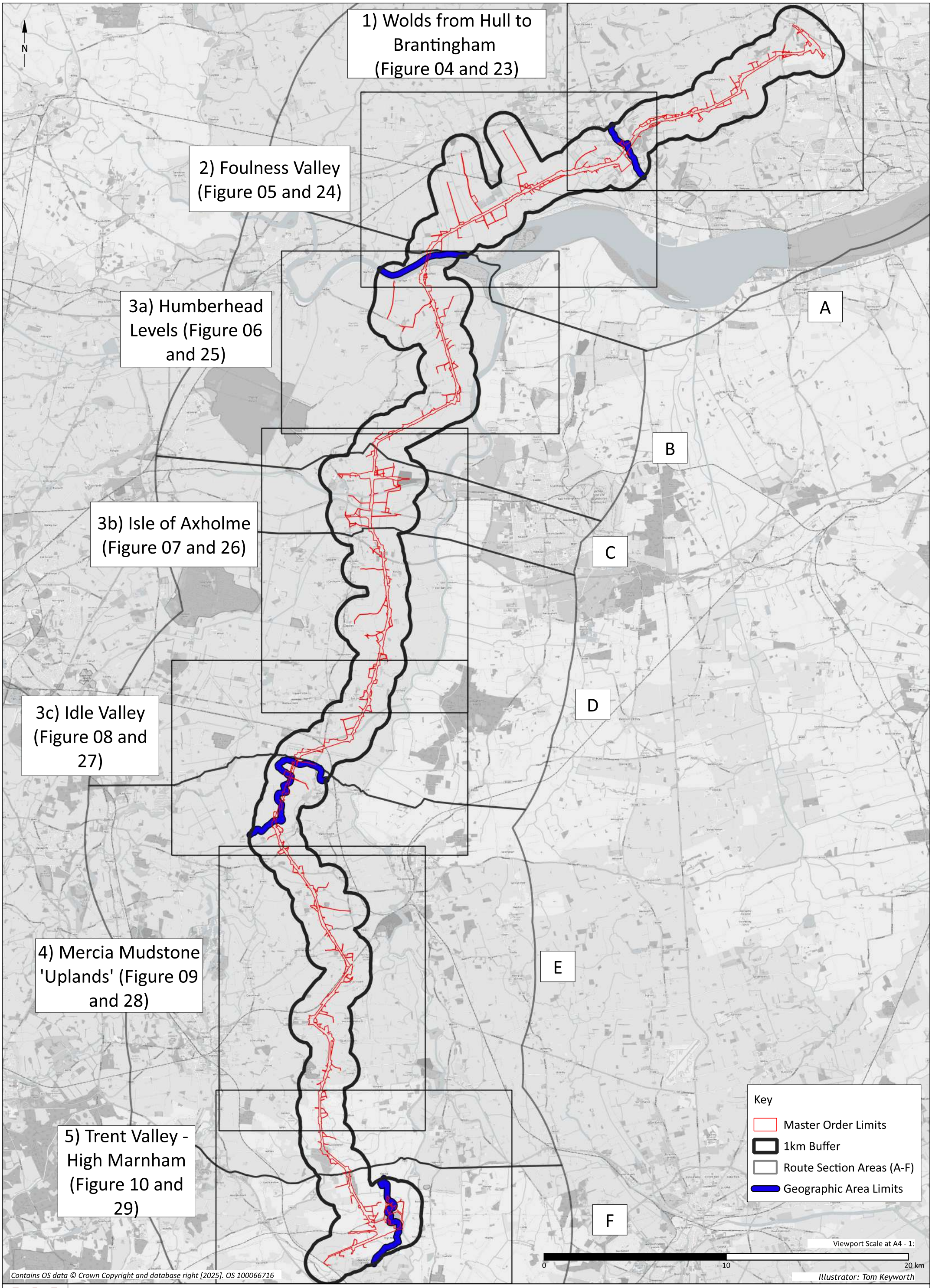


Figure 02 - Project Overview
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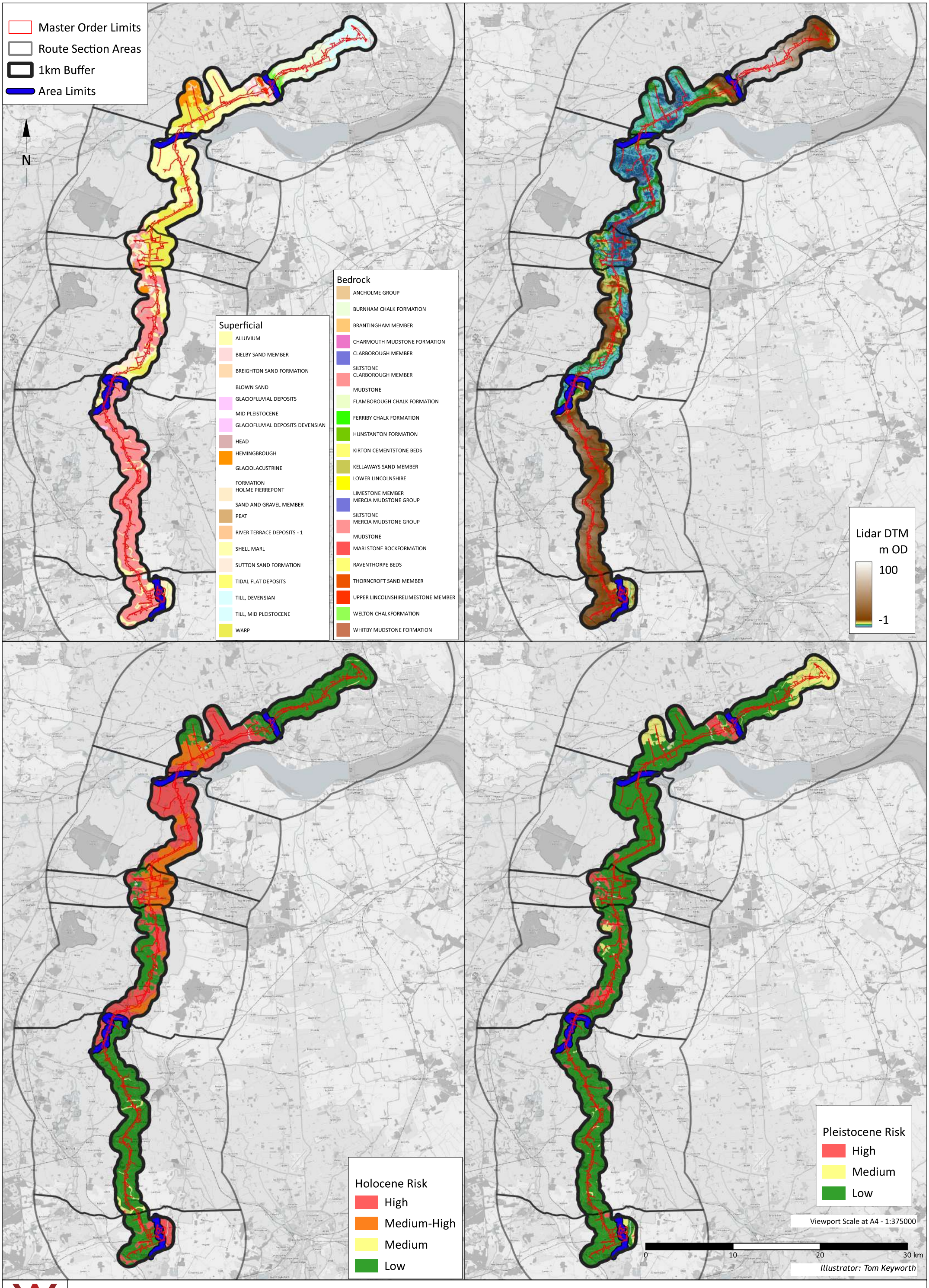


Figure 03 - Project Overview: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham

