A12 Chelmsford to A120 widening scheme

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ENVIRONMENTAL STATEMENT APPENDIX 7.8 PALAEOLITHIC AND PALAEOENVIRONMENTAL EVALUATION REPORT - PART 2

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2 Part 2: Palaeolithic and Palaeoenvironmental Stage 2 Review Report

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PALAEOLITHIC AND PALAEOENVIRONMENTAL STAGE 2 REVIEW

PART 1: REPORT

Headland Archaeology Midlands & West
Unit 1 | Clearview Court | Twyford Rd | Hereford HR2 6JR

for Costain Group plc
on behalf of National Highways

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HEADLAND ARCHAEOLOGY

PROJECT INFORMATION:

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PROJECT SUMMARY

Headland Archaeology (UK) Ltd was commissioned by Costain plc on behalf of National Highways to undertake a review of the Palaeolithic and palaeoenvironmental assets of the A12 (Junction 19 Chelmsford – Junction 25 A120) Widening Scheme. This report presents the results of the Stage 2 Review, which includes a predictive deposit model based on a Scheme-specific stratigraphy based on geotechnical and geoarchaeological data. A risk review of Palaeolithic and palaeoenvironmental assets within the Scheme has also been undertaken, which refines previous mapping of Palaeolithic and Quaternary deposit character zones.

Key findings include a greater than anticipated complexity of interglacial lake sequences in the central area of the Scheme. Previous models predicted the presence of discrete, simple lakes with defined margins, these have been superseded by models incorporating varied lake edges, complex infilling sequences and an extended wetland zone. This increases the risk of Palaeolithic archaeology over a wide area and heightens the value of palaeoenvironmental sequences. In addition, previously unknown interglacial lake deposits have been identified in the south of the Scheme. Areas of fluvial deposits most likely to contain Palaeolithic archaeology have been identified in the risk review. The character of head deposits has proven diverse, with the associated potential for Palaeolithic remains also varied. Finally, large areas of the Scheme are covered by till or near-surface London Clay, which have minimal potential. Land surface horizons at the upper interface of till and near-surface incorporation of Kesgrave deposits, however, may be present.

No direct evidence of Palaeolithic archaeology has been recorded during the 2021 fieldwork. This cannot be taken as an indication that Palaeolithic remains are absent from the Scheme. On the contrary, the likelihood of intact Palaeolithic archaeology within specific areas of the Scheme remains high, and a programme of "sampling excavation" is recommended to locate such remains. If such a discovery were made, the mitigation approach would need to be weighed against the merits of preservation in-situ by Scheme re-design. On the basis of the deposit model and risk review a number of recommendations for future work are outlined in this report.

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A12 ARCHAEOLOGICAL EVALUATION (JUNCTION 19/CHELMSFORD – JUNCTION 25/A120)

Palaeolithic & Paleoenvironmental Stage 2 Review

1. INTRODUCTION

This document presents the outcome of the Stage 2 Review of all purposive geoarchaeological works and ground investigation works undertaken by Headland Archaeology (UK) Ltd as part of the A12 (Junction 19 Chelmsford – Junction 25 A120) Widening Scheme. It builds on the archaeological trial trenching and Palaeolithic evaluation which is presented elsewhere (Headland Archaeology 2021c, 2021d). This work was required due to the high potential for Palaeolithic sites and artefact find spots in this region (Historic England, in draft). Although these finds are more common in this region, they are still incredibly rare when compared to other periods and our understanding of key points in global human evolution and the presence of humans in Britain remains severely limited. Any finds dating to the Palaeolithic therefore have the potential to be of both national and international importance. Of particular significance are deposits which are likely to be diverse and minimally disturbed, such as those preserved in lake deposits where there is high potential for stratigraphic relationships to be identified and 'well-preserved indicators of the contemporary environment can be directly related to the remains' (Historic England, 2012). Additionally (unlike later archaeological periods which can be characterised by near surface remains), for the Lower and Middle Palaeolithic record artefacts and environmental evidence are more commonly associated with deeply buried Pleistocene landscape fragments. 'Understanding of our Palaeolithic past therefore requires not only artefact finds, but also a wider appreciation of Pleistocene geological deposits and their associated palaeoenvironmental evidence' (Historic England, in draft).

The work was commissioned by Costain Group plc on behalf of National Highways. All works were undertaken in compliance with a Written Scheme of investigation (WSI) prepared by Headland Archaeology (2021a). The WSI was produced as part of an application on behalf of National Highways for a Development Consent Order (DCO) regarding improvements to the A12 in Essex which was approved by the stakeholders *(*Essex County Council, Colchester Borough Council, and Historic England*)* and conformed to a scope of works produced by Jacobs (2020b). Headland Archaeology was also commissioned to undertake the trial trenching, Palaeolithic evaluation, post-excavation assessment, reporting and the creation and deposition of an ordered archive (Headland Archaeology 2021b and 2021c).

1.1. SITE LOCATION AND DESCRIPTION

The A12 Chelmsford to A120 Widening Scheme (henceforth 'the Scheme') comprises improvements to the A12 between Junction 19 (Boreham) at NGR TL 741094, and Junction 25 (Marks Tey) at NGR TL 917238, approximately 24km (15 miles). The Scheme involves widening the A12 to three lanes throughout. It also includes safety improvements, including closing off existing at grade accesses, and reducing access to cyclists along the dual carriageway by providing an alternative route for walkers, cyclists and horse riders.

The Scheme boundary encompasses a total physical area of 1,039 ha, of which approximately 25 ha comprises the existing highway and other land which would not be physically affected by construction. Due to the large linear extent of the scheme, it has been separated into five Quaternary Landscape Evaluation Areas (QLEAs 1-5) for the presentation of results and discussion (Illus. 1A). The route of the scheme runs through a gently rolling landscape which varies between 18 m AOD and 55 m AOD (Illus. 1B). There are also a number of areas proposed for borrow pits and other temporary works comprising approximately 135 ha.

1.2. SOLID AND DRIFT GEOLOGY

The solid geology within the area affected by the Scheme comprises London Clay Formation – a clay, silt and sand bedrock formed approximately 48 to 56 million years ago in the Palaeogene Period (NERC 2021). There are discrete patches of Thanet formation of sand, which formed earlier in the Palaeogene (approximately 56 to 59 million years ago), at Witham and undifferentiated Thanet Formation and Lambeth Group at Kelvedon.

Broadly speaking the superficial deposits are dominated by till (a diamicton deposited by a glacier) to the north of the A12, and glacial sand and gravel to the south of the A12 and in the lower ground of the present river valleys. Both are part of the Lowestoft formation dating to the Anglian Stage (Marine Isotope Stage (MIS) 12), the glacial stage which separates the Cromerian and Hoxnian (Headland Archaeology, 2021c; Table A1.1).

Superficial deposits predating the Anglian glaciation include the Kesgrave Catchment Subgroup (sands and gravels) which are present near the ground surface in valley sides to the east of the scheme. Deposits post-dating the glaciation include Head deposits, a sequence of at least five late Pleistocene river terraces (sand and gravels) and Holocene alluvium (sands, silts, clays and gravels) all deposited by fluvial systems and therefore located on valley sides or bases. Patches of Brickearth are mapped on high ground to the west of the scheme, particularly to the east of Boreham (NERC 2021). Of particular significance are the interglacial lacustrine deposits mapped to the east of Witham and the Glaciolacustrine deposits mapped to the south-west of Boreham. Both are broadly dated to the Pleistocene, would have presented attractive environments to Palaeolithic peoples, and offer good potential for preservation of artefactual and paleoenvironmental archives.

Detailed discussion of the geomorphological setting of the Scheme and nearby Palaeolithic evidence have been presented elsewhere (Wenban-Smith 2020; Headland Archaeology 2021c). The stratigraphic framework set out by Headland Archaeology (2021c, pp5-10) was applied across all deposit model transects presented below. A visual representation of this stratigraphy, and the relationship between Members, is shown in Illus 2A-C and full descriptions are provided in Appendix 1.

1.3. ARCHAEOLOGICAL BACKGROUND

Previous archaeological work includes a Desk Based Assessment (Highways England 2018); a Palaeolithic Desk-Based Assessment (Wenban-Smith 2020), two phases of geophysical survey (Headland Archaeology 2020a and 2020b), a cropmark analysis (PlaceServices 2021) and trial trenching (Headland Archaeology 2021d). In the course of these intrusive and non-intrusive works a range of sites spanning the Palaeolithic to modern periods were identified. Readers are referred to Highways England 2018 for a full overview, and a summary of key results specifically relevant to Palaeolithic and palaeoenvironmental assets is presented here.

Pleistocene

A Desk Based Assessment (DBA) for the section of the Scheme from Witham to Colchester identified 68 separate Palaeolithic sites within a 3 km buffer around the Scheme boundary (Wenban-Smith 2020). These sites were divided into 5 groups:

- sites west and south-west of Witham, mapped as Boulder Clay or Glacial sand and gravel,

- sites to the north-east of Witham with varied deposits i.e. Blackwater Terrace 3 sand/gravel below Hoxnian *lacustrine deposits, and Blackwater Terrace 2 sand/gravel deposits, including in-situ palaeo-environmental and artefactual remains,*
- Blackwater Terrace 3 gravel which includes possible upper palaeolithic human skull fragments from the base of the Holocene alluvium (revealed in Roman Kelvedon excavation site, highlighting the possibility that Holocene archaeology excavations may impact Pleistocene archaeological deposits),
- sites in and near the Hoxnian interglacial lacustrine sediments at Marks Tey, including artefactual finds and palaeo-*environmental records (molluscs, mammal fossils, pollen and plant macro-fossils),*
- sites at the north-east end of the A12 scheme containing reworked artefacts from pre-Anglian deposits and residual finds from post-Anglian activity in glacial Sand and Gravel.

Wenban-Smith (2020) further divided the Scheme into 26 Palaeolithic and Quaternary (PQ) deposit character zones (Illus. 1B) and four categories of potential for preserving Palaeolithic archaeology and palaeoenvironmental sequences were identified based on prior knowledge with recommendations for future work (Table 1). Existing reports associated with this phase of trial trenching evaluation include the Fieldwork Phase 1 – Quaternary Landscape Evaluation Report (Headland Archaeology, 2021c) and Archaeological Evaluation (Headland Archaeology 2021d).

Table 1. Categories of potential utilised in the A12 Palaeolithic DBA (Wenban-Smith 2020).

Category of potential	PQ zones	Definition	Recommendation
Uncertain	6, 22 and 22b	nature of Quaternary deposits needs establishing	Phased 2-stage Palaeolithic evaluation programme, with an initial deposit-scoping stage followed by a further evaluation if/where necessary.
High	3, 5, 9 and 23	areas of previously known potential	Phased 2-stage Palaeolithic evaluation programme, with an initial deposit-scoping stage followed by a more detailed evaluation in areas of greater interest.
Moderate	1, 10, 11, 12, 13b, 15, 17 and 18	areas of limited potential	Initial phase of stage 1 evaluation, with the expectation that further stage 2 evaluation is likely to be required in places, but only if/where necessary.
Low	8, 19 and 20	areas where deposits are unlikely to contain Palaeolithic material	Initial phase of stage 1 evaluation, with the expectation that further stage 2 evaluation is unlikely to be required but may nonetheless be necessary in places.

Holocene

Holocene deposits of geoarchaeological and palaeoenvironmental potential have been targeted in each of the river valleys across the scheme to assess the potential for paleoenvironmental archives which can be used to provide a geochronology and biostratigraphy of landscape evolution associated with the human activity identified in the DBA (Highways England 2018) and during the archaeological trial trenching (Headland Archaeology 2021d), summarised here.

There are 35 prehistoric sites located within the footprint of the Scheme, ranging in date from the Mesolithic to the Iron Age. They comprise findspots of individual artefacts, cropmarks and geophysical anomalies (see Highways England 2018). A Mesolithic camp (Asset 325) is located south of Durwards Hall, Rivenhall and is likely to have been in a marshy area on the edge of a large post-glacial lake. Neolithic activity in the area is evidenced by the Rivenhall long mortuary enclosure (Asset 390) and associated cropmarks of a small circular henge like monument and lithics (Asset 519) Bronze Age evidence is widely recorded throughout the area, most notably at The Boreham Interchange site (Asset 33 and 35) and a late Bronze Age enclosure at Springfield Lyons. Archaeological evidence suggests that there would have been large Iron Age settlements at Witham and Kelvedon. The site of the Kelvedon Warrior burial lies near the Scheme (Sealey 2007). Field boundaries seen as cropmarks and small enclosed and unenclosed settlement sites provide extensive evidence for a pastoral and arable landscape across the scheme throughout the Iron Age.

Findspots of individual artefacts excepted, there are 28 archaeological sites dating to the historic period recorded within the footprint of the Scheme (Highways England 2018). The Roman period saw significant changes to the landscape and society of the area, including the establishment of major towns at Colchester (*Camulodunum*) and Chelmsford (*Caesaromagus*), linked by a road, the course of which was followed by the original A12 (Asset 6 and 125). Smaller towns and trading centres grew up at strategic points along this road network, for example the Roman settlement at Kelvedon (*Canonium*), which developed at a crossing over the River Blackwater (Rodwell, 1988). Anglo-Saxon activity within the vicinity of the scheme is attested by the presence of a number of cemeteries dated to the 5th to 7th centuries AD, including one example at Kelvedon (Asset 632) (see Sealey 2007 for an overview). Evidence of settlement through the medieval period to modern times includes an early medieval field enclosure at Rivenhall End, a variety of medieval sites including a possible deserted settlement near Hatfield Peverell. Several sites of post-medieval and modern buildings are also recorded in the Scheme.

An additional 40 sites, ranging from Mesolithic activity to potential for extensive Iron Age and Romano British settlement and on into the historic period, have been identified during the trial trenching stage of fieldwork (Headland Archaeology 2021d). Geoarchaeological analysis of the Holocene paleo channels offers potential to provide a geochronological biostratigraphic framework for the development of the wider landscape during this period. This is particularly pertinent to the introduction and changes in agricultural practices; the Roman industry, settlement, and possible trade-related activity alongside the Roman road; Medieval settlement and possible industry; and post-medieval agricultural activity identified in the trial trenching stage of work (HA, 2021d).

2. AIMS, OBJECTIVES AND SCOPE

2.1. AIMS AND OBJECTIVES

Aims

The East Anglian Regional Framework (Medlycott, 2011) has outlined the need to develop geoarchaeological and paleoenvironmental research into the archaeological investigations in Essex. This includes the need to improve on the number of targeted programmes that examine sequences associated with the river valley and floodplain developments, and the use of multi-proxy analysis to better understand the development of the floodplain and fluvial system, and the relationship between this paleoenvironment and human activity in the archaeological record.

The aim of this Stage 2 Review report is to use deposit modelling, based on geoarchaeological works and ground investigation works conducted in 2021, to assess the potential for Pleistocence and Holocene palaeoenvironmental sequences within the scheme, and preserved Palaeolithic archaeology. This assessment provides a risk review for the scheme provided as Updated PQ (UPQ) zones, which in turn informs recommendations for future investigation. The approach to evaluation is defined by the likelihood of remains alongside impacts of the scheme following the seven general themes for the Palaeolithic in and around the Scheme as identified by Wenban-Smith (2020):

- Evidence for pre-Anglian Hominin activity in borrow pits
- Lacustrine deposits for Anglian – Hoxnian transition
- Hominin activity around lake deposits (potential in-situ remains)
- Hominin activity in the Blackwater 3rd terrace
- Hominin activity on the Blackwater 1st and 2nd terraces
- Palaeoenvironmental remains in the Blackwater 2nd terrace near Witham
- Potential for Upper Palaeolithic remains beneath alluvium overlying 1st and 2nd terrace deposits

Additionally, the potential for Holocene deposits with geoarchaeological and palaeoenvironmental potential has been assessed for each of the six river valleys within the Scheme.

Objectives

To achieve this the following objectives have been set:

- Collate and integrate all available relevant datasets
- Build a scheme-specific stratigraphic framework that encompasses all major depositional sequences in the area
- Undertake deposit modelling to predict the distribution of sub-surface stratigraphy
- Assess the potential of the Scheme stratigraphy for palaeoenvironmental potential, i.e. preservation of proxies that provide information on the environmental change over the chronology of encountered deposits
- Assess the potential of the Scheme stratigraphy for Palaeolithic archaeology, i.e. in-situ Palaeolithic scatters, likely comprising stone tools and faunal remains, and secondary deposits of remains
- Provide recommendations for further work required to fully evaluate the scheme for palaeoenvironmental and Palaeolithic potential, which principally relates to works to locate and constrain Palaeolithic archaeology
- Provide a framework for future stages of mitigation, including comment on development of a scheme-wide framework WSI and the nature of mitigation excavations, if required.

2.2. PREVIOUS AIMS AND OBJECTIVES

As well as addressing the above aims and objectives, previous aims and objectives defined in the WSI have been addressed. The evaluation WSI (Headland Archaeology 2021b) specified in the following in regard to the Palaeolithic (section 4.2):

- Identifying deposits that have a potential to contain evidence of in situ palaeolithic occupation
- Identifying deposits that might contribute to understanding the contemporary environment
- Recovering artefacts from secondary deposits
- Assisting with the development of a future mitigation strategy for the scheme

The first two objectives have been addressed by assigning Palaeolithic archaeology and paleoenvironmnetal sequence risk ratings, respectively, to the UPQ zones. Screening for artefacts was undertaken on site (see Headland Archaeology, 2021a). The evaluation report (Headland Archaeology, 2021) and this document assist in the development of a future mitigation strategy.

During the course of fieldwork the strategy taken to the Quaternary deposits was refined based on the Stage 1 Review (Headland Archaeology, 2021b). This review defined the key aims in relation to Quaternary deposits as:

- Ground truthing of existing Geotechnical ground investigation work.
- Zoning of parts of the scheme available in terms of constraining potential.
- Clear identification of unevaluated parts of the scheme in terms of both spatial area and depth.
- Construction of a first order scheme-wide landscape model within which the archaeological and palaeoenvironmental records reside
- Initial sampling for artefacts and ecofacts.

Geotechnical data is reviewed as part of this Stage 2 Review report. Zonation is accomplished by refinement of the PQ zones. This report also identifies those areas within the scheme boundary for which existing data coverage is limited and presents the first order scheme-wide deposit model. As above, initial sampling for artefacts and ecofacts was undertaken (Headland Archaeology, 2021c).

2.3. SCOPE OF THE REPORT

This document builds on the results from the boreholes extracted during Fieldwork Stage 1 in May to October 2021 that were not included in the Fieldwork Stage 1 Assessment Report (Headland Archaeology 2021c). The logs of each of these boreholes are included as Appendix 1. A scheme-wide deposit model is presented to illustrate the conclusions and implications of the results from the Fieldwork Stage 1 including a re-assessment of the PQ zones. This report should be read in conjunction with the Scheme Palaeolithic DBA (Wenban-Smith 2020) and Assessment Report (Headland Archaeology 2021c).

3. GEOARCHAEOLOGICAL RECORDING AND DEPOSIT MODELLING

Full details of the methodology for field work can be found in the *Fieldwork Phase 1: Quaternary Landscape Evaluation of palaeoenvironmental and Palaeolithic report* (Headland Archaeology 2021c). Interventions comprised:

- 88 test pits were excavated to a depth of c. 3 m or less at one end of the 30m trial trenches (after it was established no later archaeological features survived at these locations)
- 113 boreholes were excavated (see Table 2)

Test pits and boreholes were arranged in transects where possible, in most cases these ran parallel to the scheme corridor, though in some instances transects were located by reference to geomorphological features. For example, Pleistocene Transect 5 targets an area mapped as Brickearth and Pleistocene Transect 15 is a perpendicular transect through the trend of the river terrace deposits, which was chosen to create a profile across the terrace sequence through to the potential margin of Hoxnian lakes to identify the lake margin deposits.

The test pit and borehole surveys (supplemented by Ground Investigation (GI) data) targeted twelve locations along the scheme including, two on the shores of the Hoxnian lakes and five across the valleys. Further bore holes were undertaken in the six Holocene fluvial valleys at 50m centres (or less) to establish whether there is potential to interpret upper palaeolithic and later prehistoric landscapes. The key landscape identified for this is the Blackwater flood plain in PQ1 (Appendix 3).

Test pits

Test pits (TPs) were entered at the maximum safe depth (1 m from the surface) to record the upper lithology. After excavation progressed beyond this depth, recording took place without entering the test pit. The lithological sequence was described from a safety observation platform, whereas the discrete deposits were examined outside the fenced area after extraction by the machine. All three accessible sections from each test pit were photographed in colour (digital) once excavation reached its full depth, and at appropriate stages during excavation when features of interest were revealed (Headland Archaeology 2021c, Appendix 4).

Boreholes

The borehole (BH) core samples were recovered to Headland Archaeology's Midland & West Office where they were opened, cleaned (by trowel, to eliminate smears and reveal sediment structure), photographed and recorded (Appendix 1).

All recording was completed by a qualified geoarchaeologist. Sediments were recorded following standard descriptive practices in accordance with Historic England guidelines for geoarchaeology (2015). The sediments were described on a digital summary proforma, according to standard methodologies based on Jones (1999). This included a description of colour, texture, sorting, inclusions (including shape and material) and boundaries. Any artefact and ecofact inclusions were noted and sub-sampled where appropriate.

The data from the purposive geoarchaeological works by Headland Archaeology has been supplemented by ground investigation works undertaken by National Highways (2021) and data available from the British Geological Survey (BGS) where required.

3.1. DEPOSIT MODELLING

The deposit modelling was undertaken using the following four key data sources;

- Test Pit data previously presented in Appendix 2 of *Fieldwork Phase 1: Quaternary Landscape Evaluation of palaeoenvironmental and Palaeolithic report* (Headland Archaeology 2021c);
- Borehole data, included as (Appendix 1 of this report);
- GI data collected by National Highways (2021) and provided to Headland Archaeology as an AGS file for import to Rockworks™ by Costain;
- Data previously collected as ongoing research at Colemans Farm by Martin Bates.

Table 2. Quantification of Fieldwork Phase 1 boreholes (* evaluated depth is total linear metres recorded from inspection pits, retrieved in cores and represented by disturbed bulk samples).

Borehole type	Borehole locations (no.)	Depth evaluated* (m)	Purpose
Window sampler	28	101.5	Transects across valleys containing Holocene alluvium to inform models of landscape evolution
Window sampler	12	58	Transects across areas suspected to contain lake margin deposits to confirm their presence and distribution
Dynamic sampler / rotary corer	34	254.65	Transects in areas of high potential for Palaeolithic archaeology, chosen for quality of core recovery, to inform scheme deposit modelling and evaluation
Cable percussion	39	301.25	Transects in areas of low or moderate potential for Palaeolithic archaeology to inform scheme deposit modelling and evaluation

Deposit records were entered into industry standard software (Rockworks™ v20.0). A sequence of commonly occurring lithological deposits was identified based on the results of the Test Pits, Boreholes and GI survey. These were correlated into stratigraphic units based on their lithological descriptions, which define distinct depositional environments (e.g., alluvium, river terrace deposits, organic silts etc.). These stratigraphic units have then been displayed in the form of representative transects. Transects are well-suited to constrained linear data sets, providing representative cross sections illustrating the range of deposits present within each area.

The deposit modelling relies on deposit records from purposive geoarchaeological interventions (as outlined above), and ground investigation works. For purposive geoarchaeological samples lithological descriptions were generated by the Headland geoarchaeology team on site at the compound or at Headland laboratory facilities off-site. Sediment descriptions from geotechnical interventions were reviewed by the geoarchaeology team and harmonised with the purposive geoarchaeology lithological sequences. Stratigraphy was applied to the lithology by the senior geoarchaeology consultant in consultation with the geoarchaeology team.

Confidence in the results of deposit modelling within a given area is determined largely by the number of available boreholes, their geographical spread in relation to relevant superficial deposits, and the accuracy of deposit descriptions and interpretations. Deposit modelling extrapolates the thickness and elevation of deposits between given data points. Where data points are sparse and widely spaced, the modelling may give an erroneous impression of the distribution of deposits (e.g. elevation and thickness) – in cases suggesting the presence or absence of deposits in locations where they are unlikely or likely to occur. This is especially true for laterally constrained deposits such as alluvium, lake margins and gravel islands seen across the scheme.

3.2. SURFACE ELEVATION MODELLING AND HEAT MAPS

The top of the till was modelled in QGIS using the Contour Plugin. This provides an approximation of the post-Anglian surface. The data from all four datasets were included where these deposits were mapped. Additional data points were added from the BGS National Geoscience Data Centre collection of onshore scanned boreholes, shafts and well records where needed to improve the overall spread of the dataset.

Heat maps were produced in QGIS for showing the density of data across the site to show the distribution of intrusive works using the Heatmap (Kernel Density Estimation) Interpolation for:

- All points incorporated in the deposit model including: (i) Headland Archaeology boreholes, (ii) Headland Archaeology test pits, (iii) GI boreholes and test pits and (iv) boreholes and test pits undertake on separate projects by Martin Bates.
- All points incorporated in the deposit model (as above) with a depth of 5m or more.

Each borehole or test pit intervention can be used to infer the geoarchaeological sequence in its vicinity. Confidence in the results of deposit modelling is, therefore, greatest where the density of boreholes and test pits is highest. In areas where few interventions are present, more distant boreholes and test pits must be relied upon, and so any local variation in sub-surface deposits may not be accurately predicted. Heat maps are an effective means of demonstrating the density of interventions. Purposive geoarchaeological interventions are more informative as they have been examined directly by the geoarchaeology team, and as such they carry a double weighting in the calculation of the heat map density. In contrast, geotechnical interventions that are not boreholes or test pits (e.g. cone penetration tests, all classed as GI-xx) are the least informative for geoarchaeological purposes, and so carry half weight for the heat map. The radius and pixel size settings were adjusted to create a circle for each point, which is one colour in the centre, fading to another at the edge. The radius determines the size of the circle, and the pixel size is in metres, a radius of 1000 m and a pixel size of 10 m were used. Interpolation was then conducted to produce the final shading. An appropriate colour scheme was then selected to best display the data. The results were then saved as a GeoTiff and are presented in Illus. 3.

Table 3. Framework for the assessment of potential for Palaeolithic archaeology and palaeoenvironmental sequence.

Potential	Palaeolithic archaeology	Palaeoenvironmental sequences
Very High	Deposits were laid down under conditions suitable for human occupation, and deposits suitable for good preservation and survival of artefacts. Proven association in well-provenanced horizons of artefacts. Liable to contain Palaeolithic artefacts, including primary depositions.	Deposits known to be suitable for good preservation and survival of palaeoenvironmental remains, spanning periods associated with human occupation. Proven preservation of palaeoenvironmental remains within a Pleistocene sedimentary context.
High	Deposits laid down under conditions suitable for human occupation, and deposits suitable for good preservation and survival of artefacts. Confident association with known artefact-yielding deposits or adjacent to Very High categorised area. Liable to contain Palaeolithic artefacts, including primary depositions.	Deposits known to be suitable for good preservation and survival of palaeoenvironmental remains, spanning periods associated with human occupation. .
Moderate	Possible presence of deposits with artefacts. Includes reworked deposits where the presence of artefacts is reduced and may contain secondary deposition of artefacts. In-situ remains are less likely.	Possible presence of deposits with palaeoenvironmental remains that may be associated with periods of human occupation.
Low	Deposits laid down under conditions prohibitive to human occupation including during the Anglian glaciation. Includes areas where potentially relevant Quaternary sediments are believed to have been mostly extracted or otherwise substantially removed. Also includes Quaternary deposits contemporary with known hominin occupation, but without any known Palaeolithic or palaeoenvironmental remains. Also includes deposits adjacent to areas of higher potential.	Deposits in which the preservation or survival of palaeoenvironmental evidence is unlikely. Includes deposits unlikely to be associated with periods of human occupation.
Minimal	No association with any known Palaeolithic archaeology. Includes areas where potentially relevant Quaternary sediments are known to have been completely extracted or otherwise entirely removed. Also includes pre-Quaternary bedrock that shares no boundaries with Quaternary deposits of any Palaeolithic potential	Deposits prohibitive to the preservation or survival of palaeoenvironmental evidence. Includes deposits known to have no association with periods of human occupation
Uncertain	Insufficient data to determine nature or timing of deposition.	Insufficient data to determine the likeliness of palaeoenvironmental remains.

3.3. DEFINITION OF POTENTIAL AND RISK

All areas of the scheme were categorised according to the potential for Palaeolithic archaeology and palaeoenvironmental sequences. The categories range from Minimal to Very High, and there is an additional

Uncertain category for areas where data availability is limited. The Palaeolithic and palaeoenvironmental *potential* of an area is synonymous with *risk*. The potential/risk of an area is the function of its *likeliness* to contain preserved archaeological/palaeoenvironmental remains and the *significance* of those remains if present. This can be likened to a risk matrix in which Probability ✕ Harm = Risk.

4. RESULTS

The distribution of all geoarchaeological and geotechnical interventions available for deposit modelling are shown in Illus. 3 and its derivatives. The modelled till surface is shown in Illus. 4, and the location of the following transects are shown in Illus. 5 and its derivatives. The Holocene transects are presented as Illus. 6-10 and Pleistocene transects are shown in Illus. 11-28.

As requested by Costain, the results and discussions from palaeoenvironmental assessments will be included as later addendums to this report. At the time of writing draft reports have been received for pollen assessment and amino-acid racemisation (AAR) dating. These unedited reports are included as appendices. Further AAR dating and mollusc assessment is scheduled and will be incorporated in future reporting. Although the pollen and AAR results have yet to be fully interrogated, their findings are reflected in the Results, Discussion and Recommendations.

4.1. PLEISTOCENE DEPOSIT MODELS

Predictive modelling to map sub-surface strata has been undertaken along eighteen transects to evaluate Pleistocene deposits. These models incorporate data from purposive geoarchaeological – including works commissioned by Martin Bates separately to his work with Headland Archaeology) and ground investigation boreholes and test pits. The locations of the transects are shown in plan on Illus. 5.

Quaternary Landscape Evaluation Area 1 (Illus. 5A, 5P1, 5P2, 11 and 12)

QLE Area 1 is slightly undulating across the area, with much of it lying between 35 m and 20 m OD. According to the BGS, the mapped superficial deposits in this zone consist of Head deposits to the north and south surrounding glaciolacustrine deposits from the Middle Pleistocene, and Blackwater Terrace 1 and Alluvium to the south-east. Middle Pleistocene glaciofluvial deposits have been mapped to the north-east. The bedrock in this area is constituted by London Clay Formation.

Pleistocene Transect 1 (Illus. 5P1 and 11)

London Clay is present towards both the south and north ends of the profile but absent in the central part of the profile suggesting the presence of a basin or valley form in this area. For example, in BH RC 1102, till is present at the base of the sequence overlain by a thick sequence of clays mapped as glaciolacustrine sediments. These were not sampled in purposive geoarchaeological boreholes although the very top of the sequence may have been sampled in TP 38, 48 and 60. In TP 48 assessment demonstrated the presence of earthworm granules, molluscs (fragments) a little plant debris and freshwater ostracods (common juvenile *Candona* – probably all *C. neglecta* and a few *Ilyocypris* sp.). These might be indicative of a freshwater lake margin or possible wet colluvial sediments. The AAR data from fossil slug plates shows very low levels of degradation, indicating an age younger than the last interglacial for these deposits. Fluvial sediments overlie this lake or colluvial deposits.

Pleistocene Transect 2 (Illus. 5P2 and12)

This area is mapped as Head by the BGS. London Clay is present through the transect rising to a high point mid transect in WS 1403. Till is present in BH 1103 while possible fluvial gravels are present in WS 1403/CPT 1304 at elevations above 28m O.D. These observations suggest the mapping as Head is perhaps, in part erroneous. The presence of possible fluvial sediments at elevations above 28m O.D. would appear to suggest that they are unlikely to belong to Terrace 3 and may belong to Terrace 4/5 or outwash gravels from the Anglian till. No dating or palaeoenvironmental material is available for the area.

Quaternary Landscape Evaluation Area 2 (Illus 5B, 5P3, 5P4, 5P5, 13, 14 and 15)

QLE Area 2 is relatively flat towards the west and centre and more undulating to the east, with much of the area lying between 30 m and 20 m OD. To the west of this Area, the mapped superficial deposits consist of Head deposits and Alluvium, with Middle Pleistocene Glacio-fluvial Deposits occurring to the east and west. To the middle part of QLE Area 2, the BGS mapped superficial deposits comprise Lowestoft Formation, with spreads of Head to the north-east and south-west, and localised patches of brickearth. To the east, this Area comprises Head and River Terrace deposits and fine alluvial deposits corresponding to Blackwater Terrace 3. The bedrock in this Area is formed by London Clay Formation.

Pleistocene Transect 3 (Illus. 5P3 and 13)

This transect traverses sediments mapped as glaciofluvial deposits in the west and till of the Lowestoft Formation in the east with a small patch of Head in the central zone. Boreholes at the west end lie below 28m O.D. and consist of fluvial sediments over bedrock (e.g., BH RC 3220). Across much of the remainder of the transect ground surface elevations vary from 34m to 44m O.D. London Clay bedrock rises to 31-36m O.D. and is overlain by probable Kesgrave Formation at the eastern end (BH 2030, c. 350m to the northeast of the presented transect). Fluvial sands and gravels, possibly Anglian outwash are present through much of this transect (e.g. BH RC 1106) replaced eastwards by till (WS 1509). No dating or palaeoenvironmental material is available for the area.

Pleistocene Transect 4 (Illus. 5P4 and14)

This transects crosses both Head and till. London Clay is present at both ends of the transect at elevations of around 32m O.D. It is overlain by sands and gravels in all boreholes with the exception of BH RC 1111 where till overlies the bedrock. A thin veneer of possible Head deposits are present. No dating or palaeoenvironmental material is available for the area.

Pleistocene Transect 5 (Illus. 5P5 and 15)

This transects traverses till as well as an overlying patch of brickearth. Ground surface elevations decline from north-west to south-east along the transect. Bedrock was only attained in BH 2034, c. 100m to the north of the south-east end of the transect. Till is present in VELL 04 and is replaced by possible Head or brickearth deposits over potential fluvial sediments in VELL 05/06. It is unclear if the fluvial sediments are fluvioglacial outwash or elements of the Kesgrave Formation. No dating or palaeoenvironmental material is available for the area.

Quaternary Landscape Evaluation Area 3 (Illus 5C, 5P6, 5P7, 5P8, 5P9, 5P10, 5P12, 5P13, 5P14, 5P15, 16, 17, 18, 19, 20, 22, 23, 24 and 25)

QLE Area 3 consists of higher ground (c. 30-35 m OD) to the northwest, and a spread of broadly level ground between c. 18 m and 23 m OD to the southeast, along the northwest side of the Blackwater valley and abutting the higher ground of the chalky Boulder Clay further to the northwest. According to the BGS, the Quaternary sediments in this area consist of Boulder Clay to the northwest and of patches of fine-grained organic-rich clayey silts/sands, overlying sands/gravels to the southeast, which in turn overlie chalky/gravelly clay. The organic-rich clayey silts/sands occur (where present) close beneath the ground surface in many places but are buried beneath 1-2 m of sandy/gravelly deposits along the northwest side of this area, where the ground surface slopes up. The superficial deposits in this land plot have been mapped as Lowestoft Formation to the northwest, alluvium in the centre, and Head deposits to the southeast. The bedrock in this Area is constituted by London Clay Formation.

Pleistocene Transects 6 (Illus 16), 7 (Illus 17), 9 (Illus 19) and 13 (Illus 23)

These transects cover the most complex area of the route corridor where BGS mapping and previous works by one of the authors (Bates) has mapped and recorded a complex sequence of sediments ascribed to interglacial lake deposits, Terraces 2 and 3 as well as Head. The basic sequence of sediments is well represented in Transect 6 (Illus. 23. 16) where till is present at the western end of the profile at elevations of around 18m O.D. plunging eastwards to below 8m O.D. in BH 2240. Fluvial sands are present next in BH 2607/2240 and overlain by bedded silts ascribed to the interglacial lacustrine association. At the eastern end of the transect these are overlain by sands and gravels ascribed to Terrace 2 with basal elevations around between 8m and 10m O.D. A similar sequence is seen in Transect 7 (Illus. 23. 17). In Transect 9 lake deposits are overlain by fluvial sands and gravels ascribed to Terrace 3. In this case the deposits in BH 2625 and BH RC 2204 are difficult to understand and may belong to the till or possibly parts of the Kesgrave Formation. Transect 13 (Illus. 23) shows the BH 2607/2021-5 cut out by Terrace 2 sediments through the central part of the transect. Significantly the basal parts of Terrace 2 contain organic rich sediments containing pollen, insects, ostracods, and rare small mammals in places and have been assigned to the last cold stage (unpublished work by Wenban-Smith and Bates). At the northern end of the transect lake deposits are again present (SSBE-01/02) although potentially much thicker than those in the south (e.g., BH RC 2264/SSBE-09/10). Geophysical survey results (CMD – Illus. 29) across a transect from SSBE-08 through SSBE-10 to SSBE-06 show a distinct pattern of changing conductivity patterns that may reflect changes in sedimentary facies associated with the lake

Palaeoenvironmental evidence is well preserved in many boreholes in these transects. Previous work at Colemans Farm (Bates, pers. comm.) identified pollen probably associated with MIS 11c was present in the area (Illus. 23. 19) as well as ostracods, molluscs and small mammal remains intermittently. Boreholes through the deep lacustrine deposits in the area at the northern end of Transect 13 (Illus. 23), SSBE09 and SSBE10, produced a pollen assemblage dominated by high concentrations of reworked material. An ascription to late MIS11c or younger is suggested. An organic horizon in borehole SSBE07 from this area revealed a unique pollen assemblage that might be associated with an interstadial, possibly MIS 11b or younger (Illus. 9). Other biological material from the lacustrine sediments include molluscs, common Bithynia opercula, a few freshwater ostracods (*Candona neglecta* juveniles) as well as plant debris.

Pleistocene Transect 8 (Illus. 18), 14 (Illus. 24) and 15 (Illus. 25)

This area is dominated by till or river terrace deposits. In Transect 8 (Illus. 18) till is present at the west end (with possible Kesgrave Formation below). The till surface dips in an easterly direction from elevations of greater than 22m O.D. to below 9m O.D. in BH RC 2267. Lake deposits are present in BH 2058 underlain by thick sequence of sands that are also seen in BH RC 2267. Lake deposits are also sealed by fluvial sediment in BH 2058. A well-developed sequence of relatively shallow lake deposits are seen in SNJA-09/10 and 11 in transect 14 (Illus. 24). The comparison between the shallow lake sequences seen in SNJA-10 compared to SSBE-09 is shown in Illus. 24.

Palaeoenvironmental material from SNJA-11 included molluscs (both gastropods and bivalves, usually fragmentary) as well as common *Bithynia* opercula and some freshwater ostracods, usually juveniles of *Candona* spp. The lowest sample in this borehole is a quite distinct facies, containing molluscs, and dominated by common *Cytherissa lacustris*, which might signify cooler or deeper lacustrine conditions. A few small invertebrate/amphibian bones were also recovered from the borehole. By contrast in SNJA-10 the microfaunas were poor, the freshwater molluscs are inevitably fragmentary. SNJA-10 has revealed a distinctive pollen sequence showing the arrival of deciduous woodland during the early to middle Hoxnian interglacial, Marine Isotope Stage 11c), which is likely to date somewhere between 425-415 ka. This sequence is directly comparable with the nearby Marks Tey record.

These records are similar to those in the shallower parts of the lake basin (Illus. 2, points 4 and 5) seen around Colemans Farm (Transects 6 and 7, Illus. 16 and 17) rather than the deeper parts of the basin seen in Transect 13 (Illus. 23).

Pleistocene Transect 10 (Illus. 20)

This transect spans an area in which BGS mapping document Terraces 1-3 being present alongside patches of interglacial lake sediments. Boreholes demonstrate that the London Clay bedrock is present around 12m O.D. at the southern end of the transect plunging steeply beneath BH 2603. Till is present at the base of most boreholes from this point northwards rising from around 11m O.D. to 17m O.D. Fluvial gravels are present in many boreholes with a thickness of between 3 and 4m of deposits. These probably belong to Terrace 3. At the northern end of the transect a complex sequence of sediments is present around BH RC 2621 that are difficult to interpret but probably contain elements of both fluvial and lacustrine sequences.

Pleistocene Transect 12 (Illus. 22)

This zone traverses Head/Terrace 3 on west side of the Blackwater, floodplain alluvium and Terrace 3/till on the eastern side of the transect. Till is present in all boreholes on the west bank but appears to disappear on the east bank by BH 3002. Here London Clay bedrock reappears for the first time since the south Witham area. Fluvial sands and gravels (potentially fluvioglacial outwash) are present in SNJA-15/12 around 26m O.D. Further spreads of potentially fluvial sands occur in BH RC 2271 at 22m O.D. and below 15m in BH 2272 and BNTW-01 immediately above the floodplain. These discrete groups of sediments may either belong to separate terraces (1-3), some may be elements of glaciofluvial outwash or be redeposited fluvial sediments moved downslope by solifluction. This evidence suggests the BGS mapping for this zone may be erroneous. Beneath the river floodplain alluvium of high energy sands and gravels are present in BH RC 2273 to a depth close to 0m O.D. Fluvial sediments mapped as Terrace 3 by the BGS are present through SABB-11/12 and BH 3001 thinning into BH 3002/3003. East of this point a sequence of bedded sands and gravels apparently mixed with till might be glaciofluvial outwash or a complex of river terrace sediments.

Quaternary Landscape Evaluation Area 4 (Illus 5D, 5P16, 5P17, 26, and 27)

To the south and west, QLEA4 is constituted by the lower slopes of the southeastern side of the Blackwater valley, with the ground slopping down towards the northwest from c. 35 m to 25 m OD. Outcrops of Blackwater terrace deposits T3 consisting of fluvial gravels with zones of alluvium have been documented in this area by the BGS, overlying till formed at the base during the Anglian. Patches of T4 and T5 are also widespread across this area. To the north and east, QLE Area 4 comprises higher ground above the southeast side of the Blackwater, slopping down to the northwest from c. 45-25 m OD. According to the BGS, numerous patches and some wider spreads of river deposits (sandy gravel) are present in this area, overlying a wide spread of chalk/gravelly clay that slopes down to the northwest. The northwestern end of this Area is a very complex region, with the presence of possible Blackwater fluvial sediments (sands, gravels and fine alluvium), Head deposits (clay and silt) and Lowestoft Formation. Situated at the base of the slope and close to the Blackwater valley erosion, this zone appears to display rapid lateral changes in lithology. The bedrock across this Area is constituted by London Clay Formation.

Pleistocene Transects 16 (Illus. 26) and 17 (Illus. 27)

These transects traverse an area mapped by the BGS as till with patches of Terrace 4 and 5 at differing elevations across the till surface. Transect 17 (Illus. 27) shows the bedrock London Clay surface lies between 18m O.D. and 24m O.D. It is covered by sands and gravels to the south (BH 2062-BH RC 3203) that are probably part of the Kesgrave Formation. These are overlain by till in most cases. Kesgraves are missing to the north of the transect and till is present only, although it is noted no boreholes attain London Clay in this area. Fluvial sands and gravels appear in the northernmost borehole (BH 2062). Transect 16 shows London Clay bedrock dipping downslope to the north-west that is covered by sands and gravels in places at differing elevations. In most cases these sands and gravels are covered by till indicating they probably belong to the Kesgrave Formation. Fluvial sediments potentially belonging to Terrace 3 occur at the end of the transect (BNTN 04).

Quaternary Landscape Evaluation Area 5 (Illus 5E, 5P11, 5P18, 21, and 28)

To the south, QLE Area 5 consists of a wide spread of ground between the Blackwater and the Domsey Brook, rising from c. 25 m OD around its southern and western edges, where it abuts these water courses, to >35 m OD in the northeast. To the centre and north, this area is formed by a wide undulating plain, with the landsurface dipping shallowly down from c. 40-30 m OD from northwest to southeast.

Pleistocene Transect 11 (Illus. 21)

Transect 11 mainly traverses sediments mapped as Terrace 3 by the BGS. London Clay is only attained in the northernmost borehole (BH 3019) while a thick sequence of till is present throughout the transect. The till surface is below 26m O.D. in BECS-10/02 and is overlain by either Head or weathered till and subsequently fluvial sands and gravels. Fluvial deposits disappear between BH RC 3208 and BH 3017 probably marking the inside of the terrace.

Pleistocene Transect 18 (Illus. 28)

Transect 18 mainly traverses sediments mapped as till by the BGS. London Clay is present at depth and is overlain by a variable thickness of sands and gravels ascribed to the Kesgrave Formation. Till deposits overlie the Kesgrave Formation along much of the transect.

4.2. TILL ELEVATION MODEL (ILLUS. 4)

To model the Scheme-wide Pleistocene topography, and therefore potential extent of the Interglacial Lacustrine deposits, an elevation model of the till surface has been created (Illus. 4). Two elongated hollows with a south-west to north-east trend run along the route corridor, to either side of Witham. These likely correspond with past topographic lows in which lakes formed, and the lacustrine sediments identified in the above Pleistocene Transects (6 (Illus 16), 7 (Illus 17), 9 (Illus 19) 13 (Illus 23),8 (Illus. 18), 14 (Illus. 24) and 15 (Illus. 25)) accumulated.

It should, however, be noted that this model predicts the surface of the till as it exists today, which is not necessarily the same surface as encountered by humans at the end of the Anglian glaciation, as till may have been subsequently eroded. For example, where the lake deposits have been eroded and river terrace sediments overlie till (e.g. Holocene Transect 6), then this surface has been modified by more recent fluvial processes. This is likely to be the case on much of the eastern side of the basin as fluvial processes and terrace formation appear to be migrating eastwards to the present location of the River Blackwater, this is evident in the Colemans Farm area. Additionally, datapoint distribution is highly skewed and although this has been partially mitigated by incorporating BGS datapoints the potential for inaccuracies in the model due to gaps in data coverage should be borne in mind. Nevertheless, in places where lacustrine deposits overlie till, the till surface is likely to give a good approximation of the late Anglian topography.

4.3. GEOPHYSICAL DATA

Electromagnetic conductivity (CMD) survey data from across the Scheme exhibits patterning across all three depth ranges (2/4/6 m) (Illus. 29). At 2 m depths conductivity values are typically low across nearly all areas surveyed with values less than 30mS in at most places. Similar patterns are also exhibited at 4 m depth. Greater variation in conductivity values are seen in the deepest (6 m) slice where conductivity values vary up to around 55mS.

Of particular interest in the deepest (6 m) slice are Areas 4, 6 and 7. In Area 4 a clear difference in conductivity values are seen from north-west to south-east across this zone where TP 1030 contains lake deposits, but these are replaced by fluvial sediments in TP 1027/1025. Thus, here conductivity values may be mapping changes in the presence of lake deposits sub-surface. A complex pattern of conductivity values are present in Area 6, where higher conductivity patterns are bisected by a linear like area of lower conductivity. This area is known to be complex in terms of the geology with gravels as well as lake deposits in the area and the results may similarly map out differences in the distribution of the lake sediments. In the north of Area 7 low conductivity results are associated with known lake deposits. The distribution of lake deposits is greater than anticipated at the pre-fieldwork stage, and consequently deposits for which CMD survey data would be beneficial were not surveyed. This includes Area 7, where the CMD survey does not extend sufficiently to the north to capture the edge of lake deposits; further coverage of CMD data would be necessary to adequately investigate the area.

A single ERT transect was surveyed through the western part of Area 7 (Illus. 30). This showed distinct patterning with a highly resistant area (pink/red) at depth in the western part of the transect overlain by much less resistant materials above it. In the eastern part much of the transect exhibited resistant units. No deep ground truth boreholes are available on the line of the transect. However, it might be surmised that the low resistance areas of the transect correspond with finer grained sediments such as clays/silts/waterlogged sands that may belong to the lake.

4.4. HOLOCENE DEPOSIT MODELS

Predictive modelling to map sub-surface strata has been undertaken along six transects to evaluate Holocene deposits in each of the river valleys. These models incorporate data from purposive geoarchaeological and ground investigation boreholes and test pits. The locations of the transects are shown in plan on Illus. 5.

Holocene Transect 1 - Boreham tributary (QLEA1: Illus. 5A and 6)

At the base of this sequence head comprise two distinct formations, a lower coarse-grained deposit of medium yellowish-brown coarse sandy gravel which coarsens upwards. This is overlain by a more homogenous fine-grained deposit of medium yellowish-brown fine sandy silty clay which also coarsens upwards. These form a surface at 2.66m BGL (21.54m O.D.) at HABH01 rising to 2.45m BGL (22.23m O.D.) at HABH04. To the east of the transect, channel margin deposits are present. These are generally coarse-grained deposits with some organic content, variously described as medium blueish-grey clayey medium sand to dark greyish brown clay, with moderate to high humified organic matter content and plant remains, and inclusions of shell and sub-angular to sub-rounded flint and quartz. The deposit is of fairly consistent thickness of c.0.45m and offers potential for scientific dating and palaeoenvironmental analysis. These deposits are likely to have formed at the edge of a former location of this river channel as indicated by a layer of light brownish-grey clayey fluvial gravels at HABH01-HABH02.

This sequence is overlain by an alluvial blanket which is likely to have accumulated throughout the later Holocene. In places it is possible to discern periods of changes in local hydrology. For example, the dark reddish-brown silty medium organic sand with rare flecks of decayed plant matter at 1.2-1.25m BGL (24.12-24.07m O.D.) at HABH05 and the sands at 1.82-1.88m BGL (2.86-2.80m O.D.) in HABH02 indicate a period of higher energy flow in this area probably indicating a flood event. The dark brownish-grey silty clay with rare shell inclusions and bedded with gravel at 1.45-50m BGL (23.23-23.17m O.D.) and 1.72-84m BGL (22.96-22.84m O.D.) and humified fibrous organic material at 1.65m (23.17m O.D) at HABH04 is more indicative of channel margin deposits or possibly a temporary backwater marsh area. A similar signal is seen in HABH03 at 1.2-1.6m BGL (23.65-23.25m O. D.) suggesting this backwater area was quite extensive. A topsoil of lightly rooted, slightly organic medium reddish/greyish-brown sandy silty clay with rare fine sub-angular clasts of flint and CBM was recorded across the site.

Holocene Transect 2 - River Ter (QLEA2: Illus. 5B and 7)

Deposits of a fluvial nature, described as dark brownish-grey silty clay bedded with gravelly material of rounded to sub-angular flint and quartz <40mm at 3.17-33 (14.78-14.94m O.D) and 4.40-63m (13.48-13.71m OD), are present to the east at HABH09 at a depth of 3.0-4.82m BGL (13.69-15.11m O.D). These deposits predate the overlying

Holocene sequence and is likely that they are related to one of the River Terraces identified in the area but without further analysis (i.e., dating and palaeoenvironmental) it is not possible to say which at this stage.

Head deposits described as medium greyish-brown silty clay with small (<20mm) sub-rounded to sub-angular flint and carbonate flecks are present between HABH07 and HABH10. These thicken to the east creating a surface which slopes to the west. It appears this surface was stable for some period of time with a potential soil forming at HABH07 at 2.22-2.33m BGL (16.03-16.14m O.D). This is described as medium brownish-grey sandy clay with small (10mm) sub-rounded flint and well humified organic material and has the potential for scientific dating and paleoenvironmental analysis.

To the far west of this valley fluvial sand and gravel deposits are present at 2.4-4m BGL(14.66-16.22m OD) in HABH06. They are described as medium orangish-brown sandy gravel which coarsen upwards with clasts of medium (<60mm) sub-rounded to rounded flint and quartz. These thin to medium yellowish-brown silty fine sand with small (<10mm) sub-angular flint clasts and dark brown mottling at 1-1.14m BGL (17.07-17.21mO.D.) in HABH08. These have been deposited by a fluvial system of high energy. This suggests the channel margin deposits are of an early Holocene date as such activity is unlikely to have been present in this valley since the end of the last glaciation. As with the Boreham Tributary valley this sequence is overlain by an alluvial blanket which is likely to have accumulated throughout the later Holocene. A topsoil of lightly rooted, slightly organic reddish/greyish-brown sandy silty clay with occasional fine sub-angular clasts of flint and CBM was recorded across the site.

Holocene Transect 3 - Cressing Brook/Rivenhall (QLEA3: Illus. 5C and 23)

The full sequence of deposits across this area is covered by Pleistocene Transect 13 (Illus. 23) and is not discussed in detail here. Alongside these deposits a sequence of Holocene floodplain deposits were recorded between SSBE05 and SSBE07. The basal deposit in this valley sequence is glacial till consisting of a sandy silty clay with chalk gravels at 9.15m BGL (11.49mOD) in SSBE05. Overlying this is fluvial sands and gravel comprising orange brown to yellow gravelly sand to coarse gravelly sand. In SSBE05 it is 6m thick pinching out in the north to only 2.20m in SSBE07 where it may have formed an island of drier stable ground as lake levels rose around it. The top of the fluvial gravels in SSBE07 between 5.28-5.32m BGL (15.08 -15.12m O.D) is a black slightly organic sandy silt which could be an indicator of incipient paedogenesis. There is a possibility that the deposit has paleoenvironmental potential.

On the western side of the valley HABH13 (not shown in Illus. 23) has a layer of orange brown to yellow grey clayey sands to sandy clays with chalk, flint and quartz gravel observed from 1m BGL to the base of the core at 4m BGL (19.05-16.05m O.D). These deposits likely represent Head on the side of the river valley. SSBE07 0.5-5.28m BGL (19.90-15.21m O.D.) consists of coarse sands and gravels between 3.05-5.28m BGL (15.21-17.35m O.D) changing into sandy clays and silts between 0.5 and 3.05m BGL (19.90-15.21m O.D.). These deposits are lacustrine deposits which would have been cut by the channel to the west. HABH14 (1-5m BGL;18.49-14.49m OD) and HABH15 (1.2-4m BGL;18.22-15.42m O.D.) largely consist of a mix of yellowish grey to brown-grey sandy gravels, clayey silts, and sands, which may imply a high energy fast flowing cold climate fluvial environment. Sealing this deposit is a layer of alluvial and sandy silts varying in thickness from 0.6m in the south (HABH14) to 0.9m in HABH15.A modern topsoil of mid grey, brown fine slightly sandy silt was recorded across the area roughly 0.3m thick.

Holocene Transect 4 - River Blackwater (QLEA3: Illus. 5C and 8):

The basal deposits in this valley sequence are fluvial gravels and sands. These are described as dark yellowish-grey clayey fine sand at the base of HABH18 varying to medium yellowish-orange sandy gravel of flint, quartz and quartzite at HABH21. Although this transect runs alongside the course of the present River Blackwater the gravel surface slopes from 5.75m BGL (13.13m O.D.) in the south up to 1.77m BGL (17.31m O.D.) to the north suggesting that a previous river course was to the south of this area running east to west. Head deposits comprising medium brownish-grey sandy clay at HABH18, with colour varying to light bluish grey and some clasts of flint and iron staining in places overlie the fluvial gravels. Again, the surface of this deposit slopes from 5m BGL (13.88m OD) in the south to 1.32m BGL (17.76m OD) in the north. Sitting directly on the Head is an organic deposit possibly representing a soil that has formed on this surface with medium yellowish-brown clayey fine sand at 4.9-5.0m BGL (13.88-13.98m O.D.) in HABH18 indicating the location of a channel at the base of the slope. The organic deposit is described as medium to dark reddish grey/brown sandy silty clay at 1.32-2.05m BGL(1700-17.73m O.D.) in HABH21 and 1.2-1.8m BGL (17.22-17.82m O.D.) in HABH22, suggesting relatively poor preservation of organic material. Sealing this is a blanket of alluvium with greatest thickness of 4.6m to the south decreasing to 0.05m in the north acting to level the ground surface across the area. To the south-west, where this deposit began to form in a depression there is a layer of sand and organics at 3.9-4.0m BGL (14.88-14.98m OD) which has potential for providing scientific dating and paleoenvironmental analysis of this area in the early Holocene. A topsoil of dark greyish-brown sandy clayey silt with some fine to medium flint clasts was recorded across the site.

Holocene Transect 5 - Blackwater Tributary (QLEA4: Illus. 5D and 9)

The surface of the Lowestoft till is present in this valley at 2.18m BGL (22.10m O.D.) to the west in HABH24, rising to 0.7m BGL (22.91m O.D.) at HABH27. The surface of this deposit shows limited evidence for soil formation at HABH27. Overlying the till at HABH24 are sands at 1.75 to 2.18m BGL (22.53-22.10m O.D) then gravels which are likely to be the River Terrace 3 deposits mapped in the area by BGS. The alluvium sealing this sequence is relatively thin (maximum thickness of 0.77m at HABH24) on which a soil of up to 0.8m (at HABH26) has formed.

Holocene Transect 6 - Domsey Brook (QLEA5: Illus. 5E and 10)

London Clay is present in this area from a depth of 3.49m BGL (20.29m O.D) at HABH30. This is overlain by a thin layer of sand and gravel most likely to be of the Kesgrave sands and gravels as it is sealed by till at 2.9m BGL (20.88m O.D.). Till is also present in HABH31 from 1m BGL (22.60m O.D) and HABH33 from 2.07m BGL (22.03m O.D.). This is overlain by terrace gravels at 1.72-3m BGL (22.13-20.85m O.D.) in HABH29 through to 1.36-2.07m BGL (22.49-21.78 O.D.) at HABH33. Both Terrace 4 and 3 are mapped in the area by BGS and this deposit could be made up of either, or both. This would need to be confirmed by scientific dating and/or paleoenvironmental work. The alluvium overlying this sequence has a maximum thickness of 1.42m at HABH29 and a topsoil of varying thickness has formed across the site.

4.5. PALAEOENVIRONMENTAL PROXIES AND DATING

Palaeoenvironmental assessment targeted the lacustrine deposits, which are located in QLEA1 (Bolton) and QLEA3 (Brice/Siggers). These deposits provide good scope to preserve evidence that could indicate the character of the palaeo-lakes (e.g. whether they were formed in warm interglacial stages, or cold glacial stages) and produce remains suitable for dating. Preservation of ostracods and mollusca was variable, with richer sequences to be found in QLEA3 lacustrine deposits. Preservation of pollen from borehole samples in QLEA3 (Siggers borrow pit area and nearby) was excellent.

The preliminary inspection of the pollen and AAR results confirm that lacustrine deposits in QLEA3 date to the Hoxnian period (Marine Isotope Stage, MIS, 11, 424,000-374,000 years ago, an interglacial warm phase). This chronology has been enhanced to show that the most likely period of deposition is the Hoxnian IIc, the main interglacial (warm) phase of the Hoxnian. This excludes the cooler Hoxnian IIb stage. In contrast, the pollen results indicate that other lacustrine deposits in QLEA3 are more recent, suggesting a two-phase of infilling of lakes with, unexpectedly, the deeper deposits infilled more recently than shallower deposits. AAR results have dated lacustrine deposits in QLEA1 to MIS5e (Ipswichian, 124,000-119,00 years ago, the most recent interglacial warm phase prior to the current Holocene interglacial), suggesting a much more recent date than anticipated.

5. DISCUSSION

The investigation of the route corridor has been effective in documenting the geological context of the deposits across the Chelmsford to Mark's Tey sector of the A12 with the following outcomes.

The broad stratigraphic context of the superficial deposits across the route corridor outlined previously has been confirmed. No hitherto unrecognised major bodies of sediment have been uncovered. However, many sequences contained deposits which cannot presently be accommodated easily within the BGS derived stratigraphic framework or which cannot be easily allocated to those extant stratigraphic frameworks. Geoarchaeolgoical investigation to date has allowed for a robust scheme-specific stratigraphy to be developed for this report, though the precise mapping of some sediment bodies and further refinement of dating for key units will be required in future stages of the project.

In places the BGS mapping has been questioned (particularly with reference to the fluvial sediments). For example, in some places the classification of the sedimentary sequences may be wrong (e.g., the brickearth in Transect 5, Illus. 15 may in fact be Head deposits). In another example Terrace 3 deposits mapped east of the river in Transect 12 (Illus. 22) at around 20m O.D. are lower than the fluvial deposits mapped as Terrace 3 to the west of the river.

The trial of geophysical surveys (CMD/ERT) has been successful and variations in conductivity/resistance across the Scheme have been documented that may reflect the differing distribution of lake, till and fluvial sediments. Further, expanded mapping is required (within the order limits) to further interpret the data including ground truthing.

The lacustrine sediments between Witham and Kelvedon have proved to be more complex than hitherto envisaged. Biostratigraphic data from the pollen assessment indicates that multiple parts of the Hoxnian interglacial (MIS 11) may be present in the area. The lithology from the boreholes indicates a complex pattern of depositional units and different elevations in the Colemans Farm to Kelvedon area. In the lake core sequences the pollen assemblage in SNJA10 is similar to pollen assessment on the lacustrine deposits at Coleman's Farm and we can tentatively conclude that lacustrine deposits in the areas in which similar sequences occur may all date broadly to the same part of the interglacial. Specifically, this would include PQ Zones 5C, 5A, possibly 5B, 8B and possibly parts of 9. In SSBE-09 the sequence is towards the latter stages of MIS 11c. It is possible that the peat from within SSBE07 may represent a similar interstadial environment, possibly contemporary with those from the Hoxne Stratum C, tentatively correlated to MIS 11b. The sequences in this area (9 and possibly 5A) are significantly deeper that those discussed above. We can therefore conclude that a shallow lake in which the Colemans Farm/SNJA10 sequence fills in during MIS 11c is followed later in 11C or after, by the infilling of the deeper parts of the basin fill in PQ Zone 9. What is unclear from our current data is whether this part of the basin (in Zone 9) was open when the shallower parts of the lake were infilling around SNJA 10 or whether a major incision event occurred between the two accumulation events. Once all this lake had infilled then fluvial sequences containing organic material (SSBE 07) accumulated across the top of the infilled lake. At least in PQ Zone 9. It is possible that PQ Zone 9 contains the most complex record of sequence accumulation in the whole of the route corridor.

The consequences of our interpretation of the lacustrine sediments around Witham is that mapping lake edge environments is complex. More than one lake might be present in the area, or that a complex infilling record will mean multiple lake edges may exist across this sector of the route. Interpreting this will require considerable thought as well as additional assessment to understand this history of deposition. In short, this area should be considered of high risk with appropriate and proportionate mitigation measures required (see recommendations below).

Both inner and outer edges of fluvial terraces have been identified associated mainly with Terrace 3 and this poses interesting archaeological questions about the potential source of Palaeolithic find spots in the area. The areas of inner terrace sequences for Terrace 3 are present in PQ Zones 26A, 11A, 13B-B, 17A while the outer terrace sequences are present in PQ Zones 26B, 3, 5B, 11A, 13B-A. For Terrace 2 the inner terrace is present in 5E and for Terrace 1 in 11B.

The till dominated area around Buntings (QLEA4, to the east of Kelvedon) remains somewhat enigmatic. While till occurs across nearly all the area it is clear that the mapped distribution of Terraces 4 and 5 of the Blackwater bears little relationship to the presence of sands and gravels beneath the topsoil. Thus, areas mapped as having sands and gravels present may simply contain till while sands and gravels may occur in areas where no terrace gravels are mapped. We presently remain uncertain as to the age of any sands and gravels in the area and they cannot be tied into the known areas of subsurface distribution of fluvial deposits (see above).

AAR dating and pollen assessment for samples collected around Boulton South are included here as Appendices 4 and 3 and discussed in context in an Addendum to this report (Headland Archaeology, forthcoming). The sediments mapped as lacustrine deposits by the BGS were not reached in any test pits. However, our test pit data does indicate the presence of waterlain or wet colluvial contexts in which palaeoenvironmental material occurs. The pollen records are equivocal with pollen indicative of both Hoxnian and post-Hoxnian stages. AAR results suggest accumulation of sediments in the area during late MIS5 times. At present this area is thought to contain lacustrine sequences of either Hoxnian or perhaps last interglacial age overlain by fluvial or colluvial sediments containing reworked material from an older interglacial.

Head deposits remain an enigmatic sequence of sediments which are difficult to map across the Scheme. Head is defined as a 'poorly sorted and poorly stratified, angular rock debris and/or clayey hillwash' by BGS. Specifically, it is formed by the downward gravitational mass movement of earth materials without the aid of running water, through solifluction and gelifluction processes. As such they are locally redeposited sediments and can therefore be difficult to differentiate from the parent material and challenging to put into stratigraphic context (i.e. they occur at many different phases and cannot be easily stratigraphically linked to more widespread landscape formation processes). Where they are deposited near the bottom of a slope they are often termed colluvium and have archaeological potential for preserving the prehistoric/historic land surfaces they bury. This is potentially problematic for our understanding of the late Pleistocene Palaeolithic archaeology of the area which might well be associated with these sediments. Head deposits are likely across many areas of the Scheme where presently till is mapped near surface and in a similar fashion to the presence or absence of fluvial deposits in the Buntings area the absence of mapped Head in PQ Zone 27A/B/20 cannot be seen as a definitive statement on its absence.

5.1. UPDATES TO SCHEME STRATIGRAPHY

In this section, the main mapped bodies of sediments are reviewed in light of the test pit and borehole data. It is worth noting here that BGS mapping of superficial sediments is primarily based on topography, shallow augering supplemented by boreholes where available.

Sub-Till sands and gravels

These deposits belong to the Kesgrave/Colchester Formations deposited by the pre-Anglian Thames system draining in a northeasterly direction through the Scheme. Kesgrave Formation deposits have been recorded at both ends of the Scheme beneath till and in places appear to be at a shallow depth beneath the ground surface (e.g., SHRW 05, Transect 17, Illus. 27). For example, they are present above 30m O.D. in Transect 4 (Illus. 14) and extensively below the till in Transect 17 (Illus. 27) and above 20m throughout much of the northern end of the route corridor between Kelvedon and Mark's Tey (Transect 18, Illus. 28). The difference in elevation of the base of the Kesgrave Formation may indicate that more than one of the terraces associated with the Kesgrave Formation are present either side of Witham.

Till deposits

These deposits are well mapped by the BGS and spread across much of the route corridor. Included in this group are glacio-fluvial sands and gravels both above and below the till that belong to the Anglian glaciation in MIS 12. These deposits contain reworked material collected by the ice from the pre-existing landscape. Consequently, these deposits have low archaeological and palaeoenvironmental potential. No attempt has been made to subdivide the till into individual units. The surface of the till has been mapped (Illus. 4) and shows two elongated hollows with a south-west to north-east trend along the route corridor to either side of Witham. Theoretically this may crudely map the topographic lows in which the lacustrine sediments (above) accumulated. However, datapoint distribution is highly skewed and while attempts to 'fill in' with additional datapoints have been attempted this figure should be treated with caution. It should also be noted that this surface is poly-cyclic, i.e. where lacustrine deposits overlie till (with or without sub-lake sands – see above) the till surface approximates the late Anglian topography. However, where the lake deposits have been eroded and Terrace 2 sediments overlie till (e.g., Transect 6, Illus. 16) then this surface has been modified by fluvial processes prior to and during the deposition of the sediments associated with this terrace (in the Devensian perhaps). This is likely to be the case on much of the eastern side of the basin as fluvial processes and terrace formation appear to be migrating eastwards, at least in the Colemans Farm area.

Lacustrine sediments

These sediments have previously been reported by the BGS in the area and work at Colemans Farm Quarry illustrates some of these deposits. Similar deposits are present to the north at Marks Tey (Turner, 1970; Tye et al., 2016; Candy et al., 2021). Two distinct suites of deposits are presently identified in these lake sequences:

- Shallow sequences (4-7m typically) of pale yellow soft calcareous silts overlying dark grey/greenish-grey clay-silts in the Colemans Farm area.
- Deep (15-30m) dark grey, "brecciated" clay silts of the type site at Marks Tey.

The relationship between the two types of sequence is unclear at present and whether they represent discrete and distinct basin stratigraphies or whether they relate to shallower and deeper parts of the same basin is presently unclear.

From our work it is clear that two discrete groups of lake like sediments are present in the area consisting of:

1) A shallow sequence of highly calcareous sediments between 2 and 5m in thickness that are underlain by unmapped fluvial sediments and overlain intermittently by fluvial sediments of Terrace 3. For example, in Transects 6, 7, 8, 9, 14 and 15 (Illus. 16,17, 18 ,19, 24 and 25).

2) Deeper sequences of grey laminated or structureless sediments that attain thickness' of 19m (BH RC 2264). These deposits may be sealed by gravels (BH RC 2260, Illus. 23) or sealed by gravels overlain by further lake deposits (SSBE-10, Illus. 23).

In places the shallower sequence of deposits is clearly seen to wedge out against till (e.g., Transect 15, Illus. 25) thicken southwards and thins over gravels. The deeper sequences of lake fills presently have an unmapped edge. Indeed, the relationship at present between the shallower and deeper lake sequences cannot presently be demonstrated physically, although the pollen evidence suggests that the shallow calcareous sediments predate the deeper laminated sediments.

Fluvial sediments (Pleistocene: Sub-Lake Sands and Gravels and Terraces 1-5)

Fluvial deposits are widespread across the Scheme at a variety of elevations and are ascribed by the BGS to either one of the terraces of the Blackwater or to glaciofluvial outwash from the Anglian glaciation. The distribution of fluvial deposits as mapped by the BGS is based primarily on surface elevation of terrace flats which project along the course of the river descending in elevation in a downstream direction. No models currently exist explaining the fluvial sequences associated with the Blackwater terraces. Consequently, we have adopted a simplified version of the Bridgland model for river terraces based on his work in the lower Thames (Bridgland, 2006) Almost no consideration of the basal elevations of the fluvial sediments in the Blackwater valley will have been made by the BGS in this mapping. In our investigation we have however used basal elevations of fluvial sediments to identify discrete bodies of fluvial sediments and consequently our interpretations may in places be at odds with the BGS mapping. While elements of the sampled sediments can be ascribed to the known units it is clear from our data that stratigraphic assignments are difficult.

Sub-lake sands and gravels: These were flagged up as relatively unknown and either represent outwash during de-glaciation of the area in the late Anglian or infilling of the lake basin in the early Hoxnian. These deposits are now known to be commonly present beneath the mapped lake sediments in many places. For example, Transects 6/7 (Illus. 16,17) and 13 (Illus. 28). These do not fall within any mappable unit at present but must predate lake formation and post-date till deposition as their stratigraphic relationship is clear in boreholes such as BH 2206 (Transect 9, Illus. 19) and BH 2240 (Transect 6, Illus. 16).

Blackwater Terraces 4 and 5: These are mapped as discrete patches of material on the left bank of the Blackwater at the foot of the Tiptree Ridge. Depending on the interpretation of the deposits these either belong to the end of the Anglian Glaciation, MIS 12 or to one of the post-Hoxnian cold stages (MIS 8 and MIS 10). Correlating our records with these deposits is problematic as the BGS mapping does not appear to be a reliable guide to their distribution here. For example, sands, interpreted as fluvial in origin are present at the northern end of Transect 17 (Illus. 27) in an area mapped as containing only till on the BGS mapping. Additionally, areas in which fluvial sediments should be present along the line of Transect 16 (Illus. 26) according to the mapping only show till at the surface (e.g., BH 3009/BUNT 20). Consequently, our understanding of these areas of fluvial sediments remains opaque.

Blackwater Terrace 3: The age of the terrace is not well constrained but clearly overlies the interglacial lake deposits (below) at places such as Colemans Farm Quarry. While in some places there is a relatively clear correlation between the BGS mapping and our data in other places this correlation is not straightforward. For example, fluvial sediments are present on the west bank of the Blackwater in the vicinity of Transect 12 (Illus. 22). These are mapped as Terrace 3 by the BGS and are clearly present at altitudes above 24m O.D. However, Terrace 3 deposits are also mapped east of the river in this transect around 20m O.D., which is somewhat lower than those to the west. Consequently, correlation and stratigraphic subdivision are difficult in this area. It is also worth noting that Terrace 3 sediments are mapped by the BGS downstream in the Witham area and correspond to fluvial deposits in Transect 10 (Illus. 20) at elevations of around 12m O.D. This appears unlikely although fluvial deposits of the same terrace are likely to decrease in elevation downstream.

Blackwater Terrace 2: Observations at Colemans Farm quarry have demonstrated that an intermittently preserved organic rich sand/silt is present at the base of the quarry in places. This organic horizon contains molluscs, ostracods, pollen, and insect remains. Pollen assessment indicates deposition of this sediment under cool climate conditions, probably in the Devensian.

Blackwater Terrace 1: As the lowest of the 5 terraces of the Blackwater this is likely to be the most recently formed of the river terraces. The age of these gravels is constrained by findings associated with Terrace 2 (see below) and therefore suggest that Terrace 1 would probably date to around the last glacial maximum (35,000-20,000 years ago). Fluvial sediments on the west bank of the Blackwater in the vicinity of Transect 12 (Illus. 22) have been mapped as Terrace 1 by the BGS and correlates with a body of sand and gravel with basal elevations around 15m O.D.

Unmapped fluvial sediments: In places (Transect 5, Illus. 15) fluvial sediments appear to be present beneath Head in areas otherwise mapped as brickearth over till by the BGS. Based on their elevation, these deposits might belong to an unmapped patch of Terrace 3. Other unmapped but potential important fluvial sediments are seen in places such as in SSBE-07 (Transect 13, Illus. 23) where apparent low energy 'lake like' sediments are interbedded with fluvial sands and gravels that are not easily ascribed to any particular fluvial aggradation.

Brickearth

These were mapped by the BGS in Transect 5 (Illus. 15) however examination of the logs from Vell5/6 suggest these deposits are likely to be Head overlying unmapped fluvial sediments (see below).

Head

Head is mapped extensively in the route corridor and is a term applied to cover a wide range of environments of deposition. Typically, Head is associated with slopes where downslope movement of sediment may occur during both warm and cold periods. In colder climates freeze/thaw and spring melt results in the downslope movement of mixes of gravels, sands, silts, and clays (solifluction) that results in an unsorted mixture of sediments at the base of the slope. Wetter periods may result in channelling of these deposits and the production of discontinuous sequences of channel fills. Less severe environments may result in fine grained sheet wash sediments accumulating as well bedded sheets of sediment parallel to slope.

Head has been located intermittently across the Scheme. In many places it is difficult to ascertain whether or not true Head deposits are present, or if they are simply patches of heavily weathered till from which many of the Head deposits will have derived. It is also noted that BGS mapping of Head will only be shown if a deposit is larger than around 200x200m in plan, and patches smaller than this are unlikely to be mapped. Good sequences of Head are present in places where they rest on fluvial sediments associated with the inner margins of a terrace (e.g., Transect 12, Illus. 26; BH 2272/BNTW 01). In other places sediments with Head like properties have been located above sediments mapped by the BGS as glaciolacustrine sediments. For example, at the extreme southerly end of the Scheme (Transect 1, Illus. 11; BH RC 1102) Head deposits are present above thick sequences of laminated grey clay/silts. These potentially correlate with sequences seen in the test pits (e.g., TP 38/48) which have the appearance of colluvium and contain elements of both terrestrial and wet ground environments dated to the early Devensian.

Alluvium

Generally, the locations of alluvium accord well with those mapped by BGS. Additionally, the finer detail of previous river channel locations has been identified along with associated channel margin deposits. These deposits have the potential for preservation of palaeoenvonmental sequences. The Holocene alluvium can also seal and act to preserve palaeosols on older land surfaces. The area around Cressing Brook has been shown to have a complex Pleistocene stratigraphy (see Pleistocene Transect 13 above). The Holocene alluvium in this area appears to seal lacustrine deposits and potential gravel islands. Of particular note are:

- Boreham tributary: Channel margin deposits between HABH04 and HABH03 at 1.45-1.84m BGL and 1.2-1.6m BGL respectively (Illus. 6).
- River Ter: Palaeosol at HABH07 2.22-2.23m BGL (Illus. 7).
- Cressing Brook: Alluvium sealing complex lake deposits with potential gravel islands at HABH14 to SSBE07 (Illus. 23).
- River Blackwater: Potential palaeosol at HABH21 to HABH22 (1.32-2.05m BGL (1700-17.73m O.D.) and 1.2-1.8m BGL (17.22-17.82m O.D.) respectively) and organic deposit representing the beginning of alluviation at HABH18 (3.9-4.0m BGL (14.88-14.98m OD) (Illus. 8).
- Blackwater Tributary: Possible palaeosol on till surface at HABH27 0.7m BGL (22.91m O.D.) (Illus. 9).

5.2. LIMITATIONS AND DATA COVERAGE

Test pits provide the best means of assessing the potential for preservation of archaeological and paleoenvironmental archives as they provide a section across the chosen area where undisturbed sediment can be recorded. Unfortunately, however, they are very depth limited with safe depth for entry at 1 m from the surface meaning any greater depths need to be stepped accordingly. Boreholes allow greater depths to be achieved but the nature of coring means the deposits are disturbed (so bedding and boundaries between contacts are less likely to be preserved) and are laterally constrained.

The location of test pits was therefore designed to evaluate the Quaternary landscape by ground truthing the BGS mapping of superficial deposits within the Scheme boundary where major mapped units of interest were close to the ground surface (i.e., where sufficient information could be gained in a 3 m deep test pit). As test pitting was constrained to those land plots in which trial trenching was planned, the distribution of test pits and some boreholes does not necessarily reflect a structured approach to a Scheme-wide, landscape-based programme of works, but a pragmatic evaluation of accessible deposits of note.

Should the construction design change, the heat maps presented (Illus. 3) and below discussion for each Quaternary Landscape Evaluation Area (QLEA) illustrate where there is greater risk due to more limited data coverage within the Scheme boundary. This is particularly pertinent for areas where construction impact is likely to reach or exceed 5m below ground level (BGL) as recovering high quality geoarchaeological data (i.e. test pits as opposed to GI boreholes) is more difficult and therefore costly at these greater depths.

QLEA1 (Illus. 3A1 and 3B1)

Intervention density is greatest in the valley of the Boreham Tributary (Illus. 3A1) where a purposive transect of Headland Archaeology boreholes were collected to investigate the Holocene stratigraphy. Early Holocene deposits with good preservation potential have been identified (Illus. 6) so any excavations made in this alluvium as indicated need to be mitigated accordingly. Other areas with slightly elevated density are where the lacustrine deposits were targeted by purposive test pits. The least represented areas here include land to the north of the A12 within the Scheme boundary where there have been no interventions, as well as parts of the Scheme to the immediate north of the grounds of Boreham House which potentially falls in the lake margins.

For deposits at a depth of more than 5m BGL there is much less data to work from (Illus. 3B1). This is particularly of concern for the three areas where excavations are anticipated to reach up to 5.5m BGL to the east of A12 at the far south of the Scheme. This is in an area where lake deposits have been mapped by BGS, in test pits TP2906 and TP2912 (HA 2021c) and here (Pleistocene Transect 1; see below and illus. 11) and is therefore highly archaeologically sensitive and needs to be mitigated accordingly. This result was unexpected, and accordingly no purposive geoarchaeological boreholes were commissioned in this area. An area between the railway line and the Chelmsford bypass is also scheduled for deep excavation where there is little to no data coverage (Illus. 3B1).

QLEA2 (Illus. 3A2 and 3B2)

As with QLEA1, the greatest density of interventions is where a purposive transect of Headland Archaeology boreholes were collected to investigate the Holocene stratigraphy of the River Ter (Illus. 7). There are relatively few interventions targeting the glaciofluvial deposits and brickearth mapped to the west of this. Interventions are sparse to the far south of the Scheme (east of Hatfield Peveral) where head deposits overlying glaciofluvial deposits are mapped by BGS, and to the far north-east of the Scheme in this area where the River Brain converges with the River Blackwater. Locations where head overlies glaciofluvial deposits and terrace deposits there is greater potential for archaeology and palaeoenvironmental sequences to be preserved in-situ. Locations where rivers converge have potential for preservation of organic Holocene deposits. Both these areas should therefore be highlighted for further assessment should any construction design change cause the development to impact on them.

There is a reasonable coverage of greater than 5m boreholes for the two locations where borrow pits/ponds are planned in this area. However, the rest of this area has very low coverage of these deeper interventions so more will be needed if the boundaries of the borrow pits are altered.

QLEA3 (illus. 3A3 and 3B3)

The greatest density of interventions in this area is in the vicinity of the previously identified lake margins where the purposive Headland Archaeology interventions are bolstered by the work already carried out in the Colemans farm area by Martin Bates. From the results presented below (Pleistocene Transect 10; Illus. 20) it appears that till is overlain by Terrace 3 deposits and sealed by Head to the south of this area. Indeed, the sequence revealed in this area not only has high potential for preserved archaeology and paleoenvironmental remains but also offers an opportunity to resolve some of the issues regarding stratigraphic chronology. There are exceptionally few interventions in zones UPQ3A, UPQ-PA5A and the south part of UPQ-PA5B; as was the case also for archaeological trial trenching. Also of concern is the sparsity of interventions (particularly those of greater than 5m depth) to the west of Cressing Brook at UPQ5A where lake and terrace deposits are present. While the area to the east of Cressing Brook gives the impression of having a higher density of interventions these are linearly constrained, so coverage does need to be improved. This is particularly important as further lake deposits have been identified to the north-east of Cressing Brook (areas UPQ8A, 8B, 9) where a borrow pit is planned. Further data would be beneficial also in UPQ11A and to the east of UPQ8A, 8B and 5, however the result shown in the south-west of Pleistocene Transect 12 (Illus. 22) show till relatively near the surface in this area suggesting it is less archaeologically sensitive.

QLEA4 (Illus. 3A4 and 3B4)

The greatest density of interventions here is in the valley of a tributary which drains south to north into the River Blackwater. A purposive transect of boreholes across the valley to sample the Holocene sequence (Illus. 8) and, perpendicular to this, two transects of Headland Archaeology test pits running along either side of the tributary give a good coverage of the valley. Although coverage becomes increasingly sparse to the south. The Holocene deposits were sampled on the west bank of the River Blackwater as access to the east bank was not possible.

There are few interventions in the rest of the zones, particularly for boreholes with greater than 5m depth (Illus. 3A4). Although greater coverage is in the two areas scheduled for greater impact depth the limited data elsewhere makes it difficult to resolve the Pleistocene deposits mapped in this area including patches of Terraces 4/5 along the edge of the till. Kesgrave sand and gravels are mapped to the north of this area by BGS and they have been identified in Pleistocene Transects 16 and 17 (Illus. 26 and 27) indicating the stratigraphy here is more complex than shown by BGS mapping. Although the Kesgrave Formation is typically devoid of important palaeoenvironmental material, it is complex and isolated pockets and patches of sediment may preserve nationally important sequences. This potential needs to be considered during mitigation, and a test pit arrays and/or borehole transects will resolve the distribution of these deposits.

QLEA5 (Illus. 3A5 and 3B5)

This area has the most limited coverage of interventions, particularly for those greater than 5m depth, and is very linearly constrained due in part to the shape of the Scheme boundary but also due to the clustering of GI interventions. Of particular note is the area to the far north (UPQ23 and the north part of UPQ20) where no purposive interventions have been made. This includes a small area within the Scheme boundary of moderate to high impact close to the Marks Tey site. GI interventions have been made in the location of a proposed attenuation pond, however the authors are aware that there has been some discussion over moving the location of this to an area where no interventions have yet been made. Indeed with the exception of the far south of QLEA5 where Pleistocene Transect 11 has identified little potential with thick deposits of till overlain by Head and Terrace 3 sands and gravels, none of the areas scheduled for moderate impact have a purposive intervention within their boundary.

6. RISKS AND RECOMMENDATIONS

6.1. UPDATED PQ ZONES

A systematic framework has been applied to characterise the potential of Palaeolithic and palaeoenvironmental evidence in light of the above findings. This system has re-drawn the ‘Palaeolithic and Quaternary’ (PQ) zones outlined in the Palaeolithic DBA (Wenban-Smith 2020). Each zone has been ascribed a two-part rating, as described in Section 3.3. The Updated PQ (UPQ) zones are shown in Illus. 31. The palaeoenvironmental risk is depicted in detail in Illus. 31A1-5, and the Palaeolithic risk in Illus. 31B 1-5.

PQ-29 has been re-defined as UPQ-29A and UPQ-29B (Illus. 31A/B.1). UPQ-29A is associated with previously unknown possibly-interglacial lake deposits, which have a High risk of Palaeolithic archaeology at lake margins and Moderate palaeoenvironmental potential. Further fieldwork is required to accurately model the location of lake margins. UPQ-29B is considered to be of Low risk, and the area of the Scheme under the current route of the A12 between QLEA1 and QLEA2 is unevaluated due to a lack of data.

The area around PQ-27 has been revised to incorporate UPQs 27A, 27B and 27C (Illus. 31A/B.2). These areas are dominated by till and are generally of Low risk. Head deposits were detected in UPQ-27C which may incorporate Kesgrave formation deposits. The presence of Palaeolithic archaeology in Kesgraves is low, but any found are of high significance; accordingly, UPQ-27C is rated Moderate for Palaeolithic risk. PQ-26 is divided into UPQ-26A and UPQ-26B, which contain fluvial deposits, and these are of Low palaeoenvironmental potential. Outside bends of the river course may contain secondary re-deposited artefacts, and so are class as Moderate Palaeolithic risk. Inside bends are more likely to contain in-situ archaeological and palaeoenvironmental remains and are therefore of higher risk.

The central area of the Scheme (Illus. 31A/B.3) contains evidence of a complex sequence of interglacial lake filling and evidence of Palaeolithic-era wetland zones. The edges of these lake and wetland zones has been resolved resulting in the re-mapping of several PQ zones as amended or new UPQ zones. Areas of till have also be resolved, which have low or minimal potential. Different types of lake fill are evident, and these vary in terms of their palaeoenvironmental potential.

The area centred around PQ-16 (Illus. 31A/B.4) has been re-zoned. The inside bend of fluvial deposits have been identified and constrained to UPQ-13B-B. UPQ-16C has areas that contain possibly fluvial and Kesgrave input, and so the area does have Palaeolithic potential (unknown at DBA stage). Further fieldwork is required to define the distribution of deposits.

The north-east of the Scheme is dominated by UPQ-20 (Illus. 31A/B.5) which largely contains near-surface till. Whilst the till has minimal potential, there was evidence of possible land surface horizons and soil formation at the upper interface of the till. Such deposits would be of some potential, and so the areas have retained a Low risk rating. At the far north of the Scheme, UPQ-23, the proximity to Marks Tey is noted. Purposive geoarchaeological works in this area would be required to determine the distribution of deposits and their risk.

6.2. RISKS ASSOCIATED WITH STARTIGRAPHIC UNITS

The local distribution of deposits across the Scheme may vary, and there is likely to be deviation from the strata modelled in areas where the density of test pits and boreholes is low. The stratigraphic framework, however, is applicable across the Scheme. This provides scope to consider the likely risks associated with certain types of deposits when they are encountered across the Scheme (Table 4), regardless of whether their presence was anticipated or not.

6.3. FUTURE ARCHAEOLGOICAL INVESTIGATION

Recommendations for the next stage of archaeological fieldwork presented in this report take into account the construction-related impact model, based on the designs shown in GIS data and design plans issued by Costain to Headland on 22nd July 2021, and includes borrow pit (HE551497-COS-HGT-SCHW-M2-C-001) and compound areas (HE551497-COS-GEN-SCHW-Mw-C-001). This has been done at the request of Costain to constrain the areas of future investigation and identify areas with the potential for preservation in-situ of some deposits. The recommendations presented below should therefore not be taken as a definitive record of the construction-related impact of the Scheme on the landscape, nor its archaeological or palaeoenvironmental assets. Additional archaeological evaluation or mitigation may be required in areas not identified in this report due either to incomplete knowledge of the Scheme design and/or changes to the Scheme design. The recommendations should be considered as indicative measures based on current understanding of the Scheme design and Palaeolithic/palaeoenvironmental potential.

It is recommended that the next task is the development of an over-arching WSI to cover all future stages of work across the Scheme (Illus. 32). Given the complexity of the Scheme and the diversity of the deposits present, different approaches and methodologies may be required in different areas of the Scheme. Thereafter, the next stage of fieldwork should be to target purposive geoarchaeological interventions at areas with potential for Palaeolithic archaeology, and to recovery sequences of palaeoenvironmental significance.

Table 4. Stratigraphic units present across the Scheme and their associated risks and recommendations.

Unit	Relevant UPQ zones	Palaeolithic archaeology risk	Palaeoenvironmental sequence risk	Overall risk	Mitigation recommendations
Sub-Till sands and gravels (Kesgraves)	27C 1C- mod	Low (low likeliness of remains, but very high significance if present)	Low but pockets of fine-grained sediment would be High	Low to Moderate	Test pitting. The interface between Kesgraves and overlying till may be of high significance, and geoarchaeological supervision is recommended within 1-metre of predicted Kesgrave deposits.
Till deposits	8A- seals lake margin? 20- low (possible soil formation sealed by head)	Low	Low. However, till may seal palaeosols at lower boundary and may have soil formation at upper boundaries; Moderate potential.	Minimal to Low	Test pitting at upper and lower boundaries.
Lacustrine sediments	29A- High 5C- V. High 5A- V. High 8B- V. High 9- V. High 23- high	High at margins and on 'islands' Complex infilling likely created multiple margin zones.	High, sequences at deepest location will give best resolution, while sequences in margins can be better linked to archaeology	High over area and Very High at margins.	Geophysics to map lake margins. Test pitting around lake margins for recovery of archaeological remains. Boreholes to give depth of lake, and palaeoenvironmental/depositional record.
Fluvial sediments	26A- high 26B- mod. 3A- mod. 5A&5B- no impact 5E- high 11A- mod. 11B- mod. 1A- no impact 13BA- mod. 13B-B- high 17A	High in some (i.e. Terrace 3) and on inside bends of terraces, low in others (i.e. glacial outwash)	Complex but generally Low in coarse grained sediments, High in fine grained sediments.	Moderate	Need careful mapping, through test pits, of sediment bodies with adequate dating programme to develop framework
Brickearth	None identified during this stage of fieldwork	If present these deposits have good potential for preserving archaeological sites in situ	Good alkaline preservation conditions	Low	Test pitting if encountered
Head deposits	27C	Moderate	Moderate to Low	Moderate but variable	Test pitting if associated with other key deposits. Locations to be guided by geophysics and other data where available.
Alluvium	29B-high 27A- mod. 5A/9- V. high 1A- high 1B- mod	Low	High	High	Boreholes to give depth of sequence, and palaeoenvironmental/depositional record of the Holocene.

Future Aims and Objectives

Work to date has been a deposit-led approach, in which the distribution of types of deposit has been mapped and characterisation of their risk has been evaluated. Future fieldwork should aim to further test the UPQ zoning and determine the presence, character, distribution and density of prehistoric finds across the landscape. For zones defined as having Minimal to Low archaeological potential, the main aim of this phase of fieldwork will be to provide a test of this classification before these areas are descoped. For areas defined as having Moderate to Very-High potential, the zoning will be tested, and meaningful sampling intervals designed to detect the presence of remains human activity.

The aim will be, for each zone, to sample through a grid of test pits within the footprint of impact to create fine-resolution, sub-zone mapping based on the archaeological and geological character. To achieve this, a series of iterative stages of survey are required, at progressively finer sampling intervals. For areas of Minimal to Low potential, a single phase of test pit sampling at 200m intervals should be sufficient to either prove the low potential scoring or identify the presence of localised sedimentary contexts with higher potential than realised.

Sampling Approach for Archaeological Prospection

For areas of Moderate, High or Very High Potential, an initial sampling grid of 100m intervals will aim to sub-zone out parts of the landscape with Low or Minimal potential and begin to define palaeo-landscape features such as terrace edges, lake margins and bodies of fine-grained head with more precision. This will operate in conjunction with a wider roll out of CMD geophysical survey. These can then be followed up with subsequent phases of 50m and 25m interval test pit sampling as sub-zoning begins to constrain significant archaeological and palaeoenvironmental records. Once significant parts of the archaeological record are mapped at 25m intervals, consideration can be given to the mitigation phase and the methodologies for area excavation set out below.

The excavation methodology for each test pit should proceed as for Fieldwork Stage 1, excavating 2x4m test pits with a flat-bladed ditching bucket in spits of no more than 100mm to a maximum depth of 4m or impact depth. For impact depths greater than 4m stepped or shored trenches will be required to ensure complete evaluation of the deposits. For areas of very deep impact on deposits with potential (e.g., in deep borrow pits), more than one prospective evaluation phase might be needed. For every 200mm spit of each unique sedimentary unit a sample of 150 litres of sediment should be put aside for sifting and the recovery of artefact and ecofacts (100 litres) and a bulk sample if necessary (40 litres). Once complete, a stratigraphic description and photographic/drawn record of at least one representative should be made.

Proportionality to Scheme design

The next stage of evaluation will be constrained both by the archaeological and palaeoenvironmental potential, and by the distribution and character of construction-related impact. In preparation of the following Targeted Evaluation recommendations the area of construction-related impact has been estimated by data provided by Costain Group plc (dated 20th July 2021) and is based on the road design scheme and temporary works (compounds and borrow pits). It is anticipated that both scheme and temporary work designs will change before completion of the Scheme. In these cases, design changes are likely to have implications for buried archaeological and palaeoenvironmental evidence and associated evaluation and mitigation. Scheme design changes will require modification to the following recommendations. The UPQ zones provide a framework for such future modifications, and where possible should be reflected in the Mitigation WSI.

Construction-related impact has been classified as follows:

- Minor impacts – topsoil strip and/or ground surface activity; these areas are excluded in the table below;
- Moderate impact – ponds, drainage and compounds, for which impact depth not likely to exceed 4m below current ground level is anticipated;
- Major impact – road cuttings, junctions and borrow pits, for which impact depth is unknown or anticipated to be greater than approximately 4m.

Major impact areas are noted because these areas may require test pits that exceed safer working depths. These test pits would require additional temporary works, e.g., stepping or shoring, or alternative evaluation methods would be required. The current estimation of impact area and categorisation are based on current knowledge of the Scheme design. It is probable that the impact area will need to be revised as the Scheme develops, and close communication between the Archaeological Contractor and Principal Contractor will be essential to ensure these changes are captured accurately.

It is important to note that design drawings provided show final height compared to current ground surface. In places where new road is shown it has not been possible to assess the potential below ground impact and these areas are omitted from impact area calculations. The possibility of cuttings for road placement are noted, and these may require additional archaeological works.

6.4. AREA-SPECIFIC RECOMMENDATIONS

The following pages detail the recommendations for the next stage of fieldwork (Fieldwork Phase 2) and their rationale. Information is provided for each UPQ and organised by QLEA. The quantification of purposive archaeological interventions has been constrained by construction design, but the potential for an increase or decrease in the actual construction-related impact from the estimates provided should be borne in mind (see Section 1.4). Quantifications are, therefore, for illustrative purposes only (Table 5-9). The number of test pits should be considered as a minimum deployed as an array for initial evaluation for the presence of Palaeolithic artefacts. If artefacts are recovered additional test pits would be required to map their distribution. The number of boreholes is a recommendation based on current gaps in knowledge. The depth of borehole recovery will vary and will likely exceed 20m in places. The size and length of geophysical surveys are approximated from the size of estimated construction-related impact.

QLEA 1

This area contains the Bolton, Paynes Lane and Countryside Zest land packages. At the DBA stage the area was covered by PQ-29 of moderate potential. During test pitting the northern part of this area (Countryside Zest and Paynes Lane) identified no deposits of concern, and accordingly the area has been down-graded to Low potential for palaeoenvironmental and Palaeolithic evidence (UPQ-29A). To the south of this area (Bolton, UPQ-29A) deposits were recovered that may represent the final infilling of a lake previously mapped by the BGS. In the field it was suspected that these deposits may be interglacial (i.e. warm periods) rather than glacial (as mapped by BGS). Pollen assessment of deposits indicate that these deposits contain elements of an interglacial flora – a full report on the pollen assessment will be submitted at a later date as an addendum to this report. While dating suggests that the sampled sequences belong to the end of MIS 5 the age of the underlying main body of the lake remains equivocal.

The possibility of interglacial lake deposits in this area has increased the potential rating. Palaeolithic archaeology potential has been increased to moderate because lake margins represent attractive habitats for human exploitation and have potential for high-resolution preservation of human activity. The palaeoenvironmental potential has also been increased, to high, because the palaeoenvironmental proxies preserved in lake sediments likely represent a unique and significant record of past environment change for the region.

Further evaluation is required to assess the potential of this area. It is noted several ponds are scheduled to be placed in this area, which have the potential for impacts to around 4m. It is recommended that CMD and ERT surveys are deployed to locate lake edges that may be impacted by development. In such area test pits, initially at 50m intervals. are recommended, with further test pitting required if artefacts are retrieved. Deep boreholes are also recommended to determine the depth and character of lacustrine deposits and provide palaeoenvironmental samples.

Table 5. Recommendations for future archaeological investigation in QLEA1. Min. TP = indicative minimum number of test pits required. Rec. BH = indicative number of recommended boreholes. CMD survey area and ERT transect length are indicative estimates.

UPQ	Overall (highest) potential	Estimated impact area (ha)		Indicative quantifications				Rationale
		Moderate	Major	Min. TP (no.)	Rec. BH (no.)	CMD (ha)	ERT (m)	
UPQ-29A	High	6.5	0	20	3	5	325	Define the location of lake edges through ERT and CMD. Systematic prospecting for traces of human activity by test pitting where lake edges are likely to be impacted by development. Boreholes provide environmental profiles.
UPQ-29B	Low	1.9	0	2	0	0	0	Low intensity test pits constrained by construction-related impact are recommended to confirm interpretation and ascertain distribution of Head. Potential for de-scope following agreement by Historic Environment Consultant.

QLEA2

Large areas (primarily Rayleigh) of QLEA2 are covered by Head deposits overlying till. The till has minimal potential, although the Head deposits could seal or contain (see below) important remains. Accordingly, PQ-29 in these areas has been downgraded from Moderate potential to Low potential, and PQ 27 has been confirmed as Low potential. Head deposits tend to be no greater that 2m in depth in this area, and so only shallow test pits are anticipated. Kesgraves are present in the Rayleigh area, however, and any impact on these should be avoided. Any recovered artefacts associated with Kesgraves would be of international significance.

Deposits mapped as brickearth by the BGS in the Vellacott area have been re-interpreted as Head. Head deposits have the potential to included re-deposited artefacts and to seal human activity horizons, Below the Head deposits, potential fluvial deposits are present in this area. In the case of the Vellacot Head deposits, the age of these remains uncertain but they could potentially correlate with Terrace 3. This area, therefore, requires further evaluation to determine the presence of Palaeolithic archaeology, and has been upgraded to Moderate potential (the area remains Low potential for palaeoenvironmental evidence). Moderate intensity test pit arrays and boreholes to characterise the depth of deposits are recommended. CMD and ERT survey has the potential to reduce the number of test pits required. The Head deposits extend to up to 8m below current ground level, and evaluation throughout the depth of the borrow pit is likely required by stepped/shored test pits and/or watching brief.

To the west of this area, previously PQ-26 of Moderate potential, the distribution of fluvial deposits is better understood. The area has consequently been divided into Moderate (UPQ-26B) and High (UPQ-26A) zones. The latter of these likely contains the inside margins of fluvial systems, in which Head deposits derived from higher ground beyond the floodplain often bury and preserve intact sequences on the floodplain surface. Construction impact in this area is expected to be limited, but where impact does occur systematic test pitting for artefact screening is required.

Table 6. Recommendations for future archaeological investigation in QLEA2. Min. TP = indicative minimum number of test pits required. Rec. BH = indicative number of recommended boreholes. CMD survey area and ERT transect length are indicative estimates.