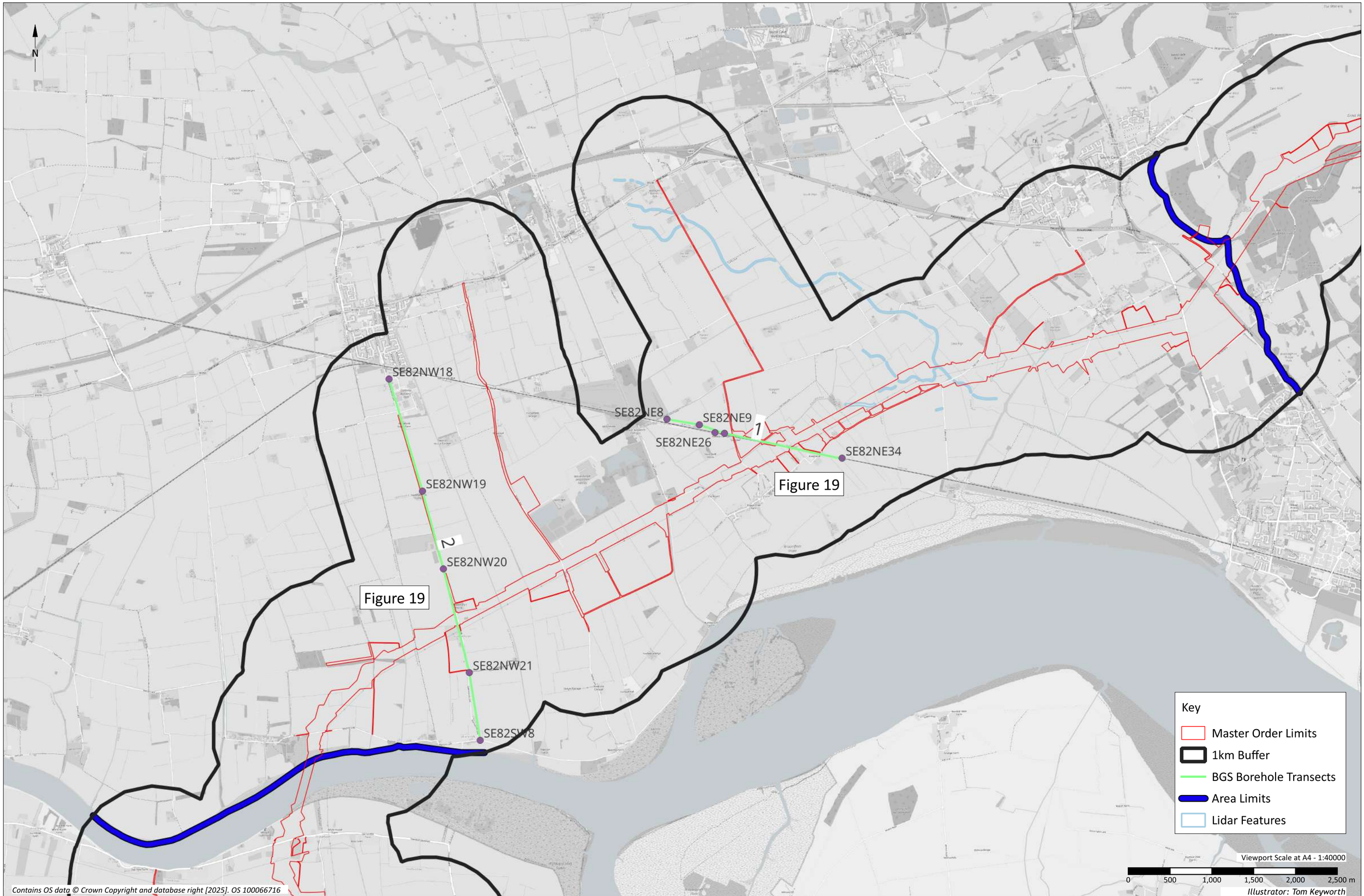


Figure 05 - Foulness Valley. See Figure 24.
10326 - North Humber to High Marnham

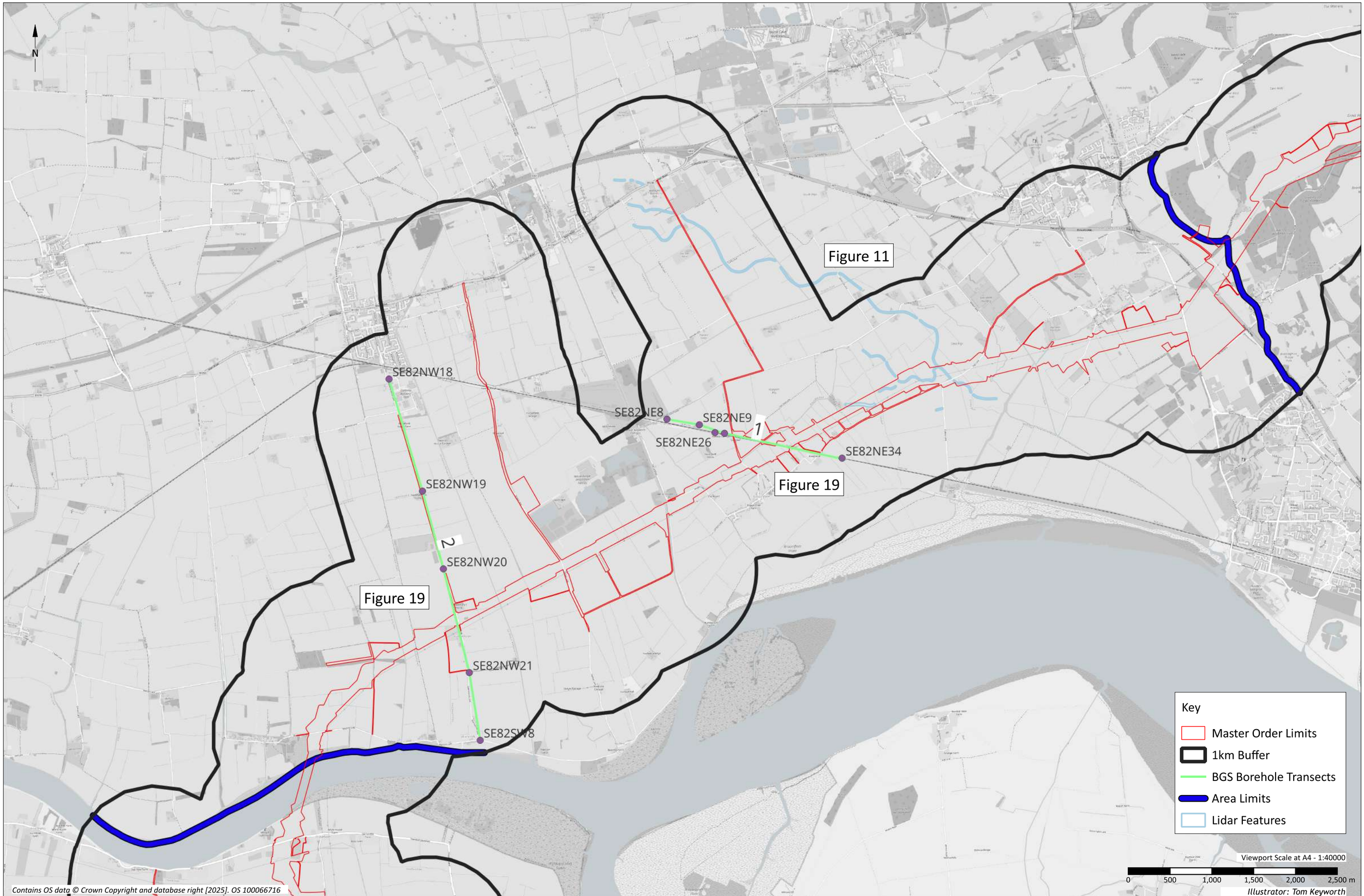


Figure 05 - Foulness Valley. See Figure 24.
10326 - North Humber to High Marnham

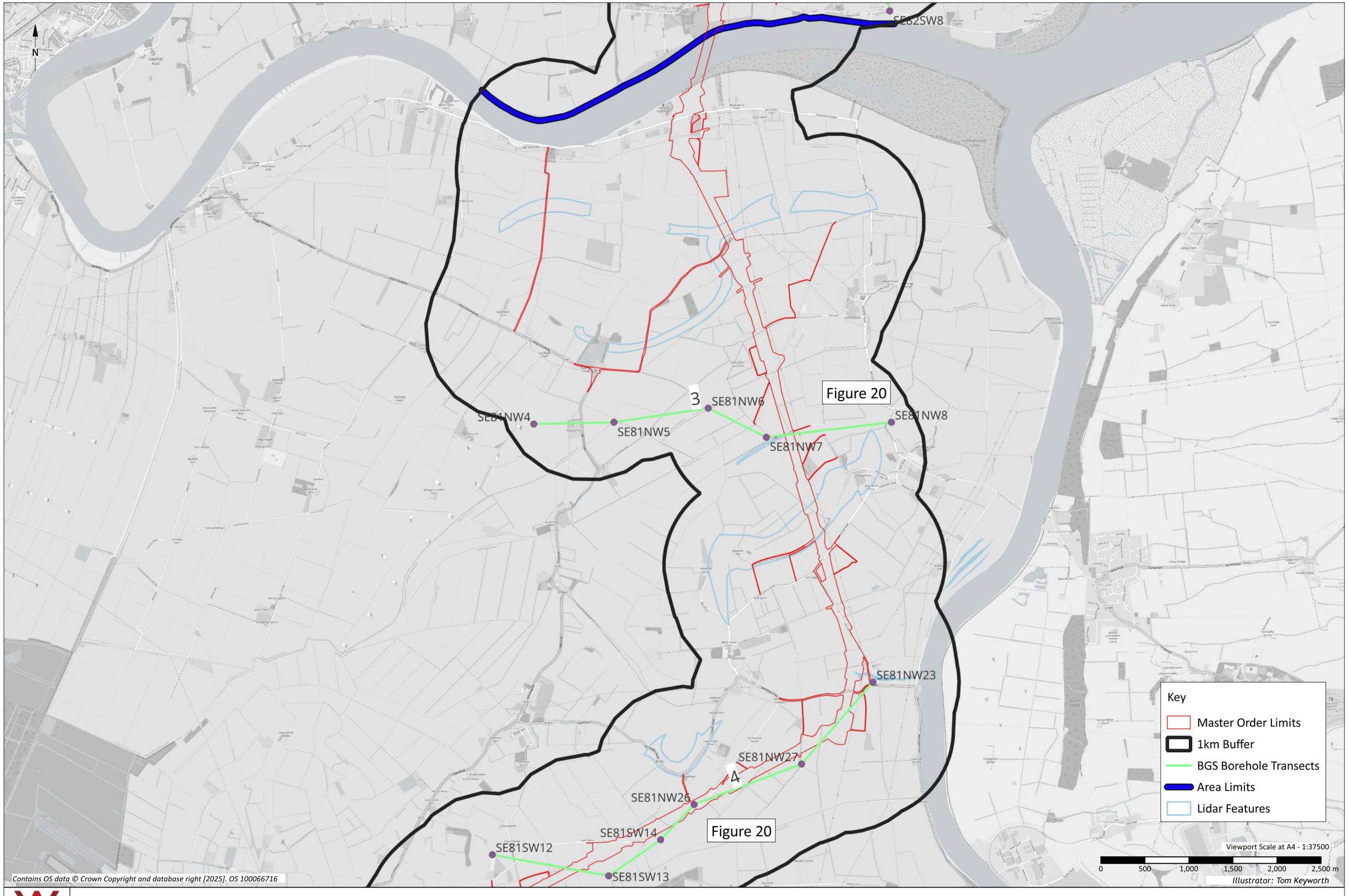


Figure 06 - Humberhead Levels. See Figure 25.
10326 - North Humber to High Marnham

a

N

SE81SW13

SE80NW21

SE80SW26

SE80SW9

SE80SW14

SK79NE5

SK79NE6

Figure 22

Key

Master Order Limits

1km Buffer

BGS Borehole Transects

Area Limits

Lidar Features

Viewport Scale at A4 - 1:40000

0 1,000 2,000 3,000 m

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Illustrator: Tom Keyworth

Figure 07 - Isle of Axholme. See Figure 26.
10326 - North Humber to High Marnham

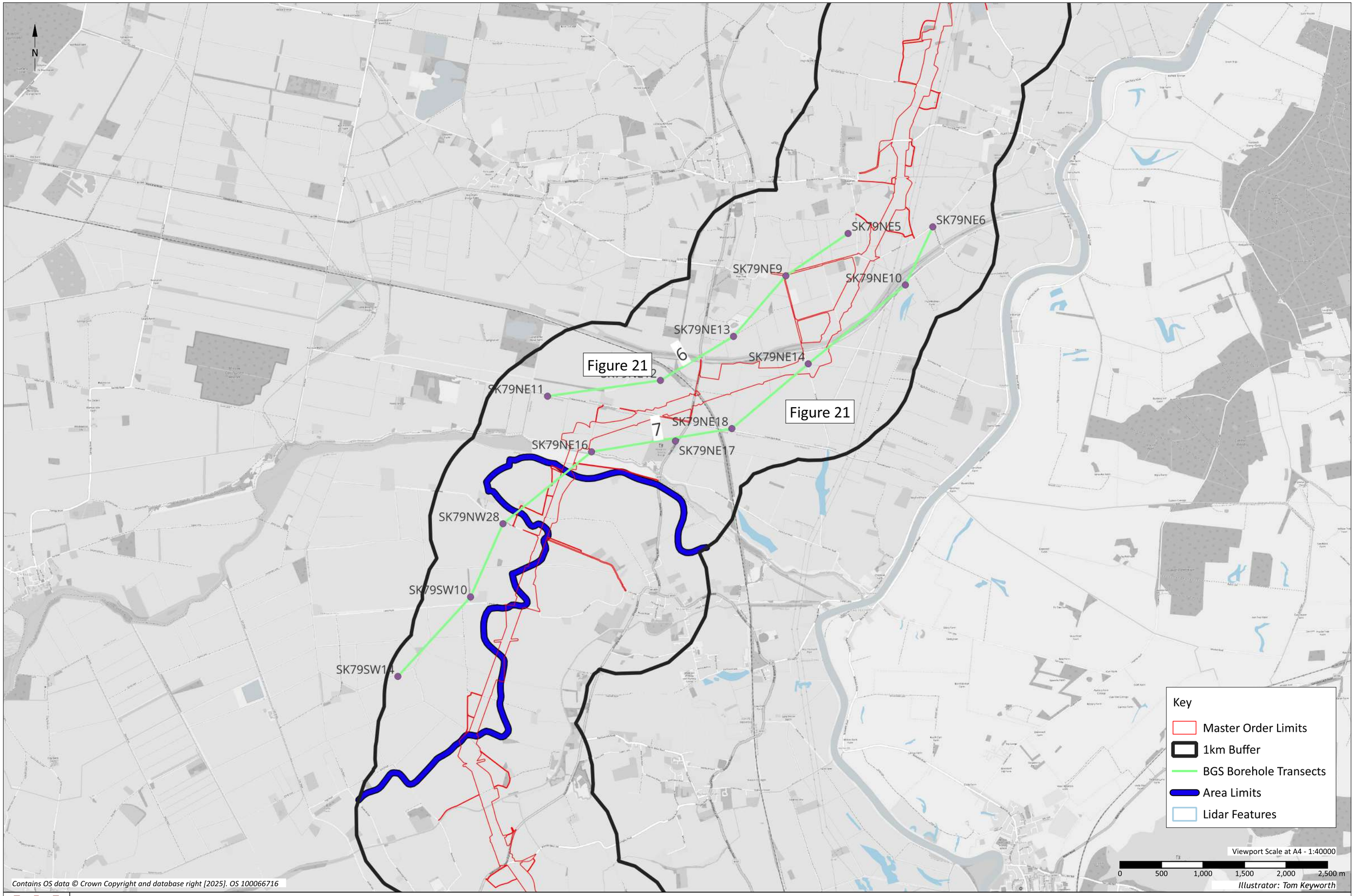


Figure 08 - Idle Valley. See Figure 27.
10326 - North Humber to High Marnham

a

N

Key

Master Order Limits

1km Buffer

BGS Borehole Transects

Area Limits

Lidar Features

Viewport Scale at A4 - 1:

0 1,000 2,000 3,000 m

Contains OS data © Crown Copyright and database right [2025]. OS 100066716

Illustrator: Tom Keyworth

Figure 09 - Mercia Mudstone 'Uplands'. See Figure 28.
10326 - North Humber to High Marnham

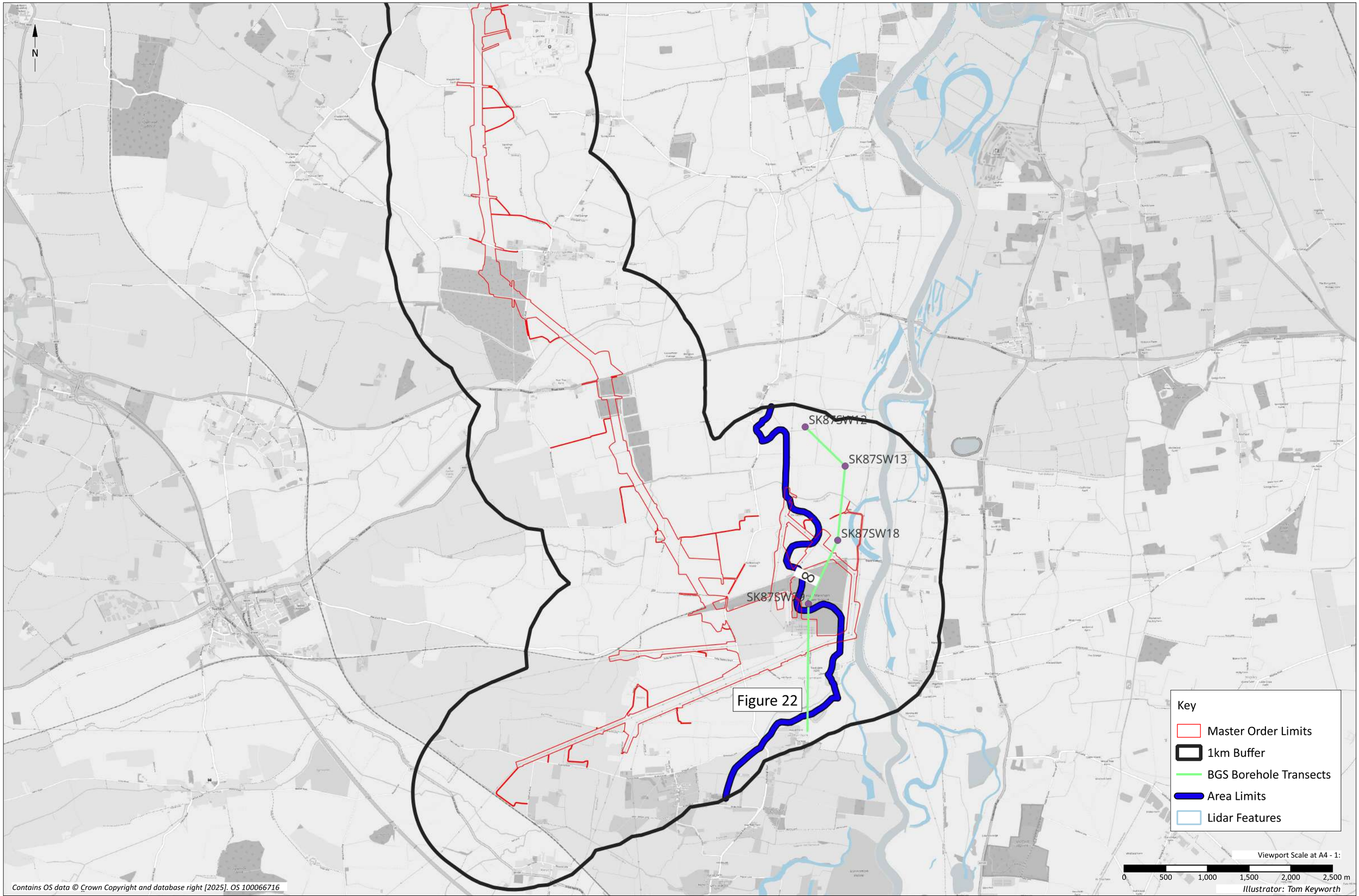


Figure 10 - High Marnham - Trent Valley. See Figure 29.
10326 - North Humber to High Marnham