UPQ	Overall (highest) potential	Estimated impact area (ha)		Indicative quantifications				Rationale
		Moderate	Major	Min. TP (no.)	Rec. BH (no.)	CMD (ha)	ERT (m)	
UPQ-27A	Low	8.2	0	9	3	0	410	Low intensity test pits constrained by construction-related impact are recommended to confirm interpretation and to assess Head deposits. Potential for de-scope following agreement by Historic Environment Consultant.
UPQ-27B	Low	5.8	24.2	30	0	0	1500	Low intensity test pits constrained by construction-related impact are recommended to confirm interpretation and to assess Head deposits. Potential for de-scope following agreement by Historic Environment Consultant.
UPQ-27C	Moderate	0	21.4	65	3	17	1070	Investigation of Kesgrave input into Head deposits, including the mapping of Head and related fluvial systems and artefact screening.
UPQ-26A	High	1.6	0	5	3	1	80	Inside bends of fluvial systems have high potential to preserve significant archaeological and palaeoenvironmental signatures. Test pits recommended to constrain their distribution and for systematic evaluation and artefact screening.
UPQ-26B	Moderate	1.9	0	6	3	1	95	Fluvial deposits with potential to preserve significant Palaeolithic archaeology. Test pits recommended to constrain their distribution and for systematic screening.

QLEA3 West

This area is the central part of the Scheme, encompassing Brice and Siggers land, and the construction design includes a borrow pit, a major road junction and several ponds. The area is, by far, the most significant in terms of Palaeolithic archaeology and palaeoenvironmental sequences and will require substantial archaeological investigation.

Prior to excavation the potential for Hoxnian period (an interglacial period with high potential for human activity) lake deposits was anticipated. The margins of lakes were attractive habitats for early humans and have good potential to yield significant archaeological remains as well as providing significant paleoenvironmental sequences.

Test pits and boreholes have refined our understanding of past geomorphology. It is now apparent that relatively shallow lake deposits (up to 7m below ground level) are present in the Siggers borrow pit and the Colemans Farm areas. Pollen assessment indicate these deposits date to pollen zone Hoxnan IIc, which lies in Marine Isotope Stage 11c. This is the main part of the Hoxnian interglacial, providing stable, warmer conditions. The Colemans Farm and Siggers deposits were broadly contemporary and may at points constituted a single body of water.

Alongside these two shallow lacustrine deposit sequences lies a deeper lake sequence (in the SSBE area). The bottom of this sequence was not reached, but it is known to extend 17.5m below ground level. One possible scenario is that the deep and shallow lake sequences were once part of the same lake, comprising a broad shallow lake with a deeper central basin. In this scenario it would be anticipated that the deeper parts of the lake would infill first. Pollen assessment suggests, however, that this is not the case, and that the deeper lake basin filled after the shallower deposits.

Consequently, two competing scenarios exist: either the shallow margins of the lake infilled first (primarily through biochemical sedimentation producing carbonate rich sediments) prior to a change in sediment input into the lake causing minerogenic sediments to rapidly infill the deepest part of the lake. Alternatively, the deeper lake was cut into the infilled shallow lake. The significance of this is that multiple lake margins, as well as extended wetland zones, may have existed at different stages during the interglacial as these lakes were created and infilled. Detailed geophysical survey as well as deep boreholes to ascertain the relationship between the base of the lake deposits and underlying deposits will be required to resolve which model is correct. These methods may allow significant refinement of areas of concern, but extensive test pitting activity will be required in areas of construction-related impact.

In addition, overlying the lake deposits are sediments associated with localised fluvial deposition. It is possible that multiple phases of fluvial activity occurred following the infilling of lakes as climate deterioration at the end of the Hoxnian period. These fluvial deposits extend 3m below ground surface and may include organic horizons (as evidenced in borehole SSBE-07) with high palaeoenvironmental potential, as well as locations with a high chance of artefactual evidence.

Finally, this area contains areas of till to the north and east of the lake deposits (UPQ-5D and UPQ-8A). Till was also recovered from boreholes from the Brice quarry entrance (BRQU), indicating an inaccuracy in the mapping of till by the BGS. Although the potential of till deposits is minimal, those in UPQ-8A are noted as their relationship with the lake edge, and the possibility of human activity surfaces cannot be excluded at this stage.

Table 7. Recommendations for future archaeological investigation in the western and central parts of QLEA3. Min. TP = indicative minimum number of test pits required. Rec. BH = indicative number of recommended boreholes. CMD survey area and ERT transect length are indicative estimates.

UPQ	Overall (highest) potential	Estimated impact area (ha) Moderate	Major	Indicative quantifications Min. TP (no.)	Rec. BH (no.)	CMD (ha)	ERT (m)	Rationale
UPQ-3A	Moderate	0	0	6	0	0	0	Fluvial deposits with potential to preserve significant Palaeolithic archaeology. Requires systematic evaluation in areas of impact to impact depth.
UPQ-PA5A	Moderate	-	-	-	-	-	-	No construction-related works planned in this area
UPQ-PA5B	Moderate	-	-	-	-	-	-	No construction-related works planned in this area
UPQ-5E	High	0	14.7	45	0	11.76	0	Fluvial deposits with potential to preserve significant Palaeolithic archaeology. Requires systematic evaluation in areas of impact to impact depth.
UPQ-5C	Very high	3.5	5.8	28	4	7.44	465	Define the location of lake edges through ERT and CMD. Systematic prospecting for traces of human activity by test pitting where lake edges are likely to be impacted by development. Boreholes provide environmental profiles.
UPQ-5A	Very high	0	3.5	11	4	2.8	175	Define the location of lake edges through ERT and CMD. Systematic prospecting for traces of human activity by test pitting where lake edges are likely to be impacted by development. Boreholes provide environmental profiles.
UPQ-8B	Very high	0	12.9	39	0	10.32	0	Define the location of lake edges through ERT and CMD. Systematic prospecting for traces of human activity by test pitting where lake edges are likely to be impacted by development. Boreholes provide environmental profiles.
UPQ-9	Very high	0	4	12	4	3.2	0	Define the location of lake edges through ERT and CMD. Systematic prospecting for traces of human activity by test pitting where lake edges are likely to be impacted by development. Boreholes provide environmental profiles.
UPQ-5D	Minimal	3.9	0	4	0	0	0	Low intensity test pits constrained by construction-related impact may be required to confirm interpretation. Potential for de-scope following agreement by Historic Environment Consultant.
UPQ-8A	Low	0	5.1	6	0	4.08	0	The possibility of lake edge deposits in this area requires mapping. The till areas subject to impact must be systematically evaluated for potential, to impact depth, before they can be descoped in agreement with ECC Archaeological team.

QLEA3 East and QLEA4

To the east of QLEA3, moving beyond the lake deposits, a sequence of fluvial deposits are present (UPQ-11A, UPQ-11B and UPQ-13AB). These fluvial deposits are similar to those in the east of QLEA2. They have the potential for archaeological horizons and palaeoenvironmental sequences, especially where the fluvial sequences thin against the rising ground at the terrace edge that are evident in UPQ-11A and UPQ-11B. These areas retain the Moderate rating of PQ-13B at the DBA stage. Comprehensive geophysical survey is recommended to map the sequences, and to primarily target test pits at those areas where construction-related impact and inside margins of the terrace intersect. It is noted that planned works in these areas is modest, and so such areas may be of limited scope.

Across the boundary of QLEA3 and QLEA4 lie fluvial (river terrace) gravels, coincide with the inner margin of a terrace at UPQ-13B-B. This area has good potential for the recovery of Palaeolithic archaeology and palaeoenvironmental sequences and has accordingly been upgraded from Moderate at DBA (PQ-13B) to High (UPQ-13B-B). Deposits associated with PQ-16 (of Uncertain potential at the DBA stage) immediately south of PQ-13B seem to extend further north into the Scheme than previously anticipated and have been determined to have Minimal potential because of the presence of till in the zone.

The majority of the Uncertain PQ-16 deposits lie to the east of PQ-13B, corresponding to the Bunting area, and are now classed as UPQ-16C of Moderate potential. Within this area patches of gravels that may be associated with Blackwater Terraces 4 or 5 or some other process (see Headland Archaeology 2021c) are present. Gravel deposits in this area may be associated with the Kesgrave Formation, for which any archaeological activity is of international significance. Systematic mapping and sampling of Head and gravel deposits is recommended.

The east of the Bunting area (UPQ-16D) has been re-graded from Uncertain potential to Minimal. Further north, in UPQ-17A, includes several deposits associated with the River Blackwater. These deposits, especially those on the inside of the terrace have potential to preserve for archaeological evidence.

Holocene alluvium is present in UPQ-1A, UPQ-1B and UPQ-1C. These deposits have potential for palaeoenvironmental sequences dating to the Holocene, although deposits are thin in UPQ-1B limiting that potential. For the most part, Holocene alluvium only occasionally contains Palaeolithic artefacts, and so these deposits provide Minimal Palaeolithic potential. In the case of UPQ-16C, however, Kesgrave Formation deposits are apparent, and these should be screened for Palaeolithic artefacts if construction-related impact is likely to interact with the Kesgraves.

Table 8. Recommendations for future archaeological investigation in the eastern end of QLEA3 and QLEA4. Min. TP = indicative minimum number of test pits required. Rec. BH = indicative number of recommended boreholes. CMD survey area and ERT transect length are indicative estimates.

UPQ	Overall (highest) potential	Estimated impact area (ha)		Indicative quantifications				Rationale
		Moderate	Major	Min. TP (no.)	Rec. BH (no.)	CMD (ha)	ERT (m)	
UPQ-11A	Moderate	2	0	6	3	1.6	100	Inside bends of fluvial systems have high potential to preserve significant archaeological and palaeoenvironmental signatures. Test pits recommended to constrain their distribution and for systematic evaluation and artefact screening.
UPQ-11B	Moderate	0.6	0	2	3	0.48	30	Inside bends of fluvial systems have high potential to preserve significant archaeological and palaeoenvironmental signatures. Test pits recommended to constrain their distribution and for systematic evaluation and artefact screening.
UPQ-1A	Moderate	0	0	0	0	0	0	No construction-related works planned in this area
UPQ-13B-A	Moderate	0.2	2.8	9	3	2.4	150	Fluvial deposits with potential to preserve significant Palaeolithic archaeology. Test pits recommended to constrain their distribution and for systematic screening.
UPQ-16A	Minimal	0	0	6	0	0	0	Low intensity test pits constrained by construction-related impact may be required to confirm interpretation. Potential for de-scope following agreement by Historic Environment Consultant.
UPQ-16B	Minimal	0	0	6	0	0	0	Low intensity test pits constrained by construction-related impact may be required to confirm interpretation. Potential for de-scope following agreement by Historic Environment Consultant.
UPQ-1B	Low	0	0	0	0	0	0	No construction-related works planned in this area
UPQ-13B-B	High	1.4	3.8	16	3	4.16	260	Inside bends of fluvial systems have high potential to preserve significant archaeological and palaeoenvironmental signatures. Test pits recommended to constrain their distribution and for systematic evaluation and artefact screening.
UPQ-16C	Moderate	5.5	35	122	0	32.4	0	Investigation of Kesgrave input into Head deposits, including the mapping of Head and related fluvial systems and artefact screening.
UPQ-16D	Minimal	5.9	0	6	0	4.72	0	Low intensity test pits constrained by construction-related impact may be required to confirm interpretation. Potential for de-scope following agreement by Historic Environment Consultant.
UPQ-1C	Moderate	0.1	0	1	0	0	0	Investigation of Kesgrave input into alluvial deposits, including the mapping of related fluvial systems and artefact screening.
UPQ-17A	Moderate	0	7.4	23	3	5.92	370	Inside bends of fluvial systems have high potential to preserve significant archaeological and palaeoenvironmental signatures. Test pits recommended to constrain their distribution and for systematic evaluation and artefact screening.

QLEA5

The vast majority of QLEA5 (Sherwood and West) areas is covered by near-surface till. This till has Minimal potential for Palaeolithic and palaeoenvironmental evidence. During test pitting possible palaesol formation was identified, indicating the potential that a stable surface existed on top of the till. This provides potential for overlying Head deposits to seal artefactual evidence. Consequently, this area has been categorised as Low rather than Minimal. Test pitting in areas of impact is recommended to ascertain the distribution of Head and assess the potential of any buried surfaces.

The extreme north-east of the Scheme is in proximity to Marks Tey and Copford (PQ-23). It is understood a pond is planned to be excavated in this area. Marks Tey is known to contain Pleistocene lake deposits with known Palaeolithic potential, while Copford (although poorly described) has a very rich record of Pleistocene megafauna. The Scheme area includes land that historic borehole data shows contain lake margin deposits, which have High potential for Palaeolithic evidence. No purposive geoarchaeological works have been undertaken in this zone, and consequently it is difficult to determine the precise distribution of suitable deposits, but the area has a high likelihood of encountering Palaeolithic and palaeoenvironmental remains. Deposits to the east of the historic land fill and south of the existing road have the greatest potential. A programme of geophysical survey, ground-truthed with boreholes is recommended.

Table 9. Recommendations for future archaeological investigation in QLEA5. Min. TP = indicative minimum number of test pits required. Rec. BH = indicative number of recommended boreholes. CMD survey area and ERT transect length are indicative estimates.

UPQ-20	Low	9	0	9	0	0	0	Areas of impact must be systematically evaluated for potential, to impact depth, before they can be descoped in agreement with ECC Archaeological team.
UPQ-23	High	5.2	0	16	6	4.16	260	Define the location of lake edges through ERT and CMD. Systematic prospecting for traces of human activity by test pitting where lake edges are likely to be impacted by development. Boreholes provide environmental profiles.

6.5. FURTHER MITIGATION

The above outlines for each QLEA detail our recommendations for the next stage of works within the Scheme. These may be subject to design change and further discussion with archaeological stakeholders. If signatures indicating high-resolution preservation of past human behaviour are encountered, it may be necessary to implement full recovery through archaeological excavation. Details of the required excavation methodology should be included in the subsequent WSI. An example outline strategy is provided in Appendix 5, detailing how the main excavation would need to be undertaken. This would be subject to change based on the type of site and any other stakeholder input. A Palaeolithic watching brief could also be required in areas of high potential, where no individual site has been identified.

6.6. CORE RETENTION POLICY

It is recommended that all bagged samples and cores comprising entirely of London Clay or till are discarded as these samples have minimal potential to provide archaeological or palaeoenvironmental information. All other cores are to be retained as they may provide samples of importance for later stages of the project. It is anticipated that the continued retention for extant cores will be incorporated into the next stage of archaeological works.

7. CONCLUSION

Purposive geoarchaeological works to evaluate the Quaternary landscape have been integrated with ground investigation data and previous desk-based information. The deposit model produced herein provides a baseline that informs future Scheme planning and can be refined with new data as it becomes available. The risk of Palaeolithic archaeology and palaeoenvironmental sequences of significance have been mapped for the full extent of the Scheme. Deposits across the Scheme can be broadly assigned to five categories, ranging from greatest to least concern:

1. Central area lake deposits. The modelling of deposits in the area to the east of Witham has been significantly improved. The model anticipated at the pre-fieldwork stage was of a single lake with an easily defined margin – the margin being the likely location of Palaeolithic remains. This model has been superseded by a more complex sequence of lake infilling and likely wetland habitants extending beyond the lake edge. This new model indicates that the deep lake sequence filled in *after* the shallow lake areas, as evidenced by AAR and pollen dating (see Stage 2 Review Addendum). The hypothesis to explain this sequence requires testing in future stages of work, and may indicate that the deeper and shallower lakes were contemporary with the former infilled first either due to the formation of a bank between shallow and deep areas, input from a delta alluviation or calcification, or that the deep lake cuts the shallow lake. The consequence of this is that multiple areas with high potential for Palaeolithic remains now exist. This area has also proven to have a rich and significant palaeoenvironmental record. Preliminary assessment of this record has materially influenced interpretation of this area. The central lake deposits continue to have the highest potential for Palaeolithic archaeology across the Scheme, and any construction-related impact should be expected to require substantial mitigation works. Currently the areas of high potential have been extended, but further geophysical and geoarchaeological evaluation works may constrain the area requiring intervention.
2. Southern area lake deposits. Deposits mapped as glacial lakes by BGS at the south of the Scheme, near Chelmsford, have proven to have been of greater potential than anticipated. Sediments encountered in that area are indicative of interglacial (warm period) deposits, and this has been confirmed by AAR dating – though whether the deposits are Hoxnian or from a more recent interglacial is to be determined. There is a possible presence of lake margins (favourable to human activity) dating to the Palaeolithic within the Scheme boundary and locating those margins through geophysics and borehole works is recommended.
3. Fluvial deposits are mapped across the Scheme, with most associated with the River Blackwater. These deposits have good potential for the recovery of secondary Palaeolithic artefacts, as well as the possible occurrence of primary deposits at the inner margins of the terraces. The location of inner margins is reflected in the UPQ zonation, and further targeted evaluation work is likely to refine these further.
4. Head has been located across the Scheme, and the nature of the deposition is highly varied. Some Head deposits have good potential for the inclusion of localised secondary deposition of artefacts, as well as the potential to seal primary depositions.
5. Till covers large parts of the Scheme, although these are of minimal potential, there are possible preserved surfaces on some till deposits that require investigation. Underlying Kesgrave deposits do appear

relatively close to the surface in places. These deposits should be screened for artefacts because the occurrence of artefacts would be highly significant. No risk is present where.there are no superficial deposits overlying the bedrock of London Clay and are therefore of minimal

The next stages of fieldwork should be undertaken with the view to:

i. test the UPQ zoning and ratings,
ii. locate and constrain primary Palaeolithic depositions, as well as determining the presence of secondary deposits, and
iii. retrieve palaeoenvironmental sequences.

Geophysical survey deployed alongside boreholes to ground-truth the interpretation of geophysical data are recommended to constrain areas that require archaeological prospection. In areas where potential for artefacts remains, the recommended mode of investigation is arrays of test pits deployed, initially, on widely-spaced grids. Once artefacts are discovered, additional test pits can then be deployed at shorter intervals to constrain their distribution. The detection of a primary deposition of Palaeolithic archaeology will be a major discovery, and careful consideration will need to be made as to whether preservation in-situ or mitigation is the most appropriate approach.

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9. ILLUSTRATIONS

10. APPENDICES

APPENDIX 1 BOREHOLE RECORDS

APPENDIX 2 STRATIGRAPHIC MODEL

APPENDIX 3 POLLEN REPORT

APPENDIX 4 AAR REPORT

APPENDIX 5 MITIGATION RECOMMENDATIONS

ATTT

A12 ARCHAEOLOGICAL EVALUATION (JUNCTION 19/CHELMSFORD – JUNCTION 25/A120)

Palaeolithic and Palaeoenvironmental Stage 2 Review

Part 2: Illustrations

Headland Archaeology Midlands & West
Unit 1 | Clearview Court | Twyford Rd | Hereford HR2 6JR

for Costain Group plc
on behalf of National Highways

HE551497-COS-HER-3_S0-RP-X-0010

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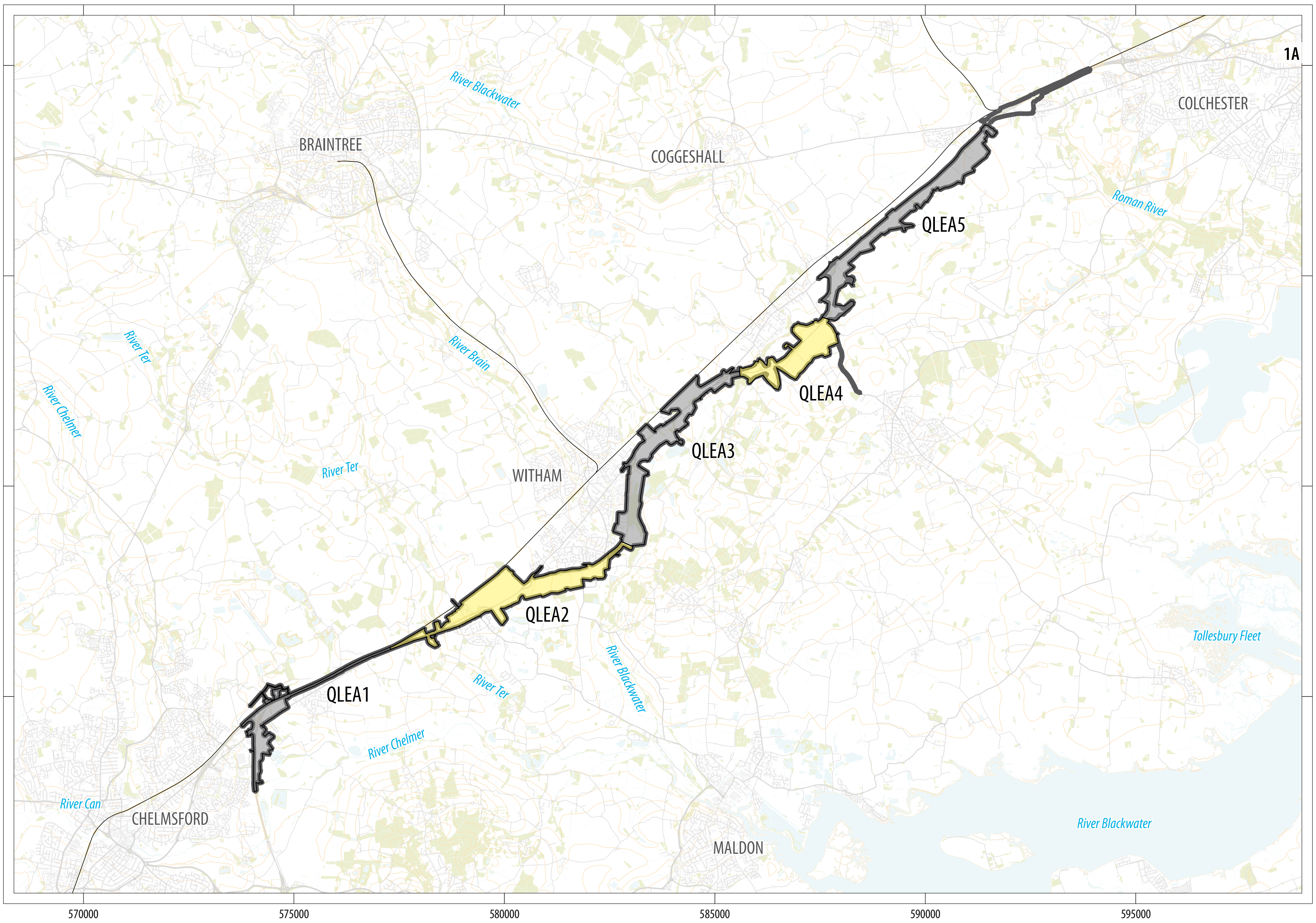
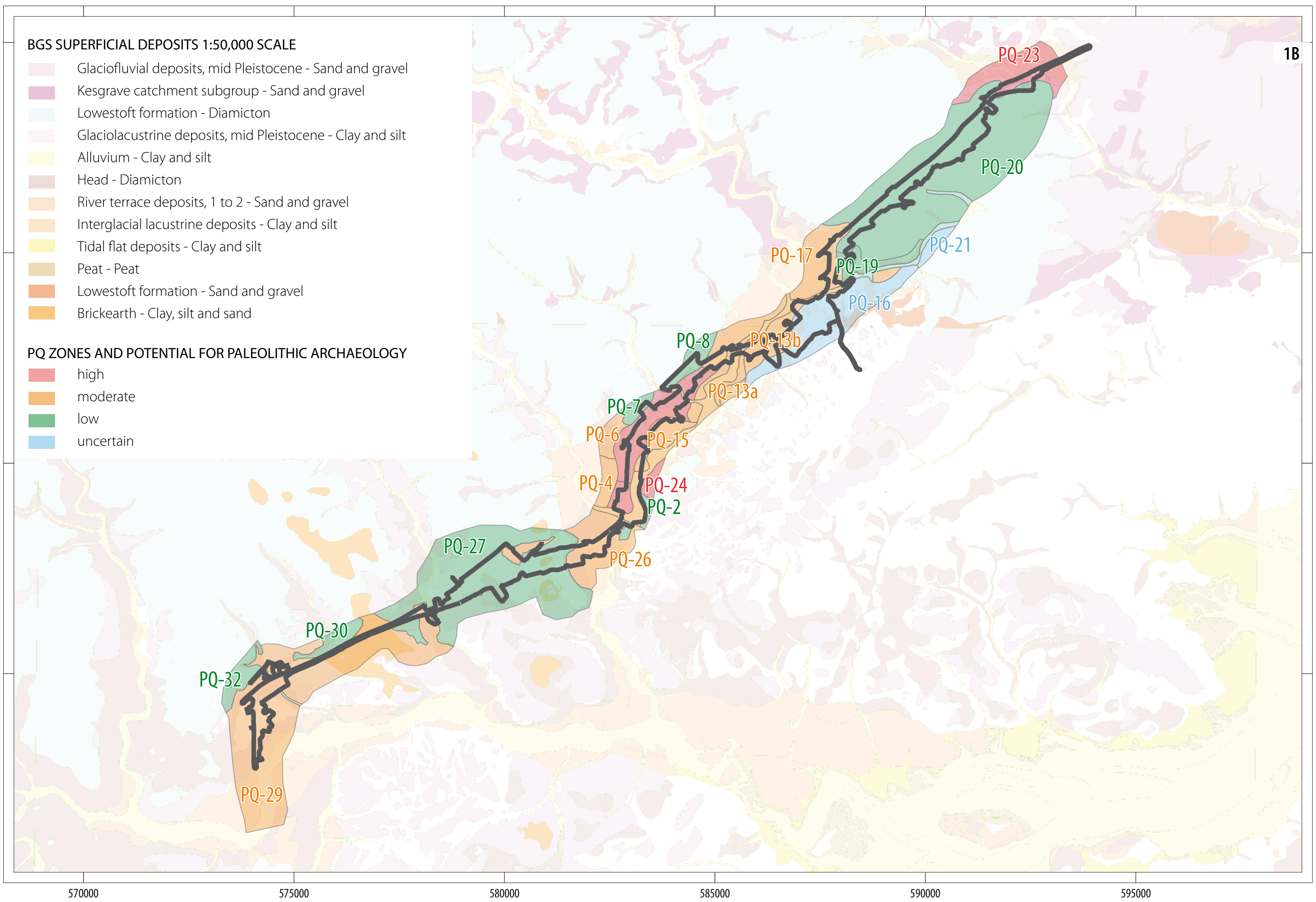
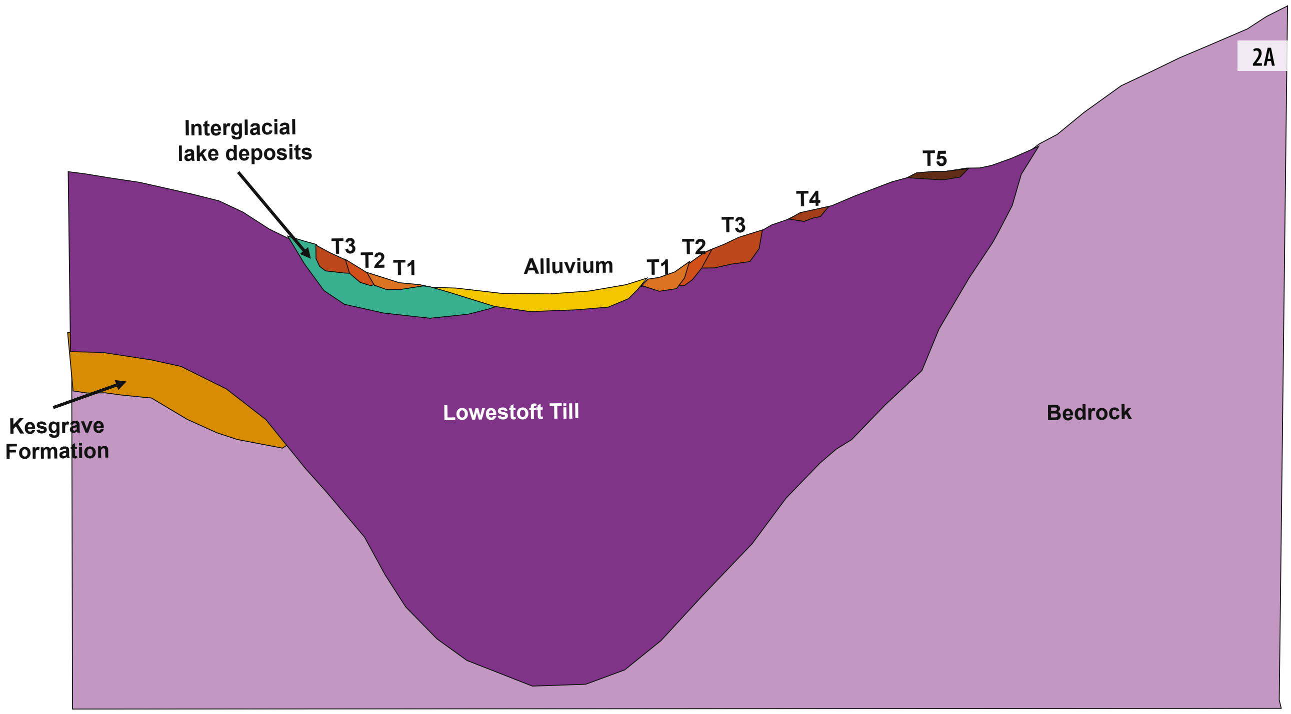
HEADLAND ARCHAEOLOGY

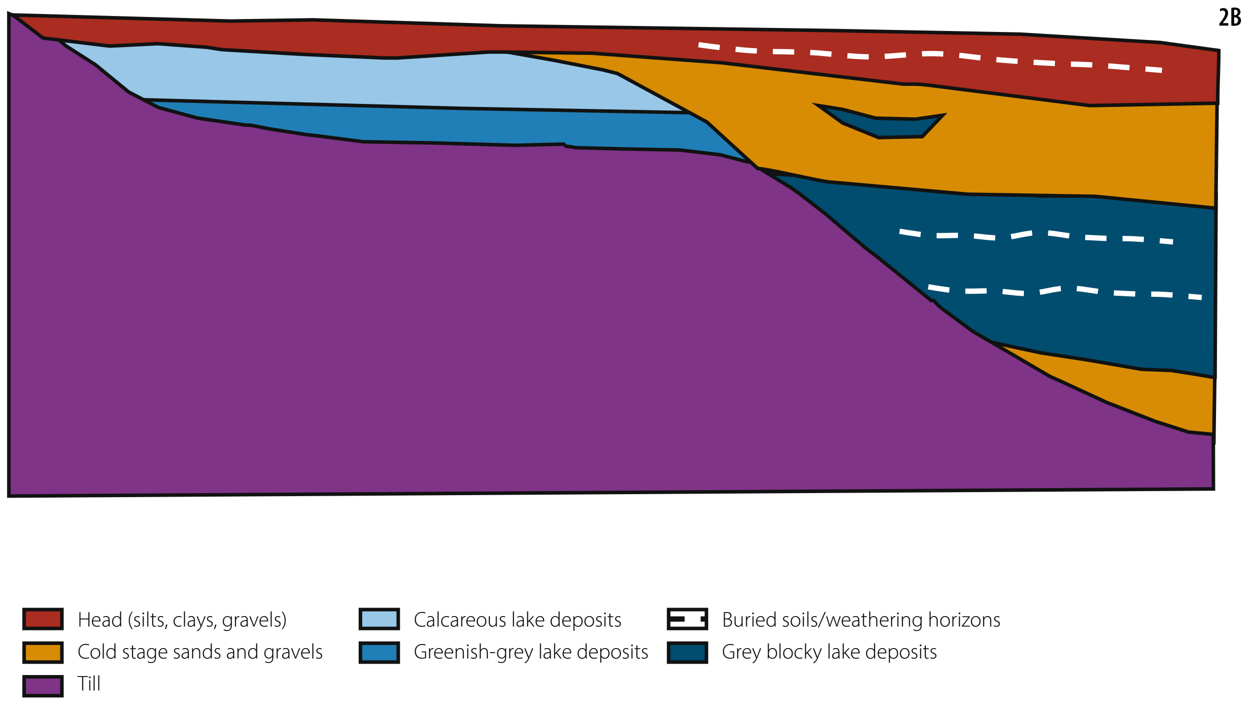
LIST OF ILLUSTRATIONS



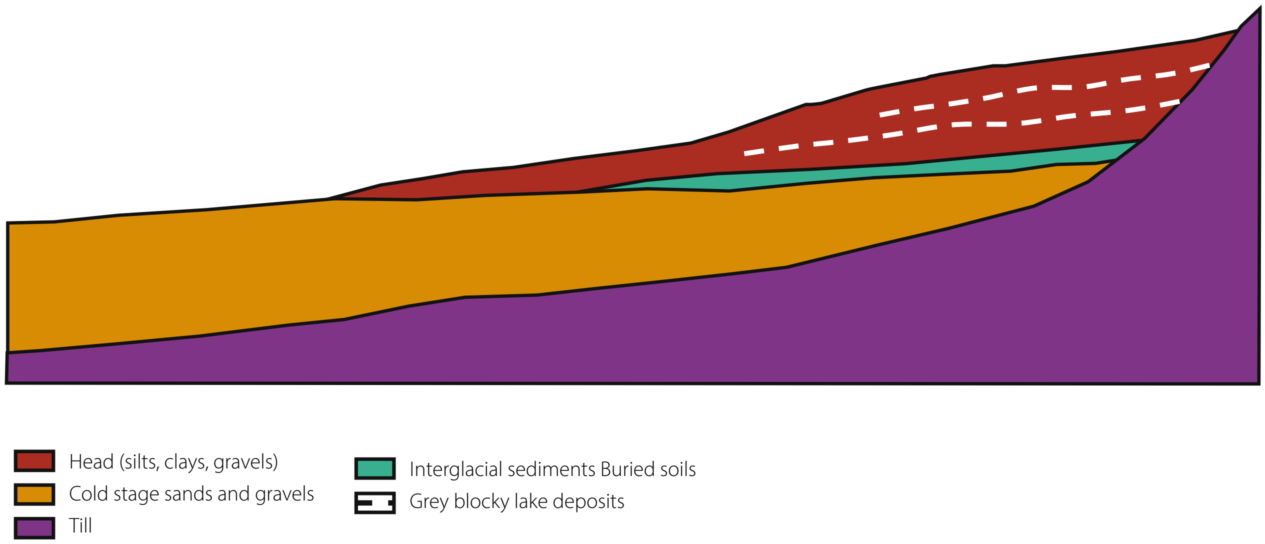


ILLUS 1 Site location. **A**: scheme shown on open street map basemap with Quaternary Landscape Evaluation Zones shown. **B:** scheme shown on British Geological Survey superficial geology basemap and PQ zones shown; colours denote potential for Palaeolithic archaeology as determined at the Palaeolithic desk-based assessment (Wenban-Smith 2020).



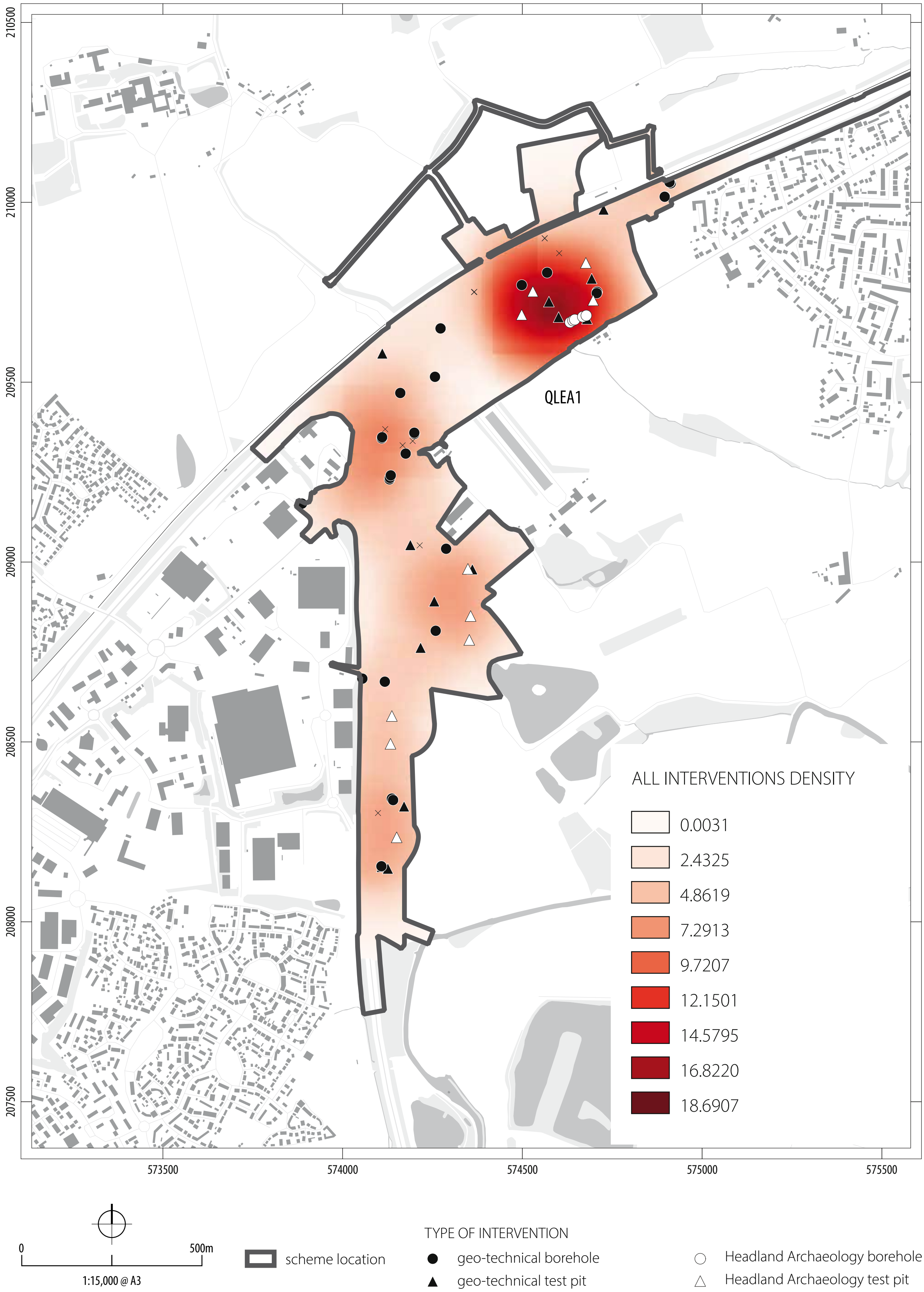


ILLUS 2A Schematic representation of the scheme geomorphology for the scheme in general **ILLUS 2B** Schematic representation of the scheme geomorphology for lake sequence deposits

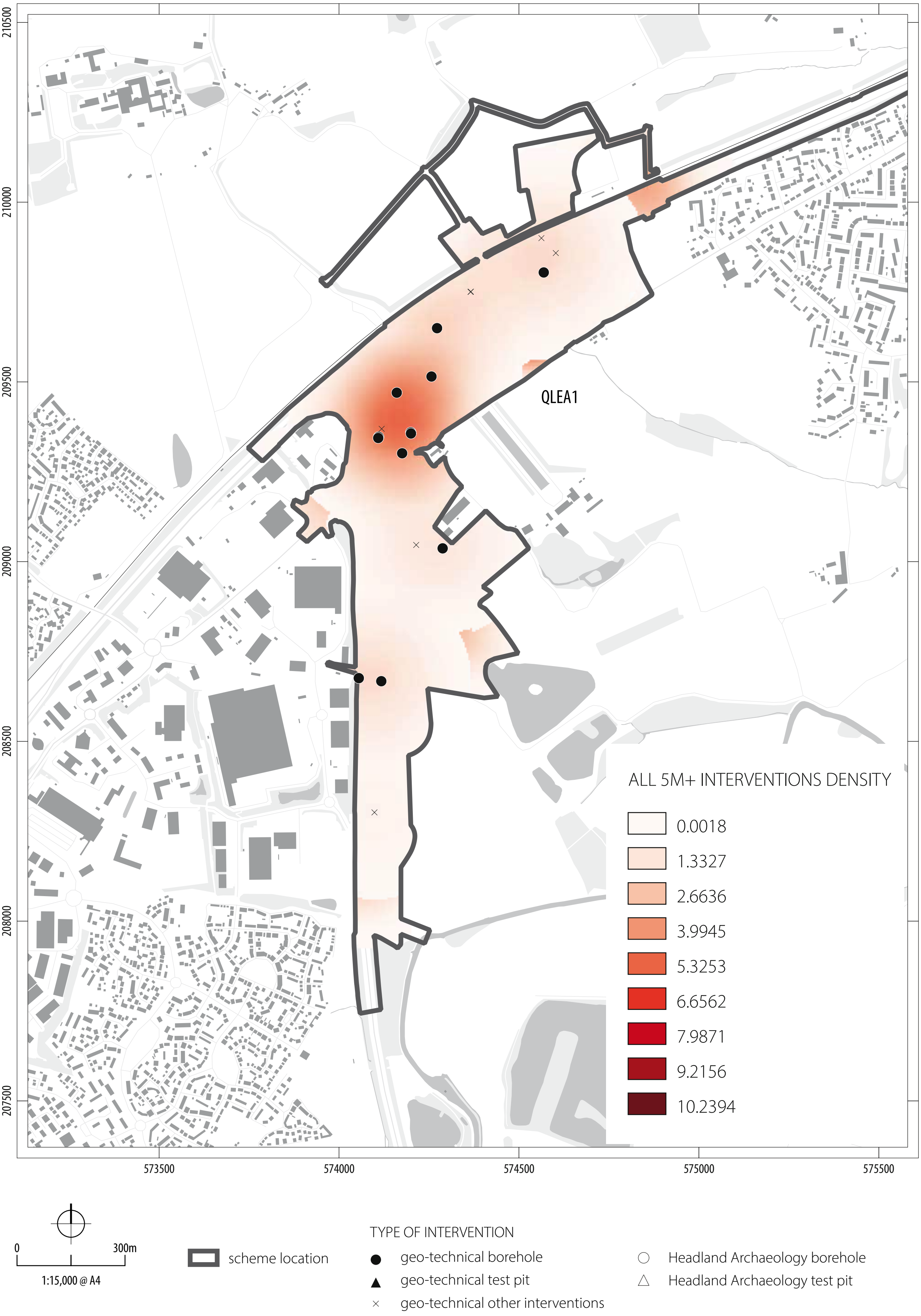


ILLUS 2C Schematic representation of the scheme geomorphology for river terrace deposits

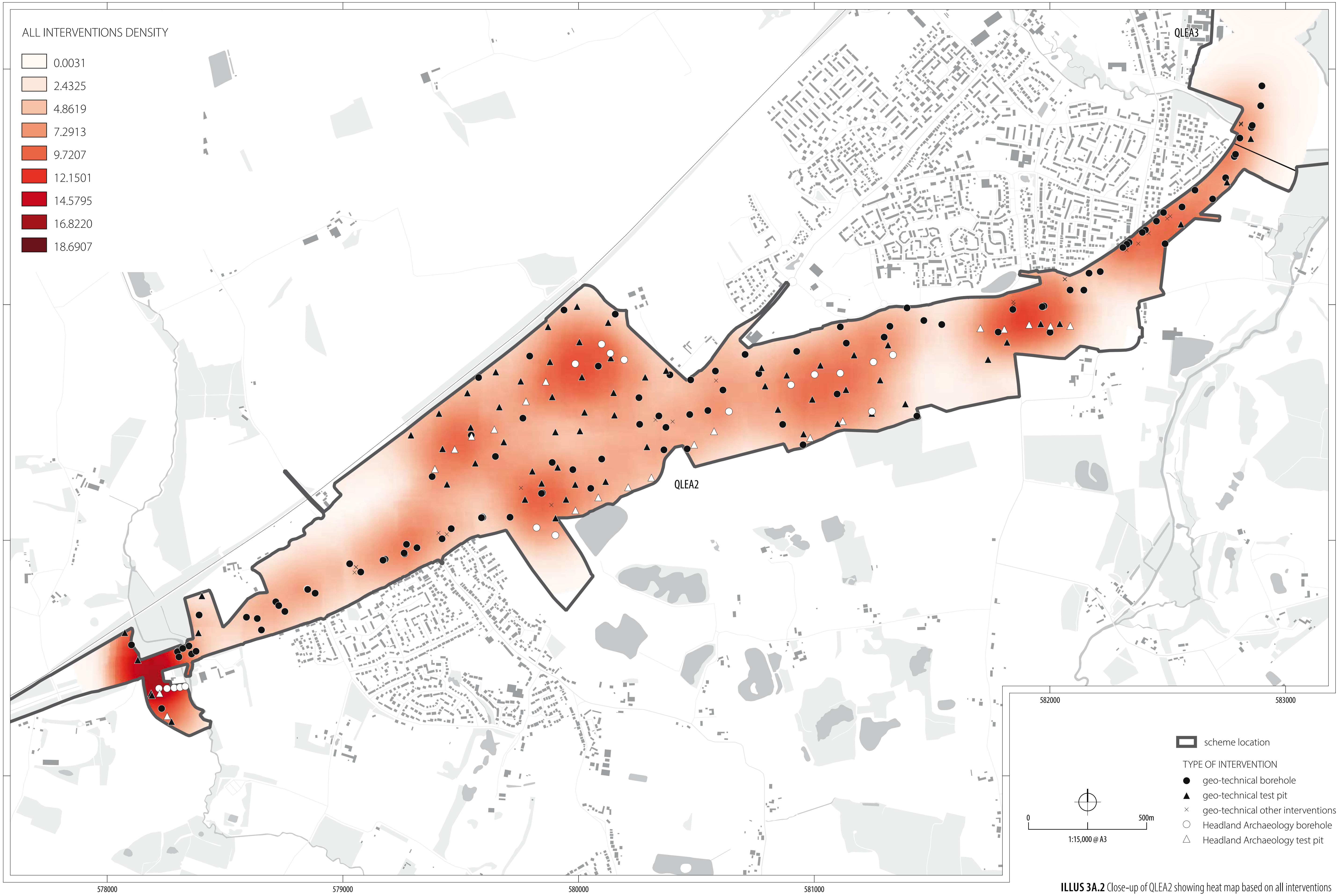
ILLUS 3 Data coverage heat maps. Hotter colours indicate higher density of geotechnical or purposive geoarchaeological interventions, including test pits and boreholes. A heat map based on all interventions. B heat map based on only interventions that reach 5 metres below surface level. Additional weighting has been added to purposive geoarchaeology interventions



ILLUS 3A.1 Close-up of QLEA1 showing heat map based on all interventions

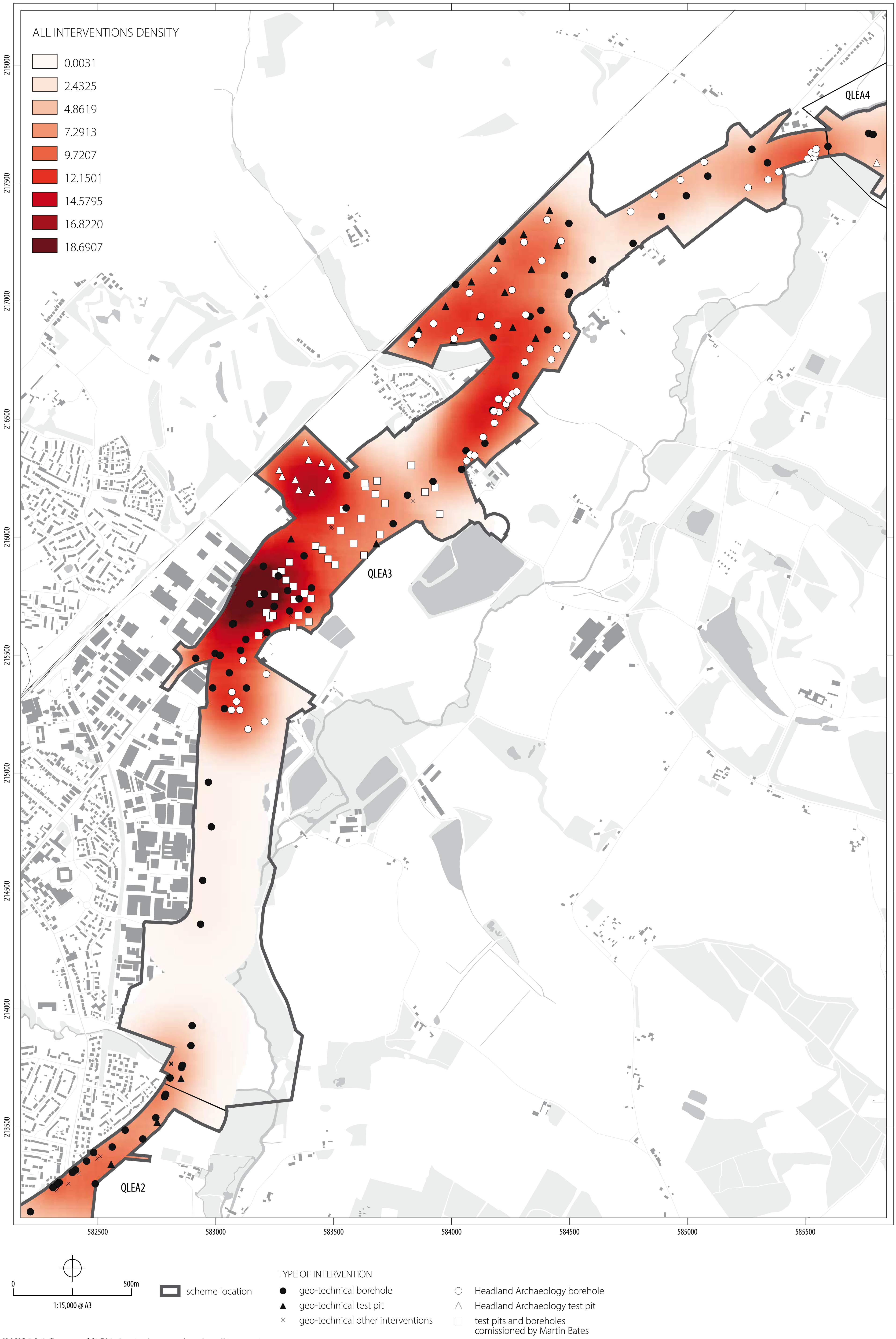


ILLUS 3B.1 Close-up of QLEA1 showing heat map based on only interventions that reach 5 metres below surface level

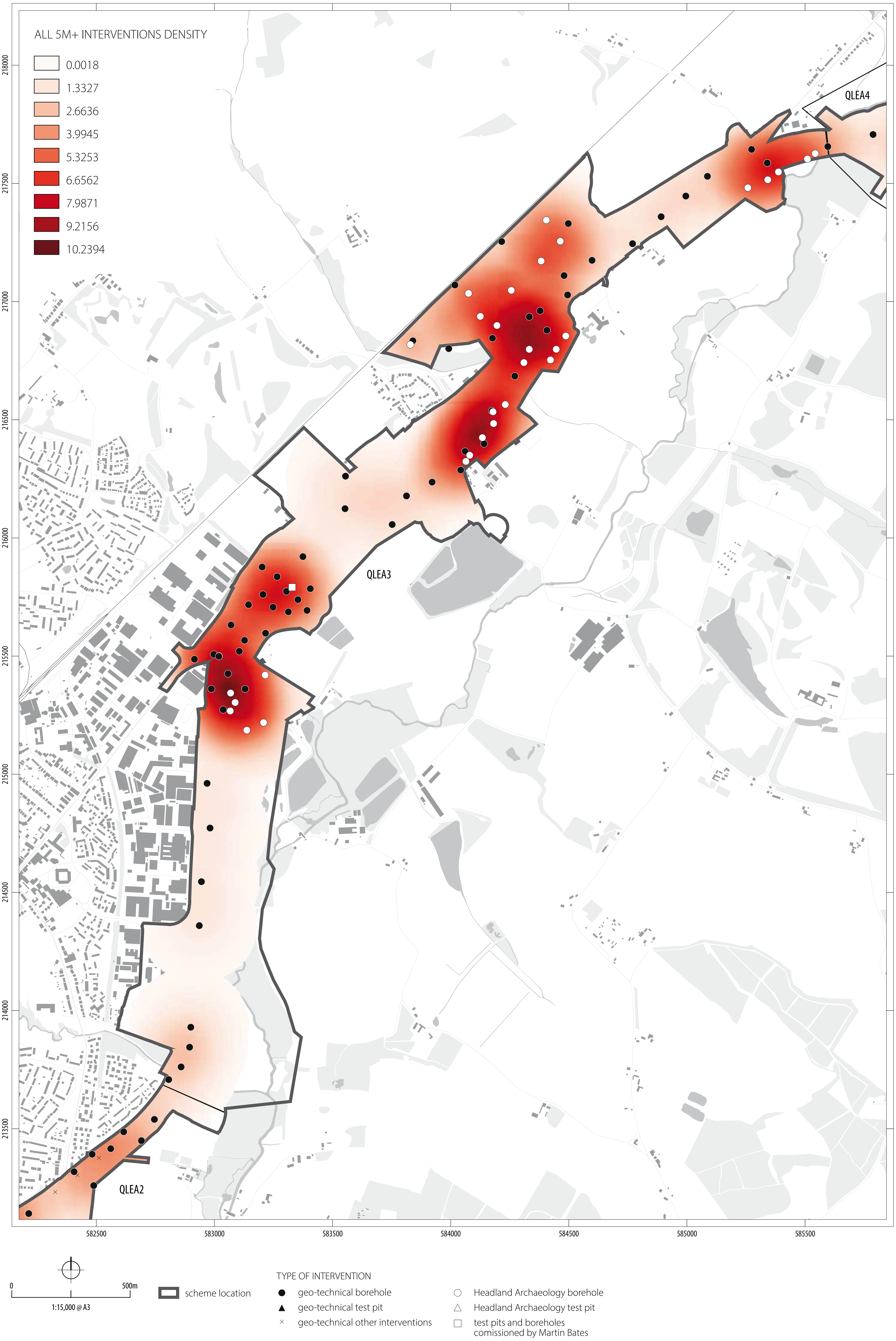


ILLUS 3A.2 Close-up of QLEA2 showing heat map based on all interventions

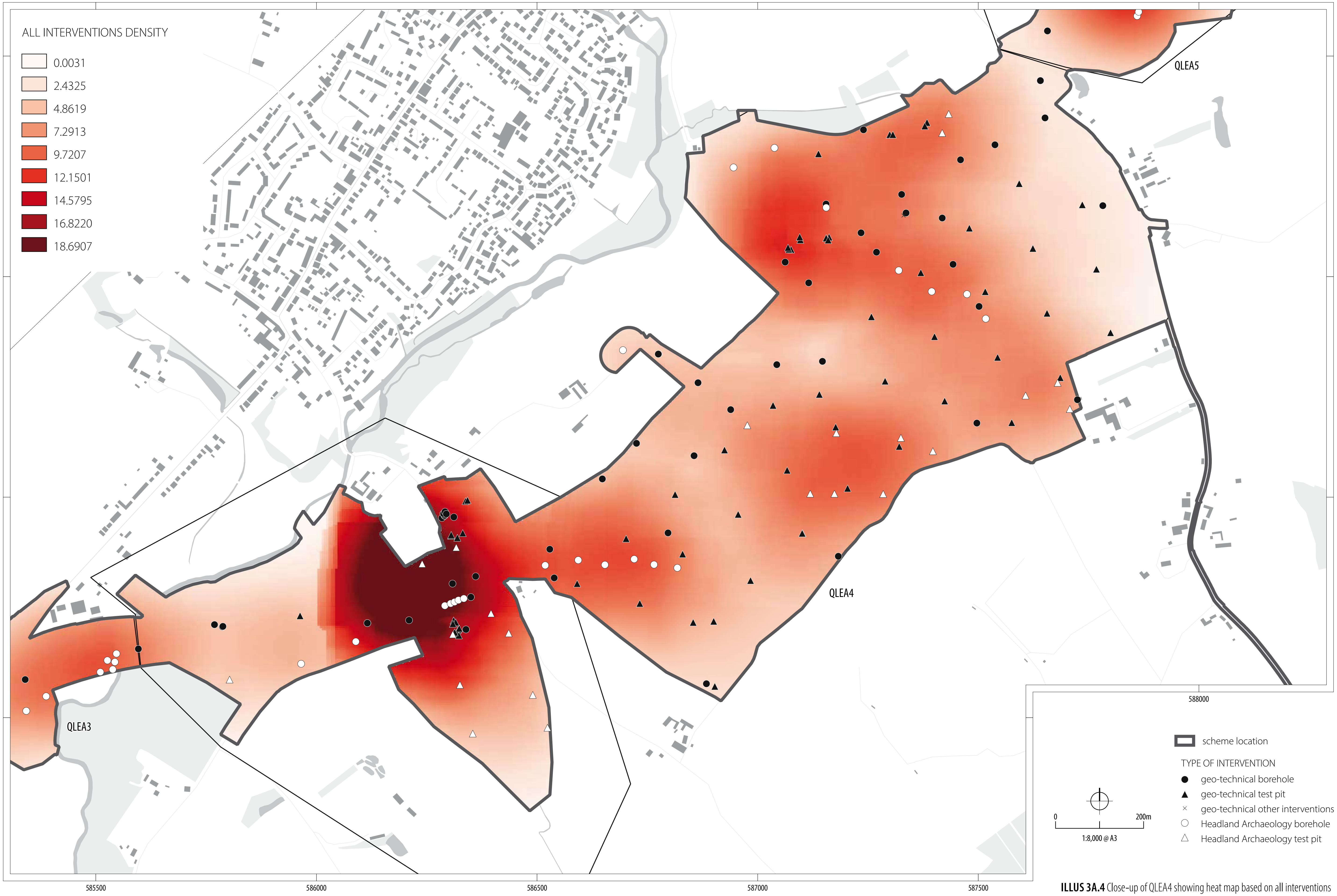
ILLUS 3B.2 Close-up of QLEA2 showing heat map based on only interventions that reach 5 metres below surface level



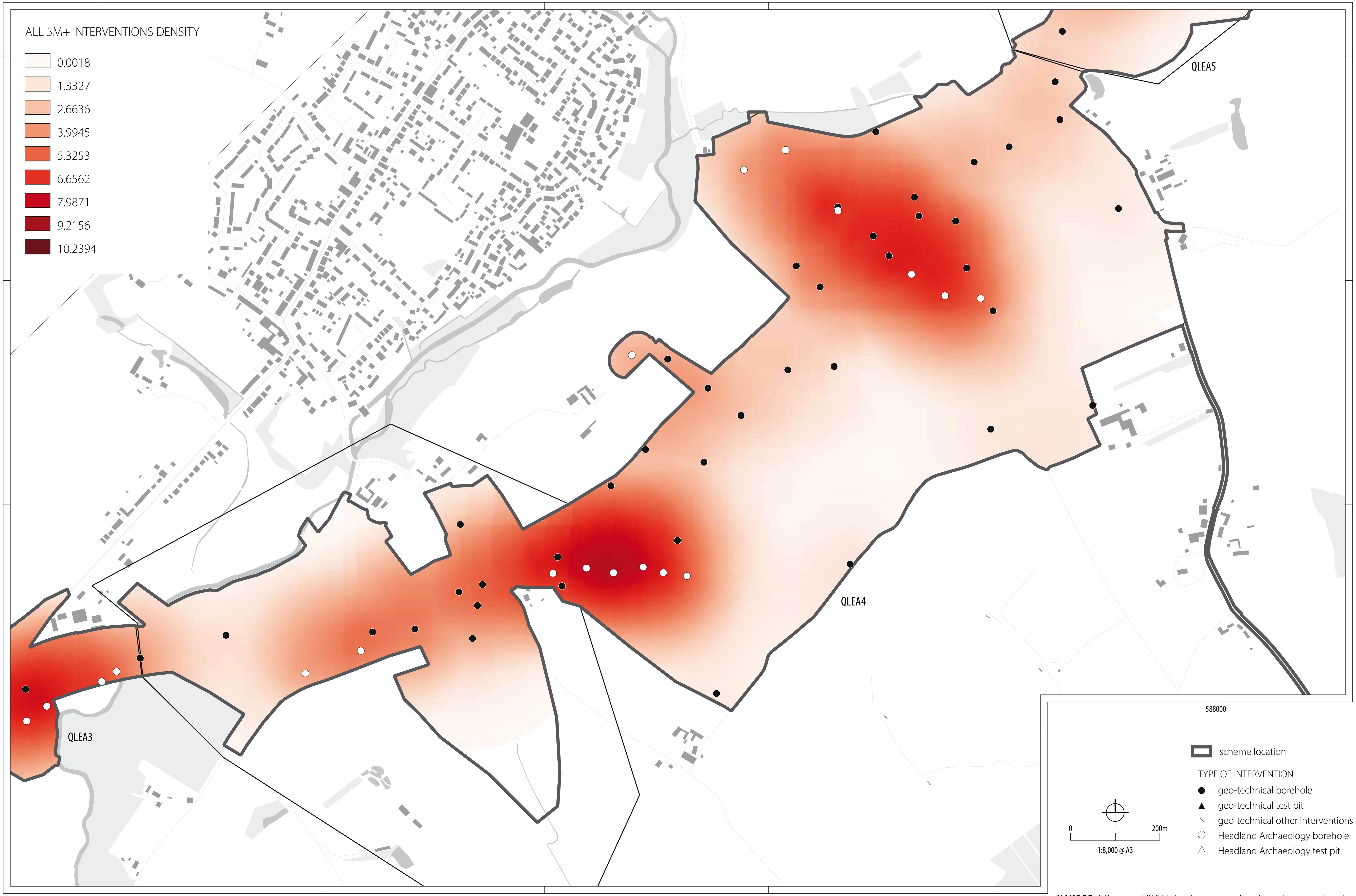
ILLUS 3A.3 Close-up of QLEA3 showing heat map based on all interventions



ILLUS 3B.3 Close-up of QLEA3 showing heat map based on only interventions that reach 5 metres below surface level



ILLUS 3A.4 Close-up of QLEA4 showing heat map based on all interventions

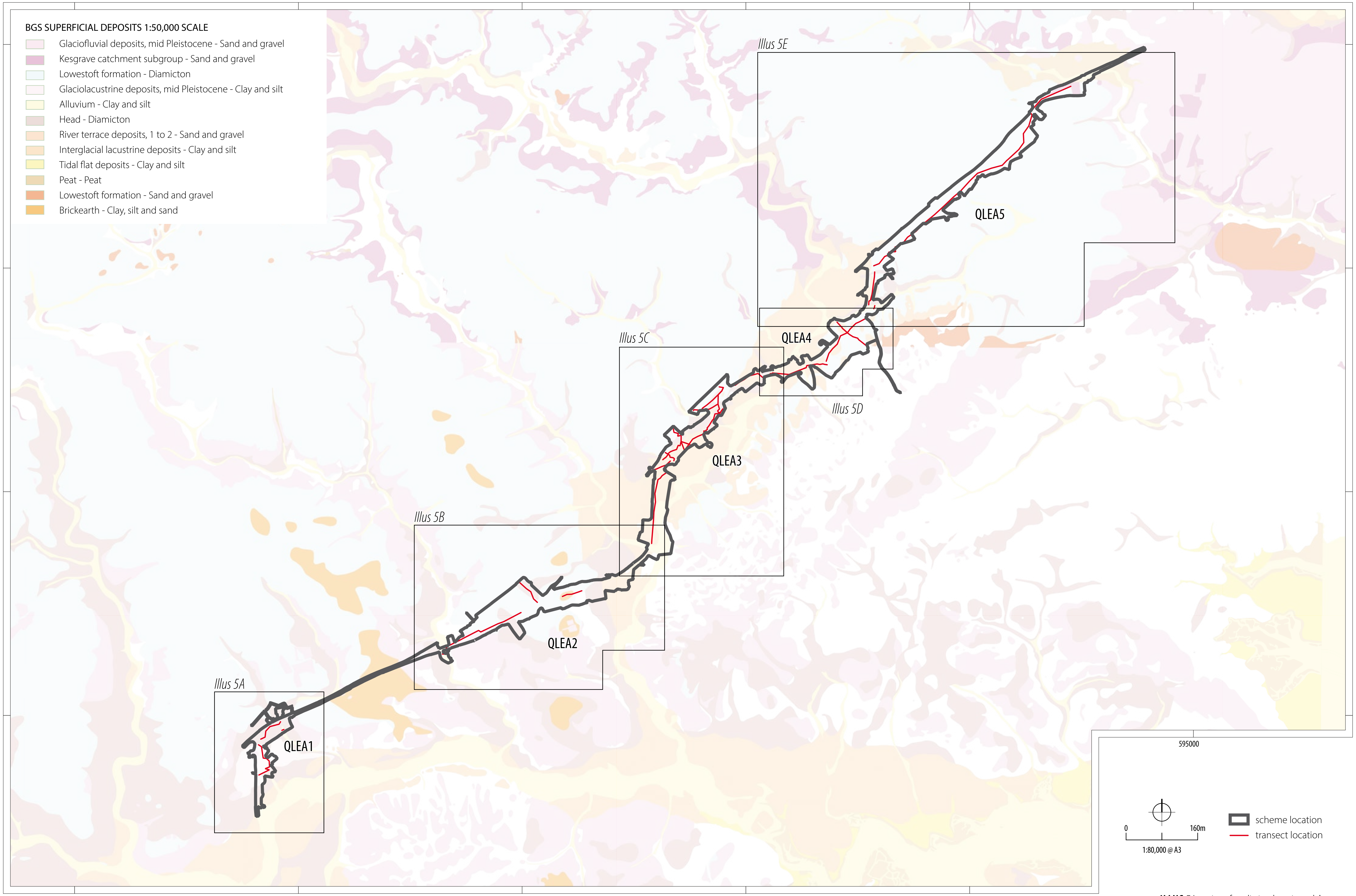


ILLUS 3B.4 Close-up of QLEA4 showing heat map based on only interventions that reach 5 metres below surface level

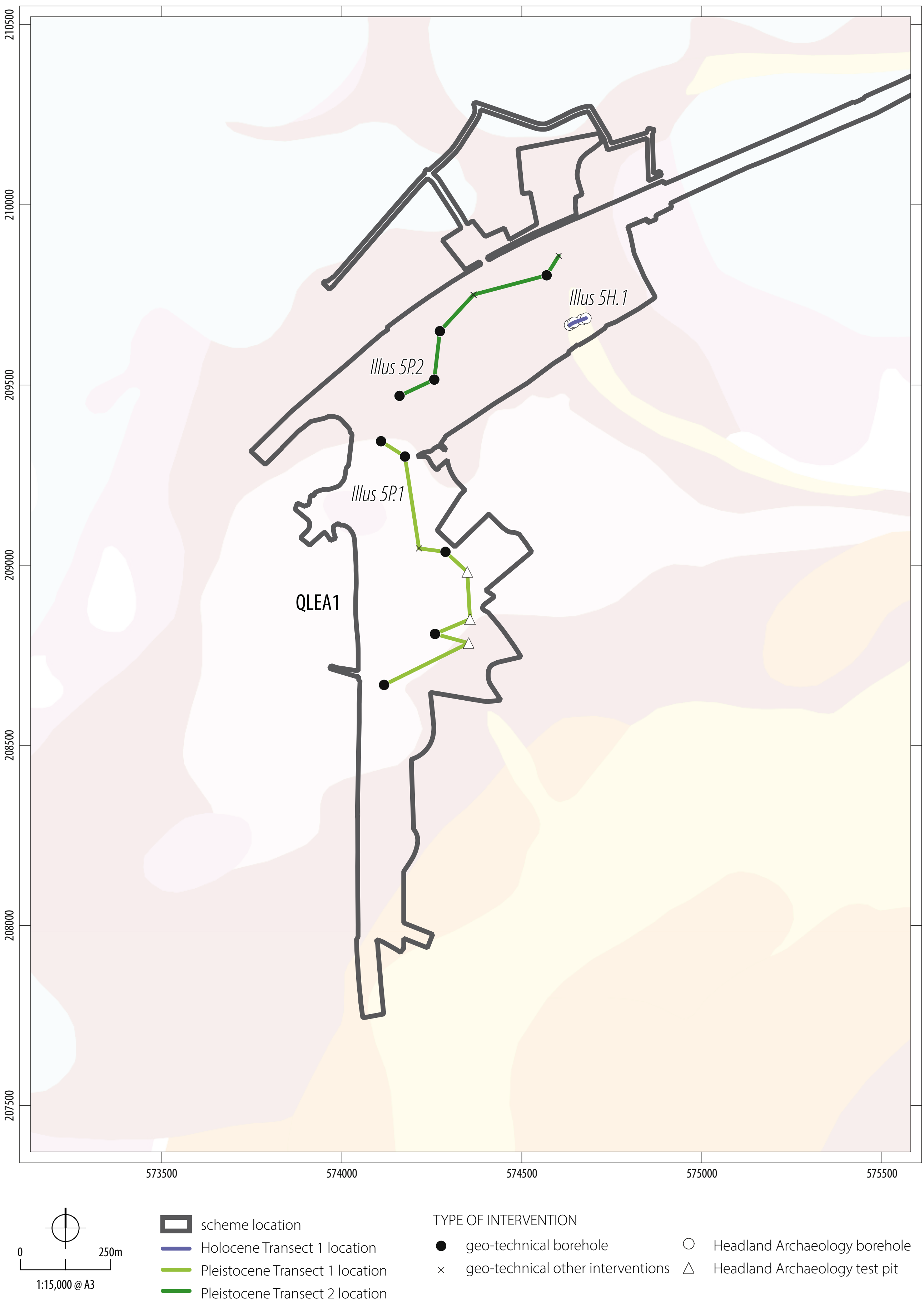
ILLUS 3A.5 Close-up of QLEA5 showing heat map based on all interventions

ILLUS 3B.5 Close-up of QLEA5 showing heat map based on only interventions that reach 5 metres below surface level

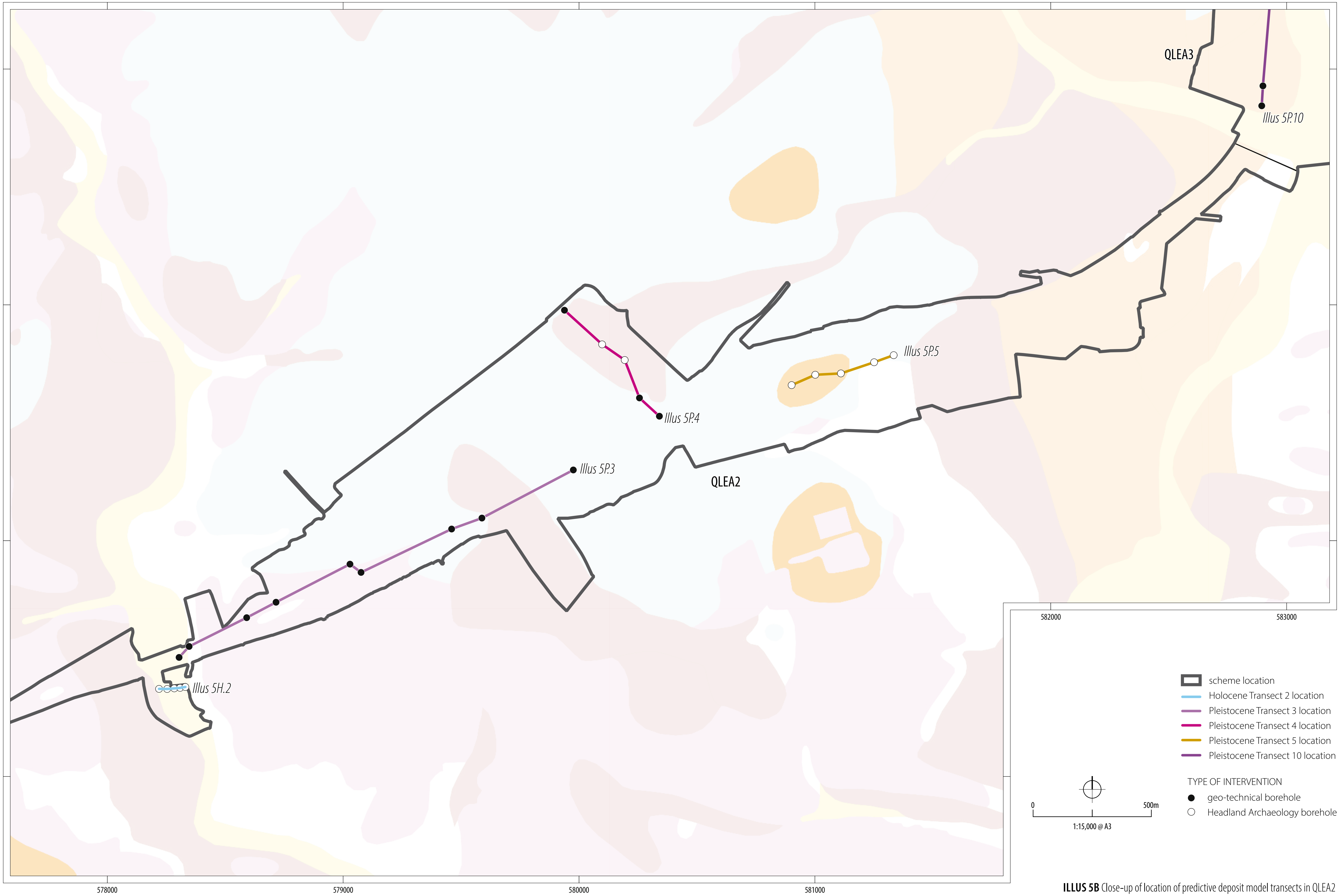
ILLUS 4 Surface elevation model for top of Till. Points indicate the location where Till deposits were detected in a geotechnical or geoarchaeological intervention. Shading indicates elevation (metres above/below datum)



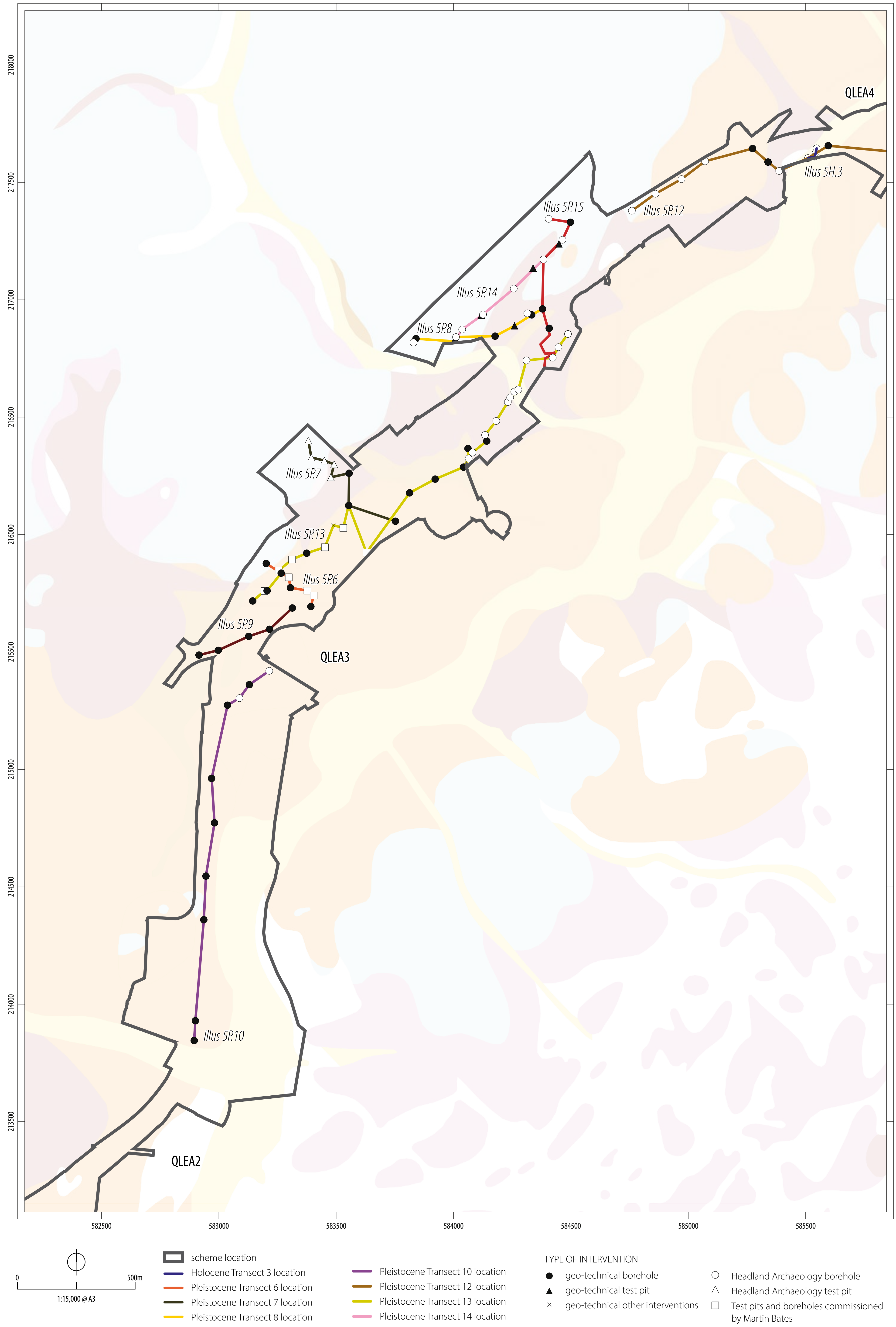
ILLUS 5 Location of predictive deposit model transects



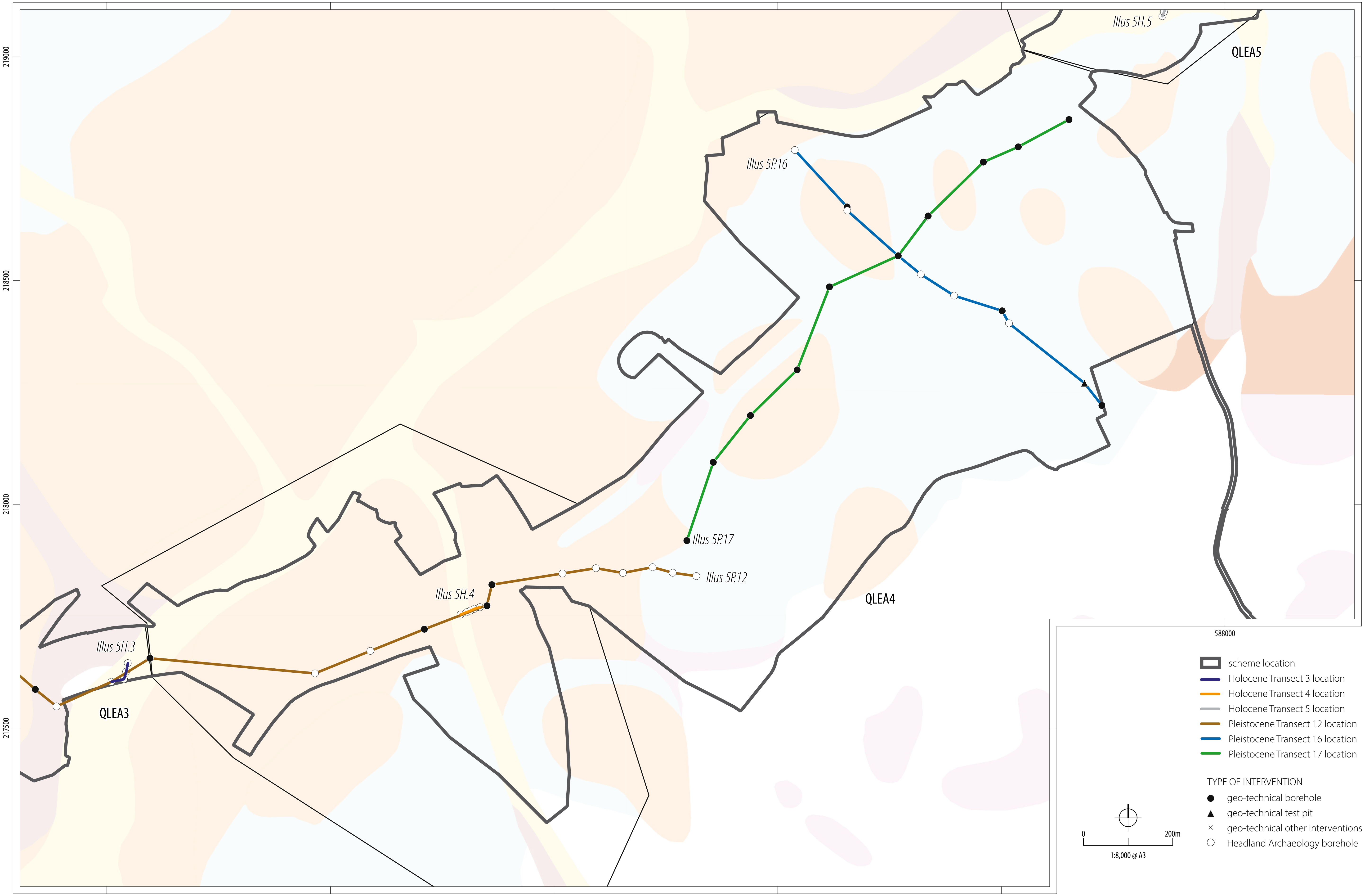
ILLUS 5A Close-up of location of predictive deposit model transects in QLEA1



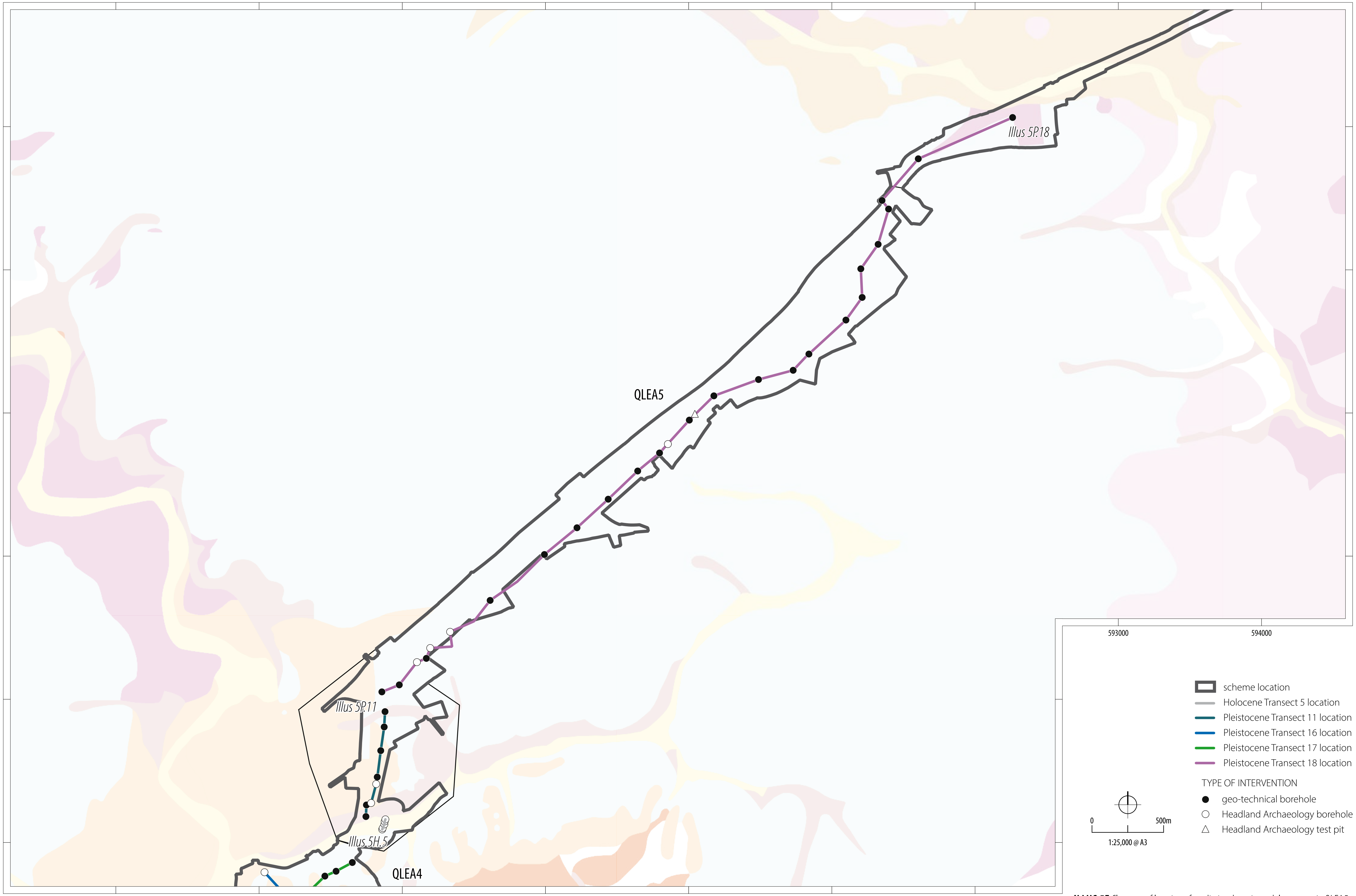
ILLUS 5B Close-up of location of predictive deposit model transects in QLEA2



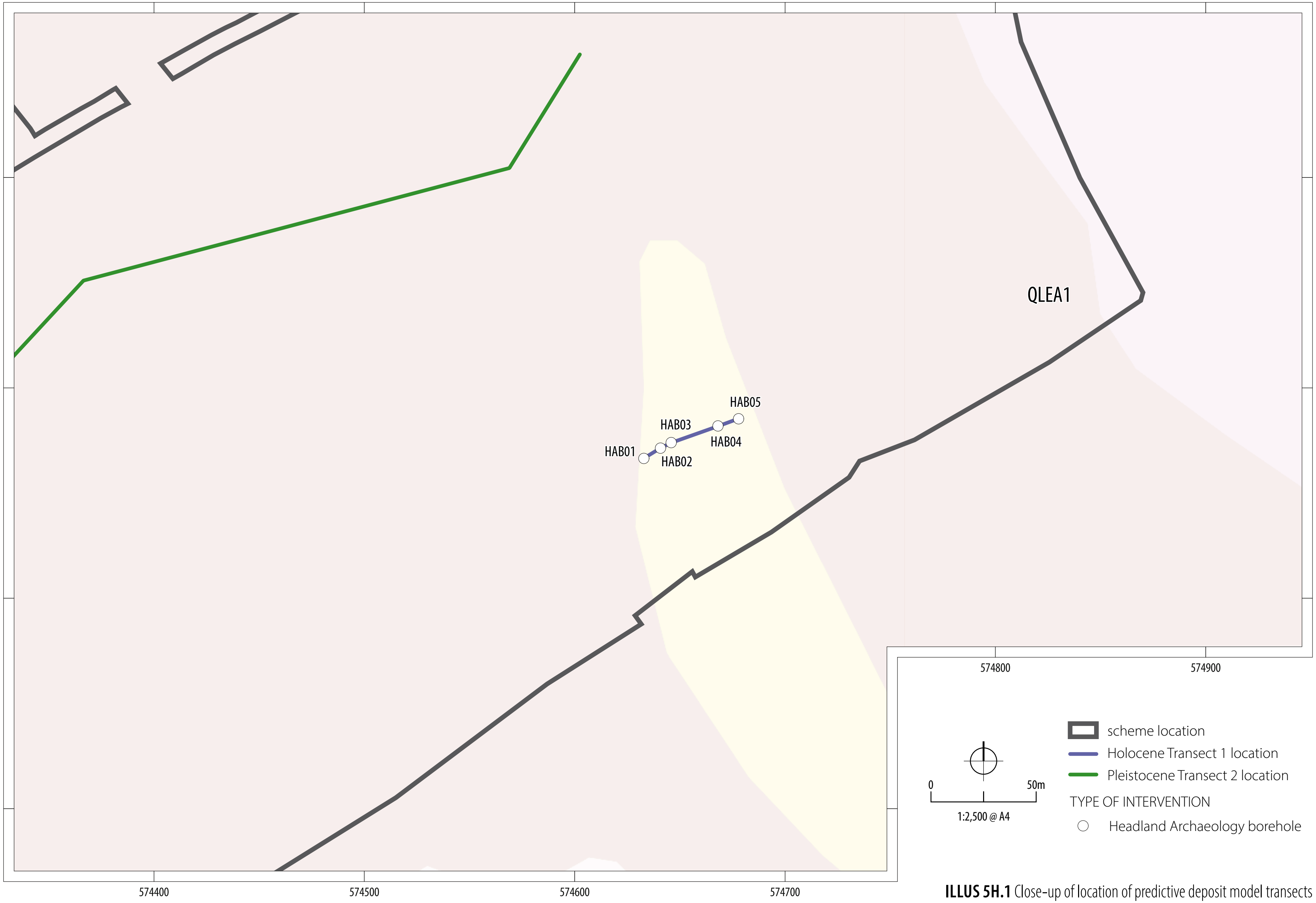
ILLUS 5C Close-up of location of predictive deposit model transects in QLEA3



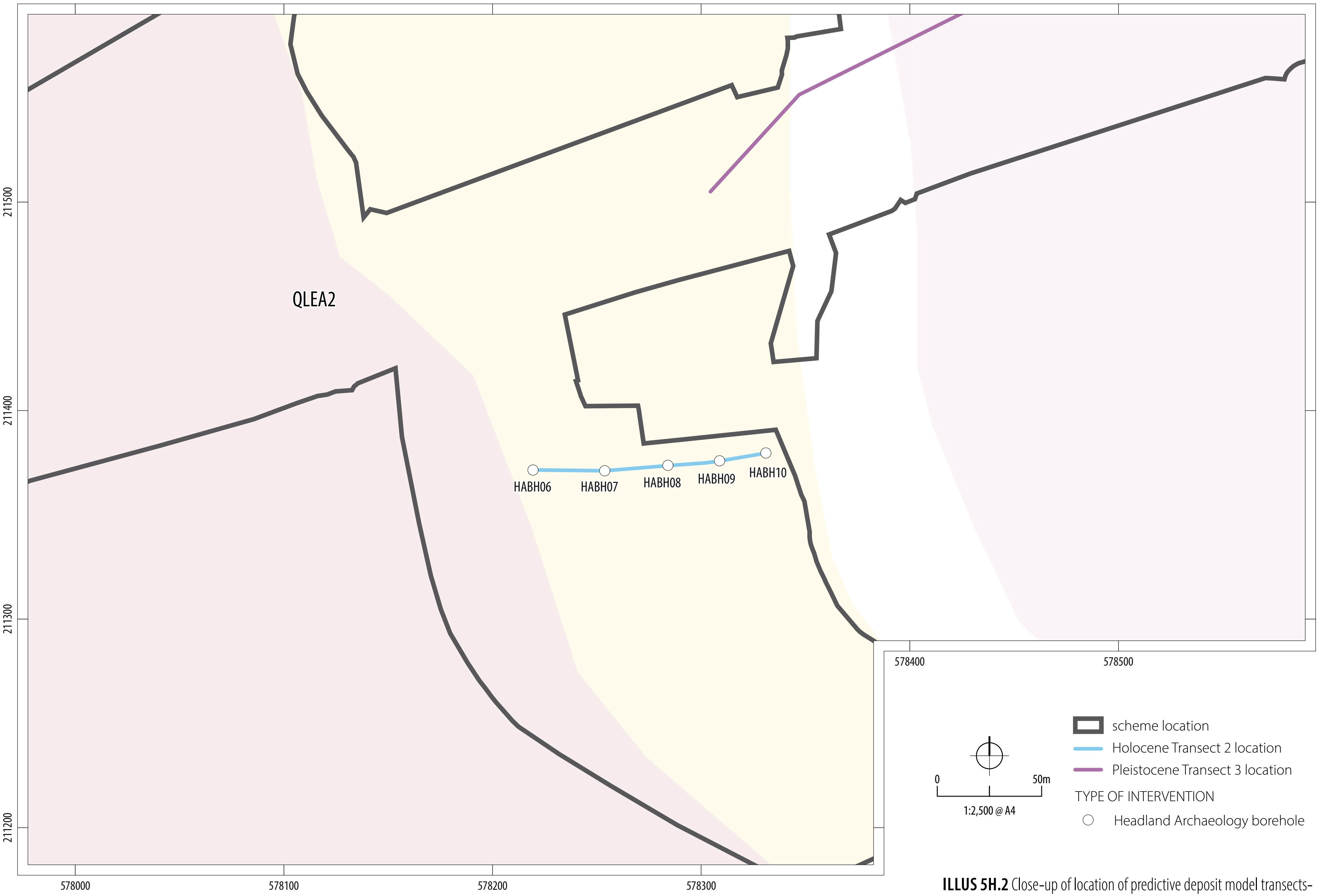
ILLUS 5D Close-up of location of predictive deposit model transects in QLEA4



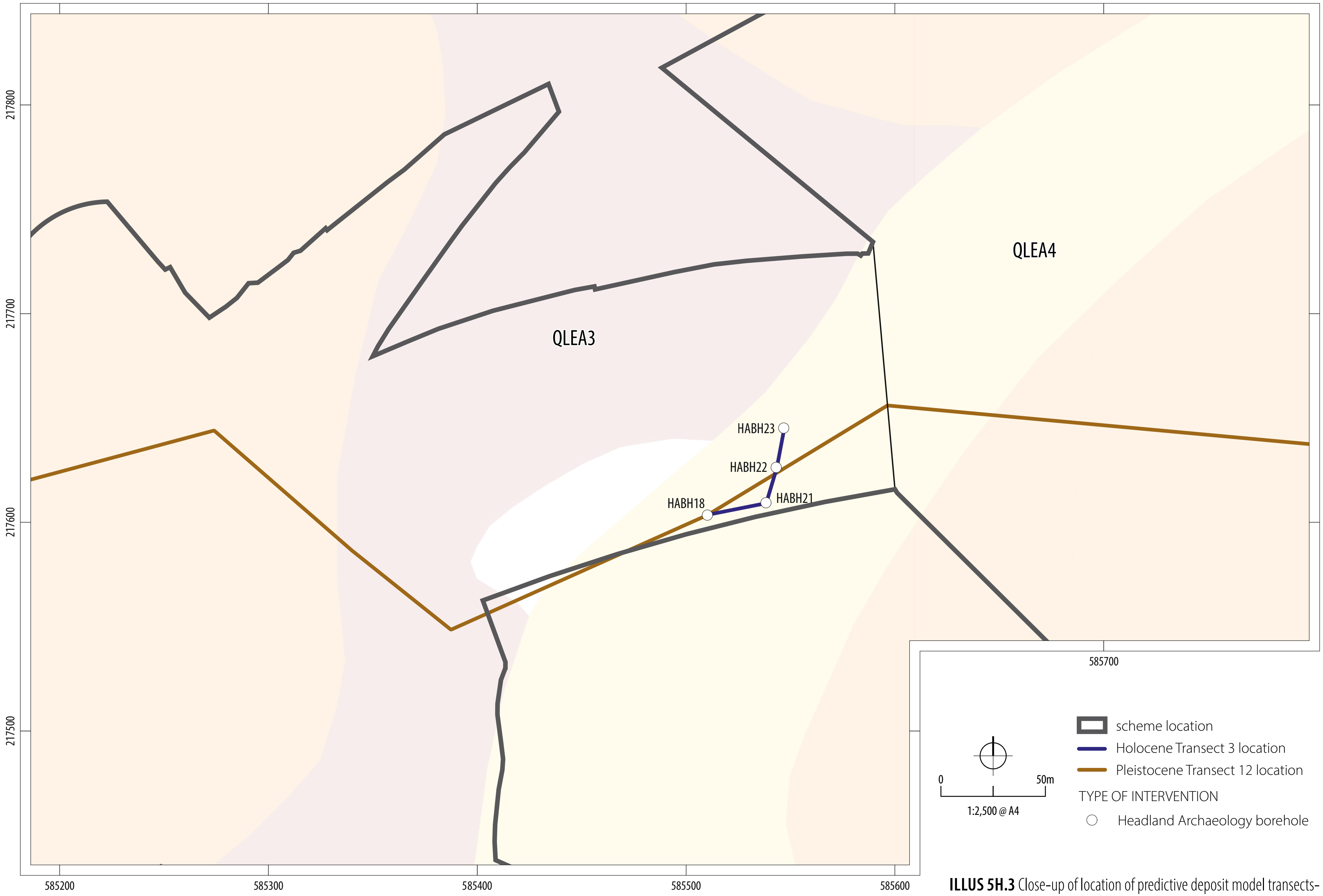
ILLUS 5E Close-up of location of predictive deposit model transects in QLEA5



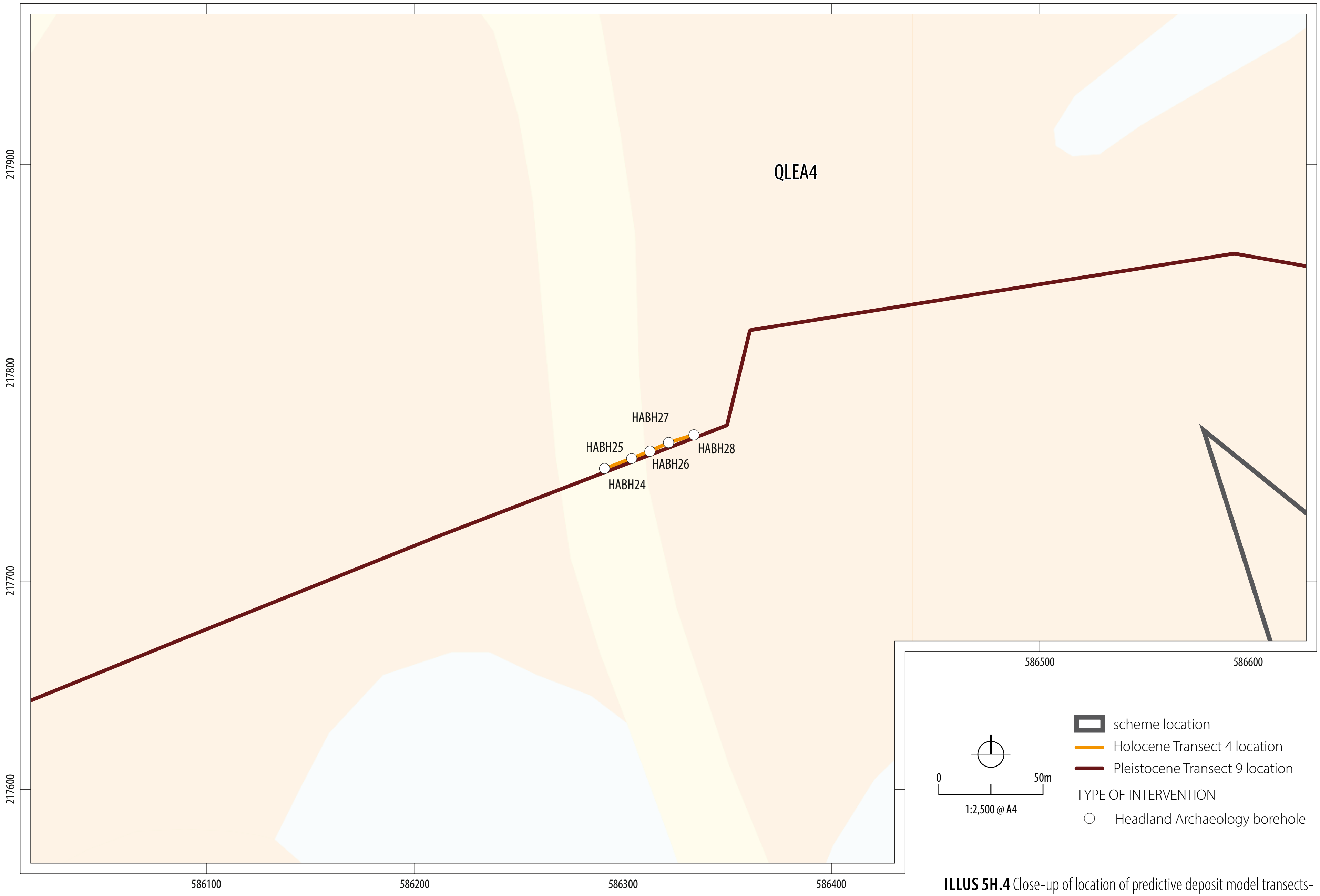
ILLUS 5H.1 Close-up of location of predictive deposit model transects -Holocene Transect 1 - Boreham tributary