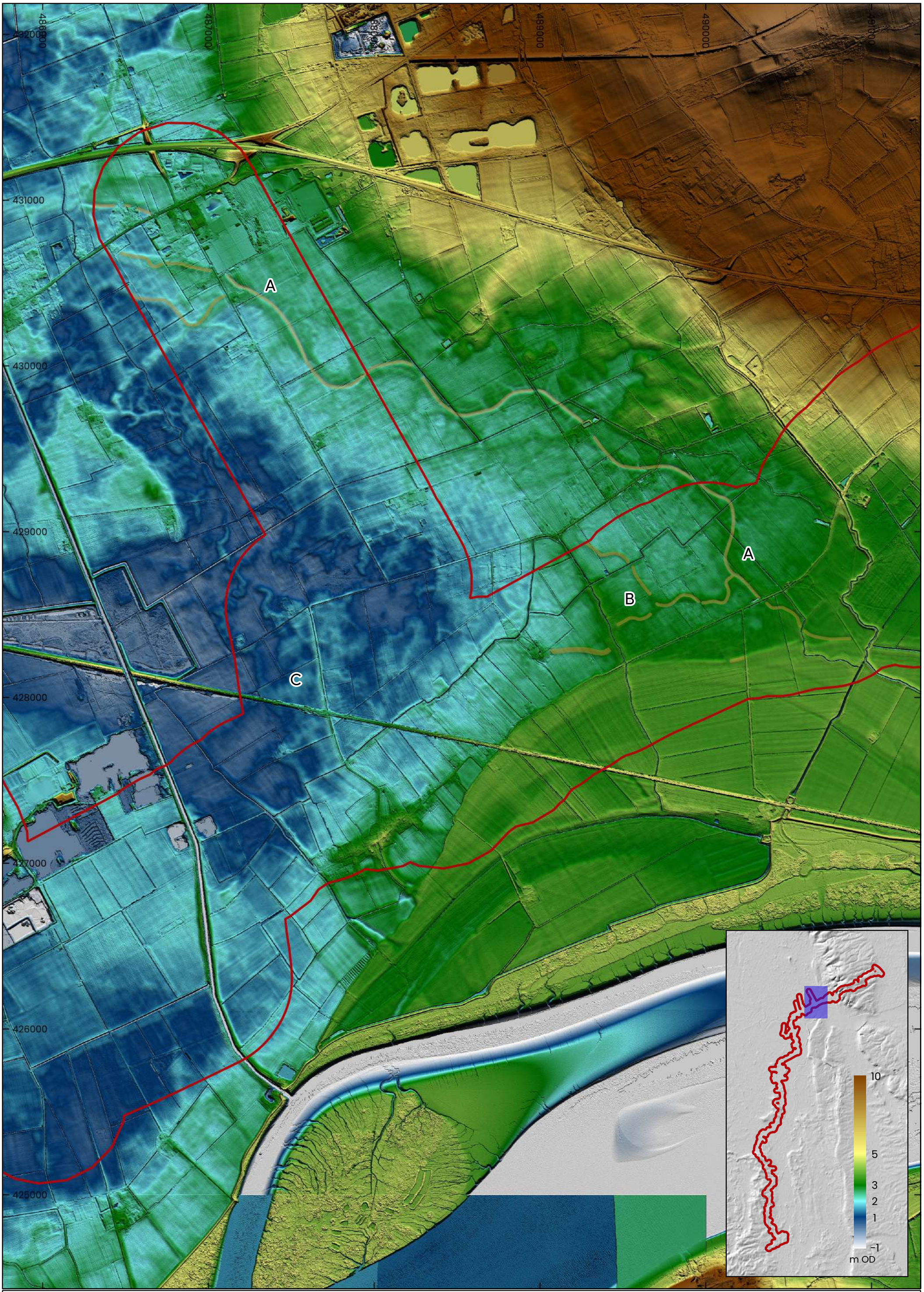


Figure 11 10326_Lidar - Foulness

0 1 2 km

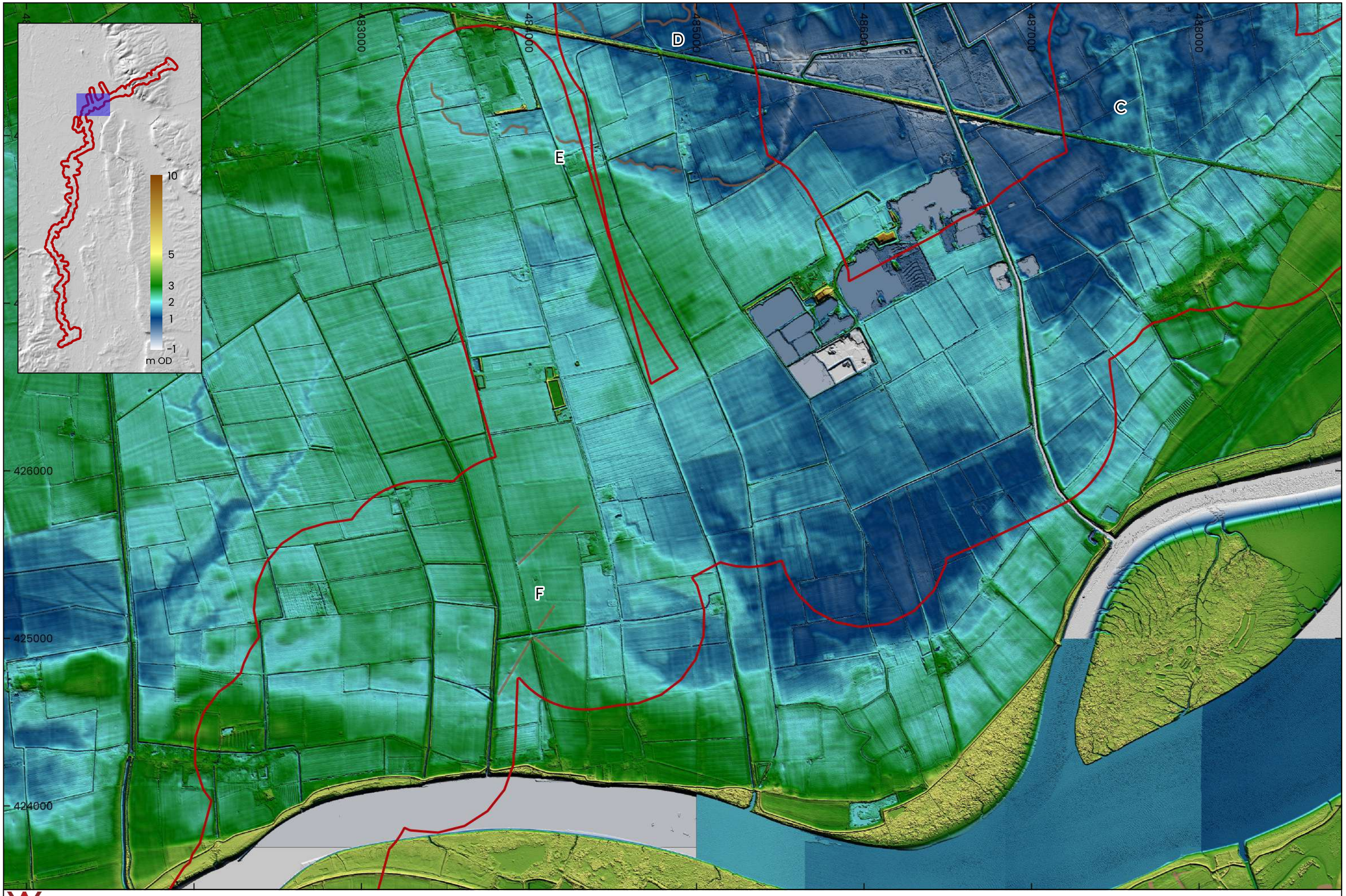


Figure 12 10326_Lidar - Blacktoft

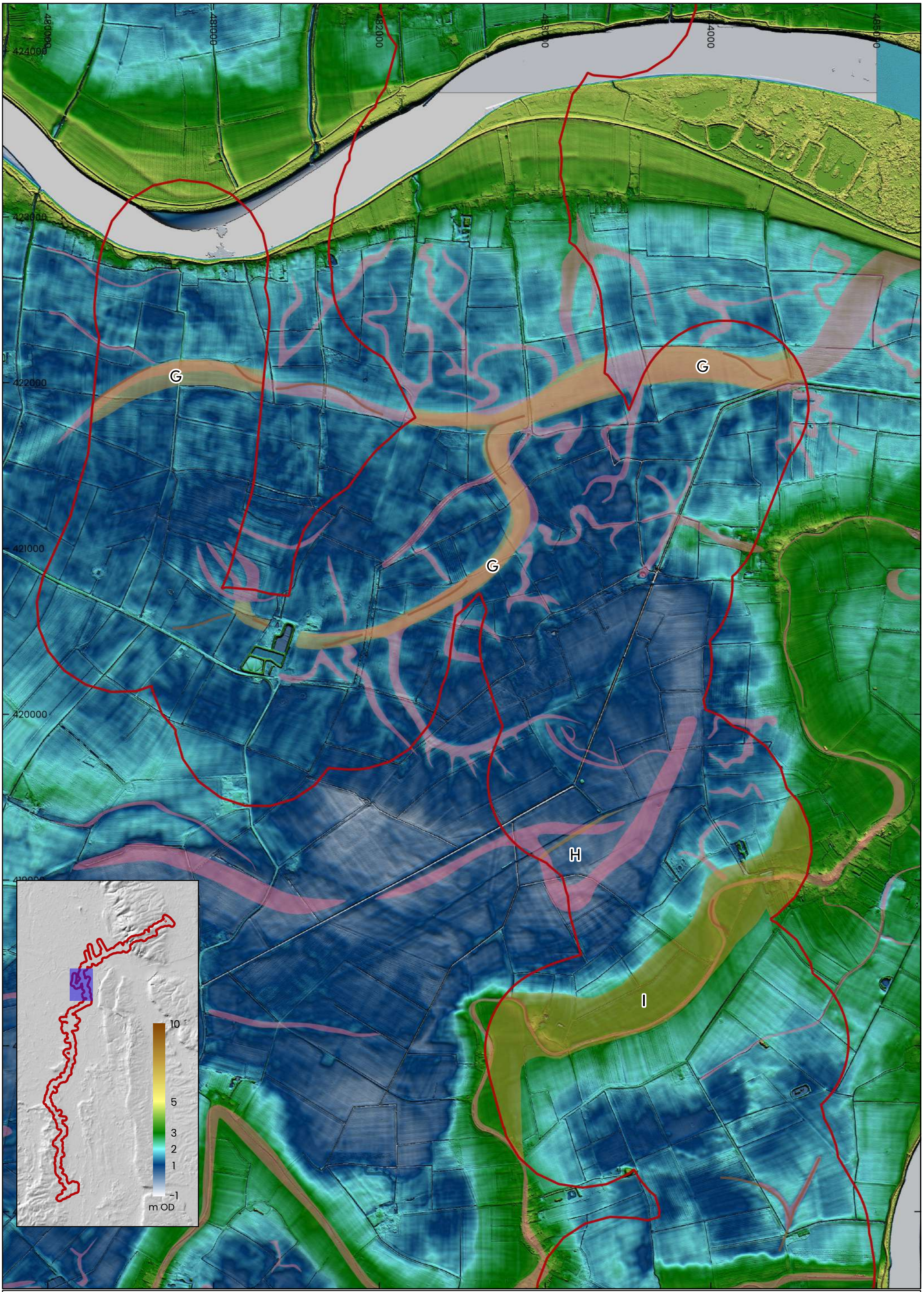


Figure 13 10326_Lidar - Ousefleet

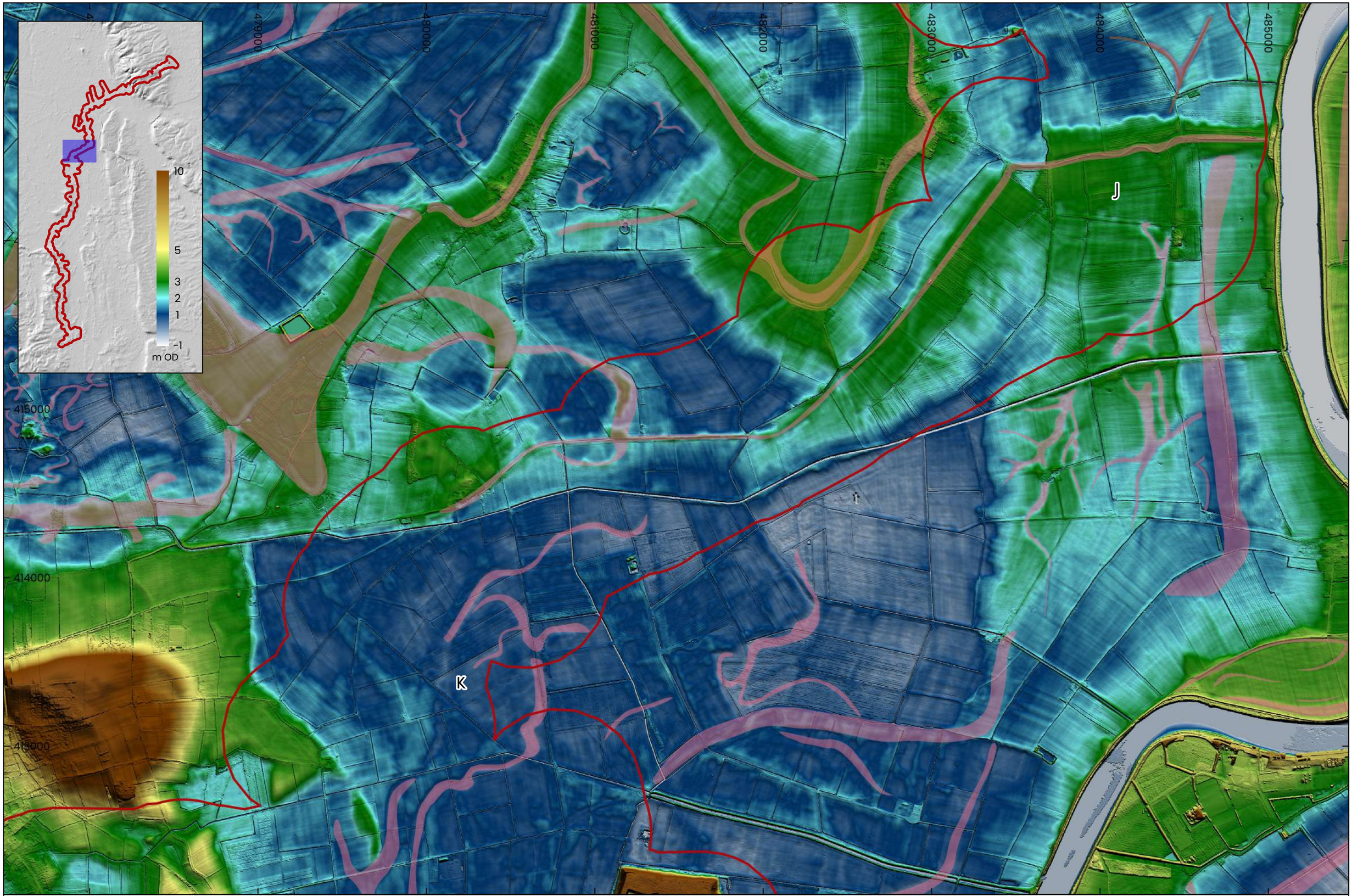


Figure 14 10326_Lidar - Luddington

0 1 2 km

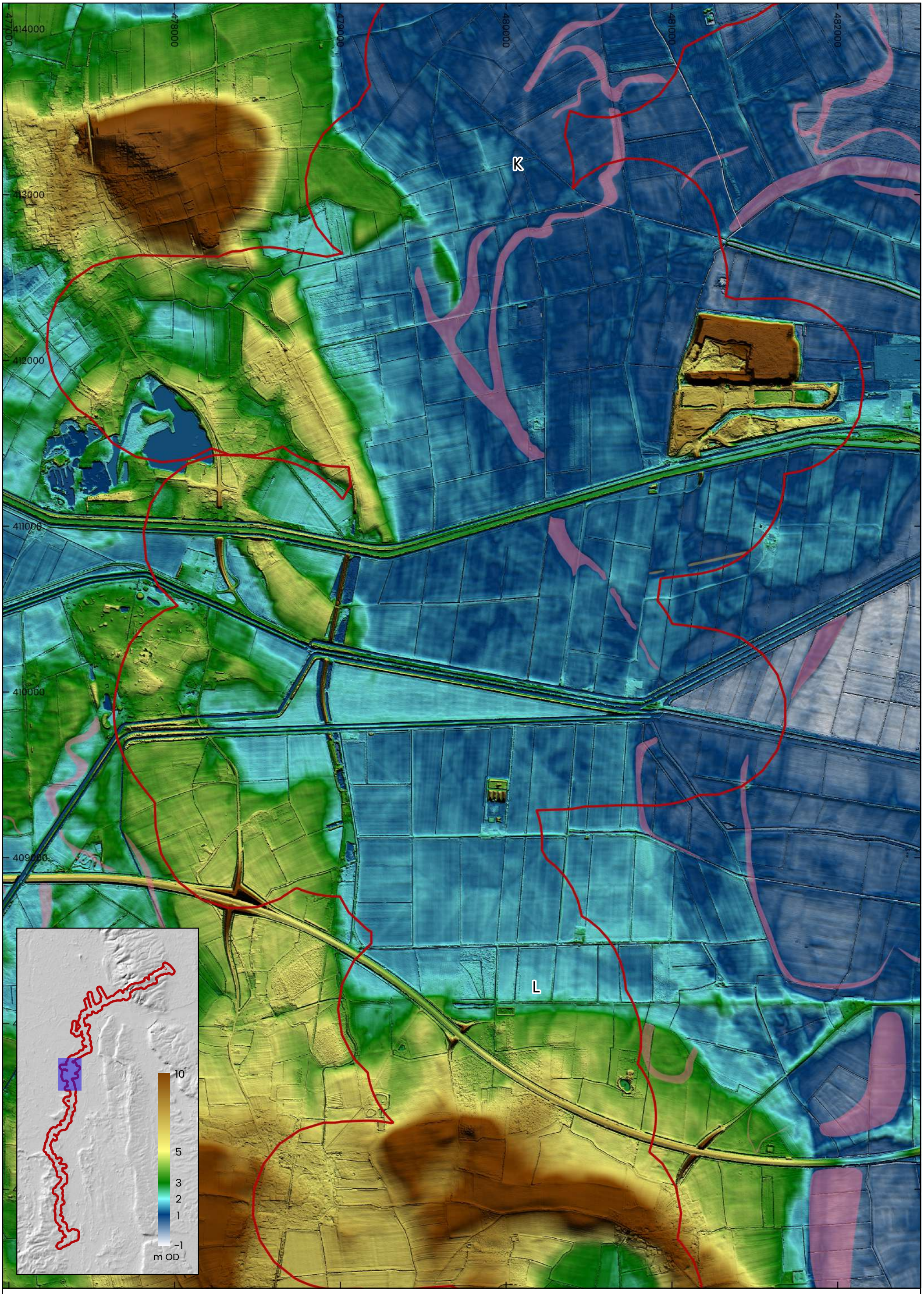


Figure 15 10326_Lidar - Crowle-Beltoft

478000
479000
480000
481000
482000
407000
406000
405000
404000
403000
M
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2
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Figure 16 10326_Lidar - Isle of Axholme