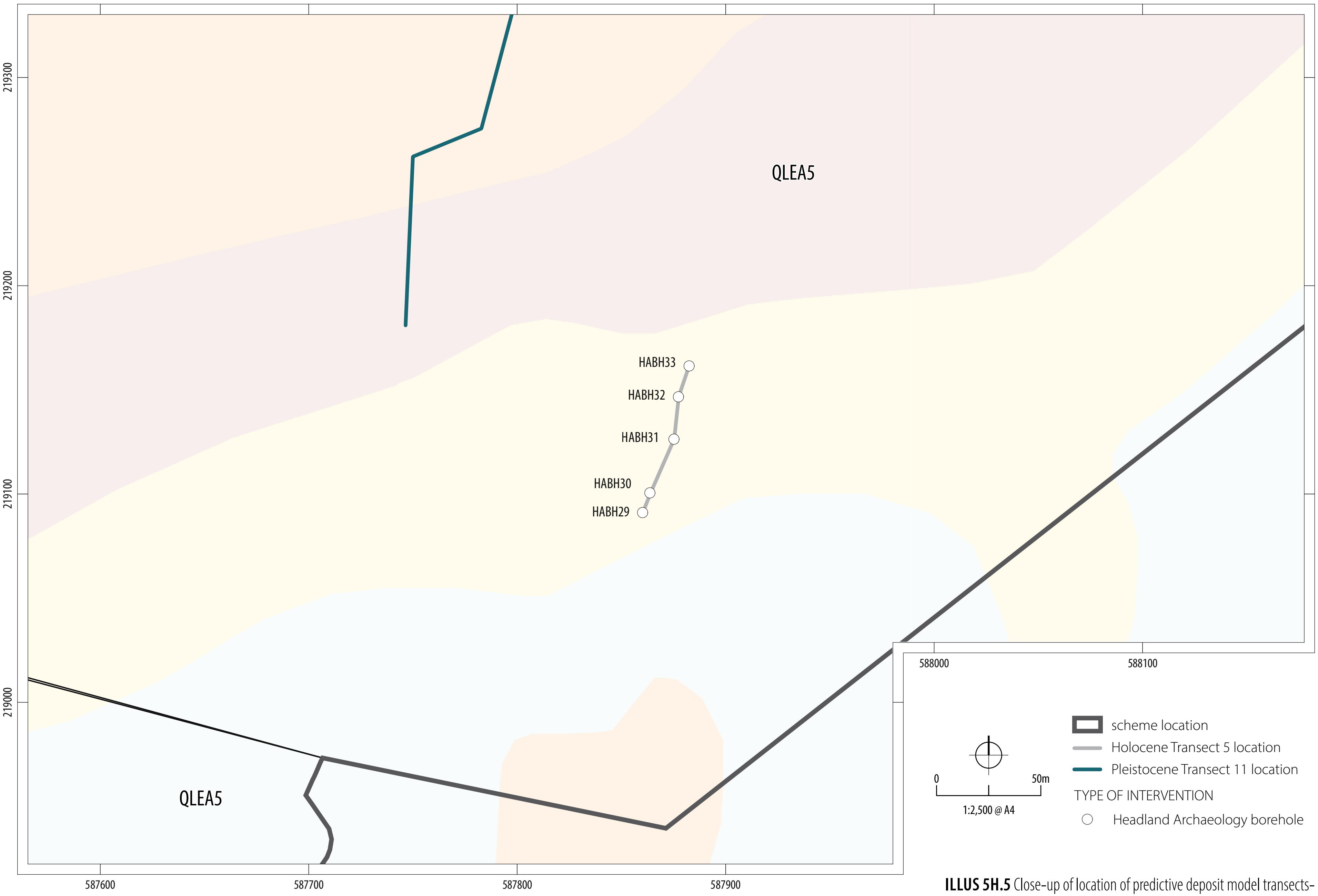
ILLUS 5H.2 Close-up of location of predictive deposit model transects- Holocene Transect 2 - River Ter



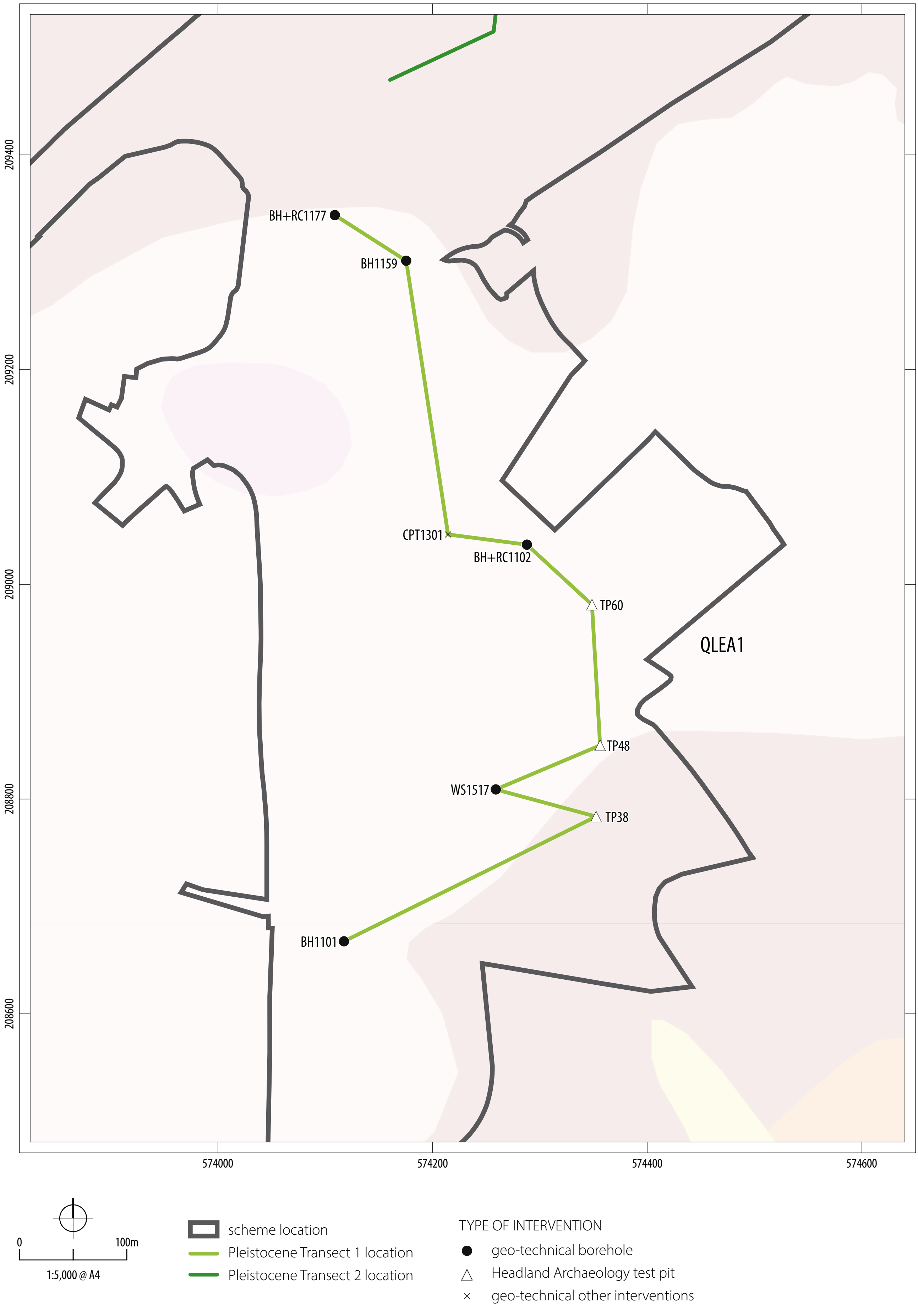
ILLUS 5H.3 Close-up of location of predictive deposit model transects- Holocene Transect 4 - River Blackwater



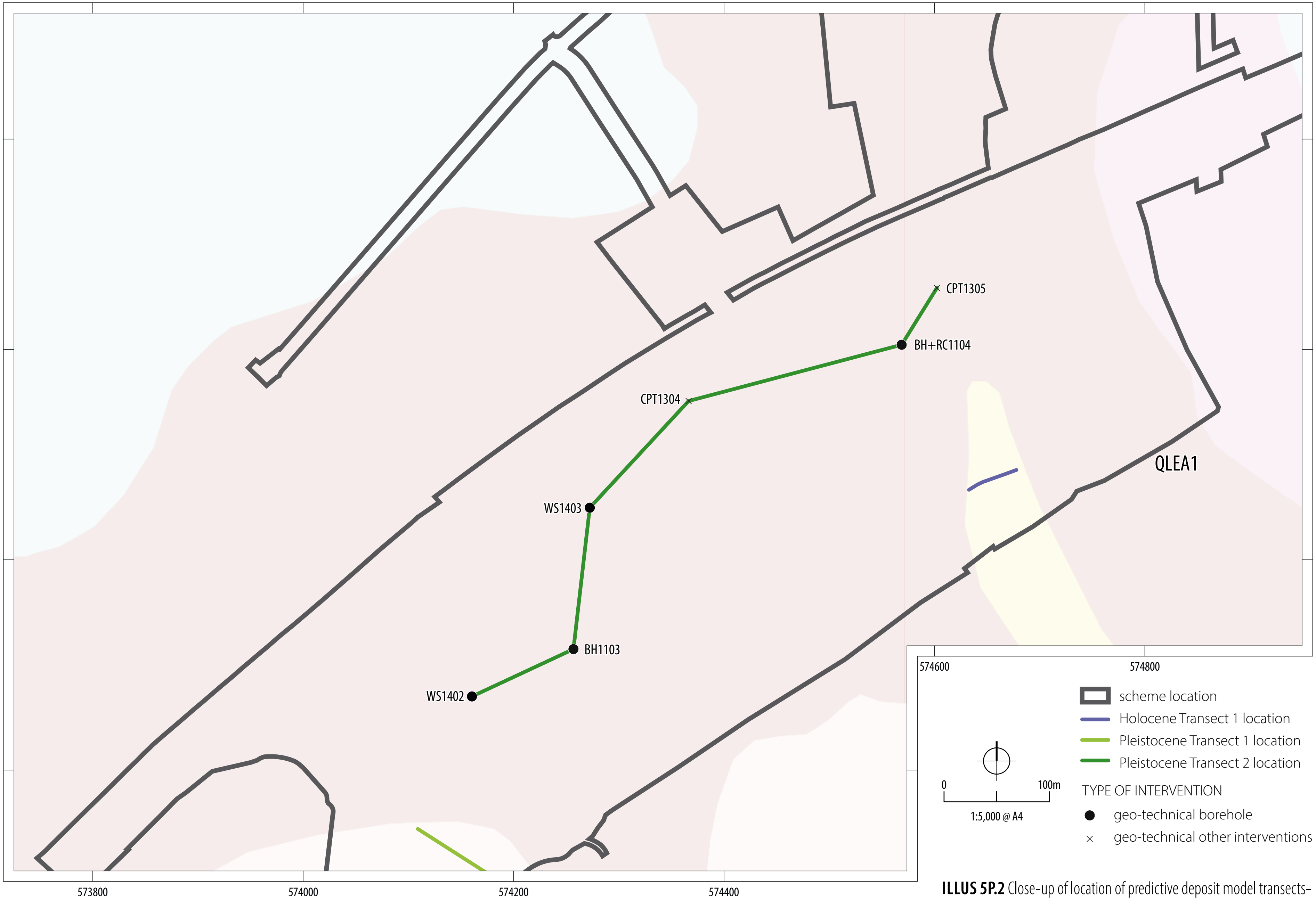
ILLUS 5H.4 Close-up of location of predictive deposit model transects-Holocene Transect 5 - Blackwater Tributary



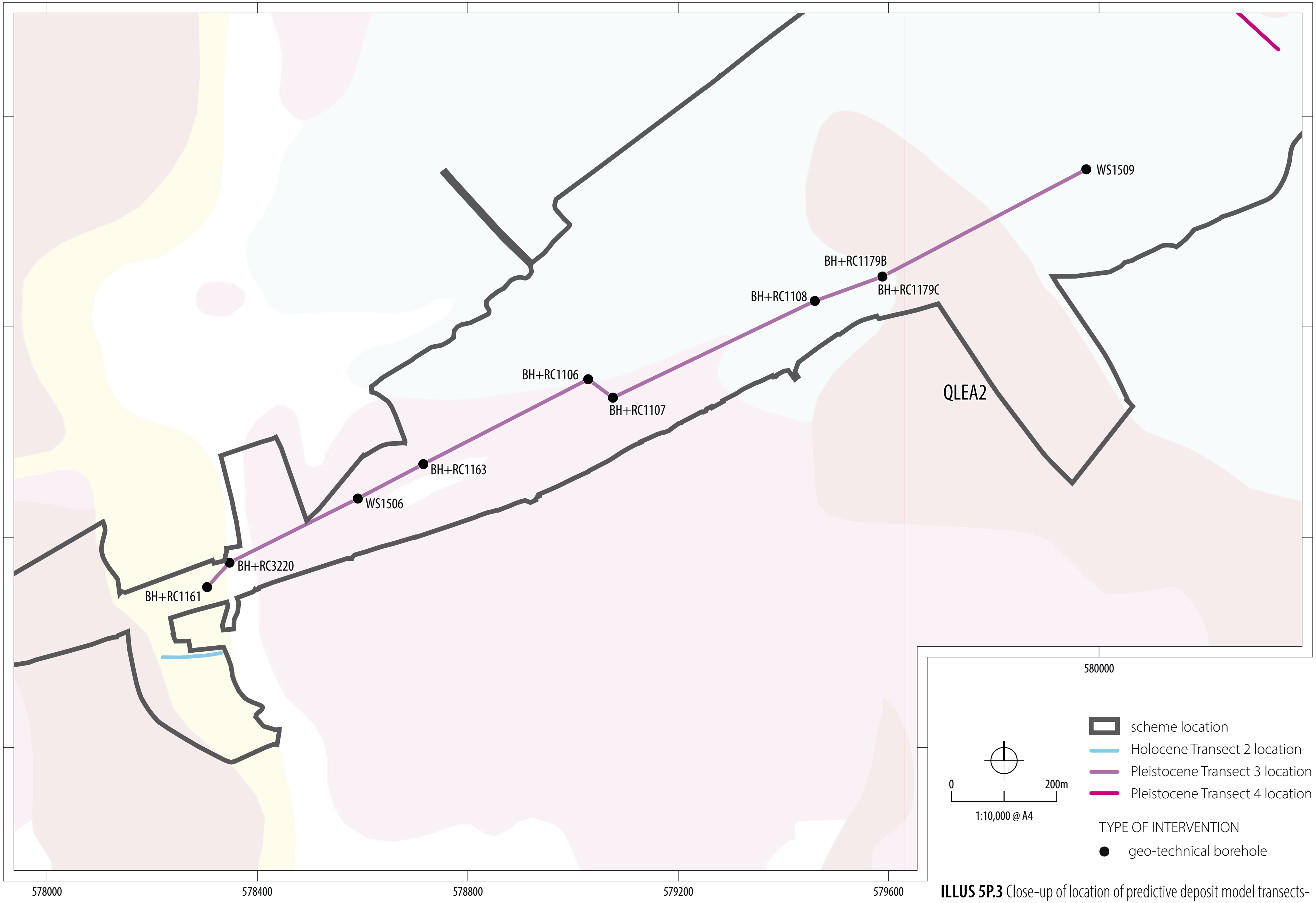
ILLUS 5H.5 Close-up of location of predictive deposit model transects- Holocene Transect 6 - Domsey Brook



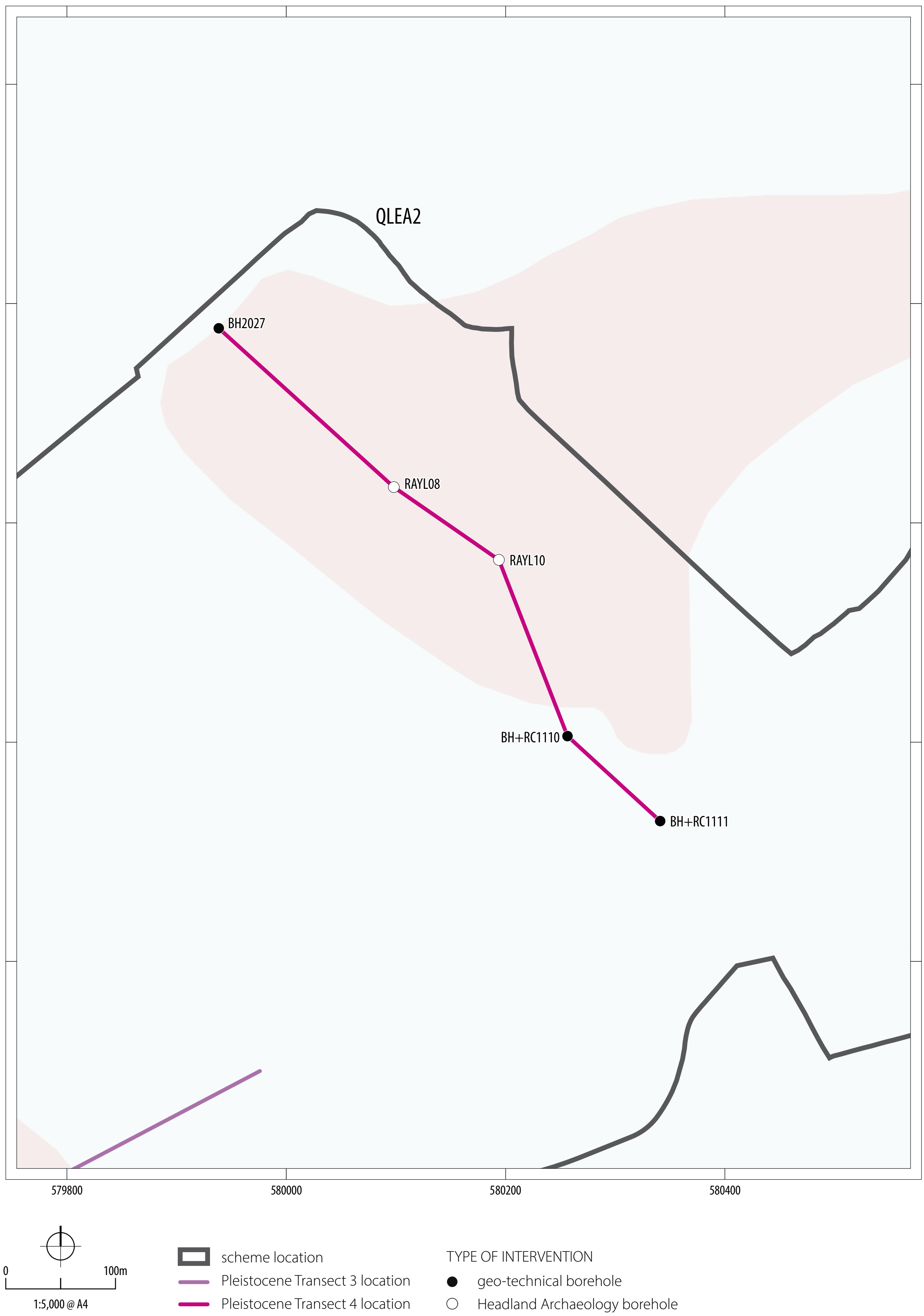
ILLUS 5P.1 Close-up of location of predictive deposit model transects-Pleistocene Transect 1



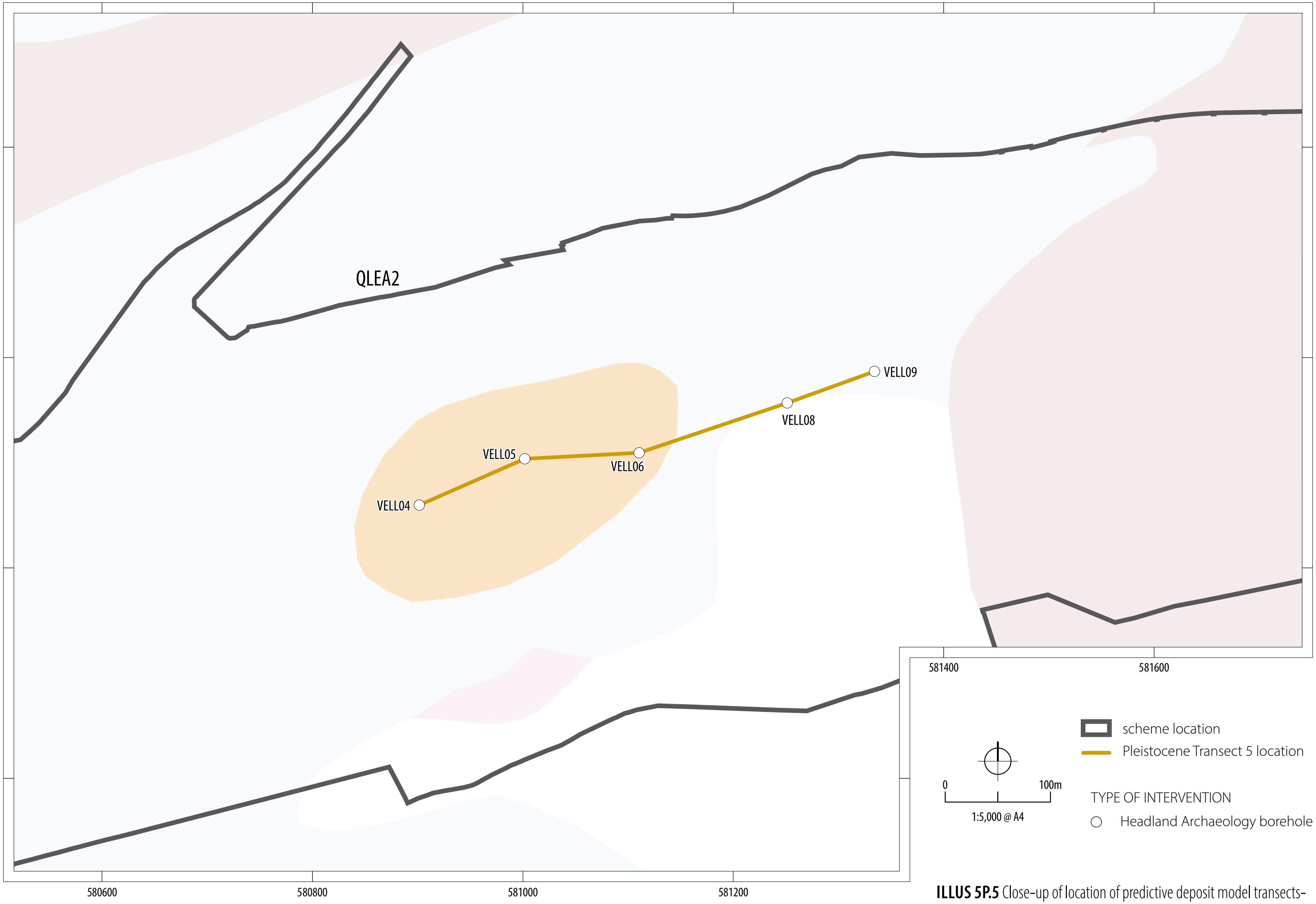
ILLUS 5P.2 Close-up of location of predictive deposit model transects- Pleistocene Transect 2



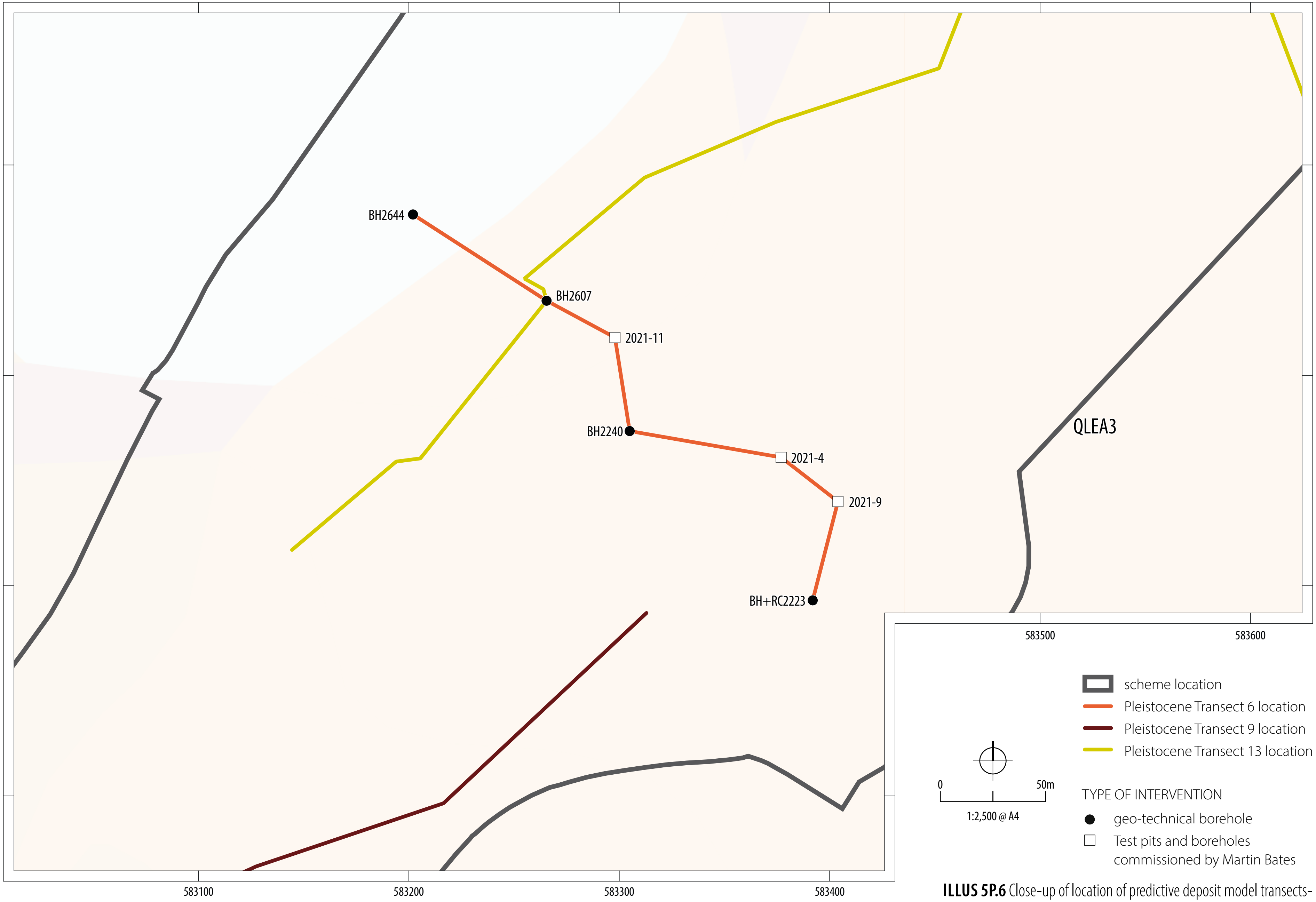
ILLUS 5P.3 Close-up of location of predictive deposit model transects-Pleistocene Transect 3



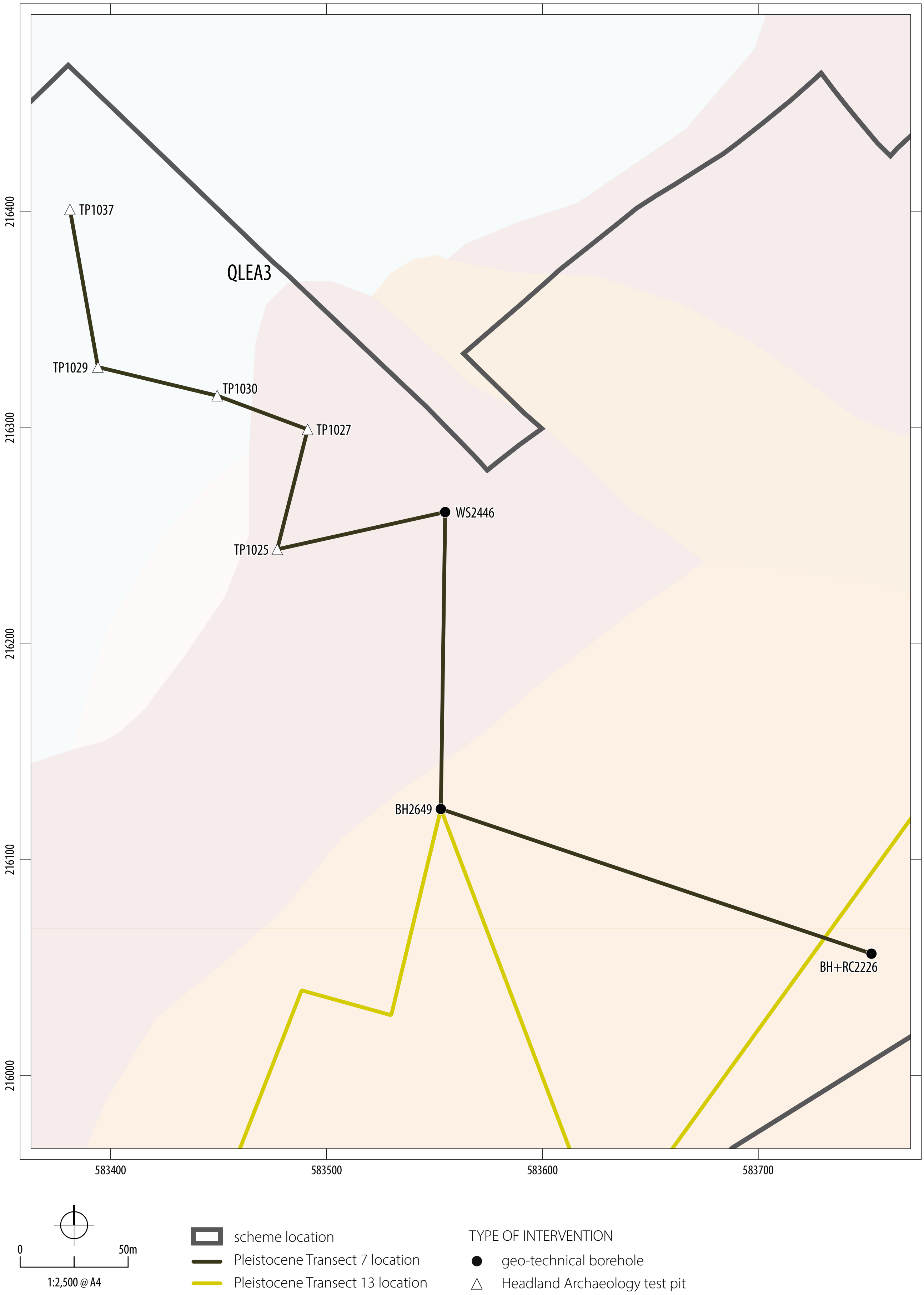
ILLUS 5P.4 Close-up of location of predictive deposit model transects-Pleistocene Transect 4



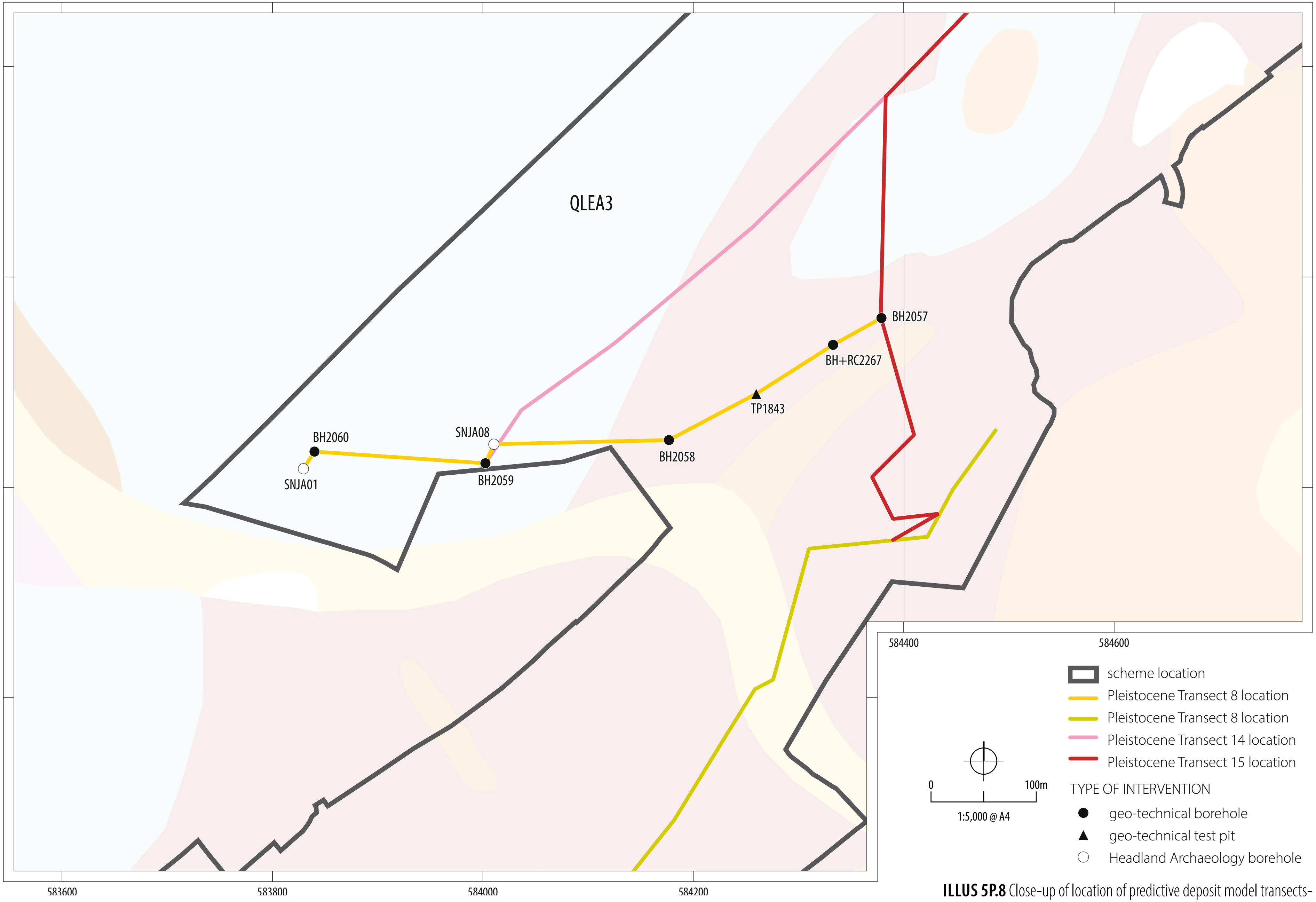
ILLUS 5P.5 Close-up of location of predictive deposit model transects- Pleistocene Transect 5



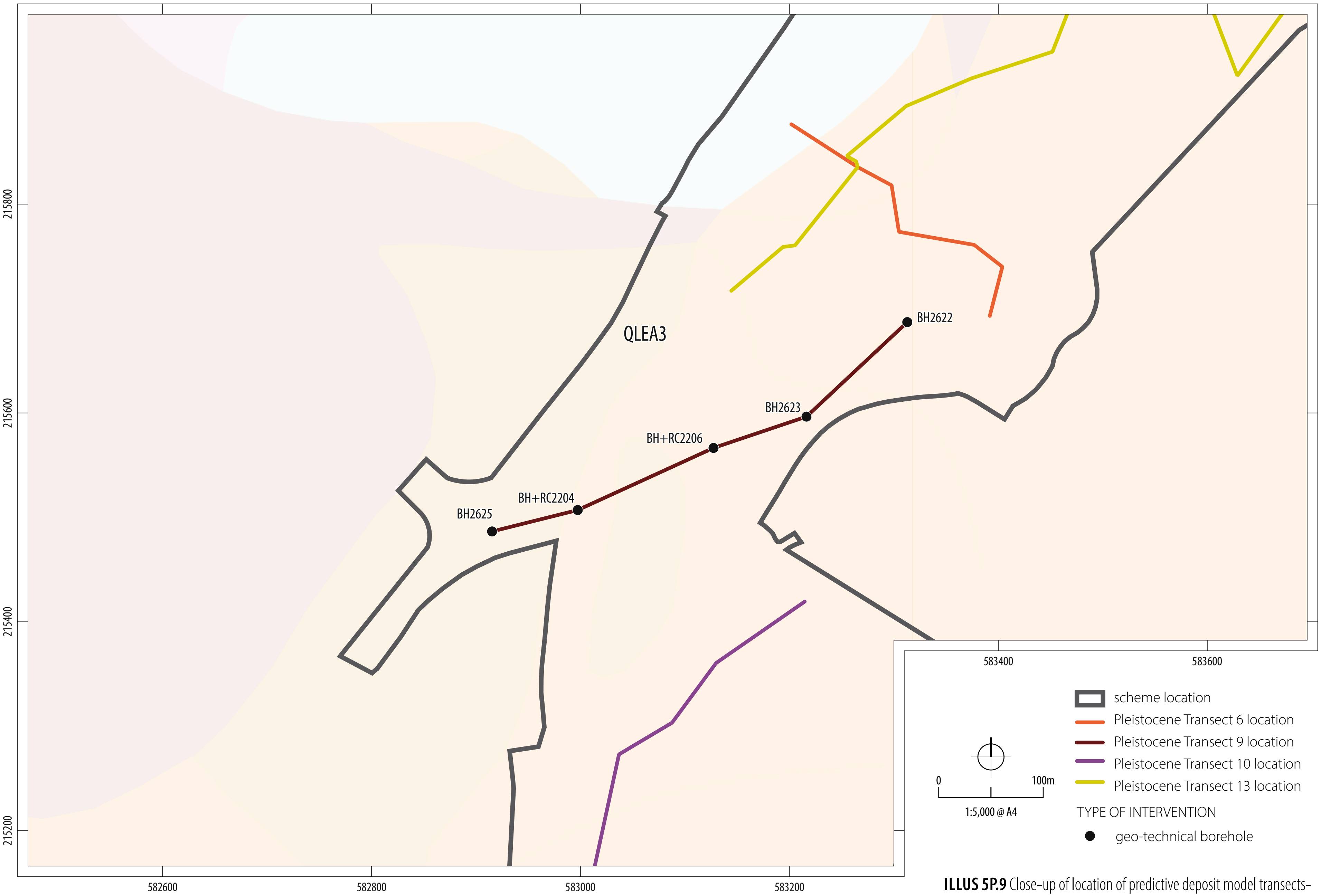
ILLUS 5P.6 Close-up of location of predictive deposit model transects- Pleistocene Transect 6



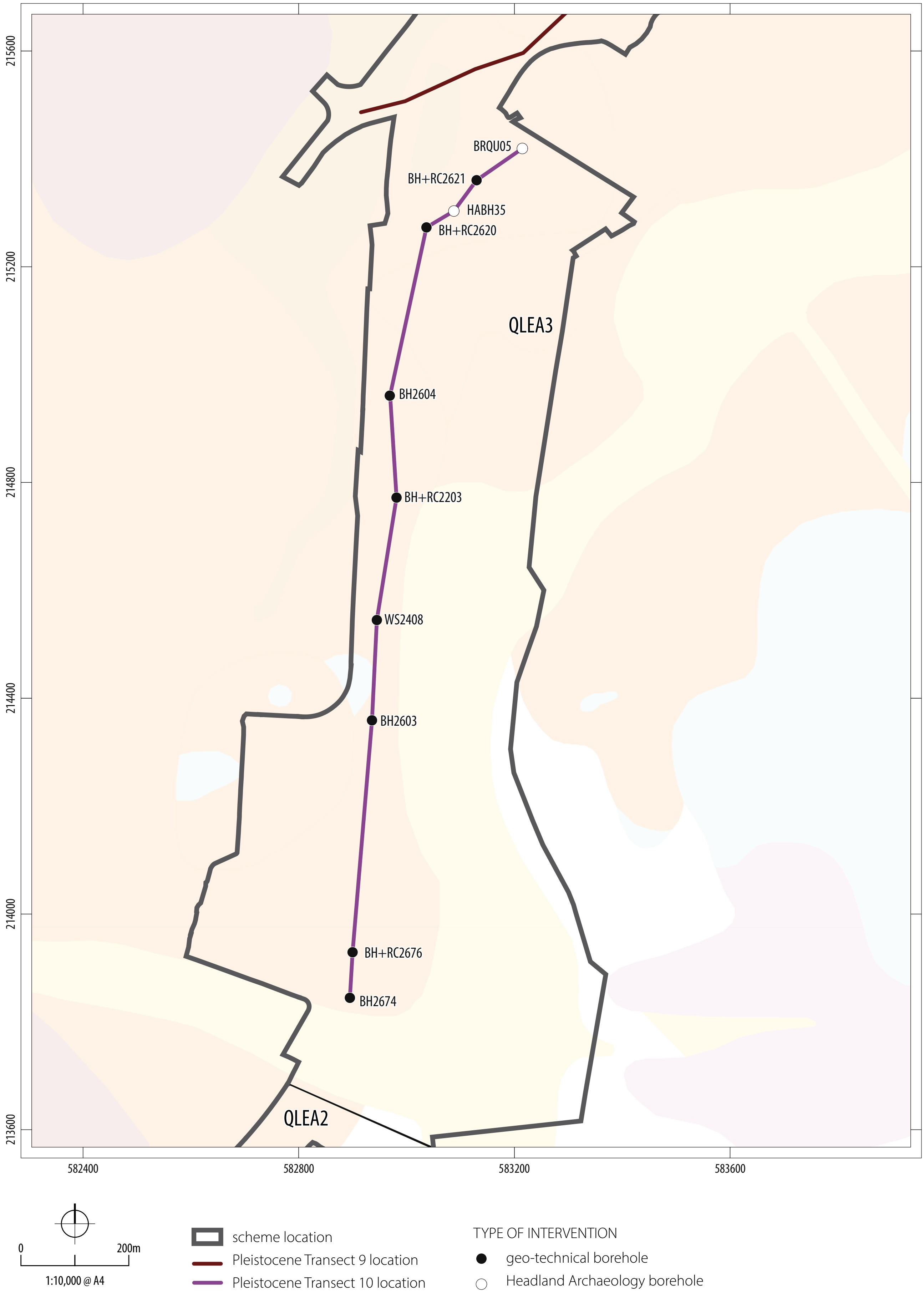
ILLUS 5P.7 Close-up of location of predictive deposit model transects-Pleistocene Transect 7



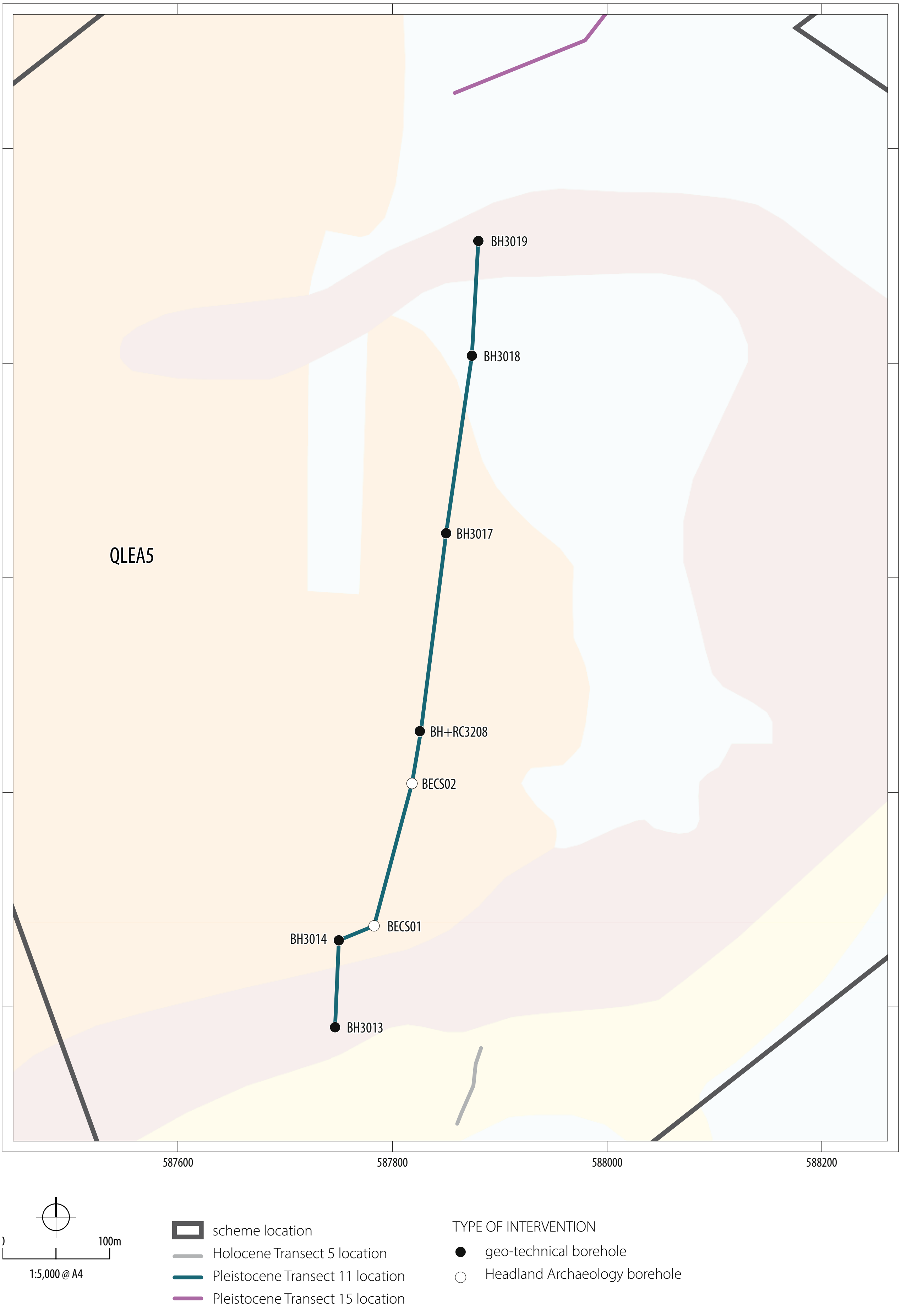
ILLUS 5P.8 Close-up of location of predictive deposit model transects-Pleistocene Transect 8



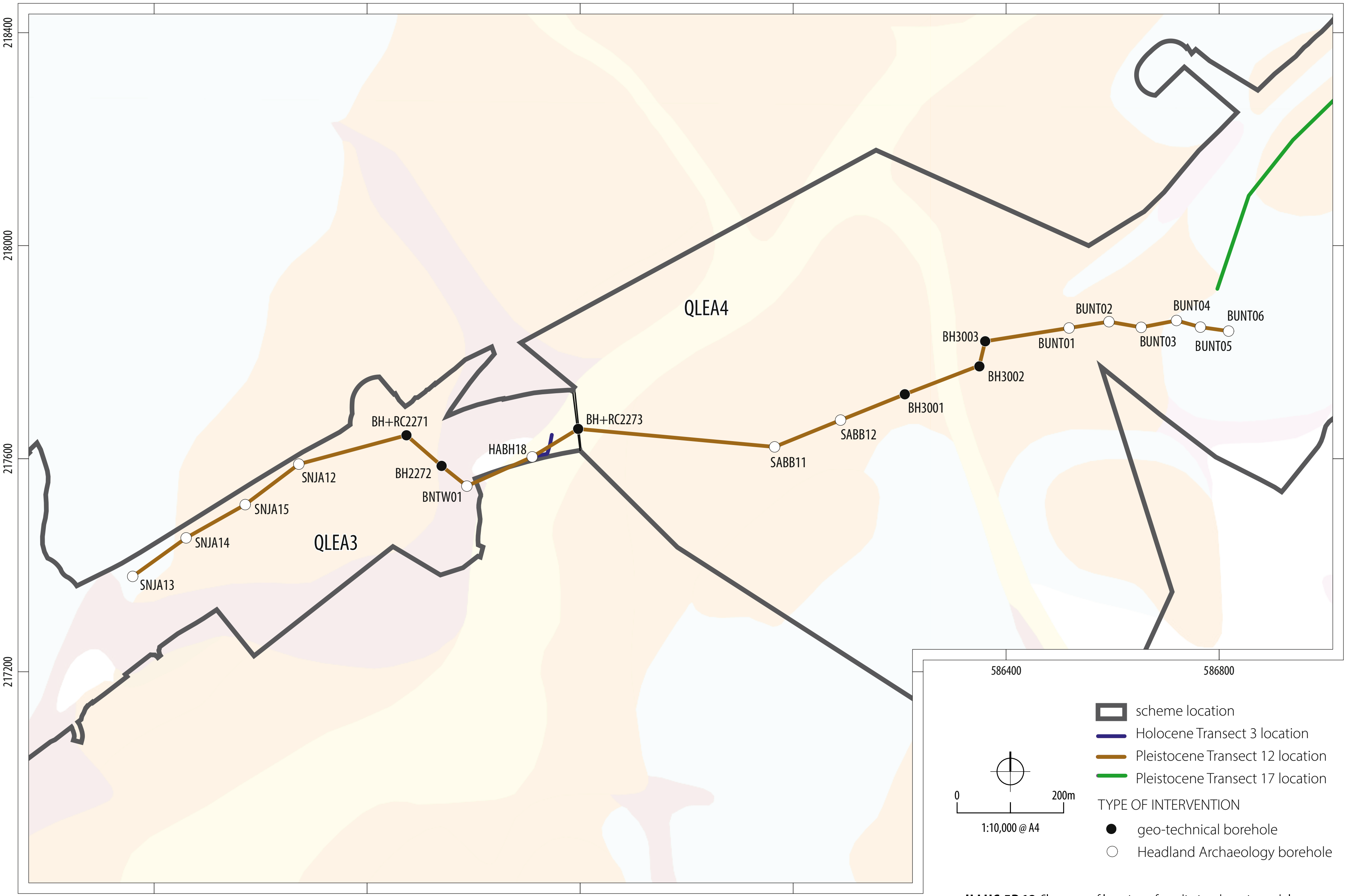
ILLUS 5P.9 Close-up of location of predictive deposit model transects-Pleistocene Transect 9



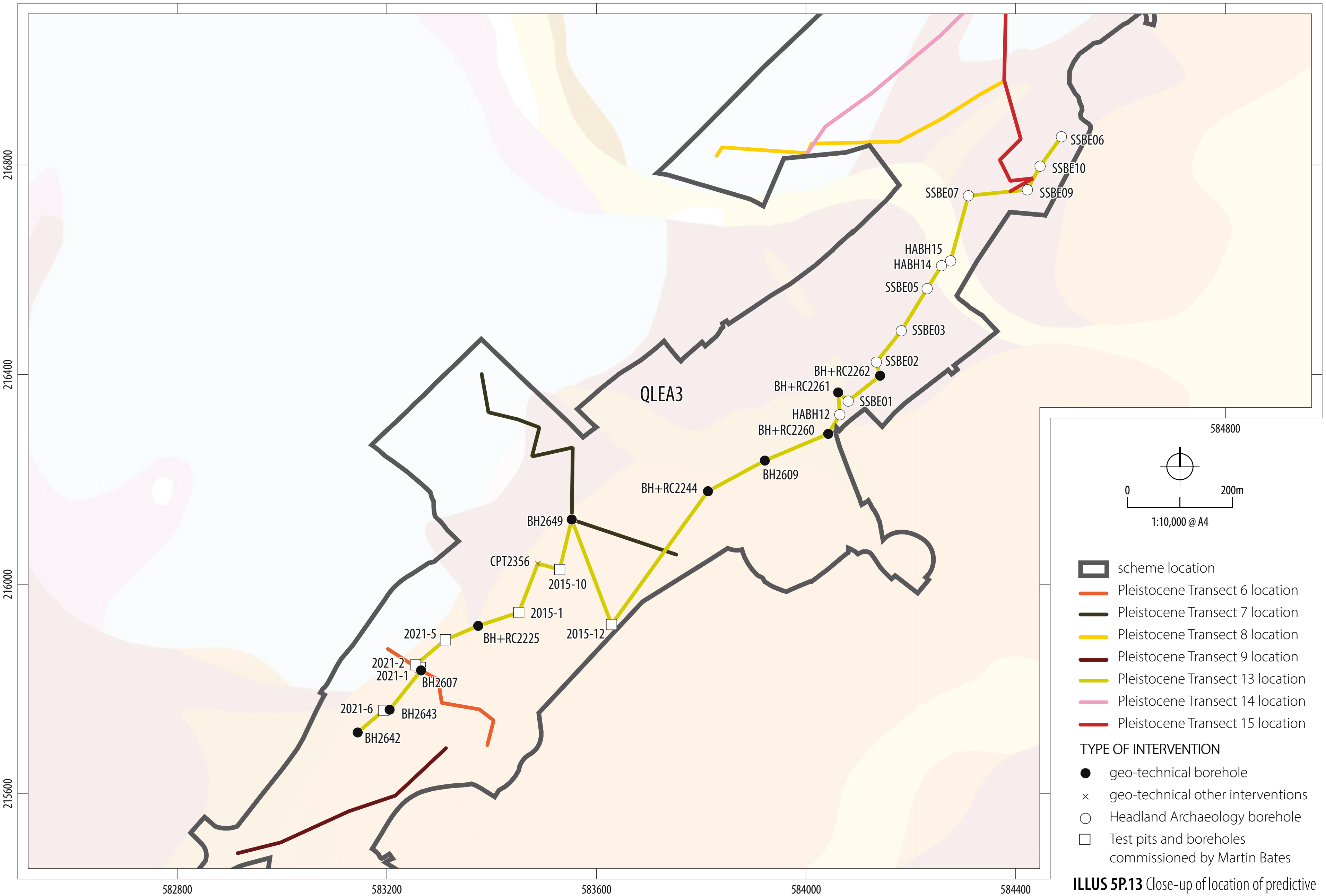
ILLUS 5P.10 Close-up of location of predictive deposit model transects–Pleistocene Transect 10



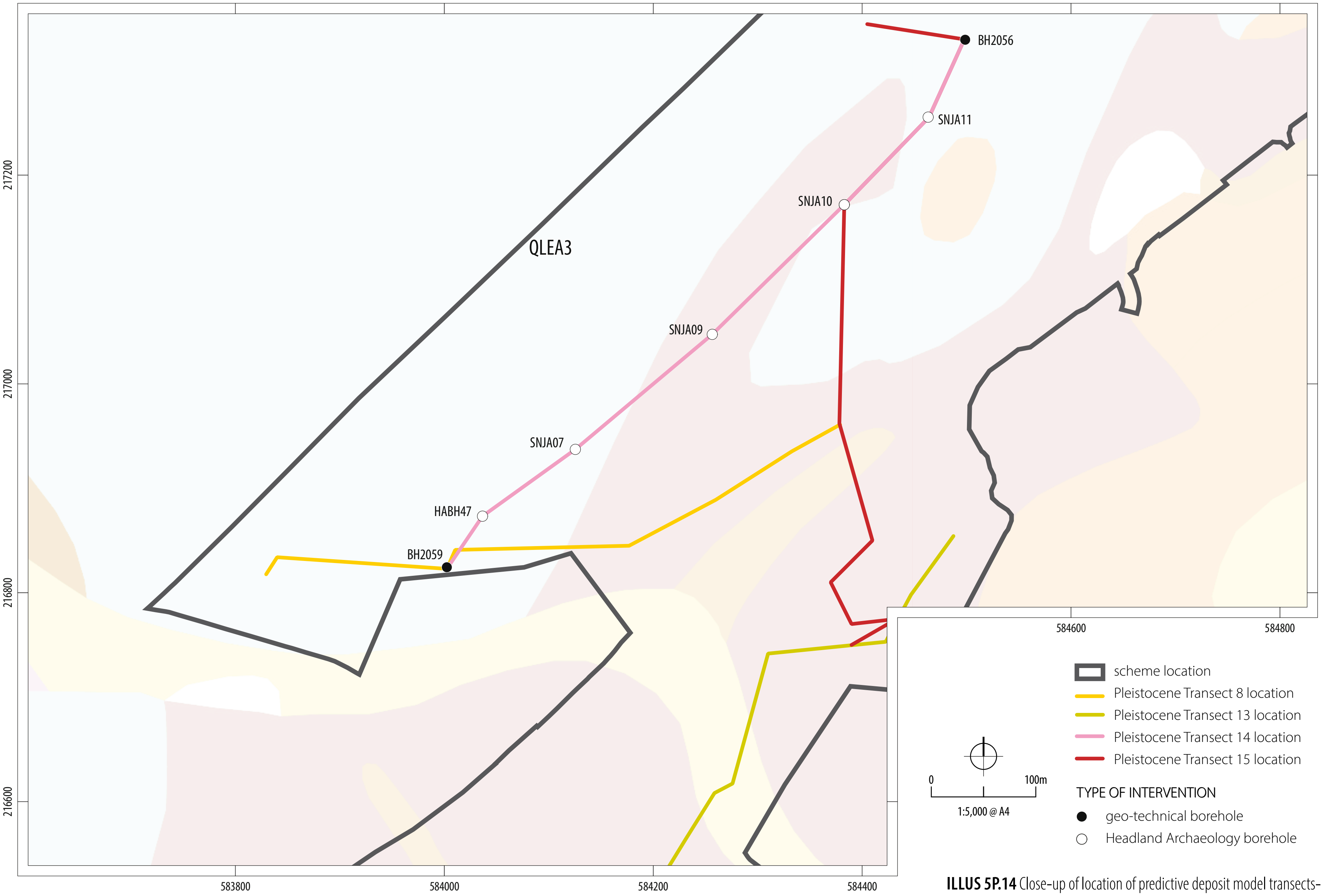
ILLUS 5P.11 Close-up of location of predictive deposit model transects-Pleistocene Transect 11



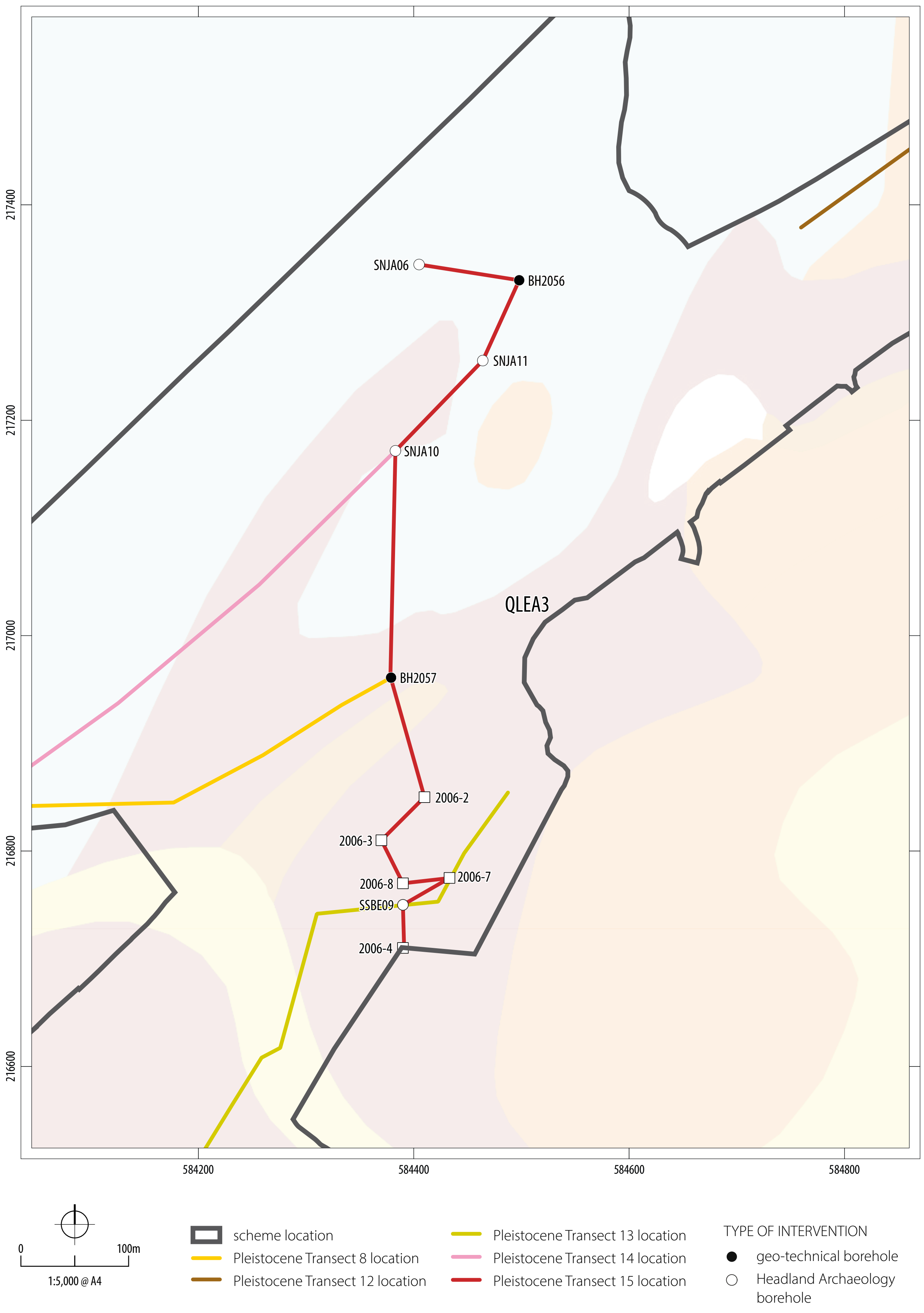
ILLUS 5P.12 Close-up of location of predictive deposit model transects- Pleistocene Transect 12



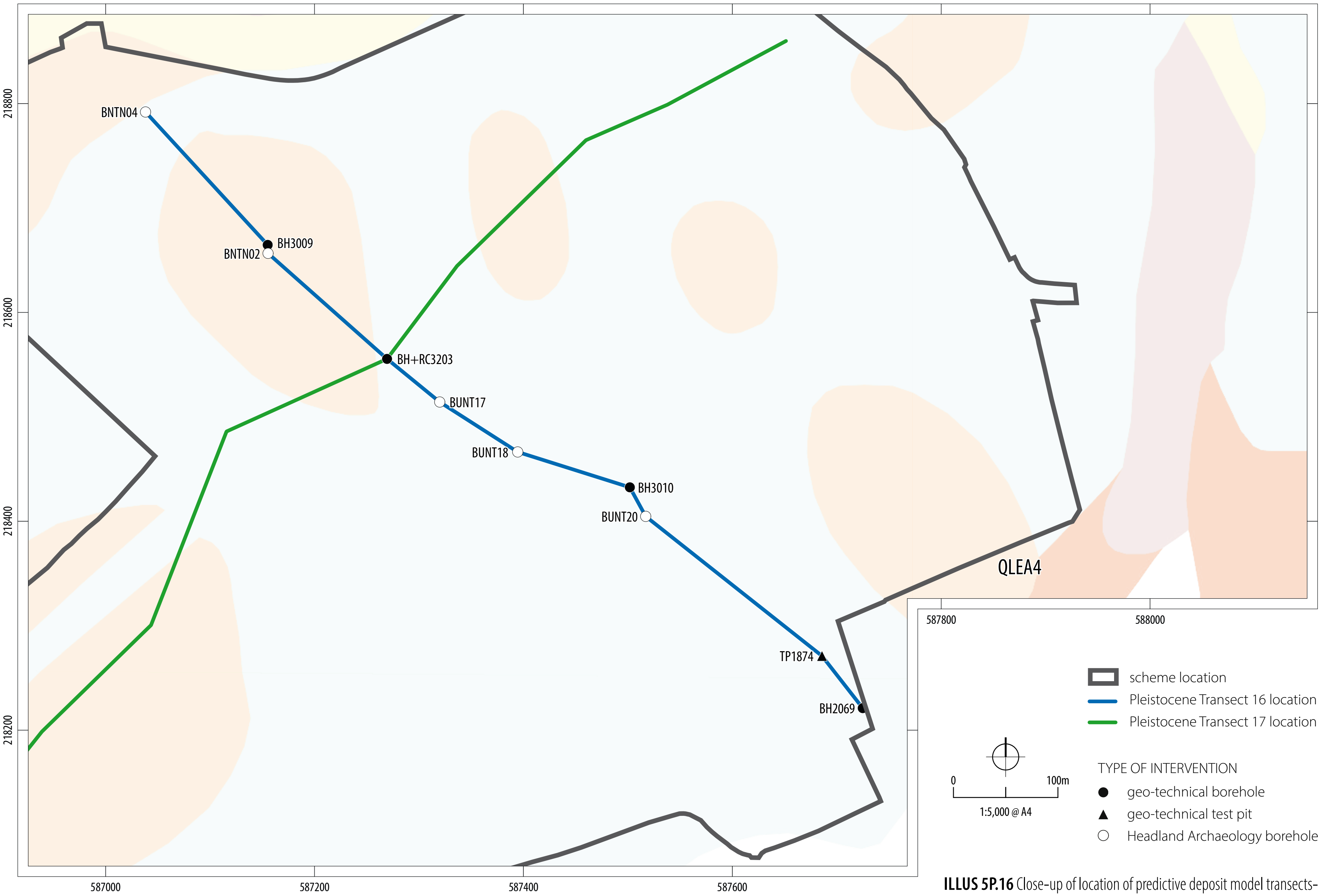
ILLUS 5P.13 Close-up of location of predictive deposit model transects-Pleistocene Transect 13



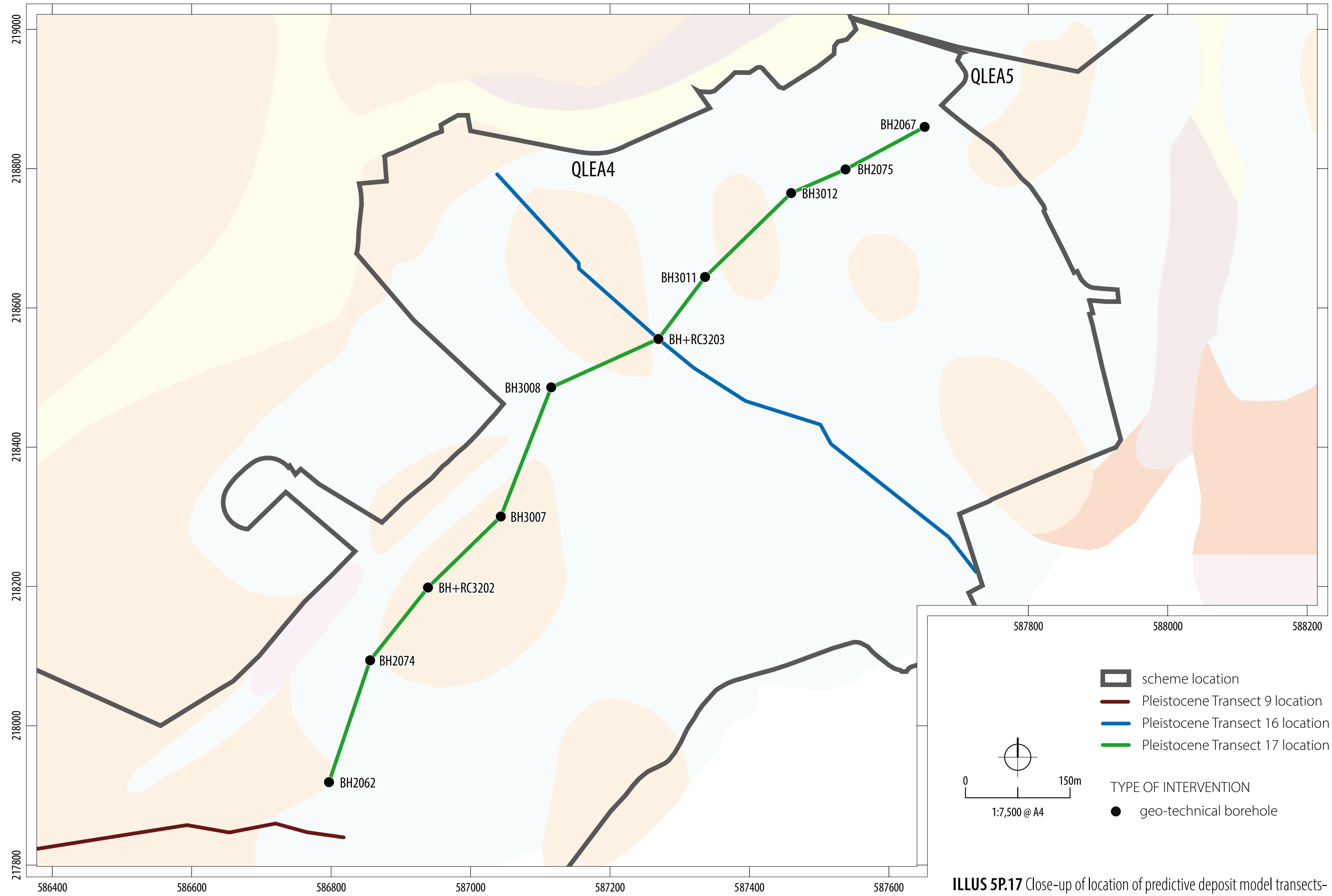
ILLUS 5P.14 Close-up of location of predictive deposit model transects- Pleistocene Transect 14



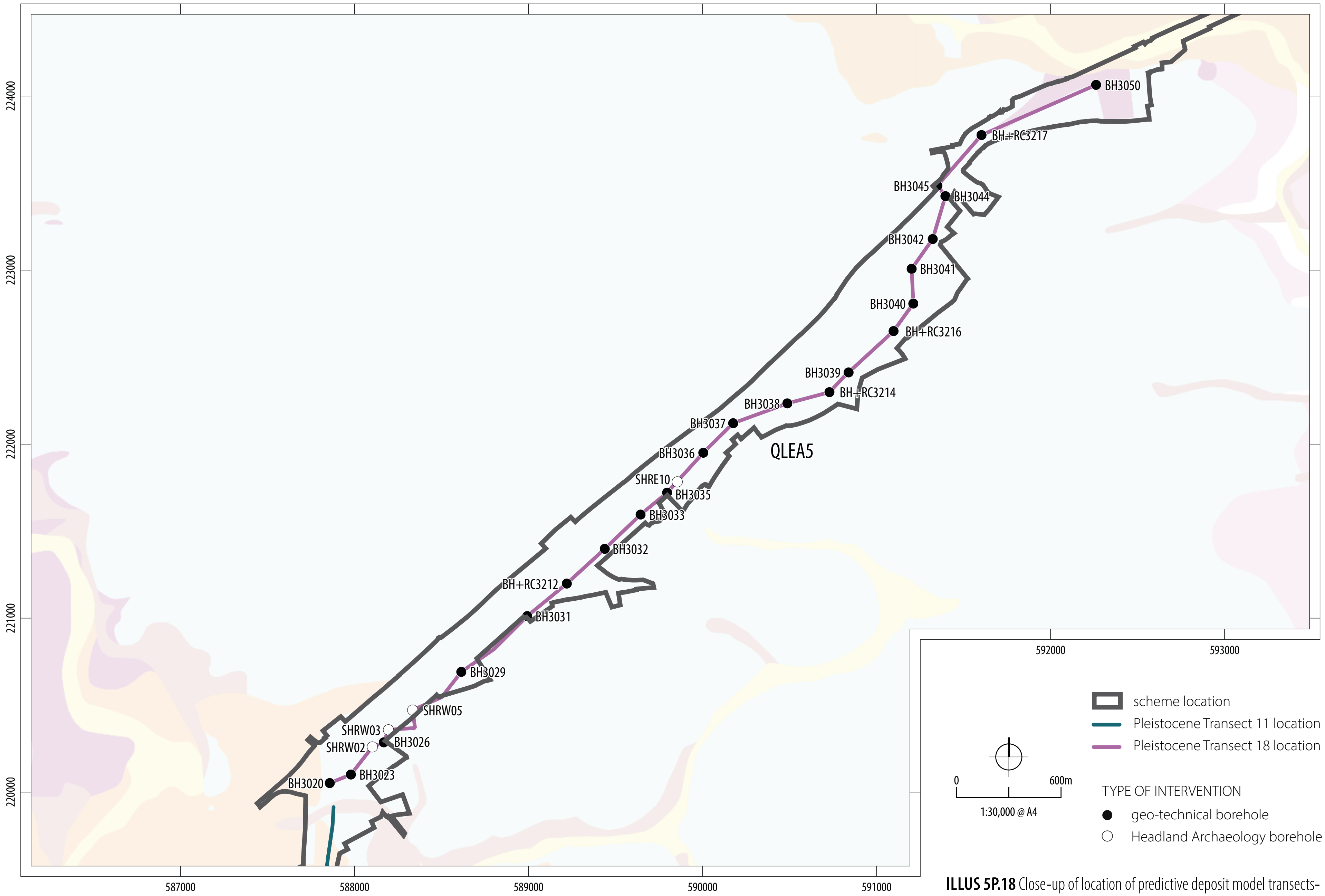
ILLUS 5P.15 Close-up of location of predictive deposit model transects-Pleistocene Transect 15



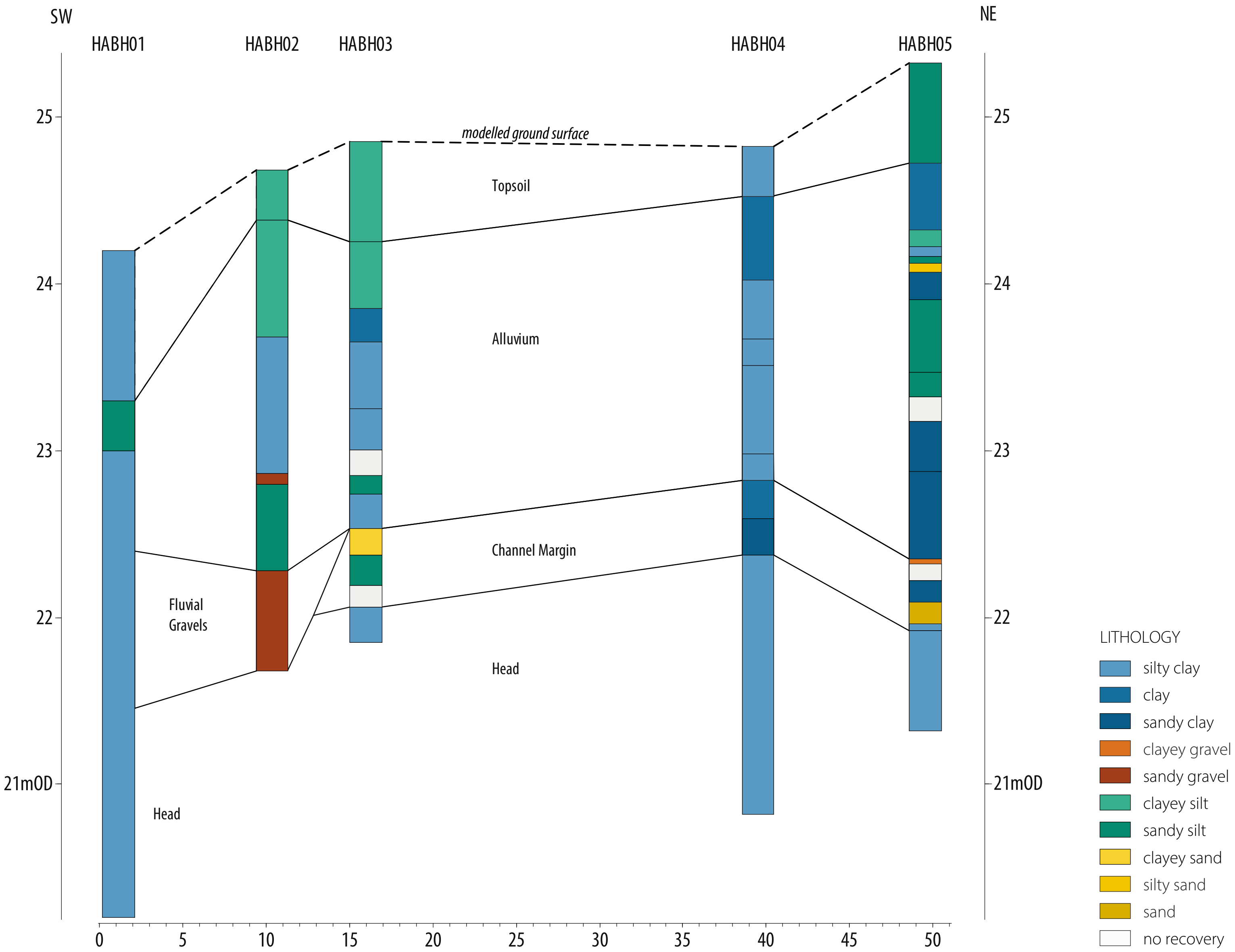
ILLUS 5P.16 Close-up of location of predictive deposit model transects- Pleistocene Transect 16



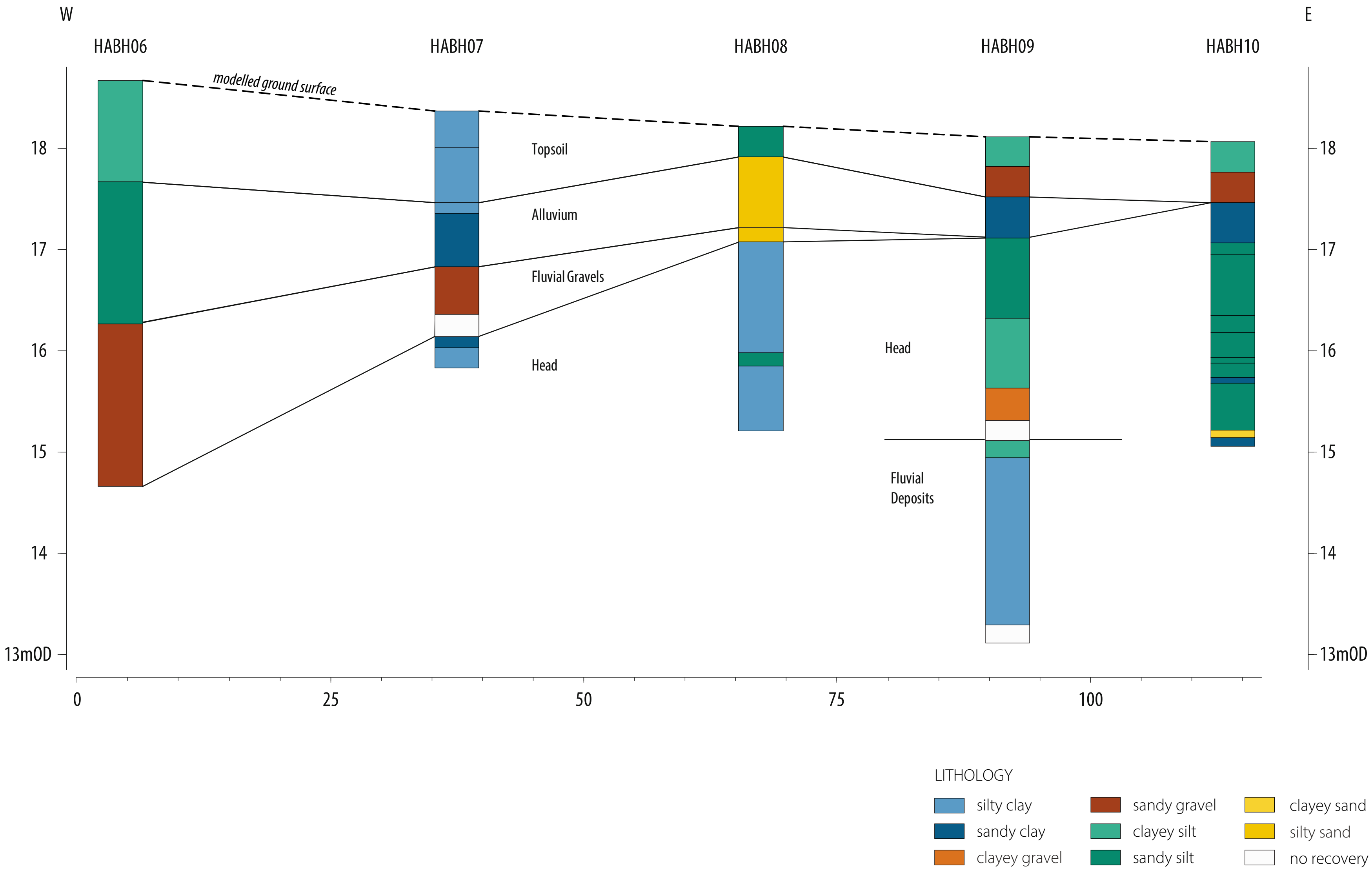
ILLUS 5P.17 Close-up of location of predictive deposit model transects- Pleistocene Transect 17



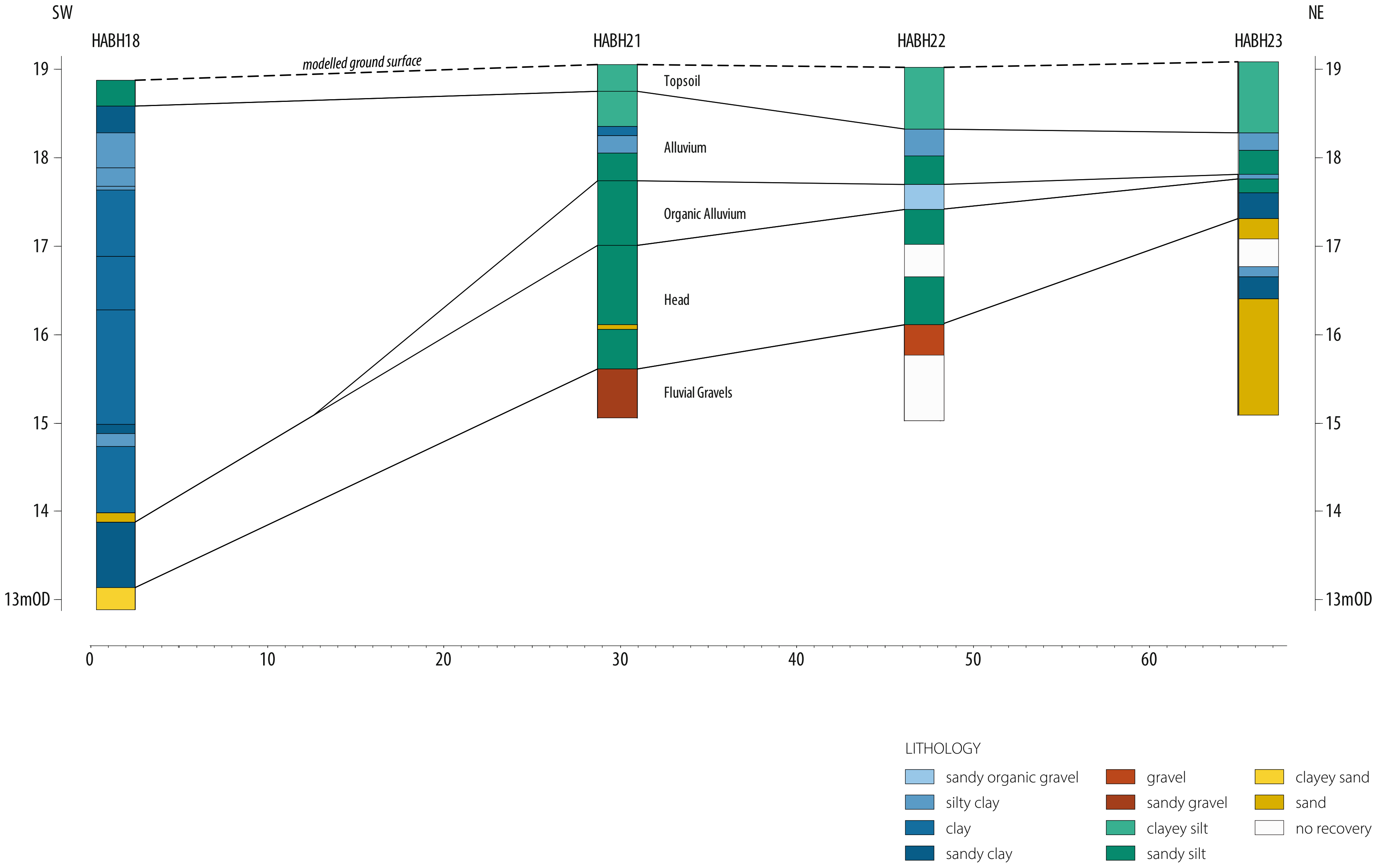
ILLUS 5P.18 Close-up of location of predictive deposit model transects-Pleistocene Transect 18



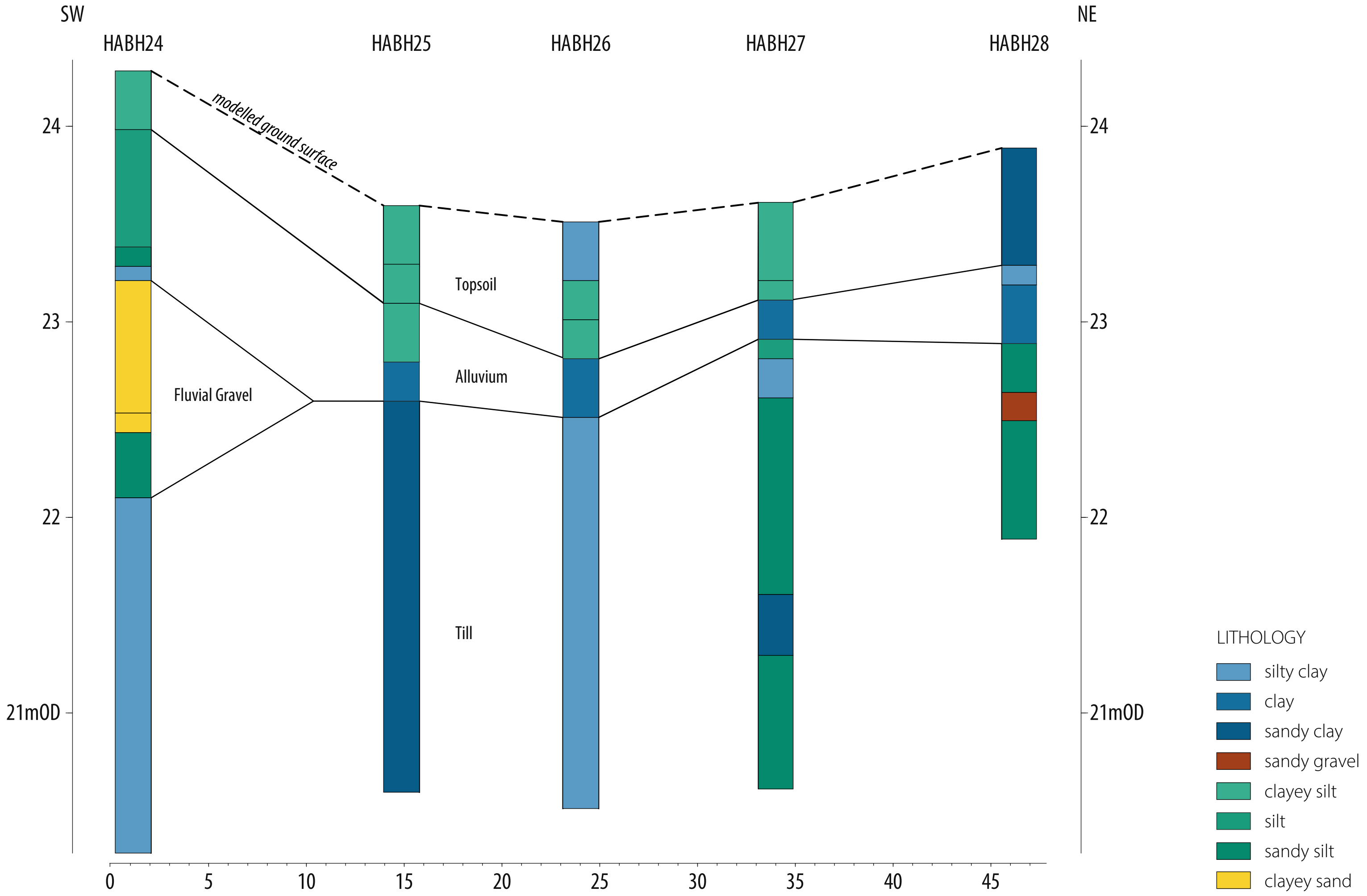
ILLUS 6 Holocene Transect 1 – Boreham tributary



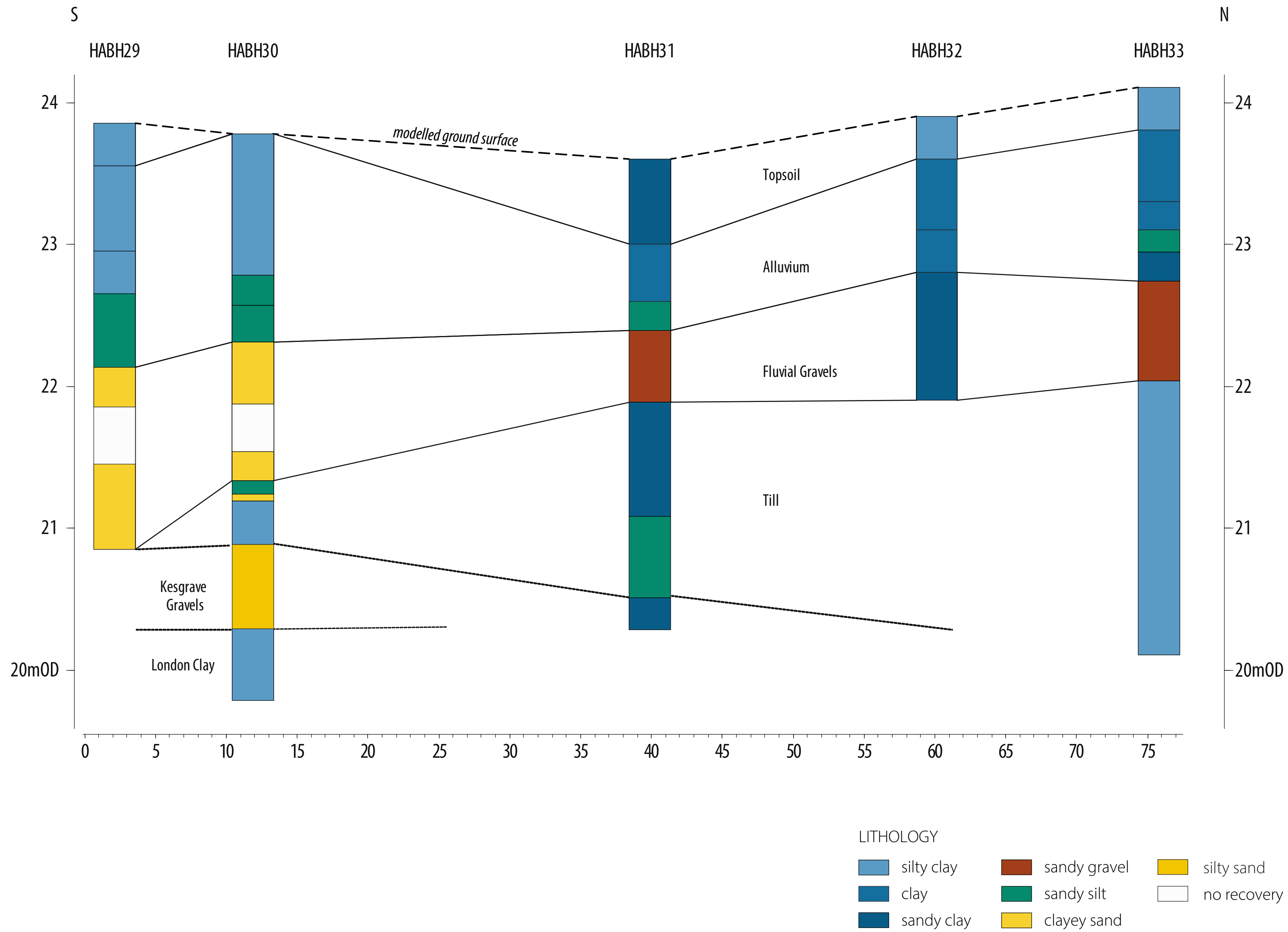
ILLUS 7 Holocene Transect 2 – River Ter



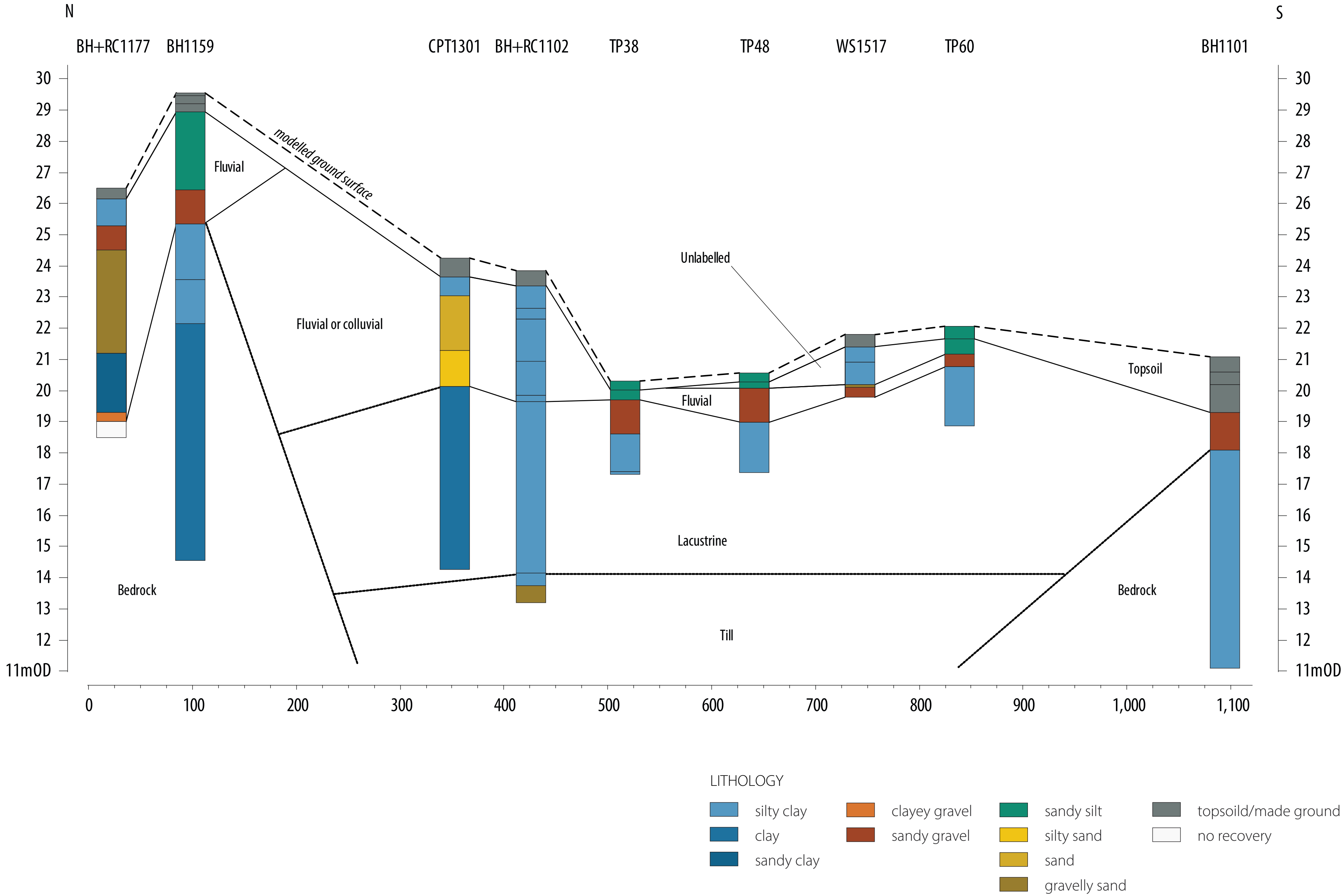
ILLUS 8 Holocene Holocene Transect 4 - River Blackwater



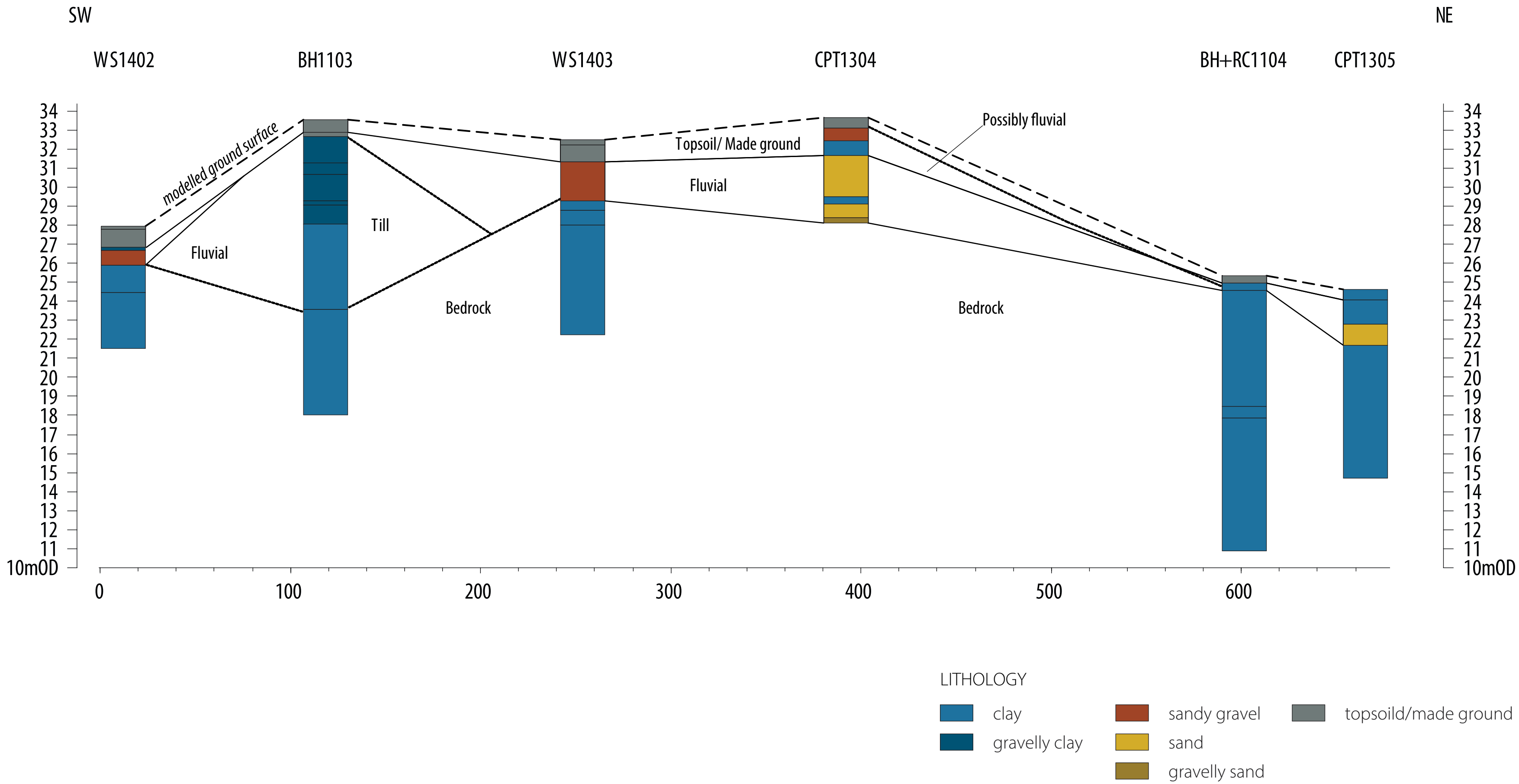
ILLUS 9 Holocene Transect 5 – Blackwater Tributary