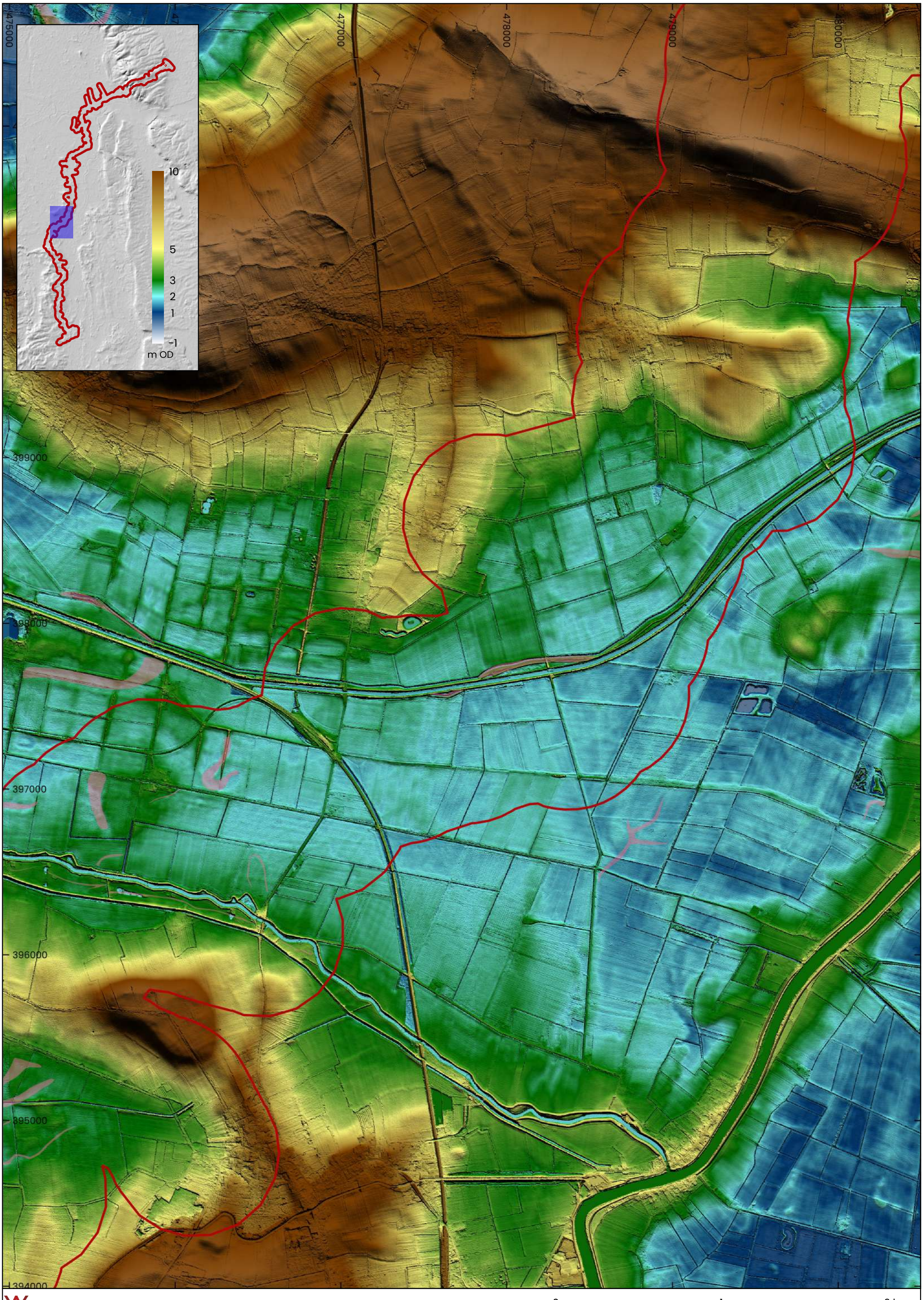


Figure 17 10326_Lidar - East Lound-Misterton

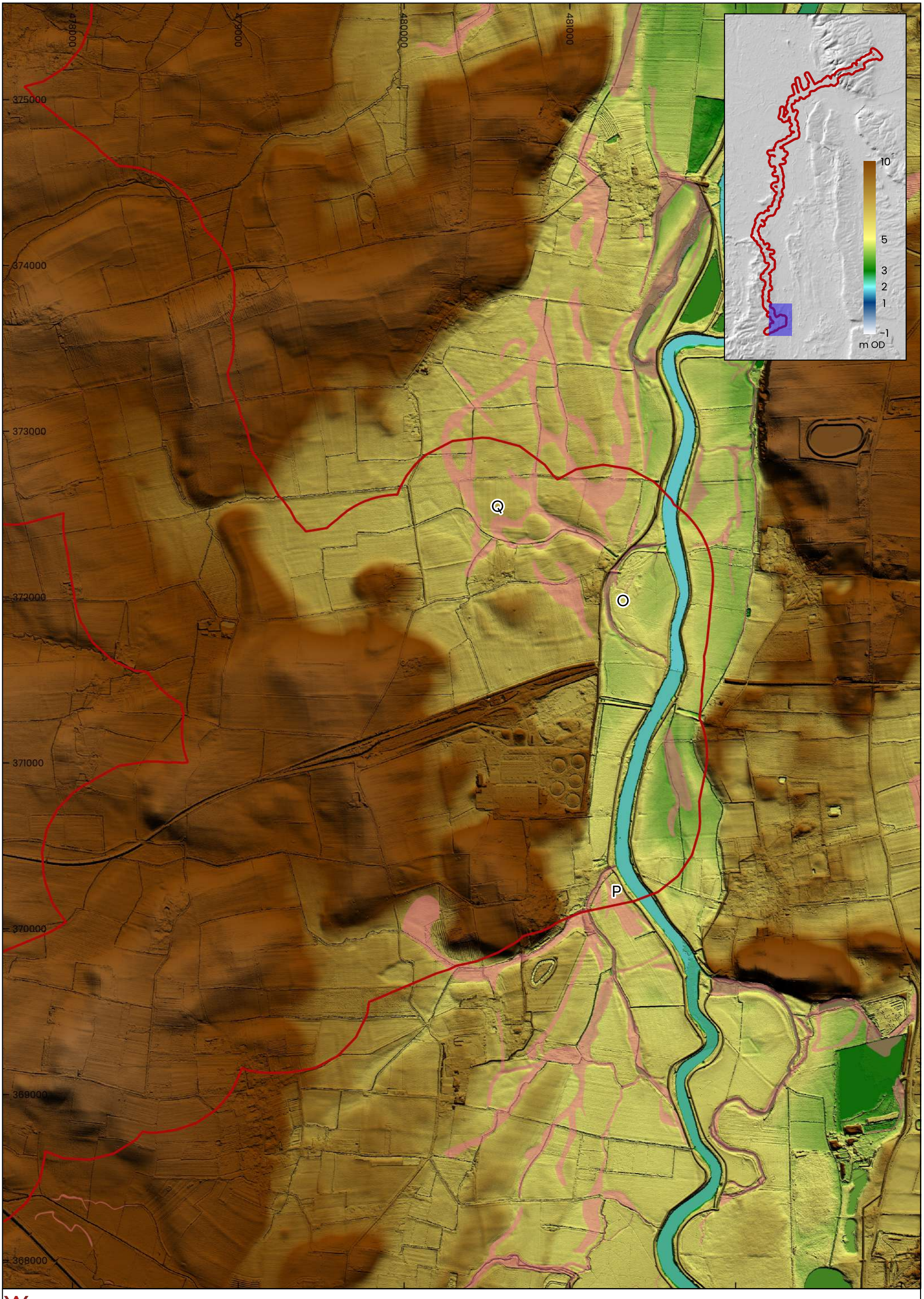


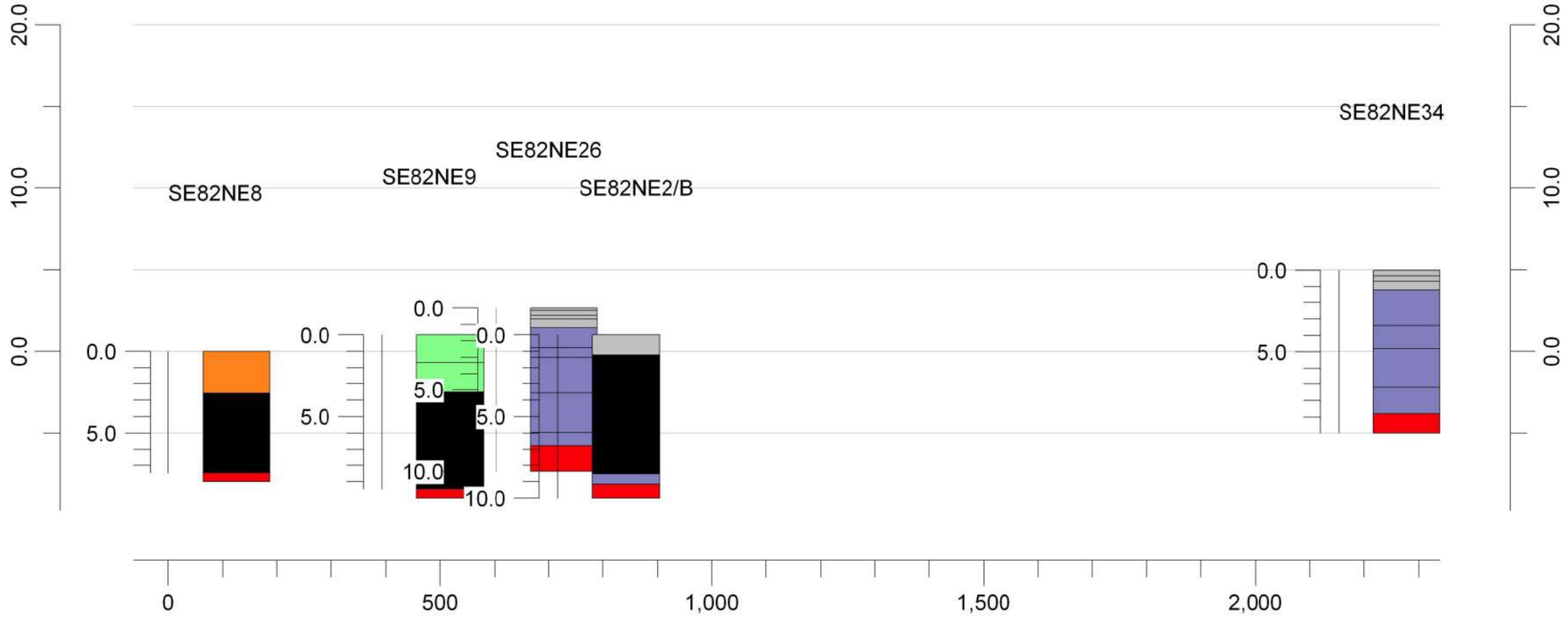
Figure 18 10326_Lidar - High Marnham

0 1 2 km

Transect 1

NW

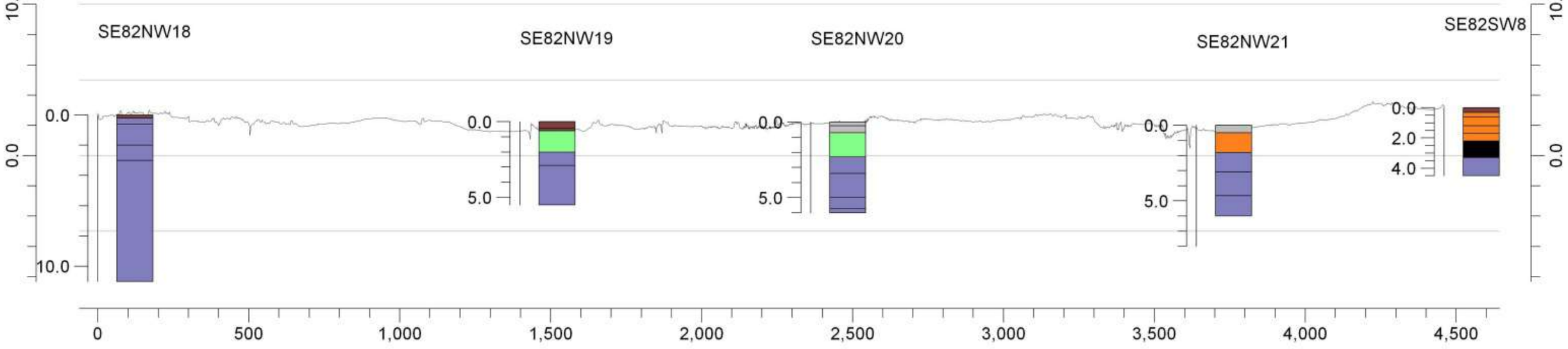
SE



N

S

Transect 2



Lithostratigraphy

- Topsoil
- Made Ground
- Warp
- Alluvium
- Aeolian Sand
- Peat
- Glaciolacustrine
- Sand and Gravel (Pleistocene)
- Mudstone Bedrock

1m 2018 DTM

Figure 19 - Transects 1 and 2 (VE 50)
10326 - North Humber to High Marnham

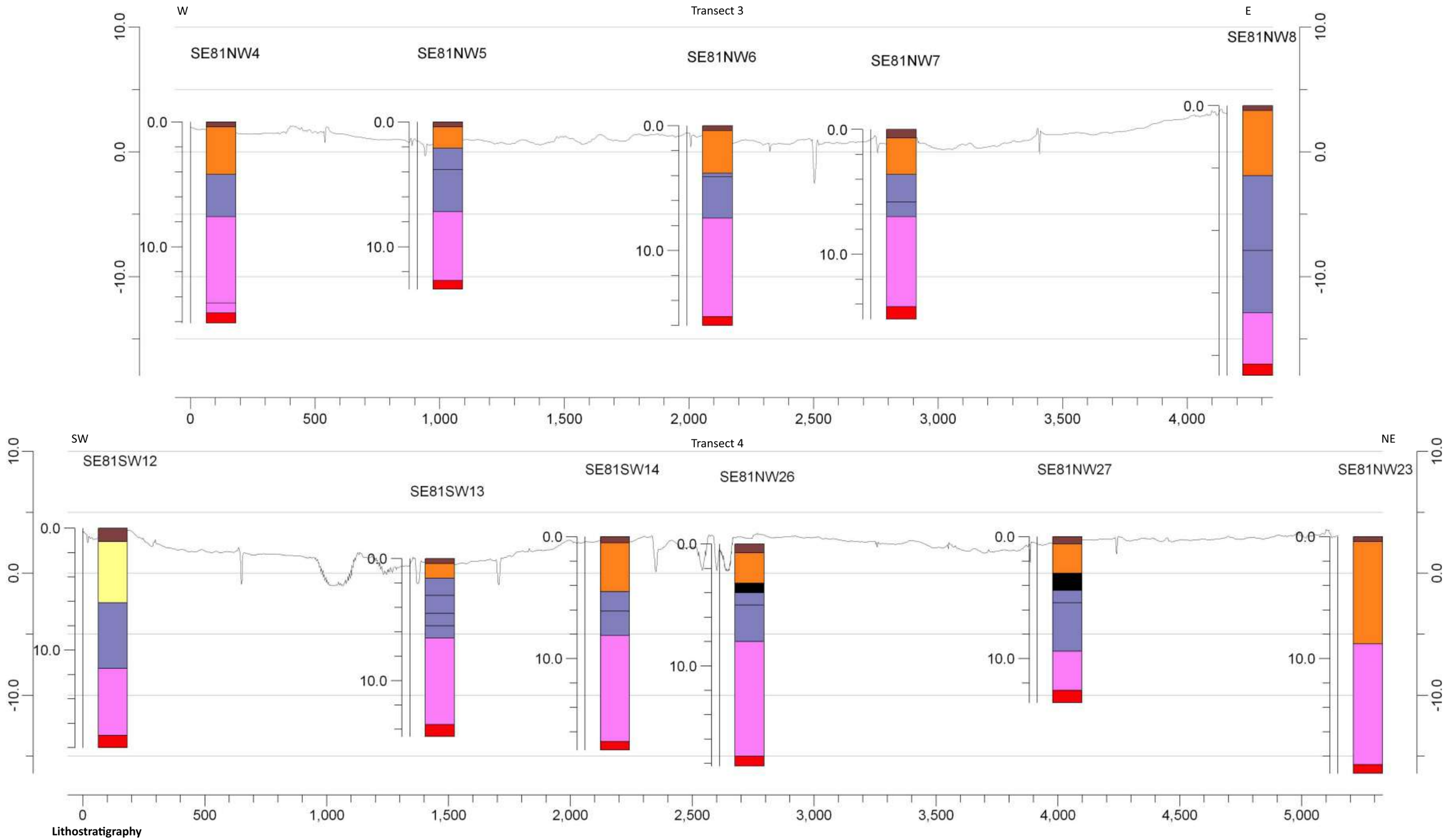
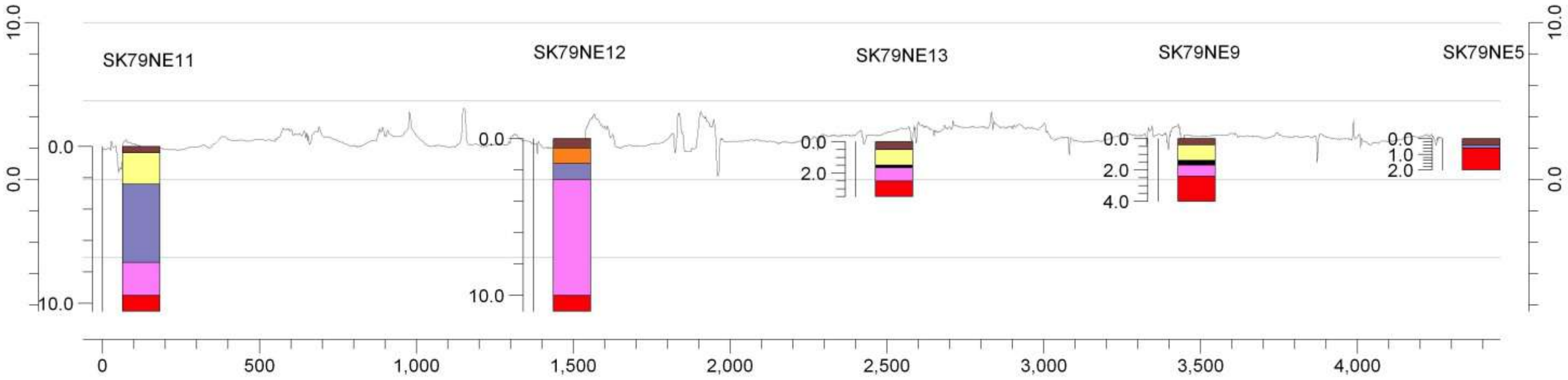