ILLUS 10 Holocene Transect 6 - Domsey Brook



ILLUS 11 Pleistocene Transect 1



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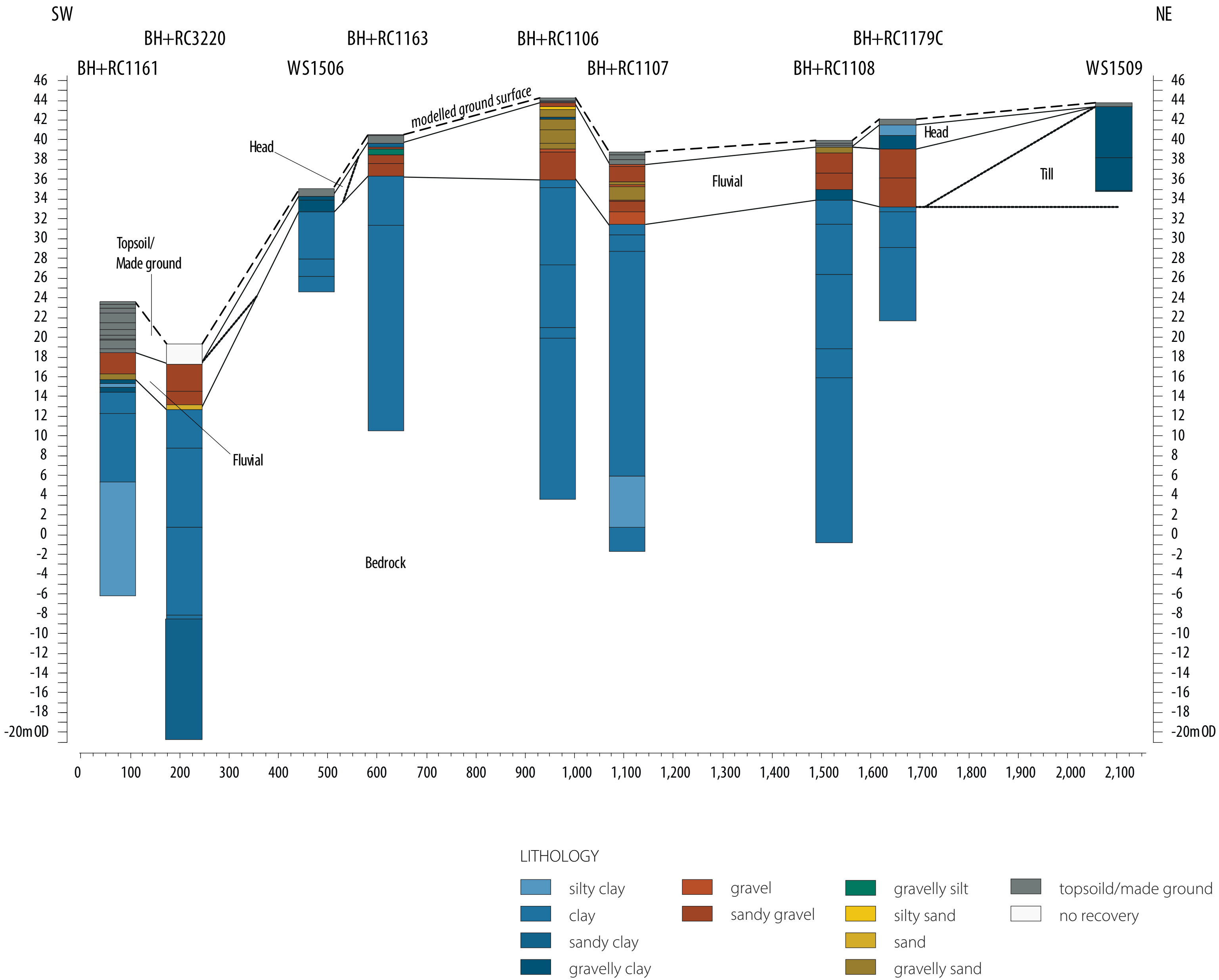
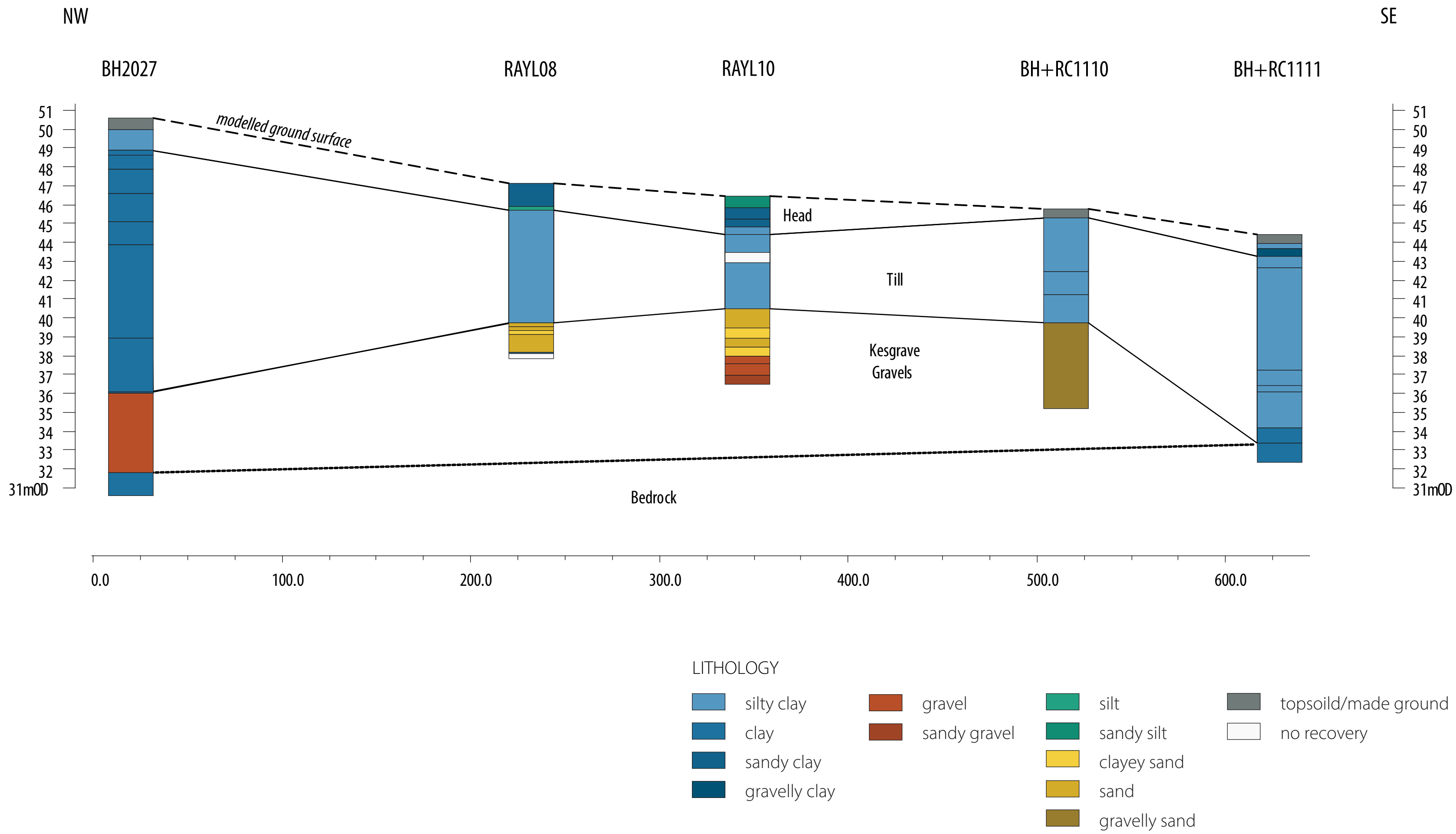


ILLUS 13 Pleistocene Transect 3



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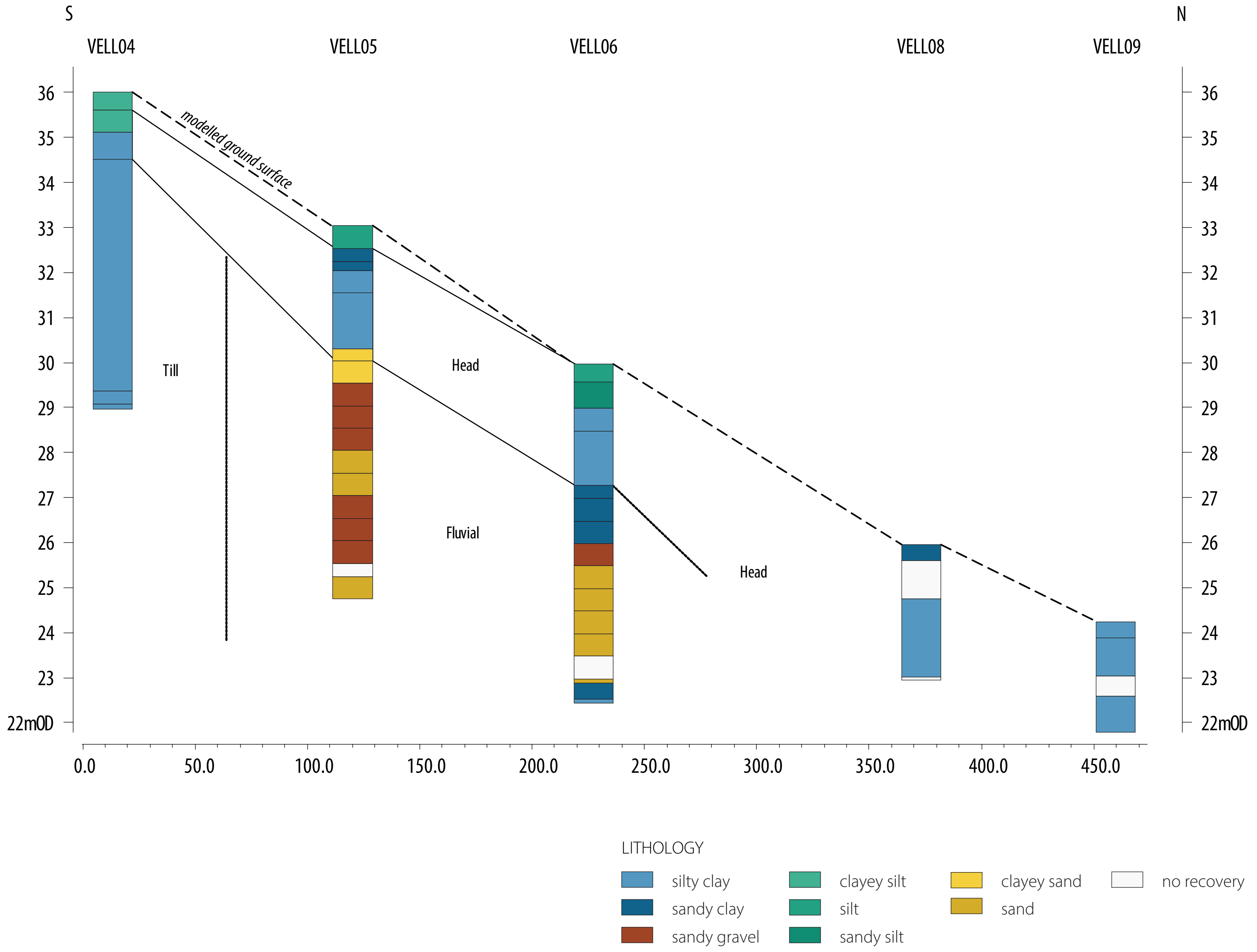

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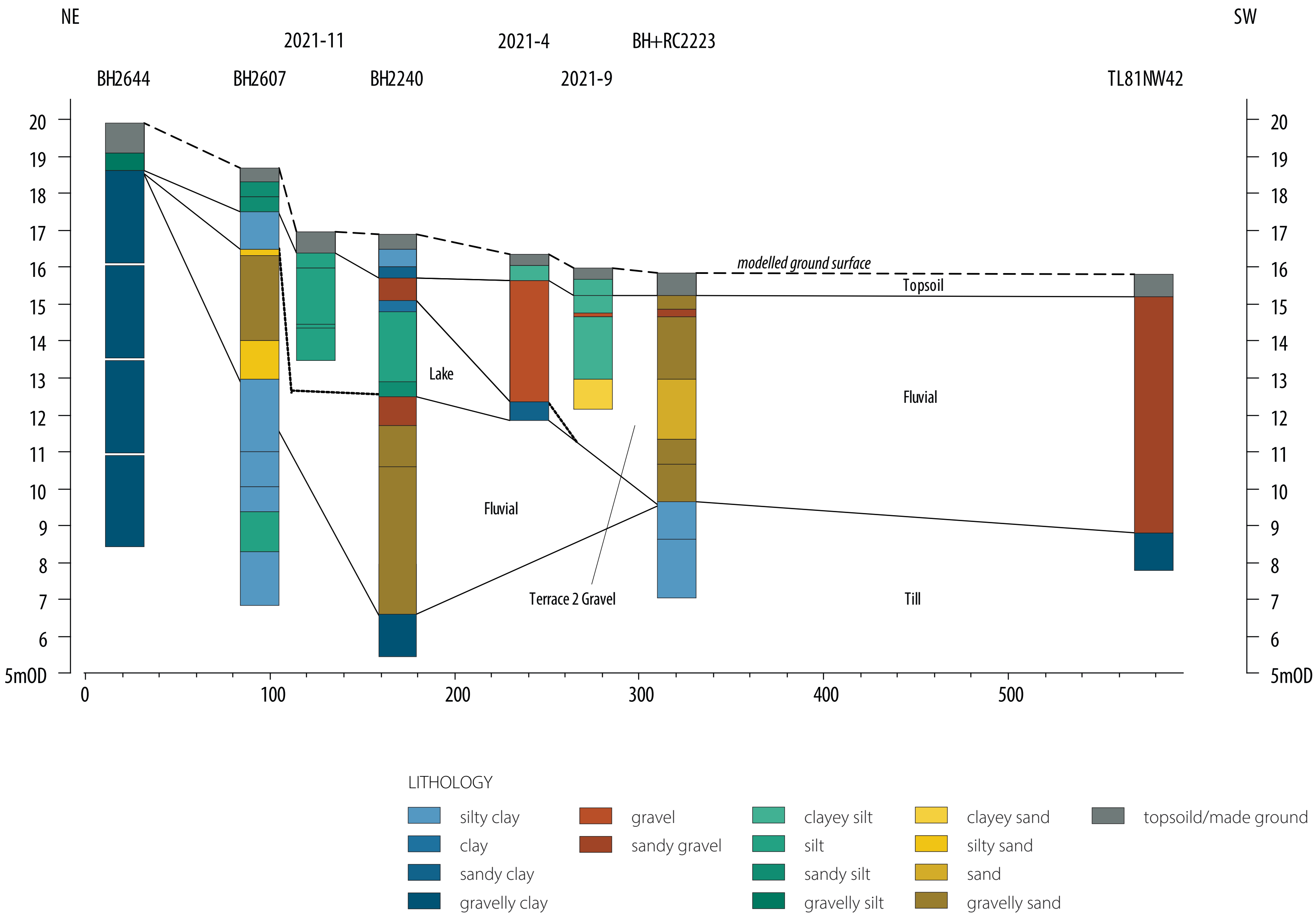

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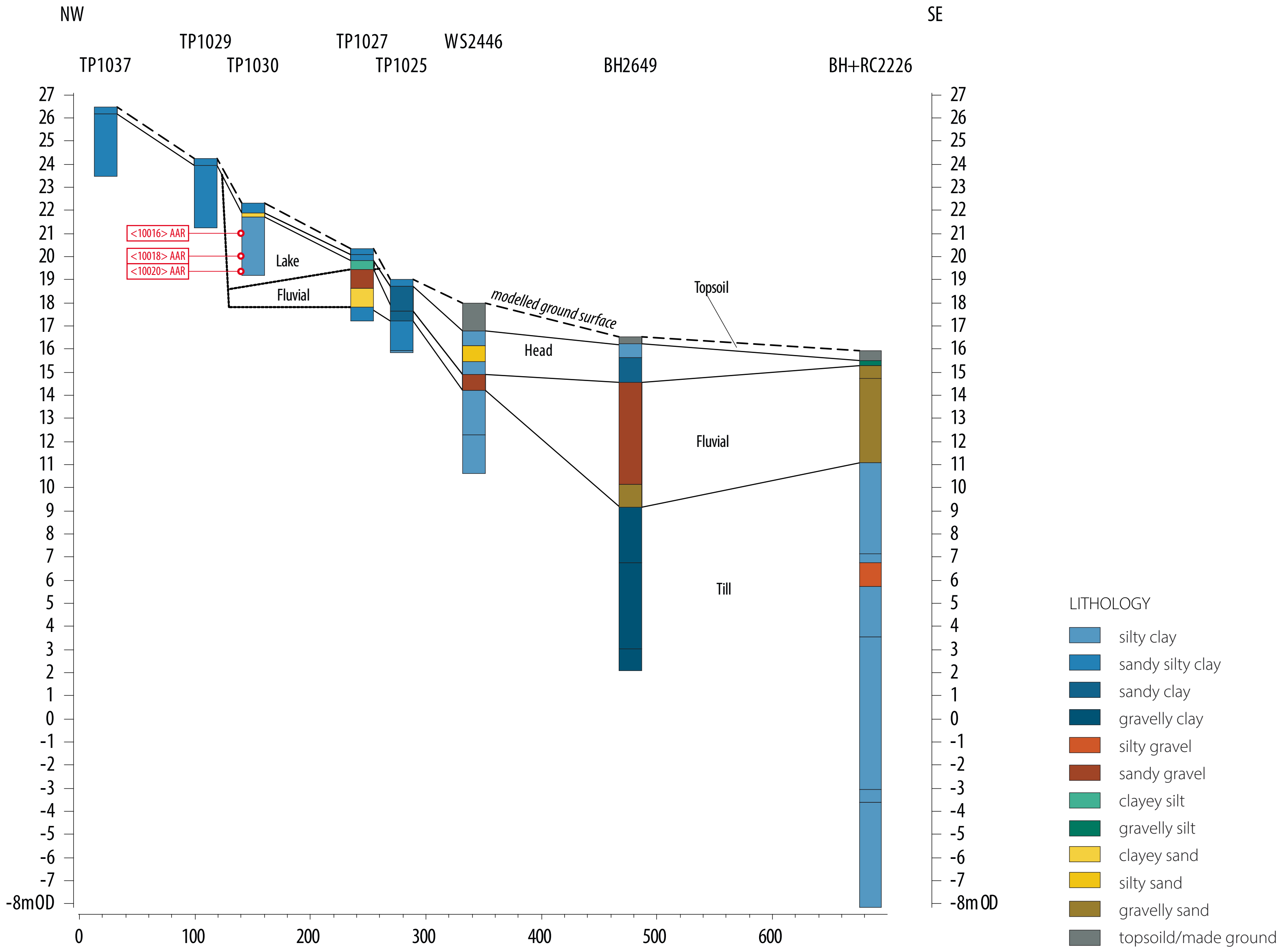

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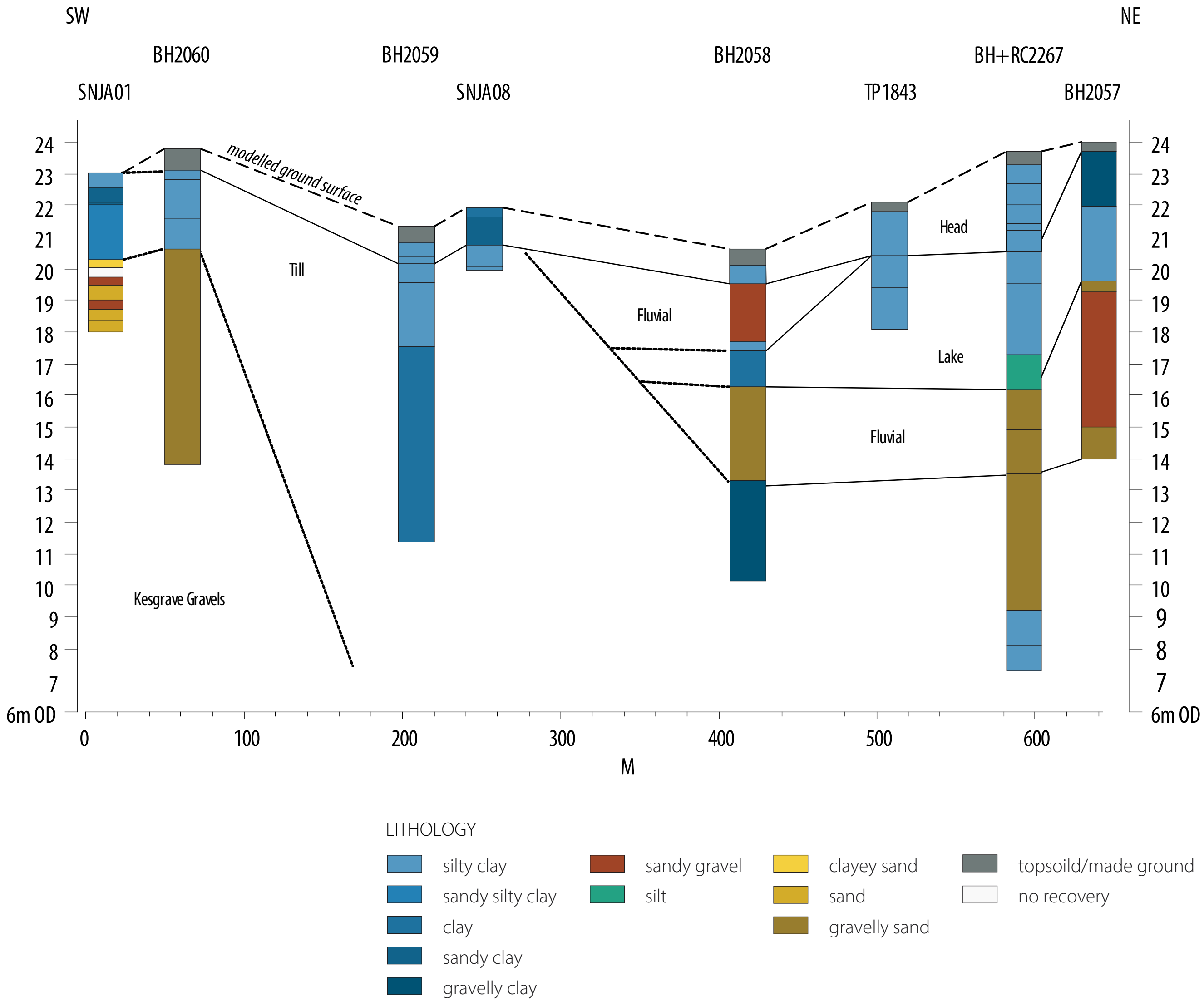

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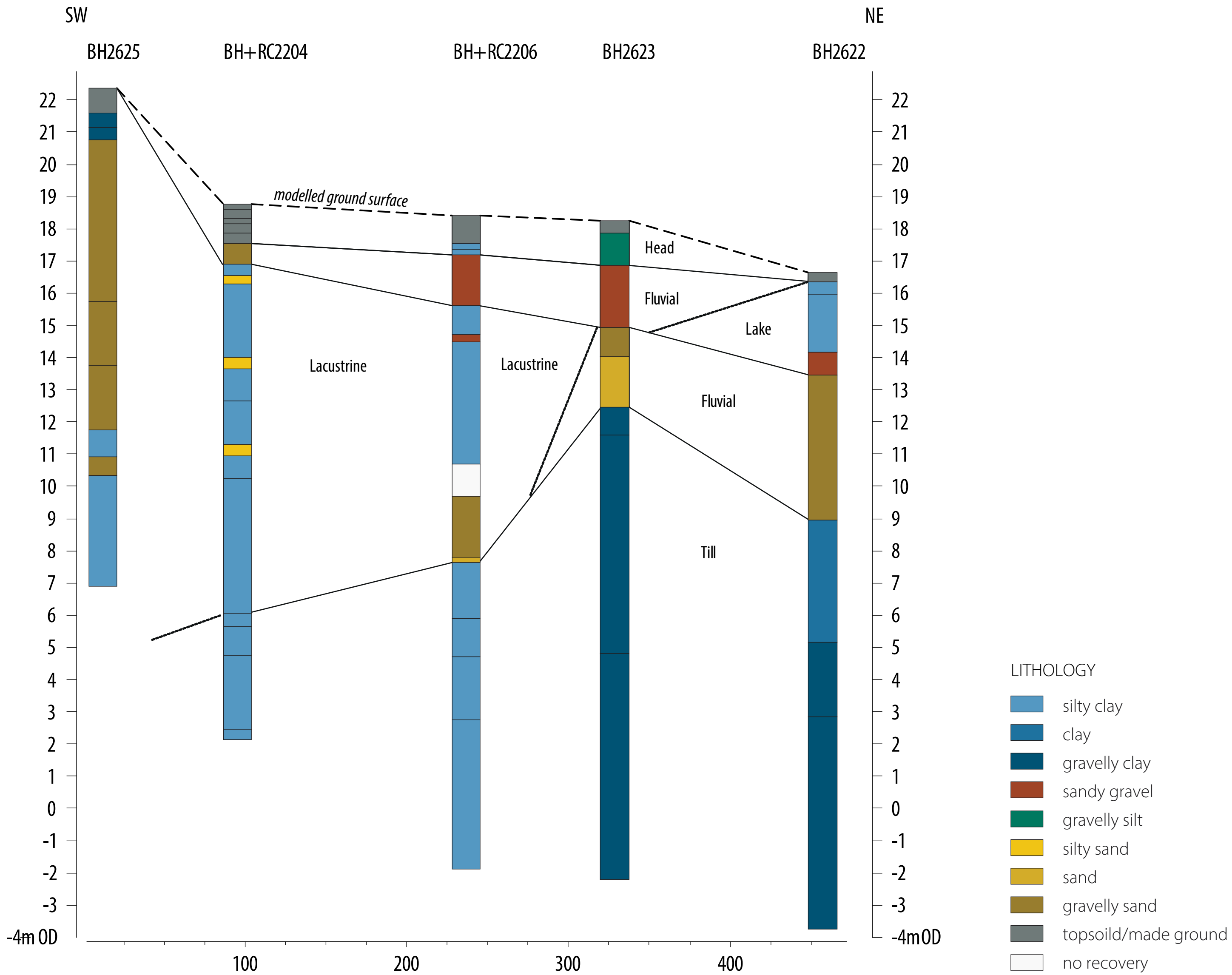
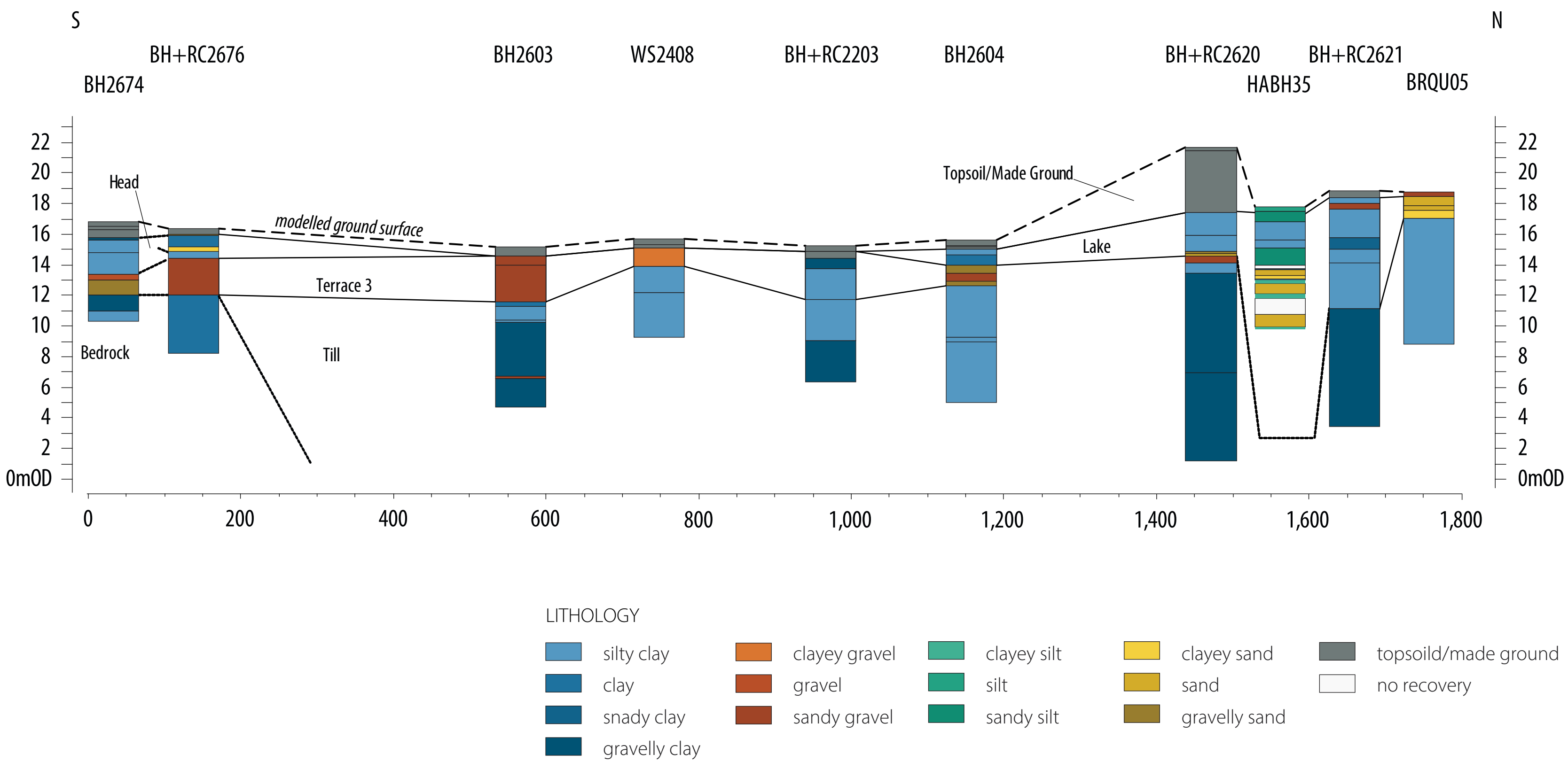


ILLUS 19 Pleistocene Transect 9



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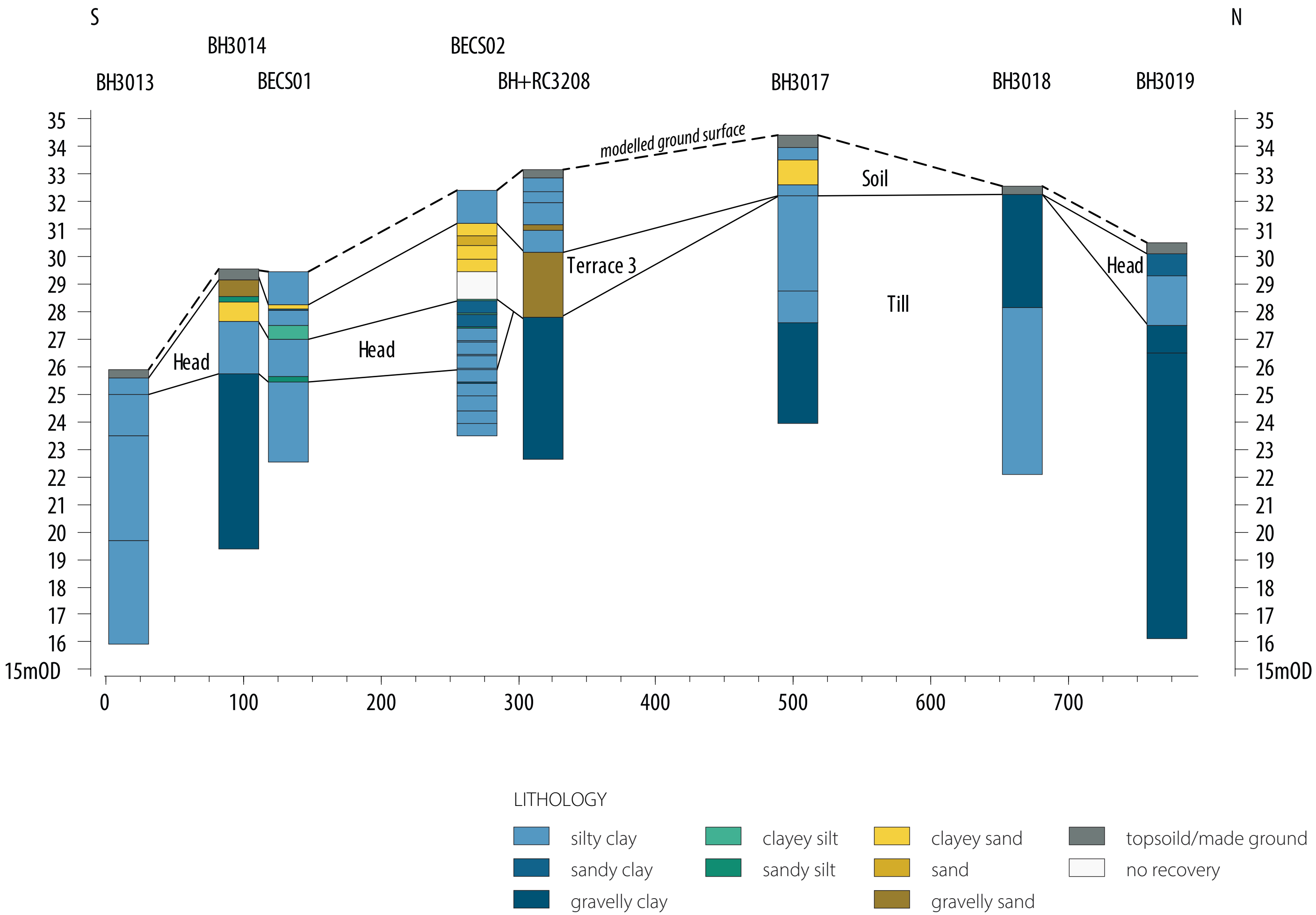

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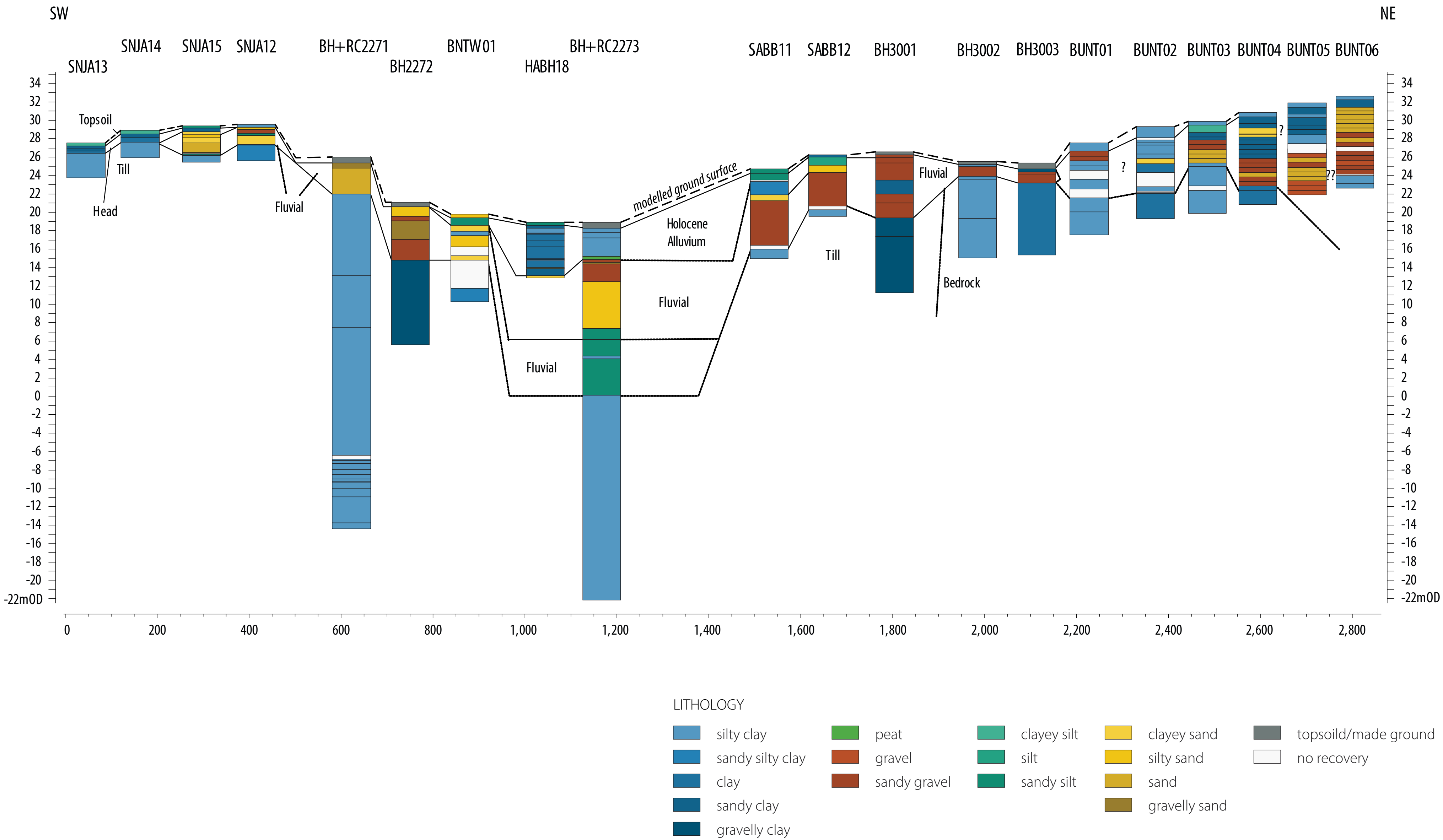
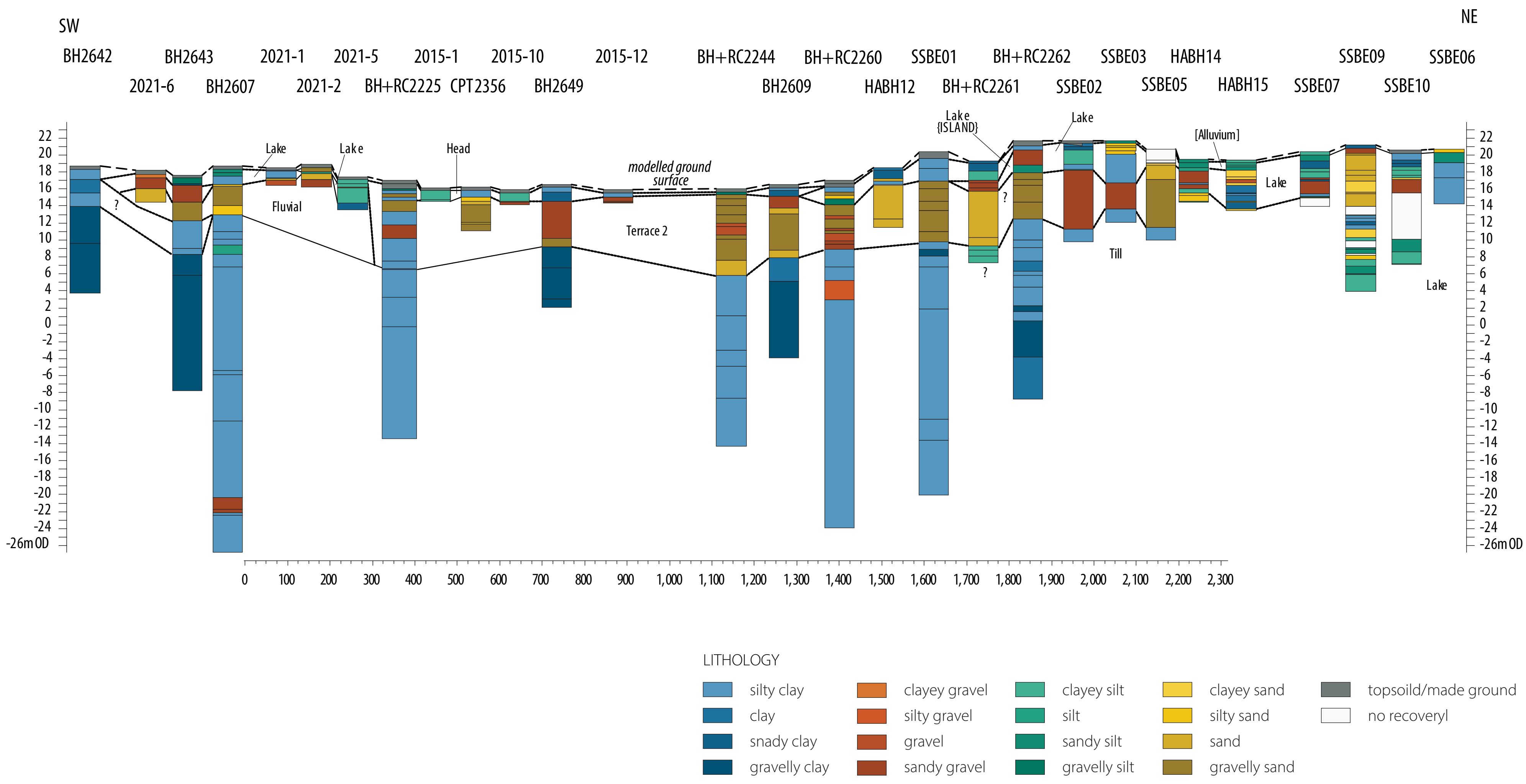
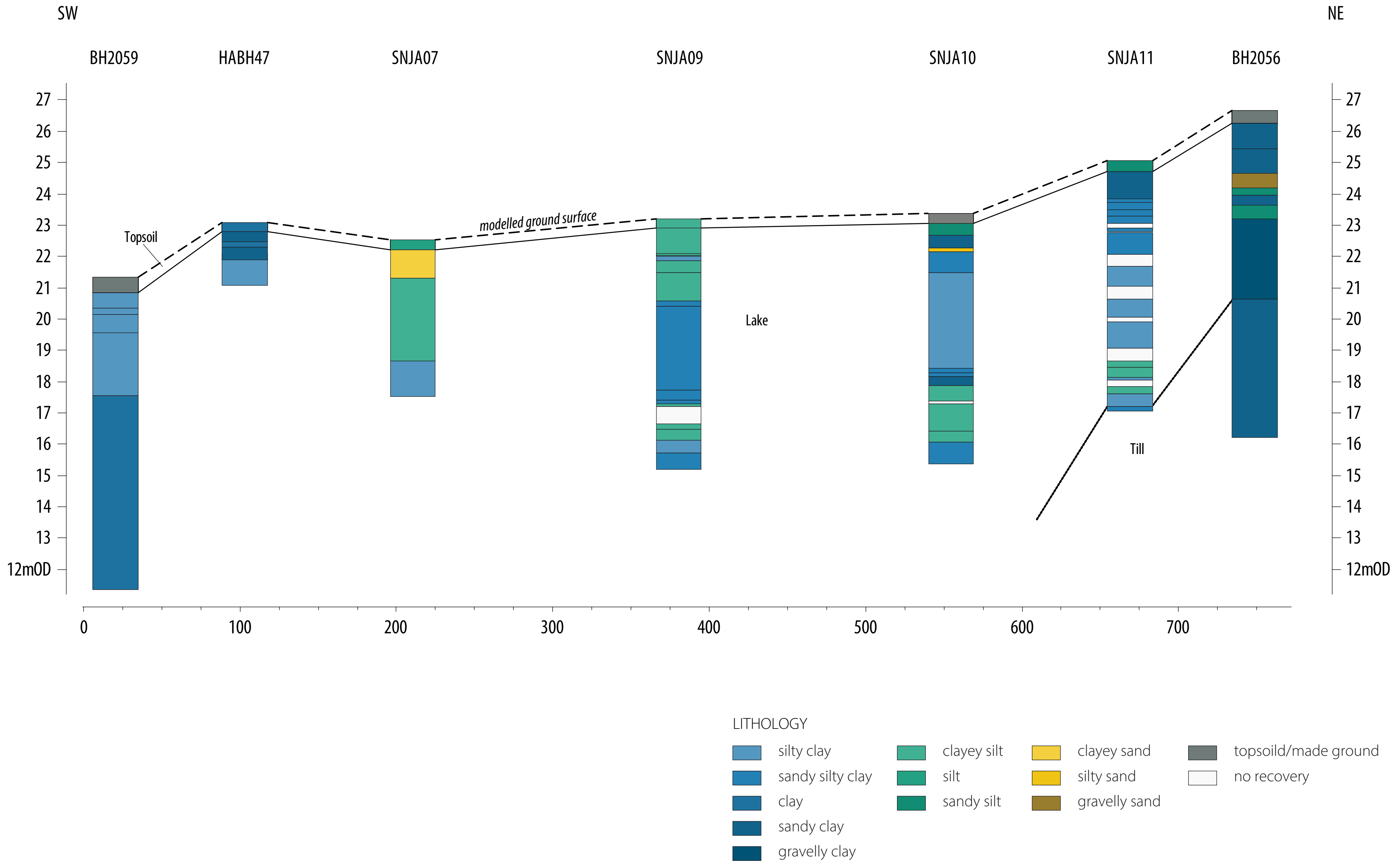


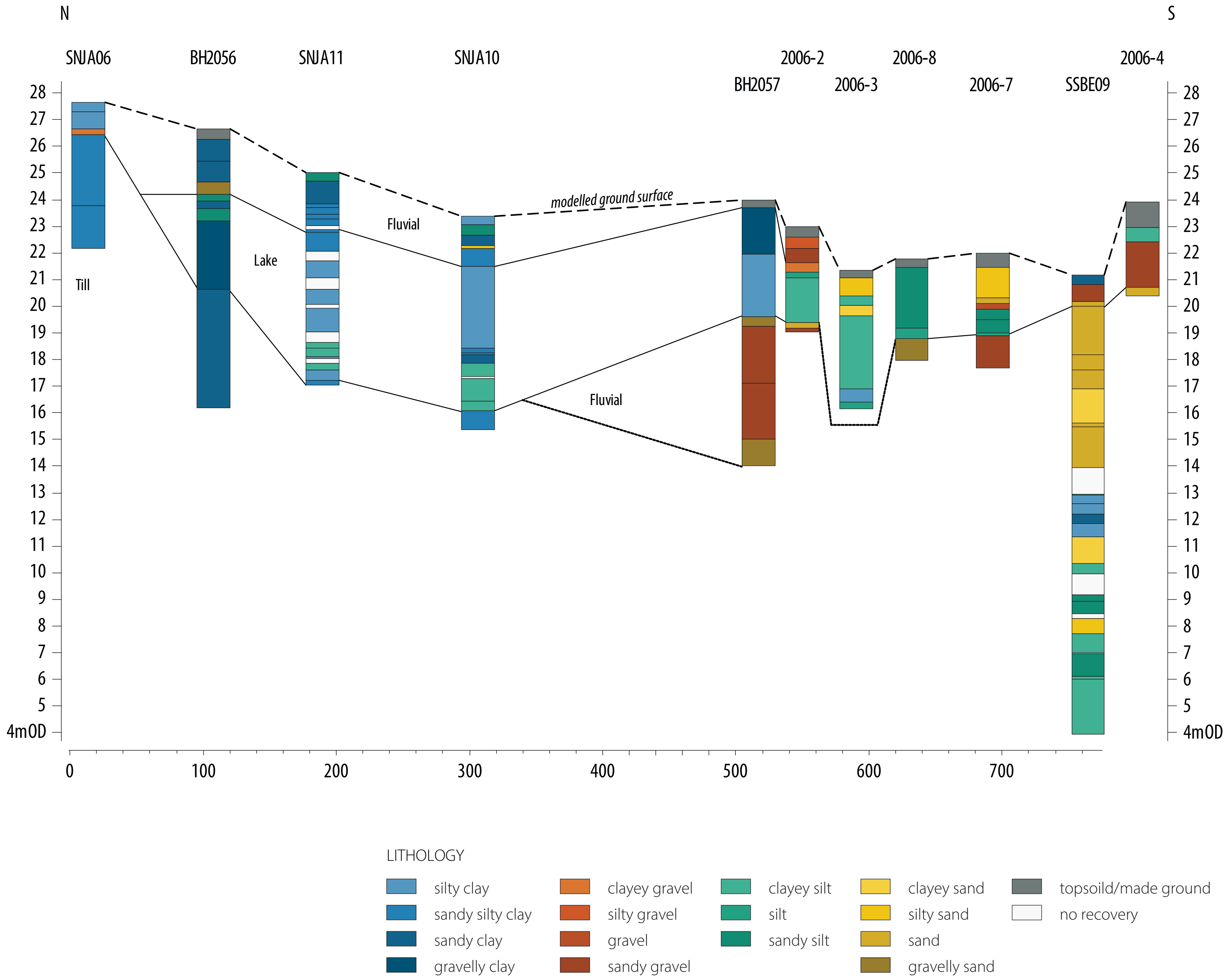
ILLUS 22 Pleistocene Transect 12



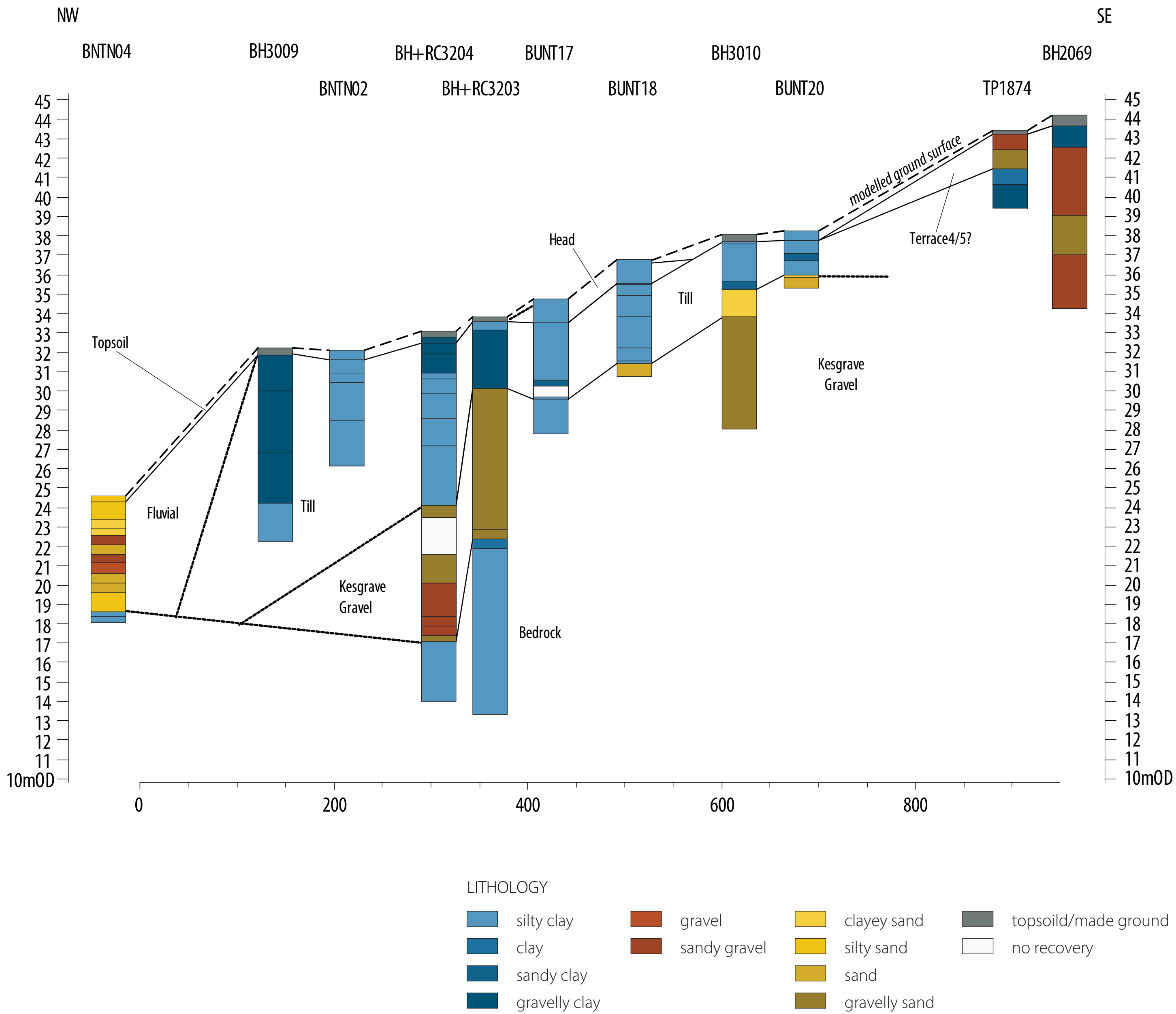
ILLUS 23 Pleistocene Transect 13



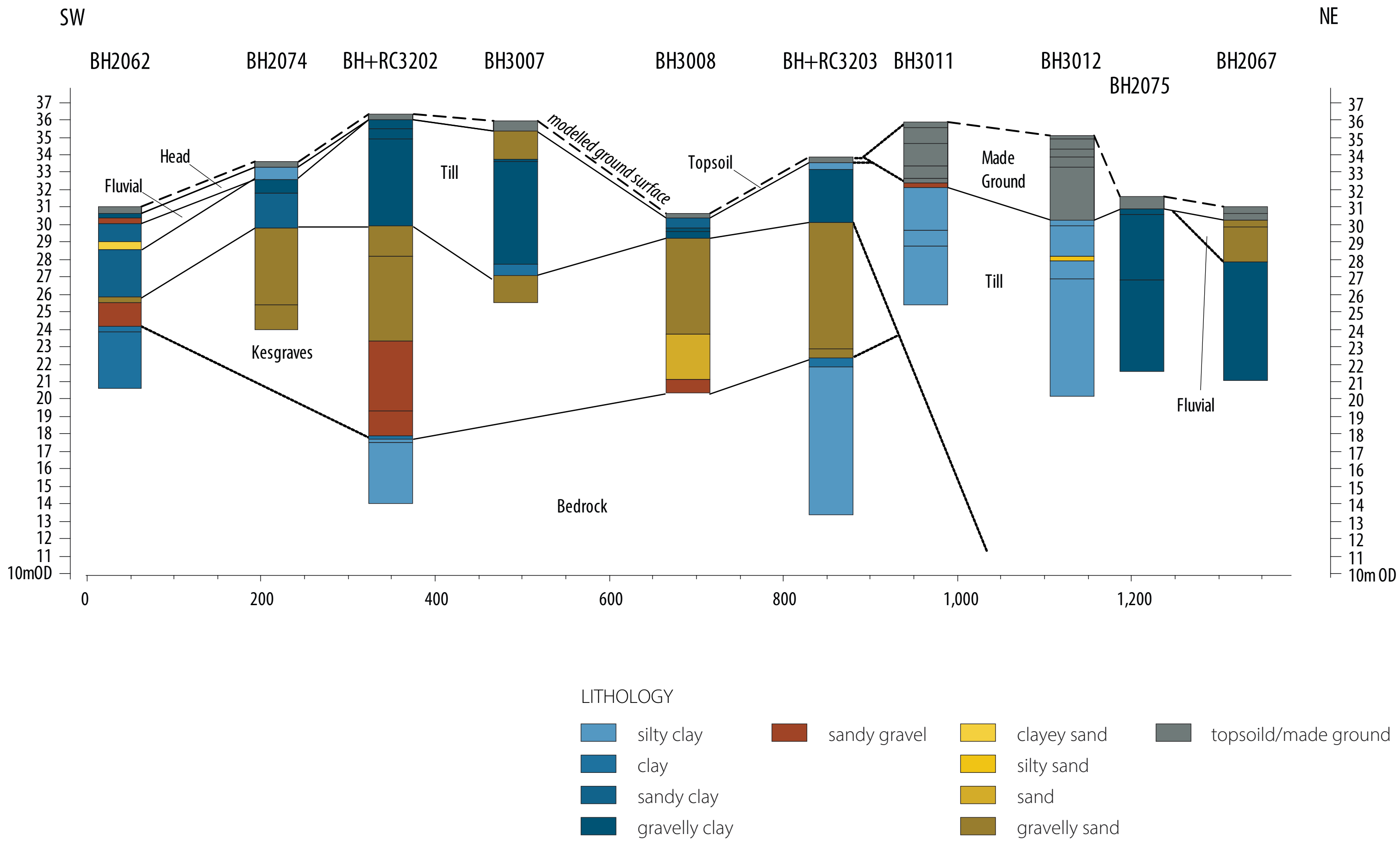
ILLUS 24 Pleistocene Transect 14



ILLUS 25 Pleistocene Transect 15



ILLUS 26 Pleistocene Transect 16



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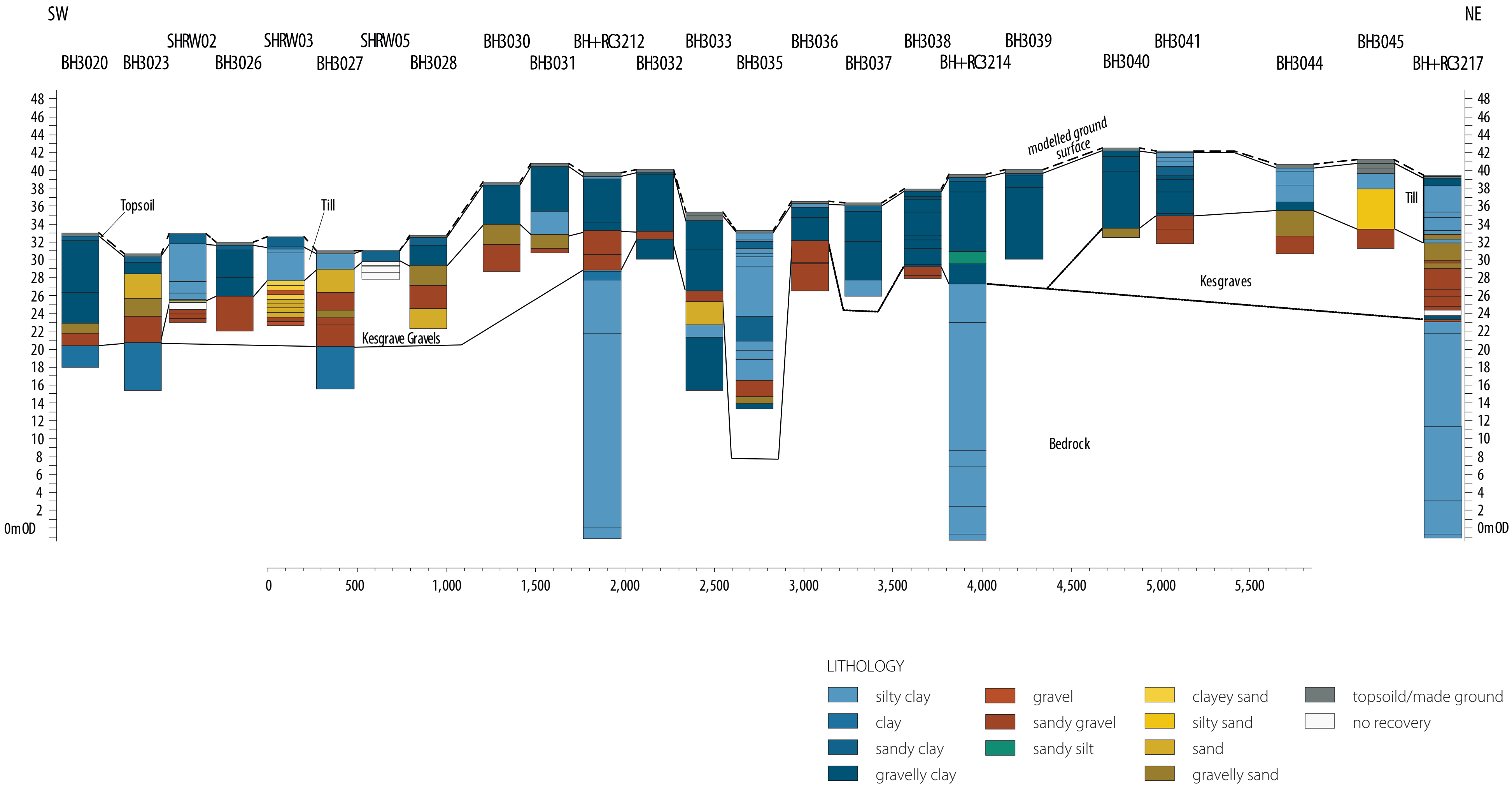

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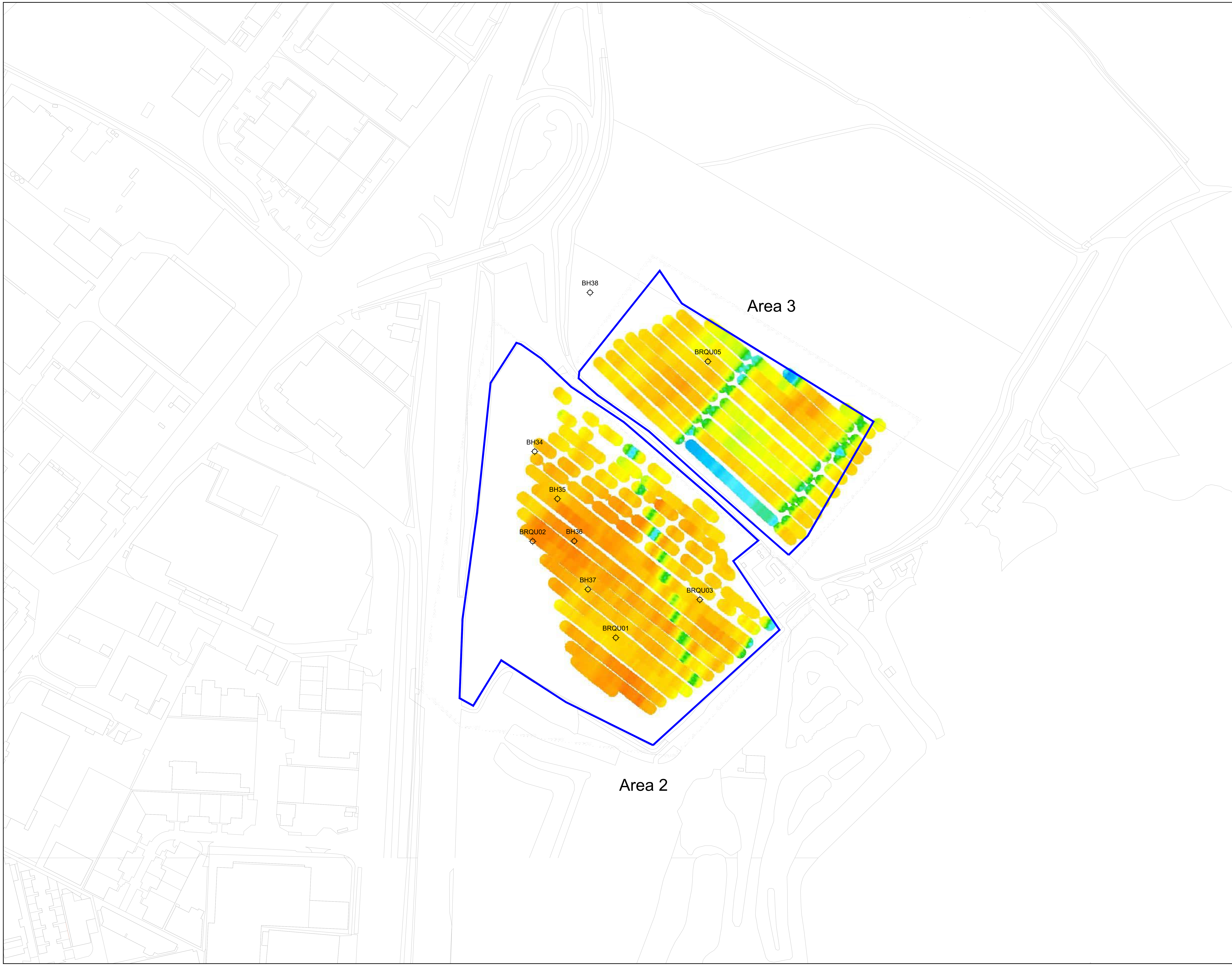

NOTES

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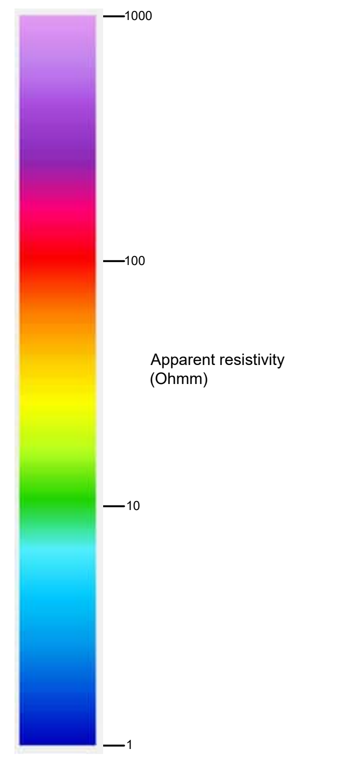
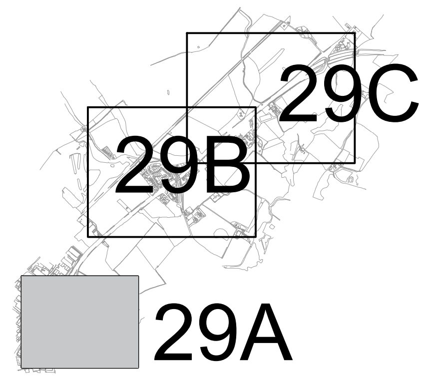
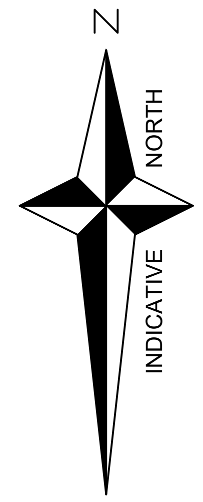
(3) Data inverted using Aarhus Workbench and apparent resistivity data points plotted with 5m buffer radius.

KEY



SHEET. LAYOUT





Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client: COSTAIN

Project Title: A12 CHELMSFORD TO A120 JUNCTIONS 19 TO 25

Drawing Title: AREA 2-3 APPARENT RESISTIVITY DEPTH 0-1M

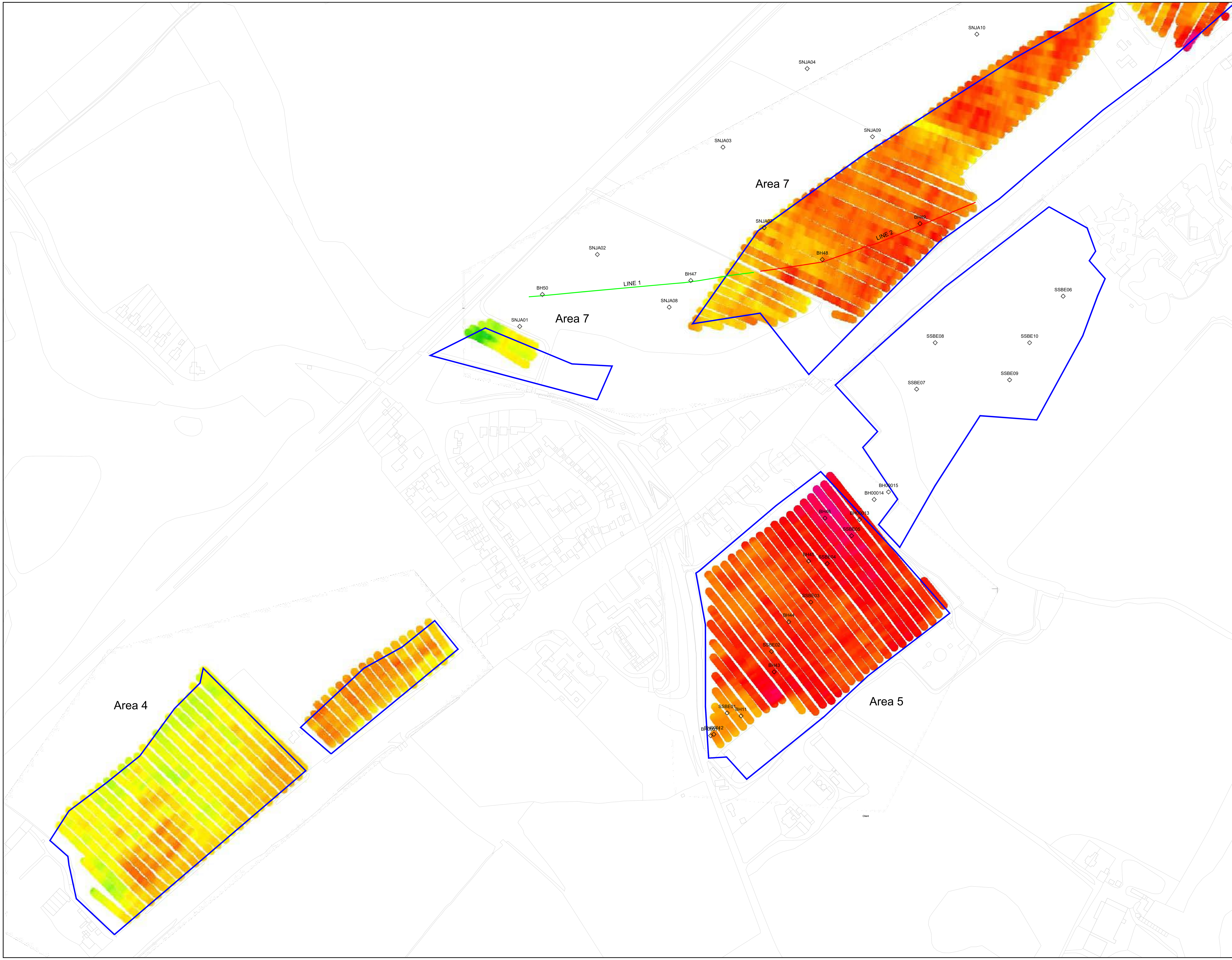
Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale	Orig Size	Dimensions
1:2000	A2	

Project No.	Drawing File
2190784	ILLUS 29A

Drawing No.	Rev.
ILLUS 29A	

Scale
0 20 40 60 80 100m



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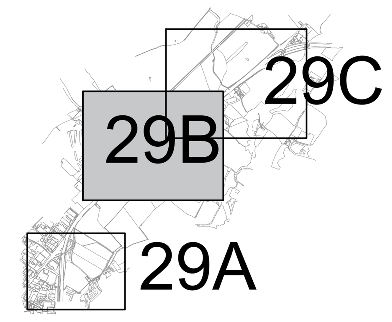
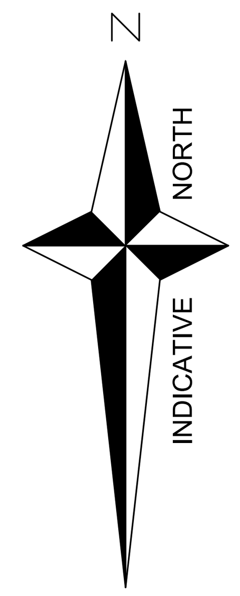
(3) Data inverted using Aarhus Workbench and apparent resistivity data points plotted with 5m buffer radius.

KEY

SHEET. LAYOUT





Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client
COSTAIN

Project Title
A12 CHELMSFORD TO A120 JUNCTIONS 19 TO 25

Drawing Title
APPARENT RESISTIVITY DEPTH 0-1M

Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale	Orig Size	Dimensions
1:2000	A1	

Project No.	Drawing File
2190784	ILLUS 29B

Drawing No.	Rev.
ILLUS 29B	

Scale
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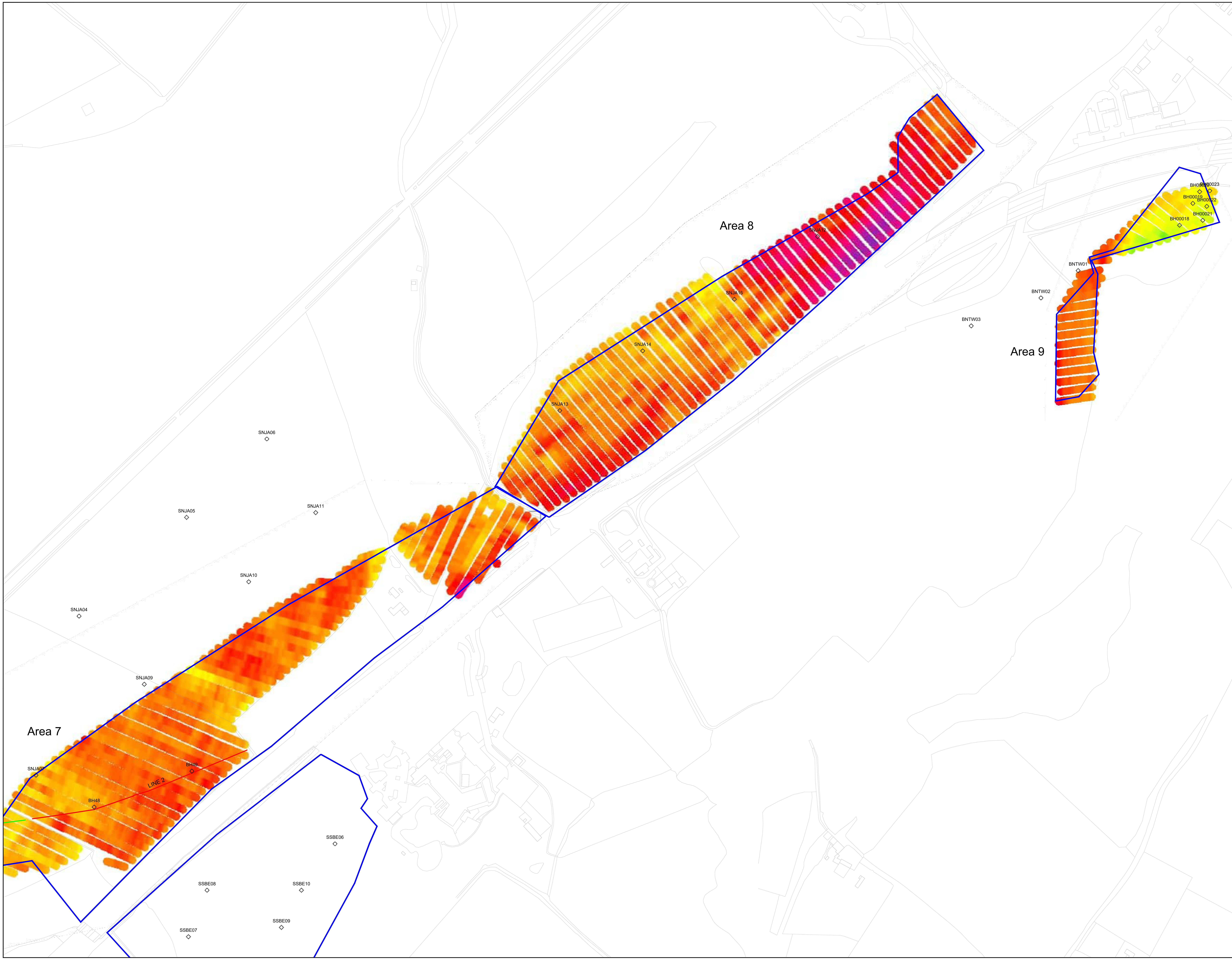

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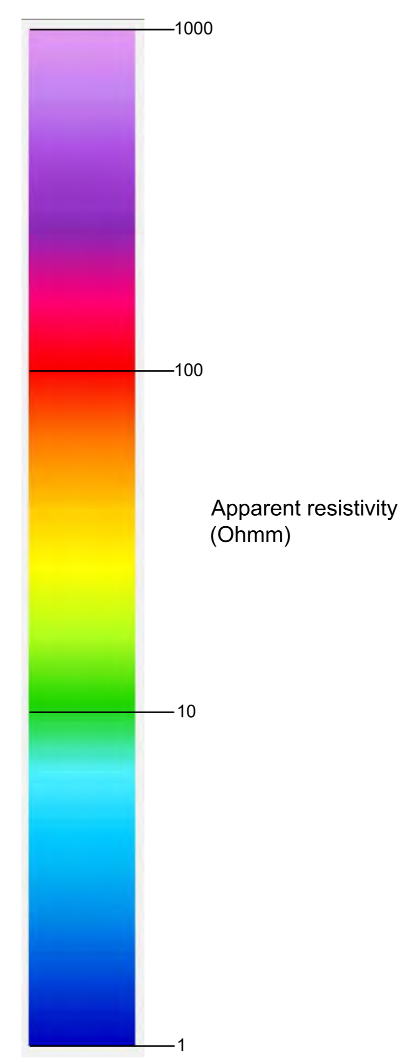
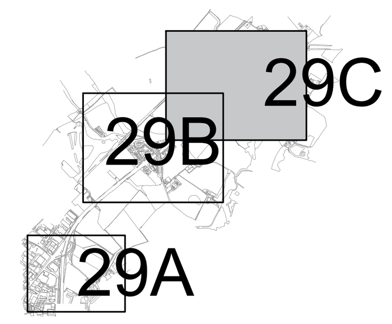
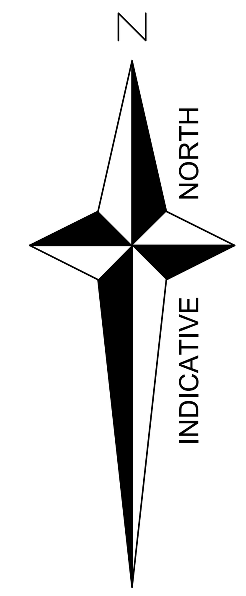
(3) Data inverted using Aarhus Workbench and apparent resistivity data points plotted with 5m buffer radius.

KEY



SHEET. LAYOUT





Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client

COSTAIN

Project Title

A12 CHELMSFORD TO A120
JUNCTIONS 19 TO 25

Drawing Title

APPARENT RESISTIVITY
DEPTH 0-1M

Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale: 1:2000
Orig Size: A1
Dimensions:

Project No.: 2190784
Drawing File: ILLUS 29C

Drawing No.: ILLUS 29C
Rev.:

Scale

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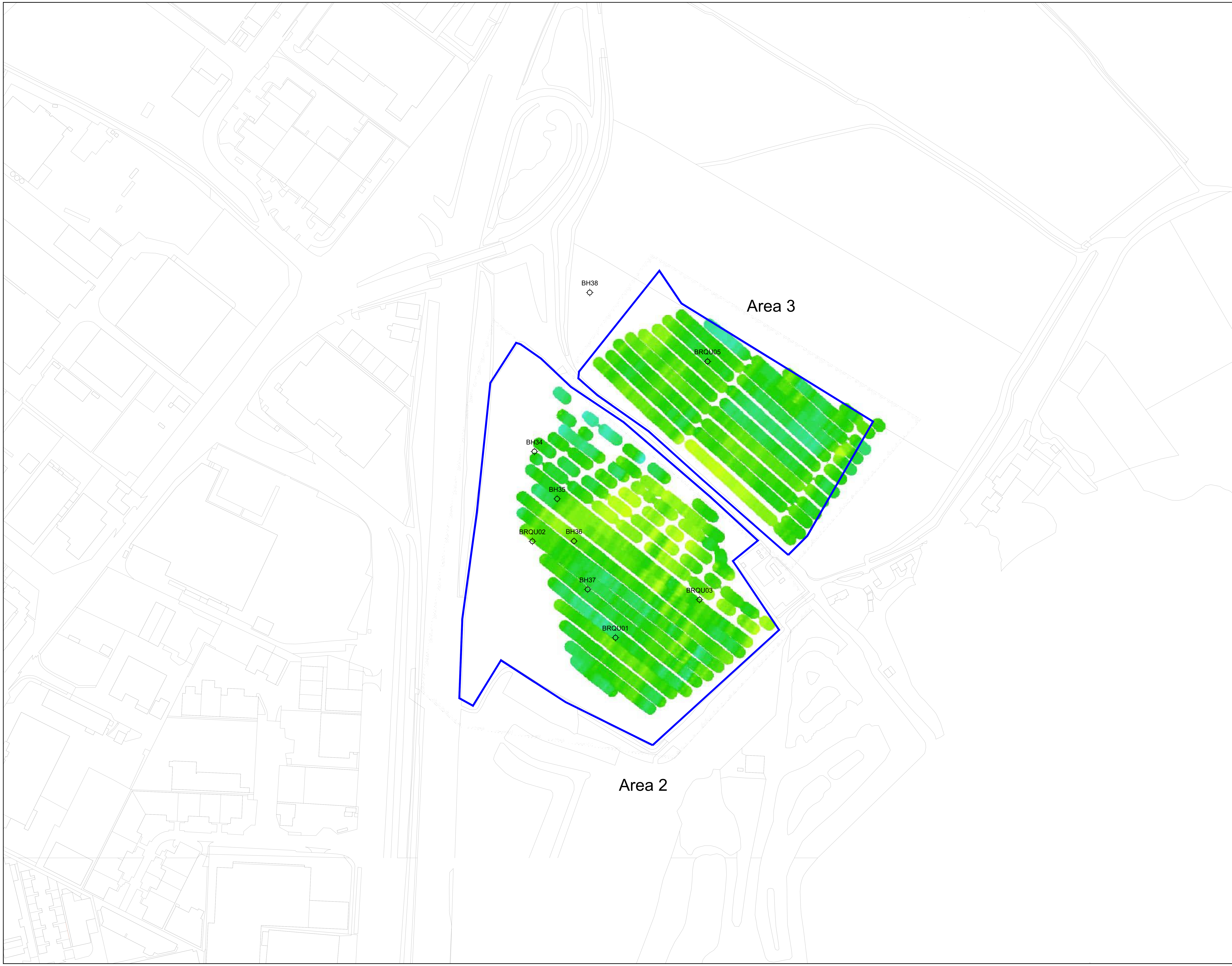

NOTES

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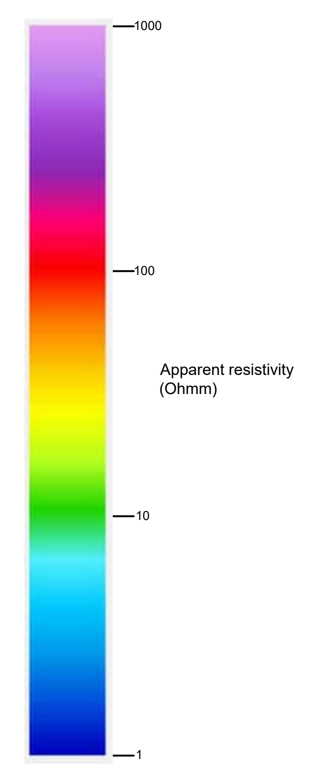
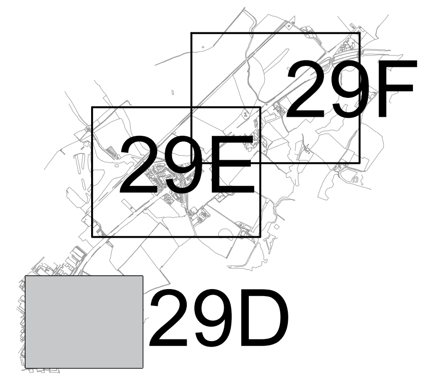
(3) Data inverted using Aarhus Workbench and apparent resistivity data points plotted with 5m buffer radius.

KEY



SHEET. LAYOUT



N
NORTH
INDICATIVE

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client
COSTAIN

Project Title
A12 CHELMSFORD TO A120
JUNCTIONS 19 TO 25

Drawing Title
AREA 2-3
APPARENT RESISTIVITY
DEPTH 2-3M

Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale 1:2000 | Orig Size A2 | Dimensions

Project No. 2190784 | Drawing File ILLUS 29D

Drawing No. ILLUS 29D | Rev.

Scale
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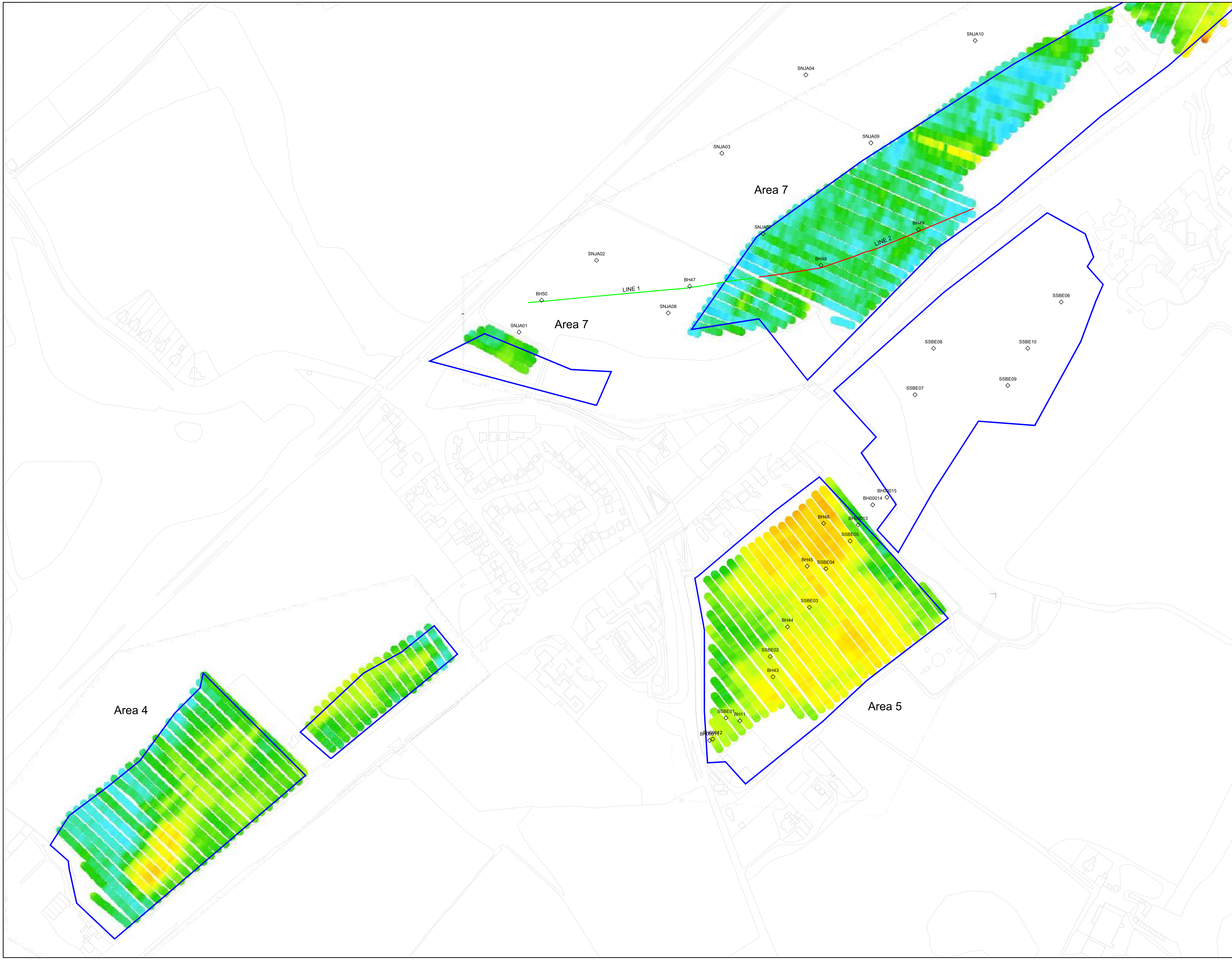

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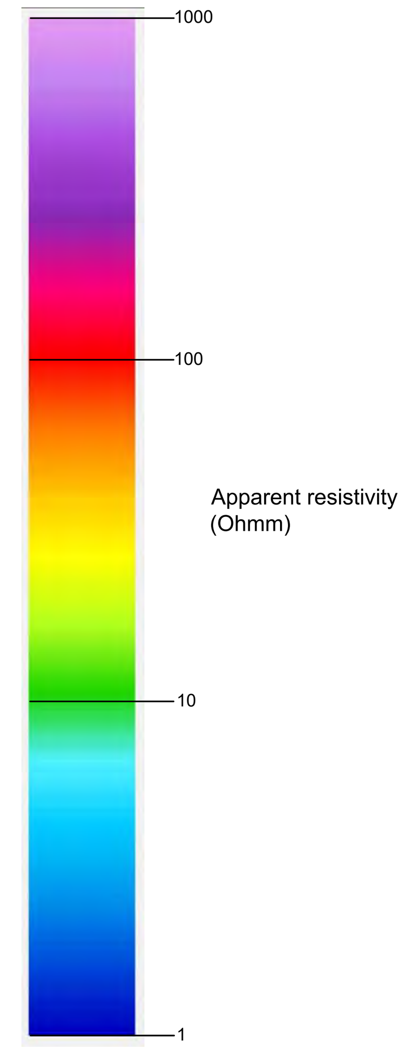
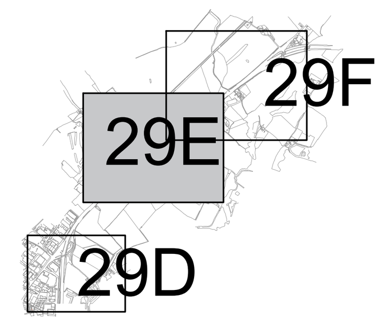
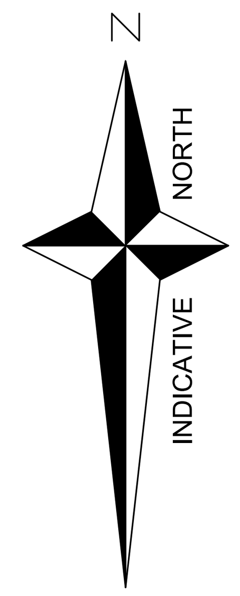
KEY



SHEET. LAYOUT





Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client

COSTAIN

Project Title

A12 CHELMSFORD TO A120
JUNCTIONS 19 TO 25

Drawing Title

APPARENT RESISTIVITY
DEPTH 2-3M

Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

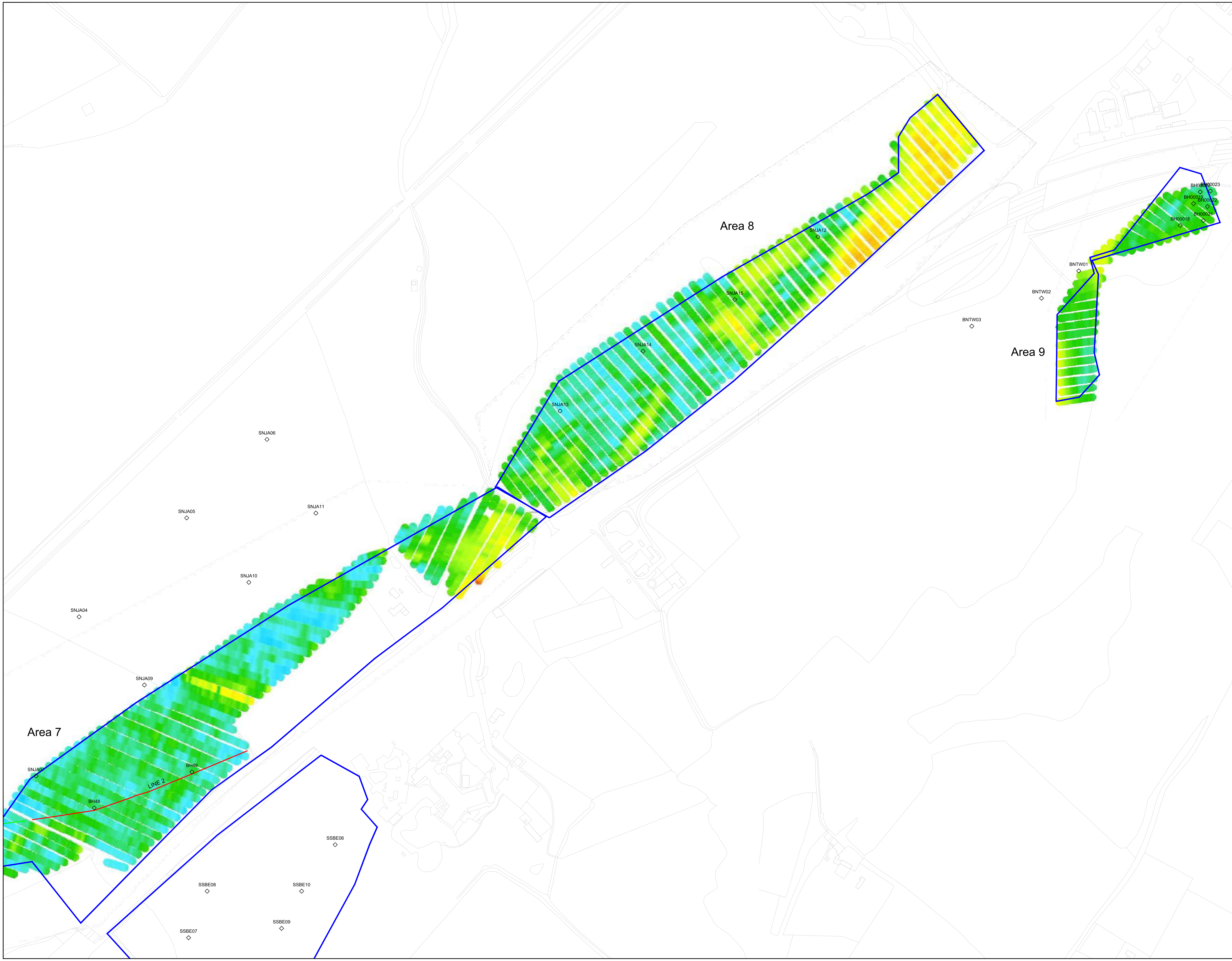
Scale	Orig Size	Dimensions
1:2000	A1	

Project No.	Drawing File
2190784	ILLUS 29E

Drawing No.	Rev.
ILLUS 29E	

Scale

0 20 40 60 80 100m



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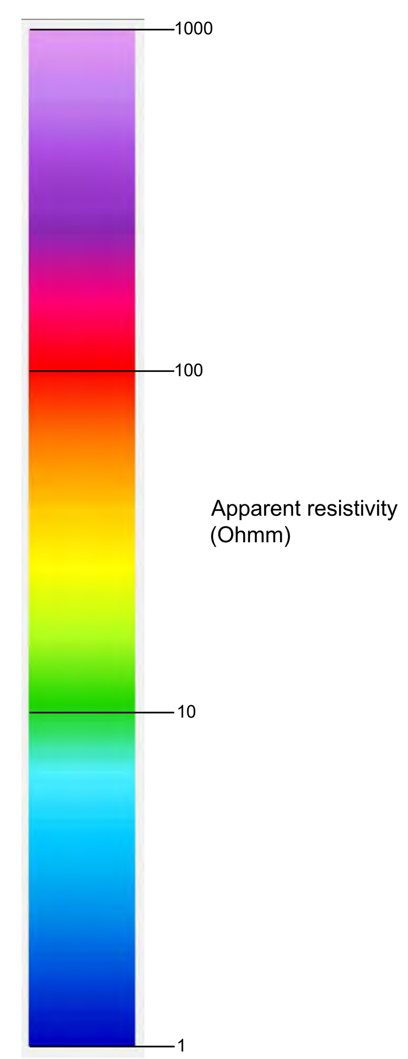
KEY



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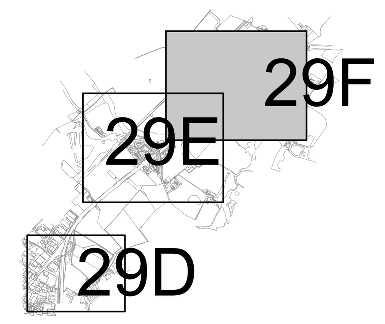
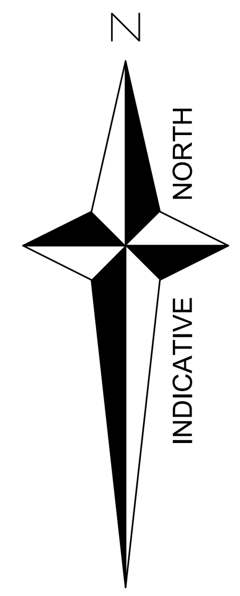




Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client: COSTAIN

Project Title: A12 CHELMSFORD TO A120 JUNCTIONS 19 TO 25

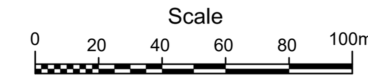
Drawing Title: APPARENT RESISTIVITY DEPTH 2-3M

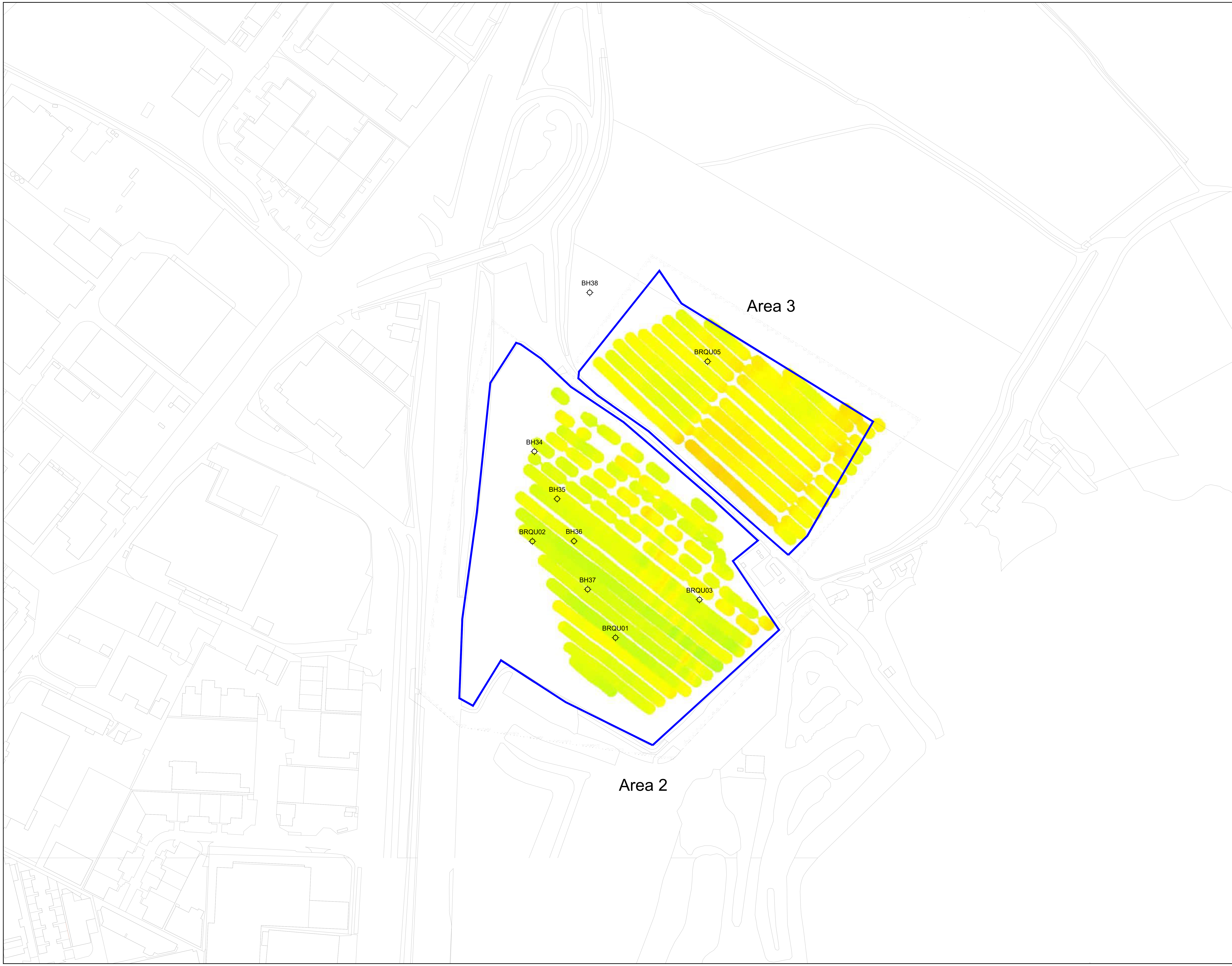
Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale	Orig Size	Dimensions
1:2000	A1	

Project No.	Drawing File
2190784	ILLUS 29F

Drawing No.	Rev.
ILLUS 29F	





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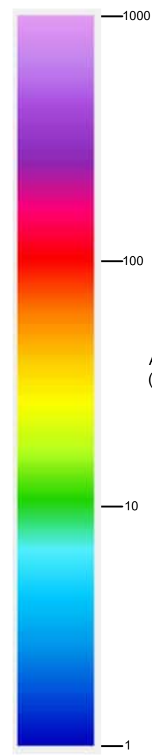
KEY



SHEET. LAYOUT

29I
29H
29G

N
INDICATIVE NORTH

Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client: COSTAIN

Project Title: A12 CHELMSFORD TO A120 JUNCTIONS 19 TO 25

Drawing Title: AREA 2-3 APPARENT RESISTIVITY DEPTH 4-5M

Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale: 1:2000 | Orig Size: A2 | Dimensions:

Project No.: 2190784 | Drawing File: ILLUS 29G

Drawing No.: ILLUS 29G | Rev.:

Scale
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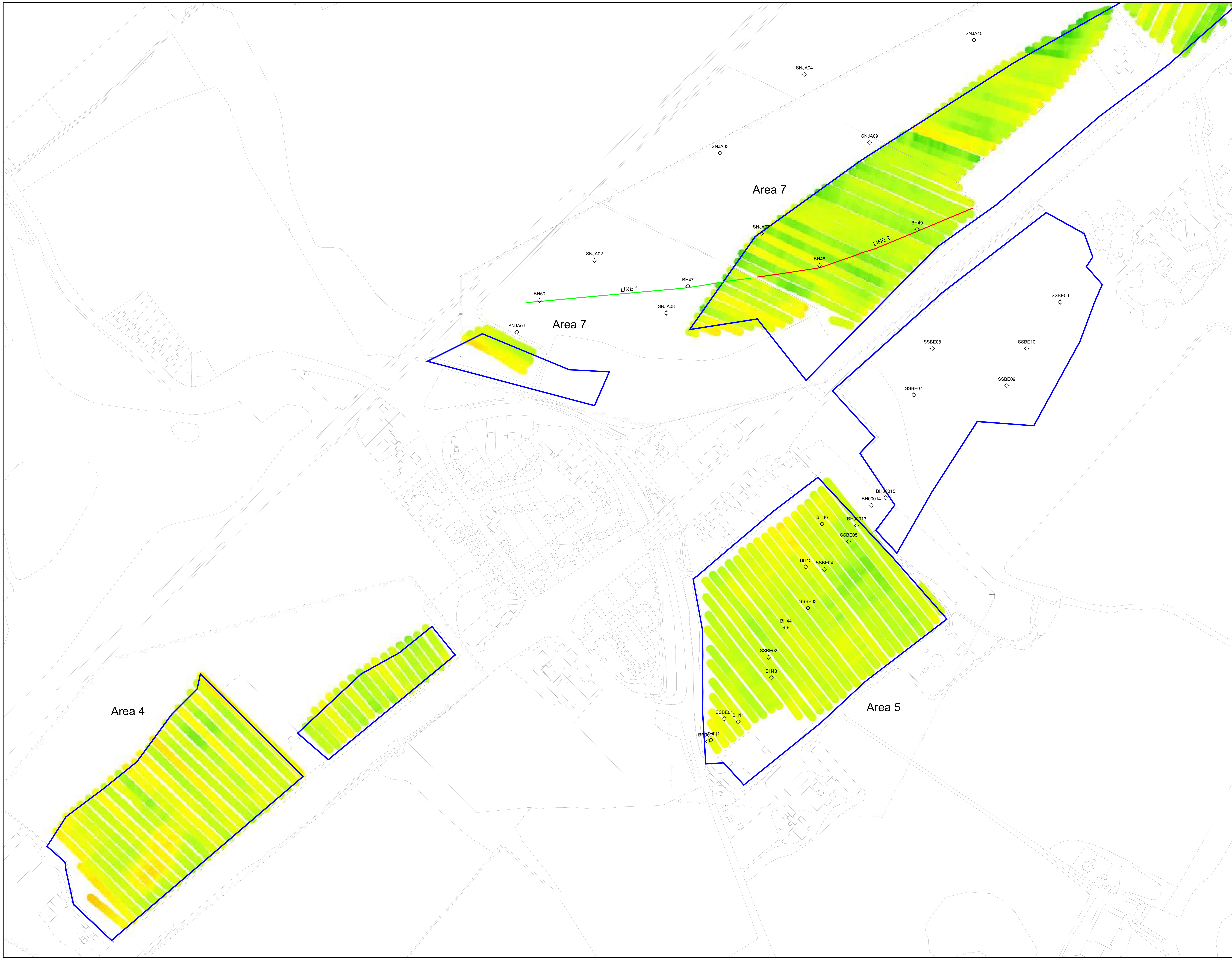
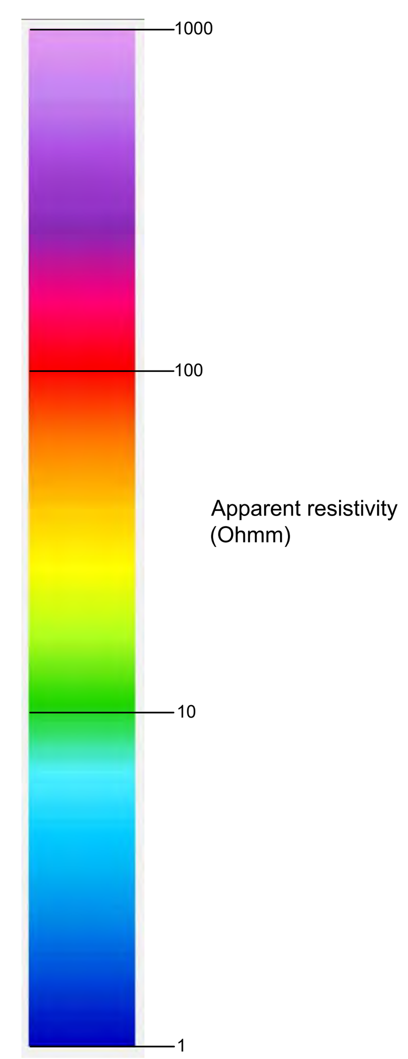


NOTES

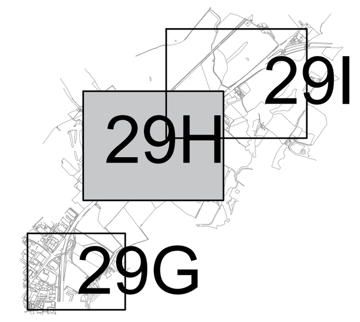
The specific risks associated with the content of this drawing are considered to be:-

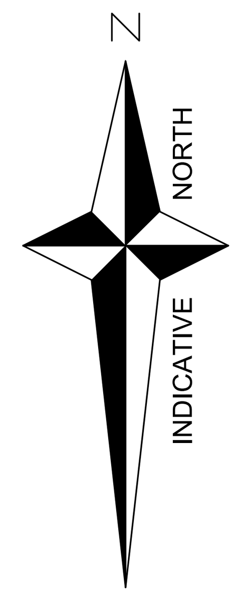
(1) The topographical baseplan has been supplied by the client and has not been checked for accuracy.
(2) Apparent conductivity data collected using CMD Explorer along bi-directional lines spaced approximately 10m apart. Position data acquired using a dGPS attached to the CMD Explorer console.
(3) Data inverted using Aarhus Workbench and apparent resistivity data points plotted with 5m buffer radius.

KEY



SHEET. LAYOUT





Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client

COSTAIN

Project Title

A12 CHELMSFORD TO A120 JUNCTIONS 19 TO 25

Drawing Title

APPARENT RESISTIVITY DEPTH 4-5M

Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

Scale	Orig Size	Dimensions
1:2000	A1	

Project No.	Drawing File
2190784	ILLUS 29H

Drawing No.	Rev.
ILLUS 29H	

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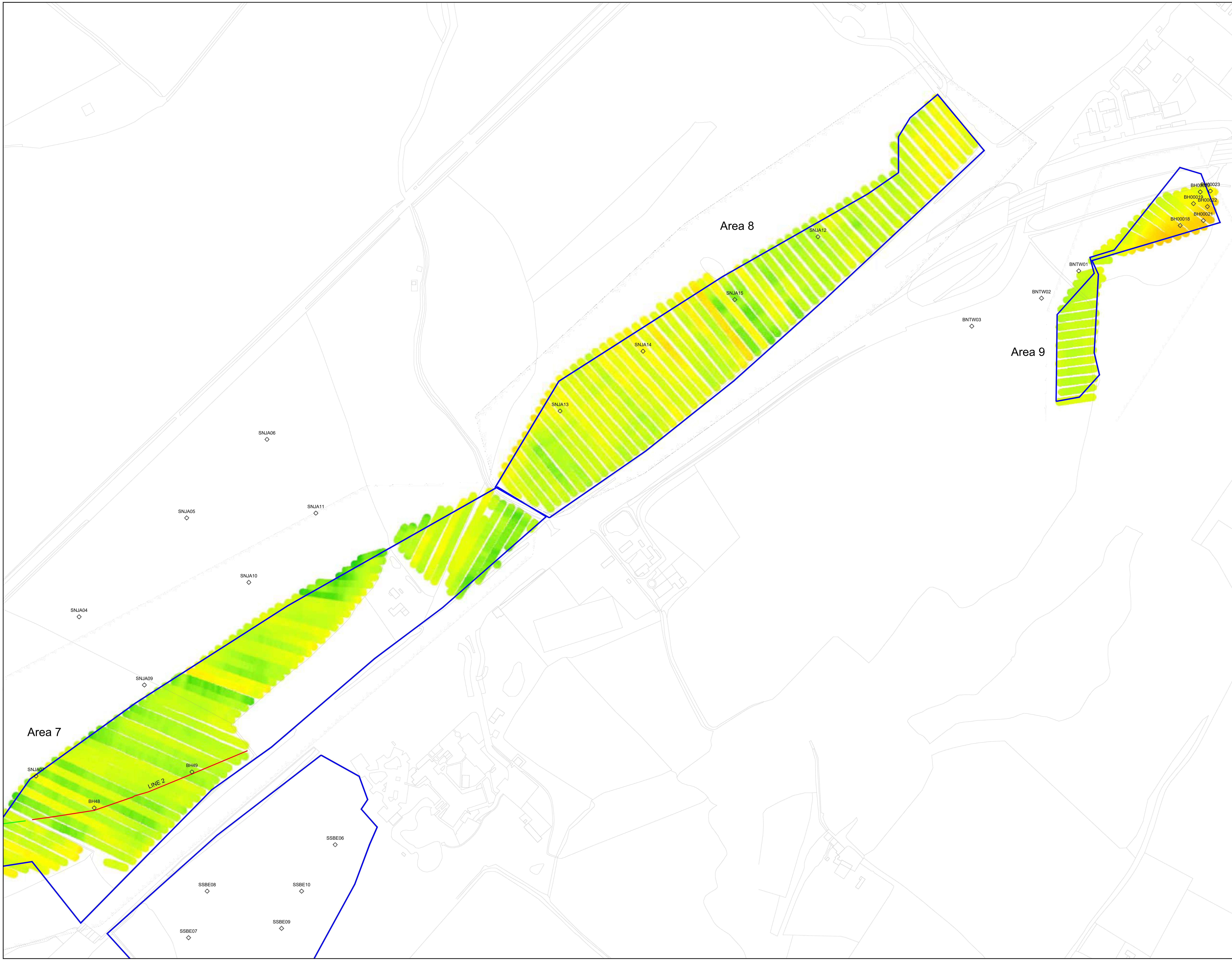
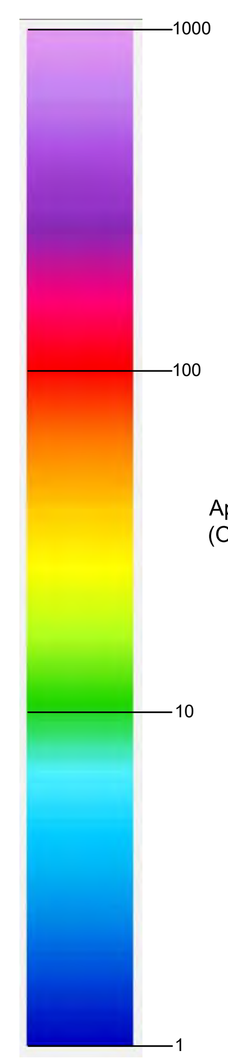


NOTES

The specific risks associated with the content of this drawing are considered to be:–

(1) The topographical baseplan has been supplied by the client and has not been checked for accuracy.
(2) Apparent conductivity data collected using CMD Explorer along bi-directional lines spaced approximately 10m apart. Position data acquired using a dGPS attached to the CMD Explorer console.
(3) Data inverted using Aarhus Workbench and apparent resistivity data points plotted with 5m buffer radius.

KEY



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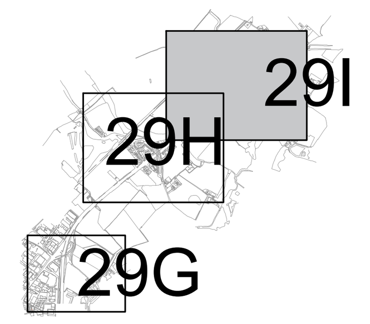
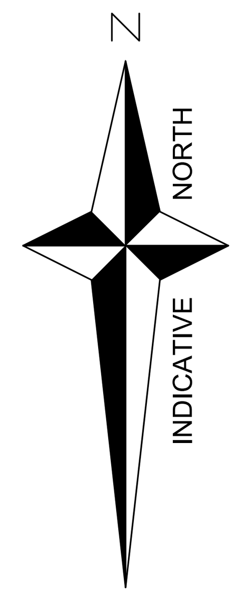




Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client
COSTAIN

Project Title
A12 CHELMSFORD TO A120 JUNCTIONS 19 TO 25

Drawing Title
APPARENT RESISTIVITY DEPTH 4-5M

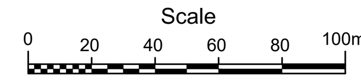
Drawn	Date	Checked	Date	Approved	Date
MJS	10/11/21	TG	10/11/21	MW	10/11/21

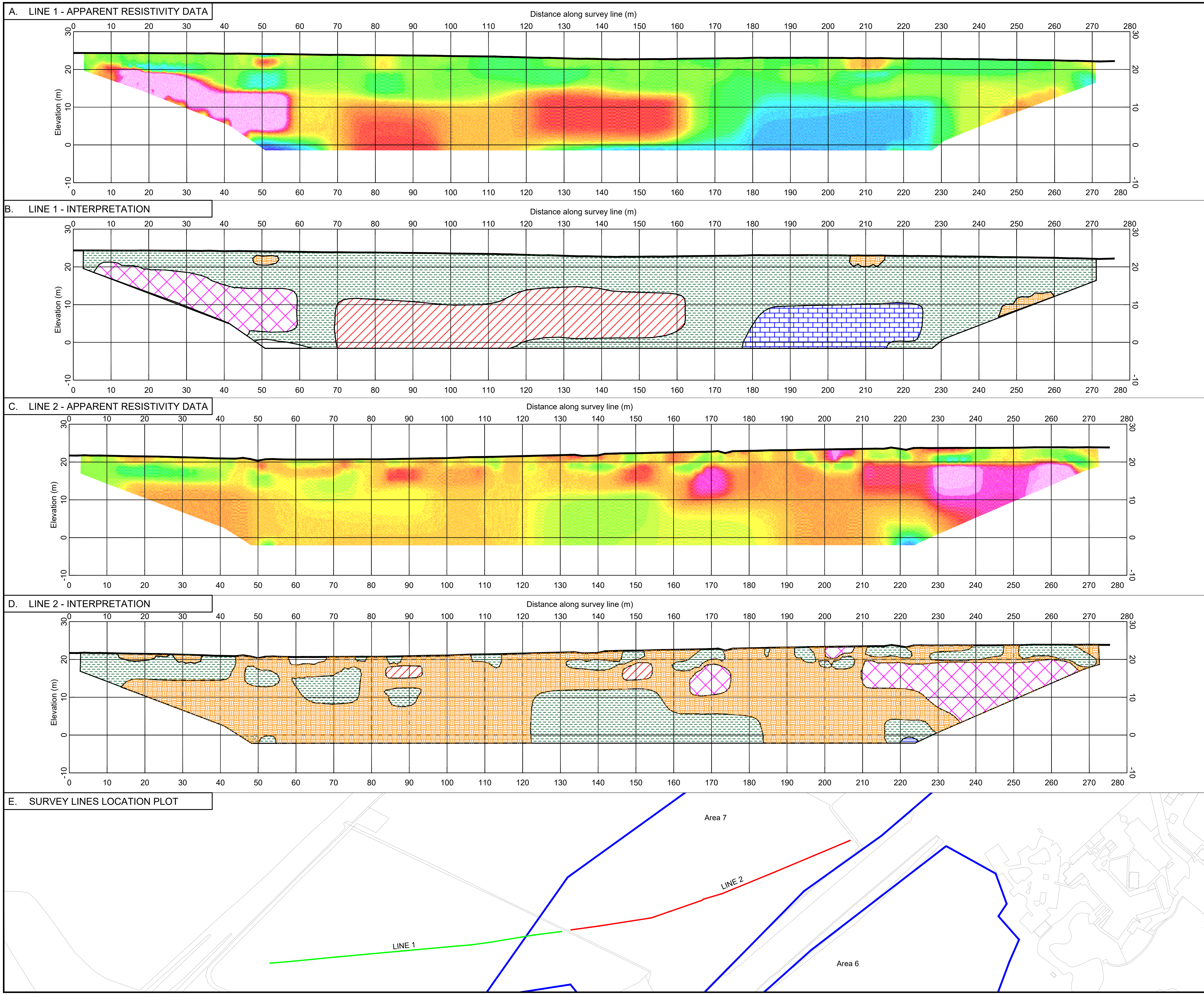
Scale	Orig Size	Dimensions
1:2000	A1	

Project No.	Drawing File
2190784	ILLUS 29I

Drawing No.	Rev.
ILLUS 29I	

Scale



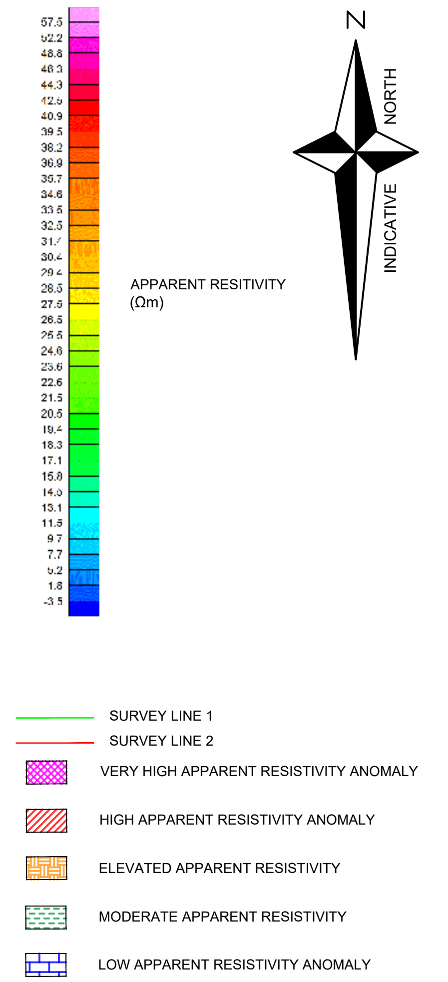


NOTES

The specific risks associated with the content of this drawing are considered to be:–

(1) The topographical baseplan has been supplied by the client and has not been checked for accuracy.
(2) Apparent resistivity data collected using Syscal Pro 72 with electores spaced approximately 2m apart. Position data acquired using a Leica GPS.
(3) Data inverted using Res2dInv and apparent resistivity data points plotted using Oasis Montaj

KEY



Rev.	Date	Amendment	Drawn	Chkd.	Appd.

HEADLAND ARCHAEOLOGY

Client

COSTAIN

Project Title

A12 CHELMSFORD TO A120
JUNCTIONS 19 TO 25

Drawing Title

RESULTS OF THE ERT SURVEY

Drawn	Date	Checked	Date	Approved	Date
VV	02/09/21	MJS	02/09/21	SH	02/09/21

Scale: 1:2000
Orig Size: A3
Dimensions

Project No.: 2190784
Drawing File: 2190784 Figure 1

Drawing No.: 2190784 Figure 30 Sheet 1 of 1
Rev.

Scale
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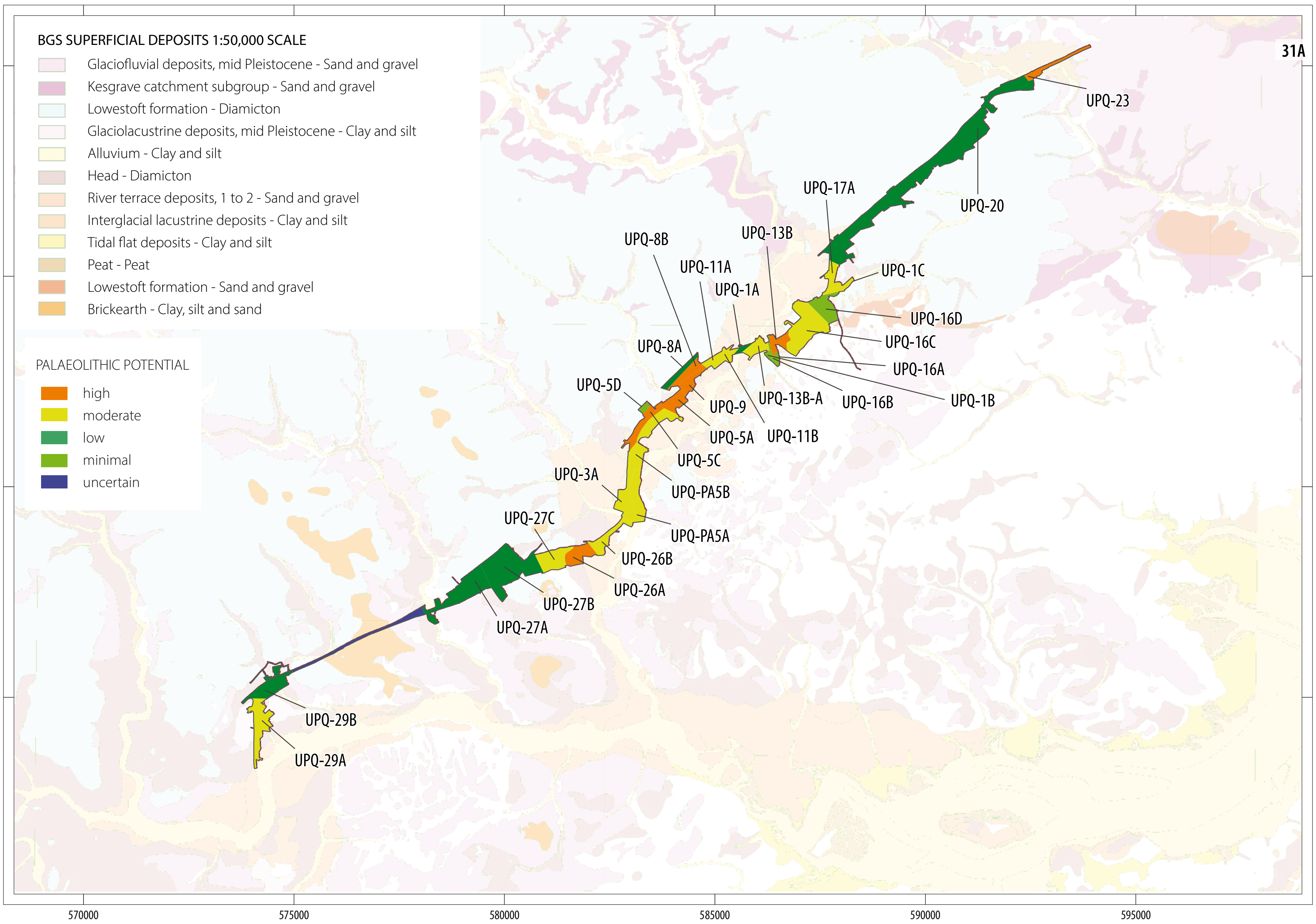
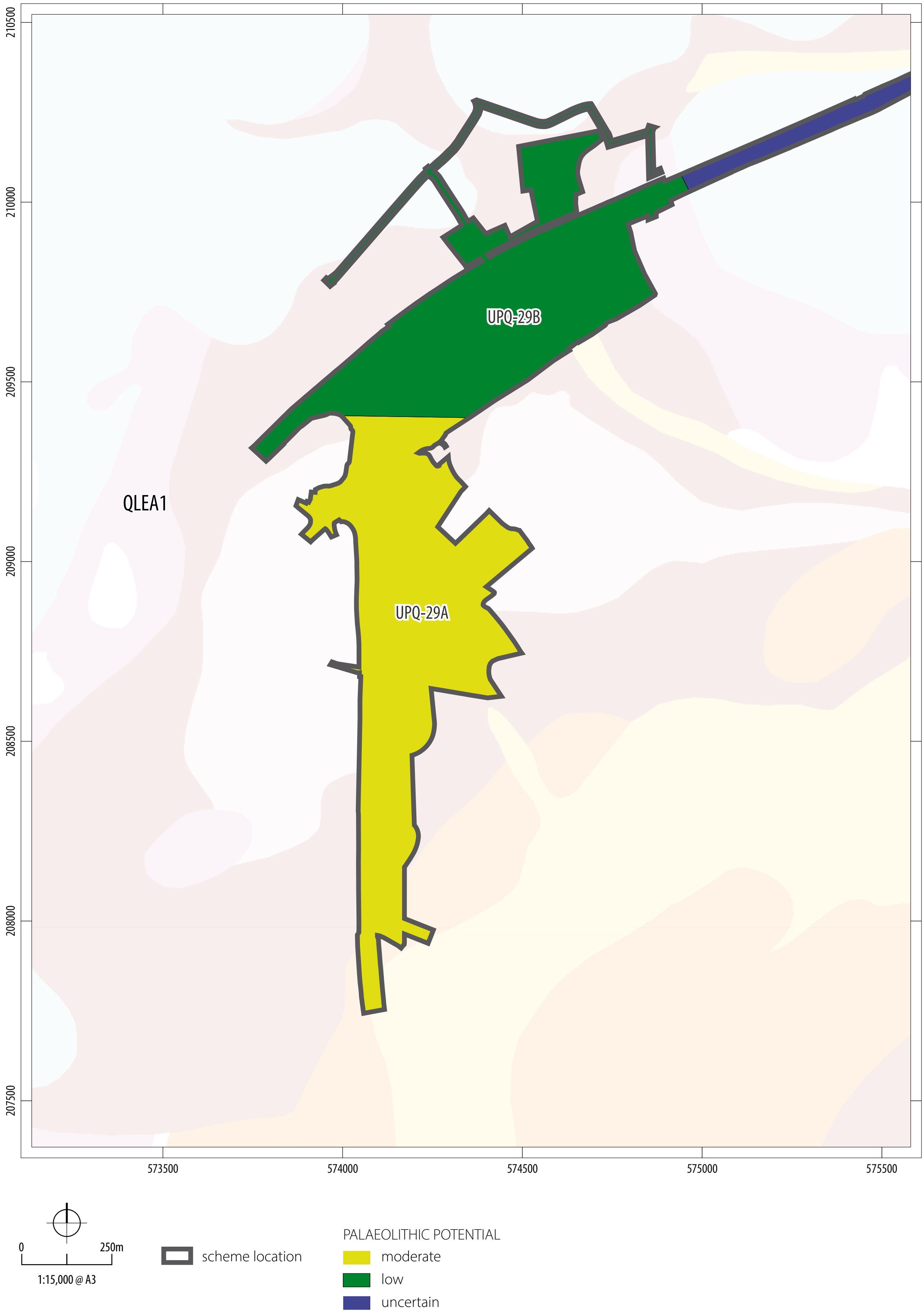
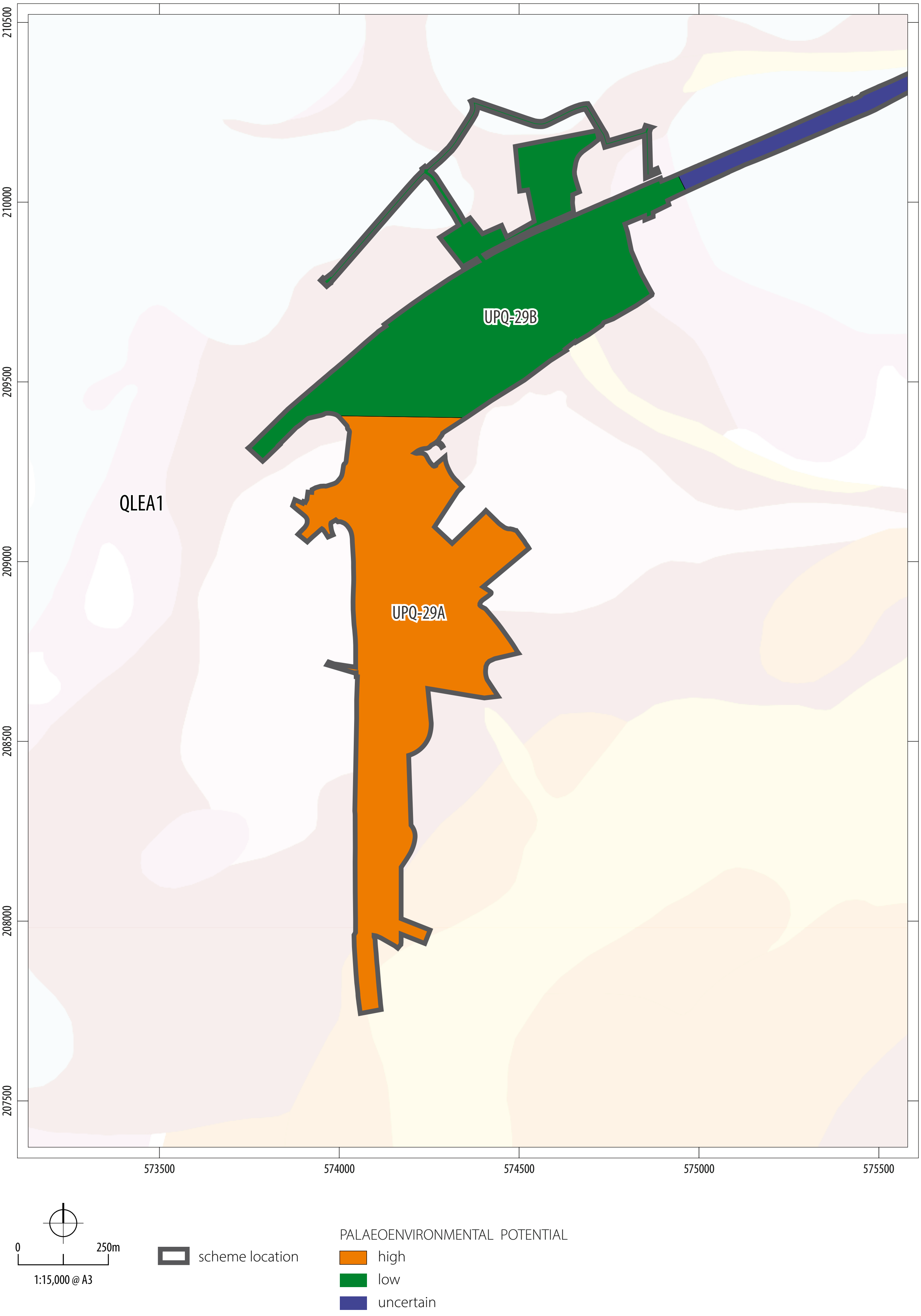


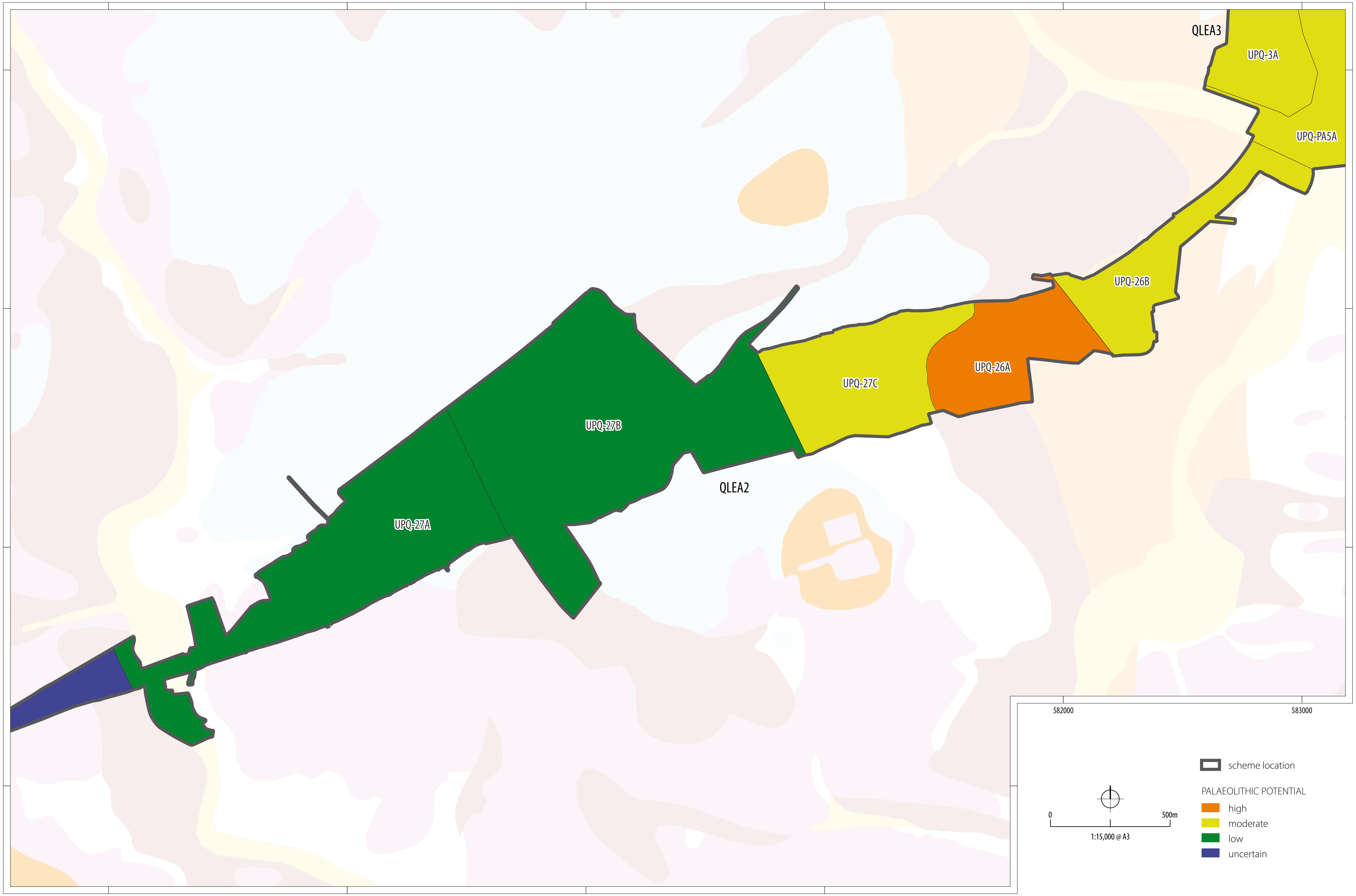
ILLUS 31 Scheme-specific updated PQ zones. **A** colour coded for Palaeolithic potential. **B** Colour coded for palaeoenvironmental potential



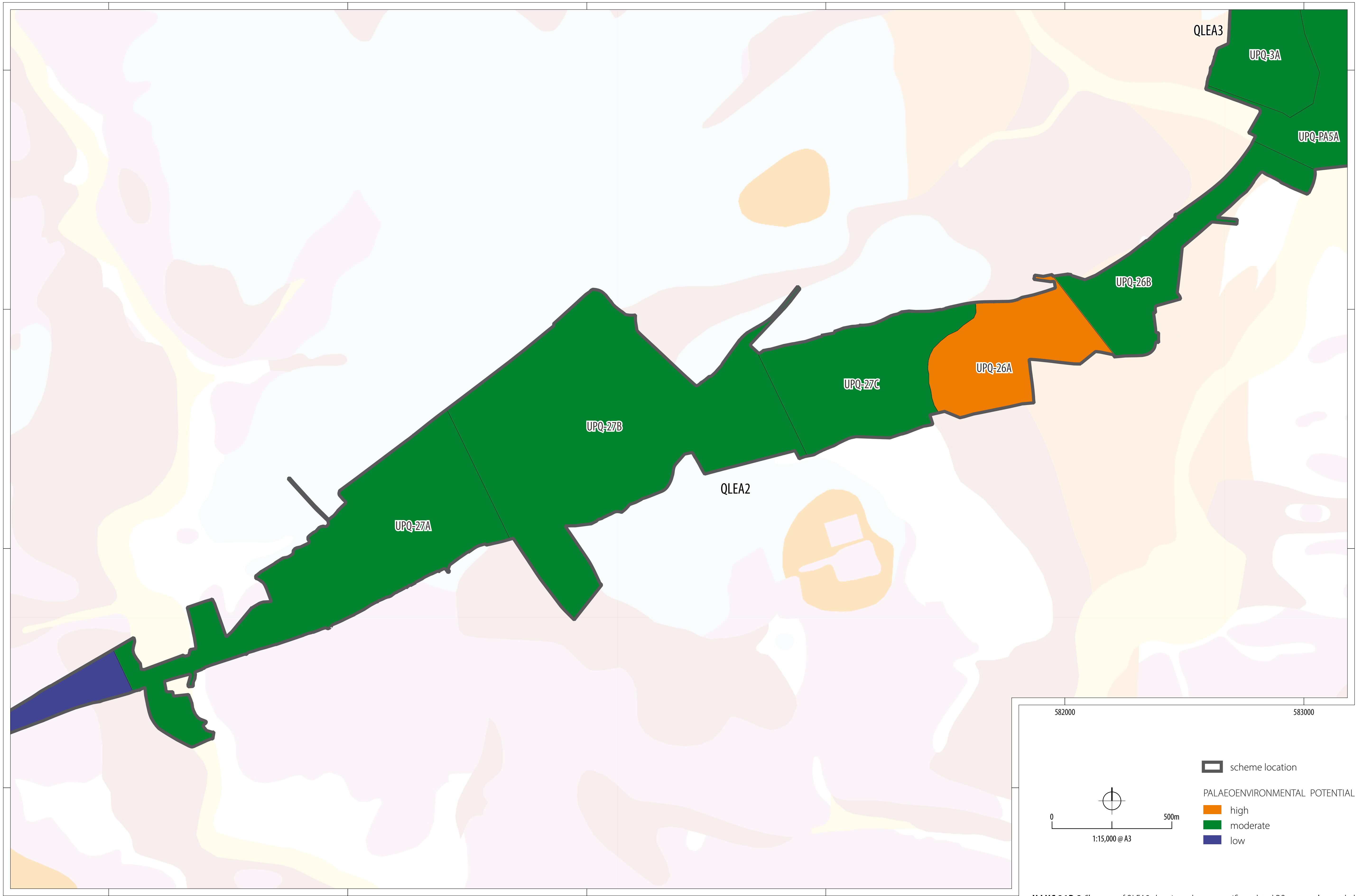
ILLUS 31A.1 Close-up of QLEA1 showing scheme-specific updated PQ zones colour coded for palaeolithic potential



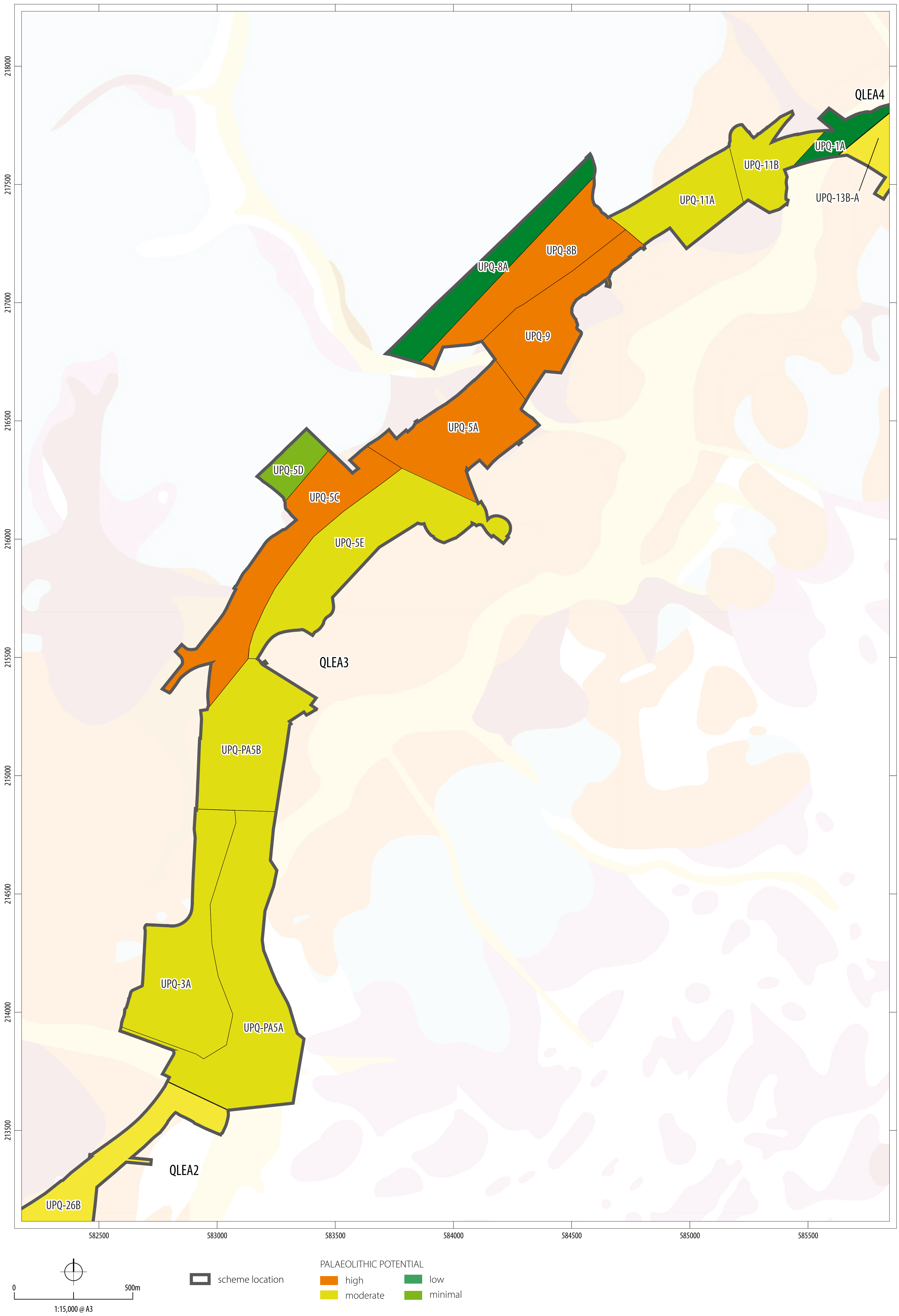
ILLUS 31B.1 Close-up of QLEA1 showing scheme-specific updated PQ zones colour coded for palaeoenvironmental potential



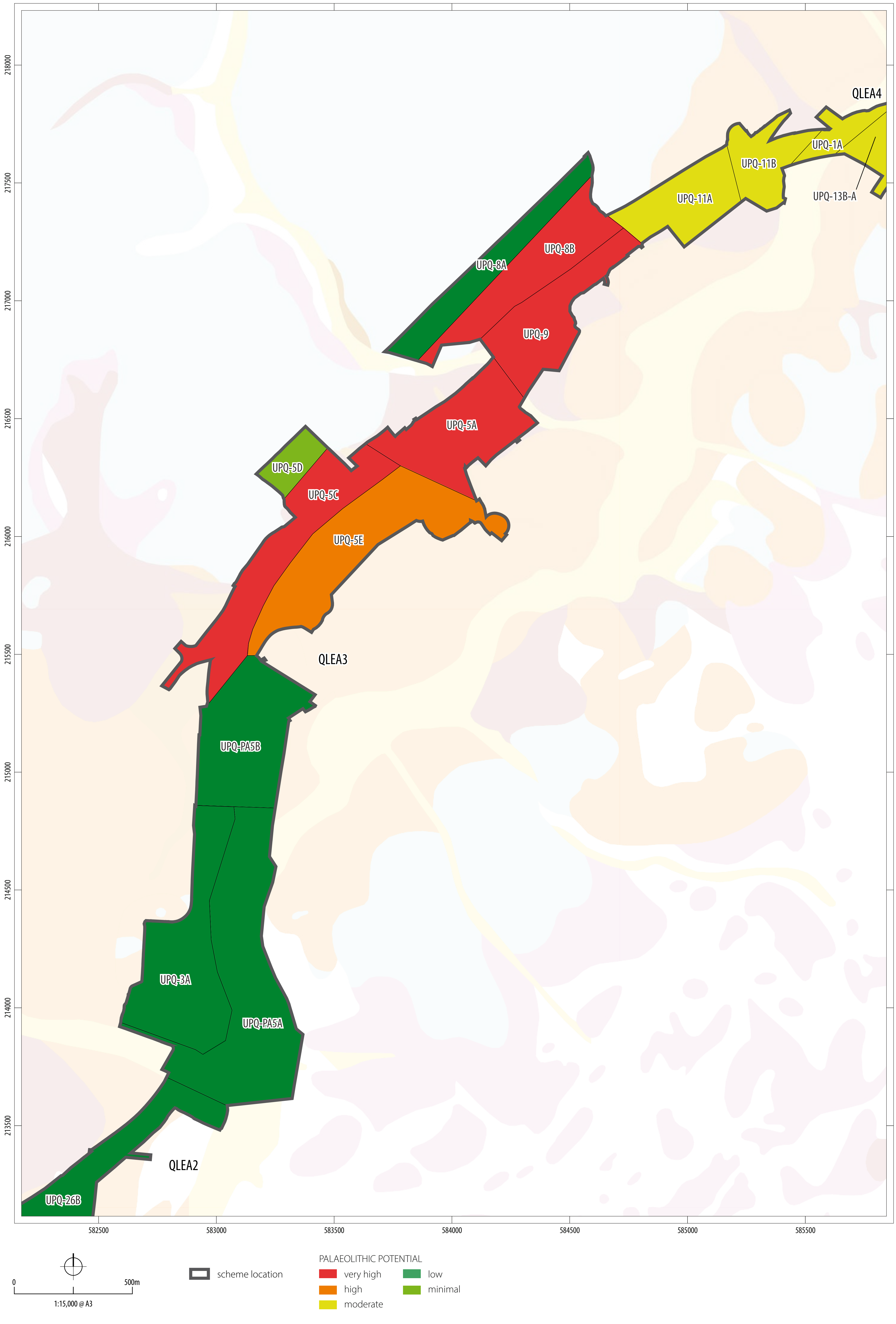
ILLUS 31A.2 Close-up of QLEA2 showing scheme-specific updated PQ zones colour coded for palaeolithic potential



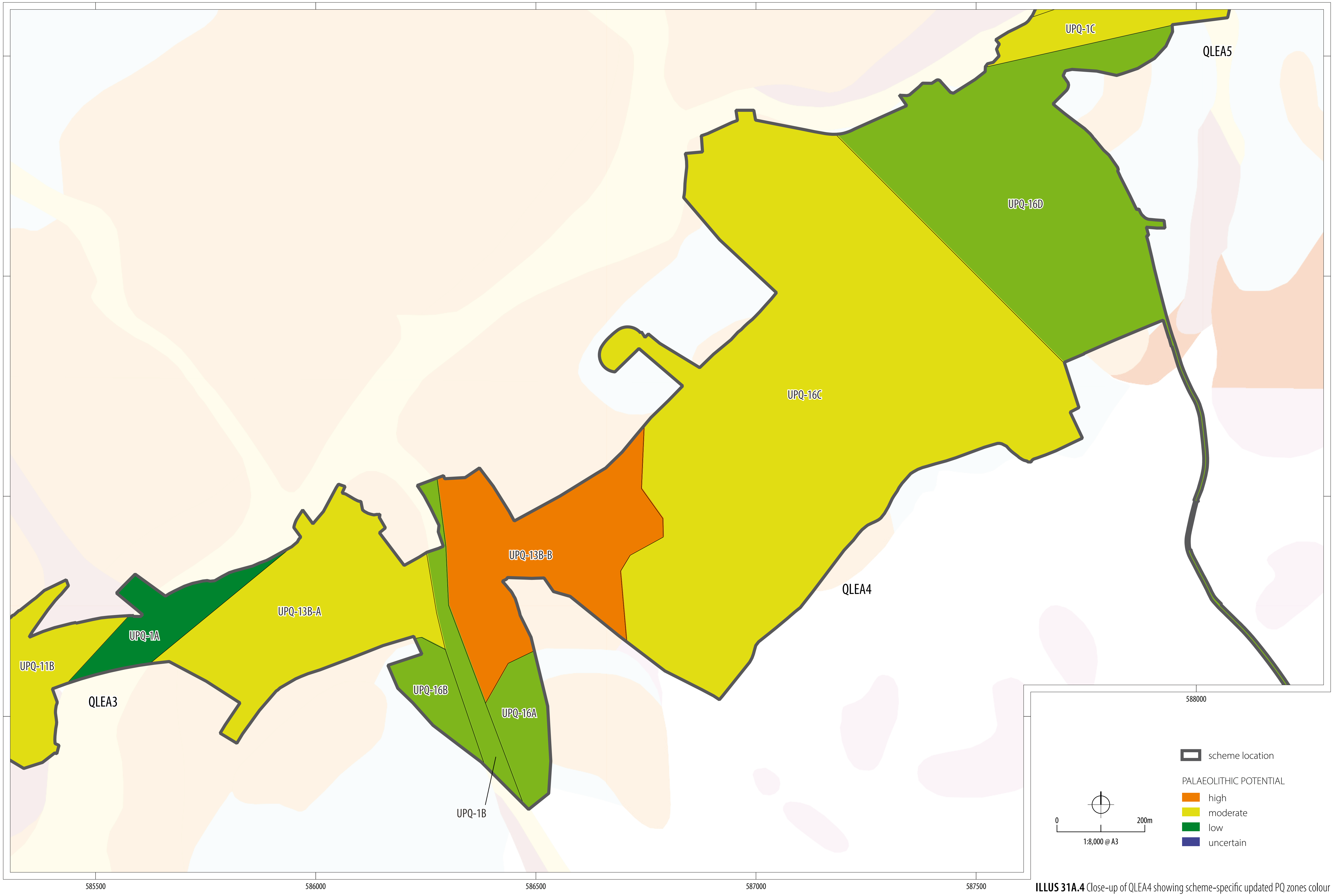
ILLUS 31B.2 Close-up of QLEA2 showing scheme-specific updated PQ zones colour coded for palaeoenvironmental potential



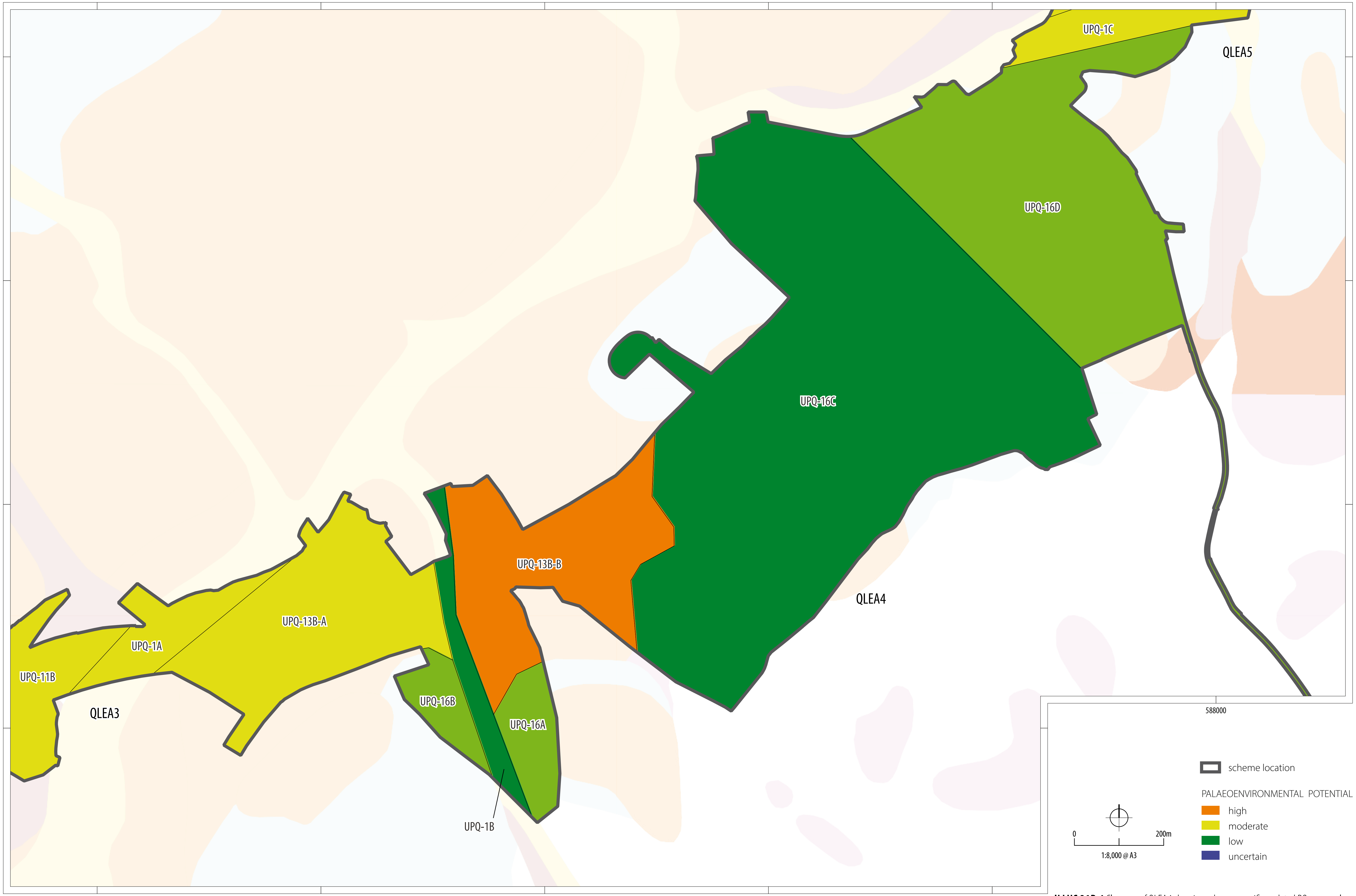
ILLUS 31A.3 Close-up of QLEA3 showing scheme-specific updated PQ zones colour coded for palaeolithic potential



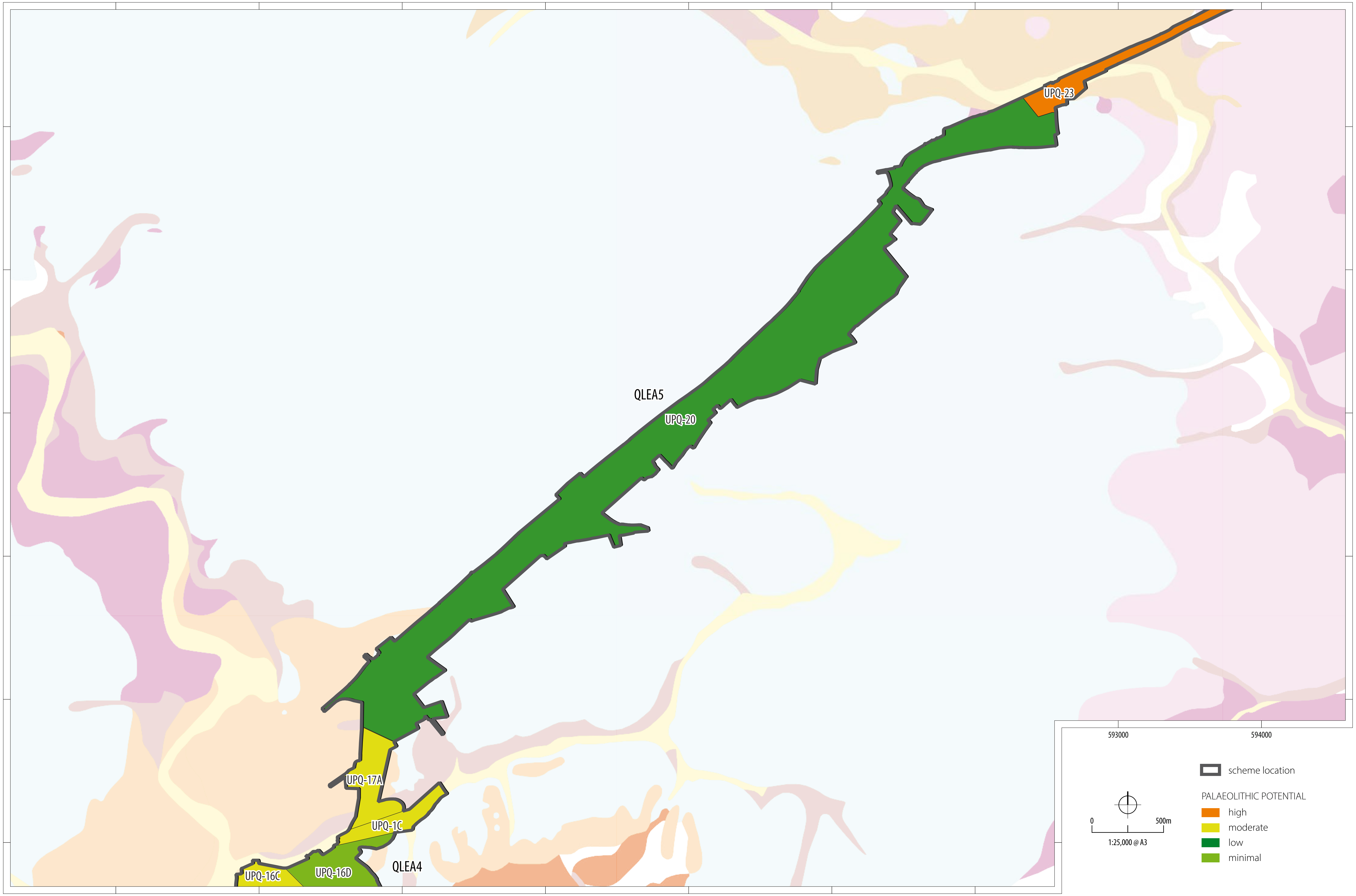
ILLUS 31B.3 Close-up of QLEA3 showing scheme-specific updated PQ zones colour coded for palaeoenvironmental potential



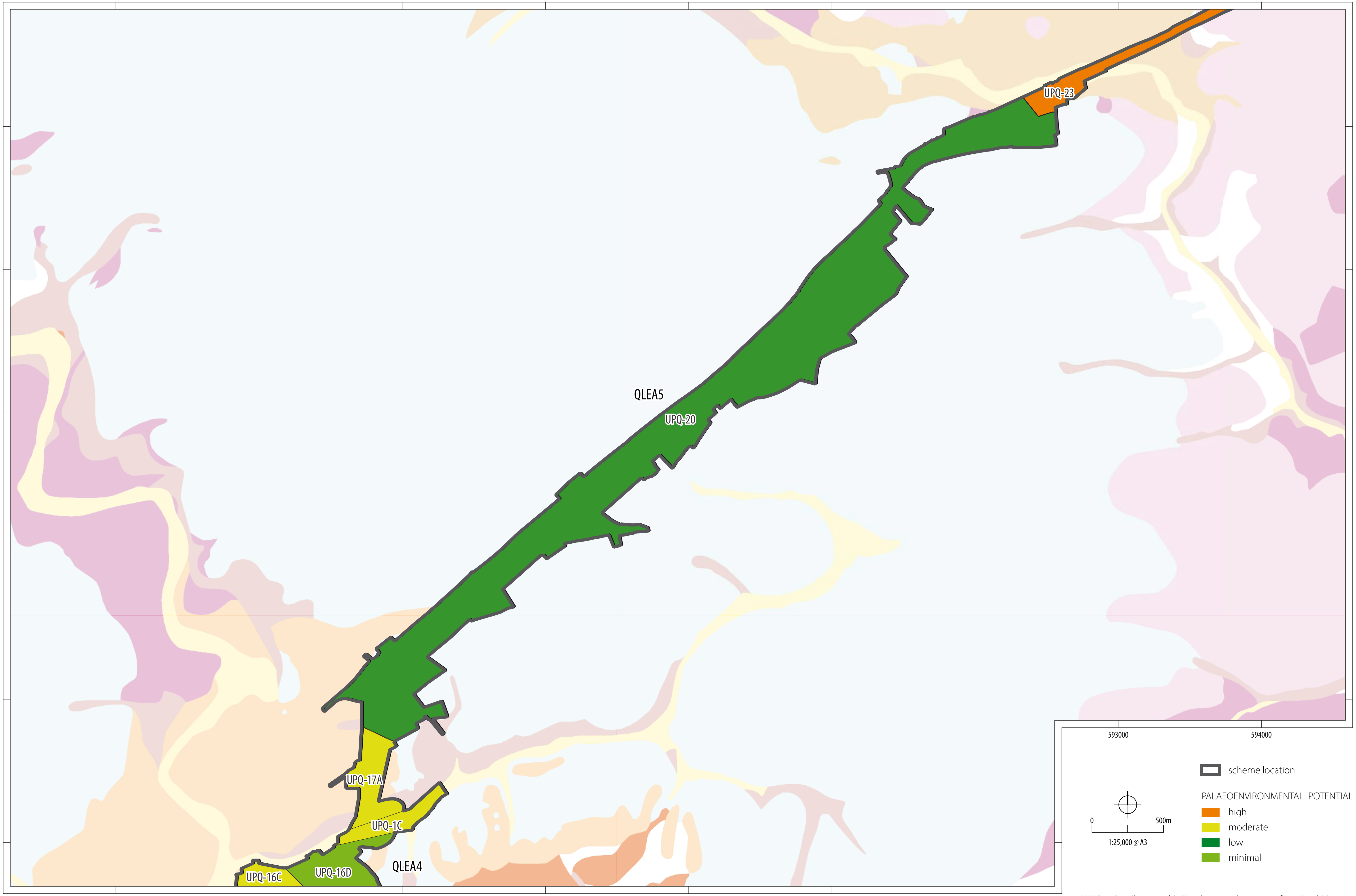
ILLUS 31A.4 Close-up of QLEA4 showing scheme-specific updated PQ zones colour coded for palaeolithic potential



ILLUS 31B.4 Close-up of QLEA4 showing scheme-specific updated PQ zones colour coded for palaeoenvironmental potential

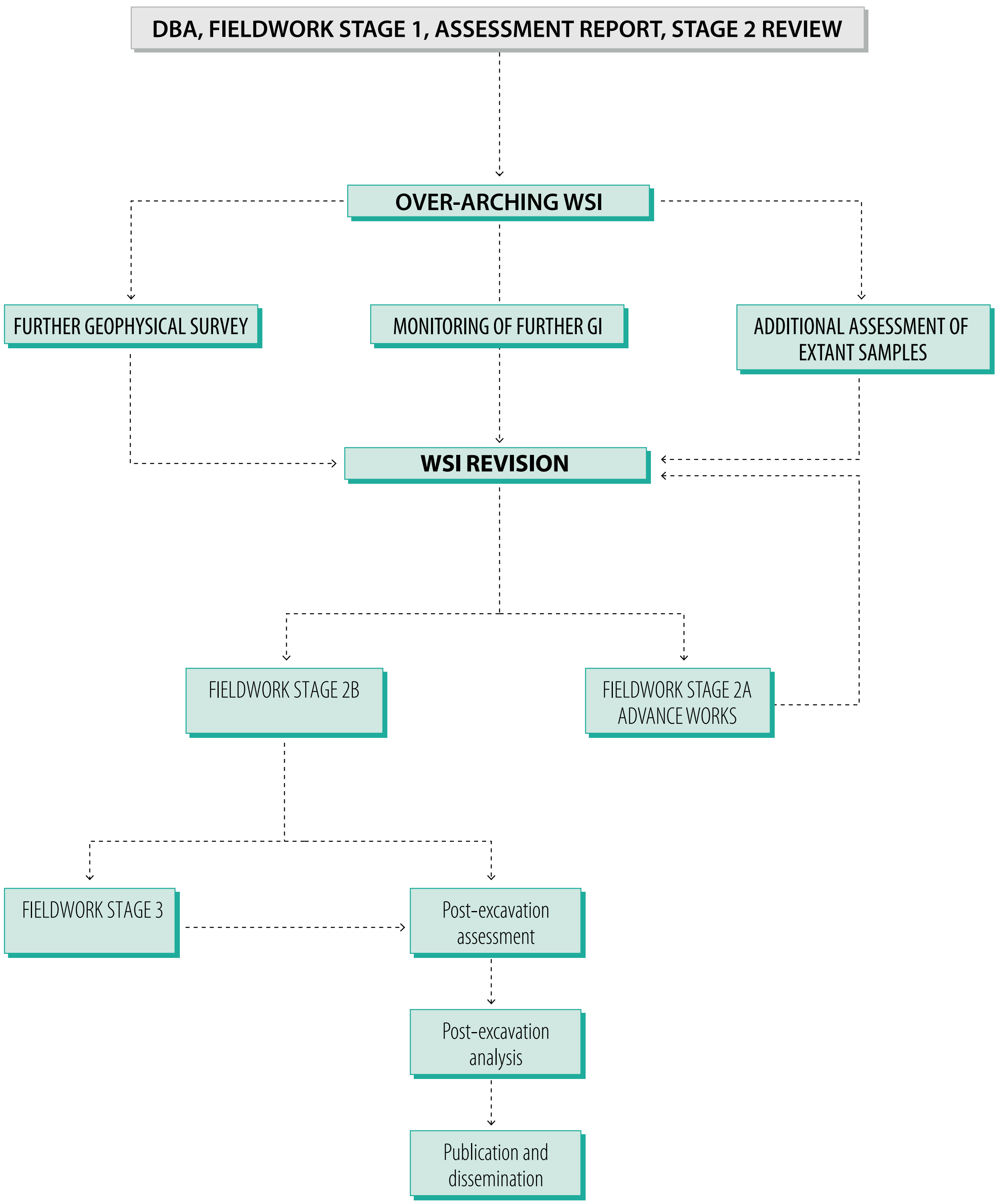


ILLUS 31A.5 Close-up of QLEA5 showing scheme-specific updated PQ zones colour coded for palaeolithic potential



ILLUS 31B.5 Close-up of QLEA5 showing scheme-specific updated PQ zones colour coded for palaeoenvironmental potential

PROJECT FLOW CHART



ILLUS 32 Indicative project flowchart

ATTT

A12 ARCHAEOLOGICAL EVALUATION (JUNCTION 19/CHELMSFORD – JUNCTION 25/A120)

Palaeolithic and Palaeoenvironmental Stage 2 Review

Part 3: Appendices

Headland Archaeology Midlands & West
Unit 1 | Clearview Court | Twyford Rd | Hereford HR2 6JR

for Costain Group plc
on behalf of National Highways

HE551497-COS-HER-3_S0-RP-X-0010

Draft v.1
28/01/2022

HEADLAND ARCHAEOLOGY

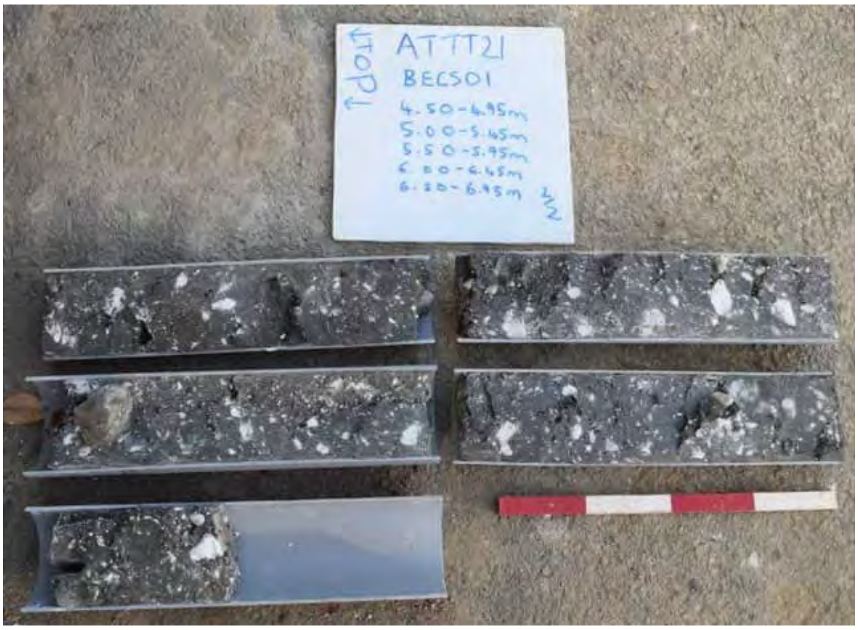
Appendix 1

Borehole records

Borehole BECS01
Easting: 587782.859
Northing: 219275.489
Elevation: 29.47 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Silty Clay	Medium brownish-grey silty clay. <40% chalk and other clasts.
1.20	1.37	Clayey Medium Sand	Medium orangish-brown clayey medium sand. 2% sub-angular flint clasts 15mm. Mn pan at 1.35-7m.
1.37	1.43	Sandy Clay	Medium yellowish-brown sandy clay. Coarsens upwards with discontinuous laminations of orange sand throughout. 2% sub-rounded chalk clasts <15mm. 5% Mn flecks concentrated at 1.35-40m.
1.43	2.00	Silty Clay	Light orangish-brown silty clay. Intermittent fine laminations of clayey silt. 10% Mn mottling. Void at 1.65-1.76m.
2.00	2.50	Clayey Silt	Light yellowish-grey clayey silt. <1% flint clasts.
2.50	3.84	Silty Clay	Medium brownish-grey silty clay. Continuous laminations of orange sand and fine chalky gravel throughout. Gravel laminations concentrated towards base of unit at 3.65-80m. 5% sub-rounded chalk clasts <10mm. Charcoal fragment 30mm in diameter at 3.83m. Void at 3.00-12m.
3.84	4.05	Sandy Silt	Medium greyish-brown sandy silt. 40% sub-rounded to rounded chalk clasts <40mm.
4.05	6.95	Silty Clay	Medium grey silty clay. 5% Mn staining and <1% Fe flecks. 40% sub-rounded to rounded chalk and 5% flint clasts <70mm.

ATTT21 BECS01 1.2-4.45m.



ATTT21 BECS01 4.50-6.95m.

Borehole BECS02
Easting: 587818.182
Northing: 219408.241
Elevation: 32.4 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Silty Clay	Medium brownish-grey silty clay. <40% chalk and other clasts.
1.20	1.65	Clayey Medium Sand	Medium brownish-orange clayey medium sand. Clasts are sub-rounded to well-rounded flint, tertiary flint and quartz <50mm.
1.65	2.00	Medium Sand	Medium brownish-orange medium sand. Clasts are sub-rounded to well-rounded flint, tertiary flint and quartz <50mm.
2.00	2.50	Clayey Medium Sand	Dark orangish-brown clayey medium sand. Clasts are sub-rounded to well-rounded flint, tertiary flint and quartz <50mm.
2.50	2.95	Clayey Fine Sand	Medium orangish-brown clayey fine sand. Clasts are sub-angular to well-rounded flint and quartz <50mm. Yellow clay pockets throughout.
2.95	3.95	Sandy Clay	Medium yellowish-grey sandy clay. Bedded with sandy clasts. Clasts are angular flint <5mm.
3.95	4.00	Clayey Silt	Medium greyish-yellow clayey silt. Clasts are sub-rounded to rounded chalk <15mm.
4.00	4.45	Sandy Clay	Medium yellowish-grey sandy clay. Bedded with sandy clasts. Clasts are angular flint <5mm.
4.45	4.50	Clayey Silt	Medium greyish-yellow clayey silt.
4.50	4.95	Sandy Clay	Medium yellowish-grey sandy clay. Bedded with sandy clasts. Clasts are sub-angular flint <5mm.
4.95	5.00	Sandy Silt	Medium yellowish-grey sandy silt. Clasts are sub-rounded to rounded chalk and flint <20mm.
5.00	5.45	Silty Clay	Medium grey silty clay.
5.45	5.50	Silty Clay	Medium grey silty clay. Mn staining.
5.50	5.95	Silty Clay	Medium grey silty clay. Clasts are sub-rounded chalk <15mm.
5.95	6.00	Silty Clay	Medium grey silty clay. Mn flecks. Clasts are sub-rounded chalk <25mm.
6.00	6.45	Silty Clay	Medium grey silty clay.
6.45	6.50	Silty Clay	Medium grey silty clay.
6.50	6.95	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <10mm.
6.95	7.00	Silty Gravelly Clay	Dark blueish-grey silty gravelly clay. 5% gravel in clay.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
7.00	7.45	Silty Clay	Medium grey silty clay. Chalk flecks. Clasts are sub-rounded to rounded chalk and flint <30mm.
7.45	8.00	Silty Clay.	Medium grey silty clay.
8.00	8.45	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to rounded chalk <15mm.
8.50	8.95	Silty Clay	Medium grey silty clay. Fe flecks. Clasts are sub-rounded chalk and flint <20mm.

ATTT21 BECS02 1.2-4.95m

ATTT21 BECS02 5.00-8.95m

Borehole BECS04
Easting: 587656.503
Northing: 219426.494
Elevation: 32.31 m OD

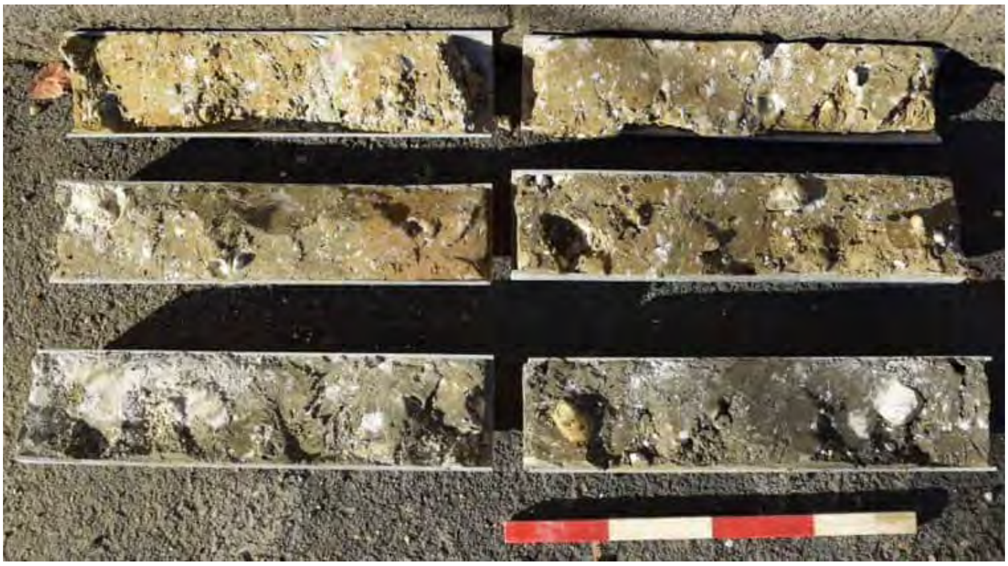
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Silty Clay	Medium greyish-brown silty clay. 40% chalk <20mm and other clasts <50mm.
1.20	1.71	Silty Clay	Medium orangish-brown silty clay. Light orangish brown 1.65-71m. Clasts are sub-rounded chalk <5mm. Pocket of reddish brown medium sand 1.23-6m. Lens of Mn staining at base of unit.Mn flecks throughout.
1.71	1.95	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Continuous clay laminations throughout. Clasts are sub-angular flint <5mm.
1.95	2.00	Medium Sand	Medium orangish-brown medium sand. Mn flecks.
2.00	2.45	Clayey Fine Sand	Medium orangish-brown clayey fine sand. Yellow clay pockets throughout.
2.45	2.95	No Recovery	
2.95	3.00	Gravelly Medium Sand	Light brownish-orange gravelly medium sand. <5% flint clasts.
3.00	3.50	Gravelly Coarse Sand	Medium orangish-yellow gravelly coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <45mm.
3.50	4.00	No Recovery	
4.00	4.50	Gravelly Coarse Sand	Medium orangish-yellow gravelly coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <45mm.
4.50	5.00	Medium Sand	Medium yellow medium sand. Clasts are rounded flint, quartz and chalk <40mm.
5.00	5.50	Medium Sand	Medium greyish-yellow medium sand. Clasts are rounded to sub-rounded flint and quartz <30mm.
5.50	6.00	Medium Sand	Medium orangish-yellow medium sand. Clasts are rounded to sub-rounded flint <40mm.
6.00	6.50	Sandy Clay	Medium brown sandy clay. 2% sub-rounded flint clasts <10mm.
6.50	7.00	Sandy Silty Clay	Medium yellow sandy silty clay. Clasts are sub-angular flint <5mm.
7.00	7.50	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded chalk <15mm.

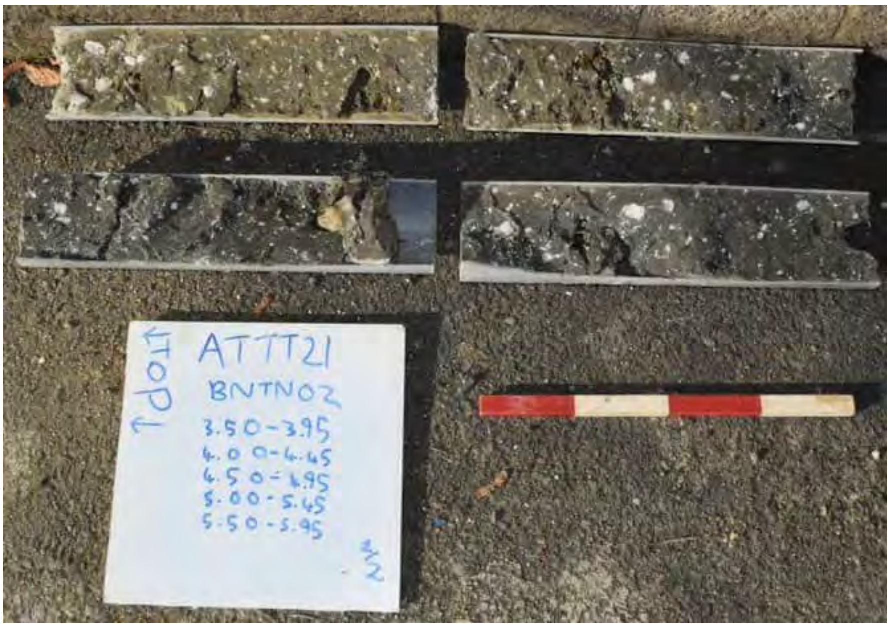
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
7.50	7.95	Silty Clay	Medium grey silty clay. Mn flecks. Clasts are sub-rounded chalk <25mm.
7.95	8.00	Clay	Medium grey clay. Clasts are sub-rounded chalk <25mm.
8.00	8.45	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to rounded chalk <25mm.
8.45	8.50	Silty Clay	Medium grey silty clay. 1% Mn flecks. Clasts are sub-rounded to rounded chalk <25mm.

ATTT21 BECS04 1.20-2.00m, 8.00-8.45m

Borehole BNTN02
Easting: 587155.553
Northing: 218656.625
Elevation: 32.12 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Silty Clay	Medium greyish-brown silty clay <30% clasts <50mm.
0.50	1.20	Silty Clay	Light orangish-grey silty clay <30% chalk and other clasts <40mm.
1.20	1.69	Silty Clay	Dark greyish-yellow silty clay. 10% light grey mottling. 40% sub-rounded to rounded chak clasts <25mm.
1.69	3.64	Silty Clay	Medium yellowish-grey silty clay. Medium brown clayey sand pocket 2.33-44m. 40% medium grey mottling. 1% Fe mottling.
3.64	5.95	Silty Clay	Medium grey silty clay. 1% Mn flecks. 40% sub-rounded to rounded chalk clasts and 2% flint clasts <60mm.
5.95	6.00	Silty Clay	Dark grey silty clay. Mn and Fe flecks. Clasts are sub-rounded to rounded chalk <25mm.


ATTT21 BNTN02 1.20-3.95m



ATTT21 BNTN02 3.50-5.95m

Borehole BNTN03
Easting: 586945.417
Northing: 218747.671
Elevation: 25.41 m OD

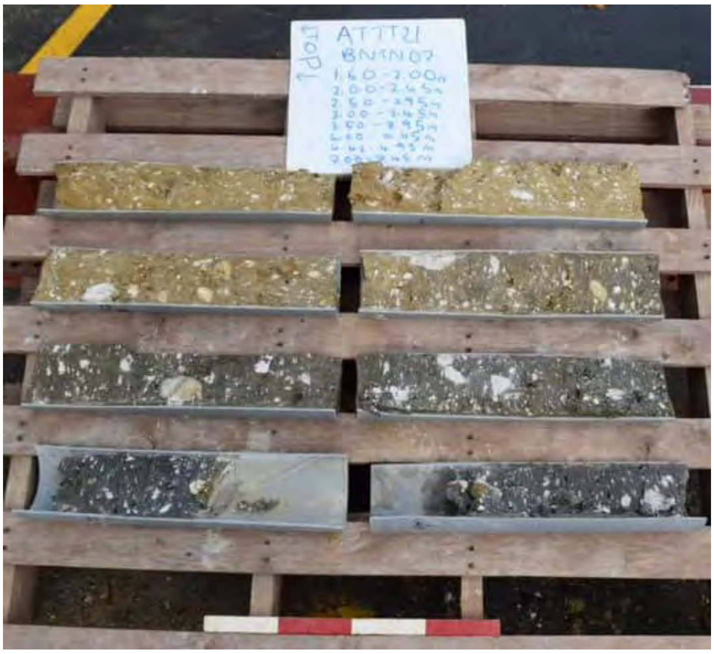
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Silty Sand	Medium reddish-brown silty sand. Fine to medium sub-angular to sub-rounded flint.
0.3	1.2	Silty Sand	Medium reddish-brown silty sand.
1.2	1.5	Gravelly Coarse Sand	Dark brown gravelly coarse sand. Slightly clayey. 40% sub-angular to angular flint <15mm.
1.5	2.0	Gravel	Medium greyish-brown gravel. Clast supported.
2.0	2.5	Sandy Gravel	Medium brownish-grey sandy gravel. Clast supported. Clasts are sub-angular to angular flint and quartz <50mm. 5% sand in gravel.
2.5	3.0	Gravel	Medium yellowish-brown gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and quartz <60mm.
3.0	3.5	Sandy Gravel	Medium yellowish-grey coarse sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and quartz <70mm. 35% sand in gravel.
3.5	4.0	Sandy Gravel	Medium yellowish-grey sandy gravel. Clast supported. Clasts are sub-angular to sub-rounded flint and quartz <40mm. 30% sand in gravel.
4.0	4.5	Sandy Gravel	Medium grey coarse sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint and quartz <60mm. 40% sand in gravel.
4.5	5.0	Sandy Clay	Light greyish-brown coarse sandy clay. 20% sub-angular to sub-rounded flint clasts and 2% quartz clasts <60mm.

Borehole BNTN04
Easting: 587038.228
Northing: 218792.002
Elevation: 24.58 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silty Sand	Medium reddish-brown silty sand. Fine to medium sub-angular to sub-rounded flint clasts.
0.30	1.20	Silty Sand	Medium reddish-brown silty sand.
1.20	1.65	Clayey Coarse Sand	Medium orangish-brown clayey coarse sand. Clasts are sub-angular to sub-rounded flint <30mm.
1.65	2.00	Clayey Medium Sand	Medium brownish-orange clayey medium sand. Clasts are rounded to angular flint <80mm.
2.00	2.50	Sandy Gravel	Medium brownish-yellow sandy gravel. Clast supported. Clasts are sub-rounded to rounded flint and quartz <50mm.
2.50	3.00	Gravelly Coarse Sand	Medium yellow gravelly coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <30mm.
3.00	3.45	Sandy Gravel	Medium greyish-yellow sandy gravel. Clast supported. Clasts are rounded to sub-rounded flint and quartz <80mm.
3.45	4.00	Gravel	. . .
4.00	4.50	Coarse Sand	Medium yellow gravelly coarse sand. Clasts are rounded to sub-rounded flint and quartz <50mm.
4.50	5.00	Medium Sand	Medium yellow gravelly medium sand. Clasts are sub-angular to sub-rounded flint and quartz <40mm.
5.00	5.95	Silty Medium Sand	Medium silty medium sand. Clasts are angular flint <5mm.
5.95	6.20	Silty Clay	Medium greyish-brown silty clay.
6.20	6.50	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to rounded chalk and flint <20mm. 1% Mn flecks.

Borehole BNTN07
Easting: 586694.796
Northing: 218333.382
Elevation: 28.93 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.80	Silty Clay	Medium brownish-grey silty clay.
0.80	1.20	Sandy Clay	Medium orangish-brown sandy clay.
1.20	1.65	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-rounded to rounded chalk and flint <30mm.
1.65	3.32	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to rounded chalk and sandstone <50mm. Mn and Fe flecks.
3.32	4.78	Silty Clay	Dark grey silty clay. 1% rounded charcoal.
4.78	5.00	No Recovery	
5.00	5.50	Clayey Sandy Gravel	Light whitish-grey clayey sandy gravel. Clast supported. Clasts are rounded to sub-angular chalk and flint <50mm.
5.50	6.00	Sandy Clay	Medium grey sandy clay. Clasts are sub-rounded to angular flint <40mm.
6.00	6.50	Sandy Clayey Gravel	Light grey sandy clayey gravel. Matrix supported. Clasts are sub-angular to angular <40mm.
6.50	6.95	Sandy Clay	Medium grey sandy clay. Clasts are sub-rounded to rounded chalk and flint <40mm.
6.95	7.00	Silty Clay	Dark grey silty clay. Clasts are sub-rounded chalk <15mm.
7.00	7.13	No Recovery	
7.13	7.45	Silty Clay	Dark grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <40mm. Mn flecks.
7.45	7.50	Silty Clay	Dark grey silty clay. Clasts are sub-rounded to rounded chalk <20mm. 1% Mn flecks.



ATTT21 BNTN07 1.6-4.95m, 7.00-7.45m

Borehole BNTW01
Easting: 585387.453
Northing: 217548.526
Elevation: 19.78 m OD

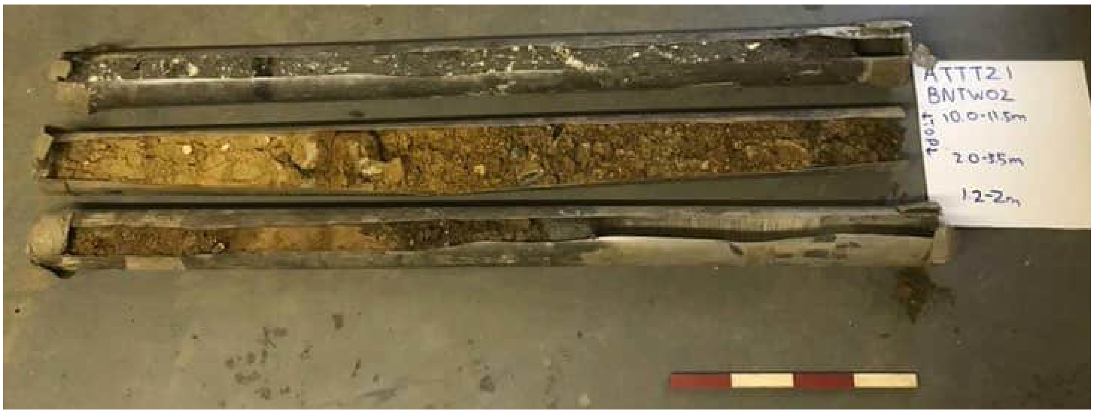
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Silty Medium Sand	Medium greyish-brown silty medium sand. 5% clasts of sub-angular to sub-rounded flint <35mm.
0.35	1.20	Sandy Silt	Medium greyish-yellow sandy silt. <1% sub-rounded clasts <150mm grading into a silty sand.
1.20	1.85	Clayey Fine Sand	Medium yellowish-brown clayey fine sand. Clasts are sub-angular flint <5mm. Mn mottling.
1.85	2.30	Silty Clay	Light yellowish-grey silty clay.
2.30	3.50	Silty Coarse Sand	Medium yellowish-brown silty coarse sand. Clasts are sub-angular to well-rounded flint, tertiary flint, and quartz <70mm. Sands and clasts.
3.50	4.50	No Recovery	
4.50	5.00	Clayey Medium Sand	Medium orangish-grey clayey medium sand.
5.00	8.00	No Recovery	
8.00	9.50	Sandy Silty Clay	Dark whitish-grey sandy silty clay. Clasts are sub-angular to rounded chalk and flint <50mm.

ATTT21 BNTW01 1.20-3.50m, 8.00-9.5m

Borehole BNTW02
Easting: 585342.403
Northing: 217515.435
Elevation: 21.7 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silty Sand	Medium greyish-brown silty sand.
0.30	0.60	Silty Sand	Medium greyish-brown silty sand.
0.60	1.20	Sandy Gravel	Medium orangish-brown sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint.
1.20	1.55	No Recovery	
1.55	1.63	Silty Clay	Medium grey silty clay.
1.63	1.87	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Sand coarsens upwards. Clasts are angular to sub-angular flint and quartz <50mm.
1.87	2.17	Sandy Silty Clay	Medium brownish-orange sandy silty clay. Clasts are sub-angular flint <10mm.
2.17	2.78	Clayey Medium Sand	Medium brownish-orange clayey medium sand. Clasts are sub-angular to angular flint <50mm.
2.78	2.91	Medium Sand	Medium orangish-yellow medium sand. Sand Coarsens upwards. Clasts are sub-rounded to sub-angular flint <40mm.
2.91	3.00	Sandy Silty Clay	Light whitish-grey sandy silty clay.
3.00	3.03	Sandy Silty Clay	Light whitish-grey sandy silty clay.
3.03	3.24	Fine Sand	Light orangish-yellow fine sand. Clasts are rounded to sub-rounded chalk and quartz <15mm.
3.24	3.29	Fine Sand	Light brownish-yellow fine sand. Clasts are sub-rounded to rounded chalk and flint <10mm.
3.29	3.50	Fine Sand	Light orangish-yellow fine sand. Clasts are rounded to sub-rounded chalk and quartz <15mm.
3.50	5.50	No Recovery	
5.50	6.00	Medium Sand	Medium yellowish-grey medium sand.
6.00	7.50	No Recovery	
7.50	8.00	Clayey Fine Sand	Medium yellowish-brown clayey fine sand.
8.00	10.00	No Recovery	
10.00	10.09	No Recovery	

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
10.09	10.16	Clayey Silt	Medium blueish-grey clayey silt. Clasts are sub-rounded chalk <5mm.
10.16	11.50	Sandy Silty Clay	Medium grey sandy silty Clay. Clasts are 25 sub-rounded to rounded chalk <25mm.



ATTT21 BNTW02 1.20-3.50m, 10.00-11.50m

Borehole BNTW03
Easting: 585257.994
Northing: 217481.605
Elevation: 25.17 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
1.00	1.02	Silty Clay	Medium yellowish-brown silty clay.
1.02	1.37	Sandy Clay	Medium orangish-brown sandy clay. Clasts are sub-angular to angular flint <5mm.
1.37	2.00	Sandy Clay	Medium reddish-brown sandy clay. Fines upwards. Clasts are angular to sub-angular flint and quartz <100mm
2.00	2.32	Sandy Silty Clay	Medium yellowish-brown sandy silty clay. Clasts are angular to sub-angular flint and quartz <50mm.
2.32	3.00	Sandy Clay	Medium reddish-brown sandy clay. Fines upwards. Clasts are angular to sub-angular flint and quartz <100mm.
3.00	3.12	No Recovery	
3.12	3.39	Sandy Silty Clay	Medium reddish-brown sandy silty clay. Clasts are angular to sub-angular flint and quartz <70mm.
3.39	3.59	Sandy Silty Clay	Medium yellow sandy silty clay.
3.59	3.69	Sandy Silty Clay	Light yellow sandy silty clay.
3.69	4.22	Sandy Silty Clay	Light greyish-yellow sandy silty clay. Clasts are quartz <5mm.
4.22	4.71	Sandy Silty Clay	Medium greyish-yellow sandy silty clay.
4.71	4.79	Sandy Silty Clay	Medium orangish-brown sandy silty clay.
4.79	4.85	Sandy Clayey Silt	Dark yellowish-grey sandy clayey silt. Clasts are sub-angular to sub-rounded chalk and flint <20mm.
4.85	4.90	Sandy Clayey Silt	Medium greyish-brown sandy clayey silt. Clasts are sub-rounded to sub-angular chalk and flint <5mm.
4.90	5.00	Silty Clayey Medium Sand	Medium reddish-brown silty clayey medium sand. Clasts are sub-rounded to sub-angular flint <15mm.
5.00	5.40	Sandy Silty Clay	Medium yellow sandy silty clay. Clasts are sub-angular to angular flint <30mm.
5.40	5.49	Clayey Medium Sand	Medium reddish-brown clayey medium sand. Clasts are sub-angular to sub-rounded flint <15mm. One larger piece of chalk.
5.49	5.65	Clayey Fine Sand	Medium yellowish-grey clayey fine sand. Clasts are sub-angular to sub-rounded flint <5mm.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
5.65	5.89	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Coarsens upwards. Clasts are sub-angular to sub-rounded flint and quartz <20mm.
5.89	7.73	Clayey Fine Sand	Medium yellowish-orange clayey fine sand. Clasts are sub-angular to sub-rounded flint <20mm.
7.73	8.00	Clayey Medium Sand	Medium yellowish-brown clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <20mm.
8.00	8.41	Clayey Fine Sand	Medium brownish-orange clayey fine sand. Fines upwards. Clasts are sub-rounded to rounded Clasts flint and quartz <50mm.
8.41	8.61	Clayey Coarse Sand	Medium reddish-brown clayey coarse sand. Clasts are sub-rounded to rounded Clasts flint and quartz <50mm.
8.61	9.69	Fine Sand	Medium greyish-yellow fine sand. Clasts are sub-rounded to sub-angular flint <10mm.
9.69	10.00	Clayey Fine Sand	Medium greyish-yellow clayey fine sand. Clasts are sub-rounded to sub-angular flint and quartz <20mm.

ATTT21 BNTW03 1.00-5.00m


ATTT21 BNTW03 5.00-10.00m

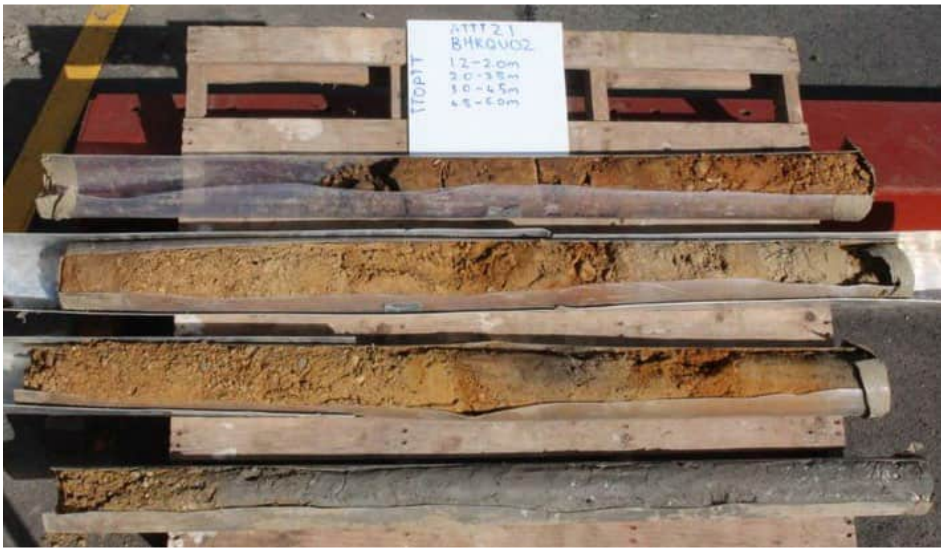
Borehole BRQU01
Easting: 583137.111
Northing: 215186.021
Elevation: 15.69 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
1.2	1.4	Sandy Clayey Silt	Light brownish-grey sandy clayey silt.
1.4	2.0	Sandy Gravel	Medium yellowish-orange sandy gravel. Matrix supported. Fines upwards. Clasts are sub-angular to sub-rounded flint <45mm.
2.0	2.5	Clayey Gravel	Light brownish-orange clayey gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <40mm.
2.5	5.0	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-angular to sub-rounded chalk and flint <10mm.

ATTT21 BRQU01 1.20-5.00m

Borehole BRQU02
Easting: 583066.913
Northing: 215267.437
Elevation: 17.11 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silty Sand	Medium greyish-brown silty sand. <5% flint gravel.
0.30	0.60	Silty Sand	Medium greyish-brown silty sand. 15% flint gravel.
0.60	1.20	Sandy Gravel	Medium orangish-brown sandy gravel. Matrix supported. Flint gravel.
1.20	1.35	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Bedded with sands and clasts. Clasts are sub-angular to sub-rounded flint and quartz <50mm. Sands and clasts concentrated at top of unit; more clayey towards base. Mn mottling throughout.
1.35	2.90	Sandy Clay	Medium yellowish-brown sandy clay. Bedded. Clasts are sub-angular-sub-rounded flint and quartz <40mm. Mn mottling.
2.90	3.75	Clayey Coarse Sand	Medium orangish-brown clayey coarse sand. Bedded. Clasts are sub-angular to well rounded flint, tertiary flint and quartz <50mm.
3.75	4.05	Sandy Clay	Medium brownish-grey sandy clay. Clasts are sub-angular to sub-rounded flint and quartz <5mm. Gradual transition into sands.
4.05	4.25	Clayey Coarse Sand	Medium brownish-orange clayey coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <5mm.
4.25	4.50	Clay	Medium brownish-grey clay.
4.50	4.75	Clayey Medium Sand	Medium greyish-brown clayey medium sand. <40mm clasts are 4 sub-angular to rounded flint and quartz.
4.75	5.35	Clay	Medium grey clay. 2% carbonate flecks. Sand input at the top.
5.35	6.00	Sandy Silty Clay	Medium whitish-grey sandy silty clay. <40mm clasts are sub-angular to rounded chalk.