Figure 20 - Transects 3 and 4 (VE 50)
10326 - North Humber to High Marnham

SW

Transect 6

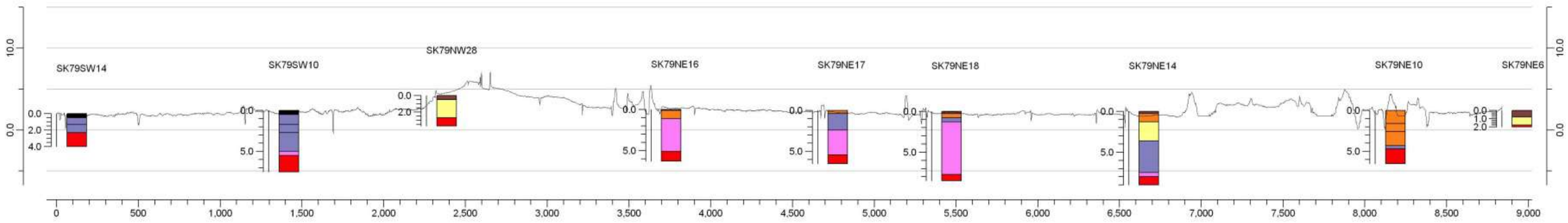
NE



Transect 7

SW

NE



Lithostratigraphy

- Topsoil
- Made Ground
- Warp
- Alluvium
- Aeolian Sand
- Peat
- Glaciolacustrine
- Sand and Gravel (Pleistocene)
- Mudstone Bedrock

1m 2018 DTM

Figure 21 - Transects 6 and 7 (VE 50)
10326 - North Humber to High Marnham

W

Transect 5

E

SE80NW21

SE80SW26

SE80SW9

SE80SW14

10.0

0.0

0.0

5.0

0.0

5.0

0.0

2.0

4.0

0.0

2.0

0

500

1,000

1,500

2,000

2,500

3,000

3,500

n

Transect 8

S

SK87SW12

SK87SW13

SK87SW18

SK87SW29

SK86NW34

10.0

0.0

0.0

1.0

2.0

0.0

5.0

0.0

1.0

2.0

0.0

5.0

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500

1,000

1,500

2,000

2,500

3,000

3,500

4,000

Lithostratigraphy

- Topsoil
- Made Ground
- Warp
- Alluvium
- Aeolian Sand
- Peat
- Glaciolacustrine
- Sand and Gravel (Pleistocene)
- Mudstone Bedrock

1m 2018 DTM

Figure 22 - Transects 5 and 8 (VE 50)
10326 - North Humber to High Marnham

Key

Master Order Limits

1km Buffer

BGS Borehole Transects

Area Limits

N

Superficial

ALLUVIUM

BIELBY SAND MEMBER

BLOWN SAND

GLACIOFLUVIAL DEPOSITS DEVENSIAN

HEAD

TILL, DEVENSIAN

Bedrock

ANCHOLME GROUP

BURNHAM CHALK FORMATION

BRANTINGHAM MEMBER

CHARMOUTH MUDSTONE FORMATION

FLAMBOROUGH CHALK FORMATION

FERRIBY CHALK FORMATION

HUNSTANTON FORMATION

KIRTON CEMENTSTONE BEDS

KELLAWAYS SAND MEMBER

LOWER LINCOLNSHIRE LIMESTONE MEMBER

MARLSTONE ROCKFORMATION

RAVENTHORPE BEDS

THORNCROFT SAND MEMBER

UPPER LINCOLNSHIRELIMESTONE MEMBER

WELTON CHALKFORMATION

WHITBY MUDSTONE FORMATION

Lidar DTM
m OD
162.90
-3.13

Holocene Risk
High
Medium
Low

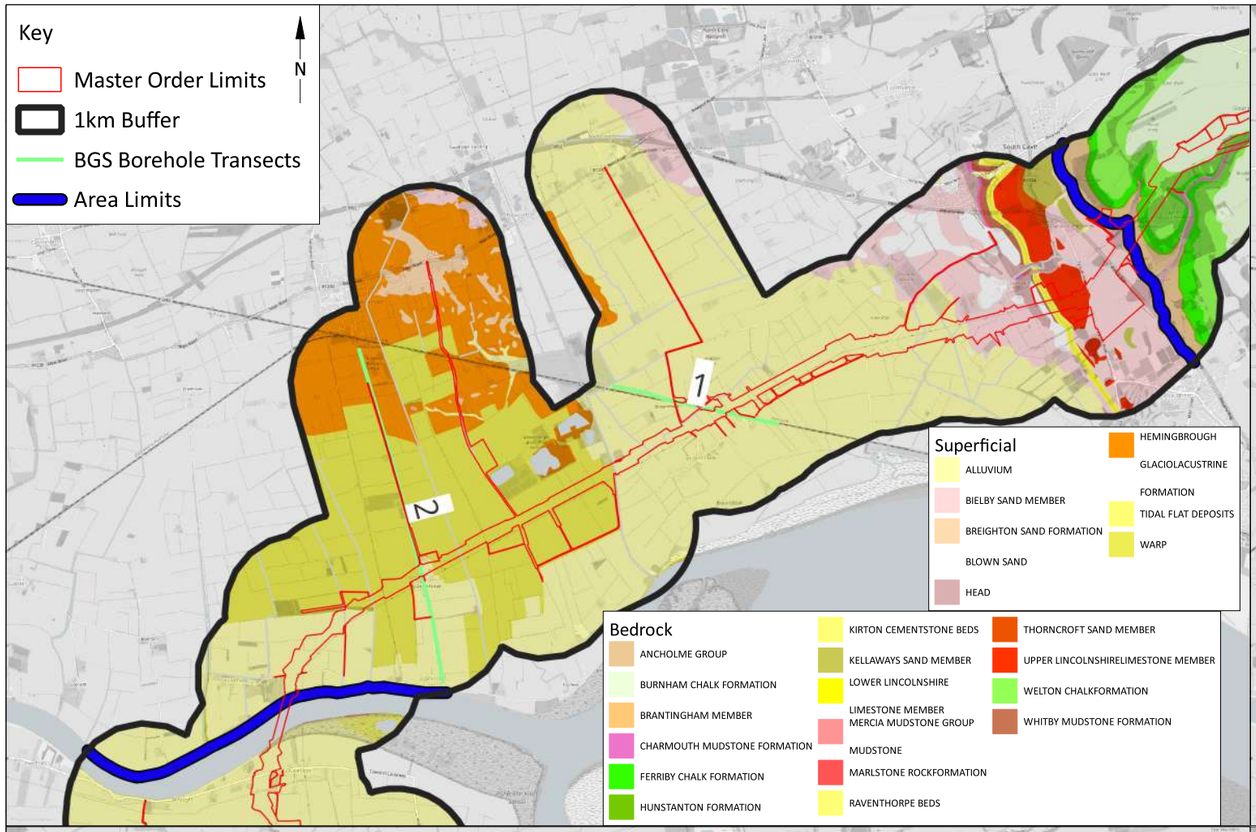
Pleistocene Risk
High
Medium
Low

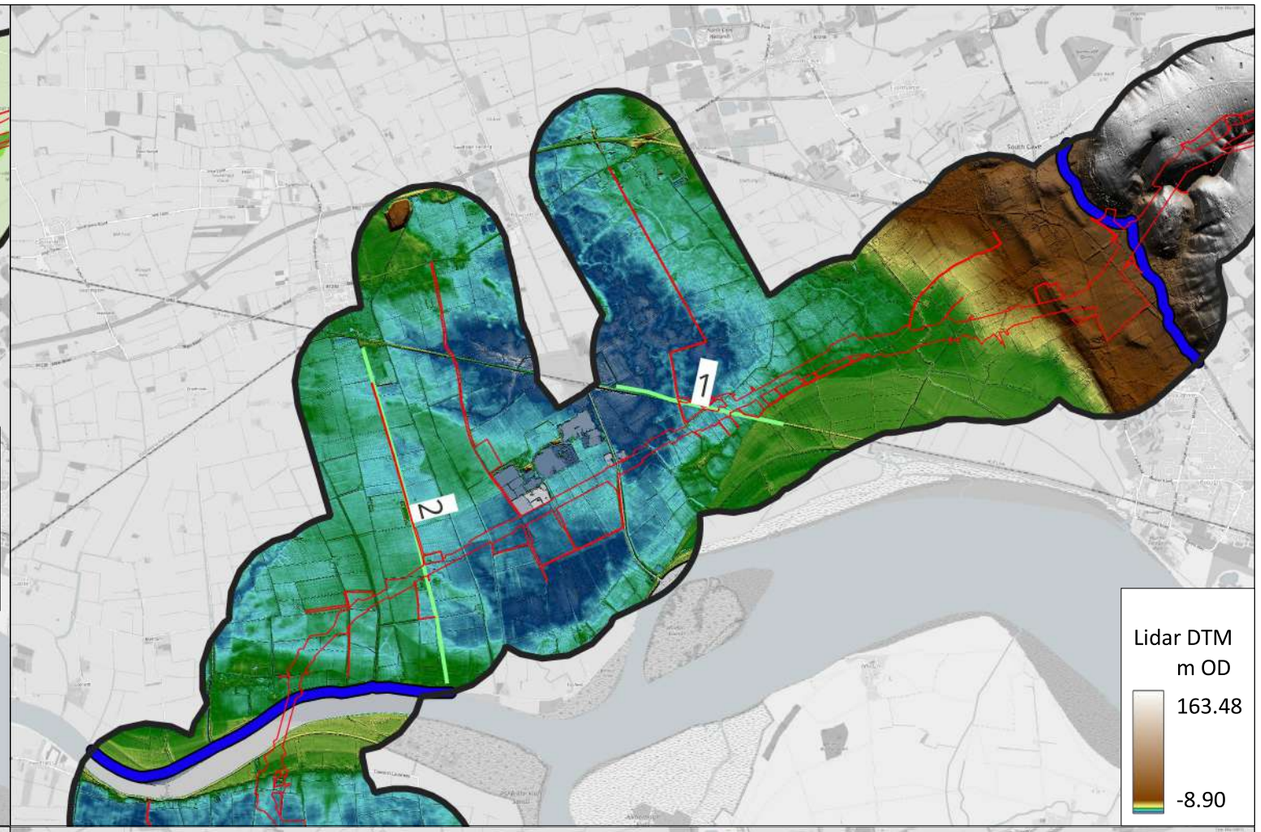
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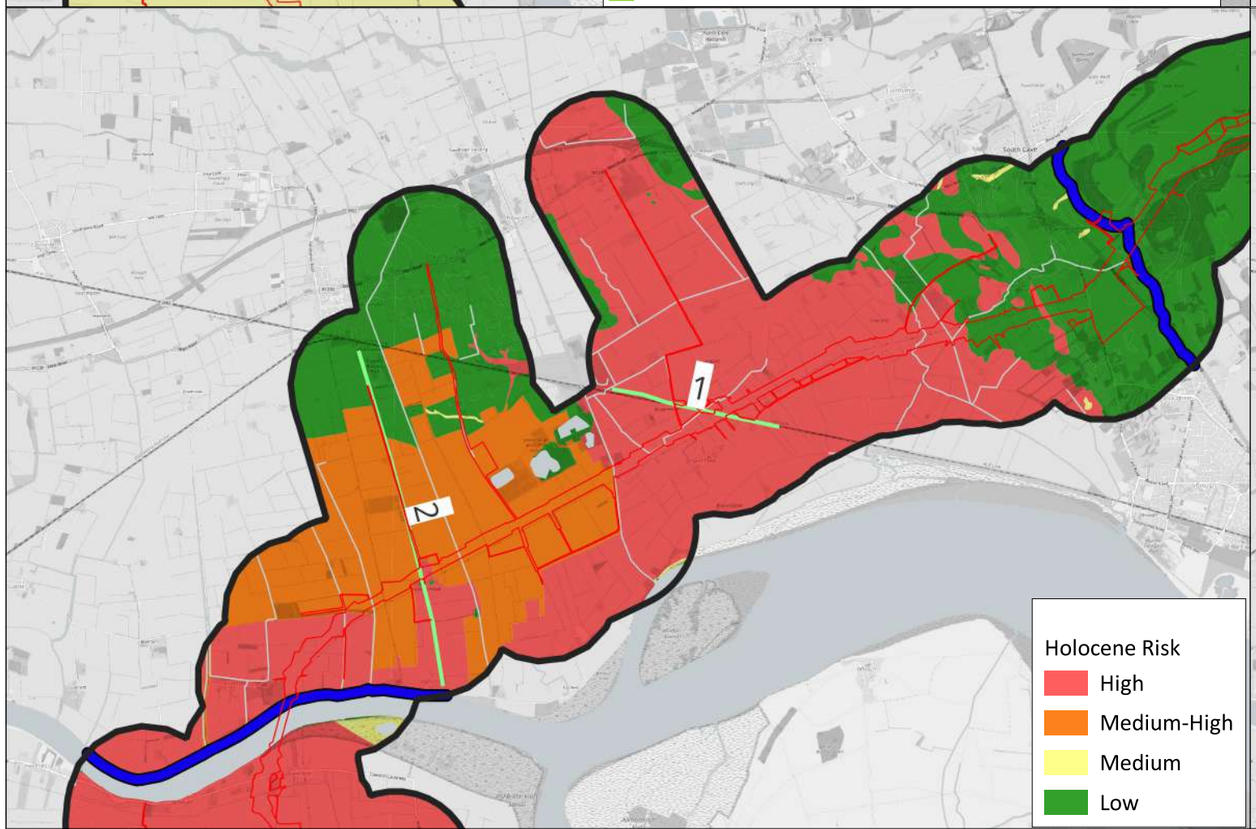
0 1 2 3 4 5 km