ATTT21 BRQU02 1.20-6.00m

Borehole BRQU03
Easting: 583208.02
Northing: 215218.13
Elevation: 15.67 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
1.20	1.38	No Recovery	
1.38	3.06	Clayey Medium Sand	Medium yellowish-brown clayey medium sand. Bedded with clay (1.82-91, 1.93-2.06 and 3.00-3.29m) and sand (1.91-3, 2.06-41, 3.30-3.71). <60mm clasts of sub-angular to rounded flint and quartz. Slight iron staining at 1.85-1.90m.
3.06	4.05	No Recovery	
4.05	5.00	Sandy Silty Clay	Medium grey sandy silty clay. <50mm clasts are rounded to sub-rounded chalk and flint. Mn flecks.

ATTT21 BRQU03 1.20-5.00m

Borehole BRQU05
Easting: 583214.839
Northing: 215419.339
Elevation: 18.79 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Gravel	Light yellowish-grey sandy gravel. Matrix supported.
0.30	0.90	Coarse Sand	Medium orangish-brown coarse sand.
0.90	1.20	Coarse Sand	Light greyish-yellow coarse sand. 15% sub-angular to sub-rounded fine to coarse flint gravel.
1.20	1.74	Clayey Silty Medium Sand	Medium greyish-brown clayey silty medium sand.
1.74	10.00	Slightly Sandy Silty Clay	Medium brownish-grey slightly sandy silty clay. Fines upwards. Mn flecks.

ATTT21 BRQU05 1.20-5.00m

ATTT21 BRQU05 5.00-10.00m

Borehole BUNT01
Easting: 586518.536
Northing: 217845.505
Elevation: 27.57 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.90	Silty Clay	Dark greyish-brown silty clay.
0.90	1.50	Sandy Gravel	Medium orange sandy gravel.
1.50	2.00	Sandy Gravel	Medium yellowish-brown sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint <60mm.
2.00	2.50	Sandy Clayey Silt	Medium brownish-grey sandy clayey silt. Clasts are sub-angular to sub-rounded flint and quartz <15mm.
2.50	3.00	Silty Clay	Medium greyish-brown silty clay.
3.00	4.00	No Recovery	
4.00	5.00	Silty Clay	Medium greyish-brown silty clay.
5.00	6.00	No Recovery	
6.00	7.52	Silty Clay	Medium brown silty clay.
7.52	10.00	Silty Clay	Medium grey silty clay.

ATTT21 BUNT01 6.00-10.00m

Borehole BUNT02
Easting: 586593.434
Northing: 217857.328
Elevation: 29.31 m OD

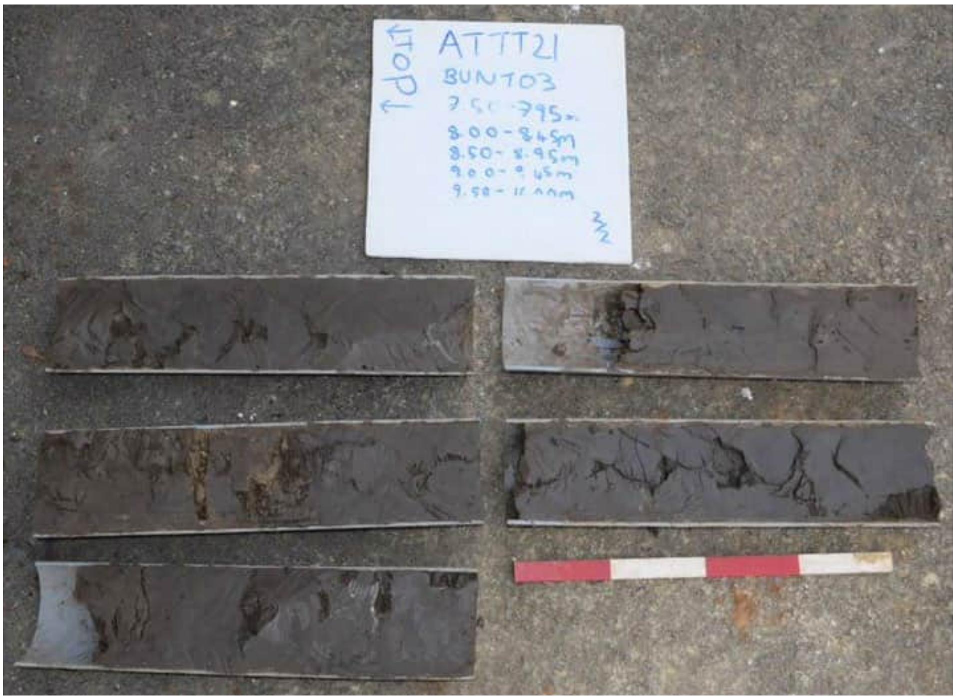
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Silty Clay	Medium brownish-grey silty clay.
1.20	1.48	No Recovery	
1.48	1.65	Silty Clay	Medium orangish-brown silty clay. Clasts are rounded flint and chalk <25mm. Mn mottling and slight Fe staining.
1.65	2.00	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded to sub-angular flint <25mm.
2.00	3.00	Silty Clay	Dark yellowish-grey silty clay. 20% sub-angular flint clasts and 2% quartz clasts <30mm.
3.00	3.45	Silty Clay	Medium greyish-yellow silty clay. Clasts are rounded to sub-rounded chalk <40mm. Grey mottling.
3.45	4.00	Clayey Coarse Sand	Medium brown clayey coarse sand. 30% sub-angular and sub-rounded flint clasts <50mm.
4.00	5.00	Slightly Sandy Clay	Medium brown slightly sandy clay. 1% Mn flecks. 5% light grey mottling. 2% sub-angular flint clasts <30mm.
5.00	6.50	No Recovery	
6.50	7.00	Silty Clay	Medium greyish-brown silty clay. Chalk flecks.
7.00	7.16	No Recovery	
7.16	7.22	Clay	Medium orangish-brown clay.
7.22	9.95	Clay	Dark brownish-grey clay. <1% clasts of sub-angular flint 5mm.
9.95	10.00	Silty Clay	Dark greyish-brown silty clay.

ATTT21 BUNT02 1.20-1.65, 7.00-9.95m

Borehole BUNT03
Easting: 586653.937
Northing: 217846.709
Elevation: 29.85 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Silty Clay	Medium greyish-brown silty clay. <30% clasts <50mm.
0.40	1.20	Clayey Silt	Medium orangish-grey clayey silt. <30% clasts of chalk and other stones <50mm.
1.20	1.65	Sandy Clay	Light orangish-brown sandy clay. 2% sub-angular flint clasts <10mm. 2% Mn flecks.
1.65	2.00	Sandy Clay	Medium greyish-brown sandy clay. 2% sub-angular flint clasts <25mm.
2.00	2.50	Sandy Gravel	Medium greyish-brown sandy gravel. Clast supported. Clasts are sub-angular to rounded flint and quartz <60mm. 15% sand in gravel.
2.50	3.00	Sandy Gravel	Dark greyish-brown coarse sandy gravel. Matrix supported. Clasts are sub-rounded to sub-angular flint and quartz <60mm. 30% sand in gravel.
3.00	3.50	Coarse Sand	Medium greyish-brown gravelly coarse sand. 40% sub-rounded to sub-angular flint and 2% quartz clasts <50mm.
3.50	4.00	Coarse Sand	Medium yellowish-grey gravelly coarse sand. 40% sub-rounded to sub-angular flint and 5% quartz clasts <25mm. 2% yellowish grey clay pockets.
4.00	4.50	Coarse Sand	Medium yellowish-grey gravelly coarse sand. 30% subrounded to rounded flint and 10% quartz clasts <50mm. 2% yellowish grey clay pockets.
4.50	4.90	Silty Clay	Medium brown silty clay. Continuously laminated. 20% light grey mottling. 5% amorphous Fe staining.
4.90	6.95	Silty Clay	Dark brownish-grey silty clay. Continuously laminated. 10% Mn mottling.
6.95	7.50	No Recovery	
7.50	10.00	Silty Clay	Dark brownish-grey silty clay. Continuously laminated. 10% Mn mottling. Voids at 8.00-8.13m and 9.50-8m.

ATTT21 BUNT03 1.20-1.65m, 4.50-6.95m



ATTT21 BUNT03 7.50-10.00m

Borehole BUNT04
Easting: 586720.244
Northing: 217859.565
Elevation: 30.85 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Silty Clay	Medium greyish-brown silty clay. <30% gravel <50mm.
0.50	1.20	Sandy Clay	Medium orangish-brown sandy clay. <50% Gravel <50mm 20% <30mm.
1.20	1.65	Sandy Clay	Medium orangish-brown sandy clay. 30% rounded to sub-rounded flint and 2% quartz clasts <20mm.
1.65	2.35	Clayey Coarse Sand	Medium brown clayey coarse sand. Slight Mn mottling. Clasts are angular to subrounded flint, quartz and chalk <50mm.
2.35	2.45	Clayey Coarse Sand	Medium orangish-brown clayey coarse sand. Bedded within medium brown clayey coarse sand. Clasts of sub angular flint <5mm.
2.45	2.69	Clayey Coarse Sand	Medium brown clayey coarse sand. Slight Mn mottling. Clasts are angular to subrounded flint, quartz and chalk <50mm.
2.69	3.00	Sandy Clay	Medium orangish-brown sandy clay. Bedded with orangish brown clayey coarse sand at 1.69-78, 1.81-2 and 1.41-2m. Clasts are sub-angular flint <10mm. Upper boundary and first two bed boundaries at diagonal angles, bottom bed horizontal. Mn flecks.
3.00	3.50	Sandy Clay	Medium yellowish-brown sandy clay. 2% sub-angular flint clasts <5mm.
3.50	4.00	Sandy Clay	Medium yellowish-brown sandy clay. 2% sub-angular flint clasts <5mm.
4.00	4.50	Sandy Clay	Light brownish-grey coarse sandy clay. Laminations of grey sandy clay. 2% sub-rounded to rounded flint <20mm. 1% Mn flecks.
4.50	5.00	Sandy Clay	Light brownish-grey coarse sandy clay. 2% sub-rounded to rounded flint <20mm.
5.00	5.50	Sandy Gravel	Medium yellowish-grey coarse sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular fllint and quartz <50mm. 2% clay pockets. 45% sand in gravel.
5.50	6.00	Sandy Gravel	Medium yellowish-brown coarse sandy gravel. Clast supported. Clasts are sub-angular to rounded flint and quartz <50mm. 2% grey clay pockets. 30% sand in gravel.
6.00	6.50	Sandy Gravel	Medium brownish-grey coarse sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and quartz <60mm. 30% sand in gravel.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
6.50	7.00	Coarse Sand	Medium brownish-grey gravelly coarse sand. 40% rounded to sub-rounded flint and 5% quartz clasts <50mm.
7.00	7.50	Sandy Gravel	Medium yellowish-brown coarse sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and quartz <70mm. 45% sand in gravel.
7.50	8.00	Sandy Gravel	Medium brown sandy gravel. Clast supported. Clasts are rounded to sub-rounded flint and quartz <40mm. 45% sand in gravel.
8.00	8.50	Slightly Silty Clay	Medium brown slightly silty clay. 1% sub-angular flint <5mm. 20% light grey mottling.
8.50	10.00	Clay	Dark grey clay. Continuously laminated.

ATTT21 BUNT04 1.65-2.95m, 8.50-9.95m

Borehole BUNT05
Easting: 586765.241
Northing: 217847.116
Elevation: 31.91 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Silty Clay	Medium greyish-brown silty clay. <30% clasts <50mm.
0.50	1.20	Sandy Clay	Medium orangish-brown sandy clay. <40% clasts <50mm.
1.20	1.65	Silty Clay	Medium brown silty clay. Slight Mn mottling.
1.65	2.45	Sandy Clay	Medium orangish-brown sandy clay.
2.45	2.95	Sandy Clay	Medium yellowish-brown sandy clay. Mn flecks.
2.95	3.45	Sandy Clay	Medium brownish-orange sandy clay. Mn staining.
3.45	4.45	Silty Clay	Medium brown silty clay. Clasts are sub-angular flint <5mm.
4.45	5.00	No Recovery	
5.00	5.55	Silty Clay	Medium orangish-grey silty clay. Intermittent laminations. 1% sub-angular flint clasts <5mm. 60% orange staining. 1% Mn flecks.
5.50	5.95	Slightly Sandy Gravel	Medium greyish-brown slightly coarse sandy gravel. Clast supported. Clasts are rounded to sub-angular flint and quartz <50mm. 15% sand in gravel.
6.00	6.50	Medium Sand	Medium yellowish-grey medium sand. 5% flint sub-angular to subrounded and 1% quartz clasts <20mm. 40% grey clay pockets with 10% Mn staining.
6.50	7.00	Sandy Gravel	Medium greyish-brown sandy gravel.
7.00	7.50	Medium Sand	Medium yellowish-brown medium sand. 30% sub-angular to rounded flint and 5% quartz clasts <40mm.
7.50	8.00	Coarse Sand	Medium brownish-grey gravelly coarse sand. 25% sub-rounded to rounded flint and 15% quartz clasts <50mm.
8.00	8.50	Coarse Sand	Medium brownish-grey gravelly coarse sand. 5% yellowish grey clay pockets. 40% sub-angular to rounded flint and 25 quartz clasts <50mm.
8.50	9.00	Slightly Sandy Gravel	Medium yellowish-grey slightly sandy gravel. Clast supported. Clasts are sub-angular to rounded flint and quartz <50mm. 10% sand in gravel.
9.00	9.50	Slightly Sandy Gravel	Medium yellowish-grey slightly sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and gravel <50mm. 5% sand in gravel.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
9.50	10.00	Slightly Sandy Gravel	Medium grey slightly sandy gravel. Clast supported. Clasts are sub-rounded to well rounded flint and quartz <50mm. 5% sand in gravel.

ATTT21 BUNT05 1.20-1.65m, 2.00-4.95m, 5.50-5.95m

Borehole BUNT06
Easting: 586818.094
Northing: 217839.696
Elevation: 32.64 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Silty Clay	Medium greyish-brown silty clay.
0.40	1.20	Sandy Clay	Medium orangish-brown sandy clay.
1.20	1.65	Coarse Sand	Medium greyish-brown coarse sand. 30% sub-rounded to sub-angular flint <30mm.
1.65	2.00	Coarse Sand	Medium orangish-brown coarse sand. 5% sub-angular to sub-rounded flint and 1% quartz clasts <10mm.
2.00	2.50	Coarse Sand	Medium greyish-brown coarse sand. 5% sub-angular to sub-rounded flint <5mm.
2.50	3.00	Medium Sand	Medium brownish-grey medium sand. 2% sub-angular to sub-rounded flint <5mm.
3.00	3.50	Medium Sand	Medium brown medium sand. 2% flint flecks.
3.50	4.00	Coarse Sand	Medium brownish-grey coarse sand. 10% sub-rounded to rounded flint and 2% quartz clasts <10mm.
4.00	4.50	Sandy Gravel	Medium yellowish-grey coarse sandy gravel. Clast supported. Clasts are sub-angular to sub-rounded flint and quartz <40mm. 35% sand in gravel.
4.50	5.00	Coarse Sand	Medium brownish-grey gravelly coarse sand. 30% sub-rounded to sub-angular flint and 2% quartz clasts <30mm.
5.00	5.50	Clayey Sandy Gravel	Medium brownish-grey clayey coarse sandy gravel. Clast supported. Clasts are rounded to sub-rounded flint and quartz <50mm. 30% sand in gravel.
5.50	6.00	No Recovery	
6.00	6.50	Sandy Gravel	Medium brownish-grey coarse sandy gravel. Clast supported. Clasts are rounded to sub-angular flint and quartz <50mm. 25% sand in gravel.
6.50	7.00	Sandy Gravel	Medium brownish-grey coarse sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and quartz <50mm. 35% sand in gravel.
7.00	7.50	Slightly Sandy Gravel	Medium brownish-grey slightly sandy gravel. Clast supported. Clasts are rounded to sub-rounded flint and quartz <50mm. 5% sand in gravel.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
7.50	8.00	Sandy Gravel	Medium greyish-brown medium sandy gravel. Clast supported. Clasts are sub-rounded to sub-angular flint and quartz <40mm. 50% sand in gravel.
8.00	8.50	Sandy Gravel	Medium brownish-grey sandy gravel. Clast supported. Clasts are sub-rounded to rounded flint and quartz <40mm. 35% sand in gravel.
8.50	8.62	No Recovery	
8.62	9.50	Silty Clay	Dark brownish-grey silty clay.
9.50	10.00	Silty Clay	Medium grey silty clay.

ATTT21 BUNT06 8.00-9.45m

Borehole BUNT17
Easting: 587319.957
Northing: 218514.204
Elevation: 34.72 m OD

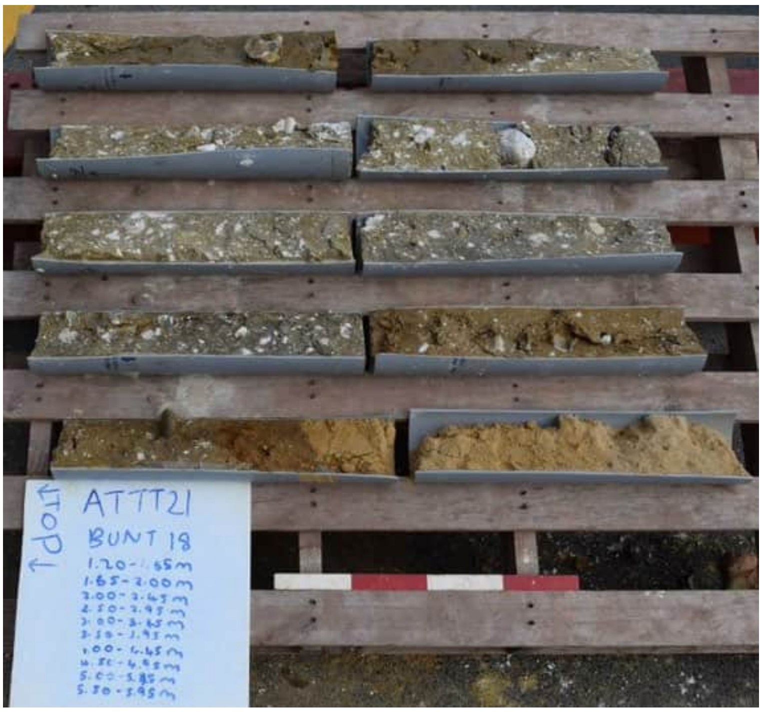
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Silty Clay	Medium greyish-brown silty clay <30% clasts <50mm.
1.20	4.16	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to sub-angular chalk and flint <60mm.
4.16	4.45	Sandy Clay	Medium brown sandy clay. Clasts are sub-rounded to angular flint and chalk <40mm.
4.45	5.00	No Recovery	
5.00	5.17	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to sub-angular chalk, flint and sandstone <60mm.
5.17	6.95	Silty Clay	Dark brownish-grey silty clay. Medium yellowish brown colour from 1.65-1.90. Blueish grey staining throughout.

ATTT21 BUNT17 1.20-3.95m

ATTT21 BUNT17 4.00-6.95m

Borehole BUNT18
Easting: 587394.618
Northing: 218466.366
Elevation: 36.75 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Silty Clay	Medium greyish-brown silty clay <30% clasts <50mm.
1.20	1.25	Silty Clay	Light greyish-brown silty clay. 20% sub-rounded chalk <10mm.
1.25	1.85	Silty Clay	Medium greyish-brown silty clay. 20% Mn mottling. 2% Fe mottling. 5% sub-rounded chalk and 2% flint <60mm.
1.85	2.90	Silty Clay	Medium greyish-brown silty clay. 20% medium grey mottling. 40% sub-rounded to well-rounded chalk and 2% flint <60mm.
2.90	4.50	Silty Clay	Medium brownish-grey silty clay. 60% dark grey mottling. 30% sub-rounded to rounded chalk and 2% flint <30mm.
4.50	5.23	Silty Clay	Light brown silty clay. 30% sub-rounded chalk and 2% flint <40mm. 40% grey mottling from 5.11-23m. 1% Mn flecks. 1% charcoal.
5.23	5.34	Silty Clay	Medium brown silty clay. 5% sub-rounded chalk <5mm. Medium orangish brown medium sand pockets 5.23-29m. 10% Mn mottling.
5.34	6.00	Medium Sand	Light yellow medium sand. Intermittently laminated. 2% sub-angular flint <5mm. Fe lens 2mm at upper boundary with clay. 2% Fe lenses throughout.1% Mn flecks.



ATTT21 BUNT18 1.20-5.95m

Borehole BUNT19
Easting: 587474.561
Northing: 218460.284
Elevation: 37.94 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Clay	Dark greyish-brown clay <40% clasts <30mm.
0.50	1.20	Silt	Medium orangish-grey silt. Clasts are chalk and other stones <40mm.
1.20	2.39	Silty Clay	Light greyish-brown silty clay. 20% sub-rounded chalk and <1% flint <30mm. 1% Mn flecks.
2.39	4.66	Silty Clay	Medium brownish-grey silty clay. 20% sub-rounded chalk and <1% flint <60mm. Grey mottling to 4.5m. Rootlets between 4.35 and 4.5m. Fe staining.
4.66	5.12	Sandy Clay	Light yellowish-grey sandy clay. Slight banding of chalky gravel within sandy clay throughout unit. 20% sub-rounded chalk and <1% flint <20mm. 1% Fe flecks.
5.12	5.25	Sandy Clay	Medium greyish-brown sandy clay. 10% sub-rounded to rounded chalk and 1% flint <20mm. 2% grey mottling.
5.25	5.29	Clayey Fine Sand	Light grey clayey fine sand. 10% sub-rounded to rounded chalk and 1% flint <10mm.
5.29	6.21	Silty Clay	Medium brown silty clay. 5% sub-rounded chalk and 1% flint <25mm. 1% Mn flecks. Mn pan at base of unit (6.20-21m).
6.21	6.22	No Recovery	
6.22	6.33	Medium Sand	Medium orangish-brown medium sand. 2% sub-angular to rounded flint <10mm. 5% pockets of dark grey clay. Slightly sloping boundary.
6.33	6.41	Silty Clay	Medium greyish-brown silty clay. 2% Mn flecks. 5% sub-rounded chalk <5mm.
6.41	6.45	Medium Sand	Medium yellowish-orange medium sand. 2% sub-angular to rounded flint <15mm.

ATTT21 BUNT19 1.20-3.95m

Borehole BUNT20
Easting: 587517.183
Northing: 218404.671
Elevation: 38.28 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Silty Clay	Dark greyish-brown silty clay <50% clasts <50mm.
0.50	1.20	Silty Clay	Medium orangish-grey silty clay <40% chalk and other stones <50mm.
1.20	1.55	Sandy Clay	Medium orangish-brown sandy clay. Clasts are sub-rounded flint, chalk and quartz <120mm. Mn mottling.
1.55	2.33	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-angular to sub-rounded chalk and flint <30mm. More orange towards base of unit. Mn flecks.
2.33	2.45	Clayey Coarse Sand	Medium brown clayey coarse sand. Clasts are sub-angular to angular flint <30mm.
2.45	3.45	Fine Sand	Medium yellow fine sand. Intermittent laminations of orange fine sand. Bed of gravelly medium sand with sub-rounded to rounded flint clasts <50mm at 3.09-3.19m.

ATTT21 BUNT20 1.20-3.45m

Borehole HABH01
Easting: 574632.925
Northing: 209666.45
Elevation: 24.2 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.9	Silty Clay	Light reddish-brown silty clay. <1% clasts of medium sub-rounded flint.
0.9	1.2	Sandy Silty Clay	Light blueish-grey sandy silty clay.
1.2	4.0	Silty Clay	Medium greyish-brown silty clay. Bedded with gravelly sand containing rounded to sub-angular flint clasts <40mm at 1.00-38, 2.66-3.00 and 3.24-4.00m. Boundaries between silty clay and gravel beds abrupt, with the exception of 2.55-66m where gravel is mixed with clay.

ATTT21 HABH01 1.00-4.00m

Borehole HABH02
Easting: 574640.841
Northing: 209671.351
Elevation: 24.68 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Dark greyish-brown clayey silt. Slightly organic.
0.30	1.00	Clayey Silt	Dark greyish-brown clayey silt.
1.00	1.82	Silty Clay	Light greyish-brown silty clay. Slightly sandy; fine sand.
1.82	1.88	Sandy Gravel	Medium yellowish-green sandy gravel. 15% sub-rounded to sub-angular flint <9mm.
1.88	2.40	Sandy Silty Clay	Medium yellowish-brown fine sandy silty clay. Coarsens upwards.
2.40	3.00	Sandy Gravel	Medium yellowish-brown coarse sandy gravel. Coarsens upwards. Clast supported. Clasts are angular to sub-rounded flint <20mm.

ATTT21 HABH02 1.00-3.00m

Borehole HABH03
Easting: 574645.93
Northing: 209673.99
Elevation: 24.85 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.60	Clayey Silt	Dark greyish-brown clayey silt.
0.60	1.00	Clayey Silt	Dark greyish-brown clayey silt.
1.00	1.20	Clay	Light blueish-grey clay. Rare fine sand.
1.20	1.60	Silty Clay	Medium blueish-grey silty clay. Slightly organic. Poorly humified plant remains. Possible Fe staining toward base of unit.
1.60	1.85	Silty Clay	Medium orangish-brown silty clay. Poorly humified plant remains- possible reed remains.
1.85	2.00	No Recovery	
2.00	2.11	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Poorly humified plant remains. Sand pockets <5mm in size.
2.11	2.32	Slightly Sandy Silty Clay	Medium greenish-blue slightly sandy silty clay. Slightly humified plant remains.
2.32	2.48	Clayey Medium Sand	Medium blueish-grey clayey medium sand. Fines upwards. Slightly humified plant remains. Clasts are sub-angular to sub-rounded flint and quartz.
2.48	2.66	Sandy Silty Clay	Dark blueish-grey sandy silty clay. Clasts are sub-angular to sub-rounded flint and quartz <5mm.
2.66	2.79	No Recovery	
2.79	3.00	Silty Clay	Medium greyish-brown silty clay. Clasts are rounded to sub-rounded flint.

ATTT21 HABH03 1.00-3.00m

Borehole HABH04
Easting: 574668.171
Northing: 209681.906
Elevation: 24.82 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silty Clay	Light brownish-grey silty clay. Clasts are sub-angular to sub-rounded <40mm. Rare cbm fragments.
0.30	0.80	Clay	Medium brownish-grey clay. <1% medium clasts.
0.80	1.15	Silty Clay	Light brownish-grey silty clay. <1% shell.
1.15	1.31	Slightly Silty Clay	Medium orangish-brown slightly silty clay. Carbonate flecks. Slight organic staining towards base of unit. Band of Fe staining at base of unit (1.30-1m).
1.31	1.84	Silty Clay	Dark brownish-grey silty clay. Bedded with gravel at 1.45-50 and 1.72-84m. Organic staining throughout. Slightly humified fibrous organic material at 1.65m. 1% shell inclusions.
1.84	2.00	Silty Clay	Medium brownish grey silty clay.
2.00	2.23	Clay	Dark greyish brown clay. Well humified organic matter. Carbonate flecks. Shell inclusions.
2.23	2.45	Sandy Clay	Medium greyish brown sandy clay. Clasts are rounded to sub-rounded quartz and flint <15mm. Well humified organic matter.
2.45	4.00	Silty Clay	Medium greyish-orange silty clay. 3.00-3.63m core shattered.

HABH04 1.00-4.00m

Borehole HABH05
Easting: 574677.973
Northing: 209685.299
Elevation: 25.32 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.60	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Rare fine sub-angular clasts and CBM. Lightly rooted. Slightly organic.
0.60	1.00	Clay	Light reddish-brown clay. Rare fine sand.
1.00	1.10	Clayey Silt	Medium greyish-brown clayey silt. Slightly organic. 1% abraded 1mm shell fragment.
1.10	1.16	Sandy Clayey Silt	Medium reddish-brown sandy clayey silt. Slightly organic.
1.16	1.20	Clayey Sandy Silt	Light brownish-grey clayey sandy silt.
1.20	1.25	Silty Medium Sand	Dark reddish-brown silty medium sand. Organic with 1% flecks of decayed plant matter <5mm.
1.25	1.42	Sandy Clay	Dark blueish-grey sandy clay. Silty medium sandy clay with 5% clasts <15mm. Mottled with light yellow grey in places.
1.42	1.85	Sandy Silt	Light yellowish-grey sandy silt. Coarsens upwards. Mottled with light blue grey. Medium to coarse sand with 5% sub-rounded to sub-angular clasts <5mm.
1.85	2.00	Sandy Silt	Light blueish-grey sandy silt. Intermittently laminated.
2.00	2.15	No Recovery	
2.15	2.45	Sandy Clay	Light greyish-brown sandy clay. <1% sub-angular to sub-rounded gravel <10mm.
2.45	2.97	Sandy Clay	Light greenish-grey sandy clay. Fines upwards. <1% sub-angular clasts <45mm. Fine to Medium sand.
2.97	3.00	Clayey Gravel	Light brownish-grey clayey gravel. Clast supported. Clasts are sub-rounded flint <40mm. Slightly coarse sandy clay infilling around clasts.
3.00	3.10	No Recovery	
3.10	3.23	Sandy Clay	Medium yellowish-grey sandy clay. Continuous laminations of orange, greenish grey and greyish blue. Sand bed at 3.15-3.18m stained black with organic matter. Clasts are rounded to sub-angular flint and quartz <10mm.
3.23	3.36	Coarse Sand	Dark grey coarse sand. Clasts are sub-angular to sub-rounded flint <15mm. Staining of sand with well humified organic material.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
3.36	3.40	Silty Clay	Medium brownish-grey silty clay. Brown clay stained with organic material. Slightly humified dark brown organic material- possible reed.
3.40	4.00	Silty Clay	Medium greyish-brown silty clay. Grey mottling throughout.Mn flecks.

ATTT21 HABH05 1.00-4.00m

Borehole HABH06
Easting: 578219.436
Northing: 211371.483
Elevation: 18.66 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	1.0	Clayey Silt	Light reddish-brown clayey silt.
1.0	2.4	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Fines upwards. Clasts are rounded to sub-rounded flint <15mm.
2.4	4.0	Sandy Gravel	Medium orangish-brown sandy gravel. Clast supported. Coarsens upwards. Clasts are sub-rounded to rounded flint and quartz <60mm.

ATTT21 HABH06 1.00-4.00m

Borehole HABH07
Easting: 578253.814
Northing: 211371.125
Elevation: 18.36 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Sandy Clayey Silt	Dark greyish-brown sandy clayey silt. Rare cbm fragments.
0.35	0.90	Sandy Clayey Silt	Light yellowish-brown sandy clayey silt. Cbm and charcoal fragments.
0.90	1.00	Silty Clay	Medium brownish-grey silty clay. 2% Mn flecks.
1.00	1.53	Sandy Clay	Medium brownish-grey sandy clay. Fines upwards. Clasts are sub-rounded to angular flint <10mm. Moderately humified organic material at 1.37m. Fe mottling at top of unit. Mn flecks throughout. Slight organic staining towards base of unit.
1.53	2.00	Clayey Sandy Gravel	Medium yellowish-grey clayey sandy gravel. Clast supported. Clasts are angular to rounded flint and quartz <40mm.
2.00	2.22	No Recovery	
2.22	2.33	Sandy Clay	Medium brownish-grey sandy clay. Clasts are sub-rounded flint 10mm. Well humified organic material.
2.33	2.53	Silty Clay	Medium brownish-grey silty clay. Carbonate flecks throughout.

ATTT21 HABH07 1.00-3.00m

Borehole HABH08
Easting: 578284.096
Northing: 211373.72
Elevation: 18.21 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silt	Light brownish-grey sandy silt.
0.30	1.00	Silty Medium Sand	Light brownish-grey silty medium sand clayey pockets from 0.6m.
1.00	1.14	Silty Fine Sand	Medium yellowish-brown silty fine sand. Clasts are sub-angular flint <10mm. Dark brown mottling.
1.14	2.23	Slightly Sandy Silty Clay	Medium brownish-grey slightly sandy silty clay. Coarsens upwards. Unweathered from 1.76-2.00. Iron mottling from 1.14-1.76m.
2.23	2.36	Sandy Silt	Medium brownish-grey sandy silt. Clasts are sub-rounded to sub-angular flint <20mm.
2.36	3.00	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to sub-angular flint <20mm. More weathered towards base of unit.

ATTT21 HABH08 1.00-3.00m

Borehole HABH09
Easting: 578308.848
Northing: 211375.904
Elevation: 18.11 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Dark greyish-brown clayey silt. <5% sub-angular to sub-rounded fine to medium clasts. Slightly organic.
0.30	0.60	Sandy Gravel	Medium orangish-brown sandy gravel.
0.60	1.00	Sandy Clay	Medium orangish-brown sandy clay.
1.00	1.79	Sandy Silt	Medium brownish-grey sandy silt. Fe mottling. Mn flecks.
1.79	2.48	Clayey Silt	Dark brownish-grey clayey silt. Fines upwards. Clasts are sub-rounded flint <10mm. Mn flecks.
2.48	2.80	Sandy Clayey Gravel	Dark grey sandy clayey gravel. Fines upwards. Clasts are rounded to sub-angular flint and quartz <40mm.
2.80	3.00	No Recovery	
3.00	3.17	Clayey Silt	Dark greyish-brown clayey silt. Carbonate flecks.
3.17	4.82	Silty Clay	Dark brownish-grey silty clay. Bedded with gravelly material at 3.17-33 and 4.40-63m. Clasts are rounded to sub-angular flint and quartz <40mm.
4.82	5.00	No Recovery	

ATTT21 HABH09 1.00-5.00m

Borehole HABH10
Easting: 578331.069
Northing: 211379.659
Elevation: 18.06 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Dark greyish-brown clayey silt. <5% sub-angular to sub-rounded fine to medium clasts. Slightly organic.
0.30	0.60	Sandy Gravel	Medium orangish-brown sandy gravel. Clasts are sub-angular to sub-rounded flint <70mm.
0.60	1.00	Sandy Clay	Medium orangish-brown sandy clay.
1.00	1.11	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-angular chalk <5mm. Mn and Fe staining. Chalk flecks.
1.11	1.71	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Mn and Fe staining.
1.71	1.88	Sandy Silty Clay	Medium greyish-green sandy silty clay. Clasts are sub-angular to sub-rounded flint and quartz <15mm. Chalk flecks.
1.88	2.13	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Chalk flecks. Fe flecks.
2.13	2.18	Sandy Silty Clay	Medium brownish-grey sandy silty clay. Clasts are sub-rounded to rounded quartz and flint <20mm.
2.18	2.33	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-rounded to rounded quartz and flint <20mm. Mn and Fe flecks.
2.33	2.38	Silty Sandy Clay	Medium brownish-grey silty sandy clay. Clasts are sub-rounded to sub-angular quartz and flint <20mm. Chalk flecks. Mn staining.
2.38	2.84	Sandy Silty Clay	Medium blueish-brown sandy silty clay. Clasts are sub-rounded to rounded quartz and and flint <5mm.
2.84	2.92	Clayey Medium Sand	Medium reddish-brown clayey medium sand. Clasts are sub-angular flint <30mm.
2.92	3.00	Sandy Clay	Medium reddish-brown sandy clay. Clasts are sub-angular to sub-rounded flint and quartz <40mm. Chalk flecks.

ATTT21 HABH10 1.00-3.00m

Borehole HABH11
Easting: 584097.491
Northing: 216345.935
Elevation: 19.24 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.45	Sandy Silt	Medium greyish-brown sandy silt. 5% clasts of sub-angular to sub-rounded fine to medium flint.
0.45	0.90	Sandy Silt	Light greyish-yellow sandy silt.
0.90	1.00	Silt	Medium whitish-grey silt. Granular structure. Chalky.
1.00	1.12	Silty Clay	Light greyish-yellow silty clay. Clasts are angular flint <5mm. Fe staining. Grey mottling.
1.12	1.19	Silty Clay	Light whitish-yellow silty clay.
1.19	1.23	Silty Clay	Light yellowish-white silty clay. Dark grey silty clay mottling.
1.23	1.35	Silty Clay	Light orangish-yellow silty clay. Fe mottling.
1.35	1.41	Silty Clay	Light yellowish-orange silty clay.
1.41	1.49	Sandy Silty Clay	Light greyish-yellow sandy silty clay.
1.49	1.66	Sandy Silty Clay	Light yellowish-grey sandy silty clay. Fe staining. Chalk flecks.
1.66	1.78	Sandy Silty Clay	Light brownish-grey sandy silty clay. Clasts are sub-angular to rounded chalk and quartz <10mm.
1.78	2.50	Medium Sand	Medium brownish-orange medium sand. Coarsens upwards. Clasts are angular to sub-angular quartz <10mm.

ATTT21 HABH11 1.00-3.00m

Borehole HABH12
Easting: 584064.577
Northing: 216323.627
Elevation: 18.46 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clay	Dark reddish brown clay. Rare sub-angular to sub-rounded sands and clasts <10mm. Slightly organic.
0.30	1.20	Sandy Clay	Light yellowish-brown sandy clay.
1.20	1.56	Medium Sand	Medium greyish-yellow medium sand. Fines upwards. Clasts are sub-angular to sub-rounded flint and quartz <15mm. Band of iron staining at base of unit.
1.56	1.96	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded chalk and flint <10mm.
1.96	2.00	No Recovery	
2.00	6.00	Medium Sand	Medium brownish-yellow medium sand. Sand bedded with gravelly sand at 2.00-2.30, 3.00-3.23 and 4.00-4.22m. Sand coloured grey at 5.72-92. Clasts are sub-angular flint <15mm. Well humified organic material 3.96m. Mn mottling and Fe staining.
6.00	7.00	Fine Sand	Medium greyish-yellow fine sand. Clasts are rounded flint and quartz <15mm.

ATTT21 HABH12 1.20-6.00m

Borehole HABH13
Easting: 584241.055
Northing: 216583.714
Elevation: 20.05 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.00	Sandy Silt	Light yellowish-brown sandy silt. <1% sub-angular gravel 5mm. Slightly organic.
1.00	1.15	No Recovery	
1.15	2.00	Sandy Silty Clay	Medium reddish-brown sandy silty clay. Fines upwards. Clasts are sub-angular to sub-rounded flint and quartz <80mm.
2.00	2.12	No Recovery	
2.12	2.30	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Clasts are sub-rounded to sub-angular flint and quartz <50mm. Pocket of sand at 2.38m.
2.30	3.00	Sandy Silty Clay	Medium yellowish-grey sandy silty clay. Clasts are sub-rounded to sub-angular chalk <15mm. Mn staining.
3.00	3.90	Clayey Medium Sand	Medium reddish-brown clayey medium sand. Clasts are sub-rounded to sub-angular flint <30mm.
3.90	4.00	Sandy Silty Clay	Medium yellowish-grey sandy silty clay. Clasts are sub-rounded to sub-angular chalk <15mm. Mn staining.

ATTT21 HABH13 1.20-4.00m

Borehole HABH14
Easting: 584258.721
Northing: 216608.1
Elevation: 19.49 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
1.00	2.72	Sandy Gravel	Medium orangish-brown sandy gravel. Clast supported. Bedded with sandy clay at 1.12-21, 1.43-59 and 1.71-9m. Clasts are sub-rounded to sub-angular flint and quartz <40mm.
2.72	3.00	Silty Clay	Medium greyish-brown silty clay.
3.00	3.43	Sandy Gravel	Medium yellowish-orange sandy gravel. Matrix supported. Clasts are sub-rounded to rounded flint and quartz <40mm.
3.43	4.00	Clayey Silt	Medium grey clayey silt.
4.00	4.27	Slightly Silty Medium Sand	Medium yellowish-grey slightly silty medium sand. Clasts are sub-rounded to rounded flint and quartz <30mm.
4.27	4.90	Slightly Silty Fine Sand	Medium brownish-grey slightly silty fine sand. Pockets of grey clay throughout.
4.90	5.00	Slightly Sandy Silt	Medium brownish-grey slightly sandy silt. Clasts are sub-rounded flint <25mm.

ATTT21 HABH14 1.20-5.00m

Borehole HABH15
Easting: 584276.05
Northing: 216617.215
Elevation: 19.42 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silt	Light greyish-brown silt. Slightly humic. Slightly sandy. Lightly rooted.
0.30	0.60	Silt	Light yellowish-brown silt.
0.60	0.80	Silt	Light greyish-yellow silt. <1% sub-angular to sub-rounded flint <30mm.
0.80	1.20	Sandy Silt	Light yellowish-brown sandy silt. Clasts are sub-angular to sub-rounded flint <80mm.
1.20	2.00	Clayey Coarse Sand	Medium orangish-brown clayey coarse sand. Clasts are sub-angular to sub-rounded flint <40mm.
2.00	2.35	Clayey Coarse Sand	Medium greyish-brown clayey gravelly coarse sand. Fines upwards. Clasts are sub-angular to sub-rounded flint <40mm.
2.35	2.67	Slightly Sandy Gravel	Medium brownish-orange slightly sandy gravel. Clast supported. Clasts are sub-rounded to rounded flint and quartz <25mm.
2.67	3.00	Clayey Coarse Sand	Medium greyish-brown clayey coarse sand. Fines upwards. Clasts are sub-rounded to rounded flint and quartz <25mm.

ATTT21 HABH15 1.20-3.00m

Borehole HABH18
Easting: 585510.253
Northing: 217603.459
Elevation: 18.88 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clay Silt	Dark greyish-brown sandy clay silt. Slightly organic.
0.30	0.60	Sandy Clay	Light orangish-brown sandy clay. 15% sub-angular to sub-rounded fine, medium and coarse gravel.
0.60	1.00	Silty Clay	Light reddish-brown silt clay. <1% sub-angular to sub-rounded clasts <10mm.
1.00	1.20	Silty Clay	Light blueish-grey silty clay.
1.20	1.25	Silty Clay	Medium greyish-brown silty clay. 2% sub-angular to sub-rounded flint and quartz <30mm.
1.25	2.00	Clay	Dark brownish-grey clay. <1% sub-rounded to sub-angular flint clasts. Frequent black, rooted organic inclusions; well-preserved.
2.00	2.60	Clay	Dark greyish-brown gravelly clay. 30% sub-angular to sub-rounded flint and quartz <30mm.
2.60	3.90	Clay	Dark brownish-grey clay. 1% sub-angular to sub-rounded flint <20mm. Mn mottling.
3.90	4.00	Sandy Clay	Dark brownish-grey sandy clay. 1% sub-angular to sub-rounded flint and quartz <5mm. Peaty. Good organic preservation of darkened, rooted plant matter.
4.00	4.15	Silty Clay	Medium brownish-grey silty clay. Mn mottling. 1% sub-angular to sub-rounded flint and quartz <5mm. More minerogenic than the other units in this borehole.
4.15	4.90	Clay	Dark brownish-grey clay. 2% sub-angular to sub-rounded flint and quartz <10mm. Mn mottling.
4.90	5.00	Clayey Silty Fine Sand	Medium yellowish-brown clayey silty fine sand. 20% sub-angular to well rounded flint, tertiary flint and quartz <30mm.
5.00	5.75	Sandy Clay	Medium brownish-grey sandy clay. 2% sub-angular to rounded flint, tertiary flint and quartz <30mm. Mn mottling.
5.75	6.00	Clayey Fine Sand	Dark yellowish-grey clayey fine sand. 15% sub-angular to sub-rounded flint and quartz <40mm.

ATTT21 HABH18 1.00-6.00m

Borehole HABH19
Easting: 585526.346
Northing: 217629.921
Elevation: 19.08 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.25	Sandy Clayey Silt	Dark greyish-brown sandy clayey silt. 15% sub-angular to sub-rounded fine to medium flint <30mm.
0.25	0.65	Clayey Silt	Light yellowish-brown clayey silt.
0.65	0.80	Sandy Silt	Medium brown sandy silt. Clasts are sub-rounded chalk <10mm.
0.80	1.00	Silty Clay	Medium brownish-grey silty clay. Fe mottling.
1.00	1.30	Silty Clay	Medium greyish-brown silty clay. 5% sub-angular to sub-rounded flint and quartz <30mm. Mn mottling.
1.30	2.25	Clayey Medium Sand	Dark greyish-brown clayey medium sand. Clasts are sub-angular to well rounded flint, tertiary flint and quartz <60mm. Mn aggregates.
2.25	3.00	Clayey Coarse Sand	Medium yellowish-brown clayey coarse sand. Clasts are sub-angular to well rounded flint, tertiary flint and quartz <70mm.

ATT21 HABH19 1.00-3.00m

Borehole HABH21
Easting: 585538.319
Northing: 217609.388
Elevation: 19.06 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Light yellowish-brown clayey silt.
0.30	0.70	Clayey Silt	Light yellowish-brown clayey silt. 15% sub-angular to sub-rounded fine to medium clasts.
0.70	0.80	Clay	Light yellowish-brown clay. Rare charcoal and mollusc fragments.
0.80	1.00	Silty Clay	Medium greyish-brown silty clay.
1.00	1.32	Sandy Silty Clay	Light yellowish-grey sandy silty clay. Fe staining in upper 2/3 of unit.
1.32	2.05	Sandy Silty Clay	Medium reddish-grey sandy silty clay. Slightly humified plant remains. Lower boundary obscured by some damage to core.
2.05	2.94	Sandy Silty Clay	Medium greyish-blue sandy silty clay. Fines upwards. Slightly humified plant remains. Clasts are sub-angular flint <15mm. Colour lightens and has a more greyish hue towards the lower boundary.
2.94	3.00	Clayey Medium Sand	Light orangish-grey clayey medium sand. More clayey towards base of unit.
3.00	3.44	Sandy Silty Clay	Light blueish-grey sandy silty clay. Fines upwards. Clasts are sub-angular flint <40mm. Slightly humified plant remains. Bedded with clayey coarse sand.
3.44	4.00	Sandy Gravel	Medium yellowish-orange sandy gravel. Matrix supported. Coarsens upwards. Clasts are sub-angular to sub-rounded flint, quartz and tertiary flint <60mm.

ATTT21 HABH21 1.20-4.00m

Borehole HABH22
Easting: 585543.207
Northing: 217626.321
Elevation: 19.02 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
1.00	2.00	Sandy Clay	Medium yellowish-grey sandy clay. Fines upwards. Clasts are sub-rounded to rounded flint and quartz <10mm. Slightly humified organic flecks. Dark brown organic staining 1.26-1.60m. Flecks of organic material throughout.
2.00	2.35	No Recovery	
2.35	2.91	Sandy Clay	Medium grey sandy clay. Clasts are sub-angular to sub-rounded flint <15mm. Slightly humified organic matter.
2.91	3.25	Coarse Sand	Medium yellowish-white gravelly coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <50mm.
3.25	4.00	No Recovery	

HABH22 1.00-4.00m

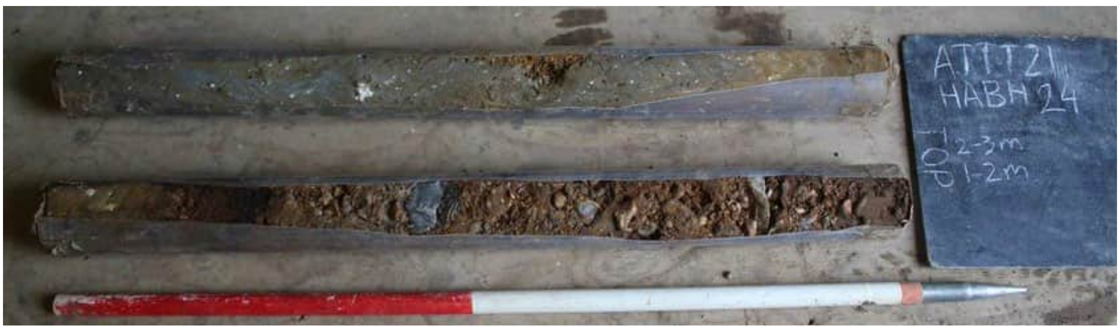
Borehole HABH23
Easting: 585546.809
Northing: 217645.173
Elevation: 19.08 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.80	Clayey Silt	Medium greyish-brown clayey silt. Gritty.
0.80	1.00	Sandy Clayey Silt	Light reddish-brown sandy clayey silt. Rare fine sub-rounded flint clasts.
1.00	1.27	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-angular to sub-rounded flint and quartz <20mm. Fe staini ng up to 1.20m.
1.27	1.32	Sandy Clayey Silt	Dark greyish-brown sandy clayey silt.
1.32	1.48	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-angular to sub-rounded flint and quartz <20mm. Iron oxide staining up to 20cm depth.
1.48	1.77	Silty Sandy Clay	Light orangish-grey silty sandy clay. Fines upwards. Clasts are sub-rounded to sub-angular flint, tertiary flint and quartz 70mm. Coarser sand and greyer colour towards base.
1.77	2.00	Coarse Sand	Medium orangish-grey coarse sand. Clasts are sub-angular to sub-rounded flint and quartz 20mm. Greying towards base.
2.00	2.31	No Recovery	
2.31	2.43	Sandy Clayey Silt	Medium greyish-brown sandy clayey silt. Well humified organic material. Clasts are sub-angular flint <60mm.
2.43	2.68	Sandy Clay	Medium brownish-grey sandy clay. Slightly humified plant remains. Clasts are sub-angular to sub-rounded flint and quartz <20mm.
2.68	4.00	Coarse Sand	Medium brownish-orange coarse sand. Coarsens upwards. Clasts are sub-angular to sub-rounded flint, tertiary flint and quartz.

ATTT21 HABH23 1.20-4.00m

Borehole HABH24
Easting: 586291.166
Northing: 217754.038
Elevation: 24.28 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Dark greyish-brown clayey silt. Slightly sandy.
0.30	0.90	Silt	Light yellowish-brown silt. 2% sub-angular to sub-rounded fine to medium clasts, <1% flint cobble <1000mm.
0.90	1.00	Sandy Silty Clay	Light yellowish-brown sandy silty clay. 15% sub-angular to sub-rounded clasts <100mm.
1.00	1.07	Sandy Clayey Silt	Medium greyish-brown sandy clayey silt.
1.07	1.75	Clayey Medium Sand	Medium reddish-brown clayey medium sand. Fines upwards. Clasts are sub-angular to sub-rounded flint and quartz <70mm.
1.75	1.85	Clayey Medium Sand	Medium brownish-red clayey medium sand. Mn staining 1.72-77m. Fe staining 1.77-1.85m.
1.85	2.18	Sandy Silty Clay	Medium yellowish-brown sandy silty clay. Clasts are sub-angular to sub-rounded chalk and flint <10mm. Mn flecks. Chalk flecks.
2.18	4.00	Silty Clay	Medium blueish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <20mm.



ATTT21 HABH24 1.00-3.00m

Borehole HABH25
Easting: 586304.211
Northing: 217758.909
Elevation: 23.6 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Clayey Silt	Medium greyish-brown clayey silt.
0.3	0.5	Clayey Silt	Medium greyish-brown clayey silt. Clasts are angular flint <40mm.
0.5	0.8	Clayey Silt	Medium greyish-brown clayey silt. Clasts are sub-angular to sub-rounded chalk and flint <15mm.
0.8	1.0	Clay	Medium greyish-brown clay.
1.0	3.0	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-angular to sub-rounded chalk and flint <15mm.

ATTT21 HABH25 1.20-3.00m

Borehole HABH26
Easting: 586312.949
Northing: 217762.366
Elevation: 23.51 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Clayey Silt	Light brownish-grey sandy clayey silt.
0.3	0.5	Clayey Silt	Dark brown clayey silt.
0.5	0.7	Clayey Silt	Dark brown clayey silt. Shell flecks.
0.7	1.0	Clay	Light yellowish-brown clay.
1.0	3.0	Silty Clay	Medium yellowish-brown silty clay. Clasts are sub-angular flint <30mm. Blueish-grey Mottling throughout.

ATTT21 HABH26 1.00-3.00m

Borehole HABH27
Easting: 586321.908
Northing: 217766.548
Elevation: 23.61 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Clayey Silt	Light brownish-grey clayey silt.
0.40	0.50	Clayey Silt	Medium greyish-brown clayey silt. Clasts are sub-angular flint <20mm.
0.50	0.70	Clay	Light yellowish-brown clay. 5% sub-angular to sub-rounded fine to medium clasts.
0.70	0.80	Slightly Sandy Silt	Medium reddish-grey slightly sandy silt. Carbonate flecks.
0.80	1.00	Clay	Dark greyish-brown clay. Clasts are sub-rounded to sub-angular flint and chalk <20mm.
0.80	1.00	Silty Clay	Medium greyish-brown silty clay. 2% Fe mottling.
1.00	2.01	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Blueish-grey mottling throughout. Pockets of lighter brown colouration throughout.
2.01	2.32	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-angular to sub-rounded flint and chalk <10mm. Blue-grey mottling and iron oxide staining throughout.
2.32	3.00	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Blueish-grey mottling throughout. Pockets of lighter brown colouration throughout.

ATTT21 HABH27 1.00-3.00m

Borehole HABH28
Easting: 586334.111
Northing: 217770.22
Elevation: 23.89 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.60	Sandy Clay	Light greyish-brown sandy clay. CBM fragments.
0.60	0.70	Silty Clay	Medium brownish-grey silty clay.
0.70	1.00	Clay	Light blueish-grey clay.
1.00	1.25	Sandy Silty Clay	Medium grey sandy silty clay. Clasts are sub-angular flint <5mm. Fe staining.
1.25	1.39	Clayey Sandy Gravel	Medium grey clayey sandy gravel. Clasts are sub-angular to sub-rounded flint, quartz and chalk <25mm.
1.39	2.00	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Common grey blue mottling.

ATTT21 HABH28 1.20-2.00m

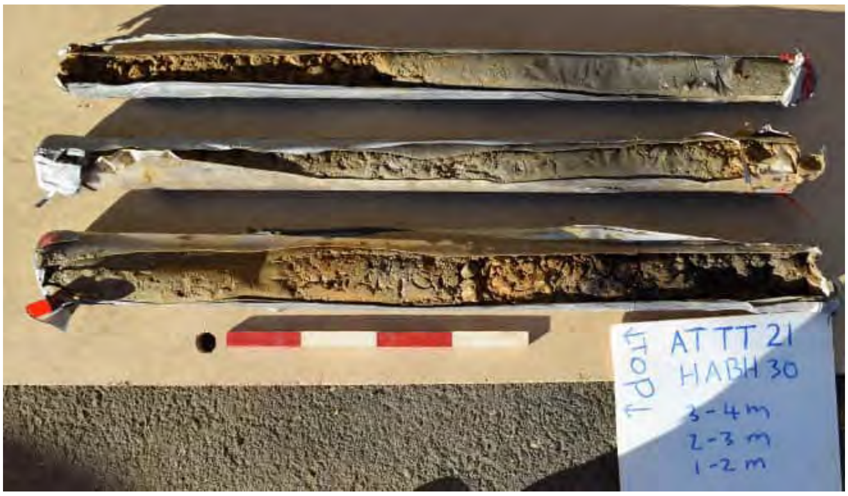
Borehole HABH29
Easting: 587860.204
Northing: 219091.084
Elevation: 23.85 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clayey Silt	Dark brownish-grey sandy clayey silt. Rare sub-angular to sub-rounded fine to medium flint clasts.
0.30	0.90	Silty Clay	Dark greyish-brown silty clay. Fe staining. <5% sub-angular to sub-rounded clasts <40mm.
0.90	1.00	Silty Clay	Light orangish-brown silty clay.
1.20	1.72	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Clasts are sub-angular flint and quartz <30mm. Grey staining at top of unit. Pocket of clasts at 1.52-1.58m.
1.72	2.00	Clayey Medium Sand	Medium brownish-orange clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <30mm. Void at 2-2.4m.
2.00	2.40	No Recovery	
2.40	3.00	Clayey Medium Sand	Medium brownish-orange clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <40mm.

ATTT21 HABH29 1.00-3.00m

Borehole HABH30
Easting: 587863.712
Northing: 219100.546
Elevation: 23.78 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.00	Silty Clay	Dark greyish-brown silty clay. 5% sub-angular fine to medium flint clasts.
1.00	1.21	Sandy Silty Clay	Light blueish-grey sandy silty clay. Clasts are angular to sub-angular flint <5mm. Patches of darker blue-grey. Fe staining in transition at lower boundary.
1.21	1.47	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Fines upwards. Clasts are sub-rounded to well-rounded flint and quartz.
1.47	1.91	Clayey Coarse Sand	Medium orangish-brown clayey coarse sand. Poorly humified plant remains. Clasts are sub-rounded to sub-angular flint and quartz <15mm. Humification is variable. Some browinish-grey staining of the fine fabric due to humification.
1.91	2.24	No Recovery	
2.24	2.45	Clayey Medium Sand	Medium brownish-grey clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <10mm. 1% chalk flecks.
2.45	2.54	Sandy Silty Clay	Medium blueish-grey sandy silty clay. Clasts are sub-angular flint. 1% chalk flecks.
2.54	2.59	Clayey Medium Sand	Medium brownish-grey clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <10mm. 1% chalk flecks.
2.59	2.90	Silty Clay	Medium blueish-grey silty clay. <1% sub-rounded chalk clasts <5mm.
2.90	3.49	Silty Coarse Sand	Medium orangish-brown silty coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <15mm.
3.49	4.00	Silty Clay	Medium blueish-grey silty clay. Fines upwards. Clasts are sub-rounded chalk <5mm.



ATTT21 HABH30 1.00-4.00m

Borehole HABH31
Easting: 587875.244
Northing: 219126.323
Elevation: 23.6 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.60	Sandy Clay	Dark greyish-brown sandy clay.
0.60	1.00	Clay	Light greyish-brown clay.
1.00	1.21	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-angular to sub-rounded chalk and flint.
1.21	1.71	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-angular to sub-rounded flint and quartz.
1.71	2.52	Sandy Clay	Medium orangish-brown sandy clay. Clasts are sub-angular to sub-rounded flint. Small amount of iron oxide staining towards top of lens.
2.52	3.09	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-angular to sub-rounded flint.
3.09	3.32	Sandy Clay	Medium brownish-grey sandy clay.
3.52	4.00	No Recovery	

ATTT21 HABH31 1.00-4.00m

Borehole HABH32
Easting: 587877.403
Northing: 219146.679
Elevation: 23.9 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Clayey Silt	Dark greyish-brown sandy clayey silt.
0.3	0.8	Clay	Medium reddish-brown clay.
0.8	1.0	Clay	Medium orangish-brown clay.
1.0	2.21	Sandy Gravel	Medium orangish-brown sandy gravel. Clasts are 80% angular to sub-rounded flint and chalk <50mm.
2.21	2.87	Silty Clay	Medium brownish grey silty clay. Clasts are 20% sub-rounded to rounded chalk <25mm.
2.87	3.00	No Recovery	

ATTT21 HABH32 1.00-3.00m

Borehole HABH33
Easting: 587882.52
Northing: 219161.491
Elevation: 24.11 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clayey Silt	Dark greyish-brown sandy clayey silt.
0.30	0.80	Clay	Medium reddish-brown clay.
0.80	1.00	Clay	Medium orangish-brown clay.
1.00	1.16	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Clasts are sub-angular to sub-rounded flint and quartz. Chalk flecks, Fe staining at base of unit.
1.16	1.36	Sandy Clay	Medium orangish-brown sandy clay. Clasts are rounded to sub-angular flint and quartz. Greyer towards top of unit.
1.36	2.07	Sandy Gravel	Medium orangish-brown sandy gravel. Clasts are sub-angular to sub-rounded flint and quartz. Transition with lower unit is sloping.
2.07	4.00	Silty Clay	Medium blueish-grey silty clay. Clasts are rounded to sub-rounded chalk. Mn mottling at 2.6m. Pocket of very humified material at 3.15m.

ATTT21 HABH33 1.00-4.00m

Borehole HABH34
Easting: 583068.623
Northing: 215343.293
Elevation: 19.53 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silt	Light brownish-grey sandy silt. Sub-angular to sub-rounded fine to medium clasts.
0.30	1.00	Silty Sand	Light orangish-brown silty sand. 5% sub-angular to sub-rounded flint clasts <30mm.
1.00	1.27	Clayey Medium Sand	Medium brownish-orange clayey medium sand.
1.27	3.00	Clayey Silt	Medium orangish-grey clayey silt. More clayey towards top of unit. Clayey sand at 3.00-3.15. Fe and Mn staining. Redder colour towards top of unit.
3.00	3.15	Clayey Coarse Sand	Medium orangish-grey clayey coarse sand.
3.15	4.89	Clayey Silt	Medium orangish-grey clayey silt. Fines upwards. More clayey towards top of unit. Clayey sand at 3.00-3.15. Slight Fe and Mn staining. Redder colour towards top of unit.
4.89	6.00	Clayey Silt	Medium grey clayey silt.

ATTT21 HABH34 1.00-6.00m

Borehole HABH35
Easting: 583087.818
Northing: 215303.306
Elevation: 17.78 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silt	Light greyish-brown silt.
0.30	1.00	Sandy Silt	Light orangish-brown sandy silt.
1.00	2.18	Silty Clay	Medium orangish-brown silty clay. Clasts are sub-rounded chalk <10mm. More weathered towards top of unit. Mn flecks.
2.18	2.66	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <15mm. Fe mottling. Mn flecks.
2.66	3.81	Sandy Silt	Light grey sandy silt. Intermittently laminated with bands of orange sand. Bedded with rounded quartz and flint gravel at 2.71-3m.
3.81	4.00	No Recovery	
4.00	4.11	Clay	Medium grey clay.
4.11	4.49	Medium Sand	Medium yellowish-grey medium sand.
4.49	4.71	Clayey Coarse Sand	Medium grey clayey coarse sand. Coarsens upwards. Clasts are sub-angular to rounded flint <40mm. Organic-stained clay 4.63-66m and band of organic-stained clay at 4.70-1m.
4.71	4.81	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-angular flint 30mm.
4.81	5.00	Clayey Silt	Medium grey clayey silt.
5.00	5.69	Coarse Sand	Medium brownish-yellow coarse sand. Fines upwards. Clasts are rounded to sub-angular flint <25mm. Included grey clay at 5.20-48m.
5.69	6.00	Clayey Silt	Medium grey clayey silt.
6.00	7.00	Coarse sand	Medium brownish grey coarse sand
7.00	7.84	Medium Sand	Medium brownish-grey medium sand. Clasts are sub-angular to sub-rounded flint <40mm. Grey staining of sand towards base of unit. Clayey silt pocket at 7.11-12m.
7.84	8.00	Clayey Silt	Medium grey clayey silt. Clasts are sub-rounded chalk.

ATTT21 HABH35 1.00-8.00m

Borehole HABH36
Easting: 583102.062
Northing: 215267.635
Elevation: 16.89 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Clayey Sandy Silt	Light greyish-brown clayey sandy silt. Rare sub-angular to sub-rounded fine to medium clasts.
0.3	0.7	Sandy Silt	Light yellowish-brown sandy silt.
0.7	1.0	Sandy Silt	Light yellowish-brown sandy silt.
1.0	2.0	Clayey Coarse Sand	Medium orangish-brown clayey coarse sand. Clasts are sub-angular to sub-rounded flint <5mm. Bedded with less clayey sand at 1.33-40 and 1.66-2.00. Mn mottling at 1.00-1.35m.
2.0	2.5	No Recovery	
2.5	3.0	Coarse Sand	Medium orangish-grey coarse sand. Clasts are sub-rounded to sub-angular flint and quartz <30mm. Gravelly sand. Redder colour towards base of unit.

ATTT21 HABH36 1.00-2.50m

Borehole HABH38
Easting: 583115.347
Northing: 215477.593Elevation: 19.85 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Sandy Silt	Light greyish-brown clayey sandy silt. Rare sub-angular to sub-rounded gravel.
0.30	0.70	Sandy Silt	Light yellowish-brown sandy silt.
0.70	1.20	Sandy Silt	Light yellowish-brown sandy silt.
1.20	1.27	Medium Sand	Medium yellowish-orange medium sand. Clasts are sub-angular flint and chalk.
1.27	1.35	Sandy Silty Clay	Medium yellowish-brown sandy silty clay.
1.35	1.96	Coarse Sand	Medium orangish-brown coarse sand. Fines upwards. Clasts are sub-angular to sub-rounded flint <60mm.
1.96	2.08	Silty Sandy Clay	Medium yellowish-brown silty sandy clay. Fines upwards. Clasts are sub-angular chalk and flint <5mm.
2.08	2.24	Sandy Clayey Gravel	Medium yellowish-brown sandy clayey gravel. Matrix supported. Clasts are sub-rounded to rounded flint <100mm.
2.24	2.37	Silty Clay	Medium blueish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint. Mn flecks. Chalk flecks.
2.37	2.62	Clayey Medium Sand	Medium yellowish-grey clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <60mm.
2.62	4.00	Silty Clay	Medium blueish-grey silty clay. Mn flecks. Chalk flecks.

ATTT21 HABH38 1.00-4.00m

Borehole HABH45
Easting: 584179.274
Northing: 216533.484
Elevation: 21.96 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.05	Silty Medium Sand	Dark greyish-brown silty medium sand.
0.05	1.00	Silty Coarse Sand	Medium reddish-brown silty coarse sand. 15% sub-angular to sub-rounded flint clasts <65mm.
1.00	2.91	Clayey Coarse Sand	Medium yellowish-brown clayey coarse sand. Bedded with fine brown clay head deposits at 1.65-81, 1.84-9, 2.00-2.65m. Clasts are sub-angular to angular flint and quartz <40mm.
2.91	3.27	Clayey Medium Sand	Medium reddish-brown clayey medium sand. Banded with brown sandy clay at 3.00-3.10m. Clasts are sub-rounded to rounded flint and chalk <40mm.
3.27	6.55	Medium Sand	Medium orangish-yellow medium sand. Bedded with gravelly sand at 3.54-57 and 4.31-6 6.35-45m. More clayey towards base of unit. Clasts are sub-rounded to sub-angular flint and chalk <20mm.
6.55	7.00	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded to rounded chalk <20mm.
7.00	7.90	Slightly Sandy Silt	Medium grey slightly sandy silt.

ATTT21 HABH45 1.00-7.00m

Borehole HABH46
Easting: 584199.135
Northing: 216585.541
Elevation: 21.51 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silt	Dark greyish-brown sandy silt.
0.30	1.00	Gravelly Sand	Dark orangish-brown gravelly sand. Slightly clayey. Sub-angular to sub-rounded flint clasts <85mm.
1.00	2.00	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Coarsening upwards. Clasts are sub-angular to sub-rounded flint <25mm.
2.00	2.10	No Recovery	
2.10	2.19	No Recovery	
2.19	2.73	Silty Clay	Medium yellowish-brown silty clay. Fines upwards. Clasts are sub-rounded to rounded chalk, quartz and flint. Colour darkens towards the upper boundary. Clasts are concentrated in the lower portion of this unit.
2.73	3.35	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz. Very slightly clayey.
3.35	4.00	No Recovery	

ATTT21 HABH46 1.00-3.50m

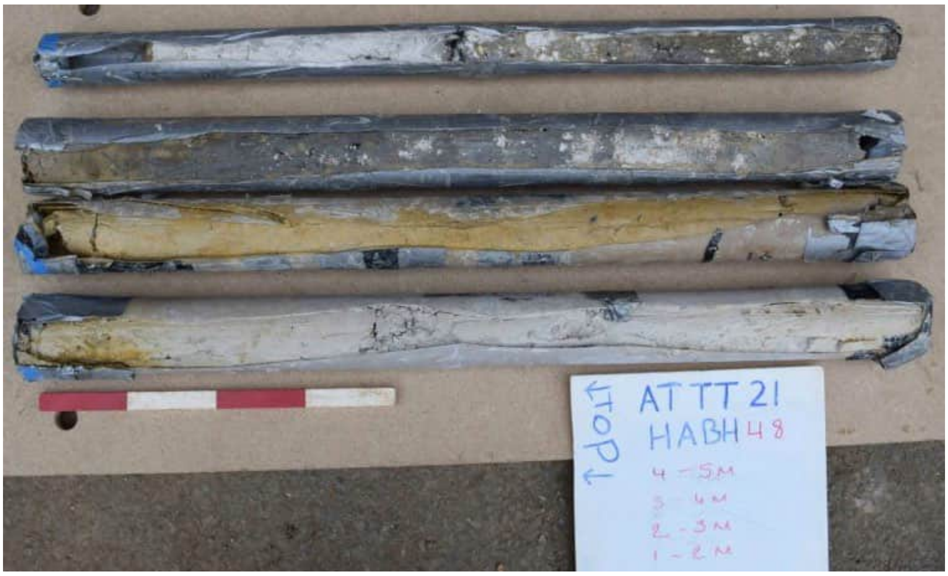
Borehole HABH47
Easting: 584036.635
Northing: 216873.312
Elevation: 23.08 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Clay	Dark greyish-brown clay.
0.3	0.6	Sandy Clay	Medium orangish-brown sandy clay.
0.6	0.8	Clay	Light orangish-grey clay.
0.8	1.2	Sandy Clay	Light yellowish-grey sandy clay.
1.0	2.0	Silty Clay	Light greyish-brown silty clay. Fines upwards. Clasts are sub-rounded to rounded chalk and flint.

ATTT21 HABH47 1.00-2.00m

Borehole HABH48
Easting: 584195.941
Northing: 216898.733
Elevation: 20.64 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
1.00	2.07	Sandy Silty Clay	Light whitish-grey sandy silty clay. Clasts are coarse sand. Sticky uniform sandy silty clay.
2.07	3.12	Slightly Sandy Clay	Light greyish-yellow slightly sandy clay. Poorly humified grass and plant remains at 2.33 to 2.89 cm. Mottled grey brown sandier clay 2.33-2.89m.
3.12	3.95	Silty Clay	Medium grey silty clay. Fines upwards. Clasts are sub-rounded to rounded chalk.
3.95	4.13	No Recovery	
4.13	4.46	Clay	Light greyish-white clay. Clasts are chalk.
4.47	4.49	Slightly Sandy Silty Clay	Dark greyish-brown slightly sandy silty clay.
4.49	5.00	Slightly Sandy Clay	Medium grey slightly sandy clay. Clasts are sub-rounded to rounded chalk.



ATTT21 HABH48 1.00-5.00m

Borehole HABH49
Easting: 584314.204
Northing: 216942.293
Elevation: 23.31 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.25	Sandy Silt	Dark greyish-brown sandy silt.
0.25	1.00	Sandy Silt	Light yellowish-brown sandy silt.
1.00	1.08	Silty Clay	Medium greyish-yellow silty clay. Mn flecks throughout. Amorphous Fe staining.
1.08	1.75	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Bedded with gravelly sand beds at 1.08-1.16, 1.18-1.26 and 1.30-1.47m. Patches of more clayey material 1.16-1.18, 1.26-28, 1.49-54 and 1.59-1.65m. Clasts are rounded to sub-angular flint <25mm. Well humified organic material at 1.35, 1.42, and 1.63m.
1.75	2.00	Silty Clay	Light yellowish-grey silty clay. Chalky. Coarse sand bed at 1.91-1.94. Mn flecks throughout.
2.00	2.80	Clay	Light grey clay. Granular structure.
2.80	2.90	Sandy Clay	Medium yellowish-grey sandy clay. Clasts are sub-rounded chalk <10mm.
2.90	3.00	Clay	Light whitish-grey clay. Laminations of yellow clay and manganese. Chalky clay.

ATTT21 HABH49 1.00-2.00m

Borehole HABH50
Easting: 583856.915
Northing: 216856.399
Elevation: 24.32 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Silt	Dark brownish-grey sandy silt.
0.3	0.6	Clay	Medium orangish-brown clay.
0.6	1.0	Sandy Silt	Light whitish-grey sandy silt.
1.0	3.0	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Clasts are sub-angular to sub-rounded chalk and flint. Hard and lighter in colour at top of unit (approx. 1.00-.73m). Included degraded sandstone.

ATTT21 HABH50 1.00-3.00m

Borehole RAYL07
Easting: 579986.228
Northing: 212749.211
Elevation: 49.08 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Sandy Clay	Medium orangish-brown sandy clay. <5% sub-angular to sub-rounded gravel. <1% chalk flecks.
1.20	1.90	Silty Clay	Medium orangish-brown silty clay. Clasts are angular to sub-rounded flint, chalk and sandstone <20mm. Mn mottling 1.65-1.90m.
1.90	7.26	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to sub-angular chalk and flint <60mm. Slight Fe and Mn staining.
7.26	7.45	Silty Clay	Medium yellowish-brown silty clay. Mn mottling 7.39-45m.
7.50	7.59	Fine Sand	Medium greyish-yellow fine sand.
7.59	7.78	Medium Sand	Medium yellowish-brown gravelly medium sand. Fines upwards. Clasts are rounded to sub-angular chalk and flint <30mm.
7.78	7.87	Clayey Silt	Medium yellowish-brown clayey silt. Lens of fine rounded chalk gravel 5.81-2m.
7.87	7.91	Clayey Medium Sand	Medium yellowish-brown clayey medium sand. Clasts are rounded chalk <5mm.
7.91	7.95	Clayey Fine Sand	Medium yellowish-brown clayey fine sand.
8.00	8.12	No Recovery	
8.12	8.50	Silty Clay	Medium yellowish-brown silty clay. Lens of sandy clay 8.22-29m. Clasts are sub-rounded to rounded chalk and quartz <20mm.
8.50	9.00	Clay	Medium orangish-brown clay. Rare fine sand, with fine flint and chalk.
9.00	9.50	Clay	Medium orangish-brown clay. Very slightly fine sandy. <2% sub-angular fine flint and chalk clasts 5mm.
9.50	10.00	Clay	Dark greyish-brown clay. Rare fine sand. <5% sub-rounded fine chalk and flint clasts 5mm.

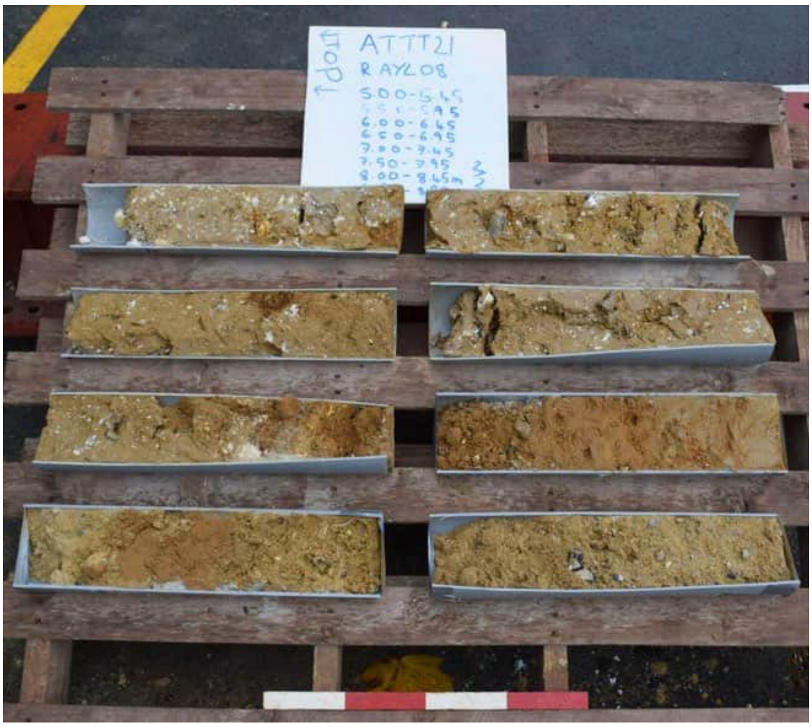
ATTT21 RAYL07 1.20-4.95m

ATTT21 RAYL07 5.00-8.45m

Borehole RAYL08
Easting: 580098.109
Northing: 212832.638
Elevation: 47.14 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Sandy Clay	Medium greyish-brown sandy clay. <10% small sub-angular clasts.
1.20	1.46	Slightly Sandy Silt	Medium brown slightly sandy silt. Clasts are sub-angular flint <40mm.
1.46	7.38	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-angular to angular chalk, flint and sandstone <100mm. Mn flecks. Some Fe mottling in top half of profile.
7.38	7.62	Clayey Coarse Sand	Dark orangish-brown clayey coarse sand. Clasts are angular to sub-rounded flint <40mm.
7.62	7.79	Clayey Fine Sand	Medium orangish-brown clayey fine sand. Clasts are sub-rounded to rounded flint <40mm. At boundary sand veins continue into clay below.
7.79	7.95	Silty Clay	Medium yellowish-brown silty clay. Clasts are sub-rounded to sub-angular flint <20mm.
8.00	8.95	Medium Sand	Medium yellow medium sand. Fines upwards. More clayey towards base of unit. Finer sand towards top of unit. Clasts are sub-rounded to sub-angular flint <60mm. Lens of well sorted orangish brown clayey fine sand at 8.14-26m.
8.95	9.00	Sandy Clay	Medium yellowish-brown sandy clay. 5% sub-angular flint clasts <20mm. 2% Mn flecks.
9.00	9.30	No Recovery	

ATTT21 RAYL08 1.20-4.95m

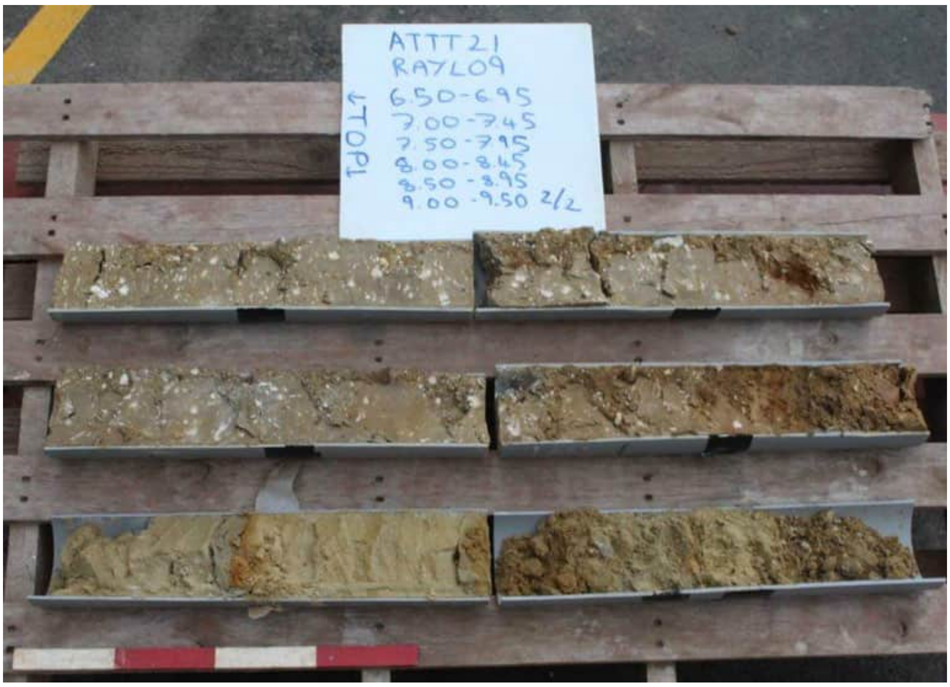


ATTT21 RAYL08 5.00-8.95m

Borehole RAYL09
Easting: 580134.986
Northing: 212793.901
Elevation: 46.69 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silt	Light yellowish-brown sandy silt. Slightly clayey. Potatoes crop.
0.30	1.20	Sandy Silt	Medium yellowish-brown sandy silt.
1.20	2.00	Slightly Sandy Silty Clay	Medium orangish-brown slightly sandy silty clay. Clasts are sub-angular to sub-rounded flint <15mm. Redder towards top of unit. Mn and Fe mottling concentrated in lower half of unit.
2.00	5.45	Slightly Sandy Silty Clay	Medium yellowish-grey slightly sandy silty clay. Clasts are sub-rounded to sub-angular chalk, flint and sandstone <20mm. Fe flecks.
5.45	5.50	Silty Clay	Light greyish-brown silty clay. 10% dark grey mottling. 20% subrounded chalk and 2% flint clasts <15mm.
5.50	6.00	Silty Clay	. . .
6.00	6.60	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to sub-angular chalk and flint <30mm.
6.60	8.33	Slightly Sandy Silty Clay	Medium yellowish-grey slightly sandy silty clay. Clasts are sub-rounded to sub-angular chalk, flint and sandstone <20mm. Fe flecks.
8.33	8.45	Clayey Medium Sand	Medium yellowish-grey clayey medium sand. Clasts are sub-angular to sub-rounded flint <20mm. Slight Mn mottling.
8.45	8.50	Medium Sand	Medium orangish-brown medium sand. Clasts are rounded to sub-rounded chalk <15mm. Pockets of grey silty clay with chalk inclusions.
8.50	9.30	Fine Sand	Medium whitish-yellow fine sand. Matrix supported. Continuously laminated with banding of grey clay with associated iron staining at 8. 69-71, 8.92-4, 9.18-21m.
9.30	9.50	Clayey Medium Sand	Medium yellowish-grey clayey medium sand. Clasts are sub-angular to sub-rounded flint and quartz <40mm.

ATTT21 RAYL09 1.20-5.45m



ATTT21 RAYL09 6.50-9.50m

Borehole RAYL10
Easting: 580193.949
Northing: 212766.236
Elevation: 46.46 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.60	Sandy Silt	Light yellowish-brown sandy silt.
0.60	1.20	Sandy Clay	Medium orangish-brown sandy clay. 15% sub-angular to sub-rounded flint clasts <20mm.
1.20	1.63	Sandy Clay	Medium brown sandy clay. 15% sub-angular flint clasts <20mm. 1% Mn flecks.
1.63	2.02	Silty Clay	Medium orangish-brown silty clay. Poorly defined gravel band at 1.89-96m.10% sub-angular flint <40mm. 1% Mn flecks. 1% chalk flecks.
2.02	3.00	Silty Clay	Light greyish-brown silty clay. 40% sub-rounded to rounded chalk and 2% flint clasts <80mm. 2% Mn flecks. 1% Fe flecks.
3.00	3.50	No Recovery	
3.50	6.00	Silty Clay	Light greyish-brown silty clay. Clasts are sub-angular to sub-rounded flint. 2% Mn flecks. 1% Fe flecks.
6.00	7.00	Medium Sand	Medium brownish-orange medium sand. Bedded with medium grey clay at 6.05-13, 6.17-24, 6.42-5 and 6.53-9m. Void at 6.50-53m.Bottom of unit compacted. Discontinuous orange laminations in sand. 10% sub-rounded to sub-angular flint <30mm. Iron pans at top of unit 6.04-11m. 1% Mn flecks in sand.
7.00	7.50	Clayey Medium Sand	Medium greyish-yellow clayey medium sand. Clasts are rounded to sub-rounded flint <40mm. Gravelly sand.
7.50	8.00	Medium Sand	Medium yellowish-grey. Clasts are sub-angular to rounded flint and quartz <40mm. Medium Sand.
8.00	8.50	Clayey Medium Sand	Medium yellowish-grey clayey medium sand. Clasts are rounded to sub-rounded flint <25mm.
8.50	8.90	Sandy Gravel	Light whitish-yellow sandy gravel. Clast supported. 10% sand in gravel.
8.90	9.50	Slightly Sandy Gravel	Medium brownish-grey slightly sandy gravel. Clast supported. Clasts are angular to sub-angular flint <40mm. 5% sand in gravel.
9.50	10.00	Sandy Gravel	Light whitish-yellow sandy gravel. Matrix supported. Clasts are sub-rounded to rounded flint <20mm. 50% sand in gravel.

ATTT21 RAYL10: 1.20-4.45m

ATTT21 RAYL10: 4.50-6.95m

Borehole SABB11
Easting: 585965.437
Northing: 217622.19
Elevation: 24.75 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Sandy Clay Silt	Medium greyish-brown sandy clay silt. 5% sub-angular to sub-rounded flint <90mm.
0.50	1.20	Sandy Silt	Medium orangish-brown sandy silt.
1.20	1.36	No Recovery	
1.36	2.82	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Clasts are sub-angular to angular flint <25mm. Mn staining.
2.82	3.50	Clayey Medium Sand	Medium orangish-brown clayey medium sand. Fines upwards. Clasts are sub-angular to angular flint and quartz <30mm.
3.50	8.30	Sandy Gravel	Medium orangish-brown sandy gravel. Recorded from drillers' logs.
8.30	8.70	No Recovery	
8.70	9.80	Silty Clay	Medium grey silty clay. Fines upwards. Clasts are sub-rounded chalk <70mm. Slightly weathered at top of unit. Chalk flecks.

ATTT21 SABB11 1.2-3,5m, 8.20-9.50m

Borehole SABB12
Easting: 586089.329
Northing: 217672.515
Elevation: 26.29 m OD

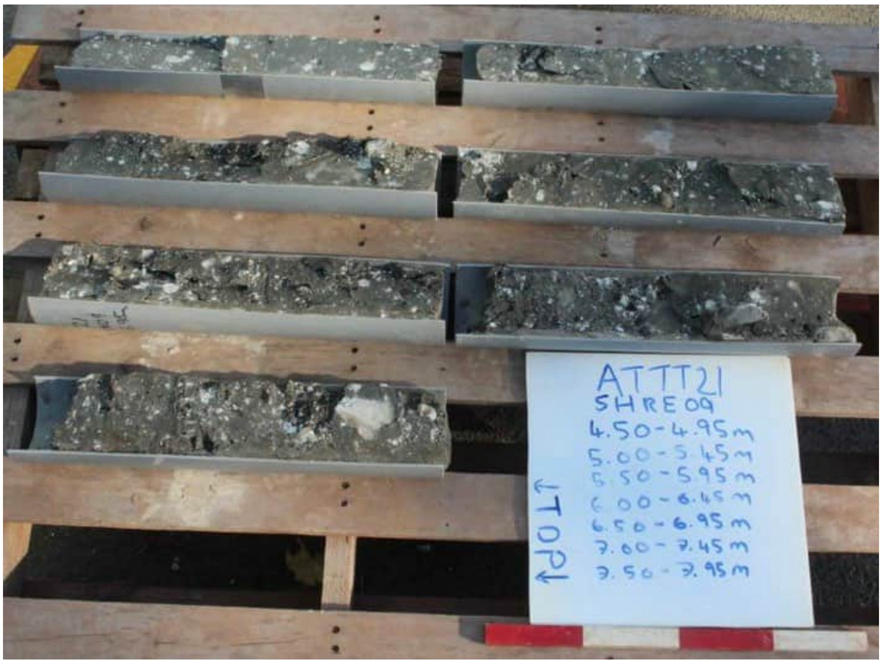
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clay	Medium orangish-brown Sandy Clay. Sub-angular to sub-rounded clasts <55mm.
0.30	1.20	Silt	Light orangish-brown silt. Slightly sandy. <1% sub-angular to sub-rounded flint clasts <50mm.
1.20	2.00	Clayey Silty Coarse Sand	Medium orangish-brown clayey silty coarse sand. Coarsens upwards. Sub-angular to angular flint, chalk and quartz <50mm. Mn staining.
2.00	5.60	Sandy Gravel	Medium reddish-brown sandy gravel.
5.60	5.98	No Recovery	
5.98	6.70	Silty Clay	Medium grey silty clay. Clasts are rounded chalk <15mm. Slight Fe staining.

ATTT21 SABB12 1.20-2.00m and 5.60-6.70m

Borehole SHRE09
Easting: 589662.026
Northing: 221672.084
Elevation: 33.45 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clay	Light brownish-grey sandy clay. <5% sub-angular to sub-rounded fine to medium clasts.
0.30	0.60	Sandy Clay	Light greyish-yellow sandy clay. Rare fine chalk flecks increasing with depth.
0.60	1.20	Sandy Silt	Light greyish-brown sandy silt.
1.20	4.16	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded chalk and sandstone <25mm.
4.16	7.95	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <60mm.
7.95	9.50	Sandy Silty Clay	Medium grey sandy silty clay. Clasts are sub-rounded to rounded chalk <25mm.
9.50	10.00	No Recovery	

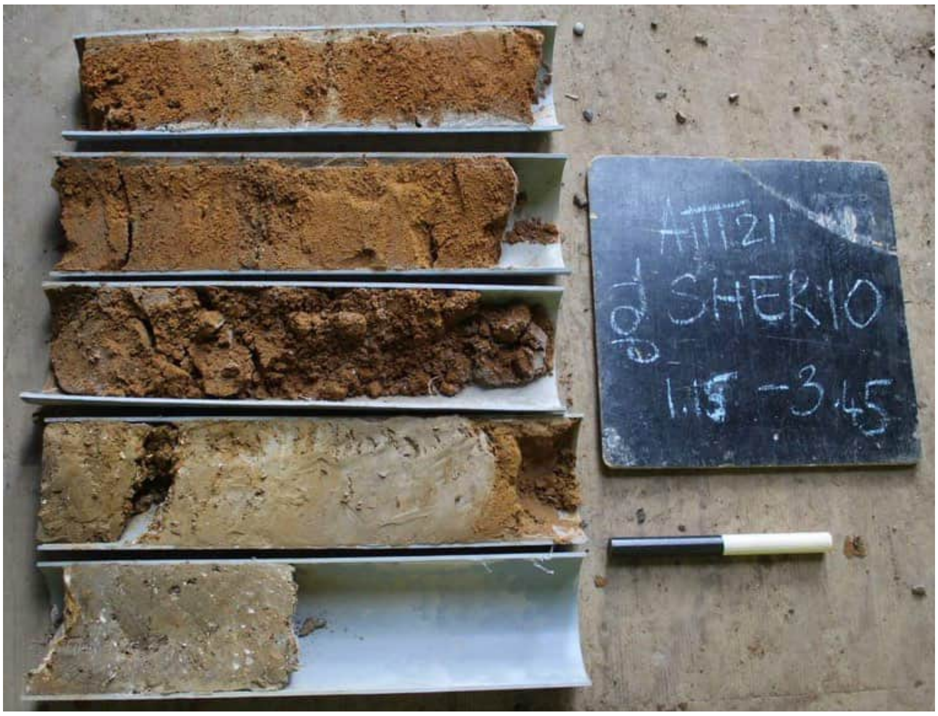
ATTT21 SHRE09 1.20-4.45m



ATTT21 SHRE09 4.50-7.95m

Borehole SHRE10
Easting: 589855.211
Northing: 221783.078
Elevation: 35.63 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clay	Medium brownish-orange sandy clay. <30% sub-angular to angular flint clasts.
0.30	1.15	Sandy Clay	Light brownish-orange sandy clay. <30% sub-angular to angular flint clasts.
1.15	2.57	Clayey Medium Sand	Medium orangish-red clayey medium sand. Bedded with coarse sand. Clasts are sub-angular flint <5mm.
2.57	3.28	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Clasts are sub-angular to sub-rounded flint and chalk <10mm. Slight grey mottling. Chalk flecks.
3.28	5.10	Sandy Silty Clay	Medium brownish-grey sandy silty clay. Slightly humified wood remains. Clasts are sub-rounded to sub-angular chalk and flint <30mm .
5.10	5.75	Sandy Silty Clay	Medium grey sandy silty clay. Slightly humified wood remains. Clasts are sub-rounded to sub-angular chalk and flint <25mm.
5.75	6.00	Sandy Silty Clay	Medium reddish-brown sandy silty clay. Clasts are sub-rounded to sub-angular chalk and flint <20mm. Mn and Fe flecks. Chalk flecks.



ATTT21 SHRE10 1.15-3.45m

ATTT21 SHRE10 3.95-5.95m

Borehole SHRE11
Easting: 589946.578
Northing: 221762.222
Elevation: 36.41 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.45	Sandy Clay	Medium greyish-brown sandy clay. <30% clasts <2400mm.
0.45	1.20	Sandy Clay	Medium orangish-brown sandy clay. <40% angular to sub-rounded clasts.
1.20	2.50	Sandy Clay	Medium brown sandy clay. Fines upwards. Clasts are sub-rounded to angular flint and sandstone <70mm. Mn mottling concentrated at top of unit.
2.50	3.00	Slightly Sandy Clay	Medium brown slightly sandy clay. 5% sub-angular flint <10mm. 5% Mn mottling.
3.00	4.75	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-rounded to angular chalk and flint <50mm. Mn flecks.
4.75	6.35	Silty Clay	Dark grey silty clay. Clasts are sub-rounded to rounded chalk and flint <90mm. Mn flecks.
6.35	6.65	Silty Clay	Dark greyish-brown silty clay. Clasts are rounded to sub-angular flint and chalk <25mm.
6.65	7.00	No Recovery	
7.00	7.50	Clayey Coarse Sand	Medium yellowish-grey clayey coarse sand. Clasts are sub-rounded to sub-angular flint and chalk <20mm. Gravelly sand.
7.50	8.00	Coarse Sand	Medium greyish-yellow coarse sand. Clasts are sub-angular to sub-rounded flint and quartz <15mm. Gravelly sand.
8.00	8.50	Sandy Gravel	Light greyish-brown sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <30mm.
8.50	9.00	Coarse Sand	Medium whitish-yellow gravelly coarse sand.
9.00	9.50	Coarse Sand	Medium yellowish-grey coarse sand. 40% sub-angular to sub-rounded flint and 5% quartz clasts <50mm.
9.50	10.00	Sandy Gravel	Medium greyish-yellow sandy gravel. Matrix supported. Clasts are sub-rounded to rounded flint and gravel <30mm.

ATTT21 SHRE11 1.20-3.95m

ATTT21 SHRE11 4.00-5.45m, 5.75-6.65m

Borehole SHRW02
Easting: 588102.722
Northing: 220259.657
Elevation: 32.96 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Sandy Clay	Medium greyish-brown sandy clay. 10% sub-angular flint clasts <80mm.
1.20	5.35	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to angular chalk, flint and sandstone <120mm. Pocket of yellowish brown clay 5.72-7m. Mn and Fe flecks.
5.35	6.70	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <50mm.
6.70	7.38	Silty Clay	Dark grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <50mm.
7.38	7.51	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <50mm.
7.51	7.70	Medium Sand	Medium brown medium sand. Clasts are sub-rounded to sub-angular flint <30mm.
7.70	8.50	No Recovery	
8.50	9.00	Sandy Gravel	Medium orangish-brown sandy gravel. Clast supported. Clasts are sub-angular to sub-rounded flint and quartz <30mm.
9.00	9.50	Sandy Gravel	Medium greyish-yellow sandy gravel. Clast supported. Clasts are sub-rounded and sub-angular flint and quartz <50mm. 15% sand in gravel.
9.50	10.00	Sandy Gravel	Medium greyish-yellow sandy gravel. Clast supported. Clasts are rounded to sub-rounded flint and quartz <40mm.15% sand in gravel.

ATTT21 SHRW02 1.2O-4.45, 4.70-5.25m

ATTT21 SHRW02 5.25-7.70m

Borehole SHRW03
Easting: 588195.308
Northing: 220358.149
Elevation: 32.61 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Sandy Clay	Medium greyish-brown sandy clay. CBM and Rooting.
1.20	1.40	Slightly Sandy Clay	Medium orangish-brown slightly sandy clay. Fines upwards. Clasts are sub-angular to angular flint <40mm.
1.40	1.89	Silty Clay	Dark greyish-brown silty clay. Mn flecks throughout. Clasts are sub-angular to sub-rounded flint and quartz <20mm.1% chalk flecks.
1.89	5.00	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to sub-angular chalk and flint <50mm. Mn and Fe flecks.
5.00	5.50	Clayey Medium Sand	Medium yellowish-grey clayey medium sand. 5% sub-angular flint clasts <10mm.
5.50	6.00	Clayey Medium Sand	Medium grey clayey medium sand. 10% sub-angular flint clasts <10mm. 5% flint flecks.
6.00	6.50	Slightly Sandy Gravel	Medium greyish-brown slightly sandy gravel. Matrix supported. Clasts are rounded to sub-rounded flint and quartz <30mm. 5% grey clay pockets. 10% sand in gravel.
6.50	7.00	Clayey Medium Sand	Medium grey clayey medium sand. 10% sub-angular flint clasts <10mm. 5% flint flecks.
7.00	7.50	Medium Sand	Medium brownish-grey medium sand. 20% rounded to well rounded flint and 5% quartz clasts <10mm.
7.50	8.00	Medium Sand	Medium greyish-brown medium sand. 30% sub-angular to rounded flint and 2% quartz clasts <60mm.
8.00	8.50	Medium Sand	Medium brownish-grey medium sand. 40% sub-rounded to sub-angular flint and 2% quartz clasts <40mm.
8.50	9.00	Medium Sand	Medium greyish-brown medium sand. 40% sub-rounded to sub-angular flint and 1% quartz clasts <70mm.
9.00	9.50	Sandy Gravel	Medium brownish-grey sandy gravel. Clast supported. Clasts are sub-angular to sub-rounded flint and quartz <40mm. 40% sand in gravel.
9.50	10.00	Gravel	Medium brownish-grey gravel. Clast supported.

ATTT21 SHRW03 1.20-4.95m

Borehole SHRW05
Easting: 588334.28
Northing: 220471.554
Elevation: 31.02 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.20	Sandy Clay	Medium greyish-brown sandy clay. 10% sub-angular flint clasts.
0.00	1.20	Sandy Clay	Medium greyish-brown sandy clay. 10% sub-angular flint clasts.
1.20	1.57	Sandy Clay	Medium brown sandy clay. Bed of angular flint clasts 10-40mm diameter at 1.25-28m.
1.20	2.45	No Recovery	
1.57	1.65	Medium Sand	Medium orangish-brown medium sand. Intermittent laminations. Slightly clayey medium sand.
1.65	1.70	No Recovery	
1.70	1.77	Clayey Fine Sand	Medium yellowish-brown clayey fine sand. Intermittent laminations. Slightly clayey fine sand.
1.77	1.92	Medium Sand	Medium yellow medium sand. Coarsens upwards. Band of Fe staining at 1.81-6m. Finer sand towards base of profile.
1.92	2.45	Medium Sand	Medium yellowish-brown medium sand. Bedded with brown clay at 1.97-2.02, 2.29-35 and 2.43-45m. 1% rounded flint clasts <10mm. 2% Mn flecks.
2.45	3.00	Medium Sand	Light orangish-brown medium sand.
3.00	3.20	No Recovery	

ATTT21 SHRW02 1.20-2.45m

Borehole SNJA01
Easting: 583829.491
Northing: 216817.684
Elevation: 23.01 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.45	Silty Clay	Dark greyish-brown silty clay. Slightly organic. Lightly rooted.
0.45	0.90	Sandy Clay	Light yellowish-grey sandy clay.
0.90	1.00	Sandy Clay	Light orangish-grey sandy clay. 10% sub-angular to sub-rounded fine to medium flint and 5% sub-rounded chalk clasts. Granular to fine.
1.00	2.72	Sandy Silty Clay	Medium greyish-brown sandy silty clay. Very humified organic material 1.00-1.30m. Clasts are sub-rounded to sub-angular chalk, flint and quartz <60mm. Chalk flecks. Fe flecks.
2.72	3.00	Clayey Medium Sand	Medium greyish-yellow clayey medium sand. Clasts are sub-rounded to sub-angular Clasts are flint, quartz and chalk <60mm. Shell flecks.
3.00	3.29	No Recovery	
3.29	3.55	Sandy Gravel	Medium yellowish-grey sandy gravel. Matrix supported. Clasts are sub-rounded to sub-angular flint, quartz and chalk <10mm. Loose gravel at top of unit towards void. Sand may relate to diffuse boundary between coast supported gravel and sand beneath.
3.55	4.00	Medium Sand	Medium greyish-yellow medium sand. Fines upwards. Clasts are sub-rounded to rounded flint and quartz <25mm.
4.00	4.31	Sandy Gravel	Medium greyish-brown sandy gravel. Clast supported. Clasts are sub-rounded to rounded flint and quartz <10mm.
4.31	4.62	Medium Sand	Medium yellowish-grey medium sand. Clasts are sub-rounded to rounded flint and quartz <30mm.
4.62	5.00	Medium Sand	Medium orangish-grey medium sand. Clasts are sub-rounded to sub-angular flint and quartz <15mm.

ATTT21 SNJA01 1.00-5.00m

Borehole SNJA02
Easting: 583923.521
Northing: 216904.853
Elevation: 24.83 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Clay	Dark greyish-brown sandy clay. <5% sub-angular to sub-rounded flint clasts <25mm.
0.3	1.0	Clayey Silt	Light yellowish-brown clayey silt. 10% fine to medium granular chalk clasts <45mm.
1.0	2.0	Sandy Clay	Light orangish-brown sandy clay. 10% sub-rounded chalk clasts <45mm; 1% sub-angular flint clasts 50mm.
2.0	3.0	Sandy Silty Clay	Dark greyish-brown sandy silty clay. 10% sub-rounded chalk clasts <45mm; 1% sub-angular flint clasts 50mm

ATTT21 SNJA02 1.00-3.00m

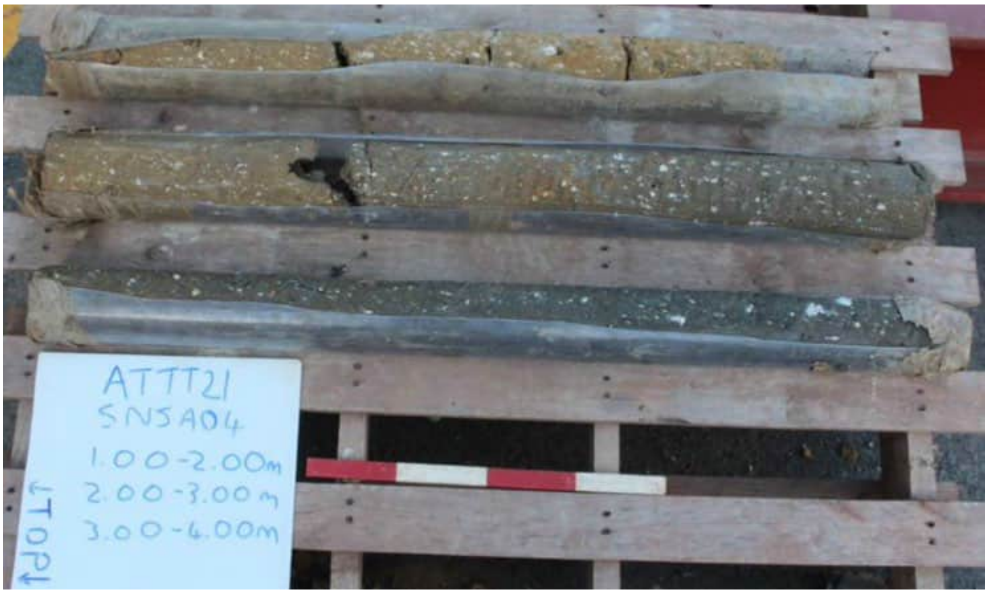
Borehole SNJA03
Easting: 584075.628
Northing: 217034.798
Elevation: 26.29 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.45	Sandy Clayey Silt	Light yellowish-grey sandy clayey silt. Slightly fine sandy clay silt.
0.45	0.80	Clayey Sandy Silt	Medium brownish-yellow clayey sandy silt. 5% sub-angular to sub-rounded flint clasts <65mm.
0.80	1.00	Clay	Medium yellowish-brown clay. Chalky.
1.00	3.81	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <25mm. More weathered towards top of unit. Mn and Fe staining throughout.
3.81	4.00	No Recovery	
4.00	4.50	Sandy Clay	Dark yellowish-grey sandy clay. Clasts are angular to sub-rounded flint, chalk and sandstone <60mm.
4.50	4.63	Slightly Sandy Gravel	Medium greyish-yellow slightly sandy gravel. Clasts are sub-angular to sub-rounded flint and chalk <10mm.
4.63	4.90	Sandy Clay	Medium greyish-yellow sandy clay. Clasts are sub-angular to sub-rounded flint and chalk <10mm.
4.90	5.16	Clayey Medium Sand	Medium grey clayey medium sand. Clasts are angular to sub-rounded flint and chalk <40mm.
5.16	5.32	Silty Clay	Dark grey silty clay. Clasts are sub-rounded chalk <10mm.
5.32	5.50	No Recovery	
5.50	7.50	Silty Clay	Dark grey silty clay. Clasts are sub-rounded chalk and flint <10mm.

ATTT21 SNJA03 1.00-7.50m

Borehole SNJA04
Easting: 584177.611
Northing: 217130.008
Elevation: 26.7 m OD

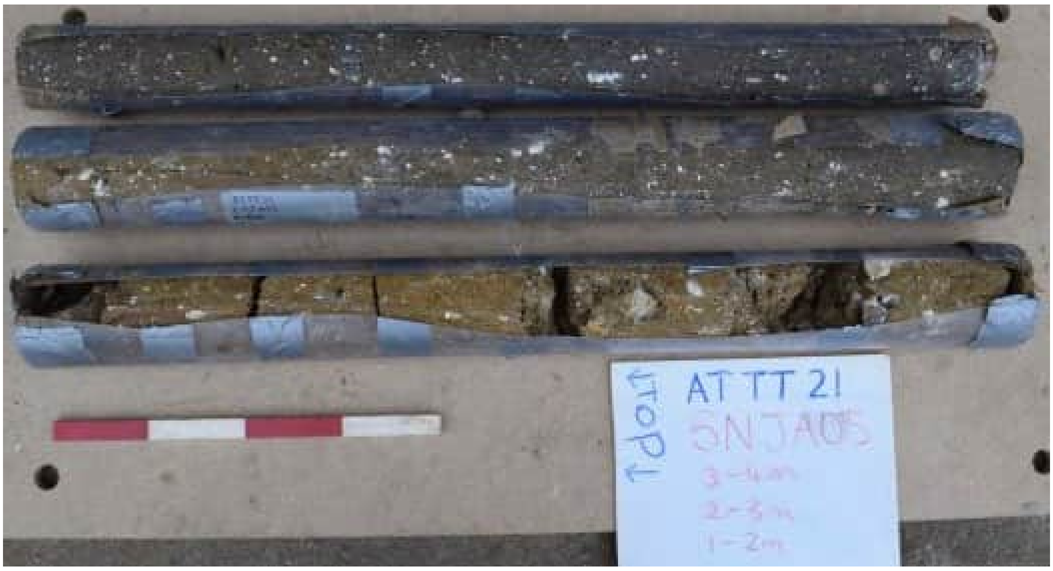
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Sandy Silt	Dark greyish-brown clayey sandy silt. Rare sub-angular to sub-rounded fine to medium flint clasts flint clasts.
0.30	1.20	Sandy Clay	Light orange brown sandy clay. 15% sub-angular to sub-rounded chalk and flint clasts <35mm.
1.20	3.43	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded to angular chalk and flint <40mm. More weathered towards top of profile. Mn flecks throughout.
3.43	4.00	Silty Clay	Dark grey silty clay. Clasts are sub-rounded chalk <20mm.



ATTT21 SNJA04 1.00-4.00m

Borehole SNJA05
Easting: 584307.813
Northing: 217249.633
Elevation: 26.68 m OD.

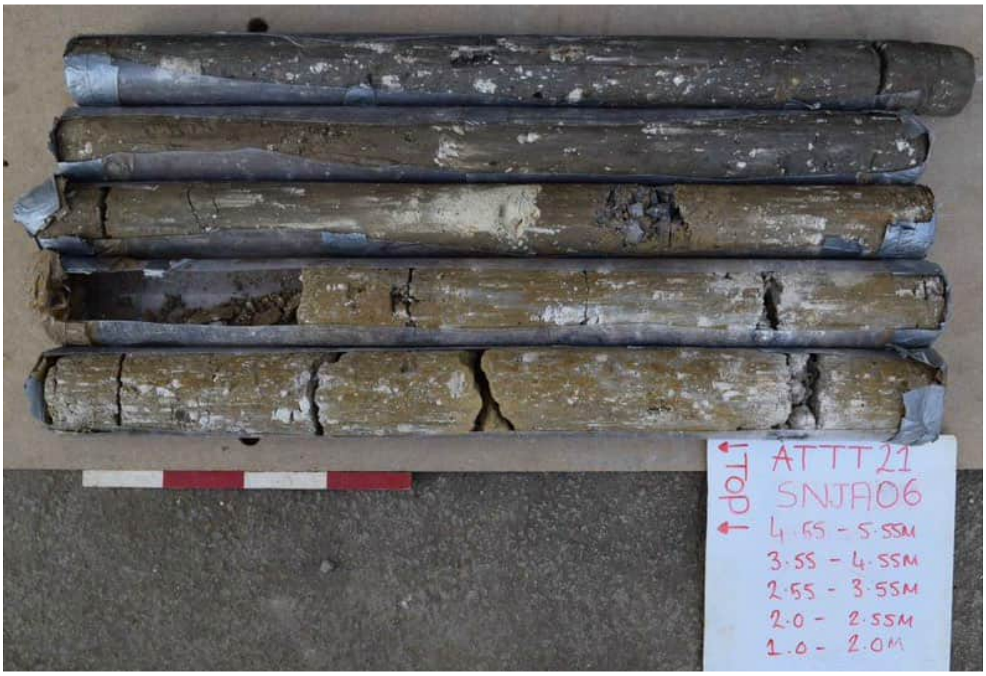
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Clay	Light yellowish-brown fine sandy clay. 5% fine calcareous fragments.
0.3	1.2	Sandy Clay	Light yellowish-brown sandy clay. <1% sub-rounded flint clasts 40mm.
1.2	2.6	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to sub-angular chalk and flint <50mm. Slight Mn staining. Chalk flecks throughout.
2.6	4.0	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-rounded chalk, flint and sandstone <25mm. Rare Mn flecks.



ATTT21 SNJA05 1.00-4.00m

Borehole SNJA06
Easting: 584405.013
Northing: 217344.619
Elevation: 27.66 m OD

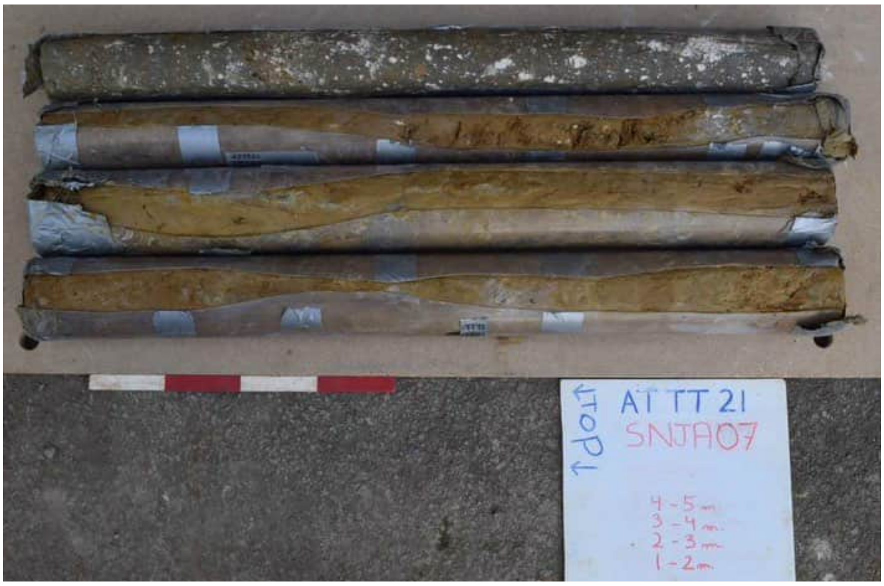
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Sandy Clayey Silt	Dark greyish-brown sandy clayey silt. <1% fine flint gravel. Fine to medium sand.
0.35	1.00	Sandy Clayey Silt	Light greyish-yellow sandy clayey silt. 15% fine to medium chalk clasts. 7% sub-angular to sub-rounded flint clasts <25mm from 0.70m. Fine to medium sand.
1.00	1.20	Sandy Clayey Gravel	Light yellowish-grey sandy clayey gravel. Matrix supported. Clasts are sub-angular to sub-rounded chalk <15mm.
1.20	3.90	Sandy Silty Clay	Medium brownish-orange sandy silty clay. 10% sub-rounded chalk clasts <45mm.
3.90	5.50	Sandy Silty Clay	Dark brownish-grey sandy silty clay. 15% sub-angular to sub-rounded chalk and flint clasts <55mm.



ATTT21 SNJA06 1.00-5.55m

Borehole SNJA07
Easting: 584125.526
Northing: 216937.306
Elevation: 22.52 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Silt	Dark brownish-grey silt. 15% sub-angular to sub-rounded flint clasts <45mm. Slightly sandy. Rare CMB fragments.
0.30	1.20	Clayey Medium Sand	Medium orangish-brown clayey medium sand.
1.20	3.85	Clayey Silt	Light grey clayey silt. Bedded with gravel 3.65-85m. Clasts are sub-rounded to sub-angular flint and chalk <15mm. Strong brown staining throughout. Fe mottling 3.00-3.50m. Flint flecks throughout.
3.85	5.00	Silty Clay	Medium grey silty clay. Fe mottling 4.00-20m. Clasts are sub-rounded chalk <25mm. Few manganese flecks throughout.



ATTT21 SNJA07 1.00-5.00m

Borehole SNJA08
Easting: 584010.505
Northing: 216841.013
Elevation: 21.93 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clay	Medium yellowish-brown clay. Slightly sandy. Rare sub-angular to sub-rounded fine to medium flint clasts.
0.30	1.20	Sandy Clay	Light yellowish-brown sandy clay. 5% sub-angular to sub-rounded flint <15mm. Chalk flecks from 0.6m.
1.20	1.85	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded chalk and flint <10mm. Mn flecks.
1.85	2.00	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <20mm. Mn flecks.

ATTT21 SNJA08 1.00-3.00m

Borehole SNJA09
Easting: 584256.638
Northing: 217047.465
Elevation: 23.21 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Light brownish-grey clayey silt. Slightly sandy. 2% sub-angular to sub-rounded flint.
0.30	1.20	Clayey Silt	Light orangish-brown clayey silt. Slightly sandy. 2% sub-angular to sub-rounded flint.
1.10	1.18	Clayey Silt	Medium yellowish-grey clayey silt. Clasts are sub-rounded chalk <10mm. Chalky fabric. Pockets of more clayey orangish brown fabric.
1.18	1.36	Sandy Clayey Silt	Medium orangish-brown sandy clayey silt. Clasts are sub-angular flint <10mm.
1.36	1.71	Clayey Silt	Medium yellowish-grey clayey silt. Bedded with yellowish brown silty clay at 1.50-2, 1.57-8 1.61-3 and 1.67-70m. Clasts are sub-angular flint <10mm. Chalky fabric.
1.71	2.62	Clayey Silt	Medium yellowish-grey clayey silt.
2.62	2.80	Sandy Silty Clay	Medium orangish-yellow sandy silty clay. Weathered fabric. Mn flecks.
2.80	5.49	Sandy Silty Clay	Medium yellowish-grey sandy silty clay. Coarsens upwards. Clasts are sub-angular flint <10mm. Iron staining throughout unit from 3.32m. Siltier towards top of unit.
5.49	5.79	Sandy Silty Clay	Light orangish-grey sandy silty clay. Fines upwards. Angular iron inclusions <5mm.
5.79	5.92	Sandy Silty Clay	Light brownish-grey sandy silty clay.
5.92	6.00	Clayey Silt	Dark yellowish-grey clayey silt.
6.00	6.57	No Recovery	
6.57	6.73	Clayey Silt	Dark yellowish-grey clayey silt. Sloping boundary. Shell flecks.
6.73	7.08	Clayey Silt	Medium grey clayey silt. Clasts are rounded flint <15mm. Shell flecks.
7.08	7.48	Silty Clay	Dark grey silty clay. Flecks of flint, shell and chalk.
7.48	7.49	Sandy Silt	Dark grey sandy silt.
7.49	7.50	Clayey Sandy Silt	Dark grey clayey sandy silt. Organic deposit.
7.50	8.00	Sandy Silty Clay	Medium grey sandy silty clay. Clasts are rounded chalk <20mm. Chalk flecks.

ATTT21 SNJA09 1.00-4.00m

ATTT21 SNJA09 4.00-8.00m

Borehole SNJA10
Easting: 584383.042
Northing: 217171.636
Elevation: 23.37 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clayey Silt	Medium greyish-brown sandy clayey silt. Lightly rooted.
0.30	0.70	Clayey Sandy Silt	Light yellowish-brown clayey sandy silt. <1% sub-rounded to angular flint clasts 5mm.
0.70	1.10	Sandy Clay	Light yellowish-brown sandy clay. 7% sub-angular to sub-rounded fine to medium clasts.
1.10	1.20	Silty Medium Sand	Light yellowish-grey silty medium sand. Sandy silt in places.
1.20	1.89	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Clasts are angular to sub-angular chalk, quartz and flint <15mm. Colour changes at 1.77-1.80m is light grey. Fe staining at the transition with lower unit.
1.89	4.95	Silty Clay	Light whitish-grey silty clay. Pockets of yellow sand, particularly at 4.23-4.28m. Fe staining/mottling.
4.95	5.10	Sandy Silty Clay	Light grey sandy silty clay. Fines upwards. Mollusc shell fragment towards upper boundary. Clasts are sub-angular flint and chalk <10mm. Fe staining toward base of unit.
5.10	5.20	Sandy Silty Clay	Medium brownish-grey sandy silty clay.
5.20	5.50	Silty Sandy Clay	Medium greyish-brown silty sandy clay. Blocky structure. Weathered.
5.50	6.00	Clayey Silt	Dark brownish-grey clayey silt. Blocky structure. Weathered. More homogeneous towards base of unit. Shell fragments.
6.00	6.07	No Recovery	
6.07	6.94	Clayey Silt	Medium brownish-grey clayey silt.
6.94	7.30	Clayey Silt	Dark blueish-grey clayey silt. Mediums and at base. Organic lens at base of lake deposit with shell fragments.
7.30	8.00	Sandy Silty Clay	Medium blueish-grey sandy silty clay. Clasts are sub-rounded to sub-angular chalk <70mm.

ATTT21 SNJA10 1.20-8.00m

Borehole SNJA11
Easting: 584464.163
Northing: 217255.421
Elevation: 25.05 m OD

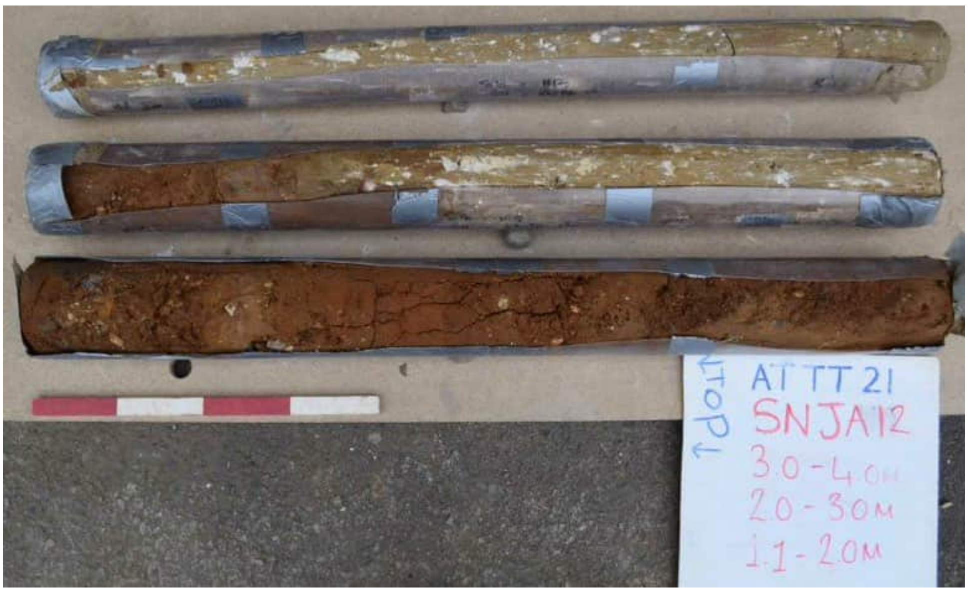
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Clayey Sandy Silt	Light yellowish-brown clayey sandy silt. Rare sub-angular to sub-rounded flint clasts <10mm.
0.35	1.20	Sandy Clay	Light brownish-orange sandy clay. <1% sub-angular to sub-rounded flint clasts <80mm.
1.20	1.32	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Clasts are sub-angular to sub-rounded flint and chalk <20mm.
1.32	1.57	Sandy Silty Clay	Medium greyish-orange sandy silty clay. Fines upwards. Clasts are sub-angular to rounded Clasts flint <50mm. Fe staining.
1.57	1.76	Sandy Silty Clay	Light orangish-grey sandy silty clay. Clasts are sub-angular to sub-rounded flint and chalk <15mm.
1.76	2.00	Sandy Silty Clay	Medium greyish-orange sandy silty clay. Clasts are sub-angular to sub-rounded flint and chalk <10mm. Weathered lake deposit.
2.00	2.15	No Recovery	
2.15	2.26	Sandy Silty Clay	Light orangish-brown sandy silty clay. Fines upwards. Soft orange band from 2.47 to 2.59m. Sand pockets. Mn staining.
2.29	3.00	Sandy Silty Clay	Light yellowish-grey sandy silty clay. Clasts are sub-angular flint <5mm. Slightly weathered.
3.00	3.36	No Recovery	
3.36	4.00	Sandy Clayey Silt	Medium yellowish-grey sandy clayey silt. Fe staining throughout.
4.00	4.40	No Recovery	
4.40	5.00	Sandy Clayey Silt	Medium yellowish-grey sandy clayey silt.
5.00	5.13	No Recovery	
5.13	6.00	Sandy Clayey Silt	Medium yellowish-grey sandy clayey silt. Grey layers at 5.60-1 and 5.75-1, light, soft orange band 5.36 to 5.69m. Some Fe staining.
6.00	6.39	No Recovery	
6.39	6.61	Clayey Silt	Medium brownish-grey clayey silt.
6.61	6.93	Clayey Silt	Medium brownish-grey clayey silt. Shell flecks <5mm.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
6.93	7.00	Sandy Clayey Silt	Dark brownish-grey sandy clayey silt. Blocky structure. Shell flecks.
7.00	7.20	No Recovery	
7.20	7.45	Clayey Silt	Light blueish-grey clayey silt. Blocky structure. Shell flecks.
7.45	7.84	Silty Clay	Medium blueish-grey silty clay. Coarsens upwards. More silty towards upper transition. Shell flecks.
7.84	8.00	Sandy Silty Clay	Dark blueish-grey sandy silty clay. Clasts are sub-rounded to sub-angular chalk and flint <15mm. Mn staining.

ATTT21 SNJA11 1.00-8.00m

Borehole SNJA12
Easting: 585071.847
Northing: 217589.809
Elevation: 29.59 m O

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Silty Clay	Light brownish-grey silty clay. 5% silty fine to medium sand. 5% sub-angular to sub-rounded flint <50mm.
0.35	0.60	Silty Coarse Sand	Medium orangish-brown silty coarse sand. 5% sub-angular to sub-rounded flint <30mm.
0.60	1.00	Sandy Gravel	Medium orangish-brown sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <70mm.
1.00	1.20	Sandy Silt	Medium orangish-brown sandy silt. 2% sub-angular to sub-rounded flint flint clasts <45mm.
1.20	2.20	Clayey Coarse Sand	Dark orangish-brown clayey coarse sand. 5% sub-angular to sub-rounded gravel <3mm.
2.20	2.28	Silty Clay	Dark reddish-brown silty clay.
2.28	4.00	Sandy Silty Clay	Medium yellowish-brown sandy silty clay. 10% granular to coarse subrounded chalk fragments <70mm.



ATTT21 SNJA12 1.10-4.00m

Borehole SNJA13
Easting: 584759.761
Northing: 217378.983
Elevation: 27.54 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clayey Silt	Dark brownish-grey clayey silt. 15% sub-angular to sub-rounded flint clasts <35mm.
0.30	0.65	Sandy Clay	Medium orangish-brown sandy clay. 10% sub-angular to sub-rounded clasts <45mm. Fine to medium sand.
0.65	0.90	Sandy Clay	Dark orangish-brown sandy clay. 5% sub-angular to sub-rounded flint and chalk clasts.
0.90	1.10	Clay	Light yellowish-grey clay. Abundant sub-angular to sub-rounded flint <80mm; 5% granular chalk clasts <45mm.
1.10	3.80	Silty Clay	Medium yellowish-grey silty clay. Mn flecks.

ATTT21 SNJA13 1.00-2.00m, 2.00-3.80m

Borehole SNJA14
Easting: 584860.156
Northing: 217451.282
Elevation: 28.93 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.4	Clayey Silt	Medium brownish-grey clayey silt. 5% sub-angular to sub-rounded flint <25mm.
0.4	0.8	Sandy Clay	Light greyish-yellow sandy clay. 15% sub-angular to sub-roundded clasts <70mm.
0.8	1.3	Clay	Medium yellowish-brown clay. Fine to coarse chalk clasts. Chalk putty in places.
1.3	3.0	Silty Clay	Medium yellowish-grey silty clay. Bedded with orangish brown coarse sand deposits containing rounded and angular flint and quartz clasts 5-10mm in size bedded at 1.35-83m (abrupt sloping boundaries) and 2.00-25m (abrupt horizontal lower boundary red staining at 1.75m).

ATTT21 SNJA14 1.00-3.00m

Borehole SNJA15
Easting: 584971.153
Northing: 217513.787
Elevation: 29.44 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clay Silt	Medium brownish-grey sandy clay silt. <5% sub-angular to sub-rounded fine to medium flint gravel.
0.30	0.70	Sandy Clay	Medium orangish-brown sandy clay. 5% sub-angular to sub-rounded flint clasts <35mm.
0.70	1.00	Clayey Coarse Sand	Light greyish-yellow clayey coarse sand.
1.00	1.31	Clayey Silty Coarse Sand	Dark orangish-brown clayey silty coarse sand. Bedded gravelly sand. Clasts are sub-rounded to sub-angular flint and quartz <30mm.
1.31	1.90	Clayey Silty Medium Sand	Medium brownish-orange clayey silty medium sand. Bedded. Clasts are sub-rounded to sub-angular flint and quartz <40mm.
1.90	2.93	Slightly Silty Medium Sand	Medium brownish-orange slightly silty medium sand. Grey clay incorporated 1.89-1.93m. Clasts are sub-angular to sub-rounded flint <15mm. Mn mottling throughout.
2.93	3.00	Silty Clayey Medium Sand	Dark orangish-brown silty clayey medium sand. Clasts are sub-angular to sub-rounded flint <10mm. Slight Mn mottling.
3.00	3.07	No Recovery	
3.07	3.25	Sandy Silt	Dark brownish-grey sandy silt. Coarsens upwards. Clasts are sub-angular to sub-rounded flint and quartz <15mm. Flint flecks.
3.25	4.00	Slightly Sandy Silty Clay	Medium greyish-yellow slightly sandy silty clay. Fines upwards. Clasts are sub-rounded to sub-angular chalk and flint <15mm.

ATTT21 SNJA15 1.00-4.00m

Borehole SSBE01
Easting: 584080.706
Northing: 216349.521
Elevation: 19.28 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Clay	Dark brownish-grey sandy clay.
0.3	1.2	Sandy Clay	Light greyish-yellow sandy clay. <1% sub-angular to sub-rounded coarse flint clasts.
1.2	2.3	Sandy Clayey Silt	Medium orangish-brown sandy clayey silt. <5% sub-angular to sub-rounded flint clasts 5mm.
2.3	2.6	Sandy Gravel	Medium orangish-brown sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <50mm.
2.6	3.2	Sandy Gravel	Light brownish-orange sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <40mm.
3.2	3.5	Sandy Gravel	Medium brownish-orange sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <25mm.
3.5	9.0	Coarse Sand	Light orangish-brown coarse sand.
9.0	10.0	Medium Sand	Medium greyish-brown medium sand. Angular to sub-rounded flint gravel <10mm.
10.0	10.5	Sandy Clayey Silt	Light greenish-grey sandy clayey silt.
10.5	11.2	Sandy Clayey Silt	Light greenish-grey sandy clayey silt.
11.2	12.0	Clayey Silt	Light blueish-grey clayey silt.

ATTT21 SSBE01 1.20-3.50m, 10.50-12.00m

Borehole SSBE02
Easting: 584134.366
Northing: 216424.016
Elevation: 21.69 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clay	Medium greyish-brown clay.
0.30	0.70	Clay	Medium brownish-orange clay. Slightly fine-medium sandy clay. <5% sub-angular to sub-rounded flint clasts <30mm.
0.70	1.10	Sandy Clay	Medium orangish-brown sandy clay.
1.10	2.80	Sandy Clayey Silt	Medium orangish-brown sandy clayey silt. Bedded with coarse gravel beds. Clasts are sub-angular to sub-rounded flint <70mm. Fe and Mn staining of finer matrix.
2.80	3.36	Silty Clay	Medium whitish-grey silty clay. Chalky clay. Vein of reddishbrown Fe staining.
3.36	3.50	Sandy Clayey Silt	Medium orangish-grey sandy clayey silt. Clasts are sub-angular to sub-rounded flint <5mm. Slight Fe staining.
3.50	10.40	Sandy Gravel	Medium orangish-brown sandy gravel.
10.40	11.90	Silty Clay	Medium grey silty clay. Clasts are sub-rounded chalk <100mm.

ATTT21 SSBE02 1.2-3.5m, 10.40-11.90m

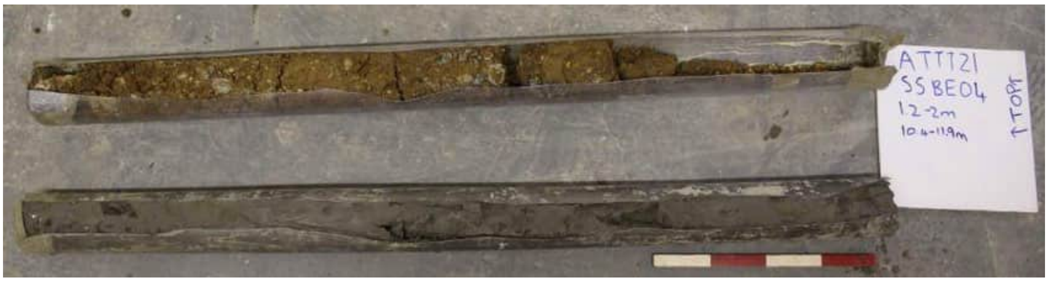
Borehole SSBE03
Easting: 584181.974
Northing: 216483.746
Elevation: 21.71 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silt	Dark greyish-brown sandy silt. Slightly organic.
0.30	0.60	Silty Medium Sand	Medium greyish-brown silty medium sand. 5% sub-angular to sub-rounded flint <40mm.
0.60	0.85	Silty Medium Sand	Medium yellowish-brown silty medium sand. 15% sub-angular to sub-rounded clasts <100mm.
0.85	1.20	Silty Medium Sand	Medium yellowish-brown silty medium sand. 15% sub-angular to sub-rounded flint <100mm.
1.50	5.00	Sandy Silty Clay	Medium yellowish-brown sandy silty clay. Bedded with gravelly coarse sand deposits at 5-1.80, 2.00-2.30, 2.47-2.65, 3.5-3.83 and 4.75-5.00m. Coarsens upwards. Clasts are flint and quartz <50mm. Reddening in areas of coarser material.
5.00	8.10	Sandy Gravel	Medium reddish-brown sandy gravel.
8.10	9.60	Sandy Silty Clay	Medium grey sandy silty clay. Clasts are sub-rounded chalk <50mm.

ATTT21 SSBE03 1.20-5.00m, 8.10-9.60m

Borehole SSBE04
Easting: 584201.89
Northing: 216530.5
Elevation: 21.7 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silty Clay	Light greyish-brown sandy silty clay. <1% angular to sub-rounded flint clasts <60mm.
0.30	0.60	Silty Medium Sand	Light greyish-brown silty medium sand. 5% sub-rounded to sub-angular flint clasts <45mm.
0.60	0.99	Silty Medium Sand	Medium orangish-brown silty medium sand. 10% sub-angular to sub-rounded fine to medium flint clasts becoming more gravelly with depth.
0.99	2.00	Silty Clayey Medium Sand	Medium orangish-brown silty clayey medium sand. Bedded. Sorting of clasts into beds of larger and finer clasts.
2.00	3.50	Clay	Medium orangish-brown clay. Slightly sandy. 5% sub-angular to sub-rounded fine to medium flint.
3.50	6.00	Sandy Gravel	Medium orangish-brown sandy gravel.
6.00	10.00	Coarse Sand	Medium orangish-brown coarse sand.
10.00	11.84	Clayey Silt	Medium brownish-grey clayey silt. Flecks of carbonate.
11.84	11.90	Silty Clay	Medium grey silty clay.



ATTT21 SSBE04 1.20-2.00m, 10.40-11.90m

Borehole SSBE05
Easting: 584231.343
Northing: 216564.227
Elevation: 20.65 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Clay	Medium brownish-grey sandy clay. 5% sub-angular to sub-rounded flint <25mm.
0.30	0.60	Clayey Silt	Light yellowish-brown clayey silt. Slightly sandy; fine to medium sand.
0.60	1.20	Silty Sand	Light yellowish-brown silty sand. Slightly silty. <1% sub-angular flint <35mm.
1.20	1.58	No Recovery	
1.58	1.86	Clayey Medium Sand	Medium reddish-brown clayey medium sand. Fines upwards. Bedded with sandy silty clay at 2.04-2.13m where clasts concentrated. Clasts are sub-angular to sub-rounded flint, quartz and chalk <70mm.
1.86	3.50	Medium Sand	Medium yellow medium sand. Coarsens upwards. Colour changes: 1.86-2.38m medium reddish orange; 2.38-2.97m medium brownish yellow; 2.97-3.21m light yellowish white; 3.21-3.50m medium greyish yellow.
3.50	9.15	Gravelly Coarse Sand	Medium orangish-brown gravelly coarse sand.
9.15	10.65	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to rounded chalk <100mm.

ATTT21 SSBE05 1.20-3.50m, 9.15-10.65m

Borehole SSBE06
Easting: 584487.563
Northing: 216854.263
Elevation: 20.72 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	1.65	No Recovery	
1.65	3.43	Sandy Silty Clay	Medium orangish-brown sandy silty clay. Bedded with redder medium sand lense 2.68-3.15m and reddish brown clayey sand 1.63-2.09m. Clasts are sub-angular to angular flint, quartz and chalk <20mm. Mn flecks.
3.43	6.50	Slightly Sandy Silty Clay	Medium grey slightly sandy silty clay. Fines upwards. Clasts are sub-rounded to roubded chalk <100mm. Slight Fe and Mn mottling.

ATTT21 SSBE06 1.20-6.50m

Borehole SSBE07
Easting: 584310.087
Northing: 216741.72
Elevation: 20.4 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.45	Sandy Clayey Silt	Medium greyish-brown sandy clayey silt.
0.45	1.10	Sandy Silt	Light greyish-yellow sandy silt. <5% sub-angular to sub-rounded flint <10mm.
1.10	2.00	Sandy Clay	Mid orangish-brown sandy clay. Fines upwards.
2.00	2.42	Sandy Clayey Silt	Light brownish-grey sandy clayey silt. Rare fine sand on teeth.
2.42	3.05	Sandy Clayey Silt	Light yellowish-grey sandy clayey silt. Calcareous between 2.70-2.85m.
3.05	3.25	Sandy Gravel	Mid orangish-brown sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <20mm.
3.25	3.50	Sandy Clay	Dark orangish-brown sandy clay.
3.50	5.00	Sandy Gravel	Medium orangish-brown sandy gravel. Clast supported. Clasts are sub-angular to sub-rounded flint <30mm.
5.00	5.29	Sandy Silty Clay	Dark blueish-grey sandy silty clay. Slanted boundary at base.
5.29	5.32	Sandy Silt	Dark reddish-brown sandy silt.
5.32	5.45	Coarse Sand	Light greyish-yellow coarse sand. Coarsens upwards. Clasts are sub-angular to sub-rounded flint <5mm.
5.45	6.50	No Recovery	

ATTT21 SSBE07 1.20-6.50m

Borehole SSBE08
Easting: 584332.616
Northing: 216798.008
Elevation: 21.89 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Sandy Silt	Light greyish-brown sandy silt.
0.30	1.44	Sandy Silt	Light yellowish-brown sandy Silt. Slightly clayey. Rare sub-rounded coarse gravel at 0.70m.
1.44	2.43	Silty Clay	Medium orangish-brown silty clay. Bedded with clayey sand containing larger clasts at 1.53-2.10m. Clasts are sub-angular to sub-rounded flint, quartz and chalk <40mm. Mn flecks.
2.43	4.41	Clayey Silt	Light yellowish-grey clayey silt. Mn flecks. Slight Fe mottling.
4.41	5.11	Clayey Silt	Medium whitish-grey clayey silt. Dark grey band from 4.88 to 4.92m. Carbonate flecks.
5.11	5.40	Clayey Silt	Light whitish-grey clayey silt. Yellow mottling.

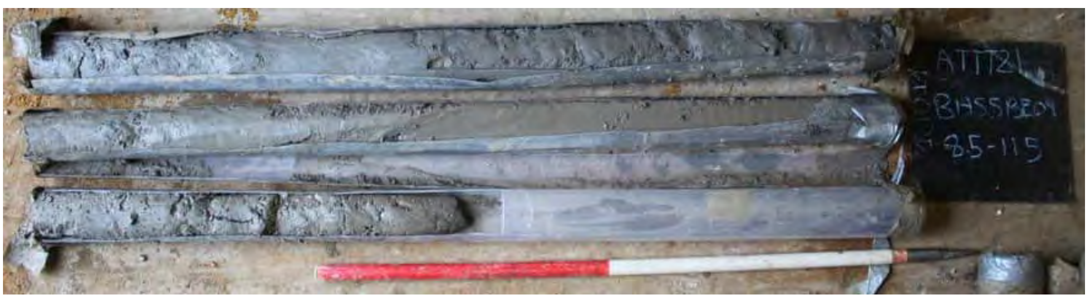
ATTT21 SSBE08 1.20-5.40m

Borehole SSBE09
Easting: 584422.661
Northing: 216752.975
Elevation: 21.19 m OD

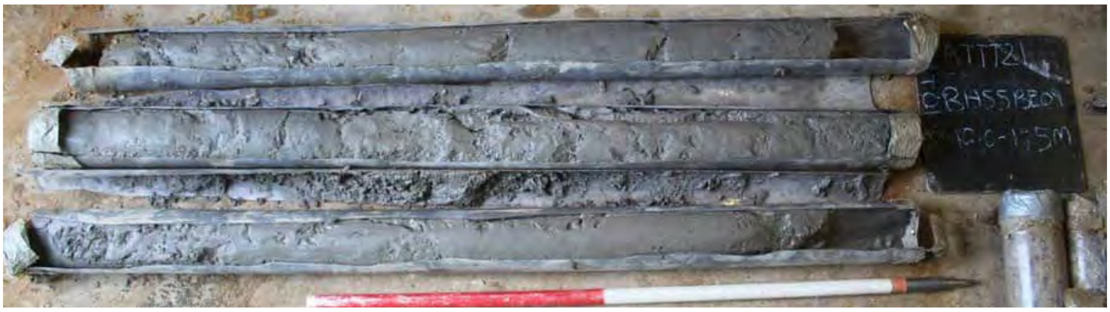
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.36	Sandy Clay	Dark greyish-brown sandy clay.
0.36	1.00	Clayey Sandy Gravel	Medium brownish-orange clayey sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <35mm.
1.00	1.20	Coarse Sand	Medium orangish-brown coarse sand.
1.20	3.00	Medium Sand	Medium reddish-orange medium sand. Bedded with coarse sand at 1.8-1.9m and 2.5-2.7m. Clasts are sub-angular to sub-rounded flint and quartz <30mm. Fe staining concentrated in coarse sand beds.
3.00	3.57	Medium Sand	Medium brownish-orange medium sand. Bedded with coarser sand at 3.25-3.35m stained with Mn. Fe laminations. Clasts are sub-angular to sub-rounded flint, quartz and chalk <30mm.
3.57	4.27	Fine Sand	Medium yellowish-orange fine sand. Clasts are sub-rounded quartz and flint <15mm. Slight Fe staining.
4.27	5.57	Clayey Fine Sand	Medium orangish-brown clayey fine sand. Fines upwards. Well humified plant remains. Clasts are sub-rounded to rounded flint, quartz and chalk <50mm. Fe/Mn staining of coarser sediments in bedded structure. 40 to 100mm bands of darker red, well sorted sediment with clasts <100mm.
5.75	6.00	Coarse Sand	Medium brownish-orange coarse sand. 5% sub-angular to sub-rounded flint <30mm.
6.00	7.50	Fine Sand	Medium greyish-brown fine sand.
7.50	8.50	No Recovery	
8.50	8.56	Sandy Clayey Silt	Dark blueish-grey sandy clayey silt.
8.56	8.86	Silty Clay	Medium blueish-grey silty clay.
8.86	9.26	Silty Sandy Clay	Medium blueish-grey silty sandy clay.
9.26	9.60	Silty Sandy Clay	Medium blueish-grey silty sandy clay.
9.60	10.13	Silty Clay	Medium blueish-grey silty clay. Fines upwards. Clasts are sub-rounded to sub-angular chalk <10mm.
10.13	11.10	Clayey Fine Sand	Medium yellowish-grey clayey fine sand. Pocket of silty clay at 10.85-89m. Few chalk flecks.
11.10	11.50	Sandy Clayey Silt	Medium yellowish-brown sandy clayey silt. Intermittently laminated. Some Mn mottling.

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
11.50	12.29	No Recovery	
12.29	12.53	Sandy Clayey Silt	Medium brownish-grey sandy clayey silt. Shell flecks.
12.53	13.00	Clayey Sandy Silt	Medium brownish-grey clayey sandy silt. Intermittently laminated. Mn staining.
13.00	13.18	No Recovery	
13.18	13.73	Clayey Silty Fine Sand	Medium brownish-grey clayey silty fine sand. Continuously laminated.
13.73	14.46	Sandy Clayey Silt	Medium brownish-grey sandy clayey silt.
14.46	14.50	No Recovery	
14.50	15.35	Clayey Sandy Silt	Medium yellowish-grey clayey sandy silt.
15.35	15.45	Sandy Clayey Silt	Medium yellowish-grey sandy clayey silt.
15.45	17.50	Sandy Clayey Silt	Medium brownish-grey sandy clayey silt. Intermittently laminated. Small patches of dark silty clay within matrix. Blocky structure towards base. Mn staining.

ATTT21 SSBE09 1.20-5.00m



ATTT21 SSBE09 8.50-11.50m



ATTT21 SSBE09 11.50-17.50m

Borehole SSBE10
Easting: 584446.893
Northing: 216797.999
Elevation: 20.58 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Sandy Silt	Medium greyish-brown sandy silt.
0.40	1.20	Silty Medium Sand	Light orangish-brown silty medium sand.
1.20	1.60	Sandy Clay	Dark orangish-brown sandy clay. Clasts are sub-angular to sub-rounded.
1.60	2.00	Sandy Clay	Light yellowish-grey sandy clay.
2.00	2.40	Sandy Clayey Silt	Light yellowish-grey sandy clayey silt. 5% fine gravel.
2.40	2.95	Clayey Silt	Light orangish-brown clayey silt. Mottled with light grey in places.
2.95	3.30	Sandy Clayey Silt	Light blueish-grey sandy clayey silt.
3.30	3.50	Silty Clayey Fine Sand	Medium orangish-brown silty clayey fine sand.
3.50	5.00	Sandy Gravel	Medium brownish-orange sandy gravel.
5.00	10.50	No Recovery	
10.50	12.00	Clayey Sandy Silt	Light brownish-grey clayey sandy silt. Intermittently laminated.
12.00	13.40	Sandy Clayey Silt	Light brownish-grey sandy clayey silt. Intermittently laminated.
13.40	13.50	Clayey Silt	Medium brownish-grey clayey silt. Clasts are sub-rounded flint and chalk <5mm.

ATTT21 SSBE10 1.20-5.00m, 10.50-13.50m

Borehole ULWK07
Easting: 579821.878
Northing: 212053.779
Elevation: 42.88 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Clayey Silt	Medium greyish-brown clayey silt.
0.35	5.00	Clayey Silt	Medium orangish-brown clayey silt.
0.50	1.50	Slightly Sandy Silty Clay	Medium greyish-brown slightly sandy silty clay.
1.50	2.84	Clayey Sandy Silt	Medium orangish-brown clayey sandy silt. Clasts are sub-angular flint <10mm. Root channel infilled with light brown sand clay 1.5-1.95m.
2.84	6.45	Slightly Sandy Silty Clay	Medium yellowish-grey slightly sandy silty clay. Clasts are sub-rounded to rounded chalk <40mm. Orangish brown medium sand at 6.44-5m. Mn and Fe flecks throughout.
6.45	6.95	No Recovery	
6.95	7.95	Clayey Fine Sand	Medium yellow clayey fine sand. Clasts are sub-angular flint <10mm.

ATTT21 ULWK07 1.50-3.95m

ATTT21 ULWK07 4.50-6.95m

Borehole ULWK08
Easting: 579901.686
Northing: 212021.304
Elevation: 41.49 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Sandy Silty Clay	Dark yellowish-grey sandy silt clay. <5% sub-angular flint clasts 5mm.
0.35	0.70	Sandy Silt	Light yellowish-brown sandy silt. Coarsens upwards.
0.70	1.20	Slightly Sandy Silt	Medium orangish-brown slightly sandy silt.
1.20	1.50	No Recovery	
1.50	3.19	Sandy Clayey Silt	Medium brown sandy clayey silt. Fines upwards. Clasts are sub-angular flint <20mm.
3.19	5.25	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to angular chalk and flint <60mm. Mn flecks.
5.25	5.45	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to angular chalk and flint <80mm. Mn and Fe flecks.

ATTT21 ULWK08 1.50-5.45m

Borehole ULWK09
Easting: 580638.363
Northing: 212546.817
Elevation: 40.59 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Sandy Clay	Medium brownish-grey sandy clay. Slightly silty. 1% sub-angular fine flint clasts.
0.40	1.50	Sandy Clay	Light orangish-brown sandy clay. 15% chalk <30mm.
1.50	5.08	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to angular chalk and flint <50mm.
5.08	5.45	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to angular chalk, flint and sandstone <25mm.
5.45	5.55	Silty Clay	Medium grey silty clay. Clasts are sub-rounded chalk <25mm.

ATTT21 ULWK09 1.50-5.45m

Borehole VELL04
Easting: 580901.633
Northing: 212659.739
Elevation: 36.02 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Clayey Silt	Medium greyish-brown clayey silt. Slightly sandy silt. <2% sub-angular to sub-rounded flint clasts <35mm.
0.40	0.90	Clayey Silt	Medium orangish-brown clayey silt. Clasts are sub-rounded to angular chalk, flint and quartz <30mm.
0.90	1.50	Slightly Sandy Silty Clay	Medium greyish-yellow slightly sandy silty clay. Clasts are sub-rounded to rounded chalk, flint and quartz.
1.50	6.65	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to sub-angular chalk, flint and sandstone <40mm. Rare Mn and Fe flecks. Chalk flecks.
6.65	6.95	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk, flint and sandstone M40mm. Rare Mn and Fe flecks. Chalk flecks.
6.95	7.05	Silty Clay	Medium grey silty clay. Clasts are sub-rounded to rounded chalk <40mm.

ATTT21 VELL04 1.50-6.95m

Borehole VELL05
Easting: 581001.864
Northing: 212703.752
Elevation: 33.04 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.50	Silt	Light brownish-grey silt. Slightly sandy. Lightly rooted. Rare sub-angular to sub-rounded fine clasts.
0.50	0.80	Silt	Light yellowish-brown silt. Slightly sandy.
0.80	1.00	Sandy Clay	Medium orangish-brown sandy clay. 10% sub-angular to sub-rounded flint clasts <150mm.
1.00	1.50	Slightly Sandy Silty Clay	Medium greyish-brown slightly sandy silty clay. Clasts are sub-angular to sub-rounded chalk and flint.
1.50	2.73	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to angular chalk and flint <40mm.
2.73	3.00	Clayey Medium Sand	Medium yellowish-brown clayey medium sand. Clasts are rounded to sub-rounded flint and quartz <40mm. Sand patches 2.73-80.
3.00	3.50	Clayey Medium Sand	Medium greyish-yellow clayey medium sand. Clasts are sub-rounded to sub-angular flint <70mm.
3.50	4.00	Sandy Gravel	Medium yellowish-grey sandy gravel. Clast supported. Clasts are sub-rounded to rounded flint and quartz <50mm.
4.00	4.50	Sandy Gravel	Dark yellowish-brown sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint and quartz <40mm.
4.50	5.00	Sandy Gravel	Medium brownish-orange coarse sandy gravel. Clasts are sub-angular to sub-rounded flint <45mm.
5.00	5.50	Coarse Sand	Medium greyish-yellow gravelly coarse sand. Clasts are sub-rounded to sub-angular flint <60mm.
5.50	6.00	Medium Sand	Medium greyish-yellow gravelly medium sand. Clasts are sub-rounded to sub-angular flint and quartz <100mm.
6.00	6.50	Sandy Gravel	Medium yellowish-grey sandy gravel. Clast supported. Clasts are angular to sub-angular flint and quartz <80mm.
6.50	7.00	Sandy Gravel	Medium yellowish-brown coarse sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint and quartz <50mm.
7.00	7.50	Sandy Gravel	Medium greyish-yellow sandy gravel. Clast supported. Clasts are rounded to sub-angular flint and quartz <60mm.
7.50	7.80	No Recovery	

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
7.80	8.30	Coarse Sand	Light orangish-brown sandy coarse sand. Clasts are sub-angular to sub-rounded flint <40mm.

ATTT21 VELL05 1.50-2.95m

Borehole VELL06
Easting: 581110.583
Northing: 212709.451
Elevation: 29.98 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Silt	Medium brownish-grey silt. Slightly sandy. Slightly clayey. Rare CBM fragment 50mm- pink brick.
0.40	1.00	Slightly Sandy Silt	Medium greyish-brown slightly sandy silt. Well humified organic material.
1.00	1.50	Slightly Sandy Silty Clay	Medium yellowish-grey slightly sandy silty clay. Clasts are sub-rounded to sub-angular flint <15mm. Chalk flecks.
1.50	2.70	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to angular chalk and flint <40mm.
2.70	3.00	Sandy Clay	Medium orangish-grey sandy clay. Bedded with orange medium sand at 2.71-3 and 2.76-8m. Clasts are sub-angular to angular flint <40mm.
3.00	3.50	Sandy Clay	Medium greyish-yellow sandy clay. Clasts are sub-rounded to sub-angular flint <25mm.
3.50	4.00	Slightly Sandy Gravel	Medium yellow slightly sandy clay. Clast supported. Clasts are rounded to sub-rounded flint <60mm.
4.00	4.50	Silty Sandy Gravel	Medium brownish-orange silty sandy gravel. Matrix supported. Clasts are sub-angular to sub-rounded flint <20mm.
4.50	5.00	Slightly Silty Medium Sand	Medium greyish-yellow slightly silty medium sand. Clasts are sub-rounded to rounded flint and quartz <40mm.
5.00	5.50	Medium Sand	Light yellowish-grey medium sand. Clasts are sub-rounded to rounded flint and quartz <25mm.
5.50	6.00	Medium Sand	Medium yellowish-grey medium sand. Clasts are sub-rounded to sub-angular flint and quartz <20mm.
6.00	6.50	Medium Sand	Light whitish-grey medium sand. Clasts are sub-rounded to rounded flint and quartz <30mm.
6.50	7.00	No Recovery	
7.00	7.10	Coarse Sand	Medium orangish-brown gravelly coarse sand. Clasts are sub-rounded flint <40mm.
7.10	7.45	Slightly Sandy Clay	Medium brown slightly sandy clay. Clasts are rounded flint <20mm.
7.45	7.55	Silty Clay	Medium greyish-brown silty clay. Clasts are angular flint <10mm. Grey mottling throughout. Chalk flecks.

ATTT21 VELL06 1.50-2.95m, 7.50-7.95m

Borehole VELL08
Easting: 581251.436
Northing: 212756.839
Elevation: 25.95 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Sandy Clay	Dark greyish-brown sandy clay.
0.35	1.20	No Recovery	
1.20	2.95	Silty Clay	Dark reddish-brown silty clay. 2% sub-angular to sub-rounded clasts of chalk, flint and quartzite <50mm.
2.95	3.00	No Recovery	

ATTT21 VELL08 1.20-2.95m

Borehole VELL09
Easting: 581334.381
Northing: 212786.834
Elevation: 24.23 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.35	Silty Clay	Dark greyish-brown silty clay. Fine slightly sandy silty clay. Clasts are sub-angular to sub-rounded flint <75mm.
0.35	1.20	Silty Clay	Medium yellowish-brown silty clay. Slightly sandy.
1.20	1.65	No Recovery	
1.65	2.45	Silty Clay	Medium brown silty clay. Clasts are sub-rounded chalk <5mm.

ATTT21 VELL09 1.65-2.45m

Borehole VELL10
Easting: 581245.326
Northing: 212547.187
Elevation: 26.01 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Silty Clay	Medium brownish-grey silty clay. Lightly rooted. Slightly sandy.
0.40	0.60	Clay	Medium brownish-orange clay. Slightly sandy. Fine sand. <5% sub-angular to sub-rounded flint <65mm.
0.60	1.50	Sandy Clay	Light yellowish-grey sandy clay. 20% granular to coarse chalk <5mm. <1% sub-angular to sub-rounded flint <65mm.
1.50	2.00	Sandy Clay	Medium yellowish-grey sandy clay. Clasts are sub-rounded to sub-angular chalk and flint <20mm. Chalk flecks.
2.00	3.00	Silty Clay	Dark greyish-brown silty clay. Mn flecks. Blue-grey veins towards base of unit. Clasts are sub-rounded to angular chalk and flint <30mm.
3.00	4.45	Slightly Sandy Clay	Dark brown slightly sandy clay.
4.45	4.55	Silty Clay	Light brownish-grey silty clay.

ATTT21 VELL10 2.00-4.45m

Borehole WEST06
Easting: 591162.121
Northing: 222700.146
Elevation: 42.39 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.30	Clay	Dark greyish-brown clay. Slightly sandy. Slightly silty. <1% sub-angular to sub-rounded gravel.
0.30	0.70	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <120mm.
0.70	1.20	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded chalk <25mm.
1.20	1.50	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded chalk <10mm.
1.50	2.00	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded chalk <5mm.
2.00	2.50	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded to sub-angular chalk and flint <20mm.
2.50	3.00	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-rounded chalk <15mm.
3.00	4.15	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to sub-angular chalk and flint <40mm. Mn flecks.
4.15	4.23	Sandy Clay	Medium greyish-yellow fine sandy clay. Continuously laminated.
4.23	4.35	Sandy Clayey Gravel	Medium greyish-yellow sandy clayey gravel. Matrix supported. Clasts are rounded to angular flint and gravel <40mm.
4.35	4.63	Sandy Clay	Light greyish-brown sandy clay. Clasts are sub-rounded to rounded chalk <50mm.
4.63	6.00	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-rounded to angular chalk and flint <60mm. More weathered towards top of unit. Greyish yellow sandy clay 5.15-24m. Mn flecks throughout.
6.00	6.20	Slightly Sandy Clay	Medium greyish-yellow slightly sandy clay. Clasts are sub-rounded flint <30mm.
6.20	7.74	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-rounded to angular chalk and flint <60mm. More weathered towards top of unit. Greyish yellow sandy clay 5.15-24m. Mn flecks throughout.

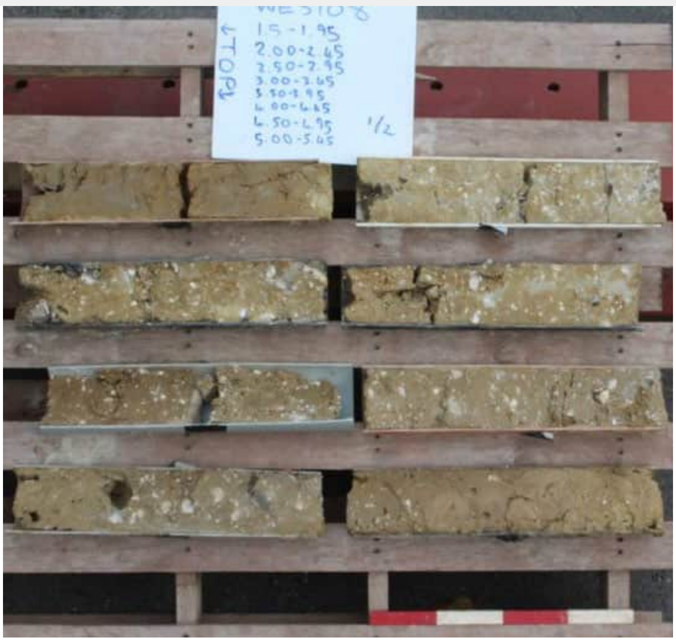
Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
7.74	10.00	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-rounded to rounded chalk and flint <50mm. Mn flecks throughout.

ATTT21 WEST06 3.00-6.50m

ATTT21 WEST06 6.50-10.00m

Borehole WEST08
Easting: 591299.783
Northing: 223180.689
Elevation: 40.73 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.0	0.3	Sandy Clay	Dark yellowish-grey sandy clay. Slightly silty. <1% sub-angular to sub-rounded clasts <35mm.
0.3	0.8	Sandy Clay	Medium greyish-yellow sandy clay.
0.8	1.0	Silty Clay	Medium yellowish-grey silty clay. Clasts are sub-angular flint <10mm.
1.0	1.5	Slightly Sandy Silty Clay	Medium brownish-grey slightly sandy silty clay. Clasts are sub-angular flint <10mm.
1.5	1.9	Silty Clay	Dark greyish-brown silty clay. 5% sub-angular to sub-rounded flint and chalk clasts <30mm.
1.9	5.8	Sandy Silty Clay	Medium greyish-brown sandy silty clay. 35% sub-angular to well-rounded flint, tertiary flint, chalk and quartz clasts <40mm. Common Mn flecks.
5.8	10.0	Sandy Silty Clay	Dark brownish-grey sandy silty clay. Clasts are sub-angular to well- rounded flint, tertiary flint, chalk and sandstone. Frequent Mn flecks.



ATTT21 WEST08 1.50-5.45m

ATTT21 WEST08 5.50-10.00m

Borehole WEST09
Easting: 591374.788
Northing: 223385.22
Elevation: 40.85 m OD

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
0.00	0.40	Silty Clay	Dark greyish-brown silty clay. Slightly sandy; fine to medium sand.
0.40	1.50	Clayey Silt	Medium orangish-brown clayey silt. Slightly sandy; fine to medium sand.
1.50	3.11	Silty Clay	Medium greyish-brown silty clay. Clasts are sub-rounded to sub-angular chalk and flint <30mm. Mn mottling.
3.11	3.50	Sandy Clay	Medium brown sandy clay. Clasts are sub-rounded to angular chalk and flint <100mm.
3.50	5.00	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to angular chalk and flint <50mm. Pocket of sandy clay 4.00-4.20m.
5.00	5.10	No Recovery	
5.10	5.35	Sandy Clay	Medium brown sandy clay. Clasts are sub-rounded to sub-angular chalk and flint <20mm. Lots of intrusive plant material.
5.35	5.45	Silty Clay	Medium greyish-yellow silty clay. Clasts are sub-rounded to rounded chalk and flint <10mm.
5.45	6.00	Clayey Gravel	Medium yellowish-brown clayey gravel. Matrix supported. Clasts are sub-rounded to sub-angular flint <60mm.
6.00	6.50	Slightly Sandy Clay	Medium greyish-yellow slightly sandy clay. Clasts are sub-rounded to sub-angular flint <40mm.
6.50	7.00	Silty Clay	Medium brownish-grey silty clay. Clasts are sub-rounded chalk <10mm. Chalk flecks. Mn flecks.
7.00	7.40	Silty Clay	Dark brownish-grey silty clay. Clasts are sub-rounded to angular chalk and flint <20mm. Pocket of sandy clay 7.25-8m.
7.40	7.45	No Recovery	
7.45	7.60	Sandy Clay	Medium brown sandy clay. Clasts are sub-rounded to angular flint, chalk and quartz <10mm.
7.60	7.80	Sandy Clay	Medium greyish-yellow sandy clay. Clasts are sub-rounded chalk <10mm.
7.80	8.00	No Recovery	

Top depth (m BG)	Bottom depth (m BG)	Keyword	Description
8.00	8.50	Sandy Clay	Medium greyish-brown sandy clay. Clasts are sub-rounded to sub-angular chalk and flint <30mm. Chalk flecks.
8.50	9.00	Sandy Clay	Medium brownish-grey gravelly sandy clay. Clasts are sub-angular to sub-rounded flint and quartz <60mm. Carbonate flecks.
9.00	9.50	Sandy Clay	Medium brownish-grey sandy clay. Clasts are sub-rounded to sub-angular flint <10mm.
9.50	10.00	Clayey Sand	Medium greyish-brown clayey sand. Clasts are sub-rounded to sub-angular flint and quartz <10mm.
9.00	9.50	Sandy Clay	Medium Brownish Grey Sandy Clay.
9.50	10.00	Clayey Sand	Medium Greyish Brown Clayey Sand.

ATTT21 WEST09 2.00-5.45m, 7.00-7.95m

Appendix 2

Stratigraphic Model

Holocene: Alluvium

The Holocene alluvium comprises fine grained sediments deposited across low lying areas adjacent to rivers. The locations of river channels are indicated by the presence of coarser grained sediments eroded and deposited in this higher energy fluvial environment. Backwater or channel margins comprise a mix of fine and coarse grained sediments with potential for preservation of organic matter including peat. Alluvium can also act to preserve the land surface over which they have been deposited with potential for palaeosols preserved in-situ at the lower contact or at any point within the deposit where conditions have been stable enough for soil formation processes to begin.

Pleistocene/Holocene: head

There are three definite deposits of Head identified across the scheme; one occurs overlying the Till and under the sub-lake sands and gravels, one overlies the Interglacial Lacustrine deposits, and one occurs overlying the terrace deposits and is sealed by Holocene alluvium. They are poorly sorted and poorly stratified due to the downhill movement during weathering. As with alluvium they can act to preserve palaeosols at their lower contact and may also contain archaeological material. Examples of Palaeolithic material being recovered in Head or solifluction deposits are at Harnham (Bates et al., 2014), at Ebbsfleet Baker's Hole (Wenban-Smith et al., 2020) and at Dartford (Wenban-Smith et al., 2010).

Pleistocene: Blackwater Terrace 1

As the lowest of the 5 terraces of the Blackwater, this is likely to be the most recently formed of the river terraces. No models currently exist explaining the fluvial sequences associated with the Blackwater terraces and, consequently, we have adopted a simplified version of the Bridgland model for river terraces based on his work in the lower Thames (Bridgland, 2006). It should however be noted that not all English rivers follow patterns of sedimentation like that proposed by Bridgland for the lower Thames, and rivers such as the Severn/Avon system (Maddy et al., 1991) and the Axe (Brown et al., 2015) contain different sedimentary architectures to the lower Thames. The fluvial sediments forming the main body of this terrace are likely to consist of a basal gravel or sand and gravel. These gravels probably date to around the last glacial maximum (35,000-20,000 years before present). Archaeological and palaeontological material may be incorporated into the gravels and are likely to be reworked, although channel cut and fill sequences within the gravels may preserve organic material and offer contexts in which archaeological material may be in primary context.

Pleistocene: Blackwater Terrace 2

The fluvial sediments forming the main body of this terrace are likely to consist of a gravel, or sands and gravels. Observations at Colemans Farm Quarry have demonstrated that an intermittently preserved organic rich sand/silt is present at the base of the deposit in places. This organic unit contains molluscs, ostracods, pollen, and insect remains. Pollen assessment indicates deposition of this sediment under cool climate conditions, probably in the Devensian. Large mammal remains, including mammoth and horse, are also being recovered from the base of these gravels in the quarry and appear typical of a Devensian faunal assemblage. Archaeological material may be incorporated into the gravels and are likely to be reworked, although the finer grained organic sequences towards the base of the gravels may preserve contexts in which archaeological material may be in primary context.

Pleistocene: Blackwater Terrace 3

The fluvial sediments forming the main body of this terrace are likely to consist of a gravel, or sands and gravels. The possibility exists that finer grained sediments associated with the interglacial floodplain of the river may exist in places over the sand and gravels (if present, this is most likely to occur where the fluvial sediments adjoin the rising bedrock surface at the inside of the terrace) where Head deposits may overlie them. The age of the terrace is not well constrained, and may date to between 374,000 and 125,000 years, but it clearly overlies the interglacial lake deposits (above) at places such as Colemans Farm Quarry. Archaeological material may not only exist as reworked artefacts in the body of sands and gravels, but in primary context associated with interglacial sediments. Both reworked and primary context material may be present in any Head deposits that bury the fluvial sequences. Biological material is most likely to be present in the interglacial sediments.

Pleistocene: Blackwater Terraces 4 and 5

Blackwater terraces 4 and 5 are mapped as discrete patches of material on the east bank of the Blackwater, at the foot of the Tiptree Ridge (Illus XX). Sediments are likely to be dominated by sands and gravels. Depending on the interpretation of the deposits, these either belong to the end of the Anglian Glaciation, MIS 12 or to one of the post-Hoxnian cold stages (MIS 8 and MIS 10). If the sequences belong to the MIS 12 glaciation, they are likely to date to sometime around 450,000-430,000 years. Contained archaeology would be reworked artefacts from the pre-Anglian period derived from the sub-till sands and gravels of the Kesgrave/Colchester Formations. The possibility exists that finer grained sediments associated with the interglacial floodplain of the river may exist in places over the sand and gravels, although the isolated nature of the patches of Terrace 4 and 5 suggests that they are less likely to preserve this sort of sequence. Where Head deposits directly overlie these fluvial sediments there is greater potential for preservation. It is also possible that these patches of fluvial sediments have been modified by solifluction processes and mobilised downslope.

Pleistocene: Interglacial Lacustrine

A range of types of sediment are associated with the post-Anglian landscapes of the route corridor that are broadly associated with the Blackwater drainage system that include the interglacial lacustrine sequences (lakes) exemplified by those at Mark's Tey (Turner, 1970; Tey et al., 2016) and fluvial sediments of the river Blackwater.

The most complete sequence of sediments dated to the Hoxnian Interglacial (MIS (Marine Isotope Stage) 11, immediately post-dating the Anglian Glaciation) has been located immediately to the north of the current scheme at Marks Tey and Copford. The sediments consist of at least 19 m of sediments lying between c. +16 m and -2 m O.D. (Turner, 1970; Tey et al., 2016; Candy et al., 2021). Of significance to our study is the presence, within the immediate vicinity of the proposed extraction area around Rivenhall End, of interglacial lacustrine sediments like those at Marks Tey as well as river terrace deposits associated with the fluvial system of the Blackwater (Illus 3). Although the lake deposits remain to be independently dated, the lacustrine sediments are likely to be Hoxnian in age (by comparison with those at Marks Tey – Turner, 1970) and are rich in palaeoenvironmental evidence. Their palaeoenvironmental potential has been demonstrated by previous work at the Colemans Farm Quarry site by one of the authors (in 2006/2009 along with Francis Wenban-Smith of Southampton University). This work focused on test pitting and borehole drilling in a field near Rivenhall Bridge. The ongoing work has so far demonstrated the nature of the lacustrine sediments, that they contain well preserved molluscs, ostracods and small mammal remains and pollen intermittently. Pollen of the unknown Type X species has been recovered from these sediments (Pete Coxon pers. comm.). This reinforces a MIS 11 age (although the presence of Type X pollen in deposits of MIS 9 age also remains a possibility).

Pleistocene: Sub-Lake Sands and Gravels

The history and timing of ice advance into the study area remains opaque and the precise impact on the pre-existing landscape of the Kesgrave Formation is likely to have varied across time and space. It is thought that ice was held up by the Tiptree Ridge (Illus 1) while meltwater processes beneath the ice or at the ice margins were impacting on the Kesgrave landscape and meltwater created a deep tunnel valley (a subglacial meltwater channel cut beneath the ice by water and entrained sands and gravels) between Witham and Kelvedon (Bristow, 1985). Other features that may be associated with the Anglian Glaciation have been suggested by Turner (in Rose and Turner, 1973) who argued that the highest terraces of the Blackwater (see below) may be kame terraces of Anglian age rather than fluvial terraces per se. The surface of the Lowestoft Formation forms the template on which sediments from the Later Middle Pleistocene are deposited.

The lake margin position and the relationship of the lake deposits to the mapped fluvial terrace deposits remain to be demonstrated, although fluvial sediments are clearly present above and below lake deposits at Colemans Farm Quarry (Ref report Illus 3). Five river terraces have been mapped by the BGS in the area (see below) but both the nature of their deposition and age remains difficult to ascertain. For example, it is possible to equate the five terraces with three post-Hoxnian cold stages (MIS 10-8-6) and the complex Devensian (MIS 5d-2) in much the same fashion as Bridgland has argued for the Lower Thames (Bridgland, 2006) (Appendix 1, Table A1.1). In contrast Turner (in Rose and Turner, 1973) has suggested that Terraces 4 and 5 (the highest terraces of the Blackwater) are kame terraces formed during the Anglian glaciation meaning that Terraces 1-3 would span nearly 400,000 years of time suggesting considerable hiatus between some known sequences. Furthermore, there appears to be some confusion regarding the status of Terrace 3 whereby Bristow (1985, p.68) has argued that the sands and gravels underlying the Hoxnian lake deposits belong to Terrace 3, while Turner (in Rose and Turner, 1973) suggests that Terrace 3 deposits overlie the lake deposits. What does however seem clear is that there is a close association (as one might expect) between the lacustrine deposits and fluvial sediments associated with Terrace 3.

Work during the summer of 2020 (in the Colemans Farm Quarry) has also demonstrated that important fossiliferous deposits lie beneath gravels mapped as Terrace 2 by the British Geological Survey) (Ref report Illus 3). These are different in character, and probably of Devensian age, to those of the lake deposits and represent colder climate environments. Artefacts in these deposits are likely to be reworked to a large extent from the sub-till sands and gravels of the Kesgrave/Colchester Formations.

Pleistocene: Anglian Till

The Lowestoft Formation (Lee et al., 2004) is used loosely here to describe a sequence of till deposits laid down by the ice in East Anglian during MIS 12 (Appendix 1, Table A1.2). Lowestoft Formation *sensu stricto* consists of a chalky till with a clay matrix and common chalk and flint clasts. The carbonate content of the till may be up to 30% in places. We also include sands and gravels mapped as Glaciofluvial Deposits by the British Geological Survey within the overall group of the Lowestoft Formation for simplicity. Additional clay and silt dominated deposits mapped as Glaciolacustrine Deposits may also be grouped under the broad classification of the Lowestoft Formation.

The history and timing of ice advance into the study area remains opaque and the precise impact on the pre-existing landscape of the Kesgrave Formation is likely to have varied across time and space. It is thought that ice was held up by the Tiptree Ridge (Illus 1) while meltwater processes beneath the ice or at the ice margins were impacting on the Kesgrave landscape and meltwater created a deep tunnel valley (a subglacial meltwater channel cut beneath the ice by water and entrained sands and gravels) between Witham and Kelvedon (Bristow, 1985). Other features that may be associated with the Anglian Glaciation have been suggested by Turner (in Rose and Turner, 1973) who argued that the highest terraces of the Blackwater (see below) may be kame terraces of Anglian age rather than fluvial terraces per se. The surface of the Lowestoft Formation forms the template on which sediments from the Later Middle Pleistocene are deposited.

Pleistocene: Kesgrave FORMATION

Sands and gravels considered to be older than c. 450,000 years before present (Marine Isotope Stage (MIS) 12) have been widely mapped across East Anglia. They belong to a former course of the river Thames that diverged from the modern course at Reading and extended north eastwards through St. Albans towards Colchester and thence to the modern coastline east of Norwich (Rose et al., 1976; Whiteman, 1992; Bridgland, 1994a; Rose et al., 1999). These form a series of mappable units lying at the surface in the west but buried beneath glacial sediments of the Lowestoft Formation to the east and through the scheme location. Within the scheme boundary the deposits that have been mapped by Rose et al. (1999) that belong to the Kesgrave Formation are the Ardleigh and Wivenhoe Gravels.

The Kesgrave Formation is usually devoid of paleoenvironmental material. However, some of the younger parts of this formation, such as the Ardleigh and Wivenhoe Gravels, do contain important palaeoenvironmental records. For example, at Wivenhoe two cold climate gravels (the Wivenhoe Upper and Lower Gravel) are separated by an organic silty clay containing fossils, insect remains, plant macrofossils and pollen from a warm or temperate climate with organic material (Bridgland et al., 1988; Bridgland, 1994b). At Ardleigh, complex deposits of up to 7.5 m of pale gravels at the base of the quarry, in places include a dark grey sand rich in organic matter that include plant macrofossils and pollen of a temperate character belonging to an interglacial in the Early Middle Pleistocene perhaps around 700,000 years before present (Bridgland (1988, 1994a), Bridgland et al., (1988) and Bridgland and Gibbard (1990)). Higher in the sequence (i.e., stratigraphically overlying the interglacial deposits but separated from them by gravels) dark grey silty deposits which contain plant and pollen remains but are indicative of arctic climates occurred as beds and lenses towards the top of the gravel, with occasional vertebrate remains also found in the gravels above the interglacial sediments. Several sites exist in the UK that broadly date to a similar period to the later parts of the Kesgrave/Colchester Formation, including Boxgrove (Roberts and Parfitt, 1999), Happisburgh (Parfitt et al., 2010), Pakefield (Parfitt et al., 2005), as well as several sites in the Bytham River system (Davis et al., 2021).

The interglacial sediments that have been located in the Kesgrave Formation usually occurred in small pockets that are probably fragments of isolated channels and the biological data suggest that different parts of the interglacial are recorded in the different channels. This evidence indicates that while the Kesgrave/Colchester Formation is complex and typically devoid of important palaeoenvironmental material, isolated pockets and patches of sediment may contain nationally important sequences in parts of the formation.

Pre-Quaternary: London Clay

Pre-Quaternary Bedrock geology along the scheme corridor consists of London Clay, a compact clay-dominated sediment deposited under marine conditions in the Eocene (56-34 million years before present). In places, small outcrops of older Thanet Formation or Lambeth Formation sediments form elongated inliers at Kelvedon and Witham according to the British Geological Survey mapping (Geology of Britain Viewer, accessed 21/10/21). The Thanet Formation is formed mainly of a pale grey or buff fine-grained glauconitic sand that is interbedded with silts and clays towards the base of the formation. At its base is the Bullhead Bed that consists of flint pebbles. The Lambeth Formation (formerly known as the Woolwich and Reading Beds) consist of a complex of vertically and laterally varying gravels, sands, silts, and clays deposited between 56-55 million years before present. Older sources (Bristow, 1985, Figure 10) suggest a more extensive distribution of the Lower London Tertiaries (i.e., the Thanet and Lambeth Formations) across the area from Witham to Kelvedon.

Appendix 3

Pollen report

The following report was commissioned by Headland Archaeology on behalf of Costain. It is presented here in an unedited form as received by Dr Michael Grant, University of Southampton. As agreed with Costain, any implications of these data - beyond those already presented in the report – and any further assessment will be provided as an addendum.

UNIVERSITY OF Southampton

A12 Trial Trenching (ATTT) project, Essex.

Pollen Assessment

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A12 Trial Trenching (ATTT) project, Essex. Pollen Assessment

January 2022

Executive Summary

The A12 (Junction 19 Chelsmford – Junction 25 A120) Widening Scheme crosses a number of areas where potentially significant Quaternary sedimentary sequences are known to occur. Archaeological site investigations, focused on evaluating the Quaternary landscape, has identified a series of lacustrine deposits with high palaeoenvironmental potential. As part of the assessment of these sampled features, pollen analysis was undertaken on 32 samples taken from five test pits and four boreholes.

Borehole SNJA10, from the area around Sigers (PQ8), has revealed a distinctive pollen sequence showing the arrival of deciduous woodland during the early to middle Hoxnian interglacial, Marine Isotope Stage 11c, which is likely to date somewhere between 425-415 ka. This sequence is directly comparable with the nearby Marks Tey record, which represents the parastratotype for the Hoxnian–Interglacial. Test pits sampled from the Bolton South (PQ29) area produced pollen with a high concentration of reworked material, making it difficult to correlate the pollen record to a known Pleistocene stage. It is estimated that this record is late Hoxnian at the earliest, and most likely late MIS 11c or younger, with one sample from TP2912 possibly from the later Purfleet interglacial (MIS 9) or younger. A boreholes through deep lacustrine deposits in the area around Siger (PQ9), SSBE09, produced a pollen assemblage with some similarities to those from the Bolton South area, also dominated by high concentrations of reworked material., and thought to date from the later stages of MIS11c. An organic horizon in borehole SSBE07 from this area revealed a unique pollen assemblage that might be associated with an interstadial, possibly MIS 11b or younger.

Some of the sequences assessed from the ATTT are shown to have high palaeoenvironmental potential and are recommended for further investigations.

A12 Trial Trenching (ATTT) project, Essex.

Pollen Assessment

January 2022

Acknowledgements

Pollen extraction was undertaken using the facilities at PLUS, University of Southampton. The pollen assessment was commissioned by Michael Wallace on behalf of Headland Archaeology. Tom Gwitt is thanked for providing additional information about the stratigraphic sequences.

A12 Trial Trenching (ATTT) project, Essex.

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1 Introduction

Archaeological evaluations have been undertaken by Headland Archaeology, with support from Pre-Construct Archaeology (HA), as part of the A12 (Junction 19 Chelsmford – Junction 25 A120) Widening Scheme. The scheme boundary runs from Junction 19 of the A12 at Boreham to Junction 25 at Marks Tey, encompassing a total of 1039 hectares of land. This route crosses a number of areas where potentially significant Quaternary sedimentary sequences are known to occur, and therefore a component of the site investigations was focused on evaluating the Quaternary landscape and determining its potential to contain Palaeolithic archaeology and palaeoenvironmental sequences. This programme of evaluation took place between 17th May and 20th October 2021, with the results reported by, and consisted for a series of test pts, boreholes and geophysical survey. The route has been divided into five Quaternary Landscape Evaluation Zones by Garcia-Suarez et al. (2021).

A preliminary palaeoenvironmental assessment of thirty-seven samples from test pits and boreholes along the scheme was undertaken by John Whittaker, focused upon lacustrine deposits that were identified in Quaternary Landscape Evaluation Areas (QLEA) 1 and 3 (see Garcia-Suarez et al. 2021: 24-25). Preservation of macrofossil remains was variable between samples, with few remains that could be used as biostratigraphic indicators for the age of the sequences. It was therefore recommended that pollen assessment was to be undertaken to better understand these sequences and indicate, if possible, the age of the sequences.

The QLEA 1 sequences were sampled through a series of test pits in the Bolton South (PQ29; P/14.1) area east of Chelmsford and north of the Blackwater River. This area has been previously mapped as containing lacustrine samples, with O'Connor (2015) also reporting extensive lacustrine deposits in the area infilling possible sub-glacial channels, with notable deposits recorded in boreholes from Sandon to the south and Boreham House to the North East. Although undated, O'Connor (2015; 74) has suggested that these may be from the Hoxnian Interglacial, which correlates with Marine Isotope Stage 11, c. 427 to 364 ka. The test pit sequences are recorded as containing water-lain sands and gravels over possible lacustrine deposits that are represented by hard bluish grey clays.

The QLEA 3 sequences were sampled through a series of boreholes in the Area around Sigers (PQ8; P/23.2 and PQ9; P/57.5) area. While both sequences contain lacustrine deposits, the sedimentary sequences are different. Within the northern area, PQ8, borehole SNJA10 contains a sequence of glacial till overlain by soft dark blueish grey clayey silt to firm light yellowish sediments, topped by head deposits. Some of the lacustrine deposits were found to be highly calcareous. By contrast, the lacustrine sequence from SSBE09, within PQ9 to the south, extends to a much greater depth below the surface, and is dominated by medium brownish grey sandy clayey silts with intermittent laminations of soft dark blueish grey sandy clayey silts, overlain by fluvial sands and gravels. The sequence from SSBE07 is shallower than SSBE09, therefore presumed to be younger, and contains a thin basal peat overlain by lacustrine dark blueish grey sandy clayey silts.

1.1 Hoxnian Interglacial and Marks Tey

Marks Tey is the parastratotype for the Hoxnian–Interglacial, a temperate episode defined by West (1956) on the basis of pollen stratigraphy from the type sequence at Hoxne in Suffolk (Mitchell et al., 1973). Marks Tey is unique as, unlike most other Hoxnian sequences, as it is thought to preserve the full interglacial vegetation succession from the end of the Anglian through the entire Hoxnian–Interglacial into the subsequent cold interval.

The pollen stratigraphy of the sequence is divided into six zones (West, 1956; Turner and West, 1968; Turner, 1970). The base of the sequence was named the Lowestoftian Late Glacial zone (Lo; equivalent to the late Anglian Glaciation Stage; MIS 12) and is characterised by a low ratio of tree to non-tree pollen, with a high abundance of *Hippophaë* and *Betula* also present. Overlying this, the Hoxnian stage begins with the pre-temperate zone (Hoxnian I or Ho I), where total arboreal pollen (AP) first exceeds total non-arboreal pollen (NAP), is characterized by the presence of closed boreal forest species *Betula* (birch) and *Pinus* (pine). The early-temperate zone (Ho II) sees the expansion of mixed *Quercus* (oak) forest that undergoes a succession of changing species dominance from *Quercus* (Ho IIa) to *Alnus* (alder; Ho IIb) to *Corylus* (hazel; Ho IIc). The late-temperate zone (Ho III) is characterized by the progressive decline of mixed *Quercus* forest and an increase in late-migrating temperate trees such as *Carpinus* (hornbeam; Ho IIIa) and *Abies* (fir; Ho IIIb). Finally, the post-temperate zone (Ho IV) is characterized by a return to *Pinus* and *Betula* dominance, first with heath communities of *Empetrum* (crowberry; HoIVa) and subsequently with Poaceae (grasses; HoIVb). Overlying this, the onset of the Gipping Early-glacial Stage (eG I) occurs, with heath communities dominating as the forest declines considerably and NAP pollen again exceeds AP, eventually transitional to a true periglacial flora.

The original work of Turner (1970) did not provide any chronological controls on the age of the sequence, beyond defining a series of sub-stages within the Hoxnian, with the assumption that the

Gipping Early-glacial stage represents the onset of the post-Hoxnian glaciation. However, further work at Marks Tey by Tye et al. (2016) and Candy et al. (2021), along with studies at Hoxne by Ashton et al. (2008), have shown that rather than representing the whole of MIS 11, these sequences actually relate to MIS 11c, dated c. 425-395 ka. This claim is supported strengthened by the presence of a tephra horizon within the Marks Tey sequence, located within the centre of pollen zone Ho IIc, estimated to date to c. 414.25 ka, places the lower half of the sequence (Ho I and Ho II) into the early part of MIS 11c. This means that the Gipping Early-glacial Stage could be associated with a cold interlude within the subsequent MIS 11b, or if the sequence is discontinuous, a later phase post-dating the MIS 11a interstadial that is reported from the Hoxne sequence (Ashton et al. 2008).

2 Assessment Aims

The pollen assessment has been undertaken with the following aims:

- Identify if pollen is preserved within the Pleistocene samples, and identify a selection of those present (c. 100 if possible) to the lowest taxonomic order;
- Infer the climatic conditions, based upon the pollen present, including differentiating between warm and cold Pleistocene stages;
- Assess the possible age of the sedimentary sequence using pollen biostratigraphy;
- Assess the palaeoenvironmental significance of the assemblages

3 Methodology

32 subsamples (see Table 1) were taken for pollen extraction using standard preparation procedures (Moore et al. 1991). 2-4cm^3 of sediment was prepared from each sample, with a *Lycopodium* spike added (one tablet from batch 14285) to allow the calculation of pollen concentrations (Stockmarr 1971). All samples received the following treatment: 20 mls of 10% KOH (80°C for 30 minutes); 20mls of 60% HF (80°C for 120 minutes); 15 mls of acetolysis mix (80°C for 3 minutes); stained in 0.2% aqueous solution of safranin and mounted in silicone oil following dehydration with tert-butyl alcohol. Due to the highly minerogenic nature of these samples, additional sieving and decanting was undertaken between the KOH and HF stages.

Table 1: List of pollen samples assessed

QLEA 1					QLEA 3		
PQ29	**PQ29**	**PQ29**	**PQ29**	**PQ29**	**PQ8**	**PQ9**	**PQ9**
P/14.1	**P/14.1**	**P/14.1**	**P/14.1**	**P/14.1**	**P/23.2**	**P/57.5**	**P/57.5**
TP2912	**TP13**	**TP60**	**TP38**	**TP48**	**SNJA10**	**SSBE09**	**SSBE07**
3.00m <10003>	2.10m <10004>	1.90m <10006>	1.80m <10009>	2.00m <10011>	5.01m <20003>	4.22m <20022>	5.30m <20056>
		2.40m <10007>	2.90m <10010>	3.00m <10013>	5.20m <20004>	15.00m <20043>	
					5.67m <20005>	15.69m <20044>	
					6.19m <20006>	16.39m <20045>	
					6.54m <20008>	17.23m <20046>	
					7.00m <20007>	8.69m <20023>	
					7.16m <20009>	9.20m <20024>	
					7.24m <20010>	9.70m <20025>	
						10.19m <20026>	
						11.19m <20028>	
						12.69m <20029>	
						13.26m <20030>	
						13.69m <20031>	
						14.19m <20032>	

Pollen counting was undertaken at a magnification of x400 using a Nikon Ci-L transmitted light microscope. Determinable pollen and spore types were identified to the lowest possible taxonomic level with the aid of a reference collection kept at COARS, University of Southampton. The pollen and spore types used are those defined by Bennett (1994; Bennett et al. 1994), with the exception of d Betulaceae, which followed Blackmore et al. (2003). Plant nomenclature follows Stace (2010). A minimum total land pollen (TLP) sum of 100 grains was sought for the pollen assessment from all samples, surpassed in all but four samples. In samples <10006> and <10007> from TP60, counts of only 50 TLP were possible, though the counts of pre-Quaternary spores were 1200 and 515 respectively. In sample <10009> from TP38, a count of only 16 TLP was possible, with a low pollen concentration of 300 grains cm^{-3}. Finally, in sample <20022> from SSBE09, only a single grain of *Quercus* was present in the sample, with a pollen concentration of 100 grains cm^{-3}.

4 Results

4.1 Quaternary Landscape Evaluation Area 1

4.1.1 Test Pit 2912

A single sample <10003> was taken from TP2912 (Figure 1). The pollen assemblage is dominated by *Pinus* with Poaceae, *Quercus* and *Betula* also abundant. Other woodland taxa present include *Abies*, *Picea* (spruce), *Alnus glutinosa* and *Corylus avellana*-type. Herb taxa present include Cheonopodiaceae (goosefoot and oraches), Brassicaceae (cabbage family), *Vaccinium*-type (heath and bilberries), *Rubus*-type (bramble), *Cichorium intybus*-type (dandelion and chicory), *Artemisia*-type (mugworts) and Cyperaceae (sedges). *Potamogeton natans-type* (pondweed) is also present. Pre-Quaternary Spores (PQS) are abundant, accounting for 40% TLP + PQS, along with dinoflagellates, indicating the incorporation of allochthonous material. The pollen concentration is 2000 grains cm^{-3}. Pollen in this sample was generally poorly preserved, with most bisaccate pollen grains broken and often corroded,

4.1.2 Test Pit 13

A single sample <10004> was taken from TP13 (Figure 1). The pollen assemblage is dominated by *Pinus* and *Picea*, with Poaceae, Cyperaceae and *Abies* also well represented. A range of other woodland taxa are present in low abundance, including *Ulmus* (elm), *Quercus*, *Betula*, *Alnus glutinosa*, *Carpinus betulus*-type (hornbeam), *Tilia platyphyllos* (large-leaved lime) and *Sorbus*-type (cherries and whitebeam). Herbs present include *Ranunculus acris*-type (buttercups), *Filipendula* (meadowsweet) and Rosaceae (rose family), with *Equestum* (horsetails) and *Pteridium aquilinum* (bracken) also recorded. PQS are abundant, accounting for 70% TLP + PQS, along with dinoflagellates, indicating the incorporation of allochthonous material. The pollen concentration is 7000 grains cm^{-3}. Pollen in this sample was generally poorly preserved, with most bisaccate pollen grains broken and often corroded, possibly leading to an over-representation of these taxa or indicating that they were derived.

4.1.3 Test Pit 60

Two samples <10006-7> were taken from TP60 (Figure 1). Pollen counts only reached c. 50 TLP due to low pollen concentrations (1800-3000 grains cm^{-3}) and a very high abundance of PQS (74-86% TLP + PQS). Both samples are dominated by *Abies*, *Pinus* and Poaceae, though in <10006> the woodland component is dominant, while in <10007> Poaceae dominates. *Alnus glutinosa* is in both samples, with *Juniperus communis* (juniper), *Quercus* and *Betula* also present in <10007>. Of particular note was a single grain of *Vitis vinifera* (grape-vine) in <10006>. Herb taxa present include *Helianthemum* (rock-rose), *Empetrum nigrum*, *Vaccinium*-type, *Polemonium caeruleum* (Jacob's-ladder) and *Artemisia*-type. While only present as single grains, these taxa are often found associated with distinctive cold-climate assemblage and can be found forming natural meadows, especially on lake shores or open woodland, and are capable for forming tall-herb and heath communities. The high PQS abundance, along with dinoflagellates, indicate the incorporation of allochthonous material., with some pollen in this sample generally poorly preserved, with most bisaccate pollen grains broken and often corroded.

4.1.4 Test Pit 38

Two samples <10009-10> were taken from TP38 (Figure 1). Pollen counts only reached 16 TLP in the upper sample due to low pollen concentrations (300 grains cm^{-3}), though sufficient pollen was present in sample <10010> to achieve 1000 TLP, with a higher pollen concentration of 8500 grains cm^{-3}. The latter is dominated by Poaceae and Cyperaceae, with Pinus also present at 14% TLP. Overall, tree pollen accounts for 20% of the TLP. *Abies*, *Picea*, *Ulmus* and *Quercus* are present in low amounts. Herb taxa include Chenopodiaceae, *Silene dioica*-type (red champion), *Helianthemum*, *Brassicaceae*, *Cichorium intybus*-type and *Solidago virgaurea*-type (goldenrod). PQS and dinoflagellate concentrations are low, suggesting a lower allochthonous input of material.

4.1.5 Test Pit 48

Two samples <10011 and 10013> were taken from TP48 (Figure 1). Pollen concentrations were highest in <10011>, at 9500 grains cm^{-3}, while in <10013> they were lower at 1700 grains cm^{-3}. In the former, *Pinus* is the dominant taxa, with *Abies*, Cyperaceae and Poaceae, while in the latter the herb taxa dominate. This correlates with PQS concentrations, which are highest in the sample dominated by woodland components. Other woodland components in <10011> including *Picea, Juniperus communis* and *Betula*. Also present were grains of *Ostrya carpinifolia*-type (hop-hornbeam) and *Pterocarya fraxinifolia* (Caucasian wingnut), which are typically associated with pre-MIS 12 (Anglian) Cromerian pollen assemblages, though Turner (1970; 1975) has stated that it might have been native as late as the Hoxnian. Herb taxa present include *Helianthemum*, *Empetrum nigrum* and *Vaccinium*-type. *Potamogeton natans*-type and *Osmunda regalis* (royal fern) are also recorded. The presence of *Linum catharticum* (fairy flax) in <10013> may also be contemporary, as pollen and macrofossils of *Linum perenne / catharticum* (perennial / fairy flax) are widespread in British and Irish glacial sites (Reid 1949; Bell and Dickson 1971; Watts 1963; 1977).

4.1.6 QLEA 1 biostratigraphy

The use of pollen for chronostratigraphic purposes is limited (Tzedakis et al., 2001; Rose 2009), as several key assumptions must be made, such as limited spatial variation in the pollen rain between contemporary sites, and that every interglacial cycle will produce a unique pollen signature that is represented in full within the fossil record. Neither of these assumptions can be fully substantiated, therefore the use of biostratigraphy can only act as a relative biostratigraphic tool that requires additional data to support any proposed chronostratigraphic correlations. For the QLEA 1 test pit samples assessed, it is assumed that the lacustrine clays are penecontemporaneous, so the pollen assemblage might be considered as a collective. However, it is notable that sample <10003>, from Test Pit 2912, contains a different flora to the others from QLEA 1, with a higher abundance of temperate tree taxa. A further complication when discussing these sample assemblages is the issue of taphonomy, with several processes that may have led to the observed pollen record. Most notably, where there are high concentrations of PQS, this is reflected in a higher amount of tree pollen in the assemblage, exceeding 50% TLP. By contrast, in samples <10010> and <10013>, where the PQS concentration is low, tree pollen is less than 20% TLP. This pattern also correlates with the abundance of temperate woodland species, which are highest in samples with high PQS (excluding <10003>). It is therefore very likely that much of this woodland pollen is a result of sediment inwash from the local area, whether these are reflecting transport of contemporary pollen into the basin, reworked interglacial deposits or eroded till deposits. The high abundance of *Abies*, along with the occurrence of *Carpinus betulus and Vitis vinifera* pollen, may indicates that these are derived from, or indeed reflect, Hoxnian (MIS 11c) deposits, tentatively placing these lacustrine deposits in the late to post-MIS 11c period. There are a number of herb taxa present that are commonly associated with cold-climate meadow, open woodland and lake shore environments. There are some similarities with the Marks Tey pollen zone Ho IV / eG I, and the sequence from SSBE09 in QLEA 3 (see below), representing a late MIS 11c or possibly post-MIS 11c environment, though these deposits could also be from a later stadial / interstadial or pre/post interglacial stage. Most notably, in sample <10003> the abundance of *Abies* is very low, and when the percentages of *Pinus*, *Picea*, *Alnus, Betula, Quercus*, *Corylus avellana*-type, Poaceae and Cyperaceae are compared against other Pleistocene records, this sample shows a strong similarities to MIS 9 (Purfleet interglacial) assemblages, such as that from Barling Hall Pit (Bridgland *et al.* 2001). However, as this is based upon a single sample only, this correlation is unlikely to be reliable. It is therefore not possible, based upon pollen alone, to clearly state the age of these lacustrine samples, though they seem to be of late MIS 11c at the earliest, and some or all could be MIS 9 or younger.

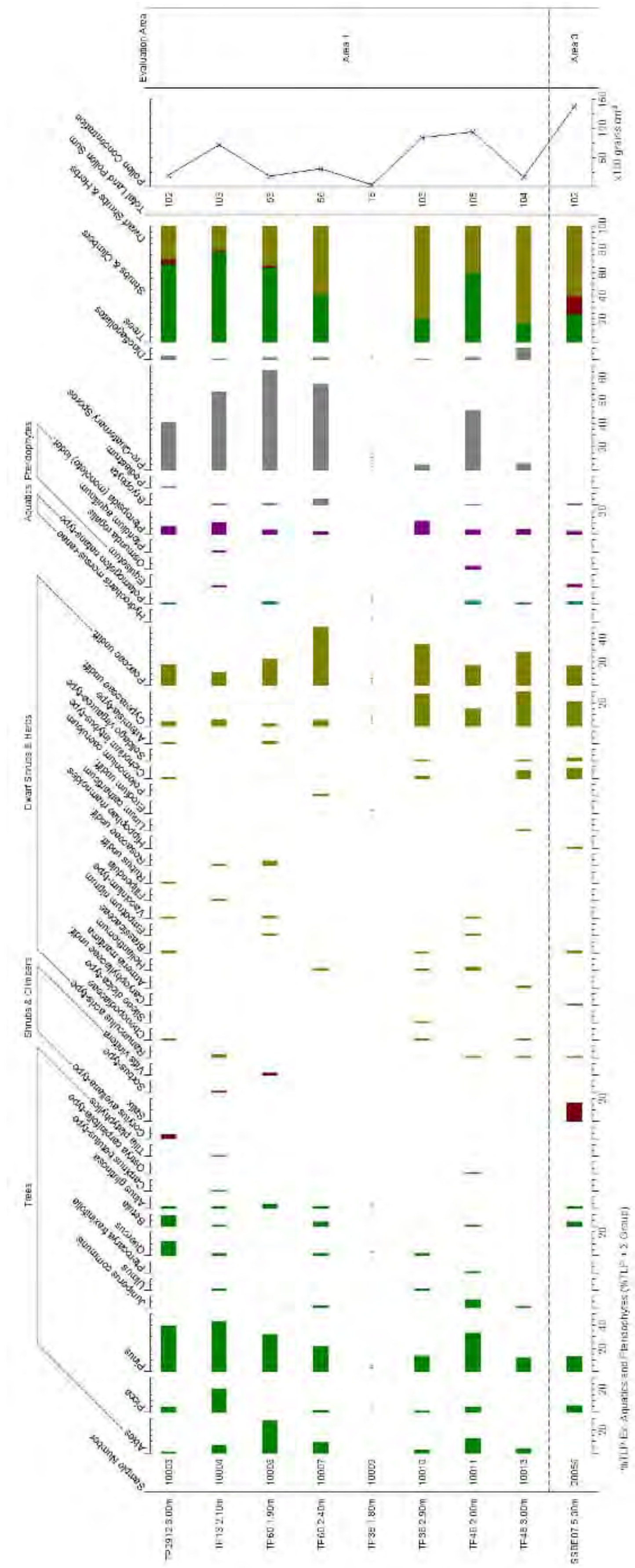

Figure 1: Pollen assessment results from test pits in QLEA 1 and SSBE07 in QLEA 3

4.2 Quaternary Landscape Evaluation Area 3

4.2.1 Borehole SJNA10

Pollen preservation and concentrations were good in all samples assessed from SNJA10 (Figure 2). The pollen sequence shows a pre-temperate to early temperate woodland succession which is comparable to the Hoxnian sequence from Marks Tey (Turner 1970). For this reason, the sequence is divided into three pollen zones, adopting the nomenclature of Turner (1970), spanning Ho I-IIb, the early temperate phase of MIS 11c. Zone Ho Ia shows a transition in the pollen record from NAP-dominated in sample <20010> to AP dominated in <20007>. At the base of the sequence, Poaceae and Cyperaceae are the dominant taxa, with *Prunella vulgaris*-type (selheals), typically found in grassland or open woodland. Taxa such as *Thalictrum* (meadow-rue) and *Epilobium* (willowherb) may indicate areas of fen or wet meadows, with *Potamogeton natans*-type and *Typha latifolia* (bulrushes) associated with the aquatic environment. *Papaver rhoeas*-type (poppy) and *Anthyllis vulneraria* (kidney vetch) may indicate calcareous soils, probably associated the Lowestoft Formation tills in the immediate area. *Hippophaë rhamnoides* (sea-buckthorn) is a characteristic taxa of the Ho I pollen zone (Turner 1970), and is thought to colonise open environments during late-glacial and pre-temperate periods, requiring cool temperatures for seed germination. At a small number of sites, it also occurs in the late-temperate and pre-glacial zones, though in the British record is absent between MIS 10 and 6 (Field et al. 2021). The woodland pollen shows low amounts of *Pinus* and *Juniperus communis. Salix* is at the base of the sequence, succeeded by *Betula* which reaches dominance by the end of the zone, indicating the development of a boreal woodland. Low amounts of *Ulmus*, *Quercus*, *Alnus glutinosa* and *Corylus* are present, indicating the arrival of these taxa, though it is in the subsequent zone Ho IIa that these expand, first with *Quercus*, then *Alnus glutinosa* at the start of Ho IIb, and *Corylus avellana*-type and *Ulmus* continuing to increase through the top of the sequence, but not reaching their full expansion, indicating that it stops in the middle of zone Ho IIb. *Abies* is present in low intermittent amounts throughout the sequence, but the characteristic increase of zone Ho IIIb is absent, as are the earlier successional species of *Carpinus betulus*, characteristic of zone Ho IIIa, and *Taxus baccata* (yew), characteristic of the start of zone Ho IIc. The absence of these taxa add confidence in categorising the top of the assessed SNJA10 sequence as being early zone Ho IIb. Also present are *Tilia cordata* (small-leaved lime), *Fraxinus excelsior* (ash) and *Hedera helix* (ivy), characteristic of zones Ho IIa/b, along with a low intermittent presence of *Picea*. The persistent high amounts of *Potamogeton natans*-type in zones Hi IIa and IIb is also characteristic of these zones within the Marks Tey pollen sequences. The dominance of woodland taxa in the pollen assemblage mean that NAP is poorly represented, though taxa such as *Ribes spicatum* (downy currant) are likely to be associated with woodland on calcareous soils.