Illustrator: Tom Keyworth

Figure 23 - Wolds from Hull to Brantingham: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham







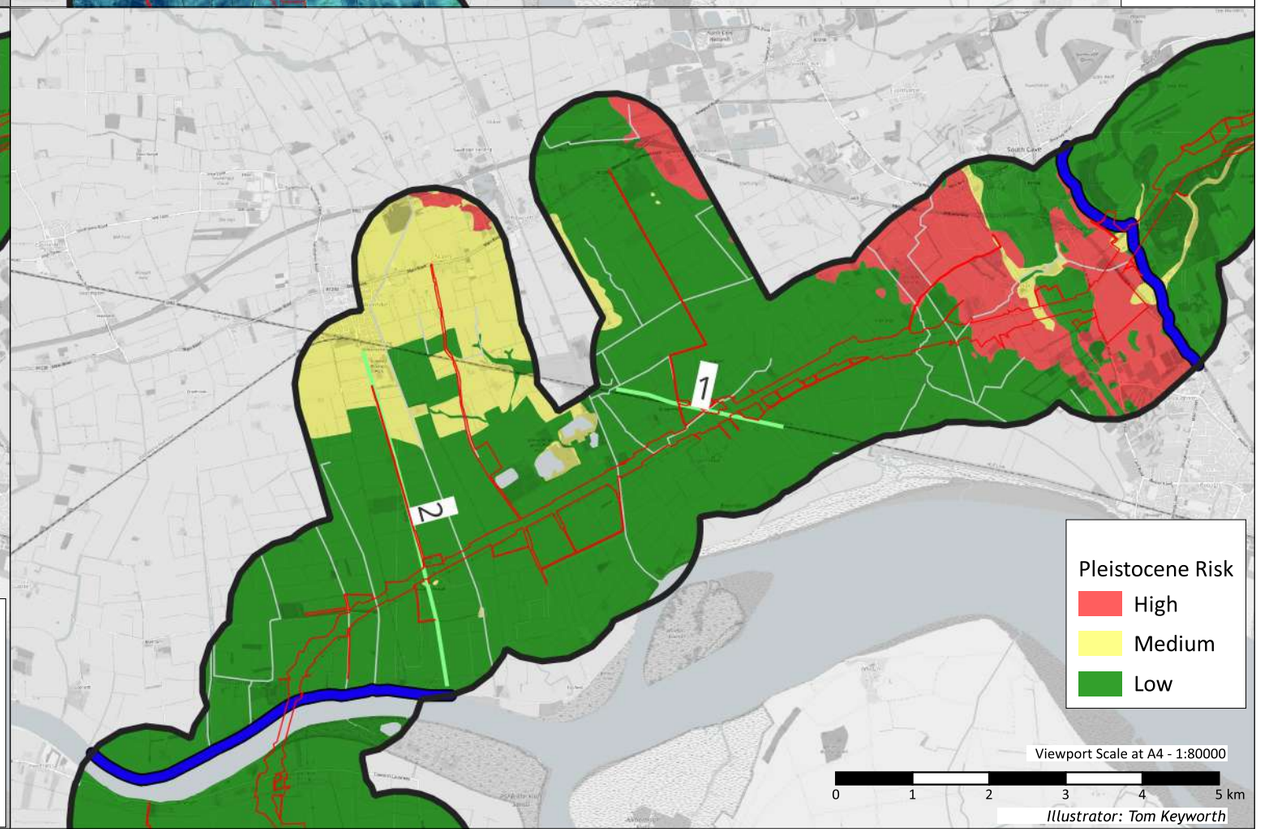
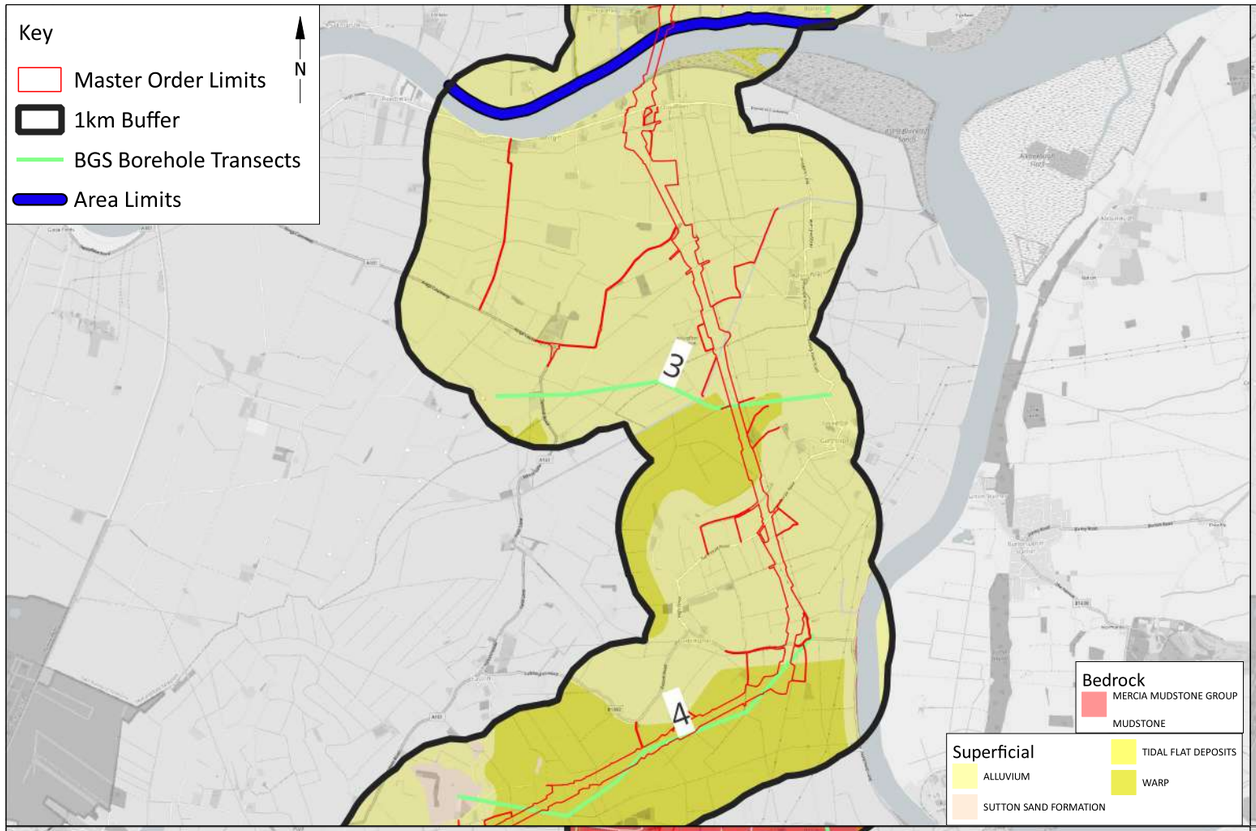
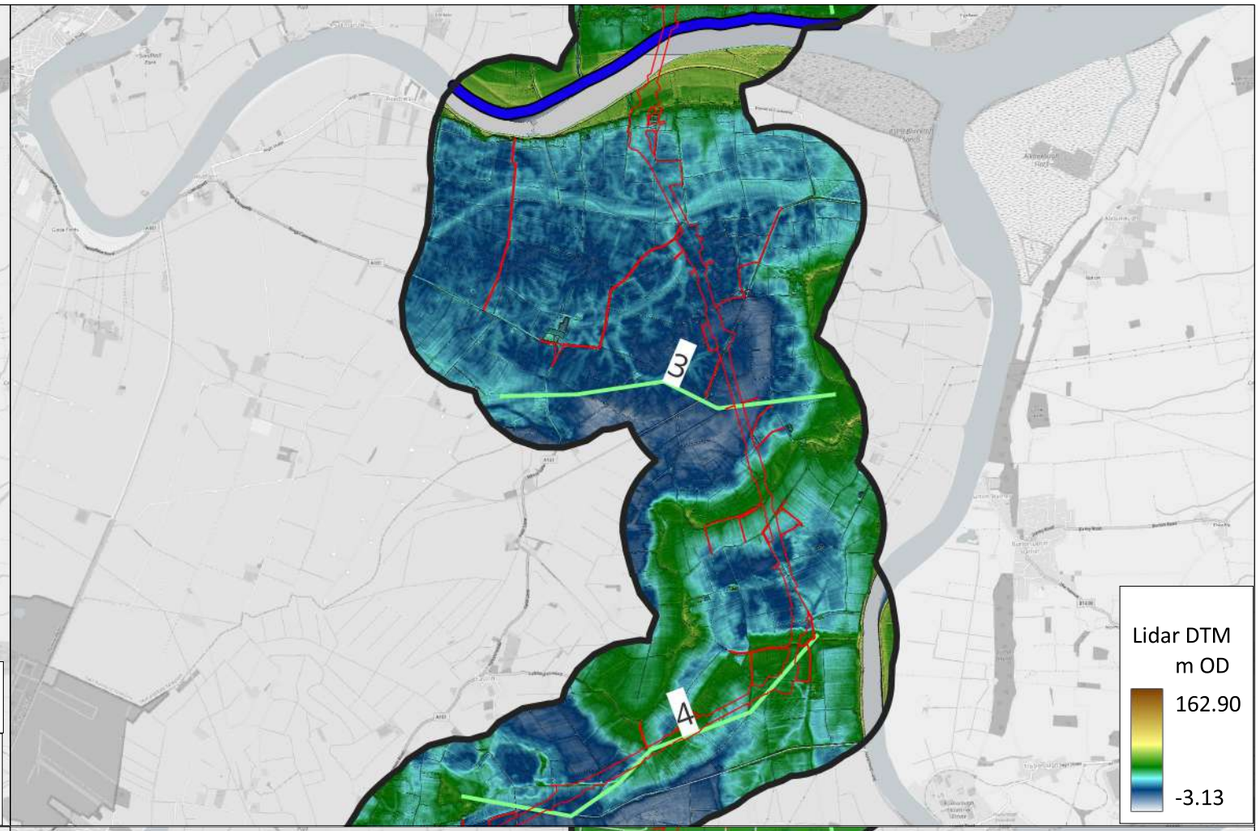
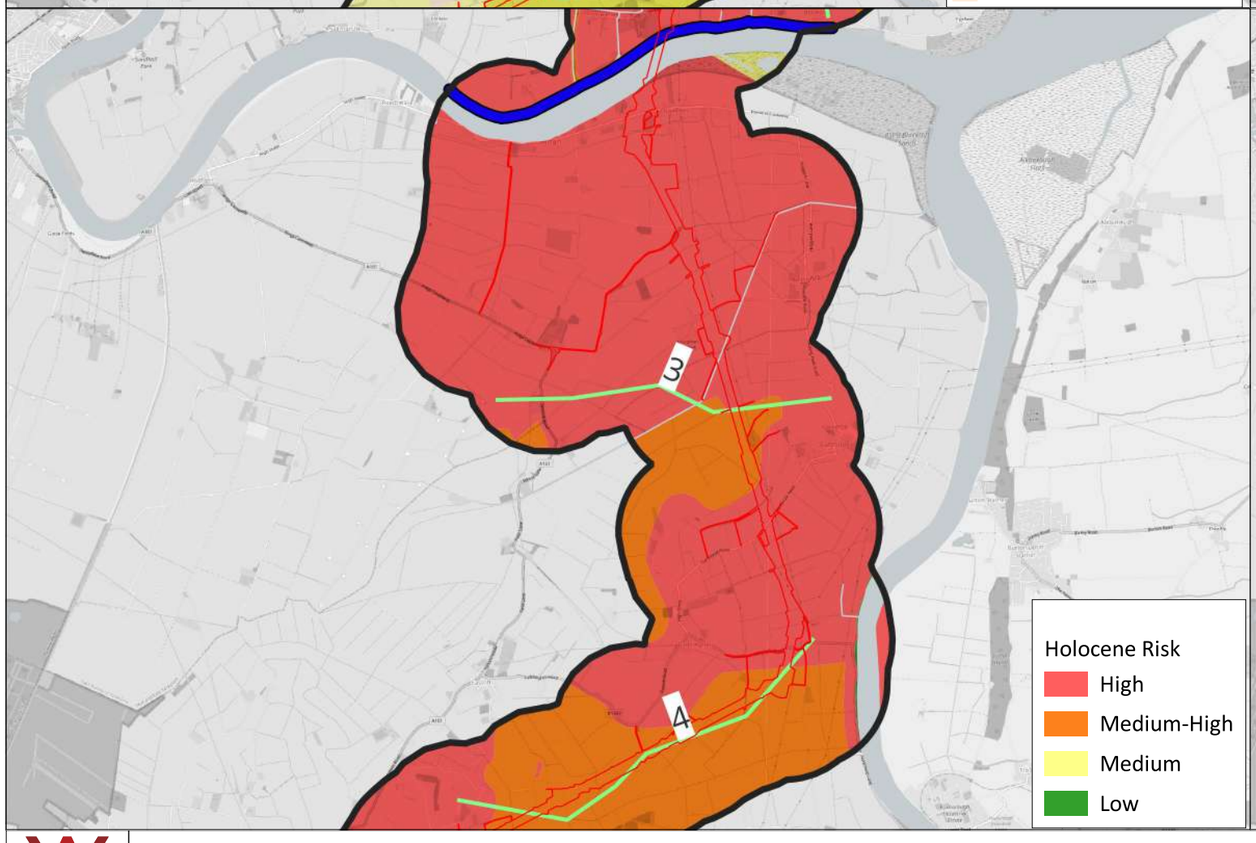