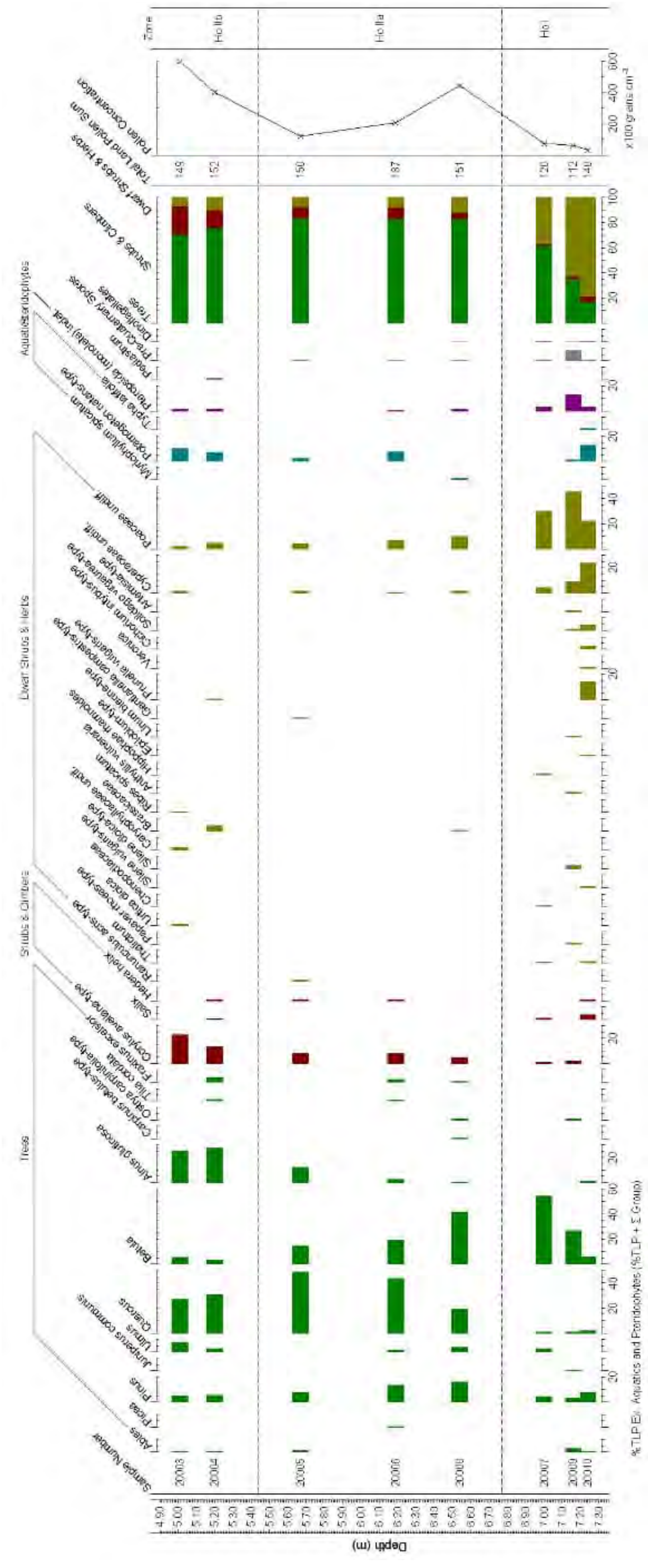

Figure 2: Pollen assessment of borehole SNJA10 from QLEA 3

The absence of the Type-X pollen taxon, a key biostratigraphic marker that is unknown in Britain after the Hoxnian (Turner 1970), may be due to the low pollen assessment counts, and might be identified by extended pollen counting. Throughout the sequence, PQS and dinoflagellate concentrations remain low, indicating little inwashed material into the site, which is also evident in the pollen assemblage as it is directly comparable with other Hoxnian sites. The presence of *Ostrya carpinifolia*-type could indicate the incorporation of some reworked pollen, though the pollen of *Ostrya* sp. and *Carpinus* sp. can be difficult to differentiate, especially as all grains were in the triporate form which can also be seen in some *Carpinus* grains (see Peglar and Lewis 2010; Akhondnejad et al. 2011). This means that the triporate *Ostrya carpinifolia*-type grains in this sequence could possibly be *Carpinus* sp.

4.2.2 Significance of the SNJA10 sequence

The pollen assemblage in SNJA10, spanning Ho I-IIb, is contemporary with the Stratum E lacustrine clays at Hoxne, attributed by West (1956; Ashton et al. 2008) to Ho I-II and associated with the Lower Industry Palaeolithic site. The borehole sequence is also contemporary with the Lower Freshwater Beds within the Clacton channel, correlated with Ho IIb-IIIb (Pike and Godwin 1953; Turner and Kerney 1971; Bridgland et al., 1999). Few pollen sequences have been recovered from the UK where the pre-temperate to early-temperate vegetation record is preserved intact (Thomas 2001). Of this selection of sites, some have taphonomic issues with the pollen assemblage, as found within the contemporary east Essex coast Hoxnian channel / estuarine sequences of Roe (1999), which make interpretation and biostratigraphic correlation difficult. A palaeoenvironmental assessment on the lacustrine deposits at Coleman's Farm (Bates 2019), south of QLEA 3, revealed Hoxnian lake deposits that are correlated to zone Ho IIc, representing an immediate chronological succession to the SNJA10 deposits. The age of the SNJA10 sequence is from the first half of the MIS 11c interglacial, preceeding pollen zone Ho IIc which, in the Marks Tey sequence, has been dated with a tephra horizon to c. 414.25 ka (Candy et al. 2021). This means that the SNJA10 sequence must fall within the period of c. 425-415 ka, likely centred on c. 420 ka.

The sedimentation rate within SNJA10 exceeds that recorded in Marks Tey and Hoxne for the early temperate period, Zone Ho IIa. At both Marks Tey and Hoxne this is covered by a lacustrine deposit c. 0.40m in thickness (Turner et al. 1970; Tye et al. 2016; West et al. 1956), whereas in SNJA10 this same pollen zone is c. 1.40m thick. While this sedimentation rate is significantly higher than these two lacustrine sites, it broadly comparable with some other Ho IIa lacustrine sequences, such as at Quendon (Baker 1977), Quinton (Horton 1989) and Nechells Borehole 7 (Kelly 1964). Higher sedimentation rates for this pollen zone are found in the east Essex channel fill sequences of Shoeburyness, North Wick and Cudmore Grove (Roe 1999), though as already stated these sequences do not fully conform to the Hoxnian biostratigraphic record outlined by Turner (1970) and Turner and West (1968), making correlation with the existent lacustrine deposits complicated. While this may represent some local variation in vegetation patterns and succession across these east Essex coastal peninsulas, the channel deposits do contain estuarine deposits where some pollen types, notable *Pinus*, are likely to be overrepresented (Roe 1999). The SNJA10 sequence therefore provides an important record of the early Hoxnian MIS 11c vegetation record which, if suitable material for dating is available, could further refine the timing of early vegetation succession within the British Hoxnian pollen record. When considered in connection with the Marks Tey and Colemans Farm deposits, it indicates the survival of Hoxnian interglacial deposits across a wide area which raises the archaeological potential for archaeological sites, contemporary with these lake sites, to be found along the route corridor in QLEA 3.

4.2.3 Borehole SSBE09

Borehole SSBE09 was taken c. 840m south of SNJA10, reaching a maximum depth of 17.50m below the ground surface and a different stratigraphic sequence. Only a single pollen grain, *Quercus*, was encountered in the uppermost sample <20022> from 4.22m, with the sequence dominated by PQS and a pollen concentration of less than 100 grains cm^{-3}. Pollen samples from the rest of the sequence were taken between 8.69m (<20023>) and 17.23m (<20046> and show an assemblage dominated by boreal woodland taxa, notably *Pinus*, at the base of the sequence, with a reduction in AP and increase in NAP pollen, most notably Poaceae, towards the top of the sequence. The pollen diagram is divided into three local pollen assemblage zones (LPAZ). At the bottom of the sequence, LPAZ-01 is dominated by *Pinus* with *Abies* also well represented. NAP is less thank 50%, reaching as low as 20% TLP in sample <20045>, and is mainly represented by Poaceae and Cyperaceae, with *Empetrum nigrum* also represented in <20045>. *Picea* values are low, though increase towards the end of the zone. *Juniperus communis* is present through the zone, with *Quercus*, *Alnus glutinosa*, *Ostrya carpinifolia*-type and *Corylus avellana*-type also present in more than one sample, albeit at low amounts. *Potamoegeton natans*-type and *Typha latifolia* are present in low amounts, along with *Osmunda regalis*. In zone LPAZ-2, there is a reduction in *Abies* and *Pinus*, while *Picea* increases, along with increases in *Quercus*, *Betula*, *Alnus glutinosa* and *Corlyus avellana*-type, and the presence of *Ulmus and Carpinus betulus*-type. Poaceae, *Empetrum nigrum* and *Vaccinium*-type also increase, possibly indicating a change to more open woodland and heath conditions, with some increase in deciduous woodland taxa as the boreal ones reduce. Zone LPAZ-3 sees further reductions in woodland cover, with NAP sums up to 70% TLP. *Pinus* is below 35%, falling as low as 15%, with *Abies* also reduced. *Picea*, although fluctuation in abundance through the zone, remains at similar levels to LPAZ-2. *Juniperus communis* is once again present, with deciduous woodland mainly presented by low amounts of *Alnus glutinosa* and *Corylus* *avellana*-type. At the start of the zone, Cyperaceae, Chenopodiaceae and *Ranunculus acris*-type, possibly indicating an increase in open ground or lake-edge communities, which may also account for the presence of *Isoetes lacustris* (quillwort) and *Equisetum*. Increases in Bryophyta spores (including *Sphagnum* moss) are recorded and, when combined with the presence of *Isoetes lacustris* and *Cryptograma crispa* (parsley fern), may indicate the onset of cooler climatic conditions.

4.2.4 Significance of the SSBE09 sequence

The high presence of *Picea* in the sequence differs from the Marks Tey record and several other Hoxnian sequences from East Anglia. During the middle to late Hoxnian, an east-west gradient of *Picea* abundance can be observed Britain, with increased *Picea* percentages in west Essex at Fishers Green (Gibbard et al. 1992), then very high amounts in the West Midland sequences of Nechells Borehole 7 (Kelly 1964) and Quinton (Horton 1989), reaching 50% of the tree pollen sum in the latter. Within these West Midland sequences, a distinct *Picea* phase of expansion is recorded in Ho IIIa, preceding the expansion of *Abies*, with *Picea* continuing to be well-represented throughout the Ho IIIa to IV zones. A local presence of *Picea* is confirmed by the presence of *Picea* cones within the Nechells sequence. While this demonstrates a distinct difference in the local flora between East Anglian and the West Midlands at this time, it is possible that more localised variations in the vegetation record of East Anglia existed during the Hoxnian, such as those seen on the east Essex coast where *Picea* accounts for up to 15% in the Tillingham (Roe 1999) and East Hyde (Roe 2001) sequences from the Dengie Peninsula, but poorly represented in contemporary deposits from the Southend and Tendring Peninsulas and Cudmore Grove on Mersea Island (Roe 1999). Coupled with the boreal woodland pollen, *Alnus glutinosa* and *Corlyus avellana*-type are present throughout the sequence, along with a low abundance of *Betula*, while *Juniperus communis* increases towards the top of the sequence, which might represent a gradual vegetation transition away from temperate woodland as temperatures cooled. The presence of *Empetrum nigrum* and *Vaccinium*-type, indicating the presence of heath. This assemblage is comparable to the Ho IV sequence from Quinton and Marks Tey, where *Betula* (albeit in higher abundance), *Pinus*, *Abies*, *Picea* (albeit in lower abundance) and *Alnus* are the main tree types, with *Corylus* and *Juniperus* also well represented, along with Poaceae and Ericaceae pollen. This would place the sequence towards the latter stages of MIS 11c, post-dating the tephra horizon associated with zone Ho III at Marks Tey, dated c. 415 ka (Candy et al. 2021), but pre-dating the end of the interglacial at c. 395 ka, with a date in the range of c. 405-400 ka most likely. However, with the amount of PQS and dinoflagellates present in this sequence, there is also a strong possibility that the relative percentages of the different taxa are affected by the incorporation of derived pollen as well as some differential pollen preservation.

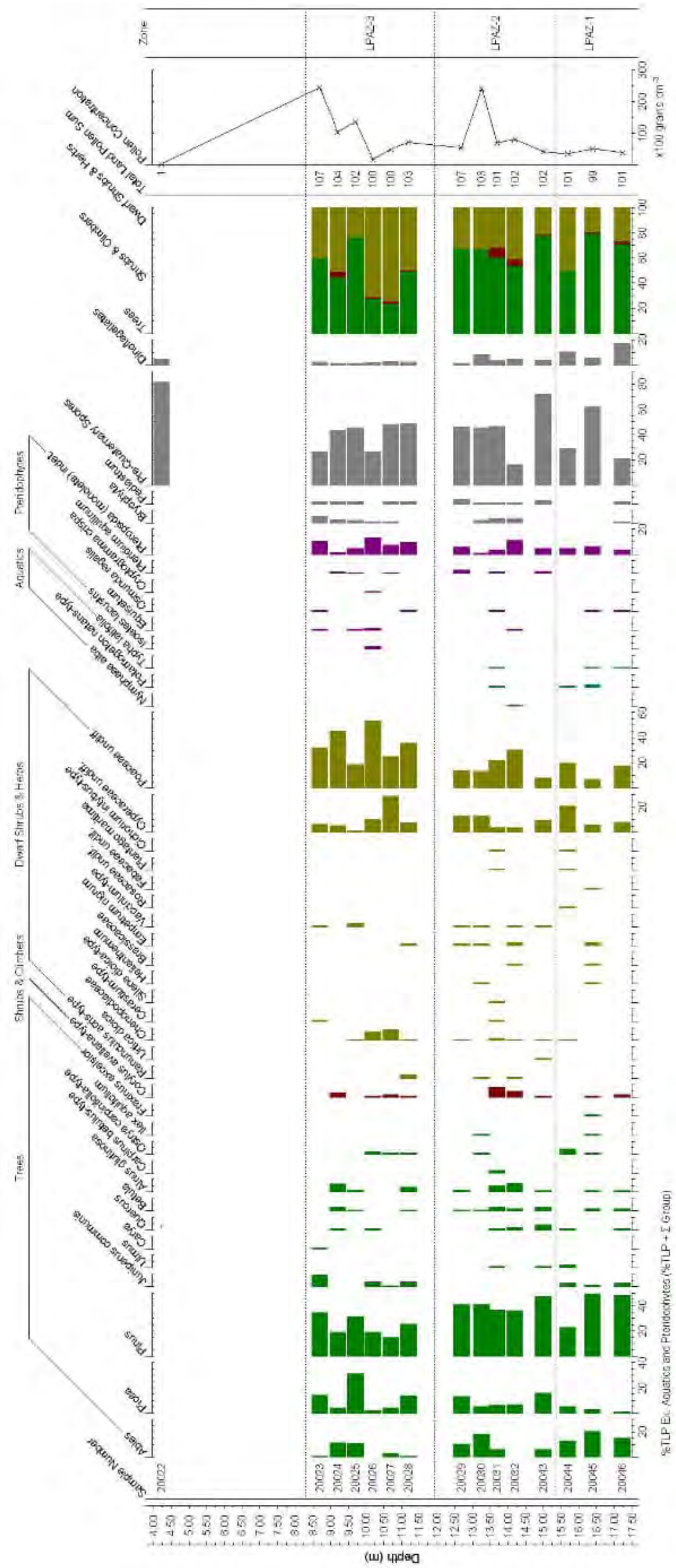

Figure 3: Pollen assessment of borehole SSBE09 in QLEA 3

4.2.5 Borehole SSBE07

The single sample from SSBE07 (Figure 1) is unique amongst the samples assessed as it contains an abundance of *Salix* pollen, along with *Picea*, *Pinus*, *Betula* and *Alnus*, though the sequence is dominated by NAP pollen (60% TLP), notably Poaceae and Cyperaceae. Pollen concentrations are higher than those in SSBE09, at 14,000 grains cm^{-3}, but much lower than the interglacial flora from SNJA10. The absence of pre-Quaternary spores and dinoflagellates within the sample suggest that there is limited allochthonous pollen incorporated into the sequence, so it may represent an assemblage contemporary with the local environment. If the lacustrine deposits of SSBE09 are assumed to be of late Hoxnian (MIS 11c), then the peat from the base of SSBE07, which is from a shallower depth in PX9, is likely to be younger. At Hoxne, part of the upper sequence is thought to be from MIS 11b/a (Ashton *et al.* 2008), with Stratum C, described as a black loam with arctic plants, containing a plant macrofossil assemblage including leaves of both *Betula nana* (dwarf birch) and several arctic and arctic-alpine species of *Salix sp*. (willow), along with *Abies* wood and a number of derived seeds of temperate tree species (Reid in Evans et al. (1896) and West 1956). While much of the pollen in this sequence was thought to be derived (West, 1956), the vegetation for this period was summarised by West (1956; 292) as representing a park-tundra with arctic willows and dwarf birch, oceanic heaths, and distant or very scattered forest with birch, pine, spruce, fir and alder. It is possible that the peat from within SSBE07 may represents a similar interstadial environment, possibly contemporary with those from the Hoxne Stratum C, tentatively correlated to MIS 11b (Ashton et al. 2008). However, with only one sample assessed from this deposit, this correlation is only tentative and there remains the possibility that it could be post MIS 11.

5 Potential

The pollen assemblages assessed from the A12 ATTT have yielded information on the Pleistocene environment of the area. The most conclusive results have been gained from borehole SNJA10 in QLEA 3, where a continuous sequence covering the early Hoxnian (MIS 11c) interglacial is well preserved. Pollen preservation was very good, which would be suitable for full pollen analysis, with the high sedimentation rate permitting additional samples to be taken through the sequence to produce a high-resolution vegetation record for this period. Other boreholes from this area, such as SNJA11 that was assessed by Whittaker (in Garcia-Suarez et al. 2021: 24-25), may also yield Hoxnian interglacial sequences, possibly covering different parts of the interglacial, as was the case at both Hoxne and Marks Tey where multiple sequences were studied, so should be considered as having high palaeoenvironment potential.

The sequence in SSBE09 appears to contain a late interglacial flora, which is tentatively correlated to Ho IV of MIS 11c, with the key indicator species being the presence of *Abies* along with increases in NAP up-sequence, indicating increasingly open conditions, and the appearance of a number of taxa commmonly associated with cooler climatic conditions. The high amounts of PQS within each sample, coupled with low pollen concentrations and some poor pollen preservation, mean that these sequences also likely suffer with some taphonomic issues, including derived inwashed pollen containing reworked pollen from earlier deposits, as well as differential preservation of some pollen types. Even after accounting for these taphonomic biases, the pollen sequence from SSBE09 shows a number of vegetation changes through the sequence that can be aligned with the late MIS 11 biostratigraphic record. Further pollen work could be undertaken on this sequence, though analysis counts would be limited to c. 250 TLP due to low pollen concentrations. However, any further pollen work should be considered alongside opportunities to date the sequence, using a technique suitable for deposits expected to exceed 400ka, such as post-infrared infrared stimulated luminescence (post-IR IRSL) on the K-feldspar mineral fraction.

The organic deposit samples in SSBE07 is shallower than the SSBE09 sequence, and therefore assumed to be younger. Although only a single sample was assessed from this deposit, it shows some similarities to the Stratum C deposits from Hoxne and might represent an MIS 11b deposit; however, in the absence of any further investigations, this correlation remains speculative. Dating of this sequence would be useful to establish if it is MIS 11b and, if so, could help strengthen the interpretation by Ashton et al. (2008) of the Hoxne Stratum C deposit.

The test pit samples from QLEA 1 share a number of similarities with the QLEA 3 sequence, notably the dominance of *Pinus*, *Picea* and *Abies* within the record, along with high Poaceae and Cyperaceae values in some samples. This might suggest that these deposits are also from the late Hoxnian period, though long lacustrine sequences would need to be sampled and investigated from this area to establish if such a correlation between sequences can be substantiated. The sample from TP2912 contains a pollen assemblage that is not distinctive of the Hoxnian only, and also shares some similarities with later Pleistocene interglacials, including MIS 9.

6 Recommendations

Pollen analysis should be undertaken on borehole SNJA10 from QLEA 3 (PQ8), with counts extended to a minimum of 400 TLP, and the number of samples from the sequence also increased. Scientific dating of this sequence should be considered as it could help to further constrain the age of the early Hoxnian interglacial, with significant benefits to other existent studies in the area, such as Marks Tey

(Turner 1970; Tye et al. 2016; Candy et al. 2021), Hoxne (West 1956; Ashton et al. 2008) and the eastern Essex fluvial and estuarine sequences of Roe (1999).

Further pollen investigations should be undertaken on the sequences in PQ8 close to SNJA10. This could take the form of further pollen assessment, allowing the best sequences to be identified and confirm if additional pollen analysis (in addition to SNJA10) is required.

No additional work is recommended on the test pit samples from QLEA 1, though further investigations of these lacustrine deposits, using boreholes rather than test pits, might reveal lacustrine deposits from which pollen analysis could be used to more conclusively establish the age of these features, which are mapped by the BGS as glaciolacustrine, though the available pollen data suggests this interpretation is incorrect.

Pollen analysis on the SSBE9 record from QLEA 3 (PX9) should be undertaken, with counts increased to 200 TLP and some increased sampling through the centre of the sequence. Any pollen analysis should be predicated on whether scientific dating can be undertaken on this sequence. While Optically Stimulated Luminescence (OSL) on quartz might yield useful dates, there is a good possibility that the sequence might be too old for this technique to be successful, and instead post-IR IRSL on the K-feldspar mineral fraction should be considered. The base of the sequence was not reached in the available borehole – deeper samples might reveal earlier HO IV or Ho III deposits that would enhance the interpretation of the sequence, as well as confirm the age of the entire lacustrine sequence.

Pollen analysis should be undertaken on the organic deposit from SSBE07, with counts extended to 400 TLP along with an increase in the number of samples from it. Sampling of the overlying lacustrine deposit should also be taken to permit comparison between the different sedimentary units. While dating of this deposit is also recommended, pollen analysis should also be undertaken even if it cannot be successfully dated as it might provide a unique interstadial deposit from the Middle to Late Pleistocene.

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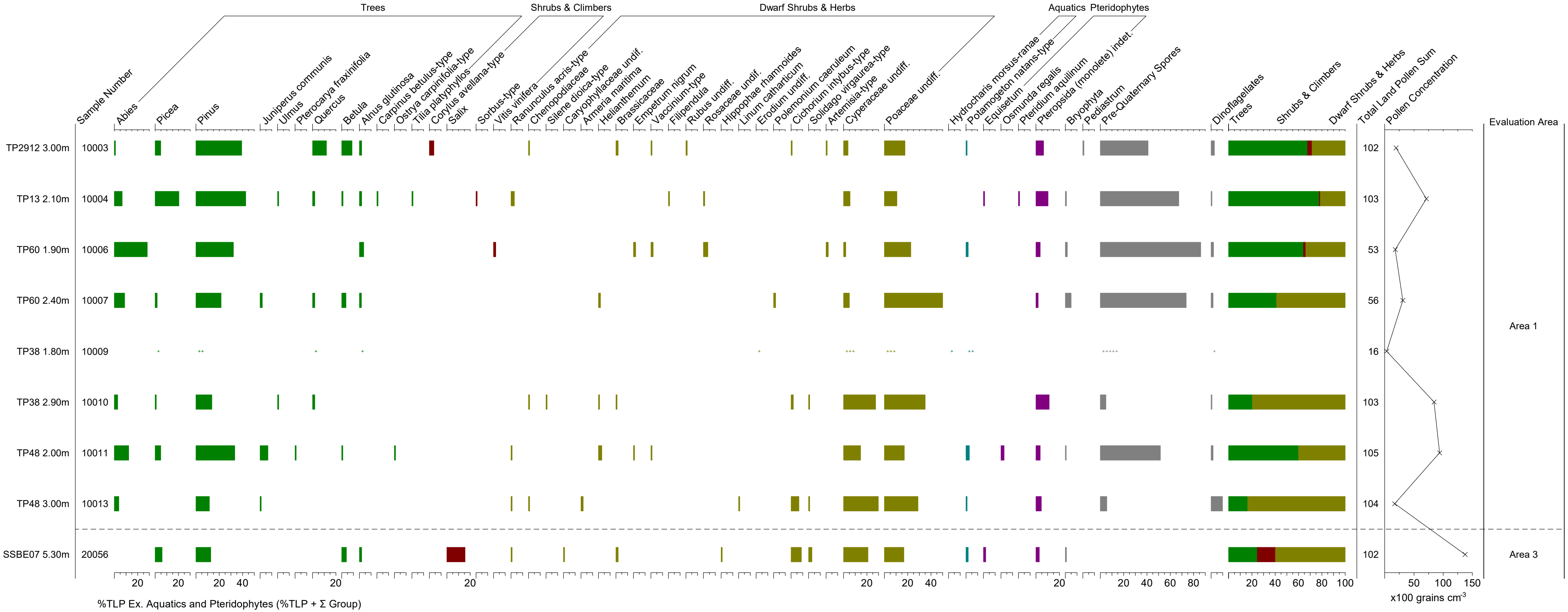
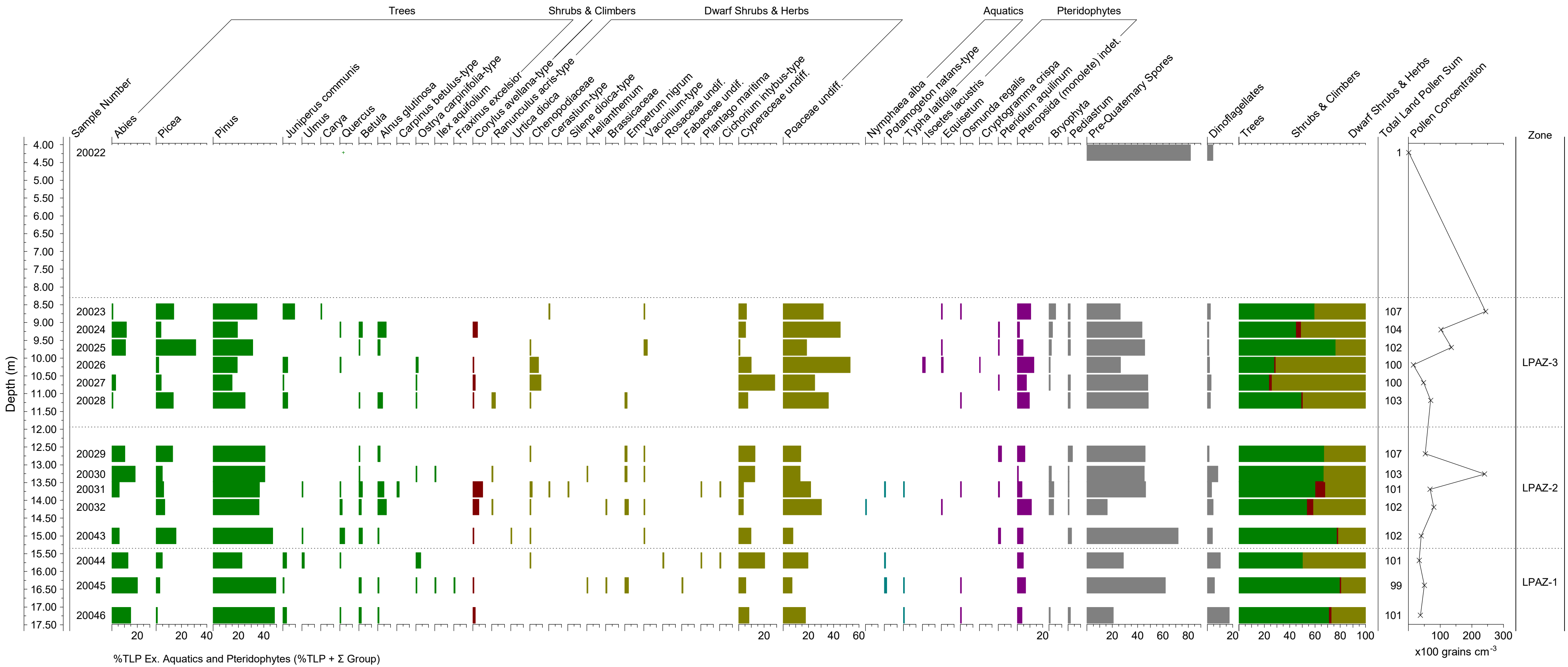
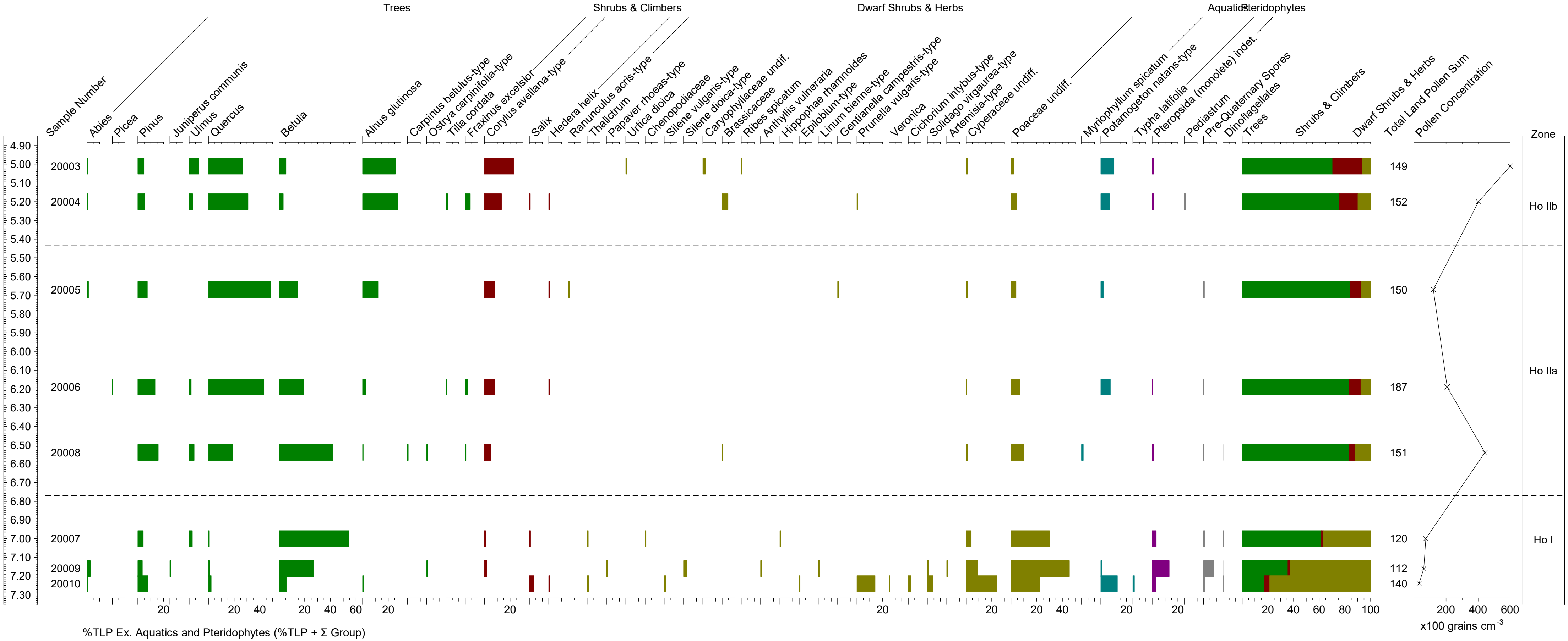

Trees
Shrubs & Climbers
Dwarf Shrubs & Herbs
Aquatics
Pteridophytes
Sample Number
Abies
Picea
Pinus
Juniperus communis
Ulmus
Pterocarya fraxinifolia
Quercus
Betula
Alnus glutinosa
Carpinus betulus-type
Ostrya carpinifolia-type
Tilia platyphyllos
Corylus avellana-type
Salix
Sorbus-type
Vitis vinifera
Ranunculus acris-type
Chenopodiaceae
Silene dioica-type
Caryophyllaceae undif.
Armeria maritima
Helianthemum
Brassicaceae
Empetrum nigrum
Vaccinium-type
Filipendula
Rubus undiff.
Rosaceae undif.
Hippophae rhamnoides
Linum catharticum
Erodium undiff.
Polemonium caeruleum
Cichorium intybus-type
Solidago virgaurea-type
Artemisia-type
Cyperaceae undiff.
Poaceae undiff.
Hydrocharis morsus-ranae
Potamogeton natans-type
Equisetum
Osmunda regalis
Pteridium aquilinum
Pteropsida (monolete) indet.
Bryophyta
Pediastrum
Pre-Quaternary Spores
Dinoflagellates
Trees
Shrubs & Climbers
Dwarf Shrubs & Herbs
Total Land Pollen Sum
Pollen Concentration
Evaluation Area
TP2912 3.00m 10003 102
TP13 2.10m 10004 103
TP60 1.90m 10006 53
TP60 2.40m 10007 56
TP38 1.80m 10009 16
TP38 2.90m 10010 103
TP48 2.00m 10011 105
TP48 3.00m 10013 104
SSBE07 5.30m 20056 102
Area 1
Area 3
20
20
20 40
20
20
20
20 40
20
20 40 60 80
20 40 60 80 100
50 100 150
%TLP Ex. Aquatics and Pteridophytes (%TLP + Σ Group)
x100 grains cm-3



Trees
Shrubs & Climbers
Dwarf Shrubs & Herbs
Aquatics
Pteridophytes
Sample Number
Abies
Picea
Pinus
Juniperus communis
Ulmus
Carya
Quercus
Betula
Alnus glutinosa
Carpinus betulus-type
Ostrya carpinifolia-type
Ilex aquifolium
Fraxinus excelsior
Corylus avellana-type
Ranunculus acris-type
Urtica dioica
Chenopodiaceae
Cerastium-type
Silene dioica-type
Helianthemum
Brassicaceae
Empetrum nigrum
Vaccinium-type
Rosaceae undif.
Fabaceae undif.
Plantago maritima
Cichorium intybus-type
Cyperaceae undiff.
Poaceae undiff.
Nymphaea alba
Potamogeton natans-type
Typha latifolia
Isoetes lacustris
Equisetum
Osmunda regalis
Cryptogramma crispa
Pteridium aquilinum
Pteropsida (monolete) indet.
Bryophyta
Pediastrum
Pre-Quaternary Spores
Dinoflagellates
Trees
Shrubs & Climbers
Dwarf Shrubs & Herbs
Total Land Pollen Sum
Pollen Concentration
Zone
Depth (m)
20022
20023
20024
20025
20026
20027
20028
20029
20030
20031
20032
20043
20044
20045
20046
LPAZ-3
LPAZ-2
LPAZ-1
x100 grains cm-3
%TLP Ex. Aquatics and Pteridophytes (%TLP + Σ Group)



Trees
Shrubs & Climbers
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Sample Number
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Tilia cordata
Fraxinus excelsior
Corylus avellana-type
Salix
Hedera helix
Ranunculus acris-type
Thalictrum
Papaver rhoeas-type
Urtica dioica
Chenopodiaceae
Silene vulgaris-type
Silene dioica-type
Caryophyllaceae undiff.
Brassicaceae
Ribes spicatum
Anthyllis vulneraria
Hippophae rhamnoides
Epilobium-type
Linum bienne-type
Gentianella campestris-type
Prunella vulgaris-type
Veronica
Cichorium intybus-type
Solidago virgaurea-type
Artemisia-type
Cyperaceae undiff.
Poaceae undiff.
Myriophyllum spicatum
Potamogeton natans-type
Typha latifolia
Pteropsida (monolete) indet.
Pediastrum
Pre-Quaternary Spores
Dinoflagellates
Trees
Shrubs & Climbers
Dwarf Shrubs & Herbs
Total Land Pollen Sum
Pollen Concentration
Zone
Depth (m)
4.90
5.00
5.10
5.20
5.30
5.40
5.50
5.60
5.70
5.80
5.90
6.00
6.10
6.20
6.30
6.40
6.50
6.60
6.70
6.80
6.90
7.00
7.10
7.20
7.30
20003
20004
20005
20006
20008
20007
20009
20010
149
152
150
187
151
120
112
140
Ho IIb
Ho IIa
Ho I
20
20 40
20 40 60
20
20
20
20
20
20 40
20
20
20 40 60 80 100
200 400 600
%TLP Ex. Aquatics and Pteridophytes (%TLP + Σ Group)
x100 grains cm-3

Appendix 4

Amino-acid racemisation dating report

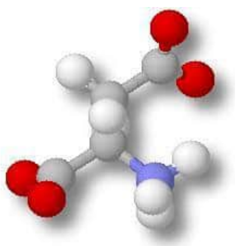
The following report was commissioned by Headland Archaeology on behalf of Costain. It is presented here in an unedited form as received by Prof. Kirsty Penkman, University of York. As agreed with Costain, any implications of these data - beyond those already presented in the report – and any further assessment will be provided as an addendum.

A12 (Essex) project

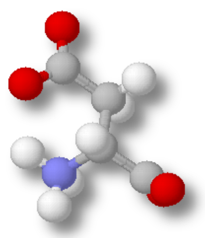
AA geochronology report: Jan 2022

Sam Presslee & Kirsty Penkman

neaar.co.uk



L-Asp



D-Asp

Summary

This report documents the attempts to conduct amino acid racemization analysis for age estimation on the intra-crystalline protein fraction of slug plates and *Bithynia tentaculata* opercula from a series of sites excavated as part of the A12 (Essex) investigation commissioned by Headland Archaeology. All the *Bithynia* opercula showed closed system behaviour, with the amino acid data indicating a correlation with MIS 11 (~400 ka) for the deposits. Less comparator material is available for slug plates, but the slug plates from the horizon analysed showed very low levels of degradation, indicating an age younger than the last interglacial (MIS 5e, ~125).

Keywords

Amino acid racemization
Geochronology

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1. Introduction

This project contributes to the development of a chronology to constrain some deposits from the A12 area, Essex. This report details attempts to obtain age estimates on fossil shell material using amino acid geochronology at the NEaar laboratory at the University of York. This involves isolating the intra-crystalline protein fraction of the opercula of terrestrial molluscs, for which an excellent and growing database of protein degradation data has recently been assembled. Slug plates, for which there is more limited comparator material, were also analysed.

1.1 Amino Acid Geochronology

The presence of proteins in archaeological remains has been known for some time. Nearly seventy years ago Abelson (1954) separated amino acids from subfossil shell, and suggested the possibility of using the kinetics of the degradation of amino acids as the basis for a dating method (Abelson, 1955). Early methods of chemical separation, using ion-exchange liquid chromatography, are able to separate the enantiomers of one amino acid found in proteins, L-isoleucine (L-Ile, I), from its most stable diastereoisomer alloisoleucine (D-aile, A). By analysing the total whole shell protein content within non-marine mollusc shells from UK interglacial sites, an amino acid geochronology was developed using the increase in A/I, with correlations made with the marine oxygen isotope warm stages (Bowen *et al.,* 1989).

A revised technique of amino acid analysis has been developed for geochronological purposes (Penkman *et al*., 2008; 2011; 2013), combining a new reverse-phase high pressure liquid chromatography method of analysis (Kaufman & Manley, 1998) with the isolation of an "intra-crystalline" fraction of amino acids by bleach treatment (Sykes *et al.,* 1995). This combination of techniques results in the analysis of D/L values of multiple amino acids from the chemically-protected protein within the biomineral; enabling both decreased sample sizes and increased reliability of the analysis.

1.2 Theory

Amino acids, the building blocks of proteins, occur as two isomers that are chemically identical, but optically different. These isomers are designated as either D (dextrorotary) or L (laevorotary) depending upon whether they rotate plane polarised light to the right or left respectively (Fig. 1). In living organisms the amino acids in protein are almost exclusively L and the D/L value approaches zero[1]. The potential application to geochronology arises because after death amino acid isomers start to interconvert, a process

[1] D-amino acids are synthesised by some organisms; they are found free in invertebrate body fluids where they play a role in osmoregulation and can occur peptide bound in bacterial peptidoglycan, where part of their function is resistance to proteases.

commonly termed racemization. In time the D/L value approaches one. The proportion of D to L amino acids is therefore an estimate of the extent of protein degradation, and if this is assumed to be predictable over time can be used to estimate the age of a sample. Other indications of protein decomposition, such as the degradation of unstable amino acids, can also be used to estimate age.

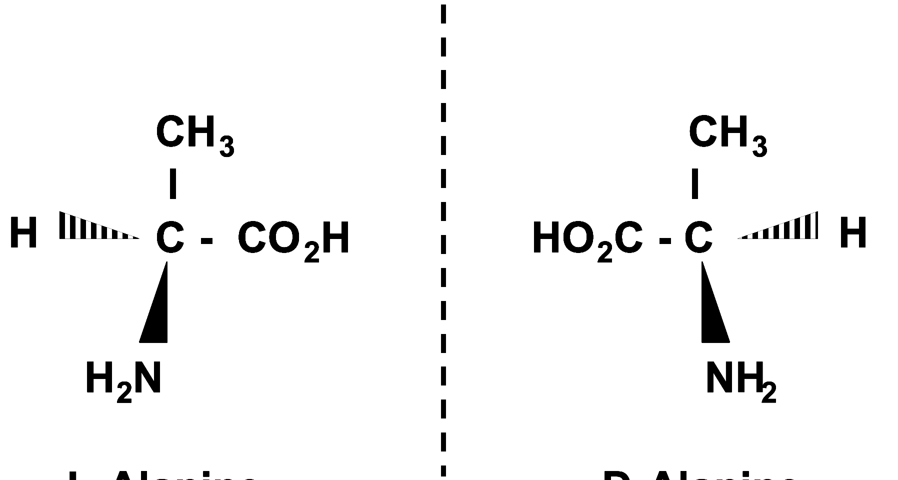

Figure 1: L- and D- amino acid structure

1.3 Mechanisms of racemization

The rate of racemization is governed by a variety of factors, most of which have been studied in detail only for free amino acids. North East amino acid racemization (NEaar) analyse the intra-crystalline amino acid fraction and in this closed system in which other factors (water content, concentration of cations, pH) are constant, the extent of racemization is a function of time and temperature. Over a small geographical area, such as that represented in this study, it can be assumed that the integrated temperature histories are effectively the same. Any differences in the extent of decomposition of protein between the samples are therefore age-dependent.

1.4 Intra-crystalline protein decomposition

The organic matter existing within individual crystals (intra-crystalline fraction) is believed to be a more reliable substrate for analysis than the whole shell (Sykes *et al.*, 1995; Penkman *et al.*, 2008). The initial bleaching step in the recovery of the intra-crystalline fraction removes both secondary contamination and the organic matrix of the shell. This organic matrix degrades and leaches at an unpredictable rate over time, leading to variation in the concentration and D/L of the amino acids. The molluscan racemisation data reported therefore contrasts with some previous work that examined D/L values from whole mollusc shells, containing both intra- and inter-crystalline material.

This isolation of the intra-crystalline fraction is believed to provide a closed system repository for the amino acids during the burial history of the shell.

Figure 2 shows a schematic of the intra-crystalline fraction with respect to the whole shell. Only the amino acids within the intra-crystalline fraction are protected from the action of external rate-affecting factors (except temperature), contamination by exogenous amino acids and leaching.

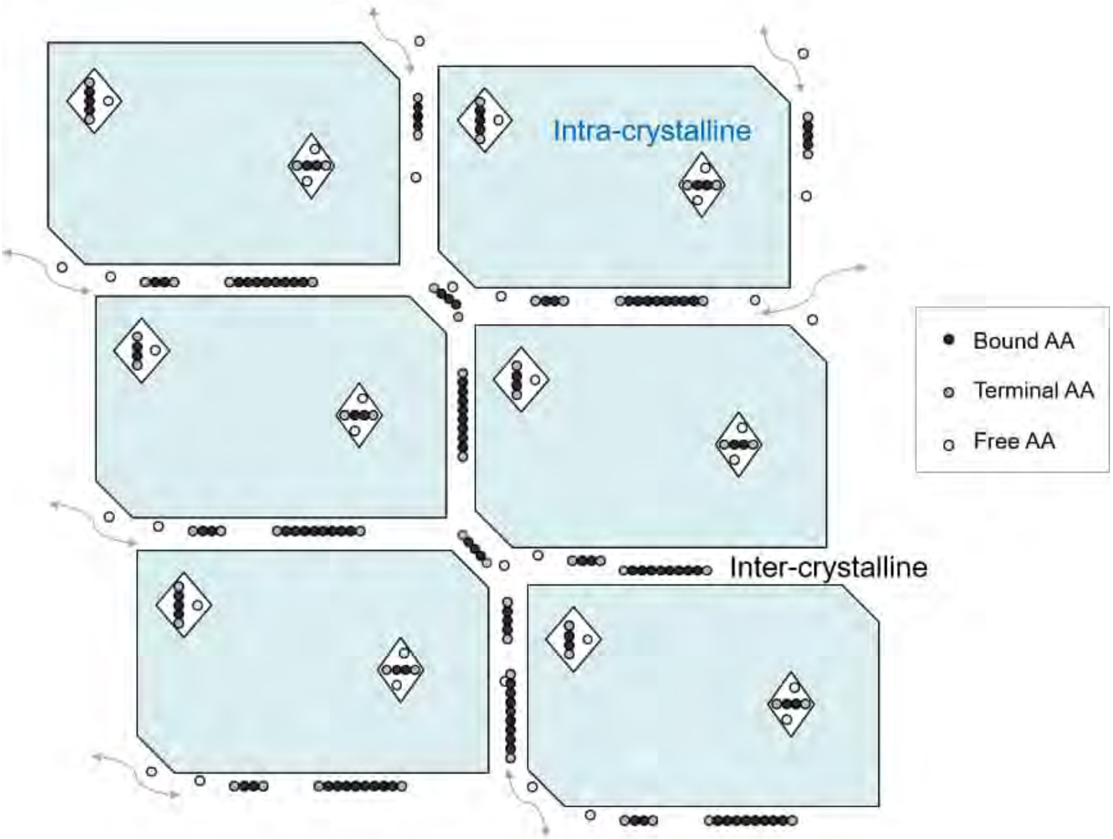

Figure 2: Schematic of intra-crystalline amino acids entrapped within carbonate crystallites. Unlike the proteins of the organic matrix between the crystallites (inter-crystalline), which can leach from the shell with time, in some biominerals a portion of the amino acids are trapped within the crystallites (these appear as faceted voids in Gries et al. (2009)). This is termed the 'intra-crystalline' fraction, and has been shown to effectively form a closed system. The intra-crystalline protein degradation should therefore be predictable and only dependent on time and temperature.

Initially amino acid geochronology studies targeted a single amino acid racemisation (AAR) reaction, that of L-isoleucine to D-alloisoleucine (A/I), due to the technical ease of separation and its slow rate of racemisation. The approach used in this study diverges from this, as dates are derived from the analysis of multiple amino acids. Whilst racemisation rates differ between individual amino acids, they should be highly correlated in a closed system (Penkman *et al*., 2011). The pattern of decomposition appears to be different between genera, requiring separate models for each genus studied.

In a closed system, it should be possible to predict the relationship between geological time and intra-crystalline protein decomposition, using not just racemisation but other measures of protein diagenesis, such as extent of hydrolysis and amino acid composition. This leads to the concept of age estimation using the extent of overall intra-crystalline protein degradation

(IcPD), which links the hydrolysis, racemisation and decomposition of all the amino acids isolated by this method. The concept behind the IcPD is to combine multiple sources of information from a single sample to derive an overall measure of the extent of diagenesis of the protein in that fossil (Penkman *et al*., 2011; 2013). Subsequently palaeotemperature information can be included and estimates made of the link between degradation and absolute age in environments with fluctuating temperatures. The results presented here do not incorporate any palaeotemperature information and are presented simply as a relative dating tool.

2. Materials and Method

2.1 Materials

Biomineral material was analysed from 4 horizons. Two different types of biomineral were analysed: slug plates and *Bithynia* opercula. 3 individual samples were prepared for each horizon.

NEaar	Sample name	Material	Site identifier
14187-9	ESA12Sp2m-1-3	slug plate	Essex A12, 14.1 (Bolton area); 10002; 2912-02; 2 m
14190-2	ESA12Bo1.4m-1-3	*Bithynia* opercula	Essex A12, 157.3 (Brice West area); 10016; 1030-03; 1.4 m
14193-5	ESA12Bo2.4m-1-3	*Bithynia* opercula	Essex A12, 157.3 (Brice West area); 10018; 1030-03; 2.4 m
14196-8	ESA12BVo3.1m-1-3	*Bithynia* opercula	Essex A12, 157.3 (Brice West area); 10020; 1030-03; 3.1 m

The only material for which full closed system tests and an aminostratigraphic framework had been developed was the *Bithynia* opercula. Small pilot studies had previously been undertaken on slug plates.

2.2 Sample Preparation

Sample preparation involves a series of steps (summarised in Fig. 3) to clean the sample, powdering to enable effective bleaching and therefore isolation of the intra-crystalline fraction, and then preparation for the amino acid analysis.

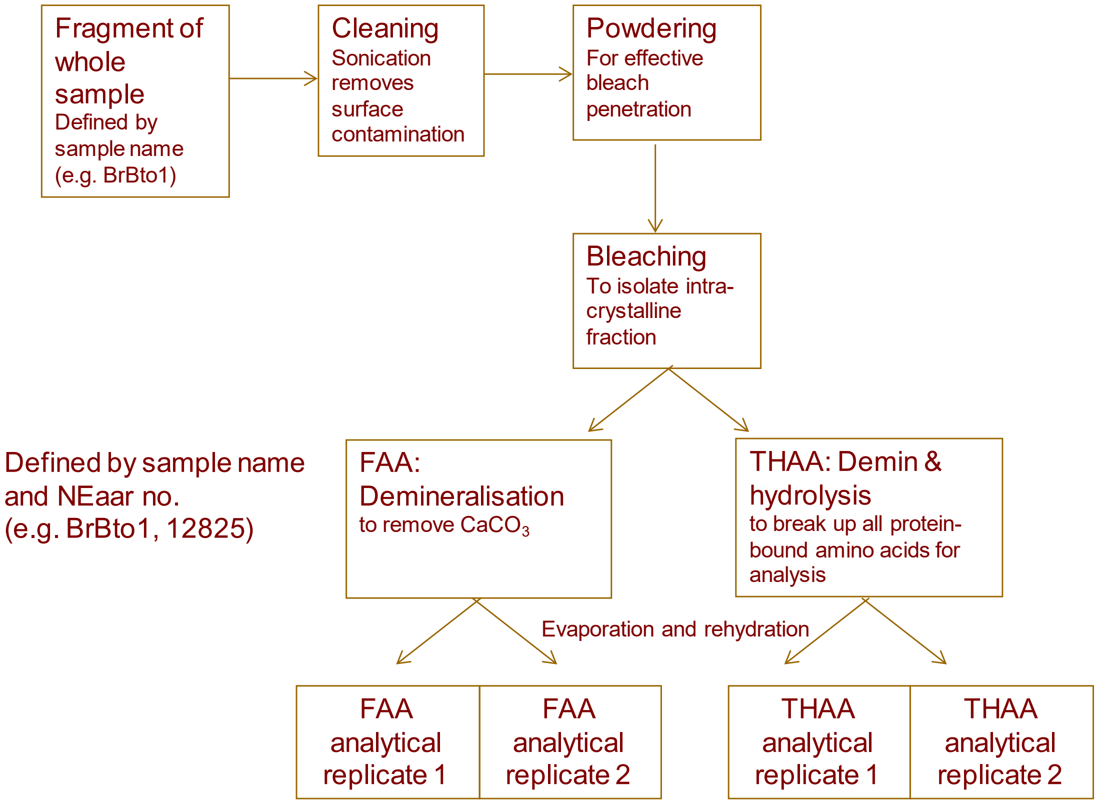

Figure 3: Preparation protocol.

Individual biominerals were sonicated and rinsed several times in HPLC-grade water. The shells were then crushed to <100 µm.

2.2.1 Bleaching

50 µL of 12% solution of sodium hypochlorite at room temperature was added to each milligram of powdered sample and the caps retightened. The powders were bleached for 48 hours with a shake at 24 hours. The bleach was pipetted off and the powders were then rinsed five times in HPLC-grade water and a final rinse in HPLC-grade methanol (MeOH) to destroy any residual oxidant by reaction with the MeOH. The bulk of the MeOH was pippetted off and the remainder left to evaporate to dryness.

2.2.2 Hydrolysis

Protein bound amino acids are released by adding an excess of 7 M HCl to the bleached powder and hydrolysing at 110°C for 24 hours (H*).

20 µL per milligram of sample of 7 M hydrochloric acid (HCl) was added to each hydrolysis (H*, THAA) sample in sterile 2 ml glass vials, were flushed with nitrogen for 20 seconds to prevent oxidation of the amino acids, and were then placed in an oven at 110°C for 24 hours. After 10 minutes in the oven, the caps of the 2 mL vials were re-tightened to prevent the escape of vapour.

After 24 hours, the samples were dried in a centrifugal evaporator overnight.

2.2.3 Demineralisation

Free amino-acid samples (F, FAA) were demineralised in cold 2 M HCl, which dissolves the carbonate but minimises the hydrolysis of peptide bonds, and then dried in the centrifugal evaporator overnight.

2.2.4 Rehydration

When completely dry, samples were rehydrated in a rehydration fluid solution containing 0.01 mM HCl, 0.01 mM L-homo arginine internal standard, and 0.77 mM sodium azide at a pH of 2. Each vial was vortexed for 20 seconds to ensure complete dissolution, and checked visually for undissolved particles.

Approximately 15 µL of rehydrated sample was then placed in a sterile, labelled 2 mL autosampler vial containing a glass insert, capped and then placed on the autosampler tray of the HPLC.

For each set of sub-samples a blank vial was included at each stage to account for any background interference from the bleach, acid, or rehydration fluid added to the samples.

2.3 Analysis of Free and Hydrolysed Amino Acids

Amino acid enantiomers were separated by reverse phase high pressure liquid chromatography (RP-HPLC). NEaar uses a modified method of Kaufman and Manley (1998) using an automated RP-HPLC system. This method achieves separation and detection of L and D isomers in the sub-picomole range.

Samples (2 µL) were derivitised with 2.2 µL *o*-phthaldialdehyde and thiol *N*-isobutyryl-L-cysteine automatically prior to injection. The resulting diastereomeric derivatives were then separated on Hypersil C_{18} BDS column (sphere d. 5 µm; 250 x 3 mm) using a linear gradient of a sodium acetate buffer (23 mM sodium acetate, 1.3 mM Na_2EDTA; pH 6), methanol, and acetonitrile on an integrated 1100 liquid chromatograph (Agilent, USA).

Individual amino-acids are separated on a non-polar stationary phase according to their varied retention times: a function of their mass, structure, and hydrophobicity. A fluorescence detector is used to determine the concentrations of each amino-acid and record them as separate peaks on a chromatogram. A gradient elution programme was used to keep the retention time to below 120 minutes.

The fluorescence intensity of derivitised amino acids was measured (Ex = 230 nm, Em = 445 nm) in each sample and normalised to the internal standard. All samples were run in duplicate alongside blank extracts that had been subjected to identical preparation procedures. Quantification of individual amino acids was achieved by comparison with the standard amino acid mixture. External standards containing a variety of D- and L- amino acids were analyzed at the beginning and end of every run, and every ten samples.

The L and D isomers of 10 amino acids were routinely analysed. During preparative hydrolysis both asparagine and glutamine undergo rapid irreversible deamination to aspartic acid and glutamic acid respectively (Hill, 1965). It is therefore not possible to distinguish between the acidic amino acids and their derivatives and they are reported together as Asx and Glx.

3. Results and Discussion

The extent of racemization in five amino acids (D/L of Asx, Glx, Ser, Ala and Val), along with the ratio of the concentration of Ser to Ala ([Ser]/[Ala]), are reported for both the FAA and THAA fractions (Appendix 3). These indicators of protein decomposition have been selected as their peaks are cleanly eluted with baseline separation and they cover a wide range of rates of reaction. It is expected that with increasing age, the extent of racemization (D/L) will increase whilst the [Ser]/[Ala] value will decrease, due to the decomposition of the unstable serine.

The data obtained from Asx, Glx, serine (Ser), alanine (Ala) and valine (Val) are discussed in detail below. If the amino acids were contained within a closed system, the relationship between the FAA and the THAA fractions should be highly correlated, with non-concordance enabling the recognition of compromised samples (Preece & Penkman, 2005). The plot of FAA to THAA data from each sample can also be used as a relative timescale, with younger samples falling towards the bottom left corner of the graph and older samples falling towards the upper right corner, along the line of expected decomposition. The data from the A12 samples have been plotted in this way below for each of the amino acids, alongside data obtained from other MIS 5e, 7, 9, 11 and Cromerian sites from the UK with independent geochronology (see Penkman *et al*., 2011 & 2013 for details).

3.1 *Bithynia* opercula

Bithynia opercula are mineralised in the form of calcite, and this mineralogically stable form of calcium carbonate has been shown to provide a closed system repository for the intra-crystalline amino acids in opercula as old as the Eocene (Penkman *et al*., 2013).

Asx is one of the fastest racemizing of the amino acids discussed here (as it can racemize whilst still peptide bound; Collins *et al.,* 1999; Demarchi *et al*., 2013). This enables good levels of resolution at younger age sites, but decreased resolution beyond MIS 7. The D/L Asx data from all of the opercula samples from the 3 sites are very similar to those from sites correlated with MIS 9 and MIS 11 (Fig. 4).

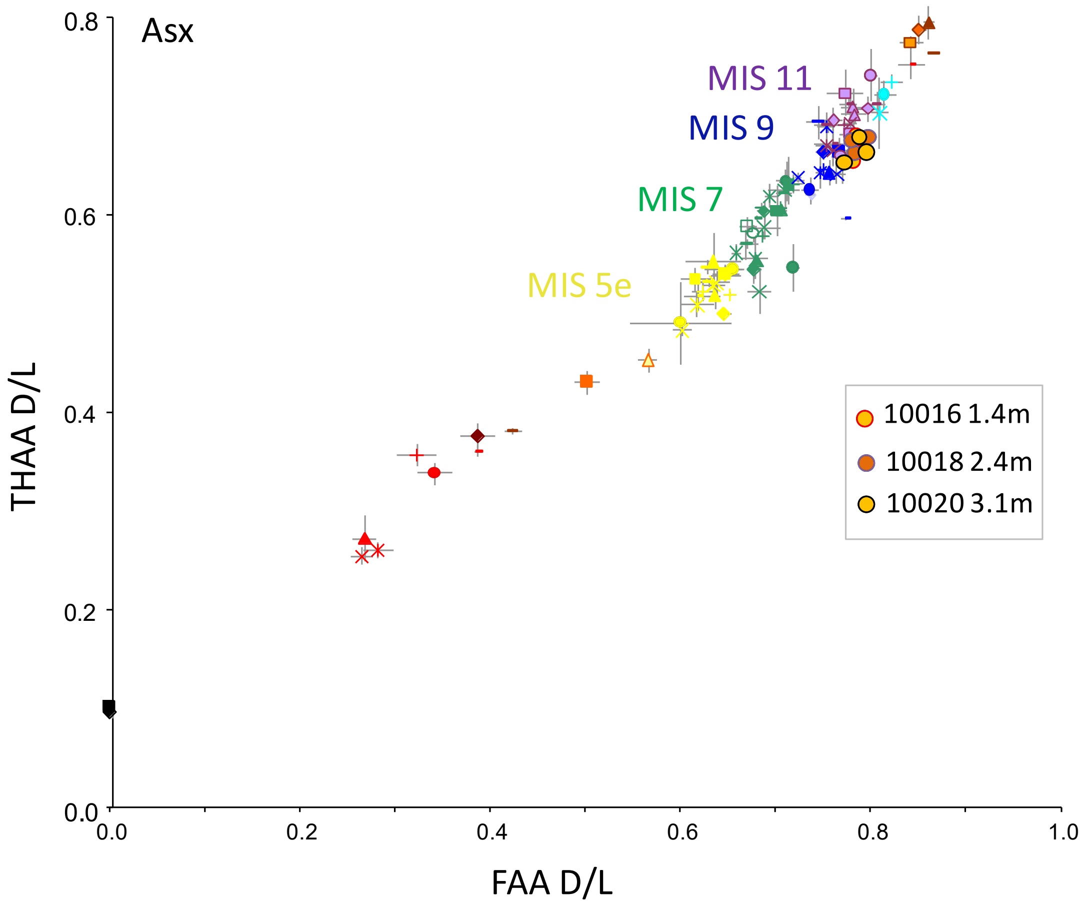

Figure 4: THAA D/L vs FAA D/L for Asx in *Bithynia* opercula from the A12 project, compared to data obtained from opercula from UK sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.

Glx is one of the slower racemizing amino acids discussed here and so the level of resolution from young sites is less than that seen with faster racemizing amino acids such as Asx. It is noteworthy that Glx has a slightly unusual pattern of racemization in the free form, due to the formation of a lactam (see Walton, 1998). This results in difficulties in measuring Glx in the Free form, as the lactam cannot be derivitized and is therefore unavailable for analysis; that can result in relative low precision for the FAA D/L, particularly in younger samples.

The Glx D/L values from the A12 sites for four of the samples show values within the range of those expected from sites in age between MIS 9 and 11 (Fig. 5). There is a larger than expected spread in the data from the 10018 2.4m samples.

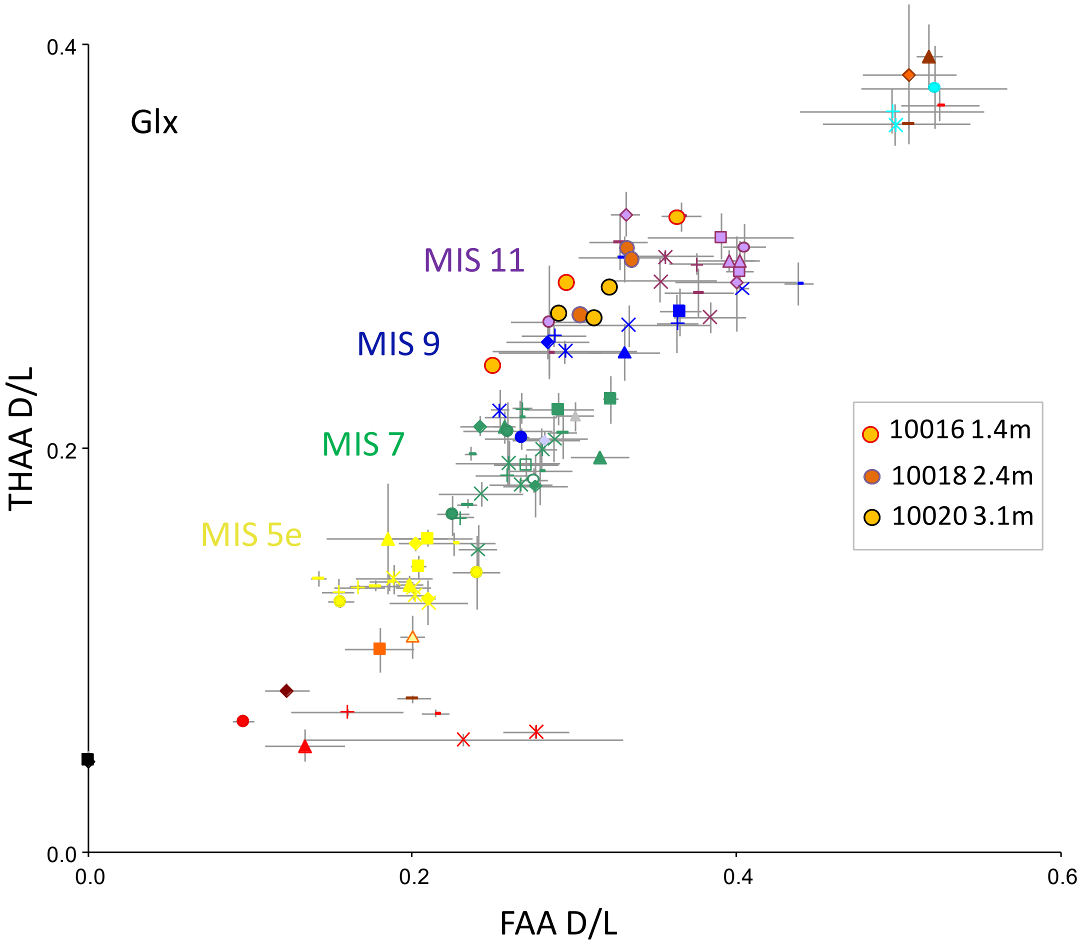

Figure 5: THAA D/L vs FAA D/L for Glx in *Bithynia* opercula from the A12 sites, compared to data obtained from opercula from UK sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.

Alanine (Ala) is a hydrophobic amino acid, whose concentration is partly contributed from the decomposition of other amino acids (notably serine). Ala racemises at an intermediate rate, so the most useful amino acid for distinguishing samples at these timescales. The results for Ala are similar to that seen in the other amino acids (Fig. 6), but show a higher level of resolution and support firmer correlation of the material with MIS 11.

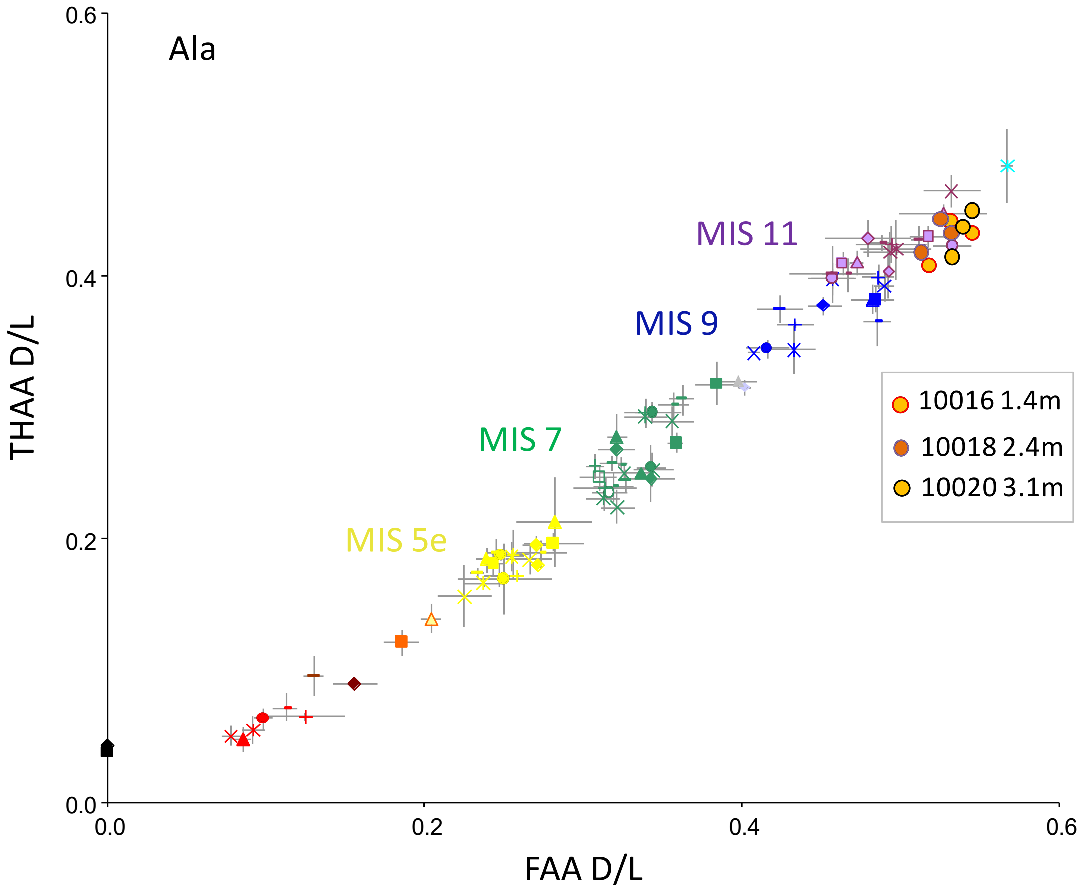

Figure 6: THAA D/L vs FAA D/L for Ala in *Bithynia tentaculata* opercula from the A12 project, compared to data obtained from opercula from UK sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.

Valine has extremely low rates of racemisation, and as the concentration of Val is quite low, the difficulty of measuring the D/L accurately results in higher variability. It does however still prove useful for age discrimination within material of Middle Pleistocene age. The Val D/L in the FAA and the THAA fractions again support the other amino acids (Fig. 7), with the samples clustering within MIS 11, although an early MIS 9 age could not be ruled out using this amino acid.

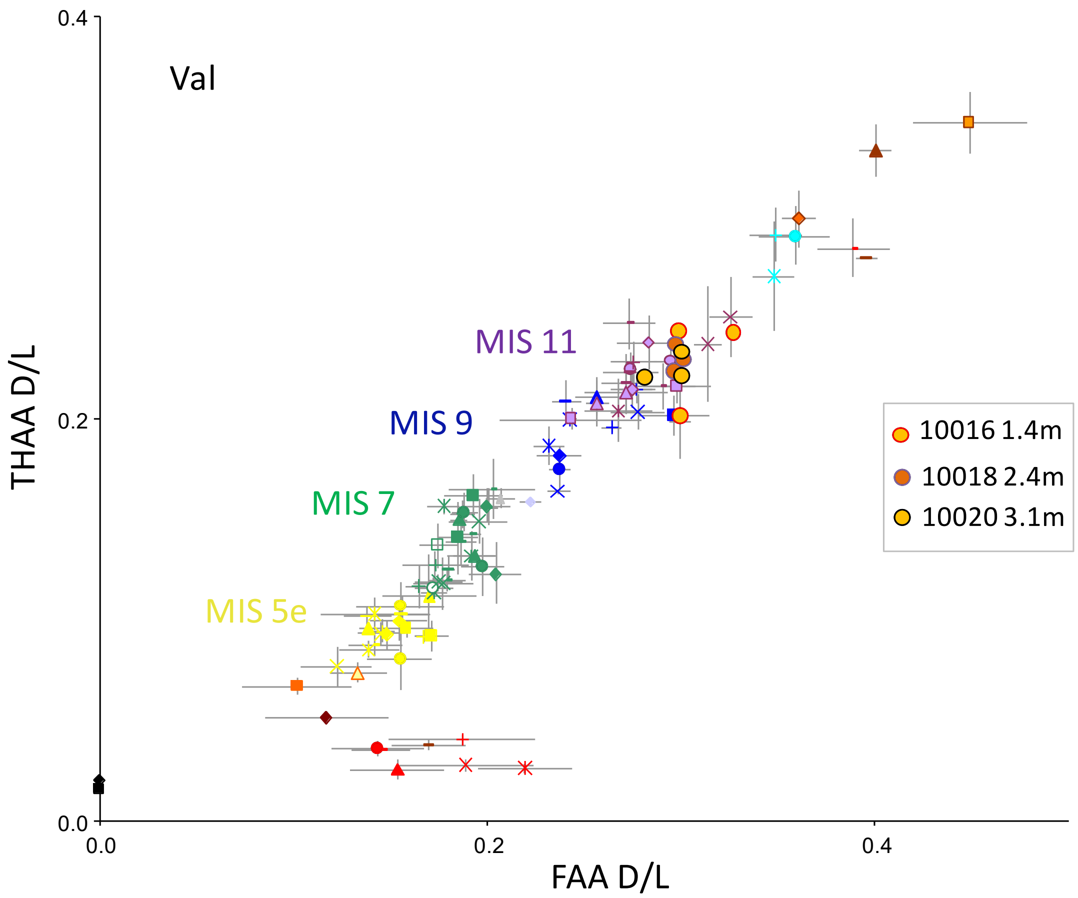

Figure 7: THAA D/L vs FAA D/L for Val in *Bithynia tentaculata* opercula from the A12 sites, compared to data obtained from opercula from UK sites correlated with MIS 5e, MIS 7, MIS 9 and MIS 11.

3.2 Slug plates

The internal shells of slugs (slug plates) are mineralised in the form of calcite, and therefore may provide a diagenetically stable biomineral for amino acid analysis. Unfortunately, it is often impossible to identify slug plates to genus level, which may impact on the variability of the IcPD reactions. Some pilot work has been undertaken on isolation of the intra-crystalline fraction of slug plates, but the comparator dataset is much more limited than that from the *Bithynia* opercula.

After bleaching, a fraction of amino acids remained, which indicates that this species does contain intra-crystalline material. Whether this intra-crystalline fraction comprises a closed system can be tested through high-temperature experiments (e.g. Penkman *et al*., 2008), but in the absence of this, certain characteristics can be explored. In order to show the general disposition of the data, each replicate is plotted for this biomineral (Fig. 8). A correlation between the FAA and THAA D/Ls is observed (Fig. 8), which indicates potential closed-system behaviour for this biomineral. There is quite a high degree of variability between samples from the same site, which may due to multiple genera being analysed.

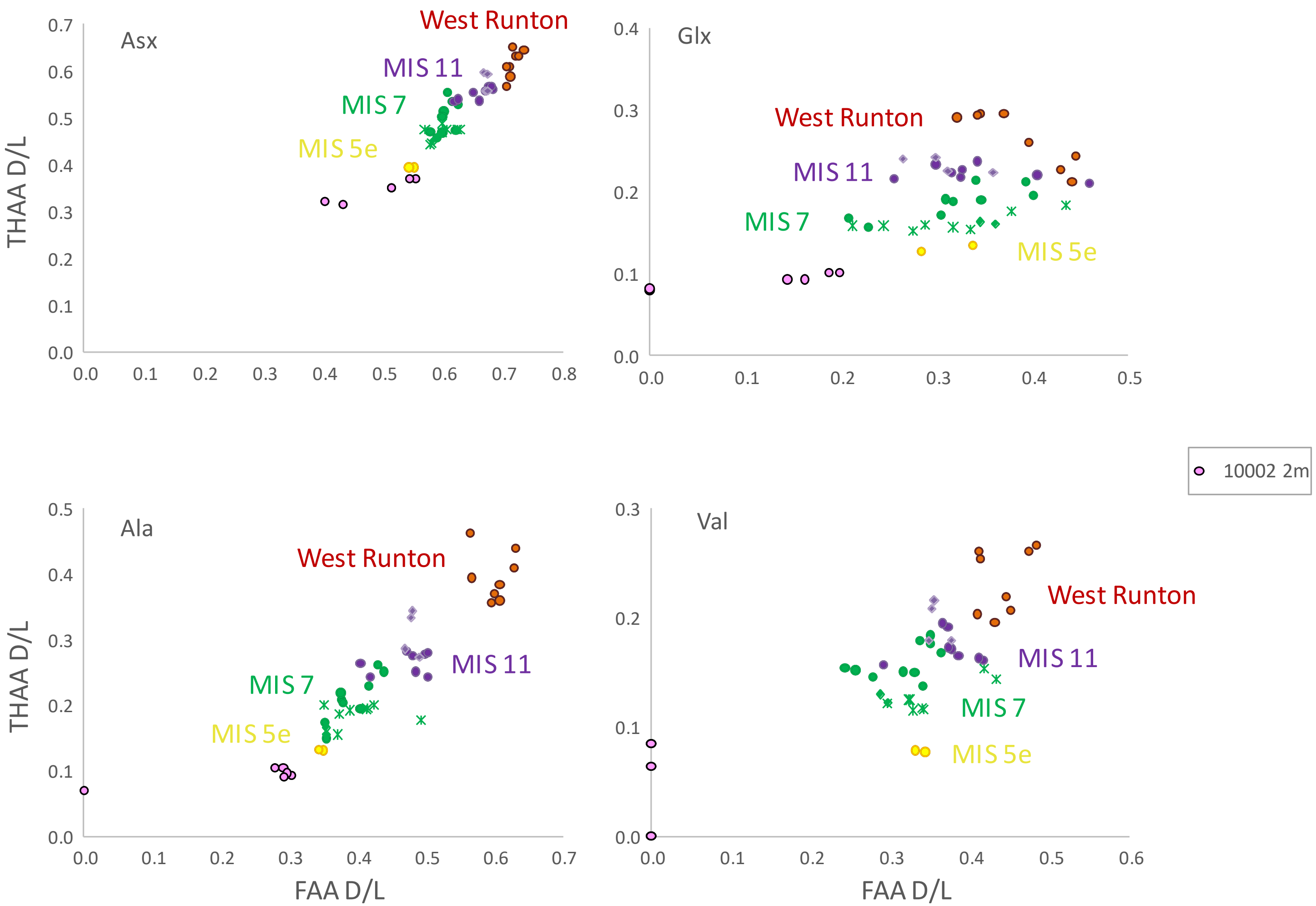

Figure 8: THAA D/L vs FAA D/L for Asx, Glx, Ala and Val in slug plates from the A12 sites, compared to data obtained from slug plates from UK sites correlated with MIS 5e (yellow), MIS 7 (green), MIS 9 (blue) and MIS 11 (purple).

However, this first IcPD data from fossil slug plates indicates that the material analysed from the A12 project (from 10002, 2 m), shows very low levels of degradation, indicating an age younger than the last interglacial (the youngest comparator material analysed so far).

4. Conclusions

The amino acid data from the *Bithynia* opercula from the three horizons analysed from the A12 project (10016, 1.4m; 10018, 2.4m; 10020, 3.1m) are very similar to the IcPD from UK sites correlated with MIS 11. The slug plate samples (from 10002, 2m) are much younger, showing lower levels of breakdown than the youngest comparator material from the last interglacial.

Acknowledgements

Thanks to David Keen and Richard Preece for supplying most of the samples for cross-comparison with the Bradwell dataset reported in this study. Funding from NERC, English Heritage, the Wellcome Trust and the Leverhulme Trust enabled the master dataset of shell and opercula intra-crystalline protein degradation to be developed.

Appendix 1: Glossary

18MΩ water: The water has a resistivity of 18MΩ/cm, indicating a lack of ions.

HPLC grade water: In addition to low ion content, HPLC grade water has a low organic content (typically < 2 ppb).

Amino acids: the building blocks of proteins and consist of an alpha carbon atom (C_α) which has four different groups bonded to it: an amino group ($-NH_2$), a carboxyl group (-COOH), a hydrogen atom (-H), and a side chain, (often called an R group). About 20 amino acids normally occur in nature and some of these can undergo further modification (eg the hydroxylation of proline to hydroxyproline). The amino acids are commonly known by three letter codes (see Appendix 2: Abbreviations). They exist free in the cell, but are more commonly linked together by **peptide bonds** to form proteins, peptides, and sub-components of some other macromolecules (e.g. bacterial peptidoglycan).

Amino acid isomers: amino acids occur as two stereoisomers that are chemically identical, but optically different. These isomers are designated as either D (dextro-rotary) or L (laevo-rotary) depending upon whether they rotate plane polarised light to the right or left respectively. In living organisms the amino acids in protein are almost exclusively L and the D/L value approaches zero. Two amino acids, isoleucine and threonine, have two chiral carbon atoms and therefore have four stereoisomers each. As well as racemization, these two amino acids can undergo a process known as epimerization. The detection of the L-alloisoleucine epimer (derived from L-isoleucine) is possible by conventional ion-exchange chromatography, and was thus the most commonly used reaction pathway in geochronology before 1998.

Asx: Measurements of aspartic acid following hydrolysis also include asparagines, which decomposes to Asx. This combined signal of aspartic acid plus asparagine (Asp +Asn) is referred to as Asx.

D-amino acid: dextrorotary amino acid, formed following synthesis of the protein as it degrades over time (remember as “dead amino acid”).

IcPD: Conventional racemization analysis tends to report an allosioleucine / isoleucine (A/I or D/L value). This amino acid ratio has the advantage of being relative easy to measure and also sufficiently slow to be used to “date” sediments in the European Quaternary. Our IcPD approach utilises multiple amino acids, which increases the level of resolution and allows a cross-check on the sample’s behaviour. If an amino acid has an unusually low ratio (e.g. due to modern contamination) or unusually high racemization (e.g. due to inclusion of bacterial cell wall contaminants) either some or all of the amino acids will no longer fit to the idealized degradation model, indicating a compromised sample.

Enantiomers / optical isomers: mirror image forms of the same compound that cannot be superimposed on one another.

Epimerisation: the inversion of the chiral α-carbon atom.

Free amino acid fraction (FAA): The fraction of amino acids directly amenable to racemization analysis. Only amino acids which have already been naturally hydrolysed (over time) are measured. These are the most highly racemized amino acids.

Hydrolysis: A chemical reaction involving water leading to the breaking apart of a compound (in this case the breaking of peptide bonds to release amino acids).

L-amino acid: levorotary amino acid, the constituent form of proteins (remember as "living amino acid").

Peptide bond: an amide linkage between the carboxyl group of one amino acid and the amino group of another.

Racemization: the inversion of all chiral carbon atoms, leading to the decrease in specific optical rotation. When the optical rotation is reduced to zero, the mixture is said to be racemized.

Stereoisomers: molecules of the same compound that have their atoms arranged differently in space.

Total hydrolysable amino acid fraction (THAA): The extent of racemization of all amino acids in a sample, determined following aggressive high temperature hydrolysis with strong mineral acid, which has the effect of breaking apart all peptide bonds so that the total extent of racemization in all amino acids (both free and peptide bound) are measured.

Zwitterion: A dipolar ion containing ionic groups of opposite charge. At neutral pH the ionic form of amino acids which predominates is the zwitterion.

Appendix 2: Abbreviations used in this report

Abbreviation		AA 1-letter code	Number of chiral centres
AA	amino acid		
AAR	amino acid racemisation		
Ala	alanine	A	1
Arg	arginine	R	1
Asn	asparagine	N	1
Asp	aspartic acid	D	1
Asx	asparagine + aspartic acid		
FAA	free amino acids		
Gln	glutamine	Q	1
Glu	glutamic acid	E	1
Glx	glutamine + glutamic acid		
Gly	glycine	G	0
His	histidine	H	1
IBLC	N-isobutyryl-(L)-cysteine		
IcPD	intra-crystalline protein decomposition		
Ile	isoleucine	I	2
Leu	leucine	L	1
MeOH	methanol		
Met	methionine	M	1
OPA	ortho-phthaldialdehyde		
Phe	phenylalanine	P	1
RP-HPLC	reverse-phase high pressure liquid chromatography		
Ser	serine	S	1
THAA	total hydrolysable amino acids		
Thr	threonine	T	2
Tyr	tyrosine	Y	1
Val	valine	V	1

Appendix 3: AA data from the A12 Essex samples

NEaar no.	Sample name	Asx D/L	Glx D/L	Ser D/L	Ala D/L	Val D/L	[Ser]/[Ala]	Species	location
14187bF	ESA12SP2m-1	0.51	0.14	0.80	0.30	0.27	1.86	slug plate	Essex A12 14.1 10002 2912-02 2m
14187bF	ESA12SP2m-1	0.52	0.16	0.80	0.29	0.29	1.83	slug plate	Essex A12 14.1 10002 2912-02 2m
14187bH*	ESA12SP2m-1	0.35	0.09	0.39	0.09	0.06	0.88	slug plate	Essex A12 14.1 10002 2912-02 2m
14187bH*	ESA12SP2m-1	0.35	0.09	0.39	0.10	0.06	0.83	slug plate	Essex A12 14.1 10002 2912-02 2m
14188bF	ESA12SP2m-2	0.55	0.20	0.86	0.30	0.27	1.50	slug plate	Essex A12 14.1 10002 2912-02 2m
14188bF	ESA12SP2m-2	0.55	0.19	0.90	0.28	0.27	0.92	slug plate	Essex A12 14.1 10002 2912-02 2m
14188bH*	ESA12SP2m-2	0.37	0.10	0.40	0.09	0.06	0.79	slug plate	Essex A12 14.1 10002 2912-02 2m
14188bH*	ESA12SP2m-2	0.37	0.10	0.41	0.10	0.07	0.73	slug plate	Essex A12 14.1 10002 2912-02 2m
14189bF	ESA12SP2m-3	0.40	0.00	0.66	0.29	ND	1.95	slug plate	Essex A12 14.1 10002 2912-02 2m
14189bF	ESA12SP2m-3	0.43	0.00	0.68	0.00	ND	2.26	slug plate	Essex A12 14.1 10002 2912-02 2m
14189bH*	ESA12SP2m-3	0.32	0.08	0.32	0.09	0.05	0.77	slug plate	Essex A12 14.1 10002 2912-02 2m
14189bH*	ESA12SP2m-3	0.31	0.08	0.32	0.07	0.11	0.34	slug plate	Essex A12 14.1 10002 2912-02 2m
14190bF	ESA12B/VO1.4m-1	0.78	0.25	1.07	0.53	0.31	0.28	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14190bF	ESA12B/VO1.4m-1	0.78	0.25	1.01	0.51	0.29	0.28	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14190bH*	ESA12B/VO1.4m-1	0.65	0.25	0.68	0.41	0.20	0.28	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14190bH*	ESA12B/VO1.4m-1	0.65	0.24	0.65	0.40	0.20	0.27	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14191bF	ESA12B/VO1.4m-2	0.79	0.36	1.05	0.55	0.33	0.29	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14191bF	ESA12B/VO1.4m-2	0.79	0.37	1.08	0.54	0.33	0.29	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14191bH*	ESA12B/VO1.4m-2	0.68	0.31	0.74	0.44	0.24	0.30	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14191bH*	ESA12B/VO1.4m-2	0.67	0.31	0.76	0.43	0.24	0.28	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14192bF	ESA12B/VO1.4m-3	0.78	0.29	1.05	0.53	0.30	0.30	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14192bF	ESA12B/VO1.4m-3	0.79	0.30	1.09	0.53	0.30	0.32	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14192bH*	ESA12B/VO1.4m-3	0.68	0.28	0.77	0.45	0.24	0.29	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14192bH*	ESA12B/VO1.4m-3	0.68	0.28	0.77	0.44	0.25	0.29	*B. tent. op.*	Essex A12 157.3 10016 1030-03 1.4m
14193bF	ESA12B/VO2.4m-1	0.78	0.28	1.01	0.51	0.29	0.27	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14193bF	ESA12B/VO2.4m-1	0.79	0.32	1.09	0.51	0.30	0.25	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14193bH*	ESA12B/VO2.4m-1	0.66	0.26	0.68	0.42	0.23	0.28	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14193bH*	ESA12B/VO2.4m-1	0.66	0.27	0.71	0.41	0.22	0.26	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14194bF	ESA12B/VO2.4m-2	0.80	0.31	1.04	0.53	0.30	0.29	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14194bF	ESA12B/VO2.4m-2	0.80	0.35	1.08	0.53	0.30	0.27	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14194bH*	ESA12B/VO2.4m-2	0.68	0.30	0.75	0.44	0.24	0.29	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14194bH*	ESA12B/VO2.4m-2	0.68	0.30	0.73	0.44	0.23	0.28	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14195bF	ESA12B/VO2.4m-3	0.78	0.32	1.03	0.53	0.31	0.30	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14195bF	ESA12B/VO2.4m-3	0.78	0.35	1.03	0.53	0.30	0.29	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14195bH*	ESA12B/VO2.4m-3	0.67	0.29	0.73	0.44	0.23	0.31	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14195bH*	ESA12B/VO2.4m-3	0.67	0.30	0.74	0.43	0.23	0.29	*B. tent. op.*	Essex A12 157.3 10018 1030-03 2.4m
14196bF	ESA12B/VO3.1m-1	0.80	0.30	1.05	0.54	0.30	0.27	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14196bF	ESA12B/VO3.1m-1	0.80	0.32	1.07	0.54	0.30	0.26	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14196bH*	ESA12B/VO3.1m-1	0.66	0.26	0.67	0.44	0.22	0.30	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14196bH*	ESA12B/VO3.1m-1	0.66	0.27	0.66	0.43	0.22	0.29	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14197bF	ESA12B/VO3.1m-2	0.79	0.31	1.06	0.55	0.30	0.28	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14197bF	ESA12B/VO3.1m-2	0.79	0.33	1.06	0.54	0.30	0.27	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14197bH*	ESA12B/VO3.1m-2	0.68	0.28	0.73	0.45	0.23	0.28	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14197bH*	ESA12B/VO3.1m-2	0.67	0.28	0.73	0.44	0.24	0.27	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14198bF	ESA12B/VO3.1m-3	0.77	0.26	0.89	0.53	0.27	0.31	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14198bF	ESA12B/VO3.1m-3	0.77	0.33	0.90	0.53	0.29	0.29	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14198bH*	ESA12B/VO3.1m-3	0.66	0.26	0.35	0.42	0.22	0.44	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m
14198bH*	ESA12B/VO3.1m-3	0.65	0.27	0.35	0.41	0.22	0.44	*B. tent. op.*	Essex A12 157.3 10020 1030-03 3.1m

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Appendix 5

Mitigation recommendations

Constraining Excavations: Defining the extent of the 'Site'

If it is decided to mitigate the impact through full archaeological recovery, the area around the test pits would ned to be stripped to define the extent of the site. This will allow for a precisely designed and costed excavation phase. A detailed WSI will need to be agreed in advance to implemented if a site is found.

The aim of all excavation from this point is to recover a record detailed enough to be useful in recording site formation processes, past human behaviour and sedimentary/paleoenvironmental context.

The Main Excavation Phase: Lay Out and Structure

Careful site reduction should be undertaken, using a skilled machine driver using a flat-bladed ditching bucket, to remove archaeologically sterile deposits from immediately above the uppermost archaeological layer. In large sites consideration might also be given to leaving baulks of intact sediment across the site to provide at least a temporary record of the upper, overlying, stratigraphy. A full reduction of over-burden across a very large site might remove the opportunity to understand the structure of the full depositional sequence, features such as solution hollows, periglacial involutions and soft sediment deformation structure might be key in understanding post-depositional transformation of lower units, losing this record through over-zealous stripping is to be avoided.

Typically the area to be excavated could range between 20m^2 and 200m^2. At the larger end of this range, it will be wise to divide the site into a series of excavation areas or trenches, separated by 1m baulks. Each trench should be excavated at the same time in concert with each other. Once excavation of the trenches is complete, the baulks can be removed through hand-excavation following the same methodology for the rest of the site described below. The baulks will allow for the recovery of dating and palaeoenvironmental samples. Typical trench-areas could range from 5x5m to 10x10m in size. This will not only allow for a series of running sections across the site, for section recording and sampling, but also for the day-to-day management of the excavation in terms of excavation teams, supervising and recording.

Specific Excavation methodologies for High-Resolution 'Sites'

The methodology presented here allows for the recovery of datasets of all finds (stone, wood, bone, and antler artefacts, potential manuports and mammalian remains), and for their detailed recording in terms of position and context. The datasets derived from this excavation methodology should be adequate for answering questions relating both to site formation processes and past human behaviour.

Excavation Team Structure

Excavation should be coordinated by a qualified senior Palaeolithic archaeologist with demonstrable experience of excavating open air sites with varying degrees of preservation within the appropriate time-period and geographical area. They should be supported by one or more archaeologists, depending on the size of the site, with direct experience of excavating high-resolution Palaeolithic archaeology. These will each take responsibility for supervising excavators and recording teams for different parts of the site. An additional surveyor and recording supervisor should work together to ensure all artefacts, ecofacts and samples are surveyed in, and the associated paper or digital record is checked. A senior Pleistocene geoarchaeologist (see below) should oversee the recording and interpretation of the lithology recovery of palaeoenvironmental sampling and dating samples. An appropriate sized team of experienced archaeologists should undertake the excavation and recovery of archaeological materials.

The supporting specialist team should include the following as appropriate:

> Pleistocene Geoarchaeologist: A senior Pleistocene specialist with experience of regional geomorphology, Quaternary stratigraphy and Palaeolithic archaeology will be required to make detailed records of the lithology, develop models of geomorphological site formation, and advise on sampling strategies and archaeological interpretation.
>
> Quaternary Dating Specialist: If sampling for OSL, palaeomag, AAR or other specialist dating methods are to be undertaken they should be done so under the supervision of an appropriate dating expert.
>
> Quaternary faunal expert: If faunal material is present, visits by an appropriate faunal specialist will be required to advise on recording and sampling
>
> Specialist Conservator: To advise on and/or undertake the lifting of faunal material.
>
> Artefact Microwear Expert: To advise on appropriate recovery and sampling.

An appropriate, experienced palaeoenvironmental specialists team should be in place and have the opportunity to visit the excavation to advise on sampling.

Excavation Procedure

Once any internal trench divisions and baulks have been laid out, the site should be gridded to at least 1m resolution. Each square should also be given a label indicating the coordinates of its south-west corner. Excavation can then proceed, once overburden has been lightly mattocked off, by hand, using trowels.

100mm spits are possible in layers with minimal finds but 20mm or 10mm spits will be more appropriate for layers with very dense or complex archaeology. Each distinct sedimentary unit should be given a context number. Where the boundary between different sedimentary layers is clear, excavation should proceed in spits to expose the surface of the underlying layer in its entirety. A topographic survey can then be made of the underlying unit before excavation proceeds through it. Where boundaries are heavily mixed through involutions, solution structures or sediment deformation it may be necessary to excavate in horizontal splits through the mixed units. In these cases care should be given to ensure that, for the written record for each artefact, clear recording of which sedimentary each came from is made.

Where isolated finds of the size agreed for XYZ recording (see below) are found within a sediment body they should not be lifted immediately. Instead their upper surface should be revealed carefully using a non-metallic excavation tool and the edge of the object defined to leave it on a small podium of intact sediment. In this way, artefacts can be found and left for subsequent recording while the front of excavation proceeds southwards.

Where finds are found to be resting directly on the contact with an underlying surface, or found within a thin sedimentary horizon such as a discrete palaoesol, clay lamination or mineralised horizon, the surface should be revealed. In these cases, especially where intact knapping scatters of otherwise densely accumulated material are preserved, several passes of hand excavation and recording will be necessary.

In sites with excellent, fine-grained preservation of unpatinated stone artefacts, consultation with a microscopic use-wear expect will be necessary. Recording of suspected tools and a sample of unmodified debitage can then be excavated in blocks of sediment to preserve their edges form chemical modification resulting in patination upon exposure to the air.

All finds below the size threshold for XYZ recording should be bagged by spit and site square.

All spoil should be dry sieved through 5-10mm meshes at the spoil heap and any recovered artefacts placed in the bag for the spit and square from which they the originated. It is consequently important that spoil is taken to be sieved by the excavator and each bucket relates solely to one grid square and spit.

If present, features such as pits, post-holes, graves and hearths should be excavated using standard archaeological recording techniques. The contents should be sampled in their entirety where reasonable for the recovery of small finds and palaeoenvironmental remains.

Recording Finds

Once excavation of a spit across a trench is complete, leaving artefacts on plinths or on a single surface, the recording and subsequent lifting of finds can take place. A photographic record should be made using either over-head photography of each square or, more effectively, high-resolution photogrammetry of the entire trench surface. High-resolution oblique photographs should be taken of the trench as an additional record. Consideration could be given to hand drawing artefact distribution.

All lithic artefacts over an agreed size should be recorded three dimensionally by survey using a total station or Differential GPS. This agreed size might be as small as 5mm Maximum Linear Dimension (MLD) for a site where microlith manufacture is prevalent, or as high as 30mm MLD for a Palaeolithic ‘quarry site’ dominated by large quantities of large debitage. Generally, 10mm or 20mm MLD are appropriate cut-offs for three dimensional XYZ recording. All lithic artefacts recorded in this manner should be individually bagged and recorded as small finds. Tools/tool fragments less than the agreed MLD can also be recorded in this manner as considered appropriate, for example where microlith fragments or micro-burins are identified. Agreed size cut-offs can also be agreed for other finds such as mammalian remains and wood fragments. If in doubt, or in the case of material of distinctive or unknown nature, XYZ recording should be undertaken.

Where lithic artefacts, fauna or wooden finds have a definite long axis (defined by maximum length of the artefact being at least twice that of the maximum width), the orientation of the artefacts’ long axis to north should be recorded. The proximal end of the artefacts should be taken to indicate the direction of orientation. An artefact with a proximal end pointing to the north east would have an orientation of 45 degrees. An artefact with a proximal end pointing to the south west would have an orientation of 225 degrees.

Where a lithic artefact is not resting flat on the surface of, or within, a sediment body, the degree to which it dips should be measured with an inclinometer and the direction of this dip with a compass. An artefact encountered on its edge within a sediment body would have a dip of 90 degrees.

Unless encountered directly on end, or on edge, the surface of the artefacts which faced uppermost at discovery (ventral or dorsal) should be recorded.

A finds register should be kept for each small find which is XYZ recorded. This should also record: Trench, Context, Square, Orientation and Dip data, Ventral/Dorsal uppermost, Maximum Dimension, and further notes. Separate registers could be considered for faunal material and artefacts. Consideration, in discussion the project Pleistocene Geoarchaeologist, could be given to recording natural clasts routinely in ways described above in order to create a detailed record of site formation processes.

Data should be checked, entered and plotted into a site GIS at the end of each day in order to detect recording errors and to create an iterative visual record for discussion amongst the project team.

Sampling and Recording Sections

The baulks between each trench will usually provide an adequate resource for sampling once excavation is complete. The full lithological sequence and key archaeological horizons will at this point be known and, depending on the lay out of the trenches, no sample point will be further than 2-3m from any part of the site. As well as providing a resource for sediment, palaeoenvironmental, dating and soil micromorphology samples, bulk samples can be taken from each unit for recovery of further palaeoenvironmental material and sieving for the recovery of microdebitage. If possible, on site wet sieving through 10mm and 5mm meshes should be established, the residues can them be retained, dried, bagged and transported for later sorting. It may sometimes be necessary to extend the scope and scale of bulk sample sieving where the recovery of small finds and ecofacts is necessary at scale.

All sections should be photographed and recorded through hand-drawings at an appropriate scale, the position of all samples taken should be annotated onto the section drawing. Detailed sedimentary descriptions should be made by the project Pleistocene Geoarchaeologist.