Figure 24 - Foulness Valley: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham







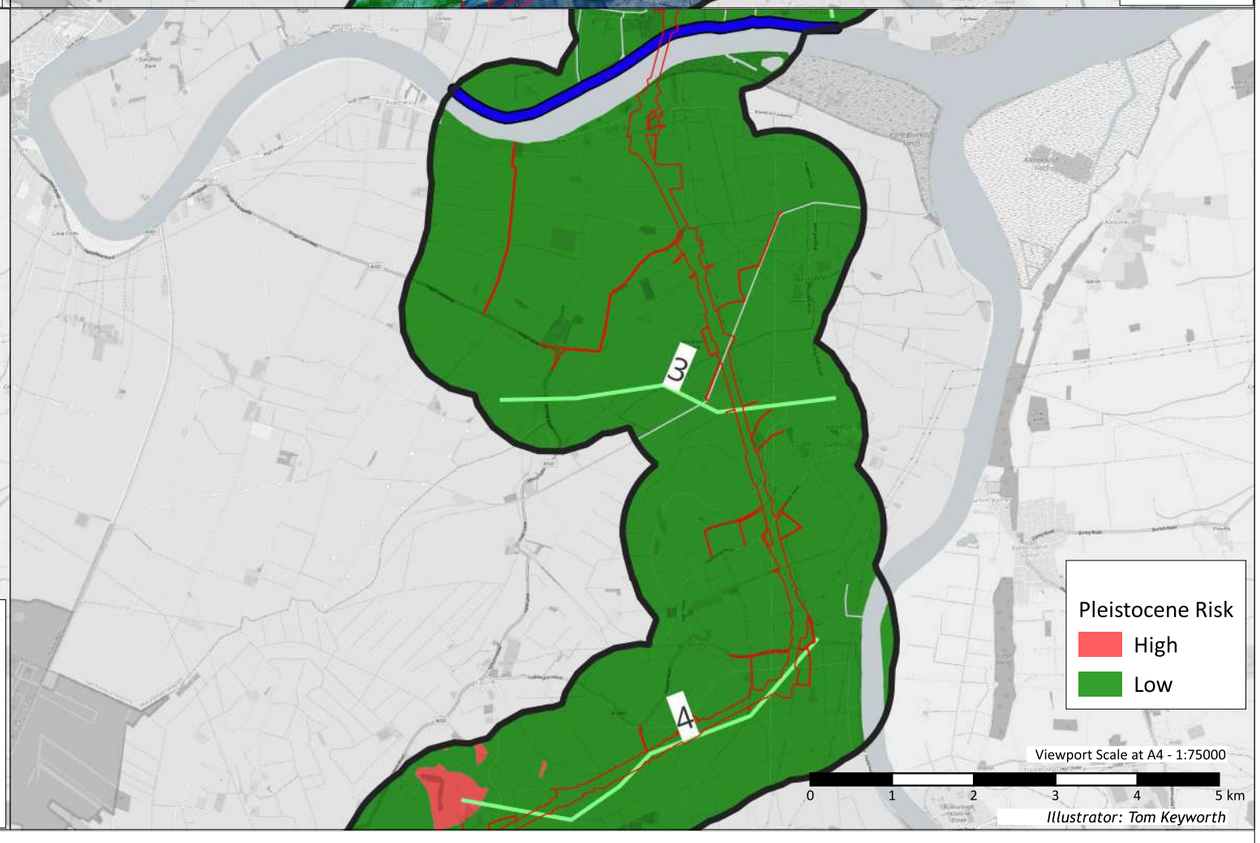


Figure 25 - Humberhead Levels: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham

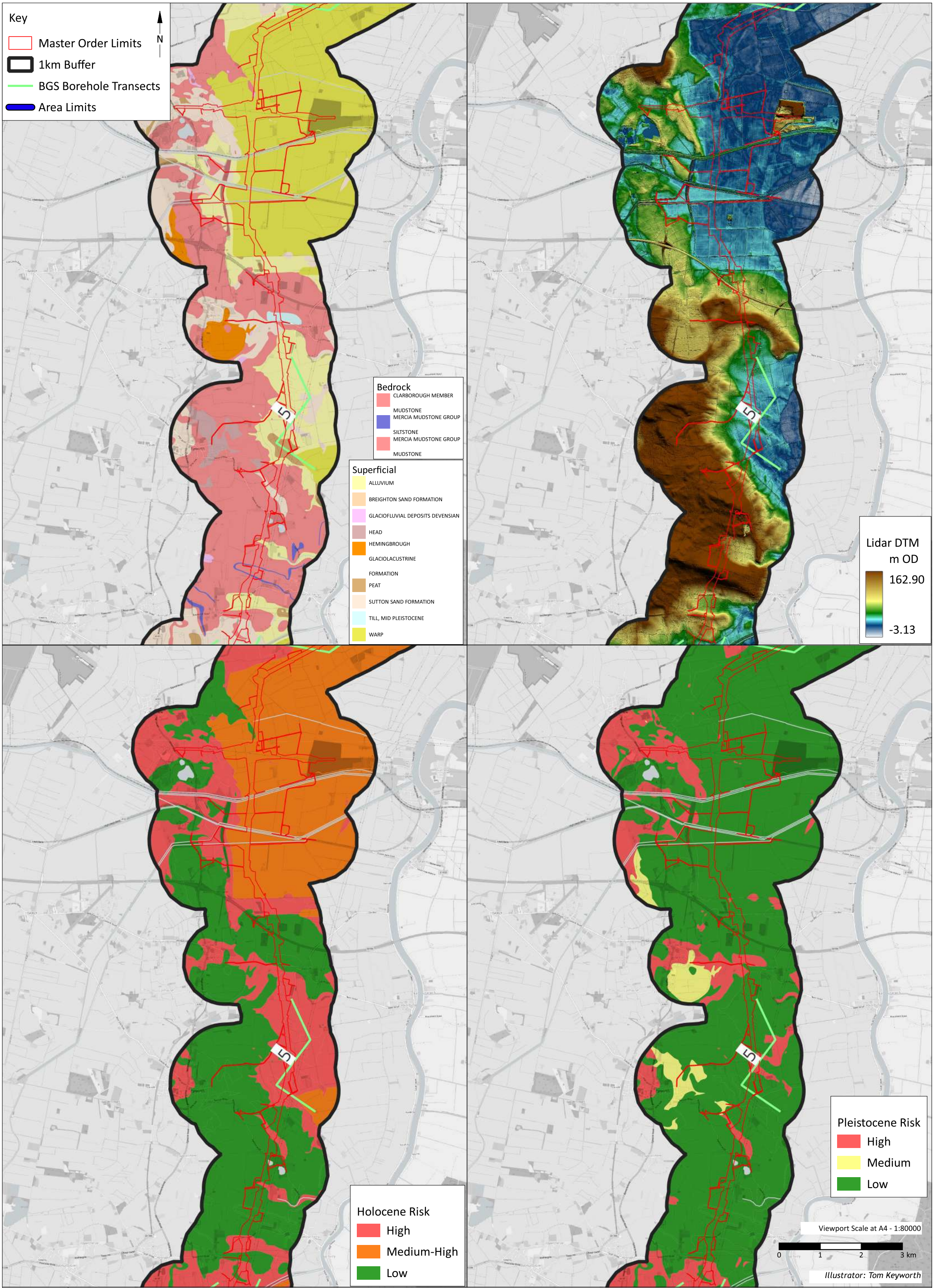


Figure 26 - Isle of Axholme: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham

Key

Master Order Limits

1km Buffer

BGS Borehole Transects

Area Limits

N

6

7

Superficial

ALLUVIUM

GLACIOFLUVIAL DEPOSITS DEVENSIAN

HEAD

PEAT

RIVER TERRACE DEPOSITS - 1

SUTTON SAND FORMATION

TILL, MID PLEISTOCENE

WARP

Bedrock

CLARBOROUGH MEMBER
SILTSTONE

CLARBOROUGH MEMBER
MUDSTONE

MERCIA MUDSTONE GROUP
SILTSTONE

MERCIA MUDSTONE GROUP
MUDSTONE

Lidar DTM
m OD

162.90

-3.13

Holocene Risk

High

Medium-High

Medium

Low

Pleistocene Risk

High

Medium

Low

Viewport Scale at A4 - 1:80000

0 1 2 3 4 5 km

Illustrator: Tom Keyworth

Figure 27 - Idle Valley: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham

N

Key
- Master Order Limits
- 1km Buffer
- BGS Borehole Transects
- Area Limits

Bedrock
- CLARBOROUGH MEMBER MUDSTONE
- MERCIA MUDSTONE GROUP SILTSTONE
- MERCIA MUDSTONE GROUP MUDSTONE

Superficial
- ALLUVIUM
- GLACIOFLUVIAL DEPOSITS
- MID PLEISTOCENE
- HEAD
- RIVER TERRACE DEPOSITS - 1
- TILL, MID PLEISTOCENE

Lidar DTM m OD
- 162.90
- -3.13

Holocene Risk
- Medium
- Low

Pleistocene Risk
- High
- Medium
- Low

Viewport Scale at A4 - 1:80000

0 1 2 3 km

Illustrator: Tom Keyworth

Figure 28 - Mercia Mudstone 'Uplands': a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham

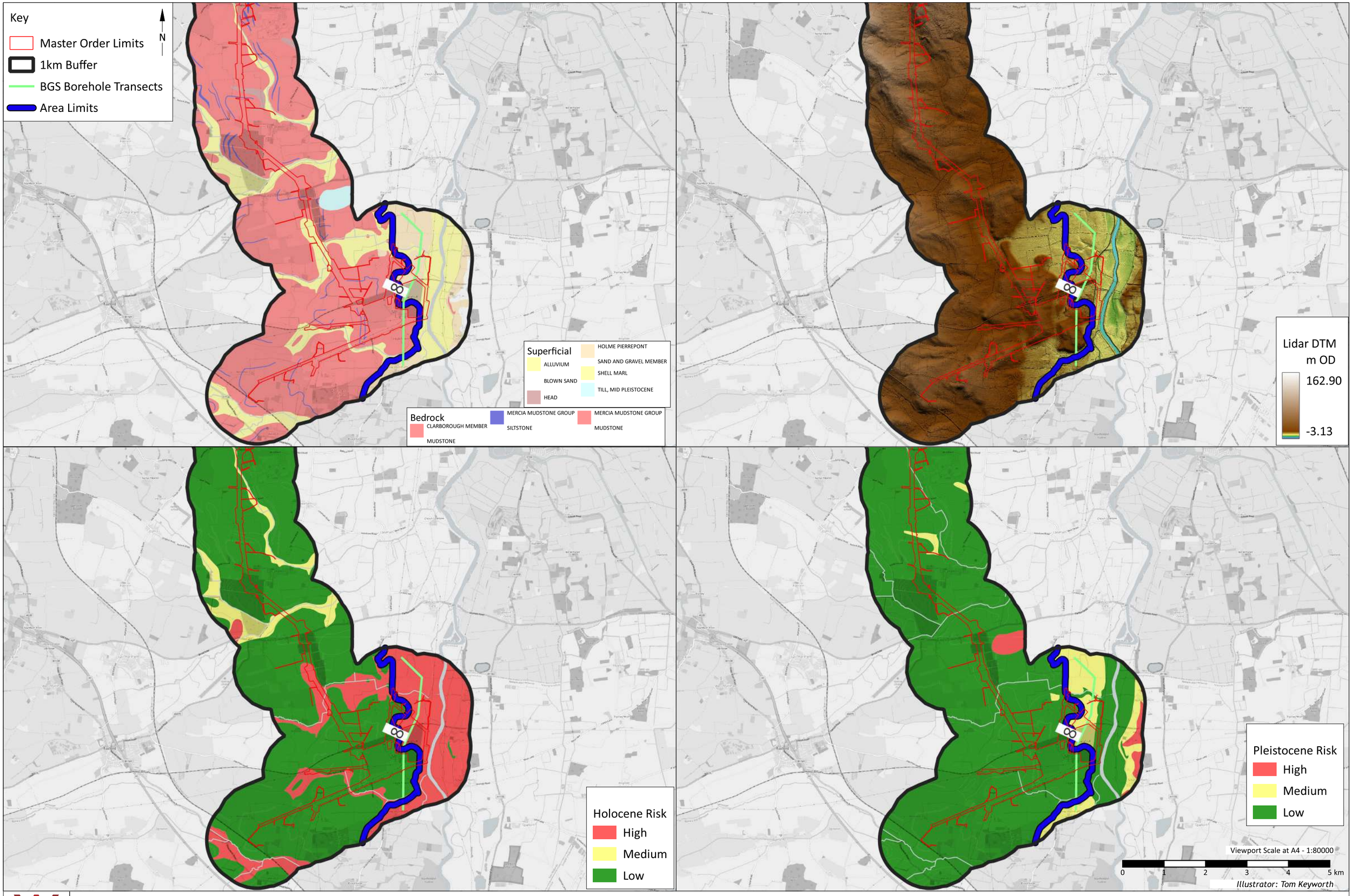


Figure 29 - High Marnham - Trent Valley: a) BGS Mapped Geology; b) DTM; c) Holocene Risk; d) Pleistocene Risk
10326 - North Humber to High Marnham

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